A Field for Interactive Learning on Climate-Energy Transition: Concepts and structure

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Abstract

This paper discusses the concepts and structure behing FILCET, a field for interactive learning on the climate-energy transition, designed to improve awarness on the climate-energy crisis (CEC) macro-problem, and communicate the structure and dynamic complexity of key policies available to face this transition. This work present FILCET's basic concepts and their application to the communication and collective learning on the energy transition, and its potential use in understanding the interrelationships existing between climate change, energy policies and innovation strategies in the pursue of sustainable development. This paper describes FILCET, its learning targets, the overall structure and mechanism and the elements of the policy game dimensions and the system dynamics model supporting it, which focuses on the dynamic complexity of CO_2 abatement policies for a power market, such as cap and trade. We include comments and observations drawn from the preliminary testing, reflexions on its potential use as a communication tool for sensitizing policy makers, educators, and energy innovation networks.

Keywords: Policy Game, Climate-Change, Electricity Market, Cap and Trade.

1 Introduction: The climate-energy risk

Climate-energy is arguably the major crisis in Man's history. It is a signal of the collapse of the fossil-fuel addicted industrial economy, and it may well represent the biggest market failure[1] responsible for the most unjust externality: those countries responsible for it are shifting its severe consequences to the most vulnerable ones in desperatly need of energy to fuel growth and development. An externality that will erode, even more, the economy, health, and wellbeing of their populations.

The complexity of the climate-energy crisis (CEC) goes beyond a *policy-problem* [2]. It is what some authors defined as *macro-problem* [3] formed by elements such as: (1) the context, (2) the definition and understanding of the issues, (3) the actors involved, (4) the definition of objectives and goals, (5) the needed and potential actions, and (6) the expected products and results.

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The climate-energy crisis has clearly emerged as the central macro-problem faced by humankind. It challenges science's reductionism and analytical power, but at the same time uncovers inadequacies of our traditional approaches for educating, learning, planning, and policy making. The old tradition of assembling scientific disciplines and social perspectives linearly has to give way to a meta-disciplinary approach. This requires the development of evolving cognitive structures with a complexity similar to that featuring the macro-problem. Ockam's razor has to be complemented by the Ashby's requisite variety [4]. We are facing the need to start a radical innovation, not only a technological one, but preeminently a cognitive and learning one.

This crisis has stimulated one of the most powerful and promising efforts in knowledge integration for climate models from many scientific fields, transforming them into powerful awareness messages to society and their governments[27]. Consensus on the origins of climate change achieved by scientists may demonstrate in the long-run to be the most significant milestone in this cognitive process. Scientific climate models may not able to predict the economic and social consequences of global warming, but consensus is irrefutable and dramatic: climate change is a calamity with anthropogenic causes. As a consequence clear scenarios, alerting about the risks we face, have emerged, and with them an urgent need to design and understand policy alternatives.

1.1 A cognitive challenge

One concluding remark is that this environmental crisis is not only technological or economic, but primarily a cognition crisis [5]. The inertia inherited from the industrial era is pervasive and persistent within the mental models determining inference modes, policy, decision making, and shaping behaviors and social attitudes towards environmental resources. The United States and China [6]– the two largest producers of greenhouse gases, illustrate clearly the pitfalls we face in dealing with perception of the risks of global warming. In 2006 roughly two-thirds of Japanese and Indians expressed serious concerns about global warming. However there is no evidence of alarm over global warming in either the United States or China, where just 19% of Americans (20% of the Chinese) who have heard of the issue consider it seriously. Misinterpretation of a macro-problem such as the climate-energy crisis is also frequent in adults including graduate students [7]. The public and their political leaders have adopted a wait-and-see attitude, resembling the systems archetype known as "the parable of the boiled frog", a cultural bias where decision makers ignore initial signals of the problem, delaying preventive actions. When the problem symptoms finally emerge exponentially, harm is irreversible.

From this perspective it can be said there is a strong path-dependance on the initial form in which the risk is perceived. Perhaps, the crucial risk is not the climate threat but the risk of trying to cope with it using oversimplified mental models cultivated within a linear way of thinking. In this climate-energy transition, society will have to struggle to build up its cognitive and social capitals, in order to accelerate its transition to a systemic and social complex learning process.

Managing the CEC risk will require a better understanding and communication among the economic, politics, social, scientific and technological actors, and their willingness to cooperate for tracing shared paths towards the required innovation. This can only be achieved by a radical change in our mind-sets, a process called by some authors as *metanoia* [8]. This transformation has not only individual implications, but also a synergy that is only possible through cooperation and social interaction leading to the new collective behavioral patterns. During the last fifty years many intellectual fields have contributed in addressing the social learning and its effects on changing collective behaviors [9]. Many other contributions deal with this topic: the relevance of social networks for sustainable development [10], the organizational change [11] and the cooperative working configurations such as the quality circles, teams, communities [12]. Advanced inter-organizations cooperative strategies to enhance innovation involve new social paradigms such as alliances, consortia [13], networks [14], the emergence of the social capital concept [15], the impulse of the science of natural [16], social [17], and technological networks. The advent of the Internet and communication technologies the proliferation of popular literature [18, 19, 20] on what is being called as *social intelligence*.

