The role of energy efficiency in the development of the Iranian energy system – energy scenario analysis

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Abstract

Iran is one of the largest oil producers and natural gas owners globally. However, it has to struggle with domestic energy shortages, economic losses through energy subsidisation and inefficient energy infrastructures. Furthermore, GHG and other energy related emissions are rapidly increasing and posing a growing threat to local environment as well as global climate. With current trends prevailing, Iran may even become a net energy importer over the next decades. Resource allocation is therefore a crucial challenge for Iran: domestic consumption stands versus exports of energy.

The energy transformation sector clarifies Iran's dilemma: soaring electricity demand leads to blackouts, and power plant new builds are far from using most efficient technologies (e.g. CHP), therefore keeping energy intensive structures. But fossil fuels could be sold on international markets if spared by having more efficient energy infrastructures.

As shown by the high energy intensity of its economy, Iran has large potentials for energy saving and efficiency. In order to highlight and better identify this potential the paper contrasts a high efficiency scenario in all sectors of energy transformation and consumption with a possible "business as usual" development.

Using a bottom-up approach, the analysis provides a sector-by-sector perspective on energy saving potentials. These can be utilised on the demand side especially in the transport sector (fuels) and in households (electricity for appliances, natural gas for heating). Electricity generation bears efficiency potentials as well.

We conclude that Iran, but also the international community, would benefit on various levels from a more energy-efficient Iranian economy: Energy exports could increase, generating more foreign currency and reducing the pressures on international oil and gas prices; energy consumption would decrease, leading to lower needs for nuclear energy and for subsidies to Iranian people, as well as to a reduction of the high external costs entailed by fossil fuels combustion (smog in cities, environmental stress)

Introduction

Over the last years a joint team of German and Iranian scientists conducted various research projects on the Iranian energy system. Energy scenarios were one of the major research challenges (cf. Moshiri et al. 2009). In this paper the core results on the relevance of energy efficiency for the introduction of a more sustainable development of the Iranian energy system are given. In this context Iran has to be seen as a developing country and as an energy exporter, therefore the results give hints on the situation in other countries facing similar challenges.

The chosen scenario type is bottom-up modelling: concrete technologies and appliances (e.g. freezers, air conditioners, building insulation) are analysed regarding firstly their future relevance in energy consumption (e.g. more computers per person) and secondly their energy efficiency potentials. Separate industrial branches (e.g. cement production, textile industry) are evaluated regarding their future role in the Iranian economy and their energy efficiency potentials as well.

METHODOLOGY OF THE SCENARIO ANALYSIS

Our analysis consists of two scenarios. The Business as usual (BAU) scenario assumes continuing policies and measures. Its purpose is to explore the future trends of the Iranian energy system under the assumption that no major changes will occur in the next decades.

The analysis of the potentials for energy efficiency uses a technology-oriented, sectoral, bottom-up energy model and it applies an expert-based simulation approach in order to explore potentials and to estimate market penetration rates of new technologies, market shares of fuels etc. Gross domestic product (GDP) and population are taken as exogenous variables to the energy system. They have been derived from the 20-Year-Vision of Iran and are mainly in line with the projections used by IEA (2004). The 20-Year-Vision lists economic and social development objectives of the Iranian government. The model further does not account for eventual feedbacks from energy policies to those socio economic drivers. Due to the expert based approach, all decisions e.g. on the future implementation of savings potentials, on market shares and on the development of new power plants are made by judgement. Existing potentials for energy efficiency, available technologies and their costs as well as the expected oil price development are taken into account but not used in the form of a mathematical optimisation.

The energy demand side is modelled with a large detail using appliance or end-use specific sub-models for every demand sector (households, tertiary, industry, transport) and a purpose-oriented model of the transformation sector. CO_2 emissions in the energy sector are calculated based on the final and the primary energy balance.

For the High Efficiency scenario achievable potentials for energy efficiency have been estimated, which should be also typically cost effective at world market prices for fuels, respectively full cost prices for electricity. However, due to a lack of detailed data in the sectors apart from residential and transport sectors we had to make rough estimates, based on the information and examples available (see below).

In the scenario analysis no explicit ranking and selection of GHG mitigation potentials and strategies by cost criteria have been made, due to the problematic nature regarding the different cost and benefit functions of actors in different countries and sectors and under different perspectives (e.g. microeconomic: company level; macro-economic: state level).

THE IRANIAN ENERGY SYSTEM: INTRODUCTION

Iran is of global relevance, as it is the second largest oil exporter of the OPEC, and it holds the second largest natural gas reserves in the world (following Russia). The development of the Iranian (domestic) energy system will have consequences on international energy markets. One example clarifies this link: Iran currently consumes about 40 percent of its oil production domestically. If historic trends persist, Iran may even become an oil importer over the next decades.

Iran is confronted with a multitude of domestic challenges such as low productivity, high unemployment rate, high budget deficit, and high inflation rate. Iran's energy intensity is one of the highest in the world, energy consumption is increasing drastically, and energy subsidies are further fuelling this trend.

The main focus of the Iranian government in energy terms is on fossil and nuclear fuels. Natural gas production can be increased further, and nuclear energy is perceived as an inevitable supply option (which caused the nuclear conflict between Iran and many Western countries on the build-up of nuclear electricity generation capacity). Renewable energies and energy efficiency are matters of discussion on decision makers' level, but not yet significant practical consequences have been drawn (CEERS et al. 2006). However, recently a feed-in law for wind energy has been introduced, guaranteeing 12.65 US cents per kWh supplied to the grid (Iranwindenergy 2009). For Iran the substitution of fossil fuels in domestic consumption is an important question as these could be exported to generate revenues.

One of the most important reasons why the Iranian energy system is very inefficient is the fact that oil, gas, and electricity prices are heavily subsidized and extremely low compared to international standard and the world market price of crude oil. The amount of subsidies in the energy sector, which has been estimated at 10 percent of GDP[1], has led to government budget imbalances as well as increasing demand for gasoline, electricity, and natural gas in different sectors. For example, gasoline prices are in the range of 10 US cents/liter, electricity prices are about 2 US cents/kWh) (TAVANIR, var. years) and as a result about one third of total fuel consumed in the transportation sector currently has to be imported. As long as the domestic price level is so low, there is no incentive to invest in technologies that are more efficient and there is only little incentive to change energy wasting behaviour at different levels of the economy.

