Complexities of saving energy in Qatar

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Abstract

Qatar presents unusual energy conservation challenges, some of which will appear elsewhere as the effects of climate change and environmental degradation increase. Qatar is endowed with huge reserves of natural gas but no fresh water. All of the fresh water is obtained through energy-intensive desalination processes – which may be responsible for as much as 40 % of total gas use – resulting in many links between the supply and consumption of energy and water. Conserving water translates directly into saving energy. About 80 % of the electricity in Qatari buildings is used to provide air conditioning; this is the highest fraction in any country in the world. The high rate of infrastructure construction temporarily distorts energy consumption patterns.

Energy efficiency policies and measures are at an early stage in Qatar. Traditional strategies and targeted end uses from Europe and North America are not appropriate. Conventional tariff-based strategies to discourage wasteful use of energy and water will be less successful in Qatar because Qatari citizens are extremely wealthy and are entitled to free electricity, water, and natural gas. A few programs have been begun, targeting both electricity and water waste. A voluntary program to benchmark commercial buildings is also under development. Qatar is trying to reduce water distribution losses from above 20 % to 10 % and to increase water recycling.

The especially strong links between energy and water use in Qatar may become common in other parts of the world with scarce water, notably Southern California, Western Australia, and the Middle East. Thus, Qatar's experiences in conserving energy and water will be broadly applicable.

Introduction

Qatar is an energy-rich country; nevertheless it faces energy problems and unusual motivations for conservation compared to western countries. We describe Qatar's energy demand situation, measures taken to reduce consumption, and the relevance of Qatar's problems to other regions.

Qatar is a small peninsula – about the size of Denmark – jutting into the Arabian Gulf. The country is entirely desert. It borders Saudi Arabia but also maintains close ties to the United Arab Emirates, about 140 km to the east. Both countries exert strong economic and cultural influences on Qatar. Almost 2 million people live in Qatar, nearly all of them in the capital of Doha. Qatari citizens are only about 12 % of the total population, with the remainder being contract workers or other expatriates. Qatar has the third largest reserves of natural gas in the world and exports about 20 % of the world's liquefied natural gas (LNG).Production of natural gas continues to increase while oil production is already declining.

Qatar has enjoyed an average economic growth rate of over 15 % in the last decade as a result of rapidly increasing LNG exports and high petroleum prices. It has among the world's highest GDPs per capita. There have been huge investments in infrastructure during this period, resulting in a construction boom of buildings, factories, highways, ports, and transportation facilities. The economy relies heavily on exports of natural gas exports and products manufactured with low-cost natural gas, such as urea, steel, and petrochemicals.

Energy Consumption in Qatar

With the exception of transportation, Qatar operates almost entirely on natural gas. Figure 1 shows Qatar's energy flows in the form of a Sankey diagram adapted from Smith, Belles and Simon (2011).This diagram uses 2007 data. Present consumption is roughly 50 % greater but the fractions and flows are still generally correct, though the fraction of gas production has increased and that for oil has decreased.

The Sankey diagram does not reveal a critical use of energy: desalination.(This consumption is mostly subsumed in "electricity and heat" and "industrial" end uses.) All of Qatar's commercial water supply is obtained through desalination. About 400 million cubic meters per year of desalinated water was delivered in 2012 (Darwish, Mohtar, and Ali 2012). Most desalination facilities in Qatar use waste multi-stage flash distillation (MSF) although reverse osmosis (RM) is also used. Regardless of the technique, roughly 5 kWh of electricity is needed for each cubic meter (1,000 litres) of fresh water produced. Energy for desalination and treatment will be a rising fraction of total energy use in other regions with inadequate natural water supplies, such as Israel, Western Australia, Southern California, China, and Gaza. However, in Qatar the "energy-water" nexus is already here and important.

Water storage is less than a week and may be as little as two days, thus leaving the country vulnerable to a supply disruption. The water distribution system has high losses given the high value of the lost water. Estimates of distribution losses range from as high as 59 % to 20 % (Boulos and AbouJaoude 2011).For comparison, Singapore's water distribution losses are estimated to be less than 5 % (Whittle et al. 2010).

Electricity generation represents the largest fraction of energy use in Qatar. The precise fraction depends on how energy for desalination is treated. Desalination facilities are usually co-located with power plants so that they can exploit the power plant's waste heat. Both electricity and water consumption has been growing at roughly 15% per annum for the last five years. Per-capita electricity consumption and water consumption are the highest in the world, about 14,400 kWh/year and 460 litres/day respectively. Both have been growing at roughly 15% per annum for the past five years.

