Renewable energy and resource curse on the possible consequences of solar energy in North Africa

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Chapter 8. Solar Energy Prolonging the Resource Curse?

8.1 The Possible Impact of the Projected Solar Energy Rent

The aim of this thesis has been to project the chances of the five North African countries to suffer from a solar energy curse in the future. In chapter 6, the current resource curse and possibility of a solar energy curse is projected by comparing the institutional quality of the five North African countries and ten boundary-countries. As seen in table 30, in general, the five North African countries have poor institutional qualities which suggest that the North African energy exporters may already be suffering from the resource curse, and all five North African countries have the potentials to suffer from a solar energy curse if their institutional qualities are to remain poor in the future. In chapter 7, on the other hand, the solar energy rent is projected in various ways and compared to the average oil and natural gas rent sizes of the MENA countries during the period of 1993-2009 in order to see whether the solar energy rent will be as high as the current fossil-fuel rent sizes. Although different approaches in comparing the projected solar rent size and fossil-fuel rent size are made in chapter 7, the projected solar rent size is not likely to exceed, or even be close to, the average fossil-fuel rent sizes (1993-2009) that the North African energy exporters, or the MENA energy exporters receive in recent years. Also, when the individual country's projected solar rent size is compared to the average fossil-fuel rent sizes, both the energy exporters and importers are not likely to receive enormous amount of rent from solar electricity exports.

When one combines the results from chapter 6 and 7, a simple conclusion may be that the five North African countries are less likely to suffer from a solar energy curse, even if the poor institutional quality remains, as the projected solar energy rent size is not as much as the fossil-fuel rent sizes. However, one should not underestimate the chances of the projected solar rent sizes to increase in the future. As mentioned in chapter 3, there are ideas that oil production is at its peak. Of course, if one is to face the declining amount of world oil, based on an assumption that oil demand remains high, the value of the oil could increase and the oil rent size will also likely to increase. However, the world is realizing the importance of the renewable energy, and there are many strategies, such as Europe's 20/20/20 climate/energy target mentioned in section 3.1, created to expand the use of renewable energy. Of course, the five North African countries are also targeting to increase the share of renewable energy as presented in table 4. Furthermore, a number of studies which this thesis' projection is based on, especially focusing on EUMENA, predict that 90-100 percent of electricity can be provided from renewable energy in 2050. If this projection is to

materialize, it means that the need for electricity via renewable energy has to increase. In this case, as the need for fossil-fuels declines, or may no longer be abundant, the price of renewable energy may rise as they will be the main sources for electricity generation. Consequently, solar energy and other renewable energy rent sizes can increase. When excluding these possibilities, however, if one is to perceive the cause of the resource curse as the combination of the poor institutional quality and enormous rent size from the natural resources, the results from chapter 6 and 7 suggest that there is little chance that the North African countries will suffer from a solar energy curse..

Despite above scenarios, one should not forget about the current resource curse. Of course, it is an important task to see whether solar energy, or other renewable energies, can become a curse. However, as the solar energy market in North Africa is still in its initial stage, and there can be various changes in the future, it may take a while for one to see whether solar energy will become a curse or not. Of course, if it is to become a curse, one should find a way to avoid/prevent it.

As measured in chapter 6, it is found that the North African energy exporters may be suffering from the resource curse. Also, it is found that the projected solar energy rent size may be similar or exceed the natural gas rent size in chapter 7. As the resource curse is present, and is a current issue, one should also pay attention to what kind of impact the successful solar energy establishment in the North African countries can have on the current resource curse. Accordingly, this section will project what kind of impact the projected solar energy rent size, which may be similar or exceed the natural gas rent, can have on the current resource curse.

8.2 North African Countries and their Heavy Reliance on Fossil-Fuels in Generating Electricity

The projected solar energy rent size obtained in chapter 7 shows that there is a possibility that it can exceed the natural gas rent size such as in Algeria. The projected solar energy rent size does not appear high enough to be considered as a great threat for solar energy to become a new curse. However, one can also ask what kind of impact this solar energy strategy will have on the North African energy exporters. In other words, the finding that the projected solar energy rent will be similar, or only slightly exceeding, to the recent average natural gas rent in the region, and the possibility that the energy exporters still have, though unsure of how much and how long, remaining fossil-fuels to export in the future can open up new perspectives on the current resource curse itself.

By looking at the projected solar rent size, one can predict that the successful establishment of the solar energy strategy does not mean that the North African energy exporters will switch their heavy reliance on exporting fossil-fuels to exporting solar electricity. In other words, the current

resource curse will not simply vanish as a result of the establishment of solar energy.