To face the CEC's risk we need not only an arsenal of diverse technologies but we must also transform the social communication patterns, and introduce new approaches for learning and education in order to foster social creativity and increase performing potential. The first step is to accelerate learning on the complexity involved in the CEC crisis. Moving beyond the traditional forms of unidirectional information fragmented by scientific specialties and governmental agencies. A basic leveler will be to share the mental models to nurture a collective model, as a platform from which to impulse the strategies to face the menace of the coming transition.

2 FILCET: A Field for Interactive Learning of the Climate-Energy Transition

The new mental models that are needed to face this global menace will not emerge only from existing information, independently of its volume and freshness. There is the need of new knowledge, and particularly of tacit nature that only can be nurtured through social acting and collective experimentation. New effective approaches are needed to inform and sensitize, to induce a systemic vision and shared new mental models, to create consensus and strategies, to stimulate cooperative behaviors, motivation and commitment for action.

This field aims to be part of this stream. For its design a syncretism effort is made that includes some ideas from: (1) concepts and methods from organizational learning and systems thinking [8], (2) application of gaming for communication of complex problems [21, 22], risk [23], and inducing cooperation and creativity [24, 25], (3) information on CE [26, 27], policies and field work on this topic [28], (4) recent approaches on stochastic modeling the effects of pricing on electric markets [29], and studies on the economic impacts of regulating CO2 emissions [30](5) models [31] for scenario building from technologies portfolios [32] and, (6) author's own experiences on related projects.

Final aim is to sensitize, inform and to challenge participants to understand CEC macro-problem. It is expected that people experimenting in the FILCET become aware about the existing gaps between their mental models and the basic CEC expert model. Achieving this learning is expected that participants will reinforce their planning skills, to think about innovation opportunities and on sustainability concepts.

2.1 Learning

FILCET is oriented to learning along two interrelated paths:

2.1.1 On the CEC macro-problem

This part emphasizes on the following CEC elements:

- Time horizonts of the energy transition. Long term dynamics, persistence and delays of the effects of CO_2 atmospheric accumulation.

- The end of the single technical solution. The importance of portfolios of a diverse of technologies instead of the risk to adhere to a single promising technology.
- Synergy that could be achieved deploying simultaneously two strategy lines: (1), policies to improve efficiency of present technologies and (2), introducing renewable (sustainable) energies. The reinforcing importance of social programs and environmental resource conservation projects. Assimilation and adaptation strategies are basic strategies from the Kyoto protocole.
- The basic causal structures and policy making to ameliorate CO_2 emissions and improve its capture. Particularly the role that a market bonus for CO_2 emissions, refered as cap and trade.
- Returns from the bonus market and their application for estimulating energy innovation, social and environmental programs for energy efficiency.
- The dynamic nature between competence and cooperative behaviors in a electric market.
- The importance of cooperation among social and economic agents, the effects of cultural aspects such as consumption habits and the effectiveness of incentives policies.
- Structure and dynamics of innovation in energy technologies. The cycle of adoption, learning curves and portfolio management.
- The concepts of market failure and externality. Facing the challenge as a triple helix effort: government (policy making), the industry and private sector (innovativeness) and social participation both at the individual and organizational level.

2.1.2 Systemic Learning

Several approaches are used: mental model elicitation, learning on archetypes through an inductive way, dialogue, conversation and dialogue [33], social behaviors deployed during auctions, negotiation and group modeling. Some of the emerging lessons are:

- Forms to interpretate complexity and non-linear structures and behaviors. Patterns of recurrent behavior and systems thinking archetypes.
- The importance of meaning and symbols about CEC, For instance: sustainability and renewability.
- The strategic role of communication and different forms of conversation.
- Interpretation and differences between stocks and flows and their meaning in CEC.
- Perception of risk dynamics and the role of policies, decisions, behaviors nas delays. The "boiled frog" attitude.
- The need for a dynamic equilibrium between analtical and systemic thinking.
- The presence and identification of constraints and defensive routines for learning.
- Ethical elements and basic principles for sustainaility.

2.1.3 Concept and Structure

Learning goals are pursued through a concept whose is described in the next illustration. The left part shows the evolution of learning and in the right the modules to administrate the process.

2.2 Learning Strategy

FILCET considers that how the risk is perceived is a determinant factor that catalyzes learning and determines how risk will be managed. Both –perception and communication- are culturally affected. Once the risk is communicated the participants initial mental model (1) is made explicit, later using system dynamic approaches [34] a collective mapping is performed. Individual models and collective map are contrasted with the experts model. The observed gaps are conversed. Then participants involve in cycles of group learning (action learning, simulations and a policy game) to improve complexity of individual mental models and collective map. At the end of the policy game a new elicitation cycle of mental models and building collective map is performed and a final cognitive gap is obtained and discussed. At the end a concluding dialogue is done to design future strategies and commitments for innovation, policy making, learning and action.

2.3 The Process

In its basic concept, FILCET is deployed in six modules lasting around sixteen hours. In each module activities are performed going from information transfer to knowledge generation, in both its tacit and explicit forms, through individual and group activities. In each module varying levels of information, sensitization, motivation and learning are achieved. Modules description is as follows.

2.3.1 Module 1. FILCET Route

Participants are introduced to the learning route by the use of traveling as a metaphor, principles and rules, learning aims, social interaction and motivation as a destiny. Activities consist of an introductory video, an individual reflection, and general information on FILCET procedures and its administration.

