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Antecedents of Adopting Emerging Energy Efficient Technologies: The Case of Iran's Energy-Intensive Industries

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ABSTRACT

The main purpose of this research is to investigate the energy efficiency adoption process in Iranian firms, which have been experiencing two shocks that are an extensive energy subsidies reform and harsh international economic sanctions. Furthermore, I examine how Iranian firms' responses to emerging energy efficient technologies are characterized by sectoral and firm level features.

This research is built on explorative and empirical case studies. This methodology has been carefully selected to discover and examine how Iranian energy-intensive firms adopt and implement emerging energy efficient technologies and practices. For this purpose, I conducted semi-structured interviews of energy management practices within six firms in three energy-intensive industrial sectors including Cement, Metal and Petrochemical.

The results show that all six companies opted only short-term plans to survive from consequences of subsidies reform. Moreover, while some Iranian firms have responded to economic sanctions by purchasing lower quality energy-efficient technologies, the others have burdened higher cost of technology acquisition.

Key words: Barriers to energy efficiency, Case study research, Economic sanctions, Subsidy reform, Technology adoption, Industrial energy efficiency, Energy efficiency in Iran.

Key words (Italian Language): Barriere all'efficienza energetica, la ricerca Caso di studio, le sanzioni economiche, riforma dei sussidi, l'adozione della tecnologia industriale, l'efficienza energetica, l'efficienza energetica in Iran.

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1 LITERATURE REVIEW

1.1 Definition Of Energy Efficiency

Energy efficiency has had a key place in the public policy agenda of most countries in the past decades. This importance is associated to the national competitiveness and energy security benefits, together with to perceived environmental benefits such as reducing damaging emissions. But as Patterson (1996) mentioned, in spite of the ongoing policy concentration on the 'energy efficiency' and abundant literature on this hot topic, there are rare precise definitions of the 'energy efficiency' term.

The critical fact about energy efficiency is the relative nature of this issue and this nature can create ambiguity about it. For example nowadays energy efficiency can be interpreted differently in developed courtiers and developing countries. In many cases technologies, which are still energy efficient in developing countries, cannot be considered as energy efficient technologies compare to the available innovative technologies in the developed countries' market. This example also will stand for the time, technologies that were energy efficient in the past, will not be considered energy efficient now. So it is necessary to have clear definition of energy efficiency in hand when discussing about energy efficiency topics.

According to the Patterson's definition (1996):

> *" Energy efficiency is a generic term, and there is no one unequivocal quantitative measure of 'energy efficiency'. Instead, one must rely on a series of indicators to quantify changes in energy efficiency."*

Based on this definition energy efficiency generally means producing the equivalent useful output by consuming less energy input. Therefore energy efficiency has been usually broadly expressed by the simple ratio (Patterson, 1996):

$$\frac{Useful\ output\ of\ process}{Energy\ input\ into\ a\ process}$$

Equation 1 Energy efficiency. Source: Patterson (1996).

Jaffe, Newell, & Stavins (2004), Herring (2006) and Gillingham, Newell, & Palmer, (2009) defined similarly 'energy efficiency' as "energy services provided per unit of energy input."

Brookes (2000) distinguished three different definition of 'energy efficiency'.

- First law efficiency (enthalpic efficiency).
- Second law efficiency (entropic or thermodynamic efficiency).
- Economic efficiency.

Brookes argued that in situations like our today critical situation, "*when the chips are down*", it is the economic efficiency of energy use definition, which will dominate the scene (Brookes, 2000).

1.1.1 Types of Energy Efficiency Improvement

There are two possible types of energy efficiency improvement, substitution of capital (or labour) or/and technical change (Sorrell & Dimitropoulos, 2008) (Sorrell, 2007).

1.1.1.1 Substitution

Substitution here means replacing capital or labour inputs with energy to improve energy efficiency of a system. This situation usually happens when energy prices increase, and if any thing else remains unchanged, the total cost of production of the same amount of output will increase.

1.1.1.2 Technical Change

Technical change may improve both energy efficiency and total factor productivity. This can happen independently of any change in input prices and desirably occurs without any loss of economic output.

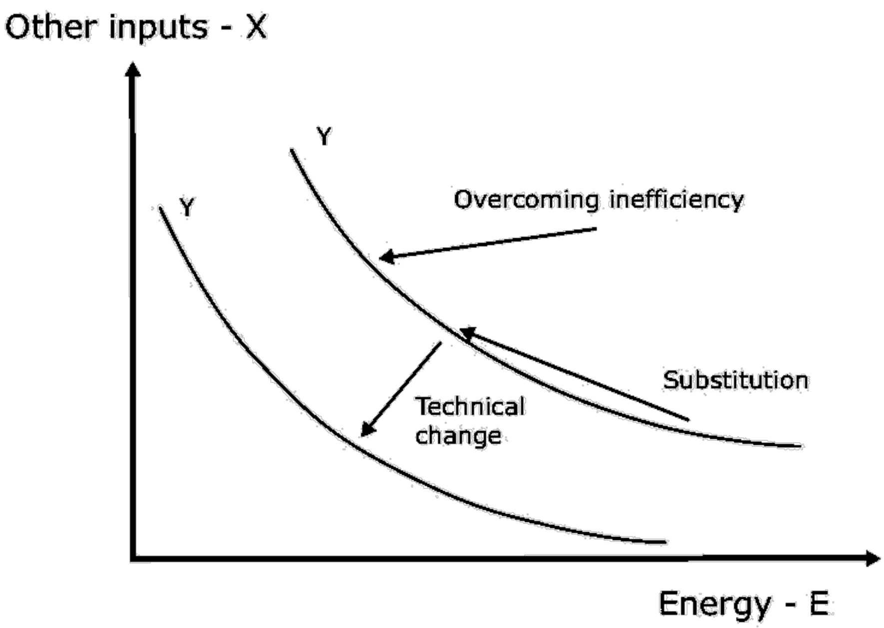

Figure 1 Energy efficiency improvements isoquants. Source: Sorrell (2007).

This conceptualization of the types of energy efficiency improvement could be mapped directly into a production function in which capital (and other inputs) (X) and energy (E) are viewed as inputs into the production of the maximum possible energy services (Y) (Figure 1). Along an isoquant describing a given level of energy services produced by different combination of inputs, the 'optimal' combination of factors input depends upon the relative prices of all inputs. When substitution is the action, it could be demonstrated as a movement along an isoquant to reflect change in relative prices (other inputs price/energy price). In reality it could be translated to the investment in an existing technology, which can works with different combination of inputs. But in the case of technical change, which denotes emergence of new technologies and methods of organisation, the isoquant will in favor of energy efficiency shift to the left. This means that the same level of output can be produced from a lower level of inputs (Gillingham, Newell, & Palmer, 2009; Sorrell, 2007).

Sorrell (2007) interprets three important implications from this distinction between substitution and technical change.

1- Although it seems that substitution is a 'frictionless' change from one existing technique to another, in reality it has costs and will take time.
2- The process of technical change is not an independent process, but it is influenced by changes in relative price of inputs.
3- The production function, as mentioned, illustrates the most efficient combination of factor inputs that is rare in practice. In this case, customer's Investment to improve energy efficiency can be showed as a move form less efficient to more efficient combinations within the identical production function 'frontier' (Overcoming inefficiency' arrow in the diagram).

1.1.2 Energy Efficiency Indicators

The next step of defining 'energy efficiency' is defining accurately the useful output of process or provided energy service, and the energy input, which in turn gives rise to a number of important methodological concerns that are often overlooked in the literature (Patterson, 1996).

Patterson categorized four main groups of indicators to monitor changes in energy efficiency (1996):

(1) Thermodynamic indicators

(2) Physical-thermodynamic indicators

(3) Economic-thermodynamic indicators

(4) Economic indicators

The first two groups of indicators are scientific and primary indicators that more rely on the essence of the energy sources. But the last two groups are more market-oriented indicators that try to measure the input and output of the process in terms of market prices. Especially the fourth group of indicators considers both numerator and denominator of the energy efficiency in monetary terms (Patterson, 1996).

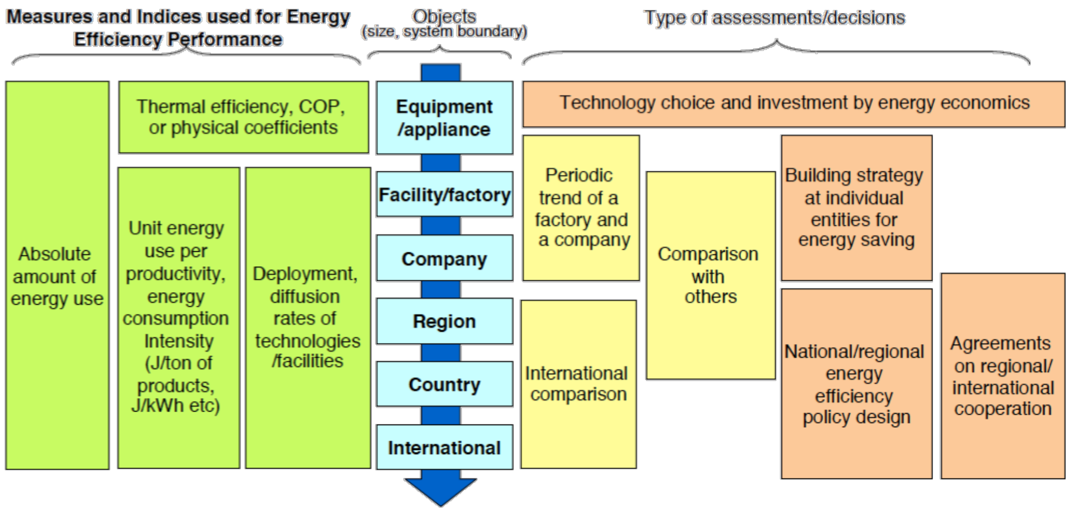

Figure 2 Measures and indices of energy efficiency performance. Source: Tanaka (2008).

Each of abovementioned sets of indicator of energy efficiency performance can be used for an appropriate purpose (Tanaka, 2008). For instance an industrial facility operator who wants to use energy economically can utilize thermodynamic measures, or a company who wants to check the trend of energy consumption in different factories and compare their productivity per unit of energy used can use Economic-thermodynamic indicators (Figure 2).

As Tanaka (2008) discussed inappropriate use of measures of energy efficiency performance (MEEP) could mislead the political direction or decision. Hence, because of the strategic purposes of this research that is looking more for the economic consequences of adopting energy efficient technologies in Iranian firms, the last two groups of indicators will be used in the following sections. So it is necessary to introduce these indicators in detail beforehand.

1.1.2.1 Economic-Thermodynamic Indicators

Patterson named these indicators as hybrid indicators, which use thermodynamic units for the measurement of energy input and monetary units for the quantity of output. This group of indicators can be used by different level of aggregation of economic activities. The main indicators of this group are:

- Energy:GDP ratio
- Sectoral Energy:Output ratios
- Energy productivity ratio (reciprocal of the Energy:GDP ratio)

1.1.2.2 Economic Indicators

When it comes to the economic benefits of energy efficiency or more precisely "economic productivity" of energy, we need a pure economic indicator that measure both input and output of the process in the market value. As Joint Economic Committee of the Congress of the United States (1981) stated the energy dollars:GDP ratio is "more accurate reflection of the economic productivity of energy, provided that energy prices reflect energy supply and demand forces." (Patterson, 1996)

However there are serious doubts about the effectiveness of these indicators, because unlike economic-thermodynamic hybrid indicator that measures energy by constant thermodynamic measurement, economic indicator tends to be unstable over time to measure energy in monetary units. Meantime it could be true that these indicators are more economic efficiency indicators than energy efficiency indicators (Patterson, 1996).

The main indicators of this group are:

- National energy input ($)/national output ($ GDP)
- Energy consumer cost savings

1.1.3 Economic Efficiency Vs. Energy Efficiency

After defining energy efficiency, there are some other terms that should be defined to have a clear image of their relation with 'energy efficiency'; one of these terms is 'economic efficiency'. Concept of economic efficiency is one of the complicated and disputed economics' concepts, which its review is totally out of scope and patient of this research. But still because there is the threat of considering it equal to the energy efficiency, explaining the differences between energy efficiency and economic efficiency will help us to better understand the path of decision making of different actors toward energy efficiency solutions. Despite energy efficiency, which is a technical and demand-side issue, economic efficiency is more a social and market-side matter (Gillingham et al., 2009; Gunn, 1997).

Energy efficiency, as a technical efficiency, occurs when there is no prospect to have more energy service by keeping the input energy constant. Economic efficiency, as a market-side issue, happens when the production cost of a product is the lowest possible amount; it is clear that energy cost is one of the components of production cost.

So maximizing energy efficiency is not necessary going to result in maximizing economic efficiency and vice versa (Gillingham, Newell & Palmer, 2009), but as Rosenberg indicated (1983), energy efficiency should appropriately be considered as just part of general economic efficiency (Brookes, 2000). Meantime there are empirical evidences that show improvements in overall productivity in all production inputs, resulted in energy efficiency increases (Rosenberg, 1983; Sutherland, 1998).

Relation between energy efficiency and economic efficiency is vague. Here the critical concern is that whether individual economic decisions about energy efficiency solutions are really economically efficient or not. To answer to this question, at the one hand the economic efficiency of the market condition (e.g., market failures), which customer faces, must be investigated, and at the other hand the economic behavior of the customer (e.g., behavioral failures) should be analyzed (Gillingham, Newell & Palmer, 2009).

1.1.4 Energy Conservation Vs. Energy Efficiency

The next controversial concept is "Energy conservation" that often wrongly is considered as the other face of "energy efficiency" coin in energy policy discussions (Herring, 2006).

Gillingham, Newell & Palmer (2009), and Herring (2006) defined energy conservation as a reduction in the total amount of energy consumed through lowering quality of provided energy service. Energy conservation would not often save money or energy; actually the amount of conserved energy comes from undone energy service, e.g. lower heating levels, through turning down thermostat levels (Herring, 2006). Energy conservation's main drivers are typically regulation, consumer behavior and life style changes (Herring, 2006).

But in the very contrary, energy efficiency, as defined previously, is more a technical (and economic) measure that will definitely save money and energy, while keep quality of energy service. Herring (2006) stated that energy efficiency is a by-product of other social goals: productivity, comfort, monetary savings, or fuel competition.

Therefore, energy conservation may or may not has a relation with energy efficiency, because energy consumption will not necessarily decrease by an increase in energy efficiency and even it may increase. The importance of this issue will be well understood when issues like "rebound effect" are up for discussion (Gillingham et al., 2009; Herring, 2006).

1.1.5 Jevons' Paradox

Jevons (1866) criticized common belief about energy efficiency, which advocates that new efficient and economical methods of using energy redeem the decline in energy supply. In other word, based on this belief, it is accepted that energy efficient applications will increase the useful output, while decrease or keep constant the total fuel consumption. He points out that by this way of thinking, "we have thus the means of completely neutralizing the evils of scarce and costly fuel" (Jevons, 1866).

Jevons in his famous book entitled "The Coal Question" wrote "it is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth." Although Jevons took coal as a general agent of energy, but interestingly he claimed that more efficient use of fuel (coal) will leads to its substantial consumption not just in past, but also in future (Jevons, 1866).

There is no doubt that despite huge enhancements in the energy efficiency or as Jevons called ‘economy of the use of fuel’, the world's energy consumption have been boosted tremendously since Jevons wrote his book. But this fact does not necessary means Jevons’ opinion on energy efficiency is completely true. As Brookes (2000) mentioned, the opponent view discusses that energy consumption’s trend has followed rising trends of populations and associated demand and supply. So logically we would experience greater energy consumption today, if the very large advances in the efficiency of use of energy have not occurred over the years since the beginning of the industrial revolution (Brookes, 2000).

Therefore, Jevons’s criticism does not mean that we should not pursue energy efficiency. As he truly mentioned:

“It is very economy of the use of coal that makes our industry what it is; and the more we render it efficient and economical, the more will our industry thrive, and our works of civilization grow.”

1.1.6 Rebound Effect, Tack-Back And Backfire

As Herring (1999) mentioned in his paper, several energy economists have argued that improved energy efficiency at the microeconomic level while causing a reduction of energy use at this level, leads not to a reduction, but instead to an increase in energy consumption, at the macroeconomic level. In reality parts of savings from efficiency enhancements will be used for additional energy consumption, which called ‘take-back’ or ‘rebound effect’ (Herring, 2006).

‘Rebound effect’ in short means that by having more energy efficient technologies the cost of energy services will fall and consequently the consumers will have more money in pocket to consume more energy than before (Berkhout, Muskens, & W Velthuijsen, 2000). Logically the rebound effect that comes from declines in marginal cost of energy services in response to the energy efficiency improvements (Gillingham, Newell & Palmer, 2009), may decrease the expected ‘energy conservation’. Nonetheless magnitude of rebound effect has not been identified yet; Herring (2006) outlined range of 10–20% as a more accepted magnitude. It is strongly argued that the magnitude of rebound effect is much less than 100% (Herring, 2006), but when rebound effect exceeds this threshold and energy efficiency gains lead to an overall increase in energy consumption, it will be named ‘backfire’ (Saunders, 2000; Sorrell, 2009).

There are three different effects of take-back phenomena (Herring, 2006):

1. Direct rebound effect: as a consequence of reduction in the price energy services caused by higher efficiency, the use of these services like any other commodity will escalate.
2. Indirect rebound effect: By lower cost of energy services, consumers will have more money in pocket to pay for other goods and services, which will add to the energy consumption of those consumers.
3. General equilibrium (economy-wide) effect: Changing in the cost of energy services will result in numerous adjustments of supply and demand in all sectors, which eventually both producers and consumers will consume more energy that before.

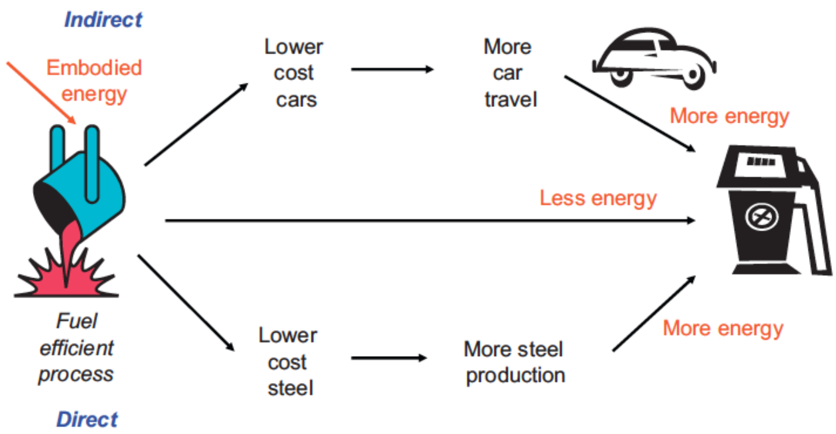

Figure 3 Illustration of rebound effects for producers. Source: Sorrell (2007).

Sorrell (2007) introduced similar categorization of rebound effect that in his scheme each of direct and indirect rebound effect (Figure 3) is divided to two subcategories, and he considered economy-side (general equilibrium) effect as the sum of direct and indirect effect. He classified direct effect for the producers into:

a) Substitution Effect: As a consequence of decrease in the cost of energy service, the cheaper energy service replaces for the usage of other production factors to keep the level of output constant.

b) Output Effect: Higher energy efficiency, by reducing costs, allows the producer to produce a higher level of output, which in turn increases consumption of all production's inputs.

And he decomposed the indirect rebound effect into:

a) Embodied Effect: The energy efficiency improvement itself consumes energy, for illustration the energy that is needed for producing and installing thermal insulation.

b) Secondary Effect: Energy efficiency improvements in one sector result in a set of changes in the users' purchase power as well as energy prices, which will encourage higher energy consumption in other sectors.

Sorrell (2007) also provided a diagrammatic representation for his categorization (Figure 4).

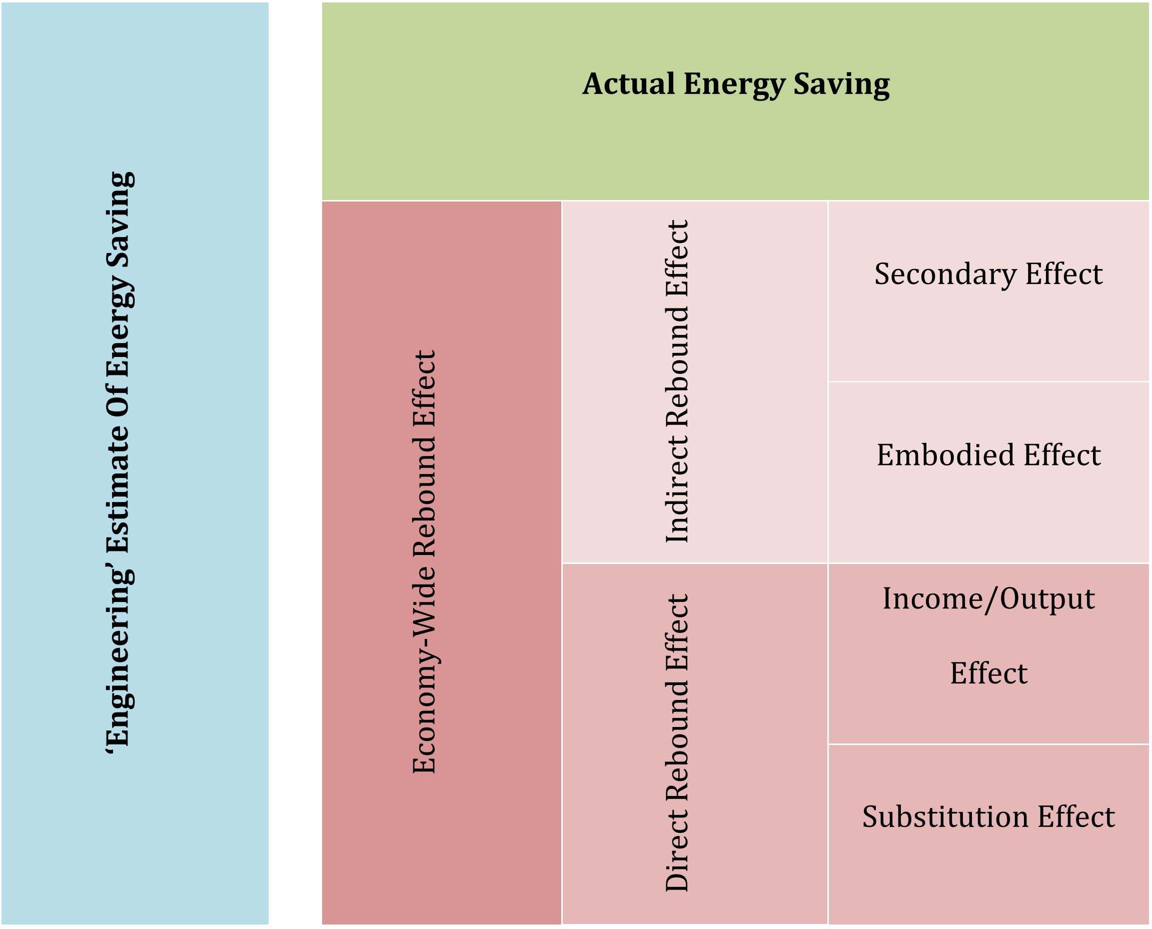

Figure 4 Rebound effect classification scheme. Source: Sorrell (2007).

Obviously the relative size of each component of Sorrell's scheme can be different form one case to another, and even it is possible that in some circumstances individual component of rebound effect turns negative. The total economy-wide effect theoretically can be negative, which is called 'super conservation', or more than engineering estimate of energy saving, which is named 'backfire' (Figure 5) (Sorrell, 2007).

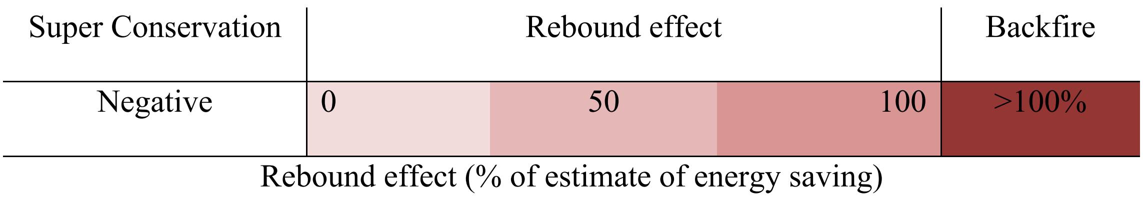

Figure 5 Rebound effect range.

But when rebound effect is going to become backfire and when there is the chance of achieving to a condition close to the super conservation? As Jevons showed in his book, 'The Coal Question', energy efficiency improvements of technologies such as steam engines and smelting iron, which have wide range of application, may have large rebound effect. Sorrell (2009), based on the Jevons' scholarship, argued that energy efficiency improvements related to the general-purpose technologies (GPTs), which have a broad range for development and expansion and are applicable across a wide variety of applications, particularly when these technologies are used by producers, can have such long term and significant effect on innovation, productivity and economic growth that as a consequence economy-wide energy consumption intensifies. In contrary to the GPTs, emergence of dedicated energy-efficiency technologies that have minor effects on productivity and economic growth, can result in decline in economy-wide energy consumption, specifically when these technologies are used by consumers or when energy service is an 'inferior good'. Not surprisingly, the first case (GPTs) is more likely to occur in the developing countries as result of their technological transitions (technology catch-up) toward modern productive technologies, and the second case is more likely to occur in developed countries that have productive industry (Sorrell, 2009).

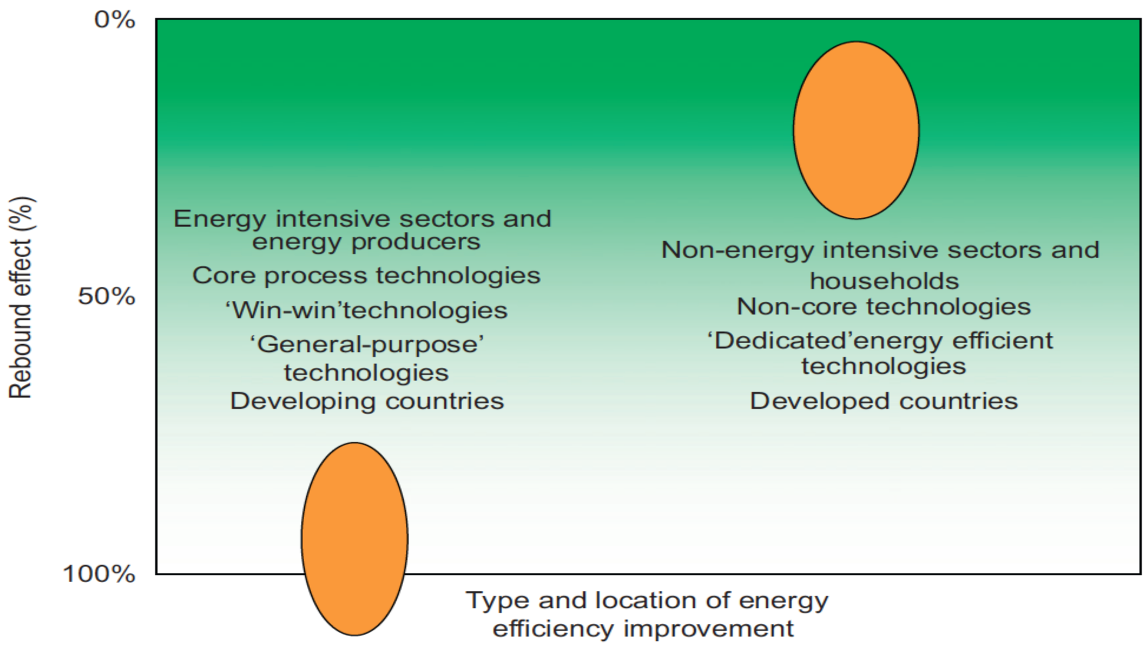

Figure 6 Conditions under which rebound effect may be large or small. Source: Sorrell (2009).

1.1.7 Conclusion And Implications For Next Steps

Despite the ongoing policy concentration on the 'energy efficiency' and abundant literature on this hot topic, there are rare precise definitions of the 'energy efficiency' term. Energy efficiency is a generic and relative term, and there is no one definite quantitative measure for energy efficiency, which can cause ambiguity about it. Energy efficiency typically defined as energy services provided per unit of energy input. This definition can be viewed from physical perspective or economic perspective, however in today volatile condition of the global energy market, it is the economic efficiency of energy use definition, which will dominate the scene and will help policy makers to understand the ongoing trends in the market.

There are two possible types of energy efficiency improvement, substitution or technical change. Logically technical change will bring more desirable economic outcomes and occur independent of any change in production factors' price. However economic outcomes of energy efficiency improvements of technical change, particularly when these changes occur for general-purpose technologies (GPTs), can be offsets by increase in overall economy-wide energy consumption.

The next step of defining 'energy efficiency' is defining accurately the useful output of process or provided energy service, and the energy input. Patterson categorized four main groups of indicators to monitor changes in energy efficiency, thermodynamic indicators, physical-thermodynamic indicators, economic-thermodynamic indicators, and economic indicators. The first two groups of indicators are scientific and primary indicators that more rely on the essence of the energy sources, but the last two groups are more market-oriented indicators that try to measure the input and output of the process in terms of market prices.

There are several myths about energy efficiency that should be explained at the beginning. First of all energy efficiency is not equal to the economic efficiency, and maximizing energy efficiency is not necessary going to result in maximizing economic efficiency and vice versa. Energy efficiency is just part of general economic efficiency and improvements in overall productivity in all production inputs will result in energy efficiency increases.

Second, energy conservation may or may not has a relation with energy efficiency, because energy consumption will not necessarily decrease by an increase in energy efficiency and even it may increase. Jevons also showed that the accepted belief, which energy efficient improvements will increase the useful output while decrease or keep constant the total fuel consumption, does not always occur in practice and even in some cases by introducing energy efficient improvement the overall fuel consumption can increase.

It has been argued that improved energy efficiency at the microeconomic level while causing a reduction of energy use at this level, leads not to a reduction, but instead to an increase in energy consumption, at the macroeconomic level. In reality parts of savings from efficiency enhancements will be used for additional energy consumption, which called 'take-back' or 'rebound effect'. Rebound effect can be classified to direct effect, indirect effect and economy-wide effect and the magnitude of each these categories varies from one circumstance to another. Sorrell documented that when energy efficiency improvements are associated with general-purpose technologies, the magnitude of rebound effect is expected to be very large, particularly when these technologies are in the hands of producers. This condition typically happens in developing countries as an outcome of technology catch up process. In contrary, when energy efficiency advances come from dedicated energy efficient technologies, the magnitude of rebound effect tends to be small and this is the case of industrial countries because of their efficient technological infrastructure.

Finally, energy efficiency improvements should be used as supply side measures for national economic productivity, not in the context of global warming and measuring level of emission of damaging gasses. Khazzoom-Brookes postulate, while not proven, shows that energy efficiency improvements can be a counter-productive measure for mitigating with global warming phenomena, by increasing the global energy consumption (Brookes, 2000; Herring, 2006). Hence the goal of CO2 reduction plans should be decreasing CO2 emissions not cutting energy use. The real solution lies in the substituting type of utilized fuels, from current fossil fuels towards less carbon intensive fuels, like natural gas, and eventually towards non-fossil fuels, such as renewables and nuclear; In this way we can decouple energy growth from the emission of greenhouse gases (GHCs). Reasonably governments should pursue revenue rising policies and regulation to invest in subsidies for introduction of non-fossil fuels, not prescriptive polices to reduce energy consumption (Herring, 2006).

Energy efficiency stimulates economic productivity, and as Jevons mentioned, the more we use energy efficient, the more our industry will blossom and our civilization will grow. Thus, according to the Herring's (2006) argument, regardless of the energy efficiency's impact on energy consumption, it should be fostered. Improving energy efficiency will increase productivity and competitiveness of an economy and subsequently raise the quality of life. The bottom-line is that the objective of energy efficiency policies should be to improve the quality of life and provide enough capital to fund the next revolution, 'Green Industrial Revolution'.

1.2 Definition of Energy Efficiency Gap

1.2.1 Introduction

After defining the concept of "energy efficiency", it is indispensable to firstly determine the optimal level of energy efficiency (Jaffe & Stavins, 1994), and then to understand if there is a difference between this optimal level and the actual level of energy efficiency in society.

As Backlund et al. (2012) indicated, based on policy documents and the scientific literature, "cost-effective energy measures have not always been utilized." Researchers usually refer the argued difference between optimal level and actual level energy efficiency as "energy efficiency gap" (Backlund et al., 2012) .

“According to the intergovernmental panel on climate change’s estimation the energy consumption of highly developed countries could be cut up to 30% by complete implementation of cost-effective technologies” (Howarth, 2004). However in reality it seems that this saving potential is far from achieving.

Klemick (2013) define energy-efficiency gap as the gap between the current energy consumption level of households and businesses and the energy consumption level that they must have based on some defined notions of optimal level of energy consumption.

Allcott & Greenstone (2012), define the energy-efficiency similarly as “A wedge between the cost-minimizing level of energy efficiency and the level actually realized”. Actually the term “cost-minimizing level of energy efficiency” here is close to what Klemick (2013) mentioned as notions of optimal level of energy consumption.

In a scientific attempt Jaffe & Stavins (1994) realized five distinguished and unique “notions of optimality” that are: Economist’s Economic Potential, Technologist’s Economic Potential, Hypothetical Potential, Narrow Social Optimum and True Social Optimum.

As explained before, there is always a relation between notion of optimality and concept of energy efficiency gap. Therefore each of Jaffe & Stavins (1994) notions of optimality has been connected to it conforming definition of the energy efficiency gap (Figure 7).

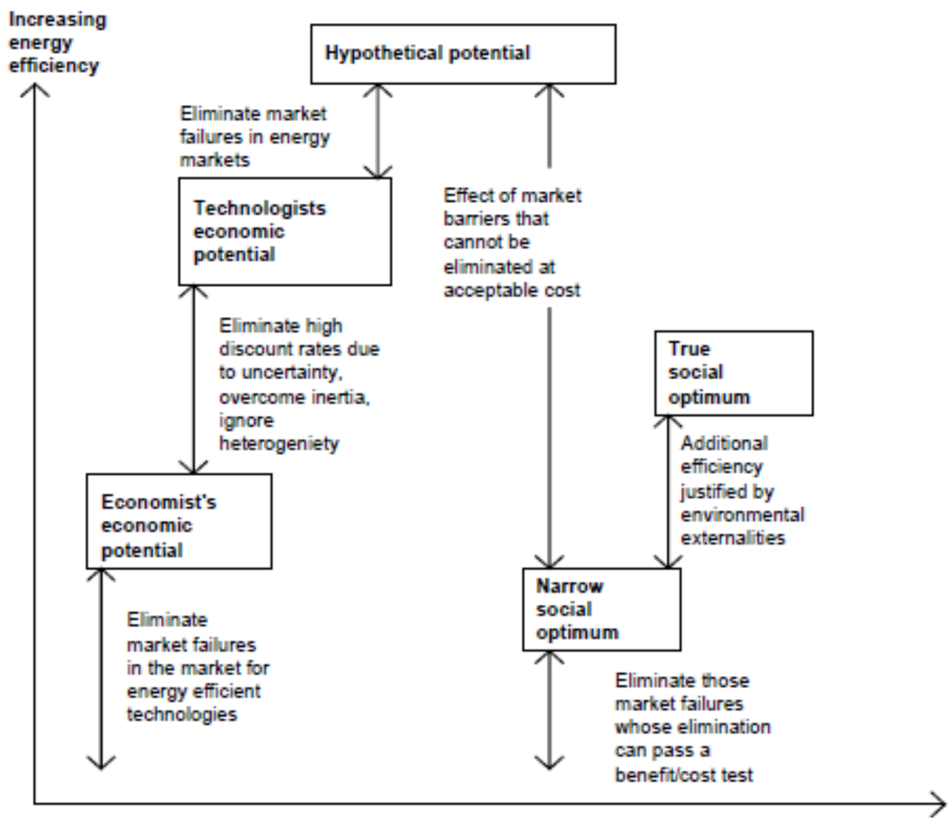

Figure 7 A framework for energy efficiency gap. Source: Jaffe & Stavins (1994).

In their model, they divide all the notions in two groups. One group includes notions based on "economic Potential" and the other comprises notions based on "social optimum".

1.2.2 The Extended Energy Efficiency Gap

Preceding research on energy consumption and energy efficiency has determined mainly to the diffusion of energy efficient technologies (Backlund et al., 2012). While empirical studies have discovered that a cost-effective way to improve energy efficiency is to combine energy-efficient technologies with continuous energy management practices (Backlund et al., 2012).

As Backlund et al. (2012) note energy management involves care and maintenance of technology to preserve an efficient operation, and It requires continuous work and improvements. Successful energy management consists of three parts: energy auditing to gain knowledge about energy flows, courses and training to increase and maintain awareness and house- keeping that includes keeping up the operations (Backlund et al., 2012). Energy management does not need large capital investments or increased operating costs, even fairly low-cost methods such as employees training and adjusting routine practices have been exhibited to have large overall effects (Backlund et al., 2012).

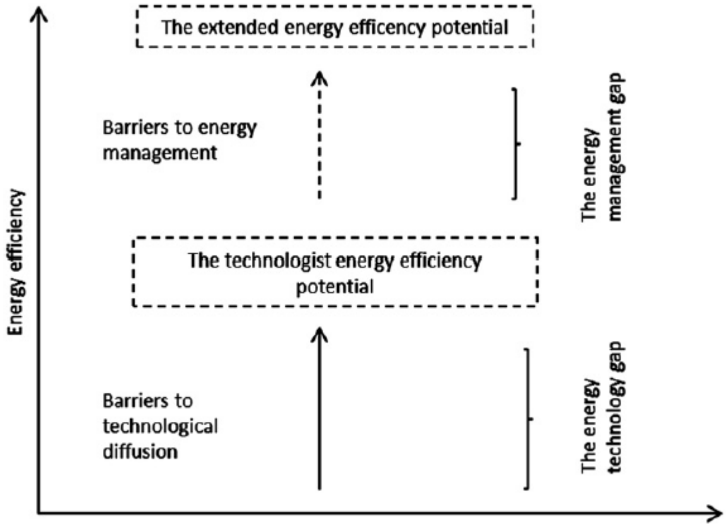

Fig. 1. The extended energy efficiency gap: the energy efficiency potential level is increased if energy management practices are also included.

Figure 8 The extended energy efficiency gap. Source: Backlund et al. (2012)

In summary, the extended energy efficiency gap (Figure 8), including energy management practices (and thus the technology related to its context or system), is greater than the technical potential but may vary widely between industries and companies (Backlund et al., 2012).

1.3 Barriers to Energy Efficiency

1.3.1 Introduction

An inclusive classification of the energy efficiency barriers in taxonomies is essential to understand how complex is the problem (Cagno et al., 2013). Such a understanding allows researchers to more effectively assimilate barriers into models for industrial energy efficiency and to articulate more exhaustive and realistic policy implications to moderate the impact of barriers (Fleiter et al., 2011). Hence, in this section firstly we have reviewed the most relevant and significant contributions in the literature that classified the barriers, and then presented several recent empirical researches that presented these barriers in their works.

Before listing these taxonomies, it is necessary to define barriers of energy efficiency. Weber (1997), in his brief viewpoint concluded with ideas for further research, mentioned barriers (e.g. hidden costs, risk, lack of capital, lack of information, Inadequate financial incentives etc.) as the main reasons that firms, public organizations, departments within Organizations or individuals decide to not invest in technologies that are both energy efficient and (apparently) economically efficient. Weber (1997) suggests a classification of the barriers into: (i) Institutional (barriers caused by political institutions), (ii) Market (barriers and failures), (iii) Organizational (barriers within organizations), and (vi) Behavioral (barriers inside individuals).

1.3.2 The Blumstein et al. Taxonomy (1980)

Blumstein et al. (1980) was the first one who defined and classified various categories of social and institutional barriers to economical energy saving methods. According to Blumstein et al. (1980), six groups of barriers can be classified, while not all barriers could be easily pointed to a particular category (Cagno et al., 2013):

1. *Misplaced incentives*: the economic welfares of energy saving do not always benefit the actor who is trying to save energy;
2. *Lack of information*: the efficient working of the market depends on the parties to transactions having adequate information;
3. *Regulation*: it is hard (or even impossible) to implement an energy efficient action, which conflicts with existing rules or standards;
4. *Market structure*: albeit an energy efficient technology is cost effective, but still it may not be on the market;
5. *Financing*: energy conservation measures often need an initial investment; hence, the accessibility of capital may be vital for these type of measures;
6. *Custom*: if an energy efficient measure involves some changes in the consumer's behavior or conflicts with some established values, it could be rejected.

1.3.3 The Jaffe-Stavins Framework (1994)

Jaffe & Stavins (1994) make the following distinction for better understanding of barriers to energy efficiency and the justification for policy intervention (Sorrell et al., 2000):

i. *Market barriers* refer to any factor, which explains why technologies that appear cost effective at current prices are not taken up;

ii. *Market failures* refer to those market barriers, which correspond to the instances indicated above, and which therefore might justify a public policy intervention to improve energy efficiency (e.g. incomplete markets, imperfect competition, imperfect information and asymmetric information).