For example, though based on an assumption that the fossil-fuel will remain in the future, the rent-seeking behavior could continue to remain in the resource cursed countries that are heavily relying on exporting fossil-fuels for their economies because the rent from fossil-fuels is much higher than the projected solar energy rent. Therefore, this section will hypothesize a situation under the assumption that there will be a successful establishment of solar energy in the North African countries, and project the possible impact it can have on the current resource curse.

As mentioned earlier, the five North African countries have enormous potentials to produce/export electricity, and meet its demand, via solar energy. However, as the solar energy plan is not fully established in the five North African countries, solar energy is not yet the main source that satisfies their electricity demand.

The five North African countries, and also many MENA countries, have been meeting their electricity demand via, whether their own or imported, fossil-fuels such as coal, natural gas, and oil. The heavy reliance on the fossil-fuels to generate electricity in the five North African countries can be perceived from table 56, which shows their total electricity production via coal, natural gas, and oil during the period of 2004-2009, presented below.

Table 56: Electricity Production via Coal, Natural Gas, and Oil in the Five North Countries 2004-2009

	2004	2005	2006	2007	2008	2009
Algeria	99%	98%	99%	99%	99%	99%
Egypt	87%	88%	88%	87%	88%	90%
Libya	100%	100%	100%	100%	100%	100%
Morocco	90%	94%	94%	95%	94%	85%
Tunisia	98%	99%	99%	99%	100%	99%

Source: World Development Indicators (WDI)

As mentioned earlier in section 7.2.2, according to Schellekens et al. (2010, p.15), the electricity demand for North Africa in 2050 is projected to be 1250 TWh/y, and the projected amount of electricity produced in North Africa is 2000 TWh/y via renewable energy. In other words, if the solar energy plan, and other renewable energy, is settled in the region with its full potentials, solar energy can be the substitution for all the fossil-fuels that are used to meet their electricity demand. Accordingly, an assumption can be made that the five North African countries could save their fossil-fuels, or save the money which is used to import fossil-fuels, which is used to produce electricity. In other words, the energy exporters could export more energy as they would have additional

resources under the circumstance that a vast amount of fossil-fuels would remain in the future, thus more revenues, and the energy importers could import less energy to produce electricity, thus, saving the money that would have been spent on importing energy.

Here, one should question whether solar energy as the substitution for the entire use of fossil-fuels in meeting their electricity demand is the most optimistic outcome for the North African countries with their current institutional quality. Especially for the North African energy exporters, if they are already considered to be affected by the resource curse, would the possibility that the North African energy exporters to export more energy, prolonging the period of time that they can rely on energy exports, bring a positive and beneficial outcome if their institutional quality remains poor in the future?

Of course, as seen earlier, a country does not have to be affected by the resource curse when heavily dependent on their energies/resources exports. However, coupled with poor institutional quality, the combination of more energy to export and prolonging the period of time for them to rely on the energy export may be harmful as this can mean prolonging the time that the energy exporters will suffer from the current resource curse. This possibility, again, highlights the importance of paying attention to the possible impacts of the successful solar energy plans establishment on the current resource curse in the five North African countries, especially for the energy exporters, instead of just focusing on projecting whether the solar energy itself will turn into a new curse. As this section is focusing on the potentially prolonged length of period that the countries to suffer from the current resource curse, the North African energy exporters will be more focused.

8.3 The Sources for the Electricity Production in the Five North African Countries

As mentioned earlier, the five North African countries can be divided into two groups as energy exporters and energy importers. If one is to divide the five North African countries more strictly, it can be also divided into three groups, the energy exporters (Algeria and Libya), the energy exporter/importer (Egypt), and the energy importers (Morocco and Tunisia). In order to find the impact of the solar energy establishment on the current resource curse, each country's energy status and sources for the electricity generation will be illustrated which can provide the base in calculating the extra revenues that the energy exporters can receive. The sources for electricity production of Morocco and Tunisia, though not the main purpose of this section, will also be illustrated in order to show how much the North African countries rely on fossil-fuels in meeting their domestic electricity demand in general.

Energy Exporters: Algeria and Libya

Algeria

Algeria is a member of OPEC and is an exporter both oil and natural gas. In 2010, the hydrocarbons sector of Algeria accounted for 60 percent of its budget revenues, 36 percent of its GDP, and about 97 percent of its export earnings. Algeria's estimated proven oil reserves, as of January 2012, was 12.2billion barrels which is the third largest reserves in Africa after Libya and Nigeria. It is estimated that 750,000 bbl/d of Algeria's crude oil was exported in 2011. As for natural gas, as of January 2012, Algeria has the tenth largest natural gas reserves in the world with 159 trillion cubic feet (Tcf). In 2010, it is estimated that the total of 1.97 Tcf natural gas was exported. Within the total exported gas, 65 percent of it was exported through the natural gas pipelines which connect Algeria with Italy and Spain, and 35 percent was exported by tanker in the form of LNG (EIA Country Analysis Algeria).

