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AN EXPENSIVE DIVERSION: ABU DHABI'S RENEWABLE ENERGY INVESTMENTS AMID A CONTEXT OF CHALLENGING DEMAND

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Executive Summary

In 2009, Abu Dhabi launched a drive into renewable energy that was trumpeted by the global media as evidence that an old-line petro-state had embraced the global low-carbon agenda. Examined closely, however, the kudos may have been premature. Abu Dhabi's expensive renewables venture will neither allow the emirate to forgo construction of conventional generation, nor will it provide more than token reduction in carbon emissions growth. The main benefit lies in improving this OPEC oil producer's international image, which, in the political context of a rentier monarchy, is an important source of domestic legitimacy. I show that a more effective policy would aim at reducing consumption by targeting the energy subsidies that account for around a quarter of power demand. Price increases could be accomplished within the political rules by maintaining differentiated tariffs for citizens and non-citizens.

Introduction

In 2009, the government of Abu Dhabi, one of seven semi-autonomous sheikhdoms that form the United Arab Emirates (UAE), launched a drive into renewable energy that was trumpeted by the global media as evidence that an old-line petro-state had embraced the global low-carbon agenda.[1] By 2020, renewable energy sources were to account for at least 7% of its total electric power generation capacity.[2] When bundled with its concurrent and much larger nuclear plans, Abu Dhabi's low-carbon sources would account for 30% of its electricity generation capacity. Through these ventures, the government said it aimed to ease the growth in carbon dioxide

[1] Hassan M. Fattah, "Abu Dhabi Explores Energy Alternatives," *The New York Times*, March 18, 2007, http://www.nytimes.com/2007/03/18/world/middleeast/18abudhabi.html?pagewanted=all&_r=0. Sonia Verma, "Extravagant party gets Abu Dhabi's eco-city off the ground," *The Times*, February 11, 2008, http://www.thetimes.co.uk/tto/business/industries/construction-property/article2164897.ece. Steve Inskeep and Joe Palca, "Oil-Rich Abu Dhabi Builds Renewable-Energy City," *Morning Edition*, National Public Radio, May 5, 2008, http://www.npr.org/templates/story/story.php?storyId=90180158. Elisabeth Rosenthal, "Gulf Oil States Seeking a Lead in Clean Energy," *The New York Times*, January 13, 2009, http://www.nytimes.com/2009/01/13/world/middleeast/13greengulf.html?pagewanted=all. Edwin Heathcote, "The greening of Arabia," *Financial Times*, October 10, 2009, http://www.ft.com/cms/s/0/11b93766-b462-11de-bec8-00144feab49a.html#axzz2sVafVyYZ. Matt Chambers, "A green city rises from the desert of Abu Dhabi," *The Australian*, January 25, 2010, http://www.theaustralian.com.au/business/a-green-city-arises-from-the-desert-of-abu-dhabi/story-e6frg8zx-1225823057250. Pilita Clark, "Gulf starts on road to a green revolution," *Financial Times*, December 3, 2012.

[2] "Abu Dhabi Commits to 7 Percent% Renewable Energy Target by 2020," *Emirates News Agency*, January 18, 2009, http://tinyurl.com/nlb5hjc.

emissions while diversifying supply and continuing to meet fast-growing demand for electricity and desalinated water. In this context, Abu Dhabi's renewables venture was cited as evidence of a unique policy transformation.

Examined closely, however, the media kudos may have been premature. Abu Dhabi's expensive renewables venture will neither allow the emirate to forgo construction of conventional generation, nor will it provide more than token reduction in carbon emissions growth. Whether it will even meet its 2020 target remains in question. The main benefit lies in improving this OPEC oil producer's international image, which, in the political context of a rentier monarchy, is an important source of domestic legitimacy.[3]

To be clear: Abu Dhabi's goal is not to generate 7% of its electricity with renewables, but to use them for 7% of the emirate's installed capacity, which, in 2020, is expected to comprise about 1.5 gigawatts (GW) of an overall capacity of 23 GW. Given the capacity factor of solar electricity,[4] which is generally below 25%—compared with roughly 80% for a baseload combined-cycle gas turbine (CCGT) plant—a 1.5 GW installation of mainly solar-driven generation capacity would only provide about 2.5% of Abu Dhabi's overall electricity. A more effective policy, in terms of efficiency gains and emissions reductions, would be a campaign that penalizes waste by raising tariffs.

Background

Abu Dhabi is the largest and wealthiest of the seven UAE sheikhdoms. For the foreseeable future, its economy will revolve around its control of 94% of the UAE's oil reserves and more than 90% of its natural gas reserves,[5] which form 8% and 3.5% of proven global reserves.[6] Abu Dhabi's 2 million inhabitants live in a desert emirate the size of Ireland that, as part of the UAE,

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[3] Rentier theory correlates externally sourced revenues, typically from hydrocarbons, with the stability of paternalistic socio-political structures, which have tended to defy scholarly predictions of their downfall. The Gulf monarchies provide exemplary cases of resource rents' association with autocracy.
[4] Capacity factor refers to the ratio of actual power output over time versus its potential output at full capacity. Since solar power is unavailable or unused during some periods, its capacity factor is reduced.
[5] Paula Vine, ed., *United Arab Emirates Yearbook 2009* (London: Trident Press Ltd., 2009).
[6] *BP Statistical Review of World Energy June 2012* (London: BP, 2012).

is associated with the world's third-largest per-capita ecological footprint[7] and, until recently, an obstructionist role in global climate change talks.[8] The UAE, in turn, is a member of the six-nation Gulf Cooperation Council (GCC) bloc of Arabian Peninsula monarchies that includes oil producers Saudi Arabia, Kuwait, Oman, Qatar, and Bahrain.

Despite its prodigious oil reserves, Abu Dhabi faces several energy policy challenges:

- Fast-rising domestic demand for exportable oil and gas resources
- Plateauing production of oil and gas
- Subsidized energy prices that encourage consumption
- High and rising carbon dioxide emissions
- Increasing fiscal burden from subsidies
- Rising marginal cost of energy and electricity production
- Political risk associated with reforms of domestic energy policy.

This paper explores whether investments into renewables constitute an appropriate policy response within such an environment. First, it examines the details of the emirate's plans in comparison with its current generation costs and future needs while teasing out the political motivations behind its investment choice. Further sections outline Abu Dhabi's challenges in coping with demand for power and natural gas, and examine the performance of renewables in the Gulf context and the role of subsidies on energy demand.

Energy Policy in the Rentier State

Abu Dhabi's electricity model is typical of oil-exporting rentier states in the Gulf and should be examined within this context. This state-led model emphasizes increases in supply while safeguarding the consumer from increases in price. The government covers most costs and

[7] Monique Grooten, ed., *Living Planet Report 2012* (World Wide Fund for Nature, 2012), http://www.panda.org/about_our_earth/all_publications/living_planet_report/lpr_2008/.
[8] Joanna Depledge, "The Opposite of Learning: Ossification in the Climate Change Regime," *Global Environmental Politics* 6.1 (2006): 1–22.

distributes power at subsidized rates. Deepest discounts are reserved for citizen consumers in the residential sector.

Numerous scholars have written about distributive politics in oil-exporting rentier states, illustrating the effects of oil and gas export windfalls on these states' governance, economies, and society. Among the characteristics described in this literature is the framework for deriving public support for unelected regimes, such as the Gulf ruling families. Regime legitimacy is said to flow through a social contract that requires the government to provide citizens with a menu of benefits that, once extended, are treated as rights of citizenship. The elements within this unwritten social contract that concern this paper are the subsidized distribution of energy, including electricity and desalinated water. This theme is covered by numerous scholars on Saudi Arabia and the Gulf, among them Beblawi, Luciani, Anderson, Crystal, Gause, Chaudhry, and Davidson.[9]

Also relevant for this paper is a less-examined by-product of rentierism. The mild form of autocratic rule in the Gulf monarchies has, over the years, empowered the citizen and made governments sensitive to policies that would challenge welfare benefits. Government giveaways, Ayubi writes, have institutionalized a situation where the citizen claims the right to tax the state*,* rather than the other way around.[10] Matthew Gray posits that rentier states have maintained control without increasing democratic participation, but despite this, their regimes have grown more responsive to citizens' needs, especially when those interests are impacted by government policy.[11] Jones adds that citizens "possess a strong sense of civic entitlement, while lacking a

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[9] Hazem Beblawi and Giacomo Luciani, eds., "Introduction," *The Rentier State* (London: Croon Helm, 1987), 1-21. F. Gregory Gause III, *Oil Monarchies: Domestic and Security Challenges in the Arab Gulf States* (New York: Council on Foreign Relations, 1994). Lisa Anderson, "The State in the Middle East and North Africa," *Comparative Politics* 20 no. 1 (1987): 1–18. Jill Crystal, *Oil and politics in the Gulf: Rulers and merchants in Kuwait and Qatar* (Cambridge: Cambridge University Press, 1990). Kiren Aziz Chaudhry, *The Price of Wealth: Economies and Institutions in the Middle East* (Ithaca: Cornell University Press, 1997). Christopher M. Davidson, *The United Arab Emirates: A Study in Survival* (Boulder: Lynne Rienner Publishers, 2005). Christopher M. Davidson, *Abu Dhabi: Oil and Beyond* (New York: Columbia University Press, 2009). Christopher M. Davidson, *Dubai: The Vulnerability of Success* (New York: Columbia University Press, 2008).