Table 1 presents a helpful characterization of these types of barrier and the rationale for intervention.

Table 1 Barriers and market failures based on Jaffe & Stavins (1994). Source: Sorrell et al. (2000).

	Explains efficiency gap	Does not explain efficiency gap
Barriers that are market failures	• Public good attributes of information • Positive externalities of technology adoption • Split incentives in energy service markets • Adverse selection in energy service • Moral hazard & principal agent relationships in energy service markets	• Distortions in energy pricing (e.g. departures from marginal cost pricing, cross subsidies, VAT differentials etc.) • Environmental externalities
Barriers that are not market failures	• Heterogeneity • Hidden costs (e.g. overhead costs, disruption) • Risk (technical or business) • Access to capital	

1.3.4 The Sorrell et al. Taxonomy (2000)

A crucial contribution to the classification of barriers to energy efficiency has done by Sorrell et al. (2000), who propose a new classification of barriers, built on the theoretical perspectives of the barrier, i.e., economic, behavioral, organizational (Table 2) (Cagno et al., 2013).

Sorrell et al. (2000) have clearly differentiated non-market failures from market failures in the economic perspective of the barriers, as presented in Section 0. Furthermore, Sorrell et al. (2000) have included the two non-economic perspectives, the behavioral and the organizational, which will be discussed, respectively in Sections 1.3.4.2 and 1.3.4.3.

Table 2 Different perspectives of energy efficiency barriers according to Sorrell et al. (2000).

Perspective	Examples	Actors	Theories

Economic	• Imperfect information, • Asymmetric information, • Hidden costs, • Risks.	Individuals and organizations considered as rational and aiming at maximizing profits.	Neo-classic economy
Behavioral	• Incapability to process information, • Form of information, • Inertia.	Individuals with bounded rationality, with non-economic behavior and/or under various social influences.	Transaction costs economy, psychology, and decisional theories.
Organizational	• Lack of power and/or influence by people in charge of energy management; • Lack of organizational culture leads to ignore energy issues	Organizations are considered as social systems influenced by objectives, routines and structures with different power.	Organizational theories.

By considering each prospective of barriers, Table 3 represents the detail Sorrell et al. (2000) taxonomy of the barriers. However, it should be noticed, "existence of environmental commitments can be an important variable to explain the take-up of energy efficient technologies" (Sorrell et al., 2000).

Table 3 Sorrell et al.'s (2000) taxonomy of barriers to energy efficiency. Source: Sorrell et al. (2000).

Perspective	Sub-division	Barrier	Description	Comments
Economic	Rational behavior	Heterogeneity	Technology may not be cost effective in a particular instance	An empirical question.
		Hidden costs	Technology investment entails extra costs or loss of benefits that are not reflected in engineering models.	Examples include overheads for staff, overheads for energy information systems, disruptions, hassle, and inconvenience.
		Risk	Stringent investment criteria may represent a rational response to risk	Energy efficiency investments may be a higher risk than others, or there may be business/market risk
		Access to capital	Some agents cannot obtain capital to invest.	A key issue is the level of gearing of a company and the expected consequences of further borrowing
	Market or organizational failure	Imperfect information	Agents lack sufficient information to make economically efficient decisions.	Information has public good characteristics and may be undersupplied by markets.
		Adverse selection	Agent cannot transmit or discover energy properties of a good.	A form of asymmetric information in which transaction costs prevent the energy efficiency benefits of a good from being signaled.
		Split incentives	Agent cannot appropriate benefit of investment - landlord-tenant type relationships.	Examples included departments not being accountable for energy consumption, and equipment purchasers not being accountable for running costs
		Principal-agent relationships	Principal may impose strict investment criteria to compensate for imperfect information	Asymmetric information creates incentives for the agent to maximize his utility to the detriment of the principal. Principal-agent relationships are pervasive within organizations.
Behavioral	Bounded rationality	Bounded rationality	Cognitive limitations lead to agents satisficing rather than optimizing and relying on routines & rules of thumb.	Well-established opposition to mainstream tradition in economics. Strongly supported by empirical studies of energy decision-making.
			Organisational routines may systematically neglect energy efficiency	Routines are an organizational solution to bounded rationality
	The human dimension	Form of information	Form of information may be inadequate to stimulate action.	Results from social psychology. Form of information as important as cost.
		Credibility and trust	Agent may not trust source of information	Credibility enhanced by interpersonal contacts.

		Inertia	Agents resist change because they are committed to what they are doing and justify inertia by downgrading contrary information.	Derives from theory of cognitive dissonance.
		Values	Lack of environmental awareness leads to neglect of efficiency opportunities	Not barrier but an important explanatory variable
Organisational Theory		Power	Agents lack sufficient power within an organisation to initiate action	Energy manager may lack status and authority
		Culture	Environmental awareness and energy efficiency play no part in corporate culture.	Not a barrier but an important explanatory variable

1.3.4.1 The economic perspective

1.3.4.1.1 The non-market failure barriers

1.3.4.1.1.1 Heterogeneity

The engineering assessments of cost effectiveness for a specific energy efficient technology are based on the characteristics of an average user within each particular class (Sorrell et al., 2000). That means some could economically purchase the cost-effective technology for an average user of their class, while others will find this technology not cost-effective (Cagno et al., 2013).

The explanatory power of heterogeneity for the efficiency gap still is an empirical question, which cannot be answered in the abstract. The nature of this issue, the distribution of characteristics within a population, shows that this question could be addressed through survey work. However, the theoretical sampling in case study analysis would allow researcher to eliminate heterogeneity as an explanation for the failure to adopt a technology in a particular class (Sorrell et al., 2000).

1.3.4.1.1.2 Hidden costs

Hidden costs represent the most important argument against the 'efficiency gap' hypothesis (Sorrell et al., 2000). According to Nichols (1994), either the reduction in benefits related to energy-efficient technologies or the surplus costs linked to them are not accounted in engineering–economic studies. Consequently, these studies overrate efficiency potential. Nichols (1994) recognized three general groups of hidden costs (Sorrell et al., 2000):

(i) General overhead costs of energy management

(ii) Costs specific to a technology investment

(iii) Loss of benefits associated with an efficient technology

Table 4 represents possible examples of each type of hidden cost.

Table 4 Possible components of hidden costs. Source: Sorrell et al. (2000).

Category	Example
General overhead costs of energy management	• Costs of employing specialist people (e.g. energy manager) • Cost of energy information systems (including: gathering of energy consumption data; maintaining sub metering systems; analyzing data and correcting for influencing factors; identifying faults; etc.); • Cost of energy auditing;
Costs involved in individual technology decisions	• Cost of i) identifying opportunities; ii) detailed investigation and design; iii) formal investment appraisal; • Cost of formal procedures for seeking approval of capital expenditures; • Cost of specification and tendering for capital works to manufacturers and contractors • Cost of disruptions and inconvenience; • Additional staff costs for maintenance; • Costs for replacement, early retirement, or retraining of staff;
Loss of benefits in individual technology decisions	• Problems with safety, noise, working conditions, extra maintenance, reliability, service quality etc. (e.g. lighting levels).

1.3.4.1.1.3 Access to capital

Numerous consumers, specifically low-income households and some SMEs, can access to capital only at cost well above the average rate of return on capital in the economy (Sorrell et al., 2000). Golove & Eto (1996) have discussed that this barrier is a kind of information problem because of cost of assessing the credit worthiness of small firms and individuals.

The capital accessibility problem could be interpreted differently in the public sector than in private sector. In the public sector, government with the aim of controlling public borrowing frequently directly provides the required capital (Sorrell et al., 2000). However, excessive public expenditure will damage economic objectives by preventing assessment of the cost effectiveness of individual projects and therefore impedes cost-effective investment (Sorrell et al., 2000).

While, in private sector firms, constraints of capital are often self-imposed. It means that private firms seem to be unwilling to use debt to finance low risk energy efficiency projects with rates of return that considerably surpass their weighted average cost of capital (WACC) (Sorrell et al., 2000). This problem has two dimensions. First, firm has general borrowing restriction. Second, energy efficiency investments typically come bottom of the budget allocation's priority list.

1.3.4.1.1.4 Risk

Sorrell et al. (2000) discussed that both high discount rates for energy efficiency and the rejection of particular energy efficient technologies may represent a rational response to risk. Three broad categories of risks can be distinguished in the literature as follows: (i) *External Risk*, (ii) *Business Risk*, and (iii) *Technical Risk* (Sorrell et al., 2000) (For examples of these categories see Table 5).

Table 5 Possible categories of Risks. Source: Sorrell et al. (2000).

Category	Example
External risk	• Overall economic trends (e.g. recession); • Expected reductions in fuel and electricity prices; • Political changes and government policy
Business risk	• Sectoral economic trends; • Individual business economic trends; • Financing risk (reaction of capital markets to increases in borrowing);
Technical risk	• Technical performance of individual technologies • Unreliability

Risk has many dimensions and its magnitude can varies with the individual country, sector, business and technology and changes over time (Sorrell et al., 2000). Still, it is hard to empirically assess the risk, and the fact that perceptions of risk may prevent cost-effective investment does not verify those perceptions as rational (Sorrell et al., 2000).

1.3.4.1.2 The market failure

1.3.4.1.2.1 Imperfect information

The *lack of information* about the energy performance of different technologies leads users to make *sub-optimal decisions* and consequently to under invest in energy efficiency (Cagno et al., 2013). According to the Golove & Eto (1996), several dimensions to imperfect information can be distinguish (Sorrell et al., 2000):

Lack of information

Consumers may have not sufficient knowledge on the energy performance of different technologies (Sorrell et al., 2000). As Eyre (1997) wrote: 'Faced with good information on capital costs and poor information on operating costs, consumers may rationally and systematically choose the low capital option'.

Cost of information:

As Harris & Carman (1983) noted: 'even when information is readily available, it is seldom costless'. Hence because of costs associated with probing and obtaining information on the energy performance of technologies, consumers often act without full information (Sorrell et al., 2000). As Harris & Carman (1983) noted, 'the problem of information cost is likely to be most serious when:

(1) The product or service is purchased infrequently;

(2) Performance characteristics are difficult to evaluate either before or soon after purchase;

(3) The rate of technological change is rapid relative to the interval between purchases; and

(4) The terms of exchange change rapidly relative to the purchase interval (e.g. life insurance, automobile tires)'.

Energy service markets have all of abovementioned characteristics (Hewett, 1998). As Sorrell et al. (2000) discussed energy efficiency comprises a broad array of complex products and services, purchased from an similarly wide range of companies. Most products (boilers, kiln, lighting equipment etc.) are purchased occasionally and the technology will have reformed significantly since the preceding purchase (Sorrell et al., 2000).

Asymmetric information

When parties to a transaction have access to different levels of information, they create the so-called asymmetric information barrier (Cagno et al., 2013). This barrier can lead to the three subsequent barriers: split incentives, adverse selection and principal–agent relationships (Cagno et al., 2013).

1.3.4.1.2.2 Split incentives (Appropriability)

Appropriability, also called misplaced incentives (Brown, 2001), is about the appropriation of the profits, and has been distinguished traditionally as a key barrier (Cagno et al., 2013). For instance, separate subdivisions in an organization may not be responsible for their energy consumption, consequently lacking incentive to improve efficiency. Or, as DeCanio (1993) notes, short term of office could kill managers' incentive to investing with a longer return period (Cagno et al., 2013).

1.3.4.1.2.3 Adverse selection

Sometimes, producers could not market suitable technologies because customers are unable to observe their features prior to deal (Sorrell et al., 2000). Credence goods, i.e., goods for which the consumers have large difficulties to ascertain the quality and the effectiveness prior to purchase, such as energy-efficient technologies or services, are specifically exposed to adverse selection (Cagno et al., 2013). Hence, in the industrial world, purchasers might tend to buy technologies according to visible aspects such as price, and be reluctant to pay the price premium for high-efficiency products (Cagno et al., 2013).

1.3.4.1.2.4 Principal–agent relationships

Principal-agent relationships occur when the interests of one party, the principal, depends on the action of another party, the agent (Sorrell et al., 2000). The agency problem happens when the principal attempts to force the agent to act in ways that are consistent with the principal's interests (Sorrell et al., 2000). The goals of the principal and agent are supposed to conflict. To guarantee her interests, the principal may stringently monitor the agent, and/or construct an proper incentive structure (Sorrell et al., 2000). This barrier could be found in the energy service market and within organizations (Cagno et al., 2013).

1.3.4.2 The behavioral perspective

1.3.4.2.1.1 Bounded rationality

According to the bounded rationality theory, individuals and companies will tend to make satisfactory decisions rather than probing for optimum decisions (Cagno et al., 2013). Furthermore, real world limitations such as constraints on time, attention, resources and the ability to process information, cause optimization to be substituted by inaccurate routines and rules of thumb (Cagno et al., 2013). Bounded Rationality theory makes it clearer that decision-making process is not a rational process given by economics. Instead, decision-makers are circumscribed by many restrictions in attention and resources, being able to elaborate only a limited set of information (Sorrell et al., 2000). While this phenomenon has not been considered in the traditional economic models, it might be critical for the energy service market (Sorrell et al., 2000). For instance, usually in manufacturing firms the attention is almost exclusively dedicated to the core production activities, underestimating importance of activities considered as a peripheral issue, as energy use (Sorrell et al., 2000).

As Sorrell et al. (2000) argued three important conclusions follow from this discussion:

1. Bounded rationality could be considered as an additional barrier that does not fit into traditional economic models.
2. Real world departures from the substantive rationality assumed in most engineering-economic models could account for a proportion of the efficiency gap.
3. The existence of bounded rationality may also undermine intervention programs designed to improve energy efficiency.

1.3.4.2.1.2 The human dimension

The second approach in the behavioral literature originates from social psychology rather than economics and has paid particular attention to improving the effectiveness of energy efficiency (Sorrell et al., 2000). This approach leads to three notions from the psychological literature that could be outlined as barriers (Sorrell et al., 2000):

- Form of information;
- Credibility and trust;
- Inertia
- Values

Sorrell et al (2000) added a further concept, values, which does not strictly represent a barrier, but is likely to be an important variable in explaining energy decision-making.

Form of information

This barrier is considered crucial, since information, for not being ignored, should be specific, personalized, vivid, clear, simple, close in time to the relevant decision and before the investment in a new energy-efficient technology (Cagno et al., 2013).

Credibility and trust

An additional aspect of information is the credibility of the source. One potential justification for why people keep away from information that is both useful and free is that they do not trust the source (Sorrell et al., 2000).

Inertia

Insights from the behavioral literature recommend that inertia could be a appropriate explanatory variable for the non implementation of an energy efficient technology (Sorrell et al., 2000). This barrier represents the combined effect of considering gains differently from losses, giving greater weighting to certain outcomes with respect to those that are uncertain, and minimizing the regret (Cagno et al., 2013). All these factors can cause individuals and organizations to favor the current situation.

Values

In reality, economic views deliver only one element of a decision. While, the environmental impact of energy consumption has driven energy efficiency for many years, and the identification of global climate change has made it more relevant than ever. Cagno et al (2013) notes that taking the stimulus outside industry, the lack of individuals motivated by environmental values may demote energy efficiency as a minor matter. Hence, Values are a relevant explanatory variable in describing the adoption or non-adoption of energy efficient technologies (Sorrell et al., 2000).

1.3.4.3 The organizational theory perspective

Organizational Structure

If we look at enterprises as systems with relationships and conflicts among individuals and departments with different cultures influencing decision-making, it is important to note that the organizational structure could represent a barrier to the implementation of energy-efficient technologies (Cagno et al., 2013).

Power

Because of conflicting interests within the firm, it is plausible that disagreements for the use of restricted resources may arise (Cagno et al., 2013). Power represents the medium, which through it conflicts of interest get resolved. The responsibility for energy issues is usually assigned to engineering or maintenance departments (and, in some cases for SMEs, the two may coincide) that have a relatively low status within an organisation (Sorrell et al., 2000). It is possible that top management considers energy as minor issue, of limited importance to the strategic direction of the firm, thus limiting its power, funds and support of the related department (Sorrell et al., 2000). Hence, energy efficiency opportunities, while are technically and economically viable, might be neglected.

Culture

The concept of organizational culture is similar to the personal values discussed above. While culture cannot be outlined as a barrier, it could still be a significant variable in describing the implementation of energy efficient measures (Sorrell et al., 2000). In a broad sense culture can be defined as the combination of knowledge, ideology, values, norms, laws and rituals that portray a social group (Cagno et al., 2013; Sorrell et al., 2000). The application of this discussion in the energy efficiency barriers debate as Sorrell et al. (2000)notes is that "the place of energy efficiency and environmental values within an organization's culture should have a major impact on the adoption of energy efficient technologies".

1.3.5 Cagno et al. Taxonomy (2013)

Authors did comprehensive literature review on energy efficiency barriers. This paper can be one of the main references for the barriers definition. In this paper they developed new taxonomy, with a clear distinction of the origin (external, or internal, with respect to the firm), and the actors affected by the barriers. Table 6 in below is the representation of what has been noticed.

Table 6 The new taxonomy, with a clear distinction of the origin (external, or internal, with respect to the firm), and the actors affected by the barriers. Source: Cagno et al. (2013)

Origin	Actor/Area	Barriers
External	Market	Energy prices distortion
		Low diffusion of technologies

		Low diffusion of information
		Market risks
		Difficulty in Gathering External Skills
	Government/politics	Lack of proper regulation
		Distortion in fiscal policies
	Technology/services suppliers	Lack of interest in energy efficiency
		Technology Suppliers not updated
		Scarce communication skills
	Designers and manufacturers	Technical Characteristics not adequate
		High initial costs
	Energy suppliers	Scarce communication skills
		Distortion in energy policies
		Lack of interest in energy efficiency
	Capital suppliers	Cost for investing capital availability
		Difficulty in identifying the quality of the investments
Internal	Economic	Low capital availability
		Hidden costs
		Intervention-related risks
	Behavioral	Lack of interest in energy-efficiency interventions
		Other priorities
		Inertia
		Imperfect evaluation criteria
		Lack of sharing the objectives
	Organisational	Low status of energy efficiency
		Divergent interests
		Complex decision chain
		Lack of time
		Lack of internal control
	Barriers related to competences	Identifying the inefficiencies
		Implementing the interventions
	Awareness	Lack of awareness or Ignorance

Every barrier in the table has been defined in this paper. In particular, they also added two more categories, generally called Technology-related barriers and Information barriers.

Technology related barriers could be categorized in two sub categories: (1) technologies not adequate, and (2) technologies not available. Information barriers could be categorized in four sections; (1) lack of information on costs and benefits; (2) information not clear by technologies suppliers; (3) trustworthiness of the information source; (4) information issues on energy contracts.

1.3.6 More Recent Papers

By considering the mentioned energy efficiency barriers taxonomy, we made also another literature review on the most recent papers, even their references in energy efficiency area and barriers in order to not miss any possible barrier.

1.3.6.1 Kounetas & Tsekouras (2010)

Kounetas & Tsekouras (2010) argue that when the impact of EETs on the firms' productive performance is potentially significantly negative, this impact itself may be considered as a barrier for the adoption of the specific technology. The economic rationale behind the possible negative impact of EET adoption on the firms' production growth may be traced to the internal cost of adjustment that the embodiment of any new technology may cause.

More specifically, the internal cost of adjustment includes factors such as the organizational disorders, which are implied by the use of the new technology, the replacement of equipment of low vintage with the new one, and the fact that learning by doing effects are practically zero compared to the corresponding positive and often significant effects that the previous technology exhibited.

1.3.6.2 Balachandra et al. (2010)

Commercialization efforts to diffuse sustainable energy technologies (SET) have so far remained as the biggest challenge in the field of renewable energy and energy efficiency. Balachandra et al. (2010) found some specific barriers for SET.

At a time when the wheels of technological progress interlock more tightly with commerce and finance, many SETs lag behind other technologies in terms of commercialization, despite– or perhaps because of– long-standing efforts to promote them. Other technologies have experienced explosive market growth while overcoming similar barriers –like skeptical consumers, lack of sales infrastructure or lack of regulatory framework– those hold back SETs.

1.3.6.3 Levine et al. (1995)

Many efficiency technologies have been accepted only slowly into the market, in spite of their apparent advantages. Some of the factors restraining market acceptance result from limitations of the technologies themselves or are intrinsic to the environment in which the technology is applied. Other factors are the result of market failures, such as lack of information, lack of capital, purchase decisions made by parties who do not pay energy costs, and energy prices that exclude environmental and social externalities.

1.3.6.4 Dyer et al. (2008)

The main barriers mentioned in this paper are Technical and economic barriers in UK industry. They found two primary drivers for change namely costs and legislations.

They mentioned several barriers for adaptation of new technologies such lack of specialist knowledge on the part of the firm, which could be information relating to the current energy consumption, the specific technology for demand management or the economic aspects of investment in such technology. Other barriers that they mentioned are limited windows of opportunity for the installation and maintenance of new plant, the limited resources to undertake this type of activity that is particularly prevalent in SMEs, the lack of expertise resulting from a rationalization of the workforce, and a general reluctance to adapt to changing practices.

Another point, which they mentioned as important factor for energy-saving potential, is Ignorance about the current energy consumption within industry on a plant level that can be as a major inhibitor. A lack of awareness of the available technologies by industry, and the poor understanding of the historical technological legacy issue in general, are important barriers to the uptake of energy demand reduction technologies.

They noticed the most significant barrier as 'ignorance, inertia and lack of interest'.

1.3.6.5 Fleiter et al. (2012)

They tried to assess the saving potential in energy efficiency in pulp and paper industry in Germany. For modeling this issue they considered some barriers in order to be more precise. The interest rate is often used in energy demand models to consider barriers to the implementation of cost-effective energy efficiency measures. They refer lack of staff time, investment priority setting, and information deficits and split incentives as major barriers.

They consider the structure of barriers that is depending on technology and firm characteristics. ''If technologies are integrated into complex production processes, the intensity of barriers is different compared to technologies that are applied somewhat detached from the production process, like space heating or lighting.''

This is further supported by the interviews with German paper industry representatives, indicating that two years is the maximum payback time acceptable for energy efficiency investments.

1.3.6.6 Sarkar & Singh (2010)

This paper draws upon selected experiences with financing energy efficiency in developing countries to explore the key factors of various programmatic approaches and financing instruments that have been applied successfully for delivering energy efficiency solutions. Figure 9 shows the result of their research.

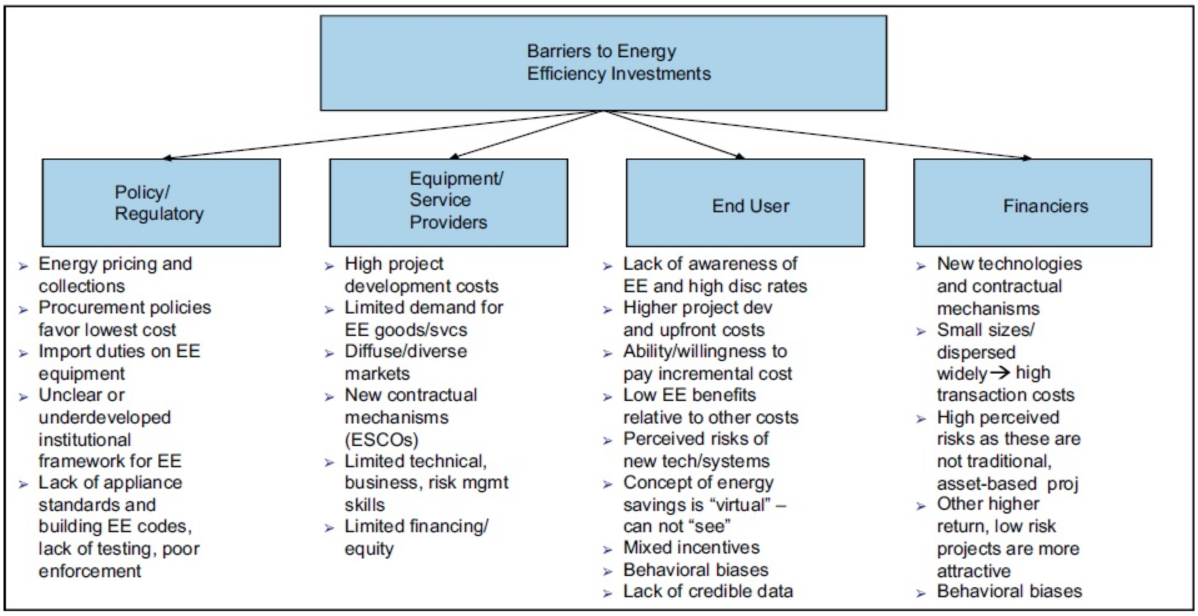

Figure 9 Barriers to energy efficiency investments in developing countries. Source: Sarkar & Singh (2010)

1.3.6.7 Apak et al. (2012)

The aim of this paper is to assemble public and private sector officials in an international strategic planning process to advance the efficient development of a hydrogen economy infrastructure and to understand six-sigma methodology and its contribution to energy efficiency.

They mentioned As a result of the global economic downturn, energy investments are generally frozen and demand for oil, gas and coal has declined globally. Many countries already foster the production and use of renewable energy through different approaches because they recognize many benefits. They mentioned some barriers to renewable energy development, i.e. import tariffs, technical barriers, and insecure financing of renewable energy projects.

1.3.6.8 Griffin et al. (2012)

In their assessment they generally mentioned lack of interests in energy efficiency. In a case of history repeated, they concluded that there was a lack of demonstration for industrial energy efficiency technologies, representing a gap in policy and support for the middle stages of the innovation chain.

1.3.6.9 De Beer et al. (1998)

They found a method for identifying and characterizing technologies that can improve the energy efficiency in the long term that is described and applied to the paper and board industry. They describe seven relevant technologies in order to assess. In their assessment they generally mentioned the economic constraints as a main barrier.

1.3.6.10 Apak et al. (2012a)

In this paper they were going to find institutional factors that facilitate the diffusion of an international management standard in the area of the renewable energy. They mentioned the main investment barriers to new renewable energy capacity is the lack of certainty, which private investors have in the end-market for clean technologies (the adoption hurdle). Without a clear expectation of demand for their product or service and therefore future revenue streams, private investors will typically under-invest in R&D or not take on the financing risks of commercial scale demonstration.

1.3.6.11 De la Tour et al. (2011)

The purpose of this paper is to understand the drivers of this success that made china as the largest solar photovoltaic cell producer in the world, and its limits, with a particular emphasis on the role of technology transfers and innovation. They found the technological barriers as the main barriers. For example the mentioned ''the main barrier to entry in the silicon feedstock market is technological.'' They noticed the main significant barriers for the upstream part of market in development of china ''the lack of competitive supply of production equipment''.

1.3.6.12 Shum & Watanabe (2009)

The purpose of this paper is to present an innovation perspective on the renewable energy deployment process by introducing the innovation value-added chain (IVC) framework. They generally mentioned the main barriers in three different groups of Technical, Economic and Institutional. These barriers increasingly shift from the technical to the economic and institutional. They noted that the most general types of barriers are due to technological 'lock-out' or to carbon 'lock-in'.

1.3.6.13 Klagge et al. (2012)

In their paper, they address the gap, based on second-hand sources and over 50 personal interviews with wind energy-related experts, especially in technology transfer. They identify and discuss challenges and obstacles in the development of an innovation-driven wind industry in China.

They mentioned wide array of barriers to wind energy technology transfer to China in the new international context, including uncertainty regarding laws and regulations, weaknesses in the enforcement of intellectual property rights (IPR) regulations, inadequate information, extraordinary tariff and nontariff barriers, protectionist industrial policies, limited human capital, insufficient financing, and bureaucracy and corruption.

1.3.6.14 Løvdal & Neumann (2011)

This paper is organized in two steps: first identification the most challenging industry barriers perceived by companies. In Second using these barriers to form propositions, which assesses through empirical data. They identified the industry barriers as shown in Table 7 and rating them in three different criteria, which are ''Relevant'', ''Neutral'' and ''Irrelevant''.

Table 7 Industry barriers rated by the respondents (%). Source: Løvdal & Neumann (2011).

Relevant	Neutral	Irrelevant	Rated barriers
80	16	4	Lack of long term governmental support
69	27	4	Difficult to get licenses
63	20	16	Low price on substitute products
63	24	12	Lack of public awareness
61	22	16	Bad access to the grid
55	33	12	Occupied area conflicts with others
47	31	22	Lack of public known energy resource assessments
43	16	41	Lack of a dominant design/technology
41	37	22	Bad access to field data in proper format
37	35	29	Lack of international collaboration
37	29	35	Lack of standardization
33	43	24	Overprotective national policy
31	39	31	Difficult to establish a supply chain
29	41	31	Big environmental impacts

1.3.6.15 Hirst & Brown (1990)

In this paper they concern about energy efficiency potential in US while only half of the potential for improving U.S. energy efficiency over the next 20 years is likely to be achieved, given current government policies and programs.

They mentioned structural and market barriers that inhibit adoption of cost-effective energy-efficient practices and measures. Structural barriers include distortions in fuel prices, uncertainty about future fuel prices, limited access to capital, government fiscal and regulatory policies, codes and standards, and supply infrastructure limitations. Behavioral barriers include attitudes toward energy efficiency, perceived risk of energy efficiency investments, information gaps, and misplaced incentives.

A variety of obstacles that prevent decision makers from adopting cost effective, energy efficiency practices and measures were discussed in this paper. The authors' judgment suggests that the primary barriers include distortions in fuel prices, limited access to capital, supply infrastructure limitations, and information gaps.

1.3.6.16 Brown (2001)

This paper provides compelling evidence that large-scale market failures and barriers prevent consumers in the United States from obtaining energy services at least cost. Assessments of numerous energy policies and programs suggest that public interventions can overcome many of these market obstacles.

''Market failures'' occur when there is a flaw in the way markets operate. They are conditions of a market that violate one or more of the neoclassical economic assumptions that define an ideal market for products or services such as rational behavior, costless transactions, and perfect information. Market failures can be caused by (1) misplaced incentives; (2) distortionary fiscal and regulatory policies; (3) unpriced costs such as air pollution; (4) unpriced goods such as education, training, and technological advances; and (5) insufficient and incorrect information.

1.3.6.17 Brown (2004)

Author analyzed obstacles same as last paper with the difference that they indicated market barriers. According to their perception ‘'Market barriers'' refer to other obstacles that contribute to the slow diffusion and adoption of energy-efficient innovations. To the extent that it is in society's best interest to use its energy more efficiently and to reduce emissions from fossil fuel combustion, it is important to understand the full range of obstacles to energy-efficient technologies. These barriers include (1) the low priority of energy issues among consumers, (2) capital market imperfections, and (3) incomplete markets for energy-efficient features and products.

1.3.6.18 Summary of recent papers

Table 8 demonstrates a summary of all the abovementioned papers.

Table 8 Summary of recent papers on energy efficiency barriers.

Type	Examples	Country	Author(s)
Financial	• Lack of capital • Economic constraints • Insecure financing, • Ability/willingness to pay	Worldwide Germany Netherland Japan USA EU Turkey China Developing countries	(Apak, Atay, & Tuncer, 2011; Blumstein et al., 1980; Cagno et al., 2013; De Beer et al., 1998; Fleiter et al., 2012; Klagge et al., 2012; Levine et al., 1995; Palm & Thollander, 2010a; Sarkar & Singh, 2010; Shum & Watanabe, 2009; Tsoutsos & Stamboulis, 2005)

Governmental	• Government policy and regulatory framework • Uncertainty regarding laws and regulations • Weaknesses in the enforcement of intellectual property rights (IPR) regulations • Extraordinary tariff and nontariff barriers • Lack of long term governmental support • Overprotective national policy • Bureaucracy and corruption	Worldwide Turkey China Norway Developing countries	(Apak et al., 2011; Blumstein et al., 1980; Cagno et al., 2013; Klagge et al., 2012; Løvdal & Neumann, 2011; Sarkar & Singh, 2010; Tsoutsos & Stamboulis, 2005)
Managerial	• Purchase decisions made by parties who do not pay energy costs • Ignorance about the current energy consumption within industry on a plant level • Investment priority-setting	Worldwide Germany Japan USA UK	(Dyer et al., 2008; Fleiter et al., 2012; Levine et al., 1995; Shum & Watanabe, 2009; Tsoutsos & Stamboulis, 2005)
Technological	• Technological barriers • Technology/service suppliers • Technical barriers	Worldwide Turkey Japan USA China	(Apak et al., 2011; Cagno et al., 2013; De la Tour et al., 2011; Shum & Watanabe, 2009; Tsoutsos & Stamboulis, 2005)
Information	• Lack of information • Lack of awareness • Lack of public awareness • Lack of demonstration for industrial energy efficiency technologies	Worldwide Germany UK China Norway Developing countries	(Blumstein et al., 1980; Dyer et al., 2008; Fleiter et al., 2012; Griffin et al., 2012; Klagge et al., 2012; Levine et al., 1995; Løvdal & Neumann, 2011; Sarkar & Singh, 2010)
Hidden costs	• Production factors • Technical risk • Impact of EETs on the firms' productive performance	Greece Germany Worldwide	(Fleiter et al., 2012; Kounetas & Tsekouras, 2010; Tsoutsos & Stamboulis, 2005)

Market	• Low price on substitute products • Demand factors • Market structure • Low priority of energy issues • Incomplete market for energy efficiency	Worldwide USA Norway	(Blumstein et al., 1980; Brown, 2001; Cagno et al., 2013; Løvdal & Neumann, 2011; Tsoutsos & Stamboulis, 2005)
Incentives	• Split incentives • Misplaced incentives	Worldwide Germany Developing countries	(Blumstein et al., 1980; Fleiter et al., 2012; Sarkar & Singh, 2010)
Organizational	• Lack of specialist knowledge • Lack of standardization • Limited human capital • Custom • Cultural and psychological factors • Lack of staff time	Worldwide UK Norway EU China	(Blumstein et al., 1980; Cagno et al., 2013; De Beer et al., 1998; Fleiter et al., 2012; Klagge et al., 2012; Løvdal & Neumann, 2011; Palm & Thollander, 2010b; Tsoutsos & Stamboulis, 2005)
Supplier's side	• Equipment/service providers • Designers and manufacturers energy suppliers • Lack of sales infrastructure or lack of regulatory framework	Worldwide India Developing countries	(Cagno et al., 2013; Reddy, Balachandra, & Nathan, 2009; Sarkar & Singh, 2010)
Stability	• Lack of certainty	Turkey	(Apak et al., 2011)
Network	• Lack of international collaboration	Norway	(Løvdal & Neumann, 2011)
Infrastructure	• Bad access to the grid	Norway	(Løvdal & Neumann, 2011)

1.3.7 Conclusion And Implication For Next Steps

So far we tried to mention most of recent and significant works on barriers to energy efficiency. This broad examination of literature helps us to have better understanding about related issues and guides next steps of this research. In our research we will mainly utilize works of Sorrell et al. (2000) and Cagno et al. (2013), and in the meantime we will benefit from extracted insights from other recent papers.

1.4 Emerging Energy-efficient Technologies

In this research the term "emerging" denotes technologies that have already entered the market but have low market share. Because of nature of research, we also have looked for technologies, which are energy-efficient that means use less energy than existing technologies and practices to produce the same output, and could have extra non-energy benefits. Table 9 represents results of our search for emerging energy efficient technologies available in the literature. It should be noticed that some of these technologies might not be emerging in developed countries such as US or Western European countries, but still they are emerging for developing counties such as Iran, which is the case of this report.

Table 9 List of emerging energy efficient technologies. Source: (Hasanbeigi, Price, & Lin, 2012; Worrell, 1995; Worrell et al., 2002)

Item	Emerging Energy Efficient Technology	Sector	Total Energy Savings	Sector Savings	Simple Payback
1	Smelt reduction processes	Iron-Steel Industry	High	High	Immediate
2	Near net shape casting		High	High	Immediate
3	New EAF furnace processes		High	High	0.3
4	Oxy-fuel combustion in reheat furnace		High	Medium	1.2

5	BOF gas and sensible heat recovery		Medium	Medium	14.7
6	High-activation grinding	Cement Industry	High	High	-
7	Fluidized bed kiln		High	High	-
8	Calcareous oil shale as an alternative raw material		Medium	High	-
9	Use of steel slag as raw material for the kiln—CemStars technology		Medium/high	High	-
10	Non-carbonated raw material for cement production—use of carbide slag		Medium/high	High	-
11	Cement with low lime saturation factor		Medium	High	-
12	Cement and construction materials based on magnesium oxide		Medium	High	-
13	Geopolymer cement		High	High	-
14	Cement/concrete based on fly ash and recycled materials		High	High	-
15	Capturing CO2 emissions from pre calcination of limestone		High	High	-
16	CO2 sequestration in concrete curing		High	High	-
17	Carbonate looping technology		High	High	-

18	Bio-technological carbon capture		Medium/high	High	-
19	Oxygen enrichment and oxy-fuel technologies		Increase energy and decrease CO2 in short term	-	-
20	Post-combustion carbon capture using absorption technologies		Increase energy and decrease CO2 in short term	-	-
21	Calera process		High in CO2	-	-
22	Industrial recycling of cement process CO2 emissions into high-energy algal biomass		High in CO2	-	-
43	Advanced forming	Aluminum	Medium	Low	Immediate
44	Efficient cell retrofit designs		High	High	2.7
45	Improved recycling technologies		Medium	Low	4.5
46	Inert anodes/wetted cathodes		High	High	4
23	Hi-tech facilities HVAC	Cross-cutting	Medium	High	4
24	Advanced lighting technologies		High	High	3
25	Advanced lighting design		High	High	1.3
26	Advance ASD designs		High	Low	1.1

27	Advanced compressor controls		Medium	Low	0
28	Compressed air system management		High	High	0.4
29	Motor diagnostics		Low	Low	Immediate
30	Motor system optimization		High	High	0.8
31	Pump efficiency improvement		High	High	3
32	Switched reluctance motor		Medium	Low	7.4
33	Advanced lubricants		Medium	Low	0.1
34	Anaerobic waste water treatment		Medium	Low	0.8
35	High efficiency/low Nox burners		High	Low	3.1
36	Membrane technology wastewater		High	Low	4.7
37	Process Integration (pinch analysis)		High	Low	2.3
38	Sensors and controls		High	Low	2
39	Advanced CHP turbine systems		High	High	6.9

40	Advanced reciprocating engines		High	High	8.3
41	Fuel cells cross-cutting		High	High	58.6
42	Micro turbines		High	Low	-

As Worrell et al. (2002) discussed many innovative technologies have a conventional “S” curve diffusion model, whereby a small segment of the industry known as early adopters, utilize a novel and unverified technology despite high costs and potential risks. As the technology becomes more common, the perceived risks decrease and the cost of the technology declines. The period needed to achieve a significant market share may vary and depends on the technology characteristics, as well as characteristics of the market and the particular sector (Worrell et al., 2002).

2 Research Methodology

2.1 Introduction And Research Questions

Caused by objective of this research and existing restrictions in accessing to the detail quantitative and qualitative data, this research is built on explorative and empirical case studies. This methodology has been selected to discover and examine how Iranian energy-intensive firms adopt and implement emerging energy efficient technologies and practices.

The empirical research findings about barriers, drivers and procedure of adopting new energy efficient technologies in Iranian energy-intensive industries are compared and weighed against key literature findings in related topics. The research tries to answer questions such as 'how Iranian firms -who are inhabiting in a developing country that experiences exceptional conditions including energy subsidies reform plan, high growth rate, pollution crisis, bilateral and international economic and trade sanctions, and high energy supply and consumption- adopt latest energy efficient technologies, how sector-specific characteristics and individual characteristics of the firms distinguish their responses to the energy efficient solutions, if there are differences between literature findings and reality, and whether or not literature appropriately reflects the weight and importance of the drivers and barriers of adopting energy efficient technologies in a developing country with unusual situations such as Iran. The purpose of studying the energy efficiency behavior of Iranian energy-intensive firms is to discover how these firms decide whether adopt and use new energy efficient technologies compare to their current technology, and why in some cases their decisions diverge from rational and cost-effective decisions, which will minimize their costs or maximize their profits. The primary aim of the research is to use the qualitative and semantic explanations to extend our understanding about attendances of implementation of energy efficient technologies in energy-intensive industries of developing countries and to add to the theoretical body of energy efficiency knowledge.

2.2 Research Approach: Qualitative vs. Quantitative Research

The question of selecting appropriate research methodology for every research must be addressed through applicability assessment of different research methodologies. Basically each methodology can be used in variety of researches based on the orientation of the investigator, investigator's attitude and the way she/he chooses to use a research technique that defines precision of that especial technique. Quantitative and qualitative researches philosophically hold for approach rather than a certain numbers of research techniques, and therefore for finding appropriate research approach one must look at the nature of the phenomena under study. Discussion of research methodology can be best served by attention to the relationship between theory and method, or in other word the link between stance of researcher (Section 2.2.1.1), the definition of research question (Section 2.1), and the technique (Section 2.2.1.2 and 2.2.1.3) that is utilized in the research (Morgan & Smircich, 1980).