The energy market in Iran is fully controlled by the state. This means that the government mostly undertakes investment, production and even distribution in the energy sector. The government also sets the production quantities (domestic, exports, and imports) and prices for different energy products. Therefore, there is no competition in production and distribution and political factors, rather than economic and market conditions, affect the energy prices. This may well be one additional reason why energy efficiency is on a low level and why there is no incentive to invest in renewable energy resources. Although the fourth Five Year Development Plan (2004-2009) outlined a price reform in energy, the new parliament and government did not implement it. Indeed, the abolishment of subsidies is a matter of controversial discussion in Iran and a source of civil unrest (Mouawad 2007). One argument pro subsidies is that cheap energy would enable the economy to grow faster and that on the contrary high energy prices would curb growth. The negative effects of subsidies in Iran however are: soaring energy consumption, very high societal burden in terms of negative health effects (due to smog in large cities), very high burden on the government to pay fuel imports (about one third of total fuel consumed in the transportation sector has to be imported), to name but a few. According to the International Energy Agency Iran generated between 50 and 60 bn. US$ of subsidies in 2007 (IEA 2008). These negative effects were acknowledged by the majority of the Iranian

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Table 1. Indicators of the energy system in Iran (History and Scenario)

	History				Scenario				
	1991	1995	2000	2004	2010	2015	2020	2025	2030
Population (in 1'000'000)	55.8	59.2	63.7	67.0	75.2	80.6	86.4	90.3	94.5
GDP									
in 10^{12} Rial (constant 1997)	245.0	267.5	320.1	399.8	548.5	648.3	766.3	888.4	1'029.9
in 10^9 US$ (const. 2004, ppp)	314.9	343.8	411.3	513.7	704.8	833.1	984.7	1'141.5	1'323.3
Sectoral shares									
Commercial sector	29%	28%	30%	31%	32%	33%	33%	33%	33%
Public sector	13%	14%	14%	15%	14%	13%	12%	11%	10%
Agriculture	14%	15%	14%	14%	14%	13%	12%	12%	11%
Industry (1991 - 2004; est.	22%	20%	20%	19%	19%	20%	21%	22%	23%
Other (1991 - 2004; est.)	22%	22%	22%	22%	21%	21%	22%	22%	23%
Primary Energy Demand (Mboe)	572	745	890	1'046*)	1'236	1'462	1'626	1'796	1'979
Energy intensity (boe/10^6 Rial)	*2.3*	*2.8*	*2.8*	*2.6*	*2.3*	*2.3*	*2.1*	*2.0*	*1.9*
Final Energy Demand (Mboe)	400	518	620	725*)	969	1'113	1'262	1'399	1'549
Energy intensity (boe/10^6 Rial)	*1.6*	*1.9*	*1.9*	*1.8*	*1.8*	*1.7*	*1.6*	*1.6*	*1.5*
Electricity generation (TWh)	64.1	85.0	121.4	152.6*)	220.3	252.3	282.3	312.7	346.4
per capita (kWh)	*1'148*	*1'437*	*1'907*	*2'277*	*2'930*	*3'131*	*3'268*	*3'462*	*3'666*
CO_2 emissions (Mt)				*381**)*	*461*	*527*	*584*	*638*	*698*
per capita (t/cap)				*5.4**)*	*6.1*	*6.5*	*6.8*	*7.1*	*7.4*

**) Values for 2003 (All data are given fort he Iranian year which lasts from 20th March to 19th March of the following year). **) Values for 2005*

Sources: Energy balance of Iran (2006), WEO 2004, Moshiri et al. (2009), The Vision, IELDB

government, hence the need to radically change the subsidy scheme is becoming more and more common sense. However, a proposal by the ministry of oil to abolish subsidies within the coming three years (2009–2011) was rejected by the Majlis (Farhi 2009). In the sight of ever increasing burdens by direct costs of subsidies it seems likely that in the coming years the subsidy regime will be changed.

Rapidly increasing energy consumption blurs the fact that various attempts have been made to slow consumption growth. In the transportation sector the so-called Note 323 deals with approaches to control fuel consumption. Compulsory scrapping of cars older than 30 years was one such measure (which is relevant in Iran, as the average age of cars is in the range of 30 years). In the industry sector the government introduced an oil saving programme to benefit companies that were willing to reduce consumption (for a compilation of measures cf. Supersberger 2007). However, these programmes showed only limited results due to their low financial basis.

The Iranian Energy system in the past and the BAU scenario

Population, GDP and energy use have been risen at an increasing pace since the end of the war with Iraq. Due to the influence of the oil income and a rapid expansion of the service sector, industrial share in GDP is quite low and has been slightly decreasing over the last one and a half decades. Furthermore energy demand grew faster than GDP, leading to an increase of primary energy intensity of the Iranian economy between 1991 and 2004. Table 1 summarizes the economic and energy indicators trends.

The BAU scenario draws on the exiting projections and plans, e.g. the 4th five year plan and the 20-year vision calling for rapid socio-economic development of the country. It has been assumed that the past trends will be roughly maintained for the next two decades. Population growth will continue at high rates and population is expected to reach almost 95 million by 2030 due to Iranian projections. GDP will grow faster and deliver an increasing per capita income, while the sectors shares are expected to change due to structural change an active policy to strengthen industrial production levels and to reduce the share of the public sector in the economy.

The increasing trend in the energy intensity will stop and slightly decrease after 2010 because of the structural changes and technological improvement. However the energy intensity will still remain significantly above world average figures[2]. Figure 1 compares the energy intensity of Iran with that of the world.

