Iran's Energy Supply

Capacities, Requirements and Options for the Future

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Contents

Abstract

Iran's current energy supply system is highly inefficient. It produces high levels of CO_2 emissions and harmful substances with considerable consequences for the health of the population in metropolitan areas, as well as considerable follow-up costs for the economy as a whole in the long term. In addition, from a budgetary point of view, the current substantial subsidies for the energy supply are also a problem. Therefore Iran is now faced with a considerable energy policy challenge which makes it a matter of urgency to restructure the energy supply system, taking into account economically reasonable and technologically feasible alternatives. These alternatives already exist and Iran could realistically use them, both in the interests of its own population and economy and in the interests of climate protection.

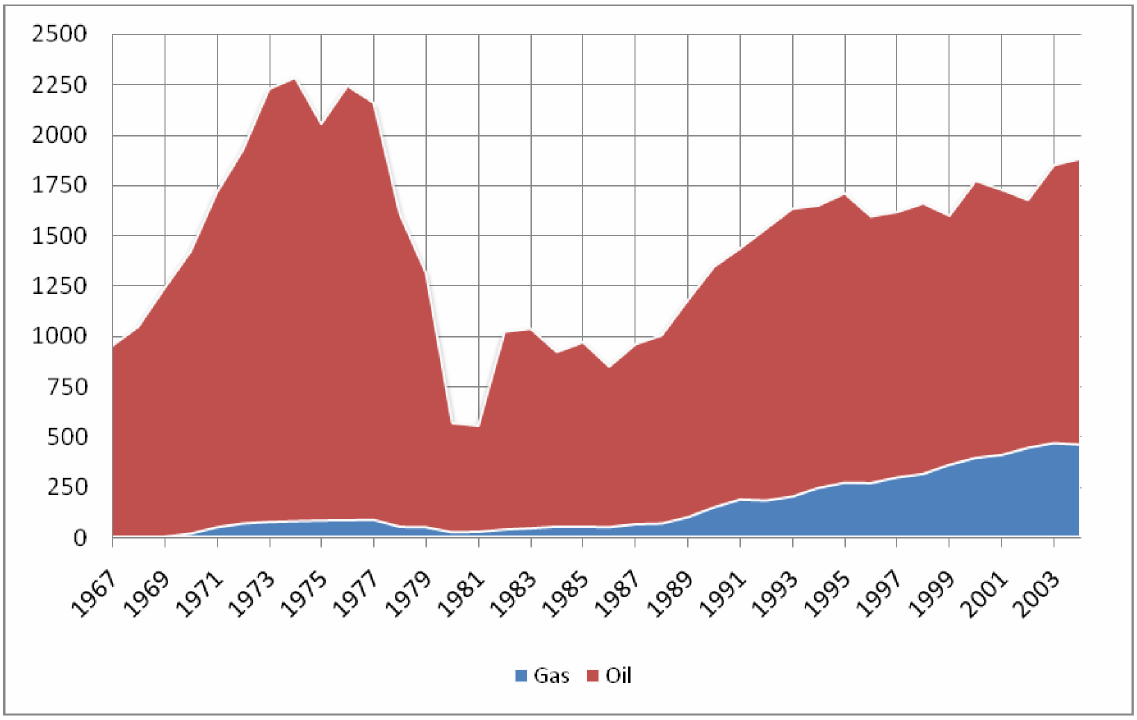
I. Iran's fossil fuel capacities and current energy supply

1. Historical development of Iran's energy supply

Iran has, with 18.9 billion tonnes of oil equivalent (toe), the second biggest oil resources in the world after Saudi Arabia (36.3 billion toe) and, with 24.07 billion toe, the second biggest gas resources in the world after Russia (43.02 billion toe). For oil and gas resources combined, Iran has, with a total of 42.97 billion toe, the second largest fossil fuel resources in the world (after Russia with 53.22 and before Saudi Arabia with 42.44 billion toe).[1] Iran's oil production began as early as the beginning of the 20th century. In contrast, gas production began only at the start of the 1960s but increased greatly in the 1990s. While oil was exported right from the start, the gas produced has always been used for internal consumption and, in order to increase oil production, a considerable amount was also injected into the oil wells. Figure 1 shows the historical development of oil and gas production.

[1] Based on author's calculations from the BP Statistical Review, June 2006.

Figure 1 Historical development of oil and gas production in Iran between 1967 and 2004 in mboe/yr