2.2.1 Creswell Research Design Framework

Creswell (2013) defined a framework for selecting the research approach and designing the research path. According to his framework the researcher must specify three elements of research process to reach to the right research approach (Figure 10): Alternative knowledge claim, strategy of inquiry, and method of data collection (Creswell, 2013).

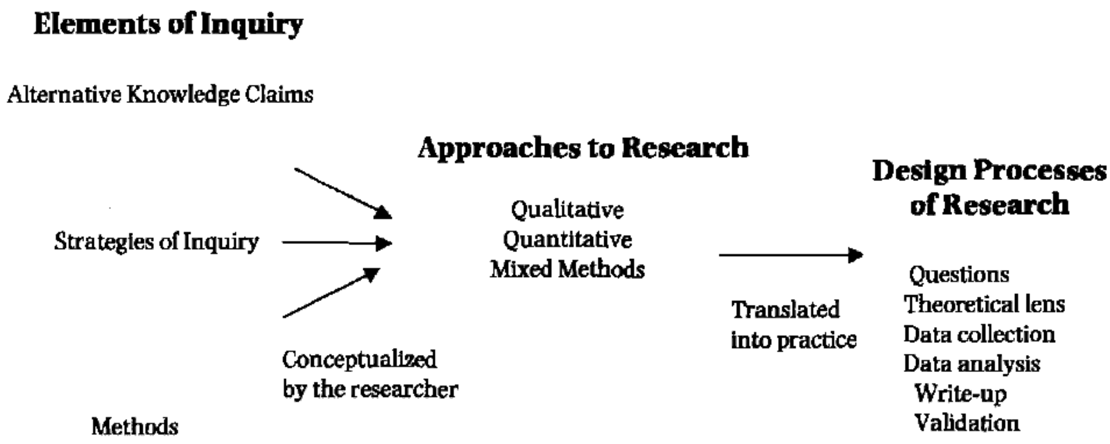

Figure 10 Creswell's framework for research design. Source: Creswell (2013).

2.2.1.1 Step 1: Theoretical Perspective and Philosophical assumptions

Alternative knowledge claim position is a set of philosophical assumptions that researchers take into account at the beginning of the research. These assumptions show that how they expect to learn and what they expect to discover from undergoing research. Alternative knowledge claims fall into four general categories:

Postpositive knowledge claims, socially constructed knowledge claims, advocacy/participatory knowledge claims, and pragmatic knowledge claims (Creswell, 2013). Major features of each knowledge claim are introduced in the Table 10. Our philosophical assumptions in this research overlap loosely with the category of social constructed knowledge claim of Creswell's framework. As mentioned before, we want to 'understand' how 'different' Iranian energy-intensive companies adopt and implement emerging energy efficient technologies and practices. More specifically, we are eager to realize how 'multiple firms', with distinct characteristics, decide whether adopt and use new energy efficient technologies compare to their current technologies, and why in some cases their decisions diverge from expected rationality. Actually we try to 'extend available theories' of energy efficiency topic to enhance our understanding about some especial cases that are not noticed before.

Table 10 Alternative knowledge claims positions. Source: Creswell (2013).

Postpositivism	Constructivism
Determination Reductionism Empirical observation and measurement Theory verification	Understanding Multiple participant meanings Social and historical construction Theory generation
Advocacy/Participatory	**Pragmatism**
Political Empowerment issue-oriented Collaborative Change-oriented	Consequences of actions Problem-centered Pluralistic Real-world practice oriented

These explanations make room for discussion of stance of this research toward available literature. Whether this research is a deductive research, which is going to utilize current theories to achieve to a specific result (figure 2), or in contrary it is an inductive research, which is going to gather data and observation to reach to a generalizable theory (Figure 11).

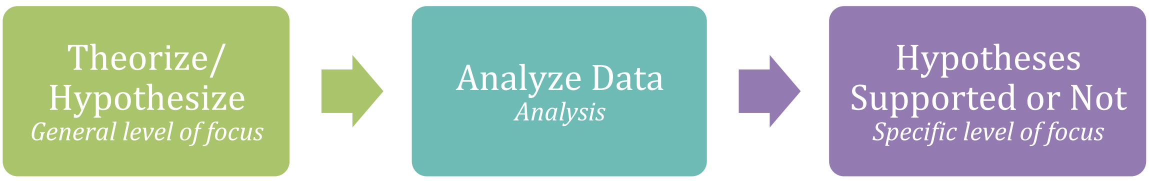

Figure 11 Deductive research. Source: Blackstone, (2012).

Figure 12 Inductive research. Source: Blackstone, (2012).

In case of our research, it is true that we started our project from investigation of available literature to find how researchers before us have articulated energy efficient technologies diffusion process in the industrial sector, but the real objective of this investigation is to prevent from duplication of the pervious researches and to extend our understanding about this issue. In short, in our inductive research, we collected data on the field of energy efficiency as well as Iran's industries' conditions, and then try to focus more on some selected energy-intensive firms as our research cases to find relevant patterns that allow us to generate propositions about motivations and drawbacks of adoption of energy efficient technologies in Iranian manufacturing firms that could be generalized for most of developing countries.

2.2.1.2 Step 2: Strategy of Inquiry

Creswell (2013) introduced three categories of frequently used strategies of inquiry (or traditions of inquiry) for conducting the social science researches: 'Quantitative', 'Qualitative' and 'Mixed Methods'. Each of these categories includes a set of different strategies, which a researcher can utilize them to run his project (Creswell, 2013). Table 11 shows these strategies.

Table 11 Alternative strategies of inquiry. Source: Creswell (2013).

Quantitative	Qualitative	Mixed Methods
Experimental designs Non-experimental designs, such as surveys	Narratives Phenomenologies Ethnographies Grounded theory Case studies	Sequential Concurrent Transformative

In parallel, Yin (2009) argued that the type of appropriate research strategy should be come from precise evaluation of the type of research question, the extent of control over behavioral events, and the general circumstances of the phenomenon to be studied. In researches like ours, which the research question type is originated from 'How' and 'Why' class, the researcher has little or no possibility to control the events under investigation, and the phenomenon to be studied is a contemporary phenomenon in a real-life context, the appropriate research methodology is 'Case studies' (Yin, 2009). We will discuss more about detail of our Case Study strategy in following sections.

2.2.1.3 Step 3: Techniques and Methods

Finally, the third main step toward shaping the research approach is selecting the specific method(s), which will be used for collecting and analyzing data about phenomenon under investigation (Creswell, 2013). Table 12 shows the full range of possible techniques for data collection that a researcher can consider in any study. Noticeably, the choice of research methods is not a completely free choice; Nature of research, presence of numeric data, access to the data, time and budget constraints, and experience of researcher, all are important considerations in selecting research method. For example in our research that is focused on the country of Iran, pervious researches on the issue of adoption of energy efficient technologies in Iranian industries are infrequent and numeric data such as surveys are inaccessible, and operational constraints do not allow us to investigate the adoption process on adequate number of firms to run statistical analyses. Hence, we mostly rely on open-ended questions, interview data and archival data in the framework of Case Studies methodology.

Table 12 Quantitative, Qualitative and Mixed Methods Procedures. Source: Creswell (2013.)

Quantitative Research Methods	Qualitative Research Methods	Mixed Methods Research Methods
Predetermined Instrument based questions Performance data, attitude	Emerging methods Open-ended questions Interview data, observation	Both predetermined and emerging methods Both open- and closed-

data, observational data and census data Statistical analysis	data, document data, and audiovisual data Text and image analysis	ended questions Multiple forms of data drawing on all possibilities Statistical and text analysis

2.2.1.4 Approaches to Research

A research approach is based on all the three mentioned steps, and can be more quantitative, qualitative, or mixed (Creswell, 2013). Table 13 shows possible combinations of knowledge claim, strategy of inquiry and method that contribute to different research approaches.

Table 13 Qualitative, Quantitative, and Mixed Methods Approaches. Source: Creswell (2013).

Tend to or Typically	Qualitative Approaches	Quantitative Approaches	Mixed Methods Approaches
Use these philosophical assumptions	Constructivist/ Advocacy/Participatory knowledge claims	Positivist knowledge claims	Pragmatic knowledge claims
Employ these strategies of inquiry	Phenomenology, grounded theory, ethnography, case study, and narrative	Surveys and experiments	Sequential, concurrent, and transformative
Employ these methods	Open-ended questions, emerging approaches, text or image data	Close-ended questions, predetermined approaches, numeric data	Both open-ended and close-ended questions, both emerging and predetermined approaches, both quantitative and qualitative data and analysis
Use these practices of research as the researcher	Positions himself or herself Collects participant meanings Focus on a single concept or phenomenon Brings personal values into study Studies the context or setting of participants Validates the accuracy of findings	Tests or verifies theories or explanations Identifies variables to study Relates variables in questions or hypotheses Uses standards of validity and reliability Observes and measures	Collects both quantitative and qualitative data Develops a rationale for mixing Integrates the data at different stages of inquiry Presents visual pictures of the procedure in the study Employs the practices of both quantitative

	Makes interpretations of the data Creates an agenda for change or reform Collaborates with the participants	information numerically Uses unbiased approaches Employs statistical procedures	and qualitative research

2.2.1.5 Thesis's Research Structure

According to above sets of combination and based what we decided in each of the past three steps, our research should have a qualitative approach. Table 14 shows the summary of the design of our research's structure.

Table 14 Elements of Our Research's Structure

Research Approach	Qualitative approaches
Philosophical assumptions	Constructivist knowledge claims
Research Type	Inductive research
Strategy of inquiry	Case study
Methods	Open-ended questions Interview data Archival data
Practices of research	Collects participant meanings Focus on a single concept or phenomenon Studies the context or setting of participants Validates the accuracy of findings Makes interpretations of the data Studies the context or setting of participants

Before going to the next section, it is necessary to clarify some concerns about selection of research approach. First, The process of decision-making in the context of energy efficiency is a complicated social phenomenon with multiple distinct actors and blurred boundaries; hence this research will be conducted in a qualitative manner through open and explorative questions.

Second, as the emphasis of quantitative approach is to count and measures things, this approach is less applicable for our research (Berg, 2007). Besides, for counting and measuring activities quantitative methods need large enough numeric data on topic of the interest, which is not possible in the case of this research. Additionally, we mentioned before that the primary aims of the research are to extend our understanding about the research question and add to the theoretical body of energy efficiency knowledge; obviously, quantitative methodologies that are mostly utilized to test a theory and posing a hypothesis, are less useful in this order (Creswell, 2013).

And last but not the least, there are some claims against credibility of qualitative researches, because scientific generalization requires numerous set of similar experiments in diverse environments (Berg, 2007). But as Berg (2007) mentioned they have missed prospect of the probability aspect of quantitative practices and replaced it by an assumption of certainty. Meantime, even in qualitative research we have generalization but to the theoretical propositions, not to the whole population (Yin, 2009). Theoretical sampling (or purposeful sampling) in qualitative researches is aimed to select a special organization, or set of organizations, precisely because it is very special and allows researcher to develop or extend theory, in contrast to the random or stratified sampling in quantitative researches that is designed to test available theories (Creswell, 2013; Siggelkow, 2007).

2.3 Case Study Research Design

In the pervious section, it was mentioned that the strategy of the inquiry for this research is case study. Case study is a highly iterative and tightly linked to data process (Eisenhardt, 1989), has procedural characteristics, can be operated as single-case or multiple-case and can involve numerous levels of analysis (Yin, 2009). Additionally, it is possible to use quantitative or qualitative, or even triangulate data in case study researches (Yin, 2009). Hence, it is indispensible to have a precise design for each element of this process, and plan consciously each step ahead to maximize the power of case study's theory building.

Several frameworks for the process of theory generation from case study research have emerged in the literature (Eisenhardt, 1989; Gersick, 1988; B. G. Glaser & Strauss, 1967; S. G. Harris & Sutton, 1986; Leonard-Barton, 1988; Miles & Huberman, 1984; Strauss, 1987; Yin, 2009). Among them Eisenhardt's framework (1989), which is more comprehensive and cited one, is the basis of our case study methodology design (Table 15).

Table 15 Process of Building Theory from Case Study Research (Eisenhardt, 1989)

Step	Activity	Reason
Getting Started	Definition of research question	Focuses efforts
	Possibly a priori constructs	Provides better grounding of construct measures
Selecting Cases	Neither theory nor hypotheses specified population	Retains theoretical flexibility
		Constrains extraneous variation and sharpens external validity
	Theoretical, not random, sampling	Focuses efforts on theoretically useful cases-i.e. those that replicate or extend theory by filling conceptual categories
Crafting Instruments and Protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence

	Qualitative and quantitative data combined	Synergistic view of evidence
	Multiple investigators	Fosters divergent perspectives and strengthens grounding
Entering the Field	Overlap data collection and analysis, including field notes	Speeds analyses and reveals helpful adjustments to data collection
	Flexible and opportunistic data collection methods	Allows investigators to take advantage of emergent themes and unique case features
Analyzing Data	Within-case analysis	Gains familiarity with data and preliminary theory generation
	Cross-case pattern search using divergent techniques	Forces investigators to look beyond initial impressions and see evidence thru multiple lenses
Shaping Hypotheses	Iterative tabulation of evidence for each construct	Sharpens definition, validity, and construct measurability
	Replication, not sampling, logic across cases	Confirms, extends, and sharpens theory
	Search evidence for "why" behind relationships	Builds internal validity
Enfolding Literature	Comparison with conflicting literature	Builds internal validity, raises theoretical level, and sharpens construct definitions
	Comparison with similar literature	Sharpens generalizability, improves construct definition, and raises theoretical level
Reaching Closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small

There are typical criticisms toward case study research that should be explained before going through each step of the above process. The very small size of the sample is the first charge against the case study research. However, sometimes even a single case can be very potent instance. Non-representativeness is another typical criticism toward case study research. But again like small size of sample, usually a researcher chooses a specific organization exactly because it is a distinct organization that allows the investigator to bring intuitions that others would not be able (George & Bennett, 2005; Siggelkow, 2007).

Meantime there are some criticisms toward case study research that can be resolved. For instance case study research is usually accused of lack of systematic handling of data, which can be easily fixed by systematic reporting of all evidences thru the process of data collection. Another allegation against case study research is there is no basis for scientific generalization that should be explained to the readers that purpose of case study research is to generalize to theoretical propositions, not to population as in numerical research (Yin, 2009)

2.3.1 Step 1: Research Question & Priori Constructs

The very first step in case study research like all other types of researches is defining an initial and broad research question. An initial definition of research question allows the researcher to identify the type of cases to be explored and the kind of data to be collected (Eisenhardt, 1989).

In addition, one should notice that the defined research question is coming from which category. Eisenhardt & Graebner (2007) identified two general categories of research questions: 'Theory-driven Questions' and 'Phenomenon-driven Questions'. Besides instructive information comes from definition of research question, this categorization shows how to scope, frame and justify the research process (See Table 16). Theory-driven questions are expected to extend existing theories, while phenomenon-driven questions are intended to generate new theories (Eisenhardt & Graebner, 2007).

Table 16 Research Question Typology (Eisenhardt & Graebner, 2007)

Type	Output	Scope	Research Frame	Justification

Theory-driven Questions	Extend existing theories	Tightly scoped within the context of an existing theory	Frame research within the context of an existing theory and then show how inductive theory-building is necessary	Rests heavily on the ability of qualitative data to offer insight into complex social process that quantitative data cannot easily reveal
Phenomenon-driven Question	Generate new theories	Broadly scoped to give the researcher more flexibility	Frame the research in terms of the importance of the phenomenon and the lack of plausible existing theory.	Rests on the phenomenon's importance and the lack of viable theory and empirical evidence

As mentioned before, in this research the big research problem is to understand how Iranian energy-intensive firms, which are inhabiting in a developing country that experiences unique conditions such as intense energy subsidies reform plan, high fluctuating growth rate, pollution crisis, bilateral and international economic and trade sanctions, and high energy supply and consumption rate, adopt and implement emerging energy efficient technologies and practices. This general question brings some subquestions with itself as below:

- How do sector-specific characteristics and individual characteristics of these firms distinguish their response to the energy efficient solutions?
- Why in some cases their decisions diverge from rational and cost-effective decisions, which will minimize their costs or maximize their profits?

- What are the most important obstacles in adopting EETs and which are the most influential motivations in favor of selecting EETs?

As it is clear now, we must look for Iranian firms with extreme energy consumption. For this purpose we have checked Iranian industries' energy consumption statistics and selected firms from energy-intensive sectors. A detail explanation of this process is available in the section of 'Selecting Cases'. Meantime, we need to collect all the related information about firms' energy policy, energy consumption's statistics, energy consumption's behavior and possible available energy conservation plans.

In parallel, this research is founded on a theory-driven research question, which tightly scoped within context of present energy efficiency and technology adoption theories. We expect that this research question will lead us to extend existing theories of energy efficiency and technology adoption. We will show in the following sections that how our justification rests heavily on the capacity of collected qualitative data from multiple source to bring insight into complex process of energy efficiency decision-making.

After formulating main research question in the first step, it is suggested to postulate some possibly significant variables, with some relation to the existing literature. Actually, this primary arrangement will help to form the preliminary design of theory-building research, and can be measured in data collection process such as interview protocol and questionnaires (Eisenhardt, 1989).

The conducted literature analysis found in chapter two suggests some possible constructs. In this step we are solely interested in following variables, not in relationship between them:

- Institutional Barriers

- Market Barriers or Market Failures
- Organizational Barriers
- Behavioral Barriers
- Energy Efficiency Policies and Strategy
- Potential Energy Saving

2.3.2 Step 2: Selecting Cases (And Unit of Analysis)

Eisenhardt (1989) considered this step just for the process of selection of the cases to be studied. But in reality besides selecting cases, we need to decide about the unit of analysis in each case study research, and more importantly we must decide whether doing a single-case study or multiple-case study research, or in other word we must quantify the number of cases under investigation (Yin, 2009).

A case study research's attitude toward unit of analysis can be 'Holistic' or 'Embedded'. In holistic design, researcher just concentrates on a single unit of analysis and wants to study the holistic nature of a phenomenon at a specific level. In contrast, in embedded design, the researcher focuses on multiple units of analysis and mainly looks for replicated pattern of evidence across different level of a particular case (Yin, 2009). (See Table 17)

Table 17 Unit of Analysis Design (Yin, 2009)

Type of design	Features
Holistic Design	Includes a single unit The aim is to study the global nature of phenomenon When no logical sub-units can be pointed Risk of abstractness

Embedded Design	Multiple units of analysis May include main and smaller units on different levels Looking for consistent patterns of evidences across units, but within a case

Choice of type of case study research, as Eisenhardt & Graebner (2007) mentioned, is depended on the importance of phenomenon under investigation and theoretical foundation. When we have a phenomenon-driven research question (See Table 16) that is funded on distinctiveness of a particular case, it is suggested to choose a single-case study research. While, when the research is trying to answer a theory-driven research question (See Table 16) and for this purpose needs to find consistent patterns of evidences to validate replication or eliminate rival explanation, it is recommended to opt a multiple-case study research (Eisenhardt & Graebner, 2007). Table 18 shows how to choose case(s) in each type of researches and outlines advantages of implementing single or multiple case research type.

Table 18 Choice of Type of Case Study Research (Eisenhardt & Graebner, 2007)

Type	Choice of Case(s)	Pros
Single-case Studies	Uniqueness of a given case Chosen because it is unusually revelatory, extreme exemplars, or opportunities for unusual research access	Sampling is straight-forward Exploit opportunities to explore a significant phenomenon under rare or extreme circumstances Richly describe the existence of a phenomenon

Multiple-case Studies	Based on contribution to the theory development within the set of cases For theoretical reasons such as replication, and elimination of alternative explanations	Provide a stronger base for theory building Enable comparisons that clarify whether an emergent finding is simply idiosyncratic to a single several cases. Create more robust theory Constructs and relationships are more precisely delineated Enable broader exploration of research question and theoretical elaboration More generalizable and testable theory than single-case research

If one compares and then combines Table 16, Table 17 and Table 18, it can be concluded that there is a direct relation between typology of research question, choice of type of case study research and level of unit of analysis. (See Table 19)

Table 19 Possible combinations of features of Case Study Researches (Yin, 2009; Eisenhardt & Graebner, 2007)

Research question	Unit of Analysis	Case Study Research
Phenomenon-driven	Holistic Design	Single-case Studies
Theory-driven	Embedded Design	Multiple-case Studies

Based on the possible combinations proposed in the Table 19, following to our theory-driven research question, we will apply an embedded design on a multiple-case study research. For this purpose, we will analysis several Iranian energy-intensive firms at levels of country, industry sector and individual organization. This research structure will allow us identify barriers to adoption and implementation of emerging EETs at different levels.

Consequently, like the work of Sorrell et al. (2000), the results of this research will prepare a foundation for future studies to suggest certain policy implications that may help government to overcome the identified barriers by posing policy initiatives in three distinct but intertwined categories: a) within single organizations; b) via sector associations; and c) nationwide policies for boosting energy efficiency. Given the range of possible barriers, initiatives at all three levels are likely to be required. But there are synergies between them: for example, national initiatives may assist organizations in developing improved energy management. However it should be noted that the core unit of analysis in this research is energy management inside individual organizations and the majority of the research work is focused on recognizing the process of different barriers. Hence, the research cannot offer comprehensive policy suggestions and its policy relevant implications are suggestive only.

About the process of selection of cases, as we indicated in the step of definition of research question, we are looking for Iranian firms with extreme energy consumption. For this purpose we have checked available Iranian industries energy consumption recent statistics and selected firms from energy-intensive sectors. The main problem in this step was that there are several datasets on the energy consumption of Iran, which most of them are in conflict. Meantime the newest official dataset is for 2010 (Ministry of Energy, 2010), which is not in detail and is just some aggregated statistics. So we had to find and use the latest available detail official dataset that is for 2005-2006 (Ministry of Energy, 2005, 2006).

Before explaining our rationale for each choice, it is necessary to clarify that why we have selected country of Iran as our research landscape. So in the following section, firstly we will briefly describe the significance of country of Iran for our research and then we will go through each selected cases.

2.3.2.1 Iran; An Exceptional Case For Energy Efficiency Research

Besides, our convenient access to the Iranian industry, Iran is the case that Siggelkow (2007) named it a 'powerful example' for the purpose of energy efficiency researches. Surprisingly, despite to the vital need of Iranian firms to be more energy efficient and productive, literature on identifying the barriers to energy efficiency development in Iran's industry is scarce.

Meantime, exceptional situation, which Iran is faced recently - such as energy subsidies reform plan, pollution crisis mainly in its big cities, bilateral and international economic and trade sanctions, and high-rate of energy supply and consumption - makes Iran an interesting case for exhaustive research on the issue of energy efficiency. Such a research will improve our understanding about behavior of different actors on this field and will allow us to recognize whether external adversities, like those Iranian firms are struggling with them, will change decision-making behavior of different actors toward energy efficiency or not.

In the following section we will try to explain the significance of the case of Iran and Iranian industries for this research, and then we will utilize official statistics to find most relevant energy-intensive industries in Iran to resume next steps of our research.

2.3.2.1.1 Introduction

2.3.2.1.1.1 Geographical and Demographical Information

Figure 13 Geographical map of Iran. Source: Source: U.S. Energy Information Administration

Iran is one of the Middle Eastern countries that positioned in the Southwest of Asia with about 1,648,195 KM^2 areas (Figure 13). The population of Iran has continuously increased from 36.39 million in 1978 to 74.73 million in 2010. According to the Central Bank of Iran's statistics, in 2010, 23.87 million of Iranian populations were active and 13.5% of these active populations were unemployed (Figure 14).

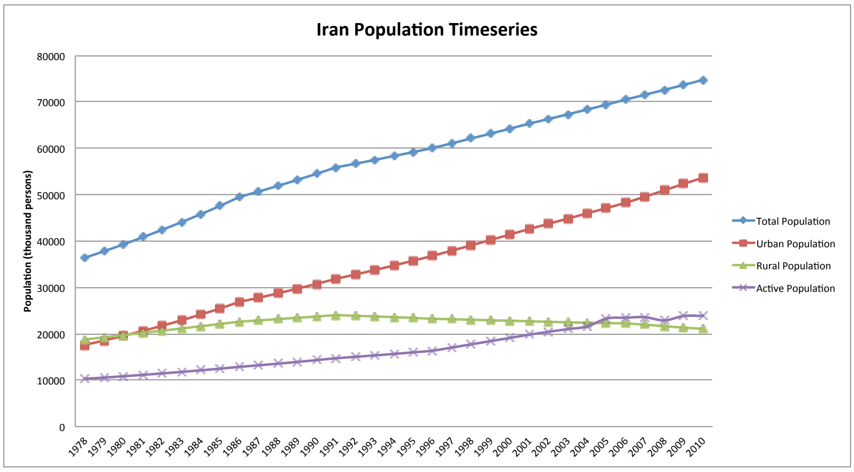

Figure 14 Iran Populations. Source: Central Bank of Iran's statistics

In parallel to the increase of Iran's population, the residency pattern has shifted toward the urban areas in the last decades. Figure 15 shows that the urban populations of Iran have been proportionally increased from 48 percent of total population in 1978 to more than 71 percent in 2010. As Bakhoda et al. (2012) discussed, urbanism evolution in Iran is not the outcome of social and economic restructuring, rather the extension of the income gap between urban and rural areas, problems related to the seasonal drought and the better accessibility of the facilities in urban areas have caused to attract Iranian people from rural areas to the cities (Bakhoda et al., 2012). Increase in overall population as well as urban population has been one of the important reasons for boosting countrywide energy consumption (Hosseini et al., 2013).

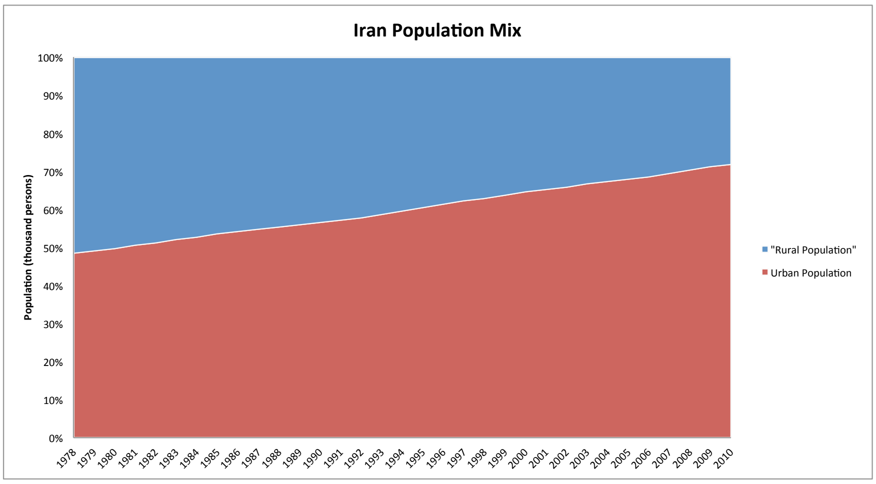

Figure 15 Mix of Rural and Urban Population of Iran. Source: Central Bank of Iran's statistics.

2.3.2.1.1.2 Economy, Industry and Development of Iran

Iran homes to the abundant fossil fuels and renewable energies resources (Figure 16, Figure 17, Figure 18 and Figure 19). By 11 percent of world oil reserves and 15.3 percent of world natural gas reserves, Iran is one of the key players in the global energy market as well as the global economy (Moshiri & Lechtenboehmer, 2011). In other word, Iran holds the world's fourth-largest confirmed oil reserves and the world's second-largest natural gas reserves. However, current international sanctions are redefining the Iranian energy sector, and the lack of foreign investment and technology is affecting the sector severely (U.S. Energy Information Administration, 2014).

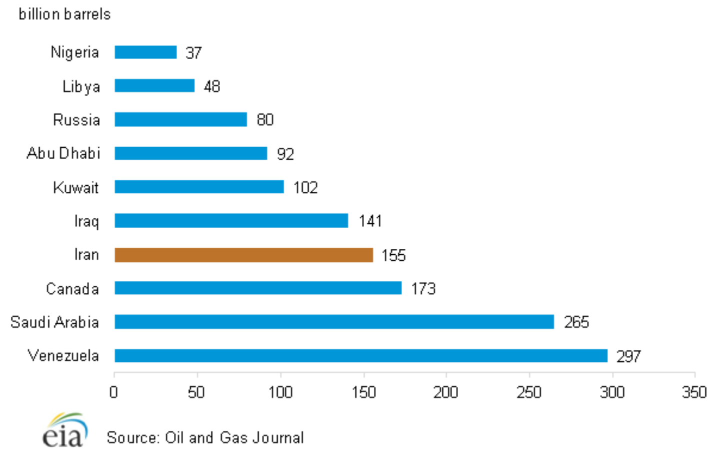

Figure 16 Largest proven reserve holders of oil, January 2013. Source: U.S. Energy Information Administration

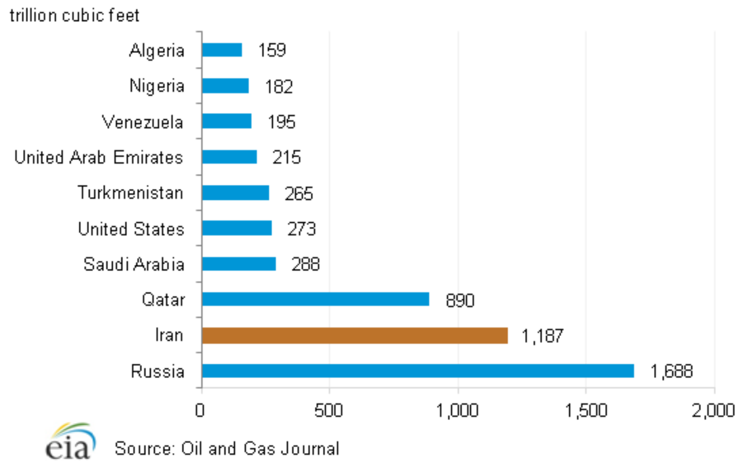

Figure 17 Largest proven reserve holders of natural gas, January 2013. Source: U.S. Energy Information Administration

According to the Iran's fourth development plan 1% of the country's total needed electricity should come from renewable energy resources. However, not just this goal has been achieved, but also 62% of renewable energy power plants planned capacity is not realized yet (Fadai et al., 2011).

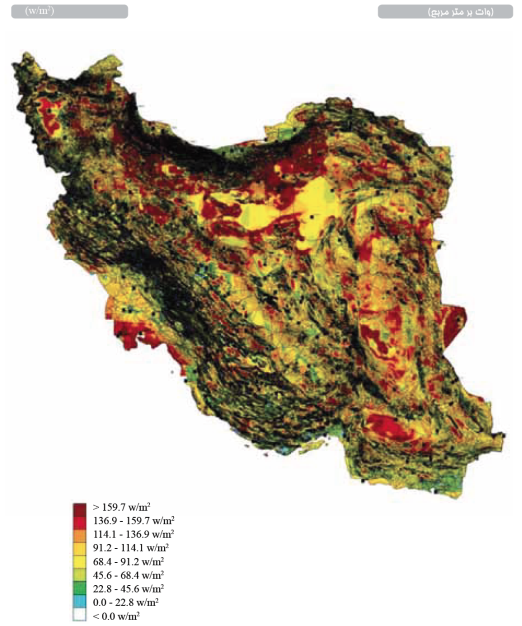

Figure 18 Map of Iran wind energy density at 80 meters above the ground level. Source: Deputy for Power & Energy Affairs of Iran, 2010.

Figure 19 Iran solar radiation potential. Source: Deputy for Power & Energy Affairs of Iran, 2010

Like many developing countries and as a consequence of industrialization, Iran has experienced a high economic growth rate during last decades. According to the World Bank's statistics Iran GDP consistently expanded with an average rate over 4.9 percent from 1989 (after eight years of imposed war with Iraq) to 2010.

As Mohammadnejad et al. (2011) stated this high rate of industrialization caused that the final energy consumption of Iran has risen continuously in the past decades. Actually this growth rate has intensified the impact of Iran's population growth on the national energy consumptions.

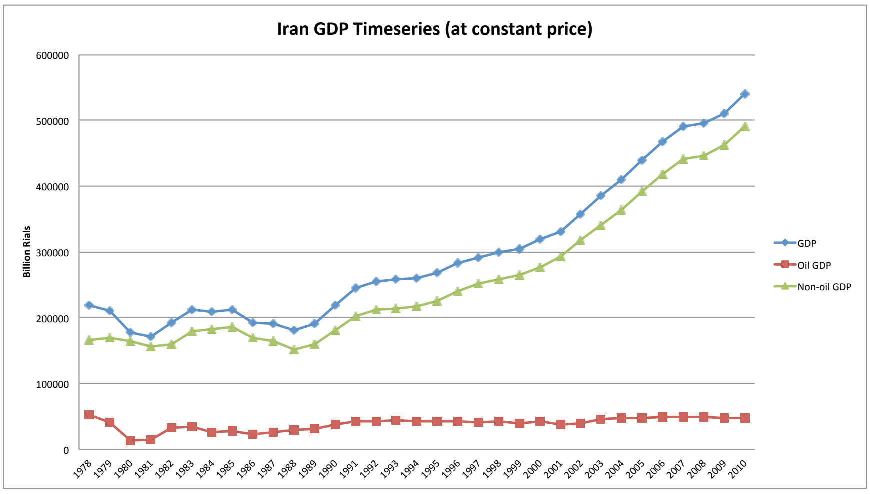

Figure 20 Iran GDP from 1978 to 2010. Source: Central Bank of Iran's statistics, 2012.

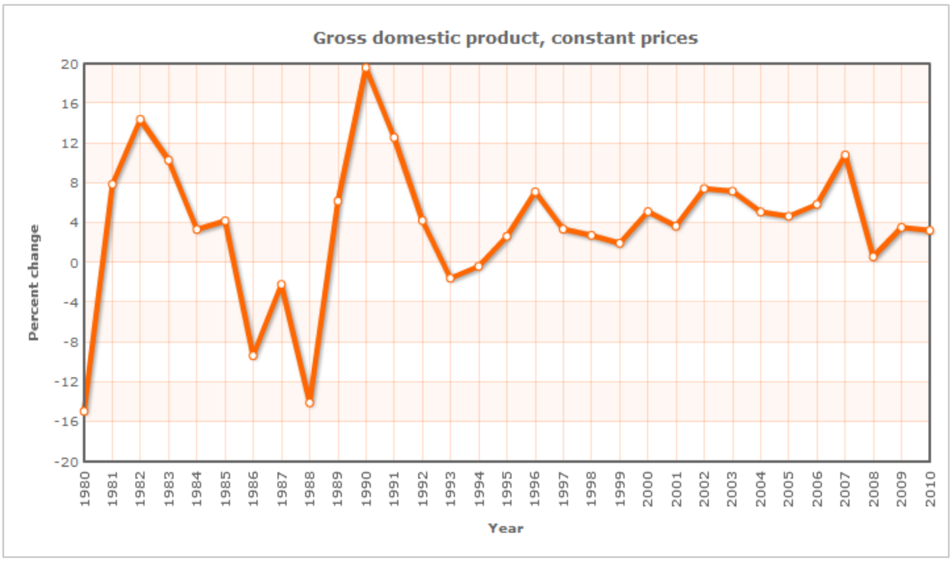

Figure 21 Iran GDP's growth rate. Source: International Monetary Fund - 2011 World Economic Outlook

According to Moshiri et al. (2012), Iranian industries had 38% share of Iran GDP in 2012, higher than agricultural sector and lower than service sector. Economy of Iran has historically been a diversified economy, which state has owned and managed oil and most of large and national firms, and private sector has been mostly involved in agriculture, small-scale trading and service enterprises. Despite this diversified structure of economy, the Iranian economy has been heavily dependent on the petrodollars since nationalization of Iranian oil resources in 1951 (Moshiri et al., 2012). Currently oil revenues account for around 80 percent of total exports incomes, more than 60 percent of the government revenues, and nearly 15 percent of GDP (Reza Farzin, Guillaume, & Zytek, 2011) (Figure 22).

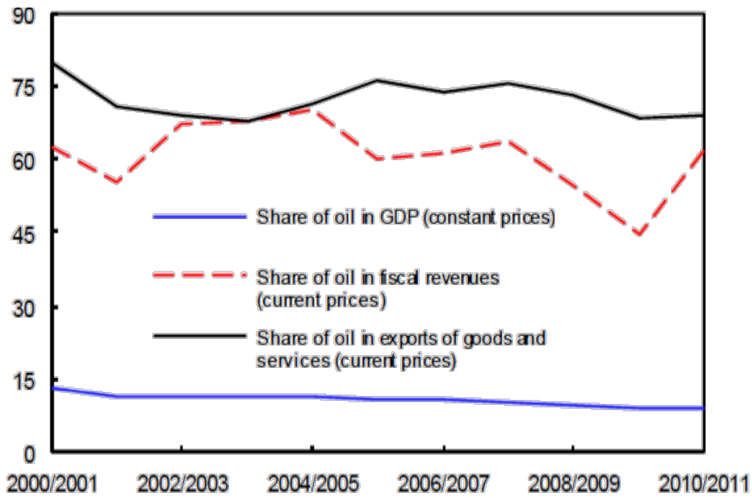

Figure 22 Share of oil in Iran's GDP, fiscal revenues, and exports (In Percent). Source: Guillaume, Zytek, & Farzin, 2011.

Share of oil exports income in Iran's export revenues has been gradually increased since 2002, mostly because of escalation of oil's price in the international market.

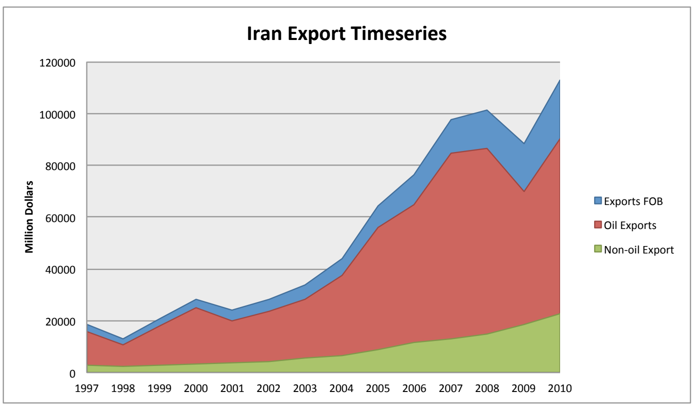

Figure 23 Iran's exports revenues from 1997 to 2010. Source: Central Bank of Iran's statistics, 2012.

According to the available data at the Central Bank of Iran, oil export have been always shaped more than 80 percent of total Iranian export since 1997 (Figure 24).

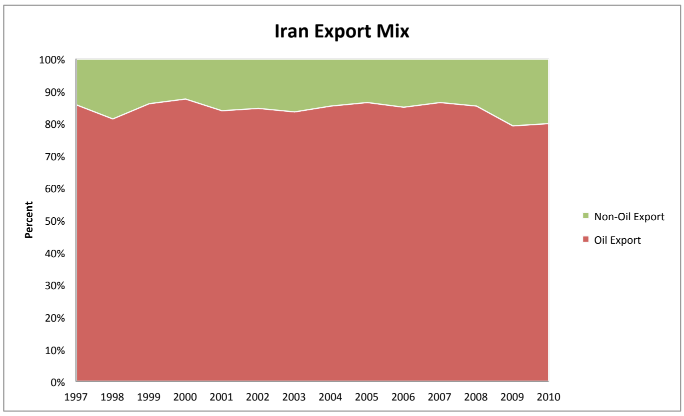

Figure 24 Iran's exports mix from 1997 to 2010. Source: Central Bank of Iran's statistics, 2012.

Contrary to what expected from high share of oil export in Iran's export, Iran still imports oil and gas products. Import of natural gas is mainly due to inability of national production capacity to cover gas demand during winter season, and import of oil products is mostly in shape of gasoline and diesel fuel for responding to the increasing transportation's energy demand (Moshiri et al., 2011).

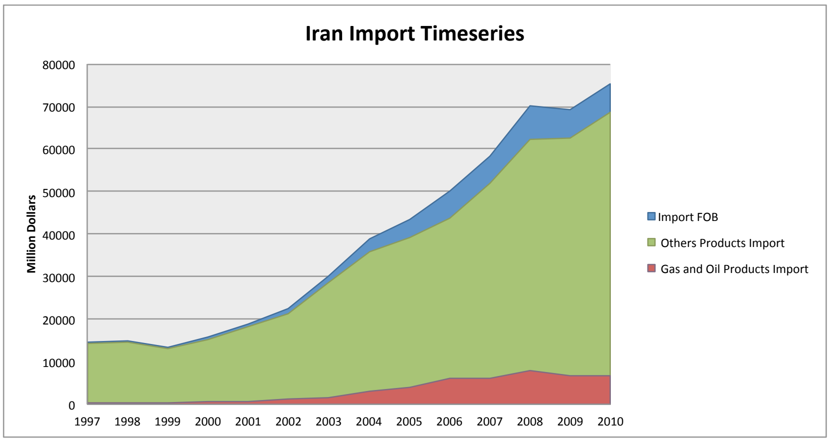

Figure 25 Iran's imports from 1997 to 2010. Source: Central Bank of Iran's statistics, 2012.