The distribution of electricity use by customer class is shown in Figure 2 (adapted from Darwish, Mohtar, and Ali 2012). The distribution is unusual because nearly one quarter of all electricity sales are unbilled. Qatari citizens are entitled to free electricity, gas, and water; rates for expatriates are also low compared to Europe and North America. Note that the aggregate residential electricity use by all expatriates is roughly equal to that of all Qatari citizens, even though the expatriates outnumber the Qataris by 4 to 1. Furthermore, about one quarter of the housing units consists of worker housing compounds for expatriates (Permanent Population Committee 2012), whose conditions are significantly lower than average.

Electricity for industrial, commercial customers, and non-Qatari residents is cheap. A 2013 tariff schedule converted into Euros is shown in Table 1 (Kahramaa – Qatar General Electricity & Water Corporation). The residential tariff is about €0.02/kWh, that is, about one tenth European residential rates. Most commercial and industrial customers do not pay any capacity charges.

Average household electricity consumption is estimated to be 34,000 kWh/year and per-capita household water consumption is over 300 litres/day, both of which are the highest in the world. The average Qatari household size is about seven

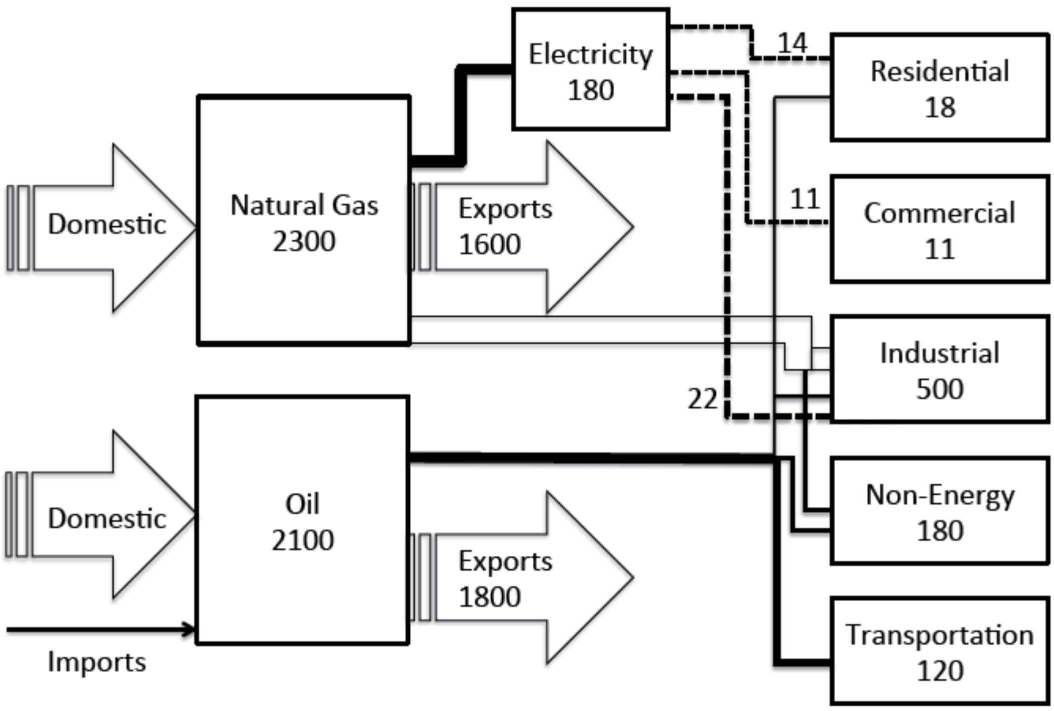

Figure 1. Qatar energy flows 2007.Values are in PJ/year. Adapted from Smith, Belles and Simon (2011).