As can be seen from table 57, Algeria's power generation is dominated by natural gas. Natural gas produces 96-97 percent of Algeria's electricity. The electricity production of Algeria's national power sector was estimated 40 TWh, and consumption was around 33 TWh in 2008. The electricity generation increased about 8 percent compared to 2007 (Supersperger & Führer, 2011, p.4460).

Table 57: Electricity Sources for Algeria 2004-2009

Electricity Sources	2004	2005	2006	2007	2008	2009
Coal	0%	0%	0%	0%	0%	0%
Hydroelectric	1%	2%	1%	1%	1%	1%
Natural Gas	97%	96%	97%	97%	97%	97%
Nuclear	0%	0%	0%	0%	0%	0%
Oil	2%	2%	2%	2%	2%	2%

Source: World Development Indicators (WDI)

Libya

Libya is also a member of OPEC and is an exporter of both oil and natural gas. In 2011, it is estimated that oil accounted for about 95 percent of nation's export earnings and 75 percent its government receipts. As of January 2012, Libya's total proven oil reserves was of 47.1 billion barrels which is the largest endowment in Africa. It is estimated that around 300,000 bbl/d was domestically consumed, and net exports were estimated to be around 1.5 million bbl/d in 2010. In the case of natural gas, as of January 1, 2012, the estimated proven natural gas reserves were 52.8 Tcf. Furthermore, in 2010, it is estimated that around 242 billion cubic feet (Bcf) of dry natural gas was

consumed within the country, and Libya exported 352 BcF of natural gas (EIA Country Analysis Libya).

Libya's electricity production is heavily dependent on oil and natural gas. As can be seen from table 58, the nation's whole electricity is produced by oil and natural gas. Furthermore, from table 58, it is possible to see that the use of natural gas to produce electricity has been increasing, while the use of oil has been decreasing. This is due to the fact that the Libyan government plans to increase the nation's natural gas production in order to expand the use of natural gas in the power sector because this allows more oil export while maintaining and expanding existing pipe and LNG exports (EIA Country Analysis Libya).

Table 58: Electricity Sources for Libya 2004-2009

Electricity Sources	2004	2005	2006	2007	2008	2009
Coal	0%	0%	0%	0%	0%	0%
Hydroelectric	0%	0%	0%	0%	0%	0%
Natural Gas	19%	28%	41%	45%	41%	41%
Nuclear	0%	0%	0%	0%	0%	0%
Oil	81%	72%	59%	55%	59%	59%

Source: World Development Indicators (WDI)

Energy Exporter/Importer: Egypt

Egypt

The oil and natural gas sectors play a substantial role in Egypt's economy. Egypt used to be a net energy exporter until the late 1990s. However, their total oil production declined since its peak in 1996. Egypt's estimated proven oil reserves, as of January 2011, was 4.4 billion barrels. Nevertheless, Egypt's oil consumption is slightly higher than production, and Egypt imports small volume of oil in order to meet the domestic demand. Despite the decline in oil production, the export of crude oil increased from 95,000 bbl/d to 114,000 bbl/d between 2010 and 2011. On the other hand, in the case of natural gas sector, it is expanding fast with production tripling between 2000 and 2010. It is estimated that Egypt's proven gas reserves stand at 77 Tcf which is the third largest in Africa after Nigeria and Algeria. Egypt produced around 2.2 Tcf and domestically consumed 1.6 Tcf in 2010. Furthermore, Egypt exported around 535 Bcf of natural gas (EIA Country Analysis Egypt).

As can be seen from table 59, a substantial amount of natural gas is used to produce electricity. Electricity consumption has been steadily growing at an average rate of 7 percent annually over the last decade (Supersperger & Führer, 2011, p.4460).

Table 59: Electricity Sources for Egypt 2004-2009

Electricity Sources	2004	2005	2006	2007	2008	2009
Coal	0%	0%	0%	0%	0%	0%
Hydroelectric	12%	12%	11%	12%	11%	9%
Natural Gas	71%	74%	72%	68%	68%	69%
Nuclear	0%	0%	0%	0%	0%	0%
Oil	16%	14%	16%	19%	20%	21%

Source: World Development Indicators (WDI)

Energy Importers: Morocco and Tunisia

Morocco

Morocco is an energy importer which has almost no conventional oil or natural gas reserves. Morocco imported around 98 percent of their primary energy supply in order to satisfy the total energy consumption of 14.7 Million Tonnes of Oil Equivalent (Mtoe) in 2008. In 2008, the nation's GDP was US$86.5 billion, and the estimated amount of the cost for energy import was around US$9.2 billion which was 11 percent of the total GDP. Morocco relies heavily on coal imports, as can be seen from table 60, in order to meet the nation's electricity demand, and coal is expected to remain as the primary fossil-fuel used in power generation for the next decades (Supersberger & Führer 2011, p.4459).