2.3.2 Module 2. Perceiving the Risk

Purpose is to make participants conscious about the risk represented by the gap between their mental models and the experts model of CEC. CEC risk is visually communicated together with a historical time table on the CEC evolution, a set of scenarios, the role of technological innovation and policy making. Individual mental models are elicited and a collective map is drawn. A discussion of the cognition gap follows. The need to innovate the energy culture is commented and the role of technology, science, policy making, social participation and individual commitment, are briefly commented. A final reflection is performed based on the simple control loop presented in next illustration.

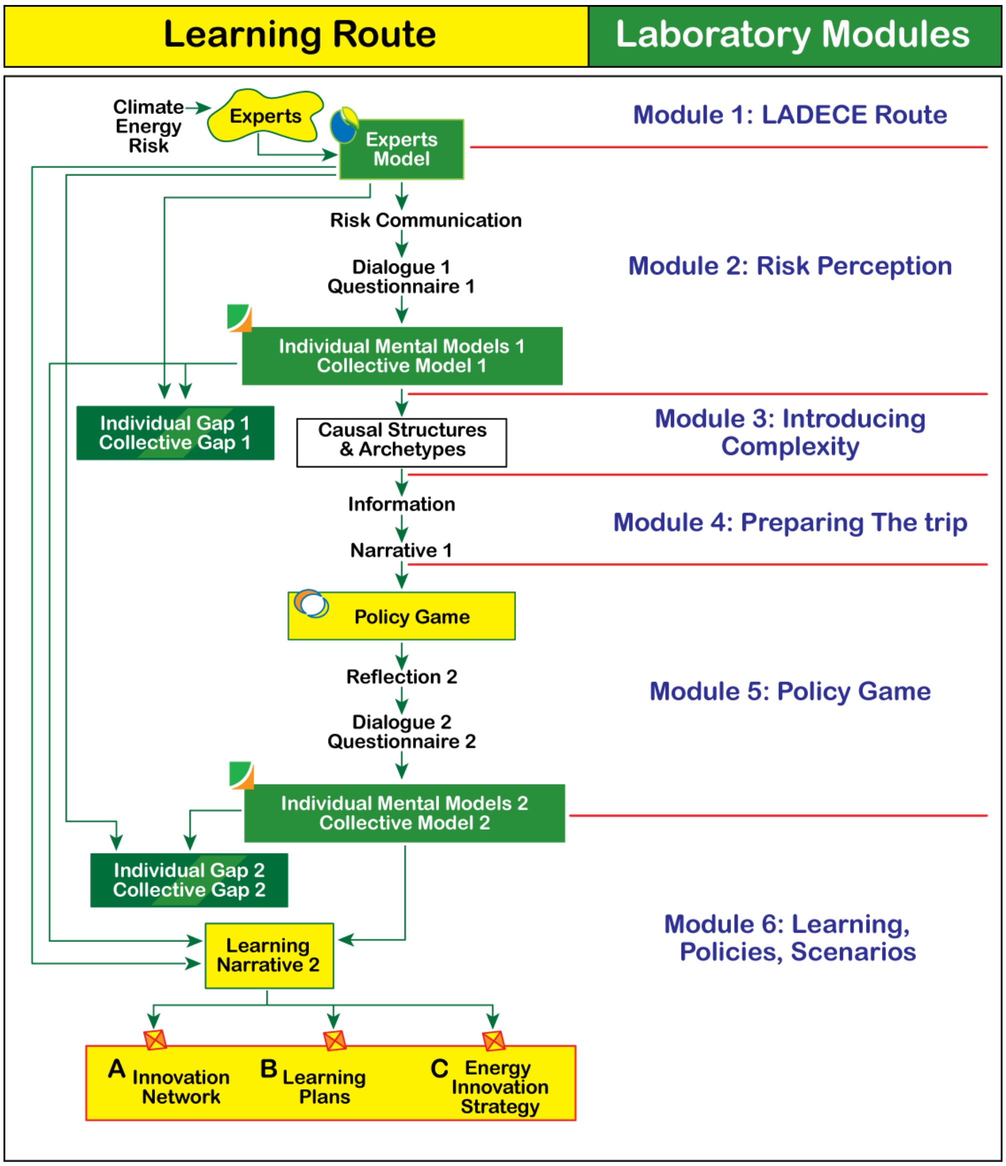

Figure 1: FILCET: Concept and structure

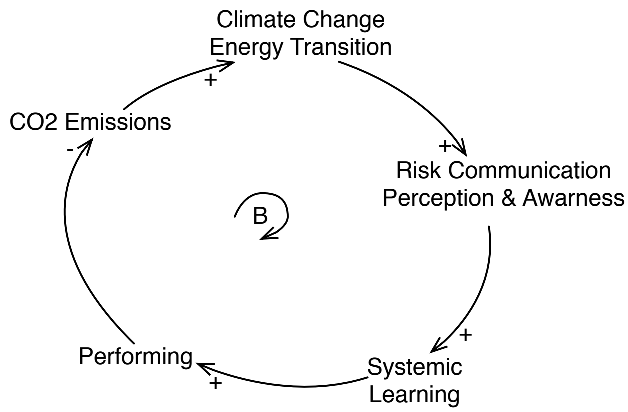

Figure 2: Basic control loop.

