7. Leveraging Companies´ Willingness to Engage in Eco-Innovation Processes and Implementing Green Chemistry and Green Engineering at the Sector Level

7.0 Introduction

The behavioral aspects of innovation are the core interest of this thesis research. In this sense, measuring and explaining Brazilian petrochemical companies´ current willingness to engage deliberately in Green Chemistry and Green Engineering (GCE)-based eco-innovation processes was its prime objective. On the other hand, identifying conditions in which such willingness could be enhanced was its second, but not less important, aspiration.

In this respect, it was proposed in Chapter 3 that such an explanation and prediction could be achieved *via* a Theory of Planned Behavior (TPB)-based structural behavioral model. This constituted the meta-theoretical model that congregated theories from diverse fields of knowledge that are related to the determinants of willingness to perform the behavior that was under study in the context of this thesis research (cf. Chapter 5). Additionally, it was also established, as a *sine qua non* condition for the conduction of acceptable exercises of willingness explanation and prediction, that the model must be valid and the measures of the variables that determined willingness were reliable. Such reliability and validity were demonstrated, based upon information presented in Section 6.6.2 and upon the results of the statistical analyses presented in Appendices A, B and C.

Chapter 4 presented and discussed the methodological aspects involved in measuring and explaining of companies' current planned behavior (willingness) towards their engagement in GCE-based eco-innovation processes. Drawing on the empirical results obtained by the thesis researcher´s quantitative survey (cf. Chapter 6), and with the support of the validity statistics presented in Appendix C, Chapter 7 delved into the theory, empirical data and statistical analyses and identified the contributions of the significant beliefs and of the behavior domains to the willingness formation (Section 7.1). It also investigated the conditions under which companies´ willingness can be enhanced and intensified (Section 7.2). Based on statistical analyses Section 7.3 identified the significant willingness determinants based on which policies and strategies, aimed at companies´ engagement in GCE-based eco-innovation, can be designed. Suggestions for such policies and strategies were presented in section 7.5.

It is important to emphasize that, in this thesis research, the significant determinants of willingness were interpreted as guidance elements that can contribute to the development of governmental, sectoral and corporate policies or strategies as a means to facilitate and to incentivize GCE-based eco-innovation at the company and sector levels of the petrochemical industry. They are not and should not be interpreted as being policy instruments themselves.

Section 7.4 presented results of a study based on this thesis survey´s qualitative survey (in-depth interviews, with managers, environmental agencies and the trade association (ABIQUIM)). That study was conducted to test, *via* qualitative means, the agreement with or disagreement with the results of the quantitative survey´s results and to explore the agents´ perceptions on GCE and on the GCE-based eco-innovation processes. It also

promoted a study on their perceptions and mutual relations regarding the promotion, dissemination and implementation of GCE at the company and at the sector levels (Section 7.6).

7.1 From Beliefs to Intention: Explaining How Beliefs Influence Willingness Formation

As noted in Chapters 3 and 5, behavioral intention (willingness) is formed by the accumulated connotative load of the beliefs an individual has about a behavior.

The understanding of how these processes occur and having a clear picture of the extent to which these determinants influence the development of willingness are fundamental elements in identifying "leverage points" that can be used in the design of strategies and policies aimed at promoting the engagement of companies in eco-innovation processes. It is expected that such policies and strategies are able to induce the formation of new innovation systems as well as to strengthen existing ones.

According to this thesis research´s TPB based structural behavioral model, willingness can be explained by its determinants in the form that it was proposed in the model´s first and second levels of explanation (cf. Figure 5.7, in Chapter 5) and via the relationships hypothesized in hypothesis 1 (H_1) and hypothesis 2 (H_2) in Section 5.3 of Chapter 5.

These hypotheses differed from one another by the nature of their determinants. While, H_1, at the most basic level of explanation, was associated with the model´s three basic constructs (H_1: $W = W(A, PSFP, PBC)$, H_2 hypothesized that willingness is a function of the behavioral domains (H_2: $W = W(EVR, ECR, PSP, RLP, PN, SI, KTC, AN, INST)$.

Although, the test of H_1 was important to verify the validity of the adaptation of the TPB to assess willingness to engage in GCE-based eco-innovation processes, "with respect to policy analysis, it was more appropriate to perform the analysis at the domain level, if the intention is, at a later stage, to simulate scenarios" (Montalvo Corral, 2002: 212). For this reason, the direct measures of the overall perceptions at the domain level were considered in the explanation and prediction of willingness in this Chapter.

By using the hypothesis system proposed in Chapter 5 in conjunction with the results of the statistical analyses of the thesis research´s behavioral model validation (cf. Section 6.6 of Chapter 6 and Appendices B and C), this section explains the degree of influence of the main determinants in willingness formation within the context of this research.

Besides demonstrating the existence and the validity of these linear causal relationships, the linear multiple regression analysis provided an extensive explanation of the degree of influence that different behavioral domains exert on companies´ willingness to engage deliberately in GCE-based eco-innovation processes. The overall contribution of each of the behavioral domains to willingness formation was presented in Table 7.1.

Table 7.1– Contributions of the behavioral domains to the willingness formation as indicated by the regression analyses[98]

Willingness Constructs	Behavioral Domains	R	R^2	Adjusted R^2	% Explained Variance (cumulative)	Std. Error of the Estimate	% Explained Variance (constructs)
Attitude	EVR	0,200	0,040	0,020	4,040	1,070	15,74
	ECR	0,400	0,160	0,120	15,740	1,050	
Perceived Social Factors Pressure	SP	0,550	0,300	0,240	30,290	0,870	26,85
	RLP	0,640	0,410	0,330	40,660	0,810	
	PN	0,650	0,420	0,339	42,190	0,790	
	SI	0,650	0,430	0,341	42,590	0,810	
Perceived Behavior Control	KTC	0,740	0,550	0,460	55,030	0,790	29,8
	AN	0,850	0,722	0,620	72,170	0,730	
	INST	0,850	0,724	0,621	72,400	0,740	

Source: author

According to Table 6.37 (cf. Chapter 6) and Table 11.4, in Appendix C, the results of the regression analysis revealed a coefficient of determination of $R^2 = 0.72$. That is, in the context of this thesis research, 72 percent of the total variance of willingness (*W*) was explained by the regression equation of willingness against the behavioral domains.

In this respect, Table 7.1 showed that the behavioral domains associated with the perceived behavior control (*PBC*) construct accounted for 29.8 percent of the variance. The largest contributions to the explanation of such variance came from the actors and networks (*AN*) and the knowledge and technologies (*KTC*) domains, which accounted for 17.13 percent and 12.44 of the variance percent respectively. The institutions' (*INST*) domain provided minimal contribution.

With regard the knowledge and technologies domain, the beliefs associated with the accessibility to knowledge (*ak*), technological opportunities (*to*) and knowledge cumulativeness (*cmt*) were presented as the most significant ones and accounted for 93.8 percent of the variance of that domain (cf. Figure 7.1,Table 7.8, Table 11.25 and Table *11.27* in Appendix C).

In respect to the actors and networks behavioral domain, the beliefs related to the availability of internal actors holding key capabilities (*avc*), to the capabilities to establish strategic alliances (*sac*) and those related to the control over the requisite resources and opportunities to form or to participate in networks of collaboration (*nwc*) appeared as the most significant ones,. They accounted for 80.7 percent of the variance of the domain (cf. Figure 7.1, Table 7.8, Table 11.28 and Table 11.30 in Appendix C).

The second largest contributing construct to the explanation of companies´ willingness to engage in GCE-based eco-innovation processes was represented by the perceived social factors pressure (*PSFP*) whose set of behavioral domains accounted for 26.85 percent of the variance (cf. Table 7.1).

[98] Methodological note: The computation of the individual contribution of the behavioral domains to willingness explanation was conducted in two steps. First, the entire multiple regression method analysis was performed to test the validity of the hypothesized causal relationship. Second, the behavioral domains were run again with a forward multiple regression method to assess their individual contributions to explain willingness.

Within this construct, the perceived social pressure domain (*SP*) accounted for 14.55 percent of the variance. Its three component beliefs, in turn, accounted for 81.10 percent of the variance of the domain (cf. Table 11.13 in Appendix C). In this case, the beliefs associated with the perceived community pressure (*cp*) and the perceived regulatory pressures (*rp*) were found to be the most significant (cf. Figure 7.1, Table 7.7and Table *11.15* in Appendix C). On the other hand, the beliefs encompassed in the perceived professional roles domains explained 10.37 percent of the variance of willingness. In this behavioral domain, managers´ professional roles, in respect to the environmental culture and values within organizations (*rlp4*), were found to be the most significant belief (cf. Table 11.18 in Appendix C) and accounted for 15.9 percent of the variance of the domain (cf. Table 11.16).

The attitudinal behavioral domain provided the lowest contribution to the explanation of formation of companies´ willingness to engage in GCE-based eco-innovation processes. Together, the two domains, environmental risk (*EVR*) and economic risk (*ECR*) accounted for 15.74 percent of the variance with individual contributions of 4.04 percent and 11.70 percent respectively (cf. Table 7.1).

The regression analysis results showed that the statistically significant beliefs associated with the environmental risk behavioral domains accounted for 57.1 percent of the variance in this domain (cf. Table 11.7). In this respect, the perception of: (a) the extent of the impacts (do not have global impacts-have global impacts), (b) the extent to which managers were affected by the environmental risks (does not affect me-does affect me), and (c) the perception of how new and known these risks were (old risks-new risks) (cf. Table 5.2 in Chapter 5) were found to be significant (cf. Table 11.9 in Appendix C).

In respect to the explanatory power of the economic risk behavioral domain, it accounted for 11.70 percent of the variance with regard to willingness to engage in GCE-based eco-innovation processes (cf. Table 7.1). In this domain, economic opportunities and technological risks were the significant beliefs, which accounted for 49.2 percent of the variance (cf. Table 11.10 and Table 11.12).

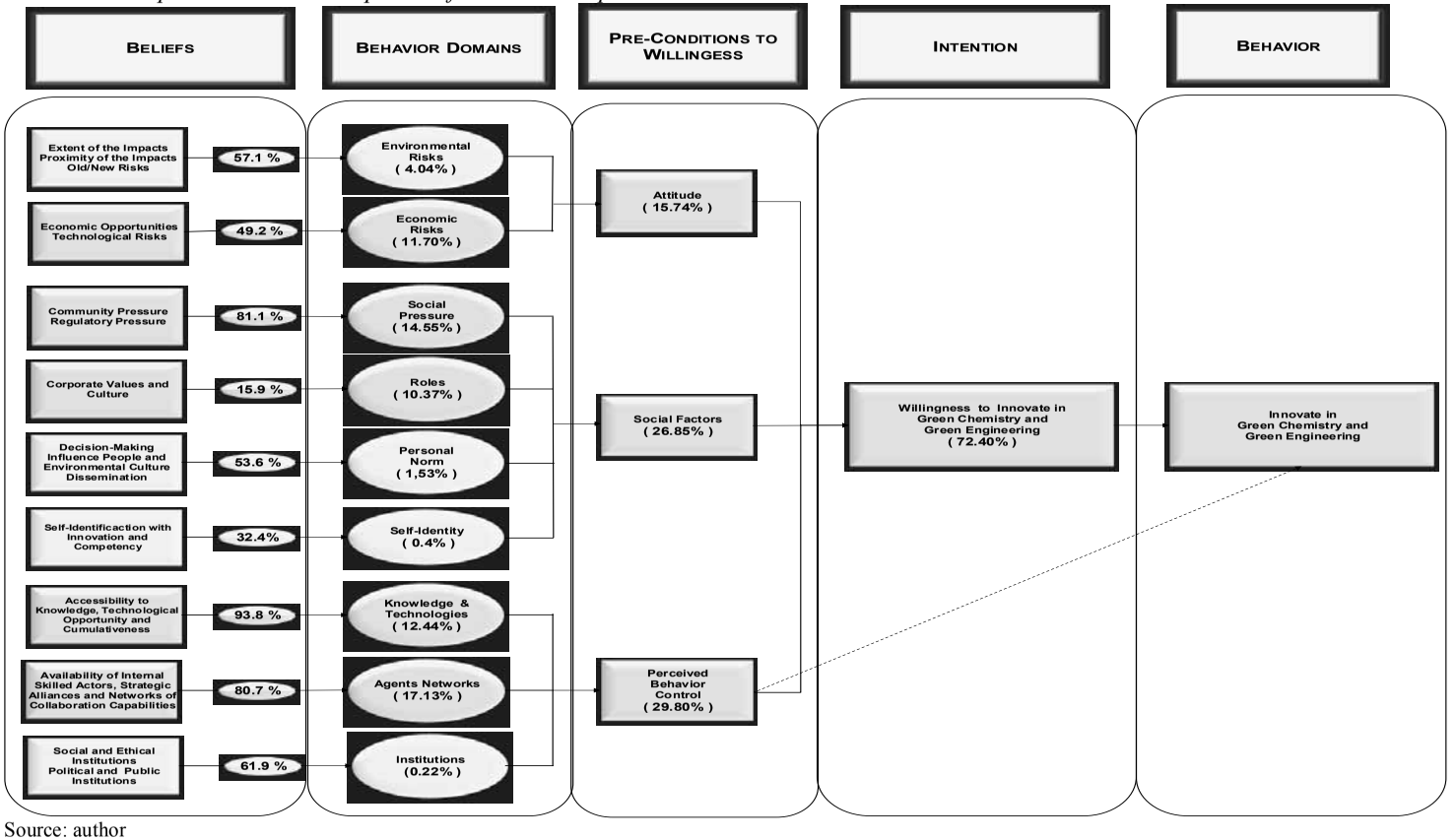
The argumentations about the explanatory power of this research´s behavioral model was synthesized and pictorially presented in Figure 7.1. The explanatory weight of the behavioral domains and their associated beliefs were obtained from the multiple regression analyses of the linear relationships that were proposed by the system of hypothesis in Section 5.3 of Chapter 5. These results were presented in Appendix C and in Table 7.1:

a) Table 7.1 provided a summary of the results of the multiple regression analysis regarding willingness against the nine behavioral domains. It showed the degree to which each of the behavioral domains and willingness constructs contributed to willingness explanation, and
b) Appendix C provided the results of analysis of variance of all proposed hypotheses of this thesis.

Figure 7.1 presented the results of the analysis of variance in a linear and hierarchical sequence that linked beliefs to behavioral intention (willingness).

a) **Beliefs → behavioral domains**: e.g., the statistically significant beliefs associated with the environmental and the economic risk behavioral domains were listed in the extreme left of Figure 7.1. In this case, environmental and economic risks accounted for 57.1 percent and 49.2 percent of the variance in their respective behavioral domains;
b) **Behavioral domains → attitude construct → willingness**: e.g., the environmental and economic risks behavioral domains accounted for 4.04 percent and 11.79 percent respectively of the variance in willingness. As a consequence, the behavior model´s attitude construct accounted for of 15.74 percent in willingness, and
c) The total explained variance was computed by the sum of the variance accounted for by the three constructs in the model

Figure 7.1– The thesis research model's behavioral domains explanatory weight regarding companies' willingness to engage in GCE-based eco-innovation processes in the companies of the Brazilian petrochemical sector



Source: author

7.1.1 Discussion

A closer look into the results of the regression analyses presented in the previous paragraphs, and in Figure 7.1, shows relevant points for the interpretation of the formation of Brazilian petrochemical companies´ willingness, to engage in GCE-based eco-innovation processes.

The first point to highlight is the relevance of the extensions that were introduced to the TPB´s original social norm construct (cf. Chapters 3 and 5) as a means to expand the thesis researcher´s behavioral model explanatory power.

As noted in Chapter 5, this proposition took the form of the incorporation of additional social and personal normative elements to the TPB's normative construct. The social elements were proposed based on the Theory of Interpersonal Behavior (TIP) (Triandis, 1977) and were represented by professional roles and self-identity. The personal normative dimension regarded Schwartz´s (1977) concept of personal moral norms.

Although self-identity played a minimal role in explaining willingness, the personal norm and the professional roles domains were able to capture managers´ perception of their moral and professional postures regarding their engagement in GCE-based eco-innovation processes.

According to Conner and Armitage (1998: 1442), studies have found that personal (moral) norm "had an effect on intention and independently predicted attitudes. The evidence, therefore, suggested that the "moral norm is closely linked to attitudes and may, at least for some behaviors, be an antecedent" as argued by Conner and Armitage (1998: 1442). In this thesis research, the bivariate correlation between personal norm and attitude ($0.45 < .01$) suggested the existence of such a relation.

As the precise role of moral norms will depend on the nature of the behavior (*ibid*), a clear picture relative to the role of personal norm and its relation to intention, in the context of this thesis research, requires further and specific research, which is beyond the objectives of this thesis.

Another finding confirms what has been found in other studies with regard to the link between personal norm and self-identity (cf. Conner and Armitage, 1998). This close link was indicated by their high bivariate correlation index of 0.738 (< .01). Personal norms differ from self-identity as they take account of personal, rather than societal values.

The last remark concerns the low contribution of the self-identity behavioral domain to the explanation of companies´ intention (willingness) to engage in GCE-based eco-innovation processes (0.4 percent). In the current study the correlation of self-identity and willingness was very low (0.05). This was an unexpected result since; according to Charng *et al*. (1988) identity theory captures the influence of the wider social context on individual actors, linking a particular behavior to some identifiable social characteristic or category of the actors. Managers in the research context showed high scores of self-identification with the roles identity proposed in this thesis research (i.e., self-identification with environmental sustainability issues and self-identification with innovativeness and competency).

According to Sparks and Shepherd (1992: 390 *apud* Fishbein and Ajzen´s, 1975), "a person's self-identity is reflected in that person's beliefs, values, and attitudes and that the inclusion of self-identity as a component of a model should not represent a theoretical or empirical advance". Despite this theoretical position, self–identity has been found to be an independent predictor of intention for a number of behaviors (cf. Armitage and Conner, 1999; Charng *et al*., 1988; Conner and Armitage, 1998; Fielding *et al*., 2008; Smith *et al*., 2007; Sparks and Guthrie, 1998, Terry *et al*., 1999).

In these studies, it was shown that the theoretical grounds for the existence, or non-existence, of such intention (willingness) predictive character of self-identity can be many and diverse. Depending on the behavior, the roles identity under study within the research context, these findings sometimes contradicted the results of other studies. This is the case of the research results relative to how the interaction of self-identity and past behavior influence intention. In such studies, depending on the behavior and on the research context, the moderating effect of past behavior on the self-identity-intention relationship can vary and sometimes they are absent (Terry *et al*., 1999)

The debate on whether self-identity effects simply reflect overlap with other TPB constructs has also been the object of extensive investigation (cf. Fekadu and Kraft, 2001; Fishbein, 1997; Sparks, 2000). In this respect, according to Conner and Armitage (1998: 1445), it is reasonable to assume that, when coupled with a strong self-identity, attitudes will become ever stronger due to mechanisms of attitudinal consistency (…) perhaps manifested in individuals seeking attitudinally relevant situations".

In this respect, although not being conclusive, the bivariate correlation between self-identity and attitude ($0.507 < .01$), in this thesis research, may indicate a congruence with Spark and Shepherd´s (1992) argument about the likelihood of existence of a bidirectional causal relationship between a person´s self-identity and his or her attitudinal evaluations.

On the basis of multiple research studies, Conner and Armitage (1998) argued that it is plausible to assume that there are certain behaviors for which self-identity is an important determinant of intention. That is, the effects of self-identity may vary depending to the behavior under study.

Based on the aforementioned research on self-identity, in the realm of the TBB, it can be argued that finding the origins for such low explanatory level of self-identity, for the context of this research requires additional specific further research, which is beyond the scope of this thesis research.

7.2 Enhancing Willingness to Eco-Innovate

Section 7.1 presented the significant determinants of Brazilian petrochemical companies´ willingness to engage in GCE-based eco-innovation processes. The findings were based upon the perceptions of companies' managers and influential decision-makers within the corporations, in respect to factors belonging to attitudinal, social, personal and behavioral beliefs that ultimately influence willingness to deliberately engage in such processes.

The results presented in Chapter 6 showed the current status of the respondent's level of willingness to engage their companies in implementing GCE. The understanding of the structural relations between these determinants and the degree of influence that they have

on willingness, provided important and useful instruments for designing policies and strategies to enhance the levels of such willingness.

It is important to emphasize that the concept of willingness, in the context of this thesis research, not only denotes the disposition to perform the behavior that is under study, it also connotes a sense of preparedness to perform such behavior. Preparedness was incorporated into this research´s behavioral model in the form that it was proposed by the perceived behavioral construct of the TPB (cf. Chapters 3 and 5). In this work, preparedness was understood as the existence of companies´ access to the opportunities as well as their possession of the requisite resources to engage in GCE-based eco-innovation processes.

Based on this argumentation, it is plausible that the enhancement of such willingness in order to increase the likelihood of the implementation of the expected courses of action should be an objective to be pursued. Willingness enhancement is not a random process. On the contrary, it requires elaboration and the identification of appropriate policies and/or strategies based on which actions can be brought about (cf. Montalvo Corral, 2002).

Although Section 7.1 presented the willingness determinants that are currently more significant, policies/strategies at the company, sectoral and governmental levels that encompass the integrity of them may not be viable in terms of conception, integration, resources, implementation timing and costs. Good policies/strategies can be designed and resources can be more efficiently allocated in cases in which they are based on specific conditions that can promote better chances of success with the use of minimum efforts. Finding such conditions is equal to the identification of the system´s "leverage points".

"Leverage points" is a term coined in the system dynamics[99] field that connotes "places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (Meadows, 1999: 1). Although the theoretical approach used in this thesis research, for the study of willingness, was not related to the theory of complex systems, the concept of "leverage points" is valid and applicable.

In the case of this thesis research, the "leverage points" were indicated by the achievement of highest values of the estimated willingness (W_{est}) produced by the introduction of changes in the preconditions associated with firms´ engagement in GCE-based eco-innovation processes. This was of obtained by a series of simulations. These simulations represented possible scenarios that can occur as a result of modifications to the current state of the nine behavioral domains that constitute the willingness determinants.

[99] System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system.

Such changes were simulated by modifying the behavioral domains' indexes (scores from one to seven) in a simulation equation that represented the linear relationship between intention (willingness) and its determinants, which was amplified upon in Section 5.6.2 of Chapter 5:

$$B = w_o + w_1A + w_2\,PSPF + w_3PBC$$

The equation´s "w_n" weighting parameters were empirically determined by the multiple linear regression of willingness (*W*) on the nine behavioral domains (the predictor variables *EVR*, *ECR*, *SP*, *RLP*, *PN*, *SI*, *KTC*, *AN*, *INST*) (cf. Section 5.6.2 of Chapter 5). Such multiple regression analyses produced the following statistical variables for the regression, which represent the willingness predictor equation in the context of this thesis research.

$$W = -2.051 + 0.029EVR + 0.2ECR + 0.239SP + 0.102RLP + 0.088PN + 0.069SI + 0.210KTC + 0.419AN + 0.05INST \quad \text{(Eq. 7.1)}$$

The low standard error of the estimate of willingness in the regression analysis (0.738) indicated a satisfactory level of accuracy of prediction (cf. Table 11.4 in Appendix C).

In the simulation process, the behavioral domains were used individually and in conjunction in order to identify the best combination that could produce the highest estimated willingness value.

As previously noted, the main idea underpinning the simulations was, based on current scenario, to find the best points to intervene (leverage points) *via* policies in order to promote the strengthening of willingness without promoting general and unnecessary changes in the whole system. In this respect, Box 7.1 presents the sequence that was used in the performance of such simulations:

Box 7.1– Procedure that was used to simulate the best conditions for enhancing companies' willingness to engage in GCE-based eco-innovation processes

a) Determination of the baseline scenario (*BLS*): by using the predictor equation (Eq. 7.1), the simulation of the current estimate of willingness was performed by incorporating the mean of the scores of the behavioral domains that were obtained in the sample related to this thesis research´s quantitative survey. These mean scores were presented in Table 7.5;

b) Determination of the optimal condition for the behavioral domains: the optimal condition for the behavioral domains were simulated by elevating the behavioral domain´s baseline value, as described in item (a), to the optimum value (7). This optimum value follows the maximum value used in the scales that were used in the questionnaire to assess the managers´ perceptions;

c) Simulation exercises: departing from the baseline scenario simulations, the willingness enhancement simulations were conducted by using the predictor equation (Eq. 8.1) and substituting the optimum scenario value for the behavioral domains that were under study (e.g. environmental risk baseline score = 3.41 → optimal condition = 7.00, economic risk baseline score = 6.00→ optimal condition = 7.00 etc.);

d) The results were presented in the form of: (1) the estimated willingness (W_{est}), and (2) the percentage improvement in respect to the baseline scenario (cf. Table 7.2, Table 7.3, Table 7.4 and Table 7.5).

7.2.1 Changes in the Attitudinal Determinants of Willingness

As noted in Section 3.7.1, attitude is a function of managers´ and key decision-makers´ perceived consequences (outcomes) of performing a behavior and of the person's evaluation of its consequences. The willingness to perform, or to not perform, a specific behavior is dependent on a favorable or unfavorable evaluation that a firm's manager has about the expected outcomes.

As noted in Chapter 5, in the eco-innovation realm, the main concept behind this evaluation was risk (Montalvo Corral, 2002). In this thesis research, the perception of risk was assumed to stem from two domains:

- The **possible environmental impacts** (perceived environmental risk) generated by the firm's operation (products, processes and services) and the perceived environmental relevance of the environmental improvement introduced by the development of cleaner and more sustainable products, processes, services, raw materials and energy sources, and
- The **possible economic consequences** (economic risk and business opportunities) in terms of perceived possible capital losses/gains and business opportunities arising from innovative incremental or radical GCE-based activities under risk or uncertainty.

The main premises supporting the environmental and economic risk domains were:

- Managers who perceived that the environmental risks, originated in the firm´s operations, are beyond their subjective and objective acceptance level, will be more likely to hold stronger willingness to engage in GCE-based eco-innovation processes, and
- Eco-innovating in GCE is likely to occur in cases in which the perceptions of low economic risks are strong and the perceptions of business opportunities are high.

For a better comprehension of the use of the scores in the simulations, it is important to make clear that the optimal scores relate to the most favorable conditions under which willingness formation, or enhancement, is likely to be facilitated. This concept was employed in the construction of all scales in this thesis research´s questionnaire. Therefore, it is important to emphasize that in respect to economic risk, the score of seven represents the most favorable condition associated with willingness development. That is, it is the condition of the lowest economic risk and the highest business opportunities associated with engaging in GCE-based eco-innovation processes.

Based on these arguments, Table 7.2 presented the hypothetical scenarios associated with the attitudinal behavioral domains and their respective estimated willingness (W_{est}). The highlighted scores represent the changes that were introduced in the domain condition as compared to the baseline scenario.

In order to avoid unnecessary repetitions, the scores related to the optimal scenarios were highlighted in dark color in all subsequent simulation results tables.

Table 7.2– Effects of changes in attitudinal behavioral domains on willingness to engage in GCE-based eco-innovation processes

	Attitude		Perceived Social Factors Pressure				Perceived Behavior Control			Estimated Willingness	% Improvement
	EVR	ER	SP	RLP	PN	SI	KTC	AN	INST	W_{est}	-
SCN1	7,00	6,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	5,91	1,77
SCN2	3,41	7,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	6,00	3,44
SCN3	7,00	7,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	6,10	5,21

Source: author

In respect to the hypothetical scenarios, scenarios *SCN1* and *SCN2* tested the individual contribution to willingness formation of the two, attitudinal behavioral domains. The results were analyzed and expressed in terms of estimated willingness (W_{est}) and the improved percentage as compared with the estimated value of willingness associated with the baseline scenario (*BLS*).

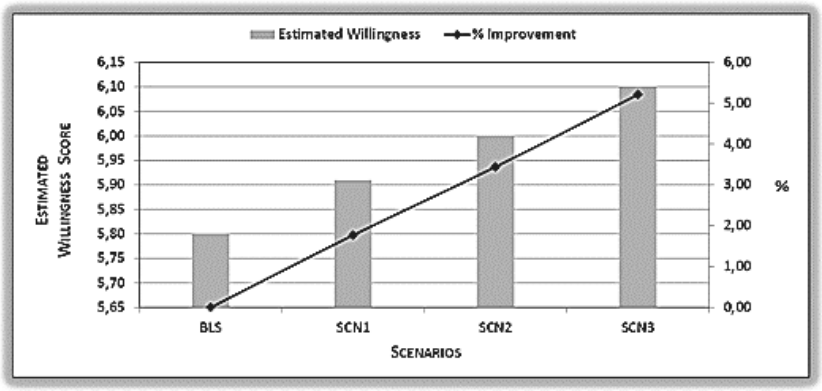
As stated in section 5.2.2, in Chapter 5, it was expected that the managers (companies), which perceived that the environmental risks produced by their companies were high would be more prone to engage in GCE-based eco-innovation processes. *SCN1* simulated such a condition by elevating the environmental risk perception (*EVR*) from the current score of 3.41 to the optimal condition score (7.00). This produced an estimated willingness score (W_{est}) of 5.91, which corresponded to an improvement in willingness of 1.77 percent in respect to the baseline condition.

Better results were obtained by increasing the perception of low economic risk and high business opportunities associated with the engagement in GCE-based eco-innovation processes. In this respect, its current condition (score 6.00) was replaced by the optimal condition of high business opportunities and extremely low economic risk (score 7.00). This produced an estimated willingness (W_{est}) of 6.00, which represents an improvement of 3.44 percent relative to the *BLS*.

Scenario *SCN3*, was designed to simulate the joint effect of the optimal conditions for both attitudinal domains: high environmental risk perception, perception of low risk and high business opportunities. Such a combination elevated the W_{est} up to 6.10 representing a gain of 5.21 percent in respect to the *BLS*. This result coincided with the expected outcome. Due to the positive correlation between willingness and both behavioral domains (cf. Appendix D), it was expected that the outcome of joint influences of both behavioral domains represented the sum of their individual contributions to the estimated willingness.

The results of the simulations of willingness based on the attitudinal behavioral domains are pictorially presented in Figure 7.2.

Figure 7.2– Results of willingness simulations regarding the attitude domain



Source: author

7.2.2 Changes in the Social and Personal Determinants of Willingness

The TPB proposed the use of a social construct as one of the main determinants of behavioral intention. It takes the form of a subjective norm (social normative beliefs) construct that captures the influences from the individuals or group of individuals for the performance of a behavior.

As noted in Chapters 3 and 5, this thesis researcher proposed an extension to the TPB´s subjective norm. For this purpose, the concept of social determinants of behavioral intentions was expanded and, besides including the social pressure behavioral domain (*SP*), it also included the following components of social and personal influence: (a) role beliefs (*RLP*), (b) personal normative (moral) beliefs (*PN*), and (c) self-identity (self-concept) (*SI*) behavioral domains.

In addition to what was presented in the previous section, the simulations of willingness were also intended to observe the influences exerted by important referents on willingness.

They also revealed conditions under which willingness can be improved as a result of their combined influence.

In this respect, scenarios *SCN4* through *SCN7* simulated the individual influence of the social pressure (*SP*), professional roles (*RLP*), personal norms (*PN*) and self-identity (*SI*) behavioral domains on willingness. Table 7.3 presents the results of the simulations in respect to the hypothetical scenarios associated with the social and personal behavioral domain and their respective estimated willingness (W_{est}).

Table 7.3- Effects of changes in social and personal behavioral domains on willingness to engage in GCE-based eco-innovation processes

Scenarios	Attitude		Perceived Social Factors Pressure				Perceived Behavior Control			Estimated Willingness	% Improvement
	EVR	ER	SP	RLP	PN	SI	KTC	AN	INST	W_{est}	-
SCN4	3.41	6.00	7.00	6.47	6.44	6.38	5.27	5.59	4.50	6.27	5.23
SCN5	3.41	6.00	5.09	7.00	6.44	6.38	5.27	5.59	4.50	5.85	0.76
SCN6	3.41	6.00	5.09	6.47	7.00	6.38	5.27	5.59	4.50	5.84	0.68
SCN7	3.41	6.00	5.09	6.47	6.44	7.00	5.27	5.59	4.50	5.84	0.68
SCN8	3.41	6.00	7.00	7.00	7.00	7.00	5.27	5.59	4.50	6.32	8.99
SCN9	3.41	6.00	7.00	7.00	6.44	6.38	5.27	5.59	4.50	6.42	10.68

Source: author

The elevation of the score relative to the social pressure domain (*SP*), in scenario *SCN4,* from its current value of 5.09 to its optimal value of 7.00, produced an improvement of 8.06 percent in willingness respective to the *BLS* and produced an estimated willingness score of 6.27. Scenario *SCN5* tested the individual influence of the professional roles (*RLP*) on willingness. The substitution of its current score (6.47) by its optimal condition score (7.00) revealed an increase of 0.76 percent in the estimated willingness relative to the *BLS* and an estimated willingness of 5.85.

Scenario *SCN6* represented the individual contribution of the personal norm domain (*PN*). The change from its current score (6.44) to its optimal condition (7.00) produced an estimated willingness score of 5.84, which corresponds to an increase of 0.679 percent in respect to the *BLS*.

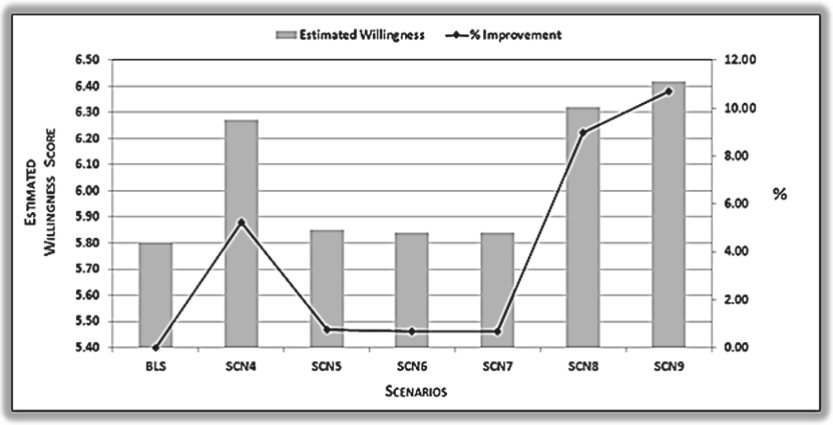
In scenario *SCN7*, the influence of self-identity (*SI*) on willingness followed about the same pattern as the personal norm domain. The result of the simulation produced almost identical results for both domains. In this case, a change in the perception of self-identity from its current mean value of 6.38 to its optimum condition (7.00) produced an increase of 0.67 percent in respect to the *BLS* and an estimated willingness score of 5.84. Such similarity stems from (a) the managers´, in the Brazilian petrochemical sector, identical level of perception regarding both domains and (b) the similar contribution of *PN* and *SI* to willingness formation as was shown by the regression equation of willingness against the thesis research´s behavioral domains (cf. Appendix C).

Scenarios *SCN8* and *SCN9* simulated the joint contributions of different behavioral domains comprised in the *PSFP* construct. Initially, a simulation was conducted by computing the joint influence of the social pressure (*SP*) and the professional roles (*RLP*) domains (*SCN8*). This combination produced an increase of 8.99 percent in the expected willingness as compared to the *BLS*, and an estimated score of 6.32.

Additionally, another simulation was conducted by simulating the simultaneous contribution of the four behavioral domains of the *PSFP* construct in their optimal state (*SCN9*). This produced an estimated willingness of 6.42, which represented an improvement of 10.68 percent in respect to the *BLS*.

The results of the simulations of willingness based on the behavioral domains pertaining to the social and personal behavioral domain were presented in Table 7.3 and in Figure 7.3.

Figure 7.3- Results of willingness simulations regarding the social and personal behavioral domains



Source: author

7.2.3 Changes in the Behavioral Control Determinants of Willingness

The concept of behavioral control (control beliefs) relates to the extent to which the performance of a given behavior is conditioned by individuals' perceptions of control over the ability and availability of opportunities and resources required to perform a given behavior.

The more resources and opportunities an individual perceives that he or she possesses, and the fewer obstacles and impediments that are anticipated, the greater should be their perceived control over the behavior (Ajzen and Madden, 1986)

As noted in Chapter 5, the perceived behavioral control construct is composed by three dimensions: a) knowledge and technological domain, b) actors and networks, and c) institutions. These dimensions are the behavioral domains of the *PBC* construct. They constitute three of the behavioral model´s determinants of willingness to engage in GCE-based eco-innovation processes.

Table 7.4 presented the hypothetical scenarios that were associated with the social and personal behavioral domains and their respective estimated willingness (W_{est}).

Table 7.4- Effects of changes in social and personal behavioral domains on willingness to engage in GCE-based eco-innovation processes

Scenarios	Attitude		Perceived Social Factors Pressure				Perceived Behavior Control			Estimated Willingness	% Improvement
	EVR	ER	SP	RLP	PN	SI	KTC	AN	INST	W_{est}	-
SCN10	3,41	6,00	5,09	6,47	6,44	6,38	7,00	5,59	4,50	6,15	6,04
SCN11	3,41	6,00	5,09	6,47	6,44	6,38	5,27	7,00	4,50	6,38	10,04
SCN12	3,41	6,00	5,09	6,47	6,44	6,38	5,27	5,59	7,00	5,92	1,97
SCN13	3,41	6,00	5,09	6,47	6,44	6,38	7,00	7,00	7,00	6,87	18,39
SCN14	3,41	6,00	5,09	6,47	6,44	6,38	7,00	7,00	4,50	6,75	16,25

Source: author

As expected, Table 7.4 shows higher contributions to the improvement of willingness. Such expectations were generated by the high correlation of willingness with the knowledge and technologies (0.702) and the actors and networks (0.818) behavioral domains (cf. Table 12.1 od Appendix D).

The individual influence of the knowledge and technologies' domain (*KTC*) on willingness was simulated by scenario *SCN10*. By changing this behavioral domain from its current condition (score 5.27) to its optimal level (7.00), a 6.04 percent increase was achieved in the estimated willingness (W_{est}) value. This increment was represented by a W_{est} score of 6.15.

The optimization of the current condition (score 5.59) relative to the actor's and network's behavioral domain (*AN*) (*SCN11*) demonstrated that this domain is the highest individual contributor to willingness formation. This statement is underpinned by the finding that it provided an estimated willingness score of 6.38, which corresponded to an increase of 10.04 percent in respect to the *BLS*.

The institutions' behavioral domain (*INST*) provided a much lower contribution to willingness when its optimal condition was simulated (*SCN12*). It produced a score of 5.92 corresponding to an improvement of 1.97 percent as compared to the *BLS* for the case in which its current condition (score 4.5) was elevated to its optimal possibility (score 7.00).

For reasons explained in section 7.2.1, along with the results of the simulations of willingness improvement, produced by the optimal conditions of *KTC*, *AN,* and *INST* individually, the joint influence of these behavioral domains were expected to produce the highest contribution to increasing companies´ willingness to engage in GCE-based eco-innovation processes.

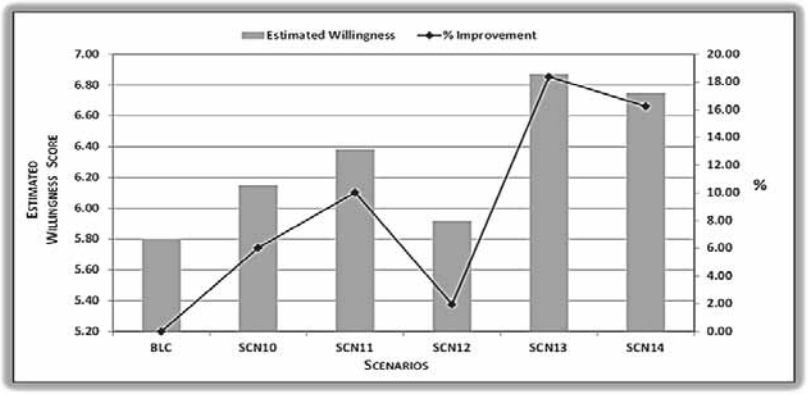
The simultaneous elevation of the *KTC*, *AN*, and *INST* behavioral domains to an optimal state, produced the highest improvement in the estimated willingness (*SCN13*). That corresponded to an estimated willingness score of 6.87, which resulted in an increase of 18.39 percent in willingness as compared to the baseline scenario.

A very similar result was obtained by only considering the two strongest contributors to willingness in the behavioral model´s *PCB* construct (*SCN14*). The *KTC* and *AN* domains

together, in their optimal conditions, contribute to an elevation of 16.25 percent in the estimated willingness and a corresponding score of 6.75.

The results of the estimated willingness based on the behavioral domains pertaining to the behavioral control domain are pictorially presented in Figure 7.4.

Figure 7.4- Results of willingness simulations regarding the behavioral control domain



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7.2.4 Willingness Change in Light of the Most Favorable Scenarios

In the preceding sections of Chapter 7, this thesis author explored the potentiality of changes, to this research´s model behavioral domains, in promoting enhancements in companies´ current willingness to engage in GCE-based eco-innovation processes. Thus far, this assessment was conducted by using each of the thesis research´s behavioral model constructs as the unit of analysis. That is, behavioral domains belonging to the attitudinal, social/personal and to the behavioral control realms were analyzed independently.

Section 7.2.4 integrated these realms and identified the combination, of behavioral domains belonging to different natures, which can produce the best overall results (the best favorable scenarios) for the development of policies/strategies aimed at stimulating companies to engage in such eco-innovation processes.

The most favorable scenarios were identified under the concept of "leverage points", which was discussed in Section 7.2. It refers to points in a system where small interventions can result in large changes.

Based on the behavioral domains that produced the largest contributions to willingness, combinations were conceived to provide the most favorable scenarios and, consequently, the "leverage points" could be identified and utilized to effect optimal changes.

Departing from scenario *SCN14*, in which companies have total control over the access to the opportunities and possess the requisite resources associated with:

a) knowledge and technologies (accessibility to knowledge, technological opportunities, appropriability of the results of innovation processes, technological and organizational capabilities and knowledge accumulation), and

b) The control over the innovation actors and networks (existence of innovation actors in the companies´ domains holding key capabilities, capability to participate in networks of collaborations, and to form strategic alliances with external actors),

scenario *SCN15* introduced a strong social pressure into the context.

As noted in Chapter 5, social pressure was comprised of three sources of pressures (market pressure, community pressure, and regulatory pressure) that can drive companies to more environmentally sustainable states. The addition of such pressures produced an estimated willingness score of 7.22, which represented an increase of 8.23 percent over *SCN14* and another 24.28 percent in relation to the *BLS*.

Building on scenario *SCN15*, scenario *SCN16* added up the perception of extremely low economic risk and extremely high business opportunities associated with the engagement in GCE-based eco-innovation processes. This scenario introduced a further improvement in the estimated willingness of 3.11 in respect to SCN15 and 27.59 percent relative to the *BLS* along with a score for willingness of 7.40.

Finally, the perception of extremely high environmental risk was introduced (*SCN16*). Although the sense of environmental risk perception was not a major contributor to willingness formation, it is this thesis author's belief that:

- The increase of managers´ perception of the environmental risks throughout the entire life cycle of companies´ products, processes and services, and
- Making clear and emphasizing the existing causal links that they have with the social and economic domain of their companies operation space

are very likely to influence decision-making processes and to induce very positive consequences for the sustainability of their companies in the short, medium and long run.

Based on these arguments and in the context of this research, the enhancement of managers´ perception of the environmental risks represented more than a contribution to willingness formation, it was an investment for the business sustainability of the company in the near, medium and long-term.

Scenario *SCN17* introduced minor improvement of willingness in respect to *SCN16* (1.77 percent) and elevated the gain up to 29.36 percent in relation to the baseline scenario (W_{est} = 7.51).

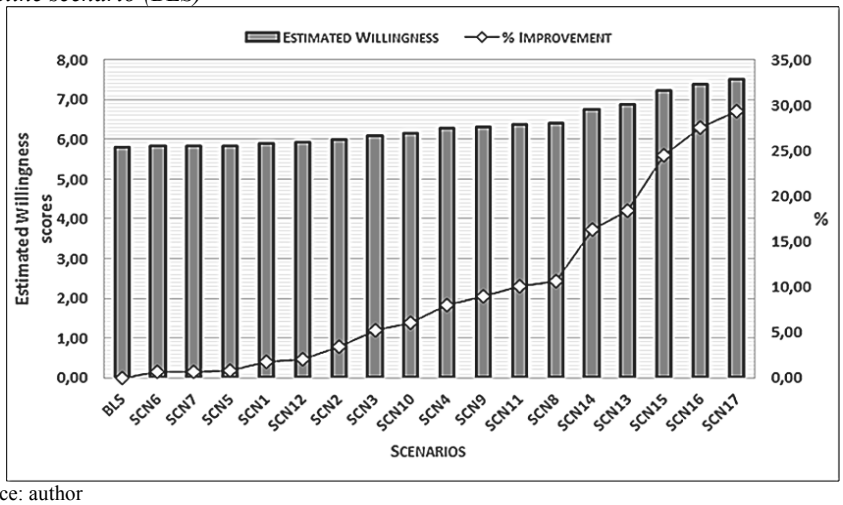
Table 7.5 and Figure 7.5 present an overall view of the simulation scenarios and their respective results. In order to facilitate the analysis in respect to the strength of the contributions of each scenario, they were ranked according to their ascendant influence on willingness formation as compared with the baseline scenario (*BLS*).

Table 7.5– Overall view of all willingness simulation scenarios and their respective results presented in the ascending order of contribution to willingness enhancement (West) relative to the baseline scenario (BLS)

Scenarios	Attitude		Perceived Social Factors Pressure				Perceived Behavior Control			Estimated Willingness	% Improvement
	EVR	ER	SP	RLP	PN	SI	KTC	AN	INST	W_{est}	-
BLS	3,41	6,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	5,80	0,00
SCN6	3,41	6,00	5,09	6,47	7,00	6,38	5,27	5,59	4,50	5,84	0,68
SCN7	3,41	6,00	5,09	6,47	6,44	7,00	5,27	5,59	4,50	5,84	0,68
SCN5	3,41	6,00	5,09	7,00	6,44	6,38	5,27	5,59	4,50	5,85	0,76
SCN1	7,00	6,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	5,91	1,77
SCN12	3,41	6,00	5,09	6,47	6,44	6,38	5,27	5,59	7,00	5,92	1,97
SCN2	3,41	7,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	6,00	3,44
SCN3	7,00	7,00	5,09	6,47	6,44	6,38	5,27	5,59	4,50	6,10	5,21
SCN10	3,41	6,00	5,09	6,47	6,44	6,38	7,00	5,59	4,50	6,15	6,04
SCN4	3,41	6,00	7,00	6,47	6,44	6,38	5,27	5,59	4,50	6,27	8,06
SCN9	3,41	6,00	7,00	7,00	6,44	6,38	5,27	5,59	4,50	6,32	8,99
SCN11	3,41	6,00	5,09	6,47	6,44	6,38	5,27	7,00	4,50	6,38	10,04
SCN8	3,41	6,00	7,00	7,00	7,00	7,00	5,27	5,59	4,50	6,42	10,68
SCN14	3,41	6,00	5,09	6,47	6,44	6,38	7,00	7,00	4,50	6,75	16,25
SCN13	3,41	6,00	5,09	6,47	6,44	6,38	7,00	7,00	7,00	6,87	18,39
SCN15	3,41	6,00	7,00	6,47	6,44	6,38	7,00	7,00	4,50	7,22	24,48
SCN16	3,41	7,00	7,00	6,47	6,44	6,38	7,00	7,00	4,50	7,40	27,59
SCN17	7,00	7,00	7,00	6,47	6,44	6,38	7,00	7,00	4,50	7,51	29,36

Source: author

Figure 7.5– Overall view of all simulation scenarios and their respective results presented in the ascending order of contribution to willingness enhancement (West) relative to the baseline scenario (BLS)



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7.2.5 Discussion

The previous analyses of the determinants of willingness presented in Chapter 6 and in the previous sections of Chapter 7, revealed relevant aspects in respect to the development of companies´ willingness in the context of this research.

The first relevant point was the fact that the mean score of willingness (5.8), obtained via the direct measure of willingness to engage in GCE-based eco-innovation processes, revealed that companies were willing to perform such behaviors. Therefore, the objective

of the simulations was not to find "leverage points" that supported the development of policies/strategies that could promote change in firms´ willingness from a state of not-willing to a state of willing. The true reason underpinning the identification of such elements was to elevate and strengthen the current state of willingness. It was proposed that it can be done *via* the development of policies and strategies aimed at the adoption of the GCE as a baseline supporting framework for innovative technological changes that can help companies, in the Brazilian petrochemical sector, to become more environmentally and economically sound due to its implementation.

Attitudinal Behavioral Domains

Another point that required attention was the low contribution of the behavior model´s attitudinal construct to willingness. According to Montalvo Corral (2002), this contrasts with the general wisdom within the environmental policy literature. A radical change towards a positive attitudinal disposition to protect the environment associated with a high environmental risk perception and a perception of low economic risk and high business opportunities achieved only minor contribution to willingness enhancement (*SCN3*). This result was similar to Montalvo Corral´s (*ibid*) findings in respect to the study of the determinants of willingness to innovate in the in-bond industry in northern Mexico.

It is also important to note the existence of significant positive correlations between the perception of economic risk and business opportunities (*ECR*) with the knowledge and technologies (0.502, < .01) and the actors and networks (0.625, < .01) behavioral domains (cf. Appendix D). Based on such relations, it can be argued that the increase of the perceptions of these risks and opportunities may be accompanied by the perception of the need for technological innovation capability building in order to decrease or eliminate such risks and to be prepared to profit from the business opportunities that eco-innovating in GCE can bring about.

In respect to the environmental risk perception (*EVR*), the analysis revealed that, besides being a poor predictor of willingness (*SCN1*), *EVR* correlated weakly with the other behavioral domains of this thesis research´s behavioral model (cf. Appendix D). The correlations, although weak, suggest that the environmental risk perception may be developed under social pressure (*SP*) (correlation coefficient of 0.302) and managers´ self-identification with environmental causes (*SI*) (0.251).

Social and Personal Normative Behavioral Domains

In respect to the social and personal determinants of willingness, two relevant issues became apparent:

a) The personal (moral) norm (*PN*) and the self-identity (*SI*) domains contributed only marginally to willingness enhancement (*SCN6* and *SCN7*). Although, according to some studies these domains have been proven to be independent predictors of intention (cf. Section 7.1.1), the results obtained in this thesis research, corroborate findings of a series of other studies in which such behavioral intention's independent predicting characters were only marginal. According to the same sources, such independency in predicting intention varies according to the behavior under study (see discussion in Section 7.1.1).
b) The social pressure behavioral domain (*SP*) (market pressure - *mp*, community pressure - *cp* and regulatory pressure - *mp*) emerged as the most influential

behavioral domain among the social and personal normative domains (scenario *SCN4*). Its positive correlations with the knowledge and technologies (*KTC*) (0.547, < .01) and actors and networks (*AN*) (0.632, < .01) behavioral domains suggested that pressures arising from the market (*mp*), from the community (*cp*) and from the regulatory (*rp*) realms can influence companies to incorporate or develop new and innovative technologies and network capabilities.

Behavioral Control over the Engagement in GCE-based Eco-Innovation Processes

The simulations involving the behavioral domains associated with the control over the requisites and opportunities for companies´ engagement in GCE-based eco-innovation processes provided a verification of what was predicated by the TPB. The TPB emphasized the importance of the control beliefs in behavioral intention (willingness) formation and in the actual performance of a given behavior.

The TPB was designed to predict behaviors that are not entirely under volitional control. Its relationship with the actual behavior is based on two rationales:

- "Holding intention constant, the likelihood that a behavior will be carried out increases with greater perceived behavioral control, and
- Perceived behavioral control will influence behavior directly to the extent that perceived control reflects actual control. In parallel, perceived behavioral control works in parallel with attitudes and subjective norms as a determinant of intentions." (Armitage and Conner, 1999; 36).

Montalvo Corral (2002: 166) illustrated the influence of the control beliefs in intention (willingness) formation by postulating that "in the case of any given firm having optimal attitudinal and normative predispositions to innovate, it was the volitional control that would ultimately determine the performance of any behavior".

The results of the simulations demonstrated that the stronger the organizations´ managers and key-decision makers perceived that their companies have access to the opportunities and possess the requisite resources, associated with the *PBC´*s behavioral domains, the more strongly inclined they will be to engage in eco-innovation activities in green chemistry and green engineering. The stronger the perception of behavioral control, the higher the behavior is under volitional control (Ajzen, 1991; Ajzen and Madden, 1986; Montalvo Corral, 2002).

Firms with low control over the opportunities and resources to engage in GCE-based eco-innovation processes will not be able to innovate even if they are willing to do so (cf. Montalvo Corral, *ibid*).

