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Enabiling Activities for Preparation of Syria's Initial National Communication to UNFCCC

Mitigation of greenhouse gas emissions within the Power Generation Sector in Syria

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GHG Mitigation Analysis in the Power Generation Sector in Syria

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 28.2.2010, in Samiramis Hotel, Damascus.

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List of Abbreviation:

GHG:	Greenhouse gas emission
GDP:	Gross domestic product
NG:	Natural Gas
HFO:	Heavy Fuel Oil
CC:	Combined Cycle
MS:	Mitigation Scenario
RS:	Reference Scenario
PEE:	Public Establishment for Electricity
PEEGT:	Public Establishment for Electricity Generation and Transmission
PEDEEE:	Public Establishment for Distribution and Exploitation of Electrical Energy).

Mcm	Million cubic meters
boe	barrel of oil equivalent
Toe	ton of oil equivalent
Ktoe	1000 tons of oil equivalent
Mtoe	million tons of oil equivalent
kW	1000 Watt
MW	Mega Watt (=1000 kW)
kWh	1000 Watt hour
MWh	Mega Watt hour (=1000 kWh)
GWh	Giga Watt hour (=1000 MWh)
TWh	Tera Watt hour (=1000 GWh)

Executive Summary

1. Introduction

The worldwide increase of energy demand with the consequence of raising GHG emissions and their negative environmental impact, presents the main challenge of the modern societies. Thus, covering the increased energy demand by protection of the environment at the same time, forms meanwhile the main goal of sustainable development of energy sector.

This analysis is part of the ongoing UNDP project on ”Enabling Activities for the preparation of Syria's Initial National Communication to the UNFCCC”. It deals with the GHG inventory calculations, analysis and evaluation of their expected future development and identifying adequate measures for future mitigation in the different GHG emission sectors. In this sense the energy sector is responsible for the most GHG emissions and inside it the sub-sector of electricity generation plays the dominant role. Thus, the proposed mitigation measures in the field of electricity generation will play a central role in reducing GHG emissions in Syria.

This report covers a set of interactive effects between electricity generation and environmental issues related to GHG emissions by focusing on policy and technology measures appropriate for lessening and mitigation of GHG emissions. The report presents also a detailed description of the power sector development during the period 1994-2007 including generation options, installed capacity and fuel consumption and its related GHG emission.

2. Overview of Syrian Electricity Generation Sector (19994-2007)

Electricity generation presents one of the most important branch of the energy sector. It is mainly controlled by the Ministry of Electricity, which is responsible for investment, tariffs, planning, and policy formulation. The generation activitis are managed by PEEGT (Generation and Transmission). The Ministry for Irrigation is responsible for water resource management and hydro power plants. The Public Establishment of Euphrates is responsible for the three main hydropower plants of Thawra, Baath and Tishreen, all located on the Euphrates River.

2.1 Electricity Consumption and Generation and Installed Capacity

The final energy consumption formed about 15.5% of total final energy demand in 2007. The by sector distribution of final electricity consumption, that amounted to 30.6 TWh in 2007, was 41% for household, 16% for service, 32% for industry, 1% for construction, 6% for agriculture and 4% for mining. To face the increased demand the electricity generation increased during the same period form 14.88 TWh to 39 TWh showing an average annual growth rate of 8%. The resulting electricty per capita arrived in 2007 about 2000 kWh. Besides, the peak load demand grew from 2474 MW to 6900 MW showing an average growth rate of 8.2%. To cope with both peak load and electricity demand increase the available installed capacity increased from 3600 MW to 6250 MW.

2.2 Historical Trends of Fossil Fuel Consumption and GHG Emission of Generation Sector

During the period 1994-2007 the Syrian electricity generation relies mainly on fossil fuel fired power plants. The share of hydro power generation fluctuated between 10% and 19% following the water availability in the Euphrates river. Thus, over the whole period the share of thermal generation exceed 80% and arrived in 2007 more than 90%. Hence, the fossil fuel consumption in the electricity generation –consisting of heavy fuel oil (HFO), Natural gas (NG) and small amounts of Diesel- increased from 3 to 7.7 Mtoe during the period 1994-2007. Following the available domestic NG its share in the fuel mix fluctuated significantly; it increased from 32% in 1994 to 60% in 1997, decreased to 48% in the year 2000 and increased again to 59% in 2002 and to 36% in 2007. Accordingly, the CO2 emission of generation sector grew from 9 million ton in 1994 to about 24 million ton in 2007 showing an average annual growth rate of 8% (Figure 1). The comparison of CO2 emission of generation sector with other energy sectors indicates that this sector contributed to more than 40% of total emissions in 2005.

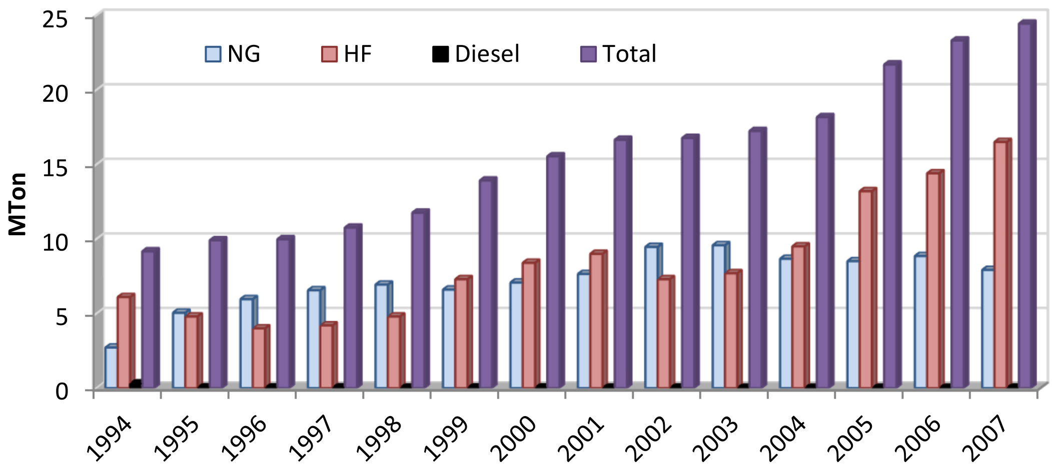


Figure1. Development of CO2 emission by type of fuel consumption

The impact of NG and HFO shares on the CO2 emission growth rate is obvious. The increased share of NG in the fossil fuel mix during the period 2000-2004, substituting partially HFO, limited the annual emission growth rate to about 4%. However, the decreased share in the period 2005-2007 boosted the emission growth rate to about 10%. Consequently, the resulting specific emission per generated kWh for thermal power plants decreased from 0.74 kg/kWh to 0.66 kg/kWh during the period 1994-1998, increased again to 0.685 kg/kWh in 2000, decreased to 0.64 kg/kWh in 2003 and oscillated finally at 0.69 kg/kWh during the last years.