2.3.3 Module 3. Systems Archetypes

This module introduces two basic systems thinking archetypes: *the Tragedy of the Commons* and *the Limits to Growth*, both referring to similar situations. Participants are sensitized on the addictive behavior and its effects on environmental resources, atmosphere depletion and climate change as a case. Active learning is facilitated by an adapted version of Fish Bank game, developed by Dennis L. Meadows. At the end participants map the "macro-problem" faced during the game, dialogue on the conflicts and the role of attitudes on the results and the importance of policies emerged through gaming. Summarizing gained lessons, the group is guided to convert their experiences in recommendations for acting in a sustainable mode.

2.3.4 Preparation for the Trip

The aim is the group preparation for the Policy Game. Information related with the Policy Game is distributed to each participant at the end of the first day to be read it overnight. Roles are assigned and specific information is included. Beginning the following day groups are formed to perform exercises and conversations to reinforce information transfer to facilitate Policy Game launching.

2.3.5 The Policy Game

This is the FILCET's core. Gaming brings to practice the information and knowledge gained and nurtured behaviors in the previous modules. The Policy Game simulates a region supplied by electricity produced by several companies that in order to transform fossil fuels are emitting considerable amounts CO2. The region just adopted a policy oriented to sustainable development based, among other objectives, on a global responsibility to reduce CO2 emissions. The energy market is starting to be regulated by a Policy Body (PB) that every year conduct an auction of CO2 bonus (CO2B) and energy generation. CO2B are assigned to those companies making the best offer, companies are able to transact those bonuses among them. Revenues from CO2B are later invested in innovation, social programs for efficiency and environmental resources projects. In the region there are four decision actors: Policy Board (PB), Power companies, Society and Technology innovation-; all of them are eager to improve their individual benefits and share a long term common goal of reducing local vulnerability by reducing region's CO2 emissions.

2.3.6 Learning, policies and scenarios

This is the final module of FILCET. Its purposes is become explicit the acquired knowledge and used in drawing policies and scenarios and outlining future actions. This module considers that in previous modules (3, 4 and 5) participants leverage their initial mental models and collective map creating a renewed perception of the CEC risk, some forms and new intuitions to face it and understanding some of the long term consequences of actions. Mental models should experiment a qualitative transformation besides a quantitative increase on information content. Mental models and collective map obtained in module 2 are the starting point for appraising learning. In this final module mental models and collective are elicited and drawn and a final gap (2 in illustration 2) is obtained. Participants' elicitations of mental models, collective maps, cognition gaps and final appraisal are the most important outcome of the FILCET. A final dialogue is conducted to sketch ideas for innovation, policies, learning, personal commitments and networking activities.

3 The System Dynamics Model

The central learning motor of FILCET is a policy game. The objective of this game is to familiarize participants with the dynamic complexities of carbon abatement policies in general, but it focus on the electricity markets in particular. The electricity market offers a particularly challenging picture: on one the long-term effects of proposed carbon abatement policies, such as cap-and-trade mechanisms or carbon taxing, are far from clear, and, on the other hand, the power market has peculiar idiosyncrasiesfailures which add uncertainty to the effect of such policies. We believe that it is a problem of dynamic complexity, where equilibrium analysis may be useful, but a steady-state analysis may be in fact ignoring most of the issues arising from eminently transient problem.

3.1 General Structure

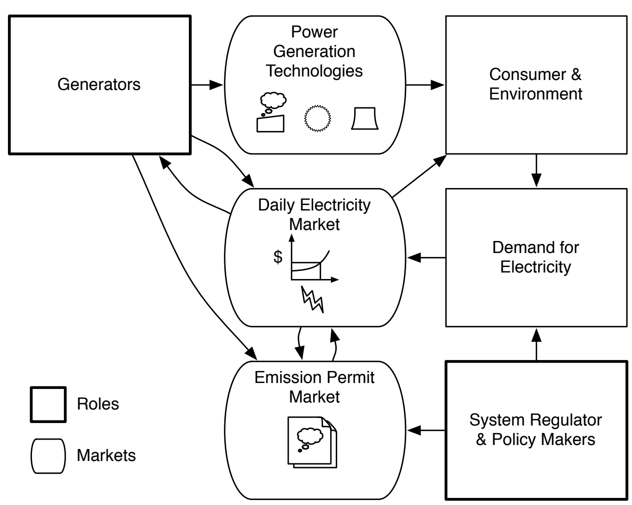

Figure 3: Model, sectors, and basic relationships.

This model of the electricity sector of a world region aims to capture the dynamic complexity that arises in the interaction of its markets, namely the capacity and daily markets, as well as a market for emission permits, which is one of the proposed mechanisms to curb CO_2 emissions under a cap-and-trade policy. Figure 3 presents a systems diagram of the main components of our model.

Generators participate in a daily auction to supply electricity to the power grid. Once dispatched, power generators must make use of emission permits to produce electricity, and may be also interested to trade emission permits market with other generators which can perhaps supply electricity at lower emission rates. A central system operator or regulator sets CO_2 abatement policies, which translate into an annual pool of emission permits. Permits are auctioned and distributed to participating generation firms at the beginning of each of the game's ten simulated years. Several power generation technologies are available, and firms may choose to invest in order to change their portfolio of generating technologies, determining the overall technology mix. Key attributes of available power-generation technologies are modeled endogenously: as a technology becomes dominant, cumulative experience in its use will result in lowered marginal costs, emission rates, as well as lowered investment costs. The consumer receives system performance signals through electricity prices, as well as overall CO_2 emission rates.

