An Analysis of Residential Energy Intensity in Iran, A System Dynamics Approach

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Abstract*: substantial development of counties needs to use the resources in an efficient way. One indicator that shows the degree of efficient use of energy resources is energy intensity. Statistics show that Iran's energy intensity was in a bad situation during past years and if this manner of using energy resources continues, it will get worse.In this study a system dynamics approach is used to model changes of energy intensity in residential sector in Iran. By implementation and simulation of this model we found some reasons of this problem in Iran. Then we tried to introduce some policies to make steady improvement in energy intensity in the future.*

Keywords:
Energy Intensity, Energy Efficiency, Gross Domestic Product (GDP), Residential Sector

Introduction

Energy intensity is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP.

* High energy intensities indicate a high price or cost of converting energy into GDP.
* Low energy intensity indicates a lower price or cost of converting energy into GDP.

Many factors influence an economy's overall energy intensity. It may reflect requirements for general standards of living and weather conditions in an economy. It is not atypical for particularly cold or hot climates to require greater energy consumption in homes and workplaces for heating (furnaces, or electric heaters) or cooling (air conditioning, fans, refrigeration). A country with an advanced standard of living is more likely to have a wider prevalence of such consumer goods and thereby be impacted in its energy intensity than one with a lower standard of living.

Energy efficiency of appliances and buildings (through use of building materials and methods, such as insulation), fuel economy of vehicles, vehicular distances travelled (frequency of travel or larger geographical distances), better methods and patterns of transportation, capacities and utility of mass transit, energy rationing or conservation efforts, 'off-grid' energy sources, and stochastic economic shocks such as disruptions of energy due to natural disasters, wars, massive power outages or unexpected new sources or efficient uses of energy may all impact overall energy intensity of a nation.

Thus, a nation with mild and temperate weather, demographic patterns of work places close to home, and uses fuel efficient vehicles, supports carpools, mass transportation or walks or rides bicycles, will have a far lower energy intensity than a nation with extreme weather conditions requiring heating and cooling, long commutes, and extensive use of generally poor fuel economy vehicles.[1]

In this paper we investigate energy intensity of residential sector in Iran. To clarifying reader's mind below there is a terminology of concepts included in the paper.

Terminology[2]:

- **Energy Efficiency**: A value-based, philosophical concept. In this report, two different concepts of energy efficiency are discussed, a technical and a more broad, subjective concept. In the technical concept, increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs. In the more subjective concept, energy efficiency is the relative thrift or extravagance with which energy inputs are used to provide goods or services.
- **Energy Intensity**: The ratio of energy consumption to a measure of the demand for services (e.g., number of buildings, total floor space, floor space-hours, number of employees, or constant dollar value of Gross Domestic Product for services).
- **Gross Domestic Product (GDP)**: The total value of goods and services produced by the Nation's economy before deduction of depreciation charges and other allowances for capital consumption labor and property located in the

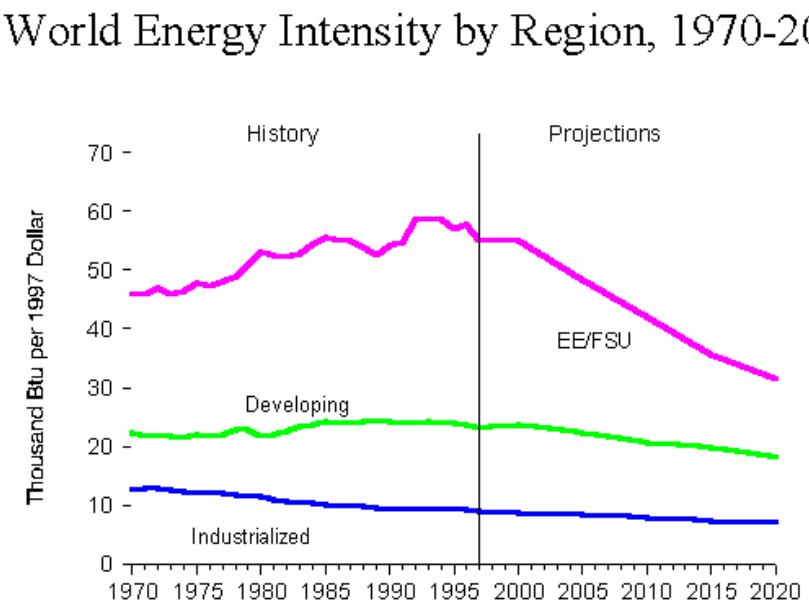
[1] http://en.wikipedia.org/wiki/Energy_intensity
[2] http://www.eia.doe.gov/emeu/efficiency/ee_gloss.htm