3. GHG Mitigation Scenario in the Power Sector

To analyze and evaluate the adequate measures for mitigating GHG emission of electricity generation sector, two future scenarios have been developed reflecting the most favorable development trends of Syrian power sector. Both scenarios depend on the least cost expansion approach of generated electricity unit over the study period 2005-2030. The first development trend refers to the Reference Scenario (RS) that reflects the baseline development in formulating future optimal expansion plan of generation sector under a set of limits and constraints that reflect the technological features of available, committed and future power plant candidates, availability of domestic fuel resources and import and export possibilities. The second is an alternative expansion scenario, so called Mitigation Scenario (MS) that focuses on introducing policy measures in term of energy saving and clean technologies that help in reducing GHG emissions.

3.1 Adopted Measures of Mitigation Scenario

The proposed mitigation measures include:

- Encouraging the introduction of renewables by imposing predefined total installed capacities of 2000 MW for wind, 2000 MW for PV and 1000 MW for CSP over the study period.
- Increasing the share of NG fired power plants and in particular the combined cycle technology (CC);
- Rehabilitation of old power plants to improve their efficiency;
- Allowing the introduction of nuclear option after 2020;
- Gradual reduction of transmission and distribution losses in the electric grid.

3.2 Results of Mitigation Scenario and its Effectiveness for GHG Emission Reduction

The results of Reference and Mitigation scenarios are compared in order to evaluate the impacts and the effectiveness of the proposed mitigation measures on the structure of future power sector and the achieved annual reduction of GHG emission during the study period (Figure 2).

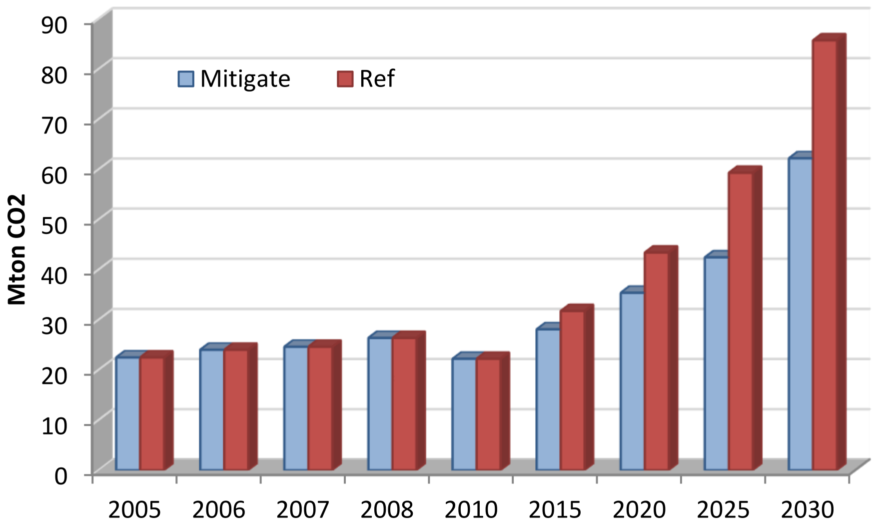


Figure2. Comparison of CO2 Emissions for RS and MS

The results indicate that the impact of proposed measure will be effective after 2010. The GHG reduction will arrive 8 Mton Co2 in 2020 and will grow to arrive 23 Mton in 2030 corresponding to a reduction of 27% of total GHG emission in 2030. The cumulative amount of the expected GHG reduction over the study period will amount to 200 Mton of CO2.

The evaluation of the achieved emission reduction by type of measure show that the emission reduction arise mainly from the proposed increase of NG and CC in the future generation system, followed by the increased contribution of renewables their share will arrive 11% in MS compared to 3% in RS, and the last is the role of the expected reduction of technical losses in electric grid. Figure 3. presents the GHG reduction results by type of mitigation measure for the year 2030. It can be concluded that the shift to use NG and CC instead of HFO fired steam turbines will contribute by 62% of total GHG reduction, followed by substitution of fossil fuel by renewables with 26% and the reduction of technical loses and efficiency improvement by 12%. The achieved results confirm the importance of increasing NG share in the generation process for reducing GHG emission and fulfilling the requirements of sustainability development of energy sector in environmental dimension.

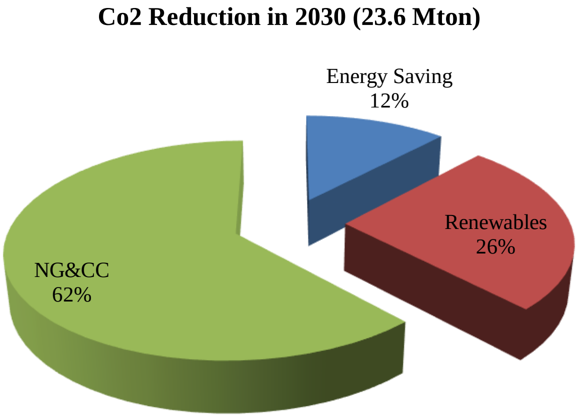


Figure 1: Expected CO2 Reduction by Type of Mitigation Measure in 2030

(NG&CC: substituting HFO by NG and shifting to CC, Renewables: increasing the share of renewable energies, Energy Saving: reduction of electric grid losses and efficiency improvements)

1. General Country Overview of Syria

The Syrian Arab Republic lies on the eastern coast of the Mediterranean Sea, bounded by Turkey to the north, Iraq to the east, Jordan and Palestine from the south and by Lebanon and the Mediterranean Sea to the west. The total area of SAR is about 185.18 thousand km^2, from which ca. 32% are cultivated land and the remained is desert and Rocky Mountains. The Syrian Desert is suitable for grass growing and is used as pastures during sufficient rainfall.