[10] Nazih N. Ayubi, *Over-stating the Arab State: Politics and Society in the Middle East* (London: I.B. Tauris & Co. Ltd., 1995), 323–5.

[11] Matthew Gray, "A Theory of 'Late Rentierism' in the Arab States of the Gulf" (Doha: Center for International and Regional Studies, Georgetown University, 2011).

corresponding sense of civic obligation."[12] This extends to nationals' refusal to recognize the state's authority to tax or carry out other revenue-extractive functions such as the retraction of subsidies on electricity and water.[13] The Arab Spring uprisings have further empowered citizens and made governments more wary of antagonizing them.[14] In short, the political structures of rentier states form strong barriers to reform of subsidies, even those that have become economically damaging, such as the low fixed tariffs encouraging consumption of electricity.

This analysis begs the question: If rentier monarchs are politically committed to providing discounted electricity to their citizens, why would they choose renewables? Why would one of the world's most energy-endowed locales commit itself to adopting low-density and expensive generation when it can pursue cheaper and more efficient means?

One explanation lies in the divergence of Abu Dhabi's internal and external political priorities. Ruling elites want to present Abu Dhabi as a responsible member of the international community, which means taking publicized action on climate change. But the most effective measure—targeting demand by reducing fossil fuel subsidies—would seem to violate the internal political rules. Investing in renewables is a policy that is acceptable to internal and external audiences. The international community applauds Abu Dhabi's embrace of the "green" agenda and the regime reaps reputational benefits. As Nonneman writes, "effective dealing with the outside world" is a key basis for regime legitimacy.[15] Thus, in the case at hand, the regime's domestic audience enjoys an increased supply of electricity and the satisfaction of being governed by a government that commands international respect. The social contract remains intact.

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[12] Calvert Jones, "The New Rentier Citizen? Political Attitudes and the Evolving Social Contract in the UAE" (working paper presented at Gulf Research Meeting, University of Cambridge, Cambridge, July 8, 2011).

[13] These arguments have been articulated in literature by several authors. See p. 61 and 82 in Gause, *Oil Monarchies*. Gwenn Okrhulik, "Rentier Wealth, Unruly Law, and the Rise of Opposition: The Political Economy of Oil States," *Comparative Politics* 31 no. 3 (1999): 295–315. Steffen Hertog and Giacomo Luciani, "Energy and sustainability policies in the GCC" (London: Kuwait Programme on Development, Governance and Globalization in the Gulf States, 2009): 7.

[14] For example, the author surveyed policymakers in the UAE Prime Minister's Office from February–March 2012, asking whether the events of the Arab Spring had affected government's willingness to raise electricity prices. Of the 25 who responded, 15 (60%) said the Arab Spring events had made government less willing to raise prices. Only one response of "more willing" was recorded.

[15] Gerd Nonneman, "Determinants and Patterns of Saudi Foreign Policy: 'Omnibalancing' and 'Relative Autonomy' in Multiple Environments," in *Saudi Arabia in the Balance*, eds. Gerd Nonneman and Paul Aarts (London: Hurst & Co., 2005): 315–351.

The renewables choice is typical of the supply-side focus within rentier states in which regimes find it easier to create redundant institutions than launch policy that would challenge citizen expectations.[16] Dasgupta argues that early resource undervaluation produces a deeply ingrained path dependence that can only begin to be addressed through appropriate price signals.[17] In the Gulf, initial pricing and supply patterns shaped personal habits as well as cities and infrastructure, allowing developers to reduce costs by ignoring energy efficient techniques and "locking in" a pattern of energy intensive development that has become difficult to change.

Abu Dhabi's adoption of renewables fits the pattern of redundant institution building. Renewables exacerbate the government's cost of providing electricity within its subsidized framework, while leaving intact incentives for energy-intense behavior. As Karl writes, by pursuing spending solutions, problems tend to become unmanageable.[18]

Context: Consumption Challenges

Abu Dhabi's renewable energy venture comes after a period of intense economic and population growth that saw the emirate, and the UAE as a whole, diversify its decades-old role as a simple rent-earning exporter of hydrocarbons. Growth in electricity consumption has remained strong irrespective of oil prices. In the two decades from 1991 to 2010, electricity generation in the UAE more than quintupled, rising from 17.4 terawatt hours (TWh) to reach 88.6 TWh, an average growth rate of nearly 8.5% per year.[19] Examined in an international context, that growth rate is comparable to the rest of the GCC, but lower than electricity generation growth in other industrializing states, such as boom time Japan, South Korea, and China. (See Table 1.)

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[16] Terry Lynn Karl, *The Paradox of Plenty: Oil Booms and Petro-States* (Berkeley: University of California, 1997). Steffen Hertog, *Princes, Brokers and Bureaucrats: Oil and the State in Saudi Arabia* (Ithaca: Cornell University Press, 2010).
[17] Partha Dasgupta, "The Environment as a Commodity," *Oxford Review of Economic Policy* 6, no. 1 (1990): 51–67.
[18] Karl, *The Paradox of Plenty*, p. 16.
[19] BP, 2012.

Table 1. Growth in GDP vs. Power Generation

	Avg. GDP growth	Avg. yearly power generation growth
UAE 2000–2010	5.4%	7.5%
GCC 2000–2010	6.5%	7%
Korea 1972–2000	7.4%	12%
Japan 1960–1970	9.4%	11.5%
China 1998–2008	10%	11%

Source: IMF, IEA

Table 2. UAE Utilities and Generating Capacity

	UAE utility	2012 capacity
Abu Dhabi	ADWEA	13.8 GW
Dubai	DEWA	7.4 GW
Sharjah	SEWA	2.4 GW
Northern Emirates	FEWA	1.3 GW
UAE combined	(total)	24.9 GW

Source: Utilities, Business Monitor Int'l

Abu Dhabi holds the largest share of the UAE's generating capacity, 13.8 GW of the nearly 25 GW total. (See Table 2.) Going forward, Abu Dhabi's installed base is forecast to reach 23 GW by 2020 and 43 GW by 2030.[20] Peak power consumption in Abu Dhabi is expected to grow by more than 11% a year—around the same pace as that of China—until 2015, when it is forecast to slow to 9.4%.[21]

In 2006, the Abu Dhabi utilities regulator found that Abu Dhabi residential customers consumed a yearly average of 41,000 kilowatt-hours (kWh) of electricity,[22] more than triple the average American home's consumption in 2010 of 11,500 kWh (and more than double the nearly 17,000 kWh/year in Tennessee, the US state with the highest average household consumption).[23] Within Abu Dhabi there was a wide differential between UAE nationals' households—which used an average of 71,000 kWh/year and paid an average yearly bill of $967—and those of expatriates—which consumed about a third as much electricity, but, due to a higher per-unit price, paid a larger average bill of $1,082.

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[20] Abu Dhabi Water and Electricity Company, *Statistical Report 1998–2010* (Abu Dhabi: ADWEC, 2011), http://www.adwec.ae/Report2010.html.

[21] Keith Miller, "ADWEC Winter 2011/2012 Electricity and Water Demand Forecasts," presentation, MEED Power and Water Conference, Abu Dhabi, February 6, 2012. *See also* Chris Stanton, "Abu Dhabi to crack down on energy use," *The National*, April 24, 2010, http://www.thenational.ae/business/energy/abu-dhabi-to-crack-down-on-energy-use.

[22] Abu Dhabi Regulation and Supervision Bureau, *Consumption Report: Water and Electricity* (Abu Dhabi: Abu Dhabi Regulation and Supervision Bureau, 2009).

[23] US Energy Information Administration, "Table 5A. Residential Average Monthly Bill by Census Division, and State," November 2010, http://www.eia.gov/electricity/sales_revenue_price/html/table5_a.html.