United States. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment, and net foreign trade. GDP figures are reported in real 1987 dollars, using the implicit price deflator published by the U.S. Department of Commerce, Bureau of Economic Analysis.

- **Sector**: The broadest category for which energy consumption and intensity are considered within the U.S. economy. For this report, four major energy-using sectors are considered: residential, commercial buildings, transportation, and industrial.

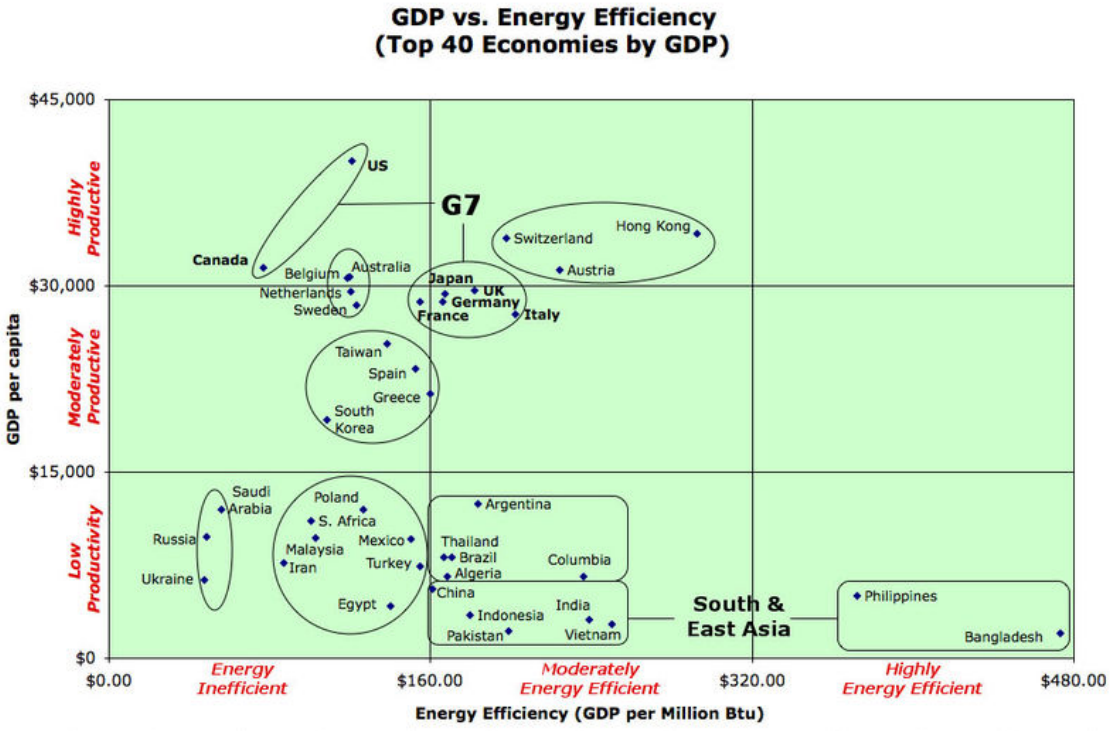
Problem Definition

In order to clarify the problem, first we note that as the table below shows world energy intensity has a decaying function.



Source: EIA, International Energy Outlook 2000

As table below shown Iran is energy inefficient with low productivity country.



But for countries like Iran energy intensity is going to be lower. For example Russia's energy intensity sketched bellow:

Reference: EIA, 2007

Fig. Russia's energy intensity

Note that not only Russia but also other countries like Turkey and China have decaying energy intensity function.