3.2 Causal-loop Structure

A key causal stucture to be learned in this game is the virtuos nature of investments in clean technology. As mentioned above, we model learning through experience (cumulative production) and its impacts on marginal costs, investment costs, and the cost of permit per MWh, as described in Figure 4. This structure models the market's ability to lower costs in the long run, as experience with a given technology is acquired. Firms learning and cost reduction effectively lowers the firm's bidding prices, and ultimately their ability to participate in the daily electricity markets.

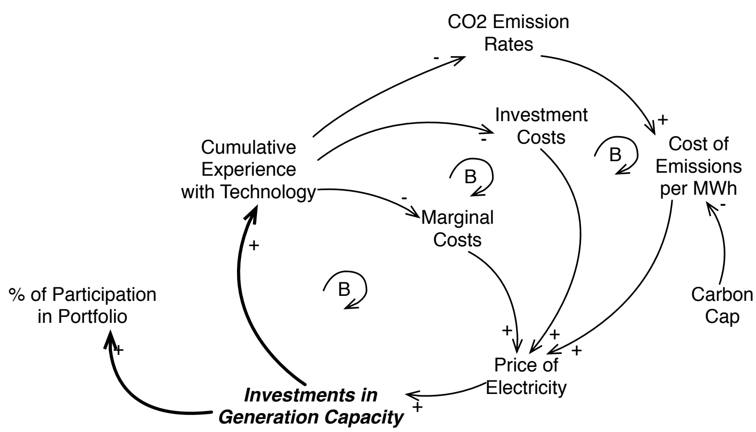

Figure 4: Endogenous model of technology.

On the other hand, while learning effects are important, the effect of permit trading must be highlighted. As experience is gathered with new technology, efficiencies with CO_2 emissions occur, leading to even lower bidding prices, and higher investment in cleaner technologies, increasing their portfolio presence, as illustrated in Figure 5.

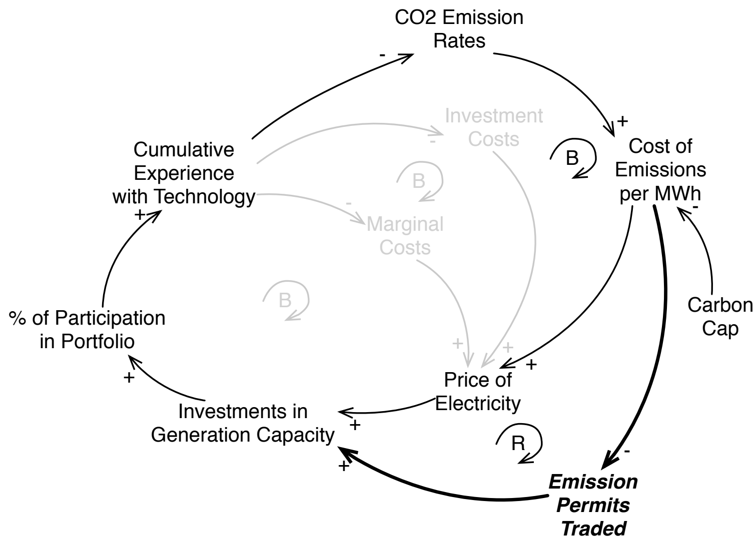

Figure 5: Effect of the emissions trading market.

Ultimately, the objective of the regulator is to reduce CO_2 emissions, while maintaining the security of supply, and control consumer electricity prices. Motivated by reduced emission permit costs, players with predominantly clean technologies, will opt to trade more of their emission permits, thus achieving an improved technology mix, which will result in lower emission permit prices in the market, as illustrated in Figure 6.

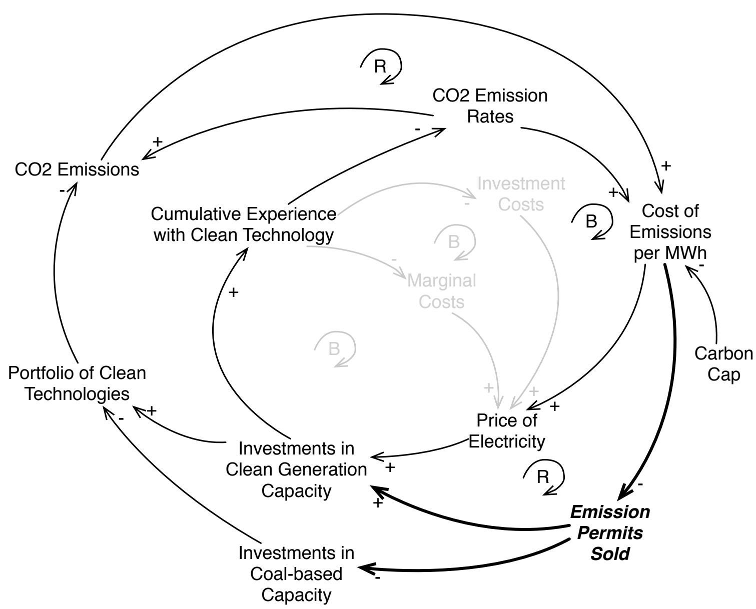

Figure 6: The long-term effect, a cleaner technology mix. Is it achievable?

A final causal structure of interest is the role of the policy maker, which can use capital raised through emission permit auctions to invest in social programs aimed to educate the population on energy consumption habits, and can results in decreased demand for electricity, as illustrated in Figure 7.