Table 3. Average Yearly Consumption and Cost of Residential Electricity: Abu Dhabi and United States

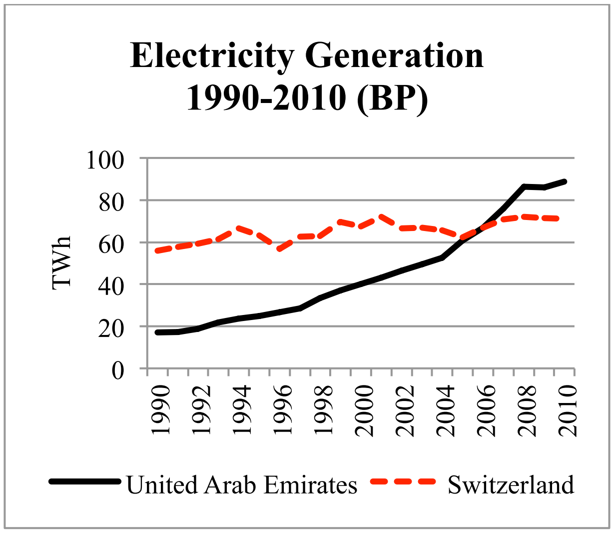
Customer	Avg. consumption (kWh)	Tariff per kWh	Avg. yearly bill
Abu Dhabi nationals	71,000 (2006)	1.4 US cents	$967
Abu Dhabi expatriates	26,500 (2006)	4 US cents	$1,082
U.S residents	11,500 (2010)	11.8 US cents*	$1,357
	(consumption is per household)	* average	

Source: RSB, World Bank, EIA

Electricity consumption in the UAE was a big factor in the country's prominent ranking on various pollution indexes. Besides emerging near the top of the World Wide Fund for Nature's ecological footprint scale, the UAE was also the world's No. 6 per-capita emitter of carbon dioxide from fuel combustion in 2011.[24] The following charts illustrate the magnitude of the UAE's growth in electricity generation and carbon dioxide emissions by comparison with Switzerland, a rich country with a similar population size.

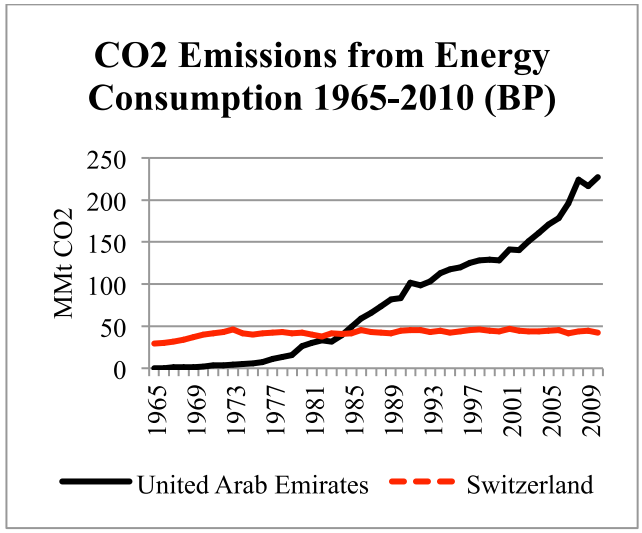
[24] International Energy Agency, *Co2 Emissions from Fuel Combustion* (Paris: International Energy Agency, 2012). For ecological footprint ranking, see World Wide Fund for Nature, 2012. Note that UAE ranked as the world's No. 1 eco-footprint holder from 2006–8 and was the No. 2 carbon emitter as recently as 2004, but it dropped down the ranks after sharp upward revisions of its population.

Figure 1. Power Generation Growth in UAE vs. Switzerland



Source: BP Statistical Review of World Energy, 2011

Figure 2. Growth in CO2 Emissions from UAE vs. Switzerland



Source: BP Statistical Review of World Energy, 2011

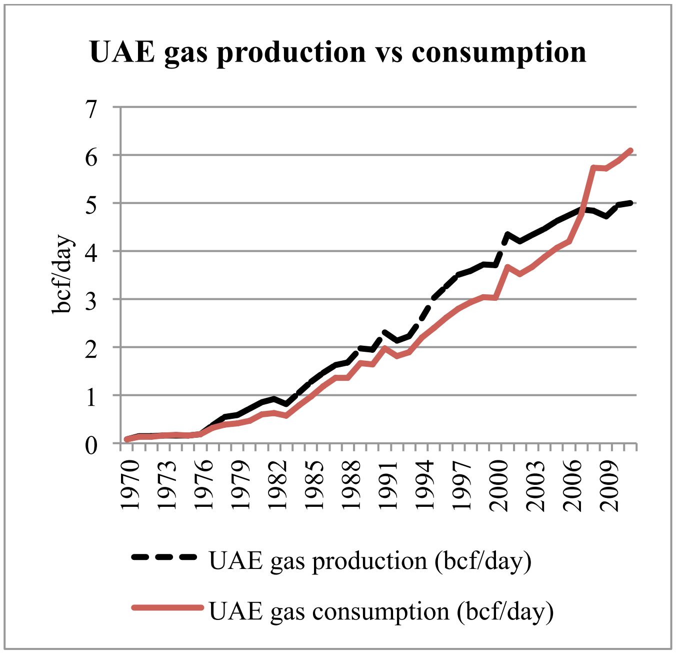
The UAE's Gas Shortage

The UAE holds the world's fifth-largest natural gas reserves, some 6.4 trillion cubic meters, yet the country—Abu Dhabi included—has grown short of gas. With demand rising nearly 6% a year for the past 20 years, by 2008 the UAE was transformed into a net importer. In 2010, the UAE imported 17.4 billion cubic meters of gas, mainly via pipeline from nearby Qatar.[25] (See Figure 3 and Figure 4.) A similar shortage affects four of the UAE's five GCC neighbors. Only Qatar, a major LNG exporter, has sufficient gas for domestic needs.[26] Abu Dhabi's electricity consumption has begun to compete with other uses for gas amid a regional trend of increasing scarcity.

[25] *BP Statistical Review of World Energy June 2011* (London: BP, 2011).

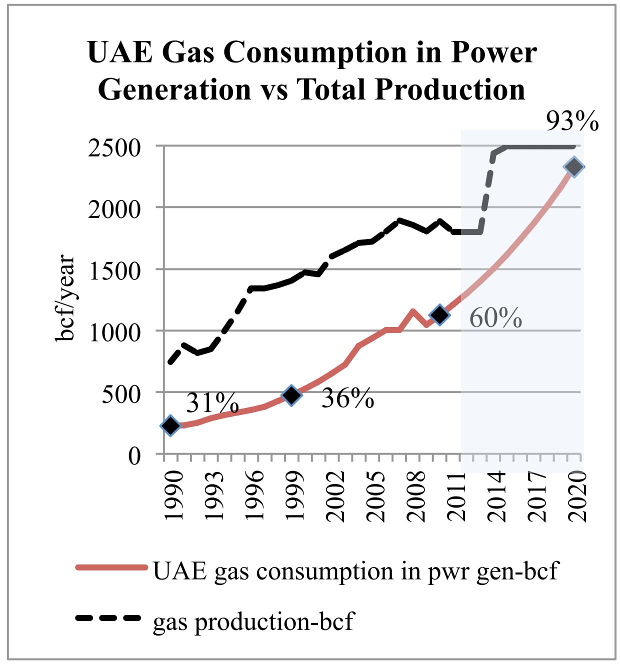
[26] For background on the GCC gas shortage, *see* P. Lotter and R Semonella, *Arabian Gulf Electricity Industry* (Dubai: Moody's Global Corporate Finance, 2008). *See also* International Energy Agency. *Betwixt Petro-Dollars and Subsidies: Surging Energy Consumption in the Middle East and North Africa States* (Paris: International Energy Agency, 2008).

Figure 3.



Source: BP, 2012

Figure 4.



Source**:** Gas production projections compiled by National Bank of Kuwait 2010. Gas consumption data is from International Energy Agency, with author's personal projections to 2020. Projections are based on continued growth at average rates since 1990.

The gas crunch has several causes. First is price: As mentioned, gas sold domestically is priced far below its netback value, which increases demand and discourages upstream investment. Next is the array of consumers: Abu Dhabi's gas is used in energy-intensive industries including aluminum, cement, and petrochemicals; for re-injection into oil reservoirs to maintain oil production; and is tied to long-term export contracts that saw 281 billion cubic feet (bcf) of LNG shipped to Asia in 2011.[27] A third factor is that most reserves are of associated gas and therefore extracted in tandem with crude oil, production of which is restricted by OPEC quota. Another factor is that a large portion of Abu Dhabi's unassociated gas reserves is of highly sulfuric "sour" gas that has proven difficult to produce. But a chief driver of the gas shortage is domestic consumption of electricity.

[27] BP, 2012.

As Figure 5 shows, if UAE utilities continue consuming natural gas at the present rate, the electricity sector alone would require the equivalent of 93% of the UAE's indigenous production by 2020. This projection does not encompass gas demand for enhanced oil recovery, industry, petrochemicals, or any other use beside power generation.