But for Iran we have a different situation.

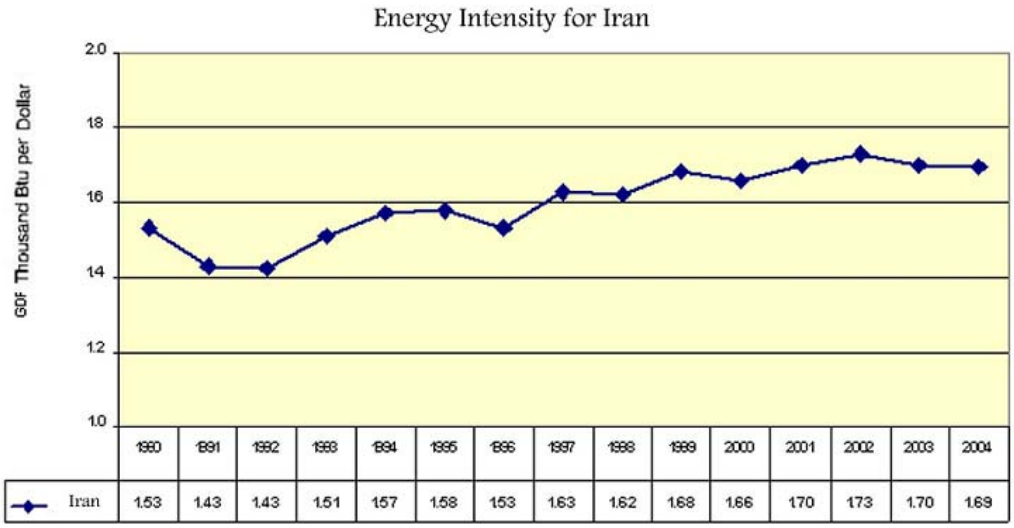
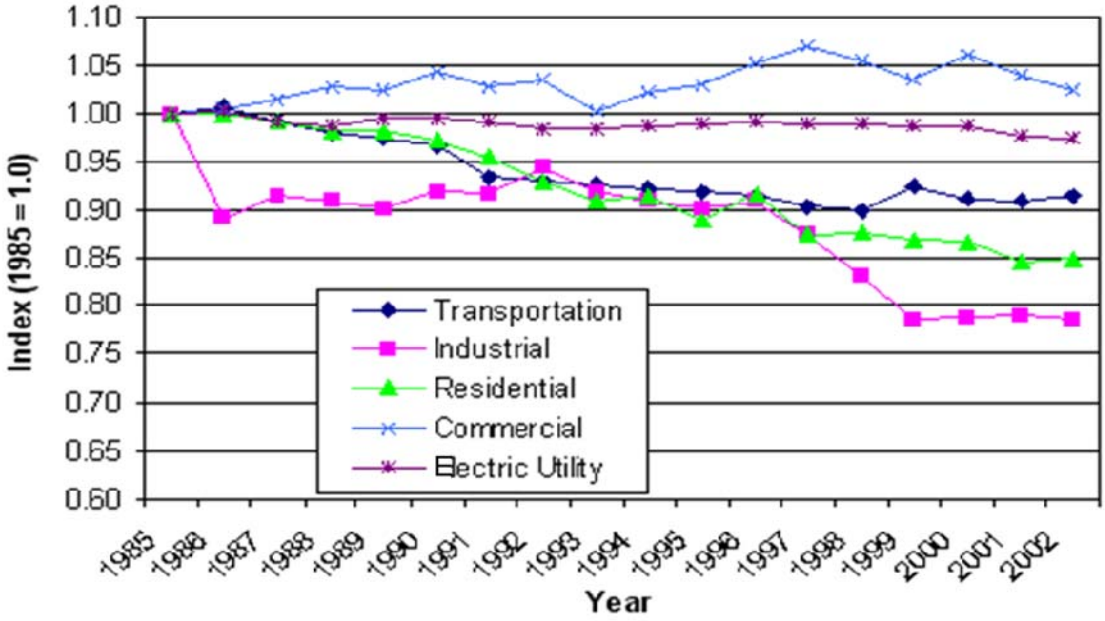


Fig. Iran's energy intensity is not decaying

This is the first phase of problem. But more accurately, table below shows each sector's share in the energy intensity. Pay attention to the residential sector's share. Its share is again decaying.