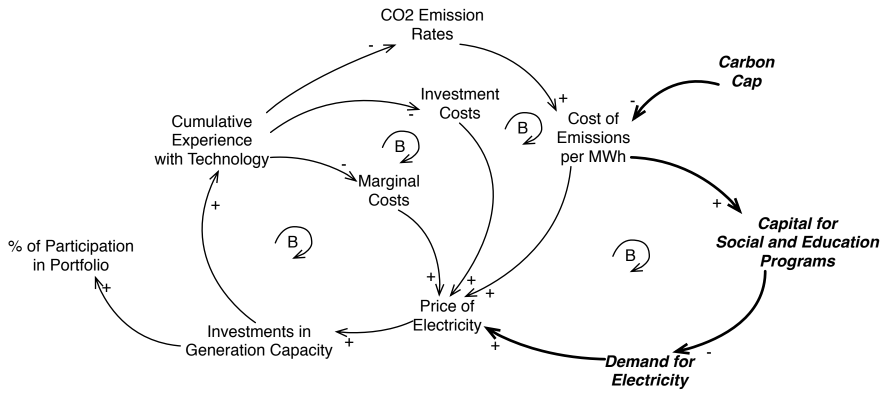

Figure 7: Investing in social capital and education is a choice for the policy maker.

3.3 Stock and Flow Model and Results

The causal-loop behavior described above is implemented in a system dynamics model simulating a region as broadly described Module 5, and was developed using iThink version 9 (model will be made available as part of this document). Converters in red denote decisions to be made by players. The model relies heavily on arrays to capture different generation firms, technologies, and social programs. We discuss briefly the main sectors of the model, which will also be made available as part of this submission.

3.3.1 Power Generator Firms

The sector modeling power generating firms is depicted in Figure 8. Note that most of the complexity of the diagram arises from our attemps to model complex decision process to emulate what players would do during the actual game. These decisions are based on standard technology valuation concepts. For example, players will bid their capacity on the daily market on the basis of their "marginal" costs, which in this case involves fuel costs (modeled endogenously), emission permit values, as well as opportunity costs (generators running out of permits will increase their bidding prices). Similarly, players decisions with regards to permit auction prices, investment in old and new technologies are modeled using standard economic approaches.

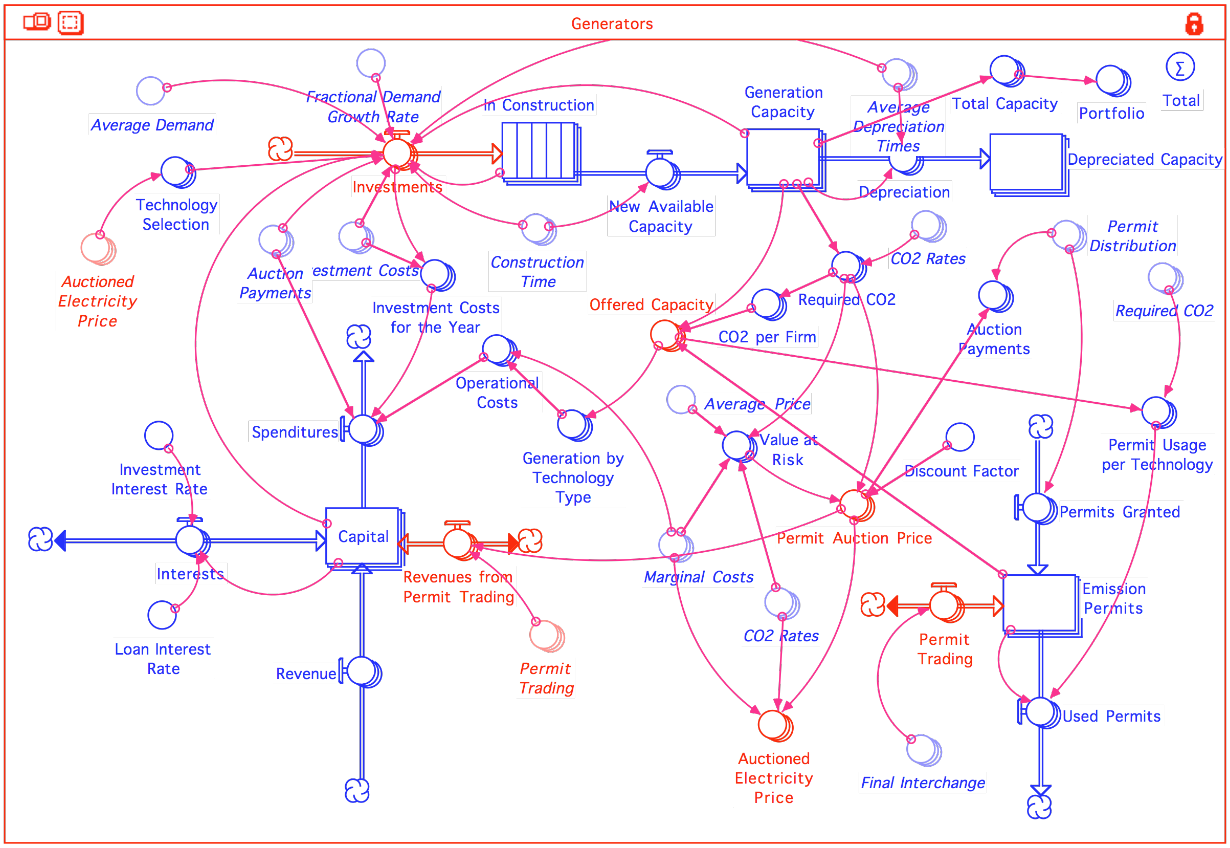

Figure 8: Stock and flow of power generation firms sector.