The high energy intensity will lead the energy demand in the BAU scenario to almost double over the scenario period, which implies that under the current regime an increasing level of energy subsidies as well as a high investment level for the expansion of the power system will be required. Under the BAU scenario, the energy related CO_2 emissions will increase

2. The BAU scenario developed here is generally in line with the WEO 2004 results for Iran.

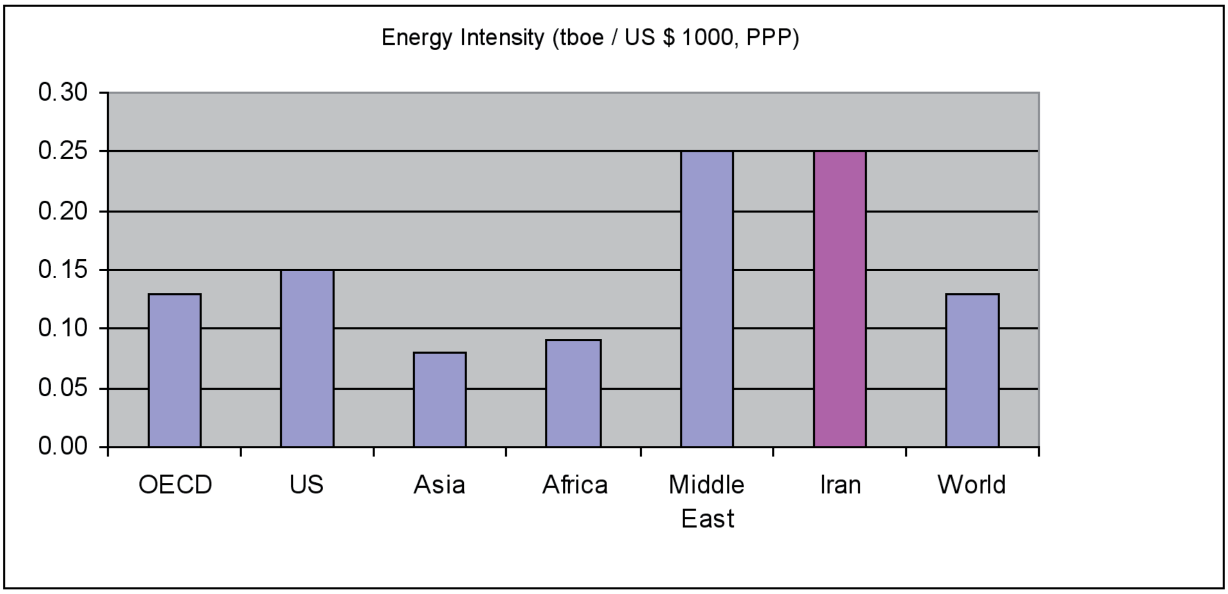

Figure 1. Energy Intensity, Iran and the world Source: IEA, International Energy Agency, Energy Balances for OECD and Non OECD Countries, 2002, 03 and 2005 Edition.

by more than 80% and per capita GHG emissions will increase by 2 t.per.capita to 7.4 t by 2030.

Furthermore soaring demand will affect the amounts of oil and natural gas Iran will be able to export under BAU conditions. E.g. Supersberger (2007) deems it possible that Iran might become a net crude oil importer over the coming thirty years due to future demand outpacing production increases.

Scenario High Efficiency

The purpose of the high efficiency scenario is to explore the potentials of energy efficiency for the pursuing of a modified and more sustainable energy pathway for Iran.

One key driver in this scenario is a basic change in the energy subsidy regime. By energy prices reflecting real costs (i.e. significantly higher prices than currently), energy demand is assumed to slow down, deviating from the pattern of strong growth in Business as Usual. The background of this dynamics is that higher energy prices create consciousness for energy consumption and that energy efficient appliances becomes economically more attractive.

Other key assumptions are:

- The domestic price for gas and oil is continuously approaching the world-market price for crude oil[3]. The electricity price will rise and reflect the true cost of electricity production and distribution. These changes have to be combined with higher income from work and pensions, so that people do not have to suffer under higher prices. It is assumed that a rise in relative energy prices will enable to change people's behaviour in energy consumption and their investments into efficient appliances, buildings, cars, and power plants. On the other hand, the possibility exists that, in case of higher income, they would not suffer from higher energy prices and therefore would not change their energy use behaviour: these rebound effects are a field for further useful research.
- Energy price increases, together with subsidies abolition, will make energy-efficiency investments more attractive, with higher investment flows (energy savings) compensating for the (often) high up-front costs of these investments. Making an investment decision, for domestic appliances or industrial devices, from the energy efficiency viewpoint, certainly relies on good information, a sound economic calculation and adequate financing.
- To gain efficiency, government will change its past policy of complete provision and allow for private sector involvement in the energy sector. In turn, it will regulate the market to protect consumers from exercising market power by monopolies. Efficient regulation would imply that consumer energy prices reflect the cost of energy supply, i.e. the long-term marginal cost for electricity and the long-term price of oil products on international markets for fossil fuels. We think that the reduction of subsidies in not unlikely: having followed the discussion in Iran for the last several years, we know that the discussion is very "lively" and that the government really recognises subsidies as a severe problem. Additionally we don't think that the move towards more privatisation is unlikely either; there have been steps in this direction.

Additionally to price and market reform, there are other conditions to remove the usual barriers to energy efficiency as follows:

- The availability of efficient appliances and energy intensive consumer products
- The availability of good information to consumers about such equipment and devices
- Energy efficiency public awareness programs through which the final consumers will be well informed about the

3. As a reference we take the crude oil price assumed by WEO (2008).

Table 2. Electricity consumption of appliances in the residential sector in BAU and High Efficiency (EFF) scenario, 2005-2030, million kWh.

		BAU Scenario		High Efficiency Scenario	
	2005	2020	2030	2020	2030
Lighting	19,583	22,344	24,000	14,575	9,828
Refrigerator	9,699	11,210	11,725	5,979	3,588
Freezer	3,054	5,375	6,872	3,684	2,375
Mincer	141	164	168	164	168
Soft cooker	504	840	1082	840	1082
Microwave	260	904	1,496	904	1,496
Tee/coffee Maker	24	311	574	311	574
Vacuum-Cleaner	979	1,507	1,865	1,507	1,865
Washing machine	1,129	1,962	2,513	1,962	2,513
Iron	2.586	4,333	5,627	4,333	2,813
Cooler (water system)	1,825	1,915	1,856	1,915	1,856
Cooler (gas system)	2,793	6,213	8,633	6,213	6,043
TV	3,830	6,877	9,469	6,877	7,058
Computer	220	1,135	2,129	1,128	2,106
Total (Mio. kWh)	**46,626**	**65,088**	**78,008**	**50,391**	**43,366**
Total (MBOE)	29	41	49	32	27

Source: own calculations, TAVANIR, Moshiri et al. (2009)

individual and national benefits of energy efficiency and climate protection

- The availability of technical, commercial and financial services

ASSUMPTIONS FOR ENERGY EFFICIENCY IN THE RESIDENTIAL SECTOR

The most important electricity consumers in households are lighting (with about one third of total electricity demand), refrigerators and freezers (26 percent), and air conditioning (about 10 percent). TV and computer's share of electricity use is 8 percent but will double in 2030 according to the BAU scenario.