But again for Iran we have a different situation. Below figure when divided by GDP shows energy intensity for each sector. So residential sector in Iran has a growing share of energy intensity.

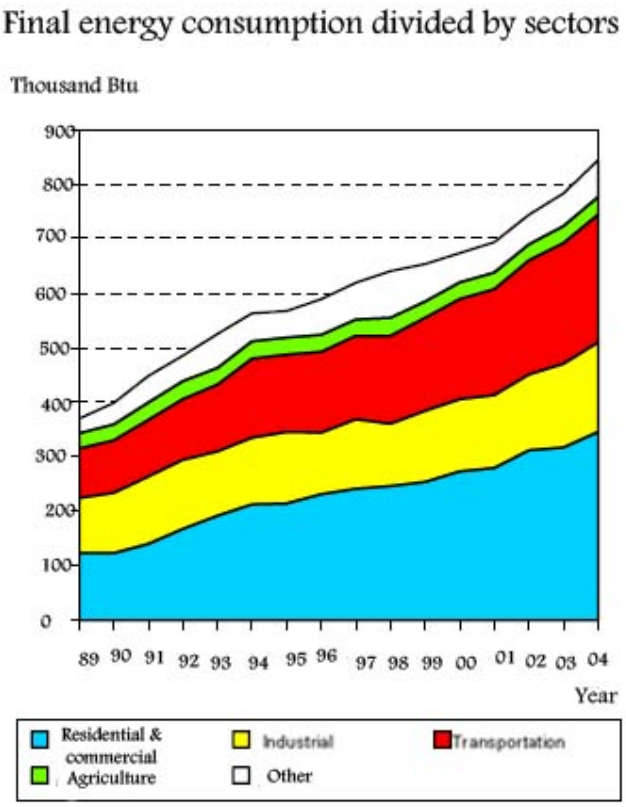


Fig. Iran's Residential Sector has growing share of GDP

Dynamic Hypothesis

High subsidy by the government results in a low virtual price.

Low virtual energy price sets by the Iran's government leaded on high and inefficient consumption without any attention to the amount of energy consumed.

In addition this low cost intensifies the consuming habits of the people, that causes more energy use.

Growth in the construction and Energy-consuming equipment used in the home when energy price is too low leads on inefficient buildings and appliances that need more energy to present an special service.(for example space heating or cooking).

Increase in GDP leads on increasing in family income that decreases the price elasticity for home and appliance and cause to buy more of these. As result energy consumption (here we make assumption that demand is equal to consumption) increases.

Government could not increase price because of two affects that cause pressure on it. One is direct effect of higher prices that cause satisfaction of people to become lower and make pressure on the government. Other is indirect effect of higher prices that causes Inflation and therefore lowers satisfaction of people.

Thus although subsidy puts pressure on the government to increase the price but people satisfaction will not allow this.

Causal Loop Diagram

This model consist of some loops affect each other. Each loop describes one part of the problem. The first group describes the effect of virtual price. (Not real because the government decides how much it is, not the market mechanism.) Having a virtual low price will increase the demand of energy in residential sector without any impact on the energy price. Because the government is the sole energy supplier, the normal supply and demand mechanism will not work. So we did not have this classic form CLD[3] for it:

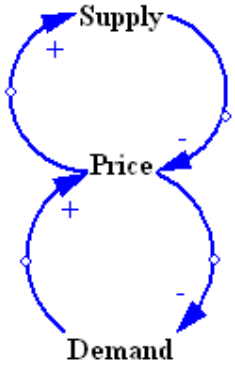


Fig. The normal supply and demand mechanism in the market

The supply will not be affected from the Price, only the Demand of energy will obliged the government to supply the proper energy.(To earn satisfaction of people.)