In short, Abu Dhabi's supply of inexpensive domestic natural gas appears to have reached its ceiling. Additional gas for power generation or other uses will either have to be imported or produced from more expensive domestic sources at a cost roughly five times the current sale price of bulk gas to power producers. Qatar supplies 2 billion standard cubic feet (scf) per day of discounted natural gas to the UAE via the Dolphin Pipeline at low long-term prices, currently around $1.50/million British thermal unit (MMBtu).[28] Qatar also sells smaller amounts of excess gas under the terms of a shorter-term "interruptible" contract with prices above $5/MMBtu. Qatari officials have insisted that they are unwilling to increase exports to neighbors at discounted prices, suggesting that Abu Dhabi faces higher prices on future imports.

Drivers of Demand

Energy demand is a function of several factors, among them income, population, technology, climate, and price. Since this paper is most interested in the effects of government policy on energy demand, a short examination of the contribution of Abu Dhabi's fixed prices is worthwhile. Price affects demand in a direct way, as well as indirectly, through choice of energy-consuming equipment and its operating efficiency, and the rate of utilization of that equipment. In Abu Dhabi, low prevailing prices relative to income offer little incentive for conservation, for investments into more efficient technology, or for reducing rates of utilization. When prices are low, it can be economically rational for people to maintain high rates of consumption using inefficient technology, rather than investing in more efficient replacements. Pricing has thus contributed to path dependence on high consumption, encouraging energy intensive infrastructure and habits. These include inefficient buildings, many of which lack basic conservation elements such as insulation, thermal-pane windows, and programmable

[28] The price, which increases slightly every year, was given as $1.30 by the International Energy Agency, October 2008.

thermostats. Air conditioning in buildings is the largest single demand source, accounting for roughly 70% of overall electricity consumption in the region.

Low prices of electricity in Abu Dhabi and the rest of the Gulf are rooted in low valuations of natural gas, which stem from an era when associated gas was considered a nuisance and often flared off, rather than put to productive use. Once gas began to be developed as an electricity generation feedstock, ruling elites decided that electricity tariffs needed only cover costs of infrastructure, operation, and maintenance.[29] Prices set in 1987 remained largely unchanged at the time of writing. "Stranded" gas was thus used to develop Abu Dhabi and lightly populated neighboring states, providing improvements in lifestyle while shoring up the political legitimacy of ruling families.[30]

Abu Dhabi provides electric utilities with gas at around $1-$2 per million British thermal units (MMBtu), which is the rough equivalent of selling oil at $6–$12 per barrel when world market prices are near $100.[31] Despite the underpricing of gas feedstock, it costs Abu Dhabi utilities about 8.7 US cents per kWh to produce, transmit, and distribute electricity to end users.[32] But a government subsidy covers most of the cost of that electricity. Power is sold to citizens for 1.4 cents per kWh, just 16% of the government's cost. This arrangement is typical of the Gulf monarchies. In Abu Dhabi, however, non-citizens and most other customers pay higher rates than citizens: 4 cents per kWh, which amounts to 47% of the government's cost.[33] (See Table 4.)

Provision of subsidized electricity is a key driver of inefficient consumption that lies behind the shortages of natural gas in Abu Dhabi and the gas and electricity shortages elsewhere in the

[29] David Scott, interview by author, November 11, 2010.
[30] There is debate about whether electricity provision was an explicit quid pro quo for citizen political support or whether its subsidization owes itself to an unintentional failure to index tariffs to inflation.
[31] Using typical calculation of $1/million Btu = $5.80/barrel.
[32] The average price per kWh used to calculate the government's cost that is published on 2012 Abu Dhabi electricity bills is 32 UAE fils. The average cost of generation is 22 fils (6 US cents), according to Hassan Radhi, "On the Value of decentralised PV systems for the GCC residential sector," *Energy Policy* 39 no. 4 (2011): 2020–2027.
[33] UAE nationals pay 5 fils per kWh, which works out to 1.4 US cents per kWh. Source: Abu Dhabi Regulation and Supervision Bureau, "Information Tariffs," http://www.rsb.gov.ae/En/PrimaryMenu/index.aspx?SubCatMenu_Name=Information Publications&SubCatMenu_ID=116&CatMenu_ID=58&PriMenu_ID=114&CatMenu_Name=Publications&PriMenu_Name=Publications.

GCC.[34] It is worth noting that gas is less abundant in the remaining six emirates of the UAE, where expensive oil-based fuels have been required to meet electricity demand. In those emirates, utilities have raised electricity prices to cost-reflective levels on all customers except citizens, whose political prominence provides the justification for continued subsidies.[35]

Table 4. Abu Dhabi Electricity Tariffs and Subsidies in US Cents/kWh, Compared with Average 2011 US Rates

Abu Dhabi Customer Category	Tariff (US cents/ kWh)	2011 Gov't cost (in US cents)	Subsidy (US cents)	Gov't % paid	Avg. 2011 US price
Residential-citizen	1.4¢/kWh	8.7¢/kWh	7.4¢/kWh	84%	11.8¢
Residential-expatriate	4.1¢/kWh	8.7¢/kWh	4.6¢/kWh	53%	11.8¢
Commercial	4.1¢/kWh	8.7¢/kWh	4.6¢/kWh	53%	10.3¢
Industrial	4.1¢/kWh	8.7¢/kWh	4.6¢/kWh	53%	6.9¢

Source: ADWEC, RSB, EIA, interviews

What portion of electricity demand can be attributed to subsidy? How would cost-reflective prices affect long-run consumption? A basic estimate can be derived through a price elasticity calculation. Looking ahead, Abu Dhabi's utility forecasts electricity demand to more than double from 62 TWh in 2011 to 152 TWh in 2025.[36] A price increase of 112% would be required to raise electricity rates (for expatriates) to cost-reflective levels, from 4.1 US cents to 8.7 US cents. A 112% increase in prices, in turn, would cause demand to drop by an amount determined by the level of price elasticity among electricity consumers in Abu Dhabi. Taking a plausible price elasticity estimate of -0.4,[37] Abu Dhabi's projected 2025 demand of 152 TWh would be reduced by 26%, to 112 TWh. (See annex for calculations.)

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[34] Mohsen Mehrara, "Energy consumption and economic growth: The case of oil exporting countries," *Energy Policy* 35 no. 7 (2007): 2939–2945.
[35] Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah, and Fujairah. Note that customers paying cost-reflective tariffs appear to be cross-subsidizing citizens.
[36] Miller, "ADWEC Winter 2012/2013," p. 17.
[37] The price elasticity estimate of -0.4 represents a middle range estimate from a survey of the literature. Estimates range from -0.07 at the low end to -0.86 at the upper end. *See* Carol Dahl and Thomas Sterner. "Analysing gasoline demand elasticities: a survey," *Energy Economics* 13, no. 3 (1991): 203–210. *See also* Pedro Rodriguez, Joshua Charap, and Arthur Ribeiro da Silva, "Fuel Subsidies and Energy Consumption: A Cross-Country Analysis," *Kuwait: Selected Issues and Statistical Appendix*, (Washington: International Monetary Fund, 2012): 21–32.

Thus, subsidy accounts for about a quarter of demand among commercial customers and the expatriate community, which forms about 85% of Abu Dhabi's population. Subsidies are much larger for citizens and therefore account for a higher portion of their demand. A 112% increase in tariffs would raise citizen electricity rates from 1.4 cents to 3 cents per kWh, leaving intact most of the subsidy.[38]

Table 5. Power Demand in 2025 in Business-as-usual (BAU) Case and with a Reduction in Subsidy

Abu Dhabi power demand growth with and without cost-reflective pricing	
2011 power demand (TWh)	62
2025 power demand BAU (TWh)	152
Price increase to displace subsidy (%)	112
Drop in demand at -0.4 price elasticity (%)	-26
2025 Power demand with no subsidy (TWh)	112
Savings in TWh in 2025	40
Savings in BOE (MMb/year)	24

(Source: ADWEC and author calculations)

Supply Diversification Amid Competition for Gas

Rising power demand has outpaced the construction timetable of Abu Dhabi's major alternative energy investment, nuclear power. In December 2009, Abu Dhabi announced it had accepted the $20.4 billion bid of a South Korean consortium to build four 1.4 GW nuclear power stations, to be completed sometime after 2020. Supply of natural gas feedstock was already falling short of demand in 2010, years before Abu Dhabi's nuclear power plants came on-stream. The supply gap in 2010 and 2011 was filled by burning expensive diesel fuel, the chief backup fuel for the emirate's CCGT-dominated generating fleet.[39]

[38] Charging citizens a cost-reflective tariff in Abu Dhabi would require a price increase of more than 500% and result in a drop in demand greater than 50%.
[39] Abu Dhabi energy official interviewed on condition of anonymity, March 2012. Note that multiple officials interviewed for this paper requested anonymity due to the sensitivity of the information and the terms of their

As the domestic gas shortage tightened, competition for supply pit Abu Dhabi's national oil company (ADNOC) against the Abu Dhabi Water and Electricity Authority (ADWEA), the state utility. With demand for power and water rising relentlessly, ADWEA by 2010 was unable to source sufficient natural gas from ADNOC. ADNOC rejected requests for additional gas due to its own enhanced oil recovery (EOR) needs, which requires gas re-injection to maintain sufficient pressure in producing oilfields. EOR gas demand has also been growing quickly, increasing by 47% between 2004 and 2008.[40] ADWEA was thus forced to burn oil-based backup fuels.[41] In the summer of 2011, with prices at $120/barrel, ADWEA's diesel costs reached into the hundreds of millions of dollars. Fixed electricity tariffs meant these costs could not be passed to consumers.