mboe: million barrel oil equivalent

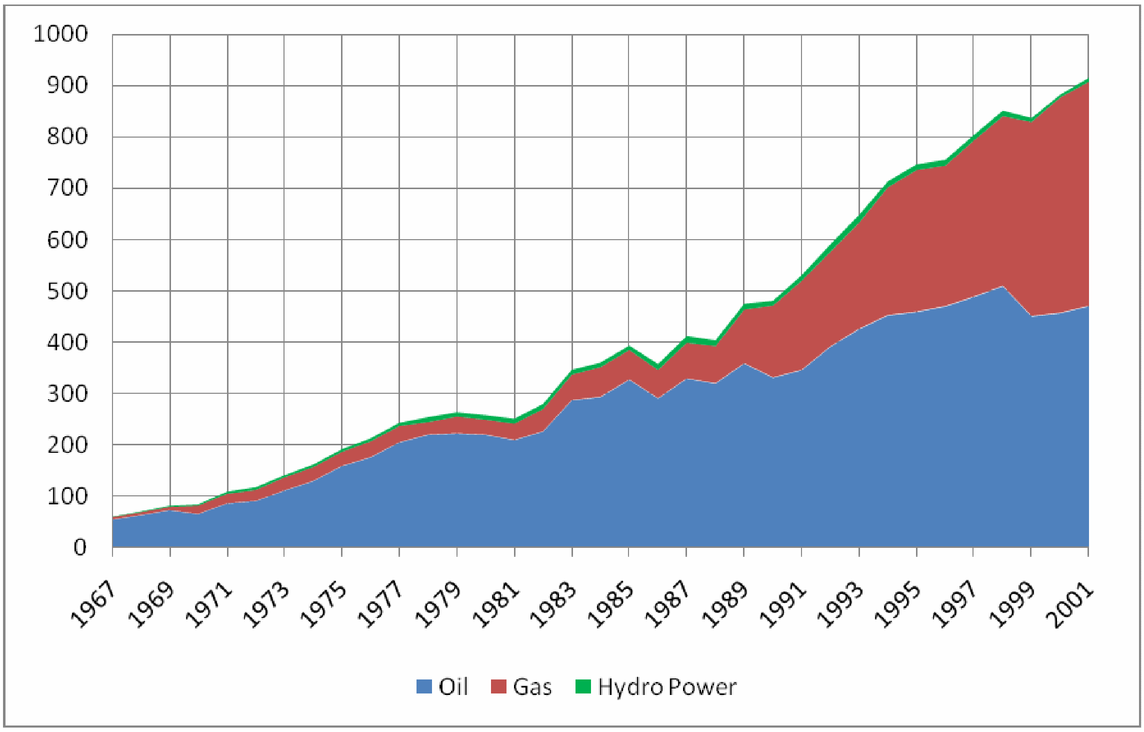
Source: Based on author's calculations from Ministry of Energy – Islamic Republic of Iran, 2005. Cf. also Massarrat 2004 and Supersberger 2007.

Oil production increased greatly in the 1960s thanks to considerable investment from multinational oil concerns and reached an historic all-time high of 2.25 billion toe/year (45.18 mb/day) in the 1970s. However, as a consequence of the Iranian oil workers' mass strikes in 1977–79 before the Islamic Revolution and the Iran-Iraq war (1981–1988), oil production sank to below 1 billion toe/year (20.08 mb/day). Currently, oil production fluctuates between 1.5 and 1.75 billion toe/year (30.12–35.14 mb/day). In all probability it will not be possible for future oil production to surpass this level due to resource depletion. However, gas production capacity could be expanded considerably thanks to the ample gas resources.

2. Historical development of internal primary energy consumption and causes of the rapidly increasing energy demand

Energy consumption in Iran rose between 1971 and 2001 with high average growth rates of 7.8% per year. Energy demand grew mostly after the revolution with yearly growth rates of over 10% in some cases. Figure 2 shows that the increasing internal demand in the 1990s was principally covered by the increase in gas production. For this purpose the internal gas-pipeline network was expanded considerably and a large proportion of the domestic commercial and industrial heating requirements switched over to gas. The power plants for electricity production were also largely switched over to gas.

Figure 2 Historical development of the internal primary energy consumption in Iran from 1969 to 2001 in mboe/yr



Source: Based on author's calculations from Ministry of Energy – Islamic Republic of Iran, 2005. Cf. also Massarrat 2004 and Supersberger 2007.

Apart from the start of industrialisation and associated increase in energy requirements, there are also demographic and energy policy explanations for the rapidly increasing energy demand. These two reasons will be discussed in more depth here.

Population growth and urbanisation

For Iran – as for all developing societies – two mutually reinforcing reasons for the growing energy demand can be distinguished: firstly population growth, and secondly urbanisation. Indeed, since the first population census in 1956, Iran's population grew from 19 million to around 64.5 million in 2001, i.e. it more than tripled in the last half-century. A deciding factor in the uncharacteristically high energy-consumption growth rates in Iran was certainly the accelerated urbanisation. While in 1956, only 31% of the Iranian population lived in cities, this proportion rose to 46% in 1976 and nearly 65% in 2001. In 1986 there were 41 cities with more than 100,000 inhabitants. Ten years later (1996), 59 cities with a population of over 100,000 were registered.[2] The three-fold population increase combined with rapid urbanisation and increasing prosperity[3] only partly explains the disproportionate growth of energy consumption. Political structures are also greatly responsible for energy policy mistakes.

[2] Cf. Confederation of Iranian Industry (ed.), 2002: 4.
[3] Massarrat 2004.

High subsidies for energy consumption

Energy consumption in Iran is heavily subsidised. Fuel for the transport sector, gas and electricity for homes, businesses, industry and agriculture, i.e. Iran's entire energy consumption, is subsidised area-wide. For example, in the financial year 1381 (21 March 2002 – 20 March 2003), around USD 13 billion was set aside for energy subsidies. The subsidies consume the lion's share of oil revenues, which amounted to between USD 10 and 24 billion per year between 1977 and 2001. The energy subsidies are counterproductive in every respect as they:

- are an effective incentive for wasteful energy consumption and they accelerate the depletion of Iran's own fossil fuels;
- cause, by high energy usage, additional pollutants and greenhouse gases;
- decrease the oil export capacities and revenues;
- hinder cost-recovery pricing and profitability of environmentally-friendly renewable energies;
- are also highly anti-social as they benefit rich people with comparatively high energy consumption far more than poorer people with comparatively low energy consumption.