In the other hand because the price is set by the government, the supply will not affect it. So there is another form of CLD in which supply plays no role, it is illustrated bellow:

[3] Causal Loop Diagram

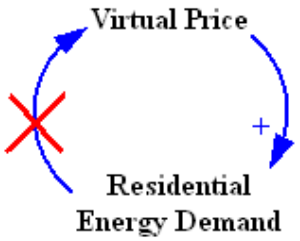


Fig. Only price affects the demand, and there is no role for supply, also demand has no affect on the price directly!

Other important loops exist to describe the subsidy and people satisfaction mechanism. The government pays subsidy and sets the price low, to earn people satisfaction. Any increase in the price (caused by lowering subsidy) will decrease the satisfaction of people and it will put pressure on the government to lower prices. A more important and stronger indirect affect is Inflation. Increase in energy price will cause Inflation and it will decrease satisfaction and put pressure on the government to lower the price. (Increasing subsidy)

Subsidy itself put pressure on the government to increase the price of energy to decrease the subsidy amount.

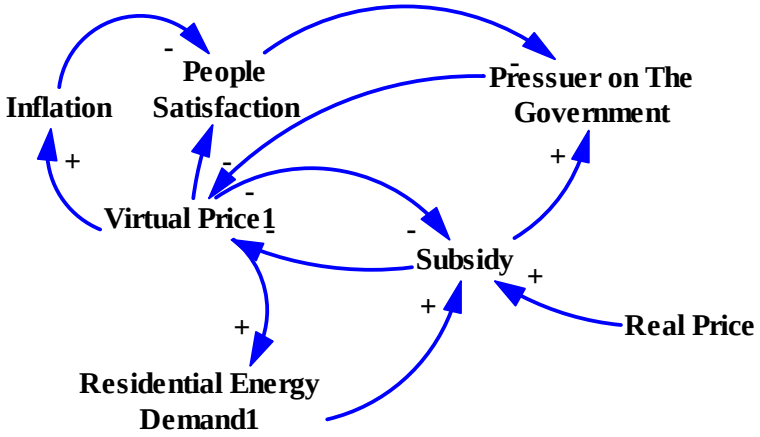


Fig. Subsidy and People Satisfaction

One other bad effects of virtual low energy price is that after a while it will become a people's habit to consume more and more energy.

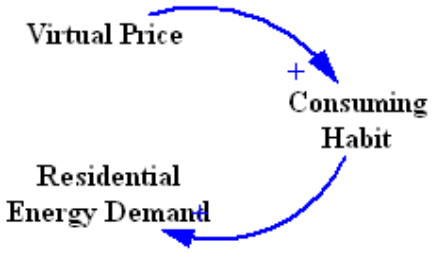


Fig. Consuming habits will increase Demand

There are special factors in the residential energy sector that affect Demand. "Building shell integrity" lowers energy consumption for heating or cooling buildings . "Appliance efficiency" lowers energy consumption of home appliances. Both factors are affected by energy price and prices needed to earn more efficiency. (For example a more efficient appliance with a better technology is more expensive.) But appliance efficiency is affected by energy price with delay, because it needs a period of time to change the appliances.

There is a happening called "Rebound Effect" that causes more energy demand. That is when appliance efficiency increases; it causes people to use it more and it results in more energy demand.

"Total building area" is an index of housing stock derived by census. It shows total area of all houses in Iran. (Number of houses multiplied by average houses area.) Greater houses need more energy for space conditioning services.

"No of appliances" indicates total number of appliances used in all houses in Iran. (Number of houses multiplied by average number of appliance in each house.) More appliances in the house increase more energy consumption.