Table 6. Abu Dhabi 2011 Feedstock Consumption and Estimated Cost

Fuel type	Consumption (MMBtu)	% of total	$/MMBtu	Cost
Natural gas	623,359,115	96.3	$1.50*	$935 million*
Diesel (gas oil)	17,571,198	2.7	$20.69	$363 million
Crude oil	6,061,648	0.9	$22.00*	$133 million*
Total	**646,991,961**			**$1.4 billion**
Average 2011 fuel cost per MMBtu = $2.21*				
(*author estimate)				

Source: Platts, ADWEC, author interviews

The only public hint of the gas conflict appeared in a news release by the UAE state news agency describing a restructuring of the Abu Dhabi Supreme Petroleum Council, led by Abu Dhabi Emir Sheikh Khalifa bin Zayed al-Nahyan. The Abu Dhabi crown prince, Sheikh Mohammed bin Zayed al-Nahyan, half-brother of the emir, was appointed to the council and ADNOC Chief Executive Yousef Omeir bin Yousef was dismissed, replaced by Deputy CEO Abdulla Nasser al-

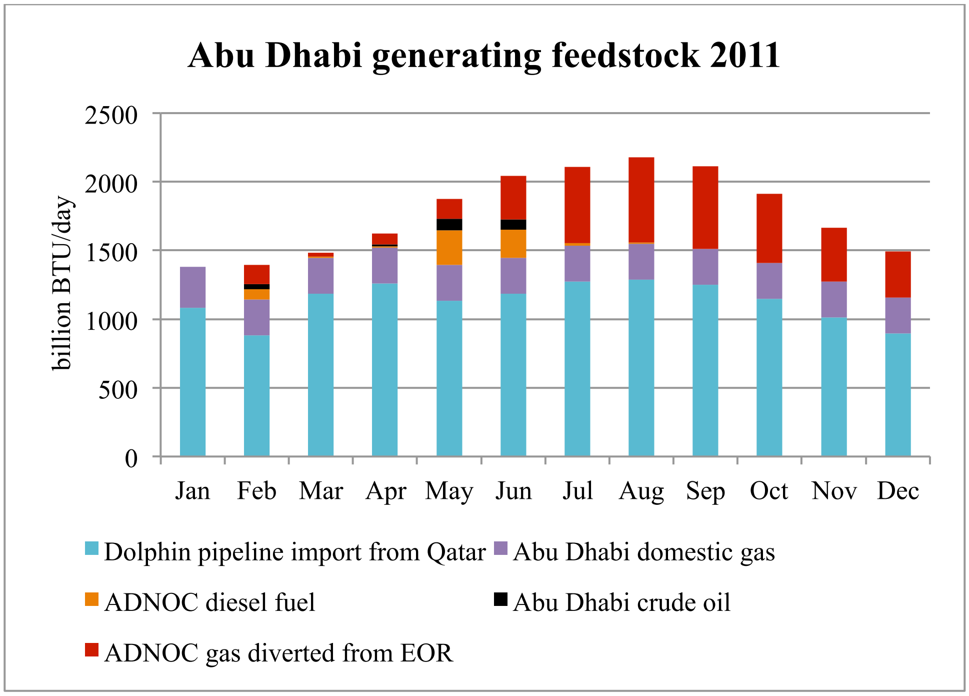
employment. It should be understood that material attributed to anonymous sources came from multiple officials and not a single source.

[40] Willis Energy Services, *A Study of Modes of Energy Consumption in the UAE: Combined Report and Final Draft*, (2011).

[41] This information was provided by an Abu Dhabi energy sector official on condition of anonymity.

Suwaidi.[42] The reshuffle resolved the gas conflict in favor of ADWEA. ADNOC immediately rerouted EOR-destined gas to the power sector. (See Figure 5.) The consumption of backup fuels ceased.[43]

Figure 5. Power-generating Feedstock Consumed in 2011



Source: ADWEC

The diversion of domestic gas is a temporary solution. In 2012, the emirate announced what appears to be its medium-term supply solution: An LNG import terminal on the UAE's east coast, where gas would be imported by 2014 to meet peak summer power generation needs.[44]

Other options appear to have been rejected. For environmental reasons, coal has not gained favor in Abu Dhabi.[45] The government also seeks to avoid using domestic crude oil as anything more

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42 The Supreme Petroleum Council, *Emiri Decree No. 1 of 2011*, June 25, 2011, http://www.adnoc.ae/Content.aspx?newid=24&mid=24.

43 This information was provided by an Abu Dhabi energy sector official in March 2012 on condition of anonymity.

44 Anthony DiPaola and Ayesha Daya, "Abu Dhabi Plans Fujairah LNG Plant to Bypass Hormuz Strait," *Bloomberg News*, March 20, 2012.

45 Abu Dhabi is unlikely to pursue coal because its high carbon emissions conflict with the spirit of its hosting agreement with the UN's renewable energy agency IRENA. However, neighboring Dubai invited bids in 2013 for construction of a 1.2GW coal-fired power plant.

than an emergency feedstock, since burning it implies a high opportunity cost in lost export revenue and faster depletion of the chief source of national income. In this environment, diversification of generating technologies made an attractive option. Policymakers in Abu Dhabi see development of nuclear and renewable electricity as a strategy to prolong the life and maximize the value of hydrocarbon reserves while reducing reliance on gas and protecting themselves from increasing import prices.[46] However, as this paper will now argue, Abu Dhabi's forthcoming renewables installation will be too small and unreliable to cover more than a marginal amount of the emirate's demand requirements.

Abu Dhabi's Renewables Investments

Abu Dhabi's rulers, especially its crown prince Sheikh Mohammed, have taken a proactive approach to the international climate change agenda, breaking with the OPEC line of treating carbon reduction as a threat to exports. The institution behind this strategy is the Abu Dhabi Future Energy Co., or Masdar, which aims to leverage clean energy investments to create jobs, diversify the oil-dependent economy, and improve the emirate's image.

Masdar was unveiled in 2006 amid announcements of $15 billion in government funding for its business unit and sundry clean energy projects.[47] Masdar's various arms were to include a zero-carbon-emitting city for 40,000 residents and 1,500 businesses, a carbon management unit, a clean technology investment fund, and a graduate school affiliated with the Massachusetts Institute of Technology. Masdar CEO Sultan Ahmed al-Jaber said in 2007 that Masdar enjoyed "an unlimited budget for renewable energy projects."[48] This exuberance was short-lived. Masdar's ambitions were scaled back after the 2009 recession, and several projects were cancelled or downsized. Among the victims was Masdar City itself, which saw its zero-carbon

[46] See analysis in UAE nuclear whitepaper: Government of the United Arab Emirates, *Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy* (Abu Dhabi: Government of the United Arab Emirates, 2008).
[47] "Abu Dhabi Commits US$15 Billion to Alternative Energy, Clean Technology," *Middle East and North Africa Business Report*, January 21, 2008.
[48] Himendra Mohan Kumar, "Phase one of Masdar City to be ready before 2010," *Gulf News*, October 28, 2007, http://gulfnews.com/business/construction/phase-one-of-masdar-city-to-be-ready-before-2010-1.119793.

promise dropped as too expensive. The city's size was reduced and completion date pushed back. Also shelved was a 400 MW hydrogen power plant that was to have been built jointly with BP.[49] The downsizing did not reduce the reputational benefits that Abu Dhabi began to accrue shortly after Masdar's launch. For example, in 2009, before virtually any of Abu Dhabi's clean energy plans had been realized, the emirate won the honor of hosting a UN agency, the International Renewable Energy Agency. IRENA became the first global organization headquartered in the Middle East. Abu Dhabi beat out front-runner Germany—despite the UAE's dismal environmental record—using intense diplomacy and promises of $135 million in support, including a headquarters building in Masdar City.[50] Thus, it appears that Abu Dhabi has been able to capitalize on its clean energy goals without actually reaching them.