For a long time, all the responsible authorities have been aware of the problem with the subsidy-distorted pricing system and it is a recurring topic at the Iranian parliament. However, to date, all initiatives to remove energy consumption subsidies and the related price distortion have failed for various reasons.

3. Structural changes in energy consumption

As Table 1 shows, energy consumption rose by 558% over a period of 25 years in household and business sectors, by 353 % in the transport sector and by 385% in the industrial sector, as against a much lower level of 254% in the agricultural sector. The energy demand's shift from the productive industry and agricultural sectors to the unproductive household, business and transport sectors can be seen clearly. These sectors' energy consumption share is, at 62.8% in 2000, considerably higher than the corresponding proportion of 39.3% in 1976. Iran's energy consumption pattern is undoubtedly unsustainable and is typical of consumer oriented, highly populated oil-producing countries with low productivity.

Table 1 Structural changes in energy consumption in Iran

Final energy consumption/year	1976		1991		2000	
	mboe*	%	mboe	%	mboe	%
Households and Businesses	50.570	20.7	134.400	30.9	282.360	40.0
Industry	49.400	20.2	125.600	28.9	190.320	27.0
Transport	45.400	18.6	102.400	23.6	160.510	22.8
Agriculture	9.760	4.0	31.350	7.2	24.820	3.5
Other	89.300	36.5	40.850	9.4	47.270	6.7
Total	244.430	100.0	434.600	100.0	705.280	100.0

*mboe = million barrel oil equivalent
Source: Author's calculations from data from the Institute of International Energy Studies, 2001.

4. Expanding electricity production

Electricity consumption in Iran between 1967 and 2000 rose from 2.220 GWh to around 100,000 GWh, i.e. a 45-fold increase.[4] The power plant capacity was rapidly expanded from around 1000 MW to 28,000 MW to cope with this. During this period the electricity production yearly growth rate is placed at 12.78%.[5] In view of these particularly high growth rates, the amount of electricity consumption in final energy consumption also rose from 3.5% to 8.6% between 1976 and 2000 – as can be seen in Table 2.

Table 2 Proportion of electricity in final energy consumption

Final energy consumption/ year	1976		1991		2000	
	mboe*	%	mboe	%	mboe	%
Electricity	8.623	3.5	31.553	7.3	61.000	8.6
Total	244.431	100.0	434.599	100.0	705.277	100.0

* mboe = million barrel oil equivalent
Source: Institute of International Energy Studies, 2001

Currently, the main electricity consumer is not, as might be expected, the industry sector, but household and business sectors. The inefficient and consumption-oriented energy consumption model is also reflected in the changes to the structure of electricity consumption. While in 1976

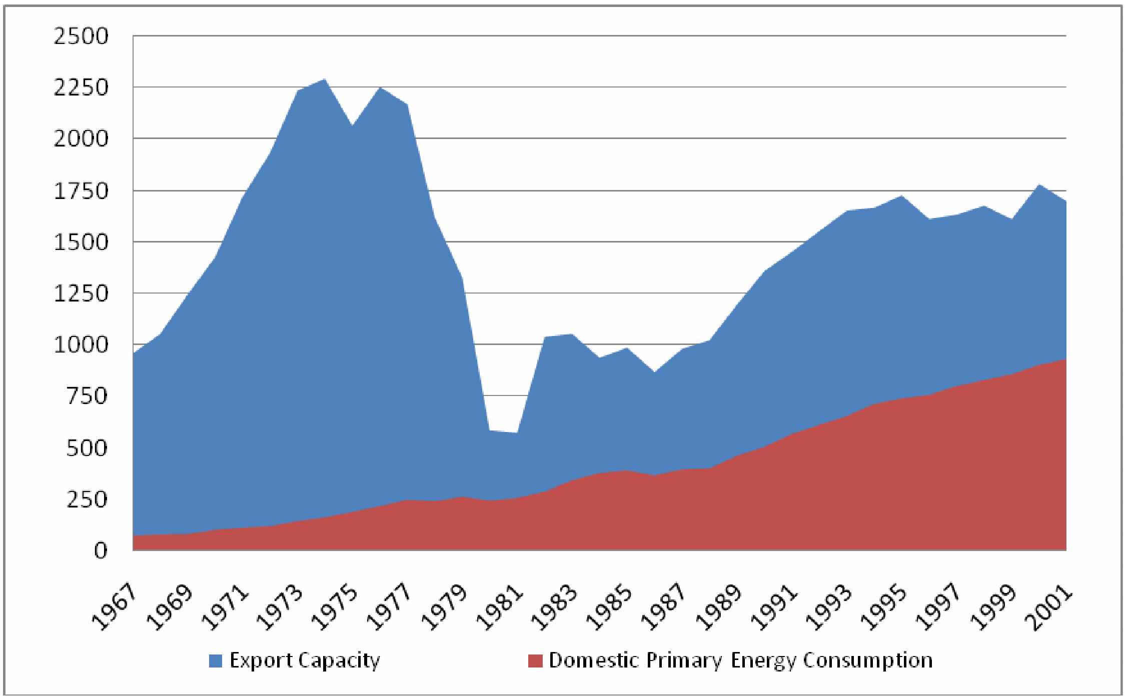
4 Ministry of Energy, 2003.
5 Assali, 2003: 55.

the industry sector accounted for 58% of electricity consumption and households and businesses for 40%, the focus of electricity use shifted by 2000 from industry, with just 35%, to households and business, accounting for 54% of use. This development is mainly due to the use of electricity-intensive domestic appliances and refrigeration units, whose numbers in cities in the service sector and high-income households has dramatically increased.