The climate of the Mediterranean Sea generally prevails in Syria; this climate may be characterised by rainy winter and dry hot summer separated by two short transitional seasons. The coastal region is characterised by heavy rainfall in winter and moderate temperature and high relative humidity in summer. The interior is characterised by a rainy winter season and a hot dry season during summer, the area in the mountains with an altitude of 1000 m or more characterized by rainy winter where rainfall may exceed 1000 mm and moderate climate in summer. The desert region is characterized by small amount of rainfall in winter and hot dry summer [2].

The population of Syria was 4.565 million in 1960, but during the next two decades the number doubled to 9 million, and has kept an increasing trend reaching 13.782 million according to the population census in 1994. According to the population censuses in 1981 and 1994 the Central Bureau for Statistic (CBS) estimated for the period 1981-1994 an average population growth rate of about 3.3%, which was one of the highest growth rate in the world. However, the last decade has depicted continuous decrease of the growth rate as result of different factors influencing the demographical situation in Syria, like changing the life style, increasing of marrying age from 26 to 29 years by male and from 20 years to 25 years by female, increasing the women share in the labour force and other factors[1]. The CBS estimated annual population growth of 2.33% during the period 2000-2006. According to the population census in 2004 the populations mounted to 17.9 million and the latest estimated population of 2007 is around 19.17 millions [7].

On the economic side the Syrian economy shows -after an economic crisis during the period (1985-1990)- a high economic growth rate of 8% resulting from the considerable increase in oil production between 1990-1996, foreigner support after the second Golf ware and new investment law. In 1991, Syria passed Investment Law No. 10, encouraging foreign and Syrian private investment through a combination of tax and custom exemptions, the right to repatriate profits and relaxation of foreign exchange controls. Private investors, with financial backing from the Gulf States, have been expanding into various sectors of industry. This has encouraged the development of textiles, pharmaceuticals, food processing (Non-durable) and other light industries, many built by wealthy Syrians from abroad. Tourism appears to be growing as well. The recent economic development prove an average economic growth rate of around 4.7% during the period 2000-2006 (during this period the Syrian GDP grew from 904 to about 1193 billion Syrian Pound). However, the government aim to achieve 6-7% growth rate by the end of this decades. Table 2-1 shows selected economic and demographic indicators of the country.

[1] According to Human Development Report 2000 (Table 19, page 225), population growth rate in Syrian Arab Republic (SAR) was 3.2% per annum during the period 1975-1998. This report predicts 2.3% p.a. population growth rate during the period 1998-2015 for the Syria. Total population of SAR will be 22.6 million by the year 2015 of which 62.1% will be in urban areas and 3.5% above the age of 65 years.

The official statistics refer that GDP per capita grew from 1108 to 1250 $ during the same period achieving 2.4 % growth rate per year

Table1. Selected economic and demographic indicators for the period 2000-2006.

	2000	2001	2002	2003	2004	2005	2006	Growth rate %
GDP(B.SP)[2]	**903.9**	**950.2**	**1006.4**	**1017.6**	**1086**	**1134.9**	**1192.7**	**4.7**
GDP ($)	**17.7**	**18.6**	**19.7**	**20.0**	**21.3**	**22.3**	**23.4**	**4.7**
Population[3] (Millions)	**16.3**	**16.7**	**17.13**	**17.5**	**17.9**	**18.27**	**18.7**	**2.3**
GDP per Capita (SP)	**55386.0**	**56830.1**	**58750.7**	**57982.9**	**60599.3**	**62121.6**	**63722.8**	2.4
GDP per Capita ($)	**1107.8**	**1122.6**	**1142.4**	**1156.1**	**1200.2**	**1206.4**	**1250.2**	2.4

Source, Reference [7]

1.1 Current Energy Sources and Use

According to international statistics the Syrian energy system is characterized by low per capita energy consumption. Table 2-2 shows selected indicators of energy sector compared with other region for the year 2004. The primary energy consumption per capita in Syria was 0.99 toe (ton of oil equivalent) compared to 1.77 toe of the world average and 2.64 toe of the Middle East. The CO2 emission per capita was at the same level of world average.

Table 1: Selected Energy Indicators for the year 2004

	Primary Energy (toe/capita)	Final Electricity Consumption (kWh/capita)	CO2-Emission (tCO2/toe)	CO2-Emission (tCO2/capita)
Syria	0.99	1317	2.59	2.57
Middle East	2.64	2881	2.47	6.51
Asia	0.63	617	1.94	1.22
Africa	0.67	547	1.39	0.93
World Average	1.77	2516	2.37	2.57

Source: IEA statistics, www.iea.org

1.2 Organizational Structure of Power Sector

The energy sector is part of the economic activities being administrated by the office of deputy prime minister for economic affairs. The main contributors in the Syrian energy sector are ministry of oil, ministry for electricity, atomic energy commission (AECS) [2]. The Ministry of Electricity is responsible for investment, tariffs, planning, and policy formulation in the power sector. The power system is managed by the Public Establishment for Electricity (PEE), which is separated into PEEGT (Generation and Transmission), and PEDEEE (Distribution and Exploitation of Electrical Energy). PEEGT is responsible for transmission including the 400-kV and 230-kV levels, while PEDEEE supervises the 66-kV, 20-kV, and 0.4-kV levels. As a result, PEEGT has 230-kV customers, that is, large industries and irrigation. All other customers are under the

[2] Using 2000 market prices and assuming that 1$ equals to 51 Syrian Pound (SP)

[3] Estimated in the mid year for all years except 2004 when the general census was performed.

responsibility of PEDEEE. The Ministry for Irrigation is responsible for water resource management and hydro power plants. The Public Establishment of Euphrates is responsible for the three main hydropower plants of Thawra, Baath and Tishreen, all located on the Euphrates River. Figure 4. presents the institutional set-up of the PEEGT [2].