However, the share of gas and oil products in Iran's total imports is comparably low and 5% of total national imports (Figure 26).

Figure 26 Iran's imports mix from 1997 to 2010. Source: Central Bank of Iran's statistics, 2012.

Corless's (2005) Analysis of top 40 largest national economies (on the basis of GDP) by plotting GDP per capita against 'energy efficiency' (GDP per million Btus consumed) shows that Iran is among the energy inefficient and low productive nations of the world besides countries like Russia and Saudi Arabia (Figure 27).

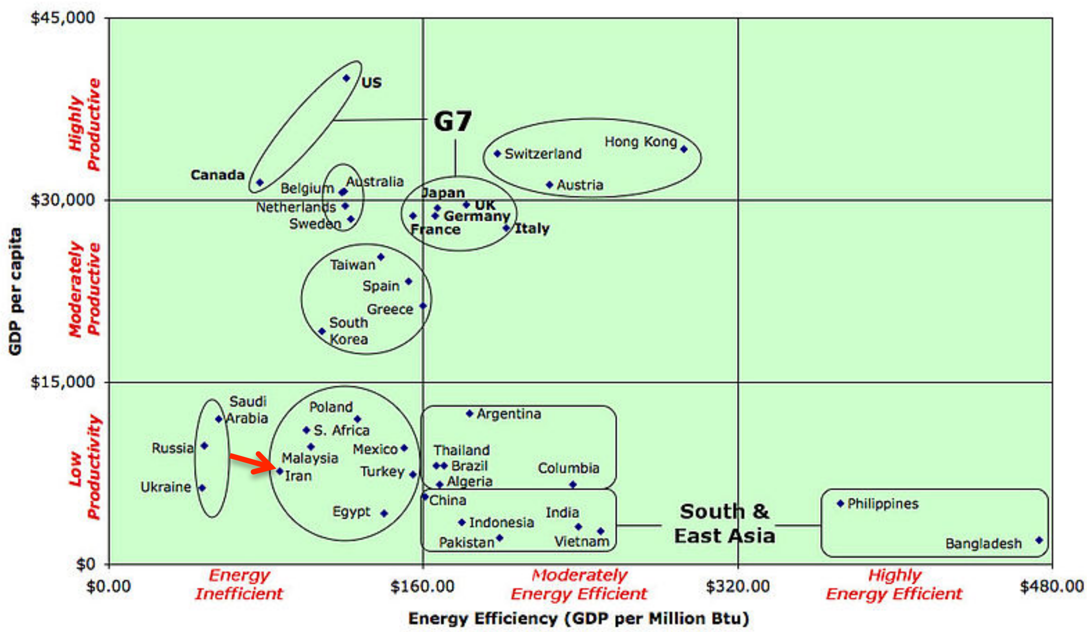

Figure 27 GDP vs. Energy Efficiency (Top 40 economies by GDP). Source: Corless, 2005.

2.3.2.1.2 Energy Supply and Consumption of Iran

The share of oil and petroleum products in energy supply in Iran has decreased from 80% in 1974 to 39% in 2010. On the other hand, the share of natural gas in energy supply has risen from 8% in 1974 to 59% in 2010. The contribution of the other energy resources such as coal, biomass, hydropower, wind and solar energy is only 1%, which is very low in comparison with the other countries (Deputy for Power & Energy Affairs of Iran, 2010; U.S. Energy Information Administration, 2013; Mohammadnejad et al., 2011) (Figure 28). Energy mix in Iran, comprise five key resources which are oil, natural gas, coal, hydro and renewable energy. Meantime, Iran has been developing peaceful nuclear technology and has planned to use nuclear as energy sources in the future (Mohammadnejad et al., 2011).

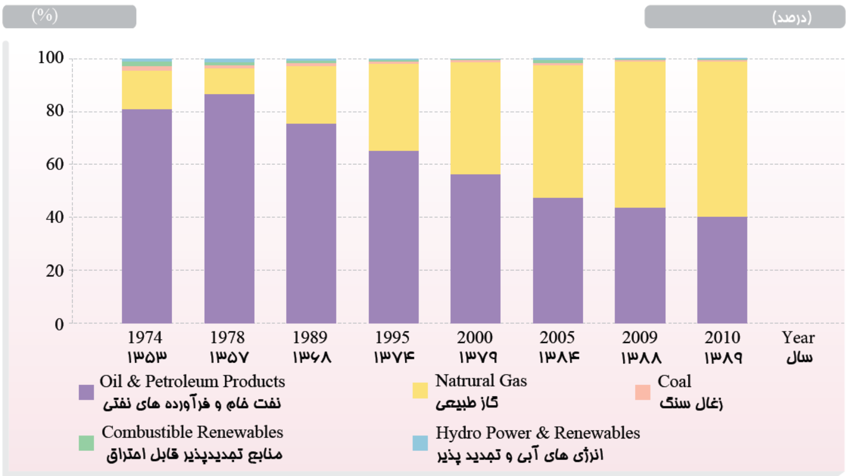

Figure 28 Share of energy carriers in total primary energy supply of Iran. Source: Deputy for Power & Energy Affairs of Iran, 2010.

Petroleum products and natural gas are the main energy demand of Iran. Electricity, coal and solid biomass have subordinate roles (Hessari, 2005). Figure 29 shows the trend of energy consumption in Iran by carriers for selected years.

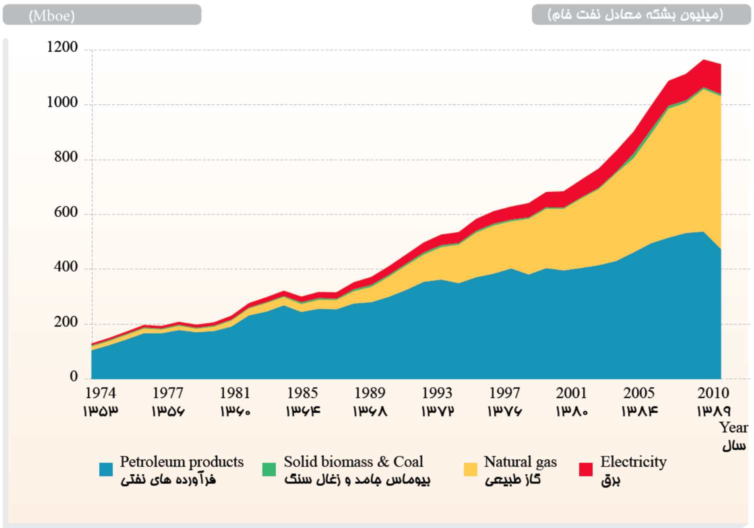

Figure 29 Total final consumption of Iran by carriers. Source: Deputy for Power & Energy Affairs of Iran, 2010.

The sectoral shares of the total primary energy consumption are as follows: Household 36 percent, industry 25 percent, transport 25 percent, others (agriculture, non-energy consumption, and others) 14 percent (Iran Energy Balance, 2011) (Figure 30). The per capita energy consumption has been growing averagely by 5 percent annually for the past 40 years (Moshiri et al., 2011).

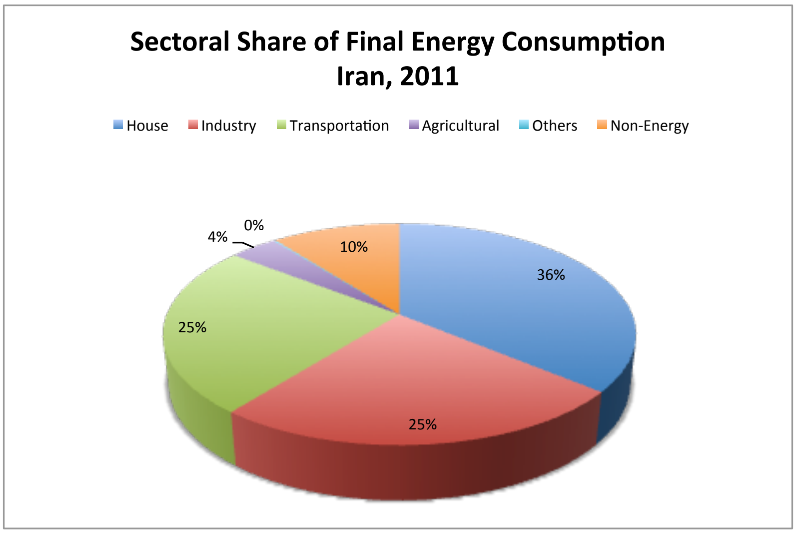

Figure 30 Sectoral share of final energy consumption of Iran, 2011. Source: Iran Energy Balance 2011.

The main consumer of Iran's petroleum products is transportation sector, which uses these products mostly in shape of gasoline and diesel fuel. The consumption of oil products of residential and commercial sectors has been gradually declined, mainly because of rapid expansion of natural gas network and replacement of gas with oil in these sectors of Iran (Figure 31).

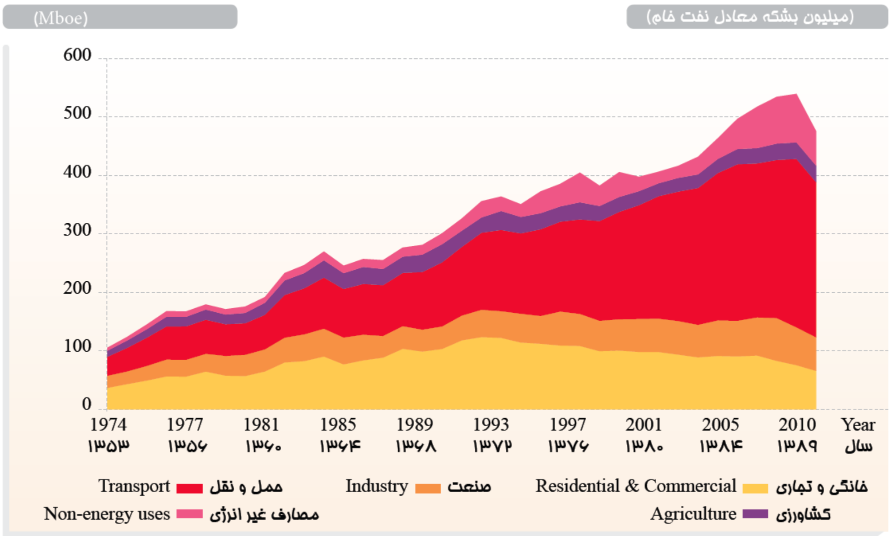

Figure 31 Final consumption of petroleum products in Iran by sectors. Source: Deputy for Power & Energy Affairs of Iran, 2010.

As Figure 32 shows the gas deployment mainly covers the residential and commercial users, industries and power plants consumptions thru nationwide network of pipelines. Furthermore, besides stimulating the exports, Iranian authorities have started to extend the pipelines even to the most inferior parts of the country like small villages (Ghorashi & Rahimi, 2011). As mentioned before presently, more than half of Iran's total energy demand is satisfied by natural gas. The government plans to heavily invest in the near future to increase the share of natural gas in country energy consumption. Specifically, gas has become a widespread choice for power generation in recent years in Iran since for Iranian gas is relatively cheaper than oil (Ghorashi & Rahimi, 2011).

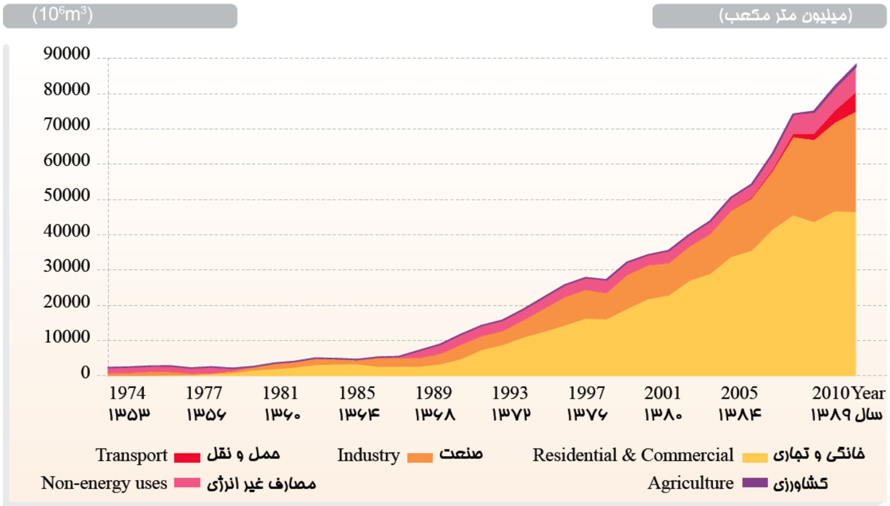

Figure 32 Natural gas final consumption in Iran by sectors. Source: Deputy for Power & Energy Affairs of Iran, 2010.

Residential, commercial and industrial sectors utilize most of generated electricity in Iran (Figure 33).

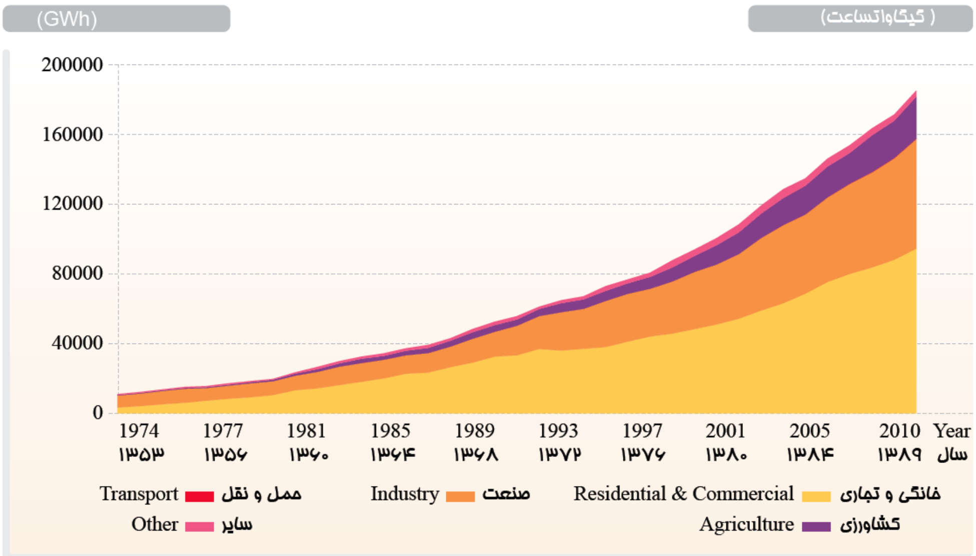

Figure 33 Electricity final consumption in Iran by sectors (Ref. Deputy for Power & Energy Affairs of Iran, 2010)

Among other energy carriers, coal is mostly employed for steel-making and cement production. It was also energy input in power generation plants formerly, which oil and natural gas rapidly substituted it in power plants. Because of the low quality of nationally produced coal that does not satisfy the needed standard of the steel making industry, part of domestic demand of coal is imported from country like Australia (Hessari, 2005).

Finally, Figure 34 shows detail energy flow of Iran in 2010 by sectors and energy carriers from energy sources to the total primary energy supply (TPES) and then to the total final consumption (TFC) of end-users of energy.

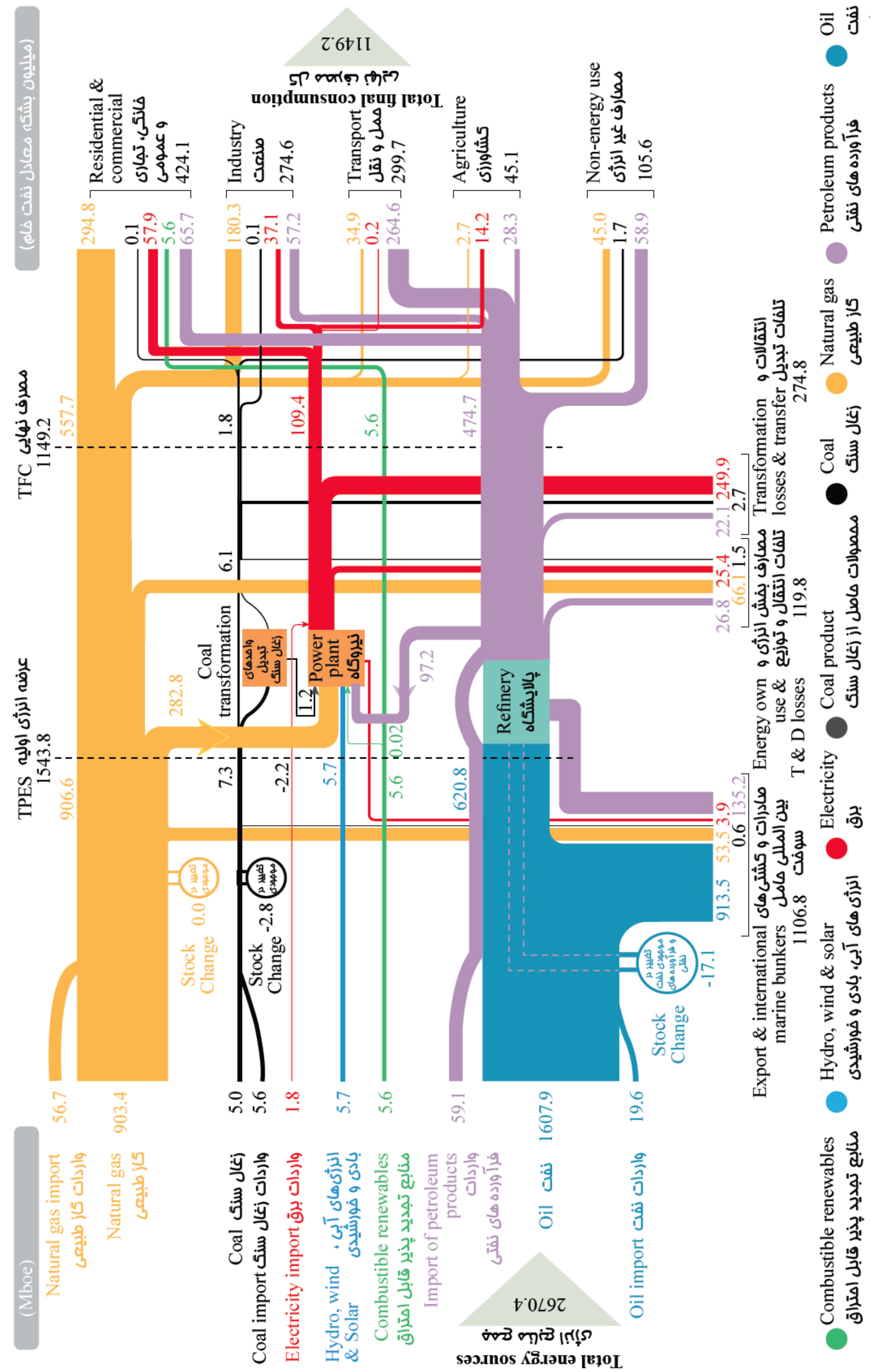

Figure 34 Iran Energy Flow, 2010. Source: Deputy for Power & Energy Affairs of Iran, 2010.

2.3.2.1.3 Energy Security of Iran

Decades ago, Churchill's historic decision to change the power source of the British navy's ships from coal to oil to have faster fleet than German navy, caused to energy security became a issue of national strategy. That switch meant that the British navy would rely no more on the national produced coal but on the vulnerable oil imported from Iran (Yergin, 2006). Several years after World War I, the 1973 crisis again draw world's attention to the question of energy security. After this crisis the term of energy security known more deeply as how to manage any disruption of oil supplies from producing countries (Yergin, 2006).

Recently, International Energy Agency (2001) defined energy security as the reliable and adequate supply of energy at a reasonable price. Reliable and adequate supply of energy means nonstop supply, which completely satisfy the demand of the global economy (Bielecki, 2002). As Hughes (2009) discussed as an outcome of the instability in world energy markets, the increasing rivalry for energy reserves, and the necessity for economic growth energy security is becoming more than ever important concern across world.

Although studies on the energy security are abundant, they have mostly focused on U.S., European Union, industrialized countries or major developing oil-importing countries such as China (Bahgat, 2006; Baran, 2007; Belkin & Morelli, 2007; Daojiong, 2006; Erica S Downs, 2004; Erica Strecker Downs et al., 2000; Greene, 2010; Leiby, 2007; Löschel, Moslener, & Rübbelke, 2010; Umbach, 2010; Wenmu, 2003; Yergin, 2011). The research on energy security in energy-producing countries is limited and to our knowledge there is no research on the measuring energy security in Iran[1]. Like what Moshiri et al. (2011) mentioned in their research, the fact that energy shortage at least in the short run has not been considered a serious economic or political risk in energy-rich countries may explain the limited research in this area.

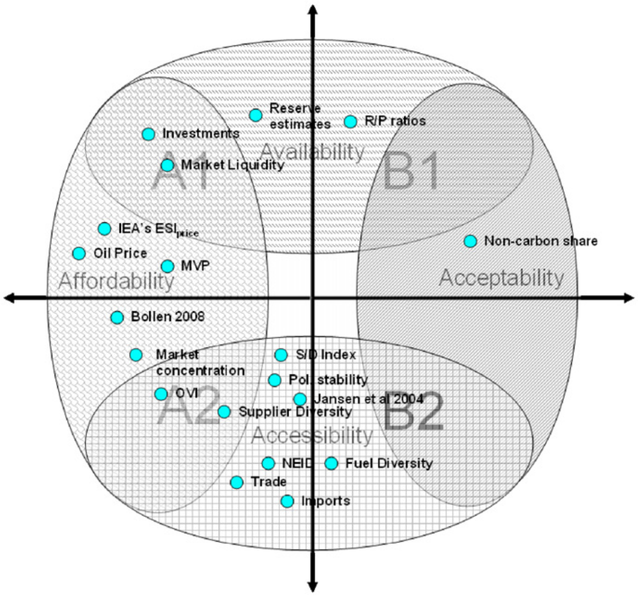

Figure 35 Indicators and elements of the energy security spectrum. Source: Kruyt et al. (2009).

Hence, we try to briefly investigate the energy security of Iran thru the set of indicators that Kruyt et al. (2009) introduced for measuring energy security or what they named long-term security of supply (SOS) more precisely (Figure 35). Among their indicators, demand-side indicators, import dependence, diversity indices and share of zero-carbon fuels are enough to show how Iran's energy security is fragile (Kruyt et al., 2009).

2.3.2.1.3.1 Demand-side indicators

The main utility of demand-side indicators is to show the size of impacts of energy shortages on the global economy. The key indicator among demand-side

[1] There is one exception, an article published in Persian language entitled "Energy security and lessons for Iran" written by Abbas Maleki (Maleki, 2007). But still this paper just suggests some options for enhancing Iran's energy security, and does not take steps to measure long-term security of Iran's energy supply.

indicators is the energy intensity of the economy, which uncovers the dependency of economies to the energy and consequently the sensitivity to price fluctuations (Kruyt et al., 2009).

In this case, Iran has been one of the most energy-intensive countries of the world, higher than countries such as Russia and Saudi Arabia (Figure 36) and its energy intensity indicator has been growing rapidly.

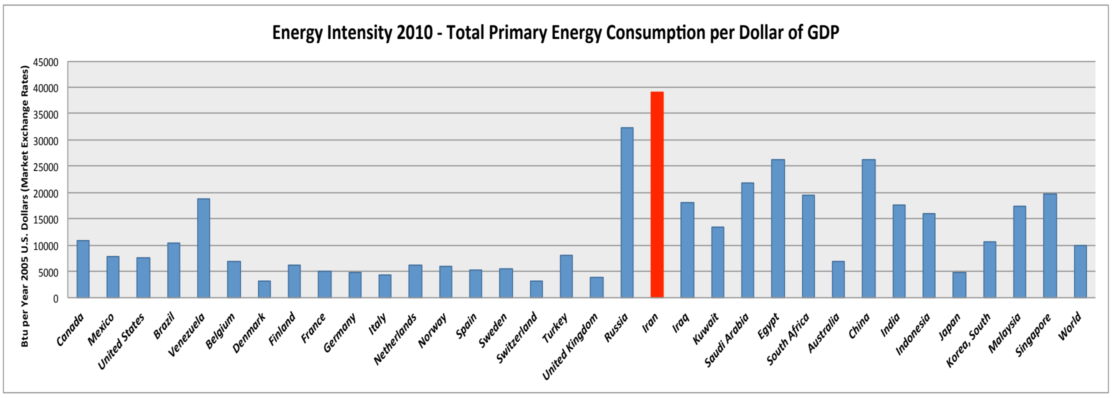

Figure 36 Energy intensity index of some selected countries, 2010. Source: International Energy Agency, 2014.

Despite the decline of the world's energy intensity, Iran's energy intensity index has been growing on average by 3.4 percent since 1967, indicating a decreasing trend in the efficiency of energy use (Moshiri et al., 2011) (Figure 37).

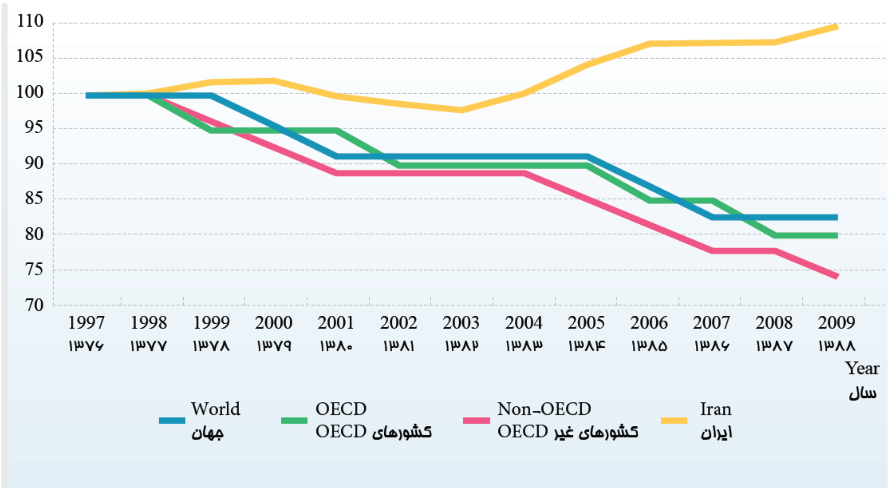

Figure 37 Comparison of energy intensity indicator using purchasing power parities (1997→100). Source: Deputy for Power & Energy Affairs of Iran, 2010.

Other demand-side indicators have similar situation. For instance, according to the Iran Energy Balance 2011 Iran's energy factor (Final energy use growth/GDP growth) for the time period of 2000-2010 is very high (1.09) compared to the world's energy factor (0.56), which is another sign of unproductive use of energy in Iran. Figure 38 shows some other demand-side indicator of energy security of Iran that all of them have been experiencing an increasing trend.

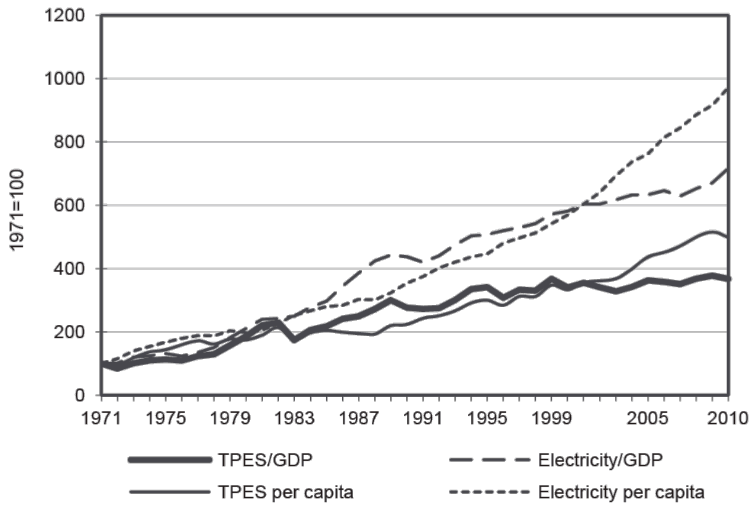

Figure 38 Demand-side indicators of Iran's energy security. Source: International Energy Agency, 2012.

2.3.2.1.3.2 Share of zero-carbon fuels

This indicator describes an economy's efforts to shift from a carbon intensive fuel portfolio to zero-carbon fuels (Kruyt et al., 2009) and measures the share of renewables and nuclear in total primary energy supply (APERC, 2007).

As mentioned before, Iran's fourth development plan dictated that 1% of the country's total needed electricity should come from renewable energy resources. However, not just this goal has been achieved, but also 62% of renewable energy power plants planned capacity is not realized yet (Fadai at al., 2011).

2.3.2.1.3.3 Import dependence

Measures of import dependence are amongst the most commonly used indicators for energy security that shows a country needs to access to the energy resources out of its borders (Kruyt et al., 2009). Obviously, more reliance on the import of the energy will lead to less energy security.

Import dependence can be measure directly by calculating the share of energy import or indirectly by the help of energy self-sufficiency indicator. Self-sufficiency indicator is calculated as total energy production divided by total primary energy supply (TPES). When this indicator is equal to or higher than 1, it means that the country does not need to import energy from abroad and even it can export energy, and vice versa.

Country	Oil (1) نفت(۱)	Gas گاز	Coal زغال سنگ	Total Energy(2) کل انرژی(۲)
Germany	0.04	0.15	0.64	0.40
Indonesia	0.72	1.91	5.47	1.74
UK	1.11	0.69	0.36	0.81
USA	0.42	0.90	1.09	0.78
Iran	2.34	1.01	0.65	1.59
Turkey	0.08	0.02	0.58	0.31
China	0.50	0.95	1.01	0.92
Japan	0.004	0.04	-	0.20
Saudi Arabia	4.84	1.00	-	3.35
Russia	3.58	1.34	1.61	1.83
France	0.01	0.02	0.01	0.51
Korea	0.01	0.01	0.02	0.19
India	0.24	0.79	0.86	0.74
World	**1.00**	**0.99**	**1.05**	**1.01**

Figure 39 Self-sufficiency indicators in some selected countries, 2009. Source: Deputy for Power & Energy Affairs of Iran, 2010.

As Figure 39 shows, Iran's total energy self-sufficiency is equal to 1.59 higher than world's index. Theoretically, Iran just needs to import coal, which in fact has been barely used in Iranian energy supply portfolio (Figure 28). But surprisingly, the natural gas self-sufficiency indicator of Iran (1.01) shows that the owner of the second-largest natural gas reserves of the world just can satisfy its domestic demand for natural gas now, and as Hamid Katouzian, head of Iran's Ministry of Petroleum Research Center mentioned "should the current energy consumption procedure not change, by 2025 Iran will be the largest natural gas importer in the world" (Mehr News Agency, 2014).

In fact, even now this self-sufficiency of Iran natural gas energy is believed to be unstable in a sense that if under unexpected circumstances there is an increase in domestic demands, mostly occurring during winters, having peaks in gas demands and during summers with highest peaks in electricity demands, then the supply shortage would be compensated by rationing scheme of gas and electricity throughout the country or by import (Moshiri et al., 2011) (Figure 40).

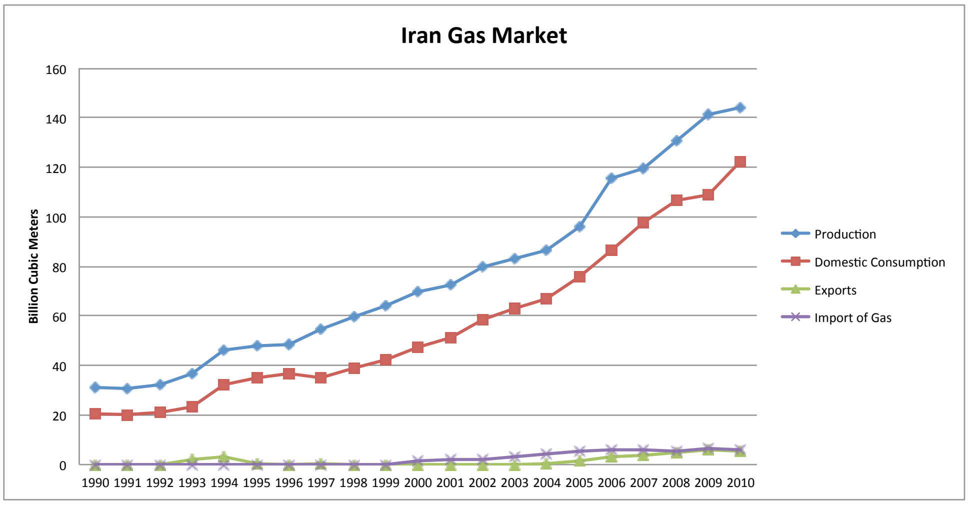

Figure 40 Iran gas supply and consumption (1990-2010). Source: Central Bank of Iran's statistics, 2012.

2.3.2.1.3.4 Diversity indices

A country can hedge against energy supply risks by diversifying its energy portfolio and can hedge against market power of energy suppliers by diversifying amongst suppliers (Kruyt et al., 2009). As mentioned above, Iran might not have serious concerns (at least in short term) about the second type of risks that are mostly related to energy-importer countries, but it should be worry about first type of risks.

As Figure 41, Iran satisfies more than 90% of its final energy demand by oil and natural gas, while big portion of the Iranian electricity energy comes from power plants that are fueling by natural gas (See Figure 34). It means that Iran's energy supply depends mostly on its supply of crude oil and natural gas, and this makes Iran's energy security highly vulnerable. For instance as Hosseini et al. (2013) mentioned current electricity demand in Iran, which includes almost 80% of what has been generated by fossil fuel consumption, will increase 400% by 2030. Apparently Iran fossil fuel supply will not be able to cover this increasing demand, and hence if Iran holds its current energy portfolio, Iran will be an energy-importer country in future (Hosseini et al., 2013).

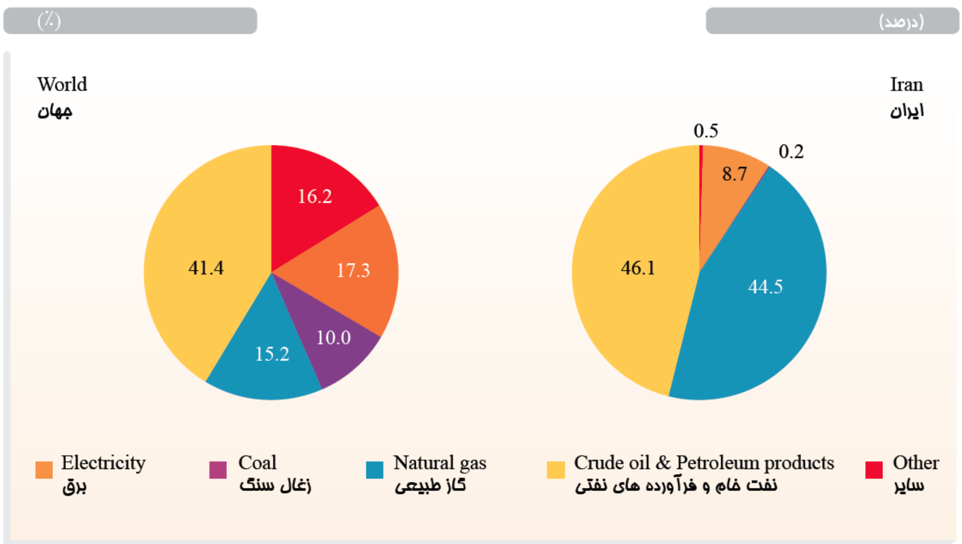

Figure 41 Share of energy carriers in total final consumption (TFC) of Iran and World, 2009. Source: Deputy for Power & Energy Affairs of Iran, 2010.

Based on the analysis of this set of selected indicators, it is appear that with the current trend of supply and demand of energy in Iran, the long-term security of energy supply of this country is fragile and will be faced with several serious problems.

2.3.2.1.4 Energy Subsidies Reform of Iran

Fuel's prices traditionally were lowest in the Persian Gulf countries, with Iran holding the record of charging the world's lowest petrol and diesel prices (Figure 42) (Fattouh & El-Katiri, 2013).

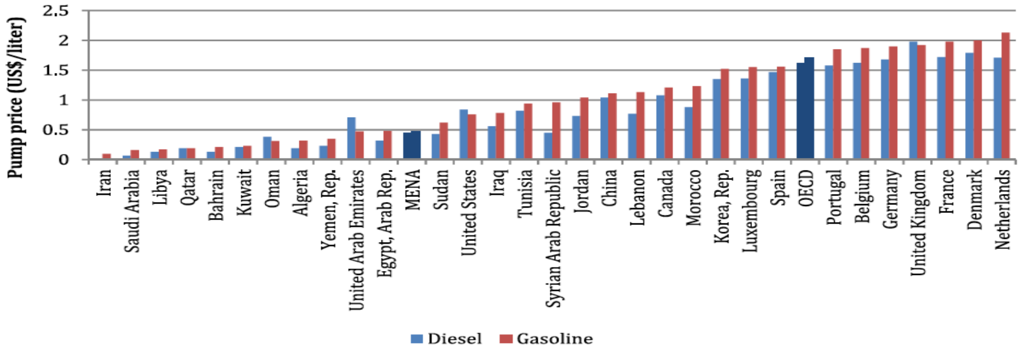

Figure 42 Average retail prices for gasoline and diesel in selected MENA-, OECD- and non-OECD Countries (in US$/liter), 2010. Source: Fattouh & El-Katiri (2013).

These low prices have been originated from the energy subsidies that these countries pay for energy carriers. The value of energy subsidies in Iran by 2010 was estimated at roughly US$90 billion almost 30% of Iran's GDP (Fattouh & El-Katiri, 2013), making Iran the country with the highest level of energy subsidy (Guillaume, Zytek, & Farzin, 2011) (Figure 43).

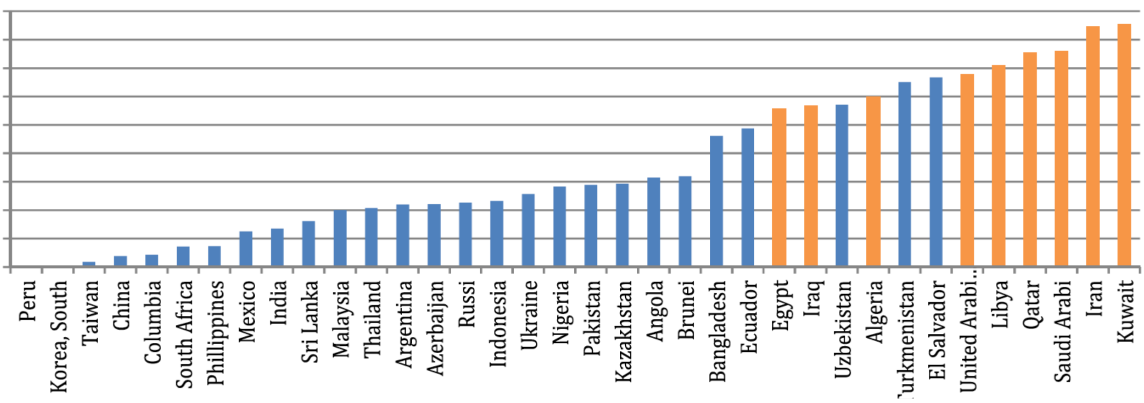

Figure 43 Average subsidization rates for domestic fuels in selected countries (in %), 2010. Source: Fattouh & El-Katiri (2013).

Like most of oil exporting countries, Iran have traditionally set domestic energy prices by considering return of production costs and occasionally changed prices. This pricing strategy was a good policy for time that international oil prices and Iranian exchange rates were stable. But in the last decade, two major events destroyed this stability and low domestic energy prices became increasingly out of line of global prices. The first event was the continuous increasing of international oil prices since 2002 (Figure 44), and the second event was the depreciation of Iranian Rials compared to US Dollar (Guillaume, Zytek, & Farzin, 2011).

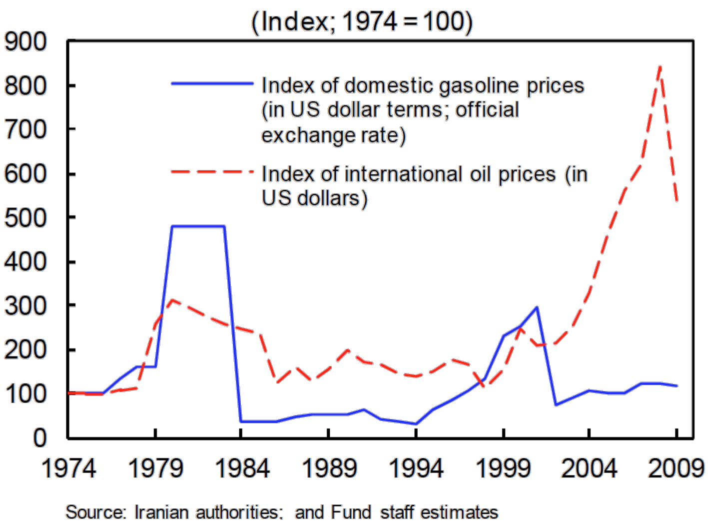

Figure 44 Iran: Domestic and International Oil Prices. Source: Guillaume, Zytek, & Farzin (2011).

