# "Modeling Future Energy Systems Focus on Sustainable Development"

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# Abstract

Modeling future energy demand, at a city level, it's a very complex problem were many agents establish complex relations between each other. To handle this big problem, it is necessary to represent the consumption of energy in the Industries, household and transportation. It is important to realize that we are considering energy demand as electric and heat demand so the models have to represent booth areas.

Industry grows in a dynamic way, industrial sectors have different levels of evolution, some are more efficient than others, some are more contaminant and others more regulated. Sectors of the industry present characteristics like; percent of grow and dead, level of evolution, efficiency, supplies, products, elasticity, etc.

To represent different sectors of the industry an agent modeling is propose. These allow to make more complex models for the most important agents and more simple ones for others less important, regarding the estimation of energy demand. Other important consideration of this approach is that the transportation can be include as an agent, in connection with almost all agents, nevertheless transportation model will run independent of industry model.

On household's models clustering techniques will be used for determinate types of electric consumption. These results will be cross with other characteristics of households (Censo's data) for finding patterns of consumption related to the characteristic of the house and the consumer. These patterns will be very important and will have incidence in the industry model.

Consumers and Industry are in a continuous feedback. The behavior of consumer affects Industry and vice versa. This relation will be incorporated to the modeling and the consumers will consume from Industry, like any other agent. The patterns of the data mining will be inputs for each type of consumer, connecting the two approaches. Consumers will act according to fuzzy rules for decision making, representing in a more realistic way human behavior.

For connecting models with the information require and to storage future simulations, a main repository or Data warehouse will be developed. All this new ideas are explain in the methodology and architecture and models chapters.

# Research Questions, Hypotheses and Outcomes

## 1. Proposed Research Questions

The main questions that models will answer are: How much energy consumption and $CO_2$ is related to households, transportation and industry?. How much energy and $CO_2$ is consume and produce per person?

Regarding the agent modeling on industry and transportation and also considering different types of consumers, models will be able to explain: Which are the driving factors that determinate energy consumption?, What policies lead to more sustainable energy consumption?. How the evolution of different type of consumers will affect the amount of energy and $CO_2$ consume and produce?

Next more specific research questions are formulate.

### 1.1 Households models

Regarding the modeling of households with real information, the specific questions are:

➪ Which are the main variables that allow to differentiate consumers?, Which rules of decision making are more important regarding sustainable development?, How much energy will consume a specific type of client? , What relations could be establish between the heat/cooling demand an electricity demand within the groups or among them?

➪ Which are the variables, not included in the data, that affect energy demand? Which is the best way to include these variables in the models?

These questions aims to identify the need for representing new variables, not present in the data, that affect energy demand. For example: windows per house, could be a variable of interest for the heat demand. This variable can be generated with the real information considering for example; Municipalities, number of rooms, number of people living in the house, house or flat, etc.

➪ What factors will be appropriate to include?. Which will be the evolution of this factors?.

A first idea to solve these problems would be to use a hybrid model, which consist of using measures, new variables generated with the data and external variables. This model might include different factors like technological factors, behavior factors and also market factors.

### 1.2 Industry and Service models

➪ Which are the main Industries in Santiago?, Which are the main Companies among this Industries in Santiago? Which are the processes that determinate energy demand in these industries?, How to treat the industry of service and how differentiate them?. How much energy consume the industry and service in Santiago? and how to relate this consumption with the population to determinate the amount of energy consumed per capita?.

➪ Which are the principal wastes of a company?, How contaminated is the process of a company?, Which is the degree of technological automatization in the Industry and the company?. Which are the parameters and criteria for a Reference Company?

### 1.3 Transportation models

➪ How is the behavior of people regarding the transportation in Santiago?, Which will be the main transport modes in the future and which are the technological factors that allow this assumptions?, How will evolve the electric transportation and which technologies are more likely to emerge?

## 2. Hypotheses

➪ Finding patterns of behavior in the energy consumption for households, using real and generated data, allow to estimate energy demand per person and energy demand per person per square meter.

➪ For estimating energy consumption in Santiago's Industry and Service it is necessary to analyzing the main processes in different areas of businesses and relate this consumption to a certain fraction of the population.

➪ To identify different behaviors in the transportation, is the key to understand future trip and determinate the amount of energy per person used in transportation.