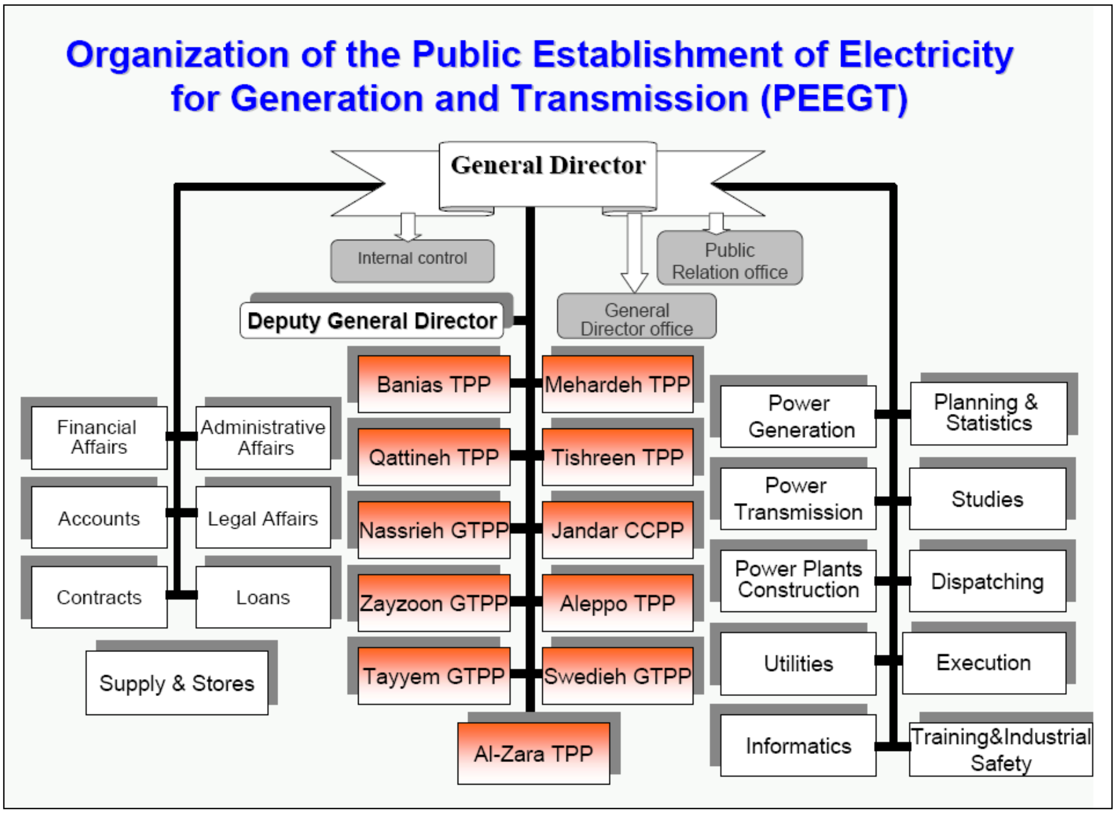


Figure 04. Institutional Set-up of PEEGT (source: reference [2])

2. Historical Development of Syrian Power Sector during the period 1994-2007

2.1 Distribution of Final Electricity Consumption

The final electricity demand[4] formed about 15.5% of total final energy demand in 2007. This demand grew rapidly during the period 1994-2007 arriving in 2007 about 30.6 TWh [4], [5], [13]. The distribution of this amount by sector of consumption shows that 41% was for household, 16% for service, 32% for industry, 1% for construction, 6% for agriculture and 4% for mining (Figure 5).

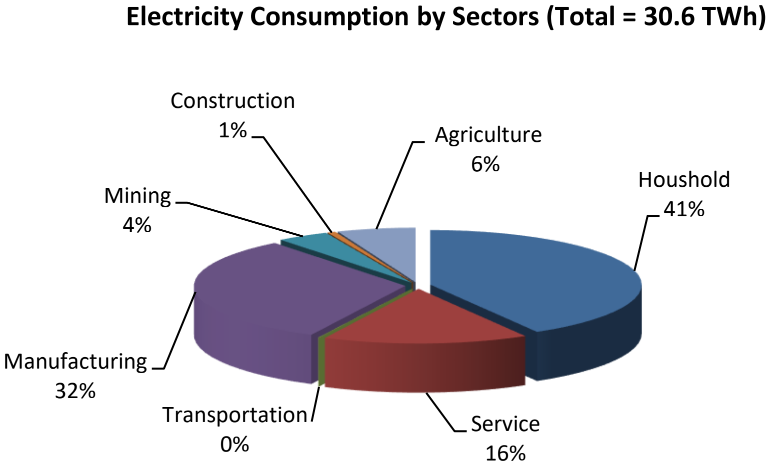


Figure 05. Distribution of final electricity by consumption sector for 2007.

Source: References [5], [13]

2.2 Development of Electricity Generation

To face the increased demand the electricity generation increased during the period 1994-2007 form 14.88 TWh to 39 TWh (Figure 6). This historical development shows an average annual growth rate of 8% [2], [4], [5], [11], [12]. The resulting electricity per capita arrived in 2007 about 2000 kWh.

[4] Final electricity represents total generated electricity after reducing own power plant consumption, transmission and distribution losses.

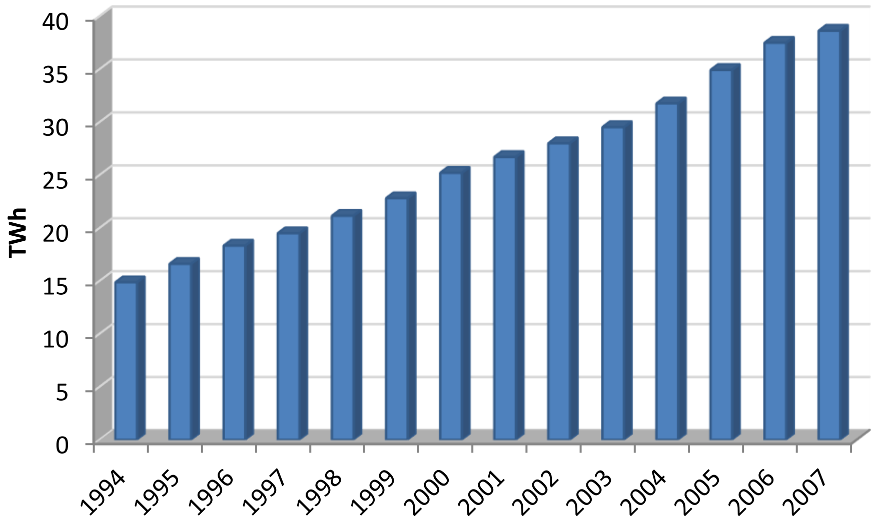


Figure 6. Development of electricity generation for the period 1994-2007

Source: References [2], [4]