Hence, the growing gap between domestic and international energy prices forced Iranian governments to pay the differences between two prices in the shape of subsidies and calculate these subsidies as 70 percent of their annual budget (Figure 45). Meantime cheap energy prices boosted Iranian energy consumptions in all sectors (Guillaume, Zytek, & Farzin, 2011).

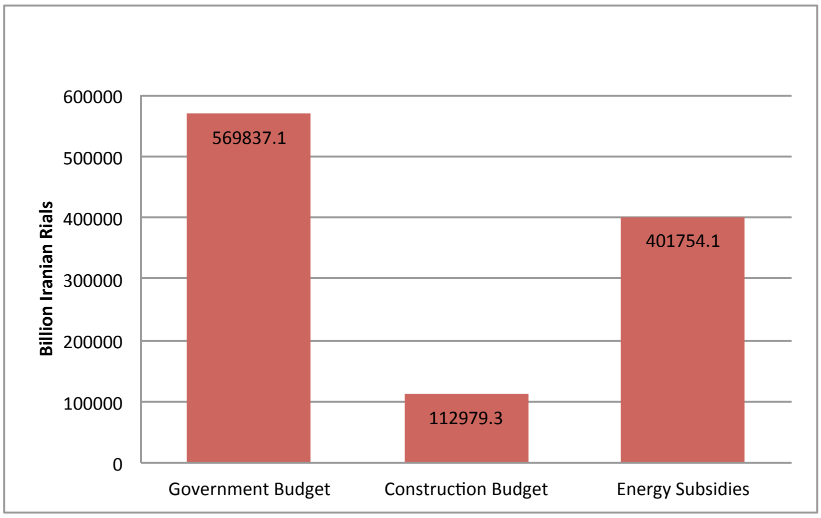

Figure 45 Government budget, Construction budget and Energy Subsidies' expenses of Iran, 2005. Source: Government of Iran.

To solve this problem, Iranian government introduced Energy Subsidy Reform Act, or as Iranian parliament named it Targeted Subsidies Law. To control the budget shortage and to stop the climbing trend of energy consumption, the Iranian government initiated an aggressive and impressive energy price restructuring in February 2010. According to Energy Subsidy Reform Law, energy (petrol, oil, liquefied gas and kerosene) prices would rise up to 90 percent of the Persian Gulf FOB prices in five years. Electricity prices would also increase to cover production expenses (Figure 46) (Moshiri, 2013).

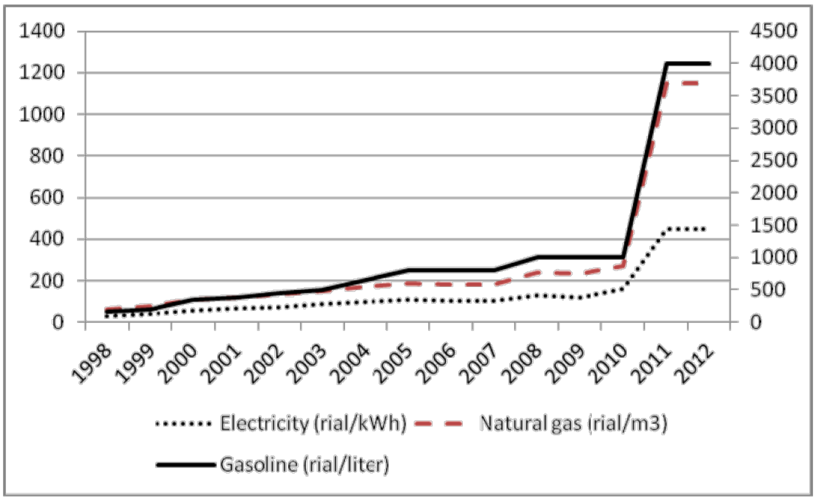

Figure 46 Energy prices (For residential sector) in Iran before and after Subsidy Reform. Source: Moshiri (2013).

These increases in energy prices would bring in between $10 billion to $20 billion in revenues. Based on the Targeted Subsidies Law, 50% of this revenues should be distributed in the form of cash aids to households, 30% should be funded to support industries most affected by the energy price hikes, public transportation, and infrastructure, and 20% should cover discretionary expenses (Moshiri, 2013).

According to the Government of Iran, the main goals of Iranian government's energy subsidy reforms, once called "grand economic surgery", are (Hassanzadeh, 2012):

- Promoting standards of living
- Distributing the national wealth fairly and equally
- Minimizing income disparities
- Raising energy prices to international market level
- Increasing efficiency and preventing wasteful consumption
- Reducing fuel smuggling
- Allocating more energy resources to boost production
- Encouraging demand for domestically produced commodities
- Enhancing country's oil and gas export capacity

What makes the Reform Act for this research relevant and critical is the impact that it have been on the Iranian industries. Iranian governments claimed that as part of the Reform Act, enterprises would receive various support packages such as interest subsidies on loans for adoption of new energy-efficient technologies, credit lines to mitigate the impact of higher energy costs on cash flow, and credit lines to spread the costs of higher energy costs over a three-year period. Meantime as the authorities were well aware of that the implementation of energy-efficient technologies would not be adequate to harvest all the benefits of the subsidy reform in term of efficiency return, they introduced several initiatives to increase firms efficiency by reducing waste and improving the production process (Guillaume, Zytek, & Farzin, 2011).

But what occurred in reality was different. First of all, industrial sector experienced one of the highest rises in the recent energy price increases. This leads to higher production costs for Iranian firms, specifically the energy-intensive industries such as steel and car manufacturing, food and beverages, power plants, and petrochemicals (Figure 47 and Figure 48) (Hassanzadeh, 2012).

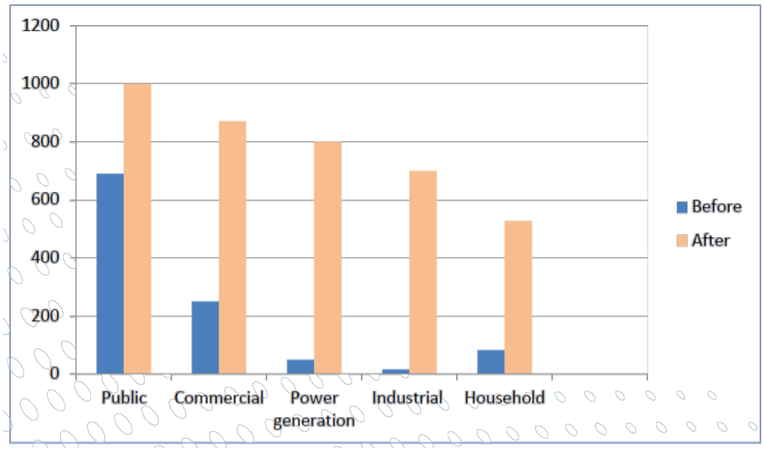

Figure 47 Natural gas price increase - IRR/M3. Source: Hassanzadeh (2012).

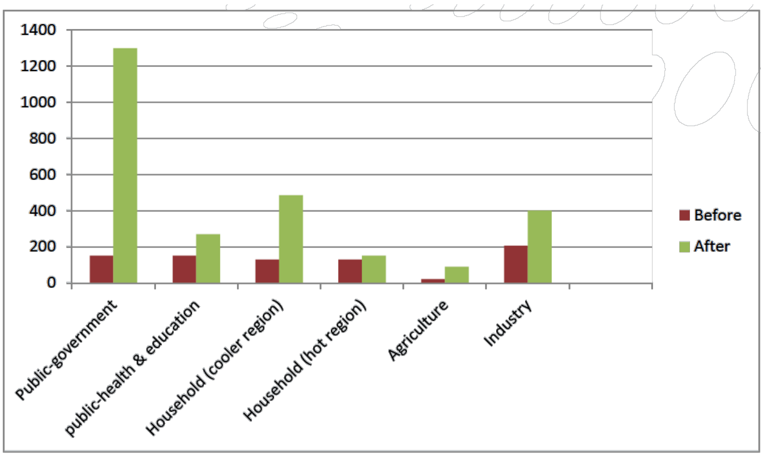

Figure 48 Electricity price increase - IRR/KWH. Source: Hassanzadeh, 2012.

Secondly, because of fright of sparking public unrest resulting from increase in commodity prices, the authorities banned manufacturers and retailers from increasing the prices of their products (Hassanzadeh, 2012).

Thirdly, government authorities did not invest 30% of the revenues in supporting industries as they had committed; insist they allocated 90% of the earned revenues from subsidy removal to the households aids plan (Moshiri, 2013).

Rising production costs, strict price controls from the government, and lack of governmental support for compensating increased production costs make it very challenging for Iranian industries to stay profitable, and consequently many small- and medium-size businesses are going to bankrupt or downgrade their businesses in these period (Hassanzadeh, 2012).

We are interested to see that in such a complicated situation whether Iranian energy-intensive firms choose a strategic plan by investing in more energy-efficient technologies and improving their production facilities, or they opt an emergency plan to rescue from faced situation by operating with their current technologies under potential capacity and decreasing their operational costs.

2.3.2.1.5 Imposed Economic and Trade Sanctions on Iran

Iranian governments have experienced unilateral sanctions after 1978 Iran's political change in several occasions, but in 2012 for the first time after Iran's 1978 Islamic revolution, international sanctions on Iran have mainly targeted the energy sector of Iran by restricting severely oil production capacity of Iran and its exports to the global markets (Farzanegan, 2013). As Katzman (2011) discussed the main objective of these sanctions has been to target Iran's energy sector, the heart of Iran's economy and the source of most of its revenue. These sanctions also have targeted financial sectors of Iran and tried to isolate Iran from the international financial system.

United Nation, United States and European Union have imposed the most important sanctions on Iran during recent years. According to the U.S. Energy Information Administration (2013), the current U.S. and EU sanctions forbidden extensive investment in the Iran's oil and gas sector, and detach its access to the Western sources of financial transactions. Additional sanctions were applied against the Central Bank of Iran, while the EU imposed an embargo on Iranian oil and banned European protection and indemnity clubs (P&I Clubs) from offering Iranian oil shippers with insurance. The execution of insurance-related sanctions was specifically effective in halting Iranian exports, which affected both European importers and Iran's Asian customers (U.S. Energy Information Administration, 2014).

Table 20 shows summary of main imposed sanctions on Iran that mainly aims at the oil and gas industry, prohibiting new investment, technical assistance and transfers of technologies, equipment and services related to these areas, in particular related to refining, liquefaction and liquefied natural gas technology.

Table 20 List of major imposed sanctions on Iran during last years. Source: UN Security Council; U.S. Center for Arms Control and Non-Proliferation.

Title of Sanction	Year	Description of Sanction
United Nations Sanctions		
Resolution 1737	2006	Banning the supply of nuclear-related materials and technology, and froze the assets of key individuals and companies related to the program.
Resolution 1747	2007	Imposed an arms embargo and expanded the freeze on Iranian assets.
Resolution 1803	2008	Extended the asset freezes and called upon states to monitor the activities of Iranian banks, inspect Iranian ships and aircraft, and to monitor the movement of individuals involved with the program through their territory.
Resolution 1929	2010	Froze the funds and assets of the Islamic Republic of Iran Shipping Lines, and recommended that states inspect Iranian cargo, prohibit the servicing of Iranian vessels involved in prohibited activities, prevent the provision of financial services used for sensitive nuclear activities, closely watch Iranian individuals and entities when dealing with them, prohibit the opening of Iranian banks on their territory and prevent Iranian banks from

		entering into relationship with their banks if it might contribute to the nuclear program, and prevent financial institutions operating in their territory from opening offices and accounts in Iran.
Non-UN Mandated Sanctions		
EU Sanctions	2010	EU member states are prohibited from supplying Iran with dual-use items and technology, as well as other equipment that could potentially aid Iranian nuclear development, or be used to aid internal repression in Iran.
	2012	The EU agreed to an oil embargo on Iran, effective from July, and to freeze the assets of Iran's central bank
	2012	All Iranian banks identified as institutions in breach of EU sanctions were disconnected from the SWIFT, the world's hub of electronic financial transactions.
	2012	The EU adopted a number of additional sanctions, including a ban on transactions between European and Iranian banks, a ban on natural gas imports, and a ban on exporting certain sensitive materials to Iran, including

		metals that could be used for shipbuilding technology and oil storage capabilities.
US Sanctions	2010	Expands previous energy sanctions by sanctioning sale of gasoline and gasoline production equipment to Iran.
	2011	Further amends the Iran Sanctions Act to sanction foreign firms that provide Iran with equipment or services that could enhance its oil, gas or petrochemical sector.
	2011	Imposes sanctions on foreign banks that transact with Iran's Central Bank. Exemptions can be issued to banks whose parent countries are certified to have "significantly reduced" their purchases of Iranian oil.
	2012	Expands on 2012 NDAA to block all property of Iranian government and Iranian financial institutions, including the Iranian Central Bank.
	2012	Sanctions foreign financial institutions that have purchased oil, petroleum, or petrochemical products from Iran. Previously, purchasing oil and natural gas from Iran were not violations of existing sanctions law.

	2013	Sanctions entities providing goods and services to Iran's energy, shipbuilding, shipping, and port sectors, as well as entities that provide previous or semi-finished metals to Iran.

Mirsaeedi (2013) in his presentation about the impact of sanctions on Iran's energy export demonstrated that after imposing severe sanctions on the Iranian energy and financial sectors Iranian crude oil exports plunge 40% in 2012 compare to 2011 (Figure 49).

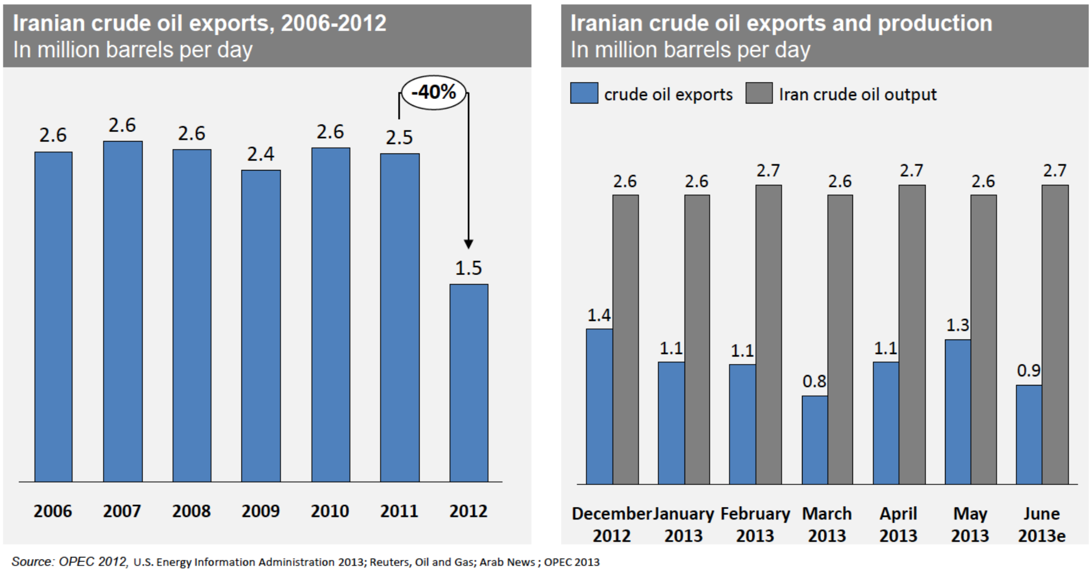

Figure 49 The Iranian crude oil exports projects a 40% decline in 2012 oil revenues. Source: Mirsaeedi, 2013.

As figure 39 shows, Iran's exports of crude oil and lease condensate declined to less than 1.5 million barrels per day (bbl/d) in late 2012 and early 2013, compared to 2.5 million bbl/d in 2011. This 39% decline in exports was combined with a 17% plunge in crude oil and condensate production and a 1% drop in liquid fuels consumption (U.S. Energy Information Administration, 2014).

Katzman (2011) claimed that as a consequence of these sanctions, numerous key international companies have been leaving Iran, as they are reluctant to destroy their position in the U.S. market to do risky business with Iran. Katzman (2011) predicted that in long term, the efficiency and productivity of Iran's economy would drop mainly because Iran has to do business with less proficient foreign firms from countries such as China, Malaysia, India and Vietnam.

In the meantime, Katzman (2011) mentioned that even small and large traders are struggling with difficulties such as obtaining trade financing and export licenses, insurance, and shipping availability, which is increasing their expenses approximately 40%, in the case that they can complete needed transactions at all.

What make imposed sanctions on Iran so important for our research are two key entangled issues:

1. On the surface, these sanction have rigorously reduced the potential of Iran's oil production and export, while Iran's energy consumption has not comparably decreased (Figure 50). In this situation and specifically if this situation remains for long-time, efficient use of energy appears more than ever important for Iranian governments to hedge pitfalls in supplying energy for country and at the same time maintain the level of country's productivity. Currently, Iranian governments have responded to the international sanctions by 'Resistance Economy' plan that aimed to reduce dependence on the oil exports and develop barter trade and an import substitution industrialization (Tehran Times, February 2014). The 4th article of the resistance economy plan has clearly commanded: "utilizing the potential of applying subsidies to increase production and employment, to drastically decrease energy consumption, and improving the indicators of social equality" (EA WorldView website, March 2014).

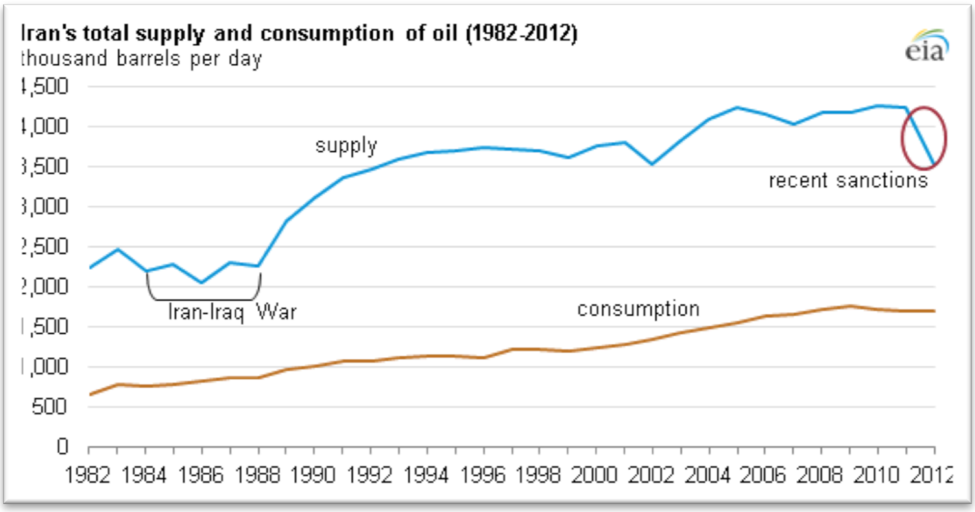

Figure 50 Iran's total supply and consumption of oil (1982-2012). Source: U.S. Energy Information Administration, 2013.

2. In depth, because of tight financial and trade sanction almost all of Iranian firms, regardless of their sectors, either cannot access to the emerging energy efficient technologies available on the global market, or acquire these technologies higher than market prices. In both cases, if Iranian firms decide to not implement emerging and more energy efficient technologies, they will face a high risk of loosing competitiveness. Because by passing time they will turn less productive and their machineries will work less efficiently, and there is no clear finishing point for this undesirable situation. Revealing this dilemma is one of the interesting issues in this research.

Noteworthy, Iranian governments reached a nuclear deal in November 2013 with 5+1 group (E3+3 group) that has eased some minors sanctions but the core leftovers effective — including sanctions targeting Iran's crude oil exports and banking system. After the first deal, Iran and 5+1 group have initiated talks for a final deal that will lift all the imposed sanctions in log run (AP News Agency, February 2014).

2.3.2.1.6 Energy Consumption of Iranian Industries

As mentioned before, Iran has met a high economic growth rate during last decades. According to the World Bank's statistics Iran GDP consistently expanded with an average rate over 4.9 percent from 1989 (after eight years of imposed war with Iraq) to 2010. According to Moshiri at al. (2012), Iranian industries had 38% share of Iran GDP in 2012, higher than agricultural sector and lower than service sector. For example, as Figure 51 shows, total outputs of three major industries in Iran (Steel, Cement and Petrochemical) have been growing continuously thru last decades.

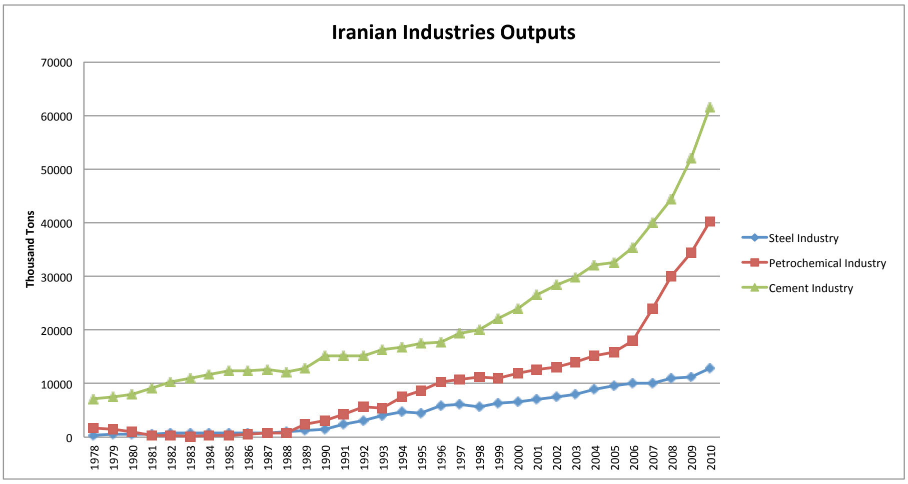

Figure 51 Iranian industries production (1978-2010). Source: Central Bank of Iran's statistics.

2.3.2.1.6.1 Rapid Growth Of Energy Consumption And Substitution Of Energy Input

As a consequence of this rapid development, Iran's industry sector has the highest growth rate of the total final energy consumption in last ten years (Iran Energy Balance, 2011). Statistics shows that total final energy consumption of Iran's industry sector has been increased from around 25 million tons of crude oil in 2005 to the more than 40 million tons in 2011 (Figure 52). As mentioned before, Iran's industry sector's total final energy consumption is equal to 25% of the total final consumption of the whole country (See Figure 30).

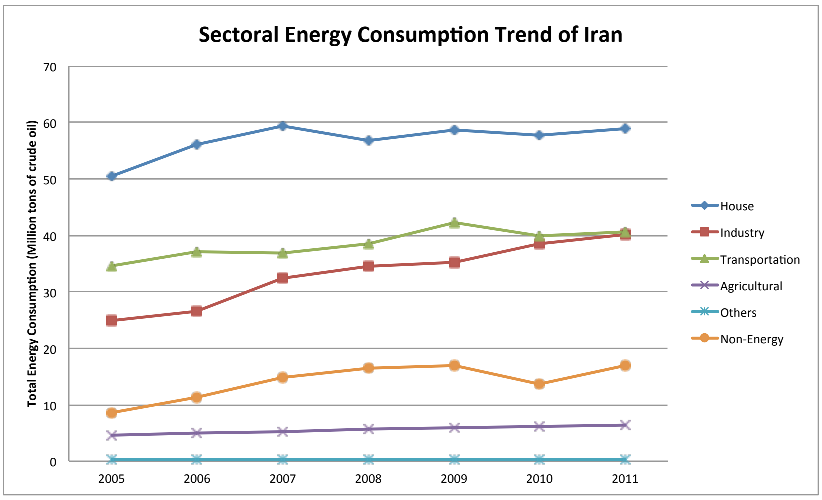

Figure 52 Sectoral energy consumption trend of Iran (2005-2011). Source: Central Bank of Iran's statistics.

Currently, Iranian industries utilize energy mostly in the shape of natural gas and electricity energy comes from gas-based power plants (Figure 53).

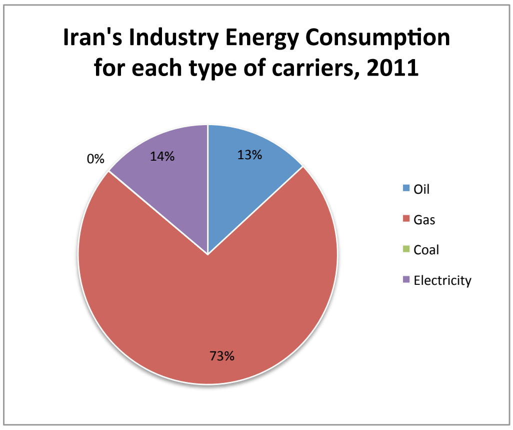

Figure 53 Iran's industry energy consumption for each type of carriers, 2011. Source: Iran Energy Balance, 2011.

Despite the rapid decline of oil consumption in Iranian industries, the consumption of gas in Iranian firms has been unceasingly intensified during last decade and shaped more than 70% of the Iranian industries energy portfolio (Figure 54).

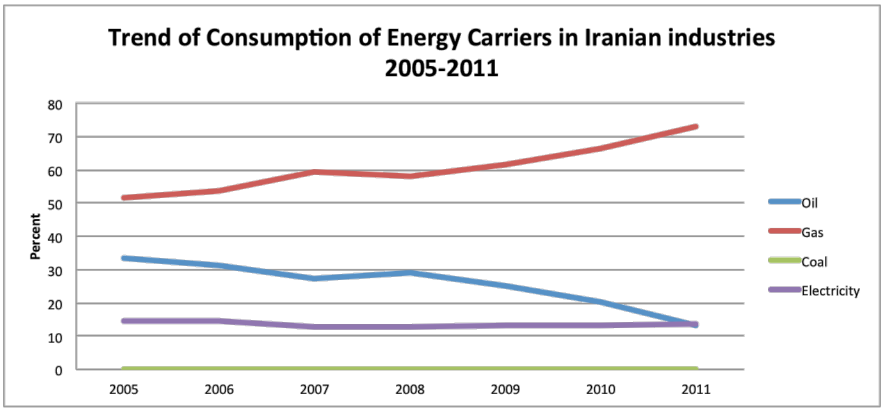

Figure 54 Trend of consumption of energy carriers in Iranian industries (2005-2011). Source: Iran Energy Balance, 2011.

2.3.2.1.6.2 National Standards For Energy Consumption

Besides energy subsidy reform, the most significant response of Iranian government to this rapid growth during last years was defining some standards for energy consumption of different industries or modifying earlier version of these standards. Iran Energy Ministry with collaboration of Iran Oil Ministry has defined and published standards of energy consumption for 13 industries sectors that are major energy consumers of Iran's industry. According to the Iran Energy Balance 2011, these industries are: Cement, Brick, Ceramic, Glass, Steel, Foundry Products, Aluminum, Paper, Edible Oil, Plaster and Lime, Chemical Products, Sugar and Wood Products (Ministry of Energy, 2011).

According to the third and forth development plans of Iran, all the Iranian firms in these industries with electricity demand of more than 5 MWH in year have to obey related energy consumption standards, and Iranian Electricity Companies must audit all the firms under their coverage with the help of certified energy service companies. The price of electricity energy for industrial firms with electricity demand of bigger than 5 MWH that cannot satisfy related standard will increase by 20% (Ministry of Energy, 2011).

2.3.2.1.6.3 Energy Saving Potential

According to the estimation of Deputy for Power and Energy Affairs of Iran in 2010, applying these standards in Iran can lead to a massive energy saving in Iranian industries. As Figure 55 shows estimated energy saving potential in just some selected industries is equal to around 22 Mboe (3.07 Mtoe) that is roughly 7.5% of total final energy consumption of the whole Iran's industry sector in 2011 (See Figure 52). Cement, Brick, Steel and Sugar industries beside petroleum refineries and Petrochemical plants have significant energy saving potential that means they are also more energy-intensive industries.

Industry	Fuel saving ratio to the applied standard (%) درصد صرفه جویی سوخت نسبت به استاندارد تدوین شده (درصد)	Energy saving potential (Mboe) میزان صرفه جویی انرژی (میلیون بشکه معادل نفت خام)	صنعت
Cement	12	2.20	سیمان
Brick	19	3.24	آجر
Glass	8	0.29	شیشه
Gypsum	14	0.34	گچ
Lime	14	0.08	آهک
Plastic	27	0.22	لاستیک
Iron and Steel	18	5.38	آهن و فولاد
Sugar	23	1.93	قند و شکر
Vegetable oil	25	0.47	روغن نباتی
Tile and ceramic	8	0.30	کاشی و سرامیک
Petroleum refineries	8	2.76	پالایشگاه های نفت
Petrochemical plants (9 plants, 15 operative units, 5 process)	11	3.83	مجتمع های پتروشیمی (۹ مجتمع پتروشیمی ۱۵ واحد عملیاتی و ۵ فرآیند)
Petrochemical plants (15 process in 28 polymer units)	13	0.89	مجتمع های پتروشیمی (۱۵ فرآیند در ۲۸ واحد پلیمری)

Figure 55 Energy saving potential due to energy efficiency standards in some selected industries by Iranian Fuel Conservation Co., 2010. Source: Deputy for Power & Energy Affairs of Iran, 2010.

However, assessment of energy saving potential in Iran is not limited to the governmental analysis. Moshiri et al. (2011) showed in their research that in efficiency scenario Iran would save more than 42 percent energy than in Business-as-usual (BAU) scenario by the year 2030.

Moshiri et al. (2011) exhibited that total final energy demand of Iran will growth on average by 2.8 percent per year from 783 Mboe in 2005 to 1549 Mboe in 2030 in the BAU scenario. Manufacturing industries will have the highest growth in demand for energy with an average growth of 3.4 percent per year followed by the residential and transport sectors with 3.2 and 2 percent annual growth, respectively (Moshiri et al., 2011). Figure 56 illustrates the results of their BAU scenario analysis for energy demand in different sectors of Iran from 2005 to 2030.

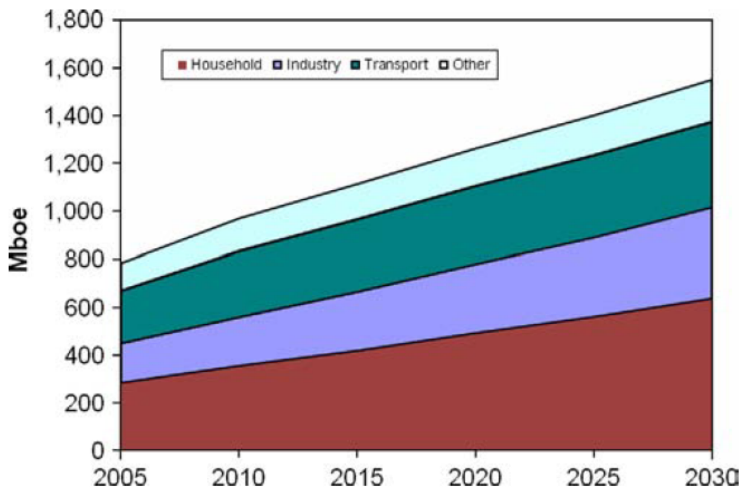

Figure 56 Total final energy demand by sectors, BAU scenario (2005-2030). Source: Moshiri et al., 2011.

While under the efficiency scenario, the total final energy demand of Iran will grow on average just by 0.5 percent per year from 783 Mboe in 2005 to 894 Mboe in 2030 (Figure 57). The greatest share of savings in this scenario will be in the household sector with more than 50 percent lower energy consumption compared with BAU scenario. Energy savings in industry, transport, and other sectors will be yet significant, between 30 and 40 percent (Moshiri et al., 2011).

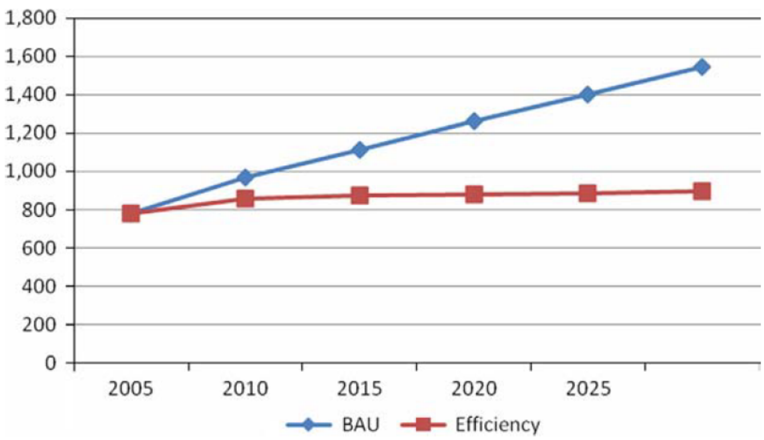

Figure 57 The energy demand scenario results (2005-2030), Mboe. Source: Moshiri et al., 2011.

2.3.2.1.6.4 Finding Most Energy-Intensive Activities And Industries

But from where will this big energy saving potential come from? The rational answer is from where the most of energy demand comes from. According to the survey results of Iran Statistics Center of energy consumption of workshops with 10 or more employees from 2003 to 2010, 82% of total final energy consumption of these companies is utilized in their production lines (Figure 58). Hence sensibly the biggest hope for improving energy efficiency in these manufacturing industries comes from technology change or modification in their production line.

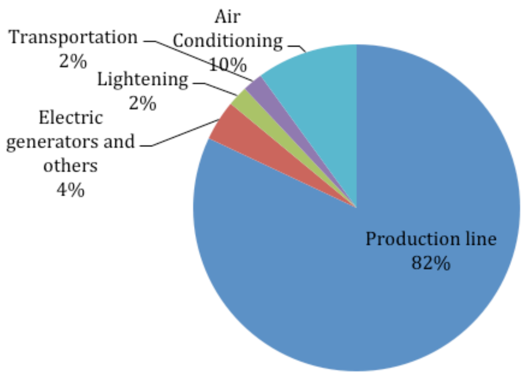

Figure 58 Energy Consumption Share in the industrial workshops of 10 or more employees, 2010. Source: Iran Statistics Center.

In an attempt to find the most energy-intensive industries of Iran, the detail data of energy consumption of Iranian industries from March 2006 to March 2007

(Corresponding to the Iranian calendar year of 1385) was collected and analyzed. Based on the official statistics of Iranian industries' energy consumption, manufacturers of non-metallic mineral products, basic metals products, coke and refined petroleum products, and chemical products were the most energy-intensive industries of Iran in 2006-2007 by shaping respectively 28%, 21%, 20% and 15% of total final energy consumption of Iran's industry sector (Figure 59).

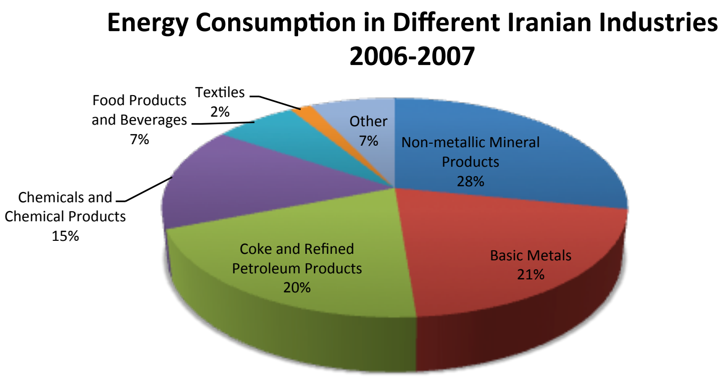

Figure 59 Energy consumption share of Iranian industries, 2006-2007. Source: Iran Energy Balance, 2007.

Table 21 shows details of energy consumption of Iranian manufacturing industries energy consumption for the period of 2006-2007.

Table 21 Total final energy consumption of Iranian industries (in tons of oil equivalent), 2006-2007. Source: Iran Energy Balance, 2007.

Industry	TFC (TOE)	Share
Non-metallic Mineral Products	8,107,951	28%
Basic Metals	5,963,295	21%
Coke and Refined Petroleum Products	5,862,264	20%
Chemicals and Chemical Products	4,422,616	15%
Food Products and Beverages	1,964,784	7%
Textiles	516,782	2%

Motor vehicles, Trailers and Semi-trailers	429,695	1%
Paper and Paper Products	304,360	1%
Rubber and Plastics Products	303,607	1%
Machinery and Equipment	301,016	1%
Fabricated Metal Products	272,579	1%
Electrical machinery and Apparatus	129,289	0%
Wood and of Products of Wood and Cork	67,460	0%
Furniture	51,407	0%
Other Transport Equipment	49,188	0%
Tanning and Dressing of Leather	27,511	0%
Medical, precision and optical instruments	23,077	0%
Publishing, printing and reproduction of recorded media	20,887	0%
Tobacco products	20,290	0%
Radio, television and communication equipment	11,410	0%
Wearing apparel	8,051	0%
Office, accounting and computing machinery	2,246	0%
Recycling	602	0%

Meanwhile, Iran Statistics Center's survey on energy use of industrial workshops with more than 10 workers in 2010 shows similar composition, except in one case; According to the results of this survey, manufacturers of chemical products consumed more energy than manufacturers of coke and refined petroleum products in 2010 (Figure 60). Although there is not accessible detail data on the energy consumption of the Iranian industries in 2010, but by considering rapid growth of petrochemical production (See Figure 51) and escalation of energy consumption of Iran's industry sector (See Figure 52) after 2006, this change is plausible and logical.

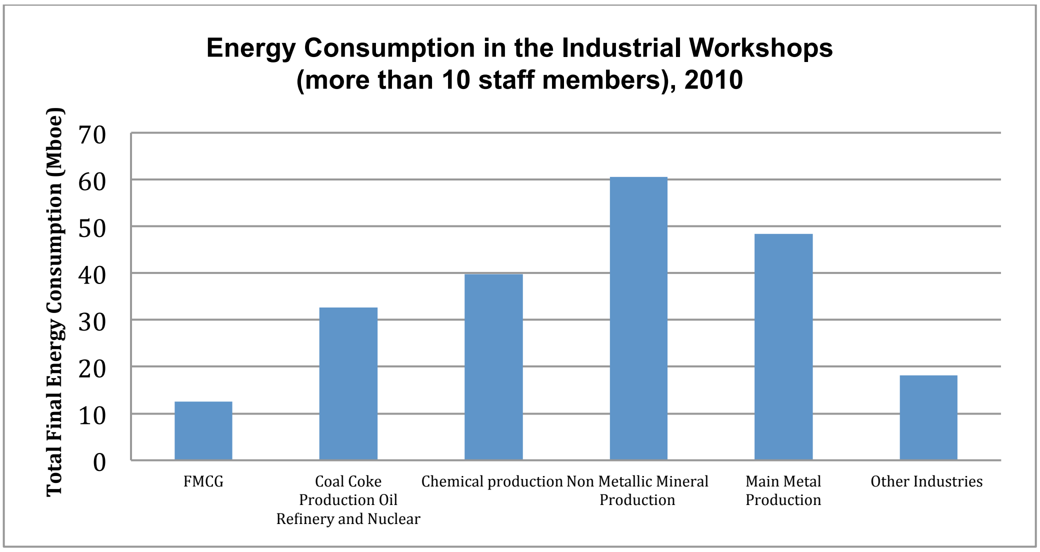

Figure 60 The amount of the energy consumption in the industrial workshops more than 10 staff members, 2010. Source: Iran Statistics Center.

In conclusion it is safe to claim that manufacturers of non-metallic mineral products, basic metals products, and chemical products are the most energy-intensive industries in Iran, and they utilize most of their energy inputs in their production lines. All of these three industries have to obey national energy consumption standards and have significant energy efficiency potential, and at the same time they are experiencing tough and unstable conditions of Iran in these years. In the following sections, based on this conclusion we will select two companies from each of these three industries, and try to understand and discover how they think about and move toward energy efficiency technologies and practices within their organizations.

2.3.2.2 Selected Industries And Firms

It has been explained in the pervious section that manufacturers of non-metallic mineral products, basic metals products, and chemical products are the three top energy-intensive industries in Iran. So in the following sections we will focus on these selected industries to answer to our research questions.

Eisenhardt (1989) mentioned it is common for researchers to decide how many cases to be studied beforehand, mainly when they are faced with resources and time limitations. In addition, however there is not a perfect quantities of cases for a multiple-case study research, but the range of 4 to 10 cases usually satisfies the requirements of the research (Eisenhardt, 1989).

Hence by considering our financial resources availability, time constraint, the satisfactory quantity of cases and convenient access to the companies we chose two firms in each selected industry for our research that counts for total number of 6 cases across all of three industries. For instance most of Iranian petrochemical firms are located in the South of Iran, while cement and basic metal manufacturers are mostly concentrated in the central part of Iran (Figure 61); This fact limits the number of cases that we can study because of time and monetary restrictions caused by long distance trips.

As the interviews and companies are to remain anonymous, in the following sections that briefly introduce the below six companies we will named them by identical letter and all of their sensitive data will be presented approximately.