Figure 9 shows the portfolio of technologies, illustrating how over a period of 10 years, coal slowly replaces coal as the preferred generation technology. The model is very sensible to changes to the generation technology.

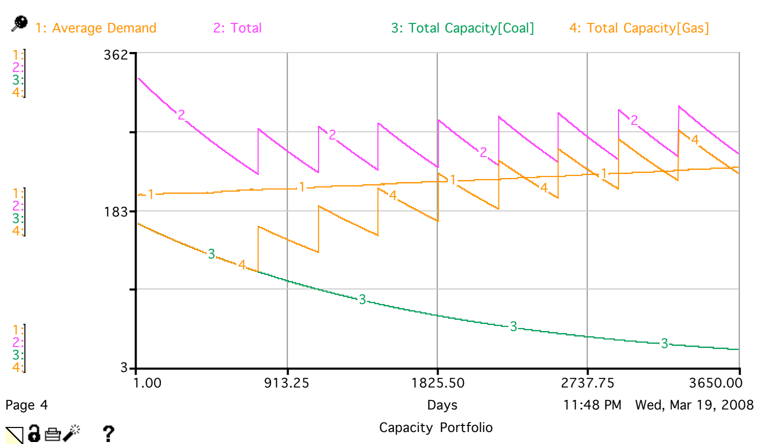

Figure 9: Technology mix for a sample run.

3.3.2 The Demand Sector

This sector, illustrated in Figure 3.3.2 left panel, captures the dynamics of demand growth by using two time scales. In the longer view, the peak demand increases at a constant rate. This reference value is used to compute the daily demand for electricity on the basis of a random distribution. In addition, investments in public education and conservation will have an impact on efficiency that can results in a diminished demand. Results of a single run are illustrated in the same figure (right).

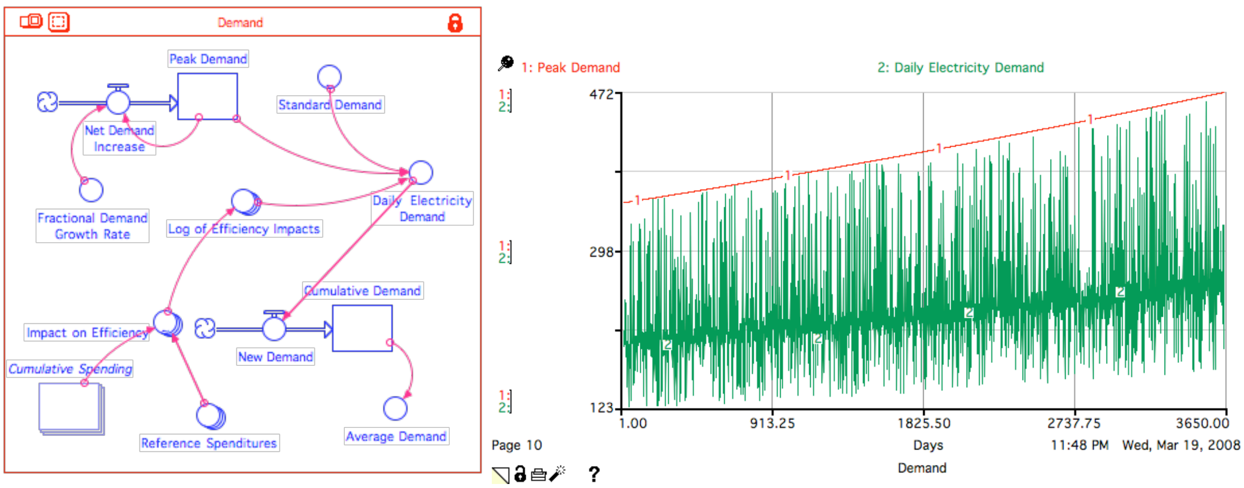

Figure 10: Sector modeling the daily electricity market, which generates based on players' decisions a dispatch, as well as "market clearing price". The output of the model is depicted on the right.

3.3.3 The Policy & Environment Sector

This aspect of the model deals with decisions about CO_2 abatement policies, permit auctions and distribution, as well as social program investments. The sector structure is depicted in Figure 11, which highlight policy makers decisions in color green.

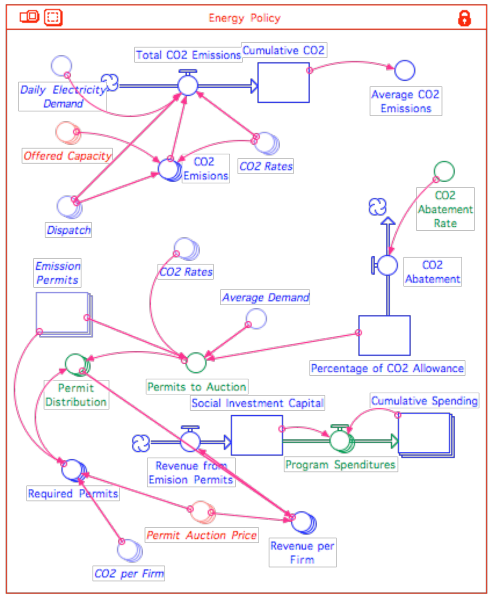

Figure 11: The energy policy sector.