2.3 Installed Capacity and Peak Load

During the period 19994-2007 the peak load demand grew from 2474 MW to 6900 MW showing an average growth rate of 8.2%. To cope with both peak load and electricity demand increase the available installed capacity increased from 3600 MW to 6250 MW (Figure 7). The installed capacity hanged on at this level since 2005 due to technical and investment problems. Thus, the reserve margin, which depected a high value of more than 30% in the year 2000, decreased afetr that gradually and the system has shown deficiet in the installed capacity in 2006 and 2007 that caused in real power shortages during the peak time. Figure 8. presents the distribution of available installed capacity by typr of generation in 2007. It should be noted that the totall installed capapcity in 2007 arrived 7160 MW of which only 6250 MW was available. The availabel capacity was distributed to 78% for thermal and 18% for hydro power plants.

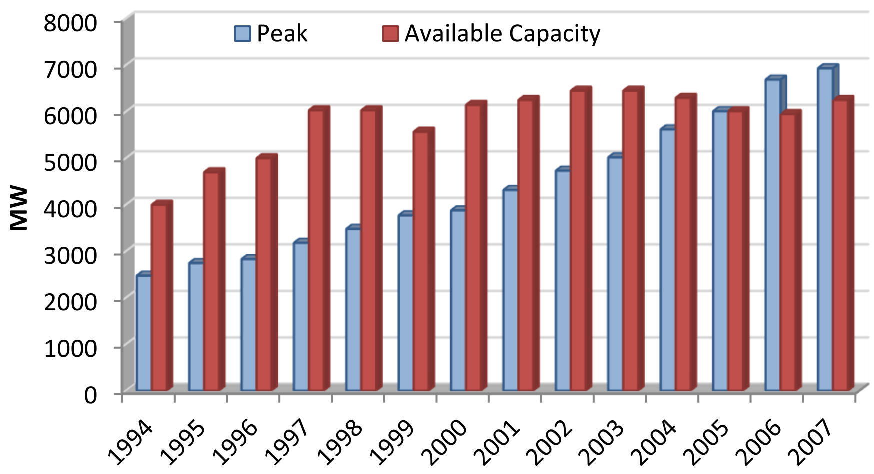


Figure 7. Peak load and available installed capacity 1994-2007

Source: References [2], [4]

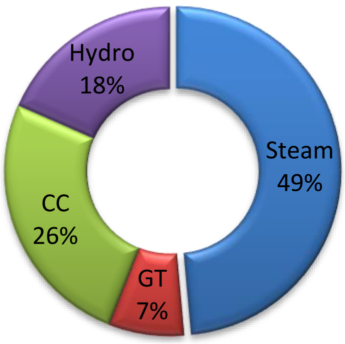


Figure 8. Distribution of installed capacity by type of generation in 2007

Source: Reference [2]

2.4 Historical Development of Fuel Consumption in the Generation Sector

Due to the limited generation of hydro power the increased electricity demand lead to steadily increase of fossil fuel for generation purpose represented mainly by HFO and NG. During the period 1994-2007 the share of hydro power generation fluctuated between 10% and 19% following the water availability in the Euphrates river. Thus, over the whole period the share of thermal generation exceed 80% and arrived in 2007 more than 90%. Hence, the fossil fuel consumption in the electricity generation –consisting of heavy fuel oil (HFO), Natural gas (NG) and small amounts of Diesel- increased from 3 to 7.7 Mtoe during the period 1994-2007 (Figure 9). Following the available domestic NG its share in the fuel mix fluctuated significantly; it increased from 32% in 1994 to 60% in 1997, decreased to 48% in the year 2000 and increased again to 59% in 2002 and to 36% in 2007.

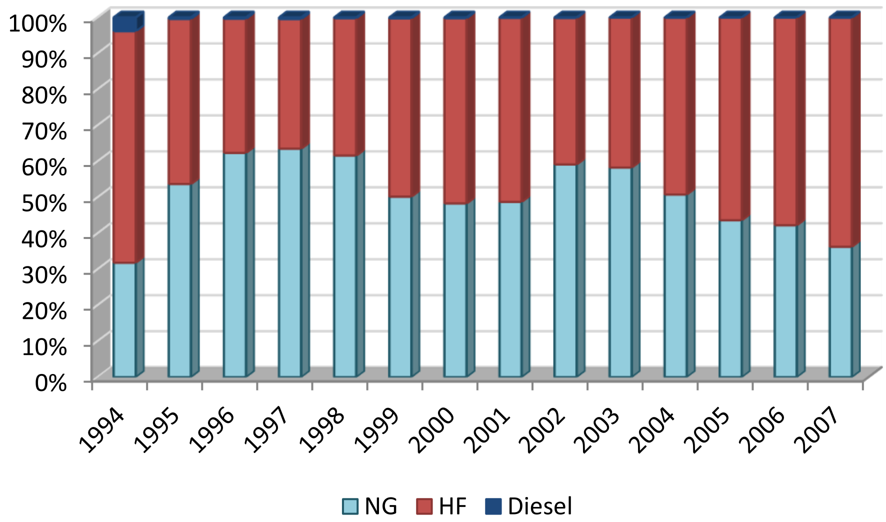


Figure 9. Development of fuel consumption for electricity generation

Source: References [2], [4]

2.5 Historical Trends of GHG Emission in the Generation Sector

Figure 10. presents the development of CO2 emission by fuel type. The CO2 emission of generation sector grew from 9 million ton in 1994 to about 24 million ton in 2007 showing an average annual growth rate of 8%. The share of remaining GHG (CH4, and N2O) was less than 0.5% over the whole period. The comparison of CO2 emission of generation sector with other energy sectors indicates that this sector contributed to more than 40% of total emissions in 2005 [6]. The impact of NG and HFO shares on the CO2 emission growth rate is obvious. The increased share of NG in the fossil fuel mix during the period 2000-2004, substituting partially HFO, limited the annual emission growth rate to about 4%. However, the decreased share in the period 2005-2007 boosted the emission growth rate to about 10%. Consequently, the resulting specific emission per generated kWh for thermal power plants decreased from 0.74 kg/kWh to 0.66 kg/kWh during the period 1994-1998, increased again to 0.685 kg/kWh in 2000, decreased to its minimum of 0.64 kg/kWh in 2003 and oscillated finally at 0.69 kg/kWh during the last years (Figure 11). This fluctuation arises mainly from the varied share of NG and HFO in the generation sector. The decrease refers to the increased share of NG in the generation processes.