## 3. Outcomes of the models

The indicators that we expect to evaluate within the energy group as an outcome of the energy consumption models are:

➪ Total final/primary energy use in GJ and GJ per capita (in relation to global average and differentiated by heat and power)

➪ Energy - related $CO_2$ emissions.

# Methodologies

## 1. Industry Models

### Mapping Industry

First of all it is necessary to research which are the most important industries in Santiago and which companies can be representative of each Industry. Another important research is to determinate which processes of production, that requires energy consumption, are the most important in each Company. The idea is to develop "Examples Companies" within Industries, that allow us to model the behavior of energy consumption for a particular Industry.

One "Example Company" (EC), will have very specific characteristics and there will be a number of different EC per Industry. One of this attributes will be its load curve of energy and electric load curve, characterized after the analysis of it processes.

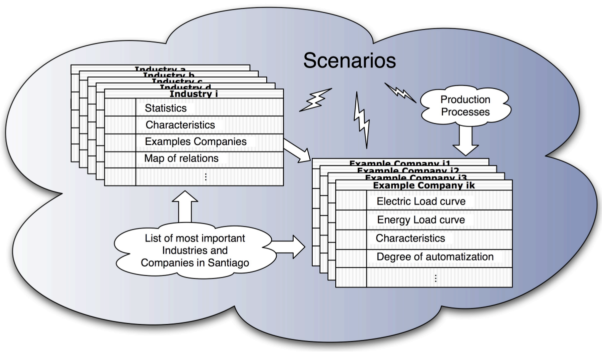


*Figure 1 : General Scheme of Agent Model*

The task of work with time series information (load curves, temperature curves process, etc), statistics (mortality and growth of industry, etc) technical factors (degree of technology, wastes of production, efficiency, etc) and market index (market share, level of competitiveness, etc), suggest the need to developed this models in a object environment, like JAVA, were the industries and companies can be objects or agents (with characteristics of their own) that can interact with each other and with the scenarios we will consider, producing levels of energy consumption in different industries. Agents define the system and they can learn and interact with other agents. The International Industry classification (ISIC) will be use to define agents in industry and service. One main repository or Data warehouse will be use for storage all these information.

**Clients and their interaction with Industry**

Different types of clients will be generated using; the results of the pattern recognition of households models and parameters of evolution to represent personality of consumers. These consumers will interact with the industries producing an equilibrium. The next Figure represent the interaction between household's models, base on data mining techniques, transportation model base on human activities and Industry models base on knowledge.

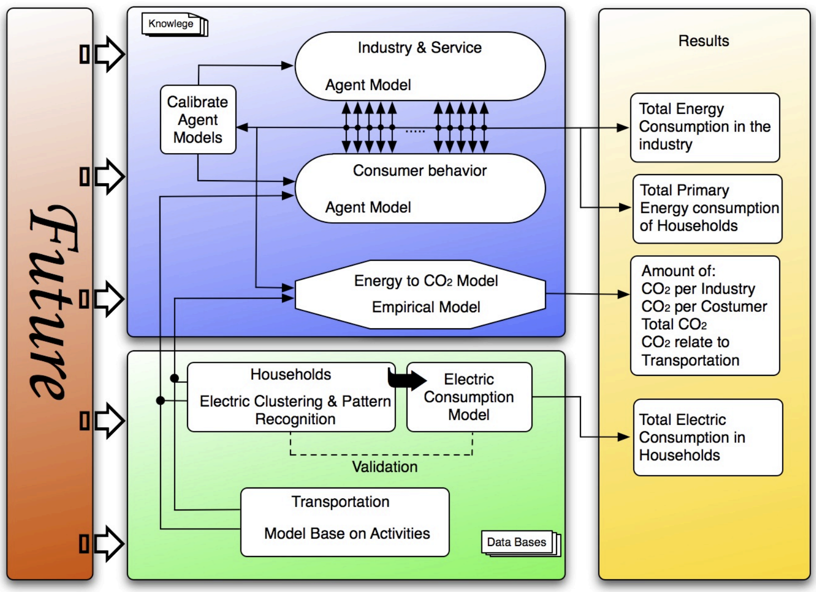


*Figure 2: Relation of models and main outcomes*

Industry and consumers are in constant interaction. Industries produce for consumers, so the evolution of customers will be important. How much will grow the average class in Santiago? , What are the main characteristic of this class?, What amount of externality is related to this class? These are some of the questions that will be answer in the process of determinate energy consumption. A general explanation of these ideas is developed next.