5. Decreasing export capacity

Figure 3 shows Iran's continually sinking oil export capacity. Since 1973 it has dropped from 90% to significantly less than 50% of total oil and gas production. Only drastic expansion of Iran's gas production could increase the export capacities and revenues or maintain them at current levels. However, even then it would be just a matter of time until Iran turns from being an energy-exporting country to an energy-importing country if its internal energy consumption continues to increase.

Figure 3 Iran's decreasing export capacity in mboe/yr



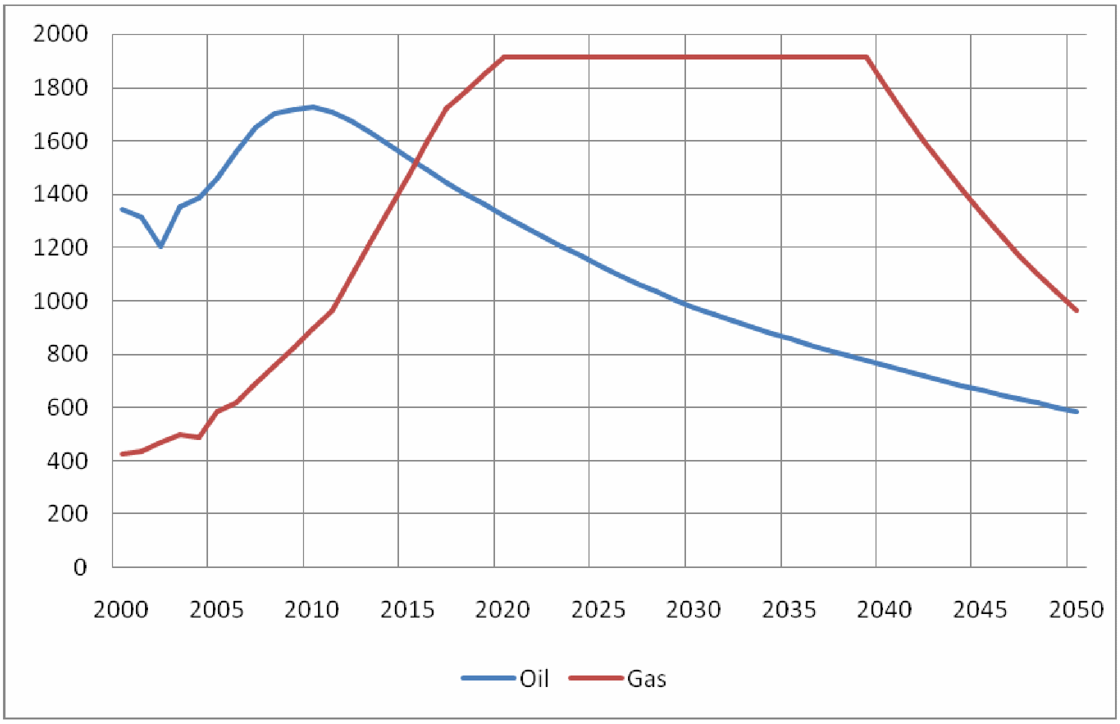
Source: Author's calculations from Ministry of Energy – Islamic Republic of Iran, 2005. Cf. also Massarrat 2004 and Supersberger 2007.

II. Development of Iran's future energy supply and export capacities based on a business-as-usual (BAU) scenario until 2050

1. Oil and gas production 2004–2050

The predictions for Iran's oil and gas production displayed in Figure 4 are based on estimations from the Association for the Study of Peak Oil and Gas (ASPO). They assume that Iran will reach its maximum oil output in 2010 and thereafter will be forced to decrease production because of resource depletion. In contrast, gas production capacity could be expanded until 2025 and continued at that level until 2040. From then on, gas production would also have to be decreased because of depleted resources.