- Cement Industry
    - Company A
    - Company B
- Metal Production Industry

- Company C
- Company D

- Petrochemical Industry
    - Company E
    - Company F

Figure 61 Geographical maps of selected companies for interview (The locations are approximate). Source: Google Maps, 2014.

As it explained before, all of three industries under our investigation must follow published National Standard for energy consumption. So all of selected six firms are working under defined standards and have energy-auditing plan annually. In addition all of these six companies are listed companies in Iran stock or going to be listed in near future.

2.3.2.2.1 Company A (Cement Industry)

Company A was registered in Qom province. This Company has been put into operation with the operation permit of one million ton in year in September 2011 (Figure 62). This Company has three main shareholders that have more than 95% of the total firm's shares.

Figure 62 A view of Company A.

Company's thread activity involves a wide range of activities such as:

1- Construction, purchasing, installation, commissioning, and operation in cement factories
2- Exploration, extraction, operation, and exploitation of the related licenses for all the required mines
3- Production of any building materials and creation of the related production workshops
4- Purchasing, education, and transferring any license for producing

Factory manufactures all types of cements including cement type 1-425, type 2 and 5. Table 22 shows the detail specification of Company A with the list of technologies that this Company is utilizing in its production lines.

Table 22 Company A's specifications.

Production Capacity	**Clinker**	**1,000,000 tons per year**			
	Cement	**1,000,000 tons per year**			
Start day		**2011**			
Type of products		**Type 2, Type 5, Type 1-425**			
Specifications of Machines and Equipment	**Name of Machine**	**Capacity**	**Model**	**Origin**	**No.**
	Impact Crusher	**1000 t/h**	**Hazemag**	**Germany**	**1**
	Roller Raw Mill	**280 t/h**	**Pfeiffer**	**Germany**	**1**
	Cement Roller Mill	**120 t/h**	**Pfeiffer**	**Germany**	**2**
	DOPOL Pre-heater	**3300 t/day**	**Polysius**	**Germany**	**1**
	PolRo Kiln	**3300 t/day**	**Polysius**	**Germany**	**1**
	Cooler	**2000 t/day**	**Polysius**	**Germany**	**1**
	Rotary Packing Load	**120 t/h**	**Haver & Boecker**	**Germany**	**1**

Company A consumes electrical and thermal energies in its production line. Electrical energy mainly powers electrical motors in different stages of production lines, while thermal energy feeds pre-heater and kiln. Table 23 listed the special energy consumption of both utilized energies and actual production statistics of Company A. According to Iran National Standard for the energy consumption in cement industry (Iranian National Standardization Organization, 2012) the energy consumption of Company A is well under the defined limitation for this standard.

Table 23 Energy consumption report of Company A (From April 2013 to April 2014).

Special Thermal Energy Consumption	740 Kcal per KG Clinker
Special Electrical Energy Consumption	91.71 KWH per Ton
Total Clinker Production	1,065,806 tons

Total Cement Production	1,030,382 tons

According to the Company A's organizational structure, the Electrical Department is responsible for all the issues related to energy efficiency within firm.

2.3.2.2.2 Company B (Cement Industry)

Figure 63 A view of Company B, 2014.

Company B is a subsidiary of cement production group that is formed by six cement production companies, two complexes of lime and concrete and one packaging company which plays an important role in cement supply of Iran by producing 5 million ton cement annually (Figure 63).

Company B is located in Isfahan province and yearly cement production of 565,000 tons, in a land equivalent to 60 hectares that 15 hectares of the land has been replaced with green space. Table 24 shows the detail specification of Company B with the list of technologies that this Company is utilizing in its production lines.

Table 24 Company B's specifications.

Production Capacity	**Clinker**	**1700 tons per day**
	Cement	**1800 tons per day**
Start day		**2005**

Type of products		Type 2- type 1-325			
Specifications of Machines and Equipment	Name of Machine	Capacity	Model	Origin	No.
	Hammer Crusher	450 t/h	PSP	Czech	1
	Roller Raw Mill	190 t/h	Pfeiffer	Germany	1
	Open Cement Ball Mill	35 t/h	Polysius	Germany	1
	Rotary Kiln	1700 t/day	Polysius	Germany	1
	Cooler	2000 t/day	PSP	Czech	1
	Closed Cement Ball Mill	70 t/h	Polysius	Germany	1
	Loading & Rotary Packing	100 t/h	Haver & Boecker	Germany	1

Company B like Company A consumes electrical and thermal energies in its factories. Electrical energy mainly powers electrical motors in different stages of production lines, while thermal energy feeds pre-heater and kiln. Table 25 listed the special energy consumption of both utilized energies and actual production statistics of Company B. According to the Iran National Standard for the energy consumption in cement industry (Iranian National Standardization Organization, 2012) the energy consumption of Company B for both types of energy is close to the defined thresholds.

Table 25 Energy consumption report of Company B, 2013.

Special Thermal Energy Consumption	817 Kcal per KG Clinker
Special Electrical Energy Consumption	100.56 KWH per Ton
Total Clinker Production	520,351 tons
Total Cement Production	605,585 tons

Like Company A the Electrical Department of Company B is responsible for all the issues related to energy efficiency within firm. Production lines of Company B are shown in a schematic plan of production cycle in Figure 64.

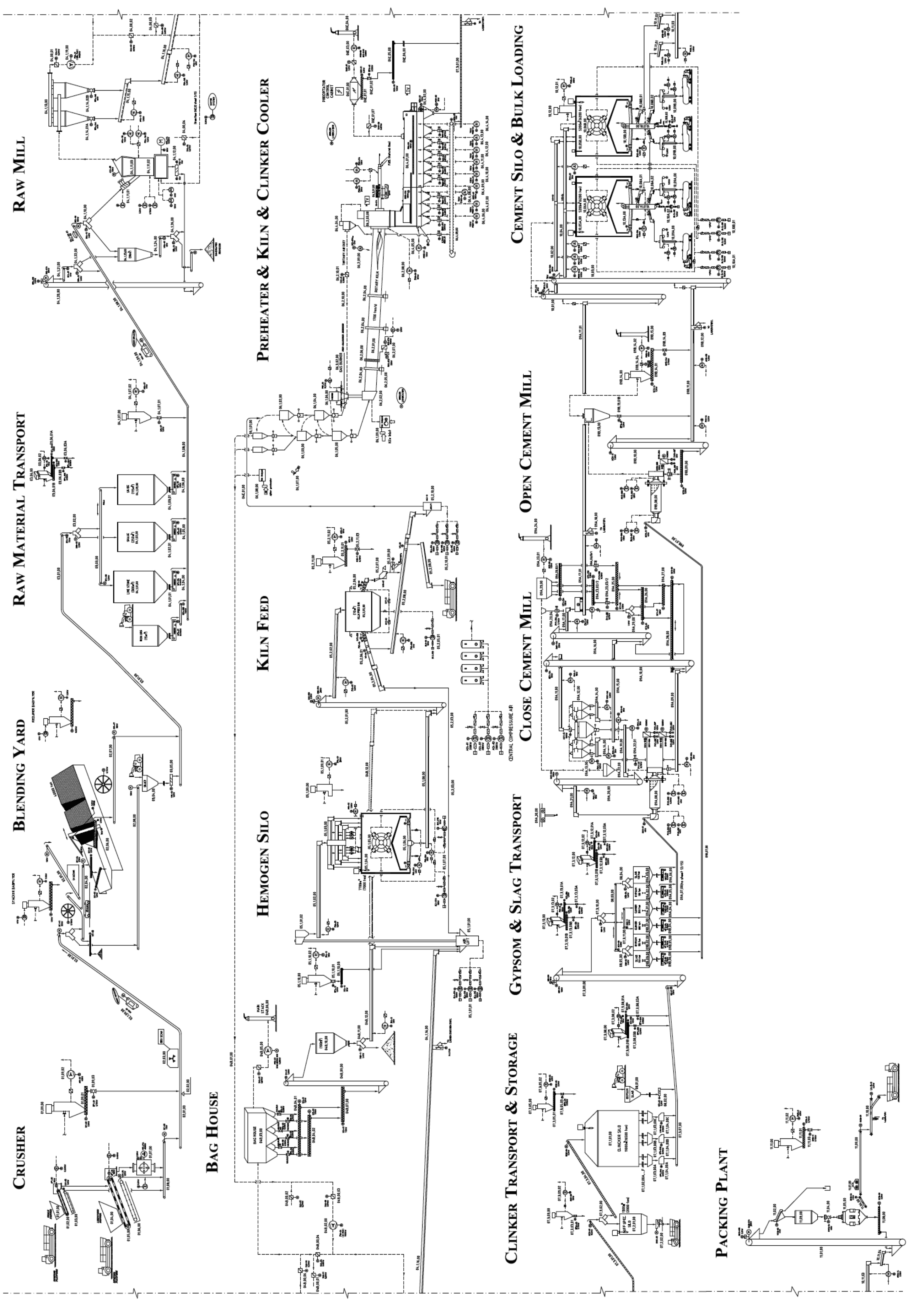

Figure 64 Schematic of production cycle in Company B.

2.3.2.2.3 Company C (Basic Metal Industry)

Figure 65 A view of Company C.

Company C (Figure 65) is one of the few Iranian Aluminum producers that was established in 1972 with the annual production capacity of 175,000 tons per year consisting of different pure ingots in the shapes of T-bar, 1000Lb, Casting alloys, Billets with different size and slab. This production brings approximately more than 350 million USD cash to this firm. Company C is located at the center of Iran and has about 4,000 employees. Meanwhile this company C is a member of London Metal Exchange and holder of ISO 9001:2000, ISO 14001:2004, OHSAS 18001:1999 standards.

The main workshops of this firm are:

1. Reduction cells work shops (Old and new)
2. Carbon plant consisting of green mill anode bake and anode rodding room
3. Cast house consisting of casting, cutting and packaging

Company C has two reduction cells (Smeller) technologies. The old technology, which called Central Work Pre-baked, consists of four lines, 560 cells and side-by-side arrangement of pots. 28 prebaked anode blocks and 14 cathode blocks are applied in each reduction cell. The production capacity in each cell is about 470 KG per day, and the voltage and amperage of each pot is 4.8 V and 70 KA respectively. The rate of electrical consumption of each pot for production of one kilogram of aluminum is in the range of 18 - 19 KWH.

The new technology, which named Pot Room, is a new 110,000 tons pot rooms that are located in two parallel and two floor buildings. Each pot line (Figure 66 Pots line in new reduction cells technology, Company C. consists of 105 side-by-side 200 KA pot, totally 210 pots, along the row of reduction cells, one set of intelligence pot control device and pollution control system (Fume Treatment Plant). There is a control room for monitoring and controlling all the process of production lines to exchange data for production process. The daily production of each pot is 1500 KG per day and the electrical consumption of each pot for production of one kilogram of aluminum in new reduction cells is in the range of 13.4 – 14 KWH.

Figure 66 Pots line in new reduction cells technology, Company C.

Table 26 Comparison of new and old smelters of Company C.

Table 26 Comparison of new and old smelters of Company C.

Title	Old Technology	New Technology	Different
Number of Pots	560	210	350
Capacity (Tons per year)	95,000	110,000	15,000
Production per Pot (KG per day)	470	1500	1030
Pot's Voltage (V)	4.8	4.18	0.62
Line Amperage (KA)	70	200	130
Amperage Efficiency (%)	82	93	11
Energy Consumption (KWH per 1 KG of Aluminum)	18.5	13.5	5

It is noteworthy that Company C fully obeys Iranian National Standard of energy consumption for aluminum industry (Institute of Standards and Industrial Research of Iran, 2013) that means their consumption level is lower than criteria specified by this standard.

This Company also has its own power station that is supplied from a 230 KV over headline directly from Iranian National Electrical Network to provide power for two sets of 240 MVA main transformers (Figure 67).

Figure 67 Power station of Company C.

Figure 68 shows organizational structure of Company C. Although there is a department named 'Technical and Energy', but issues related to the energy efficiency are out of responsibilities of this department. In fact the Planning and R&D Department will design all the plans for improving energy efficiency such as incremental improvements in the current technologies or bringing new energy-efficient technologies to the company. After these plans received final confirmation of the managing board and CEO, all other Departments will work under supervision of Planning and R&D Department to execute designed plans.

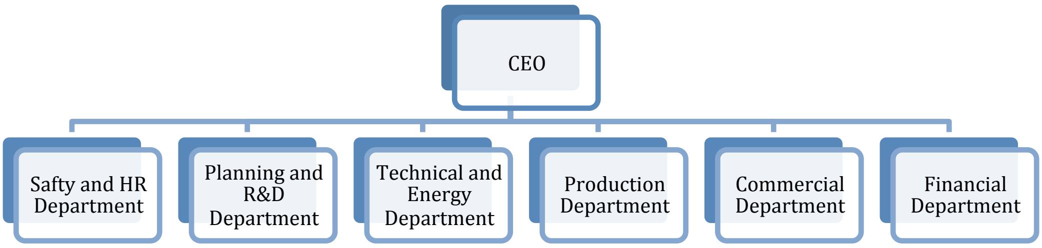

Figure 68 Simple organizational structure of Company C.

2.3.2.2.4 Company D (Basic Metal Industry)

Figure 69 A view of Company D, 2014.

Company D (Figure 69) was founded in 2000 aiming at production of galvanized sheet with continuous hot dip galvanizing procedure. This company is located in Isfahan province and has about 260 staffs that work in three working shifts in a day.

Currently, the products of Company D are galvanized sheet with commercial and drawing quality, cold rolled steel sheet with full hard quality and cold rolled and annealed sheet with commercial and deep drawing quality. Total capacity of production is 540,000 tons per year including 140,000 tons of galvanized sheets, sinus and trapezoidal sections, 250,000 tons of cold rolled sheets, and 150,000 tons of oiled annealed sheets. Also this company has a development plan for establishment of hot roll, thick material galvanizing and color coating plants. Company D exports its galvanized products to some countries such as Italy, Turkmenistan, Armenia, UAE, Kuwait, Iraq and Afghanistan.

Table 27 Production lines of Company D.

Production Line	Running Time (Year)	Capacity (ton/year)
Continuous Hot Deep Galvanizing (CGL-1)	2000	1000,000
Sheet Shearing Line (SSL)	2000	40,000
Cold Roll Reserving Mill (CRM)	2006	250,000
Forming (RFL)	2008	40,000
Batch Annealing (BA)	2010	150,000
Pickling (PL)	2010	300,000
Hot Roll (HSP)	Under Study	NA
Thick Material Galvanizing (CGL-2)	Under Study	NA
Color Coating (CCL)	Under Study	NA
Spiral Pipes	Under Study	NA
ERW24 Pipes	Under Study	NA

Table 27 lists production lines of Company D that are shown in a schematic plan of production cycle in Figure 70.

Figure 70 Schematic of production cycle in Company D (Some lines are under development, see table 4).

According to the energy auditing report of this Company for the year 2012, they consume more electricity energy than thermal energy that does not match with criteria for share of energy, which the National Standard has designated for energy consumption in steel industry -61% thermal energy, 39% electricity energy (Institute of Standards and Industrial Research of Iran, 2013). Still their special energy consumption is under the standard limitation most of times except in winter that because of shortage of gas supply they have to increase their electricity energy consumption (Table 28).

Table 28 Summary of Company D's energy consumption

	Electricity Energy	Thermal Energy
Share of total consumption	56 %	44 %
Special Energy Consumption	105 KWH per Ton	1.8 GJ per Ton

Company D has four main departments that among them R&D Department is responsible for all the issues related to the efficient use of production inputs including energy (Figure 71). According to the defined mission of this department presentation of methods to control the consumption, presentation of techniques to control the waste, innovation in products and processes, improvement of current processes, compilation and preparation of required technical instruction and documentation, participation in scientific events, and training of staffs are some of the duties of this department that can strongly effect the overall efficiency of the firm. However as they have not a specific department for energy all the issues related to the energy supply, consumption and monitoring should be reviewed in a mixed committee of managers of production, facilities, electricity and automation units.

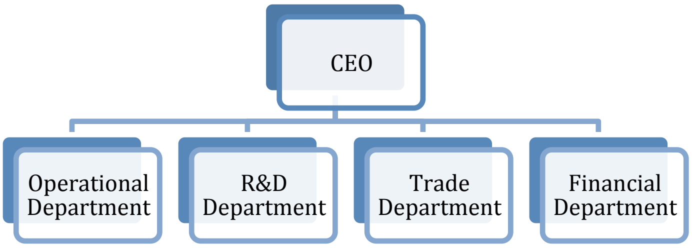

Figure 71 Simple organizational structure of Company D.

The average age of staffs in this Company is 32 and the average education level of them is associate degree. However, Company D has allocated a per capita education time of 40 hours per year for the personnel to promote their level of knowledge and expertise. This educational program includes specialized, organizational and general training.

2.3.2.2.5 Company E (Petrochemical Industry)

Figure 72 A view of Company E.

Company E (Figure 72) is a subsidiary of Petrochemical Group. The main objective of this group as a holding company, which was established with the investment made by National Petrochemical Company (a subsidiary to the Iranian Petroleum Ministry) and other private investment companies, is to organize and arrange the financial resources and ascertain correct implementation of western petrochemical projects.

Company E founded in 2005, is responsible to supply the required feedstock into the Western Ethylene Pipeline for other projects established under the owner group's holding.

The project is executed in the Pars Special Economic Energy Zone (PSEEZ). PSEEZ was established in 1998 under the supervision of the National Iranian Oil Company based on an authorization accorded by the High Council of Free Zones. Covering an area of 10,000 hectares, the zone lies east of the Bushehr Province and 100 KMs away from the maritime South Pars Gas Field. The zone is located on the coast of the Persian Gulf and has access to the rich hydrocarbon resources in the region with its reserves estimated at 14 trillion cubic meters of gas and 18 million barrels of condensates providing suitable conditions for investment. Considering availability of feedstock provided through different developed gas field phases, many petrochemical projects have been developed in PSEEZ including Company E.

The designed production capacity of Company E is two million tons ethylene per year. But in reality because of the feed constraints Company E is producing around 400,000 tons annually. The main technology used by Company E is known as 'Demethanizer Front' or 'Tail-end Hydrogenation' technology that is designed by French Company, Technip.

Because of some problems like operating below the designed capacity and high amount of loss of energy and loss of fuel gas, Company E is now consuming energy with a rate higher than that was designed for. For instance its average total energy consumption in 2013 was 36.9 GJ/ton HVP, while its designed energy consumption rate is just 21 GJ/ton HVP.

2.3.2.2.6 Company F (Petrochemical Industry)

Company F (Private Joint Stock) was established on June 16, 2004 in Pars Free Energy Zone. The mission of this company is to commission and manage the polypropylene plant of the Tenth Olefin Complex. The Pars Free Energy Zone is located on the northern shores of the Persian Gulf thereby allowing a convenient access to the global markets.

Meanwhile, Company F is in a unique position to operate in the global petrochemical to produce, market and sell an annual 300,000 tons of polypropylene under Basell technology with a variety of over 80 grades of homopolymer, random copolymer and impact copolymer. To achieve this goal, Company F enjoys some significant logistic advantages including availability of low-cost feedstock, capacity of production at global scale, appropriate location and proximity to Port Assaluyeh that expedites the export operation and timely delivery of products.

Another advantage of Company F is producing under the license of Baseil Company, as the world leader in the field of polyolefin and polypropylene production. With a 35% share of global polypropylene production in 87 active plants applying Spheripol method, Basell Company, is recognized as the foremost holder of polypropylene production technology. Using the fourth generation of Ziegler Natta catalysts, Basell Company's advanced production process of Spheripol has brought high quality for the products of Company F.

2.3.3 Step 3: Crafting Instruments And Protocols

Case study researches usually combine multiple data collection methods (Eisenhardt, 1989). Possible sources of evidences in case study researches are documents, archival records, interviews, direct observations, participant observations and physical artifacts (Yin, 2009). Among these sources of data interviews, direct observations and archival records are specifically common, but it does not mean that inductive researches are solely utilized these type of data (Eisenhardt, 1989). Triangulation or use of multiple sources of evidences strengthens the constructs validity and provides solider proof for hypotheses (Eisenhardt, 1989; Yin, 2009). Besides triangulation, Yin, (2009) listed two other principles for data collection in case study researches: creating a case study database separated from final report, and maintaining a chain of evidences.

Although the main sources of information in this research are semi-structured interviews, other types of evidences have been utilized to verify the information we received in our interviews. Both quantitative data such as national energy statistics and companies' energy auditing reports, and qualitative data such as archival records of companies, news articles, website of companies and direct observations have been gathered during this research and recorded in a specific database.

In the meantime, we collected and organized evidences in a team of three investigators to increase the chance of serendipities and build confidence in our finding (Eisenhardt, 1989). In this research, multiple investigators method was particularly useful in translating interviews' transcript and comparing them with the actual statistics.

Six companies were selected and an official invitation letter for an hour-long interview sent to their managers. These six case studies were conducted of adoption of energy efficient technologies within Iranian energy-intensive industries. Interviews were conducted on site with one or more members of key staff from each organization, including the energy manager. Each interview was semi-structured and followed detailed interview protocol based on the outcomes of literature review and group brainstorming. Interview protocol contains detail questions on history and statistics of firms, technology in-use specification, energy policy & strategy, motivation for implementing EETs, implementation process of EETs, responsibilities and performance assessment (KPIs), energy management practices, absorptive capacity of firms, and perceived barriers to adoption of EETs (Detail interview protocol is available at Appendixes chapter). Follow up telephone interviews or E-mail communications were also used as means of resolving ambiguities or seeking additional information.

2.3.3.1 Interview Structure

How a case study and inclusive interviews are structured and performed depends on what the researcher aims to discover. Systematic samples combined with highly structured interviews and close-ended questions serve the purpose of uncovering information about large populations (Yin, 2009). In contrast, open-ended questions give interviewees more flexibility in their responses. Aberbach and Rockman (2002) confirm this by concluding that semi-structured interviews reinforce the natural course of the interview; overshadowing the advantages of consistent ordering and maximizing the response validity as respondents verbalize their opinion in their own framework.

It's important to note that the cost and time aspect combined with open-ended question are remarkable (Yin, 2009). In order to escape this pitfall, as the understanding grows through the process and experience of interviewing, the intention is to shorten and hone in on the questions that are most relevant for the specific interview. In summary, mostly open-ended questions will be utilized in order to provide variety and to allow for spontaneity and flexibility during the interview process (Kobro & Hattrem, 2014).

2.3.3.2 Interview Approach

As Kobro & Hattrem (2014) mentioned the most important instrument in the process of interview is the interviewer himself. Several reasons lie behind this statement and the most obvious is that it is the researcher who interprets the collected data. The personal attributes and the sociocultural background of the researcher also affect the information gathering process and results. The results of the empirical research also depend on the interviewees and the amount and kind of information shared during the conversations. The goal throughout the process is to make the situation as comfortable for the interviewee as possible (Kobro & Hattrem, 2014). Therefore the interviews in this work are conducted in Persian language and on-site.

In cases studies that depth, context or historical records are the basis of the data collection, Berry (2002) states that 'elite interviewing' using broad, open-ended questioning to be the preeminent approach. By elites, Berry (2002) refers to employees who hold prestigious positions in their firms such as energy manger in our research and who often possesses the most valuable knowledge about the company's strategic undertakings. In elite interviews, the researcher reviews necessary information to arrive at a provisional analysis and the interviewees are chosen on the basis of participation in specific projects and undertakings (Berry, 2002). This interview format is well suited for this particular research's purpose and thus the chosen method to conduct the case studies.

Moreover, all the interviews were conducted face-to-face and were recorded by digital sound recording device by the authorization of interviewees. Afterwards, all the recorded files were translated to the English and fully transcribed. The full interviews' transcription is available in Appendix chapter.

2.3.3.3 Interview Quality

The quality of case studies must be ensured and secured through four design quality elements: construct validity ("identifying correct operational measure for the concepts being studied"), internal validity ("relevant for explanatory or causal studies; seeking to establish a causal relationship whereby certain conditions are believed to lead to other conditions"), external validity ("defining the domain to which a study's findings can be generalized") and reliability ("demonstrating that the operations of a study can be repeated with the same results") (Yin, 2009).

As the results from this work derive from interviews, where the content of the information is dependent on the researchers and interviewees interrelation (Kobro & Hattrem, 2014) they cannot be seen as independent. Therefore it is important to operate as comprehendible as possible, giving a clear report on the data information process.

Furthermore reliability means according to (Yin, 2009) to minimize failures and biases in a research study. Taping the interviews and giving access to all data, the research aims to be as transparent as possible. Validity tests are engaged with how subjective results are and aim to secure that data information commensurate with the objectives of the research (Yin, 2009). The reader is supported with this data as well as the interview guidelines, such that one can easily follow the researcher's conclusion as well as critically review the data independently from the researcher's perceptions.

As (Richards, 1996) claims that knowledge about respondents improves the process of gathering information, all necessary preparations have been made. Through the literature work in this project the researchers have become experts on the respective topic.

2.3.3.4 Interview Partners

Interviewees are selected on the basis of their knowledge that can complement or confirm the interviewer's preliminary results and conclusions (Aberbach & Rockman, 2002). In addition data from other sources has supported the findings of the research, as for instance utilizing annual energy auditing reports as well as homepages of the respective firms to find valuable research objects. The interviews and companies are to remain anonymous.

2.3.4 Step 4: Entering the Field

During a case study research it is usual that data analysis overlaps with data collection. This overlap can be partially or as Glaser and Strauss (1967) named joint collection, coding, and analysis of data (K. M. Eisenhardt, 1989). Field notes are one of the most useful tools to benefiting from occurred overlap between data collection and data analysis (K. M. Eisenhardt, 1989). Similar to this research, these notes can be written during an interview, direct observation, and even in the middle of work lunch with interviewees.

2.3.5 Step 5: Analyzing Data

"One cannot ordinarily follow how a researcher got from 3600 pages of field notes to the final conclusions, sprinkled with vivid quotes though they may be" wrote Miles & Huberman (1984). This huge gap should be covered by discussion of analysis. Analyzing data as the heart of building theory from case studies is the most challenging and the least methodized part of the process (K. M. Eisenhardt, 1989; Yin, 2009). This difficulty indicates that investigators should have a general analytic strategy that helps them to choose right techniques (Yin, 2009). It is suggested starting the analysis with some simple but initiative techniques such as matrixes, tabulation and temporal schemes (Yin, 2009).

Eisenhardt (1989) introduced two general analytic strategies for this step (Table 29). The first strategy is 'Analyzing Within-Case Data', which usually contains pure descriptions of each site and is central to the generation of insight. This strategy helps researchers to cope early in the analysis process with the regularly vast volume of data, and to become quietly accustomed with each case as an independent entity (K. M. Eisenhardt, 1989). There is no standard format for such analysis or in other word as Eisenhardt (1989) mentioned "there are probably as many approaches as researchers".

Within-case analysis, as prerequisite of the second analytic strategy, allows the distinctive patterns of each case to arise before researchers start to generalize patterns across cases, and accelerates next phase of analysis, 'Searching for Cross-Case Patterns' (K. M. Eisenhardt, 1989).

Looking at the collected data in many different angels is the key rule of the Eisenhardt's (1989) second analytic strategy. Eisenhardt (1989) suggested three tactics for a good cross-case comparison. The first tactic is categorization, which helps to find within-group similarities coupled with intergroup dissimilarities (Eisenhardt, 1989). Research problems, or existing literature, or even the researcher can simply define some dimensions for categorization (Eisenhardt, 1989).

The second tactic for cross-case comparison is to select pairs of cases and then to list the similarities and differencies between each pair (Eisenhardt, 1989). In this way researchers can look for the hidden similarities and differencies between cases by contrasting of similar cases to find differences, or by comparing different pair for similarities (Eisenhardt, 1989). The results of both methodes can break simplistic frames and lead to more sophisticated understanding. This tactic can be extended by selecting groups of three or four of cases for comparison (Eisenhardt, 1989). The last tactic of cross-case comparison is to dividing the data by data sources (Eisenhardt, 1989). Aim of these tactices is to help researchers to look beyond initial impressions and probe evidences by structured and diverse tactics, and at the same time increase the chance of serendepities (Eisenhardt, 1989).

Table 29 Eisenhardt's analytic strategies for theory building thru case study researches. Source: Eisenhardt, 1989.

Analytic Strategy	Tactics	Aim
Within-Case Analysis	• No standard tactic	• Allows the distinctive patterns of each case to emerge before researchers start to generalize patterns across cases

Cross-Case Comparison	• Categorization • Pair Comparison • Divide data by data source	• To help researchers to look beyond initial impressions and probe evidences by structured and diverse tactics • To increase the chance of serendepities

Similar to Eisenhardt (1989), Yin (2009) introduced two general analytic strategies and three analytic techniques for case study researches (Table 30). However, Yin's strategies are not complementary and could be used independently (Yin, 2009). The first Yin's analytic strategy is relying on theoritical propositions, which means the analyses will follow theoretical propositions that are the foundations of the research and aims to focus on specific data and to ignore other irrelavent data to the theoretical propositions (Yin, 2009). This strategy could be coupled with both within-case analysis and cross-case comparison strategies of Eisenhardt (1989), for instance researcher focus just on some certain emerging patterns or categories.

The second Yin's stratey is developing a case description, which tries to prepare a narrative framework for organizing of the case study (Yin, 2009). This strategy is very similar to within-case analysis strategy of Eisenhardt (1989).

Yin (2009) proposed three analytic techniques for implementation of abovementioned general analytic strategies. The first technique is *pattern matching* that tries to compare emprically based patterns with predicted one(s) (Yin, 2009). Results of this specific technque could be patterns, which show intially predicted outcomes (*expected outcomes*), or articulate some of the theoritically noticeable describing conditions that the presence of them exclude the presence of others (*rival explanations*), or finally suggest some simpler patterns that have enough clear differences (*simpler patterns*) (Yin, 2009).

The second technique is *explanation-building* technique that tries to probe case study's data by building an explanation about the case and identify a set of casual links (Yin, 2009). This explanation is an outcome of series of iterations between research's tehorical statement and finding of cases (Yin, 2009).

Time-series analysis is the last analytic technique that focuses on realtionships and changes of events over time, and tries to compare theoretically propesed sequences of an event with what have found in empirical data points (Yin, 2009).

Table 30 Yin's analytic strategies and techniques for case study researches. Source: Yin, 2009.

Analytic Strategy	Aim	Techniques
Relying on Theoritical Propositions	Focusing on specific data and to ignore other irrelavent data to the theoretical propositions	• pattern matching • explanation-building • Time-series analysis
Developing a Case Description	Preparing a narrative framework for organizing of the case study	

In this research we tried to benefit from a combination of these analytic strategies and techniques. For instance we developed a brief case description for each of cases in section 'Selected Industries And Firms' (Section 2.3.2.2) that gave us a head start in next steps of analyses. More detail analyses are discussed in the next chapter.

2.3.6 Step 6: Shaping Hypotheses

This step involves gauging constructs and validating relationships, and is similar to traditional hypothesis-testing research (Eisenhardt, 1989). Though, as researchers cannot run statistical tests such as an F statistic in case study researches, they need to asses the vigor and consistency of relationships within and across cases and also to utterly exhibit the indications and methods (Eisenhardt, 1989).

Here as Eisenhardt (1989) argued "*the central idea is that researchers constantly compare theory and data iterating toward a theory, which closely fits the data*". *Shaping hypotheses* is a two steps process, which its first step is the *sharpening of constructs* (Eisenhardt, 1989). The first step could be split into two processes; (1) *refining the definition of the construct* and (2) *building evidence* that measures the construct in each site (Eisenhardt, 1989). These processes need continuous comparison between data and constructs until when accumulating evidences from various sources converges on a specific sharp construct (Eisenhardt, 1989).

The second step of *shaping hypotheses* is validating that the emergent relationships between constructs fit with the evidence in each case (Eisenhardt, 1989). The key rule of this step is *replication*, which means considering a series of cases as a series of experiments with each case is utilized to verify or refute the hypotheses (Eisenhardt, 1989). Accordingly if cases verify discovered relationships then the validity of these relationships would be enhanced, and if cases refute the relationships then perhaps there is a chance to polish and broaden the theory (Eisenhardt, 1989).

In our research we utilized this two steps process first to find and sharpen credible constructs (Some priori constructs have been presented in section 2.3.1), and consequently to show that each case supports discovered relationships between constructs by the help of replication logic.

2.3.7 Step 7: Enfolding Literature

For case studies, literature review as part of the design phase is vital (Yin, 2009). Furthermore, comparison of the emergent concepts, theory, or hypotheses with the existing literature is an indispensable aspect of theory building researches (Eisenhardt, 1989).

For the design phase, we utilized *traditional or narrative literature review* (Cronin, Ryan, & Coughlan, 2008) to critique and summarize a body of literature and draws conclusions about the energy efficiency, energy efficiency barriers and emerging energy-efficient technologies. The results of our literature review are available in the chapter 1, which involves a comprehensive framework of energy efficiency barriers. This body of literature is founded on the relevant studies and knowledge that address aforesaid topics. As Cronin, Ryan, & Coughlan (2008) discussed, the main purpose of *narrative literature review* is to deliver a comprehensive grounding to readers that helps them to understand extant knowledge and highlight the importance of fresh studies.

During analysis phase, comparison of reviewed literature with research's findings comprises distinguishing similarities and contradictions between them, and finding underlying reasons for these relationships (Eisenhardt, 1989). Conflicting findings offer a deeper insight into the emergent theory and the conflicting literature, and sharpen the limits to generalizability of the research (Eisenhardt, 1989). Likewise, similar findings lead to theory with stronger internal validity, wider generalizability, and higher conceptual level (Eisenhardt, 1989).

In the following chapter, we will discuss deeply about plausible similarities and contradictions of our finding with the literature, which we reviewed in chapter 1.

2.3.8 Step 8: Reaching Closure

To cognize when is the right moment to finalize a case study research, as Eisenhardt (1989) mentioned it is necessary to realize when to stop adding cases, and when to stop iterating between theory and data. The key idea in both situations is saturation (Eisenhardt, 1989). It means that in the first ideally researchers would stop inserting new cases when reach to a *theoretical saturation* (Eisenhardt, 1989); Theoretical saturation occurs when simply incremental learning is minimal because the investigators are observing phenomena seen before (B. Glaser & Strauss, 1967). However, in reality researchers should combine *theoretical saturation* with usual constraints such as time and money constraints to decide when case collection stops (Eisenhardt, 1989). In the second situation, saturation occurs when the incremental improvement to theory is negligible, and at this point researchers can stop iterating between theory and data (Eisenhardt, 1989).

In this research, as discussed before in section 2.3.2.2, pragmatic considerations such as financial resources availability and time constraint forced us to stop inserting new cases to the research.

After reaching to the closure, it is time to introduce the final output of research. This output could be a conceptual framework, or propositions or possibly midrange theory. However, there is always the risk of replicating prior theory, or observing no clear patterns within the data (Eisenhardt, 1989) that we hope be not case of this research.

3 Data Analysis and Summary of Results

This section summarizes the evidence for barriers to energy efficiency in the Iranian energy-intensive industries. The results from the Cement, Metal and Petrochemical manufacturer case studies are reported in turn.

Figure 73 Interviews' words cloud. Source: Word frequency query by Nvivo 10 software.

In each sector, two case studies were conducted of energy management practices within individual firms. Interviews were conducted on site with person in charge of energy management issues. Each interview was semi- structured and based around detailed interview protocols (Section 5.2) based on the theoretical framework (Section 1). This contained questions on historical background of company, energy consumption, energy management practices, the adoption of energy-efficient technologies, and perceptions of barriers to energy efficiency. Follow up telephone and email communication were also used as a means of resolving ambiguities or seeking additional information.

3.1 Case Studies Of Energy Efficiency Barriers In The Iranian Energy-Intensive Industries

Case studies were undertaken of energy consumption management within six companies, drawn from three sectors. All had more than 150 employees and all had turnover more than $25million. Except cases from Cement industry, all other cases are actually public firms with some sold shares to the private sectors. All these case were established after 2000 except Company C, which actually renovated its core production technology on 2001. Their energy bills were at least more than 30% of their turnovers. Table 31 summaries the key features of each case study.

Table 31 Summary of key features of Iranian energy-intensive industries case studies.

Features	Company A	Company B	Company C	Company D	Company E	Company F
Sector	Cement		Metal		Petrochemical	
Ownership	Private	Private	Public-Private	Public-Private	Public-Private	Public-Private
Main products	Cement type 1-425, type 2 and 5	Cement type 1-325 and type 2	Aluminum ingots and slabs	Steel sheets	Ethylene	Polypropylene
Establishment year	2011	2005	1972	2000	2005	2004
Technology in use	New	Old	New	New	New	New
No. of employees	150-200	150-200	4000	250-300	550-600	250-300
Capacity (tons)	1,000,000	565,000	175,000	100,000	2,000,000	300,000
Production (tons)	1,030,000	605,000	185,000	110,000	400,000	200,000
Turnover ($/year)	45 million	25 million	500 million	120 million	400 million	80 million
Annual electrical energy consumption (GWH/year)	100	56	2685	10	-	-
Electrical Energy expenditures/Turn over (%)	30	28	40	>10	-	-
SEC (Kwh/ton)	91.7	100	13500-18500	105	-	-
Annual thermal	740	460	-	36,000	-	-

energy consumption (GCal/year)						
Thermal Energy expenditures/Turn over (%)	7	8	-	>10	-	-
SEC (Kcal/kg)	740	817	-	430	8,813	-
Main responsibility for energy	Electrical Dep.	Electrical Dep.	Planning and R&D Dep.	R&D Dep.	Site Manager	Site Manager
Payback criteria	Short-term	Short-term	Short-term	Short-term	Short-term	Short-term
Have conducted energy audits in the recent past?	Yes	Yes	No	Yes	No	No
Qualitative assessment	Average	Poor	Average	Average	Poor	Poor

Some of the main features of the case study results are as follows:

- *Organisation:* None of the firms had a dedicated energy manager with energy efficiency responsibilities. However, management of energy consumption was one of a number of responsibilities of the R&D Department, Electrical Department or Site Manager. Just in cases of Cement industries, firms have dedicated committee to the energy efficiency improvement.
- *Energy information systems*: Three of cases (Company A, C and D) have adopted SENSIS energy monitoring system, which allows them to check details of their energy consumption. The other three cases have poor information on energy consumption, for instance Company B metered electricity and gas consumption solely at the site level for the sake of national standard obligations but still they have not analyzed consumption data in a useful way. Company A, B and D had undertaken a recent energy audit by an external auditing company as a part of national standards confirmation procedure and no further actions had resulted.

- *Capital budgeting and investment criteria*: None of the companies had a dedicated budget for efficiency investment. All of companies used short-term payback criteria (less than four years) for cost saving investments, however they often called 3-year payback criteria as a long-term investment. This short-term point of view can be linked to the short duration of top managers, which means top managers like to invest in projects that would be finalized before they leave managing chair.
- *Operational aspects*: Four of six cases were working over their capacity and they tried by producing more outputs for the same energy inputs, decrease their energy cost per capita. Contrary to these four cases, both petrochemical firms were running under production capacity and their related interviewees noted that this issue causes they do not care about energy efficiency.
- Technology in-use: The core production technology that companies utilized was relatively new. Only company B's production technology and part of Company C's production line were outmoded. All of six cases imported their technologies a second-hand technology from western countries such as US, French, Italy and Swiss.

3.2 Experiences From Adopted Energy Efficiency Interventions

As explained before in section 1.1.1, energy efficiency improvements are classified in two groups: Substitution and Technical Change. The first one counts for investment in an existing technology, which can works with different combination of inputs, and usually happens when the prices of energy increase.

But technical change denotes emergence of new technologies or methods of organisation and can happens independently from inputs' price.

Table 32 shows summary of interviewees' responses to the questions regarding done or planned EE interventions in their companies. Then, their responses compared to the prepared list of emerging EETs (Table 9) to confirm the potential of adopted technologies.

Table 32 Summary of adopted EE interventions in cases.

Features	**Company A**	**Company B**	**Company C**	**Company D**	**Company E**	**Company F**
Sector	Cement		Metal		Petrochemical	
Have adopted EE interventions in the recent past?	Yes	Yes	Yes	Yes	No	Yes
Type of main intervention	Substitution	Substitution	Technical change	Substitution	-	Substitution
Description	EFCs, Use of carbide slag	EFCs, Ball Crashers, Use of steel slag as raw material for the kiln	Pot cell (Efficient cell retrofit design)	SENSIS monitorin g system, measuring counters	-	Flare Gas Recovery, Stretch films for packing, Pallet-less
Best Practice	Additives	Ball Crashers	Pot cell	Measuring counters	-	Flare Gas Recovery

Except Company E, all cases adopted some interventions to improve their energy efficiency in recent past. However, among these five companies just Company C opted a technical change, by bringing a modern production technology that leaded to huge energy saving for them. One should note that Company C is a relatively bigger and older firm than other five firms, and have better access to the financial resources, which allow it to invest for changing the whole production technology. In the meantime as we will discuss in the next section, the main reason of the all firms that chose substitution energy efficiency improvements was start of subsidies reform or in other word increase of energy prices.