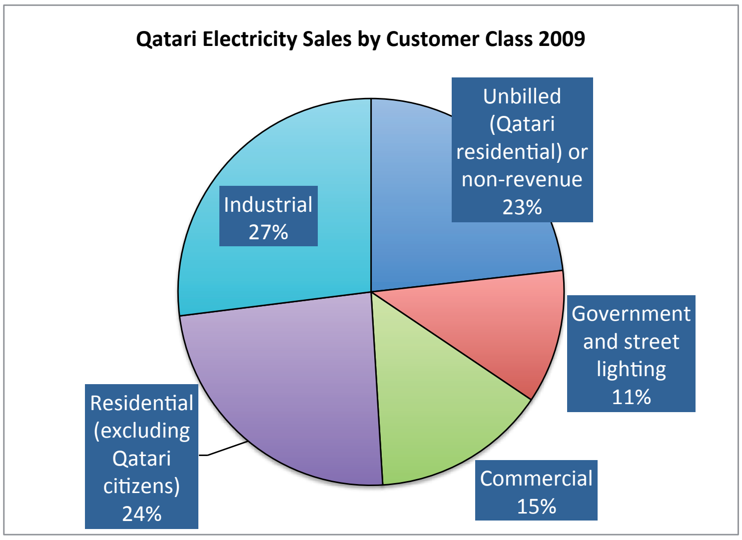

Figure 2. Qatari electricity sales by customer class 2009.

Table 1. Tariff schedule for electricity and water in Qatar.

Sector Type	Electricity From (kWh)	To (kWh)	Tariff (€/kWh)	Potable Water Tariff (€/m³)
Residential Flat	1	4000	0.017	0.924
	4001	Maximum	0.021	
Residential Villa	1	4000	0.017	0.924
	4001	Maximum	0.021	
Commercial	1	4000	0.019	1.09
	4001	15000	0.025	
	15001	Maximum	0.029	
Bulk Hotel	1	300000	0.019	1.09
	300001	500000	0.025	
	500001	Maximum	0.029	
Non Bulk Hotel	1	50000	0.019	1.1
	50001	100000	0.021	
	100001	Maximum	0.025	
Industrial	1	Maximum	0.015	0.92
Government	1	Maximum	0.032	1.47

persons (Department of Social Development 2011), which is unusually large. As a result, the daily household consumption is roughly 2,100 litres/day. For comparison, the average European household electricity consumption (excluding space and water heating) is about 2,700 kWh/year (De Almeida et al. 2011). Water consumption in Northern European households (not per-capita) water consumption is less than 150 litres/day (Salameh 2012). Household water consumption in Sacramento, California (a near-desert but where consumers are also not billed for their use) is about 1,000 litres/day (Reebs 2009).

A second invisible category of energy consumption is construction. Qatar is experiencing a boom in construction of buildings and other infrastructure. About one quarter of Qatar's GDP has been devoted to infrastructure in the past five years (Economic Statistics and National Accounts Department 2012). Numerous "megaprojects" are under construction, including a new airport – one of the world's largest – enormous residential complexes, a bridge to Bahrain, and many, many large commercial buildings. An underground Metro system (consisting of three lines) is being built to serve (among other destinations) a complex of new stadiums that will host the 2022 FIFA World Cup. All of these activities require large amounts of concrete, steel, electricity, fuel, water, and other materials. Equally important, these projects require a large labour force, which is also responsible for considerable indirect energy consumption for housing and transportation. The energy impacts of infrastructure construction has been observed in China (Sinton and Fridley 2000), but is probably even greater in Qatar. The present distribution of energy use is unlikely to persist after these projects are completed and construction rates decline. However, the new occupants of the residential complexes are likely to use much more energy and water than the labourers that constructed them, so the net impacts are not clear.

A third invisible category of energy consumption is flaring of natural gas. Qatar's economy depends on production of oil and gas. A large amount of natural gas is simply wasted through flaring. In 2007, natural gas flaring represented 12 % of Qatar's total carbon emissions (Luomi 2012) and contributes other emissions that severely affect the country's air quality. Qatar upgraded its Al Shaheen Oilfield to capture and exploit this untapped energy source. This field alone accounted for 20 % of Qatar's flaring (UNFCCC 2012). The upgrade involved injecting the gas back into pipelines, utilizing it for generating electricity, and supplying it to local industries. These measures cut flaring 80 % while generating electricity and other economic activities. Qatar has committed itself to achieving zero flaring from all of its oil and gas activities. Eliminating flaring represents Qatar's single largest energy-saving measure.