Figure 4 Predictions for oil and gas production from 2004 to 2050 in mboe/yr

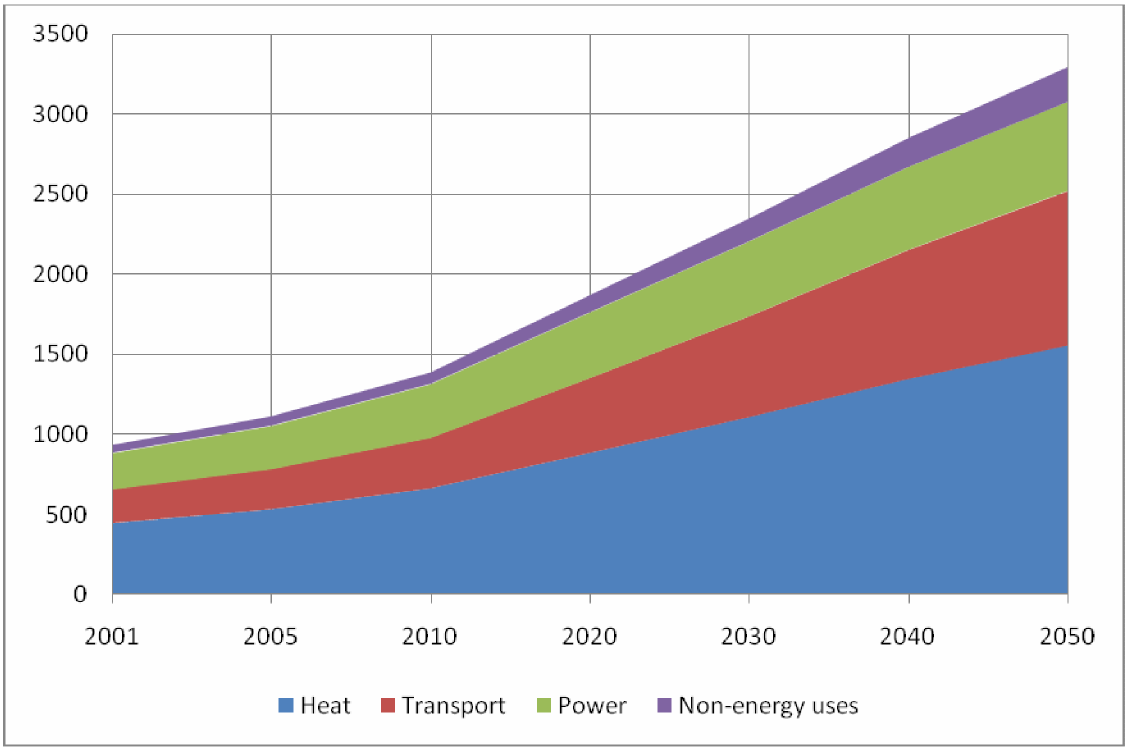


* Actual production values up to 2004
Source: Supersberger 2007: 31 ff.

2. Future primary energy consumption

In contrast, based on a BAU-scenario between 2001 and 2050, Iran's total primary energy consumption for all energy forms (fuel for transport sector, heat and electricity for all sectors) will grow 350% from 933 mboe to 3,291 mboe. In this scenario, future development is based on the assumption that the current supply and demand trends will continue during the period under review. All variables and the interdependencies between them were taken into account in this scenario (Figure 5).

Figure 5 Primary energy demand in Iran until 2050 based on a business-as-usual-scenario (BAU-scenario) in mboe/yr



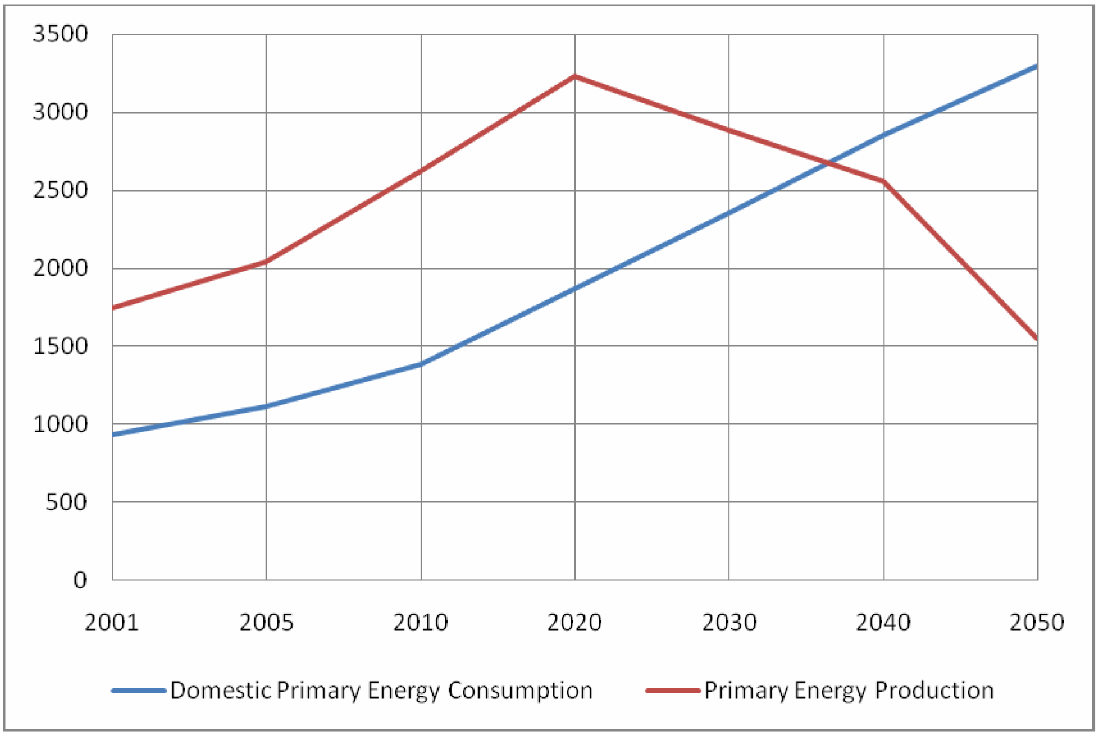
Source: Supersberger 2007: 49 ff.

3. Iran to become a fossil fuel importer

If Iran's current consumption pattern in the industry, transport, domestic, commercial and service sectors stays the same in the future and if Iran's government also continues with the current subsidy practices then the primary energy demand will grow by 450% in the transport sector, 348% in the heating sector and 243% for electricity production.[6] When the predictions for long-term energy production (Figure 4) are compared to energy consumption in a business-as-usual scenario (Figure 5), it emerges that Iran's export capacities will successively drop until 2036 and Iran would thereafter be forced to cover its needs by importing energy (Figure 6). In this event, Iran would both lose its entire oil revenue and the energy costs on the general economy would rise dramatically.