Such an expectation with respect to the power of control beliefs to determine willingness (intention) has been confirmed in this thesis research. Despite the low influence of the institutions behavioral domain (*INST*), the knowledge and technologies (*KTC*) and the actors and networks (*AN*) behavioral domains highly contributed to make the *PBC* the largest contributor to willingness formation in respect to the firms´ engagement in GCE-based eco-innovation processes.

7.3 Enhancing Willingness to Eco-Innovate: Sources for Policy Development

As noted in Chapter 3, this thesis research concerns the measurement of the current state of the Brazilian petrochemical sector´s willingness to incorporate the principles established by the Green Chemistry and Green Engineering (GCE) frameworks as economic and environmental development means. This requires innovation. Technological advancements from the current technological paradigms to more sustainable technological states guided by the principles of GCE required the pursuit, by the petrochemical companies, of innovative approaches to face current (and future) economic and environmental challenges. Such a journey to more sustainable technologies was considered, in this thesis research, to be mediated by companies' engagement in GCE-based eco-innovation systems (cf. Chapter 3 and Appendix H).

This work was built upon the assumption that such engagement is fundamentally dependent on companies´ behavioral change. In parallel, such behavioral change, was considered to be conditioned upon a series of factors associated with individuals´ attitude, with the perception of the social and personal pressures and with the perceived behavioral control over the requisites and opportunities for innovating in GCE.

According to the TPB, these perceptual elements are associated with cognitive traits of the managers and influential individuals in the realm of the Brazilian petrochemical sector. Based on this theory, it was proposed that in order to achieve an expanded degree of willingness, new knowledge may be required, new sources of knowledge acquisition may be needed, new technical and organizational capabilities may be mandatory, new institutions may be necessary, signs from the market may be essential and inputs from the social and regulatory dimensions may impose demands for more sustainable products, processes and services etc.

Up to this point, the discussion was focused on mapping such elements (cf. Chapter 5) and identifying those that can represent the main determinants of companies´ willingness to innovate in GCE as a main approach towards more sustainable states of their products, processes and services (cf. Section 6.2).

Stimulating companies to eco-innovate in GCE was found, in this study, to be synonymous to enhancing companies´ willingness to engage in such processes. This should be conducted *via* the development and implementation of appropriate policies and strategies that can guide the promotion of changes at both the meso-level (the petrochemical sector) and the micro-level (companies in the sector).

7.3.1 Basic Behavioral Elements as Inputs for Policy and Strategy Design

Section 7.2 presented the simulation results of the most favorable scenarios that can enhance Brazilian petrochemical companies´ willingness to engage deliberately in innovation systems aimed at the development or acquisition of GCE-based technological solutions for their current and envisioned sustainability challenges.

According to scenario *SCN17* (cf. Table 7.5), the combination of:

a) Companies´ perception of high environmental risk associated to their operations;
b) In situations of perceived low economic risk and high economic opportunities in relation to GCE-based eco-innovation;

c) Pressures from the market, from the community and from the regulatory organizations;
d) Companies´ high control over the requisites and opportunities related to knowledge, technologies and capabilities to form networks of cooperation and strategic alliances, and
e) The existence of appropriate actors holding key and innovation required capabilities and competences

constituted the most appropriate conditions under which willingness would reach its highest strength.

Scenario *SCN17* produced the highest stimulus for willingness enhancement. In this respect, the direct use of its elements in the development of policies and strategies, aimed at the promotion and facilitation of the engagement of companies in GCE-based eco-innovation processes, represent an effort to touch the "leverage points" for more effective policies. Identifying such points requires some elaboration and an assessment of some between-domains relations, which can help to identify best results with minimal policy development and implementation efforts.

Environmental Risk Perception: Direct and Indirect Influences in Willingness Determination

In the simulations conducted in Section 7.2.4, the environmental risk behavioral domain did not provide a relevant contribution to willingness enhancement (1.77 percent) (cf. Table 7.5). Although it is questionable if it should be considered to be a true leverage point, it was included in this analysis for philosophical and practical reasons.

a) As this sector "is one of the, or maybe the, most polluting sector in industrial societies" (Mol, 1995: 87), the philosophical reason relates to the need for a perception, on the part of the petrochemical companies´ managers, of the environmental risks regarding companies´ products, processes and services that goes down as far as the origins of the problems and not only addressees their effects;

   The simulations presented in Section 7.2 demonstrated that "when managers were assumed to be aware – that is when they cognitively associate - the possible environmental effects of their firms' operations, they were expected to perceive that their firms will be more willing to innovate in cleaner technologies" (Montalvo Corral, 2002: 172).
b) The practical reason comes from the need for the connection of the environmental risk domain with the perception of economic risk and business opportunities, which ultimately influence managers´ willingness to eco-innovate.

   The negative correlation between the environmental risk and the economic risk and business opportunities domain (cf. Table D1 in Appendix D), although weak, suggests that managers´ perception of low environmental risk relative to their companies´ operations, products and services was statistically associated with perceptions of low business opportunity and high economic risks associated with GCE-based eco-innovation processes.

The intensification of the manager's perceptions of their companies´ environmental risks is likely to make clear the need for a move to higher states of corporate sustainability. Such move is due to be conducted through cleaner and more sustainable innovative technologies, such as those that are based on GCE.

It is proposed that individuals that are more conscious of the environmental risks will be more prone to innovate. Because this stronger inclination to innovate, they will be more aware of the business opportunities that eco-innovation can bring about, at the same time that they will be more prepared to anticipate and to diminish the economic risks embodied in GCE-based eco-innovation processes.

That is, such awareness augmentation may push companies to take proper measures to decrease these economic risks and to take advantage of the business opportunities that may arise from the use of more sustainable GCE-based innovative solutions for the firm´s products, processes and services.

In parallel, the statistical correlations indicate that low economic risks and high business opportunities are positively correlated with the domains associated with the knowledge and technologies and actors and networks. This indicates that low economic risks and high business opportunities can be a direct result of companies´ increase of control over such the resources and opportunities associated with these domains..

This argumentation suggests that the false perception of safe operations may contribute to blindfolding companies in respect to: (1) the need for advanced states of sustainability of companies´ products, processes and services, which are achievable through GCE-based eco-innovation processes, (2) the market opportunities created by existing and future demands for more innovative and sustainable products, processes and services, and (3) the need for the anticipation of measures to overcome the economic risks associated with such immobilism and with the eco-innovation processes (e.g. appropriability of innovation, and technological and financial risks)

Based on these arguments, the development of policies and/or strategies aimed at promoting the perception of safe operations (cf. Section 6.2.1, in Chapter 6) to a perception of risky operations that can be conceived, developed and applied.

In this respect, it is expected that:

a) Making clear the existence, the nature and the extent of such environmental risks throughout the entire company's operations and product's life cycles, and
b) Making the proper associations with their consequences in respect not only to the biosphere and society, but also regarding their connection to the company´s business sustainability (economic, market, materials, energy etc.) (cf. Section 1.0 in Chapter 1),

will directly contribute to the perception of the need for innovative cleaner technological solutions such as those that are based on the principles predicated by the GCE framework.

This is likely to induce anticipated measures to overcome, or at least to reduce, the economic risks associated with such eco-innovation processes and to increase the potential for profiting from the business opportunities that may arise.

Such attitudinal changes induced by the modification of the managers´ and influential decision-makers´ risk perceptions, requires the support of elaborate and robust policies and strategies both at the meso (the sector) and at the micro level (the companies).

Based on the literature (Atman *et al*., 1994; Bostrom *et al*., 1994; Fishhoff, 1993; Lundgren and McMakin, 2009; Montalvo Corral, 2002; Morgan *et al*., 2009), it is plausible that the risk communication field provides companies with the proper theoretical and practical framework to support such policies and strategies.

For the context of this thesis research, "risk communication means communication intended to supply (…) people with the information they need to make informed, independent judgments about risks to health, safety and the environment" (Morgan *et al.*, 2002: 4).

Among the various approaches to communicating risk (cf. Lundgren and McMakin, 2009), the mental model approach seems particularly adequate to be brought into the context of this thesis research as a platform for policy development for attitudinal change regarding managers´ environmental risk perception.

The concept of mental model relates to how people view and understand various phenomena (Lundgren and McMakin, *ibid*).

> "In the absence of evidence, no one can predict confidently how to communicate about risk. Effective risk communication requires empirical study". (Morgan *et al*., 2002: 182)

According to Fishhoff *et al*. (1993), the best way to avoid misconceptions about such views and understanding is to generate evidence by capturing people´s entire mental model on a topic. "Doing so would also identify those correct beliefs upon which communications could be built (and which should be reinforced)" (*ibid*: 195).

Once mapped, this elicited mental model can be compared with an expert model and the gaps found between both models can provide the elements for developing a risk communication strategy. According to Fishhoff (*ibid*), communications:

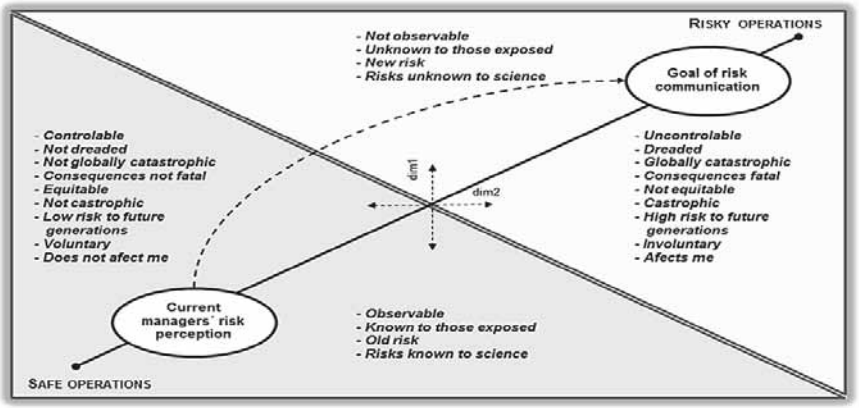
- Should be designed to convey a comprehensive picture of the processes by creating (and controlling) a risk;
- Could focus on cases where people confidently hold incorrect beliefs that could lead to inappropriate actions or lack the confidence in correct beliefs needed to act on them, and
- Could attempt to provide the pieces of information that have the largest possible impact on pending decisions.

In this thesis research, such beliefs were represented by those proposed by Slovic *et al*. (1984), which relate the environmental risks associated with the safe or risky character of firm´s operations. Such beliefs were presented in Section 5.2.2, in Chapter 5. In addition, Section 6.2.1 of Chapter 6 presented and discussed managers´ perceptions relative to them

(i.e. empirical evidence), which ultimately represented their mental models in respect to their companies´ operations environmental risks.

In light of these elements, it can be argued that risk communication policies, strategies and efforts can help to catalyze a shift of the managers´ perceptions from environmentally safe to environmentally risky operations. Figure 7.6 pictorially presents that type of shift.

Figure 7.6– Risk perception policy strategy proposed in this thesis research to shift managers' perception from companies´ safe to risky operations



Source: Montalvo Corral (2002)

Enhancing Willingness through the Perceived Social Pressures

The results of the regression analysis, presented in Table 7.1, as well as the simulations conducted in Section 7.2.4, identified the social pressure behavioral domain (*SP*) as one of the largest willingness´ determinants in the context of this thesis research. Such importance entitles this domain to be considered a "leverage point" in respect to the development of policies and strategies aimed at increasing managers´ willingness to deliberately engage in GCE-based eco-innovation processes.

As in the case of environmental risk perceptions, the *SP* domain also exerts influences on willingness in direct as well as in indirect fashion. Therefore, the knowledge of such influences is important to reinforce the importance of the development of "holistic" policies that could interconnect various determinants of willingness.

In this respect, although the direct influence of *SP* on willingness was demonstrated by the results of the statistical analyses presented in Appendices C and D, it also unveiled relations that suggested that such influences can also be exerted indirectly *via* other willingness determinants.

These relations were indicated by the bivariate correlations between the social pressure behavioral domains (*SP*) and two other important contributors to willingness determination: (a) knowledge and technologies (*KTC*), and (b) actors and networks (*AN*) domains, which pertain to the behavioral model´s *PBC* construct (cf. Chapter 5). These correlations are presented in Table 7.6 and Appendix D.

Example Appendix D (see page 402)

Table 12.1– Correlation analysis for the behavioral domain scales (behavioral model's second level of explanation)

	W	EVR	ECR	SP	RLP	PN	SI	KTC	AN	INST
W	1									
EVR	0.184*	1								
ECR	0.370*	-0.130*	1							
SP	0.764**	0,302	0,147	1						
RLP	0.642**	0,112	0,301	0,633**	1					
PN	0.377*	0,141	0,042	0.346*	0.629**	1				
SI	0.053*	0,251	0,213	0,083	0,324	0.735**	1			
KTC	0.702**	0,022	0.502**	0.547**	0.511**	0.368*	0,211	1		
AN	0.818**	0,038	0.625**	0.632**	0.698**	0.348*	0,155	0.757**	1	
INST	0.167**	0,014	0,196	0.207*	0.463**	0,274	-0,009	0.348**	0.342**	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 12.2- Correlation analysis for the direct measures of the behavioral domains (behavioral model's third level of explanation)

	W	evr	ecr	sp	rlp	pn	si	ktc	an	inst
W	1									
evr	0,096	1								
ecr	0,214	-.084*	1							
sp	0.649**	0,216	0.390*	1						
rlp	0.473*	0,307	0,181	0.394*	1					
pn	0.279*	.0382*	.0170*	0,321	0.644**	1				
si	0.122*	-0,015	0,199	0,324	0.657**	0.417*	1			
ktc	0.629**	0,128	0.457**	0.499**	0,292	0.366*	0,121	1		
an	0.833**	0,046	0.623**	0.540**	0,311	0,241	0,045	0.726**	1	
inst	0.114**	0.355*	0,096	0.602**	0.497**	0.179**	0,283	0.328**	0.587**	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 7.6– Correlations between the social pressure behavioral domain and its associated scales with the knowledge and technologies and actors and networks behavioral domains

	Behavioral Domains			Social Pressure Scales		
	KTC	*AN*	*SP*	Market Pressure (*mp*)	Community Pressure (*cp*)	Regulatory Pressure (*rp*)
KTC	1					
AN	0.757**	1				
SP	0.547**	0.632**	1			
Market Pressure (*mp*)	0.546**	0.701**	0.529**	1		
Community Pressure (*cp*)	0.562**	0.627**	0.712**	0.789**	1	
Regulatory Pressure (*rp*)	0.400*	0.522**	0.764**	0.572**	0.605**	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
Source: author

As this thesis research´s methodological approach considered the managers´ beliefs the cornerstone for the development of policies and strategies, the influence of social pressure was also assessed at the *SP* behavioral domain´s scales level (*mp*, c*p and rp*).

At this level of analysis, the market pressure (*mp*), the community pressure (*cp*) and the regulatory pressure (*rp*) scales also correlated positively at a significant level with the *PCB* domains.

From these evidences, it can be argued that the data obtained by this thesis researcher´s quantitative survey for the domain level (*SP)* and for the domain scales level (*mp*, *cp* and *rp*), can establish direct causal relationships with *KTC* and *AN* behavioral domains, which can ultimately influence willingness.

Given the importance of social pressure in stimulating managers' willingness to engage deliberately in GCE-based eco-innovation processes, it becomes necessary to propose the development of the appropriate policies for building up the capabilities required to capture the pressures arising from the market (*mp*), from the community (*cp*) and from the regulatory set (*rp*). These pressures regard the need for companies to develop, use and provide innovative cleaner and more environmentally and economically sustainable products, processes and services.

This thesis research contributed with policy efforts by eliciting companies´ managers' significant beliefs based on which more efficient and effective policies can be developed. Therefore, this can help "to overcome the long chain of resistance to change from individuals and organizations" (Montalvo Corral, 2002: 2).

The results of the analysis of variance (cf. Appendix C), presented in Table 7.7, showed that four beliefs accounted for 81 percent of the variance of social pressure. According to Table 7.7, the influence exerted by trade and industry representative organizations (e.g. ABIQUIM and ICCA)[100] *via* agreements and initiatives (e.g. ISO norms series 14000 and

[100] ABIQUIM - Brazilian Chemical Industry Association
ICCA – International Council of Chemical Associations

26000, Responsible Care Program[101], Global Product Strategy[102] etc.) (*rp5*) accounted for 38.4 percent of the explained variance. It was closely followed by concerns about the community´s near future lobbying capability towards cleaner and more sustainable products, processes and services. According to this perception, it was expected that these lobbying initiatives would exert pressures that will be strong enough to push companies to engage in GCE-based eco-innovation processes (*cp11*). This belief accounted for 30.37 percent of the variance.

In parallel, beliefs regarding the governmental organizations´ power to enforce legislation, although at a lower level, were also significant.

In this respect, the perception that the environmental regulatory agencies have a strong position in respect to the adoption, by companies, of cleaner and more sustainable products, processes and services (*rp1*) accounted for 7.06 percent of the variance. This reflected the perception of the managers in respect to the likelihood that future regulations will push companies to pursue advanced states of environmental performance. This belief accounted for 5.29 percent of the variance.

Table 7.7– Significant beliefs on the determination of social pressures to effect changes in behavior within the Brazilian Chemical Industry's companies. Limitations

Beliefs scales	Beliefs	% Variance explained (cumulative)	% Variance explained (beliefs)
Regulatory Pressure (national and international standards, trade organizations and agreements)	Influence exerted by ISO, ICCA and ABIQUIM	38,4	38,4
Regulatory Pressure (regulators)	Environmental agencies	45,47	7,06
Social Pressure	Community future lobbying capability	75,83	30,37
Regulatory Pressure (regulators)	Risk of future regulations	81,12	5,29

Source: author

These findings indicated that these beliefs pertain to the regulatory pressure (*rp*) and to the community pressure (*cp*) in the social pressure behavioral domain scales. Surprisingly,

[101] "Responsible Care is a voluntary initiative, designed to help the chemical industry to continuously improve its performance in areas related to health, safety and the environment. Launched in Canada in 1985 by the Canadian Chemical Producers Association - CCPA, Responsible Care was adopted by the Brazilian chemical industry, represented by ABIQUIM, in April 1992".
Source: ABIQUIM (http://www.abiquim.org.br/english/content.asp?princ=rec&pag=pre), accessed in July, 2012.

[102] "The Global Product Strategy (GPS), an initiative developed by the International Council of Chemical Associations and launched in 2006, builds on the product stewardship elements of industry's voluntary Responsible Care initiative. GPS aims to improve the safe management of chemicals, harmonize approaches between developing, emerging and industrialized regions, and strengthen public confidence that our products are handled safely at all stages of the life cycle. Together with the Responsible Care Global Charter, the GPS positions industry as a constructive contributor to the UN-led Strategic Approach to International Chemicals Management (SAICM)".
Source: The European Chemical Industry Council (http://www.cefic.org/Regulatory-Framework/Voluntary-Initiatives1/Global-Product-Strategy/), accessed in July, 2012.

none of the beliefs pertaining to the market pressure (*mp*) realm was found to be statistically significant and salient.

One factor that may partially clarify these results is the small sample size obtained from the research survey. As noted in Appendix C, in multiple regression analyses, small sample sizes can fail to detect some weaker relations and only strong relations between variables were expected to be detected. The larger the sample size the greater the sensitivity of the multiple regressions to capture weaker relations.

Besides such evidence, it can be argued that, in the context of this thesis research, the relevance of the market pressures may not be completely ignored as the perceptions of managers and key decision-makers, captured by the qualitative and quantitative surveys (cf. Table 6.10 and Section 7.4.1), demonstrated that they are sensitive to this issue. In addition, the market pressure may be indirectly present *via* the influences that are exerted by the trade associations and agreements whose initiatives are usually the result of the pressures of the ample "landscape" (cf. Section 2.3.1 of Chapter 2 for the definition of landscape) on the chemical sector. Such pressures commonly arise from the socio-economic and environmental set and usually contain elements of market pressure. In addition, market pressures may increase in the coming years as they have already done in Europe and some other parts of the world.

Enhancing the Behavioral Control over the Resources for Eco-Innovation

As previously noted in Chapter 3 and in Section 6.2, the *PCB* construct proposed by the TPB (Ajzen, 1991), represents the element of the theory, which considers the behavioral volitional control. According to the TPB, such characteristic of the *PBC* provides it with the possibility to influence the performance of a given behavior not only *via* its contribution to the determination of the behavioral intention but also by directly influencing individuals to undertake such behavior.

> "(…) perceived behavioral control will influence behavior directly to the extent that perceived control reflects actual control. In addition, perceived behavioral control works in parallel with attitudes and subjective norms as a determinant of intentions." (Armitage and Conner, 1999; 36)

In this thesis research´s domain, the *PBC* construct emerged as the largest determinant of willingness as compared to the behavioral model´s other constructs (*A* and *PSFP*). In this domain, two behavioral domains stood out as the most important contributors to willingness: (a) the knowledge and technologies (*KTC*), and (b) the actors and networks (*AN*).

Given the importance of these behavioral domains in explaining willingness to engage in GCE-based eco-innovation processes, it became important to propose policies that could develop the capabilities that permeate these domains.

Knowledge and Technologies: Sources for the Development of Eco-Innovation Policies

Knowledge and technologies constitute one of the pillars of the concept of Sectoral System of Innovation (SSI) (Malerba, 2002, 2004, 2005a, 2005b) (cf. Section 5.2.2). Section 5.2.2

besides providing an explanation about its importance for innovation in sectors, it also posed a basic question that is fully pertinent to the discussion conducted in this section in respect to eco-innovating in GCE.

It relates to the requisites that are required for knowledge and technologies to be developed and incorporated either by firms in a given sector or by the sector itself.

Once these prerequisites were identified, two other questions remained. The first was related to the degree of control that companies´ leaders perceive to have over these requirements (perceived behavior control). The second was associated with the existence of opportunities for innovation processes to be implemented so that company managers feel confident and willing to invest and engage in innovative activities

The answers to these questions are not simple and require elaboration and detailed, careful planning. Sometimes *ad hoc* solutions were necessary to cope with companies´ and sectors´ specificities. Although undertaking efforts to provide such answers was out of the scope of this thesis research, it can be argued that the elements that these questions address represent objectives to be pursued in the innovation realm and that they can be approached *via* the conception, development and implementation of appropriate, efficient and effective policies.

As stated earlier, the core beliefs that were related to knowledge and technologies policy development were identified *via* the regression analysis of the knowledge and technologies behavioral domain (*KTC*) against its associated beliefs (domains scales). The results of this analysis were presented in Appendix C and in Table 7.8.

Table 7.8- Significant beliefs in the determination of the perceived behavioral control relative to knowledge and technologies[103]

Beliefs scales	Beliefs	% Variance explained (cumulative)	% Variance explained (beliefs)
Knowledge integration	Self-management teams	52,39	53,39
Advanced technological innovation capabilities	Development of new production systems	71,61	19,21
Technological opportunities	Advances in scientific understanding and technique	80,35	8,74
Accessibility to knowledge	Knowledge external to the sector	87,44	7,09
Technological opportunities	Technological advances from other industries and private and governmental organizations	89,33	1,89
Capabilities versus organizational structure	Hierarchies of capabilities correspondence with authority-based hierarchies	91,06	1,73
Learning processes	Integration of learning processes	92,48	1,42
Advanced technological innovation capabilities	Colaboration with suppliers and partners for technological development	93,77	1,29

Source: author [104].

[103] Some beliefs pertain to the same belief scales. For the complete list of the belief scales, their associated beliefs and acronyms refer to Chapter 7.

[104] Methodological note: the screening of what beliefs need to be influenced or changed in order to modify the managers´ pre-disposition to engage in Green Chemistry and Green Engineering based eco-innovation processes was conducted in two steps. First a stepwise regression was performed to screen the beliefs that accounted for most of the variance. Second, the beliefs included in the selected model from the stepwise regression were run again in a forward regression to assess their individual contributions to explain the dependent variable.

To provide a better interpretation of the data presented in Table 7.8, they were presented and explained, in the following paragraphs, in the following way: (a) the beliefs were clustered according their belief scales, (b) the values of the variance were computed to provide a single value for the variance explained by each of the belief scales, and (c) the beliefs were presented according to the descending order of the values of their belief scale's explanation power.

According to these results, the belief related to the existence, efficiency and effectiveness of self-management teams in firms (*cmt20*)[105] was documented to be of very high salience as it accounted for the 53.39 percent of the variance. Self-management teams refer to a knowledge integration mechanism for complex and non-routine organizational tasks especially when task uncertainty, novelty, and complexity precluded the use of existing routines or directives.

The realm of the advanced technological innovation capabilities (research based) also emerged as salient. This belief scale accounted for 20.50 percent of the variance explanation. In this respect, the capabilities required to develop new production systems (*cmt12*) was found to be a significant belief that accounted for 19.21 percent of the variance. It was followed by the belief associated with the collaboration with suppliers and partners for technological development (*cmt16*), which accounted for 1.29 percent of the variance.

At a lower level of variance accountability, the beliefs pertaining to the technological opportunities scale explained 10.63 percent of the variance. This result was obtained by the joint contribution of two beliefs: (a) the belief associated with the technological opportunities arising from advances in scientific understanding and techniques that accounted for 8.74 percent of the variance, and (b) and the technological opportunities that can be identified in the technological advances in other industries and private and governmental organizations (1.29 percent).

In terms of access to accessibility knowledge, the prevailing belief was related to knowledge that is external to the sector (governmental research centers, national and international universities, independent inventors, technology supplier organizations etc.) (*ak2*). Such access was seen as possible through, among others, technology purchase and cooperation agreements. This belief accounted for 7.09 of the variance.

Organizational capabilities were also found to be significant. The correspondence of the capabilities hierarchies with the authority-based hierarchies (*cmt21*) accounted for 1.73 percent of the variance. This belief had was supported by the premise that "if knowledge is to be integrated effectively by the firm, the architecture of capabilities must have some correspondence with the firm's structure of authority, communication, and decision-making, whether formal or informal" (Grant, 1996a: 378).

Finally, significance was detected in respect to the learning processes. The belief associated with the learning processes and knowledge acquisition (knowledge internalization and externalization) mechanisms (*cmt5*) accounted for 1.42 percent of the variance.

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[105] These notations along these Sections refer to the identification of the question or statement in the thesis research´s questionnaire and can be found in details in Chapter 7.

Actors and Networks: Sources for the Development of Eco-Innovation Policies

The actors and networks behavioral domain (*AN*) incorporates the concept that knowledge creation and innovation are increasingly an outcome of interaction among actors belonging to the same or from different market and non-market organizations (Cesaroni *et al*., 2004).

As in the case of the analysis regarding the knowledge and technologies behavioral domain that was presented in the preceding section, the core beliefs related to actors and networks policy development were identified *via* the regression analysis of the actors and networks behavioral domain (*AN*) against its associated beliefs (domains scales). The results of the regression analysis relative to the actors and networks behavioral domain are presented in Appendix C and in Table 7.9.

Table 7.9- Significant beliefs in the determination of the perceived behavioral control relative to actors and networks

Beliefs scales	Beliefs	% Variance explained (cumulative)	% Variance explained (beliefs)
Availability of corporate actors holding key capabilities	Culture building, motivation and participation	58,00	58,00
Networks of Collaboration	Consutlancies	68,31	10,31
Strategic Alliances with External Actors	Support from CEO and sharehorders	72,49	4,19
Availability of corporate actors holding key capabilities	Polifunctionality and technological knowledge	76,41	3,91
Networks of Collaboration	Specialized engineering firms (SEF)	80,71	4,3

Source: author

The presentation and explanation of the results followed the procedure used in the preceding section.

According to Table 7.9, the regression of the actors and networks behavioral domain (*AN*) against its associated scales revealed that, the sum of the beliefs of the scales related to the availability of corporate actors holding key capabilities to innovate accounted for most of the variance (61.91 percent).

Within this realm, two beliefs were documented to be significant. The first belief, accounting for 58.0 percent of the variance, was the availability of actors within the companies´ domains holding the capabilities that are required to build and disseminate the culture associated with the GCE as well as the culture of corporate sustainability (*avc5*). The second significant belief in the scale, relates to the availability of polifunctional professionals (*avc1*). Such polifunctionality includes the capability of speaking one or more professional languages, which allows for the interpretation of companies´ challenges in different perspectives. Such an "holistic" view can be an important element in the dynamics of innovation processes.

Additionally, the beliefs pertaining to the networks of collaboration accounted for 14.61 percent of the variance. In this realm, the engagement in techno-scientific networks of collaboration with consultancies (10.31 percent) and with specialized engineering firms (*SEF*) (4.3 percent) for the development or acquisition of GCE-based solutions for the companies´ environmental sustainability challenges emerged as the significant beliefs.

The undertaking of GCE-based eco-innovation initiatives may require the constitution of strategic alliances with external actors and new capabilities building, which can only be possible in the presence of strong support and commitment by the firms´ CEO´s and shareholders. The significance of this belief (*sac7*) was captured by the regression analysis and accounted for 4.19 percent of the variance.

7.4 Verifying and Expanding upon the Research´s Findings

The results generated by this thesis research´s quantitative survey and by the subsequent statistical analyses, revealed that, according to the surveyed managers and important decision-makers, companies in the Brazilian Petrochemical sector, are willing to accept and to build upon the GCE frameworks and to engage in GCE-based eco-innovation processes (cf. Section 6.5 of Chapter 6). In parallel, they also identified the important determinants that underlay the development of that willingness (cf. Chapters 6 and 7).

Although those results provided clear information, it lacked insight into managers´ underlying motivations for the development of such willingness and on the relations between the company and the different agents at the sector level regarding the promotion, diffusion, and implementation of GCE-based initiatives in the Brazilian Petrochemical Sector context.

In order to overcome this shortcoming, this thesis author conducted qualitative research with important agents at the company, at the sectoral levels and with agents at the Environmental Protection agency. As noted in Section 4.7, this investigation was conducted *via* a series of in-depth, face-to-face interviews that were based on open-ended questions. As a way to deepen this researcher's knowledge, these interviews were designed and developed based on the thesis' quantitative survey results (cf. Chapter 6 and previous Sections of Chapter 7) and were designed to:

a) Evaluate the validity of the qualitative survey findings through triangulation (cf. Section 4.7 in Chapter 4);
b) Gain a deeper understanding of the underlying motivational elements of corporate leader's willingness to implement GCE;
c) Explore the relations between the company and different agents at the sectoral levels with regard the responsibilities and incentives for the promotion and implementation of GCE-based initiatives;
d) Identify current and future initiatives that reflect and support the company's willingness to go beyond willingness to implement actual CGE innovative technological and management solutions for their policies, products, processes and services;
e) Document the current state of the use of the GCE principles in the Brazilian petrochemical sector.

Because this thesis' quantitative survey results revealed the importance of meso-level agents as significant determinants of companies´ willingness, it was, therefore, important to include such agents in the qualitative interview process. In that context, such agents were represented by the Brazilian chemical and petrochemical sectors´ trade association (ABIQUIM) and by the Environmental Protection Agencies in the Brazilian territory.

7.4.1- In-depth Interviews at the Micro-Level within the Companies

At the company level, in order to achieve these objectives and to obtain the required information, the structure and the interview guide (cf. Appendix F) were constructed based on the following eight points presented in Table 7.10:

Table 7.10- Structure of the in-depth interviews conducted with company managers and other relevant decision-makers.

1	• Perceptions on the importance of sustainable development and sustainability for the petrochemical sector.
2	• Perceptions on the benefits of Green Chemistry and Green Engineering (GCE), the likelihood of their acceptation and the company´s engagement in GCE-based eco-innovation initiatives.
3	• The level of agreement with the thesis research´s qualitative survey´s findings; • Contributions and the benefits of these findings to clarifying and improving company's knowledge in respect to eco-innovation determinants; • Contributions of the findings to promoting and facilitating to effect eco-innovation technological changes in the company.
4	• Perceptions on the importance of the development of eco-innovation policies based on the thesis research´s findings for the introduction, diffusion and incentivizing GCE based eco-innovation at the company and the sector levels.
5	• Perceptions on the importance of ABIQUIM and its "Responsible Care Program" in the process of disseminating, supporting and fostering the use of the GCE frameworks in the Brazilian Petrochemical sector.
6	• The existence of current and future planned sustainability initiatives that: (a) support the development of a sustainable development culture, and (b) promote and facilitate the acceptance, incorporation and the implementation of GCE practices at the company level; • Changes (organizational, personal, learning processes, knowledge base, institutional etc.) that have been required for the company to introduce, implement and manage these initiatives.
7	• Perceptions and comments on the thesis research´s recommendations and the identifications of missing points.
8	• Verification of GCE principles that are already in use by the company even if they are not related to the GCE frameworks as proposed in this thesis research.

Source: author

Perceptions of the Importance of Sustainable Development and Sustainability for the Petrochemical Sector

As noted throughout this thesis research, GCE encompasses concepts and principles that are firmly tied to and were developed under the overarching concepts of Sustainability (S) and Sustainable Development (SD).

In this context, this thesis author sought to obtain insights into the perceived applicability of GCE concepts and principles within the industrial realm, and to determine if industrial leaders are conscious of the need for the adoption of sustainable practices based upon GCE. That means that they must be convinced that the long-term survival of their companies is dependent on an increasing harmony and balance of their businesses with the societal and environmental demands *via* the use of practices that are socially accepted, environmentally friendly and economically feasible in both the short and longer-term.

In this regard, willingness of companies to accept GCE and to engage in GCE-based eco-innovation initiatives can be linked to and be justified by the strength of the perceptions and motivations of managers of how important S and SD are for the survival and the prosperity of their firm, in the short and long run.

Table 7.11 presented the degree of acceptance and summaries of the perceptions and motivations of the interviewed managers and decision-makers regarding the importance of the adoption of sustainable practices in the survival of their companies. The interview protocol was presented in Appendix F.

Table 7.11- Manager's perceptions and motivations regarding sustainability, sustainable development and green chemistry and green engineering

RESPONDENT	DEGREE OF IMPORTANCE	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING SUSTAINABILITY, SUSTAINABLE DEVELOPMENT, GREEN CHEMISTRY AND GREEN ENGINEERING
1	High	• Sustainability and sustainable development are the base and the pillars of the long-term existence, survival and success of the organizations. Organizations that intend to exist and succeed, in the long-term, must adhere to sustainability concepts and practices.
2	High	• Unsustainable companies will not overcome the selection processes imposed by nature, by the market and by societies unless they implement GCE concepts and procedures • Sustainability; innovation, green chemistry and green engineering are basic for the survival of the company in the long-term. They are *sine qua non* conditions for the success and the sustainability of their firm
3	High	• The role played by GCE in the journey to advanced states of corporate sustainability was highlighted repeatedly by this respondent. • Sustainability; innovation, green chemistry and green engineering are basic for the survival of the company in the long-term. They are *sine qua non* conditions for the success and the sustainability of their firm.
4	High	• The search for, adoption and implementation of economically viable GCE-based solutions, in the petrochemical sector, is essential for the future of my company. • The adoption of S, SD and GCE concepts by the company is not just a way to demonstrate its commitment to environmental and social causes. It is also a strong concern with regard to its economic sustainability.
5	High	• Demonstrating to be socially, economically and environmentally responsible has become a major point in companies' marketing strategies. • Micro, meso and large-scale environmental problems of anthropogenic origin are already visible. Becoming increasingly sustainable is fundamental for companies to survive in the medium and long term as costs of materials, energy, and water are increasingly rising. • It is mandatory for industry and society to find and to implement renewable alternatives. If old industrial practices of production persist, they will eventually result in the unsustainability and collapse of the petrochemical companies.
6	High	• The petrochemical sector is in a globalized market, competition and business universe. Therefore, sustainability-related pressures do not arise only at the country level but also at the global level.

Source: author

Summary

The summation of these responses provided a clear and undisputable picture of the high importance that was given, by the companies´ managers, to corporate sustainability and its relationship to their firm's survival. It also revealed that the underlying motivations reside and cover the multi-dimensions of the concept of sustainability including its social, economic and environmental pillars.

The responses corroborate the thesis' quantitative survey findings with regard to the direct positive relations of managers´ pro-sustainability posture and their acceptance of GCE initiatives as a mainstream contributor to corporate sustainable development.

Perceptions of the Benefits of Green Chemistry and Green Engineering (GCE): the Prospective of their Acceptance and Companies´ Engagement in GCE-Based Eco-Innovation Initiatives.

As noted in Section 4.7, in Chapter 4, one of the overarching objectives of the in-depth interviews was to use them to independently test the validity of the thesis survey´s quantitative survey findings.

In this regard, the first point that required testing was the extent to which managers and decision-makers are willing to accept GCE and to engage deliberately in GCE-based eco-innovation initiatives. In addition, this approach was very useful to help the author to discover and to map their basic underlying general perceptions and motivations for implementing GCE-based approaches within their companies.

It is important to note that many principles that are included in the GCE frameworks were already in use in the companies. They were introduced *via* diffuse sources and initiatives none of them was specifically and directly related to the GCE frameworks. They were introduced based both on structured and intuitive ways. In none of these cases was the introduction of planned and structured initiatives conducted at the sectoral and/or the company level, to promote and disseminate the frameworks that were proposed in this thesis.

This explained the reason why no manager reported to have previous knowledge of these frameworks and showed lack of knowledge on some of their principles. Such knowledge varied across the interviewed companies. Based on these arguments, this question was made based upon the premise that the GCE frameworks still have to be promoted at the sectoral and company levels. A view on the extent of the use of the GCE principles in the interviewed companies was presented in the last question of Section 7.4.1.

In order to avoid misunderstandings, it was important to make it explicit that these frameworks were: (a) the Green Chemistry framework proposed by Paul Anastas and John Warner (cf. Section 2.2.1 of Chapter 2) and (b) the Green Engineering framework proposed by Paul Anastas and Julie Zimmerman (cf. Section 2.2.2 of Chapter 2).

Table 7.12 presented summaries of managers´ and decision-makers´ perceptions and motivations regarding the likelihood that their companies will undertake initiatives to acquire and/or to develop GCE based technological solutions once the GCE frameworks are diffused and disseminated at the company and/or the sector level. The interview protocol was presented in Appendix F.

Table 7.12- Managers´ perceptions and motivations regarding the likelihood of companies' adoption of the Green Chemistry and Green Engineering Frameworks for Undertaking Eco-Innovation Initiatives

RESPONDENT	LIKELIHOOD OF ADOPTION (LIKELY-UNLIKELY)	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE LIKELIHOOD OF COMPANIES´ ADOPTION OF THE GREEN CHEMISTRY AND GREEN ENGINEERING FRAMEWORKS FOR UNDERTAKING ECO-INNOVATION INITIATIVES
1	Very likely	• Once the GCE principles are well known and understood they are very likely to be accepted. The majority of companies are conscious about the importance and the necessity of the use of increasingly cleaner and more sustainable technologies. • It is rare for a CEO or a manager in a petrochemical company not to be acquainted with at least some of the principles of GCE. The GCE frameworks provide companies with important guidance for the development and production or use of cleaner products, processes and services. • Although environmental principles are well accepted and understood, costs and economic returns are key points in the choice of technologies. Currently, less sustainable technologies, which are socially accepted, are very likely to be chosen over GCE technologies that produce less economic returns. • The amount of investment that is needed for acquiring or developing GCE innovative technologies and underscored the need for governmental support for their implementation.
2	Very likely	• As the company highly values questioning and knowledge, once the GCE principles are well known and understood they are very likely to be accepted. • When individuals at the company perceive that the GCE-based solutions are possible, feasible and effective, they will be more willing to adopt and apply them in the development of new cleaner and more sustainable solutions for the company's products, processes and services. • The company leaders see sustainability-related spending as investments and not as costs. Therefore, GCE based eco-innovation initiatives perfectly fit the company's investment policies and strategies. • The GCE concepts have strong support in the company´s sustainability and business policies. The GCE principles embody ethical factors that are in full harmony with the policies and principles that guide his company´s operations.
3	Quite likely	• The respondent called attention to the importance of knowledge in promoting changes towards sustainability. • The knowledge embodied in the GCE principles educate, guide and facilitate decision-making towards more sustainable products, processes and services. • Environmental and market motivations are very important drivers for companies to make improvements based on more sustainable technologies.
4	Quite likely	• The GCE principles are useful guidelines for his decision-making processes for the actual development of

RESPONDENT	LIKELIHOOD OF ADOPTION (LIKELY-UNLIKELY)	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE LIKELIHOOD OF COMPANIES´ ADOPTION OF THE GREEN CHEMISTRY AND GREEN ENGINEERING FRAMEWORKS FOR UNDERTAKING ECO-INNOVATION INITIATIVES
		cleaner and more sustainable solutions for products, processes and services. • Although the GCE concepts are very likely to be accepted by the company, the likelihood of their implementation increases as the GCE-based solutions are proven to be economically viable and there is the availability of the required means (internal and external to the company) for the development and implementation of GCE-based solutions. • If such solutions are proven to be economically feasible, the adoption of the GCE principles for the development of new solutions for the company's products, processes and services will contribute to the company's economic sustainability.
5	Very likely	• The respondent did not anticipate resistance, on the part of his company, regarding the adoption and the implementation of the GCE frameworks. • It is also important that GCE are promoted at the sector level by the chemical and petrochemical sector trade association (ABIQUIM). • The company is associated to ABIQUIM and is signatory of ABIQUIM´s Responsible Care Program (RCP). Because both, RCP and the company, are committed to sustainability, the acceptance of GCE is very likely to occur • GCE concepts have strong support in their companies´ sustainability and business policies.
6	Very likely	• The company is strongly sustainability and sustainable development oriented. • Many directives, guidelines, principles that have been incorporated to the company's institutional set, both in a structured and in an intuitive fashion, match the GCE principles. Such elements have been used as guidance to select and implement more advanced cleaner technological solutions • It is very likely that my company will incorporate the GCE frameworks, in a structured way, as the baseline for the development of technical solutions towards more sustainable products, processes and services. • It is part of the culture of my company to move beyond legislation regarding sustainability issues. Engaging in innovation-based GCE eco-innovation processes is a natural move into the company's consolidated journey to sustainability. • The respondent added that a sector level promotion and diffusion of the GCE frameworks could facilitate their implementation as official baseline principles for technological development.

Source: author

Summary

The analysis of the responses produced the following observations and insights:

a) The respondents were unanimously in favor of the use of GCE as a baseline framework for the promotion of technological changes towards advanced sustainability states of their companies;
b) The acceptance was dependent on a solid acquaintance of the GCE principles on the part of the company personnel and on the likelihood of GCE to produce economically feasible products and processes;
c) The promotion and the dissemination of the GCE principles at the petrochemical sector level are very important elements for the engagement of their companies in GCE-based initiatives. In this regard, the chemical and petrochemical sector's trade association (ABIQUIM) plays an important and fundamental role in promoting and disseminating the GCE frameworks throughout the sector;
d) Although stated in many different forms, the respondents agreed upon the drivers for the acceptance of GCE and the implementation of GCE-based approaches. The drivers are based upon the conceptual grounds of social, economic and environmental dimensions of sustainability and of the companies' responsibility to contribute positively to societal and to their corporate sustainability. This thesis author observed that these perceptions and motivations are the results of the change of culture regarding companies' environmental and socio-economic relations during the last decades;
e) Some managers stated that their acceptance of GCE and that companies´ engagement in GCE-based initiatives are contingent on the availability of adequate and proper financial and human resources. This view corroborated the premises of the Theory of Planned Behavior (TPB) regarding the intention to perform a behavior or the performance of the behavior itself. According to the TPB, the intention to perform a behavior will be produced as individuals perceive that they hold the required resources and opportunities (cf. Chapter 5). In relation to this thesis research, such resources are associated with the realms of knowledge and technologies, actors and networks and institutions.

Conclusions from this Thesis Research´s Qualitative Survey Findings: Agreement with the Results and Perceived Contributions and Benefits to Knowledge, Eco-innovation and Technological Change

This section was designed to document the interviewed managers´ perceptions and beliefs regarding the extent to which:

a) They agreed with this thesis research qualitative survey´s findings,
b) The findings can contribute to clarifying and improving company's knowledge in respect to eco-innovation determinants and
c) Appropriate knowledge can help to promote and facilitate to effect the eco-innovation based technological changes towards more sustainable states in their company's.

Table 7.13 presents summaries of managers´ and other decision-makers´ perceptions regarding these issues. The interview protocol was presented in Appendix F.

Table 7.13- Managers´ degree of agreement with this thesis' research findings and their perceptions of the findings contributions to companies´ knowledge on eco-innovation determinants and to the promotion of Green Chemistry and Green Engineering

RESPONDENT	AGREED - DISAGREED	MANAGERS´ DEGREE OF AGREEMENT WITH THIS RESEARCH FINDINGS, PERCEPTIONS OF THE FINDINGS´ CONTRIBUTION TO COMPANIES´ KNOWLEDGE AND TO THE PROMOTION OF GREEN CHEMISTRY AND GREEN ENGINEERING
1	Agreed	• The respondent agreed with the results of this thesis research and reported that they will have positive impacts on companies and on the sector. • The results represented a true picture of the sector's reality. Since they reflect perceptions of the sector's managers, regarding eco-innovation and GCE, a positive impact will be generated at the sector and the company levels. • The results will provide ABIQUIM, governments and the petrochemical companies with important information, which can help and guide them to plan and to effect technological advancements towards sustainability in the industrial domain. • The research was very comprehensive and the results revealed important determinants of GCE-based eco-innovation and their links to key agents who can ultimately influence, support and promote technological changes in the petrochemical domain such as companies, ABIQUIM, environmental agencies, market etc. • The integration of the knowledge and information, produced by this thesis research, into the company's planning and decision-making processes can effectively contribute to enrich and to facilitate the establishment and the development of eco-innovation processes.
2	Agreed	• The respondent agreed with the results and stated that they reflect and encompass very important and relevant issues that are present in the company's context. • He called special attention to the aspects concerning knowledge, professional multi-functionality and innovation capabilities. • The findings of this research can be beneficial and can contribute to clarifying and improving his company's knowledge in respect to eco-innovation determinants as they provide the company with new, systemic and contextualized information. • The knowledge conveyed by the research results can help in facilitating the company's innovation efforts.
3	Agreed	• The respondent agreed quite strongly with the research's results; • The research's results matched quite highly with the respondent's beliefs regarding the attitudinal, personal and social, and behavioral control aspects associated with eco-innovation and GCE. • The results make clear, many aspects that are known but are not usually orderly and systematically compiled. Therefore, they will be important in clarifying issues related to GCE and eco-innovation in the Brazilian petrochemical context. • The research's results are very important. They can give substantial contribution to the company by providing it with

RESPONDENT	AGREED - DISAGREED	MANAGERS´ DEGREE OF AGREEMENT WITH THIS RESEARCH FINDINGS, PERCEPTIONS OF THE FINDINGS´ CONTRIBUTION TO COMPANIES´ KNOWLEDGE AND TO THE PROMOTION OF GREEN CHEMISTRY AND GREEN ENGINEERING
		significant information regarding behavioral change, innovation and their association with technological change towards more advanced states of corporate and planetary sustainability. • The results can contribute to the decision-making process regarding the types and areas of investments, cleaner technologies and eco-innovation processes. • It is important to integrate the knowledge and information, produced by this thesis research, into the company's planning and decision-making processes regarding the types and areas of investments they are making in cleaner technologies and eco-innovation processes. • This research represents a starting point for future developments. • If this research and its results reach and are acknowledged by important decision-makers ("the right people"), substantial progress can be made in terms of behavioral change and investments efforts (human, knowledge, capital etc.) towards sustainability.
4	Agreed	• Although the respondent agreed quite strongly with this thesis research's findings, exception was made for the case that the managers' perception of risk was low. In his opinion, although the operations intrinsic risks are high the risk control measures put them under control; • The research's findings reflected real concerns of the company and of the petrochemical sector. Aspects related to environmental risks, economic risks, social pressures, knowledge and technologies and actors and networks are part of the company's daily concerns; • The respondent agreed quite strongly that this thesis research's findings can be beneficial and contribute to clarifying and improving your company's knowledge in respect to eco-innovation determinants; • Such findings can generate important insights that can be translated into initiatives that can produce benefits to the company's business and image; • The results definitely aggregate new and useful knowledge to the company. • The company aims at being ahead of the legal requirements, and it is sensitive to societal and market demands, such knowledge can help to promote and facilitate to effect advanced eco-innovation based technological changes towards more sustainable states. • In the medium-term, as a consequence of changes to the current scenario, GCE can be used as a baseline approach in solving the company's technological challenges.
5	Agreed	• The results of the thesis research are in harmony with the thoughts and perceptions of the majority of the corporate leaders with regard to important requirements for the companies to innovate and to proceed towards advanced states of sustainability. • The research´s findings can contribute to clarifying and improving knowledge regarding eco-innovation determinants. They will be beneficial as new knowledge and information always promote valuable inputs and

RESPONDENT	AGREED - DISAGREED	MANAGERS´ DEGREE OF AGREEMENT WITH THIS RESEARCH FINDINGS, PERCEPTIONS OF THE FINDINGS´ CONTRIBUTION TO COMPANIES´ KNOWLEDGE AND TO THE PROMOTION OF GREEN CHEMISTRY AND GREEN ENGINEERING
		influence and promote the onset of new initiatives. • The results will aggregate new knowledge to the company's current knowledge base. • New knowledge almost always helps to promote the development of new solutions for environmental and sustainability problems. • This study can contribute to eco-innovation initiatives in the company as it brings new information that, together with the current knowledge, can be useful in identifying and establishing innovation related priorities. • The results can help companies to deliberately formulate the appropriate measures and initiatives that can contribute to anticipate the demands of the broad society in respect to cleaner and economically feasible products, processes and services.
6	Agreed	• There are no doubts about the importance of this thesis research's results in contributing to clarifying and improving companies' knowledge regarding GCE eco-innovation determinants. • The sooner companies have access to this information and the sooner they start to look in this direction, the more prepared they will be to approach their environmental and innovation challenges. • The results help to enrich the company's ongoing reflections on environment and innovation. They reinforce some priorities and help to enhance the confidence that the company is making the right choices; • The results highlight points that can be introduced in the company's innovation processes and routines in a structured and systemic fashion. They can also help to establish and to identify the interconnections between such elements and the company's well established routines; • By providing information on GCE and eco-innovation determinants, the results can help the company to establishing innovation processes that can ultimately translate customers' needs for greener products and services into the expected solutions.

Source: author

Summary

As concluding remarks, it can be argued that the reactions of managers to the four questions documented that:

a) Managers are in full agreement with the findings of this thesis research´s quantitative survey;
b) The findings contributed to clarifying and improving their company's knowledge on GCE and related eco-innovation determinants;
c) This knowledge is helping them to promote and to facilitate implementation of GCE technological changes;
d) In order to make GCE pervasive in all companies´ and sector´s domains, there is a need for promoting and introducing GCE in a systemic way via cooperation initiatives involving the companies, the trade association (ABIQUIM) and Brazil's environmental protection agencies;
e) The managers responses revealed that the underlying motivations for their conclusions are based upon the range of theoretical/practical possibilities presented throughout this thesis research, and
f) The managers emphasized the pivotal importance of promotion and dissemination of GCE at the sectoral level. In this case, ABIQUIM, governmental organizations (e.g. Environmental Agencies, the Ministry for the Industry and Commerce etc.), and Universities must all play important roles.

Perceptions of the Importance of the Contribution of this Thesis Research´s Findings for the Development, Introduction and Diffusion of Eco-innovation Policies

One of the main contributions of this thesis research was to provide important agents, within and outside the petrochemical sector (companies, trade association, governmental organizations, the academy etc.), with recommendations for GCE bases eco-innovation policies.

The most important aspects of these recommendations were that they were generated from the scientifically based and empirically tested eco-innovation determinants that were proposed by this thesis research.

For such policies to be developed, accepted and implemented, it was necessary that important agents and decision-makers believed and perceived that they are valid, efficient and effective. This section explored the perceptions of these agents at the company level.

Table 7.14 presented summaries of managers´ and other decision-makers´ perceptions regarding these issues. The interview protocol was presented in Appendix F.