Table 60: Electricity Sources for Morocco 2004-2009

Electricity Sources	2004	2005	2006	2007	2008	2009
Coal	70%	66%	66%	63%	56%	52%
Hydroelectric	9%	5%	5%	4%	4%	12%
Natural Gas	0%	10%	12%	14%	14%	13%
Nuclear	0%	0%	0%	0%	0%	0%
Oil	20%	18%	16%	18%	24%	20%

Source: World Development Indicators (WDI)

Tunisia

In 2007, Tunisia's total primary energy consumption amounted to 7.7 Mtoe where 14 percent of this was imported. Tunisia has some oil and gas reserves and used to be a net energy exporter until 2000. For example, the estimated national output of crude oil and condensates was 34.6 million barrels in 2007. In the case of the natural gas, Tunisia developed new domestic gas reserves in the

1990s. However, the country still remains as a net natural gas importer. The total domestic natural gas produced was estimated as 2.2 billion cubic meter (m^3), another 1.2billion m^3 received as royalties from the trans-Mediterranean gas pipeline, and the total consumption stood at 4.3 billion m^3 (Supersberger & Führer 2011, p.4459).

The nation's two main primary energy sources in consumption are petroleum products and natural gas. Especially in the electricity production, which can be observed in table 61, Tunisia relies heavily on natural gas. Furthermore, a steady increase in the energy and electricity demand has been seen between 2003 and 2008 on average by 5-6 percent per year (Supersberger & Führer 2011. p. 4459).

Table 61: Electricity Sources for Tunisia 2004-2009

Electricity Sources	2004	2005	2006	2007	2008	2009
Coal	0%	0%	0%	0%	0%	0%
Hydroelectric	1%	1%	1%	0%	0%	1%
Natural Gas	90%	91%	85%	83%	89%	90%
Nuclear	0%	0%	0%	0%	0%	0%
Oil	8%	8%	14%	16%	11%	9%

Source: World Development Indicators (WDI)

As can be seen above, the five North African countries rely heavily on fossil-fuels, whether their own or imported, in order to produce electricity. Most countries, except for Morocco, rely on the use of natural gas to meet their domestic electricity demands. Based on the date illustrated above, a hypothetical case study will be made in order to project how much of the possible additional resources that the energy exporters can export if the solar energy is to be successfully established in these countries.

8.4 Hypothetical Situation

As this section is trying to investigate the possibility of solar energy extending the current resource curse, it makes more sense to focus on the energy exporters; Algeria, Libya and Egypt. As mentioned earlier, Egypt is considered as both energy exporter and importer. In this section, Egypt will be considered as an energy exporter because this section is focusing on the extra revenues that the North African energy exports can get from their fossil-fuel exports due to the possible establishment of solar energy, and also the fact that natural gas is the main electricity source for

Egypt which they export. Furthermore, it must be mentioned that, though oil is still the main electricity source for Libya, natural gas consumption will be focused as the production of the electricity via natural gas has been growing in the country. Table 62 shows how the three North African energy exporters exploit their natural gas. As can be observed, they export a vast amount of natural gas.

Table 62: Natural Gas Production, Consumption, Export/Import, and Proved Reserves in the Three Energy Exporters (m^3)

	Production	Consumption	Exports	Imports	Proved reserves
Algeria	84.61billion (2010)	28.82billion (2010)	55.79billion (2010)	0 (2010)	4.502trillion (1 January 2012)
Libya	16.81billion (2010)	6.844billion (2010)	9.97billion (2010)	0 (2011)	1.495trillion (1 January 2012)
Egypt	61.33billion (2010)	46.16billion (2010)	15.17billion (2010)	0 (2009)	2.186trillion (1 January 2012)

Source: Central Intelligence Agency[96]

Although the purpose of this section is to find additional natural gas that can be exported or saved rather than consumed to meet the three North African energy exporters' domestic electricity demand, one needs to take a careful look at the details of the domestic consumption of natural gas. This is due to the fact that one can not say that the amount of domestically consumed natural gas, presented in table 62, was all used for one purpose. More specifically, for example, the domestically consumed natural gas is used in different sectors such as electricity sector, industry sector, transport sector, residential sector, and commercial and public services. Among different sectors mentioned above, only the amount of natural gas used for the electricity sector will be qualified as the possible additional natural gas which can be exported and bring extra revenues under the circumstances that the solar energy is to substitute the use of natural gas.

One may expect that the amount of natural gas that is domestically used to produce electricity may not be so much when considered as the proportion of the total natural gas production in a country. However, though it may be a small amount, the possible additional natural gas can be exported, or it can be used for different purposes which can, if properly used, help their economies. However, if not properly used, under the assumption that the poor institutional quality is to remain, this can also mean the prolonging of the resource curse.