[6] Relevant variables such as demographic development, increasing urbanisation rates and system-induced decreases in energy intensity were considered for the scenario period. More information on increases and model calculations can be found in Supersberger, 2007.

Figure 6 Predictions for primary energy production and consumption in Iran from 2001 to 2050 based on a BAU-scenario in mboe/yr

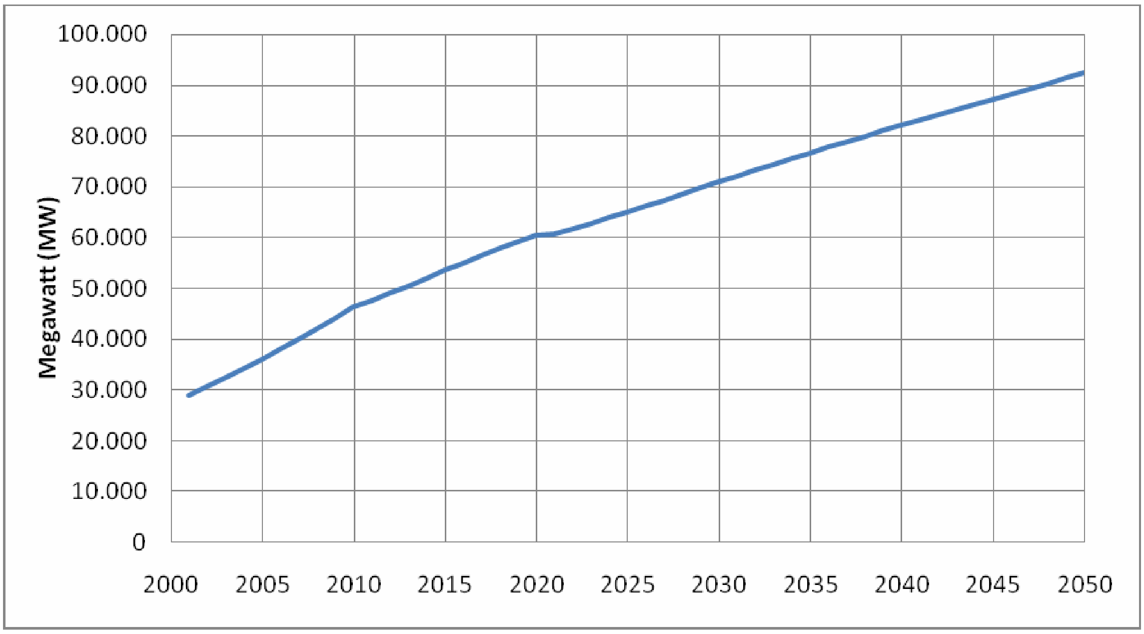


Source: Based on data from Figure 4 and Figure 5

4. Future development of Iran's electricity needs

The future need for electrical energy and the necessary power plant capacities are of particular importance as the Iranian atomic programme, which has been the subject of a worrying ongoing conflict between Iran and western countries since 2003, must be taken into account. As Figure 7 shows, based on a BAU-scenario, Iran would have to more than triple its power plant capacities from 28,900 MW in 2001 to 90,000 MW in 2050 in order to supply the increased electricity demand of 410 TWh in 2050 (2001 = 130 TWh).

Figure 7 Iran's power plant output requirements based on a BAU-scenario in MW



Source: Supersberger 2007: 66 f.

III. Alternatives for Iran's future energy supply

1. Developing nuclear power plant capacity

Currently, two nuclear power plants are being built in Bushir; each with a 1,300 MW capacity. The first reactor should already have come into service in 2004 but has still not been completed due to differences between Iran and Russia, which is building it. By building further reactors, Iran's nuclear power plant (NPP) capacity would be increased to 6000 MW in the long term. The Ministry of Energy frequently justifies the need for nuclear power capabilities by indicating the total energy requirements of 100,000 MW by 2020, although they do not go into any more detail. Irrespective of how high demand actually is, there is consensus in the Iranian government that developing NPPs in Iran is necessary. The director of the Iranian nuclear energy board, *Reza Aghazadeh*, gives the following reasons for building NPPs in Iran:

(a) diversification of the energy supply in view of growing energy demand and shortage of fossil fuels,
(b) maintaining oil export capacity and foreign revenue, and
(c) environment and climate protection.[7]

[7] Aghazadeh, 2003

For the time being, developing the nuclear power plant capacity appears to be a long-term option under the following conditions:

(a) NPPs are economically profitable,
(b) disposing of the nuclear waste does not pose a problem for Iran,
(c) there is no other cheaper or more technologically feasible option for increasing Iran's primary energy supply,
(d) NPPs increase Iran's energy supply security and independence.

Careful planning for Iran's future energy supply and the convincing substantiation for developing nuclear power plant capacity require a thorough investigation into the options for increasing efficiency and reducing electricity production capacity by using more modern technologies both among electricity consumers and for electricity production itself. Furthermore, an investigation must be carried out into the profitability of nuclear power plants, considering all operational and economic costs, in comparison to fossil-fuel power plants and above all to renewable energies (wind power, solar-thermal power plants etc.).