To give insight into the modelling procedure and into specific data sets, refrigerators and freezers as well as air conditioners will be described in detail. It was assumed that in the year 2020 the average consumption of an Iranian refrigerator will be 20 percent higher than the consumption of an average refrigerator bought in Central Europe today. For the year 2030, the average consumption could be 20 percent higher than that of the highly efficient refrigerators which are sold in Europe today. The same relation was assumed for freezers and combined appliances (refrigerator and freezer in one appliance). The overall electricity consumption by refrigerators and freezers in the residential sector in 2030 will be 67 percent less in the High Efficiency scenario compared to the BAU scenario.

For air conditioners it was assumed that no significant changes in current water-cooler systems will occur, but there will be an efficiency improvement in new air conditioning technologies. Taking into account comfort demands and the efficiency improvements, the electricity consumption for the cooling system in the residential sector will be reduced by 30 percent in 2030 under the High Efficiency scenario compared to BAU (Figure 1).

There is a wide range of measures that can start such modernisation processes and keep them running over longer time periods. Among these measures are:

- Minimum standards for appliances
- Market oriented electricity prices
- Consumer information about electricity consumption of appliances and about efficient products
- Efficiency labelling
- Special marketing measures for highly efficient appliances
- Building standards for efficient cooling system

For heating demand, the following assumptions were made:

- Refurbishment rate of 2 percent for existing buildings. This means that during a period of 50 years, all buildings are refurbished to a better standard[4] The energy saving per building was assumed to be 50 percent on average, a value that has already been shown to be feasible in several case studies for Iran.[5] The technical potential to make a building more efficient is about 90 percent. These are the results of many projects and studies in Germany.
- A new standard that is about 80 percent better than the average consumption of today's buildings for new buildings from 2010 onwards
- By the year 2030, 10 percent of the houses will be broken down and replaced by new and more efficient buildings. The average size of living-area per person will increase by 10 percent by 2030 in Iran.
- The population will grow by 34% until 2030.
- For the supply of heated water, a higher efficiency through better boilers and better insulation of storage and taps was assumed.

4. This assumption is quiet ambitious, but it could be reached, if the suggested policy measures are taken to foster the refurbishment of the buildings.

5. Energy Conservation in Selected Buildings audited by the Ministry of Power, Department of Planning, 2004

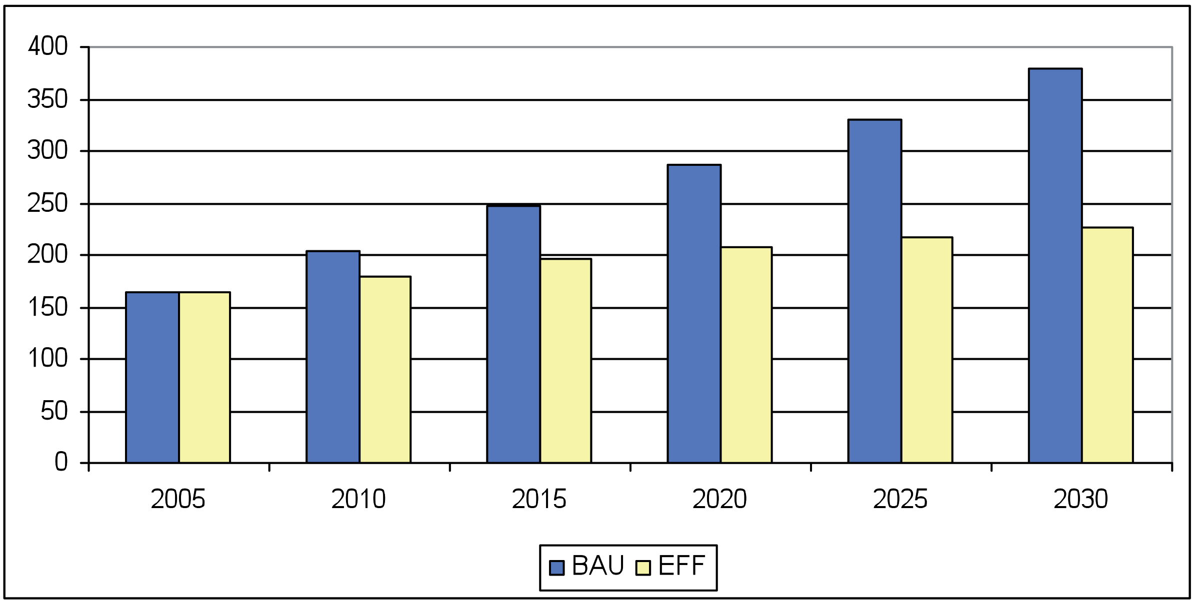

Figure 2. Industrial final energy demand under the BAU and High Efficiency (EFF) scenarios (2005-2030), MBOE.

The total energy savings in heating demand in the household sector in the efficiency scenario compared with the BAU scenario will be 11 percent in 2030.

Necessary instruments for achieving these results from the perspective of the Iranian government are:

- Implementation of standards for new buildings and for building-refurbishment
- Financial help for home-owners to bear the investment
- Education for builders and architects
- Control systems for monitoring the building standard

ASSUMPTIONS FOR EFFICIENCY IN THE INDUSTRY SECTOR

The Iranian industry in Iran grew by more than 10 percent per year over the last 15 years. In spite of decreases of energy intensity of about 7 percent per year between 1990 and 2005, the energy intensity of many industrial installations is still significantly (30 percent) above world average (IFCO 2007). This is mainly due to the low energy prices, lack of capital for investment in new and/or more efficient machinery and - last but not least - poor management of the majority of industrial plants (TAVANIR, var. years).