Table 7.14- Managers´ perceptions and motivations regarding the importance of the contribution of this thesis' research´s findings for the development, introduction and diffusion of eco-innovation policies at the sector and the company levels

RESPONDENT	IMPORTANT NOT IMPORTANT	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE IMPORTANCE OF THE CONTRIBUTION OF THIS THESIS RESEARCH´S FINDINGS FOR THE DEVELOPMENT, INTRODUCTION AND DIFFUSION OF ECO-INNOVATION POLICIES
1	Important	• Policies are of maximum importance for supporting, organizing, developing and implementing any initiative directed to sustainability issues. • The presentation of scientifically and empirically-based recommendations for the development of policies, such as those that are based on this thesis research, can play a very important role and can make a great contribution to the development of more effective policies. • This policy effectiveness is grounded on the fact that they touch real and proven needs and include important and necessary agents. • In order to promote and develop policies aimed at promoting GCE and eco-innovation, at the sector level, good coordination and by ABIQUIM is needed. Articulation with governmental sectors is necessary for supporting and developing such policies.
2	Important	• Policies are mandatory for guiding companies towards their objectives. They legitimize and discipline actions and behavior. • The incorporation of the findings of this thesis research into corporate eco-innovation policies can contribute to planning and to the establishment of requirements for corporate innovation processes.
3	Important	• According to this respondent, policies based on this research's results can contribute to the introduction, diffusion and incentivization of implementation of GCE based eco-innovation because it provides the required elements for educating, training, planning and decision-making. • Such policies must be developed, implemented and be active and effective in companies daily activities. • Such policies can help companies CEO´s and managers, the sector´s representative associations and governmental organizations to develop specific programs and plans based on specific and empirically measured issues, which are likely to increase the likelihood of success.
4	Important	• This respondent stated that such policies provide a baseline and a common starting point for companies to approach GCE eco-innovation and competitiveness challenges. • These findings are in harmony with his perceptions with regard the sustainability and sustainable development principles and eco-innovation. • As the petrochemical sector and its representative organizations have the same perception, they will eventually be deliberately legitimated *via* the development and implementation of such policies.
5	Important	• As the results reflected elements that were elicited from true cases, this thesis research's results can

RESPONDENT	IMPORTANT NOT IMPORTANT	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE IMPORTANCE OF THE CONTRIBUTION OF THIS THESIS RESEARCH´S FINDINGS FOR THE DEVELOPMENT, INTRODUCTION AND DIFFUSION OF ECO-INNOVATION POLICIES
		undoubtedly help the company and the sector to develop more specific policies and programs regarding the introduction, diffusion and incentivizing GCE based eco-innovation processes. • As the results represented information that was elicited from the perceptions of the petrochemical companies, it can be easily understood and can be completely inserted in the sector's context.
6	Important	• Corporate policies based on this thesis research's results can enhance reflections on the issues covered by the research at the same time that they can provide stronger support for the development and the implementation of GCE based eco-innovation processes. • Governmental policies based on the results of this thesis research aimed at supporting and fostering GCE based eco-innovation can be very useful and positive in stimulating companies to search for more sustainable solutions via eco-innovation. • At the sector level, such results can be important for the development of eco-innovation policies associated with the sector's self-regulation regarding sustainability and sustainable development objectives and incentives. That is, if the sector and ABIQUIM are prepared to adequately interpret this thesis research and to produce a set of self-regulatory initiatives, such efforts will be more assertive and anticipative and it will inexorably be ahead of the legislation.

Source: author

Summary

Three important points were distilled from the managers' responses:

a) Managers emphasized that they are positive to the GCE concepts and are fully supportive to the policy recommendations that were proposed based on the results of this thesis research;
b) They understand that as such, policies are developed based on scientifically and empirically based recommendations, they will address real and proven needs and will include important and necessary agents. This very much enhances their likelihood of being accepted and successfully implemented;
c) Managers saw that the development of such policies at the sectoral level as being fundamental for the success of the dissemination and the incorporation of GCE at the company level. They emphasized that companies, ABIQUIM and governmental organizations are the most important agents in development and implementation of appropriate supportive policies at the governmental and corporate levels.
d) If the sector and ABIQUIM are prepared to adequately interpret this thesis' research findings and to produce a set of self-regulatory initiatives, such efforts will be more assertive and anticipative and it will inexorably be ahead of the legislation.

Perceptions of the Importance and Effectiveness of ABIQUIM and its "Responsible Care Program" in Disseminating, Supporting and Fostering GCE in the Brazilian Petrochemical Sector

ABIQUIM plays an important and fundamental role in promoting initiatives that foster increased competitiveness and sustainable development of the chemical industries in Brazil. Currently, one of the sector´ main initiatives towards sustainability and sustainable development in the chemical and petrochemical industry is ABIQUIM´s Responsible Care Program (RCP), which is mandatory for all ABIQUIM´s associated companies.

The RCP embraces the development and application of sustainable chemistry, helping the industry contribute to sustainable development while allowing meeting the world´s growing need for essential chemicals and products[106].

This section explores the perceptions of managers and other decision-makers, in the Brazilian petrochemical sector, regarding the importance of ABIQUIM and its RCP in the process of disseminating, supporting and fostering GCE in the Brazilian Petrochemical Sector.

Table 7.15 presents summaries of managers´ and other decision-makers´ perceptions regarding these issues. The interview protocol is presented in Appendix F.

[106] Source: International Council of Chemical Associations (ICCA) (http://www.icca-chem.org/en/Home/Responsible-care/). Accessed in February, 2013.

Table 7.15- Managers´ perceptions and motivations regarding the importance and effectiveness of ABIQUIM and its "Responsible Care Program" in disseminating, supporting and fostering GCE in the Brazilian petrochemical sector

RESPONDENT	IMPORTANT NOT IMPORTANT	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE IMPORTANCE AND EFFECTIVENESS OF ABIQUIM AND ITS "RESPONSIBLE CARE PROGRAM" IN DISSEMINATING, SUPPORTING AND FOSTERING GCE IN THE BRAZILIAN PETROCHEMICAL SECTOR
1	Important	• ABIQUIM and its RCP are basic and extremely important elements in the development and implementation of any sector level initiative concerning the sustainability of the chemical and petrochemical sectors. • The RCP has a critical importance in promoting the sustainability awareness in the chemical and petrochemical sectors. • The RCP has multiplying effect and is the main instrument, in the petrochemical sector, for the diffusion for influencing companies towards sustainability and sustainable development. • It can be a powerful instrument for the diffusion and the adoption of GCE in the Brazilian petrochemical sector.
2	Important	• ABIQUIM is a major actor in promoting the GCE principles at national level. The RCP is the main mechanism for the introduction, dissemination and implementation of the GCE principles in the Brazilian petrochemical sector. • The introduction and dissemination of the GCE frameworks can be conducted in wake of ABIQUIM's past successful efforts and initiatives regarding the RPC. • Results could be expedited and enhanced if ABIQUIM's RCP efforts were done in conjunction with local chemical industry associations.
3	Important	• As ABIQUIM congregates and represents the Brazilian petrochemical sector and accommodates and defend its interests, it can be a powerful actor in fostering innovation and the use of GCE in the petrochemical realm. • ABIQUIM can/should provide information and exert pressures on the governmental sector in order to promote institutional support for the implementation of GCE-based eco-innovation processes in the petrochemical sector; • ABIQUIM´s RCP is a strong, consolidated and well-structured voluntary initiative aimed at helping the chemical industry to continuously improve its performance in areas related to health, safety and the environment. It has been historically an important initiative in promoting and pushing the petrochemical sector towards more advanced environmental protection levels. It can undoubtedly be a very important program for disseminating, supporting and fostering the use of the GCE frameworks within such domain; • As ABIQUIM strongly promotes and supports sustainability and sustainable development via its consolidated programs, initiatives, such as the RCP, companies will be increasingly incentivized and motivated to incorporate GCE and eco-innovation in their routines.
4	Important	• This respondent emphasized the high importance of the existence of external actors that can mediate/influence

RESPONDENT	IMPORTANT NOT IMPORTANT	MANAGERS´ PERCEPTIONS AND MOTIVATIONS REGARDING THE IMPORTANCE AND EFFECTIVENESS OF ABIQUIM AND ITS "RESPONSIBLE CARE PROGRAM" IN DISSEMINATING, SUPPORTING AND FOSTERING GCE IN THE BRAZILIAN PETROCHEMICAL SECTOR
		the introduction and the dissemination of GCE in the petrochemical sector; • Such mediation and influence represent very important contributions to culture building and to the enhancement of initiatives and the promotion of GCE as baseline principles for technical change. • ABIQUIM plays a major and unique role in mediating and influencing the introduction and the dissemination of GCE in the petrochemical sector as baseline principles for technical change. • ABIQUIM and local industry associations have the power to exercise influence upon the petrochemical companies regarding new sustainability issues; • ABIQUIM is a major actor in promoting the GCE in the petrochemical sector at national level. ABIQUIM's RCP is the most important initiative for the introduction, dissemination and implementation of the GCE principles in the Brazilian petrochemical sector.
5	Important	• ABIQUIM is a very strong agent in the Brazilian petrochemical sector; • ABIQUIM's RCP is a central program in the petrochemical sector regarding health, safety and environmental issues towards companies' sustainability; • The nature, the objectives and the structure of the RCP make the program very important adequate to promote and incentivize the adoption and use of sustainable practices. This includes harboring the GCE frameworks and promoting them as baseline principles for more sustainable products, processes and services.
6	Important	• ABIQUIM is a major and very important agent in influencing and supporting sustainability initiatives in the petrochemical sector. In light of this importance, the likelihood of success with regard the incorporation of GCE, as baseline frameworks and guidance for technological change in the petrochemical sector, could be much higher if conducted by ABIQUIM. • Initiatives that have been proven to be successful must be fully explored. Therefore, ABIQUIM's RCP represents a good initiative, an adequate framework and an effective vector for disseminating and incentivizing the adoption and implementation, by the petrochemical companies, of GCE in their innovation processes.

Source: author

Summary

Although some respondents mentioned other initiatives such as the ISO 14000 series and the National Quality Prize, they considered them to be less effective than RCP for promoting GCE in the Brazilian petrochemical sector.

The insights and recommendations presented in this section provided clear evidence of the high esteem that the company managers and other decision-makers have for ABIQUIM and its RCP in disseminating, supporting and fostering GCE in the Brazilian petrochemical sector.

Have Brazilian Petrochemical Companies Advanced Beyond Willingness?

One of the main objectives of this thesis research was to measure and understand the depth of Brazilian petrochemical companies´ willingness to engage in GCE based eco-innovation activities. The results obtained by this thesis research´s quantitative research demonstrated that companies are willing for such engagement and explained its underlying determinants (cf. Chapter 6 and in Sections 7.1, 7.2 and 7.3 of Chapter 7).

Based on those findings, this thesis researcher explored managers´ perceptions and examined the extent to which companies have already departed from willingness and have advanced towards sustainability through sustainable development practices. It is the proposal of this author that by analyzing leader's views it will be possible to have a better understanding of their underlying motivations for such willingness to continue on the SD journey.

In parallel, by having a clear view of the extent to which companies have moved beyond willingness to actions, it will be possible to infer if GCE can be effectively used as a framework to catalyze the Brazilian Chemical Industry's network of companies to rapidly continue on their SD journey.

This inquiry explored two important points:

a) The company's past, current and planned initiatives (policies, programs, business strategies, investments, directives, standards etc.) to effect the required technological changes to make it more sustainable, and
b) The changes (organizational, personal, learning processes, knowledge base, institutional etc.) that were required for the company to introduce, implement and manage these initiatives.

The information from this inquiry was complemented by information derived from companies´ official and publicly disclosed documents.

The analyses regarding both questions corroborated answers obtained to the question regarding the importance of the concepts of sustainability and sustainable development for the Brazilian petrochemical companies. The analyses provided actual and solid evidence that S and SD are serious concerns and that they have effectively moved, although in different degrees, beyond willingness to actualization.

Table 7.16 presents examples of companies´ initiatives towards advanced states of sustainability. The interview protocol is presented in Appendix F.

Table 7.16- Examples of companies´ advancement towards higher states of sustainability (moves beyond willingness to actualization)

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
1	• The company has a worldwide sustainability policy and commitments. • Publishes an Annual Sustainability Report to report its advances towards sustainability and to its Communication on Progress (COP) for the UN Global Compact's ten principles. • The company is a signatory of ABIQUIM´s Responsible Care Program and it is ISO 1400, ISO 18001 certified. • In order to cope with the environmental policies, programs, objectives and goals, the company has undergone, throughout the last decades, substantial organizational changes regarding organizational structure, learning processes, knowledge integration capabilities.	• Developed and implemented a large number of programs, standards, guidelines, directives, clear sustainability objectives and goals, indicators (Global Reporting Initiative based), special task forces for continuous improvement and study groups etc. towards the sustainability • Installed and use energy co-generation using renewable, non-fossil-based fuel as a substitute for natural gas in their production processes. • Implemented an industrial ecology-inspired project that uses petrochemical process residues as raw materials for other manufacturing process. • Implemented improved process control systems and strategies. • Implemented the use of environmentally friendlier catalysts and solvents, and less toxic products; • Uses product life cycle in their environmental analyses. • Implemented a manufacturing process, based upon ethylene oxide that is a more sustainable process, which requires a minimum use of water. • Performed research on the substitution of asbestos with safer materials in specific separation processes • Innovation plays a central role in such sustainability efforts. • Such innovation processes are conducted by the company's own R&D and by a series of partnerships; • The company uses the energetic integration in its processes as the basic design guideline. • The company developed and implemented waste recycling programs.
2	• The company is strongly committed to sustainability and sustainable development as is attested to in its Mission & Vision statement and in its integrated, advanced management policy regarding safety, health, industrial hygiene, environment and quality.	• The company has developed and implemented initiatives, programs, directives, guidelines, checklists, procedures, indicators, engineering norms, standards and sustainability objectives. • New catalysts have been developed and implemented in the production process. This improved selectivity resulted in 30%+

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	• The company's management principles, commitments, initiatives and results are reported in its annual socio-environmental report and in a variety of media including the company's web site. • Currently the company utilizes a corporate management and planning system that integrates aspects related to the triple bottom line (People, Planet and Profit) into the company's operations. • The company implemented initiatives regarding stakeholders (academy, governmental organizations, communities etc.) consultation for helping to identify weak points within operations and its relations with the community. • The company has strong ethical institutional principles regarding investment practices. Ethical principles related to the environment, to the people and to business are closely followed. • The company is registered in the sustainable company's stock market. • The company is a signatory of ABIQUIM´s Responsible Care Program and it is ISO 9000 and ISO 14001 certified. • With respect the organizational changes, they were implemented in three evolutionary steps: (a) environmental issues were introduced as a main topic in the company production processes, (b) environmental concerns were diffused to every aspect of the company's activities and (c) the company developed an integrated management and planning system, which incorporated sustainability and sustainable development concepts. • Organizational changes were necessary in every phase in order to make the structural changes	improvement in conversion efficiency in some processes. • Reduction of 70% in the volume of the liquid industrial effluents. • Reduction of production of solid wastes. • Industrial ecology-based projects for the use of solid residues as inputs for other manufacturing processes. • Development and implementation of energy consumption reduction directives and guidelines, which have been incorporated into engineering, process and operations. Good progress has been made. • The company has succeeded to operate some processes at lower pressures, which achieved reductions in energy consumption. • Under the concept of sustainable cleaner technologies, the company has introduced process solutions to convert process byproducts into saleable products.

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	possible. The organizational changes included the redefinition of the required capabilities for the conception, development and implementation of sustainability directed initiatives (environmental, health, safety).	
3	• The company´s commitments regarding sustainability are stated in its corporate policies, signed by the top management, at the corporate and site levels. These commitments are fully communicated to the society and to the different stakeholders; • The corporate policies were designed as a result of extensive consultations with a wide variety of internal and external stakeholders; • The company is officially and ostensibly committed to become acknowledged as a sustainable company; • Sustainability commitments and advances are published on the company's Global Reporting Initiative reporting framework based sustainability reports. • The company is an ABIQUIM member and it is signatory of the Responsible Care Program and is ISO 14001 and 18001 certified. • With respect the organizational changes the company has undergone vertical (hierarchical) and horizontal (functional) restructuring to accommodate the needs for changes towards its sustainability objectives. They aimed not only at the promotion of the generation of more sustainable solutions to meet the challenges, but they also sped up the rate at which they addressed them.	• The company has developed and implemented a series of sustainability directed programs, project standards and guidelines, rules, routines, indicators, initiatives, projects etc. that permeate the company at all its levels (at the global and local level); • The company has invested extensively in recycling and reusing industrial ecology-based projects for its residues (solid, liquid and gaseous). This is a result of changes in the company's beliefs system and behavior. Residues are not viewed as wastes but as potential inputs for other processes. • The company has designed new processes and modified old ones according "greener" principles (cf. Figure 7.7 and Figure 7.8).
4	• The company's commitment to sustainability (economic and socio-environmental responsibility) is attested to by the introduction of socio-environmental responsibility into its corporative governance. It is	• Their progress on their improvement journey is demonstrated by the initiatives, programs, directives, guidelines, check lists, procedures, indicators (Balanced Scorecard), engineering norms, standards and sustainability objectives that have been produced as a consequence

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	clearly manifested in the company's Mission and Vision, statements, which are open and disclosed to all its stakeholders. • The company's commitment to innovation and sustainability and to sustainable development, its associated initiatives and their respective results are documented in its annual sustainability reports, which follow the Global Reporting Initiative reporting framework. • to sustainability and sustainable development; • The company's sustainability guidelines were developed based on mainstream international references such as: o Triple Bottom Line (Elkington, 1999); o The United Nations Global Compact initiative; o OECD Guidelines for Multinational Enterprises *(OECD, 2000);* o Dow Jones Sustainability Group Indexes *(DJSGI, 1999), and* o Compendium of Sustainability Reporting Practices and Trends for the Oil and Gas Industry *(API.IPIECA, 2003).* • The company has been awarded the National Quality Prize (the Brazilian version of the Malcolm Baldrige National Quality Award), which has strong socio-environmental responsibility and social development excellence criteria. • The company is signatory of ABIQUIM´s Responsible Care Program and it is ISO 9000 and ISO 14000 certified. • With respect the organizational changes the company has undergone organizational structure and capabilities changes that resulted in: o New positions in different hierarchical levels were created that are dedicated to socio-environmental responsibilities;	of the company's public commitment. • As examples of the results obtained by the company regarding advancements towards more advanced states of sustainability, the following can be mentioned: o Implemented water reuse projects; o Substitution of toxic product additives with less toxic ones; o Implemented energy efficiency projects; o Invested in advanced process automation regarding on-line control and real time optimization. This helped them to enhance their efficiency of conversion and separation processes and the reduction of product losses and energy consumption o Industrial ecology-based projects for the use of solid residues as input for other manufacturing processes. These projects have significantly reduced the residues that had to be treated as hazardous solid wastes; • Energy consumption reduction directives and guidelines have been incorporated to engineering, process and operations. Good advances have been obtained

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	○ New communication channels and structures were created to facilitate and expedite decision-making and to follow-up processes relative to environmental issues; ○ Internal committees were created to identify, to approach and to discuss environmental challenges in a multidisciplinary manner	
5	• The company has implemented many initiatives have been produced as a consequence of the company's public commitment to sustainability that is disclosed to the company's stakeholders via its sustainability policy. • Such sustainability initiatives include sustainable chemistry, socio-environmental management, safety, relations with stakeholders. • The company's corporate management is based upon three pillars: ○ Innovation: to provide innovative solutions within ethical boundaries; ○ People: aimed at human development; ○ Sustainability: sustainability objectives include engagement of stakeholders. ○ Sustainability objectives were developed aimed at protecting the environment and human health, contributing to the success of communities, sustainable chemistry, contributing to solving the main global challenges, establishing commitment to product safety, energy conservation, and promoting initiatives to counteract global warming. • These corporate sustainability commitments, initiatives and results are audited and reported via the company's annual sustainability reports that are published on a variety of media including on the company's web site. • The company is signatory of ABIQUIM´s Responsible Care Program and it is ISO 9000, ISO 14001 and 18001	• The company developed and implemented initiatives, programs, guidelines, indicators, engineering norms, standards and sustainability objectives demonstrated the company's advances towards sustainability. • Integration of electricity and steam co-generation using renewable biomass as a substitute for fossil fuels in their production processes. • Industrial ecology-inspired project that uses petrochemical process residues as raw materials for other manufacturing processes. • The development and use of environmentally friendlier catalysts and solvents, less toxic products, utilization of product life cycle in the environmental analysis. • The respondent revealed that the company's sustainability and sustainable development guidelines and product life cycle approaches are applied in the development of every new product and process.

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	certified. • In order to cope with the sustainability policies, programs, objectives and goals, the company has undergone, throughout the last decades, substantial organizational changes regarding organizational structure, learning processes, knowledge integration capabilities etc.	
6	• The company's commitment to sustainability (economic and socio-environmental responsibility) and innovation is attested to its annual sustainability report, which follows the Global Reporting Initiative sustainability-reporting framework. • The company is signatory to the United Nation's Global Compact initiative. • The company embraces the principles of the "Green Economy" that are being promoted by the United Nations Commission on Sustainable Development (CSD) and by the United Nations Environmental Program (UNEP). • The company has established and made public, seven priority macro-objectives: o To be a leader in chemicals safety; o To reduce the intensity of the emission of Greenhouse Gases (GHG); o To increase water use efficiency; o To increase energy efficiency; o To be the largest renewable raw materials based thermoplastic resins producer; o To contribute to reduce the impact of plastics afterlife; o To be perceived as an important agent of human development. ▪ For each of these objectives there are a series of ongoing and planned initiatives to be conducted up to the year 2020: ▪ - 2010	• The company´s technological progress is documented by the initiatives, programs, directives, guidelines, check lists, procedures, eco-indicators, engineering norms, standards and sustainability objectives that have been produced as a consequence of the company's public commitment to sustainability and sustainable development. • The following are examples of the results obtained by the company regarding innovative advancements towards more advanced states of sustainability: • The company developed and produced "Green Ethylene" produced from renewable raw-materials (sugarcane); • The development and production of "Green Polyethylene" produced from renewable raw-materials (sugarcane); • The company will soon initiate the production of "Green Polypropylene" from renewable raw-materials (sugarcane); • Among the results obtained by the company's eco-innovation initiatives, it can also be noted its ethyl-tert-butyl ether (ETBE). production processes. ETBE is a gasoline bio-additive partially made from sugarcane ethanol. This product, which required nearly three years of research to develop, is an innovation that replaces the traditional methyl tert-butyl ether (MTBE) additive and reduces chemical and human health risks. • The respondent stressed that other cleaner technologies and cleaner product's projects are currently under development. Due to confidentiality reasons, information on them could not be disclosed.

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	○ to be registered on REACH (Registration, Evaluation, Authorization and Restriction of Chemical Substances); ▪ 2011-2015 ○ To lead the implementation of the International Council of Chemical Associations (ICCA) Global Product Strategy Program (GPS) in Latin America; ○ To participate in the continuous improvement of the Risk Rating and achieve at least a mean of 90 points, which will place the company's plants at "above standard" level; ○ To abolish mercury and asbestos from their production processes; ▪ 2020 ○ To be a world reference in the use and in the responsible production of chemicals; ○ To ban the use and the production of chemicals that are listed in global "black lists". ○ According to the respondent, the company is deliberately committed and develops efforts to continuously improve its processes and their respective operations. This can be attested to the reduction of its processes effluents and residues generation. Their data are regularly disclosed to the company's stakeholders through the company's diverse information channels. • The company is signatory of ABIQUIM´s Responsible Care Program and it is ISO 9000 and ISO 14001 and OSHAS 18000 certified. • The company has developed and implemented a corporate social responsibility policy. Social responsibility norms based on the ISO 26000 norm series are due to be fully implemented by 2015. • With regard the organizational changes new areas and	

RESPONDENT	NON-TECHNICAL INITIATIVES	TECHNICAL INITIATIVES
	positions in different hierarchical levels were created to fulfill the company's innovation and socio-environmental responsibility needs and commitments. • Organizational changes aimed at increasing the proximity with stakeholders (industry, discussion *fora*, customers etc.) were implemented, new communication channels and structures were created to facilitate and expedite decision-making and follow-up processes relative to socio-environmental issues. Internal committees were also created to address environmental challenges in a multidisciplinary manner.	

Source: author

Summary

The information obtained *via* this inquiry produced many insights that helped this thesis author to clarify the managers' willingness to accept the GCE frameworks and to engage in GCE-based eco-innovation processes. They also helped this author to develop a forecast regarding the implementation of GCE as a baseline framework for the corporate technological changes towards more sustainable products, processes and services.

First, it was clear that the interviewees responses supported the idea that the Brazilian petrochemical company managers' willingness to implement GCE was derived from and is underpinned by a sustainability and sustainable development culture that has been implemented in many ways within the Brazilian petrochemical sector. This culture strongly pervades the companies and it is the result of the national and international efforts and initiatives that have been conducted by the companies during the last two decades.

As the concepts of sustainability and sustainable development are strongly bounded to the petrochemical companies´ operational culture, companies have taken many steps beyond willingness, in fact, by using some GCE principles as a reference (cf. next sections). It is plausible to state that, in the context of the Brazilian petrochemical sector, there are conditions that represent fertile grounds on which the implementation of the GCE as the baseline framework for technological changes could prosper. It is important to note that this line of argumentation is based upon the premise that GCE will be properly and adequately promoted by key agents such as companies´ leaders, ABIQUIM and governmental environmental (e.g. Ministry and States´ Secretariat for the Environment, EPAs etc.) and non-environmental (Ministry for the Science, Technology and Innovation, Ministry of the Industry and Commerce, Ministry for Education etc.) organizations.

Managers´ Agreement with this Thesis Research Recommendations for Eco-Innovation Policies Development

As noted in Sections 4.1 of Chapter 4 and in Sections 7.2 and 7.2.1 of Chapter 7, one of the important contributions of this thesis research was to provide decision-makers with recommendations for the development of policies and strategies. In addition to facilitating the promotion and the implementation of GCE, at the company and the sector levels, such recommendations can be also used as a reference in developing GCE-based eco-innovation policies, procedures, processes and products.

In order to build upon those recommendations, this thesis researcher presented the findings to six Brazilian petrochemical company managers who were asked to provide additional comments as well as to point out elements that according to them were missing.

Table 7.17 presents summaries of the managers´ and other decision-makers´ levels of agreement with and their perceptions regarding the recommendations of this research for the development of eco-innovation policies. The interview protocol was presented in Appendix F.

Table 7.17- Managers' levels of agreement with and their perceptions regarding this thesis' research recommendations for the development of Eco-Innovation policies

RESPONDENT	AGREE - DISAGREE	MANAGERS´ AGREEMENT WITH AND THEIR PERCEPTIONS REGARDING THIS THESIS RESEARCH RECOMMENDATIONS
1	Agreed	• The recommendations are adequate and can help to promote effective GCE and eco-innovation policies both at the company and at the sector levels. • The recommendations can make valuable contributions and help the Brazilian petrochemical companies in identifying their policy needs for a more sustainable future. They can also provide companies with information that are valuable for eco-innovating in more sustainable fashion.
2	Agreed	• This respondent stated that this thesis research's recommendations match his perceptions and beliefs and in general, he does not identify other points that could be recommended.
3	Agreed	• This research's recommendations are well suited to the Brazilian context. • The recommendations allow for the sector and company levels decision-making based on actual data that have been collected via scientific methods. • The recommendations can provide decision-makers with important and effective guidance for planning.
4	Agreed	• This research's recommendations match his perceptions and beliefs and that, in general, he did not identify other points that should be recommended. • He corroborated with the recommendation that the information, education and training regarding the company's environmental risks and their relations to economic consequences and business opportunities should be adapted and communicated to the different levels in the corporation. This is likely to generate different insights in the different hierarchical levels and to enhance the participation and the involvement of different agents in approaching and solving the environmental challenges. • As ABIQUIM is a major representative of the petrochemical sector, he agrees that the use of the guidelines provided by the RCP, which are designed to promote the interaction of companies with their stakeholders, is an adequate choice to monitor and to capture the market, community and regulatory agents' demands regarding cleaner and more sustainable products, processes and services.
5	Agreed	• The recommendations are adequate to help the petrochemical companies to improve their learning and innovation mechanisms and routines; • The presentation of the thesis research's recommendations, in a systemic and comprehensive form, will support better, effective and selective objectives setting and a better allocation resources. • According to this respondent such argument is supported by the fact that these results were developed based on empirical results, and were strongly based on robust theoretical foundations. • The recommendations can make important contributions and will help the Brazilian petrochemical companies in addressing their sustainability challenges.

RESPONDENT	AGREE - DISAGREE	MANAGERS´ AGREEMENT WITH AND THEIR PERCEPTIONS REGARDING THIS THESIS RESEARCH RECOMMENDATIONS
		• The respondent did not identify missing points.
6		• Due to time constraints, this question was not covered in the interview with this respondent.

Summary

All six interviewed managers and other decision-makers, who answered this question, were in full agreement with this research's recommendations. They concluded that they are sufficient and can help to promote effective GCE and eco-innovation policies both at the company and at the sector levels. In addition, they did not identify any missing points.

Some important points underpinning their agreement:

- The recommendations can support the sector and company level's decision-making;
- The recommendations were produced based on solid theoretical background and consistent and reliable empirical methods;
- The recommendations can provide decision-makers with important and effective guidance for planning;
- They can also provide companies with information that is valuable for eco-innovating in a more sustainable fashion.

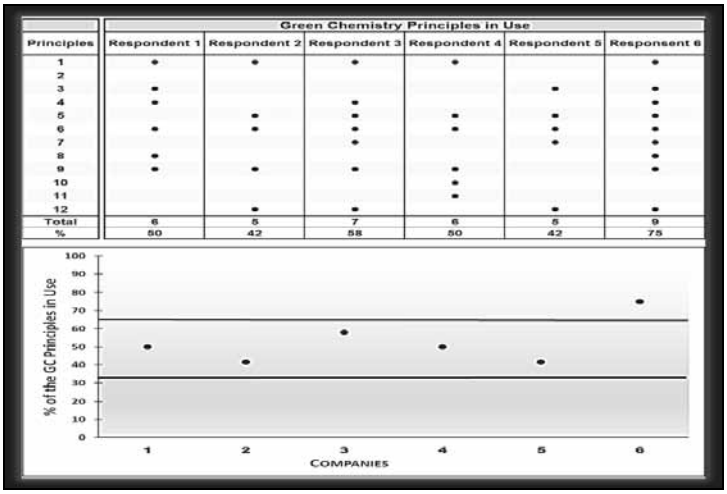
Are the CGE Principles Already in use by the Brazilian Petrochemical Companies?

The previous sections of this inquiry provided substantial evidence that companies, in the Brazilian petrochemical sector, have moved beyond willingness regarding sustainability and sustainable development. The results showed that companies are promoting and implementing sound GCE changes. Therefore, measuring the extent to which they have applied the principles of GCE seems to be a plausible way to further test this thesis research´s finding regarding companies' willingness to incorporate GCE in their operations and to engage in GCE based eco-innovation processes.

Such argumentation was supported by the fact that, even though not directly associated with the GCE frameworks, some directives, guidelines and principles that have been incorporated within the company's institutional policies, goals, procedures and productions processes match the GCE principles. Those types of incorporation are being implemented both in a planned and structured manner as well as in an intuitive fashion.

Managers were confronted with the twelve principles of Green Chemistry and the twelve principles of Green Engineering and were asked to mark the principles that they believed that are already being used by his company. The results are presented in Figure 7.7and Figure 7.8.

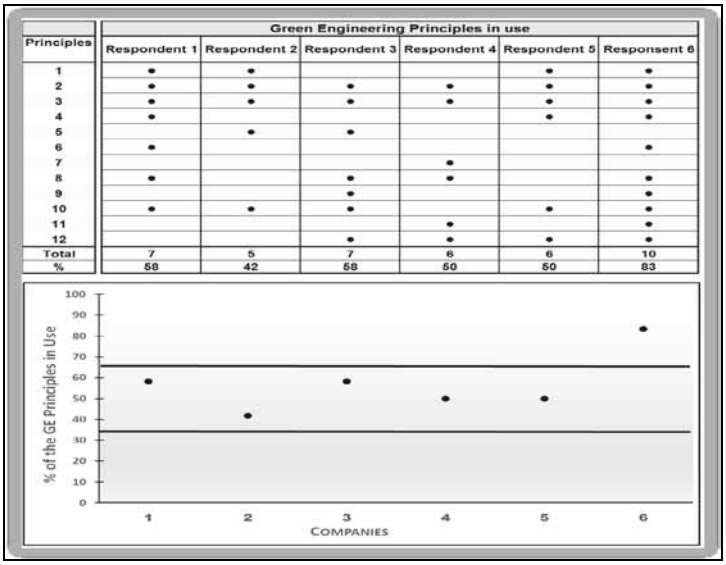
Figure 7.7- Green Chemistry principles in use in the surveyed Brazilian petrochemical companies



Green Chemistry Principles in Use						
Principles	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Responsent 6
1	•	•	•	•		•
2						
3	•				•	•
4	•		•			•
5		•	•	•	•	•
6	•	•	•	•	•	•
7			•		•	•
8	•					•
9	•	•	•	•		•
10				•		
11				•		
12		•	•		•	•
Total	6	5	7	6	5	9
%	50	42	58	50	42	75

Source: author

Figure 7.8- Green Engineering principles in use in the surveyed Brazilian petrochemical companies



Green Engineering Principles in use						
Principles	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Responsent 6
1	•	•			•	•
2	•	•	•	•	•	•
3	•	•	•	•	•	•
4	•				•	•
5		•	•			
6	•					•
7				•		
8	•		•	•		•
9			•			•
10	•	•	•		•	•
11				•		•
12			•	•	•	•
Total	7	5	7	6	6	10
%	58	42	58	50	50	83

Source: author

The dots in the upper part of the figures show the principles that are in use by each of the surveyed companies. The lower part represents these numbers expressed in percentages relative to the total number of principles.

In order to classify the companies according the number of GCE principles they are using, three levels of use were conceived:

a) 0% to 33.33%- laggards;
b) 33.34% to 66.66%- moderate users, and
c) 66.67% to 100%- front-runners.

The inquiry results demonstrated that none of the companies was classified a "laggard" with regard to both Green Chemistry and Green Engineering.

According to the classification scheme that was used, with regard to Green Chemistry, the results demonstrated that five out of the six interviewed companies were classified as "moderate users" and the one remaining company was classified as front-runner.

In the case of Green Engineering, five of the companies in the sample were classified as "moderate users" and one reached the class of the "front-runners".

These results are in harmony with and corroborate the managers´ perceptions, manifested in the preceding sections, with regard to corporate sustainability, sustainable development and willingness to engage in GCE-based eco-innovation processes.

7.4.2- In-depth Interviews at the Meso-Level within the State Environmental Agencies

As noted in Section 7.3.1 of Chapter 7, according to this research´s qualitative survey results, the environmental agencies emerged as one of the most significant determinants of companies´ willingness to engage in GCE-based eco-innovation activities.

As Global Climate change and other environmental challenges become increasingly severe, it is more evident that diverse stakeholders must co-work to help societies make the transition to sustainable patterns.

In that context, environmental protection agencies (EPA) have responsibilities and opportunities, in many ways, to help societies make the transition to more sustainable behavioral patterns. They can and do work in many ways including developing and enforcing environmental legislation and through training programs to facilitate the process of change of the perceptions of the socio-economic actors with regard the (un)sustainability of their activities.

In the industrial realm, the pressures exerted by both elements have been an important catalyzing element regarding the search for technological practices that can promote more sustainable states of social, economic and environmental performance of companies´ products, processes and services.

As a starting point for the analysis of the influence of governmental EPAs in catalyzing such technological changes in the industrial domain, three areas of influence/pressure can are often used:

- Development and improvement of the environmental legislation;
- Enforcement of the environmental legislation, and
- Cooperation with stakeholders (industry) in the search for and implementation of increasingly sustainable practices.

Brazil is a vast country, which ranks fifth in the world according to area and has a population of almost two hundred million inhabitants. The country is a federated republic composed of twenty-six states and a Federal District. Each one of the states and the Federal District has its own EPA.

The petrochemical industry is not evenly distributed across the Nation. Due to the territorial dimensions of the Country, and to the spatial distribution of the petrochemical sector, these in-depth interviews with the environmental agencies were limited to cover two very important *nuclei* of the Brazilian petrochemical companies. This choice was made based on two criteria: (a) the number and density of companies, and (b) access to the respondents.

The six topics presented in Table 7.18 guided the analysis on the environmental agencies'´ perceptions of the role that they play in influencing and catalyzing companies, in the petrochemical sector, to adopt GCE-based technical and non-technical initiatives. Such initiatives will help to ensure that they develop and implement cleaner and more sustainable strategies, products, processes and services. The complete protocol that guided the interviews is presented in Appendix F.

Table 7.18- Structure of the in-depth interviews conducted with managers of the Brazilian Environmental Protection Agencies

1	• Initiatives that have been conducted by the Environmental Agency aimed at influencing, promoting and catalyzing changes towards cleaner and more sustainable technological states in the petrochemical sector, and • Future planned initiatives.
2	• Perceptions on the influence exerted by the environmental agency and by future legislation, on petrochemical companies, to push them to engage in eco-innovation activities towards higher states of sustainability.
3	• Perceptions on cooperative work between the Environmental Agencies and the petrochemical companies in order to promote more effective actions regarding the search for solutions that could help companies to make expedited progress towards sustainability.
4	• Perceptions on how and on the extent to which the Environmental Agency can influence and pressure companies to adopt sustainable approaches that were proven to be successful.
5	• Perceptions on the extent to which the respondent and/or the Environmental Agency are willing to support and to promote GCE-based initiatives; • Perceptions on how prepared the Environmental Agency is to engage in activities aimed at influencing companies to adopt and use GCE as baseline principles in the process of meeting their environmental challenges, and • Perceptions on what can/will the Environmental Agency do in this regard.
6	• Perceptions on the possibility and willingness of the Environmental Agency to promote joint initiatives in cooperation with ABIQUIM and other industry representative associations to promote GCE in the Brazilian petrochemical sector.

Source: author

Although the perceptions and opinions of both respondents converged in many aspects, the context, the approaches and dynamics varied from one environmental agency to another. In order to preserve the information in its original state and to provide a clear exposition of the respondents´ views, such perceptions were presented separately.

Initiatives Conducted by the Environmental Agency for Influencing, Promoting and Catalyzing Changes Towards Sustainability and Future Planned Initiatives.

Table 7.19 presents the EPAs managers' views on the initiatives that have been conducted by their agencies for influencing, promoting and catalyzing changes towards advanced states of sustainability at the companies´ level. The interviews protocol is presented in Appendix F.

Table 7.19- Environmental agencies views on their past, current and planned future initiatives for promoting and influencing changes towards advanced states of companies´ sustainability

RESPONDENT	ENVIRONMENTAL PROTECTION AGENCIES VIEWS ON THEIR PAST, CURRENT AND PLANNED FUTURE INITIATIVES FOR PROMOTING AND INFLUENCING CHANGES TOWARDS ADVANCED STATES OF COMPANIES´ SUSTAINABILITY
1	• The respondent stated that the State Environmental Agency has played a very important and fundamental role in the past in incentivizing and pushing the introduction and the implementation of ABIQUIM's Responsible Care Program at the State level. Those initiatives were implemented in cooperation of with the companies and with ABIQUIM. • Since the beginning of the 1990's, the EPA, besides its regulation enforcement role, it has worked closely with the petrochemical companies, in a cooperative way, to help them in their environmental planning and in the establishment of environmental objectives, priorities and deadlines. • These initiatives produced new approaches, routines and tools that represented real advancements with regard to companies' behavioral changes and taking responsibilities and commitments upon environmental protection and sustainability. • This cooperative approach created motivation on the part of the companies, which stimulated the creation of very effective discussion *fora* with regard to planning towards implementation of more advanced environmentally sustainable states. • The close participation of the EPA throughout the environmental licensing process (from the identification of the environmental risks and their impacts through the establishment of deadlines for their solutions and follow-up) and the constant dialogs and negotiations, have overcome usual bureaucracy and stimulated companies to make real changes and advancements beyond compliance with the existing legislation. • The respondent stated that, in the Environmental Agency perspective, one possible way to influence companies and to catalyze the implementation of the GCE principles, in the petrochemical sector, is *via* negotiations and posterior incorporation of those principles into the company's operation license. Thus, they use the companies' operation licensing as a sustainability and sustainable development-planning tool. • In respect to the future, the respondent underscored that resuming and strengthening the cooperative approach is of extreme urgency and need, otherwise an increase in the distance between companies and the State Environmental Agency will progressively occur. Such engagement is fundamental for the Agency to help to foster, influence, catalyze and expedite behavioral and technological changes towards advanced states of sustainability.
2	• The State Environmental Agency has historically guided its actions based on the prevention and on preventative approaches. The preventative approach has been historically based on companies' environmental licensing. On the other hand, corrective actions have been mainly supported by inspections and legislation enforcement. • In the last 20 years the pro-active approach has been given a much higher importance and, as a consequence, new and more appropriate institutions, strategies and mechanisms have been developed and implemented. • The EPA promotes initiatives that are based on cooperation and shared responsibilities. This is conducted *via* in-depth discussions, with the productive sector, regarding environmental issues, their challenges and their solutions. The various environmental chambers held in the Agency's domains conduct these discussions. These chambers have a permanent character, aggregate diverse stakeholders (regulators

	and manufacturing sectors) and promote discussions and planning activities on the diverse issues associated with the environment and sustainability. • Due to the lack of uniformity of companies in respect to their size, technological and organizational development and resource availability, these environmental chambers are very useful as they take such elements into consideration in the discussions and in the decision-making processes regarding the companies' capability to identify and solve the environmental problems and to stimulate the sustainability culture building; • He noted that economic and environmental aspects are the top elements in these discussions.

Source: author

Summary

EPA´s managers' reactions to this question indicated that both agencies, although keeping strong their role of legislation enforcers, they rely on cooperative initiatives with the petrochemical companies for promoting sustainability initiatives. Cooperation was reported by the interviewees as an important way to overcome bureaucracy, create trust and to help companies to move beyond legislation.

Perceptions on the Influence Exerted by the Environmental Agency and by Future Legislation on Companies Willingness to Engage in Eco-innovation Activities

As noted in Section 7.3.1 in Chapter 7, the results of this research´s quantitative survey indicated that the EPAs and the risk of future tighter environmental legislation represent significant determinants of companies´ willingness to engage in GCE-based eco-innovation activities

The respondents were presented the results and were asked to provide their opinions about the findings and the implication of them for the EPAs´ future activities.

Table 7.20 presents the EPAs managers' views on the influence exerted by their organizations and by the prospect of future tighter legislation on companies' willingness to engage in eco-innovation processes. The interviews protocol is presented in Appendix F

Table 7.20- Views of the environmental protection agencies managers on the influence exerted by their organizations and by the prospect of future tighter legislation on companies' willingness to engage in eco-innovation processes

RESPONDENT	ENVIRONMENTAL PROTECTION AGENCIES´ VIEWS ON THEIR INFLUENCES AND ON THE PROSPECT OF FUTURE TIGHTER LEGISLATION ON COMPANIES´ WILLINGNESS TO ENGAGE IN ECO-INNOVATING PROCESSES
1	• The respondent agreed that the EPA is an important motivational factor with respect to companies´ willingness to engage in GCE-based innovation processes. He noted that this perception is actually a sample of companies´ general perception regarding the role, the authority and the legislation enforcement power of the Agency. • Environmental Agencies also have a pro-active role. This has demonstrated to be a powerful motivational factor for companies to move towards advanced states of sustainability. This is very likely to occur whenever the EPA achieves the establishment of trust and cooperative planning regimes without abdicating their legal roles and obligations. • The velocity of advancements in legislation is very much slower than the actual environmental facts, challenges and needs. This pro-activity is necessary for inducing and helping companies to move beyond merely complying with existing legislation. • The respondent agreed that future legislation is and should always be a constant preoccupation for all companies. This argument was grounded on his experience and on the perception of the finitude of the planet's socio-environmental assets and limits to pollution. As the scarcity of such assets deepens and pollution increases and social pressures escalate, legislation must become increasingly tighter, restrictive and demanding. • Companies should constantly be aware of this and that this awareness represents an important determinant of companies' pro-activity with regard sustainability issues. • The perception of environmental risks and the prospect of future tighter legislation increase companies´ awareness regarding the actual and potential socio-economic and environmental unfavorable consequences associated with the company's operation. Therefore, they will push companies to engage in initiatives that can overcome such risks and preclude unfavorable consequences.
2	• The respondent stated that, according to his experience, companies' concerns regarding future socio-environmental legislation have been true and constant. • This preoccupation has been demonstrated by companies in various discussion *fora* and involved a variety of concerns that included technical, investments, legal and related aspects. • He strongly agreed with the research's finding regarding the importance and the power of the environmental agencies to induce changes. He illustrated that argument by stating that many technological and procedural changes in petrochemical companies have only taken place, in his State, through strong demands and pressures exerted by the EPA. • The EPA represented an important determinant of GCE-based eco-innovation processes, at the company level, because of two factors: (a) the Agencies' legal power and obligations to promote the environmental protection of societies via the legislation enforcement, and (b) the Agencies' current knowledge capabilities and their capacity to promote changes through dialogue and planning.

Source: author

Summary

According to the reactions of the two EPA respondents, both strongly agreed with this thesis research´s finding about the influence of the environmental agencies and the risk of future more stringent legislation on companies´ willingness to engage in GCE-based eco-innovation processes. Although they expressed it in different forms, both respondents reported that such perception was based fundamentally on the EPAs´ legal power to enforce legislation and on their ability to dialogue, to influence and to work in cooperation with the companies.

With respect to the perceptions of the petrochemical companies' managers regarding the risk of more stringent future legislation, both respondents expressed their agreements with the thesis research findings.

They supported their opinion by stating that companies constantly demonstrate such preoccupations in the discussion *fora*. In addition to that, respondent one reported that, in his view, companies are aware that the combination of increasing pollution levels, resource scarcity and social pressures will inexorability lead to tighter legislation.

Perceptions of the Possibilities of Cooperation between the Environmental Protection Agencies and the Petrochemical Companies for Promoting Expedited Progress Towards Sustainability

The relations between the EPA and the petrochemical companies in Brazil have greatly evolved in the last three decades. From the command and control times, such relations have undergone learning processes that generated substantial changes and advances on how the EPA and industry could reconcile companies´ and the broad societal sustainability interests in more effective ways.

Cooperation emerged from this processes as one very important mechanism for generating advancements towards companies´ sustainability. Such importance was testified by the EPA managers´ views expressed in the preceding questions of this section (Section 7.4.2). In these responses, the importance of cooperation work was repeatedly mentioned and was associated to different circumstances.

This section is intended to elicit the respondents' views with regard the strengthening of these cooperative relations. Respondents were questioned on how they believed that the environmental agencies should or could promote more effective cooperative actions regarding the search for solutions that could help companies to make more rapid progress toward sustainability.

The reactions to this questioning were presented in Table 7.21. The interview protocol is presented in Appendix F.

Table 7.21- Managers´ perceptions of the possibilities of cooperation between the Environmental Protection Agencies and the petrochemical companies for promoting expedited progress towards sustainability

RESPONDENT	Environmental Protection Agency Managers´ Perceptions the possibilities of Cooperation Between their organizations and the Petrochemical Companies for Promoting Expedited Progress Towards Sustainability
1	• In order to improve the quality of the discussions with the petrochemical companies, the EPA should improve and enlarge its knowledge on advances in scientific understanding and techniques related to GCE-based cleaner production. This will effectively facilitate the negotiations and planning with regard to companies' environmental objectives and performance. • This could be helpful for the establishment of achievable environmental objectives and for setting feasible deadlines. *Via* the choice of the most appropriate and advanced technologies. That approach was successful in the past. • That approach is not limited to promoting discussions over established and available technologies, it also includes approaches, guidelines and frameworks (such as GCE) that can induce and help companies to search for and research more sustainable technologies. o These initiatives can be supported by a series of legal tools such as the use of the legal mechanisms associated with companies' operating licensing process: For instance: o The establishment of the time validity of companies' operating license as a function of the introduction of new and cleaner technologies for companies' specific socio-environmental problems, o The location of industrial plants as a function of the technologies they use and the socio-environmental risk they bear, o Providing economic and non-economic incentives for the introduction of such technologies. He emphasized that close follow-up and auditing are fundamental and mandatory for such processes to evolve and be successful. • The respondent stated that, although the EPA is required by law to enforce legislation, in his opinion, cooperation and joint environmental planning are basic requisites for expediting the petrochemical companies' advancements towards more environmental sustainable states; • These efforts should be conducted consistently and regularly. Thereby, problems and solutions can be detected and discussed in an effective manner with the more efficient use of human resources. • He mentioned that that approach has enabled the implementation cleaner production approaches by a number of petrochemical companies in the State. Such initiatives involved all important stakeholders in the discussion process, which provided solutions that turned out to fulfill environmental requisites and standards in ways that went beyond legislation and provided solutions that covered points that sometimes were not covered by the environmental legislation; • He noted that this approach is very useful due to the heterogeneity of behavior of different companies. Companies in which socio-environmental responsibility is more consolidated have been demonstrated to be more proactive.

2	• Cooperation between environmental agencies and the industry, although not yet perfect, has evolved along the past decades. Currently, such interactions have been implemented through discussion *fora* such as the environmental chambers, which are hosted by the EPA. • This process tends to progress and to evolve provided that the agency implements long-term policies, which support these initiatives. Such policies will ensure that their initiatives endure and that they are immune to changes in management styles of successive EPA's administrations. • These initiatives were possible due a behavioral change on the part of the EPA, which increasingly embraced cooperation as an efficient and effective approach to promote environmental protection and sustainability. He also emphasized that such posture does not preclude the agency to perform its legal obligations of legislation enforcement.

Source: author

Summary

The cooperative posture on the part of the EPAs has been possible due behavioral changes that evolved in the last two decades. The EPA progressively embraced cooperation as an efficient and effective approach to promote environmental protection and sustainability. This posture did not preclude the agency from performing its legal obligations of legislation enforcement.

Although respondents cited different initiatives for their respective contexts, three common findings are highlighted:

a) Due to the existence of a consolidated cooperation culture as well as previous cases of success, implementation of these initiatives is entirely possible;
b) Implementation is effectively facilitated by the existing institutional procedures and by the fluid environmental agency/companies relations structure, and
c) There is a need for the agencies to implement long-term policies supporting these initiatives.

Perceptions on the Environmental Agency´s Power to Influence, Pressure and Stimulate Companies to adopt more Sustainable Approaches for their Products, Processes and Services

This section presents the views of the EPA managers regarding the perceived power of their organizations to influence, to pressure and to stimulate petrochemical companies to adopt more sustainable approaches regarding their operations (Table 7.22). The interview protocol was presented in Appendix F.

Table 7.22- Perceptions of the Environmental Protection Agency managers´ of the power of their organization to Influence, to pressure and to stimulate petrochemical companies to adopt more sustainable approaches for their products, processes and services

RESPONDENT	PERCEPTIONS OF THE ENVIRONMENTAL PROTECTION AGENCY MANAGERS´ OF THE ORGANIZATION´S POWER TO INFLUENCE, TO PRESSURE AND TO STIMULATE PETROCHEMICAL COMPANIES TOWARDS SUSTAINABILITY
1	• The respondent emphasized that in addition to its extremely important role and obligations for enforcing legislation, it also has the equally important mission of pushing and incentivizing companies to move towards more sustainable states at the fastest possible pace. • The EPA should work together and influence other governmental bodies to develop policies that support these initiatives. • This support can be achieved via economic and fiscal *stimuli* for the implementation of eco-innovation processes at the company level aimed at the development or acquisition of cleaner and more sustainable solutions for the companies' products and processes. • This is likely to facilitate and incentivize companies' decision-making towards investments that are economically and socio-environmentally more sustainable.
2	• In general, the EPA does not establish the kind of technologies that should be used to reduce or preclude environmental contamination and resources depletion. The EPA promotes discussions on the available technologies or control strategies and defends the ones it considers the most appropriate. • He illustrated his argument with real world examples regarding, solid wastes, manufacturing processes, air pollution sources, solid waste incinerators etc. • According to the respondent, the environmental licensing process is a very effective tool to influence and pressure companies to adopt cleaner and more sustainable approaches for its processes.

Source: author

Summary

The reactions to this question complemented and reinforced the ones in previous sections. The EPAs rely on legal and cooperation tools and dynamics to influence and push companies to implement cleaner solutions for their products, processes and services. Moving beyond compliance with the legislation is their usual objective.

Perceptions of the Environmental Protection Agencies´ and their Managers´ Willingness and Preparedness to Support and Promote the Implementation of GCE-Based Initiatives

This section presents the views of the EPA´s managers regarding their organization´s and their own willingness and preparedness to support and promote GCE and GCE-based initiatives that help to meet companies´ environmental challenges. In parallel, they were asked to provide their impressions on how this can or will be done.

Table 7.23 presents a synthesis of the EPA´s managers' reactions to these questions. The interview protocol was presented in Appendix F.