[96] https://www.cia.gov/library/publications/the-world-factbook/geos/ag.html (accessed: 17.01.2013)
https://www.cia.gov/library/publications/the-world-factbook/geos/ly.html (accessed: 17.01.2013)
https://www.cia.gov/library/publications/the-world-factbook/geos/eg.html (accessed: 17.01.2013)

Table 63: Oil and Natural Gas Consumption (Algeria)

	2010[a]	2011[a]	2012[b]	2013[b]	2014[b]	2015[b]	2016[b]	2020[b]
Oil								
Petroleum products: domestic consumption (ktoe)	16,345	16,699	17,007	17,333	17,723	19,019	20,609	25,646
Petroleum products: transport (ktoe)	9,550	10,307	10,555	10,852	11,192	12,084	13,180	15,490
Gasoline: demand ('000 b/d)	56.4	57.6	59.7	61.3	63.1	67.9	73.6	93.4
Distillates: demand ('000 b/d)	173.5	176.8	181.2	186.1	191.6	197.4	203.6	225.0
Natural gas								
Energy consumption (ktoe)	23,657	25,123	26,023	27,116	28,349	29,597	30,919	36,031
Electricity sector (ktoe)	10,261	11,426	11,552	11,679	11,807	11,937	12,091	12,557
Industry sector (ktoe)	3,611	3,777	3,947	4,114	4,353	4,587	4,875	6,164
Transport sector (ktoe)	925	937	994	1,070	1,152	1,235	1,318	1,635
Residential sector (ktoe)	4,310	4,369	4,635	4,987	5,368	5,758	6,146	7,624
Other (ktoe)	4,551	4,614	4,895	5,266	5,669	6,080	6,489	8,051

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=658843650&country_id=210000021&pubtypeid=1142462499&industry_id=&category_id (accessed: 05.06.2012)

Table 64: Oil and Natural Gas Supply (Algeria)

	2010[a]	2011[a]	2012[b]	2013[b]	2014[b]	2015[b]	2016[b]	2020[b]
Crude oil: production ('000 b/d)	1,741	1,751	1,763	1,913	1,965	2,018	2,073	2,305
Refineries (no.)	4[c]	–	–	–	–	–	–	–
Natural gas: production (ktoe)	72,569	71,844	74,719	76,969	77,119	77,369	78,369	80,519

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=658843650&country_id=210000021&pubtypeid=1142462499&industry_id=&category_id (accessed: 05.06.2012)

Table 65: Oil and Natural Gas Consumption (Egypt)

	2010[a]	2011[a]	2012[b]	2013[b]	2014[b]	2015[b]	2016[b]	2020[b]
Oil								
Petroleum products: domestic consumption (ktoe)	33,700	34,283	35,436	37,011	38,676	40,536	41,821	50,326
Petroleum products: transport (ktoe)	13,879	14,089	14,324	14,845	15,456	16,084	16,809	20,028
Gasoline: demand ('000 b/d)	119.3	120.5	123.1	126.9	131.2	135.4	139.3	156.5
Distillates: demand ('000 b/d)	281.9	290.3	300.4	309.9	320.6	332.2	344.5	403.4
Natural gas								
Energy consumption (ktoe)	38,212	39,927	42,272	44,384	46,497	48,809	51,712	62,568
Electricity sector (ktoe)	21,644	23,039	24,931	26,061	27,003	28,133	29,801	34,144
Industry sector (ktoe)	11,524	11,985	12,557	13,365	14,312	15,283	16,148	21,497
Transport sector (ktoe)	362	352	343	355	372	387	413	497
Residential sector (ktoe)	807	784	765	892	933	971	1,037	1,524
Commercial and public services (ktoe)	0	0	0	0	0	0	0	0
Other (ktoe)	3,875	3,767	3,675	3,710	3,878	4,035	4,312	4,907

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=388827823&country_id=1640000164&pubtypeid=1142462499&industry_id=&category_id (accessed: 05.06.2012)

Table 66: Oil and Natural Gas Supply(Egypt)

	2010[a]	2011[a]	2012[b]	2013[b]	2014[b]	2015[b]	2016[b]	2020[b]
Crude oil: production ('000 b/d)	698	688	678	673	668	668	663	643
Refineries (no.)	9[c]	–	–	–	–	–	–	–
Natural gas: production (ktoe)	50,347	51,518	53,376	56,129	58,211	60,031	60,570	66,064

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=388827823&country_id=1640000164&pubtypeid=1142462499&industry_id=&category_id (accessed: 05.06.2012)

Table 67: Oil and Natural Gas Consumption (Libya)