In the High Efficiency scenario, a further cut of energy intensity by more than half was assumed to be achieved by 2030, which is equivalent to an annual rate of decline of 3.1 percent. The following assumptions comprise the modelling frame for the industry sector:

- Real monetary growth and physical production will be decoupled (by a rate of 1 percent per year) in the future, as it is typical in most "more advanced economies". Existing plants will increase their production levels (by better employed capacity and by refurbishment of existing plants) by about 1 percent per year.
- For the technical standard of refurbished and new plants current best available technology (BAT) will be applied due to its economic advantages and possibly also due to increased standards of regulation as well as potential subsidies for energy efficient technology. This standard will further improve in the future by around 1 percent per year. For sectors not covered by the analyses of SABA (The Iranian Renewable Energy Organization), an average savings factor of 50 percent by using BAT vs. currently installed technology has been assumed based on detailed study results from Ecofys (2006).
- Existing plants will be almost completely (83 percent) reinvested by 2030, which also enables most existing plants to produce with BAT by 2030.

Feeding these ambitious but nevertheless feasible assumptions into the scenario calculations, strong energy reduction dynamics develop compared to BAU: in 2030 a consumption path like High Efficiency would lead to energy savings of about 40 percent in the industrial sector (Figure 2).

Energy savings in the industry sector can be achieved by introducing the following measures, which are not specific measures for Iran, but represent the general options (ECOFYS 2006):

- Introduction of efficient motor system to reduce electricity consumption of electric motor systems (which account for 65 percent of the electricity consumption use by industry)
- Improved monitoring and process control, which can lead to more efficient use of energy in industry
- Process optimization and integration (pinch analysis). The potential saving by process optimization and integration is 10 to 25 percent. Possibly efficiency potentials are even larger. Recycling, especially in the aluminium and steel production, bears large saving potential

ASSUMPTIONS FOR EFFICIENCY IN THE TRANSPORT SECTOR

The basic assumption in the transport sector is that the price for gasoline and gas oil will gradually be increased to the level of world market or border price for gasoline (which is still sig-

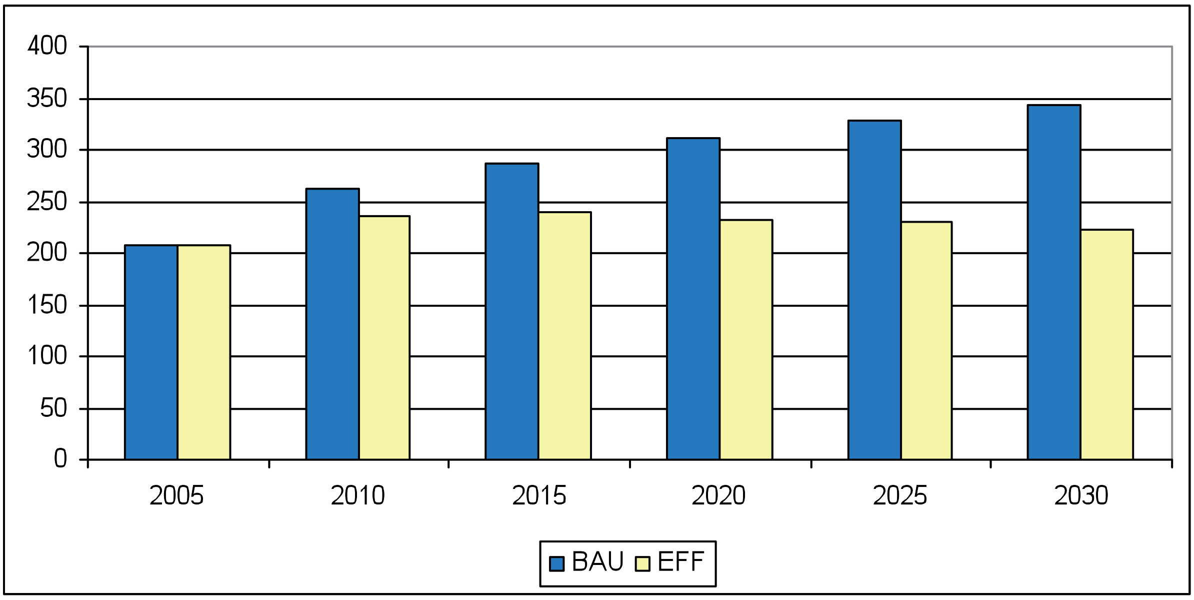

Figure 3. Final energy demand of the transport sector under the BAU and High Efficiency (EFF) scenarios (2005-2030), MBOE.

nificantly less than in most OECD countries, most of which have high taxation levels of transport fuels.). In the High Efficiency scenario, the number of private vehicles will be lower and the average yearly travel distance will be shorter compared to the BAU scenario. Also, there would be a higher share of public transport, because of the higher costs of private cars. The number of private cars that enter the Iranian transport system annually in High Efficiency will almost double from 244,800 in 2005 to 433,800 in 2030 (instead of 602,400 in BAU scenario). The average travel distance per private car will decrease from 24,000 km/year to 17,600 km/year (a twenty percent decrease compared to BAU). This is still about 60 percent more than e.g. in Germany today.

Passenger cars can be more fuel efficient if they have better engines, reduced weights, friction, and drag. Hybrid cars, which combine a conventional engine with an electric engine, are now consuming about 4.3 liter gasoline equivalents per 100 km. The average specific energy consumption for Iranian private cars in the BAU scenario will decrease from currently 15 to 10.1 litres/100 km by 2030 (IFCO 2004). In the High Efficiency scenario the average consumption of private cars in 2020 will be the same as the average consumption of all private cars in Germany in the year 2006, which was 7.8 litres/100 km. For the year 2030 the average fleet consumption in Iran will be 6 litres/100 km. The efficiency of busses and trains rises by 20 percent, the efficiency of aviation rises by 45 percent through newer and bigger planes. Figure 3 shows the total energy consumption by the transport sector under the BAU and the High Efficiency scenarios from 2005-2030. Significant energy savings of about 30 percent are possible in this sector.

Policy instruments that could foster such an energy efficient consumption path are the following:

- Stepwise increase of gasoline price to world-market level
- More investment in bus and train-system
- Consumer awareness
- Labelling for cars and trucks
- Introduction of car fleet efficiency-standards for car importers
- Education courses for efficient driving
- An improvement in road conditions
- Efficiency Improvement in domestic refineries

Some of these instruments and approaches are already in the discussion phase among Iranian decision makers. However, without the reduction of fuel subsidies the possible impact of measures will remain limited.