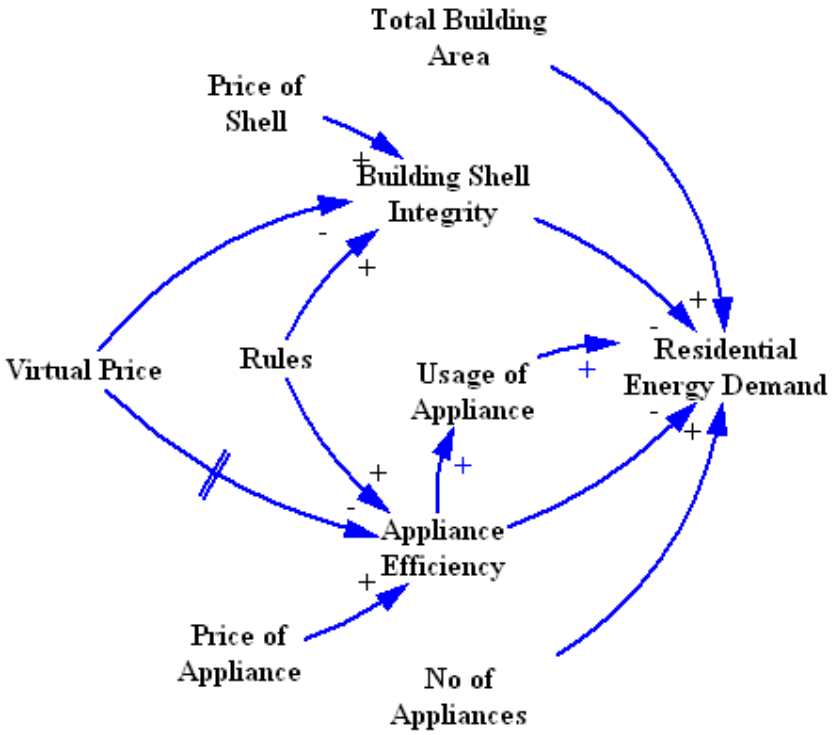


Fig. Low price of energy will decrease efficiency, as a result Demand for energy increases. Also "Rebound Effect" causes increase in Energy Demand

The last group describes how energy consumption and GDP affect each other. All parts of GDP in the Residential Energy Consumption Sector are added to it and other parts as an exogenous variable. Energy expenditures calculated by multiplying Demand and virtual Price, Inflation as the government expenditures, building area and Appliances as Private expenditures, and energy export income calculated by multiplying Energy Export and real price, are indigenous variables that affect GDP.

Another meaning of increase in GDP is increasing Family incomes, that illustrated by an arrow. As family income grows both "Total building area" and "No of appliances" increases, that is because people want to ease their lives. Also the same thing happens for energy demand. We can describe these events more scientifically as increasing in family income decreases the price elasticity for these products.

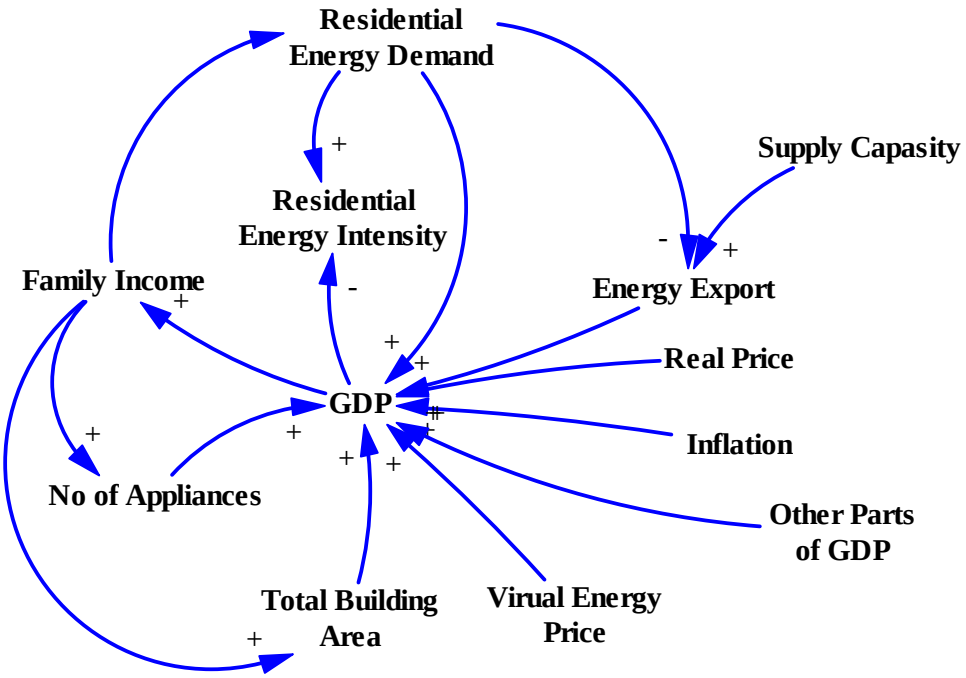


Fig. How GDP and Energy Consumption (Demand) affect each others.