## 1.1 Consumer or Client

Clients will be generated with the characteristics of the pattern recognition (household model). Also every client will have variable parameters that will represent different behavior on decision making. Each client will be classify by the electric clustering i (♺) and it type j (A, B, C, etc).

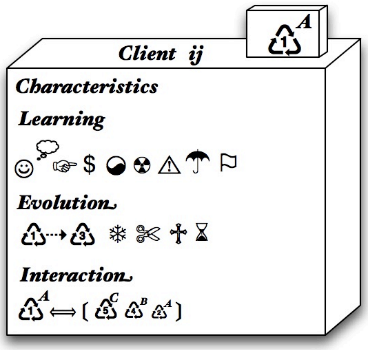


*Figure 3: Representation of Clients*

One client ij is representing a group of people gather or a family that consume energy. The client ij will have a group of main characteristics that define it. For example one client 1A can be characterize by; the importance of money for it ($), the non ecological conscience (☢) and reluctance of helping others (☂).

Nevertheless other Client 1B could have exactly the opposite characteristics compare to the first one.

These "ideas" that define types of clients can be addressed to the client decision making with fuzzy logic and objective functions, therefore representing human behavior in a more realistic way.

Different type j of clients i will be generated. The characteristics and the types of rules use on decision making will be explain by detail in the final paper, regarding the consumption of energy. Also a client will have the possibility to evolve and changes from one type of client to another. Some clients will have more interaction with certain groups and specifically with clients with specific characteristics j.

Clients will grow and die. In theory, one client is generate when a part of an old client form a new spot of consumption. When a client changes from one house to another, this client might or might not evolve to a different class of client. A client die when the house that he use stop consuming energy, or when all the people of the client die or form other client. To handle the generation, grow and dead of clients we will define the concept "stages of life". The "stages of life" will be the main steps that a client makes in his life. For example in the first stage a client could be a group of friends that move out of their parents house or a new family (with out child), in the second stage we will find a family with son(s) in primary school. The third stage could be a family with son(s) in high school or university and the fourth stage could be the parents with son(s) that move out of the house. Aggregate information of the transportation database can be an input in this case, because the "stages of life" will be part of the trip generation model of transportation. Also a random approach can be implemented for this task.

Every client will have an electrical load curve that represents his electric consumption, and also have structural characteristics of the house. This information, add to standard levels of heating in Santiago, will be use for the estimation of heat demand (primary energy) like a complement of electric load behavior. In this case the evolution and the type of clients will affect the amount of energy demand.

Clients buy things with money and depending of what they buy they will be responsible for the externality within the product they are buying. For this reason ecologic clients will buy less contaminant cars than non ecologic client, etc. This kind of relation between decision making and consumption will be clarify in the final paper.

Salaries will be defined from a series of characteristics of the client and the house, considering for example the number of children living in the house, the neighborhood, PIB, etc.

The act of buy things and assign time to activities will be associated to the characteristics of the client, considering that he maximize an objective function. The list of thing that consumers can do or buy are define in the final paper. Every client will buy at list a minimum first necessity products for living.

Activities will be in deep relation with the energy consume in transportation and in some cases this activities will produce purchase. Many levels of aggregation will be helpful to model transportation based on the idea that trips are not justify by it self but in the necessity of doing activities.

### 1.2 Industry

All main industries will be mapped with technical information about it processes, statistics and historical data. Industry will produce a limited amount of product and we will be interest only in product that are related with significant energy consumption.

Industry give products to the consumers, consumers give money in return. Every industry will have examples companies that manage an inventory of their supplies and products. Each supply and product will have a list of attributes useful for determinate its nature, levels of contamination, previous processes, amount of $CO_2$ generate by one unit of product, price, elasticity, etc.

Industry will have degrees of knowledge in some sectors, related to improve in technology, management and staff.

The International Industry classification (ISIC) will be use to generate agents in industry and service. The electricity and gas industry will be important connected to all costumers. Also a transportation agent, connected to all clients will be generating with the information of transportation models.

Public products will be trade like any other product. Consumer use public industry and pay a part of the externalities that it's produce. The Government will be responsible in a certain percent for the public Industry emissions and externalities.

Behind the production of industries and the consumption of client is a model of equilibrium that restricts the amount of goods that clients can buy. These results will be compare with the outcome of the FoA economy.