Energy Consumption in Qatari Buildings

No detailed study of energy consumption in Qatari buildings has been performed. However, an end use breakdown is actually much easier create than in most temperate climates. In Qatar, essentially every building has air conditioning and air conditioning is responsible for 70–80 % of most buildings' energy bills. This is probably the highest fraction in the world. For nine months in the year, the average high temperature exceeds 27 °C and summer temperatures regularly exceed 45 °C, with little respite during the nights. Summer temperatures are so high and prolonged that outdoor swimming pools need to be artificially cooled. An unusual interplay between the desert and the surrounding Gulf causes huge daily fluctuations in humidity, from 40 % to over 70 % in a few hours. It is common practice to operate a commercial building's air conditioning system 24 hours/day, 365 days per year (and in many residences, too). Some of the larger, new developments, as well as central business districts, are served with district cooling systems. The remaining electricity consumption mostly goes to lighting and refrigeration.

Water consumption represents one of the largest – though indirect – end uses of energy in Qatari buildings. Desalination adds at least one kWh for every 200 litres of water consumed. A Qatari home using 2,000 litres per day of water requires over 3,000 kWh/year at the desalination plant.

Energy-Saving Policies and Programs in Qatar

The incentive to conserve energy in Qatar is generally low because of the high per-capita incomes and very low energy prices (free for Qatari citizens). The large transient population of contract workers is less inclined to invest in higher efficiency equipment because they expect to leave in a few years. Nevertheless, the high bills caused by extreme air conditioning use has encouraged some consumers to conserve. Improvements in lighting and appliance efficiencies translate into direct savings from those end uses, plus reduced cooling loads (all year). However, a shortage of experts, such as skilled operating engineers, materials, and energy-saving products make it harder for building owners to implement even simple measures.

There are also compelling national motives to reduce energy use and to adopt renewable sources. First, the government recognizes the environmental impacts of high energy use. Natural gas is a relatively clean fuel but carbon emissions have climbed sharply and local air quality is declining. (Asthma is a serious ailment among Qatari children.) The output from desalination plants is a brine even saltier than the Persian Gulf surrounding Qatar. Water circulates poorly in the Gulf and increasing salinities have been observed around Qatar (and other Gulf States). Desalination will require even more energy as the salinity rates rise and will, eventually, be technically constrained (Elimelech and Phillip 2011).

Second, energy not consumed in Qatar can be profitably exported. Thus, there is an economic incentive to reduce Qatar's energy consumption. In neighbouring Saudi Arabia, projections show that rising internal consumption will eliminate all exports, and that it will be forced to import oil, as early as 2025 (Salameh 2012). Qatari policymakers want to avoid this scenario in Qatar.

Third, excessive energy use wastes capital in the form of unnecessary power plants and other energy infrastructure. Qatar already overinvested in electricity generating capacity, so it appreciates the costs of overinvestment.

Finally, there is an element of national sensitivity to the fact that Qatar has the highest CO2 emissions and levels of energy and water use in the world. The Qatari government would be a more politically effective agent in global climate negotiations if other countries occupied the first position.

An overall strategy was presented in Qatar National Vision 2030 (GSDP 2008) and in more detail in the Qatar National Development Strategy (QSDP 2011). The electric and water utility, Kahramaa, has announced plans to reduce electricity consumption by 20 % and water consumption by 35 % in the next five years (The Peninsula 2012). In practice, only a few mandatory efficiency regulations have actually been implemented, especially with respect to buildings.

A 2008 regulation, Conservation Law 26, lists responsibilities, regulations, violations and fines for wasting water and electricity ("Electricity and Water Consumption Rationalization Law. No for Waste" 2009). The Law authorizes Kahramaa and relevant authorities to:

- Develop the technical specifications for thermal insulation and power-saving measures in residential buildings as well as commercial, industrial, and investment facilities;
- Update the technical specifications of electricity and water internal installations;
- Upgrade the audit methods to reduce power and water loss in customer premises with high consumption;

- Develop and update technical specifications and standards for instruments, tools and equipment used in electricity and water installations and link them to the specifications for granting building permits;
- Provide technical consultancy on the usage of the modern instruments, tools, and equipment that will help rationalize the use of electricity and water;
- Employ the media to establish and disseminate a culture of rational consumption of electricity and water; and
- Work with relevant authorities to incorporate electricity and water rationalization values into the curriculums and the religious propaganda, preaching, and guidance programs.