	2009[a]	2010[a]	2011[b]	2012[b]	2013[b]	2014[b]	2015[b]	2020[b]
Oil								
Petroleum products: domestic consumption (ktoe)	14,746	15,021	12,997	13,260	13,616	14,090	14,317	15,462
Petroleum products: transport (ktoe)	4,013	4,083	3,925	4,013	4,127	4,232	4,334	4,677
Gasoline: demand ('000 b/d)	30.0	30.2	25.1	28.9	32.2	34.0	35.6	39.4
Distillates: demand ('000 b/d)	133.0	136.1	120.7	131.1	140.0	148.0	152.7	174.0
Natural gas								
Energy consumption (ktoe)	5,496	5,959	4,142	5,073	5,838	6,552	7,230	9,781
Electricity sector (ktoe)	2,997	3,390	2,373	2,922	3,378	3,882	4,319	6,317
Industry sector (ktoe)	2,346	2,426	1,684	2,033	2,329	2,528	2,756	3,256
Transport sector (ktoe)	0	0	0	0	0	0	0	0
Residential sector (ktoe)	0	0	0	0	0	0	0	0
Commercial and public services (ktoe)	0	0	0	0	0	0	0	0
Other (ktoe)	152	142	85	118	131	143	155	207

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=1868551171&country_id=1200000320&pubtypeid=1142462499&industry_id=&category_id (accessed:05.06.2012)

Table 68: Oil and Natural Gas Supply (Libya)

	2009[a]	2010[a]	2011[b]	2012[b]	2013[b]	2014[b]	2015[b]	2020[b]
Crude oil: production ('000 b/d)	1,506	1,638	443	830	1,260	1,474	1,561	1,710
Refineries (no.)	5	5	–	–	–	–	–	–
Natural gas: production (ktoe)	12,984	12,903	5,403	7,453	9,553	11,538	12,581	15,179

Source: Economist Intelligence Unit
http://www.eiu.com/index.asp?layout=ib3Article&article_id=1868551171&country_id=1200000320&pubtypeid=1142462499&industry_id=&category_id (accessed:05.06.2012)

Table 63-68 present natural gas production and consumption in different sectors in North African energy exporters. If one is to take the year 2010, it is possible to see that a vast amount of natural gas (about 43.4 percent for Algeria, 56.6 percent for Egypt, and 56.9 percent for Libya) was used for the electricity sector in the three North African energy exporters. This also means, that if electricity can be produced by the solar energy instead of natural gas, Algeria, Egypt, and Libya could have saved 43.4 percent, 56.6 percent and 56.9 percent, accordingly, of natural gas consumed in electricity sector, and these are equivalent of 14.1 percent, 43 percent and 26.3 percent, accordingly, of the total natural gas production. If one assumes that the rest of natural gas was exported, subtracting the total amount of consumed natural gas from the total production without any transmission loss, the total amount of natural gas that was exported would be 48912 Ktoe for Algeria, 12135 ktoe for Egypt, and 6944 Ktoe for Libya. However, with the additional natural gas, when one considers the situation where the solar energy was substituted for the natural gas to produce electricity, Algeria, Egypt and Libya could have exported 59173 Ktoe (21.0 percent more), 33779 Ktoe (178.4 percent more) and 10334 Ktoe (4.8 percent more), accordingly, amount of natural gas.

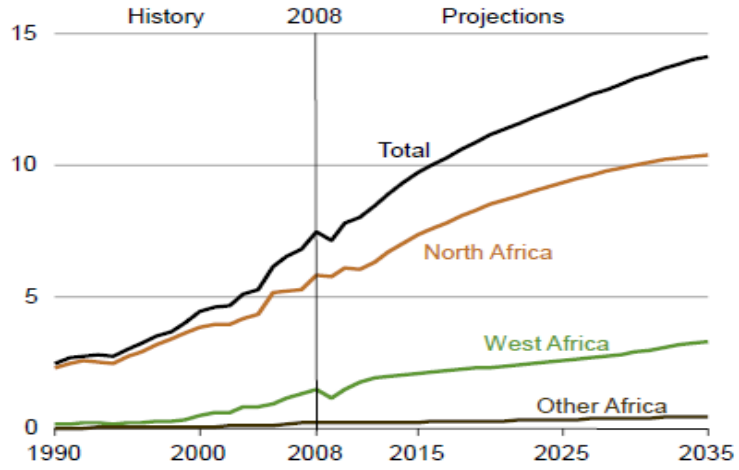
Of course, though a hypothetical analysis, the possible impact of the solar energy in the three North African energy exporters show additional natural gas they could have saved or exported. However, this hypothetical analysis is made with the statistical information regarding the year 2010.