ASSUMPTIONS FOR EFFICIENCY IN OTHER SECTORS

Other sectors include commercial, public and agricultural sector. Public buildings and in particular hospitals have extremely high energy consumption in Iran. Nevertheless, high cost effective saving potentials from 30 percent to 50 percent have been proven even with current low energy prices. For existing buildings in the public sector, an average savings potential of 35 percent over the next 25 years has been assumed to be feasible by a systematic upgrading of existing buildings. While savings of 35 percent and more seem to be easily achievable from a technical point of view, according to the currently very high consumption levels, the crucial factor will be the possible speed of refurbishment. For new buildings, savings potentials of up to 80 percent compared to the current average are feasible. The average energy intensity of the sector will be 45 percent below BAU levels by 2030. Figure 2.5 shows the energy consumption of the public sector under the BAU and the High Efficiency scenario.

In order to achieve the efficiency targets above, government should take the following measures:

- Implementing standards for new buildings and for building-renovations

Table 3. Energy savings in selected public buildings

Project	Energy Use Before the Plan		Energy Use After the Plan		Savings
	GJ	MJ/m²	GJ	MJ/m²	(%)
Hospital(600 bed)-Tehran	169'999	4'404	111'171	2'880	35
Hospital(400 bed)-Tehran	109'216	3'248	68'530	2'038	37
Public Building (13 Storey)-Tehran	22'041	2'388	11'057	1'198	50
Public Building –Fars	12'678	1'822	8'319	1'195	34
Public Building – East Azerbayejan	13'369	1'774	7'552	1'002	44
Public Building –Khorasan	10'843	1'807	6'220	1'037	43
Educational Building	75'594	2'645	54'426	1'904	28
Total	413'740		267'276		35

Source: Energy Statistics in Iran and the World, Ministry of Power, Department of Planning, 2004

- Regulating energy use in public buildings such as monitoring use of lamps during the out of office and holiday hours
- Implementing article 44 of the constitution with increasing role of private sector in the economy[6]
- Control system for monitoring the building standard

In commercial buildings, the situation is comparable to public buildings. However, due to a more dynamic development, higher refurbishment rates and rates of new buildings are achieved in this sector. This leads to the optimistic assumption of overall savings of about 55 percent vs. BAU by 2030.

In the agricultural sector the achievable savings are probably lower. The main reason is the distributed use of energy, low exchange rates of stock and often limited availability of capital and knowledge about technology due to remote location and the socioeconomic situation. Savings are assumed to be 40 percent vs. BAU for electricity and 30 percent vs. BAU for fuels. The results are shown in Figure 4.

TOTAL ENERGY SAVINGS IN THE HIGH EFFICIENCY SCENARIO

The total final demand for energy under the High Efficiency scenario will grow on average by 0.4 percent per year reaching from 970 MBOE in 2005 to 1,084 MBOE in 2030. This means that the energy demand growth will slow down on average by 2.2 percent per year compared to the BAU scenario. Figure 4 shows the total final energy demand under the high-efficiency and the BAU scenarios.

In general, the High Efficiency scenario will lead to more than 40 percent energy saving by the year 2030. The major share of the savings will be in the household fuel consumption with more than 50 percent. The relative savings will be between 30 to 40 percent in industry, transport, public, and commercial sectors. It should be noted that even though the saving rates in the commercial and public sectors are higher than those in industry and transport sectors, the absolute amount of energy saved in the latter are much higher due to the their higher level of energy consumption.

The total energy demand by energy carrier in BAU and High Efficiency scenarios in 2030 are displayed in Figure 5. Demand for all energy carriers decline in the High Efficiency scenario relative to BAU. The most significant decline will be in natural gas consumption which will decrease by almost 50 percent. Gasoline will also decrease remarkably by about 42 percent. The consumption of electricity will decrease by 35 percent, and gas oil, fuel oil and LPG by about one third.

A Comparison among Scenarios

The following table gives an overview of the overall energy balance of the High Efficiency scenario including its CO_2 emissions and compares it with the BAU scenario. Additionally, results from another scenario which combines an ambitious strategy for the use of renewable energies with the high efficiency scenario as also given.

The overall energy balance shows that by exploiting the described techno-economic potentials for increased energy efficiency in all sectors of the Iranian economy has the potential to:

- Stabilise final energy demand at a level about 9% below current (2010) levels.
- Reduce electricity demand by about 17% by 2030 and thus reduce investment needs into power plant capacity to refurbishments of existing plants and investment into the grid to expansion to regions so far without access to it.
- Push domestic oil demand back below current levels while limiting growth of natural gas use to about 6% vs. 2010 and thus maintaining the ability to export significant amounts of both fuels.
- Reduce per capita CO_2 emissions by 1.8 t by 2030 instead of increasing them by 2 t.

Energy efficiency compared to the effects of renewable energy expansion

If the High Efficiency strategy is combined with an ambitious expansion strategy for the use of renewable energies energy savings are expected to be even higher than savings in the High Efficiency scenario alone. This is due to the direct use of renewable energy such as solar hot water systems in the final use and to the higher efficiency of solar and wind electricity generation as compared to fossil power plants. The potential for the use of renewable energies in Iran lies mainly in the electricity sec-

6. According to the Article 44 of the Iranian Constitution, the economy of Iran consists of three sectors: state, cooperative, and private; and is to be based on systematic and sound planning. Article 44 has been amended in 2004 to allow for privatization of the Iranian economy. The privatization effort is primarily backed by the expectation that it will lead to a higher economic efficiency and social change.