Table 7.23- Perceptions of the Environmental Protection Agencies´ and their managers´ willingness and preparedness to support and promote the implementation of GCE-based initiatives

RESPONDENT	PERCEPTIONS OF THE ENVIRONMENTAL PROTECTION AGENCIES´ AND THEIR MANAGERS´ WILLINGNESS AND PREPAREDNESS TO SUPPORT AND PROMOTE GCE-BASED INITIATIVES
1	• According the respondent, he and the Agency are fully in accordance with and supportive of the GCE frameworks. • Although the Agency is prepared to support and promote GCE-based initiatives, he believed that, in order to CGE-related concepts to be introduced, accepted and implemented in the petrochemical sector, it is very important and necessary that there is the support of a powerful aggregative agent, to which the petrochemical companies are associated. In his opinion ABIQUIM and local industry representative associations are the perfect partners to help to achieve that objective.. • That partner should be responsible for presenting the GCE concepts to the companies in the sector and for promoting initiatives for incentivizing and supporting their dissemination and implementation. • The respondent argued that he sees ABIQUIM's Responsible Care Program as a fundamental initiative in the promotion of advancements, in the petrochemical sector, towards more sustainable states. He added that it could also stimulate companies to move beyond compliance with existing legislation. • In addition to emphasizing the role of the EPA and of ABIQUIM, the participation of the local petrochemical sector's representative associations is important in agreeing and promoting an agreement to introduce the GCE concepts as baseline guidelines in companies´ operating license issued by the EPA. • This initiative should be based on cooperation and dialogue and never be mandatory in nature especially because they are not currently supported by legislation. • He believed that such cooperative initiatives could generate much better and more effective results then trying to introduce subjective concepts in the form of laws. He called attention to the fact that, although subjective elements cannot be introduced into legislation, provisions for the support to such cooperative approaches and for the use of sustainability frameworks should be introduced into the legislation.
2	• The respondent was fully supportive of such initiatives. He also believed that the great majority of the agency personnel are likely to be in favor of the introduction of such newer and more sustainable approaches to the development of products, processes and services. • He stated that the environmental chambers are the best and very appropriate *fora* for the promotion, incentivizing and catalyzing the adoption and the implementation of GCE-based innovation processes by the petrochemical companies at the state level.

Source: author

Summary

Both interviewed, EPA managers stated that they and their organizations are fully supportive to the GCE frameworks and to the implementation of GCE-based initiatives.

As in the previous section, the EPAs rely on legal and voluntary tools and dynamics to influence and push companies to implement cleaner solutions for their products, processes and services. It is important to call attention to the importance that was given by respondent one to the cooperation and contribution of ABIQUIM and of the local industry representative organizations in the GCE implementation processes.

Perceptions of the Willingness of the Environmental Protection Agency to Promote Cooperation Initiatives with ABIQUIM to Influence and Stimulate GCE in the Petrochemical Sector

This section presents the views of the EPA´s managers regarding their organization´s willingness to promote cooperation initiatives with ABIQUIM aimed at influencing and stimulating GCE in the petrochemical sector. Table 7.24 presents a synthesis of the EPA´s managers' reactions to this question. The interview protocol was presented in Appendix F.

Table 7.24- Perceptions of the willingness of the Environmental Protection Agency to promote cooperation initiatives with ABIQUIM to influence and stimulate GCE in the petrochemical sector

RESPONDENT	PERCEPTIONS OF THE WILLINGNESS OF THE ENVIRONMENTAL PROTECTION AGENCY TO PROMOTE COOPERATION WITH ABIQUIM TO INFLUENCE AND STIMULATE GCE IN THE PETROCHEMICAL SECTOR
1	• The respondent argued that he sees full willingness of the State Environmental Agency to work in cooperation with ABIQUIM and with local chemical industry associations to promote and plan for the implementation of GCE as viable baseline frameworks towards technological change, aimed at conducting the sector to more advanced states of sustainability (social, economic and environmental). • Cooperation initiatives with these agents and with the companies were conducted in the past. Such initiatives generated very good outcomes. The implementation of ABIQUIM's Responsible Care Program in the petrochemical sector at the State level[107] can be cited as an actual example.
2	• The EPA has historically worked with ABIQUIM in many initiatives. The State EPA is hierarchically linked to the State's Secretariat for the Environment, which maintains an open and permanent channel of communication with ABIQUIM. • There is a great organizational and institutional interaction and a high level of dialogue between the EPA and ABIQUIM. This allows for cooperation, on a wide range initiatives. He interpreted that relationship as very symbiotic. • These relations will definitely facilitate cooperation between the EPA and ABIQUIM in promoting and incentivizing GCE-based eco-innovation in the petrochemical sector at the State level.

Source: author

[107] This is valid for one specific State in Brazil, which is associated with the respondent's jurisdiction.

Summary

According to both respondents, joint GCE promotional initiatives conducted by the EPAs, ABIQUIM and other petrochemical industry representative organization are entirely feasible as these agents have a sound history of close cooperation and have efficient and operative communication channels.

8.4.3- In-depth Interviews at the Meso-Level within the Brazilian Chemical Industry Association (ABIQUIM)

As noted in Section 7.3.1 in Chapter 7, in the context of this thesis research, the pressures exerted by the chemical and petrochemical industry trade association (ABIQUIM) emerged as one of the most significant determinants of companies´ willingness to engage in GCE-based eco-innovation activities. In addition, the in-depth interviews within the Brazilian petrochemical companies and within the Environmental Protection Agencies corroborated this view (cf. Sections 7.4.1 and 7.4.2)

In modern industrial societies, as environmental challenges become increasingly severe, it is more evident that many stakeholders must co-work to help societies to make the transition to sustainable patterns.

In that context, ABIQUIM has many responsibilities and opportunities, to help the chemical and petrochemical sectors make the transition to more sustainable behavioral patterns.

ABIQUIM can work in many ways including developing and supporting initiatives to facilitate the process of change of the awareness, perceptions and actions of the socio-economic actors with regard the (un) sustainability of their activities.

Such efforts have been important in catalyzing initiatives designed to encourage the search for technological practices that promote more sustainable states of social, economic and environmental performance of the Brazilian petrochemical companies´ products, processes and services.

This is attested to by ABIQUIM´s public commitment to the Brazilian chemical industry´s competitiveness and sustainable development as it is proclaimed in its official Mission and Vision statements. That commitment has been effective *via* ABIQUIM´s various sectoral and thematic commissions, which aim at the search for continuous improvements by the chemicals manufacturing companies in the Brazilian economy within standards that are accepted by the communities, environmental organizations and by the public sector.

It represents the Brazilian chemical and petrochemical sector in the international negotiations and agreements and it is a member of the *Mercosur*[108] *Chemical Industry*

[108] Mercosur or Mercosul (Southern Common Market) is an economic and political agreement among Argentina, Brazil, Paraguay, Uruguay, and Venezuela; with Bolivia becoming an accessing member on 7 December 2012 to be ratified by the Member State's legislatures. Its purpose is to promote free trade and the fluid movement of goods, people, and currency. (source: http://en.wikipedia.org/wiki/Mercosur)

Council (CIQUIM), and of the *International Council of the Chemical Associations* (ICCA).

This was exemplified by ABIQUIM´s Responsible Care Program (RCP) whose implementation and maintenance is under the responsibility of leadership commissions represented by the ABIQUIM´s member organizations. The RCP has helped the participating companies to make contributions to the sector on its move to more sustainable states.

The six topics presented in Table 7.25 guided the analysis on ABIQUIM´S perceptions of the role that it plays in influencing and catalyzing companies, in the petrochemical sector, to adopt technical and non-technical initiatives. Those initiatives will help to ensure that they develop and implement cleaner and more sustainable products, processes and services.

The complete protocol that guided the interviews and the answers provided by the respondent was presented in Appendix F.

Table 7.25- Structure of the in-depth interviews conducted with the Brazilian Chemical Industry Association (ABIQUIM)

1	• Initiatives that have been conducted by the Environmental Agency aimed at influencing, promoting and catalyzing changes towards cleaner and more sustainable technological states in the petrochemical sector, and • Future planned initiatives.
2	• Perceptions on the influence exerted by the environmental agency and by future legislation, on petrochemical companies, to push them to engage in eco-innovation activities towards higher states of sustainability.
3	• Perceptions on cooperative work between the Environmental Agencies and the petrochemical companies in order to promote more effective actions regarding the search for solutions that could help companies to make expedited progress towards sustainability.
4	• Perceptions on how and on the extent to which the Environmental Agency can influence and pressure companies to adopt sustainable approaches that were proven to be successful.
5	• Perceptions on the extent to which the respondent and/or the Environmental Agency are willing to support and to promote GCE-based initiatives; • Perceptions on how prepared the Environmental Agency is to engage in activities aimed at influencing companies to adopt and use GCE as baseline principles in the process of meeting their environmental challenges, and • Perceptions on what can/will the Environmental Agency do in this regard.
6	• Perceptions on the possibility and willingness of the Environmental Agency to promote joint initiatives in cooperation with ABIQUIM and other industry representative associations to promote GCE in the Brazilian petrochemical sector.

Source: author

The questions pertaining to the following sections guided the analysis on ABIQUIM´s roles and responsibilities regarding its potential to influence and catalyze technical and non-technical initiatives that can ensure the development and implementation of GCE-based cleaner and more sustainable technologies for the Brazilian petrochemical companies´ products, processes and services.

The results of this analysis are presented in Table 7.26 through Table 7.31.

Table 7.26- ABIQUIM´s initiatives to influence and catalyze GCE-based activities regarding the adoption of technical and non-technical initiatives towards advanced states of sustainability

ABIQUIM´S INITIATIVES TO INFLUENCE AND CATALYZE GCE-BASED ACTIVITIES REGARDING THE ADOPTION OF TECHNICAL AND NON-TECHNICAL INITIATIVES TOWARDS ADVANCED STATES OF SUSTAINABILITY.
• ABIQUIM's interactions with its associates are conducted via its sectoral and thematic commissions. These commissions were formed by ABIQUIM's associated companies' representatives and by other invited stakeholders. • In these *fora*, problems are discussed, diagnoses are made, solutions are proposed and planning is done for solving such problems (such as future environmental legislation and agreements, sustainability trends and demands of markets, environmentally-based barriers for products etc.). In addition, strategies and plans are discussed for making advancements with regard to common objectives of the chemical and petrochemical sectors. • ABIQUIM's actions are planned and conducted based on the outcomes of the discussions that are conducted in regard to its domains. • As a result of such initiatives, ABIQUM has placed a strong focus on capabilities and culture building. This was implemented via a large number of seminars and courses that are hosted by ABIQUIM, which are related to all areas that comprise the RCP. • As the RCP is fully committed to S and SD as well as to related issues. • These initiatives and mechanisms greatly help to solidify, in the petrochemical domain, the sense of the importance of S and SD in the companies' environmental and socio-economic relations. As a consequence, such initiatives represent an important aid in diminishing the differences among companies' perceptions on SD and the consequent levels of advancements towards S. • ABIQUIM is consistently and regularly in contact with national and international organizations in order to capture new information, demands and trends that can be used in its strategic planning as well to provide *stimuli* and support for companies in their initiatives aimed at their socio-economic and environmental continuous improvement. • ABIQUIM supports a series of initiatives aimed at promoting advanced states of sustainability of the sector such as: o Aiding the structuring of the Brazilian School of Green Chemistry and the Brazilian Green Chemistry Network; o Conducting cooperative initiatives with EMBRAPA-Agroenergia Bioenergy for the development of a renewables-based chemical processes; o Supporting national and foreign governments and private companies representatives that are interested in investing or expanding their research investments in renewables-based chemical processes. • In terms of initiatives that are envisioned for the near future, ABIQUIM intends to make mandatory for its members, as is the case with the RCP, the implementation of the Global Product Strategy Program (GPS)[109] initiative. The GPS was originally developed and hosted by the International Council of Chemical Association (ICCA), which established a framework to be globally applied with regard to chemical products' management throughout their life cycles. • According to the respondent, the GCE frameworks can be integrated as a baseline to and are in harmony with the GPS principles.
Summary In this section, the respondent demonstrated that ABIQUIM is fully committed with the sector´s sustainability and with the promotion of SD. It´s

[109] The GPS is a chemical industry worldwide initiative, which advocates a combination of regulations and voluntary programs to harmonize the global level of product safety assessment

initiatives are consistent and are a part of an ongoing process of continuous improvement that involves cooperation initiatives that involve all important stakeholders.

Source: author

Table 7.27- Perceptions about the usefulness and contributions of this research´s findings for the engagement of companies in GCE-based initiatives: the important catalyzing agents and the possible means

PERCEPTIONS ON THE USEFULNESS AND CONTRIBUTIONS OF THIS RESEARCH´S FINDINGS FOR THE ENGAGEMENT OF COMPANIES IN GCE-BASED INITIATIVES: WHO SHOULD CATALYZE THOSE ACTIONS? HOW?
• Because this thesis research's results reflect the perceptions and practices of the companies regarding GCE, they are also useful at the sector level (represented by ABIQUIM). • Since these findings may not be structured at the company level, once they are complied, organized and structured, they will provide the responsible agents that are responsible for the development of the sector with a baseline from which planning for new initiatives towards GCE-based eco-innovation can be conducted. • This will help to improve the communication channels with the broad society and with the government and help to enhance the level of trust regarding the socio-environmental responsibility of the sector. This is likely to strengthen current partnerships and to facilitate the occurrence of new associations and projects. • The introduction and the promotion of GCE should be, at its basic level, conducted at schools and at the universities in order to exercise citizenship and create a strong basic culture and behavior in respect to sustainable products, processes and services. • Many agents can play very important roles in promoting eco-innovation and GCE. As examples she mentioned that the NGOs awareness raising and pressuring elements are important. Additionally, the government can be an important incentivizing element, and the media can function in investigating and divulging information and in bringing pressure for change toward more sustainable approaches in industry. • In the respondent´s view, GCE-related initiatives should be promoted and catalyzed by the trade association (ABIQUIM) in cooperation with all important stakeholders.
Summary The respondent´s reactions to the question attested to the importance and the usefulness of the results of this thesis research for the promotion and the implementation of GCE in the Brazilian petrochemical sector. They highlighted the importance that such initiatives should be conducted at the sector level, by ABIQUIM in cooperation with initiatives with other important stakeholders. That view corroborated the perceptions of the petrochemical companies´ managers and of the environmental agencies respondents that were presented in previous sections.

Source: author

Table 7.28- Perceptions about the contributions of the findings of this thesis research to ABIQUIM's initiatives towards a more sustainable Brazilian petrochemical industry

PERCEPTIONS ON THE CONTRIBUTIONS OF THIS THESIS RESEARCH´S FINDINGS TO ABIQUIM´S INITIATIVES TOWARDS A MORE SUSTAINABLE BRAZILIAN PETROCHEMICAL INDUSTRY
• The fact that the findings were presented in an organized, structured and contextualized form provided ABIQUIM with a good, systemic view of the (behavioral) determinants of GCE-based eco-innovation processes and their interrelations. This allowed ABIQUIM to start its projects and initiatives, from a clearer and defined baseline. • In terms of initiatives towards a more sustainable chemical enterprise, the respondent reported that ABIQUIM's main purpose is to exert influence. This is conducted through education and training as well as in conducting a great variety of cooperative programs directed to ABIQUIM´s affiliates in association with external private and governmental stakeholders. The findings of this research can provide rich content base upon which these initiatives can be formulated, developed and implemented.
Summary According to the respondent, the findings of this research provides a useful information base on which ABIQUIM can develop technical and non-technical initiatives towards more sustainable Brazilian petrochemical enterprises.

Source: author

Table 7.29- Perceptions about ABIQUIM´s willingness to support and to promote the implementation of GCE: ABIQUIM´s preparedness, importance of the Responsible Care Program, and stakeholders participation

Perceptions on ABIQUIM´s Willingness to Support and to Promote the Implementation of GCE: ABIQUIM´s Preparedness, Importance of the Responsible Care Program, and Stakeholders Participation
• ABIQUIM is fully supportive to GCE and it is prepared to engage in actions aimed at promoting GCE and eco-innovation in the Brazilian petrochemical sector. • ABIQUIM's RCP represents its overarching initiative that supports all initiatives regarding sustainability and sustainable development initiatives. • The RCP is the best and is the key instrument to harbor and to promote the full spectrum of GCE principles and practices (some of the GCE principles and GCE-based eco-innovation approaches are already being promoted by ABIQUIM. • The introduction and the implementation of the GCE principles requires maturity of the different agents with regard not only to GCE but also with regard to their relations to the environmental and the socio-economic relations associated to the companies' operations. ABIQUIM's influence contributes largely to help to increase such maturity and to help to promote the equalization of the different states of sustainability of companies within the sector. Once the desired level of maturity is achieved, it will be possible for ABIQUIM to institutionalize GCE as the sector's baseline for the development of cleaner and more sustainable products, processes and services. • ABIQUIM has developed initiatives to obtain governmental support for Green Chemistry (GC) and to engage in GC initiatives. Emphasis has been placed in making clear that GC is not limited to renewables-based chemicals but that they go much beyond it.
Summary The respondent reactions to this question demonstrated that ABIQUIM is willing and is fully supportive to promote the implementation of GCE-based initiatives in the Brazilian petrochemical sector. It is already engaged in enhancing the maturity of the sector with regard companies´ relations to GCE and to the environmental and the socio-economic relations associated to the companies' operation. ABIQUIM´s view on the RCP corroborated the ones reported by companies´ and EPA´s managers (cf. Sections 7.4.1 and 7.4.2. of Chapter 7). According to them, the RCP is the best and is the key instrument to harbor and to promote the full spectrum of GCE principles and practices and GCE-based eco-innovation.

Source: author

Table 7.30- Perceptions about ABIQUIM´s willingness to engage in cooperation initiatives with environmental protection agencies and other governmental and non-governmental organizations to promote GCE in the Brazilian petrochemical sector

PERCEPTIONS ABOUT ABIQUIM´S WILLINGNESS TO ENGAGE IN COOPERATION INITIATIVES WITH ENVIRONMENTAL PROTECTION AGENCIES AND OTHER GOVERNMENTAL AND NON-GOVERNMENTAL ORGANIZATIONS TO PROMOTE GCE IN THE BRAZILIAN PETROCHEMICAL SECTOR
• ABIQUIM has open and active channels of cooperation and communication with governmental organizations at Federal, State and Municipal levels. • ABIQUIM is respected and accepted by governmental environmental and non-environmental organizations (e.g. Ministry of the Environment, State Secretariat for the Environment, State Environmental Agencies, Municipal Environmental Organizations etc.) as the official representative association of the Brazilian Chemical and petrochemical industry; therefore, the appropriate formal and informal cooperation and partnership consultations and initiatives have been consistently implemented.
Summary ABIQUIM is the official representative association of the Brazilian chemical and petrochemical industry. It has open channels of communication with the Environmental Protection Agencies and other important governmental and non-governmental organizations across the country. It has open channels of communication and cooperation with those organizations and the engagement of cooperation initiatives to promote, disseminate and implement GCE in the Brazilian petrochemical sector is fully feasible.

Source: author

Table 7.31- Perceptions about the extent to which the findings of this research and the frameworks of GCE can be helpful and can contribute to the innovation and sustainability-related objectives of the National Pact of the Brazilian Chemical Industry

PERCEPTIONS ABOUT THE CONTRIBUTION OF THE FINDINGS OF THIS RESEARCH AND OF GCE FRAMEWORKS TO THE INNOVATION AND SUSTAINABILITY-RELATED OBJECTIVES OF THE NATIONAL PACT OF THE BRAZILIAN CHEMICAL INDUSTRY[110]
• According to the respondent, GCE and this thesis research's results can positively contribute to the Pact. • Changes have occurred throughout the world, in the last few years, after the onset of the Pact. Such changes directly and indirectly affected the interests and operations of the Brazilian chemical and petrochemical sectors. Therefore, a review of the Pact will be needed. The results of this research can contribute to the development of such a comprehensive review.
Summary This thesis and its results match the contents and objectives of the National Pact of the Brazilian Chemical Industry. The findings of the study can positively contribute to the development of sustainability initiatives associated with the Pact. The thesis findings can contribute to the upcoming review of the Pact, which was originally issued in 2010.

Source: author

[110] According to the Pact, the chemical industry agrees to:

- Keep developing high standards of conduct and promoting sustainability;
- Encourage Brazil's economic growth and long-term economic sustainability through investments;
- Develop technologies, and innovate with advanced products and solutions;
- Raise standards for management, tax responsibility and productivity improvement;
- Continuously promote the qualification of chemical industry professionals, and
- Contribute to developing human resources in related sectors.

7.5 Suggestions for Eco-Innovation Policies

7.5.1 The Importance of Adequate Policies in Eco-Innovation Processes

This thesis research was designed to contribute to the promotion of GCE-based eco-innovative technological changes in the Brazilian petrochemical sector. Such contribution builds upon the identification of favorable conditions upon which companies´ willingness to engage in such processes can be developed.

As noted in Chapter 3, innovations do not emerge and evolve unexpectedly. Firms deliberately innovate through complex dynamic processes that involve a series of interrelated, interdependent environmental and socio-economic variables and agents (individuals and organizations) relationships (Edquist, 2005).

This research´s primary interest resides in the study of the behavioral aspects of eco-innovation processes. In this respect, its core interest was the study of behavioral determinants associated with GCE-based technological change.

According to its underlying theoretical foundations, the occurrence of technological change is contingent on changes in the perceptions and beliefs of the key agents in respect to the environmental and socio-economic variables that ultimately determine the behavior (cf. Chapter 3).

Regardless of the trajectory that such processes may take, the human element occupies a central position. In fact, according to the theoretical approach adopted in this study, the occurrence of these processes is largely dependent on the existence of behavioral intention (willingness) of the key actors to eco-innovate.

Processes of technological changes through innovation are complex. They require careful elaboration and need to be supported by properly designed policies and strategies that can maximize the likelihood of companies´ engagement in eco-innovation processes.

In the context of this thesis research, properly designed policies are understood as those that address the origins of the problems as opposed to the others that focus on their symptoms. According to Montalvo Corral (2002: 1), “at the core of most environmental problems lies a conflict between individual interests in the short term, with long term social interests”. A properly designed policy to promote such reconciliation, in the field of environmental preservation, requires the inclusion of the determinants of the environmental behavior in companies (*ibid*).

In order to identify the determinants and the preconditions that generate companies´ intention (willingness) to engage deliberately in GCE-based eco-innovation, a framework was developed. It was conceived to identify, explore, differentiate and assess a set of structural relationships among determinants and their influence on the environmental planned behavior of the firms (cf. Chapter 5).

The identification and the use of the most favorable pre-conditions and determinants of willingness in the development of policy by governmental organizations, by the petrochemical sector representatives and by petrochemical company shifts the focus of the policies from a general to a specific approach. Such specificity is expected to help to

produce properly designed policies that are more precise as they act on the "leverage points" for the willingness enhancement. Consequently, they theoretically maximize the chances of success in encouraging companies to engage in GCE-based eco-innovation processes.

> "An accurate identification and weighting of the factors that account for the resistance or willingness to change would allow policies to be formulated that prioritize the encouragement of behavioral change on a collaborative basis over and above regulation" (Montalvo Corral, 2002: 8)

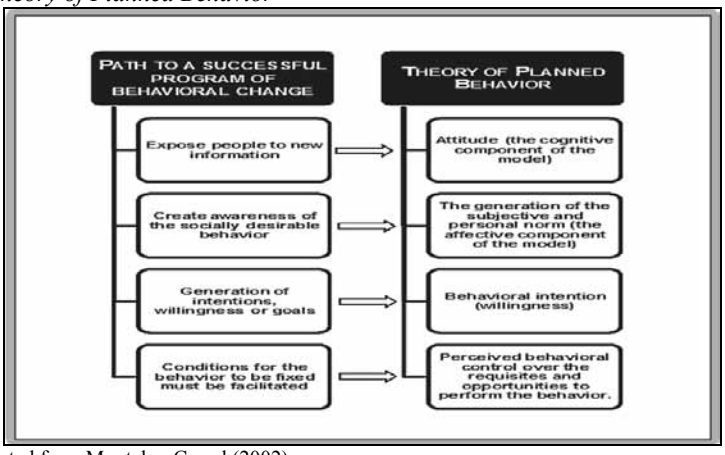
Although an in depth study of environmental and innovation policy development is out of the scope of this thesis research, the identification of these contextual "leverage points" allowed for the elaboration of suggestions, or guidance, based on which these policies and strategies can be developed by the aforementioned agents. These recommendations can be used in their entirety or segmented according to the users´ objectives.

7.5.2 From Beliefs to Design of Policies: Suggestions from the Empirical Evidence

The suggestions for policy design proposed in this thesis research follow the *path to a successful program of behavioral change* for a specific target group. That path is commonly agreed upon in the literature of social psychology (*ibid*) and has been compiled by Montalvo Corral.

The preference for the utilization of that approach resides on the facility of the incorporation of the TPB into the steps that compose the *path*. That characteristic facilitated the translation of the results of this thesis research, relative to the behavioral, normative and control beliefs, from a theoretical state into objective and practical policy recommendations. Figure 7.9 presented this correspondence in a pictorial form.

Figure 7.9- The correspondence of the path to a successful program of behavioral change with the Theory of Planned Behavior



Source: adapted from Montalvo Corral (2002)

The sequence presented in Figure 7.9 was used to organize and to present policy suggestions in an orderly fashion that is in harmony with the theoretical grounds that supported this thesis research.

The suggestions for policy development proposed in this section were based on the results from the statistical analyses, upon this thesis author's insights from the face-to-face interviews and from his work experiences in the industry during the last twenty-five years. They were designed to be utilized in the Brazilian petrochemical realm at both the micro (companies) and meso (the sector) levels as well as in the governmental domain.

Policy Suggestions for the Facilitation of Innovative Behavior and for Promoting Companies´ Engagement in GCE-based Eco-Innovation Processes

Step 1: Expose People to New Environmental Information

Following the *path to a successful program of behavioral change*, the first suggestion was derived from the TPB´s attitudinal realm.

As noted in Chapter 6, the statistical analyses showed that managers perceived that the environmental risks associated with the operations of their companies were low. In addition, the statistics indicated that there was a negative correlation of the perception of environmental risks with business opportunities and with the economic risks associated to innovation (cf. Appendix D).

This perception of low risks was likely to decrease managers´ sense of necessity in respect to the adoption of cleaner and more sustainable products, processes and services. In addition, it also makes it difficult to identify the actual sources and the root causes of environmental problems and challenges.

It is this thesis researcher´s belief that the failure in identifying the technological origins of firms´ environmental risks may impede the company from identifying basic needs towards advanced states of sustainability. It may preclude the firms from detecting the need for innovating and making more appropriate choices regarding the innovative technological paradigms, regimes and trajectories and solutions that are required to take the corporation to advanced states of sustainability in more efficient and expedite ways.

The consciousness of the need for innovating is likely to create awareness regarding the economic barriers and business drivers associated with GCE-based innovation processes. It can also develop companies' sense of anticipation that can eventually counteract the negative impacts, diminish the economic risks and take advantage of the market opportunities associated with such processes (cf. Section 7.3.1 of Chapter 7).

Figure 1.2 in Chapter 1 provided a contextualization and visualization of those arguments. It depicted the circular and causal relationships between the production processes and the environmental and socio-economic domains. These relationships demonstrated how the production processes affect the biosphere´s diverse capitals (environmental, human, social, organizational, manufactured), environmental services, investments, and ultimately the creation of welfare and utility in societies,

Based on these arguments, it was suggested that education-oriented policies are necessary and should be developed. These policies are expected to support and promote educational initiatives that develop in individuals the sense of safe and risky operations (cf. Section 7.3.1 of Chapter 7). In parallel, they should educate individuals with regard the environmental risks that their companies generate throughout the entire life cycle of its products, processes and services.

It is important to stress that such educational initiatives must focus on the origins of the environmental, health and safety problems. That is, they must address problems by making the proper associations of the risks and hazards (toxicity, explosion risks, process parameters etc.), of products and processes, with their conception and design. This would make the differences clear between a "design-related" safe and risky operations. The "design-related" safer the operations are, the fewer risk control measures will be required.

Such educational efforts should identify the links and the consequences of these environmental risks and impacts with the environmental and socio-economic space within which the company operates. Additional, emphasis should be placed on the consequences, for the company's economic sustainability, of the adoption of cleaner and more sustainable GCE-based innovative technologies.

Policies for providing corporate, trade associations, governmental, academic and society members with new information should also include those that communicate people about the concepts and the principles that underpin GCE.

As noted in Chapter 1, the Brazilian chemical industry is listed among the ten largest chemical industries in the world. In 2010, the industry made official and explicit, *via* the *Brazilian Chemical Industry Association* (ABIQUIM), its qualitative and quantitative planned expansion initiatives to rank the world´s fifth largest chemical industry in the world by the year 2020.

Its trade activities embrace market and non-market relations with various regions across the planet (cf. Appendix E). Such relations are not limited to product exports; it also includes the import of raw materials, knowledge and equipment.

The Brazilian petrochemical sector´s dimension, its global coverage, its high technological characteristics and its worldwide capillarity and interrelationships, naturally expose its companies to contemporary and future global demands, information and trends in respect to environmental (un)sustainability and its consequences to business.

For this reason, the concepts of sustainable development and cleaner technologies are currently undisputable in the sector. They are attested to by virtually all disclosed social and environmental commitments of their companies.

Such acknowledgement was verified by this thesis research in two ways. First, the score obtained by the measurement of the planned behavior of the firm (cf. Section 6.5 of Chapter 6) revealed that companies, in the Brazilian Petrochemical sector are currently willing to engage in GCE-based eco-innovation processes. Secondly, these perceptions regarding managers´ acceptance and consciousness regarding corporate sustainability, sustainable development and the GCE principles were captured and confirmed by the in-depth interviews conducted with companies´ managers and with other decision-makers (cf. Section 7.4.1).

In addition to these findings, the qualitative and the quantitative surveys revealed two other important factors associated with the GCE frameworks and principles. The first revelation showed that most managers were not acquainted to the GCE frameworks in the form that they were proposed in Chapter 2. The second showed that, despite this lack of acquaintance, some of the principles were already in use in varying degrees by all interviewed companies.

According to the managers, the reason for that is associated with the fact that some principles are commonly known in the sector, as they have been individually introduced by different initiatives throughout recent decades. This introduction was not uniform and varied across the sector.

With regard to the thesis survey´s quantitative survey, the acquaintance of the managers with respect the principles of GCE was also tested in an indirect fashion. In order to try to avoid or to diminish bias what could be produced by direct questions, that acquaintance was tested in the following way:

a) First, the Twelve Principles of the Green Chemistry, and the Twelve Principles of Green Engineering were presented to the managers in the first two pages of the qualitative questionnaire;
b) The questions intended to measure managers´ willingness to engage in GCE-based eco-innovation processes were placed as the first (*W1*) and the last question (*W2*) of the questionnaire (cf. Appendix E). It is important to call attention to the fact that these two questions were identical.

The idea behind this approach was to measure the variation of the answers before and after the respondents had gone through the entire questionnaire. That is, before and after they had been exposed to the information relative to GCE and companies engagement in GCE-based eco-innovation processes.

The results showed that 30.56 percent of the respondents changed their opinion and adopted a more favorable posture after they reflected about and became more familiar to the issues presented in the questionnaire regarding CGE and companies engagement in GCE-based eco-innovation processes. Another 22.2 percent became more unfavorable and the remaining 47.2 percent kept their favorable initial opinion.

Table 7.32 presents the information that is more detailed on the 22.2 percent of the questionnaire answers that indicated a decrease in managers´ willingness to engage in GCE-based eco-innovation processes after they have gone through the survey questions.

Table 7.32- Detailed results of the answers in the thesis research´ survey questionnaire that indicate a decrease in managers´ willingness to engage in Green Chemistry and Green Engineering after they have been exposed to more detailed GCE information

W1		W2	
Strength of the Responses	Responses Scores		Strength of the Responses
Extremely High	7	6	Quite High
Extremely High	7	6	Quite High
Extremely High	7	6	Quite High
Extremely High	7	5	Moderately High
Extremely High	7	5	Moderately High
Extremely High	7	5	Moderately High
Extremely High	7	4	Uncertain
Quite High	6	1	Extremely Low

Source: author

A close look into Table 7.32 reveals that, although there was a decrease in managers´ willingness to engage in GCE-based eco-innovation processes, this decrease was not strong enough to produce a decrease in companies´ willingness (companies´ planned behavior) to levels that were unfavorable to their engagement in GCE-based eco-innovation processes.

In fact, in the universe of eight answers that produced scores for *W2* that were lower than *W1*, three of the managers held quite high willingness to eco-innovate in GCE. Three other managers reported a decrease in willingness from extremely high to moderately high. One manager became uncertain and one changed radically his/her opinion and reported to be strongly not willing.

It can be argued that, based on the TBP, these results suggest that although these managers perceived that companies were willing to eco-innovate in of GCE, they might have perceived that they did not possess full control over the requisites and opportunities regarding knowledge and technologies, actors and networks and institutions that are required to eco-innovate in GCE.

That argumentation was supported and verified *via* the in-depth interviews (cf. Section 7.4.1).

Upon the detection of these shortcomings, they can be overcome through the implementation of adequate initiatives supported by appropriate policies.

This represents an indication of the importance of properly designed environmental policies that include education and information regarding:

a) The GCE frameworks and their potentiality to solve or diminish the company´s environmental challenges;
b) The environmental impacts on the biosphere produced by companies´ operations throughout the entire life cycle of their products, processes and services, and
c) The relations of such impacts on the diverse socio-economic factors that are important for the corporation´s social and economic relations

It is expected that they have great potential for stimulating and promoting the acceptance of the GCE frameworks. In parallel, they can also increase participation and enhance creativity, which are very important factors in innovation processes.

Based on these arguments and evidence, this thesis author suggests that, in terms of knowledge creation policies, the concepts and principles relative to GCE should be introduced and/or reinforced.

As was documented, policy efforts to provide environmental risk information as well as to promote and educate about the fundamentals of GCE should be adequately incorporated by the petrochemical industry at the meso-level by the trade association and at the micro-level by the companies.

It is expected that this approach can be used to effectively deepen the awareness and commitment of corporate leaders to apply that knowledge in light of the extensive and growing evidence of the benefits that GCE can bring to their company's social, environmental, and economic performance.

Step 2: Awareness of the Social Desirability of the Behavior (engaging in GCE-based eco-innovation activities)

Environmental and sustainability policies, in the social domain, can be understood as those policies aimed at the generation of mechanisms that allow for responses to the social pressures arising from the market, from the community and from the regulatory actors regarding the adoption of cleaner and more sustainable products, processes and services.

According to this thesis research´s behavioral model:

a) The pressures that the market exerts on the firm, to develop cleaner technologies, arise mainly from the competitive context and from customer's expectations regarding specific environmental qualities of its products and services;
b) The community pressure transmits to the companies signals and demands arising from the community and from the managers´ and companies´ important referents (personal, internal and external to the corporations) regarding the adoption of cleaner and more environmentally sustainable practices, technologies products and services;
c) Regulatory pressures concerning current and potential future pressures are derived from the regulatory authorities and legislation as well as from the pressures arising from the trade associations, standardization and industry´s representative organizations, and the companies´ national and international agreements.

According to the results of the statistical analyses, presented in Section 7.3.1, the perception of social pressure in respect to social, environmental and economic sustainability of companies in the petrochemical sector arise from:

- Trade organizations,
- The sector´s representative associations and companies´ agreements at the national and international levels ;
- Communities;
- Legislation, and
- Regulatory authorities.

Pressures arising from the trade organizations and from the sector´s representative associations and companies´ agreements at the national and international levels explained

most of the variance in the social pressure behavioral domain. This can be explained by the fact that, in the Brazilian context, most corporate mechanisms used by companies to capture such social pressures derive from: (a) regulatory authorities and legislation, and (b) voluntary initiatives and agreements.

Such initiatives mostly encompass management, quality, social responsibility, environmental standards and norms (e.g. ISO series 9000, 14000, 26000; The National Quality Prize; ABIQUIM´s Responsible Care Program, The Global Product Strategy etc.), and sustainability reporting initiatives such as those that are based on the Global Reporting Initiative framework.

In-depth interviews with the managers in the petrochemical sector revealed that, in the Brazilian petrochemical sector, among the existing initiatives, the Responsible Care Program (RCP) [111] occupies a central position (cf. Section 7.4.1). Currently the implementation of the RCP is mandatory for all ABIQUIM associated companies.

The search for achievement of those objectives are guided by general directives that are issued, by ABIQUIM, at sector level, and implemented at firms´ level according to companies´ culture, beliefs and characteristics. Sections 7.4.1, 7.4.2 and 7.4.3 provided a detailed view on petrochemical companies´ managers, EPAs´ and ABIQUIM´s perceptions on the importance and the effectiveness of the RCP in the Brazilian context.

The RCP is an extensive initiative containing sixty-two directives, which are used by companies to build the foundations of their "Responsible Care Program (RCP) Management System", which involves the environmental, economic and social realms according the following dimensions:

- Health;
- Safety;
- Environment;
- Corporate protection;
- Quality, and
- Social

It is the belief of this thesis author that the RCP policy guidelines, designed to promote the interaction of companies with their stakeholders, are effective in helping the companies to monitor and to respond to the market, community and regulatory pressures.

Once sensing and responding mechanisms are properly developed and implemented by companies, they can be used to promote the development and usage of good communication channels with their target stakeholders to:

[111] "Responsible Care is the chemical industry's unique global initiative that drives continuous improvement in health, safety and environmental (HSE) performance, together with open and transparent communication with stakeholders. Responsible Care embraces the development and application of sustainable chemistry, helping our industry contribute to sustainable development while allowing us to meet the world's growing need for essential chemicals and the products those chemicals make possible. Responsible Care helps the industry to operate safely, profitably and with care for future generations. Through the sharing of information and a rigorous system of checklists, performance indicators and verification procedures, Responsible Care enables the industry to demonstrate how its health, safety and environmental performance has improved over the years, and to develop policies for further improvement. (International Council of Chemical Associations) (http://www.icca-chem.org/en/Home/Responsible-care/), accessed in August, 2012.

- Capture and identify market, community, regulatory and other organizations´ demands, and
- Use this information to fulfill such demands *via* eco-innovation and other processes.

The importance of these elements is exemplified by the contents of Section 4.6 of the document "Responsible Care Program: Requisites for the Management System" published by ABIQUIM[112], The document prescribes communication, participation and consultation with the stakeholders (internal community, external community, clients, suppliers, media, governmental and non-governmental organizations and shareholders) through the following steps:

- Identification of stakeholders;
- Creation, implementation, and maintenance of instruments and communication channels and dialogue with stakeholders;
- Creation, implementation, and maintenance of appropriate and adequate procedures and means that allow for the acknowledgement and the response to the demands, expectations and suggestions of the stakeholders;
- Creation, implementation, and maintenance of appropriate and adequate procedures that allow for effective and efficient communication actions.

The spectrum of stakeholders embraced by these communication channels allow for their use in monitoring and responding to the social pressures arising from the market, community, regulators, legislation and companies´ agreements with regard the societal desire towards cleaner products, processes and services as long as they are adapted and orientated to do so.

As a suggestion for policy development, the creation of mechanisms that link the RCP´s guidance to the decision-making *nuclei*, within the companies´ realm, would help companies to profit from useful and valuable information that could demonstrate the need for firms´ engagement in GCE-based eco-innovation processes.

Such engagement could generate solutions that help companies to be ahead in terms of taking advantage of business opportunities, to go beyond current environmental legislation and taking precautionary measures regarding future tighter environmental regulations. Finally, these solutions certainly could help companies to obtain and continue to retain a *societal tacit license to operate* by reconciling their interests with those from the society.

It is important to note that to be ahead of the environmental legislation was reported by many interviewed managers as a highly desired objective. Despite this willingness, they posed that such advances can be obtained in a better and faster manner *via* self-imposed and deliberate initiatives and objectives. They emphasized that such initiatives and objectives should take into account companies´ resource limitations, feasible deadlines and their economic and competitive sustainability.

The results of the in-depth interviews indicated that these initiatives find full acceptability on the part of the interviewed EPAs. According to the in-depth interviews, cooperative

[112] http://www.abiquim.org.br/atuacaoresponsavel/pdf/Programa-AR-2012-manual-de-requisitos-de-gestao.pdf

initiatives such as RCP are very much supported by the EPAs. Although not minimizing their role as regulators and legislation enforcers, they reported that they allocate a high level of importance on cooperation work with companies (cf. Section 7.4.2).

Step 3: Facilitation of Behavioral Change

As previously noted in the outset of Section 7.5.2, the *path to a successful program of behavioral change for a target* group prescribed that for a behavioral change to take place, conditions for the behavior to be fixed must be facilitated.

In terms of the TPB, and in the context of this thesis research, it corresponds to the *perceived behavioral control* that a company must have over the requisites and opportunities for changing its perceptions and behavior and deliberately engage in GCE-based eco-innovation processes.

In this respect and according to the analysis of variance, this research documented that the path to such behavioral change is predominantly associated with the control (control beliefs) over the capabilities pertaining to the knowledge and technologies (*KTC*) and to the actors and networks (*AN*) behavioral domains.

The Brazilian petrochemical sector, just like other petrochemical sectors worldwide, is characterized by its high technological state and by its capacity for innovation and product diversity (García-Johnson, 2000). Consequently, the competence of the sector for building the required capabilities to find, develop and implement the solutions for the challenges, posed by the environmental and the socio-economic landscapes, is undisputed and has been demonstrated during past decades.

The suggestions for policies presented in this section are based upon the results of the statistical analyses that were presented in Section 7.3.1. They intend to provide scientifically based information, to the chemical sector at the meso and micro levels, with respect the significant determinants of companies´ willingness to engage deliberately in GCE-based eco-innovation processes.

The richness of these suggestions resides in the fact that they have been identified *via* a judicious, scientifically based, look inside the companies with a very strong focus on the sources of willingness to eco-innovate in GCE.

In respect to the knowledge and technologies domain, policies and strategies aimed at eco-innovating in GCE should be placed in the integration of knowledge and learning processes. Knowledge integration should be stimulated *via* the formation and the establishment of self-management teams. Such organizational capability is plausible and adequate as self-management teams refer to a knowledge integration mechanism for complex and non-routine organizational tasks especially when task uncertainty, novelty, and complexity preclude the use of existing routines or directives.

Additionally, it is important that such policies and strategies for knowledge integration should include mechanisms that promote, as much as possible, the correspondence of the architecture of the capabilities with the firm's structure of authority, communication, and decision-making, whether formal or informal

The research results also highlighted the need for the development of eco-innovation policies that supported and stimulated the building of advanced technological innovation capabilities.

In this regard, corporate, sector and governmental policies should be used to foster the development of capabilities that are essential for the development of new production systems. Such policies should equally stimulate companies´ collaboration with suppliers and other partners for technological development.

In terms of access to knowledge, the governmental, sector and corporate policies and strategies should stimulate the search for new GCE-based knowledge, outside the petrochemical sector. Such policies should foster the exploration of advancements in scientific understanding and technique, technological advancement in other industries and in private and governmental organizations.

In terms of the actors and networks behavioral domain, the statistical analyses detected the relevance of culture building, motivation and participation in developing companies´ willingness to engage in GCE eco-innovation processes. The results highlighted the importance of the availability of key corporate actors who could help to implement and develop such elements. Usually, such professionals have extensive knowledge, are polifunctional, speak more than one professional language and can see the world from two or more professional perspectives. They are very important for corporate behavioral change and help to set the grounds for companies to move to advanced states of sustainability. Consequently, policies that support the incorporation and the maintenance of those professionals in the company´s workforce should be developed and implemented.

In respect to companies' engagement in networks of collaboration, according to the results of the statistical analyses, consultancies and specialized engineering firms (*SEF*) should be addressed by policies and strategies. In parallel, strategic alliances with external actors were also identified as a significant element in GCE-based eco-innovation processes. In this realm, the support of CEOs and shareholders was documented to be a basic and mandatory element for the outset and success of such alliances.

The suggestions for the development of policies and strategies intended to support GCE-based eco-innovation processes are intended to provide guidance and to help companies to make more efficient and effective progress towards more sustainable states by using information that has been elicited from their internal environment. They provide the foundation upon which policies and strategies can be developed in harmony and congruence with companies´ spacificities, culture and objectives.

7.6 Implementation of Green Chemistry and Green Engineering at the Sector Level: The Main Agents, Their Roles and Their Relations

This thesis research analyzed the Brazilian petrochemical companies' willingness to engage deliberately in GCE-based eco-innovation processes. Additionally it identified the main determinants of such willingness.
In that context, the study revealed that pressures and influences originated at the sector level represented important determinants, or pre-conditions, for companies to incorporate GCE and to implement relevant progressive concepts, approaches, processes and technologies.

Based on this finding, it can be argued that conducting sector level initiatives for the promotion, stimulation and implementation the GCE frameworks, by meso-level agents, represents an important contribution for a successful incorporation of GCE at the company level.

In the context of this thesis research, these relevant agents were represented by the *Brazilian Chemical Industry Association* (ABIQUIM) and the Environmental Protection Agencies (EPA).

This section was designed to explain the empirical relations between the micro (companies) and meso-level agents (ABIQUIM and EPAs) regarding the promotion, dissemination and implementation of GCE at the sector level as baseline frameworks for technological changes. In parallel, additional specific recommendations were made to each of these groups of agents regarding their participation in the process of incorporating GCE and fostering GCE-based eco-innovation processes at the sector and companies levels.

Companies´ Willingness and Preparedeness for Green Chemistry and Green Engineering and Their Perceptions on Sector Level Initiatives

As an initial consideration and based on the TPB, it can be argued that the success in implementing GCE as the primary frameworks for more sustainable technological development is contingent upon two basic points: (a) companies´ willingness to adopt GCE and to engage in GCE-based eco-innovation processes, and (b) companies´ preparedeness for such engagement.

These points were clarified by managers´ responses to this thesis research´s quantitative survey (cf. Chapter 6) and to the questions of the in-depth interviews (cf. Section 7.4) associated with the qualitative survey. According to their reactions, they demonstrated that their companies are willing and prepared to incorporate GCE and to engage in GCE-based eco-innovation processes. According to the results of the interviews, managers unanimously reported that they believed that corporate sustainability is highly important for firm survival. They stated that the underlying willingness´ motivations covered a wide spectrum of possibilities that pertain to the concept of sustainability regarding its social, economic and environmental pillars.

They were unanimously favorable to the use of GCE as a baseline framework for the promotion of technological changes towards advanced sustainability states of their companies. In addition, they reported that such acceptance is contingent on a solid acquaintance of the GCE principles on the part of the company (cf. Section 7.4.1).

With regard to companies´ preparedeness, the responses, given by the interviewed companies´ representatives, provided clear evidence that such companies have already gone beyond willingness and have implemented actual technical and non-technical initiatives towards the improved sustainability of their products, processes and services.

In addition, the in-depth interviews revealed that, all interviewed representatives of companies are already using some GCE principles in varying degrees (cf. Section 7.4.1).

With regard the sector level, the managers reported that the promotion, dissemination and stimulation of the GCE principles, at the petrochemical sector level, are very important elements for the engagement of their companies in GCE-based initiatives. In this regard,

the chemical and petrochemical sectors trade association (ABIQUIM) and its RCP play an important and fundamental role in promoting, disseminating and implementing the GCE frameworks throughout the sector.

Recommendations for Companies´ Managers and Important Decision-Makers Regarding Incorporating GCE and Fostering Companies´ Engagement in GCE-Based Eco-Innovation Processes

As noted in Chapter 3, companies *per se* are inanimate entities that are guided and steered by individuals that have the responsibility to help them to achieve envisioned futures that fulfill consolidated interests and pre-established objectives. This implies the choice of trajectories that, many times, are profoundly challenging and innovative. This is the case of the introduction of GCE, at the companies' level, as baseline frameworks for effecting technological change *via* eco-innovation processes.

Throughout this thesis research, managers perceptions and beliefs, regarding the determinants of companies´ willingness to incorporate GCE and to engage in such eco-innovation processes, have been measured and elicited through quantitative and qualitative methods. Although such perceptions and beliefs have been mapped, and the significant willingness determinants were identified, it was also important to discuss what actions managers and decision-makers could develop to foster and facilitate GCE-based eco-innovation processes to become reality in their companies.

According to Chapter 3 and Appendix H, innovations do not occur unexpectedly nor do companies innovate in isolation. In this regard, it can be argued that Brazilian petrochemical companies´ managers and important decision-makers need to make efforts inside and outside the companies´ domains aimed at the provision of adequate means and requisites towards the implementation of GCE both in their companies' realms and at the sector level..

As these agents demonstrated full agreement with the GCE frameworks and their perceptions demonstrated that their companies are willing to engage in GCE-based eco-innovation processes, two initial steps are recommended: (a) to create awareness of the importance and the feasibility of GCE-based technological solutions, and (b) to introduce GCE in the decision-making *nuclei* of the company and to include them in the companies´ short, medium and long-term technological change planning.

Assuming that support from shareholders and from CEOs was granted, once these steps have been accomplished and GCE-based technological sustainability objectives have been established, it is very important that managers plan and conduct initiatives for identifying and acquiring the technical and non-technical capabilities required for eco-innovating in GCE. This includes the identification of essential new knowledge and technologies and strengthening or improving companies´ learning processes. In addition, it is important that they promote, if required, the adaptation of companies´ organizational structure to effect GCE-based eco-innovation in a fluid way. This could facilitate the development of internal eco-innovation networks and the consequent facilitation of the engagement of companies' personnel in such networks. This is likely to generate diverse insights in the different hierarchical levels and to enhance the participation and the involvement of different agents in approaching and solving the environmental challenges.

In parallel, it is fundamental that managers and important decision-makers get involved in developing adequate corporate institutions (rules, norms, policies, conventions etc.) that can give full support and stimulate GCE initiatives.

With regard the promotion of an institutional infrastructure that can support and facilitate the implementation of GCE frameworks and GCE-based eco-innovation processes in companies, managers are required to make efforts to insert GCE in the corporation governance. In parallel, it is also recommended that they promote the development of a governance structure that specifies the distribution of responsibilities among different participants in the corporation (such as the board of directors, managers, shareholders, auditors, regulators, and other stakeholders) and specify the rules and procedures for making decisions regarding GCE-based eco-innovation issues.

Innovation networks should include agents and relations outside the companies´ domains that can help to facilitate and promote GCE at the companies' level (e.g. suppliers, academia, research laboratories, workers, governmental environmental and non-environmental organizations, communities, customers). Managers and important decision makers are recommended to strengthen these ties and to build new ones according to their companies' needs.

It is very important that corporate leaders, by taking advantage of companies´ proximity and strong ties with ABIQUIM and local industry representative organizations, discuss and promote joint efforts that facilitate the introduction of the GCE as baseline frameworks for technological change and for eco-innovation processes. These efforts should be conducted within the sectoral domain and with governmental environmental (e.g. Ministry and States´ Secretariat for the Environment, EPAs etc.) and non-environmental (e.g. Ministry for the Science and Technology and Innovation, Ministry of the Industry and Commerce, Ministry for Education etc.) organizations. These initiatives should aim at the attainment of governmental, institutional support in, among others, the political, financial, technological, knowledge, educational, and organizational development domains.

In addition to searching for political and institutional support through coalitions with ABIQUIM and other organizations, companies are also recommended to search for these types of support, through extensive and intense negotiations, on their own in the governmental domain according to their idiosyncratic and to the petrochemical sector´s collective needs.

Leaders are also recommended to work in partnership with ONGs and market survey organizations to be acquainted and updated with societies´ socio-environmental claims, demands and pressures. These sources of information should be processed and taken to the companies´ *locus* of planning and decision-making so solutions can be conceived and effected in a faster way.

Companies´ leaders are also encouraged to promote the search for technological and knowledge building initiatives in the academic and technology providers domains at the same time that they are challenged to improve their companies´ learning processes and their overall management system.

Environmental Agencies´ Perceptions on the Implementation of Green Chemistry and Green Engineering at the Company and the Sector Level

The in-depth interviews revealed that the interviewed EPAs were fully supportive and cooperative regarding the promotion, dissemination and implementation of GCE-based eco-innovation processes at the company and sector levels. In their view, these sector level cooperative initiatives should be conducted through their own initatives or in partnership with ABIQUIM.

It is important to clarify that EPA´s initiatives at the sector level are comprised of:

- Contributions to the development and enforcement of the general or sector-specific institutions that are applied at the company level, and
- Cooperative initiatives conducted in partnership with ABIQUIM, companies and other agents for the dissemination, stimulation and implemention of environmental sustainability initiatives at the company level.

A comprehensive exposition of their perceptions was presented in Section 7.4.2. The following summary points were extracted from that information.

At the general level, the responses demonstrated that the interviewed EPA representatives besides keeping their role as legislation enforcers strong, they also rely on cooperative initiatives with the petrochemical companies. The interviewees stated that cooperation is an important and useful way to overcome bureaucracy, to create trust and to help companies to move beyond compliance with existing legislation.