Finally a combination of all these loops together will result in the whole system's CLD.

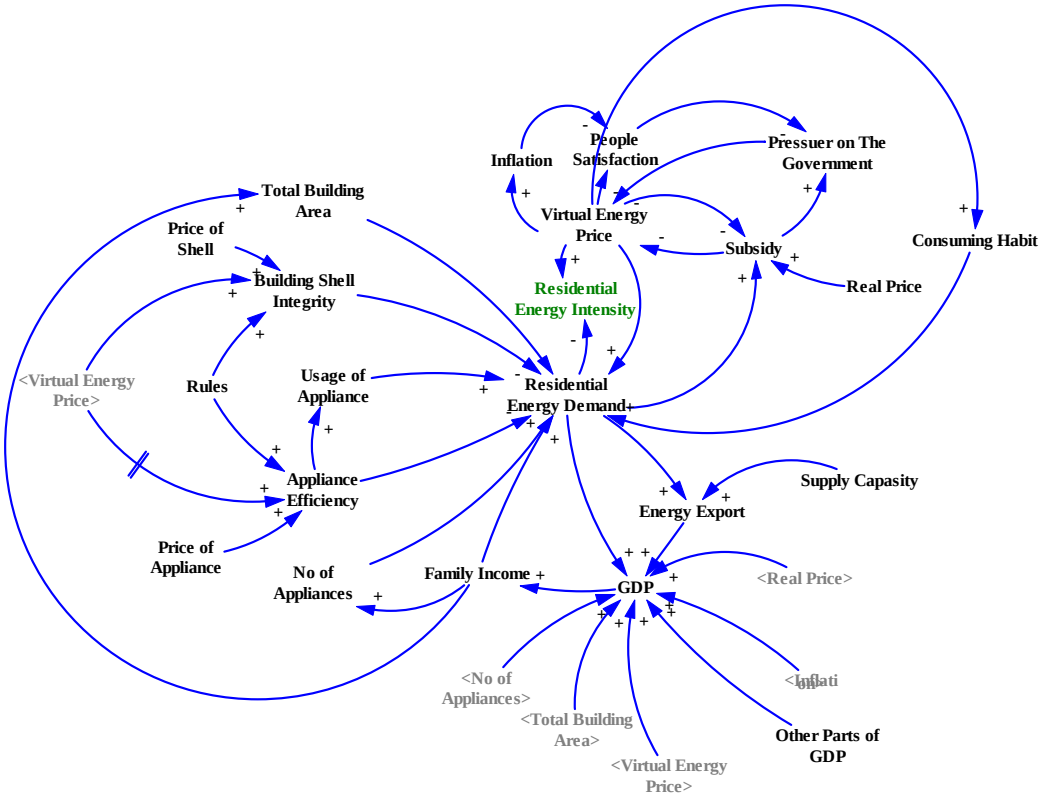


Fig. Causal Loop Diagram for Whole System

References

1. Sterman, J. (2000). “Business Dynamics: Systems Thinking and Modeling for a Complex World”, Boston, MA: McGraw-Hill Companies.
2. “Iran energy balance sheet”, Tehran, Iran’s Statistics Center, 2004.
3. Energy Information Administration Official Energy Statistics from the US Government, Annual Energy Outlook, 2004.
4. Torkan, Akbar. An Investigation on Energy intensity in Iran and the world, in Farsi:” Bar resie sheddate energy dar Iran va jahan”, 2007.
5. Office of Integrated Analysis and Forecasting Energy Information Administration U.S. Department of Energy Washington, DC,”Model Documentation Report: Residential Sector Demand Module of the National Energy Modeling System”. April 2005.

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