3.3 Energy Efficiency Training Program in Selected Cases

Training programs are one of the effective tools for enhancing organizational awareness about energy efficiency and shaping strong culture of energy efficiency. As it shown in Table 33 four out of six cases have dedicated energy efficiency training program, which among them just Company A made these program as obligatory for its staffs and evaluated the results of these programs by tracking changes in daily energy consumption statistics. Company D also has some sorts of knowledge sharing after these programs as evaluation procedure. Interestingly Company A and Company D were the only cases that also considered incentives for employees who improve firm's energy efficiency.

Table 33 Summary of interviewees' responses about EE training programs.

Features	Company A	Company B	Company C	Company D	Company E	Company F
Sector	Cement		Metal		Petrochemical	
Have EE specific training programs in the recent past?	Yes	Yes	Yes	Yes	No	No
Mandatory or Optional?	Mandatory	Optional	Optional	Optional	-	-
How evaluate the result?	By taking into account the changes in data provided on daily basis	No evaluation	No evaluation	Report, and interview with the attendants	-	-
Are these programs effective?	Yes, in short-term	No opinion	Yes	Yes	-	-

3.4 Evidences of Impacts of Sanctions, Subsidies Reform and National Standards on Energy Efficiency

3.4.1 Sanctions And Adoption Of Energy Efficient Technologies

As mentioned in section 2.3.2.1.5, Katzman (2011) claimed that in long term, the efficiency and productivity of Iran's economy would drop mainly because Iran has to do business with less proficient foreign firms from countries such as China. In the meantime, Katzman (2011) mentioned that small and large traders are struggling with difficulties such as obtaining trade financing and export licenses, insurance, and shipping availability, which is increasing their expenses approximately 40%.

Table 34 summaries opinions of interviewees about the impacts of imposed sanction specifically on adoption of energy efficient technologies in their firms that confirm Katzman's (2011) predictions about this issue. The dominated themes in their responses were difficulties in accessing to the world market of EETs, higher costs of procurement, and purchasing lower quality technologies from countries such as China. However, all of cases claimed that these sanctions could not stop them from buying what they need, and in log term they will reach to new market equilibrium.

Table 34 Summary of impacts of imposed sanctions on Iran on energy efficiency of six cases.

Features	Company A	Company B	Company C	Company D	Company E	Company F
Sector	Cement		Metal		Petrochemical	
Sanctions & EETs	We have mainly problems in procurement of spare parts.	Sanctions are posing constraints to us for buying equipment and spare	We didn't have barrier for technology and budget because of sanctions	Sanctions are helping us to be on our own. There is no barrier to bring new	Sanctions cause that we cannot access to the world market of EETs.	We couldn't have access to the world market, so we have to turn to China with

		parts.		technologies however with a bit lower quality.		extra-costs.

3.4.2 Subsidies Reform And Adoption Of Energy Efficient Technologies

It mentioned in section 2.3.2.1.4 that one of the main goals of Iranian government's energy subsidy reforms is increasing efficiency and preventing wasteful consumption. But results of this subsidies reform for Iranian industries were not exactly what governments expected. Hence, in this research we have been interested to see that in this situation whether Iranian energy-intensive firms choose a strategic plan by investing in more energy-efficient technologies and improving their production facilities, or they opt an emergency plan to rescue from faced situation by operating with their current technologies under potential capacity and decreasing their operational costs.

The result of our research (Table 35) show that all six companies opted some short-term plans to decrease their energy consumption and survive from occurred situation. None of these companies had previous plan for improving their energy efficiency and just started to enhance their energy efficiency after commencement of the reform, when energy's prices escalated suddenly.

The main reasons that interviewees expressed for this behavior were lack of meaningful governmental support, fixing the prices and not receiving expected financial fund from Iranian government.

Table 35 Summary of impacts of subsidies reform on energy efficiency of six cases.

Features	Company A	Company B	Company C	Company D	Company E	Company F
Sector	Cement		Metal		Petrochemical	
Subsidies Reform & EETs	After Subsidies reform, more expenses led us the companies to consider energy efficient solutions much more than before because before that thinking of these strategies would not make financial sense.	Before Subsidies reform, energy efficiency had not high priority. But after reform because of shift in prices energy efficiency became really important for us.	Governments planned to subsidize the energy price for the companies, so that was the real moment that we decide to move a bit to energy efficiency. Governments didn't pay all what they said. No body supported us; we spend from our old budgets.	For fixing the prices it needs the market's tolerance, if market cannot handle it we cannot also cut our profits and it means that we cannot invest.	No comment	No comment

In the meantime, petrochemical firms again were not concerned about subsidies reform and prices increase for two main reasons: First, because of the shortage of feed they were working under their designed capacity. Hence in any case they were operating inefficiently and cost of energy was not any more an important issue for them. Second, low production costs and inelastic market brought high profit margin for them that in turn makes increase of energy prices meaningless for them.

3.4.3 National Standards And Adoption Of Energy Efficient Technologies

As indicated in section 2.3.2.1.6.2 one of responses of Iranian government to the rapid growth of industrial energy consumption during last years is defining some standards for energy consumption of different industries. Iranian governments hope that these standards boost industrial energy efficiency or at least stop the growth of industrial energy intensity. But according to the responses of interviewees, these standards did not work as governments expected.

While, these standards were useful to force some firms such as Company A, Company B and Company D to move toward energy efficiency, but still large firms such as Company C did not think that standards are influential or firms with inelastic demand such as Company E and Company F even did not aware about defined standards (See Table 36).

It was surprising that Company C was the designer of the related standard for Iranian Institute of Standard as this institute has not enough expertise and equipment to define standards for this specific industry, but still Company C did not consider this standard seriously, as they told: “If we can do something for sure will do, if we can’t do that in advance even if ministry come and say do that, we will say that we cannot do that! (Since it is out of our abilities).”

It is noteworthy that responses indicated that companies were faced with several problems in execution and communication of defined standards, and also supervision of third-party auditing firms that decrease the likelihood of realization of the stated goals of the standards.

Table 36 Summary of impacts of national EE standards on energy efficiency of six cases.

Features	Company A	Company B	Company C	Company D	Company E	Company F
Sector	Cement		Metal		Petrochemical	
EE Standards	They had positive impacts as the managers were forced to provide the required tools to comply with the standards. Main weaknesses are in execution, supervision and communicati ons.	These standards are helpful and force firms to move toward EETs, but still there are some problems in communicatio n and third parties ESCo.	I don't know honestly where it can be influential. However any slice change will cause million $ in our company. If we can do something for sure will do, if we can't do that in advance even if ministry come and say do that, we will say that we cannot do that! (Since it is out of our abilities).	They are very useful but not really for small companies, as they did not involve details information .	Not aware of such standards	Not aware of such standards

3.5 Evidences Of Barriers To Energy Efficiency

The empirical results have been interpreted in terms of the theoretical background, which gathered during literature review (Section 1.3). The dominated barriers found to be of relevant in this research are:

- Organizational culture
- High initial cost of energy efficient technologies
- Management instability caused by frequent changes in top managers

Table 37 elaborates the list of identified particular instances of barriers to adoption of energy efficient technologies.

Table 37 Summary of founded barriers to energy efficiency in each of cases.

Case	Sector	Barriers to EETs
Company A	Cement	• High costs of new EETs • Management instability • Short-term approach of top managers
Company B	Cement	• High costs of new EETs • Management instability • Human capital constraints • Lack of information • Low priority of EE
Company C	Metal	• Hidden costs • Financial barriers • Management instability • Split incentive • Time and human capital constraints
Company D	Metal	• High costs of new EETs • Culture • Motivation • Source of power • Risk
Company E	Petrochemical	• Culture • Working under capacity • Low priority of EE • Cheap energy • Lack of training and specialist operators • Lack of competition and high marginal profits • Lack of access to the EETs' market • Bounded rationality
Company F	Petrochemical	• Culture • Management instability • Working under capacity • Lack of competition and high marginal profits • Inertia • Values • Corruption

The first difference among perceived barriers by these six firms is barrier related to split incentive category. As it is clear in Table 37 only Company C has indicated this barrier. This difference could be linked to the size of company. Company C is relatively bigger than other five firms, as interviewee of Company C stated this firm actually is "4 companies in one complex", and consequently there are more chances for occurrence of split incentives among several departments and units of Company C compare to other cases.

The second difference is barriers related to inelasticity of the demand, which renders energy efficiency an ignorable issue for firms. In contrast to the cases from Cement and Metal industries, which have elastic demand in Iran, both cases from petrochemical industry, which has an inelastic demand in Iran, specified lack of competition and high profit margin as significant barriers to the energy efficiency improvement because these barriers will kill motivations for changing the current situation.

Petrochemical firms had also another specific barrier named working under designed capacity, which actually was the consequence of imposed sanctions on Iranian energy sector (Shortage of feed of petrochemical industry). Working under production capacity caused production costs of these companies increase in such a magnitude that energy costs loose their importance in calculation of production costs.

4 Conclusion and Suggestion for Future Studies

The main purpose of this research was to examine the energy efficiency adoption process in Iranian firms, which have been experiencing both extensive energy subsidies reform and harsh international economic sanctions. Furthermore, I examine how these firms' responses to emerging energy efficient technologies are characterized by sectoral and firm level features.

This research is built on explorative and empirical case studies. The methodological approach employed in this study is a mixed methodology based on works of Creswell (2013), Eisenhardt (1989) and Yin (2009). This methodology has been carefully selected to discover and examine how Iranian energy-intensive firms adopt and implement emerging energy efficient technologies and practices. For this purpose, I conducted semi-structured interviews about energy management practices with six firms in three energy-intensive industrial sectors including Cement, Metal and Petrochemical.

A key aspect of case study research is case selection. For this, I have checked recent statistics of Iranian industries' energy consumption and selected firms from three top energy-intensive sectors that are: non-metallic mineral products, basic metals products, and chemical.

Meanwhile, I applied traditional or narrative literature to criticize and summarize a body of literature and draws conclusions about the definition of energy efficiency, energy efficiency indicators, definition of energy efficiency gap, barriers to energy efficiency, and emerging energy-efficient technologies.

The results reveal that all six companies chose only short-term plans, in another words, substitution energy efficiency improvements to survive after subsidies reform. Moreover, while some Iranian firms have responded to economic sanctions by purchasing lower quality energy-efficient technologies, the others have burdened higher cost of technology acquisition.

The results also highlight the significance of three main barriers to adoption of energy efficient technologies in Iranian industries, which are organizational culture, high initial cost of energy efficient technologies, and management instability caused by frequent changes in top managers.

This research is just a preliminary step toward understanding of adoption process of energy efficient technologies in Iranian industries and future studies on the current topic are therefore recommended. In future investigations, it might be possible to use quantitative methods to testify these results. Furthermore, more research on this topic is needed to suggest proper policy implications for mitigating identified barriers to energy efficiency improvement at different levels.

5 Appendixes

5.1 Sample Of Invitation Letter For Interview

[April 13, 2014]

To: CEO of Company D

Dear Sir,

My name is Ali Samei, and I serve as research assistance of the Energy & Strategy Group of School of Management of Polytechnic University of Milano.

As part of our research project entitled: "Antecedents Of Adopting emerging Energy-efficient Technologies: The Case Of Iran's Energy-Intensive Industries." that is also my M.Sc. dissertation, I am writing to invite you to participate in a new research project to document barriers on the way of implementation of emerging energy-efficient technologies in Iranian energy-intensive industries. I have identified a list of Iranian energy-intensive industrial sectors that have great potential in improving the Iran's industrial energy efficiency during recent years including Steel, Petrochemical and Cement Manufacturers, and your company as a Steel producer is a very suitable case for our study.

The majority of interviews will be conducted in the place of your organization, with individuals interviewed either in person or via telephone as scheduling and resources allow. The interviews will be recorded digitally and interviewees will be provided with paper copies of the final transcripts [and, if desired, a CD of the audio recording]. Name of company, sensitive business information, names of interviewed personals, transcripts and sound files will be kept confidential unless you allow us to share them.

As per our research guidelines, all interviewees retain the right to review and edit their interview transcript before the final version is deposited, and, if they wish, to place restrictions on the availability of the interview or to specify conditions under which researchers may access it. Surely, after complementation of the project, all the participants will receive a copy of final report and all the achieved results.

I sincerely hope that you will consider participating in this important effort to document the process of adoption of energy-efficient technologies in the country of Iran. I will be contacting you via telephone or email in the near future to confirm your interest in being interviewed. Please feel free to contact me as specified below with any questions.

Sincerely yours,

Ali Samei

M.Sc. Student, Management Engineering

School of Management

Politecnico di Milano

Email: ali.samei@mail.polimi.it

5.2 Interview Protocol

- **History And Firms Statistics**
  - Please specify below information:
    - Turnover of Company
    - Type of products and annual production volume
    - Number of employees
    - Organization structure of Company
    - Production volumes of different production line
    - Energy consumption
      - Absolute value
      - Split into electrical and thermal (steam, heating, cooling, etc.)
    - Auto-production of electricity / thermal energy (renewables, cogeneration, etc.) if existed
      - Type of plants
      - Size of plants (power, annual production, etc.)
- **Technology In-Use Specification**
  - Please explain for us following considerations:
    - The main steps that comprise the production process
    - Energy consumption of the different phases
    - Key technologies used
- **Energy Policy & Strategy**

- When and why did you start to care about energy efficiency in your company? Where did the initiative come from? Did the top management support the initiative?
- Do you think about energy efficiency in terms of a strategic goal? How do you pursue it?
- (Alternative: How did you plan to earn monetary gain out of energy efficiency? How is energy conservation related to your business?)
- Could you name key actions for energy efficiency practices that you adopt or planned to adopt?
  - Done interventions
  - Input (internal audit, proposed by an ESCo, etc.)
  - Adopted technology (investment benefits obtained, energy and economic benefits, etc.)
  - "Best practices" (that do not involve interventions "infrastructure") adopted for energy saving
  - Planned interventions
- Why the company decided to include energy efficiency in their strategy? (Internal motivations or regulations/external incentives?) Do you have cost reduction because you are energy efficient?

- **Motivation For Implementing EETs**
  - Do you measure any energy related issues in your performance management systems?
  - What is the effective incentive system for your employees in energy matters? (Monetary or non monetary? Direct or complementary?)

- Are you willing to pay monetary incentives for the realization of objectives linked to energy conservation? Which other kind of benefit?
- What are your strength and weaknesses in performance management/incentive/compensation?

- **Implementation Process**
  - Describe the early phases of the integration of energy conservation goals within company objectives/mission/operations. What was the degree of changes? At which level in the organization did you start to implement them? Which new roles have been defined?
  - Where (at which level) do you think energy efficient measures have the greatest impact in your company (production and manufacturing, HRM, logistics and marketing)?
  - What was your role as energy manager/ production manager in the process?
  - What was your stakeholders' role in shaping the overall energy conservation strategy of the company and the implementation process?
  - What were the strengths and weaknesses in the implementation of the energy efficiency strategies?
- **Responsibilities And Performance Assessment (KPIs)**
  - Who are the principal planners of energy policies in your company? How do they work? How do they coordinate their work with the rest of the organization?
  - **(Alternative:** If you had to think to the most influential actor in your company regarding energy issues, whom would you say? Why?)

- Which is the role of external stakeholders? How are they involved in your energy efficiency programs?
- Who is in charge of measuring the achievements of the company in terms of energy efficiency? How are they measured? Who is involved? Is there internal communication about it?
- How do your stakeholders assess your energy efficiency performances?
- What is your personal overall evaluation of the company energy conservation performance? What are the key areas of improvement?

- **Energy Management Practices**
  - How are employees involved in the energy management practices? At which level (is it a passive or active role)?
  - Do you explicitly include energy management practices in your job descriptions? Examples?
  - What are your strength and weaknesses in employee involvement in energy conservation process?
- **Absorptive Capacity**
  - Do you have any training program about energy management? How do you plan for trainings? (Specific program or routine plan? How many of employees have to participate Are employees forced to participate training?)
  - How do you evaluate the effectiveness of these trainings?
  - In your experience is there any evidence to show that trainings can also affect employees' attitudes toward energy consumption?

    - How many employees participate the training programs? Where in the organization do they work? Mandatory or not?
    - What are your strength and weaknesses in training?
- **Perceived Barriers To Adoption Of EETs**
    - Does enough information exist about modern technologies among decision makers in your sector?
    - In your sector, are you familiar with how to absorb both technology and financial support?
    - Does enough capacity exist for adoption of new technologies or renovating the existing ones?
        - How do you assess the existing capacity?
        - Are there any plans for expanding this capacity?
        - How effective do you think these plans are in capacity building?
    - Does any regulatory/Standard exist in your sector which hinders/promotes the use of more efficient technologies? (e.g. makes it easier or more difficult to compete with firms which use non-efficient technologies)
        - How effective do you think these measures are?
        - Do you have any recommendation to eliminate the obstacles facing adoption of new technologies?
    - Does enough long-term policy exist in your sector, which makes it safe for investment?
    - How important do you think technology transfer is in your sector?

5.3 Interviews' Transcripts

5.3.1 Company A

Interviewee: Head of Electrical Department

Interviewer: Ali Samei

Time: 45 min

[Greeting]

Question (Q): Would you please provide the following information?

- *Plant layout*
- *Number of employees*
- *Type of products*
- *Turnover*
- *Capacity*
- *Energy balance sheet*

Answer (A): We produce 1 million ton a year; although, depending on some situations this amount varies and the price is not fixed. Considering the fluctuations in the price of cement, the company's turnover differs; actually, this company was started by a loan and it, certainly, has an impact on the company.

We started working in 1388 and now it is about three years that we have reached the break-even point; the capacity of the company is 3300 tons per day and sometimes it can be even more depending on the conditions of the kiln and raw materials.

I would say that the limestone mine is close to the factory and, as you know, limestone is the principal part of cement. The sources of limestone are abundant otherwise it would not make financial sense because of transportation costs. Therefore, before establishing a plant it is necessary to investigate how long a mine would last to feed the plant; as for us, it was anticipated that the mine could last at least 50 years.

We have only one production line producing Cement type II that is the most demanding type of cement nowadays.

We already have 140 employees who directly work for our company but actually there are about 400 employees involved in some other ways as well. For example, in our electricity department, having to do with specialty, we have 13 engineers out of 20 employees and for the mechanic department since there is less need of specialized experts and more workers, we have only 5 engineers. Besides, in production department we need some chemist specialists and furthermore, we have around 35 specialists out of 140 employees.

Regarding the energy consumption, it should be said that each company here has its own standard indicators; for instance, we have different indicators for thermal energy, fossil energy, and electrical energy. The standard indicator for electrical energy ranges between 90 to 100 Kw/ton; and naturally for 100 Kw/ton the consumption of energy would be higher and the efficiency would be lower. The unit of measure for fossil energy is Kcal/Kg that should be something around 750 or 740 that we are consuming less than this amount. For example, in the last year we were operating with 89.90 Kw/ton and 730 Kcal/Kg.

It is important that you would be able to produce more than the nominal capacity and consequently the indicators will fall to some extent. More importantly, due to the fact that we have limited number of EFCs, having a significant impact on reducing the energy consumption, we are supposed to regulate the cycles using dampers which are not as energy efficient as EFCs; I would say we need 10 more EFCs to be deployed.

Thermal energy is dependent on a few parameters such as raw materials, kiln and operation. We are actually using one of the best kilns present in the market. Considering the fact of energy consumption, we provide daily, monthly, and yearly reports to clarify, we need to take into account the indicators separately but the largest amount of energy consumption can be attributed to electrical energy and fossil energy is only used for the kiln. Our consumption would be around 18 Mw/year that can be also 18,200 or 18,300 depending on production capacity. As for natural gas, we consume something around 11,000-m3/hour.

Q: Do you measure any energy related issues in your performance management systems?

A: In order to monitor the consumption rate the process is automated and workers cannot manipulate the data captured. We are interested in optimization of systems by taking into account creative solutions and ideas provided by different workers and we, usually, provide them with some incentives as well.

Q: Who are the principal planners of energy policies in your company? How do they work? How do they coordinate their work with the rest of the organization?

A: Of course, board of directors should make the final decision in order to apply the provided solutions or not by considering, mainly, financial evaluation. We try to optimize the current systems rather than deploying some new technologies due to the fact that new technologies cost a lot for the company. Actually, the optimization solutions are considered to be in short-term rather than long-term because the board of directors have meetings on monthly basis and would like to see feedback on improvements as soon as possible.

Q: How do you assess the success of an improvement solution in a system?

A: First of all, production output and then the mentioned indicators, which are provided every day. The reports will send to the board of directors every day to be investigated and if the solutions were not successful they would be examined again. For example, what were really important were additives, which played a critical role in optimizing the process in terms of energy consumption and also the indicators in order to obtain a standard clinker. We normally use 10% additives.

Q: How are employees involved in the energy management practices? At which level (is it a passive or active role)?

A: Employees here are also required to follow a provided roadmap indicating some energy efficiency factors from the beginning of the next month. Therefore, we are going to apply this strategy in order to see how it works, it was actually introduced and verified by an authoritative company.

Q: When and why did you start to care about energy efficiency in your company?

A: After Subsidies reform, more expenses led us the companies to consider energy efficient solutions much more than before because before that thinking of these strategies would not make financial sense; consequently, companies feel the necessity to move towards such strategies. On the other hand, there are still some companies operating with worn out machinery that cannot really optimize their process due to high cost of these solutions.

Q: Do you have any training program about energy management? How do you plan for trainings? (Specific program or routine plan? How many of employees have to participate Are employees forced to participate training?)

A: Our Company provides the employees with some training programs held by some specialists for energy efficiency purposes. The way we assess the outcome of the training programs is directly connected to the management department; they, actually, evaluate the effectiveness of training programs by taking into account the changes in data provided on daily basis.

Q: How do you evaluate the effectiveness of these trainings?

A: I believe that the short-term training programs have been so effective while for long-term programs we need to evaluate the future costs and it also depends on company's strategies.

Q: How many employees participate the training programs? Where in the organization do they work? Mandatory or not?

A: These programs are provided, basically, to the engineering department; there are some theoretical aspects to be learned by specialists and some operating trainings for technicians and foremen. Managers should decide which employees are required to pass what type of training courses; therefore, I can say these programs can be considered as obligatory for employees. Since 2009 we started the training sessions almost two years ago while more specific trainings in the area of energy started almost 1 year ago.

Q: Do you have collaboration with academia to improve your energy efficiency?

A: If universities and researches have some proposals and projects to be working with us we would like to work with them but we rarely carried out projects with university scholars and, to be honest, most of them will not keep in touch after having their project done.

Q: Does enough information exist about modern technologies among decision makers in your sector?

A: New technologies are introduced to the companies in seminars held each year and then these are the managers who have to decide which technology to deploy.

Q: Does any regulatory/Standard exist in your sector which hinders/promotes the use of more efficient technologies?

A: There are some regulations and standards defined by the government that the companies are required to comply with. In this regards, I would say that these standards and regulations have had positive impacts on our company as the management team was forced to provide the required tools to comply with the standards.

Q: Do you think if some of the standards and regulations can be considered as some barriers to your company?

A: No I don't think so, due to the fact that these standards are international standards and most of companies have advanced equipment. Considering the fact that there may be some weak points in terms of execution, supervision and so on there could be some problems in developing the standards since we are lagging behind developed countries; consequently, we cannot completely comply with some of the items mentioned in the standards. Of course, there is a fine or penalty defined by the government if we do not follow the standards in a proper way.

Q: Is there a long-term plan for energy efficiency in cement industry?

A: Long-term plans cost a lot so we are only taking into account only short-term plans.

[End]

5.3.2 Company C

Interviewee: Head of R&D Department

Interviewer: Ali Samei

Time: 60 minutes

[Greetings]

Question (Q): Financial turnover from product point of view or anything that you might know?

Answer (A): Yearly 175000 tons is our pure aluminum production within usage of 5000 or 6000 tons of scraps we can reach 185000 tons of production. Well we reach 185000 tons not every year; it depends on our overhauling plans but we might have 185000 tons 2 years by 2 years; But currently 175000 tons is the right number, maybe it's good to mention that last year we had 178000 tons, (it is all depends on the amount scraps we might buy to increase the production capacity). We reduced 6000 to 7000 tons in our production capacity to our energy efficiency goals.

Q: How about financial turnovers and costs?

A: well we sell according to London Metal Exchange (LME) price in Tehran stock market in which our pure ingots are sold out now by 6730 Toman per kg but it's a bit different for our alloyed product, for them you have to add an extra 30 to 40 Toman. Multiple it within tonnage that I explained you will see the selling turnover or revenue. In general if I want to classify our costs; I can say approximately 30% is related to raw materials, 30% to 40% is related to energy costs in which 95% of our energy consumption is electricity however we use gas for rest. 10% to 15% is personnel costs. The rest is some other procurements or profit related ones. In our R&D we didn’t consider that much about financial issues.

Q: how is your R&D?

A: in our department we have two subcategories; in Research we collaborate with universities, we may reach 200 to 300 million Toman. In our development, one is long term oriented for instant change in one technology in the production that we cannot predict them in advance, top managers will say for example we need casting workshop, then suddenly the budget will be allocated for the development of this plan, the other type is our incremental developments, which are introduces in the world and we want also do it but with our existing technology in order to make it more efficient in terms of energy or doing incremental improvements. Yearly we spend 2 billion Toman a year for this. In our long-term developments we might spend 4 to 5 billion for 5 years. It can have reduction in energy consumption in long-term within changing technologies.

Q: Do you often have long-term plans?

A: of course we do have them and plan yearly.

Q: What about your products?

A: we just produce products as an input for other companies, we don’t do the finishing, we produce ingots, bars in different shapes according to standards in 25 kg or even 500 kg, they can be alloyed or pure or for extrude we have circled or billets that are mostly alloyed.

Q: Do you have different technologies for your different products or not?

A: No, we don’t have different technologies but we do have different molds for each.

Q: About your OS?

A: It is the same as what we gave to you, but it is going to be changed but not yet now.

Q: In your OS you have technology and energy managers, what are their roles?

A: Well there is an antecedents, the energy manager that you see is not related to efficiency, it's related to providing and distribution of energy that is working under supervision of deputy of technology and energy manager. About energy efficiency is one the parts of our R&D and it is not related to them. We are consuming electricity more or less the same as the whole province, our electricity consumption is 98% of our total energy consumption. It's a lot, we need a manager for that to manage all the related issues about that like maintenance or technical supports, this is what energy manager is doing.

Q: do you have yearly energy statistics?

A: Yes, all of the sections have energy and electricity controller, and we calculate the related costs by the controllers i.e. energy costs related to the warehouse is different from others, we also consider the holidays or picks, we monitor and calculate everything. Since two or three years ago we have energy counters for each workshop, it is the same for gas, despite the air conditionings just two of our workshops are using gas which has furnaces.

Q: do you have a statistics that you can tell me how much you consume energy per year?

A: you should request it formally; we will give the numbers from our database. It needs to be permitted.

Q: How many personnel do you have?

A: well 3250 are the number of personnel with project-based contract or full employed contract. 700 people are our partners, like transportation or gardeners and etc. Let's say 4000 people, out of these 4000 people, we can say 300 to 400 are related to technical supports and managerial levels and the rest are in the production sections. Here we are 4 companies, and not one. Preparation, our electricity, reduction or refinement and foundry in some countries aluminum production is totally different in term of not all the companies in one complex, different companies, collaborate to produce aluminum, but we are all in one complex.

Q: Are you state owned or private?

A: Formally we are private owned, but kind of shared, our boards are consisting of 5 members, 2 of them are related to state and three are totally private. 60 % are kind of related to state and 40% are really private.

Q: Do you produce energy?

A: We have some plans for that, we have permission and certification to make the plant but we don't have the enough budget, we need sponsor to invest, it should be noticed that the consuming energy here is kind of a lot and it is really hard to provide that with wind energy, but before, our electricity was provided by Dez dam, so let's say hydropower which is in common in aluminum industry in the world, but now we are getting it from Iran national energy ministry from all electricity network. And usually investing is taking place with Iran national energy ministry rather than industry ministry.

Q: Does inflation of energy costs leads you to produce your own energy especially when governments are eliminating subsides?

A: Everything is inflating, gas, wind energy; investors should pay more for every price. But we analysis the projects by different software especially about the trade off, profits. And we did all. Imagine now we have 100 billion Toman, which is better, improvement in production line or making a power plant? Power plant is not just our only project; we have in priority, different more profitable projects within better turnovers. It is not in our priorities.

Q: Can you tell me about your technologies? Are they licensed? Or is it old? New?

A: Let focus on energy since we want to talk about that more, we in comparison to other companies that in energy efficiency are focusing on changing lights or whatever, have broader strategy. The other companies are consuming energy more or less 98% in their reduction or refinement units. The remaining 2% or 1% however can be equal to ten small manufacturing firm's energy consumption. It is the reason why they focus on that. Our previous reduction and refinement units had been licensed by an US manufacturer have been installed on 1346 (1967) and start working from 1351 (1972) within 45000 ton capacity and it increased to 120000 tons till 1373 (1994). Since the technology was old, we needed to consume 17-19 kWh electricity per kg. That was a lot, so on 1380 (2001) due to these reasons plus environmental issues we shut down the units and brought new technologies with more efficiency and less pollution. I should say that those days pollution control was more focused. New devices are 200 kA, and the efficiency of that is approximately 13.5 Kwh per Kg. Newer ones reduced to 5 Kwh per kg. Let's see in this manner, we are spending 3 to 4 billion Toman electricity monthly, if you can reduce it around 20%, it will be 1 billion Toman saved cost monthly and 12 billion Toman yearly. It can be also more cost savings, I'm telling it in general, and I don't concrete numbers. You can multiple all the numbers by what I said to reach the right numbers. Let's multiply 175000 tons, which 65000 tons are produced by old technology 18 Kwh per Kg, 110000 tons by 13.5 Kwh per Kg. for this small change in technology we spent 400 billion Toman plus 200 billion Toman hidden cost. Which is in total 600 billion Toman.

Q: where is this new technology comes from?

A: It's from France, they sold it out to Japan, and Japanese sold it to Chinese, they changed a bit in that and we bought from them. Within new technology implementation, the old technology which was supposed to be out of the unit remained in the unit for the country needs and are working to have higher production capacity. Now we are also improving the old units which is consuming 18 kwh per Kg, we have some agreements with investors and suppliers from china for the technology and spare parts to reach efficiency in terms of energy and environment within two years. But we cannot reach 13.5 Kwh per Kg still, since if you reduce that much, you will have less efficiency in production.

I like to open this discussion, sometimes you are shutting down one car production line, why you do that? One reason can be that car does not have any demand. Then you should go for another car to produce. But we are producing aluminum, in the market they are not asking which technology or line you used. Customers are not influencing us to change our lines or technologies. I'm talking about raw aluminum not customized request that we might not have the technology. Look in this way, we paid 600 billion Toman, and installed aluminum production line within 110000 tons capacity. Here we were producing 70000 tons. In comparison you are producing 70% less, it means the value of 400 billion Toman. For this 400 billion you are also paying more electricity bill. Let calculate the bank interest rate. You will see that it is better to pay more for the electricity. If you want to invest this 400 billion Toman to new technology you will be in deficit and no profits. Till the moment that we can produce with our current system, we will do that, no new technology. But in case of environmental issues we will invest. As I said also in advance we have 2 years plan and are collaborating with china to reduce the environmental issues.

We use our current technology until we can have profits and economic reasons. Sometime you see that you don't have profits or in the world market there is not any spare part any more for your production line for maintenance or whatever. Then we will go for new technologies. Thanks to God our old production line can be overhauled and more than 98% of the spare parts are provided by Iranian market. So we don't have technology problem is terms of maintenance.

Q: you are in the company for many years, I like to see managerial point of view about energy, when energy efficiency became important?

A: I can say after revolution. After 1351 (1972) we had an agreement with Iranian energy ministry (TAVANIR). It was like 1 Rial (0.1 Toman) per each Kwh. They did not care what is the actual price of the electricity. From 1351 (1972) till 1371 (1992), we didn't have inflation in our electricity prices. So there are no incentives for energy reduction. It should be noticed that our company was also reaching new production capacity. On 1371 we reached the higher capacity, concurrent to that the oil price increased in the world market, so energy costs increased. Governments planned to subsidize the energy price for the companies, so that was the real moment that we decide to move a bit to energy efficiency to reduce the costs and we did some researches. But we unexpected costs in other things that kind of stopped us, but in last 4 or 5 years due to governments plan to reduce the cost we are also taking that again into our consideration but we are not the follower of others since it is a new trend.

Maybe it can be interesting for you but we are paying the highest price for the electricity in aluminum sector all around the world. EU companies they mostly have their own power plants and they sell even to outer market, but since we are buying we pay more. According to Iran condition, we cannot move forward to build power plants; I like to say that most of the aluminum manufacturing companies are near the dams.

Q: Which level is usually integrated with energy issues? High-level managers or technical advisors?

A: You cannot distinguish between them, top managers are focusing on broader issued such as changing in the new technologies, changing production line. In example we changed our furnaces, which were consuming gasoline to furnaces which are using gas instead. This type of change is just to pay less; you just changed in the fuel not the furnace really but again it is not obvious that you are consuming less, you just pay less for energy units. It is a trade off in general.

Lower levels are more engineering, that manager is far from them, and there are some suggestions as proposal that advisor in lower level gives to top managers. For example in 1371 engineers made a research on pots energy reduction in engineering details. It has been implemented in time. But it was not changing in the technology or one step back.

Q: Are managers looking at energy efficiency in long term or short term?

A: We have some projects that when they are done I don't know that we are going for some others or not, but just an example in our 2% consumption in plant heater, we have 22 transistors in each sections; each of them needs efficiency project. 3 of them in the progress and in the two years we will do for the 18 rest. We also worked on lightings but less in electromotor, currently there is ongoing project in lightings. If you do all of them, it will be 1 % of all energy consumption.

Q: By long term I mean that do you have 5 to 10 years plan to change the production line?

A: We don't have plan for the changing the existing production line, but about the new technologies. Due to our capacity increasing plan to 500000 tons, we propose new technologies for instance 12.5 kWh per kg for energy reductions.

Q: Among all the things that you did or even something that you may missed…

A: We are working on heating area, we have 16 or 17 companies inside, in intelligent way such insulations, we are now monitoring two of our heating centers. The rests are two years planned to reduce the energy consumption. But we have to do them after maintenance. So the leading is overhauling and energy efficiency is after them. That is why we need two years, we could do them in 6 months but we have to wait for the maintenance to their plan. For the transistors it is different, we have to monitor them and then energy reduction changes. Actually also the budget was kind of limited but now is more and reached from 20 million to 150 million to accelerate the process to make it done in 6 months.

Q: Have you ever been audited by outers or even internal audits that you might have?

A: We didn't do that, but there was one 3,4 years ago when I was not in charge for all the company. Most of their points were related to changing technology, which we could not afford.

Q: Do you have routine auditing?

A: No, we don't have.

Q: How about electromotor, i.e. putting a drive and changing them? Do you have them?

A: Yes, we have lot of them; just in one of our workshops we have 800 motors with gearbox. About the drive, in our new system everything is with drive but in the older ones there are problems, our technical wall (avionics) cannot accept changing in the parts easily. Basically if the motor have problem, basically it will substitute it with another motor within same characteristics to prevent the stops in production. You cannot take risks or maneuvers. But if you want a new system and project, we can control and having motors with drive, we don't accept a motor without drive in order to control and monitor all the indexes, in that workshop all the motors are working and we cannot monitor their temperature and etc. We can see the energy counter for whole the workshop. It is really good to go in this direction to make them efficient and monitor them one by one but in total it is not that convenient in compare to the other sections and needs a lot of effort and procurements, but we just started from transistors. For the transistors since we are paying penalties about 700 to 800 million because of using more than threshold. If we can correct it and going back to the coefficient that electricity network says, we can reduce the costs, it is not really about energy consumption. After these we can go through motors and so on. For new motors and equipment that we are buying we have energy efficiency approach. Its rule even you have to pay more. Anyway since we have old lines, all the units needs less energy consumers,

Q: Among all you did in maintenance or… which one was caused most significant changes?

A: Change in the energy system, we reduced 20% of energy consumption; it is like 10 billion Toman cost reduction. In transistors it is not really done, but we speculate 40 million Toman reductions in penalties and as a consequence energy reduction.

Q: Do you have online energy monitoring?

A: New production line has it, and older one also has energy units, that can monitor voltage, current and fluctuations. But our transistors don't have it which we are going for that in the ongoing project. In new line for each pot you can monitor the energy consumption but in older one each line you can monitor. New line is in detail but older one no.

Q: Do you monitor monthly or early your energy consumption as a plan, (As you do for you production)?

A: We analysis in terms of costs, energy cost per Kg, i.e. we paid x Toman energy per Kg aluminum for electricity. It was calculated 15 days by 15 days but now is monthly. The system, which is working on that, is calculating weekly and gives us summation monthly.

Q: about your incentives for organizations, members, and employees for instance do you have some monetary prize for improving energy efficiency?

A: No we don't do it. These are a part of responsibilities, job description and no prize. But if you do something beyond that, you will have prize, we have defined some indexes for everything, for example in index of energy consumption is 18, if it increases to 18.1, the person who are in charge of the workshop within 18.1 have to explain why? It is really important for us and sensitive. Any increase will lead us to pay more for energy costs. New lines are monitored in detail but old ones, each workshop manager will see it by counters at sense in the workshop.

Q: About what you said, that technical people can analysis and suggest what to do about energy?

A: there are some, for instance in one section we installed one sensor and controlled one device (air pressure compressor to the computer to not consume in lunchtime). Maybe it is not that significant, but we did it however it can be really significant for small companies.

Q: Is there any prize for new suggestions?

A: We had it before in a systematic way. But now if somebody does something or suggest we will write a letter for him to the manager and they will pay him in different manners and can be significant sometimes.

Q: What are your strength and weaknesses in energy consumptions, operations?

A: Mostly in monitoring, in small workshops, finding problems, we see them broadly and no detail. For our equipment we don't have indexes to say really that they are good or not, they don't have document, they are not like coolers that you grade them by labels and say they are A or not. We have general and broad counters.

But in reduction and refinement, new technologies that had been implemented there was good. For old line of reduction we are doing a project to monitor each pot separately in detail that is good. In our gas consumption, we have the same broad monitoring unfortunately that needs to work on. We have plan for all but skeptical about time frame, in addition we classify our project not by sector; we prioritize each by costs, investments and turnovers. We think about money not energy.

Our budget is not really fix and we don’t threshold in researches that we do, the most significant barriers that we have are time and human capital within specialties in energy. It is not just our problem; it is the entire country problem.

Q: Do you have any plan for employ or get some human capital?

A: We had some changes in our organizational structure but now we added some technical parts to that however we know that it is not enough due to diversity of projects, so we prefer to go to third parties and partners. We need two specialists to control and the rest we have outsource policy.

Q: About the documentation that you said, some equipment don’t have document? Do you have ISO certificates or…?

A: We have all of them, see, ISO is not going to your parts and equipment, in 20 sections you need documentation, one is production line but not specific equipment or parts and devices. ISO will ask us for some indexes, you will show them that you are improving in them or you have some plans for them, then you will have ISO. We have ISO 18000, 14000, 9000.

Q: Iranian standard Institute has some rules for each industry; do they have for aluminum too?

A: They had passed some specification to the industry, they ask us to improvise energy consumption, based on our documents and equipment that we have, it is based on our specific equipment. And we defined it based on similar companies that have same devices. We got prize for improving energy efficiency in aluminum industry due to our improvising.

Q: Do you obey their standard?

A: Of course, since it is designed according to our equipment.

Q: Do you have penalty and encouraging rules by ministry of industry like ones are in steel or cement industry?

A: Let's see how Penalties and encouraging effect?

Q: By paying, i.e. if you pass this you have to pay more or less

A: You have to see that where it can be influential, I don't know honestly. However any slice change will cause billion Toman in our company. If we can do something for sure will do, if we can't do that in advance even if ministry come and say do that, we will say that we cannot do that! (Since it is out of our abilities). About environment there are some rules and even they can close of production lines.

Q: Back to what you mentioned at the beginning and changes in energy manager and organizational structure, what were the changes in the OS exactly and which levels?

A: First they hired technical energy advisor in technical department, the manager changed to energy manager within 3,4 personnel, then the concept of energy manager totally changed, their personnel went to research and it tuned to head of energy (boss) within head of workshops and so on. It is kind of become smaller. I like to say that by energy manager first we thought about real manager as a person, then they we saw differences between energy provider and efficiencies, then we came in to managing concept not really the manager.

Q: Did cause some changes in the job descriptions?

A: Job description were not that specific, so no, but for the manager of course yes. They are responsible all for energy efficiency however we didn't change the positions in the workshops in general.

Q: what were the most significant changes due to OS changes?

A: There were mostly in production.

Q: What are the roles of shareholders in energy?

A: The CEO is receiving the monthly reports of energy consumption.

Q: How about shareholders?