However, even under the optimistic assumption that, under the above-mentioned conditions a–c, nuclear energy is a better option than the alternatives, the question of supply security and energy independence (assumption d), which is the most important matter from the Iranian government's point of view, remains open. It is precisely because of this that particular consideration has been given to the investigation of this assumption here. Energy independence from nuclear energy assumes first and foremost that Iran would be in a position to supply the as-yet unbuilt power plants with its own uranium. However, Iran's uranium reserves as currently identified, according to Iranian experts, will only suffice to supply very few nuclear power plants.[8] Experts from the Tehran Institute for Nuclear Research even argued at a public meeting that Iran's own uranium reserves would merely be enough to supply only the Bushir power plant with Iranian fuel.[9]

From this it follows that, for its nuclear power plants, Iran would be dependent either on importing uranium as a raw material and turning it into fuel rods in its own fuel cycle, or on buying the necessary fuel rods directly from the world market. With regard to the first option, Iran would be in constant conflict with the USA and would have to take into account the risks and costs of UN sanctions on the Iranian economy. Both options, however, would result in new energy dependencies for Iran, either on uranium exporting countries or on the international nuclear industry, i.e. on Russia or even nations such as the USA, which have been in conflict with Iran since the Islamic Revolution and are trying to bring about a regime change in Iran. In summary it can be noted that developing nuclear capacity contradicts the main political aim of long-term supply security and energy policy autonomy and for this reason alone should be excluded as an option for Iran.

[8] Salimi, 2005
[9] These statements were made at a public discussion meeting on 6 March 2007 at the Faculty for Politics and Economics at the Shahid Beheshti University in Tehran.

Irrespective of the above-mentioned objections against implementing nuclear energy, according to Article IV of the NPT, Iran has, without any doubt, the right to make full use of nuclear technology for peaceful purposes. The question of whether it is in Iran's energy and security policy's short and long-term interests to exercise this right is an entirely different issue.[10]

2. Increasing energy efficiency

When compared internationally, the Iranian energy sector is highly inefficient. Although in the period 1976 to 2001, energy intensity dropped in all industrial and most newly industrialising countries (e.g. China) by between 28% (USA) and 94 % (Japan), Iran's energy intensity rose by 280% in the same period.[11] This means that use of the primary energies oil and gas in the transport sector, heating and also electricity production could all be reduced by between 60 and 80% in the long term without this decreasing wealth.

In the transport sector the current fuel consumption is, at 16 litres per 100 km[12], double that of industrialised nations. Compared to the BAU-scenario, fuel consumption could thus be decreased by at least 50% and it could yet be reduced to a considerably larger extent in the long run by the use of new technologies.

Measures: Introducing efficient drive technology, moving as much passenger and goods transport as possible from the roads to the railways, expanding the under-developed rail-linked transport system, mainly for long-distance transport, and developing underground trains in metropolitan areas.

In terms of heating for the industry and household sectors, savings of up to 75% could be made by using high-efficiency technologies (high-efficiency scenario) in comparison to the BAU-scenario.[13]

Measures: Improve insulation in building construction, efficient room heating, refrigeration and water heating, passive houses as well as implementing cogeneration in the industry sector.

In the *electricity production* area, considerable saving potentials are possible on both the supply and demand sides: in electricity production, the power plants' efficiency could be increased from the current 26.8% to 50%, i.e. that nearly double the amount of electricity could be produced with the current capacity. Also on the demand side, electricity consumption can be reduced by up to 60% compared to the BAU-scenario.[14] In terms of modernising the existing Iranian power plants and increasing efficiency of electrical appliances on the consumer side, the electricity demand can be covered in the long term even without building further power plants.

[10] See also section IV.
[11] Massarrat, 2004.
[12] IFCO, 2004 (Sup.).
[13] Supersberger, 2007: 56.
[14] Ibid.

Measures: Introducing efficient lighting and domestic appliances, modernising the pumping systems of the water supply and sewage disposal sector as well as the agricultural irrigation systems, using cogeneration for electricity production and modernising working power plants.

Apart from the above-mentioned measures in individual sectors, two strategic and trans-sector steps are necessary and possible: *firstly* the successive reduction of energy subsidies and *secondly* the creation of management agencies to provide energy- and money-saving proposals for industry, private households, and public institutions.

Conclusion: If the above-mentioned strategic steps and individual measures for increasing energy efficiency by using highly efficient technologies are introduced, the demand for fossil-fuel primary energy (oil and gas), compared to the BAU-scenario, would drop by over 70% by 2050 and macroeconomic profits would also simultaneously be achieved. Nikolaus Supersberger comes to this conclusion in his as yet unpublished thesis.[15] According to this scenario, the primary energy demand would grow until 2010 and then drop by 2050 to the 2001 primary energy demand level of 933 mboe. A cumulative macroeconomic profit of USD 1,527 billion could also be achieved during this period.[16] This profit would be the result of the difference between higher revenues from the oil and gas exports saved by lower domestic demand, and the investment costs involved when implementing the efficient technologies. It was assumed that the population will increase from the 2001 figure of 65 million to 105 million in 2050, and that the gross national product will rise from USD 112 billion in 2001 to USD 507.7 billion, i.e. a nearly five-fold increase in the same period.[17]

3. Developing renewable energies

Iran has access to a considerable potential of renewable energy sources in the form of water power, geothermal energy, wind energy and, above all, solar energy. Water power is currently being used to produce electricity. The available water-power output is 3000 MW. This can be increased to a total output of 13,000 MW. The geothermal sources could also be used to produce electricity. A facility for a 100 MW plant is currently under construction.[18] The geothermal energy sources discovered so far are enough to supply a power plant output of 5,000–6,000 MW in total. Solar irradiance in Iran amounts to 2,200 KWh/m^2 per year on average and is one of the highest irradiance levels in the world.[19] This energy source could basically be used to produce warm water, heating and above all electricity. In terms of using renewable energies for the transport sector, for example by using hydrogen technology, Iran is faced with the same challenges as all other countries.