In other words as solar energy is yet to become a substitute for natural gas in these three North African energy exporting countries, the outcome of the analysis made above can not guarantee that there will be any additional natural gas that can be exported or saved because one does not know how much these countries will be producing natural gas in the future. Therefore, one needs to make a hypothetical analysis with the projected future natural gas production rate and its use in the three North African energy exporters first, and then see whether there will be any additional natural gas for the three North African energy exporters in the future.

8.5 Projections of the Natural Gas Production and Consumption in the Three Energy Exporters

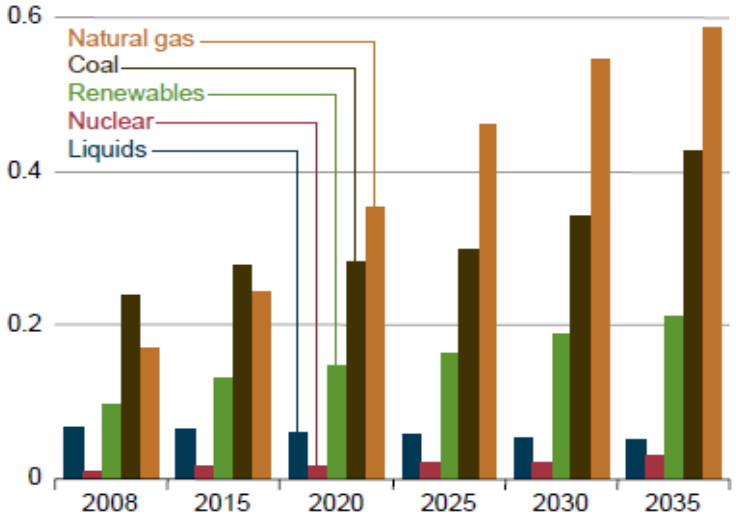
When looking at table 63-68, one is able to see that the three North African energy exporters' natural gas production and consumption are projected to increase. Similar projections are also made by other sources. For example, according to the EIA (2011, p.55), the natural gas production in Africa is projected to grow substantially, from a total of 7.5 Tcf in 2009 to 14.1 Tcf in 2035. Similarly, International Energy Agency (IEA 2011, p.27), in their Golden Age of Gas Scenario, also projects the growth in the natural gas production in Africa in the future, from 207 bcm in 2008 to 438 bcm in 2035. It is estimated that North Africa, mainly from Algeria, Egypt, and Libya, accounted for 78 percent of Africa's natural gas production in 2008. Although the annual natural gas production growth is projected to be higher in West Africa, by 3.1 percent, than North Africa, by 2.2 percent, the natural gas production in North Africa and the rest of the region is projected to grow as can be seen from figure 25 (EIA 2011, p.55).

Figure 25: Africa Natural Gas Production, 1990-2035 (Tcf)



Source: EIA (2011, p.55)

Figure 26: Net Electricity Generation in Africa by Fuel, 2008-2035 (TWh)



Source: EIA (2011, p.100)

Figure 26 presents the fuel sources for the electricity generation in Africa. As can be observed from figure 26, the reliance on fossil-fuels in generating the electricity is projected to continue.[97] The coal-fired power plants were Africa's largest source of electricity in 2008 which are expected to decline throughout the period. However, as can be seen from figure 26, it is projected that natural gas-fired generation is to expand from 29 percent of the total in 2008 to 45 percent in 2035 (EIA 2011, p.100). Although above figures do not present the predicted amount of natural gas which will be used to produce electricity for the individual three North African energy exporters, it certainly shows that natural gas will still play a crucial role in meeting the future electricity demand in the region.

When observing table 63-68, although the natural gas production and consumption in the three North African energy exporters are projected to increase, the projection of natural gas used for the electricity sector varies among the three North African energy exporters. More specifically, the projected amount of natural gas used to produce electricity will increase for all the three North African energy exporters. However, the proportion in the use of natural gas to produce electricity does not increase in all three countries when compared to the other sectors. For example, it is only Libya that is projected to be using more natural gas in electricity sector in the future (59.7 percent in 2015 and 64.6 percent in 2020) whereas Algeria's use of natural gas in electricity sector is projected to decline (40.3 percent in 2015 and 34.9 percent in 2020). Egypt's use of natural gas in

[97] Of course, the projection by EIA (2011) is different from other studies focusing on renewable energy such as Schellenkens et al. (2010) or Zickfeld et al. (2012) because it is not based on the assumption that 90-100 percent of electricity can be produced by renewable energies. Nevertheless, it still projects the growth in renewable energies production in the future.

electricity sector is projected to increase, compared to the year 2010 (56.6 percent), in 2015 (57.6 percent), but it is projected to decline in 2020 (54.6 percent) compared to 2015. As can be seen from table 63, 65, the decline in the use of natural gas, in terms of proportion compared to other sectors, to produce electricity in Algeria and Egypt may be due to the more use of natural gas in their industry sectors as the proportion of the natural gas used for the industry sectors for both countries are projected to increase (Algeria: 15.5 percent in 2015 and 17.7 percent in 2020, Egypt: 31.3 percent in 2015 and 34.4 percent in 2020).