Luomi writes that IRENA's presence implies a commitment of the emirate's fossil fuel revenues toward renewables.[51] In return, ruling elites receive international prominence that sends an important signal to the domestic audience. As mentioned, recognition as an effective handler of foreign affairs is, alongside welfare benefits, a key pillar of public support for the unelected rulers of rentier states.[52] Abu Dhabi's actions have been held out as a model for the region, and other Gulf states have followed with similar renewables targets.[53] Prestige enhancements for the regime increase the attractiveness of renewables, despite the weak economic case for investment.

How significant are Abu Dhabi's plans? In global terms, a goal of generating 2.5% of total power by renewable means is a modest one. In 2009, Austria produced 78% of its electricity from renewable sources, mainly hydroelectric, and Denmark produced 30%, mainly from wind. But Abu Dhabi's target appears more ambitious when measured against low levels of clean energy investment in the developing world—especially the Middle East—and given the fact that

[49] "BP and local partner shelve hydrogen power project in Abu Dhabi," *The Oil Daily*, January 14, 2011. See also *Hydrogen Power Abu Dhabi (HPAD),* accessed May 13, 2010, http://www.zeroco2.no/projects/masdar-precombustion-ccs-project.
[50] Mari Luomi, "Abu Dhabi's Alternative-Energy Initiatives: Seizing Climate-Change Opportunities," *Middle East Policy* 16 no. 4 (2009): 102–117.
[51] Ibid.
[52] Nonneman, "Determinants and Patterns of Saudi Foreign Policy."
[53] Kuwait and Iran have also set renewable generation targets of 5% and 2 GW of capacity, respectively. *See* "FACTBOX: Renewable energy targets around the world," *Reuters*, January 28, 2010, http://www.reuters.com/article/idUSTRE60R46320100128.

under the UN's Framework Convention on Climate Change the UAE is under no obligation to reduce its emissions.

Of the 1,500 megawatts in renewables required to meet Abu Dhabi's declared goal, only 110 MW of capacity was functioning at the time of writing. Most of this was encompassed by the $700 million Shams I project, a 100 MW concentrating solar power (CSP) plant, which uses a square-mile array of mirrored parabolic troughs to concentrate solar energy and drive a turbine.

To reach its goal, Masdar must install an additional 1,390 MW of renewables in six years, about 230 MW per year. The specifics of that installation remain in flux. Shams I was expected to be the first of a three-phase CSP array, producing a total of 300 MW or 20% of Abu Dhabi's renewables target.[54] Levelized cost of electricity generated is estimated as high as 40 US cents per kWh—as much as six times the cost of conventional power. Shams I also lacks an electricity storage capability featured in CSP installations elsewhere. Instead, the plant is equipped with a conventional, albeit inefficient, gas-fired steam turbine that can provide 50 MW of the plant's 100 MW peak capacity, allowing it to dispatch power during Abu Dhabi's peak evening period. An Abu Dhabi utility official said in 2012 that disappointing performance and high costs of Shams I cast doubt on the viability of the next two phases.[55]

Masdar has received construction bids for a second solar generation scheme, a 100 MW photovoltaic (PV) project titled Nour I, near the inland oasis city of Al Ain. The installation was expected to cost around $350 million and produce power for 15–20 US cents per kWh.[56] Abu Dhabi has also commissioned a trial project of 2.3 MW of rooftop PV panels, which, if successful, could be expanded to 200 MW.[57]

[54] Chris Stanton, "New solar power plant for Abu Dhabi," *The National*, June 9, 2010.
[55] This information was provided in March 2012 by an Abu Dhabi energy sector official on condition of anonymity.
[56] The 15–20 cents estimate comes from two interview sources, including Vahid Fotuhi of the Emirates Solar Industry Association, in April 2012. *See also* Robin Mills, *Sunrise in the Desert: Solar becomes commercially viable in MENA* (Dubai: Emirates Solar Industry Association and Pricewaterhousecoopers, 2012).
[57] UAE energy analyst, interview by author, March 23, 2010. Information provided on condition of anonymity.

As understanding of performance has grown, electricity sector officials in Abu Dhabi have altered their visions of the renewables installation from a CSP-dominated one to a technology mix including PV, wind, and waste-to-energy[58] generation.

Table 7. Abu Dhabi's Renewables Announcements in the Context of its 2020 Goal

The road to 1500 MW: Abu Dhabi renewables announcements			
Site	**Amount**	**Completion date**	**Cost**
Masdar PV array	10 MW	In operation	n/a
Shams I CSP	100 MW	In operation	$700m
Nour I PV	100 MW	2014-15	$350m
Shams II and III CSP	200 MW	?	?
Nour II and III PV	200 MW	?	?
Rooftop PV	200 MW	?	?
Sir Bani Yas wind	30 MW	2014-15	?
Saudi border wind	100 MW	?	$200m
Waste-to-energy*	300 MW	100 MW by 2016	?
Total announced	**1340 MW**		
Deficit remaining	**160 MW**		
(* not fully renewable)			

Source: Press reports, interviews

Wind Power

Abu Dhabi's resource advantages did not initially appear to extend to wind. The emirate's wind resource is rated "poor" or "marginal" by the US Department of Energy[59] with average wind speeds below 4.5 meters per second,[60] providing the lowest generating potential of the six GCC

[58] The renewable content of incinerated waste is unclear since waste streams carry non-renewable materials, including a plastics content of around 40%.
[59] US Department of Energy, National Renewable Energy Laboratory, *United Arab Emirates: 50m Wind Power* (map), 2008, http://www.nrel.gov/gis/images/international_wind/ae_50mwind.jpg.
[60] Konstantinos D. Patlitzianas, Haris Doukas, and John Psarras, "Enhancing renewable energy in the Arab states of the Gulf: Constraints and efforts," *Energy Policy* 34, no. 18 (2006): 3719–3726.

countries.[61] An 850 kilowatt-capacity wind turbine installed on Sir Bani Yas Island in 2008 receives average wind speeds at turbine level of just over 5 m/sec,[62] among the lowest of any offshore wind turbine in the world.[63] By contrast, average wind speeds at UK offshore turbines in the North Sea run over 10 m/sec.[64] The capacity factor of the Sir Bani Yas turbine, at under 15%, is also well below the typical 20–40% for offshore wind.[65] Despite this, Abu Dhabi officials have pressed ahead with a small development of 20–30 MW on Sir Bani Yas Island.

ADWEA's resource assessments in remote inland areas and along the Indian Ocean coast found unexpected wind speeds near 6 m/second, enough to produce power at a similar price to that of PV solar generation.[66] Masdar followed this finding by announcing the possibility of a 100 MW wind farm near the Saudi border.[67]

Problems with Renewables

It is clear that Abu Dhabi's ambitious renewables plans have encountered difficulties. More significant than the issues related to generating efficiency is the subsidized distribution model, characterized by fast-growing and wasteful consumption. This would seem a more appropriate setting for energy efficiency measures than for supply-side efforts that significantly raise costs. Renewables will substantially increase the government's subsidy burden unless tariffs are also raised.

Another problem pertains to the mismatch between solar generation and Abu Dhabi's power demand profile. The typical summer electricity demand curve for a city in the lower Persian Gulf

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[61] W. E. Alnaser and N. W. Alnaser, "Solar and wind energy potential in GCC countries and some related projects," *Journal of Renewable and Sustainable Energy* 1, 022301 (2009): 1–28.
[62] Joachim Käufler, *Umwelt Dienstleistungen: Win-Win Potenziale und Exportchancen fur Deutsche Unternehmen—Wind Power Application in Abu Dhabi (UAE)* (Berlin: SYNLIFT Systems, 2007). See slides at: http://www.umwelt-dienstleistungen.de/vortraege/AG1_5_Joachim_Kaeufler.pdf.
[63] 4C Offshore, "Global Wind Speed Rankings," accessed June 22, 2010, Global Offshore Wind Farms Database, http://www.4coffshore.com/windfarms/windspeeds.aspx.
[64] Ibid.
[65] Wind Energy Center, University of Massachusetts at Amherst, "Wind Power: Capacity Factor, Intermittency, and what happens when the wind doesn't blow?" (Amherst: Wind Energy Center, University of Massachusetts at Amherst).
[66] Bruce Smith, remarks at MEED conference (Abu Dhabi, March 7, 2012).
[67] April Yee, "Masdar plan for $200m pioneering wind farm," *The National*, April 27, 2011, http://www.thenational.ae/business/energy/masdar-plan-for-200m-pioneering-wind-farm.