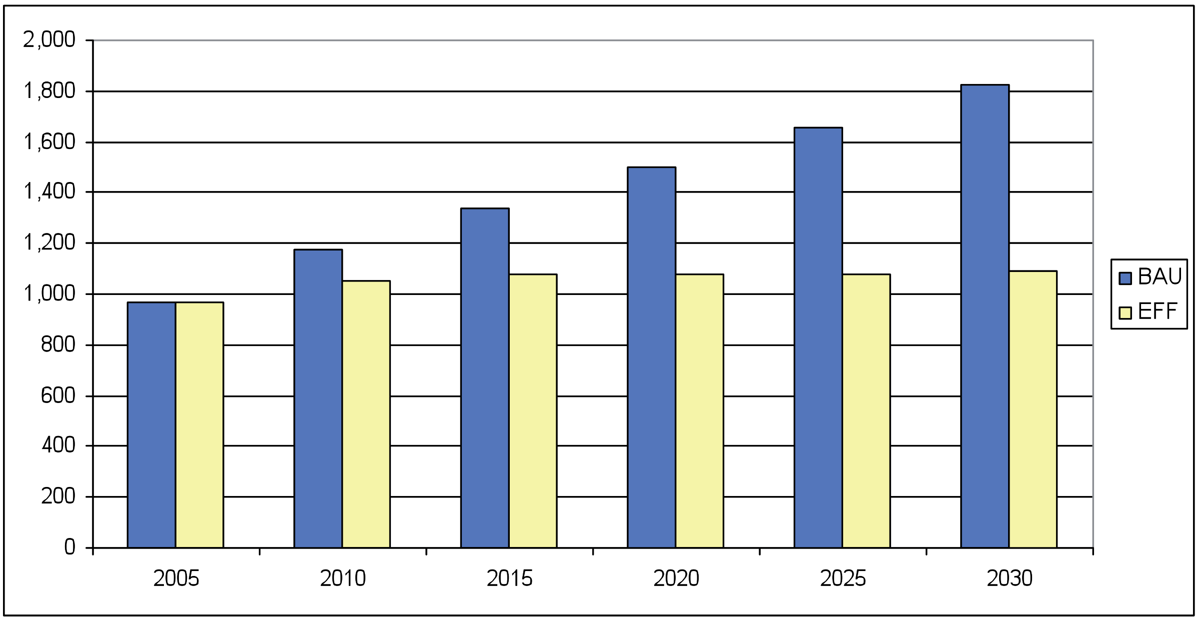

Figure 4. Total final energy demand in BAU and High Efficiency (EFF) scenarios (2005-2030), MBOE.

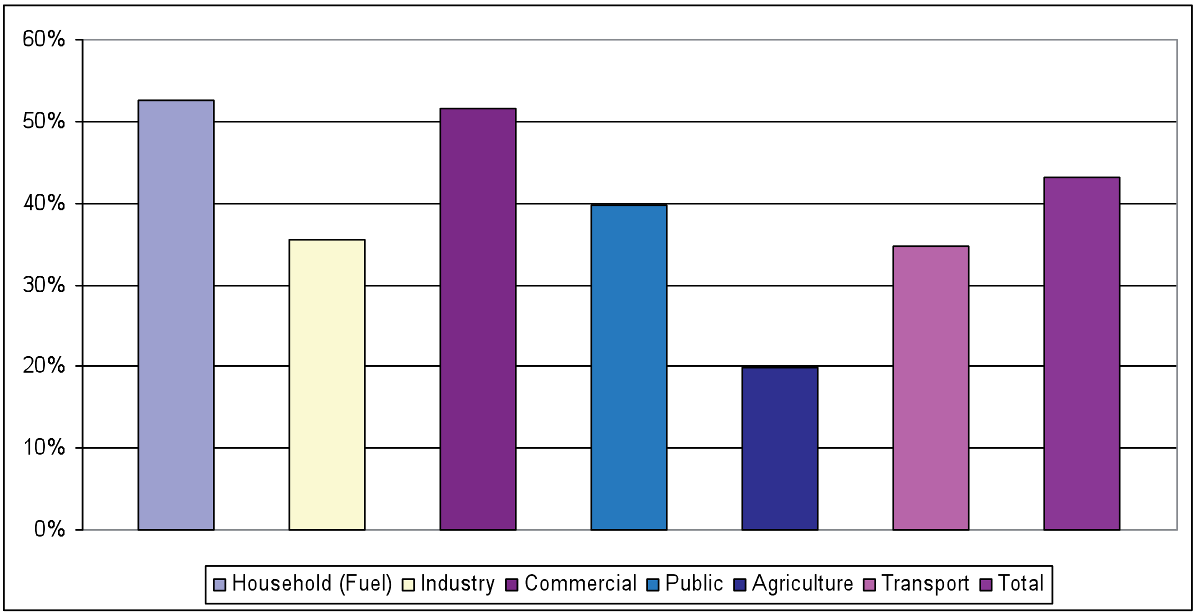

Figure 5. Savings in High Efficiency scenario compared with the BAU scenario between 2005 and 2030, %.

tor and in direct solar use in households. Biogenic energies are restricted by the low amount of biomasses available.

Table 4 shows that the active use of renewable energies could significantly increase the benefits of the efficiency strategy. CO_2 emissions could be decreased by another ton to 3.3 tons per capita by 2030 which would be 55% below the level to be expected under BAU conditions and about 28% below the level of the year 2005. Primary energy demand as well could be further reduced, which could make free the financial resources to pay for the expansion of renewable energies.

Comparing both alternative scenarios to BAU it becomes clear, however, that the lion share of energy savings and CO_2 emission reductions will be delivered by the exploitation of the energy efficiency potentials. Renewables can significantly add to this but are more limited in their potential: According to the scenario results more than three quarters of the crude oil savings and the same amount of the CO_2 emission reductions vs. BAU by 2030 will be achieved in the High Efficiency scenario, and one quarter from renewable energy use.

Conclusions

Energy consumption in Iran is an issue of global concern, as the country is one of the major oil exporters and holds the second largest natural gas reserves after Russia. At the same time energy efficiency and renewable energy utilisation could be introduced at probably quite low costs in the Islamic Republic. As a developing country and as one of the 20 largest energy consuming countries Iran could become a major player in sustainable energy development.

Table 4: Energy balance and CO_2 emissions for Iran (2010-2030) for BAU, High Efficiency and Combined scenarios.