Although respondents cited different initiatives, from their respective contexts, they had three common points:

a) Due to the existence of a consolidated cooperative culture as well as based upon previous cases of success, the implementation of these initiatives is entirely possible;
b) That type of implementation can be effectively facilitated by the existing institutional organization and by the fluid environmental agency/companies relationship structure and
c) There is a need for the agencies to implement long-term policies to support these types of initiatives.

With regard to cooperation at the sector level, according to the respondents, joint initiatives conducted by the EPAs, ABIQUIM and other petrochemical industry representative organizations are entirely feasible because these agents have a strong history of cooperation and have efficient and fully operational communication channels.

Recommendations for the Environmental Protection Agencies´ Leaders Regarding the Process of Supporting and Fostering the Introduction, Diffusion and Implementing GCE in the Brazilian Petrochemical Sector

This thesis researcher´s qualitative and quantitative surveys, identified the Environmental Protection Agencies in the Brazilian territory as fundamental agents in helping the promotion of the implementation of GCE in the Brazilian petrochemical industry both at the sectoral and companies levels.

This is a perception that was shared by companies, ABIQUIM and by the EPAs themselves. Therefore, based on the evidence produced by this thesis research and based

upon this researcher insights, some recommendations can be made to the EPAs leaders. These recommendations arise from two domains and aim at providing information that is useful in the effort to implement GCE in the Brazilian petrochemical industry both at the sector and companies levels.

Cooperation and Enforcement

Cooperation efforts with the petrochemical companies and ABIQUIM should be conducted in order to incorporate the GCE frameworks as an official and feasible way to promote technical change towards a more sustainable petrochemical (and chemical) enterprise. These efforts should take into consideration short, medium and long-term planning.

In addition to these tripartite initiatives and to the EPAs´ responsibilities regarding legislation enforcement, EPA leaders are recommended to incentivize and to promote bilateral cooperation efforts between companies and the EPA. These efforts should emphasize the incorporation of GCE in the governance of the companies and on the development and implementation of GCE-based solutions for companies´ sustainability technological challenges towards advanced sustainability states.

These efforts could have the form of companies-EPA joint cooperative corporate environmental planning whose results are formalized by bilateral agreements and verified by self and bilateral follow-up and auditing.

This represents a possible effective way to influence companies and to catalyze the implementation of the GCE principles, in the petrochemical sector, *via* negotiations and posterior incorporation of those principles into the company's operation license. Thus, this approach represents the use of the companies' operation licensing as an environmental sustainability and sustainable development-planning tool. These recommendations were based on the EPA´s managers' perceptions that as the velocity of advancements in legislation is very much slower than the actual environmental facts, challenges and needs. Therefore, this pro-activity is necessary for inducing and helping companies to move, in a more expedited way, beyond merely complying with existing legislation.

This approach allows for companies to implement agreed upon self-regulations, the progress of which should be followed and audited by the EPA. In addition, it promotes and facilitates the development of short, medium and long-term corporate plans and measures regarding technical change towards advanced states of companies´ environmental sustainability that take into account, the companies' specificities and capabilities to identify and solve the environmental problems. It also represents a good mechanism to stimulate the sustainability culture building. This allows for a more realistic identification of companies needs and measures that should be taken in order to implement GCE-based initiatives and measures. Such a more realistic approach also enables companies and EPAs to identify the adequate instruments that support such required technological changes.

EPAs´ cooperation initiatives with companies and ABIQUIM can be conducted *via* the existing discussion *fora*, cooperation mechanisms and communication channels.
On the other hand, because voluntary initiatives are not always appropriate or effective to provide the required level of advancements towards environmental and health preservation, it is fundamental that the different EPAs use their experience and accumulated knowledge to help to improve and expand the environmental legislation regarding cleaner, safer and more sustainable products, chemicals manufacturing and chemicals management. This will

certainly reflect societies´ short, medium and long-term environmental sustainability expectations. In addition, it is mandatory that EPAs use their full power to enforce such regulations and exert pressures that, in the end, are expected to contribute to expediting the development of a more sustainable petrochemical enterprise.

Institutions

As noted in the previous section, EPAs hold two main responsibilities. The first one regards the contributions to the development and enforcement of the general, sectoral and company specific regulations aimed at increasing the protection of the biosphere. The second line of responsibilities of the EPAs reside in promoting an environment in which companies´ environmental sustainability can be developed and prosper.

Before discussing such aspects, it is relevant to underscore the necessity that leaders at the EPAs develop and implement long-term internal organizational policies, which support GCE-based initiatives as well as other cleaner production initiatives. Such policies will ensure that the official commitment to their approaches endure and that they are immune to changes in management styles of successive EPA's administrations

In respect to the enhancement of the environmental legislation, EPAs´ leaders are recommended to take full advantage of EPA´s experience of their cooperative work with companies, ABIQUIM, the academia, the NGO's, the press etc. to help to modernize and to adapt the environmental legislation to societies´ current and the envisioned environmental and socio-economic needs.

With regard the promotion of an institutional infrastructure that can support and facilitate the implementation of GCE frameworks at the companies' level, EPA´s leaders are recommended to promote an active discussion with other governmental bodies in order to create and/or enhance governmental support instruments to incentivize the development and the implementation of GCE-based solutions. This support can be achieved via economic and fiscal *stimuli* for the implementation of eco-innovation processes at the company level aimed at the development or acquisition of cleaner and more sustainable solutions for the companies' products and processes. These supports and incentives should cover a broad spectrum of possibilities such as basic research financing at universities, the introduction of GCE in education at the university level, tax cuts, low interest rates loans for companies´ GCE-based investments etc.

The Trade Association´s Perceptions on the Implementation of Green Chemistry and Green Engineering at the Company and the Sector Level

According to the in-depth interviews, ABIQUIM is fully supportive of GCE and is prepared to engage in actions aimed at promoting eco-innovation and GCE in the Brazilian petrochemical sector.

A comprehensive exposition of those perceptions was presented in Section 7.4.3. Some points were extracted from that discussion.

The RCP represents ABIQUIM's overarching initiative regarding sustainability in the Brazilian chemical and petrochemical sector. According to the interviewed individuals at the sector and company levels, the RCP is the best and key instrument to harbor and to promote the full spectrum of GCE principles and practices as well as eco-innovation.

ABIQUIM is acknowledged by private and governmental environmental and non-environmental organizations as the official representative association of Brazilian chemical and petrochemical industries. Consequently, formal and informal cooperation and partnership initiatives and consultations towards sustainability issues have been regularly conducted.

The findings from the interviews demonstrated that, because ABIQUIM and the EPAs share the same interests and beliefs regarding sustainability and sustainable development, working together for the promotion of GCE-based initiatives is perfectly viable and of uppermost interest. This view was also expressed with regard to engagement of other governmental and non-governmental organizations.

Recommendations for ABIQUIM´ Leaders Regarding the Process of Supporting and Fostering the Introduction, Diffusion and Implementing GCE in the Brazilian Petrochemical Sector

According to the qualitative survey, with regard ABIQUIM´s initiatives towards a more sustainable chemical enterprise, its main purpose is to exert catalytic influence. This can be accomplished through education and training as well as in conducting a great variety of cooperative programs directed to ABIQUIM´s affiliates in association with external private and governmental stakeholders (e.g. suppliers, workers, governmental environmental and non-environmental organizations, communities, customers).

Based on the researcher´s in-depth interviews, on his professional experiences in the Brazilian Petrochemical industry and on his knowledge on ABIQUIM´s structure and initiatives towards a more sustainable chemical and petrochemical sectors, it is his opinion that ABIQUIM holds the appropriate knowledge, mechanisms, instruments, institutional set, governmental and non-governmental relationships and initiatives that can help it to be a effective force in promoting GCE at the sectoral and companies levels.

With regard to ABIQUIM, the primary recommendation regarding the introdution, dissemination and implementation of GCE in the petrochemical industry at the sectoral and the company levels, is the need to incorporate, in its corporate initiatives, such as the Responsible Care Program and the Global Product Stretegy, guidelines and policies to

promote the GCE frameworks as a priority in the managerial and technical changes in the sector.

Once this step is concluded, it is recommended that ABIQUIM mobilize its efforts to develop a supportive, broad-based mix of alliances and partnerships with companies, EPAs, government, academia, business and a range of stakeholders, including society. Such alliances are expected to promote close cooperative work on strategies, policies, and the design of systems to introduce, disseminate and implement GCE in the petrochemical sector and its companies to catalyze the needed sectoral and societal transformations to more sustainable patterns.

It is also very important that ABIQUIM uses its sectoral and thematic commissions to place GCE and GCE-based innovation processes as a central and priority issue in the environmental sustainability discussions. These commissions are formed by ABIQUIM's associated companies' representatives and by other invited stakeholders. In these *fora*, problems are discussed, diagnoses are made, solutions are proposed and planning is done for solving such problems (such as future environmental legislation and agreements, sustainability trends and demands of markets, environmentally-based barriers for products etc.). In addition, strategies and plans are discussed for making advancements with regard to common objectives of the chemical and petrochemical sectors.

In this regard, it is equally important that ABIQUIM continues to be consistently and regularly in contact with national and international organizations in order to capture new information, demands and trends that can be used in its strategic planning as well to provide *stimuli* and support for companies in their initiatives aimed at their socio-economic and continuous environmental improvement.

Lastly, similar to the petrochemical companies and the EPA´s, ABIQUIM, should also engage in and promote continuous improvement of its communication channels with significant stakeholders in order to respond to societal demands on greener products and production processes. In addition to being aware of the needs of society, it is important to be in close contact with stakeholders such as:

- **The press**: by disseminating information, exposing societal demands, and pushing for solutions, the press is a powerful stakeholder, which can help to catalyze changes in the environmental behavior of different segments of society. It can also help to promote environmental behavioral changes *via* the promotion of conferences and seminars involving a wide spectrum of stakeholders[113];
- **The academia**: the academia represents a major repository and generator of knowledge that can help in the implementation of GCE by providing new knowledge and visions of futures. In parallel, the academia has the power of creating cultute and of facilitating behavioral changes. The academia should work

[113] As an illustration, it can be mentioned the "Green Minds" seminar that was promoted in September 2012 by "VOTO" magazine in Brasilia, Brazil. "Voto" magazine is a Brazilian publication dedicated to politics. The "Green Minds" seminar´ main objective was to promote discussions on the sustainable development of the Brazilian industry with a focus on the need for incorporating innovation and sustainability, as priority, in the agendas of the Brazilian government. In addition, the seminar was intended to make governmental authorities, and public and private enterprises aware of the importance to contribute to innovation and sustainability in the industrial sector.

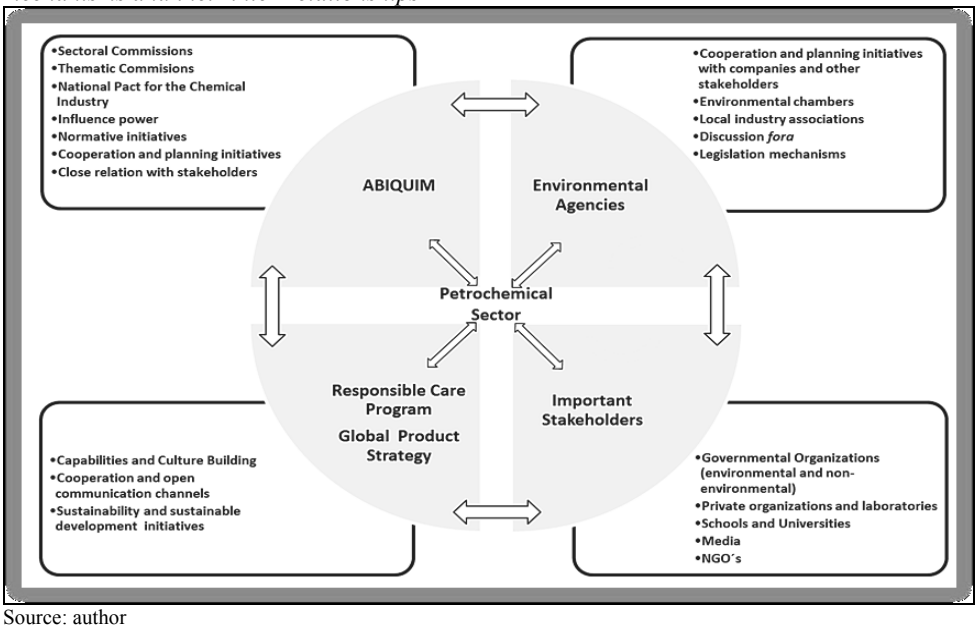
hand-in-hand with petrochemical companies, ABIQUIM and the EPAs by joining forces and intellecual resources to help to introduce, disseminate and implement GCE and GCE-based innovation processes in the Brazilian petrochemical sector.

Figure 7.10 depicts a synthetic representation of the implementation of GCE at the sector level. This representation was created based on the in-depth interviwes that were conducted on the company's managers, environmental agencies and with the trade association (ABIQUIM).

The petrochemical companies are at the core of the figure. They are surrounded by the important and interrelated agents and key mechanisms for the promotion, disseminstion and implementation of GCE at the sector level.

These elements are supported by core stakelolders, initiatives and mechanisms that were envisoned by the interviewees as being basic and essential for the implementation of GCE. The arrows provide a simplified view of the relationships among all of these elements.

Figure 7.10- Implementation of Green Chemistry and Green Engineering: the main agents, mechanisms and their inter-relationships



Source: author

7.7 Summary

Chapter 7 concluded the discussions that were initiated in Chapter 6. By using all elements of the theoretical foundations that underpinned this thesis research, as well as the empirical and statistical findings, this chapter provided a thorough examination of the representativeness of the behavioral domains as determinants of companies´ willingness to engage in GCE-based eco-innovation processes. In parallel, simulations were conducted in the search of the most favorable scenarios under which engagement and implementations of GCE-based changes are most likely to occur.

A further exploration was conducted, *via* in-depth, qualitative interviews with companies´ managers to promote an independent verification of this thesis research´s results. The interviews were intended to elicit further clarifications of the perceptions of companies´ managers, environmental agencies and the trade association regarding the company and sectoral level initiatives to support and to implement GCE in the entire petrochemical sector.

Based on the results of the simulations, this author deeply analyzed the thesis' behavioral model, at the belief's level, and identified the significant variables that could provide key elements for the design of policies aimed at the engagement of firms, in the Brazilian petrochemical sector, in GCE-based eco-innovation processes. The analyses revealed that:

a) Using this thesis researcher´s behavioral model as a reference, the perceived behavior control (*PCB*) construct was the largest contributor to the explanation of the variance in companies´ willingness to engage in GCE-based eco-innovation processes. It was followed by the perceived social factors pressure construct (*PSFP*) and the smallest contributor was found to be the attitude construct (*A*);
b) In respect to the *PBC* construct, the knowledge and networks (*KTC*), and the actors and networks (*AN*) behavioral domains provided the largest contributions to the variance explanation;
c) Social pressure (*SP*) emerged as the largest contributor to the explanation of the variance in the *PSFP* construct;
d) In the case of the attitude construct, the economic risk and business opportunity (*ECR*) behavioral domain was found to be the most important domain in companies´ willingness explanation;
e) Although the environmental risk domain was found to be a minor contributor to willingness explanation, it was introduced in the analysis due the fact that it was found to influence economic risk and market opportunities in an inverse fashion. That is, managers´ perception of low environmental risk in respect to their companies´ products, processes and services emerged to be associated with conditions of high economic risks and low business opportunities;
f) Social pressure (*SP*) was found to influence willingness in a direct and indirect fashion. The indirect mode of influence on willingness was related to *SP´*s strong positive correlation with the knowledge and technologies (*KTC*) and actors and networks (*AN*) behavioral domains, which, in turn, influence willingness in a direct fashion;
g) In terms of sources for the development of eco-innovation policies, in the social pressure behavioral domain, beliefs associated with community pressure and regulatory pressure were found to be the most significant;
h) In respect to willingness formation, sources in the knowledge and technologies domain, the beliefs related with accessibility to knowledge, knowledge integration, learning processes, technological opportunities, advanced technological innovation capabilities and organizational capabilities were documented to be the significant variables for policy development;
i) In the actors and networks domain, the significant beliefs were represented by beliefs associated with the availability of corporate actors holding key capabilities, strategic alliances with external actors and networks of collaboration,

Chapter 7 provided evidence that supported the argument that the challenges, faced by the Brazilian petrochemical companies, to promote behavioral changes towards their

engagement in GCE-based eco-innovation processes, reside in all three dimensions of the behavioral model proposed in Chapter 5.

The first class of challenges pertain to the control over the resources and opportunities that were associated with the capabilities required by them to eco-innovate in GCE. In this realm, two domains emerged:

a) Knowledge and technologies: in this domain, the capabilities related to the learning processes, technological opportunities, advanced technological innovation capabilities and organizational capabilities to constitute companies´ current challenges, and
b) Actors and networks: the capabilities related to availability of corporate actors holding key capabilities, strategic alliances with external actors and networks of collaboration emerged as the most relevant.

The second class of challenges resided in the realm of the social pressures towards cleaner and more sustainable products, processes and services. In this dimension, the issues related to community and regulatory pressures were found to be the most relevant challenges.

Finally, issues associated with managers´ attitudes towards eco-innovating were also documented to be relevant challenges in respect to such behavioral changes. The analysis indicated that issues associated with the economic risk and business opportunities behavioral domain (i.e. economic opportunities and technological risks) represented the most relevant challenges.

Additionally, the need to promote changes in the ways to perceive the environmental risks generated by their companies´ operations emerged as an important issue. The concepts of safe and risky operations should be discussed in light of the products' and processes' hazards and risks, intrinsic to their design conception, without regard to the risk control measures.

With regard to the opportunities for companies in the Brazilian petrochemical sector to make progress in GCE, the following characteristics provide a sound foundation for progress:

a) Their size;
b) Their innovation history;
c) Their belief on the importance of S and SD for their short, medium and long-term survival;
d) Their worldwide market and non-market relations and penetration;
e) Their organizational structure;
f) Their synchronism with the state-of-the art of scientific, technological and knowledge advancements worldwide;
g) Their financial and organizational capabilities;
h) The quality and dimensions of their planned investments for this decade aimed at placing the Brazilian chemical sector among the five largest in the world, and
i) The current competitive power of the Brazilian petrochemical sector provides a wide horizon of opportunities. These opportunities can stimulate companies to engage in eco-innovation processes as a means to develop and/or adopt new technological paradigms and trajectories that could help the companies to make rapid progress in environmental and socio-economic sustainability.

Finally, it is important to emphasize that these arguments were verified by the in-depth interviews with the managers and with other important decision-makers. More than that, the interviews revealed that the surveyed Brazilian petrochemical companies have already gone beyond willingness and have implemented sustainability initiatives through sustainable development practices by implementing innovative solutions that are based on some of the GCE principles to "solve" their sustainability challenges.

In terms of implementing GCE at the sectoral level and in promoting GCE as the sector´s baseline principles for technological development, the interviewed company managers, the EPAs representatives and the spokesperson of trade association (ABIQUIM) were all fully in favor of such initiatives. They highlighted that, although much negotiation still needs to be conducted and more stakeholders must be engaged in these processes, much work has already been done. They expressed confidence that they have the basic required mechanisms, relations and dynamics for the rapid expansion of implementation of GCE initiatives throughout the Brazilian petrochemical sector.

8. Summary of the Results and Conclusions

8.0 Introduction

Throughout the last forty years, the petrochemical industry has been central in the ongoing debate and submitted to strong societal pressures with respect to industrial pollution and the intensive use of non-renewable natural resources. At the global level, societal pressures increased and more stringent legislation towards the chemical industry evolved in the wake of the environmental disasters produced by accidents or by environmentally and socially unaccepted practices that took place in the 1970s and early 1980s. More specifically, a pesticide production plant explosion in Seveso, Italy, in 1976, the gradual poisoning of a community at Love Canal toxic waste site in the USA and the Bhopal incident[114] triggered dramatic societal reactions.

After the Bhopal incident, in 1984, the public's confidence in the chemical industry was even more shaken and the chemical industry itself questioned whether its provisions for protection of the environment, workers, and the general citizens against disasters were adequate (Mannan *et al*., 2005).

At the Brazilian level, these international societal and regulatory pressures on the petrochemical companies were also felt by organizations operating in the Country. In 1986, a survey conducted by ABIQUIM in many Brazilian cities evidenced that fifty-six percent of the surveyed individuals were more concerned with the negative environmental impacts of the chemical and petrochemical industries as compared with other industrial sectors. The majority of the respondents did not trust the chemical companies and demanded that the government should impose more stringent controls on them through much more rigorous legislation (Soares and Demajorovic, 2006 *apud* Johnson, 2000).

Despite the international and national evidence, the response of the Brazilian chemical and petrochemical was slower than in the Canada and United States. As compared with the chemicals industries in those countries, which launched their Responsible Care Program (RCP) initiative in 1985 and 1988 respectively, as a response to those pressures, the chemicals sectors in Brazil did not launch their RCP until 1992. According to Soares and Demajorovic (*ibid*), the RCP was mainly motivated by factors associated with the public image of the industry, with the anticipations of tighter future legislation resulting from these large accidents and from the increasing perception of the hazards of industrial pollution. They further stated that, as pressures increased, the chemicals industry became more conscious of the potential consequences: bad reputation, increasing governmental intervention and difficulties in obtaining locations for new facilities (*ibid*).

These efforts evolved in Brazil as the societal, governmental and market demands for cleaner and less hazardous chemical and petrochemical enterprises became stronger. On

[114] "The Bhopal disaster, also referred to as the Bhopal gas tragedy, was a gas leak incident in India, considered the world's worst industrial disaster. It occurred on the night of 2–3 December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh. Over 500,000 people were exposed to methyl isocyanate gas and other chemicals. The toxic substance made its way in and around the shanty towns located near the plant. Estimates vary on the death toll. The official immediate death toll was 2,259. The government of Madhya Pradesh confirmed a total of 3,787 deaths related to the gas release. Others estimate 8,000 died within two weeks and another 8,000 or more have since died from gas-related diseases". (source: https://en.wikipedia.org/wiki/Bhopal_disaster)

the industry side, a sustainability culture started to develop within petrochemical organizations and evolved during the last twenty years. This culture evolved because it was realized that the sustainability of the industry was strongly bonded to its social acceptability, i.e. that its practices must be socially responsible and acceptable and must be committed to the socio-environmental sustainability of the planet or it will lose its right to operate. In addition, it must act preventatively, in light of increasing evidence that it is dependent on the planets´ limitations, imposed by the natural physical and biological laws, to supply indefinitely the sector with material and energy (cf. Appendix I).

This view is being integrated into the petrochemical sector as evidenced by the results of this thesis researcher´s in-depth interviews (cf. Chapter 7) conducted with its top and mid-level managers and key decision-makers. These results showed that the sustainability and sustainable development concepts and beliefs pervaded the companies and that it is the result of the national and international efforts and initiatives that have been conducted by environmental agencies, environmental NGOs, the petrochemical companies and trade associations throughout the last decades.

Consequently, the issue of reconciling the industry´s self-interests of being profitable with the broad societal sustainability goals is one of the greatest challenges that is being and must increasingly be faced by modern industrial societies.

This is the background upon which this thesis research was conceived and maturated throughout the last five years.

The timeline of the evolution of the behavior of the basic and intermediate petrochemicals producers from a completely reactive posture to sustainability searching organizations coincided with the timespan of the professional activities of this researcher, as a chemical and environmental engineer. Along this period, a great personal interest evolved regarding how changes could be operated to help to develop a more sustainable petrochemical enterprise.

This thesis author acknowledges that this aspiration involved initiatives that are complex, extremely challenging and is comprised of numerous variables that are impossible to be covered by a single individual in a lifespan. In this respect, this author´s experience in working in source pollution control, in the petrochemical domain, generated an intrinsic interest on technological change and innovation processes (its determinants, agents and instruments) aimed at the development of viable alternatives for helping the sector to generate the next generation of environmentally, socially and economically benign technologies for their products, processes and services.

Although progress has been made, most of the petrochemical industry is experiencing a technological lock-in that, according to Arthur (1989), could/should be supported by learning effects and increasing returns to scale, supply-side factors, economies of scale in production, infrastructure availability thus limiting the number of possible directions that technological development may take. In order to overcome such technological states, it is commonly agreed in industrial societies that new, more sustainable types of technological development for the sector´s products, processes and services are needed for the reconciliation of the interests of the petrochemical organizations and the interests of societies regarding the triple bottom line in the short and long-term.
The main intellectual premise of this research acknowledges that, for such processes to occur, human´s willingness to engage in such change processes is a pre-condition and a

central element. This led this researcher to the domains of behavioral and innovation theories.

In this respect, willingness was examined *via* the operation of a behavioral theory, the Theory of Planned Behavior - TPB (Ajzen, 1991), adapted to the eco-innovation and environmental policy realms and *via* a framework for innovation in sectors represented by the Sectoral Systems of Innovation Framework – SSI (Malerba, 2002, 2004). These elements were used to integrate insights drawn from several bodies of literature in a systematic way in order to produce a behavioral model of the willingness of companies to engage in Green Chemistry and Green Engineering (GCE)-based eco-innovation processes. This behavioral model was used as the framework for the construction, and testing of a quantitative questionnaire that was applied to companies´ top and mid-level managers and important decision-makers. The interviewees' answers provided empirical data that were used to reveal companies willingness and to assess the factors that are likely to influence that willingness to be transformed into action to implement GCE concepts and approaches..

This research has examined the propensity of Brazilian petrochemical sector to promote such advancements *via* the incorporation and implementation of the principles of GCE as a means to migrate from current industrial practices, for products and processes, to advanced states of environmental sustainability. This propensity was examined with regard the willingness of companies, in the Brazilian petrochemical sector, as expressed by the perceptions and beliefs of their top and mid-level managers and important decision-makers, to promote technological changes by deliberately engaging in GCE-based eco-innovation processes.

The principles of GCE represent frameworks for the design, development, and implementation of chemical products and processes to reduce or eliminate the use and generation of substances hazardous to human health and the environment and use less quantities of non-renewable materials and energy. GCE have been given importance and the acceptance by specialists representing major chemicals manufacturing companies, consulting and research organizations, sustainability institutes, chemical societies and by a broad range governmental and academia representatives as a sound way to produce the next generation of environmentally benign technologies, products and services for society via a transformed chemical and petrochemical industry (cf. Chapter 2).

In this study, technological changes were interpreted as processes that are designed to achieve advanced states of environmental sustainability by means of the development and implementation of incremental and/or radical solutions achieved by means of technical (eco) innovation processes. In addition, technological changes through eco-innovation were studied as a function of organization's behavioral changes and, therefore, were explored in light of the innovation and the behavioral theoretical fields.

This thesis researcher's premises were:

- If Brazilian petrochemical companies, in the perception of their managers and key decision-makers, have a positive attitude towards accepting GCE and their companies´ engagement in GCE-based processes;
- If social and personal norms towards these issues are strong and these agents are prone to comply with these pressures, and
- If companies perceive that they have control over the requisites, capabilities and opportunities to engage in these processes,

they will be willing to effect GCE-based eco-innovative changes. It was assumed that these changes will be better catalyzed and facilitated if influential agents and policy-makers and other stakeholders (i.e. industry, trade association and governmental environmental and non-environmental organizations) are empowered with appropriate information to have a better understanding of the what the determinants of changes are and how to ensure that the conditions to promote those changes are in place. Therefore, plans can be made, resources can be allocated, existing instruments can be better used and new ones can be developed.

8.1 Discussions on the Research Questions in Light of the Findings

As noted in the previous section, the underlying interest of this researcher was to contribute to the ecological modernization of the Brazilian petrochemical companies and sector *via* its engagement in GCE-based eco-innovation processes as a means to engage in more ecologically sound practices.

Changes towards ecological modernization, as towards other sustainability initiatives, are the types of behavioral changes that are both wide in scope and deep in complexity as they are conceived and effected based on a large number agents and dissimilar variables. Corporate behavioral changes in this direction require a good understanding of the nature of the challenges, of its influencing factors and are a function of the perception and beliefs of the decision-making agents regarding these elements. This ultimately defines willingness to change, which indicates how hard people are willing to try, or how much of an effort they are planning to exert in order to perform this behavior change.

In this regard, the purpose of this research was to provide an extensive view on the attitudinal, social and personal normative elements and on the perceived control over technological and organizational capabilities that influence companies´ willingness to engage in GCE-based eco-innovation processes in the context of the research. Therefore, it was expected to contribute to the promotion of the, managerial and technological shifts to expedite initiatives that are theoretically supported by the GCE frameworks. In addition, the main influential agents to the implementation GCE at the Brazilian petrochemical sector and companies levels were identified and their roles were discussed.

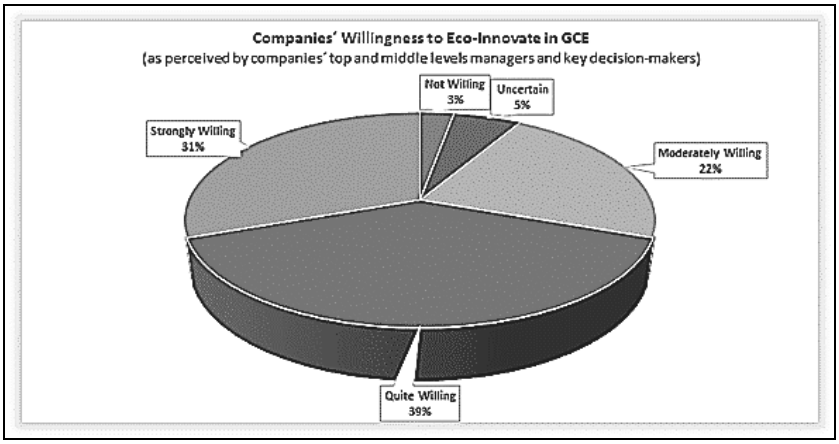
This research also contributed to the field of policy analysis and design as recommendations, based on the research findings, were made for policy development by governmental bodies, by companies and trade associations. The research findings fully addressed the three research questions.

8.1.1 Yes, the Brazilian Petrochemical Companies are Willing to Engage in GCE-Based Eco-Innovation Processes

The first research question addressed the extent to which the surveyed companies were willing to engage in eco-innovation processes. In order to explore this question, the concept of behavioral intention of the TPB was used to assess the willingness of Brazilian petrochemical companies to engage in such behavior, as perceived by the companies´ top and mid-level managers and key decision-makers.

The result of the quantitative and qualitative surveys indicated that the surveyed companies not only accepted GCE as viable baseline frameworks towards technological change, aimed at conducting the sector to more advanced states of sustainability (social, economic and environmental), but they were also willing to engage in GCE-based eco-innovation processes. Such argumentation is pictorially presented in Figure 8.1

Figure 8.1- Companies´ willingness to eco-innovate in GCE as perceived by companies´ top and mid-level managers and key decision-makers as evidenced by this research´s quantitative research



Source: author

This result was not received with expressions of surprise. Based on this thesis researcher´s experience in the Brazilian petrochemical domain, it was clear that in the last decades, because of the pressures to which the sector has been submitted to, the petrochemical industry has undertaken efforts to *greening* and to improving its products, processes and services in order to re-gain societal confidence.

Although stated in many different ways, the respondents agreed upon the drivers for the acceptance and implementation of GCE-based approaches. These drivers were based upon the conceptual grounds associated with the social, economic and environmental dimensions of sustainability and with the companies' responsibility to contribute positively to societal and corporate sustainability.

According to independent observations (cf. Johnson, 2000, Soares and Demajorovic, 2006) and to this thesis researcher´s quantitative and qualitative surveys, the sector´s sustainability culture building can be exemplified by the chemical and petrochemical´s industry flagship initiative: the Responsible Care Program (RCP). In spite of criticisms regarding its implementation, operationalization and, it sometimes being considered to be a "comfort blanket" (ENDS, 2005) for the companies, the RCP has evolved beyond aiming at short terms goals of achieving public credibility. Currently, the Responsible Care Global Charter[115], is addressing new, long-term, challenges facing the chemical industry and global society, including the growing public dialogue over sustainable development, public health issues related to the use of chemical products and the need for greater industry

[115] http://www.icca-chem.org/ICCADocs/09_RCGC_EN_Feb2006.pdf

transparency. According to ABIQUIM, the RCP, in the Brazilian context, has capillarity with other globally accepted sustainability initiatives as they provided important contributions for the development of the RCP´s directives (e.g. UN Global Compact; requisites of norms such as ISO 9000, ISO 14000, ISO 2600 OHSAS 18001[116], SA 8000[117], AA 1000[118]; National Quality Prize)[119]. In Brazil, the implementation of the RCP is mandatory for all *Brazilian Chemical Industry Association* (ABIQUIM) members.

It is important to note that this research has evidenced a significant array of initiatives, driven by the RCP requisites, based on globally accepted initiatives such as:

- The UN Global Compact Initiatives;
- The principles of the "Green Economy" that are being promoted by the United Nations Commission on Sustainable Development (CSD) and by the United Nations Environmental Program (UNEP);
- Chemical safety initiatives;
- REACH (Registration, Evaluation, Authorization and Restriction of Chemical Substances);
- The International Council of Chemical Associations´ (ICCA) Global Product Strategy Program (GPS);
- OECD Guidelines for Multinational Enterprises (OECD, 2000);
- The Dow Jones Sustainability Group Indices (DJSGI, 1999);
- The National Quality Prize;
- Global Reporting Initiative´s (GRI) guidelines;
- The Balanced Score Card (BSC) for development of sustainability indicators.

This was attested to Brazilian national and foreign petrochemical company and trade association´ official and publicly disclosed declarations, corporate policies and sustainability reports and signed CEO´s commitment regarding the protection and development of the triple bottom line. In this research, this was empirically documented by the verification of such documents and by the interviewed managers' reactions to the qualitative survey´s questions regarding their perceptions of the importance of sustainable development and sustainability for the petrochemical sector and to their perceptions of the benefits of GCE to their companies and to the sector (cf. Section 7.4.1).

Their responses provided a clear picture of the high importance that was given, by the surveyed Brazilian petrochemical companies, to incorporate sustainability and its relationship to their firm's short and long-term survival. It also revealed that the underlying motivations encompass the multi-dimensions of the concept of sustainability represented by its social, economic and environmental pillars.

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[116] OHSAS 18001is a British Standard for occupational health and safety management systems. It exists to help all types of organizations put in place demonstrably sound occupational health and safety performance programs. It is widely seen as the world's most recognized occupational health and safety management system's standard.
(source: http://en.wikipedia.org/wiki/OHSAS_18001).

[117] SA8000 is an auditable certification standard that encourages organizations to develop, maintain, and apply socially acceptable practices in the workplace. (source: http://en.wikipedia.org/wiki/SA8000)

[118] "AccountAbility's AA1000 series are principles-based standards to help organizations become more accountable, responsible and sustainable. They address issues affecting governance, business models and organizational strategy, as well as providing operational guidance on sustainability assurance and stakeholder engagement. The AA1000 standards are designed for the integrated thinking required by the low carbon and green economy, and support integrated reporting and assurance".
Source: http://www.accountability.org/standards/).

[119] http://abiquim.org.br/atuacaoresponsavel/arquivos/ar_apresentacao.pdf

The observed sustainable culture currently held by companies supported their managers and key decision-makers´ declared willingness regarding the use of GCE as a baseline framework for the promotion of technological changes towards advanced sustainability states of their companies. It was also common sense among these companies that the promotion and the dissemination of the GCE principles at the petrochemical sectoral level provides important elements for stimulating the engagement of companies in GCE-based initiatives.

As the concepts of sustainability and sustainable development are being integrated within the Brazilian petrochemical companies' policies and directives, this research revealed they are advancing beyond willingness to change to implementing a significant array of technical and non-technical initiatives towards cleaner and more sustainable products and processes (cf. Section 7.4.1). Such argumentation was supported by the fact that, even though not directly associated with the GCE frameworks, some directives, guidelines and principles that have been incorporated within the company's policies, goals, procedures and production processes matched many of the GCE principles (cf. *ibid*). Those types of incorporation have been implemented both in a planned and structured manner as well as in an intuitive fashion.

8.1.2 What Determines Brazilian Petrochemical Companies' Willingness to Engage in GCE-Based Eco-Innovation?

The second research question addressed the perceptions of the top and mid-level managers and key decision-makers, within the Brazilian petrochemical companies, regarding the determinants of their companies´ willingness to engage in CGE-based eco-innovation processes

Based on this research´s TPB-based structural descriptive behavioral model, in conjunction with statistical analyses, it was possible to identify the significant determinants that influence companies' willingness to engage in such eco-innovation processes. These findings helped this researcher to draw a profile of the companies' perceptions and engagement in GCE-based innovation processes (cf. Section 7.1 of Chapter 7).

The results of the statistical analyses demonstrated that the behavioral model´s three willingness-determining constructs provided significant contributions to explain and to predict willingness in the context of this research.

Requisites and Opportunities for Innovating: There is Still the Need for Enhancing Governmental Support

According to the statistical analyses, greater contributions to willingness, in this construct, had their roots in companies´ perceived behavioral control regarding GCE culture building, technological and organizational capabilities to innovate, technological opportunities, knowledge development, learning processes and their engagement in innovation networks and strategic alliances.

These findings corroborated the TPB argumentation regarding the importance of the perceived behavioral control (*PBC*) in predicting behaviors that are not entirely under

volitional control. As noted in Section 7.2, the *PBC* relationship with the actual behavior was based on two rationales:

- "Holding intention constant, the likelihood that a behavior will be carried out increases with greater perceived behavioral control, and
- Perceived behavioral control will influence behavior directly to the extent that perceived control reflects actual control. In parallel, perceived behavioral control works in parallel with attitudes and subjective norms as a determinant of intentions". (Armitage and Conner, 1999; 36).

Based on these elements, it can be argued that the higher influence of the *PBC* construct on behavioral intention (willingness), demonstrated companies´ confidence that they hold key technical and organizational requisites and opportunities to eco-innovate in GCE and that their influence are likely to facilitate and/or to increase their engagement in these processes.

Surprisingly, institutions were not perceived as a great contributor to companies' willingness to engage in GCE-based innovation processes. It was an unexpected finding as institutions provide general and specific sets of social and economic behavioral control elements, which establish the required order and support for innovation processes to function and to exist

This perception of the low contribution of institutions can be explained by the results of this research´s quantitative survey. In general, although a slight majority of managers and key decision-makers perceived that the existing institutional set was positive for the development and the functioning of innovation processes, a breakdown in these perceptions provided a clearer picture of the barriers to innovation associated with innovation.

Although managers manifested positive perceptions regarding corporations´ internal institutions and regarding Brazilian and international legal institutions in providing support and protection and risk reduction in the case of the establishment alliances and agreements, with other actors, towards the development/acquisition of GCE-based technologies, other institutional domains failed to make positive contributions to companies willingness to change.

According to a majority of the managers, current political and public institutions (laws, decrees, programs, policies etc.), at the Federal, State and Municipal levels, were not sufficient to stimulate companies to engage in innovation processes. This perception was corroborated by this research´s qualitative survey in which claims for governmental GCE-based innovation supportive institutions were recurrent not only by companies´ managers but also by the personnel of the surveyed Environmental Protection Agencies (EPA). In addition, the research evidenced a clear uncertainty regarding the effectiveness of the current social and ethical institutions, commonly found in the business relations, to generate the required confidence for their companies to become more involved in innovation activities with external agents. In this respect, this author highlights and emphasizes the recommendations made in Section 7.6 of Chapter 7 on the need for petrochemical companies, ABIQUIM, EPAs and other important stakeholders to work individually and in conjunction with other partners in order to develop institutional frameworks to stimulate and facilitate innovation processes within the companies and throughout the sector.

Social and Personal Pressures: The Power of the Moral Norms and the Pressures from the Market, Communities, and Regulators/Regulators

The second highest contributions to willingness formation, stemmed from the behavioral model´s social and personal norm construct. Willingness development associated with social and personal norm, refer to the personal moral beliefs regarding individuals´ engagement in eco-innovation processes and to the internalization of the social pressures from important referents regarding the development or the incorporation of cleaner and more sustainable products, processes and services.

The first points that should be noted were the high sense of moral obligation of the respondents regarding environmental protection and their high self-identification with respect environmental issues. This corroborates their responses to the qualitative survey when they declared their full agreement with the sustainability concepts and made strong statements regarding the need for cleaner and more sustainable GCE-based solutions for their companies´ products and processes.

In this respect, managers´ perceptions of their professional roles regarding environmental protection appeared as one of the main determinants of willingness. Social roles are intrinsically related to social norms in the sense that roles are a product of social norms and social norms can be a product of roles as some norms are intensely *role-specific* (Sunstein, 1996). According to Lopopolo (2001), the role incorporated by individuals in a group is formed by a reoccurring exchange of expectations between societal groups' members and role incumbents. According to Triandis (1997), the role's concept, holds the ideas about the correct behavior for a specific position that a member of the organization holds.

According to this thesis author's perception, this finding is a product and reflects the influence of two factors on managers´ professional roles regarding the environment and sustainability. The first relates to the environmental protection and corporate and planetary sustainability culture, bonded to managers´ belief system (cf. Section 7.4.1), that has been progressively built within the Brazilian petrochemical sector in the last two decades. The second is related to the social pressures arising from societally important referents such as trade associations, the regulators, the regulatory set and communities. This was evidenced by the positive statistical correlations between the direct measures of the professional roles and social pressures in this researcher´s behavioral model.

In the social and personal norm construct, social pressure emerged as the highest influential domain to willingness formation. In this thesis research, these pressures were considered to arise from three sources: market, community and regulatory (regulation and regulators). These pressures and influences were verified by the research´s quantitative and qualitative surveys.

In this respect, companies were found be sensitive to market pressures arising from the competitive context and to the consumer demands for cleaner and more sustainable products, manufacturing processes and services. The majority of industrial respondents were found to be in favor of being pioneers in product and process technologies. This suggests an inclination to fulfill market´s pressures and demands for more sustainable goods and for a cleaner environment and for the need to stay ahead of their competitors.

The influence of regulations and regulators on willingness formation corroborates the literature on environmental protection in industry (cf. Montalvo Corral, 2002). In those

studies, the enforcement of environmental regulations represents a major drive of corporate engagement in environmental protection. According to the results, two streams of regulators/regulations have been identified. The first refers to the governmental environmental protection sphere and mandatory regulation compliance. This was associated with EPAs´ role as environmental regulation enforcement agents and environmental legislation developers and improvers. The second stream, regards companies´ deliberate initiatives to improve their environmental performance and to make advancements towards advanced states of corporate sustainability by complying with prevention-oriented agreements and commitments. Such efforts to make changes were represented by the pressures arising from the trade association and from companies' bi or multilateral agreements and initiatives aimed at improving their relations with the triple bottom line. That is, they are aware that they are likely to be more profitable and socially accepted if they are more environmentally friendly and receive less criticism from the public.

One important finding was the evolution of the relationship between EPAs and companies. The surveyed EPAs, although keeping strong emphasis of their role of legislation enforcers, they have broadened their spectrum of strategies and included cooperative efforts with companies and other important stakeholders towards meeting societal broader environmental interests and expectations. These evidences indicated that although the EPAs are required by law to enforce legislation, a cooperation and joint environmental planning culture has evolved, in the surveyed companies and the EPAs, as requisites for expediting the petrochemical companies' advancements towards more environmentally, socially and economically sustainable states. Thereby, problems and solutions can be detected and discussed in an effective manner with the more efficient use of human and financial resources.

The researcher´s quantitatively analyzed cases in which the close participation of the EPA throughout companies´ environmental licensing process, from the identification of the environmental risks and their impacts through the establishment of deadlines for their solutions and follow-up The constant dialogs and negotiations have helped to overcome the usual bureaucracy. According to the respondent, this stimulated companies to make real changes and advancements beyond compliance with the existing legislation.

With respect to community pressures, companies were documented to be susceptible to managers´ personal and corporative referents and declared their motivation to comply with their environmental responsibilities. One important finding was that communities´ current environmental lobbying capability did not pose much concern for the majority of respondents.

It is this thesis author's perception that companies are likely to perceive that current local communities' articulations and political support are not yet powerful enough to cause concerns regarding the need for companies to undertake profound technical changes. However company leaders expressed the opposite perception when they reflected upon communities´ future lobbying capabilities.

In this case, concerns were significant, which suggested that companies are likely to perceive that they must continue to evolve with regard to societal concerns regarding human health, the environment and the socio-economic sustainability of societies. In this respect, the results suggested that companies captured trends and projected a relevant socio-political evolution of societies with respect the tipple bottom line, which will lead to stronger political, regulatory, market and tighter societal pressures on the petrochemical industry with regard to the hazards, the pollution and nature depletion potential of its

manufacturing processes and products. It is clear that these perceptions are the result of companies´ communication programs with stakeholders and their interactions with communities *via* the Consultive Communities Councils. The implementation and the operalization of the Consultive Communities Councils are a requirement of the RCP, because they establish direct and permanent communication channels among companies and the local communities.

Attitudes Towards GCE: Environmental and Economic Risks do not Preclude Willingness to Innovate

The attitude construct, was one of the three constructs that were systematized to provide a framework that could address this researcher´s questions. Attitudes are indices of the degree to which individuals like or dislike, approve or disapprove, agree or disagree with any aspect of her or his life. It is the positive or negative evaluation of performing a behavior (Montalvo Corral, 2002).

In this domain, economic risk provided the largest contribution to willingness formation. Although companies perceived that GCE-based eco-innovation processes imply some degree of financial and technological risks, they also perceived that such processes could conduct companies to take advantages of the business opportunities and to appropriate the benefits of innovation.

Based on these findings and on the results of the research´s qualitative survey, it is clear that the surveyed Brazilian petrochemical companies´ managers were convinced that producing cleaner, more sustainable and safer GCE-based products and manufacturing processes imply in environmental and socio-economic benefits. According to this view, benefitting from the business opportunities, which may arise in the near and in the far future, justify the engagement of these organizations in GCE-based eco-innovation processes. According to this researcher´s findings, based on empirical evidence and on his personal observations, companies´ consumers´ claims regarding innovative, cleaner and more environmentally friendly products are perceived by companies as not only a momentary event but also as strong trend for the future. This established a correspondence between the sense of business opportunities for GCE-based eco-innovative and more sustainable products, processes and services with being successful in overcoming the selection processes imposed by nature, by the market and by societies despite the intrinsic technological and financial risks that eco-innovation implies.

With regard to environmental risk perceptions of the surveyed managers and decision-makers, they had low influence on willingness formation. According to one of the premises, adopted for this thesis research, companies that perceive that their operations are safe are less prone to eco-innovate. The results suggested that low perceptions of environmental risks produced a sense of safe operations in “one of the, or maybe the, most polluting sector in industrial societies” (Mol, 1995: 87).

For the purposes of this research, the environmental risk perception concept was expressed by how and why individuals perceive technologies and activities as (environmentally) risky or safe and, as a consequence of such perception, accept or reject that risk.

The results of the quantitative survey revealed that although the majority of the managers and decision-makers perceived that the risks generated by their companies were low, 91.7 percent of them gave high importance to the development or adoption of cleaner and more

sustainable technologies, such as those that are based on GCE, for their companies´ products, processes and services.

Although this might appear to be paradoxical, the foundations for these perceptions may be explained based upon two streams of motivations.

The first relates to a defensive posture of the respondents. Although, anonymity of the respondents to this thesis research´s quantitative survey was a highest and inviolable principle, nevertheless some respondents might have been defensive in order to protect themselves and their companies.

The second and more likely explanation has been elicited in indirect manner by the in-depth interviews. When confronted with the results of the quantitative survey regarding the low environmental perceptions of the managers and key decision-makers, it was highlighted that although the intrinsic risks of companies´ operations and products were high, the risk control measures used in such operations put them under control or reduced the occurrence of environmental risky events to low probabilities. Despite such argumentation, the respondents were unanimously in favor of the use of GCE as a baseline framework for the promotion of technological changes towards advanced sustainability states of their companies.

The attitude of the respondents towards GCE reinforces and matches their declared commitment to the planetary and corporative sustainability that was expressed in the in-depth interviews. Their perception of low environmental risks of their companies' operations suggests a technological lock-in where the concept and the sense of safe operations is prioritized by risk reduction initiatives upon reducing exposure that were conducted *via* risk control measures and not by reducing risks acting directly on their unsustainability roots. That is, by promoting more, deeper technological changes aiming at reducing the intrinsic hazards associated with the properties of the chemical substances and with the processes design.

Therefore, they perceived that their companies´ operations were/are safe. This evidenced the need for effecting a change regarding the notion of safe and risky operations by shifting the focus from the risk control measures to the risks associated with the intrinsic properties of the chemical substances. This will not only have influence on the toxicity of the chemical substances but it is also expected that it will have effects on the resources and energy consumption that can be achieved by the new design approaches for products and production processes that operate under safer and more cost-effective operating conditions.

This research findings suggested that the failure in identifying the technological origins of firms´ environmental risks may impede the company from determining the fundamental needs towards advanced states of sustainability. It may preclude the firm from identifying the need for innovating and making more appropriate choices regarding the innovative technological paradigms, regimes and trajectories and solutions that are required to take the corporation to advanced states of sustainability in more efficient and expedite ways.

8.1.3 Agents, Mechanisms and Actions to Implement GCE at the Brazilian Petrochemical Sector Level

This thesis research findings are in full harmony with Ajzen´s (2005: 113) statement regarding behavioral intentions. According to him, "intentions are assumed to capture the

motivational factors that have an impact on a behavior, they are indications of how hard people are willing to try, or how much of an effort they are planning to exert in order to perform a behavior. These intentions remain behavioral dispositions until, at the appropriate time and opportunity, an attempt is made to translate the intentions into action".

In this respect, questions one and two of this research addressed companies´ behavioral intentions (willingness) and its main determinants. The third research question, addressed the last part of Ajzen´s statement in which intentions remain behavioral dispositions until, at the appropriate time and opportunity, an attempt is made to translate the intentions into action.

The translation of intention to engage in GCE-based eco-innovation processes into action is contingent on the engagement of organizations´ leaders who will ultimately effect the required actions for the introduction, the dissemination and the implementation of GCE.

The results of this research revealed that the success of GCE implementation in an orderly, structured, systematic and systemic way can be much expedited if meso-level (sector-level) and micro-level (company-level) agents are fully engaged and committed and the sector´s structure, instruments and institutions are used to promote and incentivize GCE implementation throughout the entire sector.

According to the perception of this thesis author, this could promote an evolution from isolated initiatives, at the company level, into an expansion to collective and systemic efforts. The evidences suggested that the implementation of GCE at the sector level could incentivize, facilitate and strengthen the implementation of GCE and the development of GCE-based eco-innovation processes at the companies' level. This collective effort could produce effective GCE supporting structures represented by new and more effective institutions, stronger ties with an array of governmental and non-governmental stakeholders, which can be developed based upon ABIQUIM's and the companies´ commitment to incorporate GCE into their policies and practice.

The incorporation of GCE at the sector level is a multi-agent and a multi-mechanism enterprise. The thesis results demonstrated that companies, ABIQUIM and the EPAs stood out as the main agents in this processes. These agents, in association with a variety of other stakeholders (government, academia, press, communities etc.) and by utilizing existing and custom developed dynamics and instruments, can provide the required leadership, institutional and political support and human and financial resources for the GCE frameworks to be implemented as guiding principles and basic frameworks towards technological changes and corporate environmental and economic sustainability.

For the Brazilian petrochemical industry, at the company and the sectoral levels, to implement GCE it is required that the leaders of these organizations depart from their current state of willingness and take leadership by discussing, planning and implementing actions. These actions will progressively introduce and consolidate the GCE frameworks and promote GCE-based individual and collective initiatives as a means to achieve the industry´s short, medium and long-term environmental and socio-economic objectives.

This argumentation reflects the perception of one of the respondents of this thesis research's in-depth interviews. When asked about his opinion on this thesis research and its results he stated that "if this research and its results reach and are acknowledged by

important decision-makers, 'the right people', substantial progress can be made in terms of behavioral change and investments efforts (human, knowledge, capital etc.) towards sustainability.

8.2 The use of the Method´s for the Analysis and Design of Policies

This research was primarily conceived and developed to help top and mid-level managers and key decision makers in the individual organizations and in the industrial sectors to gain a better understanding and to assess the possible determinants of implementation of eco-innovation. This was expected to make it possible to engage in the development of strategies that are more efficient, better planning for implementing eco-innovation processes and provide help to conduct a better allocation of human and financial resources.

A secondary objective was also established. It expanded the primary objective and focused upon the use of the eco-innovation determinants to generate suggestions and to help policy analysts, at the corporate, sector and governmental domains, to design specific eco-innovation policies. The main supporting argument for this approach is that policies that are designed based on a good understanding of the nature of the challenges of eco-innovating in GCE, in specific contexts, can be better formulated to provide policy-makers with clearer idea on what is and what is not possible to do. In addition, plans can be better formulated to overcome barriers and enhance companies´ strengths.