It should be noted that the high specific emission is due to no availability of CC power plants where the first CC entered the system in 1995. Although its share increased in the following years leading to reducing the specific emissions markedly in 2003, the last years 2005-2007 indicated a new increase in the specific emission due to the new increase of HFO share to compensate the lack of NG for generation purposes.

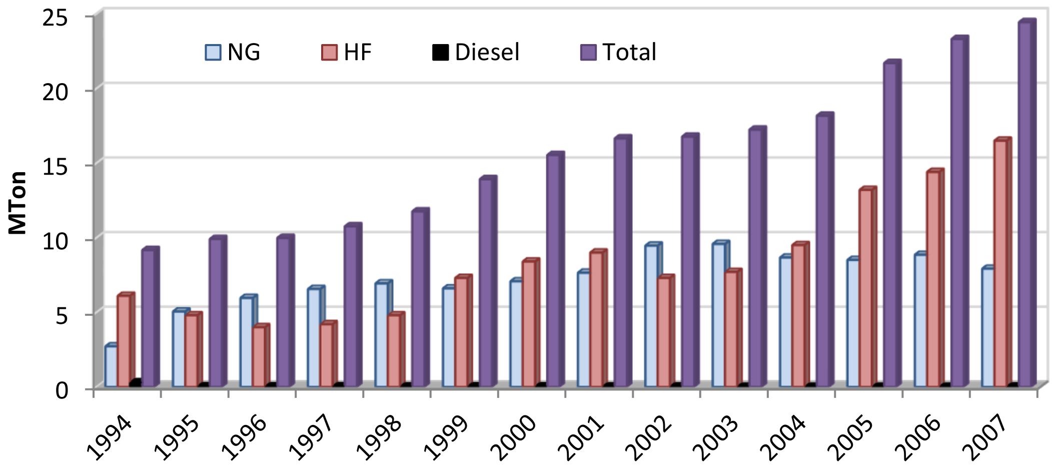


Figure 10. Development of CO2 emission by type of fuel consumption

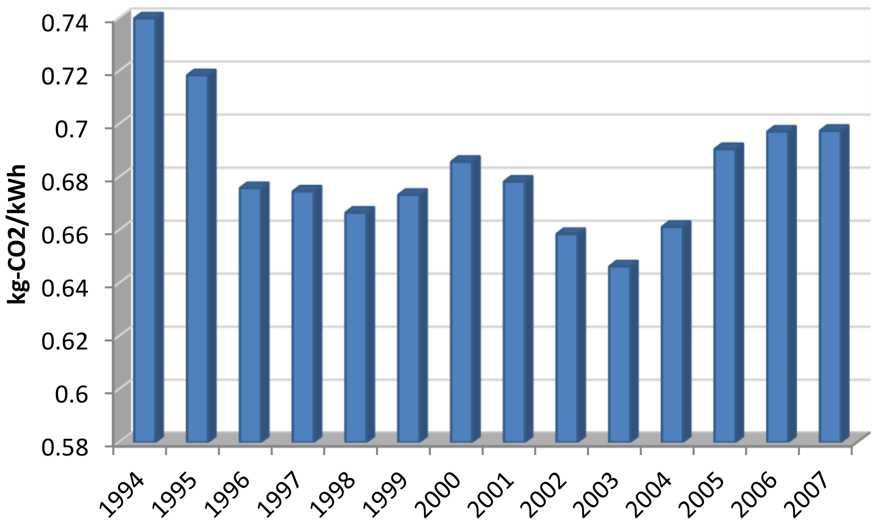


Figure 11. Development of specific GHG emission of Syrian generation system

3. Future GHG Mitigation Scenario of Generation Sector up to 2030

As already mentioned, the Syrian generation sector relies mainly upon fossil fuel with an average share above 80% during the last two decades. In its ambition to reduce GHG emission the power sector will face high challenges depending on the expected technical, financial and structural limitations. The following measures were proposed to construct future Mitigation Scenario (MS):

- Improving the technical performance of the power plants to increase their efficiency
- Enhancing the electric load factor of the system;
- Substituting HFO by NG;
- Enhancing the average system efficiency by increasing the share of CC;
- Increasing the share of clean technologies by encouraging renewables and nuclear options;
- Reducing the technical losses and illegal consumption of distribution network.

To analyze and evaluate the adequate measures for mitigating GHG emission of electricity generation sector, two future scenarios have been developed reflecting the most favorable development trends of Syrian power sector. Both scenarios depend on the least cost expansion approach of generated electricity unit over the study period 2005-2030. The first development trend refers to the Reference Scenario (RS) that reflects the baseline development in formulating future optimal expansion plan of generation sector under a set of limits and constraints that reflect the technological features of available, committed and future power plant candidates, availability of domestic fuel resources and import and export possibilities. The second is an alternative expansion scenario, so called Mitigation Scenario (MS) that focuses on introducing policy measures in term of energy saving and clean technologies that help in reducing GHG emissions.

3.1 Reference Scenario of Electric Generation System

The data of RS presented here depends on the assumptions adopted in the development of optimal future supply strategy given in reference [5] with further additional information according to [6], [7], [8], and [9]. The CO2 emission for RS were calculated according to IPCC guidelines [10] and using physical properties of Syrian fuels. The achieved emission results of RS are used as reference to evaluate the results of Mitigation Scenario.

3.1.1 RS Expansion Plan of Generation System

According to RS the electricity generation will increase from 34 TWh in 2005 to about 148.4 TWh in 2030. The optimal expansion plan of RS shows an increase of installed capacity from 6200 MW to 29600 MW during the period 2005-2030. the new capacity addition is distributed to 14360 MW for CC, 12200 MW for fuel fired steam power plants, 900 MW GT, 300 MW wind turbines and 1600 MW for two nuclear power plants that will enter the system in 2020 and 2025 with 600 MW and 1000 MW respectively. Other alternatives, like PV and CSP are not competitive due to the high investment cost.