Today, the simplest option for using solar irradiance economically and thus saving primary fossil energy and avoiding CO_2 emissions is using solar panels to heat water. This was the subject of a

[15] Supersberger 2007: 174 ff.
[16] Ibid.: 92.
[17] Ibid.: 44 f.
[18] Supersberger 2007: 107 f.
[19] German Aerospace Centre 2005.

detailed study by the Wuppertal Institute, carried out in cooperation with Iranian experts in 2005. According to the study, if 25% of households in Tehran switched their current hot water supply methods over to solar panels, and even if state subsidies completely covered the switchover costs for an amortisation period of 25 years, Iran's economy would benefit from an additional economic profit of USD 1.8 billion for the state budget and simultaneously reduce CO_2 emissions by 503,000 tonnes per year.[20]

Measures: Implementing the recommendations from this study.

Heating supplies for industry and buildings as well as hydrogen technology for the transport sector have not been considered in this study, which concentrates more on implementing renewable energy sources for electricity production. Using wind farms is of particular importance. However, the implementation of solar-thermal power plants is extremely relevant for Iran. It is assumed that solar-thermal technology will soon be so advanced that it will be ready to go into production and that it will even be able to economically produce electricity at the current oil and gas global market prices. The construction of the largest solar-thermal power plant with an output of 50 MW is scheduled in Spain for 2008.[21] In principle, it is technologically possible to cover Iran's total electricity needs, both short and long-term, by using the above-mentioned renewable energy sources. The following Table 3 shows the results of the afore-mentioned scenario study on switching the entire electricity production to renewable energy, per form of energy.

Tab. 3 Electricity production output by 2050 on the basis of renewable energy, in 1,000 MW

	2005	2050	
Scenario		BAU	HE
Total output	36,0	87,6	36,2
Remaining capacity of fossil fuel power plants (2001)	32,1	0,0	0,0
Hydro power	4,0	13,4	13,4
Geothermal	0,0	5,0	3,7
Solar thermal power plants	0,0	69,1	19,1

BAU: business as usual
HE: high efficiency

Source: Supersberger 2007: 113 ff.

For a complete switchover of electricity production to renewable energy sources by using the energy forms described in the above table, investment in the order of USD 44.5 billion (at 2005's prices) would be needed until 2050. However, investment for increasing efficiency in traditional electricity production would save around USD 36.8 billion and additional profit from increased

[20] Wuppertal Institute for Climate, Environment and Energy 2005.
[21] DIE ZEIT, 22 June 2006.

gas exports would achieve around USD 10.8 billion, so that the Iranian economy would actually gain around USD 3.1 billion (at 2005's prices) by switching over.[22]

Measures: Immediately carry out feasibility studies on building solar-thermal power plants. With the current state of technological advancement this technology promises to deliver the greatest contribution to producing solar electricity and switching Iranian electricity production to renewable energy sources. Therefore, developing solar power plants should be given utmost priority.

IV. Conclusions

Iran has – as seen in II.3 – a serious energy supply problem, both in the short and long term. Furthermore, it is indisputable that Iran already has, even independently of the political system, a security problem that must be taken seriously. Despite the size of its territory and geopolitical significance in the Middle East, the country feels itself to be under military threat from all sides: from the east, south (Persian Gulf) and from the west because of the US military presence in Afghanistan, the Arab Gulf States and Iraq. In addition, there are also the threats stemming from the two nuclear states of India and Pakistan in the south east, the nuclear super power Russia in the north and above all from Israel's nuclear weapons potential, as Iran has been in constant political conflict with Israel since the Islamic revolution.

Combining the future energy supply with the existing latent security dilemma – which is de facto already occurring with Iran's nuclear programme being seen as a possible solution to both – is, for the author's view, not a solution to either problem. In fact this link actually gets in the way of the search for suitable and feasible alternatives. It is therefore necessary to unhook the energy problem from the security dilemma. In this way many options can be opened up for both challenges.

For example, with regard to Iran's security problems, the option of 'Common security and regional cooperation', i.e. a CSCE process for the Middle East, could be a particularly attractive solution and would position Iran as one of the most influential peace powers in the region. In this way, it could also place a durable and long-term restraint on foreign powers' geostrategic and energy-political interests.[23] New options would also arise for the energy policy challenges, as mentioned in section III.

Detailed studies are certainly needed for Iran to actually switch its current energy supply to a new, efficient energy system with a successively increasing proportion of renewable energy technologies. However, the above figures indicate that with today's technical knowledge, Iran's economy would not suffer any loss from the change, not to mention the other indisputable advantages, such as avoiding CO_2 emissions, long-term supply security and energy autonomy, stretching its own fossil fuel resources by many decades, protecting the environment from other

[22] Supersberger 2007: 117 f.
[23] For more information see Massarrat 2007.

pollutants, decentralising the energy supply and much more. According to this scenario, the CO_2 emissions alone would be 78% lower in 2050 than with the BAU-scenario. Instead of 1,040 million tonnes of CO_2, an emissions level in 2050 of just 227 million tonnes is in both Iran's and humanity's interests.

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