In this respect, although this research identified the determinants of companies´ willingness to engage in GCE-based eco-innovation processes, policies/strategies that encompass the integrity of them may not be viable in terms of conception, integration, resources, implementation timing and costs. Good policies/strategies can be designed and resources can be more efficiently allocated in cases that they are based on specific conditions that have better chances of success with the use of fewer resources.

The simulations conducted in Section 7.2 of Chapter 7 identified the most favorable conditions under which willingness could be enhanced. These conditions provided elements for policies development that stemmed from five out of the nine behavioral domains of this research´s behavioral model. As a result, willingness determinants belonging to the environmental risks, economic risks and business opportunities, social pressures, knowledge and technologies and agents and networks behavioral domains were used to make recommendations for governmental, sectoral and corporate eco-innovation supporting policies.

This method, gives policy analysts a valuable, selective, systemic and integrated perspective of eco-innovation determinants instead of focusing on isolated elements. This holistic approach can support the development of innovation policies that are generated based on judicious scientifically-based look inside the companies with a very strong focus on the sources of willingness to eco-innovate in GCE and addressed the origins of the problems and not only focused upon the symptoms of their inattention.

The method could be criticized from the point of view that it was not necessary to develop such an elaborate method to propose such policy suggestions. In principle, this is wrong in that the goal of policy analysis is to gain a better understanding of the possible ways of acting and of the possible responses to specific determined policies (Montalvo Corral, 2002). This can generate the required knowledge and the understanding on the elements that are important for the promotion of changes in the behavior of individual companies or

of whole sectors *via* the development of effective policies that address key points and help to promote the reconciliation of companies' self-interests of being profitable in the short and long term with societal environmental needs and aspirations.

8.3 Reflections on the Research

8.3.1 Theoretical Contributions of the Research

This research belongs to a stream of studies that approach innovation in light of its behavioral aspects. Usually, successful innovative efforts are seen as being a function of their cognitive capacities and abilities. These cognitive resources can be traced to the agents that are directly or indirectly engaged in the innovation processes (Beckenbach and Daskalakis, 2008; Montalvo Corral, 2002). Thus, in accordance with Beckenbach and Daskalakis (*ibid*), this thesis author has the opinion that analyzing the behavioral foundations of innovation should be viewed as a main topic in this domain. In addition, they argued that agent-related surveys have their legitimate place in innovation research, since they enable a disaggregated assessment of observable innovation elements and enable one to take into consideration innovation determinants, which cannot be observed with the usual toolbox. In this regard, empirical surveys for investigating these elements are also important for theory formation.

Many studies have explained behavior in light of cognitivism. In these cases, behavior was explained as a function of individuals´ mental operations (perceptions, beliefs and attitudes), which are produced by cognitive processes (e.g. attention, memory, information processing, knowledge application, producing and understanding language, problem solving, decision-making). According to the cognitivist approach, these mental operations can be explained by the use of experiments, measurements, and the scientific method; they may be described in computational terms. Empirical surveys for investigating these elements are also important for theory formation.

In this respect, and in order to achieve the aforementioned objectives, in this thesis research, a multidisciplinary approach was used with an organizing framework that was based upon social psychology. The meta-theoretical characteristic of the TPB allowed for the development of a TPB-based organizing framework, which integrated several bodies of research to explore the phenomena under investigation in a systematic manner. This provided great flexibility in the sense that a behavioral model could be constructed or modified according to the needs of the study, instead of allowing the study to be molded according to the possible rigidities of the model.

Taking advantage of this flexibility, the largest contribution of this thesis research to innovation studies was the development of an organizing framework for the study of the behavioral determinants of innovation in sectors. Although, behavioral aspects of innovation, in the industrial realm, have been examined by Montalvo Corral (2002), his study was not devoted to consider innovation in light of theoretical grounds that are specific to innovation in sectors. By merging the TPB and Franco Malerba´s (2002) Sectoral System of Innovation (SSI) framework, it was possible to develop a behavioral model that represented an organizing framework and analytical tool that allowed for a more detailed view on the behavioral determinants of innovation in sectors.

Based on the foundations of the TPB, it was possible to verify that eco-innovating in GCE is part of the list of behaviors that cannot be assumed to be under volitional control as it is fully dependent on the availability of skills, resources and opportunities. In this regard, according to the SSI framework, innovation in sectors are a function of elements as diverse as knowledge and learning processes, technological opportunities, technological and organizational capabilities, the appropriability of innovation results, capabilities to form and join innovation networks and strategic alliances, and institutional set, which are not always perceived to be under volitional control.

The assessment of the extent to which companies perceived that they have control over sector- specific resources and opportunities, represented by the building blocks of the SSI, represents a significant and powerful approach to help to develop appropriate measures and policies to stimulate and to promote the engagement of companies in sectoral eco-innovation.. This is expected to enhance the likelihood of success as, according to the TPB, the perceived behavioral control over resources and opportunities to innovate will influence behavior directly to the extent that perceived control reflects actual control. Also, perceived behavioral control works in parallel with attitudes and subjective norms as determinants of intentions (Armitage and Conner, 1999).

8.3.2 Generalization of the Method

According to the TPB, behavioral entities may be viewed as being defined by four different elements (a) the ***action*** (a given action is always performed with respect to a given target), (b) the ***target*** at which the action is directed, (c) the ***context*** in which the action is performed, and (d) the ***time*** at which the behavior is performed. This provided a reference point and a target behavior for the development of the research´ structural descriptive behavioral model and its related quantitative questionnaire (cf. Chapters 3 and 6). It is plausible that a question arises on the possible generalizations of this research model. The response to this question resides in the capacity of the model to measure the willingness constructs under investigation in different contexts and on the origin of the elements used to construct the model.

The capacity of the model to be used to measure the constructs under investigation was tested with regard to its statistical validity and the reliability of the structured quantitative questionnaire. This represented a decisive step in the study as the model could only be relied upon, to provide further understanding on the determinants of companies´ willingness to engage in GCE-based eco-innovation processes, after the model had been found to be valid and that the questionnaire was reliable.

In this regard, the questionnaire reliability was found to be reliable as the parameters used to test it were, in general, above the recommended levels by the norms of psychometric tests. The content validity of the model was considered satisfactory as the structure of the empirical data were confirmed to correspond with the theoretical model. In respect to the construct validity, several multiple regression analyses tested the explanatory predictive power of the model and the coefficient of determination of willingness was found to be satisfactory. Similar results were obtained for different domains.

Once these elements were verified, confidence in the results was established and further, deeper investigations were conducted on the motivational aspects based on which companies´ top and mid-level managers and key decision-makers responded to the quantitative survey. This survey was then done *via* a triangulation method by the use of a

qualitative survey. This allowed for the verification of not only Brazilian petrochemical companies´ full support to GCE and their willingness to engage in GCE-based eco-innovation processes but also that they have advanced beyond willingness, by implementing some GCE principles. Another important point was that it was possible to verify the importance of the trade association, ABIQUIM, and the EPAs in the promotion, diffusion and implementation both at the company and sectoral levels.

With regard the origin of the elements used to construct the model, the fact that the model was constructed based on relevant bodies of literature rather than on elicited beliefs as originally suggested by Ajzen produced a generalizable model. Owing to the fact that literature is not location-specific, the model can be applied in different regional and national contexts. The weight of the different constructs, domains and beliefs on willingness will be contingent on the perception and the attitudinal, social and personal normative motivational elements and on the perceived control over the requisites and opportunities to eco-innovate in GCE held by key agents in different environmental and socio-economic contexts.

8.4 Final Considerations

Some considerations emerged from the diverse analyses conducted throughout this thesis research. The first was related to the companies´ willingness to engage in GCE-based eco-innovation processes as documented by the surveyed managers in respect to their companies. Such willingness, reflected the awareness of the individuals regarding the need for more advanced states of environmental and socio-economic sustainability of the sector. It also demonstrated their alignment with the current efforts and initiatives of the sector, nationally and worldwide, towards the sustainable development of the petrochemical and chemical industries.

This suggests that, although a transition to more sustainable technological states is currently at its infancy, it seems that those efforts have promoted an evolution of the sector´s "collective-consciousness"[120] in respect to the needs for companies´ long-term socio-economic and environmental sustainability. The GCE framework appears to provide fertile grounds within which to grow.

The second consideration relates to the verification of the adequacy of the use of the methodology in contexts and industrial realms, which are different from the ones to which it was originally developed by Montalvo Corral (2002).

This methodology uses a cognitive approach, which makes full use of fundamentals from social psychology and links cognitive, normative and instrumental factors into the explanation of the dissonance between cognition, motivations, intentions, goals, plans and actions (Montalvo Corral, 2002).
As this thesis researcher´s behavioral model was designed to explain and predict innovation related behavioral intentions in sectors, it is expected that its behavioral model can be adopted by the sector in the development of innovation related policies and strategies based on the causes and not on the symptoms of the problems.

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[120] Collective consciousness is a term coined by the French sociologist Émile Durkheim (1858–1917) to refer to the shared beliefs and moral attitudes, which operate as a unifying force within society.
Source: http://en.wikipedia.org/wiki/Collective_consciousness, accessed in August 2012.

The third remark emerged from the analysis of the importance of the environmental risk perception and its consequences for long-term corporate environmental and economic sustainability. From that analysis, it was found that "there is a clear need to change the local reinforcements of the self-interest that pre-dispose and form the environmental risk perceptions and, as a consequence, determine environmental attitudes" (*ibid*: 197). Such reinforcements preclude managers and decision-makers from envisioning viable and more sustainable futures as if they were blindfolded by their short-term, non-sustainable objectives

Additionally, the next three considerations emerged in the form of recommendations for further research, to be conducted by this thesis research´s author in association with universities and other research organizations, in the future.

Although, this thesis research covered a broad spectrum of beliefs related to attitudinal, normative and instrumental factors that can explain and predict firms' willingness to engage in eco-innovation processes, due to the type of agents, the level of analysis and the objectives of the study, it has not required the inclusion of detailed economic aspects.

The first direction for further research emerged from the importance of economics in technological innovation. In this respect, and in order to study the influence of the determinants of eco-economic behavioral intention of the social agents, it is recommended that such studies should be conducted by using a modified version of this thesis researcher´s structural behavioral model. The modified version encompass variables pertaining to the fields of innovation and environmental economics[121]. This could provide a valuable contribution to the field of behavioral economics[122].

Another line for future research could be based upon the possibility of utilizing a systemic approach that uses the statistical results of the survey and the relationships between a larger number of variables in order to more deeply simulate behavioral intentions (willingness). This author proposes that such research could be conducted *via* the use of agent-based computerized models[123] supported by theories such as: game theory, complex systems,

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[121] Environmental economics can be defined as that "part of economics which deals with interrelationship between environment and economic development and studies the ways and means by which the former is not impaired nor the latter impeded." (Pavithran, 2008: 1)
"Environmental economics seeks to measure the external environmental effects, or costs, of economic decisions and propose solutions to mitigate or eliminate those costs to better manage natural resources and promote social well-being. Unlike traditional economics, which focuses on private ownership of property, environmental economics primarily concerns itself with the management of common or public property, such as lakes, rivers, game and parks. Environmental economics functions on the theory of 'market failure'. Simply stated, market failure occurs when markets fail to efficiently allocate limited resources in a way that benefits society most"
(http://www.whatiseconomics.org/environmental-economics, accessed in April, 2013).

[122] Behavioral economics: "a method of economic analysis that applies psychological insights into human behavior to explain economic decision-making". (Oxford Dictionaries – accessed in April, 2013 http://oxforddictionaries.com/us/definition/american_english/behavioral%2Beconomics)

[123] Agent-based modeling is a powerful simulation modeling technique that has seen a number of applications in the last few years, including applications to real-world business problems. (…) In agent-based modeling (ABM), a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. (…) In addition, agents may be capable of evolving, allowing unanticipated behaviors to emerge." (Bonabeau, 2002: 7280)

emergence, computational sociology, multi-agent systems, evolutionary programming, Monte Carlo methods, neural networks, or other learning techniques to allow realistic learning and adaptation (cf. Bonabeau, 2002). The better understanding of the influences of the determinants of eco-innovation on companies´ willingness, in specific contexts, will make it possible to perform more precise policy analyses and, as a consequence, to enable the development of more appropriate policies and strategies, by companies, sectors and governmental agents, to stimulate eco-innovation at company and sectoral levels. It is expected that the identification of such relations can provide an efficient identification of more specific and effective types of collaborations when designing eco-innovation processes.

In order to take advantage of the generalizability of the thesis research's behavioral model, it is recommended to test/apply this model in other contexts. As this research was focused upon measuring and predicting the willingness, of basic and second generation petrochemical manufacturing companies, to deliberately engage in GCE-based eco-innovation processes, in the next five years, similar research could be applied to different petrochemical sectors in different countries on different continents. It could also be tested in other industrial sectors and in organizations, which are primarily service providing such as the hotels, hospitals and food-service sectors.

Such an evaluation could produce valuable information not only on the degree of willingness that companies hold in respect to such engagement, but also valuable information could be generated in respect to the differences and similarities of willingness determinants in different contexts.

This information could be relevant for governments and for the sector´s representative associations, worldwide. They could be used in the development of guidance for more efficient policies for promoting GCE as a viable framework to help to reconcile the socio-economic and environmental self-interests of the sector with those pertaining to the broad societal domain worldwide. They certainly could contribute to promoting technological and management transitions to more sustainable societies.

Also, longitudinal studies could/should be done within the Brazilian petrochemical manufacturing companies to document if or how fast companies actually do adopt the GCE frameworks as guiding principles and basic frameworks towards technological changes and corporate environmental and economic sustainability and engage in GCE-based eco-innovation processes in accordance to their demonstrated willingness.

At the conclusion of this thesis research, it can be argued that this study revealed that companies´ willingness to accept the GCE frameworks and to engage in implementing GCE-based eco-innovation processes were perceived by the surveyed managers and decision-makers as viable alternatives; this provides baseline guidance for the construction of the next generation petrochemical industry (products, processes and services).

The resultant actions of that willingness are dependent on proper stimulation, on the opportunities, on the availability of resources and on the removal of the barriers that may arise along the way.

In this respect, efforts should be placed on the development and the application of increasingly efficient policies and innovation stimulating strategies at the company, sectoral and societal levels. Such policies should seriously focus upon solving the

problems from the side of their causes and not continue to be focused upon treating the symptoms of the challenges. This thesis researcher hopes and expects that this scientific investigation will contribute to building cleaner and more sustainable societies where mistakes from the past can be overcome and nature´s gifts can be preserved.

The future of human societies depends on what we do today and tomorrow. The quality of life we will have in the future will be the consequence of our current choices just as the environmental and socio-economic conditions in contemporary societies are the results of our past decisions.

"The past is done. Finished. The future does not exist. It must be created microsecond by microsecond by every living being and thing in the universe."

-Edward Teller

"But the future does not yet exist and may not exist for any given individual or even for the whole species. Its truth cannot be discovered and known, but is must be created."

-Horst Hutter

9. Appendix A - Reliability Statistics

Appendix 5 represents a complement to the discussion about the importance of the reliability of questionnaires items in producing consistent results along with deliberations about the theoretical foundations for reliability verification that were conducted in Section 5.6.1, in Chapter 5. It presents the reliability statistics calculation results that were generated from this thesis research´s collected empirical data. The results of the statistical analyses, presented in Appendix A, supported the discussion, the explanations and the conclusions, presented in Section 7.6.1 of Chapter 7, related to the reliability of the items of this thesis research´s survey questionnaire.

As previously noted, in Chapter 5, the reliability values associated with this research´s questionnaire items were assessed through the calculation of the Cronbach´s alpha indexes that were applied to the scales and subscales related to this thesis research´s TPB-based model´s Attitude, Perceived Social Factors Pressures and Perceived Behavioral Control constructs.

Table 9.1- Results of the reliability calculation for this thesis research survey´s questionnaire items

Scales	Subscales	Scales (Cronbach´s α)	Subscales (Cronbach´s α)	Deleted items	No. of Items
Attitude					
Environmental Risk		0,743			12
Economic Risk		0,704		ecr12, ecr13 and ecr18	17
Perceived Social Factors Pressures					
Social Pressure		0,960			
	Market pressure		0,912		12
	Social pressure		0,950		15
	Regulatory pressure		0,793		7
Personal Motivations (Roles, Personal Norms and Self-Identity)		0,891			9
Perceived Behavioral Control					
Knowledge and Technologies		0,897			
	Accessibility to knowledge		0,929		7
	Technological opportunities		0,809		3
	Appropriability		0,704		5
	Cumulativeness		0,847		21
Actors and Networks		0,896			
	Availability of internal actors holding key capabilities		0,871		5
	Strategic alliances		0,828		14
	Networks of collaboration		0,796		5
Institutions		0,794			4

10. Appendix B - Results of the Statistical Content Validation of this Thesis' Research´s Behavioral Model

B.1 Results of the Confirmatory Factor Analysis Results

B.1.1 Principal Component Analysis for the Behavioral Domain Scales

Table 10.1- Measure of sampling adequacy for factor analysis

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.628
Bartlett's Test of Sphericity	Approx. Chi-Square	118.726
	df	36
	Sig.	.000

Table 10.2- Explanation of the total variance of the three factors associated with willingness to engage in CGB eco-innovation processes at the behavioral domains´ scales level

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.334	37.041	37.041	3.334	37.041	37.041	2.734	30.375	30.375
2	1.777	19.745	56.785	1.777	19.745	56.785	2.335	25.949	56.325
3	1.256	13.951	70.736	1.256	13.951	70.736	1.297	14.412	70.736

Extraction method: Principal Components Analysis

Table 10.3- Rotated component matrix of the principal component analysis at the behavioral domains´ scales level

Rotated Component Matrix

	Component		
	1	2	3
sum_evr			.719
sum_ecr			-.675
sum_sp	.649	.421	
sum_rlp		.824	
sum_pn		.697	
sum_si		.843	
sum_ktc	.905		
sum_an	.894		
sum_inst	.763		

Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 4 iterations
Component 1 = Perceived Behavior Control (*PBC*)
Component 2 = Perceived Social Factors Pressure (*PSFP*)
Component 3 = Attitude (*A*)

B.1.2 Principal Component Analysis for the Direct Measures of the Behavioral Domain

Table 10.4- Measure of sampling adequacy for factor analysis

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.641
Bartlett's Test of Sphericity	Approx. Chi-Square	108.292
	df	36
	Sig.	.000

Table 10.5- Explanation of the total variance of the three factors associated with willingness to engage in CGB eco-innovation processes at the behavioral domains level

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.643	40.474	40.474	3.643	40.474	40.474	3.021	33.568	33.568
2	1.674	18.595	59.069	1.674	18.595	59.069	2.288	25.423	58.992
3	1.174	13.045	72.114	1.174	13.045	72.114	1.181	13.122	72.114

Extraction method: Principal Components Analysis

Table 10.6- Rotated component matrix of the principal component analysis at the behavioral domains level

Rotated Component Matrix

	Component		
	1	2	3
EVR			.808
ECR			-.612
SP	.676	.312	
RLP	.597	.583	
PN		.901	
SI		.898	
KTC	.847		
AN	.835		
INST	.820		

Rotation Method: Varimax with Kaiser Normalization
Rotation converged in 4 iterations
Component 1 = Perceived Behavior Control (*PBC*)
Component 2 = Perceived Social Factors Pressure (*PSFP*)
Component 3 = Attitude (*A*)

11. Appendix C - Results of the Statistical Construct Validation of this Thesis' Researcher´s Behavioral Model

C.1- Results of the Multiple Regressions Analysis at the Behavioral Model´s First and Second Levels of Explanation

Hypothesis H_1: Regressions of Willingness to Engage in GCE-based Innovation Processes Against A, PSFP and PBC

H_1: $W = W(A, PSFP, PBC)$

Table 11.1- Model summary (stepwise regression for H_1)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	.806	.650	.613	.730

Dependent Variable: W

Table 11.2- ANOVA calculation results for H_1

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	28.664	3	9.555	19.784	.000
Residual	15.455	32	.483		
Total	44.119	35			

Table 11.3- Regression coefficients for H_1

Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
3	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-2.060	1.262		-1.632	.113		
PBC	.748	.167	.536	4.479	.000	.842	1.187
PSFP	.529	.184	.327	2.877	.007	.935	1.069
A	.164	.067	.286	2.456	.020	.889	1.124

Hypotheses H_2: Regressions of Willingness to Engage in GCE-based Innovation Processes Against the Behavioral Domains

H_2: *W = W(EVR, ECR, PSP, RLP, PN, SI, KTC, AN, INST)*

Table 11.4- Model summary (enter regression mode for H_2) [124]

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.851	.724	.628	.738

Dependent Variable: W

Table 11.5- ANOVA calculation results for H_2

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	37.151	9	4.128	7.574	.000
Residual	14.169	26	.545		
Total	51.320	35			

Table 11.6- Regression coefficients for H_2

Model Summary

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(constant)	-2.051			-1.384	.048		
EVR	.029	1.068	.037	.260	.037	.534	1.873
ECR	.200	.110	.171	.868	.033	.890	1.124
SP	.239	.127	.310	2.757	.011	.586	1.706
RLP	.102	.104	.070	.383	.035	.422	2.369
PN	.088	.230	.052	.826	.016	.416	2.404
SI	.069	.269	.038	.295	.040	.487	2.053
KTC	.210	.132	.233	.060	.023	.506	1.977
AN	.419	.207	.377	2.364	.036	.607	1.259
INST	.050	.108	.055	.460	.049	.670	1.493

C.2- Results of the Multiple Regressions Analysis at the Behavioral Model´s Third Level of Explanation (Regressions of the Behavioral Domains Against their Respective Scales´ Variables)

$$H_3: EVR = EVR\left(\sum_{b=1}^{12} evr_b\right)$$

Hypothesis H_3: Perceived Environmental Risk

Table 11.7- Model summary (stepwise regression for H_3)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	,756	,571	,520	1,429

Dependent Variable: EVR

Table 11.8- ANOVA calculation results for H_3

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	68.090	3	22.697	14.218	.000
Residual	51.082	32	1.596		
Total	119.172	35			

Table 11.9- Regression coefficients for H_3

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	1,316	,673		1,956	,062		
evr7	,534	,121	,626	4,422	,000	,855	1,170
evr2	,346	,160	,296	2,160	,041	,916	1,091
evr11	-,435	,203	-,291	-2,143	,042	,929	1,076

Hypothesis H_4: Perceived Economic Risk

$$H_4: ECR = ECR(\sum_{b=1}^{20} ecr_b)$$

Table 11.10- Model summary (stepwise regression for H_4)

Model Summary

Model	R	R Square	Square	the Estimate
2	.702	.492	.458	.860

Dependent Variable: ECR

Table 11.11- ANOVA calculation results for H_4

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	21.504	2	10.752	15.988	.000
Residual	22.193	33	.673		
Total	43.697	35			

Table 11.12- Regression coefficients for H_4

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	3.450	1.257		2.743	.010		
sum_econom_opport	.104	.023	.578	4.437	.000	.996	1.004
sum_tech_risk	-.128	.046	-.363	-2.787	.009	.996	1.004

Hypothesis H_5: Perceived Social Pressure

$$H_5: PSP = PSP(\sum_{b=1}^{12} mp_b + \sum_{b=1}^{15} cp_b + \sum_{b=1}^{7} rp_b)$$

Table 11.13- Model summary (stepwise regression for H_5)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.901	.811	.787	.720

Dependent Variable: SP

Table 11.14- ANOVA calculation results for H_5

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	69.112	4	17.278	33.306	.000
Residual	16.081	31	.519		
Total	85.193	35			

Table 11.15- Regression coefficients for H_5

Coefficients

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-1.070	.774		-1.383	.177		
rp2	.208	.127	.177	1.641	.111	.588	1.701
rp1	.020	.114	.015	.174	.863	.912	1.096
rp5	.439	.139	.402	3.147	.004	.418	2.392
cp11	.524	.116	.483	4.519	.000	.600	1.668

HYPOTHESIS H_6: ROLES

$$H_6: RLP = RLP\left(\sum_{b=1}^{4} rlp_b\right)$$

Table 11.16- Model summary (stepwise regression for H_6)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.399	.159	.132	.788

Dependent Variable: RLP

Table 11.17- ANOVA calculation results for H_6

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.639	1	3.639	6.422	.022
Residual	19.266	34	.567		
Total	22.905	35			

Table 11.18- Regression coefficients for H_6

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	4.024	1.034		3.891	.000		
rlp4	.392	.162	.399	2.420	.022	1.000	1.000

Hypothesis H_7: Personal Norm

H_7: $PN = PN(\sum_{b=1}^{3} pn_b)$

Table 11.19- Model summary (stepwise regression for H_7)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.732	.536	.508	.455

Dependent Variable: P**N**

Table 11.20- ANOVA calculation results for H_7

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.904	2	3.952	19.050	.000
Residual	6.846	33	.207		
Total	14.749	35			

Table 11.21- Regression coefficients for H_7

Coefficients

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	2.662	.661		4.023	.000		
pn3	.302	.089	.465	3.410	.002	.755	1.324
pn1	.315	.113	.380	2.785	.009	.755	1.324

Hypothesis H_8: Self-Identity

$$H_8: SI = SI(\sum_{b=1}^{2} si_b)$$

Table 11.22- Model summary (stepwise regression for H_8)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.569	.324	.302	.512

Dependent Variable: SI

Table 11.23- ANOVA calculation results for H_8

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.377	1	4.377	17.951	.001
Residual	8.290	34	.244		
Total	12.667	35			

Table 11.24- Regression coefficients for H_8

Coefficients

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	3.032	.859		3.528	.001		
si2	.525	.136	.569	3.857	.001	1.000	1.000

Hypothesis H_9: Control over Knowledge and Technologies

$$H_9: KTC = KTC\left(\sum_{b=1}^{7} ak_b + \sum_{b=1}^{3} to_b + \sum_{b=1}^{4} app_b + \sum_{b=1}^{21} cmt_b\right)$$

Table 11.25- Model summary (stepwise regression for H_9)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
8	.968	.938	.917	.350

Dependent Variable: KTC

Table 11.26- ANOVA calculation results for H_9

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	44.126	8	5.516	50.795	.000
Residual	2.932	27	.109		
Total	47.057	35			

Table 11.27- Regression coefficients for H_9

Coefficients

	Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-1.749	.471		-3.715	.001		
cmt20	.153	.067	.178	2.299	.031	.431	2.318
cmt12	.286	.055	.312	5.229	.000	.730	1.370
to1	.376	.080	.399	4.730	.000	.365	2.736
ak2	.265	.060	.288	4.435	.000	.616	1.624
to2	-.142	.062	-.175	-2.294	.031	.448	2.233
cmt21	.132	.059	.129	2.224	.036	.772	1.295
cmt5	.157	.054	.189	2.915	.008	.619	1.614
cmt17	.140	.063	.142	2.226	.036	.636	1.573

Hypothesis H_{10}: Control over Actors and Networks

$$H_{10}: AN = AN\left(\sum_{b=1}^{5} avc_b + \sum_{b=1}^{14} sac_b + \sum_{b=1}^{5} nwc_b\right)$$

Table 11.28- Model summary (stepwise regression for H_{10})

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.898[a]	.807	.771	.497

Dependent Variable: AN

Table 11.29- ANOVA calculation results for H_{10}

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	27.851	5	5.570	25.104	.000[b]
Residual	6.656	30	.222		
Total	34.507	35			

Table 11.30- Regression coefficients for H_{10}

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-.239	.718		-.332	.742		
avc5	.207	.147	.194	1.411	.049	.580	1.634
nwc3	.260	.079	.317	3.283	.003	.767	1.303
sac7	.405	.104	.561	3.883	.001	.343	2.917
avc1	.441	.137	.359	3.227	.003	.577	1.734
nwc5	-.221	.090	-.283	-2.454	.021	.539	1.857

Hypothesis H_{11}: Control over Institutions

H_{11}: $INST = INST(\sum_{b=1}^{4} inst_b)$

Table 11.31- Model summary (stepwise regression for H_{11})

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.787	.619	.594	.828

Dependent Variable: INST

Table 11.32- ANOVA calculation results for H_{11}

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	33.491	2	16.745	26.859	.000
Residual	20.574	33	.623		
Total	54.064	35			

Table 11.33- Regression coefficients H_{11}

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	1.041	.570		1.826	.078		
inst4	.436	.091	.569	4.808	.000	.907	1.103
inst3	.398	.119	.397	3.359	.002	.907	1.103

12. Appendix D - Behavioral Domains and Behavioral Domains´ Scales Correlation Analysis

Table 12.1– Correlation analysis for the behavioral domain scales (behavioral model´s second level of explanation)

	W	EVR	ECR	SP	RLP	PN	SI	KTC	AN	INST
W	1									
EVR	0.184*	1								
ECR	0.370*	-0.130*	1							
SP	0.764**	0,302	0,147	1						
RLP	0.642**	0,112	0,301	0.633**	1					
PN	0.377*	0,141	0,042	0.346*	0.629**	1				
SI	0.053*	0,251	0,213	0,083	0,324	0.738**	1			
KTC	0.702**	0,022	0.502**	0.547**	0.511**	0.388*	0,211	1		
AN	0.818**	0,038	0.625**	0.632**	0.698**	0.348*	0,155	0.757**	1	
INST	0.167**	0,014	0,196	0.207*	0.463**	0,274	-0,009	0.348**	0.342**	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 12.2- Correlation analysis for the direct measures of the behavioral domains (behavioral model´s third level of explanation)

	W	evr	ecr	sp	rlp	pn	si	ktc	an	inst
W	1									
evr	0,096	1								
ecr	0,214	-.084*	1							
sp	0.649**	0,216	0.390*	1						
rlp	0.473*	0,307	0,181	0.394*	1					
pn	0.279*	.0382*	.0170*	0,321	0.544**	1				
si	0.122*	-0,015	0,199	0,324	0.657**	0.417*	1			
ktc	0.629**	0,126	0.457**	0.499**	0,292	0.366*	0,121	1		
an	0.833**	0,046	0.623**	0.540**	0,311	0,241	0,045	0.726**	1	
inst	0.114**	0.355*	0,086	0.602**	0.497**	0.179**	0,283	0.328**	0.587**	1

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

13. Appendix E – The Thesis Research´s Quantitative Survey Questionnaire

DIRECT MEASURE OF WILLINGNESS		
W1 and W2[125]	According to your perception, what is the likelihood that you company, in the next five years, will develop strategies and promote investments in eco-innovation activities regarding the development and/or the acquisition of cleaner and more sustainable technological solutions that are based on the principles of Green Chemistry and Green Engineering (GCE)?	unlikely-likely
DIRECT MEASURES OF ATTITUDE, PERCEIVED SOCIAL PRESSURE FACTORS AND PERCEIVED BEHAVIORAL CONTROL UPON COMPANIES´ ENGAGEMENT IN GREEN CHEMISTRY AND GREEN ENGINEERING BASES ECO-INNOVATION PROCESSES		
Attitude		
	For our company, and in light of the environmental, social and economic perspective, its engagement in GCE-based eco-innovation processes will produce:	bad consequences -good consequences
A1	Currently: (bad consequences-good consequences)	
A2	In the next five years: (bad consequences-good consequences)	
A3	For our company, its engagement in GCE-based eco-innovation processes will produce locally, nationally and globally:	
Perceived Social Factors Pressures		
PSFP	The degree to which: a) The social pressure arising from the market, from the community, from the regulatory authorities, and from your company´s social and professional commitments and responsibilities, and b) The personal pressure (individuals´ moral obligation) regarding the environment perceived by your company to develop cleaner and more sustainable GCE-based products and processes is:	low-high

[125] As noted in Chapter 8, in order to measure managers´ willingness perception change before and after they went through the entire questionnaire, the question designed to provide a direct measure of companies´ willingness (*W*), to engage in Green Chemistry and Green Engineering based eco-innovation processes, was included two times in the questionnaire as its the first (*W1*) and the last (*W2*) questions. For a more thorough discussion on this issue, refer to Section 8.4.2, in Chapter 8.

Perceived Behavioral Control		
PBC1	For our company, our engagement in GCE-based eco-innovation processes is:	difficult-easy
PBC2	Our company has the required control over the following resources and opportunities: a) Access to knowledge and technologies; b) Trained and skilled human resources; c) Economic and organizational resources; d) Capabilities for establishing strategic alliances and to participate in networks of collaboration, and e) Support from the institutional set that are required for eco-innovating in GCE:	disagree-agree
DIRECT MEASURES OF THE PERCEPTIONS ON THE BEHAVIORAL DOMAIN		
Environmental risk		
EVR1	The environmental risks generated by your company are likely to be:	low-high
EVR2	The importance that is given to the development or adoption of cleaner and more sustainable technologies, such as those that are based on GCE, for our products, processes and services is:	irrelevant-relevant
Economic Risk and Business Opportunities		
ECR1	Economically, for our company, developing cleaner and more sustainable GCE-based solutions for our products and processes implies in:	losses-benefits
ECR2	The business opportunities, currently and in the near future, for companies that are environmentally more sustainable, justify the engagement of our company in GCE-based eco-innovation processes:	disagree-agree
Social Pressure		
SP	In general, the pressures that are exerted on your company by (a) the market, (b) the community, (c) the environmental authorities, (d) by the trade associations, and (e) the sector´s representative organizations that can push your company, in the next five years, to engage in GCE-based eco-innovation processes are:	weak-strong
Professional Roles		
RLP	I perceive that having an innovator and pro-environmental behavior as well as making efforts to influence our company to develop/acquire cleaner and more sustainable GCE-based products and processes is expected from someone that occupies my position in the corporation:	disagree-agree

Personal Norm (moral obligation)		
PN	I am conscious of my personal moral obligation of having a pro-environmental behavior, I incorporate this feeling to my professional activities in order to contribute to overcome our company´s environmental and economic sustainability challenges:	disagree-agree
Self-identity with Innovation, Competence and Environmental Causes		
SI	I consider myself an innovating and competent person who is identified with the environmental preservation causes. Therefore, I believe that my objective engagement in the promotion of eco-innovation activities, in my work environment, is an important part of my obligations as a professional and as a citizen:	disagree-agree
Knowledge and Technology		
KTC	According to your perception, in general, the extent to which your company: a) has access to new knowledge and technological opportunities; b) possesses protection mechanisms against imitation, and c) holds technological, organizational and learning capabilities that can promote and facilitate its engagement in GCE-based eco-innovation processes is:	low-high
Actors and Networks		
AN	In our company, taking into consideration our current availability of individuals holding key technical and motivational capabilities, our competence to form strategic alliances and to participate in techno-scientific networks of collaboration, it can be argued that the engagement of our company in GCE-based eco-innovation processes is:	unlikely-likely
Institutions		
INST	In general, the degree of protection, support, trust and stimulus given to your company, by the current corporate, legal, social, ethical, political and public institutional set, which can make you feel confident to engage in GCE eco-innovation processes is:	low-high

SCALES TO ASSESS THE PERCEPTIONS ON THE BEHAVIORAL DOMAINS

SCALES TO ASSESS ATTITUDES

Scale to Assess the Perceived Environmental Risk

evr1		Controllable	1 2 3 4 5 6 7	Uncontrollable	
evr2		Do not have global impacts	1 2 3 4 5 6 7	have global impacts	
evr3		Consequences not fatal	1 2 3 4 5 6 7	Fatal consequences	
evr4		Evenly distributed	1 2 3 4 5 6 7	Unevenly distributed	
evr5		Low risk to future generations	1 2 3 4 5 6 7	High risk to future generations	
evr6		Voluntary for those exposed	1 2 3 4 5 6 7	Involuntary for those exposed	
evr7		Does not affect me	1 2 3 4 5 6 7	Affects me	
evr8		Not observable	1 2 3 4 5 6 7	Observable	
evr9		Known for those exposed	1 2 3 4 5 6 7	Unknown for those exposed	
evr10		Delayed effects	1 2 3 4 5 6 7	Immediate effects	
evr11		Old risks	1 2 3 4 5 6 7	New risks	
evr12		Risks known to science	1 2 3 4 5 6 7	Risks unknown to science	

Scale to Assess the Perceived Economic Risk and Business Opportunities

Please, answer the questions or statements below in light of your perception regarding the likely economic risks and business opportunities associated with the introduction (development and/or acquisition) of cleaner and more sustainable technologies that are based on the principles of Green Chemistry and Green Engineering (GCE) for your products, processes and services.

	Economic opportunity	
ecr1	The likelihood of loss of business opportunities due to failing to launch a new product to a new market niche for more sustainable products is:	low-high
ecr2	The benefits of reducing uncertainties and economic risks from future environmental legislation are probably:	low-high
ecr3	For our company, the advantages (e.g. novelty of products) of pioneering the launch of cleaner products are likely to be:	low-high
ecr4	We believe that it will be risky to launch a new and more sustainable product currently and in the near future.	agree-disagree
ecr5	Our company is rather a follower than a pioneer regarding the development and the adoption of the development or the adoption GCE.	agree-disagree
ecr6	The willingness of our customers to pay more for products that are environmentally more sustainable is:	low-high

ecr7	The business opportunities growth that may be created following the development of cleaner and more sustainable GCE-based products are likely:	low-high
	Appropriability	
ecr8	The opportunities for our company to sustain its growth and its development via the development or the adoption of GCE-based technologies are:	low-high
ecr9	The likelihood of the appropriation of the benefits generated by the development of cleaner and more sustainable products and processes are:	low-high
ecr10	In innovation processes, the risks of losing the confidentiality over your companies´ technology secrecy due to subcontracting is:	high-low
ecr11	The likelihood of your company losing control over its own technology secrecy and appropriability due to its participation in strategic alliances is:	high-low
	Technological risk	
ecr12	The intensity of R&D required to create new product or to develop a new production process that are cleaner and more sustainable, such as those that are based on GCE, is probably:	high-low
ecr13	The costs associated with this level of R&D is:	high-low
ecr14	The likelihood that you company can bear the costs associated with GCE-based eco-innovation processes is:	low-high
ecr15	The duration of a clean product and process innovation project, such as those that are based in GCE, is likely to last:	long - short time
ecr16	The certainty that a venture developing a GCE-based cleaner and more sustainable product and/or processes concept can be accomplished is:	uncertain-certain
	Financial risk	
ecr17	The likelihood that investments in GCE-based eco-innovation affect the fixed costs of your company and its competitiveness is:	likely-unlikely
ecr18	The likelihood of your company losing trained human resources who hold the required knowledge for the development of more sustainable and cleaner technological solutions for its environmental and economic challenges, due to turnover, is:	likely-unlikely
ecr19	The likelihood of your company having the human, economic and intellectual resources for eco-innovating in GCE is:	low-high
ecr20	If your company were to engage in GCE-based eco-innovation activities, what is the chance that it would lose its capital investment?	high-low
	SCALE TO ASSESS THE PERCEIVED SOCIAL AND PERSONAL PRESSURE	
	Market pressures	
	Competitive context	
mp1	The pace of the technological innovation, in the petrochemical sector, will push our company soon to develop or adopt cleaner and more sustainable GCE-based technologies:	unlikely-likely

mp2	Our competitors intend to develop cleaner and more sustainable products and processes:	unlikely-likely
mp3	The market competition will push us to adopt GCE-based innovative, cleaner and more sustainable solutions for our products, processes and services:	unlikely-likely
mp4	The competition in our sector is fierce. Cleaner and more sustainable products and processes can be a competitive differential for our company:	disagree-agree
mp5	The dynamism of our sector (customers´ behavior and the technological changes) will push us towards the development or the adoption of GCB based innovative and environmentally more sustainable technologies in order to pre-empt the entry rival entries:	disagree-agree
mp6	The market in which our company operates is very heterogeneous and there are demand signs for cleaner and more sustainable products. The introduction of these products in the market, by our company, is a good way of taking advantage of these opportunities:	disagree-agree
	Pioneer-Follower	
mp7	In general our company is a pioneer with regard to advancements in **product** technologies. Therefore, the development of cleaner and more sustainable GCE-based products is not an exception:	disagree-agree
mp8	In general our company is a pioneer with regard to advancements in **process** technologies. Therefore, the development of cleaner and more sustainable GCE-based manufacturing processes is not an exception:	disagree-agree
mp9	In general our company is a follower with regard technological advancements in products and processes. Therefore, the adoption of GCE-based cleaner and more sustainable technologies is not an exception:	disagree-agree

	Consumers	
mp10	Our customers think that our company should develop/adopt cleaner and/or more sustainable products and production processes:	disagree-agree
mp11	Our customers will, in the next five years, be pushing our company to develop/adopt cleaner and more sustainable products and production processes:	unlikely-likely
mp12	In general, our company does what our customers think we should do in respect to environmental issues:	disagree-agree
	Community Pressure	
	Managers´ personal important referents	
	Pease, express the degree to which the following social agents have the opinion that your company should develop/adopt cleaner and more sustainable production processes such as those that are based on Green Chemistry and Green Engineering:	low-high
cp1	Yourself:	
cp2	The majority of those that are important for you in your personal relations:	

	Firms´ important external referents	
	Pease, express the degree to which the following social agents have the opinion that your company should develop/adopt cleaner and more sustainable production processes such as those that are based on Green Chemistry and Green Engineering:	
cp3	Most outsiders who are important for the success of your company:	low-high
cp5	Environmental experts from universities, and research originations who are convinced that that your company should adopt cleaner and more sustainable production processes. Your company agrees with such beliefs:	low-high
cp6	Your company´s environmental experts:	low-high
cp4	The likelihood that most of the important outsiders will, in the next five years, exert pressures that can push your company to engage in GCE-based eco-innovation processes is:	unlikely-likely
cp7	In general, your company does what the environmental consultants think it should do in respect to environmental issues; developing cleaner technologies is not an exception:	disagree-agree
	Perceived community pressure	
cp8	Express the degree to which the local community thinks that your company should develop/adopt cleaner and more sustainable production processes such as those that are based on Green Chemistry and Green Engineering:	low-high
cp9	In general, your company does what local community thinks it should do in respect to environmental issues. Developing cleaner technologies is not an exception:	disagree-agree
cp10	The current pressures form the local community, on your company, towards the development/adoption of cleaner and more sustainable production processes, such as those based on GCE are:	weak-strong
cp11	The likelihood that the local community will, in the next five years, exert pressures that can push your company to engage in GCE-based eco-innovation processes is:	unlikely-likely
cp12	Express the degree to which the NGOs, at local, regional and national levels, think that your company should develop/adopt cleaner and more sustainable production processes such as those that are based on Green Chemistry and Green Engineering:	low-high
	Firms´ important internal referents	
cp13	Express the degree to which the majority of your company´s influential employees thinks that your company should develop/adopt cleaner and more sustainable production processes such as those that are based on Green Chemistry and Green Engineering:	low-high
cp14	The likelihood that the majority of your company´s influential employees will, in the next five years, exert pressures that can push your company to engage in GCE-based eco-innovation processes is:	unlikely-likely
cp15	In general, your company does what company´s influential employees think it should do in respect to environmental issues. Developing cleaner technologies is not an exception:	disagree-agree

Regulatory Pressures		
	Regulators	
rp1	The environmental authorities think that our company should develop/adopt cleaner and more sustainable products and processes such as those that are based on GCE:	disagree-agree
rp2	The likelihood that current and future environmental legislation will, in the next five years, exert pressures that can push your company to engage in GCE-based eco-innovation processes is:	unlikely-likely
rp3	The environmental authorities have the necessary legal means and capabilities to force our company to develop/adopt new cleaner and more sustainable products and production processes:	disagree-agree
rp4	In general, your company does what the environmental authorities think it should do in respect to environmental issues. Developing cleaner technologies is not an exception:	disagree-agree

	National and international standards, trade organizations and agreements	
	The likelihood that the following factors will, in the next five years, exert pressures that can push your company to engage in GCE-based eco-innovation processes is: Note: ABIQUIM- Brazilian Chemical Industry Association ICCA- The International Council of Chemical Associations ISO- International Organization for Standardization	
rp5	The market demands for initiatives associated with socio-economic and environmental sustainability of the petrochemical industry (e.g. ISO 14000 and 26000 series norms, ICCA/ABIQUIM Responsible Care Program, ICCA´s Global Product Initiative):	unlikely-likely
rp7	New agreements and programs, developed at national and international levels, with focus on the environmental and economic sustainability of the petrochemical industry, which have direct influence on the company´s business and operations:	unlikely-likely
rp6	In general, your company does what the standardization organizations and the chemical industry representative organizations, nationally and internationally (such as ISO, ICCA, ABIQUIM), think it should do in respect to environmental issues. Developing/adopting cleaner technologies is not an exception:	disagree-agree

	SCALE TO ASSESS THE PERCEIVED PROFESSIONAL ROLES	
rlp1	In my perception, I believe that someone that occupies the same position that I currently do, in any company, should hold the following requisites that are intrinsically associated with my roles, obligations and professional roles:	disagree-agree
rlp2	To be environmentally responsible and to have a favorable posture regarding cleaner and environmentally more sustainable products, processes and services such as those that are developed based on GCE:	
rlp3	To advocate and to have a favorable behavior regarding pro-environmental issues (technological or not) as a means to profit from business opportunities that emerge from a market that has been increasingly demanding towards a cleaner environment:	
rlp4	To give priority to issues concerning cost, effectiveness, efficiency, company´s business competitiveness, economic and environmental sustainability and search for innovative GCE-based solutions that can meet these criteria:	
	To acknowledge the importance and the influence that the values and the culture have on in individuals´ behavior and make efforts to help in building a corporate culture and values that prioritize innovation and sustainability:	

	SCALE TO ASSESS THE PERCEIVED PROFESSIONAL PERSONAL (MORAL OBLIGATION) PRESSURES	
	The moral obligation that I feel regarding the reduction or the prevention of the environmental impacts to the biosphere that are a result of the activities of our company, makes me feel the following moral obligation:	not responsible-responsible
pn1	Regarding being favorable to decisions that favor pro-environmental behaviors and the adoption of GCE-based eco-innovative technologies:	
pn2	Regarding my own active engagement in influencing people, in all company´s hierarchical levels, regarding the importance of pro-environmental actions and behaviors as well as in respect to the adoption of eco-innovative GCE-based cleaner and more sustainable technologies:	
pn3	Regarding my personal engagement in the identification of new cleaner and more sustainable innovative alternatives, such as those that are based on GCE, that can help our company to achieve advanced states of competitiveness and environmental and economic sustainability:	
	SCALE TO ASSESS THE PERCEIVED SELF-IDENTITY WITH ENVIRONMENTAL CAUSES, INNOVATION AND PROFESSIONAL COMPETENCE	
si1	I identify myself with and I believe in the importance of the environmental preservation of our planet. Therefore, I am favorable to the idea of adopting cleaner and more sustainable solutions, such as those that are based on GCE, for products, processes and services in the industrial domain:	disagree-agree
si2	In addition, my engagement in eco-innovation activities, such as those that are based on GCE, expresses my innovating and professionally competent profile:	disagree-agree

SCALE TO ASSESS THE PERCEIVED BEHAVIOR CONTROL		
SCALES TO ASSESS THE PERCEIVED BEHAVIOR CONTROL OVER KNOWLEDGE AND TECHNOLOGIES		
	Accessibility to Knowledge	
	Currently, the degree of access that your company has regarding new knowledge, via purchase, cooperation agreements and other means of knowledge acquisition that can promote advances towards advanced states of sustainability and competiveness is:	low-high
ak1	Within the petrochemical sector:	
ak2	Outside the petrochemical sector:	
	Currently, the degree of access that your company has to the following sources of knowledge that can help its engagement in GCE-based eco-innovation processes is:	low-high
ak3	Public research organizations:	
ak4	Brazilian and foreign universities:	
ak5	Professional or technical organizations:	
ak6	Independent inventors:	
ak7	Technology providers:	
	Technological Opportunities	
to1	Currently, the scientific and technological advances in the fields of cleaner and more sustainable products and processes can incentivize our company to engage in GCE-based eco-innovation processes:	disagree-agree
to2	To what degree the various product and process technologies, current available, within and outside the petrochemical, sector can contribute and facilitate the engagement of your company in GCE eco-innovation processes?	low-high
to3	According to your perception, to what degree the products and processes technological and environmental feedbacks that your company gets from other firms can contribute for the acquisition or development of GCE-based eco-innovative solutions?	low-high
	Appropriability	
	According to your perception, regarding the appropriation of the benefits generated by the eco-innovation processes, such as those that are based on GCE, what is the degree of motivation of your company to:	low-high
app1	To invest in the acquisition of lower cost knowledge and technologies, which have easy general access and, therefore, providing low appropriability:	
app2	To invest in the development or acquisition of limited access higher costs technologies, which provide high	

app3	appropriability: To invest in both of the preceding options depending on the context and the objective of the company:	low-high
	According to your perception, the current available means that can ensure the appropriability (confidentiality and benefits) of knowledge and technologies resulting from eco-innovation processes are:	low-high
app4	Outside the corporation´s domain and at the national and international levels;	
app5	Within the corporate´s domain in order to prevent information "leaks":	
	Cumulativeness - Learning Processes	
	In your opinion, regarding the engagement of your company in GCE-based eco-innovation activities, how easy or difficult is it for your company the acquisition of new knowledge via the following learning processes?	
cmt1	Learning processes that are external to your company (e.g. external consultancy, technical assistance, international training, systematic knowledge import from various sources):	easy-difficult
cmt2	Learning processes that are internal to your company (e.g. routine activities that span from process operations through research activities):	easy-difficult
	What is the degree of existence, efficiency and effectiveness, in your company, of the following learning mechanisms that can be useful in the GCE-based eco-innovation processes?	
cmt3	Formal and informal learning mechanisms that promote the interaction of individuals and promote mutual learning and facilitate the creation of innovative solutions for the company´s environmental challenges:	low-high
cmt4	Mechanisms that can convert knowledge held at the individual level into formal language that can be diffused to all company´s sectors and hierarchical levels:	low-high
cmt5	The learning mechanisms that your company currently holds that can promote the integration of the learning processes and knowledge acquisition (knowledge internalization and externalization) at personal and collective levels are:	unsatisfactory-satisfactory
	Cumulativeness - Intermediate technological innovation capabilities (search based)	
	In case your company promoted technological changes via the **acquisition** of cleaner and more sustainable new eco-innovative technologies, the degree of difficulty that it may find in obtaining the following capabilities (within the company´s domain, or outside via outsourcing) is:	difficult-easy
cmt6	Search for new technological sources, contract negotiation, and bargaining suitable terms:	
cmt7	Equipment procurement, detailed engineering, recruitment and training of skilled people:	

cmt8	Equipment stretching, process adaptation and cost saving, and licensing new **process** technology:	
cmt9	Product quality improvement, licensing and assimilating new imported **product** technology:	
cmt10	Monitoring productivity, and project coordination:	
cmt11	Technology transfer, coordinated design, science and technology links:	
	Cumulativeness - Advanced technological innovation capabilities (research based)	
	In case your company follows the trajectory of **developing** new eco-innovative technologies, the degree of difficulty that it may find in obtaining the following capabilities (within the company´s domain, or outside via outsourcing or partnerships) is:	difficult-easy
cmt12		
cmt13	Development of new production systems:	
cmt14	Basic process design and related research and development:	
cmt15	In-house **process** innovation and basic research:	
cmt16	In-house **product** innovation and basic research:	
cmt17	Collaboration with suppliers and partners for technological development:	
	Turnkey capability, cooperative research and development:	
	Cumulativeness - Knowledge Integration	
	In your company, the degree of existence, efficiency and effectiveness of the following mechanisms of knowledge acquisition integration and application is:	low-high
cmt18	Rules and directives (set of procedures, heuristics and instructions):	
cmt19	Operational routines (operational protocols, process specifications, norms):	
cmt20	Self-management teams (for complex and non-routine organizational tasks especially when the degree of uncertainty and novelty preclude the use of the existing routines and directives):	
	Cumulativeness - The correspondence of the capabilities/knowledge structure with the power structure of the company	
cmt21	To what extent the hierarchical and functional structures of your company hold the required capabilities for knowledge integration and application for the GCE-based technological development of the firm?	low-high
	SCALES TO ASSESS THE PERCEIVED BEHAVIOR CONTROL OVER ACTORS AND NETWORKS	
	Availability of Internal Actors Holding Key Capabilities	
avc1	Our company´s staff has individuals who can speak various professional languages and can see the world in two or more different professional perspectives:	disagree-agree
avc2	Our company´s staff has individuals who hold critical knowledge that can help our firm to successfully engage in the acquisition and/or the development of GCE-based cleaner and more sustainable technologies:	disagree-agree

avc3	Our company´s staff has individuals who hold the required skills for collecting new information about cleaner and more sustainable products, processes and services and including them in the company´s decision-making nuclei:	disagree-agree
avc4-	Our company´s staff has individuals who have the power of influencing decision-makers favorably in regard to technological changes as well as in respect to the company´s engagement in GCE-based eco-innovation processes:	disagree-agree
avc5	Our company´s staff has individuals who are committed with our environmental and sustainability policies and with development and dissemination of cultures that support cleaner production, sustainability and eco-innovation processes such as those that are related to GCE:	disagree-agree
	Actors and networks -Strategic Alliances with External Actors	
	Strategic synergy	
	For our company, finding partners for the formation of strategic alliances, aimed at GCE-based eco-innovation, who:	difficult-easy
sac1	Can ensure strengths complementarity and interaction in respect to knowhow and innovation capabilities, is:	
sac2	Can ensure trust, honesty, commitment regarding the professional relations, good reputation, predictability under pressure and creativity facing adversity, is:	
sac3	Have a good operational fit for both partners (i.e. time frame for investments, information and communication methods, management stiles, labor relations, technologies and business and government relations), is	
sac4	Can provide capital in favorable conditions as well as support for our investments in GCE-based eco-innovation activities, is:	
	Support and Commitment	
sac5	In the processes of negotiating strategic alliances reaching a point that maximizes gains and value for both partners in a win/win fashion is:	difficult-easy
sac6	Finding partners that share the same environmental values and interest in GCE-based technological development:	difficult-easy
sac7	The likelihood of approval, support and commitment from your company´s CEO and shareholders regarding the firm´s engagement in GCE-based eco-innovation processes is:	unlikely-likely
sac8	Our company has successful experiences making strategic alliances in order to innovate. Making new alliances to develop new cleaner and more sustainable GCE-based products and processes would be the same:	disagree-agree
	Cooperation - influence	
	What is the degree of influence that company has over the following suppliers for the development of GCE-based technological solutions?	
sac9	Suppliers of **inputs**, **components**, **raw materials** and **services** to develop cleaner substitutes for current environmentally sensitive critical parts of our **product portfolio** with cleaner options:	low-high
sac10	Suppliers of **production process technologies** to develop cleaner substitutes for current environmentally sensitive critical parts of our **process technologies** portfolio with cleaner options:	low-high

sac11	For our company, influencing our customers to promote joint investments for the development of new cleaner and more sustainable GCE-based products, processes and services is:	difficult-easy
	Outsourcing opportunities	
	For our company, outsourcing the following tasks is:	difficult-easy
sac12	Life cycle analysis:	
sac13	Cleaner and more sustainable GCE-based **product** technologies such as cleaner design for inputs, materials and components from the technological marketplace:	
sac14	Cleaner and more sustainable GCE-based **production process** technologies for inputs, materials and components from the technological marketplace:	
	Networks of Collaboration	
	The degree of difficulty that your company finds in participating of techno-scientific networks of collaboration, aimed at the development/acquisition of new knowledge and GCE-based technologies, with the following organizations is:	difficult-easy
nw1	Public research and development laboratories:	
nw2	Providers of raw materials and other inputs:	
nw3	Consultancy organizations holding specific techno-scientific knowledge that can support the development of GCE-based solutions for your products and processes	
nw4	Companies within the petrochemical sector, which are open to technology transfer:	
nw5	Specialized engineering firms holding specific techno-scientific knowledge that can support the development of GCE-based solutions for your products and processes:	
	SCALES TO ASSESS THE PERCEIVED BEHAVIOR CONTROL OVER INSTITUTIONS	
inst1	Our corporate´s internal institutions provide the required support, protection and flexibility for our engagement in GCE-based eco-innovation processes:	disagree-agree
inst2	The extent to which the current the Brazilian and the international legal institutional sets provide your company with protection and risk reduction in the case of the establishment alliances and agreements, with other actors, towards the development/acquisition of GCE-based technologies is:	low-high
inst3	The extent to which the current social and ethical institutions, commonly found in the business relations, generate the required confidence for your company´s engagement in GCE-based eco-innovation processes is:	low-high
inst4	The extent to which current political and public institutions (laws, decrees, programs, policies etc.), at the Federal, State and Municipal levels, provide your company, currently and in the next five years, with incentives for its engagement in GCE-based eco-innovation processes is:	low-high

14. Appendix F - Protocols of the In-Depth Interviews (Qualitative Survey)

Protocol for the In-depth Interviews at the Micro-Level within the Companies

	Questions
1	Perceptions on the importance of sustainable development and sustainability for the petrochemical sector.
2	Once the principles and the benefits of Green Chemistry and Green Engineering (GCE) are well-known, understood and properly diffused to important managers and decision-makers (you included) within your company, in your perception, what is the likelihood that your company would undertake initiatives to acquire and/or develop GCE based technological solutions towards more sustainable products, processes and services?
3	Please answer the following questions with respect to this thesis research results that have been presented to you: a. To what extent do you agree with the findings? b. To what extent do you believe that they are important and will be beneficial and contribute to clarifying and improving your company's knowledge in respect to eco-innovation determinants? Do you believe that such knowledge can help to promote and facilitate to effect the eco-innovation based technological changes towards more sustainable states in your company's domain?
4	To what extent do you believe that policy efforts (corporate, sectoral and governmental) based on the findings of this thesis research can contribute to the introduction, diffusion and incentivizing GCE based eco-innovation in your company and in the Brazilian petrochemical sector?
5	How important do you believe that ABIQUIM and its "Responsible Care Program" are in the process of disseminating, supporting and fostering the use of the GCE frameworks by the Brazilian Petrochemical sector?
6	Previous, current and envisioned sustainability initiatives: a) What are your company's past, current and planned initiatives (policies, programs, business strategies, investments, directives, standards etc.) to effect the required technological changes that are required to make it more sustainable and environmentally responsible? b) What kinds of changes (organizational, personal, learning processes, knowledge base, institutional etc.) have been required for your company to introduce, implement and manage these initiatives?
7	I will now show my recommendations for eco-innovation policies. I would like ask you please to make comments on them and point out the points that, in your opinion, are missing.
8	Based on your previous answer, please review the twelve principles of Green Chemistry and the twelve principles of Green Engineering and specify which have been used as part of the initiatives that you mentioned in your answer to question 5.