### 1.3 Validation

For validation two approaches are proposed. The first one is to have one starting point of information in the past to get to the present and compare the result with actual data of industry, population and transportation. This will be call validation test (past to present).

The second approach use two points of information in the past to go from the first point to the second, studying the parameters of evolution for doing it. This will be the training of the agents (past to past).

Different Censo information (2004-2002) will generate different results in pattern recognition, changing the starting points that will represent the current situation in the past.

The study of the sequences of parameters that produce the pathway between the first and second point in the past is not an easy problem of the second approach. An artificial neural network (ANN) will be trained with the actual parameters of evolution that affect industries and consumers and then, associate this with the vector of parameters that define a scenario. The training of ANN will be supervised. At the end the ANN will be prepare to determine the parameters of evolution to characterize scenarios. So this ANN will determinate the parameters that the evolutionary algorithm need to evolve to a certain scenario in the future. ANN will be evaluated in the validation test and in futures test to prove its logic.

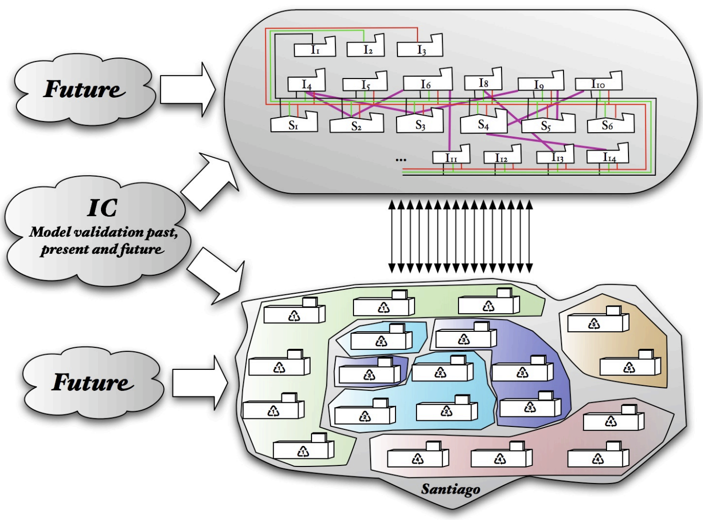


*Figure 4: Validation Scheme*

## 2. Transportation Models

For modeling energy demand in transportation we can use a Manheim approach, that consider activities the cause of tripping and not the trips in it self, or a Stopher-McDonald approach that make a trip generation by cross classification.

**Four steps model (Manheim approach)**

Levels of aggregation will reduce this enormous problem, and a four stage model will be used for the estimation of energy demand (generation of trips, distribution of trips, mode of trips and route assignation). Only the main activities that produce trips will be consider in the generation of trips. One of the most important division will be the trips generate base on households and trips generate no base on households. Other division in deep relation with activities will be the "stage of life", regarding that composition of house affect activities. Also season and week behavior will be considered in the aggregation of the time scale. For the distribution of trips it will use an origin-destiny matrix with the number of trips between zones. The geographic aggregation in zones will be defined in more detail in the final paper. The third step of the model will be the distribution of trips according to the type of transport, making an important distinction in transports that use primary energy and electricity. The fourth step of the model is the route assignation. Which routes of the network use, flow and timing.

**Trip generation by cross classification (Stopher - McDonald approach)**

This model is base on a category analysis, so demand in transportation is estimate considering the characteristics of houses and we assume that same type of houses generate a number of trips. This model allow to model demand independent of zones and with out functional forms, but requires a lot of information. Censo's data with data mining techniques could be apply in this case, although it is necessary to cross Censo's data with a transportation survey like (EODD).

## 3. Household Model

The first approach in the household's models is to develop the KDD processes (Figure 5) (knowledge Discovering Data Bases) in order to find patterns of different residential consumer behavior. The KDD process allow us to cluster households in different groups with the same consumption behavior, therefore for each cluster a representative load curve will be developed. This reduces the nonlinearity that a single model would have to represent the consumption of all households.