A: If the energy consumption would be so high or strange, yeah it will be reported to the shareholders, but if it is in the range or fluctuated, so there is no necessity. We are consuming a lot but no fluctuation in consumption.

Q: Is it like this that shareholder says that new technology should be implemented or not?

A: No, it is not like that, we some time suggest to the main board, and they will analysis.

Q: Are you designers of energy efficiency?

A: Yes, we are designers and implementers but CEO is the decision maker.

Q: How do you collaborate with other units? Are the other units obliged to collaborate with you?

A: Yes, not just in energy projects in all of the research projects. All the units are collaborating even in sharing staffs; sometimes we just pay or provide equipment.

Q: How do you communicate? Letter? Bureaucracy? Monthly meetings?

A: We communicate via managers and deputies. If we defined the project then they will collaborate with us as partner. It is not like that we commend them.

Q: about investors, partners, and suppliers … are they helping and paying?

A: Yes they do that when there are no limitations.

Q: Who is measuring the energy reductions? Or you tell the units to do that and give the data to you?

A: There are two approaches, for example in transistor project that we are doing, yes we are monitoring and receiving data. But for new technologies that we done, they have centralized controlling area that is monitored by technical and energy and control rooms for providing energy, they have daily, weekly and monthly reports.

Q: How about real details, such lights, do you have some rules for example turn off the light if you are not in the room?

A: Yes, we had them, but now it is kind of in the culture and everybody is obeying these unwritten rules. We have some problems for the workshops, they are really dark the design is too old and it is metallic, we cannot have natural lights, basically 24 hours a day the lights are on, we can change some but some are really not changeable.

Q: Can you monitor?

A: Not really since our counters cannot show the details.

Q: Do you hold some training programs for the staff and personnel in energy?

A: Yes we had, by our self, third parties, once even we send some staffs to practical workshops, and it was for one week with laboratories.

Q: Were they effective? Do you analysis if they were improvised by these workshops?

A: Not me, but educational department should do that, however I'm skeptical if they do that.

Q: Do you invite the staffs after workshop to ask what they have learnt?

A: Not really…

Q: By your experience, is workshops helps?

A: Of course, it changes their point of views even in their private life. But in the company if you want to change, you need infrastructure to be changed not just workshops and education.

Q: I'm talking about awareness.

A: We mostly are aware the problems but step by step.

Q: Are these workshops mandatory?

A: No, we encourage them to go; however most of the technical advisors and staffs went for them.

Q: Let's consider your company and all Iranian metal industry, in your opinion, are the top-level managers know and aware about energy efficient technologies?

A: In aluminum, there are monthly magazines, brochures that partly are focusing on energy efficiency, and some companies are monitored there how they consume energy. In technology selection we have all the criteria. I think the only barrier is budget and financial barriers. We know all the things.

Q: Are the managers familiar how to bring money by loans or procedures of bringing new technologies?

A: Actually for the new technology that we said we were bringing from china, we were paying the installments to china

Q: How did you find the Chinese bank?

A: The technology provider introduced it and they helped.

Q: About project prioritization that you said you have turnover, cost criteria. What is your assumption for interest rate in energy projects? Do take more risk for energy projects?

A: No, there is no difference between energy projects and others. Our IRR is based on banks, sometimes you have low IRR but you have to do that to do another project due to chain nature of the projects. It is more complex just to say it in a simple way as you ask.

Q: Can I ask about the time frame of planning in energy? Long term, short term? How many years for return?

A: It depends, long term could be 3 to 4 years, but for small projects like transistors that I said is less than one year.

Q: Do you have something like 10 years or more?

A: No, which manager survived more than 1 year?

Q: Is there any possibility to change the technology now?

A: There are no possibilities, but we will develop by new technologies, adding capacity and so on.

Q: about standards and environmental rules, have you been ever got prized or fined?

A: For the prized two times but since I'm here for two years to say, but for penalties, for so many years we didn't paid anything. Environment and energy are different, environmental issues are related more to furnaces.

Q: Is there any subject that you like to suggest to government in energy, standards, and technical to intervene?

A: I don't have any specific suggestion, but if any new startups want to start aluminum production line, they should really analysis from the beginning, about the place of plant, technologies and all controlling factors. Sometimes there are big gaps between decisions and technical analysis, due to some political issues you cannot bring new technologies from EU and you will go to china.

Q: About the managers, who are managers for short time, not really long time? Does it influence?

A: Definitely, some projects need time. It is really difficult for really long term plans, which involve the infrastructures.

Q: My last question is about fixing the price and subsidies by government and recent sanctions. Is it really a problem? Did you overcome that?

A: In energy, we didn't have barrier for technology and budget, last year we made a contract about 150 billion Toman which maybe have mostly effects on energy, about subsidies, they didn't pay all what they said. Also we have to sell according to aluminum world stock market, 2,3 years late we had big decreases in aluminum prices and copper, no body supported us, we spend from our old budgets. We didn't sell some of the production and waited for the right moment to sell.

[End]

5.3.3 Company D

Interviewee: Head of R&D Department

Interviewer: Ali Samei

Time: 45 minutes

[Greeting]

Question (Q): What are your products?

Answer (A): I'll give you brochures

Q: What about technologies that you are using currently? Are they updated?

A: Yes, we are updated almost. We started on 1379 (2000), another line 1384 (2005) and 1385 (2006). We have been audited by Iranian national standard organization I'll send you the documents by email.

Q: What about turn overs if they are not in brochures?

A: We have 100 thousands tons of galvanic sheets, sometimes we reached 130 thousands tons, we use all the capacity, but if you want to see the turnover by international market and prices is about 300 billion Toman per year, we export to neighbor countries such Iraq and Afghanistan and once in 1383 (2004) to Italy.

Q: Is the company state owned or private?

A: It is private but shareholders are related to state. And Mobarake steel company in Isfahan is managing research department of us. They are the main shareholders. This happened recently. They influence in corporate level in management board as shareholders not more.

Q: the number of employees and personnel?

A: its 280 in total, we don't have outsourcing.

Q: how many of them are engineers and labors?

A: 40 of them are engineers. The rest are technicians, production, security, procurement, Tehran branch and all.

Q: about organizational structure, I saw from the website, is it the same now?

A: it is the same, but maybe we'll have some changes but now it is the same as what is presented in the website.

Q: I didn't see any section specified for energy. How it is included there?

A: we don't have it in OS, but we have it somehow like R&D but we have energy manager as control manager to see how it adopts to standards.

Q: how you calculate the energy consumption?

A: we monitor it daily.

Q: which energy you use?

A: Electricity and Gas, gas for furnaces, we have for each section a counter. It is monitored monthly, we have monthly reports within indexes, and each 6 months it will be double check.

Q: do you have your own power plant?

A: no but we have two urgent energy generators we have melting pots. We need them for melting which is in daytime.

Q: how much you use them?

A: well it depends but we use weekly, if the electricity was off we use them.

Q: let's talk about your technologies? Do you have production lay out? For each section which type of technology you use?

A: it is different; our rolling is four rollers it is from MINO, an Italian company. Our galvanizing line is hot heat galvanizing is from India; both of them are new and updated yet. We upgrade them routinely.

Q: do these companies come to visit, check or repair or…?

A: since when they gave them to us and check out the performance and quality, no, in a case we need something, calling them to upgrade.

Q: let's move to strategy makings, policies about energy efficiency? Since when have you had this approach?

A: since the beginning, however we didn't have energy manager but we had a form that we had to fill out in daily control meetings, if we were consuming more than manual and standards, gas, electricity, water or whatever. We could monitor and see the reasons and solve them.

Q: so you were careful to not increase, how about decreasing?

A: according to our production line we cannot do anything, but for example our new line has the same technology but with different drives and motors have lower energy consumption.

Q: so it seems to be you were controlling not to increase rather to decrease?

A: for decreasing we need a lot of changes; we need to go for some changes for our new line but not in the technology but in automations it will be updated as well as control systems and its electricity consumption will be well optimized.

Q: do have some long-term plans as well renewing technologies, managerial practices, and workshops for employees?

A: we defined some strategies in energy efficiency, practices like if I'm leaving the room I should turn of the cooler or lights, and we have some manuals. About the site (plant) we used a structure as much as we could, up to not effecting the production and not new technology.

Q: how about long term plans like in five years? For example reducing in energy consumption like 10%?

A: we took a policy from SENSIS Company, which is American, but we got it from another country, it is doing our energy management. Our energy consumption is daily control that means better energy management. In 6 months to one year 10% to 15% of our energy consumption will be reduced.

Q: what is the main reason to go for this energy management? Environmental or costs?

A: we don't have environmental problems and issues; we are doing this to reduce the costs however we have ISO 14000, which environmental in partially included in it.

Q: how do calculate for cost reduction? ROA in how many years?

A: if we implemented energy consumption manager, it will be probably 1 year. It is because we want to do it in short term and continually managing our energy consumption, not just for electricity, for raw materials, gas, water and other gases like nitrogen and..

Q: it is like investment? What is the rate of turn over? Are taking more risk?

A: we don't have more risks, we control everything by detail to balance, for example there different energy consumption and prices for different product with different thicknesses, it helps us to define the prices more precisely to reduce the costs and increasing the profits.

Q: about the shareholders? Are they looking at energy efficiency from long term point of view or short term or cost reduction way?

A: it is totally long term plan,

Q: do have some other activities to reduce your energy consumption? Which one was the best practices and useful?

A: beside what I said till now, let's bring an example from water consumption, we have a green area around the plant which should be, we change the watering system to drop system, for electricity, we implemented counters for each section, devices and… every morning at 7 am they are checked to have reports.

Q: so which one is the best one in cost reduction or energy consumption reduction? Include all the examples like SENSIS contract?

A: we just made a contract; I may answer you next year about the impact

Q: how about now, exclude SENSIS?

A: daily reports and adaption to standards, unfortunately some Iranian standards in steel companies by Iranian standard institute is so broad and not detailed, but we tried to be detailed and got profit by being detailed.

Q: can you estimate somehow the profit by being detailed oriented?

A: I think more than 20% yearly. Its cycle and we can use the existing saved energy.

Q: it's amazing, I think like petrochemical plants?

A: yes, we store the remaining electricity in our electricity capacitors.

Q: let's talk about measures again, let's be focused more on employees? Their motivations? Prizes? In which term they might be motivated? It is a part of job description? Punishments? Penalties?

A: we have a topic as a rule, prize for efficiency and increases in production; it is subcategorized in different terms and parameters. One of the parameters is related to energy consumption that is 10% of efficiency; it is for all the personnel but with different percentage,

Q: for example if you have efficiencies in production line, you will pay 10% to all? Not just production, it can be for other sections.

A: yeah, we calculate them and share it proportionally to who were the most relevant ones.

Q: how about promotions?

A: If there are some workshops, training programs, we will send them, for instant in Tehran University there is one that in next month, we will send some of good personals by our funding.

Q: for implementing these plans as you said like daily reports, did you change anything in organization or OS?

A: we changed almost the job description, and we did enrichments and enlargements. We added some committees such as electricity committee and mechanical committees that are also in charge of energy issues despite the other things that they are in charge.

Q: about the impact of these changes, which sections have been affected more? Production? Management?

A: most of the effects were on electricity and HSE department and energy sectors.

Q: how about energy unit and department?

A: our energy department is doing energy things besides; they don't have daily tasks.

Q: it means that they are complementarity, there is no specific energy unit but it is consist of other units' personals?

A: yeah exactly, it is like you have two positions.

Q: do you have developmental plans for energy department or separation of it, extensional?

A: we didn't plan yet, but if the main organizations do it, here I think will do the same, as the policy set by outer forces. I like to say about also ISO 10015.

Q: do you have manager or a position in charge of ISO?

A: yeah, we do have a specific person in charge, ISO 9001, 14000, 18001 and 10015.

Q: some other petrochemical plants, their managers told me that 9 to 11 months we do our own staffs but one month before auditing or ISO we will do those things, how do you coop with ISO?

A: we have auditing twice a year internally and once externally, it is important for us. Since we believe in that, we take it serious and unconsciously doing that.

Q: is energy consumption important for your shareholders such as Mobarake complex?

A: energy efficiency is important for our shareholders in comparison to other companies that for them it is like that, our shareholders set some goals in this manner that we take it into our consideration, and it is one of our motivations to for controlling energy consumption.

Q: about your strength, weaknesses? Potentials to be improved?

A: our weaknesses mainly was about lack of measurement tools we solved it after, they were also potentials.

Q: can tell me who is the main decision maker in energy area? How?

A: Technology manager mostly does it. Technology manager by collaboration will recognize and send it to board of management and CEO, they will confirm it and authorized for the rests.

Q: How about the assessment of the costs?

A: for the costs we control monthly, and it is by me, and the success index is based on cost reduction. This was so successful about 10% of cost reduction.

Q: which kind of reports you give to the board?

A: both types, energy consumptions and cost.

Q: about the manuals for the employees? Are all of your employees doing that? It is now in the culture?

A: I think it is the culture and most of the personnel are obeying the standard rules in the manuals.

Q: about the impact of manuals, was it significant and measurable?

A: in term of costs I don't know in detail but generally yes.

Q: do you have some training in energy?

A: we usually attend the seminars and workshops; also we attended one seminar and workshop in Tabriz city, which was held by Iranian energy organization. We attended one seminar near Taleghan city about renewable energies like solar.

Q: do you have some plans about solar cells? You have great environment?

A: not yet, it is expensive, mostly state does have money for that in comparison to private sectors.

Q: do have informative campaigns?

A: yeah sure, we have them, always there is a new topic that we will aware and inform personnel.

Q: how do you assess that the seminars and workshops for the attendants were useful?

A: report, and interview with the attendants. If they don't report about the output we don't certify or confirm their certification. What did they learn? They show by the power point even.

Q: did it impact on energy consumption reduction?

A: yes, it was influential

Q: how can you improve you training programs?

A: by attending programs by universities, work and job organization and we pay for them. We routinely update our personals.

Q: let's consider not just your company, also all Iranian steel industry. In your opinion, information about new energy efficient technology is available among managers?

A: it is existed and knows them, sometimes there are some barriers such as motivation, or not complete authorization, or sometimes it is risky and costly, it can be overcome by government and updated investors. Our culture is like that we don't look for challenges. The world is open now; there are plenty of information sources. It needs culture makings, it is among Iranians, if you can solve it from your home, and then government will do that.

Q: about the information sharing and selling technologies by foreigners?

A: information is available but there is another thing if they cannot sell us the technology, which is political.

Q: Two important subjects in two recent years, first elimination of subsides, it was supposed to give 30 % of the profit of the reform act to the industry but finally they received just 10%. The second issue is that the costs were increased in industry because of the increasing the prices; it is so significant in B2C. Do you have the fixing price policy?

A: there was a meeting in Isfahan city; I went there, all were so angry about ministry deputy. For fixing the price it needs the market tolerance, if market cannot handle it we cannot also cut our profits and it means that we cannot invest.

Q: about sanction? World market, import, export and technologies.

A: sanctions are helping us to be on our own, I know that it was bad for us, but we need to make the culture, if there is now sanction we might never build or make any technology by our own. There is no barrier to bring new technologies however with a bit lower quality. I think also about research we develop a lot, we have the potential. It is good to have no sanctions, but it needs managing. Check Mobarake steel complex, how they developed independently.

Q: standards of Iranian standard organization and ISO, how much they are useful?

A: it is very useful, mostly because of our approach, our documents; the standards are not really useful for small companies, why? They don't want? They bring the engineers in small industries and use them, as not really engineers, like labors, engineer is just doing some simple documentation. Engineer doesn't suppose do this; he/she should do designs or specific controls and being creative.

Q: about the thing that government should do, does the standards proposed by government useful for industries?

A: it is good for small industries, but for big industries I don't think so, they cannot be that useful. For big they have details but for sub industries no.

Q: they prefer major industries and big ones?

A: not really, they cannot adapt with really small sub-industry. They should extract all the data and come up with a result for all.

Q: about government policies in energy? Is there any long-term plans? Inspiring? Penalties?

A: yeah there are. We inform them that we don't have consumption in one specific period, and we will be prized.

Q: how about government investing consulting's? Loans?

A: I'm sure that there are, but I don't know details.

Q: do you trust them? Do you think that if government changes problems will arise?

A: if they well constituted and became rules, government changings cannot affect them. I think the policies are good in energy. There is a good policy, which is taken by government to help the private sectors, it is to aggregate so many private companies and build their own energy plant and make them independent from Iranian national energy ministry. I don't know what the progress is.

Q: very last question, what is the main barrier for new energy efficient technology from your point of view for companies?

A: there is no barrier, Iranizing is my approach, of course maybe I will use 60% foreigners but 40% ours. Economical is not the main barriers, they should ask the banks; they help by concrete proposals to have the support by ministry and banks.

Q: did you ever do this to ask for the support?

A: Yes, we did it successfully and also for the future we will do that.

Q: any suggestion for Iran energy issues?

A: it is mostly related to the culture, we should enrich the culture.

[End]

5.3.4 Company E

Interviewee: Site Manager

Interviewer: Omid Maghazei

Time: 40 minutes

[Greeting]

Question (Q): Would you please provide the following information?

- *Plant layout*
- *Number of employees*
- *Type of products*
- *Turnover*
- *Capacity*
- *Energy balance sheet*

Answer (A): The capacity of this company was designed for 2 million ton ethylene annum (two plants with the capacity of 1 million ton/year), which in reality is producing around 400,000 ton annum regarding the feed constraints. With respect to the current capacity situation (400,000 ton/year) the cost for finished products is 460$/ton approximately while the average price is around 1000$/ton (although it reached 1200 and recorded 800 as well in the market).

Product: "ethylene" and a co-product: "C3+" (11ton/hour and consequently around 80'000 ton/year for each plant, therefore, in overall: 22ton/hour and 178'000 ton/year)

Number of employee: 580 (engineering staffs, commissioning staffs and office staffs) + 370 employees in maintenance who are outsourced

Q: Would you please provide us the information about energy consumption?

A: design and what is really in practice are different.

Design:

Electrical: 7.5 MGW/hour

Steam: 65ton/hour (high pressure steam)

(And these data should be unified in terms of equal consumed energy.)

Currently, due to some problems like operating below the maximum capacity, and high amount of loss of energy and loss of fuel gas. As a result, the present operating situation is as below:

Steam: 200ton/hour

(Electrical the same as design)

Technological aspects:

Designed by Technip (France) and they are known as Demethanizer front or Tail-end Hydrogenation.

Energy consumption

We calculate it per ton ethylene, which I would provide it accordingly.

Q: When and why did you start to care about energy efficiency in your company? Where did the initiative come from? Did the top management support the initiative?

A: Unfortunately, these considerations are not taking into account since we are just thinking about producing under current circumstances (problems about buying equipment, install them and starts up). As you see we are producing with 20% of total capacity that the plant is designed for. Therefore, the energy efficiency aspects are not on the agenda. Also, energy is so cheap in Iran and nobody cares about loss of energies, consequently, managers will never ask about extra consuming fuel gas and steam, but they are happy that the plant is just working. On the other side of the same coin, the problems arising from sanctions, which are posing constraints to us for buying equipment and spare parts, are other factors to not consider energy efficiency at all. Nonetheless, I personally was taking care of these issues; for instance why the energy consumption is too much (we found that we had lots of problems in our furnaces which had high loss of energy).

Q: what were the main reasons for high loss of energy? Was it technological problems or operational?

A: they were mostly because operational aspects. As you know, our baseline is design as the main criterion, although we had some changes in design. These changes have been occurred due to the problems for purchasing, installment, performance and commissioning. Commissioning itself is tied up with training since mostly the operators have not been well trained and it's worth mentioning that generally training is not considered at all.

Q: Could you name key actions for energy efficiency practices that you adopt or planned to adopt?

A: First step should be formed in the mindset of the project owners and executers especially in the engineering phase. Second step is taking care of procurement. For example, when you are in charge of buying insulation brick for the furnace, you should check out some sort of specifications and standards. And sometimes you are paying more for the same brick with higher quality, which in turn would reduce loss of energy and energy consumption accordingly. Consequently, you are inherently saving your money by reducing the energy costs. But unfortunately the viewpoints are not based on these characteristics. To cite an example, we were in a dilemma over choosing two different types of brick for our furnaces, one of them from an Italian producer and the next was produced by an Iranian company (in Amol) that at the end we bought the Iranian one with lower price. As a result, the negative consequences are emerging in the furnace's temperature that in some circumstances the temperature is falling to 100 Centigrade instead of 700 Centigrade. Another example goes about buying 1MGW turbines we have purchased that in comparison with original plant have more steam consumptions that change our steam balance. This is because of the fact that we bought them from low efficient producers. Imagine that the difference of the turbine prices was around 200'000 Euros while the impacts on the cost of the final production are everlasting higher per each ton. Third step stands for operator and personnel training. For instance, if the operator couldn't be able to set the torch and the furnace's air temperature those negative outcomes would be encountered.

Q: Motivation for Implementing EETs and should it be measured through performance management systems?

A: Since there is no competition in the market and for what we produced there is one certain customer regardless of the price! And the marginal profit is so high as well. For instance, the final cost of the ethylene we are producing is about 460 $/ton, whereas in the same plants with the same specifications in the world market it is costing around 370-380 $/ton. This difference is even negligible here since the owners have constant high margins around 600$/ton ethylene. While if we were producing with high competition in the world market, every 1$ was important for us as well.

Q: Is this difference in ethylene production cost per ton coming from energy aspects or there are other parameters in this regard?

A: the feeds are cheaper and also the human resources here are cheaper than the world pool of resources. For example, the engineers in Asaluyeh (South of Iran) have an average income about 30'000'000 IRR (Iranian Rials) that is about 1000 USD.

Q: What about implementation process?

A: there are two issues here. Firstly, it is talking about plans that it should be implemented in a stepwise process which consists of engineering, procurement and training. Secondly, it is targeting the operational phase and the plant is running. At this stage, it is hard to change some basics although the training plans are still high on the agenda. Moreover, we should find out some modifications in order to reach the energy efficiency goal. For instance, we could work on burners in the furnaces to change them steadily and we could work on refractories to steadily change them as well. Also, most of the furnaces are equipped with advanced control systems, which could enable them as an online self-control system, and setting the parameters; however, we have no advance control or they are out of service.

Q: Responsibilities And Performance Assessment (KPIs)

A: There is no managerial implication in the organization for energy consumption and so on. The only important thing for them is to increase the operational capacity (400ton/year) to the designed capacity (1’000’000 ton/year).

Q: How about the owners and the shareholders?

A: they even don’t care to ask why the plant is out of order! And it is mostly because they don’t have enough knowledge on this industry! Also, maybe it should be the role of academia to organize seminars, workshops to spread the energy efficiency concerns across the society and among the ordinary people. By this approach and implementing such action we could reach energy-efficiency targets in the next 20 years while it is far beyond access in the next 300 years if we want to just talk about them without implantation mechanisms.

Q: Who are the main planners to formulate energy efficient strategies? And if there is no one in charge, who should take this responsibility?

A: It should be mapped out in a broader sense and from an overall perspective. These issues along with cost/benefit analysis are required firstly from smaller entities (like building constructions) to the whole industries.

Q: barriers toward implementing energy-efficient technologies?

A: the point is that our options are not too many to choose among. For example it is hard to imagine having different possible scenarios in which we could select the energy-efficient ones. Moreover, most of the plants are being copied regarding sanctions, even though in the world market some efficient processes might be developed. On the other hand, based on my experience if there were some more efficient processes to be followed, the managers basically don't consider the item of energy efficiency issues and they do care the price criterion.

Q: how about the employees' behavior? How much do they respect the energy efficiency issues?

A: Since they are not in charge of making decisions for choosing technologies, practically they don't play any roles in this regard; however, they could effectively play some roles when the debate goes on operational aspects and at this stage training issues should be highlighted then.

[End]

5.3.5 Company F

Interviewee: Site Manager

Interviewer: Ali Samei

Time: 65 minutes

[Greeting]

Question (Q): Could you briefly introduce the main production process at your firm?

Answer (A): We have raw material and some sort of products. When we talk about a chemical reaction, we look at from the beginning to the end and there are no observations in between. In fact it is called the engineering process. However, we have a sort of activities which some of them are energy consumer and some of them energy producer. Each reaction consists of some small processes. Some of these small processes as we said are energy consumer while the rest are energy producer. Nevertheless, the whole process is energy consumer. For example, in the poli-olefins' reactors, the PI- bound would be broken and the SIGMA-bound would be formed: energy is released, and it is consumed for heating the water in the jacket of the reactor. We utilize this heat in other parts of the system.

Q: To clarify a point, you mean that meanwhile you produce energy as well?

A: Yes, though we use it for the process itself.

Q: All in all, the energy balance for your process is negative?

A: Absolutely it is negative. In the Mechanics, we study a term named: GIBBS, GIBBS free energy. Why was free energy of GIBBS important? In the guidance school we had a concept:

Total energy= useful energy + useless energy => useful energy = total energy – useless energy

And useless work = Q which means heat.

We are always seeking for DELTA (G), sometimes DELTA (G) is negative which means the process could keep continue itself, with the presence of Catalyst the heat would be released.

Q: Where do you use this released heat from the water in the jackets of the reactors?

A: For dry or for detaching the remained material. That's why we should be precise, sometimes the reaction is endothermic and sometimes exothermic but overall, it is endothermic.

Do we have the processes that DELTA (GIBBS) < 0? No, they're all consuming energy

Q: By this question I mean, do you auto-production? And with regard to your responses so far, you're producing some amount of required energy by your own process?

A: Yes.

Q: what do you mean by turnover of the company? We are looking for the size of the company (scale) in terms of financial terms.

A: Full capacity:

900 ton/day, assuming: 8000 hours (approximately) or exactly 7992 hours in a year since we are continuous process production. Although, practically we produced around 192,000 ton/annum due to the feed problems (propylene). As a result, with regard to this amount of production, the net profit of the company for last year was: 200 Billion IRR, however, some of the costs have not been accounted so far because they should be reported by the upstream companies.

Type of products:

We are able to produce 4 types of polymers, which they are all polypropylene: Homo-polymer, Random-Copolymer (in the reactor we feed both Propylene + Ethylene 4%), High-pack (when Homo is produced, it is entered in a gas-based reactor with more ethylene that eventually rubber (elastics) will be produced, since polypropylene and polyethylene are plastics but ethylene (50%) and propylene (50%) would produce elastics which is high-pack and is stronger under impact), Trepolymer (ethylene, propylene and Butane-1) which has high transparency and be noted that we don't add much ethylene and Butane-1 to transform it to rubbery shape, in fact 4% ethylene and 4% Butane-1 would create a transparent substance. The letter is utilized in producing films. Our main production is Homo-polymer and this Homo-polymer has a range of grades.

Q: the technologies to be used are different or the same for these four products?

A: yes, the current researches all around the world are based on the fact that how to produce different types of polymers in a same plant and same catalyst. Each type of polymer has grades. Homo-polymers have different grades for pipes, film, and fiber…

Q: grades are based on the functions?

A: yes, since the bond length would bring some unique characteristics. Longer bond length has higher strength and so on. Moreover, another criterion to classify (control) the grades is MFI (Melt Flow Index).

Q: Number of employees?

A: Normally 180 employees are required for this plant with these characteristics and the reason is that in the petrochemical plants the maintenance department is an independent complex to not employ maintenance staff in every plant. Consequently, this maintenance department is in charge of maintenance services for the plants. For instance Navid Zar Shimi, which is a private PP plant, has kept the number of employees on 180 (including central office staffs). However, unfortunately our employees are much higher than 180. To sum up, we have 190 staffs in the plant, 50-60 staffs in the central office in Tehran and 115 staffs outsourced (contract) who are in charge of labor stuffs and such things.

Q: interestingly, we had the same differences in terms of number of employees between private companies and government ones in cement industry.

A: we are officially a private company, however it is semi-private, and semi-government. Before revolution in 1979, oil ministry set some tight standards in which it was hard to enter into this industry but the high-qualified ones with passing adequate training courses were able to join while the status quo is totally different.

Q: Also, this could be refer to the question regarding the training issues in which lack of training and low-qualified and low experienced employees bound the companies to reach the set amount of energy consumption.

A: there are so many staffs that are almost useless for the system while they could not be criticized for the relationships they have! And they never care the energy consumption even at their office. On the contrary, in western companies the energy consumption is even controlled in the offices by exploiting smart lighting systems and so on. I was in South Korea in winter and I saw that there are some families who establish a tent in their apartment and sleeping in sleep bag to reduce energy consumption in their home! And this is due to the pattern, which is followed by the bosses and top managers and the highest hierarchy.

Q: that's a good point which address the question that why some employees care about energy related issues and some others not. Based on your comments on the patterns in higher hierarchy which people mostly set their behaviors with respect to their top managers' behavior and sometime we address these issues by motivation theory in science of management. Some incentives are based on money matters like compensation, profit and so on, and some of them are based on spiritual issues, which are articulated in leadership. From your point of view, what are the significant incentives in Iran?

A: In Iran the employees are not tailored to their main tasks and they are frequently multi-task persons who are not focused on the core task.

Q: why do they do multi tasks? Why do they not focus on their jobs?

A: when in Iran you could find a minister who has 4-5 responsibilities, for sure he/she could not be able to perform his/her main responsibility as good as is expected although his salary is high enough. Therefore, the money is not an issue here. For some cases that has not enough salary, their problems they are facing with is imposing constraints on them to be focused on the job they are assigned for. To shed some light on the other problems, in Iran we have multi-cultural society in which even for wearing clothes we have some considerations when we're planning to go to the northern part of Tehran rather than southern part. Our behaviors are complex. We lie though we want it not to be exposed! Sometimes the system forces us to lie, for instance, when in the recruiting process they ask us some personal religious questions!

Q: what's the effect of these attitudes in energy-consumption? When there are lots of considerations in 20-Year-Vision and recently in resistant economy in Iran and all the managers have formulated some strategies for energy consumption reductions and they are frequently reporting the progress of those actions.

A: they are all lying! Resistant economy is a motto here and the scholars have not coined it. If we succeed everyone says that it was due to the following the resistant economy! And if not, we would say that the type of resistant economy has not been implemented in a way that was expected! Everything needs documentation.

Q: in the other interview we had with another petrochemical plant, they were restating the same problems even for the documented plans. Because we are facing with sanction problems which is imposing so many constraints on our sector pushing us to buy some equipment higher than the real price in the world market *and last but not least nobody cares about energy consumption and energy efficiency issues.*

A: in wall-street crises in US, they firstly accepted they have problems then afterwards they sought out for solutions and the same situation in EU's economic depression. But, in Iran we have problems while insisting on that we don't have any difficulties. We even are not accepting the point that we have problems! I had an experience in my previous job in which the CEO was manipulating the system and hiding the problems when the ISO auditors where planning to come and when I took a chair as a board's represent, the auditors haven't reissued the certificate. Because, the problems have not been hidden anymore. Afterwards, they gave us a time to adopt the system for reissuing the certificate and we gave some budget to improve the system in real terms. Moreover, in that company we had some colleagues who had other occupations and they were handling the other jobs in the official time of the office they were working for. As a result, there was no real progress neither in his current job nor in the occupation he had outside of the office. All in all, there is huge gap between what we say and what we really perform in Iran. We need to change the culture. I know in South Korea in order to rehabilitate their forests after the World War II, its president accompanying their citizens went to grow trees for one week. This means reforms need a holistic approach including the leaders and the whole members. When the economy, the politics and the society have been shaped in an appropriate manner the system goes well accordingly. But in Iran, even when a middle manager would be changed, many other relevant parts would be changed due to the lack of integrity in the system. To count the problems: lying, lack of integrity, lack of proper working culture.

Q: what is strategic view and long term considerations of your company toward energy efficiency? Have you taken energy efficiency into account e.g. in study plan?

A: yes, we are a small plant in a large-scale complex. The way that they have been designed, we have a constant gas as OFF product which consists of 99% propylene. In most of the petrochemical companies they burn this gas as a flare. We don't do so because of the Basell design; however, we were the first plant, which implemented it. What we do is sending back the off gas to the upstream company in order to input to the gas (which consists of more than 95% propylene, Propane, Ethane and other gases) to Olefin while normally it is burnt as flare in other companies.

Q: you mean that practically, you stop wasting 95% of the gas that could be reused.

A: yes, though be noted that this is not our design, but is designed by Basell and the technology we used accordingly. Another thing which could be evaluated in the Assaluyeh zone and unfortunately it's not on the agenda anymore is zero flare. Zero flare is looking for all the gases, which potentially should be flared, to compress them and removing them from the zone that means there would be no flare anymore. This plan would be brought into practice again for upstream companies after removing sanctions; however, Qatar is using this mechanism.

Moreover, there is another argument, which pointed out this waste from different perspective. It is said to burn those gases to produce carbon fibers and Nano-carbon fibers. We are currently, working on two technologies: 1. Stretch films for packing and 2. Pallet-less to not use pallets anymore to save forests.

Q: what is your best practice from your point of view?

A: sending back the off-gas to the starting point of the line in upstream is the best practice in this regard. Which approximately 10-12 tons/day is being saved.

Q: Do you address energy efficiency in your performance reports? For instance, representing that how much energy savings have you had per annum? Do you frequently measure them?

A: mostly yes.

Q: And if it experiences ups and downs, would you look for the reasons?

A: Not exactly, we just measure them.

Q: Back to managerial practices, which sort of motivation mechanism do you take into account for employees? Would it be money motivation mechanisms or not?

A: Yes, there are some rewards; however, none of them are rewarded for energy efficiency efforts.

Q: do you plan to assign them for energy efficiency efforts?

A: we are planning though you should talk with CEO about it.

Q: What are the strengths and weaknesses of the system in terms of energy efficiency and performance measuring?

A: the problem is that we still haven't reached the steady state. For example, based on the letters we received they stated that we have to produce 150'000 ton/annum while we produced 190'000 ton/annum, in another case we had letters stating that we have to produce 210'000 ton/annum whilst we produced 140'000 ton/annum.

Q: what are your strengths?

A: in this chaos status we are producing with profitability.

Q: let's take the off-gas project into consideration, how much efforts have you put in to implement that project and how much changes you had in terms of technological and organizational issues?

A: there were some arguments that were restating that it probably encounter some problems in next few years after implementation; however, there was not so much resistance toward that aim.

Q: why there were a few defensive actions against that project?

A: Firstly because it was designed under authority of Basell and also there were some debates that why the other companies could effectively implement same projects and we still have not brought it into practice. All in all, it was not that much hard to proceed.

Q: which sort of changes you had during the implementation? In terms organizational chart, production line, staffs?

A: no, but it is worth mentioning that since we were sending back the gas into another plant, there was some resistances there. Because they were arguing that this action could bring some fluctuations in our towers. However, it has not come up with big changes in their plant as well.

Q: How have you developed the project?

A: It was simply progressed with just giving an entry point at the beginning of their production line.

Q: what about the new upcoming projects? Is there any resistance over those projects? And, do you think there would change the organization to be carried out?

A: not necessarily. But it is pointed out that we would be an iconic example and a model for other companies.

Q: For that pallet-less project, would it call for a new establishment inside your company?

A: no

Q: I am asking this question to know about potential changes inside the company for initiating such project that eventually charge some extra-costs?

A: this project needs some investments at the beginning (cost) though it would turn to a profitable project. (After approximately 1 year)

Q: What's your vision in setting up new projects? Long term or short term?

A: long term, from 1 to 10 year. Packing line (which is a mechanical line) has a specific efficient time. Imagine that when the packing line started to charge additional cost, it would be better to renew the line.

Q: what is your rate of return in investments? With respect to the interest rates, how much risk do you take in energy saving projects?

A: since a handful of projects have been undertaken so far, no considerations like that were taken in to. Nevertheless, we have calculated these issues for the forthcoming projects.

Q: so for these upcoming projects, do you expect a higher rate of return when you invest in an energy saving project or you expect same results with ordinary projects?

A: no, we don't expect higher rate of return for energy saving projects.

Q: who is in mainly charge of energy matters in your company? Top managers? Board members? Or the whole system?

A: basically, the site manager is in charge and the board members don't influence these stuffs. The idea is initiated by site manger (or let's say top managers) and CEO should issue it.

Q: do the CEO and managers in charge usually accept energy-saving projects with precise calculations and showing long-term benefits?

A: it depends, if it would be a high cost project, they would probably reject it.

Q: what about the investors? Do they have adequate power to intervene?

A: here is not like that

Q: who is in charge of analyzing the idea formed by for example site manager? Do you have some technicians or specific teams?

A: We form the teams in this regard in R&D department. On the other hand, I would say that it is not just assigned in one specific team. For example, sometimes process engineering department and commissioning department take this responsibility as well.

Q: in the end, how do you come up with one master plan?

A: the final plan would be a combination of all reports.

Q: Do you have any special training plan for the employees with regard to energy efficiency and so on?

A: No!

Q: what about the posters, information campaigns?

A: yes, to some extent there are some plans like this

Q: what about the courses for top managers? Like MBA for energy management and …?

A: I don't know exactly.

Q: have the posters and information campaigns been effective?

A: From my point of view, no.

Q: what was the problem?

A: as I said we are a small plant in a big complex. We are binding with the restrictions imposed from the whole system.

Q: what about the barriers when a new technology is coming to play that potentially could save the energy? Especially in current situation when reforming *the subsidies is in progress and the final price is more or less fixed, meanwhile the energy costs increased. On the other hand, due to the sanctions, you have lack of financial resources and you don't have a good access to the novel technologies. Moreover, government didn't pay enough attention to the production plants in process of subsidies reform. In this situation what are the barriers in moving toward energy-efficiency in petrochemical plants?*

A: most of them have plans and they mostly know everything about the new technologies. They are lots of producers and the market is competitive.

Q: so practically lack of information is not an issue.

A: again sanctions come into play in Iran's industry context.

Q: how these barriers could be removed? Apart from rounding sanctions!

A: if the company had access to the world market, they would spontaneously come toward ours.

Q: how about now that there's no free access to the world market?

A: now we couldn't exploit this opportunity, and we have to turn to China with extra-costs.

Q: Does your system have enough capacity to completely change the technology?

A: No

Q: how about renovating it?

A: I don't think so

Q: why?

A: when we argue that EU countries reach this level, it's because they have worked around 40 years with different software that eventually been succeeded. For example there is a simple car named Renault L90, why we could not copy it and produce it? Because it needs lots of calculations. You cannot say that we have a 50’000 ton plant and we desire a 200’000 ton plant and in turn to quadruple everything.

Q: you practically need some expertise as well, don’t you?

A: to what extent these expertise exist in our country? These expertise don’t exist. And again we will turn to this fact that whether they would provide the technologies or not…

Q: imagine that all technologies are available; do you and your counterparts have adequate financial resources to achieve them?

A: yes, financial resources are not issue here in Iran

Q: what about your company?

A: it depends on the manager’s policy. For instance you study in Italy, how long do the CEO of Fiat, Alfa Romeo and their oil industries exist?

Q: Fiat has somehow a family structure and they usually take position around 10-15 years.

A: if here also a CEO had the possibility to stay in a company for 10-15 years, he/she could create a long-term vision. But a CEO who has around 1, 2 or 3 years couldn’t be able to develop a long-term plan. Please read the book written by Jack Welch, he was CEO of General Electrics for around 30 years and for sure he had the opportunity to execute his plans.

Q: role of governments, I read the instructions written by Standard Institute in Iran for some industries like oil, gas, petrochemical, and cement and so on in terms of energy consumption. The instructions are applicable for those industries with more than 5 GWH consumption. What was the role of these standards? Have you ever considered them or not?

A: I haven’t seen them

Q: how about incentives? Are there any governmental incentives for energy efficiency?

A: as I said these are normally brought up in high hierarchies and top managers' positions. I am in charge of the contracts and I haven't seen this before.

Q: what about governments' loans for technologies?

A: they're mostly allocated to small technologies.

Q: if you want to propose something to the government to stimulate the process, what will you propose?

A: all I have said so far!

Q: in terms of strategies, because when I took a look on Standard reports, they were articulating that information campaigns were effectively influenced our energy consumptions. And with respect to the existing facts and high-energy consumption we could say they are not that much accurate. Therefore, what would you propose? This is an important question since it would be compared with the practices in EU countries.

A: if you want to supply electricity in Italy how many providers do they have? Four companies within a competitive environment in terms of services and so on. You could supply the electricity among them and you will consider which component is less and which company would assist you sooner in case of difficulties and which one offer you lower price. In this competitive environment, when a company finds out that there is a new technology, they will step up their efforts to develop it with lower price or they will establish R&D to develop it by their own knowledge and resources to cut the costs. This is not defined in Iran's industrial context. You won't see that somebody in Europe has established a fuel station by himself. But you will see that in top of the station some brands have stuck like Eni, Shell, and Total and so on with different prices. And those with higher prices are offering more services like car wash, shorter queues, and promotions and so on. Do we have this in our Country? Competition is a vital factor for development. For example in automotive industries we have Iran-Khodro and Saipa and they set the prices in a mutual consent to sell more. However, in EU companies compete with each other even to force their competitors cease to exist.

Q: what's the impact of competition in energy matters?

A: when you save energy you would cut the costs and it would call for competition.

[End]

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