As for conserving water, the Law forbids:

1. Using or allowing the use of potable water for washing cars or other equipment, or cleaning up the yards of buildings or constructions by using a hose or any other water flow tools. This excludes the permitted car wash facilities, in accordance with the regulations and conditions determined by the Corporation.
2. Leaving the outdoor lights, fixed on public or private building and construction fences or facades, switched on from 7 am to 4.30 pm.
3. Leaving the damaged or broken down parts of the internal water network, that would cause water leakage, without repair, after the owners and tenants have been notified by the Corporation.

The most frequent violations are: using fresh water for washing cars or cleaning building yards by a hose or any other flushing tools; failure to repair leaking taps, pipes etc.; and leaving outdoor lights switched on from 7 am to 4:30 pm (The Peninsula 2012).

In 2012, Qatar announced plans to gradually phase out use of incandescent bulbs (The Peninsula 2012). It also announced plans to require customers to install photovoltaic systems to displace 2 % of electricity demand and solar thermal systems to reduce energy consumption for water heating.

A Green Building Code is a key element of Qatar's strategy to reduce energy use in buildings (QSDP 2011). The code is presently voluntary; however, the goal is to make it mandatory as architects and builders become more familiar with its requirements. Another element is the Global Sustainability Assessment System (GSAS), which seeks to create a means of benchmarking green building developments throughout the Gulf region (GSAS/QSAS Technical Committee 2012).

No minimum efficiency standards for appliances have been established (beyond those limiting incandescent light bulbs). Qatar has no domestic production of appliances and its wealth allows it, in principle, to identify and purchase the world's most efficient products. In practice, the haste to complete projects, a private reluctance to invest in efficiency, and the presence of some low-efficiency suppliers in the Middle East, results in relatively low product efficiency (especially for small air conditioners). In 2009, neighbouring Saudi Arabia established energy labels for efficiency standards for air conditioners, refrigerators, freezers, and washing machines and, more recently, announced plans for minimum efficiency standards for many appliances and industrial equipment (Avancena 2012). The United Arab Emirates has also announced initiatives to promote appliance energy efficiency. These actions by neighbouring countries are likely to stimulate similar efforts in Qatar.

Recycling waste water reduces the need for produced water and saves energy. Presently about 25 % of Qatari water is recycled and (after treatment) used to irrigate plants and for industrial processes. Increasing the rate of recycling (and reducing the distribution losses) appears to have considerable potential.

An Energy-Efficient Future for Qatar?

Qatar illustrates many of the problems of a small country that is initiating an energy efficiency policy. It lacks the legal and technical depth to implement all the necessary steps. As a result, the steps appear tentative and scattered, often relying on voluntary measures and guidelines where more advanced countries use regulations, codes, and technical expertise. The utility started a few experimental conservation programs, such as installation of smart meters and information outreach, and has recently created a department dedicated to energy conservation. Private firms and individuals likewise lack the access to expertise, products, and materials necessary to take measures on their own initiative.

Qatar is located in an energetically inhospitable climate but has been wealthy enough to supply a high level of goods and services. Economic growth and construction of infrastructure has been more important than reducing energy use. The situation is gradually shifting, with at least lip service paid to energy conservation and increased use of renewable energy. For the immediate future, however, there will be no shift towards radically more efficient use of electricity and water. The gradual completion of major infrastructure projects in the next decade may translate into sharply lower energy growth rates (and possibly even declines).

Many countries and regions already face severe water shortages and have begun to rely partly on desalination. Climate change and continued population growth in desert areas promises that reliance on desalination will increase. These regions are all around the world, from the Middle East to California to China and Australia. Most of these regions outside the Middle East are still at the experimental stage. Qatar already occupies the extreme end of this spectrum because it relies entirely on desalination. The merging of energy and water networks has already occurred. (Indeed, engineers at power plants already speak of delivering both power and water into the grid.) The big difference in Qatar is that its extreme wealth permits it to mostly ignore the energetic costs of its energy-water grid. Other regions will not have this luxury.

Qatar has the ability to improve the efficiency of new equipment by adopting regulations already established by some of its largest trading partners, such as the European Union. The technical aspects of such a policy shift need to be coordinated with its neighbours, notably the UAE and Saudi Arabia, so as to simplify inventories and enforcement. But Qatar must still develop its own strategy for buildings to deal with its unique problems of constructing and operating buildings in an extremely hot climate with an extreme scarcity of water. It must also confront the pricing policies that result in free energy and water for Qataris and exceptionally low prices for all residents.

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