	BAU			High Efficiency		Combined. Efficiency plus Renewables	
MBOE	2010	2020	2030	2020	2030	2020	2030
Total Final Energy Demand	**969.2**	**1261.9**	**1549.0**	**869.0**	**879.1**	**839.1**	**820.1**
Oil	452.5	511.1	550.4	379.0	357.6	371.8	345.5
Gas	414.9	616.9	830.5	393.8	433.3	363.2	364.6
Electricity	101.3	133.2	167.2	95.8	87.9	96.1	89.3
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables	0.5	0.7	0.9	0.4	0.4	7.9	20.6
Industry	**203.7**	**287.6**	**380.0**	**211.2**	**236.0**	**210.8**	**234.0**
Oil	71.7	97.4	124.4	66.1	67.5	64.2	63.1
Gas	98.5	145.9	200.3	115.4	141.8	112.1	130.6
Electricity	33.1	43.7	54.4	29.3	26.3	29.6	27.7
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables	0.5	0.7	0.9	0.4	0.4	4.9	12.7
Transport	**273.4**	**324.6**	**356.2**	**241.6**	**232.4**	**241.4**	**232.1**
Oil	265.4	315.9	347.9	235.6	227.5	235.4	227.1
others (CNG)	8.0	8.7	8.3	6.0	5.0	6.0	5.0
Other sectors	**492.0**	**649.6**	**812.9**	**416.2**	**410.7**	**386.8**	**353.9**
Oil	115.4	97.8	78.1	77.3	62.6	72.1	55.3
Gas	308.4	462.3	621.9	272.4	286.5	245.1	229.0
Electricity	68.2	89.5	112.8	66.5	61.6	66.5	61.6
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewables	0.0	0.0	0.0	0.0	0.0	3.1	7.9
Non-energy use	20.5	27.4	34.2	27.4	34.2	27.4	34.2
Electricity generation in TWh/a	**220.3**	**282.3**	**346.4**	**203.1**	**182.0**	**203.7**	**185.0**
Fossil	208.6	267.3	330.3	188.1	165.9	150.7	49.3
Nuclear	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Renewables	5.7	9.0	10.1	9.0	10.1	47.0	129.7
Total Primary Energy Demand	**1'236.2**	**1'625.8**	**1'979.2**	**1'180.9**	**1'195.3**	**1'122.5**	**1'048.1**
Oil	540.9	607.4	651.4	476.7	451.0	452.7	388.8
Gas	680.2	994.3	1'302.8	680.3	719.8	612.4	538.1
Nuclear	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Hydro & other REN elec.	4.1	6.0	6.7	6.0	6.7	32.1	83.2
other renewables	0.5	0.7	0.9	0.4	0.4	7.9	20.6
Coal	0.0	6.8	6.8	6.8	6.8	6.8	6.8
Energy intensity (boe/10^6 Rial	2.3	2.1	1.9	1.5	1.2	1.5	1.0
CO_2 in Mt	**252.9**	**284.0**	**304.5**	**222.8**	**210.8**	**211.6**	**181.8**
in t/Cap	6.1	6.8	7.4	4.8	4.3	4.4	3.3

Source: own calculations / Moshiri et al. (2009)

Iran has shown a typical development for Middle East economies. Based on the domestic fossil resources energy intensity (as well as subsidies) has been increasing over the 14 years between 1991 and 2005. And, in spite of political targets and certain actions to reduce energy subsidies and increase energy efficiency of the economy, under the BAU trend only small improvements are to be expected here.

This trend puts a major threat on the Iranian economy as it might lead to the situation that Iran will become a net importer of crude oil (cf. Supersberger 2007). It would also have consequences on the amount of energy subsidies and the efficiency of the Iranian economy, which would not even reach current world average by 2030 in the BAU scenario. Moreover, CO_2-emissions in the study period would increase by 37 percent from the current 5.4 t/cap to 7.4 t/cap.

However, the High Efficiency scenario analysed shows that harnessing the huge potentials for energy efficiency in all sectors of the Iranian economy might put the country on track to cut overall energy intensity by about half by 2030 and thus reach current world or OECD average. Such a development as envisaged in the High Efficiency scenario would have significant economic benefits which could pay for the investment needed in the scenario: Any efficiency improvements in oil consuming sectors like the transport sector will result in direct benefits to the balance of oil trading, because Iran would have to import less gasoline from abroad and subsequently benefit Iran's economy. Improving energy efficiency through highly efficient appliances or efficient lights will have two major benefits: Demand growth will slow down, which reduces the expansion of investment needs in the electricity sector. Furthermore, the cost for the saved kilowatt hours (kWh) is usually lower than the cost of electricity production.

Additionally our High Efficiency scenario shows a significant potential to reduce its CO_2 emissions in Iran by 22% vs. BAU by 2020 and by 30% by 2030. If the potentials of renewable energies are taken into account as well the total CO_2 emissions reduction vs. BAU could even increase to 25% and 40% respectively.

In order to change its current economically and ecologically unsustainable energy trend Iran needs to exploit the potentials shown in our scenario analysis. This would need a comprehensive policy, comprising an energy price reform, possibly energy market reforms, introduction of supporting schemes for energy efficiency and renewable energy investment, as well as numerous other instruments in all sectors in order to step by step remove the barriers for energy efficiency and renewable energies. However, as the failure of the most recent proposal for the removal of energy subsidies shows this will be a politically delicate process.

Still, a more sustainable energy path would bring important benefits not only to Iran but also to the international community, and to the EU in particular: developing countries need to reduce their greenhouse gas emissions between 15 to 30% below business as usual by 2020 to contribute to reaching the 2°C objective[7] (European Council 2009) and Iran could then take its share of this target. With regard to its economic needs for exporting, Iran would also be in a better position to further export significant amounts of oil and particularly natural gas[8], a possibility which might be questionable under BAU development; at the same time, Iran would also reduce its needs for nuclear energy and the pressures by the international community and the United States in particular.

In order to support Iran with such a favourable energy path, Iran and the European Union could start co-operation schemes to foster energy efficiency and renewable technologies to the benefit of both sides and to the benefit of climate protection. Initiatives could target rapid capacity building measures in Iran to accomplish technology transfer. With Iran having introduced a feed-in tariff the first step in this direction is made. On the scientific level more bilateral projects would enhance mutual learning and understanding. Iran could also benefit from the multitude of policies and regulations already in place in the European Union to develop a set of best suiting and most effective policies in the Iranian context. Furthermore, the EU could support Iran with the creation of the necessary investment framework for harnessing the energy efficiency potentials (e.g. in the building sector) and to foster renewable energy generation.

7. Avoiding global temperature to rise above 2°C is thought necessary to avoid dangerous climate change effects.

8. E.g. as a supplier to the Nabucco pipeline which is favoured by the EU.

Units

Here we use the common energy unit used in the Energy Balances of Islamic Republic of Iran which is BOE barrel of oil equivalents. It has an energy content of 6,119 MJ according to the Ministry of Energy.

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