3.1.2 Electricity generation and fuel demand of RS

The increase electricity generation will boost the future fuel demand for generation purposes. The fuel demand will grow by an average annual of 5.8% from 7 Mtoe (distributed to 58% HFO and 42% NG) to 11 Mtoe in 2015 (distributed to 78.3% NG, 20.4% HFO and 1.3% diesel) and arriving 30 Mtoe in 2030 (distributed to 24.6% NG, 65.2% HFO, 9.7% nuclear and 0.5% diesel) as presented in Figure 12. The electricity generation by fuel type shows that the share of NG will increase to a maximum of 83% in 2017 and decline later to 31% in 2030. The decreased NG availability will be compensated by HFO and nuclear [5].

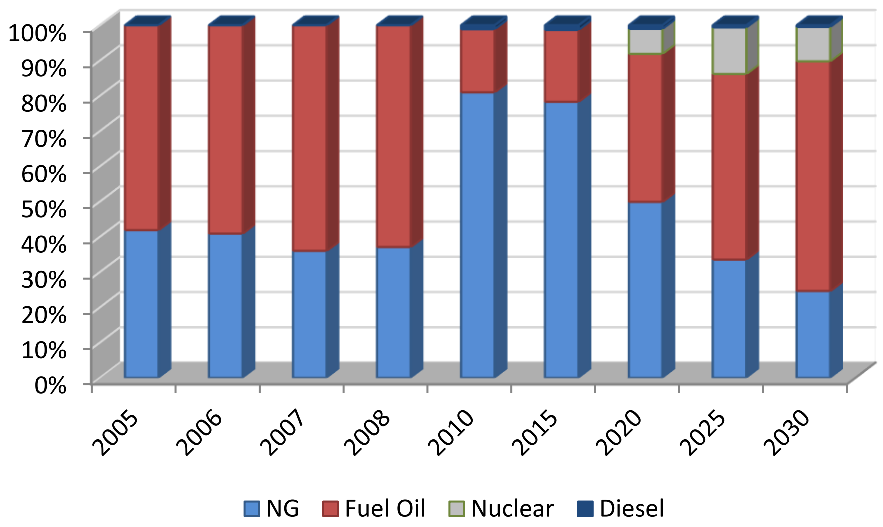


Figure 012. Development of fuel share for electricity generation (RS)

3.2 Mitigation Scenario of Electric Generation System

MS scenario adopts a future energy policy that focus on environmental requirements by increasing the share of renewables and other clean technologies in the future supply mix. It aims at exploring the possibility of increasing supply security by reducing the dependency on fossil fuel and limiting the GHG emission at the same time. MS offers the possibility to assess the cost of such GHG abatement policy in the power sector by comparing its results with those of RS. As already mentioned the proposed mitigation measures in this scenario cover wind, PV, CSP and soft solar for thermal application according to following assumptions:

- Encouraging the introduction of renewables by imposing predefined total installed capacities of 2000 MW for wind, 2000 MW for PV and 1000 MW for CSP over the study period.
- Increasing the share of NG fired power plants and in particular the combined cycle technology (CC);
- Considering future power plant candidates using LNG;
- Allowing the introduction of nuclear option after 2020;

- ◈ Gradual reduction of transmission and distribution losses in the electric grid from present 22% to 12% in 2030.

3.2.1 Results of Mitigation Scenario (MS)

Figure 13. present the optimal expansion plan of electric system for the MS. The optimal expansion plan of MS shows that the installed capacity will arrive 32360 MW in 2030. The new capacity addition is distributed to 16500 MW for CC (of which 900 MW will be converted form GT to CC), 2100 MW LNG fired power plants, 2600 MW for fuel fired steam power plants, 3100 MW GT, 1600 MW for two nuclear power plants (that will enter the system in 2020 and 2025 with 600 MW and 1000 MW respectively), 1500 MW coal fired power plants, 2000 MW for wind, 2000 Wm for PV and 1000 for CSP. The expected share of installed renewables will arrive about 15% in 2030. It is noticeable that the share of renewables in this year will exceed the share of HFO that will amount to 8% only. The total installed capacity of MS is higher than that of RS due to the increased share of renewables with their low availability factors.

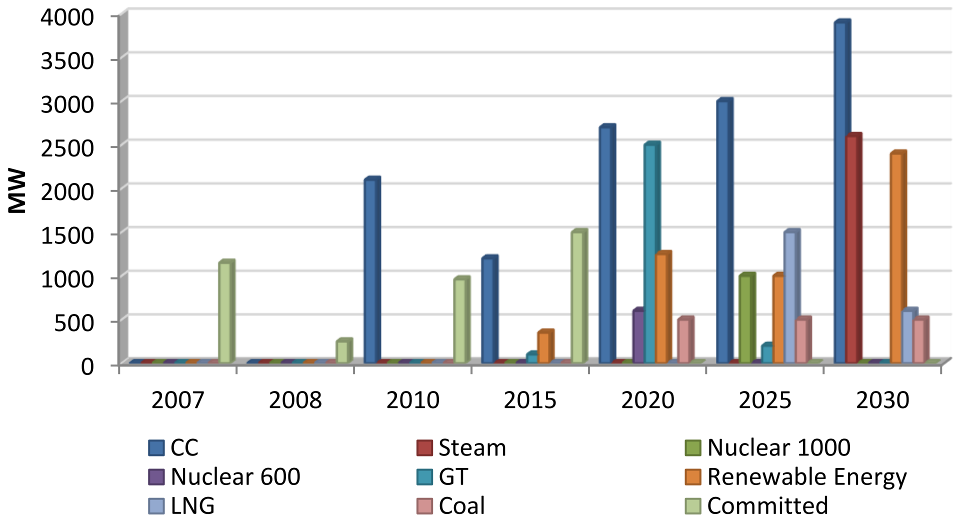


Figure 13. New capacity addition by power plant type (MS)

Following the above results the achieved structure of the generation system for MS show more diversity in type of generation and increased contribution of CC. Besides, the share of the installed renewable will arrive 15% in 2030 compared to 1% for RS. Figure 13 presents the development structure of the optimal expansion plan for MS including the installed capacity and peak demand.