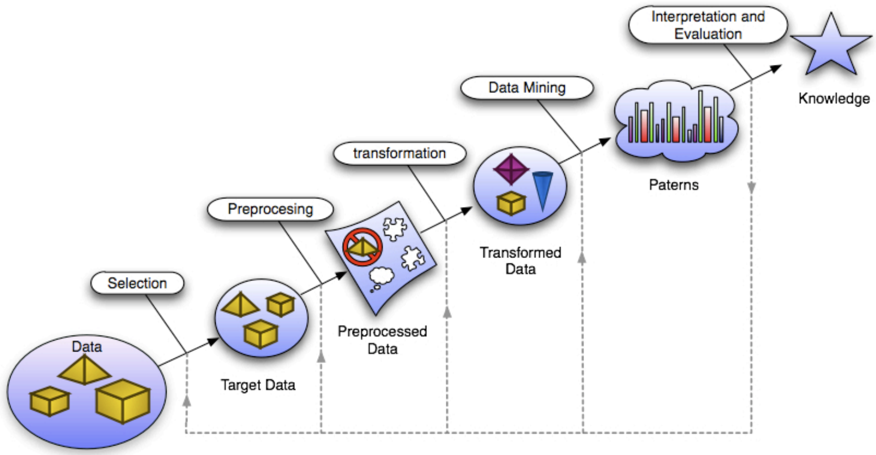


*Figure 5: Knowledge Discovery Data Base Process*

The first step of the methodology is to get the necessary data for characterized households (Censo's information) and measures of local consumption. Then the attributes that are more correlated with the objective of the study are selected, in the selection stage of KDD. These attributes can be aggregated or new variable of interest can be created in the preprocessing stage. In the next step the data is transform to be use as an input of a data mining technique. The data mining stage is where the model is developed. In households clustering we can use a supervised method like artificial neural network (ANN) and decision tree or a non supervised method like Fuzzy C-means, G&K, etc. When the clustering gives be the KDD process a time series model will be develop for each cluster, obtaining dynamic models for all household.

### 3.1 Data Bases Requirement and work in progress

Another important aspect of the project are the databases we will need to use. To characterize different types of house we need Censo's database. For modeling electric demand we need data from the distribution company Chilectra. These measures had been used in previous works and are register per fifteen minutes and per month so the time series models will be adapted to this time scale. Figure 6 show the Integration of data bases and the order of processes.

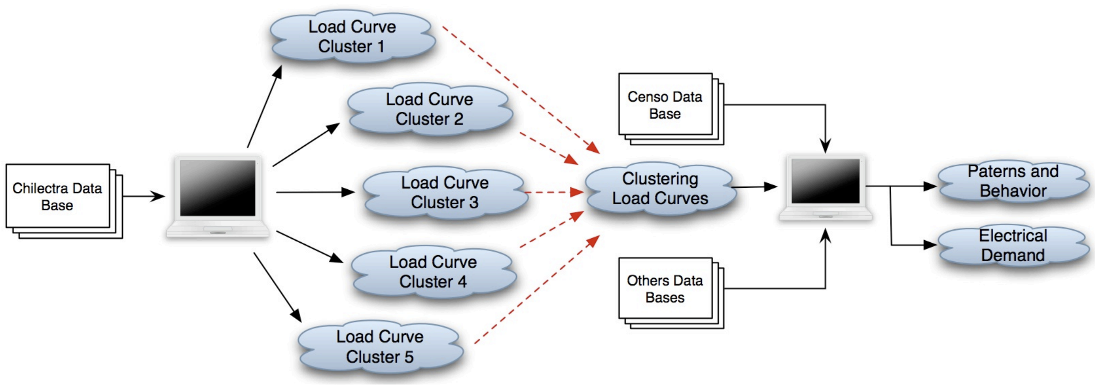


*Figure 6: Clustering Electric Behavior and Pattern Recognition*

There is one important work done for Chilectra that will be use as an input in the modeling of residential demand of electricity [2]. For more graphical explanation of the models we are trying to develop I present one example of Flatow's work.

The picture in Figure 7 is the result of clustering residential electrical demand in a few days of summer time. The different time series are representatives of one type of residential consumption. These "average days" show the behavior of households, which change from one season to another and also have week cycles. These clustering, based on Fuzzy C-Mean and G&K (non supervised methods) are focus on daily load curves.

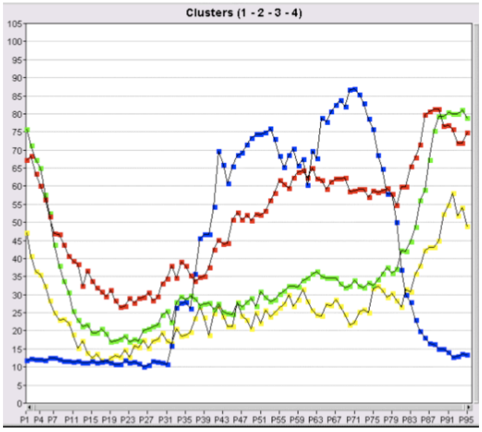


*Figure 7: Clustering electric load*

This method was applied to a small group of costumers selected with no clear methodology, so it has to be done again. The progress in this area is basically in the algorithms and methods developed.