Nevertheless, what is more important is the proportion of natural gas used to produce electricity in the total natural gas production. As mentioned earlier, if the solar energy plan is to be successfully established and substitute natural gas, Algeria, Egypt and Libya would have saved 14.1 percent, 43.0 percent and 26.3 percent in 2010, accordingly, out of the total natural gas production. Though the proportion of the natural gas used to produce electricity, when calculated within the consumed natural gas, is projected to decline except for Libya, the proportion of the natural gas used to produce electricity is projected to increase when calculated as the proportion of the total natural gas production.

Table 69: % of the Consumed Natural Gas from the Total Natural Gas Production and Projected % of 'Additional Natural Gas' in the Total Projected Amount of Exported Natural Gas in the three Energy Exporters in 2010, 2015, and 2020

	Algeria			**Egypt**			**Libya**		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
% of the total Production	14.1%	15.4%	15.6%	43%	46.9%	51.7%	26.3%	34.3%	41.6%
Additional Natural Gas %	21.0%	25.0%	28.2%	178.4%	250.7%	976.6%	48.8%	80.7%	117.0%

Table 69 presents the percentage of the consumed natural gas out of the total natural gas production, and the projected 'additional natural gas' percentage out of the total projected exported natural gas in the three North African energy exporters. Here, again, it must be mentioned that the projected amount of exported natural gas is the subtraction of the total consumed natural gas from the total natural gas production under the circumstance that there is no transmission loss.

Despite the proportion of the natural gas used to produce electricity which is calculated within the total consumed natural gas, table 69 shows that the use of natural gas to produce electricity is projected to gradually take a higher proportion when calculated out of the total natural gas

production in all three North African energy exporters. When the amount of the possible additional natural gas (amount of natural gas used for the electricity production) is compared to the projected exported natural gas, it shows that the three North African energy exporters could export much more natural gas than they are projected to export. Algeria and Libya could export more natural gas gradually throughout the periods if solar energy is to substitute the use of natural gas. Egypt, on the other hand, already could have exported 178.4 percent more amount of natural gas in 2010 if solar energy substituted the use of natural gas. The amount of projected additional natural gas increase dramatically for Egypt as it could export 250.7 percent and 976.6 percent more natural gas in 2015 and 2020, accordingly, if solar energy can substitute the natural gas in meeting the domestic electricity demand in the country.

Table 70: Increase in the Domestic Consumption of Natural Gas in the Three Energy Exporters

	2010 to 2015	2015 to 2020	2010 to 2020
Algeria	25.1%	21.7%	52.3%
Egypt	27.7%	28.2%	63.7%
Libya	21.3%	35.3%	64.1%

Another finding is that the domestic consumption of natural gas is projected to increase. Table 70 presents the prediction of the increase in the domestic natural gas consumption in the three North African energy exporters. The consumption of natural gas in all three countries is projected to gradually increase. If one compares natural gas consumption of 2010 and 2020, its consumption increases by 52.3 percent, 63.7 percent and 64.1 percent for Algeria, Egypt and Libya, respectively. In other words, the solar energy substitution for natural gas can save them a vast amount of natural gas.

By looking at the hypothetical analysis made above based on the projection of the production and consumption of natural gas in the three North African energy exporters, it is possible to project that the three energy exporters are likely to produce and consume more natural gas in the future. Furthermore, more importantly, it is projected that there can be more additional natural gas exported if solar energy is to replace the consumption of natural gas to produce electricity. The projected additional amount of natural gas which can be exported or used in different sectors can be a great factor which can attract the solar energy plans for the three North African energy exporters. However, the additional natural gas also can mean that solar energy can prolong the period of time for these countries to rely on their energy exports, thus prolonging the current resource curse. Of course, the outcome of this section is based on the assumption that these countries will continue to have poor institutional quality, and they will still be abundant with fossil-fuels in the future. If the

above assumptions are to occur in the future, it can mean that the earlier success in solar energy, or renewable energy, establishment in the region, the higher chance that the current resource curse is to be prolonged. This is not to say that solar energy will be harmful to the resource-abundant countries. As seen earlier, when used correctly resource abundance does not necessary lead a country to suffer from the resource curse. However, one should always take into a consideration that, whether solar energy becomes a curse or not in the five North African countries, solar energy to substitute other resources still has the potential to keep them in the current resource curse. In other words, though this situation may not be regarded as the so called 'solar energy curse' or a 'renewable energy curse' the above hypothesized situation i.e prolonging the reliance on exporting natural gas may be considered as a new curse effect.