Protocol for the In-Depth Interviews at the Meso-Level within the State Environmental Agencies

	Questions
1	In your view, what initiatives have been conducted by your Environmental Agency aimed at influencing, promoting and catalyzing changes towards cleaner and more sustainable technological states in the petrochemical sector? What are the plans for the future?
2	The findings of this research revealed that the Environmental Agency's activities and the risk of future legislation are significant driving forces in fostering companies´ willingness to engage in eco-innovation activities towards higher states of sustainability. What is your opinion in respect to these findings? What are your reasons for answering in this way?
3	In the domain of cooperation with the petrochemical companies, and without violating their self-determination, do you believe that the Environmental Agencies should or could promote more effective cooperative actions regarding the search for solutions that could help companies to make more rapid progress toward sustainability? What are your reasons for answering in this way?
4	The choice, adoption and implementation, by the petrochemical companies, of more sustainable practices are their responsibility. In your opinion, in what ways can/should your Environmental Agency influence and pressure companies to adopt more sustainable approaches regarding their products, processes and services? What are your reasons for answering in this way?
5	With regard to implementing the Green Chemistry and Green Engineering (GCE) frameworks, in your opinion, what is the likelihood that you and/or your Environmental Agency are willing to support and to promote such initiatives? Are you ready to engage in activities aimed at influencing companies to adopt and use them as their priority principles in the process of meeting their environmental challenges? What can/will you and your Environmental Agency do? What are your reasons for answering in this way
6	In your opinion, do you see any possibility and willingness, of your Environmental Agency, to promote joint initiatives in cooperation with ABIQUIM and other industry representative associations, to promote GCE in the Brazilian petrochemical sector? What are your reasons for answering in this way?

Protocol for the In-Depth Interviews at the Meso-Level within the Brazilian Chemical Industry Association (ABIQUIM)

	Questions
1	Could you please explain, in more details, what ABIQUIM is doing to influence and catalyze the companies, in the petrochemical sector, to adopt technical and non-technical initiatives that will help to ensure that they develop and implement cleaner and more sustainable products, processes and services? What is it planning to do in the near future?
2	In light of the research's findings, do you believe that they can be useful and contribute for helping companies to engage in eco-innovation processes towards more advanced states of sustainability? What else do you believe should be done? Who should catalyze those actions? How should they catalyze them? What are your reasons for answering in this way?
3	At the sector level, can they contribute to ABIQUIM´S initiatives (policies, programs etc.) towards a more sustainable Brazilian petrochemical industry? If so, how can these initiatives be promoted and implemented? What are your reasons for answering in this way?
4	With regard to promoting and implementing the Green Chemistry and Green Engineering (GCE) frameworks in the petrochemical sector, in your opinion, what is the likelihood that you and/or ABIQUIM will be willing to support and to promote such initiatives? Are you ready to engage in activities aimed at influencing companies to adopt and use them as baseline principles in the process of meeting their sustainability challenges? What can/will you and ABIQUIM do? How useful can the Responsible Care Program be in this process? What else is needed from the government, universities, or other stakeholders? What are your reasons for answering in this way?
5	In your opinion, do you see any possibility and willingness for ABIQUIM, to promote joint initiatives in cooperation with environmental agencies and other governmental and non-governmental organizations, to promote GCE in the Brazilian petrochemical sector? If so, under what circumstances? How do you propose to proceed? What else is needed? What are your reasons for answering in this way?
6	Do you believe that the findings of this research and the frameworks of Green Chemistry can be helpful and can contribute to the innovation and sustainability-related objectives of the National Pact for the Chemical Industry? In your view, how can it be done? What are your reasons for answering in this way?

15. Appendix G - Profile and Specificities of the Survey Respondents

Figure 15.1- *Hierarchical level of respondents*

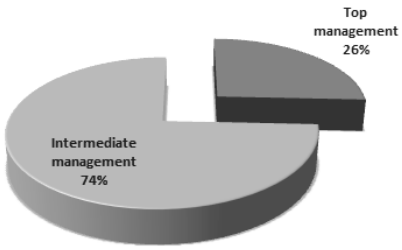


Figure 15.2- *Respondents´ main activity*

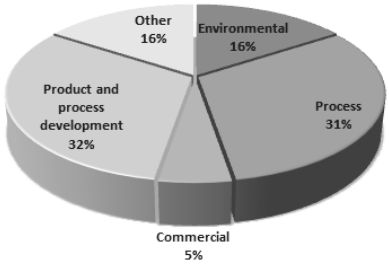


Figure 15.3- *Class of petrochemicals manufactured by the surveyed companies*

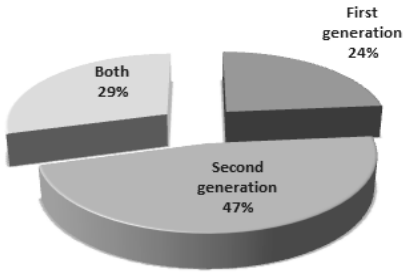


Figure 15.4- *Location of the surveyed company*

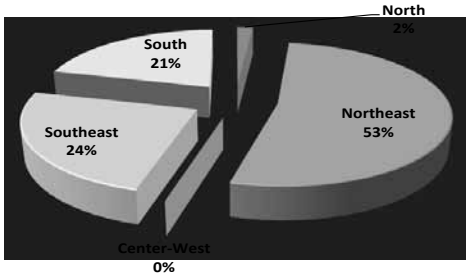


Figure 15.5- *Global dimension of the surveyed companies*

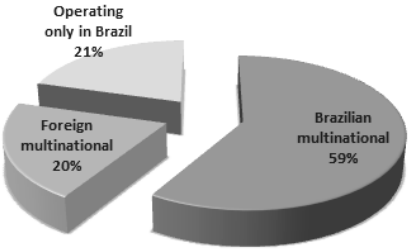


Figure 15.6 - *Surveyed companies´ exports as a percentage of the total production*

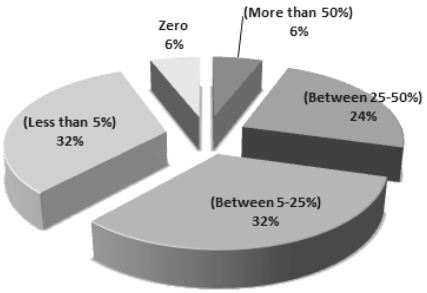


Figure 15.7- *Surveyed companies´ export markets*

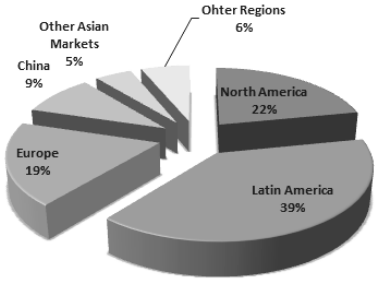


Figure 15.8- *Surveyed companies´ sources of product innovation*

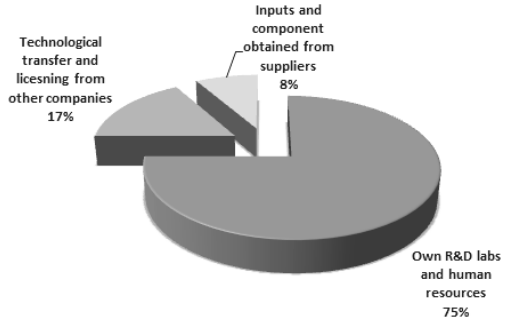


Figure 15.9- *Surveyed Companies´ Sources of Process Innovation*

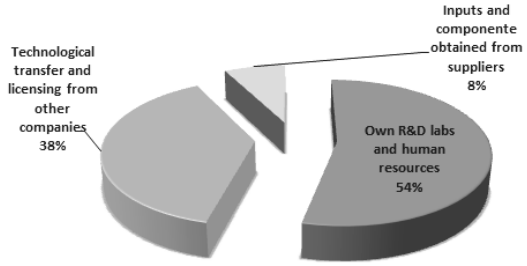
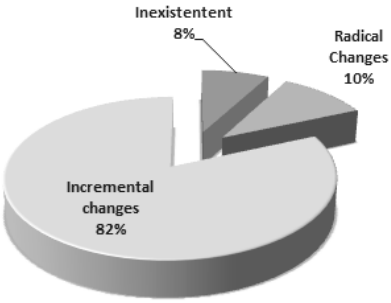


Figure 15.10- *Surveyed companies´ focus of products/processes innovation*



16. Appendix H - Considerations of Innovation Processes: Economic Competitiveness, Evolutionary Perspectives, Structure of Technical Change, the Systemic Nature of Innovation, Eco-Innovation

H.1 The Importance of Innovation in Economic Competitiveness, and the Economic Environment

The three main dimensions (environmental, social and economic) of sustainability (S) and sustainable development (SD) concepts were repeatedly mentioned throughout this thesis and, following the common understanding of their use, they were used and adapted to the specific contexts and needs of this research.

As noted in the previous sections, the main interest of this thesis research resides on behavioral aspects of GCE-based technological eco-innovation. It acknowledged that the three dimensions of S and SD are interconnected, interdependent, and complementary and are implicitly important for this study. Despite this argumentation, due to the nature and objectives of this research, corporate environmental and economic sustainability, assume a higher relevance. It was assumed that social benefits to firms' stakeholders and to the broad society are intrinsically associated with higher states of the other two dimensions of S and SD.

Because the prospect of economic feasibility is a basic pre-condition for the development and the diffusion of technologies, it is appropriate to emphasize that the industrial domain has no interest in innovative cleaner and more sustainable technological solutions that are not economically feasible (cf. Section 8.4.1).

Section H.1 demonstrated the importance of innovation in companies´ competitiveness and established the foundations for a better understanding of the relations between the environment and the economy. Such relations were implicitly and explicitly exposed in this work.

Enterprises in modern economies operate in a rapidly changing social, economic and technological environment. The way corporations respond to these challenges, demands and expectations may signify their potential success or failure to be competitive and to survive. Adaptation and anticipation to pressures generated by the streams of continuously changing societal and business environments may require novel and unprecedented solutions.

Patterns of organizational and individual behavior and problem solving methodologies that were successful in the past do not represent a paved way to successfully navigate and solve present and future challenges (North, 1997; Nelson and Nelson, 2002). Companies' leaders need to change their perceptions of the nature and *locus* of their problems and challenges and develop new and creative manners to provide the adequate solutions. Companies need to be innovative.

Innovating has often been connected to the idea of bringing something new to an environment[126]. Innovative ideas give the sense of problem solving and expectations fulfillment *via* unprecedented new creative manners. In the economic and innovation literature domains, since the pioneering works by Schumpeter, the concepts of innovation and technological advance have been intimately connected to the economic competitiveness and growth. It has been equally associated with social changes of countries and organizations (Arora *et al*., 1998; Dosi, 1982; Cantwell; 2005; Nelson and Winter, 1977 and 1982; Mytelka, 2001; OECD and EUROSTAT, 2005; OECD, 2008a).

> "Today, much confusion exists about the proper definition of entrepreneurship. (…) At the heart of that activity is innovation: the effort to create purposeful, focused change in an enterprise's economic or social potential" (Drucker, 2002: 2-3).

The innovating firm "in the attempt to differentiate itself from competitors in its industry (…) seeks to transform the technological and market conditions" (Lazonick, 2005: 31). Innovating is also a matter of being competitive by changing in unprecedented ways that promote differentiation from the competitors.

According to Arora *et al.* (1998), economic competitiveness has been traditionally associated with productivity and growth[127], which permeate the economic spectrum spanning from macro to microeconomic aspects. Fagerberg (2005) argued that innovation is a powerful explanatory factor underpinning the differences between firms, regions and countries. He also emphasized that innovative countries and regions have higher productivity than less innovative ones.

Macroeconomic main elements for growth policy are related to the creation of a stable climate for savings, investment, for demand growth and to the development of a climate for improving labor productivity by assuring a broad level of education and establishing and enforcing anti-trust laws to prevent the emergence of monopolistic forces (Arora *et al.*, 2000).

Arora *et al*. (*ibid*) further stated that the microeconomic aspects deal with the growth and productivity (and development) at the firm level. Its focus is on how new technologies are developed, commercialized and diffused. This approach incorporates "the processes of design and innovations, learning by doing, using technology transfer from abroad, and the incentives from research and development. All of which can produce new and improved products, processes and services" (*ibid*: 12)

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[126] Websters online dictionary (http://www.websters-online-dictionary.org/definition/innovate) accessed in November 2009.

[127] In this thesis research, complementary to the use of the concept of productivity and growth as elements of economic competitiveness, the concept of economic development as advocated by Herman Daly and Kenneth Townsend is also used: "To grow means to increase naturally in size by the addition of material through assimilation or accretion. To develop means to expand or realize the potentialities of; to bring gradually to a fuller, greater, or better state." (Daly and Townsend 1993: 267).

Due to the dynamic interrelationships and interconnectivity of the economic agents, the macroeconomic and microeconomic approaches to productivity, growth and development are linked and are complementary concepts. "Firms create the growth and the wealth in the capitalist society, but governments and societies create the business climate, the conditions, and the boundaries, within which firms must act" (*ibid*: 13.).

The macro and microeconomic approaches exemplify the amplitude and the interconnectivity of relationships involved in the process of creation of wealth, growth and development in societies. Competitiveness, growth, economic change and innovative processes are characterized by complex relationships among multilevel economic agents and by diverse scientific disciplines as is elaborated upon in Chapter 5, Section 5.2.2.

H.2.0 An Evolutionary Perspective of Innovation and its Relation to Technological and Economic Change

As noted in the introductory section of Chapter 3 (Section 3.0), innovation theory appears among the main theoretical domains that supported this research. Within this realm, the systemic nature of innovation is of significant importance. In this regard, the "Sectoral Systems of Innovation" framework (SSI), developed by Malerba (2002, 2004), due to its focus on sectors, matched this thesis researcher's interests, and consequently, it was used as one of the theoretical pillars of this study. The SSI framework approaches innovation in sectors in a systemic and evolutionary[128] manner.

In order to allow for a better understanding of the fundamentals underpinning this thesis´ innovation related theoretical background, Section H.2 discusses some aspects of evolutionary (neo-Schumpeterian[129]) approach and its relations to technological change and innovation.

According to Nelson and Winter (1982), technical progress is considered to have an intimate relation with a variety of economic phenomena such as productivity growth, competition among firms and patterns in international trade of manufactured goods.

The relation between technological change and economic growth and the understanding of their emergence and dynamics has been the object of numerous studies in the economic and political spheres. In this regard, another relevant stream of studies has been how the processes

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[128] "The broader connotations of "evolutionary" include a concern with processes of long-term and progressive change. The regularities observable in present reality are interpreted not as a solution to a static problem, but as the result that understandable dynamic processes have produced from known or plausibly conjectured conditions in the past – and also as features of the stage from which a quite different future will emerge by those same dynamic processes" (Nelson and Winter, 1982: 10).
"The core concern of evolutionary theory is with the dynamic processes by which firm behavior patterns and market outcomes are jointly determined over time". (*ibid*: 18). The evolutionary theory of economic change involves the evolution of capabilities and behavior of business firms in a market environment (*ibid*).

[129] The Neo-Schumpeterian Economics is "the branch of economic literature which deals with dynamic processes causing qualitative transformation of economies basically driven by the introduction of novelties in their various and multifaceted forms. By its very nature, innovation and, in particular, technological innovation is the most explicit and most visible form of novelty. However, Neo-Schumpeterian Economics should be concerned with all facets of open and uncertain developments in socio-economic systems". (Hanusch and Pyka, 2007: 275).

of innovation, imitation and competition influence the industrial performance and industrial structures (Dosi, 1988). These studies produced two dominant economic approaches: the neoclassical and the evolutionary. Despite disagreements on their behavioral foundations, both acknowledge the importance of innovation and technology for economic growth (Verspagen, 2005).

H.2.1 Evolutionary Principles Underpinning innovation and Technological Change

As discussions on and exploration of economic theory and technicalities are beyond the purposes of this research and due the fact that the innovation research line and approaches followed herein were fully based on the evolutionary theory of economic change, the aspects and features of the neoclassical theory related to growth and change were not considered.

Many authors have contributed to put innovation, technological change and growth into an evolutionary perspective (cf. Dosi, 1988a). Richard Nelson and Sidney Winter made a fundamental and extremely valuable contribution to innovation studies in the evolutionary domain and in the firm's realm.

Their seminal work, "An Evolutionary Theory of Economic Growth", published in 1982, on industrial dynamics, knowledge-based firms, organizational memory, entrepreneurial and routinized technological regimes, "has produced extensive and valuable empirical work on how to measure and to determine what factors drive the development of 'general' innovations in firms" (Díaz Lopez, 2008: 24).

Nelson and Winter (1982: 22) argued that "the treatment of innovation within the evolutionary model provide a better basis for modeling economic growth fueled by technical advance than does the neoclassical model amended by the introduction of variables that represent technical change". In the evolutionary theory perspective, Nelson and Nelson (2002: 269) emphasized the need for economic growth "to be understood as the result of the progressive introduction of new technologies, which were associated with increasingly higher levels of worker productivity and the ability to produce new or improved goods and services".

The central idea underpinning the term "evolutionary theory", and its basic principles, borrowed from the scientific field of biology, projects the idea of a *simile* made between the natural biological selection processes with "natural economic selection".

> "Market environments provide a definition of success for business firms, and that definition is very closely related to their ability to survive and grow. Supporting our analytical emphasis on this sort of evolution by natural selection is a view of the 'organizational genetics' – the processes by which traits of organizations, including those traits underlying the ability to produce outputs and make profits, are transmitted through time" (Nelson and Winter 1982: 9).

It can be argued that the successfulness of an output, in an economic system, is directly and intimately connected to its ability to adapt to the circumstances, needs and demands. Over time, the economic system produces a variety of novel outputs. Variety is then reduced by

selection processes influenced by "economic forces" as well as by institutional and social factors (Dosi, 1982 and Geels, 2004). The better adapted and the more fit innovations survive.

According to Verspagen (2005), evolution is the outcome of the constant interaction between variety and selection. Nelson (1995) emphasized that the dynamics of the opposing forces of variety creation, replication and selection, explain the extent of firm heterogeneity. In this dynamics, innovation functions as an important source of novelty generation and the selection mechanisms are largely based upon the economic and social institutions in modern economies (Geels, 2004).

A key idea behind the evolutionary concept of economic and technological change are partly based on the bounded rationality of individuals (economic agents) who are unable to maximize profits due to their incapacity to perceive all opportunities generated by the technological possibilities (Verspagen, 2005). Additionally, decision-makers operate under uncertainty in a changing and complex environment. For decision-making, they rely on simple and adaptive decision rules, which, evolved and accumulated from past experiences and can be changed overtime if changes prove to be successful and to be appropriately adapted to the changing environment. These concepts are assumed to be of great importance when studying the behavioral aspects of innovation.

The decision-making rules and routines represent the accumulated knowledge of the organization that has been developed *via* learning processes. They incorporate the organizations' skills, capabilities, culture and belief systems, and are transmitted through time. In Nelson and Winter's (1982) words, these processes constitute the "organizational genetics" or the "organizational memory". Organizational routines are part of a larger institutional environment. The institutional context can act as a facilitator or as an impediment to technological change (Verspagen, 2005).

The "organizational genetics" of the firm have direct influence on the types and the quality of the interactions between technology, economy (economic agents) and institutions[130], which provide the elements and dynamics required for economic and technological change to take place (Fagerberg, 2005 and Malerba, 2005). Moreover, the neo-Schumpeterian concept of economic and technological change indicates that knowledge, learning, technology, innovation and interaction are the major features and influencers of competitiveness and growth in globalizing and knowledge-based economies (Christ, 2007).

H.2.2 Evolutionary Economic and Technology Change: a Theory Based on Many Research Traditions

Although most visible analogies related to the economic evolutionary theory are the ones borrowed from biology, according to Saviotti and Metcalfe (1991) the conceptual foundations

[130] Many meanings are attributed to the concept of institutions in the broad economic and environmental literature. In the present research, for coherence with its objectives and its theoretical background, institutions are considered to be "a set of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups, and organizations. They are the rules of the game". (Edquist, 2005: 182).

of the evolutionary approach stems from five research traditions. It is appropriate to review them as their principles are valuable for a good understanding of the rationale behind the issues concerning innovation that are addressed in this thesis.

The first tradition has its origins in the work of economists such as Veblen, Marshall and Schumpeter who, according to Saviotti and Metcalfe (1991), were eminently evolutionary. "With evolution, Schumpeter meant qualitative, economic change brought about through innovation" (Fagerberg, 2002: 11).

> "The changes in the economic process brought about by innovation, together with all their effects, and the response to them by the economic system, we shall designate by the term Economic Evolution" (Schumpeter, 1939; vol. I: 86)

The second tradition stems from biological research. Its long evolutionary tradition with a more complete conceptual structure provides the grounds from which the evolutionary metaphor "acts as a powerful force of suggestion and of questions to be posed in the economic sphere. It was therefore, quite important to see what similarities and differences there are between the conceptual foundations of an evolutionary approach in economics and in biology." (Saviotti and Metcalfe, 1991: 2)

The third tradition relates to modern developments in chemistry and physics especially from non-equilibrium thermodynamics from which the concepts of chaotic and irreversible behavior derive, indicating the possibility of strongly path-dependent phenomena. "From this it follows that history matters and that the accumulation of 'small' random events can fundamentally shape behavior and options of future choice" (*ibid*: 3).

The fourth research tradition is the theory of complex systems, which gives an important contribution to the studies of the systemic nature of innovation. "(…) understanding the evolution and development of complex adaptive systems thus involves understanding how cooperation, coalitions and networks of interaction emerge from individual behaviors and feedback to influence those behaviors" (Levin, 2002: 3).

The fifth contribution to the evolutionary approach to economics, according to Saviotti and Metcalfe (1991), is the theory of firms and organizations from which the behavioral theories of the firm, the transaction cost analysis and the analyses of technological changes were developed.

These five research traditions *per se* represent a vast array of cross-disciplinary elements of innovation and technological change.

H.3.0 The Structure of Technical Change: Technological Paradigms, Trajectories and Regimes

Technology undoubtedly occupies a central position in societies and it is believed to be a central tool to respond to the challenge of sustainability (Montalvo Corral, 2002). Even though technological changes alone may not be considered sufficient for achieving higher states of sustainability (Kemp, 1994), and may be considered secondary to institutional changes (Kemp

and Rotmans, 2005), "it is necessary to discuss how technology evolves and intertwines with the logic of industrial organizations" (Montalvo-Corral, 2002: 17).

Technology and technical changes have been the object of numerous studies of historians, economists and sociologists who attempted to conceptualize its ordering and structure (Kemp, 1994; Verspagen, 2005). According to Dosi (1982: 151) technology is defined as:

> "(…) a set of pieces of knowledge, both directly 'practical' (related to concrete problems and devices) and 'theoretical' (but practically applicable although not necessarily already applied), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment."

This definition suggests that technology is a result of cumulative, evolutionary learning processes. Dosi (*ibid*) further illustrates that technology holds two intrinsic conceptual parts. The first is expressed by the "embodied" part of technology. It is represented by the achievements in the development of a technology and in a defined problem-solving activity that is embodied in physical devices. The second part of technology, the "disembodied" part, "consists of particular expertise, experience of past attempts and past technological solutions, together with the knowledge and the achievements of the 'state of the art'" (*ibid*: 152).

Although the foregoing paragraphs shed a light on the nature of technology, they do not clarify much about the structure of its development. According to Dosi (Montalvo-Corral, 2002 *apud* Dosi, 1988b), at the core of any technological development is a "technological paradigm". "A technological paradigm embodies strong prescriptions on the directions of technical change to pursue and those to neglect." (Dosi, 1982: 152).

According to Dosi (1988b: 225) a technological paradigm is:

> "(…) a pattern for the solution of selected techno-economic problems based on highly selected principles derived from the natural sciences. Therefore, it defines contextually the needs that are to be fulfilled, the scientific principles to be used for the tasks, and the material technology to be used. A technological paradigm is both a set of exemplars, basic artifacts, which are to be developed and improved and a set of heuristics. Where do we go from here? On what sort of knowledge should we draw?"

It can be argued that evolutionary mechanisms support and explain the development and survival of the technological paradigms in the socio-economic realm. Technological paradigms are part of Dosi's "disembodied" conception of technology. They result from complex interactions of socio-economic agents, undergo a selection process by socio-economic forces and may become dominant for a long time. In this sense, the domination of a paradigm over others, sometimes better, competing technological possibilities lead to path dependence and technological "lock-in"[131] that, according to Arthur (1989), would be

[131] Lock-in means that a particular technology or product is dominant, not because its inherent cost is low or performance is good, but because it enjoys the benefits of increasing returns to scale (source http://en.wikipedia.org/wiki/Lock-in_(decision-making)), accessed in February, 2013)

supported by learning effects and increasing returns to scale[132], thus limiting the number of possible directions technological development may take.

The nature of the technological paradigms defines a multi-variable space within which the problem solving activities occur. "Once a path has been selected and established, it shows a momentum of its own, which contributes to define the directions toward which the 'problem solving activity moves'" (Dosi, 1982: 153). That means that the paradigm, although establishing the technological limits, it allows for degrees of freedom, within its multidimensional space, for choices that conduct the evolution of technologies in selected directions termed, "technological trajectories".

"A technological trajectory is a cluster of possible technological directions whose outer boundaries are defined by the nature of the paradigm itself" (*ibid*: 154). It represents a path of improvement taken by a given technology based on the perceptions, of technology agents, of a vast array of "opportunities, and the market and other evaluation mechanisms that determined what kinds of improvement would be profitable" (Dosi and Nelson, 1994: 161).

H.3.1 Technological Regimes: the Multidimensional Character of Technological Change

As aforementioned, technology is commonly believed to be one of the most central elements to respond to the challenges of sustainability. Under the perception that technologies are made by humans guided by new ideas, a new outlook and a new set of assumptions, technological changes may be secondary to institutional changes (Kemp and Rotmans, 2005).

The environmental debate clarified and enhanced the value and the importance of innovation and the institutional contexts in the dynamics of technological change. This emergence evolved as the importance of technological innovation in reconciling economic development with ecological sustainability, as conceptualized by the ecological modernization theory[133], demanded meso-level explanations and proposed that the focus should be placed on the co-evolution of technical and institutional innovations (Berkhout, 2002). This provided a multidimensional character to the structure and mechanisms of technological change.

This spirit was captured by the concept of the "technological regime". This concept, proposed by Nelson and Winter (1982), relies on cognitive aspects, defines the limits for technological progress and it "is related to the technicians' beliefs about what is feasible or at least what is worth trying" (Nelson and Winter, 1982: 258). Georghiou *et al.* (1986: 32) stated that:

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132 Returns to scale: in economics, the quantitative change in output of a firm or industry resulting from a proportionate increase. Source: Encyclopedia Britannica at:
http://global.britannica.com/EBchecked/topic/500194/returns-to-scale, accessed in May 2013).

133 Ecological Modernization Theory is a social theory for understanding and explaining how and to what extent industrial production is transformed in a more ecologically sound direction. (Mol, 1995).
According to the theory, environmental productivity, i.e. productive use of natural resources and environmental media (air, water, soil, ecosystems), can be a source of future growth and development in the same way as labor productivity and capital productivity. This includes increases in energy and resource efficiency as well as product and process innovations such as environmental management and sustainable supply chain management, clean technologies, benign substitution of hazardous substances, and product design for environment.
(source: http://en.wikipedia.org/wiki/Ecological_modernization), accessed in March, 2013.

> "(…) a technological regime is "a set of design parameters, which embody the principles that will generate both the physical configuration of the product and process and materials from which it is to be constructed. The basic design parameters are the heart of the technological regime, and they constitute a framework of knowledge which is shared by the firms in the industry".

The concept of technological regime provides a description of the technological environment in which firms operate (Nelson and Winter, 1982).

As a technological regime evolves and survives the socio-economic and institutional selection processes, it becomes dominant and the reference of the techno-economic system.

A technological regime involves of a variety of technological paradigms and technological trajectories. This can be illustrated by the aircraft industry (Nelson and Winter, 1977) in which the manufacturing of its artifacts "require many different knowledge bases, different types of engineering skills, linkages with information networks and interactions with different supply industries." (Kemp, 1994 *apud*: Georghiou *et al.,* 1986: 34).

Technological regimes are composed of stable assemblages of technical artifacts, organized in co-evolving market and regulatory frameworks (Berkhout, 2002). Dosi and Nelson (1994) define technological regime as ample interconnections of economic agents and institutional frame interacting along specific trajectories. According to them, the "technological regime" is:

> "(…) the complex of firms, professional disciplines and societies, university training and research programs, and legal and regulatory structures that support and constrain development within a regime and along particular trajectories." (Dosi and Nelson, 1994: 161).

On the other hand, Breschi *et al.*, (2000) argued that the development of a "technical regime" and its preponderance in the techno-economic domain are related to a particular combination of four fundamental factors: (a) technological opportunities, (b) appropriability[134] of innovations, (c) cumulativeness of technological advances, and (d) properties of the knowledge base.

"A technological regime defines the modal properties of learning processes, sources of knowledge and nature of knowledge bases that are associated with the innovation processes of firms active in distinct sets of production activities" (Marsili, 2002: 218, *apud* Dosi, 1982).

Because the nature, rate and direction of change in technological regimes differ from change in discrete technological artifacts, there has been an increasing interest and emphasis on technological regimes (Berkhout, 2002).

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[134] Appropriability: (a) a term used in microeconomics that refers to "the ability of a social initiative to extract or capture value" (Husted and Allen, 2011: 91), (b) "appropriability of innovations summarizes the possibilities of protecting innovations from imitation and of reaping profits from innovative activities (Malerba, 2002: 252), (c) (*economics*) the environmental factors that govern an innovator's ability to capture profits generated by an innovation (http://www.allwords.com/word-appropriability.html). Accessed in January, 2011.

The concepts of technological paradigms, trajectories, and regimes exposed two fundamental characteristics of the structure of technological change. The first revealed its multidimensional, multidisciplinary, systemic and complex character. The second shows that technological change can be supported and guided by evolutionary processes whereby, the development and cumulativeness of knowledge and the behavioral and learning processes play a pivotal role.

H.4.0 The Systemic Nature of Innovation

In the previous sections, innovation and technological changes were presented in light of their evolutionary characteristics. The concluding paragraph of Section H.3.1 synthesized the foregoing discussions by highlighting two characteristics of technological change that call attention to its multidimensional, multidisciplinary, systemic, complex and evolutionary character.

Innovations are not produced unexpectedly. Firms deliberately innovate through complex dynamic processes that involve a series of relationships between interrelated and interdependent agents and environmental and socio-economic variables (individuals and organizations) (Edquist, 2005). Section H.4 takes a closer look into these characteristics end explores the systemic nature of innovation.

At this point, this researcher emphasizes that, although the systemic nature of the innovation processes provided important theoretical elements for this thesis research, this study does not include the dynamics (dynamics of innovation) underpinning the formation and the functioning of the innovation systems.

The interests of this thesis author focused upon the motivational factors that represent incentives or disincentives for such processes to take place. It can be argued that they could be called pre-innovation behavioral elements.

More specifically, the main objective was to identify and assess important factors (determinants) that can contribute to promote firms intention (willingness) to deliberately engage, or not, in innovation processes (cf. Chapter 5). According to Ajzen (1988 and 1991), intention is the immediate determinant of an action (behavior). In this research, companies´ willingness to engage in eco-innovation activities was considered a pre-condition and a precursory stage of actual engagement processes.

In this thesis, as a result of the chosen behavioral theoretical approach ("The Theory of Planned Behavior") (cf. Section 3.2), firms´ engagement was related to pressures exerted by the firm´s internal and external factors on companies´ managers and decision-makers beliefs and perceptions. Many of these potential determinants were provided by the building blocks of the "Sectoral Systems of Innovation" (SSI) (cf. Section 3.1) framework, which were developed under the tenets that support the systemic nature of innovation.

H.4.1 Systems of Innovation Seen from a Complex and an Evolutionary Perspectives

The systems of innovation (SI) concept emerged in the 1980s and had its first appearances in the works developed by Christopher Freeman, Bengt-Åke Lundvall and Giovanni Dosi.[135]. According to Lundvall (2007), the concept was developed as "an alternative analytical framework to standard economics and was used to criticize its neglect of dynamic processes related to innovation and learning when analyzing economic growth and economic development" (Lundvall, 2007: 96).

The concept was initially developed for the analysis of economic and innovation processes at the national level. It was further adopted as a theoretical base for the analyses at different levels of aggregation (boundaries of the system) that "can be supranational, national or sub-national; at the same time there may be sectoral dimensions within any of these geographical demarcations" (Edquist, 2005: 199) in a mutual complementary character. Systems of innovation can also assume the character of a technological system when it is delimited by specific technological fields or product areas. In this case it occupies the same category as the sectoral systems of innovation (Johnson *et al.*, 2003).

The idea of innovation, as a systemic process, was developed upon observations that companies almost never innovate in isolation (Edquist, 1997 and 2005; Fagerberg, 2005). They interact with other economic agents (firm and non-firm) in multiple ways. Putting it in a simple way, Lundvall (2007) stated that in the process of innovative economic and technological change, these interactions between elements are as important as the elements themselves and that the whole is more than the sum of the parts.

> "The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socioeconomic structures which determine the rate and direction of innovation and competence building emanating from processes of science based and experience based learning." (Lundvall *et al.*, 2009: 7)

The formulation of the systemic approach to innovation processes can be interpreted as an application of theoretical foundations of the "Advanced Systems" [136] formulations. Such systems apply nonlinear dynamic systems theory (complex systems) to social phenomena (Deneke, 1998).

Deneke (*ibid*: 106) further argued that these "Advanced Systems" involve the following types of elements:

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[135] For a brief historic view of the emergence and background of the concept of systems of innovation refer to Freeman (1995) and Lundvall (2007).

[136] An advanced system is a term invoked by Deneke (1998) to represent a variety of applications of nonlinear dynamical systems theory to social phenomena and to distinguish these from conventional systems.

- "Techniques, which explore how patterns of order arise out of disequilibrium ('self-organization'[137] and 'dissipative structures'[138]);
- Methods that account for nonlinear dynamics (including 'chaotic attractors') through which small changes can produce dramatic results;
- Ecological representations of human behavior ('systemic' and 'synergistic' as well as individualistic), and
- Indices, which represent 'novelty' and 'creativity', as well as learning and adaptation."

This corroborates Lundvall's (2007: 101) argument that the innovation process "may be seen as an intricate interplay between micro and macro phenomena where macro-structures, condition micro-dynamics and vice versa new macro-structures are shaped by micro-processes". He further stated that, from this perspective, systems need to be seen as complex and as being characterized by processes of co-evolution and self-organization. In complex systems, the system's properties emerge as a product of the interaction of their constituent parts, feedback mechanisms, and are different from the properties of the individual parts.

Edquist (2005) emphasized the usefulness of relating the SI approach to the "general systems theory". He also quoted Ingelstam (2002) to define the main characteristics of a system which are synthetically described:

- A system is comprised of two kinds of constituents: its components and the relations among them;
- The system has a function; it performs or achieves something;
- It must be possible to discriminate a system from the rest of the world.

Additionally, by incorporating the evolutionary heritage of the processes of technological change and innovation, the SI concept provides a systems-oriented perspective that introduces the sense of evolution and complex dynamics to innovation processes. These processes include the predominance of feedback mechanisms, and the interactive relations involving scientific and social elements.

This constitutes a much different approach than the linear-oriented innovation models used in the past when industrial innovation processes were perceived as a linear progression from

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[137] "Self-organization is a process where some form of global order or coordination arises out of the local interactions between the components of an initially disordered system. This process is spontaneous: it is not directed or controlled by any agent or subsystem inside or outside of the system; however, the laws followed by the process and its initial conditions may have been chosen or caused by an agent. It is often triggered by random fluctuations that are amplified by positive feedback. The resulting organization is wholly decentralized or distributed over all the components of the system. As such it is typically very robust and able to survive and self-repair substantial damage or perturbations."
Source: http://en.wikipedia.org/wiki/Self-organization. Accessed in April 2012.

[138] "A dissipative structure is a dissipative system that has a dynamical regime that is in some sense in a reproducible steady state. This reproducible steady state may be reached by natural evolution of the system, by artifice, or by a combination of these two. A dissipative structure is characterized by the spontaneous appearance of symmetry breaking and the formation of complex, sometimes chaotic, structures where interacting particles exhibit long-range correlations. Source: http://en.wikipedia.org/wiki/Dissipative_system. Accessed in April 2011.

basic research to the placement of products in the market domain (Edquist, 1997 and Berkhout *et al.*, 2007).

H.4.2 Important Features of the Systems of Innovation

As noted in Section H.4.1, firms almost never innovate in isolation. In the complex process of innovation, they interact with other firms and non-firms organizations for the creation of new solutions of economic significance. These processes allow for the creation of innovations that have direct relation to the emergence and diffusion of knowledge elements (Edquist, 1997). These relations between organizations are regulated by institutions, which are increasingly seen by evolutionary economists to "mold the technologies used by a society and by technological change itself" (Nelson and Nelson, 2002).

Lundvall (2007) presented what he considered the main constituents of the systems of innovation. He highlighted that the economic structure of production (organizations) and the institutional setup are the two dimensions of the systems of innovation and placed knowledge as the most important resource and learning as the most important process.

Lundvall's argument that the economic structure of production, institutions, knowledge and learning are the most important components of the systems of innovation, fully embraces the evolutionary theory and institutional analyses.

On the evolutionary side, the theory puts knowledge, learning and routines at a central place. Routines are the "organizational genetics" and are important elements for the creation and diffusion of knowledge and are a result of learning processes (Nelson and Winter, 1982).

According to Nelson and Sampat (2001) routines encompass two different aspects. The first aspect is called "physical" technologies. "Physical" technologies are related to the division of labor and to aspects associated with specialization of the agents (individuals and organizations) involved in the process. The term is related to what is normally considered "technology". The second, called "social" technologies, correspond to institutions in the sense that they are predicated by the field of institutional economics[139]. They are the set of factors that mold and define human interactions, both within and among organizations (Nelson and Nelson, 2002).

Organizations are formal structures that are consciously created and have an explicit purpose. They are the players or the actors (Edquist and Johnson, 1977 *apud* Edquist, 2005). It is important to call attention that, at least for the purposes of this thesis research, organizations are made by and are comprised of individuals, which are ultimately responsible for organizational behavior.

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[139] Institutional economics focuses on understanding the role of the evolutionary process and the role of institutions in shaping economic behavior. Source: http://en.wikipedia.org/wiki/Institutional_economics accessed in December, 2011

Another important feature concerning the systems of innovation that is very useful in the analysis and the comprehension of these systems, in terms of their relevant organizations (actors), institutions, behavior and dynamics interactions, is how its borders can be defined.

According to Lundvall (2007), systems of innovation can be defined in two steps: the core and the wider setting of the system. "It is possible to define the core with reference to innovation theory and empirical research. The question about what parts of the economy need to be included in the wider setting has much to do with the purpose of the analysis and with *ex ante* insights about causalities and interdependencies in the system" (*ibid*: 102).

He further stated that to "visualize these two 'levels' one can locate a core and place a wider setting around it. The core of the innovation system is thus, the firms in interaction with other firms and with the knowledge infrastructure" (*ibid*: 102).

The theoretical exploration and exploitation of the systemic nature of innovation provides an appropriate structure for knowledge to be created, to evolve and to be diffused within and across its boundaries. Learning processes are facilitated and enriched by dynamic relationships of agents, which are interconnected, are submitted to feedback processes and whose capabilities and competences are complementary.

The development of the concept of systems of innovation, due to its flexibility and openness, establishes the theoretical framework for different forms of specialized efforts in the field of innovation research and on the learning economy (Lundvall, 2007). It can be exemplified by the concept of sectoral innovation systems.

H.5.0 Environmental Innovation Systems (Eco-Innovation)

It is widely accepted by academic and economic circles that innovation is one of the main driving factors for the promotion of technical change and represents a powerful engine for economic development, competitiveness and societal wealth creation (cf. section H.1). Despite the importance of the environment in the economy (cf. Chapter 3), "most research in this tradition was concentrated on economic consequences of innovation and has seldom taken environmental considerations into account" (Weber and Hemmelskamp, 2005: 1).

One ought not to forget that the economy is supported by and is inextricably inter-dependent upon natural resources (cf. Chapter 3) and that detaching the environment from the focus of economic and innovation analysis will result in economic and social "suicide" in the long-term.

According to Weber and Hemmelskamp (*ibid*), it is essential that innovation advances must go beyond the technological domains. It should also address the environmental, social, psychological and other qualitative outcomes. These challenges must also include system level changes along the production-consumption chain, its flows, its multi-level architecture, its institutions and structures, and the behavior of actors involved in it.

> "Innovation systems that are required to generate environmental system innovation require new policies and governance approaches operating at and

coordinating between different levels and realms of policy-making". (Weber and Hemmelskamp, 2005: 1)

That is precisely the main concern of this section. Here, the intention is to explore the underpinning concepts and foundations of the domain of the environmentally induced technological innovation processes. That is, environmentally induced innovation studies that in addition to focusing upon the environment, they also relate to changes in technology, institutions and behavior of the market actors (Berkhout, 2005).

It is important to emphasize that eco-innovation, at its basic level, differs from "normal innovation" [140] in the sense that it proposes profound changes in the: (a) the ways of life, (b) the way products are manufactured, and (c) the logic behind services. The concept of eco-innovation carries the challenge for a radical remodeling of societies' relations with the environment.

It can be argued that, even though sharing the same theoretical and conceptual origin, eco-innovation processes differ from "normal innovations". Such differences are based upon the fact that, while both have fundamental concerns for business competitiveness, eco-innovation focus on sustainable development´s demands for broad structural changes in society (OECD, 2009). Additionally, two more characteristics of eco-innovation make it different:

- "It is not an open-ended process as it represents innovation which explicitly emphasizes the reduction of environmental impacts, whether intended of not;
- Eco-innovation is not limited to innovation in products, processes, marketing methods and organizational methods, but also includes changes in social and institutional structures". (OECD, 2009 *apud* Rennings, 2000)

Section H.5 represented a shift from the foregoing innovation related sections to the realm of eco-innovation. The ideas and conceptual fundamentals, herein discussed, can be exemplified by the concept of "Environmental Innovation Systems" (EIS) (cf. Weber and Hemmelskamp, 2005).

By merging the innovation and environmental (sustainability) streams of research, EIS concepts were designed "to provide a theoretical and conceptual foundation for a better understanding of the role of framework conditions for innovations towards sustainability and in particular the possibilities of inducing systems innovation by means of policy" (*ibid*: 2),

The EIS approach combines elements of innovation research, environmental economics and policy analysis to develop a new and applied perspective of environmental innovation characterized by the following five characteristics:

- "Functional changes with a jump in eco-efficiency[141];

[140] "Normal" innovations are developed for normal market reasons of reducing costs or for providing better services to users" (Merit *et al.* 2007: 5).

[141] As defined by the WBCSD: Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and

- A combination of technological, organizational and institutional innovations;
- The involvement of a multitude of actors;
- The existence of new, guiding principles and sets of goals, and
- Long-term changes at micro and meso levels". (*ibid*: 1)

H.6.0 Defining Eco-innovation

Since its first appearance in 1996, in the book "Driving Eco-Innovation: A Breakthrough Discipline for Innovation and Sustainability", by Claude Fussler and Peter James, the term and the concept of eco-innovation have sparked an ongoing academic debate on its meaning and nature (Díaz López, 2008). Scholars across the globe have proposed a multitude of definitions reflecting their own personal visions and understanding. Those definitions contain varying degrees of similarities and differences. MERIT *et al.* (2008a) highlighted that those definitions are fundamentally based on motivational and on performance aspects. Díaz López (*ibid*) and Carrillo-Hermosilla *et al.* (2008) reviewed an interesting array of such definitions.

According to Díaz López (*ibid*), his analysis of the definitions of eco-innovation showed that, because eco-innovations are different from the conventional notion of innovation, different authors have recognized the need for providing an operational definition of environmental innovation.

He also observed that the assessment of such definitions indicated that the use of knowledge constitutes a core element in the eco-innovation domain. Although knowledge occupies a central position in the development of innovations, it assumes different characteristics in the eco-innovation processes as compared to "normal innovations". Its focus on environmental problems (and their specific solution patterns) and the inclusion of companies' organizational and managerial aspects associated with markets and the broad societal demands and behavior, calls for the use and the development of specific and trans-disciplinary knowledge and competencies along the value chain (Kemp *et al.*, 2004) as illustrated in Figure 16.1

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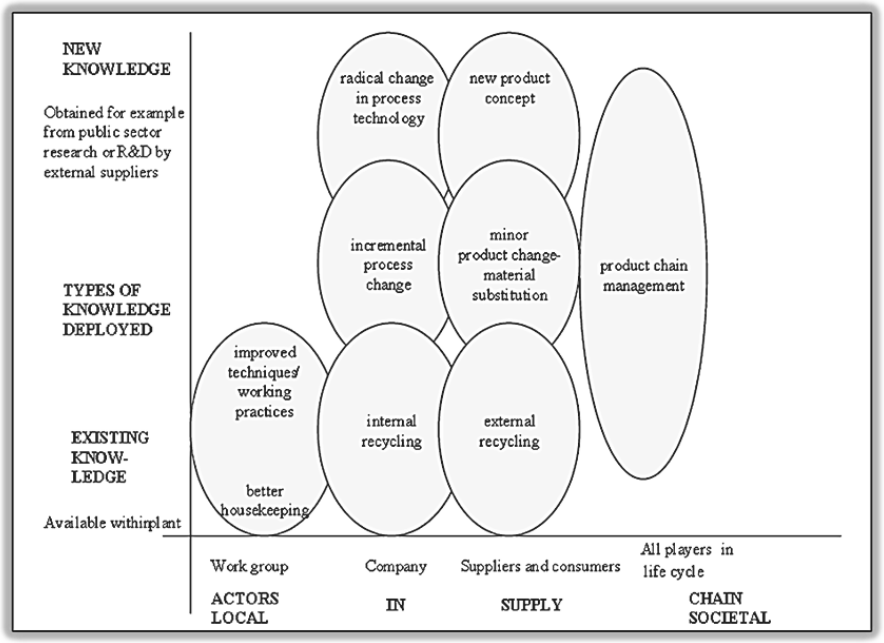
resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. In short, it is concerned with creating more value with less impact (World Business Council for Sustainable Development (2000), *Eco-efficiency: creating more value with less impact).* Eco-efficiency is a management philosophy to guide and to measure companies and other actor's development in environmental performance. Eco-efficiency combines environmental gains with economic gains (Kemp *et al.*, 2004)

Figure 16.1- The relations of knowledge and actors in eco-innovation processes along the production chain



Source*: Kemp et al., 2004 apud Clayton, Anthony, Graham, Spinardi and Robin Williams (1999), Policies for Cleaner Technology: A New Agenda for Government and Industry. Earthscan Publications Ltd., London, p.273*

In the vast universe of definitions of eco-innovation in the literature, two appear (cf. Table 16.1) to be consistent with what has been discussed in this section. In fact, both have the same inspirational origins in the OECD Oslo Manual (OECD and EUROSTAT, 2005) and are in line with "MEI Project"[142] (MERIT *et al.*, 2008b) standpoint that eco-innovation operational definitions should be based on environmental performance because it is essential to know whether there are positive environmental effects related to its production and use. "Past studies of eco-innovation have focused on environmentally *motivated* innovations, overlooking the environmental gains from 'normal' innovations" (MERIT *et al.*, 2008b: 5).