The next step is to identify the factors that produce this type of curves using a supervised method, being the load curve the dependent variable of the model (an input). For example, the blue demand curve present a commercial consumption, with a peak only in the hours of work, nevertheless this is a residential client its behavior reveals commercial activities. What factors allow us to discriminate the type of load curve a household will have?. It could be related with the location of the house, the number of peoples living in this type of house, the number of rooms, etc. Using Censo's information we will determinate the main factors that allow explain the consumption behavior in a KDD process. Also there is a strong interaction between electricity and heat demand, therefore knowledge in electric behavior will help us to built a coherent model of heat demand.

# Architecture and Models

It's very important to clarify how the models will interact and which will be the architecture that will be use. Modeling energy demand in a Mega-city it is a complex problem specially because it's require a lot of information and modeling in different areas. For this reasons the approach we will use consist in one main repository or Data Warehouse (DW) surrounded by different applications appropriate for modeling a specific issue. The main repository will have all the information that some programs will require and this information could be upgrade, when one program runs, if the user wants. Operate like this allow to run applications not at the same time and use programs already developed to model, for example transportation. There will be two types of models, the first one use the DW to run and the second will run independent of the DW. The next figure shows the scheme use. Green models use data information from interviews or data available, and blue ones use more theoretic models: expert, fuzzy, evolution, objective functions, etc.

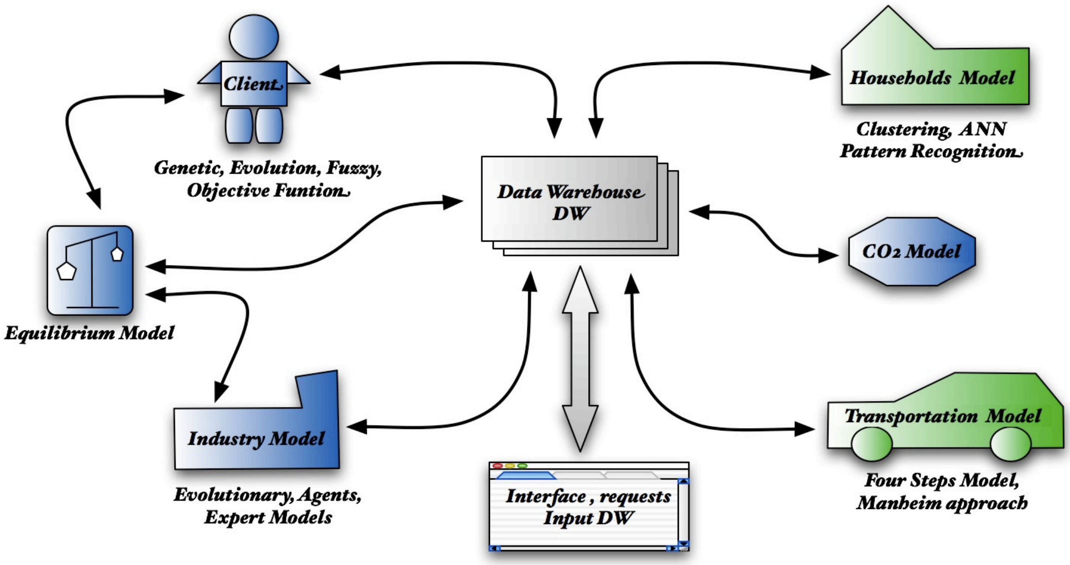


*Figure 8: Architecture of the Energy model*

For example, the transportation model will be developed in Gauss in a independent platform (type one), but the results of the transportation will affect all the others models, so the outputs of the transportation model will be incorporate to the DW. This information could be aggregated if there is no need of to much detail.

Household, clients, $CO_2$ and industry models use the information of the DW to run and these data could be upgrade if the user wants. In these cases inputs and outputs will be in plain text codify specifically for each program. Finally an interface will be use to make requires of information and to modify control parameters of evolution, scenarios, time frame, etc.

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