reveals two daily peaks. The first comes at midday, when the sun is overhead. The second peak comes after sundown in the early evening, when Gulf humidity effects are at their most intense. Solar radiance is well matched to the first peak, but not the second.[68] Therefore, Abu Dhabi would not be able to deploy solar power capacity *in lieu of* conventional generation capacity, making it unable to forgo the cost of building and operating conventional power plants. Solar power would merely allow the emirate to *reduce its fuel consumption*. Wind power, given its intermittency and weak resource, may also amount to an expensive fuel-saving option in the UAE environment, rather than a capacity addition.[69]

Other GCC-specific issues have caused delays and raised costs. Miller and Coan documented several costly externalities, including stipulations requiring developers to purchase expensive local content, a lack of installation experience, higher cost of capital, and a tendency for market guarantees and unlikely bankruptcy prospects to drive up costs. Their paper also found a disappointing summertime drop in direct solar radiation in the UAE and Qatar—during the season of peak demand—due to dust and humidity haze.[70] Atmospheric conditions reduce electricity production for PV by about 10%[71] and CSP by up to 20%.[72] Prevalent dust accelerates solar panel degradation, shortens project lifetimes, and drives up maintenance costs through frequent cleaning using desalinated water.[73]

On the positive side, Abu Dhabi's advantages include plentiful sunshine and empty state-owned land near population centers that could be given over to solar generation. Its propensity to build utility-scale projects ought to further reduce long-term electricity costs. Further, the cost of PV solar infrastructure has dropped in recent years. Mills found that large-scale PV solar installations in the Gulf context could produce electricity for a levelized cost of electricity

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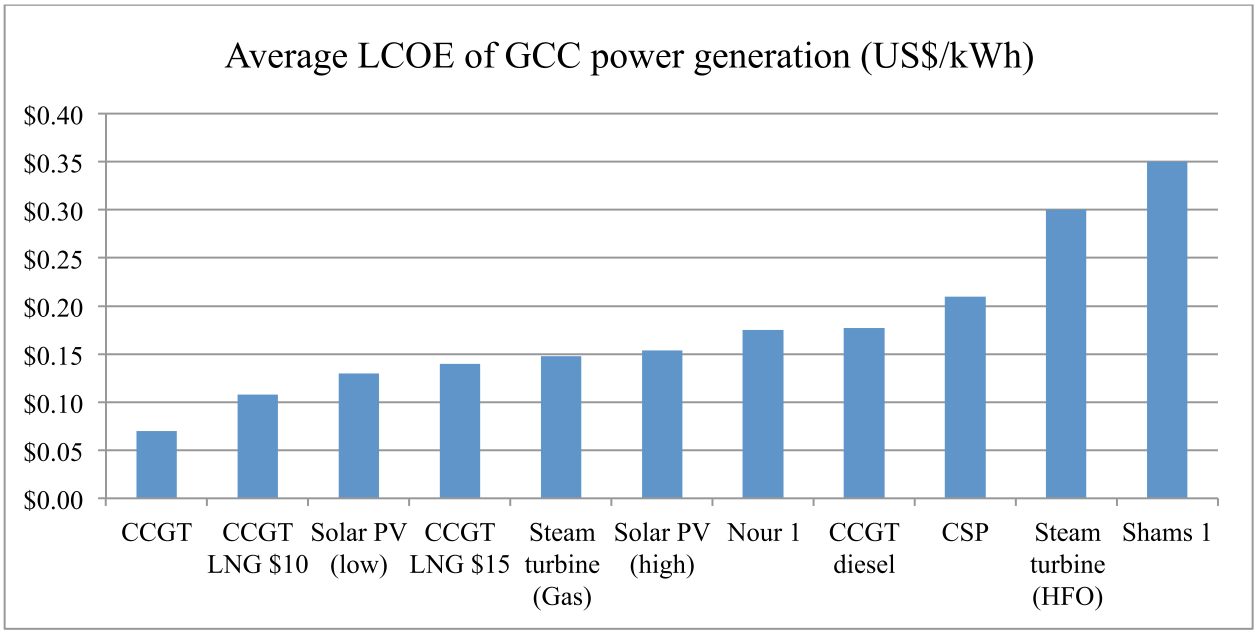
[68] CSP typically allows for some thermal storage that could be effective in covering the evening peak.
[69] M. A. Darwish, "Prospect of using alternative energy for power and desalted water productions in Kuwait," *Desalination and Water Treatment*, 36 (2011): 219–238.
[70] Keily Miller and James Coan, "Current Competitiveness of Solar Investment in the GCC Power Sector," research paper (Houston: James A. Baker III Institute for Public Policy, Rice University, 2012).
[71] Chris Stanton, "Masdar's solar panel plant seeks policy jolt," *The National*, January 21, 2010. Note that crystalline PV experienced degrading of 22% of its effectiveness in Abu Dhabi's summer conditions.
[72] Chris Stanton, "Dust a factor in best solar power option for emirate," *The National*, October 22, 2009.
[73] Abu Dhabi's CSP plant employs various modifications to cope with the dust and unavailability of water, including a wind-screening fence, frequent cleaning of mirrors using treated wastewater, and a turbine that is cooled by air, rather than water. *See* Yousif Al-Ali, "Masdar Power," accessed April 12, 2012, http://www.eugcc-cleanergy.net/LinkClick.aspx?fileticket=ArXM_6fmnMo=&tabid=296&mid=1027.

(LCOE) of 15.4 US cents per kWh over a 20-year lifetime. Thus, he argues, solar is cost-competitive with conventional power when fuels such as diesel, crude oil, or LNG are priced above $80/barrel or $13/MMBtu.[74] Miller and Coan produced even lower LCOE for PV, which is shown in Fig. 7 along with other estimates. As these estimates show, had significant PV solar capacity been available in 2011, the emirate would have been able to reduce its $364 million diesel bill.

Figure 6. Average Levelized Cost of Electricity for Various Technologies and Fuels



Source: Miller and Coan; Mills; author interviews

However, even at such high costs, fuel savings alone are insufficient to justify the cost of a PV solar installation that simply duplicates the capacity of an existing gas turbine plant. Abu Dhabi's *average* fuel cost in 2011 was around $2.11/MMBtu. A solar installation would ideally be used to replace some of the expensive diesel burn, but over an entire year solar would mainly be offsetting cheaper natural gas. Solar power might also indirectly replace diesel fuel or, in coming years, LNG if the natural gas it replaces is then used to cover evening peak periods when solar is unavailable. However, the undeniable requirement for duplicate fossil generation capacity remains.

[74] Mills, *Sunrise in the Desert*.

Perhaps with a similar conclusion in mind, Abu Dhabi announced its intention to begin importing LNG around 2014.[75] LNG was cheaper at 2012 prices than diesel, which averaged $21 MMBtu. As a guide, Kuwait paid $15 MMBtu for LNG cargoes in 2011,[76] although an Abu Dhabi utility official told this author in 2012 that the emirate would be able to source long-term LNG supplies for $10–12 MMBtu.[77] And perhaps most importantly, LNG can replace diesel within the same CCGT plants. Thus, no additional capital investment is required.

Abu Dhabi makes a less attractive market for solar power for another reason: It will produce nuclear-generated electricity toward the end of the decade at a price that is expected to undercut even the lowest LCOE for solar power.[78] Thus, current requirements for backup fuel are expected to be temporary.

More attractive locales for PV solar can be found in Gulf electricity markets dependent upon higher-cost generating feedstock. Kuwait is one. Kuwait's prevailing humidity tends to be less severe than that in the lower Gulf. Thus, Kuwait's daytime peak electricity load occurs near 3 p.m., which corresponds more closely to solar power production. Kuwait also produces 70% of its power by burning liquid fuels, including crude oil, diesel, and heavy fuel oil.[79] The implied opportunity cost for crude oil was $22/MMBtu in 2011, meaning that substantial savings could have been realized by generating with PV solar and exporting that crude. Kuwait also imports LNG at a cost near parity with PV solar. And finally, unlike Abu Dhabi, Kuwait has rejected nuclear power as a future generation option.

Energy security in Abu Dhabi remains firmly tied to its conventional plants and natural gas feedstock, most of which is imported from Qatar.[80] Several of these plants also serve the vital dual purpose of generating desalinated water. By contrast, Abu Dhabi's renewable energy

[75] DiPaola and Daya, "Abu Dhabi Plans Fujairah LNG Plant."
[76] Kuwait LNG import price is from *Petroleum Economist* 78, issue 9 (2011), http://www.petroleum-economist.com/Article/2912531/Kuwaits-growing-need-for-LNG-imports.html.
[77] Abu Dhabi energy official interviewed by the author on condition of anonymity, March 2012.
[78] David Scott of Abu Dhabi Executive Affairs Authority estimates that Abu Dhabi's nuclear power will be competitive with gas-fired power at a gas price of $10/MMbtu, perhaps as low as $8/MMBtu. Interview by author, November 11, 2010.
[79] International Energy Agency, "Energy Statistics," *Gross Electricity Generation by Fuel: Kuwait* (2011).
[80] Some 60–80% of ADWEA's natural gas feedstock is imported from Qatar via the Dolphin Pipeline.

installations will neither produce water, nor provide an appreciable diversification of electricity production or a reduced reliance on imported fuel. The renewables deployment will be too small to provide much reduction in carbon emissions growth. These deficiencies will only be substantially addressed after the first nuclear generation plant enters service toward the end of the decade.