[142] MEI is a project for the European Commission funded by DG Research. MEI stands for Measuring Eco-Innovation. Specifically, MEI offered a conceptual clarification of eco-innovation (developing a typology) based on an understanding of innovation dynamics. It identified and discussed the main methodological challenges in developing indicators and statistics on eco-innovation and how these may be overcome. Source: http://www.merit.unu.edu/MEI/. Accessed in January, 2010.

OECD Coutries (Source Wikipedia.com)

Table 16.1- Operational eco-innovation definitions that underpin this thesis research

Eco-innovation Definition	Author	Background
"The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"	Merit *et al.*, (2008)	- OECD Oslo Manual (2005) - MEI Project about Measuring Eco-Innovation, Final Report Under the EU's 6th Framework Programme
"The creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives"	OECD, (2009)	- Oslo Manual (2005) - METI (2007) - Reid and Miedzinski (2008) - MERIT *et al.* (2008)

Source: Author. Adapted from MERIT (2008a) and OEDC (2009)

In line with Arundel and Kemp (2009), some important points emerged from these definitions: (a) the inclusion of implementation[143] of eco-innovations developed by a different firm (b) explicit emphasis on product life cycle and on (c) institutional innovations.

Another important point is the prominence that was given to the concept of novelty. MERIT *et al.* (2008a: 6) emphasized that "while there should be an element of novelty, the novelty does not have to be a novelty new to the world but may also exist in something being novel to a firm. This distinction between innovations that are 'new to the market' and those that are 'new to the firm' is important for assessing the diffusion of innovations".

One point that is important to be highlighted is that, in practice, business and the academic world are still struggling to come up with a universally agreed upon operational definition of eco-innovation. In this regard, the fact that the definitions stated in Table 16.1) are partially based on the OECD´s Oslo Manual (OECD and EUROSTAT, 2005) may help in facilitating a broader acceptance of and agreement with their ideas and concepts as the manual is the guidebook for the official innovation surveys of almost all OECD countries.

[143] Combined invention, innovation and implementation constitute what is called the innovation process that should also be applicable to eco-innovation (OECD, 2009)

H.6.1 Typological Aspects of Eco-Innovation

Taxonomic structuring of concepts and data related to any field of study essential for achieving a better understanding of the related processes, their organization, the measuring of its properties and characteristics to carry out comparative studies and to support the process of theory development. “One plausible reason for the popularity of typologies is that they appear to provide a parsimonious framework for describing complex organizational forms and for explaining outcomes such as organizational effectiveness or groupthink” (Doty and Glick, 1994: 230).

In technological innovation studies, classification schemes help in providing explanations “that have implications for our understanding of the sources and directions of technical change, firms’ diversification behavior, the dynamic relationship between technology and industrial structure, and the formation of technological skills and advantages at the level of the firm, the region and the country” (Pavitt, 1984: 343).

Eco-innovation is a new approach and is unique in some sense. Different attempts have been made to construct a classification system for eco-innovations (Arundel and Kemp, 2009). In the case of eco-innovation definitions, scholars and practitioners have not come up with a commonly agreed upon classification. Table 16.3 through Table 16.6 show some examples of eco-innovation classification schemes excerpted from recent works in the mainstream eco-innovation literature (Andersen, M. M., 2006; MERIT *et al.*, 2008a and 2008b; Carrillo-Hermosilla *et al.* 2009 and OECD, 2009).

They present some important points drawn from innovation and environmental studies, which are noteworthy. One is the fact that, although authors clarify their own perceptions on the subject, they mostly share the same concepts underpinning eco-innovation. This suggests that even if there might be some divergences in perceptions, these authors support the main theories and approaches underpinning them. Secondly, corroborating with Arundel and Kemp (2009), eco-innovation, from a wider system point of view, are classified as being sustaining or disruptive (incremental and radical). The third point is related to the extensive incorporation of organizational and institutional innovation in the different classification systems. Fourthly, this thesis author’s perception of eco-innovation at the system level and along life cycles calls attention to the inclusion of the concept of boundaries of the innovation system and to the time- frame domain(s).

Another interesting classification scheme is the one proposed by MERIT *et al.* (2008b). They regard the way innovative firms can be classified based on “how each firm innovates (by developing innovations for other firms or by adopting innovations developed elsewhere in a strategic or passive way)” (*ibid*: 8). The classification is composed by four mutually exclusive categories, which are presented in Table 16.2.

Table 16.2- Classification of eco-innovating firms according to the Mei Project

Innovative Firm Class	Characteristics
Strategic eco-innovators	Active in eco equipment and services sectors, develop eco-innovations for sale to other firms
Strategic eco-adopters	Intentionally implement eco-innovations, either developed in-house, acquired from other firms, or both
Passive eco-innovators	Process, organizational, product innovations etc. that result in environmental benefits, but where there is no specific strategy to ecoinnovate.
Non eco-innovators	No activities for either intentional or unintended innovations with environmental benefits.

Source: author - adapted from MERIT *et al*. (2008b)

Table 16.3- Classification of eco-innovation according to Carrillo-Hermosilla, Gonzalez and Konnola

Author	Dimensions/Categories	Types	Characteristics
Javier Carrillo-Hermosilla, Pablo del Rio Gonzalez and Totti Konnola	Design	Component addition	Development of additional component to improve environmental quality.
		Sub-system change	Improvement of the sub-system to reduce negative impacts on the environment.
		System change	Re-design of systems to be compatible with eco-systems.
	User	Development	Innovation is initiated and/or developed by users
		Acceptance	Changes in user behavior, practices and processes for the application of the innovation.
	Product service dimension	Change in product service deliverable	Changes in the product service delivered and changes in the perception of the customer relations.
		Change in the value-chain process and relations	Changes in the value-chain process and relations that enables the delivery of the product service.
	Governance	Governance	Refers to all new and applied institutional and organizational solutions for resolving conflicts over environmental resources both in the public and private sectors.

Source: Carrillo-Hermosilla *et al*. (2009).

Table 16.4- Classification of eco-innovation according to the MEI project

Author	Dimensions/Categories	Types	Characteristics
MEI (MEI Project about Measuring Eco-Innovation under the EU's 6th Framework Programme)	Environmental technologies	Pollution control technologies	Includes waste water treatment technologies
		Cleaning technologies	Treat pollution released into the environment
		Cleaner process technologies	New manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives
		Waste management equipment	
		Environmental monitoring and instrumentation	
		Green energy technologies	
		Water supply	
		Noise and vibration control	
	Organizational innovation for the environment	Pollution prevention schemes	
		Environmental management and auditing system	Formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste.
		Chain management	Cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave).
	Product and service innovation offering environmental benefits	New or environmentally improved products (goods)	Includes eco-houses and buildings
		Green financial products	Such as eco-lease or climate mortgages
		Environmental services	Solid and hazardous waste management, water and waste water management, environmental consulting, testing and engineering, other testing and analytical services.
		Services that are less pollution and resource intensive	
	Green system innovation	Alternative systems of production and consumption	Are more environmentally benign than existing systems.

Source: author - adapted from MERIT *et al*. (2008a)

Table 16.5- Classification of eco-innovation according to the Organization for Economic Co-operation and Development (OECD)

Author	Dimensions/Categories	Types	Characteristics
Organisation for Economic Co-operation and Development (OECD)	Target (refers to the basic focus of eco-innovation)	Products	Involving goods and services.
		Processes	Production methods of procedures etc.
		Marketing methods	Referring to the promotion and pricing of products and other market-oriented strategies.
		Organizations	Such as the structure of management and the distribution of responsibilities.
		Institutions	Which include the broader societal area beyond a single organization's control, such as institutional arrangements, social norms and cultural values
	Mechanism (relates to the method by which the change in the eco-innovation target takes place or is introduced. It is also associated with the underlying nature of the eco-innovation – whether the change is of a technological or non-technological character)	Modification	Such as small, progressive product and process adjustments.
		Re-design	Referring to significant changes in existing products, processes, organizational structures, etc.
		Alternatives	Such as the introduction of goods and services that can fulfill the same functional need and operate as substitutes for other products.
		Creation	The design and introduction of entirely new products, processes, procedures, organizations and institutions.
	Impact (refers to the eco-innovation's effect on the environment, across its lifecycle or some other focus areas)		Potential environmental impacts stem from the eco-innovation's target and mechanism and their interplay with its socio-technical surroundings. Given a specific target, the potential magnitude of the environmental benefit tends to depend on the eco-innovation's mechanism, as more systemic changes, such as alternatives and creation, generally embody higher potential benefits than modification and re-design.

Source: author - adapted from OECD (2009)

Table 16.6- Eco-innovation classification according to Maj Munch Andersen

Author	Dimensions/Categories	Types	Characteristics
Maj Munch Andersen	Add-on innovations	Pollution- and resource handling technologies and services.	These are products (artifacts or services) that improve the environmental performance of the customer. The product in itself need not be environmentally friendly.
	Integrated innovations	Cleaner technological processes and cleaner products.	These are innovations, which contribute to the solutions of environmental problems within the company or other organizations (public institutions, families..), in this sense they are integrated. They are the solutions which contribute to changing production and consumption practices in organizations, most importantly in companies.
	Eco-efficient technological system innovations	New technological paths.	These are innovations that represent a technological discontinuity. They are not cleaner than similar products but rather offer very different solutions (a new technological trajectory) to existing solutions. These radical innovations have wide systematic effects; they built on new theories, competencies and practices and may demand a change of both production and consumption patterns.
	Eco-efficient organizational system innovations	New organizational structures.	These innovations entail new concepts for an eco-efficient way of organizing society. This means new ways of organizing our production and consumption at the system level, with new functional interplays between organizations, e.g. between companies ("industrial symbiosis"), between families and workplaces etc. ("Urban ecology").
	General purpose eco-efficient innovations		Changes in the general purpose technologies that will have major effect on eco-innovations. Special attention should therefore be given to developments within these.

Source: author - adapted from Andersen (2006)

At the closure of this Section on eco-innovation, it is this thesis author's belief that the review of the mainstream recent literature, on its definitions and classification schemes, suggests that its principles and supporting theoretical background appear to be consolidated and accepted by academic and practitioner's communities. The literature analysis has also revealed that even though there are a few differences in the categories of eco-innovations, the literature consulted for this review demonstrated that authors mostly agree with the principles behind the eco-innovation research field. This makes a strong point and develops the required confidence for their utilization within this research.

H.7.0 Theoretical Aspects of Eco- Innovative Behavior

As stated previously, innovation theory and its behavioral aspects are important theoretical pillars that support and form the structure for this thesis´s research. In this respect, the previous sections were entirely devoted to present the aspects, principles and relations that underpin technological change, innovation and eco-innovation that are of interest in this work.

Section H.7 discusses the behavioral theoretical grounds that support eco-innovation processes. It builds upon the previous sections of this thesis research. The main objective of this section is to provide a testable theoretical body for conducting the micro to meso level study designed to gain an understanding of the determinants of eco-innovative behavior in the Brazilian petrochemical sector.

H.7.1 The Contribution and Importance of Behavioral Theory and Behavioral Models to the Innovation Domain

Social human behavior in the industrial realm, at the firm and sector levels or at the supply and demand sides, plays a fundamental role in the innovation processes. At the firm level, owing to its evolutionary heritage, innovation studies establish a primary dependence of innovation on individual and organizational behavior. This is illustrated by Nelson and Winter (1982: 72) who addressed concerns "with the behavioral aspects of firms and other organizations". They explored the connections between routines and innovations and clarified how innovative activities relate to the general image of firm's behavior that is governed by its routines.

This view is shared and reinforced by (Meeus and Oerlemans, 2000) who argued that innovative activities were understood as a component of behavioral routines, which determine the competitive edge of firms.

As previously noted in Section H.4, innovations and routines are not produced unexpectedly. Firms deliberately innovate and dedicate financial, material and cognitive resources to that purpose. Cognitive resources can be traced back to the individual level (Beckenbach and Daskalakis, 2008). "Investigating the reason why a firm's agents leave well-established routines and switch to a highly uncertain innovation process, is a further important aspect of a behavioral foundation of innovation processes" (*ibid*, 182).

In this regard, the study of determinant factors that can influence companies to change their behavior towards the environment and promote their deliberate engagement in eco-innovative activities, is the most important contribution of this thesis research to innovation studies.

By providing an understanding on and an explanation of these influences on the development of companies´ intention (willingness) to engage in pro-environmental behaviors, it is expected that this work contributes to diminish the "somewhat strange neglect of the behavioral aspects related to the innovation process" (Beckenbach and Daskalakis, 2008: 181).

It is important to underscore that innovating means undergoing processes of change. As these processes are socially induced and constructed, it seems plausible that, as in any human social activity, they are molded and mediated by factors that determine and shape human behavior.

Explaining why and how innovative behavior takes place at the firm level and identifying the elements that determine and influence (incentives and disincentives) innovation processes have been major challenges in theoretical and empirical innovation studies (Montalvo, 2006). According to Montalvo (*ibid*: 312), these studies and challenges have been historically adversely influenced by some shortcomings that reside in "three fundamental concerns about the current state of the innovation literature (…) concerning the capacity of current models to explain and predict innovative behaviors":

a) A commonality of current theories and studies is that they tend to put emphasis on individual factors as determinants of the innovative behavior and much of the knowledge is still rather fragmented due to the lack of the unification of diverse insights;
b) No models have been provided to facilitate the quantitative empirical test of the influences of these individual factors;
c) The literature does not propose methodologies to assess the origin of such dissonance between cognition and behavior.

This vision of fragmented, dissimilar factors influencing behavior was also shared by Bamberg and. Schmidt (2003: 265):

> "(…) many of these studies were exploratory in nature. As such, many of them examine variables without providing a strong theoretical basis for doing so. Often it remained unclear how these factors relate to each other when studying environmental behavior".

In order to overcome these shortcomings, Montalvo (*ibid*) emphasized the need for the provision of a single theoretical body that could unify the many fragmented insights, individual determinants and dissimilar factors[144] attributed to the occurrence of innovative behavior in organizations by current theories and studies (*ibid*).

This was translated as a need for the development of a theoretical and methodological approach that enabled the integration of insights from diverse areas of innovation studies towards the explanation of innovative behavior of the firm in specific contexts.

[144] "e.g. institutional arrangements, entrepreneurial or risk taking behaviors, economic opportunities, organizational learning, technological and organizational capabilities, etc.". (Montalvo, 2006: 312).

According to Bamberg and Schmidt (*ibid*: 265) "a great advantage of theory-driven models is that they contain precise operationalization of the theoretical constructs used and specify the causal processes through which they affect behavior".

As a consequence, Montalvo Corral (2002) proposed a behavioral structural descriptive model (cf. Chapter 5) that:

> "Compared to previous models that explain the innovative behavior of firms, the structural model proposed (…) not only enables to comprehensively explore the internal and external operating contexts of the firm. In addition, it allows assessing the influences between the predictors and the propensity of the firm to innovate and explore what type of relationship could exist among variables". (Montalvo, 2006: 320)

Following Montalvo Corral´s (2002) seminal work, this thesis research was designed to contribute to behavioral sciences and innovation research fields. It developed insights and reflections designed to help to reverse the historical neglect related to the behavioral aspects of innovation. In addition, this research can contribute to the field of innovation economics as "analyzing the behavioral foundations of innovation should be viewed as a one main topic of innovation economics" (Beckenbach and Daskalakis, 2008: 181).

In addition, this thesis research contributes to the field of behavioral economics, which "uses evidence of psychology and other disciplines to create models of limits on rationality, willpower and self-interest, and explores the implication in economic aggregates" (Camerer, 2006: 181).

> "(…) economic theory is more than an analogy to behavioral psychology; economics is also a science of behavior, albeit that of highly organized human behavior" (Hursh, 1984: 435).

The need for a unifying theoretical body for predicting and explaining human social behavior has produced a variety of social-psychological theories used for the explanation and prediction of social behavior. They cover different grounds and incorporate many diverse insights, approaches and theoretical formulations. Such theories have been applied to a variety of different contexts producing many different results (cf. Bamberg and. Schmidt, 2003). Additionally, behavioral theories and models harbor the analytical problem related to the level of analysis.

> "Notably, for more than a hundred years, economics (…), sociology (…) and the philosophy of science (…) have witnessed a debate as to whether individuals ('micro') or social collectives ('macro') have explanatory primacy. This debate has raged under the label of 'methodological individualism' versus 'methodological collectivism'. The issue and debate carry very substantial theoretical and explanatory implications; for example, what are the relations between micro and macro levels? Do we always need to invoke micro-level explanatory mechanisms when trying to explain some macro-level phenomenon? Is it legitimate to rely on aggregate constructs as part of the *explanans* − or, are these only present in the *explanandum* of an explanatory structure?" (Felin and Foss, 2006: 2).

In this respect, as this work regards firms as the central object of study, the choice of the most appropriate level of analysis, which can best explain innovative behavior at the firm level, is of extreme relevance.

According to Staw (1991: 815), "many rather universalistic tendencies on the part of the individuals will aggregate into organizational level behavior". Additionally, he argued that psychological models are of relevance under circumstances in which individual behaviors and individual-level processes influence and mediate organizational actions, and theories of human behavior serve as a metaphor for the actions of organizations.

In the same line of argumentation, Beckenbach and Daskalakis (2008) called attention to the importance of agent-related surveys in the innovation research. According to them, the usefulness of such surveys resides in their capability of enabling a disaggregated assessment of observable innovation elements. In parallel, they allow for taking into consideration innovation determinants, which cannot be observed with the usual methods.

They further emphasized that this kind of survey is able to capture agent-related micro-foundation topics that have often been neglected. This includes the agents´ cognitive processes in terms of knowledge, memory, attitudes and beliefs involved in the process of novelty creation. Such processes depart from the development of agents' perceptions on market processes up to their transformation into courses of action. Although this issue is fundamentally important in the study of firms' behavior, it is more appropriately dealt with in Chapter 5 in which it is addressed in details.

Based on the foregoing paragraphs, and in line with this thesis research objectives, Ajzen's (1991) "Theory of Planned Behavior" (TPB) and Montalvo Corral´s (2002) TPB based structural descriptive behavioral model (cf. Chapter 5) are referred to as the behavioral theoretical body, organizing framework and analytical tool for the study of the determinants of the eco-innovative behavior of companies. Following the work of Montalvo Corral (*ibid*), this study is conducted at the individual level as a proxy to infer the planned behavior of the firm. The TPB is presented in Section 3.2 in the depth required by this thesis research.

17. Appendix I - Some Views on Environmental Sustainability in the Industrial Sector: the Importance of Greener Production Processes

I.1.0 Introduction

Although the concepts of sustainability and sustainable development are quite simple to understand, they do not provide enough guidance for the development of unique solutions to address the innumerous sustainability challenges in modern societies.

Although successful transition processes towards more sustainable forms of development require the incorporation of general sustainability concepts and tenets as guiding principles, particular solutions for specific needs must be developed for specific environmental and socio-economic contexts.

Appendix I addressed the problematic of environmental sustainability in the industrial domain and its relations to products and production process technologies. The focus on the environmental dimension of sustainability does not signify that this thesis´ author is not aware, neglects and takes for granted the importance of the other dimensions and their variables, which are important for companies in:

- Addressing their social responsibilities while respecting cultural, societal, environmental and legal differences and economic development conditions;
- Identifying and engaging with stakeholders, and enhancing the credibility of corporate reports and claims made about social responsibility;
- Increasing confidence and satisfaction in organizations among their customers and other stakeholders;
- Being consistent with and not being in conflict with existing documents, international treaties and conventions and existing ISO and other standards and initiatives;
- Not being intended to reduce government's authority to address the social responsibility of organizations;
- Promoting the social responsibility field; and broaden its awareness (Schwartz and Tilling, 2009).

Although this study mostly focused on helping to promote environmental and economic sustainability, via technological eco-innovation, it can be argued that technological change influences and is influenced by all dimensions of sustainability. That means that technological changes towards cleaner and more environmentally sustainable products and manufacturing processes are interdependent on a set of determinants that are associated with the economic, environmental and social dimensions of sustainability. This integrated approach provides an important and fundamental contribution to industry´s "Triple Bottom Line" (cf. Section 1.1 of Chapter 1)

The study of the determinants (environmental, economic, social, moral, technological, organizational, and institutional), that are important for the context of this thesis research, is presented in Chapter 5.

Appendix I represents a complementary reading to Chapter 1 and supports Chapter 2 in which the GCE frameworks were presented.

In this respect, and in order to provide an overview of the extent of the environmental sustainability challenges to in the industrial domain, Section I.1 discussed some aspects of environmental sustainability and its relations to the limits to economic growth imposed by natural physical and biological laws.

The first concern, in Section I.1, was to provide some clarifications on the context dependent character of sustainability (S) and sustainable development (SD) (Section I.1.1). It is argued that the beliefs underpinning S and SD are dependent on what humans perceive to be the environmental and socio-economic needs of individuals and societies in specific contexts; i.e. it is a function of what is to be sustained and what is to be developed (NAS, 1999).

Section I.1.2 approached the industrial domain´s problematic of reconciling capitalism, economic growth and development with the biosphere´s physical limits. It brought to the research´s context some considerations that are based on the long-standing debate on the limits to economic growth, on the interactions of the industrial economy and the environment.

It introduced some points of view related to sustainability and economic growth that considered the finitude of the natural capital and the limitations imposed by the biophysical laws. Additionally, the section discussed some aspects of the classic debate on the importance of entropy as a limiting factor in the industrial transformation processes.

I.2.0 Environmental Sustainability in the Industrial Sector: the Importance of Contextual Influences and the Limits to Growth Imposed by Nature

In the wake of the debate over the limits to economic growth, Section I.1 was conceived and developed to contextualize, in general terms, some concepts and views associated with the relationships of economy and the environment. In parallel, it promoted a review of the contextual, multifaceted, multidimensional, multidisciplinary and systemic characteristics of sustainability

These aspects represent a background that provided the justification for the need for the adoption, by firms in the industrial sector, of innovative cleaner and more sustainable technologies (technological change). Additionally, they provided a view of the environmental and socio-economic dimensions that underlie the motivational factors associated with firms´ willingness (intention) to deliberately engage in technological eco-innovation activities (cf. Chapter 5).

I.2.1 Sustainability and Sustainable Development: a Matter of What is to be Sustained and What is to be Developed

Although the *Brundtland Commission*[145], in 1987, defined sustainable development and clearly expressed its guiding principles (cf. WECD, 1987), its openness produced hundreds

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[145] "The Brundtland Commission: In the 1980s the UN set up the Commission on Environment and Development, also known as the Brundtland Commission, named after its Chair Gro Harlem Brundtland.

The outcome of the Brundtland Commission was a comprehensive document entitled "Our Common Future", otherwise known as the Brundtland Report. This report framed much of what would become the 40 chapters of Agenda 21 and the 27 principles of the Rio Declaration on Environment and Development. The report

of alternative definitions and interpretations. They expressed a variety of perceptions and interests of an extensive set of groups and organizations, throughout the world, on what sustainable development should be and on what could be the pathways that could lead societies to the their envisioned type of environmental and socio-economic sustainable development.

> "In the years following the Brundtland Commission's report, the creative ambiguity of the standard definition, while allowing a range of disparate groups to assemble under the sustainable development tent, also created a veritable industry of deciphering and advocating what sustainable development really means." (Kates *et al.*, 2005: 11)

Diversity is a basic characteristic of human societies. The heterogeneity of human perceptions, influenced by a myriad of personal, social and cultural factors produces many and diverse views of the world. Therefore, it is understandable that different actors, in different geographic areas and in different cultural and socio-economic contexts, developed a multitude of interpretations of the meaning of sustainability. This might be true even for the cases and contexts in which a group of individuals shares the same sustainability concepts and principles.

> "Within this general framework, an extraordinarily diverse set of groups and institutions have taken the concept of sustainable development and projected upon it their own hopes and goals (…) while sharing a common concern for the fate of the earth, proponents of sustainable development differ in their emphases on (1) what is to be sustained, (2) what is to be developed, (3) the types of links that should hold between the entities to be sustained and the entities to be developed, and (4) the extent of the future envisioned." (NAS, 1999: 23).

Despite the fact that the basic and general concepts of sustainability and sustainable development can be easily understood, they are very elusive when companies take one-step ahead and proceed to plunge into transition processes aiming at more sustainable states (Blackburn, 2007). The definition and concepts of sustainable development connote a sense of hopeful progress suggesting "an evolving process that restores the balance needed for a long-term organizational and societal well-being" (*ibid*, 18). Despite the clarity of the argumentation, the concepts do not provide enough direction to translate sustainability from the pure philosophical order to its real, palpable and practical operationalization.

In order to clarify this fuzziness and in an effort to help setting some directions for plunging into deeper layers of the sustainability, Blackburn (*ibid*) called attention to the necessity of a good understanding of the needs of the present generation. In addition, he called attention to the need for the comprehension of what the economic, social and environmental responsibility really mean and what topics they embrace.

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defined sustainable development as development which: *meets the needs of the present generation without compromising the ability of future generations to meet their own needs.*"
Source: http://www.earthsummit2012.org/about-us/previous-summits/58-the-brundtland-commission

In this respect, due to the existing variety and quantity of interpretations of sustainable development, the *Board on Sustainable Development of the Policy Division of the United States National Research Council* conducted a study aimed at identifying, in an orderly way, the common aspirations that are related to sustainability and sustainable development, their interconnections and interrelationships.

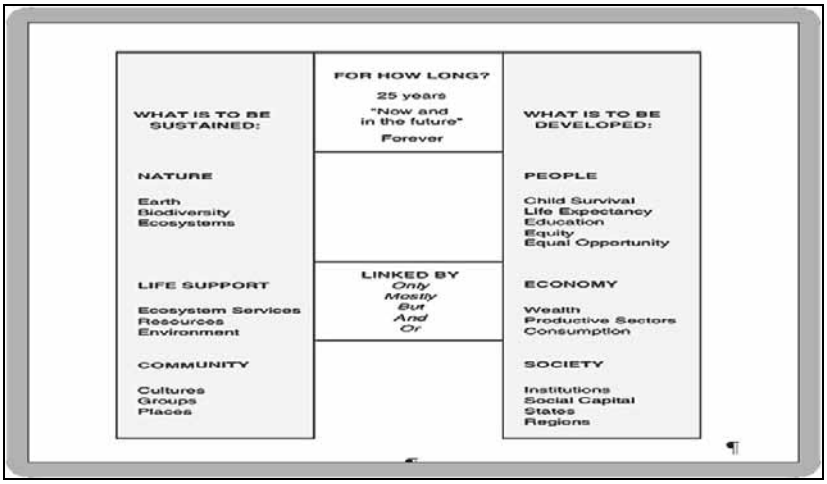
> "Our analysis (…) is based on goals for human well-being and environmental preservation that have been defined through recent extensive and iterative processes of international political debate and action, and sanctioned at intergovernmental conferences over the last several decades". (NAS, 1999: 2).

By reviewing the broad literature[146], they produced the report *Our Common Journey: A Transition Toward Sustainability* (NAS, 1999), which:

> "(…) presents a scientific exploration of the 'transition toward sustainability' that would be constituted by successful efforts to attain internationally sanctioned goals for human welfare and environmental protection over the next two generations". (*ibid*: 3).

Through the report, the "Board" presented key, worldwide, common, sustainability and sustainable development aspirations that were synthesized and structured as shown in Figure 17.1.

Figure 17.1- An overview of Sustainability and Sustainable Development aspirations according to the Board on Sustainable Development of the Policy Division of United States National Research Council



Source: NAS (1999)

[146] The report *Our Common Journey: A Transition Toward Sustainability has "drawn upon nearly* 375 reports of the National Research Council and hundreds of other works cited in the text. In the course of its four-year effort, the board held eight meetings, two summer studies, three workshops, and a public symposium, and commissioned two studies." (NAS, 1999: xiii).

A close look at Figure 17.1 leads to the identification of a vast set of possibilities related to sustainability and sustainable development objectives that could be originated in different environmental, economic and societal contexts for various time frames. This suggests that the choices of what is to be sustained, what is to be developed, how, when by whom and for how long is dependent on specific needs, interests, contexts, domains and time-frames within diverse cultural contexts.

By drawing on these considerations and following their underlying reasoning, this thesis research was focused upon the domain of the environmental and economic sustainability in the Brazilian petrochemical industrial sector in the short, medium and long-term (a thirty years time-span). This choice was of significant relevance and usefulness since the petrochemical sector is one of the most important and strategic socio-economic activities in the Brazilian economy whose environmental and economic sustainability, is an essential contributor to the country´s wealth and welfare creation.

Due to its significant economic and social impacts, and because of its high potential for overshooting the biosphere´s environmental resilience capacity, a collapse or a strong decay of this economic activity, due to environmental factors (pollution, nonrenewable raw materials and energy resources scarcity etc.), would produce extreme socio-economic negative impacts.

It is important to emphasize that reaching advanced states of environmental sustainability, in the aforementioned sector, is a gigantic challenge. That challenge is dependent upon a variety of socio-economic and technological challenges that encompass a set of factors that are as diverse as *inter alia* societal and organizational structures, ethics, production processes, level and patterns of consumption, economic growth and market dynamics (Næss, 2006; Stahel, 1994).

By focusing on these aspects (cf. Chapters 5 and 6), this thesis author addressed the key and sensitive points that influence technological changes towards eco-innovative, cleaner and more environmentally sustainable products and production processes.

I.2.2 The Environmental and Economic Sustainability in the Industrial Sector: the Reconciliation of Economic Growth/Development and the Biosphere´s Physical limits

The Interactions and Interdependences of the Industrial Economy and the Environment

Presently, developed and developing economies show a structural dependence on the industrial sector for the promotion of economic growth, development[147] and societal welfare.

[147] Based on the work by Hermann Daly (1987), in his study, growth was considered the "quantitative increase in the scale of the physical dimensions of the economy; i.e., the rate of flow of matter and energy through the economy (from the environment as raw material and back to the environment as waste), and the stock of human bodies and artifacts" (*ibid*: 323). Development, in turn, was considered "qualitative improvement in the structure, design, and composition of physical stocks and flows that result from greater knowledge both of technique and of purpose" (*ibid*: 323).

The dynamic character, the types of variables and the complexity involved in the socio-economic and environmental relationships make environmental sustainability and sustainable development, in the petrochemical sector, a challenging subject. Nevertheless, for a clearer and better understanding some generalizations and simplifications of these relations can be made.

The first is related to the need for the understanding of how the productive sectors of the economy and the environment interact through strong mutual dependency and feedbacks. According to Smoulders (2000: 603) some facts prevail:

- "The environment is a sink for wastes and a source of resources for the economy;
- Societies have significant preferences for a clean environment due to the amenity and existence value of the environmental quality;
- Part of economic activity may be directly devoted to cleaning up spoilt parts of the environment, that is, abatement and recycling may take place."

It is important to highlight that capitalist economic activities are dynamic, are oriented to and follow specific economic philosophical tenets. Created and developed under the expansionist and capital accumulation economic fundamentals, the industrial sector holds, among its peculiarities, the characteristics of endless, continuous and increasing consumption stimulating character, which directly influences its relation with the biosphere. This generates a direct dependency of the industrial sector on the natural capital[148] as a means of materials and energy supply, for its functioning, economic expansion and for the absorption of the wastes it produces.

This expansionist character of the economy is characterized by an endless and increasing consumption of goods and by an increasing use of materials and energy. These patterns of consumption and use of materials and energy are major sources of concern because of the planet´s limited stock of natural resource and pollution depuration capacity.

Such attributes have been central elements in debate on the viability of these economic practices in the long-run if present technological paradigms, trajectories and regimes and social and economic practices persist (Daly, 1987 and 1996, Daly and Townsend, 1993; Daly and Farley, 2004; Georgescu-Roegen, 1976 and 1986; Porritt, 2007; Stahel, 1994; Næss, 2006).

Moreover, for the transition towards advanced sustainable societies, it is essential that the promotion of changes in the perceptions and beliefs of the economic agents regarding the environment-economy relationships be done systematically. In addition, it is necessary to reexamine the philosophical and political doctrines underpinning the development models on which such economic activities are based (Næss, 2006; Porritt, 2006; Stahel, 1994).

[148] Natural capital comprises the elements on which civilizations depend to create economic prosperity. "Natural capital includes all the familiar resources used by human kind: water, mineral, oil, trees, fish, soil, air etc. But is also encompasses living systems, which include grassland, savannahs, wetlands, estuaries, oceans coral reefs, riparian corridors, tundras and rain forests". (Hawken *et al.*, 1999: 2)

Some Views on the Relations of Environmental Sustainability and Economic Growth

Human´s socio-economic activities pose multiple pressures on the environment and trigger changes, beneficial or not, to the dynamic equilibrium of the biosphere *via* a virtually infinite series of complex interactions (feedback loops). These interactions involve anthropogenic influences on the environment, dynamics of ecologically complex systems and biophysical thresholds (UNEP, 2007).

The economy and the environment realms have mutual dependency due to the biosphere's characteristic of being a source of material and energy resources and a sink for the economy´s wastes. In the one hand, decays in the quantity and quality conditions of the natural stocks will increasingly restrict the economic process. On the other hand, the intensity and the quality of the economic process have a direct influence on the quality of the environment. Biosphere and economy interact in constant feedback loops.

> "The ecological process is described by relying on biophysical laws, which deal with changes in physical states and conditions of biomass, material, and energy. Economic value creation represents the process in which human beings combine their ability and ingenuity with natural resources to produce desirable and marketable goods and services. Hence value creation is driven by technology and preferences which can both be viewed as the result of the human state of knowledge." (Smoulders, 1995: 321)

Smoulders (*ibid*), argued that although the economy and the environment interact in a mutually dependent fashion, they should be seen and treated as two different dimensions that are subjected to different laws. While the economy is a human creation to which economic value is of maximum significance, the physical and qualitative magnitudes are of upmost relevance to ecological processes.

> "Nature has value if and only if humans value nature. Humans might value nature for whatever reasons, however, and not merely because it contributes to the production and consumption of goods or directly produces utility through environmental amenities. Humans might very well value nature as such and for its own sake in attributing to it 'intrinsic' value. But it is still humans who determine value". (Neumayer, 2003: 8)

Næss (2006) argued that, in the profit-oriented capitalist economy, the capital accumulation is the prime driving force and that the absence of growth tends to result in serious economic and social crises. Although some economists fiercely advocate the no growth, or steady state economy (Daily and Townsend, 1993), many others are in complete favor of constant economic growth. For the latter group, growth represents a *sine qua non* condition for the economic sustainability. "When the economic system contributes each period more to welfare by creating more value, economic growth arises" (Smoulders, 1995: 320).

Growth encompasses the increase of throughput of matter and energy in the economy. Industrial economic processes would be environmentally sustainable if the natural capital was not finite and if the biosphere capacity to absorb residues was not limited. In addition, it is important to call attention to humans´ and other living creatures´ limited capacity to withstand pollution.

In this respect, another issue that has been under fervent discussion is the extent to which the biophysical limits can impose restrictions to the material and energy reuse in the long-run. This constitutes an important issue within the sustainability debate.

Important Lines of Argumentation on the Debate of Economic Growth Versus the Finitude of the Natural Capital and Biophysical Laws

As an ample set of publications testify (e.g. Brüseke, 1994; Corazza, 2005; DOE, 1997; Herrera, 1976; Meadows *et al.*, 2004), the 1970s experienced the first and extensive debates over the limits to economic growth in modern industrial societies. These debates are still ongoing and valid.

In order to illustrate the dimensions and relevance of the arguments posed by numerous scholars and to illustrate and emphasize the degree of difficulty associated with industrial environmental and economic sustainability, this thesis author presents important argumentations related to the limits of economic growth *versus* the limits posed by the biosphere and the natural laws.

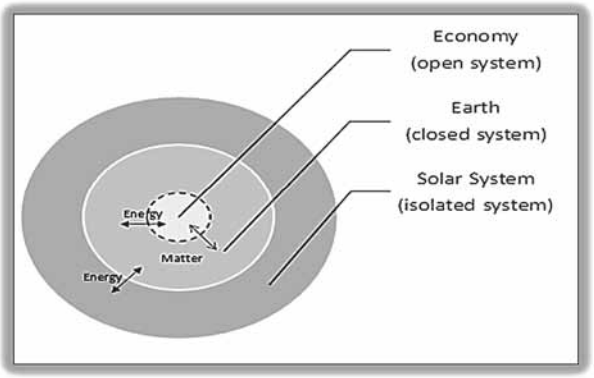
In the heat of the discussions over the relationships and feasibility of development and economic growth, the publication of the seminal book "The Entropy Law and the Economic Process" (Georgescu-Roegen, 1971) called attention to the importance of the laws of thermodynamics to economics. It provided new optics on the limits of the endless usage and exploitation of natural resources by the economy.

This time, instead of focusing only on the use of the finite stocks of nonrenewable natural capital, he argued that the physical laws, like the entropy, and the conservation laws of mass and energy were a relevant issue in the economic analysis (Krysiak, 2005). They would eventually be a limiting factor to economic growth.

According to McMahon and Mrozek (1997) and Meadows *et al.* (2004), in physical and energetic terms, the environment and the economic systems relate hierarchically as depicted in Figure 17.2 and in Figure 17.3. On the one hand, the planet earth and its global environment, upon which the economy depends, are essentially a closed systems. They receive constant energy flows from outer space and radiate heat back to it in a virtual absence of matter exchange. An exception is made for insignificant flows of matter from outer space (Daly and Townsend, 1993; Georgescu-Roegen, 1971; Krysiak, 2005; McMahon and Mrozek, 1997; Smoulders, 1995). Matter cannot be created nor destroyed. On the other hand, "the economic sub-system is an open system, extracting usable matter and energy from the biosphere and returning unusable wastes to surrounding environment" (McMahon and Mrozek, 1997: 503).

Figure 17.2 shows that the maximum size of the economy coincides with the physical limits of the biosphere.

Figure 17.2- Hierarchical relations of the physical and economic systems in relation of matter and energy exchange



Source: adapted from McMahon and Mrozek (1997)

Viewed in a simpler way, planet earth is a gigantic transformation plant whereby, matter and energy are submitted to physical, chemical and biological transformation processes that produce the biosphere. Matter cannot be created nor destroyed, but it certainly can be recycled, using solar energy flows, as we witness in the nature's ecological circular flows. Inevitably, obvious questions are raised on the capacity of science to mimic nature's circular flows and to recycle and rearrange matter and energy that flow through economic processes.

According to Georgescu-Roegen (1971) entropy laws would hamper these processes. A discussion on the limits imposed on these processes, by the natural laws, is conducted in the following paragraphs.

> "Since the rearrangement of matter is the central physical fact about the economic process, we must ask what determines the capacity to rearrange matter? Is that capacity conserved, like matter-energy itself, or is it used up? Is all matter equally capable of being rearranged? The answers to these questions are provided by the second law (of thermodynamics)." (Daly, 1987: 326)

The first law of thermodynamics, the law of the conservation of matter and energy, states that in an isolated system the total content of matter and energy is fixed. In addition, it states that in a closed system only the total matter is fixed with energy being exchanged through the system´s boundaries.

> "In brief, raw material inputs to economic processes are not 'consumed'. Having been extracted from the environment in the first place, they eventually return to the environment as wastes." (Ayres, 1998: 189)

Complementary to the first of law of thermodynamics, which proclaims the indestructibility of matter and energy, the second law of thermodynamics (the entropy law) regards their availability and imposes an extra limitation for recycling. According to the second law, matter and energy irrevocably degrade into unavailable states (Georgescu-Roegen, 1971).

Entropy as a Limiting Factor in the Industrial Transformation Processes

> "Matter and energy -like money- just keep going around in an isolated system with no inlets and no outlets. Since the circular flow model of the textbooks has no points of contact with anything outside itself, the environment cannot possibly constrain economic growth, or influence the economy in any way whatsoever! However, there also exists a second law of thermodynamics, the implications of which modify this picture fundamentally. (Daly, 1987: 326)

Entropy is an extensive[149] state variable that is definable for any substance or any system. It expresses the index of available energy in any system and a measure of disorder of a system. The second law of thermodynamics states that the transformation and the rearrangement of material and energy, in an isolated system, produce an irreversible process of transformation of matter and energy.

> "The capacity to rearrange matter is variously called 'free', 'available', or 'low-entropy' energy, and is irrevocably used up. Structured, concentrated (low entropy) matter is easier to rearrange (i.e., uses up less available energy) than is the case for unstructured, dissipated (high entropy) matter. In effecting these rearrangements, available energy is degraded into unavailable energy, which, as the name suggests, can no longer be used to rearrange matter." (Daly, 1987: 326)

Free or available energy is converted into bound or unavailable forms of energy and material becomes dissipated and less available.

"All kinds of energy are gradually transformed into heat, and heat becomes so dissipated in the end that mankind can no longer use it" (Georgescu-Roegen, 1976: 8). This is translated into an increase of disorder of the systems, or an increase of the system's entropy, which consequently produces the irreversibility of the process of material rearrangement and set limitations to energy reuse (Georgescu-Roegen, 1971; Daly, 1987 and 1992; Hueseman, 2003; McMahon and Mrozek, 1997; Smoulders, 1995).

The majority of industrial processes in contemporary developed and developing societies basically consist of the transformation of highly ordered matter and energy, contained in the non-renewable natural capital, used as inputs for the production processes, into dissipated (scattered) high entropic ones (*i.e.* wastes) (Georgescu-Roegen, 1971; McMahon and Mrozek, 1997) (cf.Figure 17.3). "As low entropy resources run out, especially fossil fuels, economic activity becomes increasingly limited by the accumulation of waste (pollution) and scarcity of energy" (Schwartzman, 1996: 4 *apud* Georgescu-Roegen, 1971). Due to the fact that the use and transformation is an entropic process, the same amounts of energy or materials cannot be used over and over again" (Smoulders, 1995).

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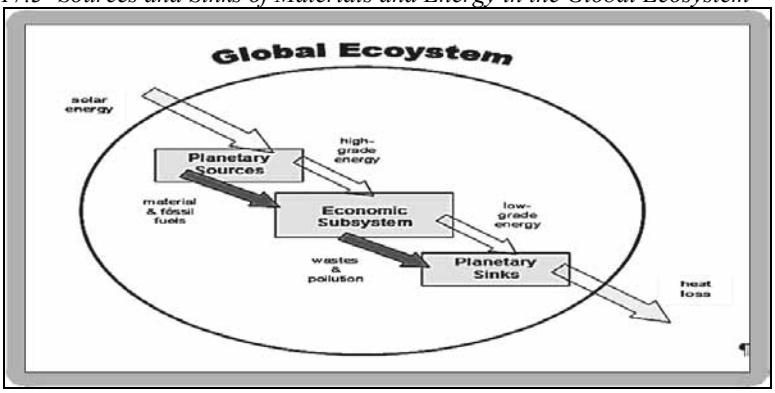
[149] Extensive variable means that it is proportional to the size of the system as opposed to the term intensive variable, which is not (i.e. temperature, pressure *etc*.).

New inputs of low (highly ordered) entropy resources are then required to recollect material and to compensate for entropy (Daly, 1992; Smoulders, 1995; McMahon and Mrozek, 1997).

Figure 17.3- Sources and Sinks of Materials and Energy in the Global Ecosystem



Source: Meadows *et al.* (2004)

According to the aforecited authors, fortunately, with regard to energy, the Earth is an open system. The entropic degradation produced by the transformation processes occurring in the natural systems is off set by the constant inflow of the low entropy, highly ordered energy flow from the sun, allowing for sustainable resilience of natural systems *via* self-regulating and adaptive processes.

> "Solar radiation provides the energy that compensates for the entropic processes on earth so that resources are renewable (…). This explains the equilibrium in ecosystems and the renewable nature of natural resources". (Smoulders, 1995: 321).

It is important to note that these natural transformation processes are carried out in time spans that mostly do not coincide with the economy's notion of time. There is incongruence and incompatibility between the notion of time regarding the ecological and economic processes.

In the one hand, nature requires long periods to form and to recycle the natural capital, using solar energy in circular flows. On the other hand, the economy requires very short periods for using and recycling matter at the pace required by the logic of the capitalist doctrine for processing and transforming natural capital in goods bearing economic value in increasing quantities (production increases, economic growth and economy expansion)

In this sense, while nature's resilience time comprises time spans from months to millennia, time in the economy is considered to be the shortest possible. This provokes the rupture of the circular flows present in the natural processes.

There are Many Answers to the Question of the Limits of Economic Growth

In another line of argumentation in respect to the limits of economic growth imposed by the natural capital, Ayres *et al.* (1998), stressed that an important point in the debate on sustainability is related to the substitutability between the economy and the environment.

That is, the substitutability between "natural and manufactured capital" [150]. "A debate captured in terms of 'weak' *versus* 'strong' sustainability[151] [152]" (*ibid*: 1).

In the environmental economy domain, economists have also been struggling to solve the problem of the reconciliation of growth, the physical finiteness of the planet and the limits imposed by the biophysical laws. As the inclusion of the environmental economics analysis on environmental sustainability and growth is beyond the scope and objectives of this thesis research, no further considerations are made on this issue. A synthetic overview, on the two major positions on the entropy law and the economic processes has been written by Krysiak (2006), which is partly transcribed in Box I.1.

Box I.1- Two major positions on the entropy law and the economic process according to Frank C. Krysiak

"Since the publication of 'The Entropy Law and the Economic Process' (Georgescu-Roegen, 1971) the question whether physical laws like the entropy law or the conservation laws of mass and energy are relevant to economic analysis has given rise to many disputes. Two major positions have developed.

The mainstream position was formulated by R. Solow as '(…) everything is subject to the entropy law, but this is of no immediate practical importance for modeling what is, after all, a brief instant of time in a small corner of the universe' (Solow, 1997: 268). Thus mainstream economists acknowledge the existence of these laws, but they claim that these laws have no substantial consequences for economic analysis and can therefore, be safely neglected.

This position has attracted much criticism, especially from ecological economists. Daly (1997), among others, argued that it is based on a misinterpretation of the entropy law and the conservation laws; in a form suitable for open systems, these laws do not only apply to the universe as a whole but to all systems that process mass or energy, including economic production and consumption activities. Furthermore, these laws have important consequences as they rule out the common model of a closed, nature-independent economy that can grow without limits.

The problem to determine, which of the above positions is the better description of reality is surely of importance. But an agreement on this problem seems to be out of sight. One reason is that although there has been a sometimes heated debate, the arguments that derive notable consequences from the above physical laws are often imprecise and remain obscure to many economists."

Source: Krysiak (2006:182-183)

In relation to the arguments on the limits to growth, Ekins (2000: 49) stressed that:

[150] Manufactured capital or "man-made capital is what has been traditionally subsumed under 'capital', that is factories, machineries, roads, and so on…Human capital is knowledge and human skills." (Neumayer, 2003: 8)

[151] For a good understanding on the concepts of week and strong sustainability, refer to Ayres *et al.* (1998) and Neumayer (2003).

[152] The concept of "weak sustainability" is built on the assumption of unlimited substitutability of natural resources" as opposed to "strong sustainability" whose essence is that it regards natural capital as fundamentally non-substitutable through other forms of capital. (Neumayer, 2003).

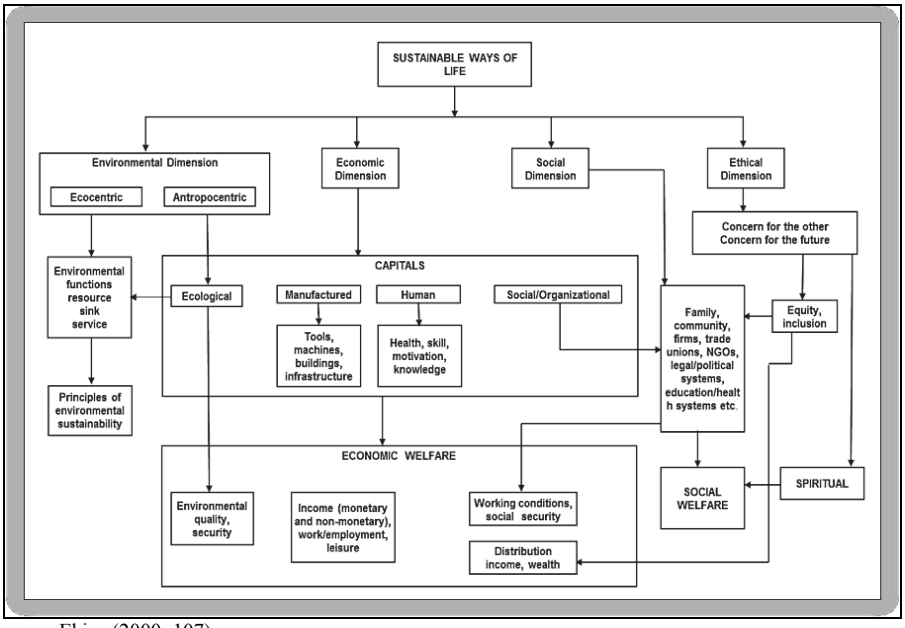
> "The debate on the limits to growth has been left hanging in the air with the resources optimists either dismissing it as *passé* or regarding it as somehow resolved by the mere incantation of 'sustainable development', and the resources pessimists sticking doggedly to their line of 'indefinite growth is not possible in a finite world', without adequate differentiation between the different kinds of growth, or specification of what kinds of growth they have in mind"

He further called attention to the need for "clear specifications and clarifications of the differences between production, welfare, growth and development that it is desired to sustain and why it may prove problematic" (*ibid*, 1999: 50).

In this regard, it is important to note that, although these arguments were found to be useful in exposing the importance of the limitations imposed by nature´s biophysical laws upon the limits to economic growth, they did not consider other basic factors from other dimensions of sustainability.

These factors are equally important contributors to and have great influence on the overall environmental, economic and social sustainability. Example of the amplitude, the interrelations and the diversity of these factors are presented in Figure 17.4.

Figure 17.4- The dimensions of sustainability and their interrelations according to Paul Ekins



Source: Ekins (2000: 107)

As a consequence, it is required that the elaboration of studies that are intended to help the industrial sector to achieve advanced states of sustainability include strategies that are based on multifaceted, multidimensional, multidisciplinary and systemic approaches. Such strategies should take into consideration variables that represent the both natural (physical,

biological, geological, chemical etc.) and anthropogenic (social, economic. political, cultural etc.) realms (Cavalcanti, 1994; Stahel, 1994).

This is exemplified, in Chapter 1, by the model proposed by Paul Ekins (2000) that was used to introduce this kind of approach to this study. The model diagrammatically links a production function to a utility function as a means to explain the circular influences of these variables on the industrial production processes for creation of economic and social utility. In this respect, among the multidimensional aspects that are taken into account, the model, in agreement with has been previously argued, assumes the limitations imposed by the nature´s biophysical laws.

18. References

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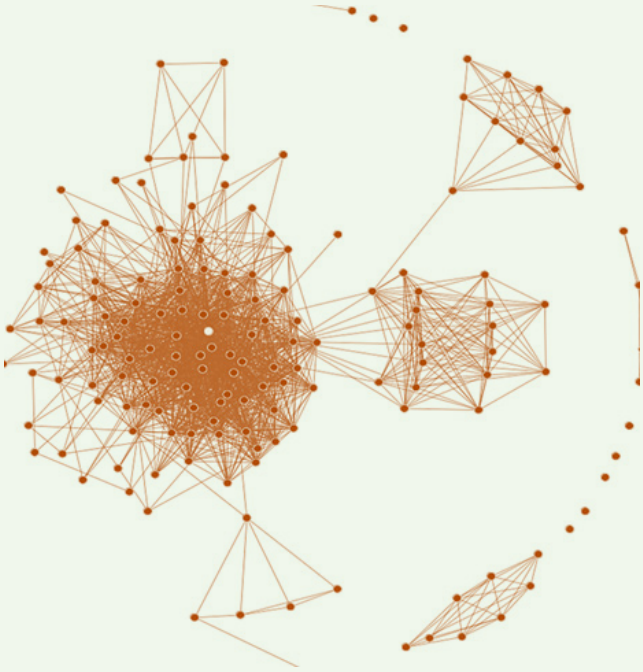

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