3.3.4 The Technology Sector

Models marginal costs, emission rates, and investment costs for a portfolio of technologies (see Figure 12, left). The impact of experience in marginal costs is depicted in the same figure (right). As generators produce more, they gain efficiencies that allows them to lower marginal costs.

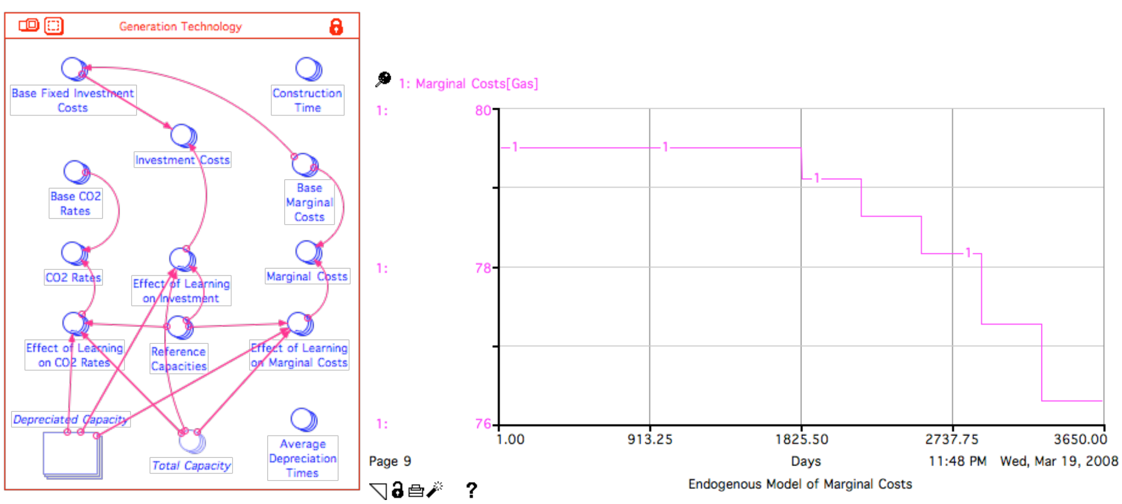

Figure 12: The technology sector models key technology characteristics endogenously, and its output.

3.3.5 Other Sectors

Other sectors not discussed here include the daily "spot" market for electricity, as well as the emission permit market, depicted in Figure 13.

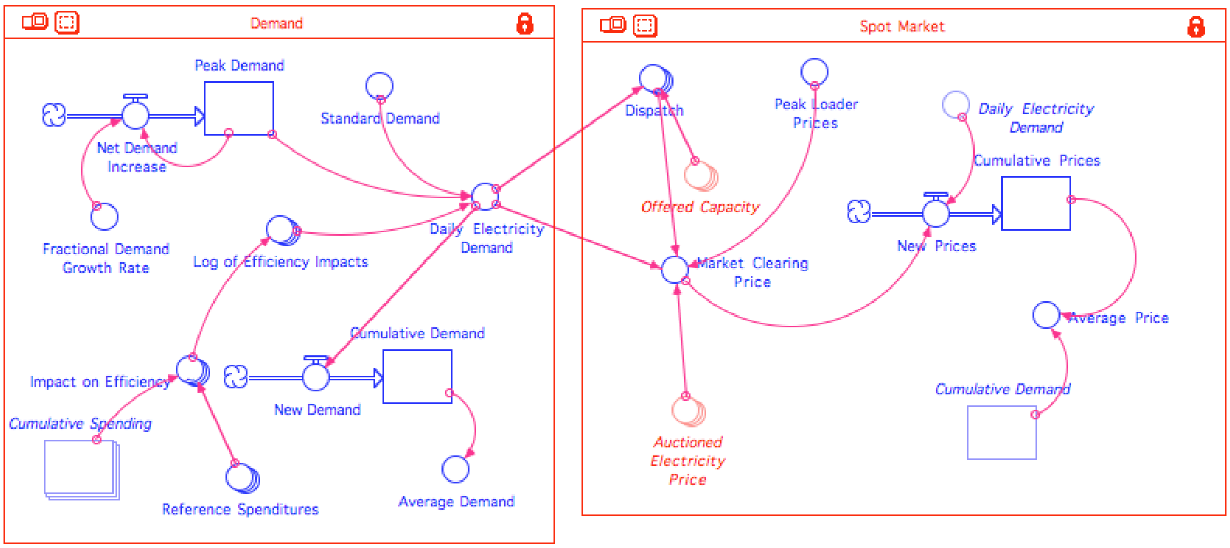

Figure 13: The technology sector models key technology characteristics endogenously, and its output.

4 Users

The FILCET first target are regional communities. It is expected to become a communication tool that facilitate the emergence of social networks for CEC risk management and innovation. This basic concept is on its first experimentation stage with the collaboration of the Renewable Energy Network (REN) operating in Coahuila under the support of the COECYT (the same institution supporting the FILCET project).

4.1 Results and Observations

First trials with REN concept are ongoing. Initial results are:

1. Testing of the system dynamics model shows behaviors valuable for gaming.
2. Workshops with REN groups are giving insights about the proposed route. Observations collected heavily concentrate on mechanics of module 5 and in building the collective map.

The results of the first FILCET appraisal will be presented at the conference.

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