Discussion: Improving Policy

Renewables, in the Abu Dhabi context, provide an inefficient route to meeting energy policy goals. A demand-side management program based upon increases in energy prices offers a more sensible approach to rising demand in Abu Dhabi.

A rapid increase of all energy prices to cost-reflective levels would certainly accomplish some of these goals. As shown above, subsidized prices alone account for about a quarter of electricity demand. But an across-the-board rationalization would also damage—perhaps irreparably—the political legitimacy bestowed by Abu Dhabi's citizens on their ruling elites. If subsidy reform experiences elsewhere are a guide, Abu Dhabi risks serious political unrest (along with inflation, damaged business competitiveness, and other economic effects) if subsidies are abruptly eliminated.

Until recently, Abu Dhabi officials have said that increasing costs of generation associated with renewables would not be passed along to residential customers.[81] The government instead emphasized pursuit of efficiency through its *Estidama* initiative of tightened building standards. However, if prices were raised on customers who remain outside the influential "selectorate" circles[82] that remain crucial in providing political support for the ruling family, many of these goals might be accomplished without serious ructions in state-society relations. At the time of

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[81] Nick Carter, director-general of Abu Dhabi Regulation and Supervision Bureau, the emirate's electricity regulator, quoted in: Chris Stanton, "Green subsidy for solar power," *The National*, June 9, 2010, http://www.thenational.ae/apps/pbcs.dll/article?AID=/20100609/BUSINESS/706099928/1053.

[82] For an explanation of selectorate theory see Bruce Bueno De Mesquita, James D. Morrow, Randolph M. Siverson, and Alastair Smith, "Political Institutions, Policy Choice and the Survival of Leaders," *British Journal of Political Science* 32 (2002): 559–590.

writing, the country's energy minister had suggested as much, saying that the government sought to revise prices "to direct the subsidies to those who need them."

In this case, "need" for subsidy appears to be based upon political, rather than financial, criteria. UAE Energy Minister Suhail al-Mazrouei,suggested that expatriate households, despite paying higher prices and consuming less than UAE nationals' households (see Table 3), were still using more electricity in the UAE than they had in their home countries. He singled out generally poorer expatriates for most of the "misuse of energy" and advocated increased electricity tariffs for expatriates as a demand-reduction measure. "Why do we subsidize if people continue to consume at high levels, especially expats?" al-Mazrouei said. "You will find expats consuming three times more than what they consume back home. Why? Because it is so cheap here."[83] As for citizens, he suggested that their accounts need not be touched since their consumption accounts for "less than 30%" of demand.[84]

However discriminatory such a targeted price increase looks in a democratic context, it makes eminent sense in the setting of a rentier autocracy. As mentioned, low prices are extended to citizens in exchange for political support for the regime. By contrast, expatriates tend to understand low prices as a windfall. Targeting demand of citizens therefore constitutes a high-risk undermining of regime legitimacy. The risk involved in targeting the consumption of expatriates, whom enjoy far less political clout, is much reduced.

Combined with efficiency goals already enshrined in the Estidama program, a reduction in energy subsidies could bring about savings in future energy demand that would more than offset the increases in supply and decreases in carbon growth associated with renewables. As shown above, subsidies account for roughly a quarter of power demand. Raising tariffs would also *generate* revenue for the state while reducing future capital investment in the power sector. By contrast, Abu Dhabi's renewables would provide only a marginal supply increase of 2.5%.

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[83] Summer Said, "U.A.E. Oil Minister: Cut Energy Subsidies to Lower Domestic Consumption," *Wall Street Journal*, January 21, 2014, http://blogs.wsj.com/middleeast/2014/01/21/u-a-e-oil-minister-cut-energy-subsidies-to-lower-domestic-consumption.

[84] "UAE residents may face new hike in energy bills – minister," *Reuters*, January 23, 2014, http://www.arabianbusiness.com/uae-residents-may-face-new-hike-in-energy-bills-minister-535859.html.

More broadly, a shift in the implementation of energy subsidies would also further Abu Dhabi's energy goals. Allowing natural gas prices to rise to market levels—with any remaining consumption subsidies shifted to end consumers—would spur increases in gas exploration and production and potentially lessen import dependence, with implications for enhanced energy security. Finally, rationalizing prices for expatriates and commercial customers could act as a prelude for a more provocative increase of prices on citizens. Neighboring Dubai did just that in 2011 while retaining a substantial citizen discount. Political fallout was minimal.

Conclusion

Faced with a growing shortage of natural gas and intensifying competition over insufficient domestic production, Abu Dhabi chose to make highly publicized investments into renewable energy. These investments are characterized by significant cost and effort that will provide only marginal help in meeting fast-growing electricity demand. This article has illuminated the economic and technological hurdles facing renewable generation despite the existence of a large and predictable solar resource. The solar-dominated systems chosen by Abu Dhabi do not appear capable of making significant contributions to electricity supply in a government-controlled market dominated by hydrocarbon-based technologies and subsidized tariffs. Further, the challenging climactic, geographic, and demand conditions appear beyond the design capacities of the technologies chosen.

Since Abu Dhabi's envisioned renewables configuration is unable to reliably meet daily peak consumption that occurs after sunset, the sheikhdom will be unable to forgo the capital investment and operating costs of duplicate conventional generating capacity. As such, the outlays required to build, operate, and maintain renewables plants will not be offset by the fuel savings that is their chief economic benefit. Further, a renewables portfolio that provides no more than 2.5% of overall electricity will be too small to appreciably improve energy security or to reduce carbon emissions or dependence on imported gas. And while Abu Dhabi is building expertise in renewables through its investments, the sector appears a long way from providing substantial diversification to its oil-dominated GDP.

However, the Abu Dhabi government has leveraged its investment to enhance its international prestige, recasting itself as a clean energy leader in OPEC and the developing world despite its slow on-the-ground progress. This benefit carries a high value in a traditional sheikhdom and should be understood within the political economy context of the rentier state, where external image enhancements translate into a strengthening of the regime's domestic legitimacy.

This paper argues that a demand-driven campaign to reduce energy consumption and penalize waste by raising tariffs would be many times more effective in stabilizing the energy balance than the tiny increase in generation capacity from renewables. Roughly a quarter of Abu Dhabi's electricity consumption can be attributed to excessively cheap prices, whereas renewables—if ambitions are realized—will contribute an additional 2.5% to supply. Increased tariffs could be managed within the political rules of a rentier tribal monarchy as long as a substantial gap remained between prices levied on citizens and those charged to non-citizens and commercial customers.

Annex: Price Elasticity Calculation

This paper uses a simplification of the demand equation $q_{i,t} = \alpha\gamma t \quad A_i y_{i,t}^{\delta} p_{i,t}^{\beta}$ from an IMF paper authored by Rodriguez et al., where $q_{i,t}$ denotes energy demand of country i at time t; α denotes a constant; y_t denotes technology; A_i denotes country-specific factors such as weather; $y_{i,t}$ denotes the real income of country i at time t; $p_{i,t}$ denotes the real price of energy; δ is the income elasticity of energy demand; and β is the (negative) price elasticity of energy demand.[85] In the case of Abu Dhabi, where energy prices for expatriates (by the government's account) would need to rise from 4.1 cents/kWh to 8.7 cents/kWh or by 112% to account for the opportunity cost of foregone revenue, the demand adjustment is calculated as follows:

Conforming to the equation above, elasticity is derived by: $\frac{Y_1}{Y_0} = (\frac{P_1}{P_0})^{\beta}$, where β is the price elasticity, in this case a plausible mid-range figure of -0.4. Given the required 112% increase in prices, $\frac{P_1}{P_0} = 2.12$, which, raised to power of -0.4, equals 0.74; this means $\frac{Y_1}{Y_0} = 0.74$. It thus

[85] Rodriguez, Charap, and Ribeiro da Silva, "Fuel Subsidies and Energy Consumption," p. 24.

follows that a 112% increase in price leads to a long-run drop in demand of 100*(1-0.74), or 26%. Note that the large increases in energy price required to reach cost-reflective levels requires use of this non-linear function, rather than the simpler linear price elasticity function.