3.2.2 Eelectricity Generation and Fuel Consumption of MS

The results indicate that the electricity generation will increase by an average annual of 6% from 34 TWh in 2005 to 141 TWh in 2030 (Table 14). Hence, the fuel demand will grow by an average annual of 4.7% from 7 Mtoe (distributed to 58% HFO and 42% NG) to about 23 Mtoe in 2030 (distributed to 46% NG, 29% HFO, 11% LNG and 13% nuclear) as presented in Figure 15.

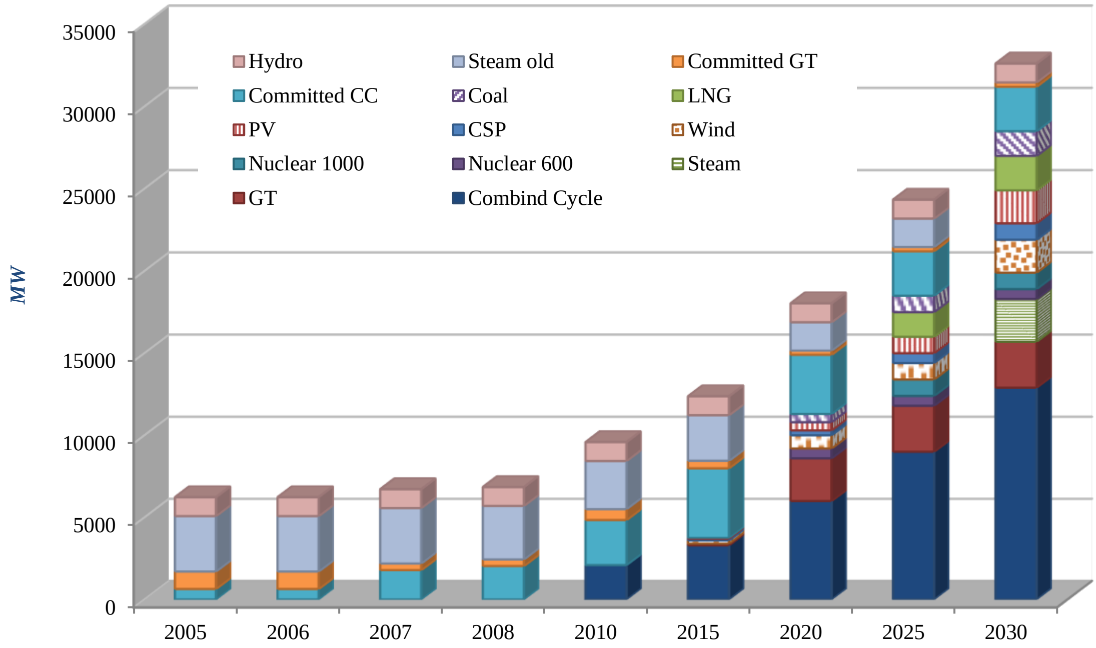


Figure 014. Optimal expansion of future generation system (MS)

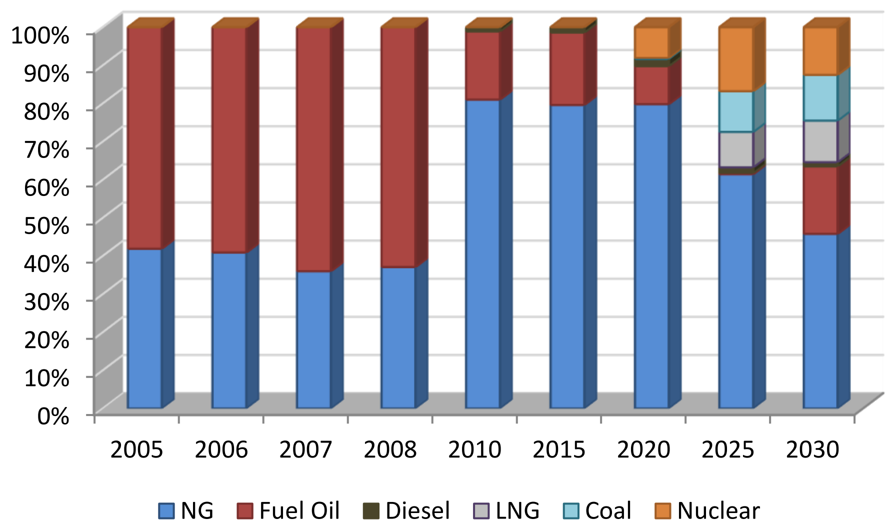
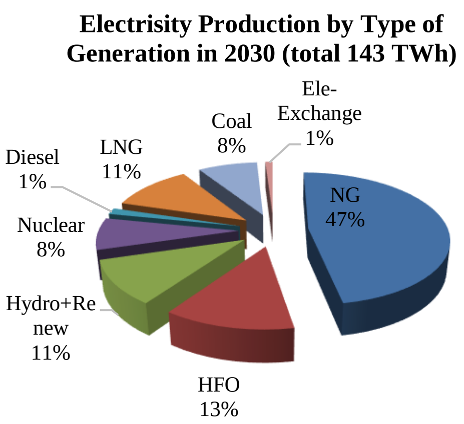


Figure 015. Distribution of fuel shares for electricity generation (MS)

Figure 16 shows a comparison of the expected generated electricity for RS and MS in 2030. It can be seen that for MS about 11% of the electricity will be generated from renewables (including hydro) compared to 3% for the RS. Besides, the share of CC will arrive 46% compared to 31% for RS.



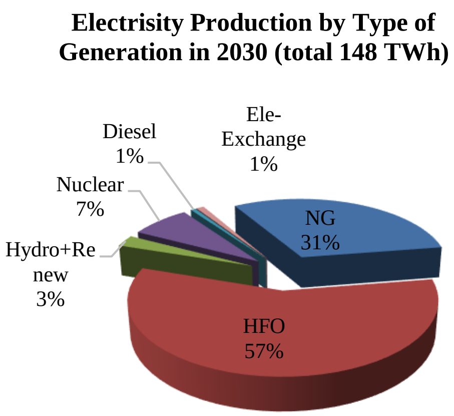


Figure 16. Distribution of generated electricity by type of generation

3.3 Comparison of GHG Emission for both Scenarios

The results of Reference and Mitigation scenarios are compared in order to evaluate the impacts and the effectiveness of the proposed mitigation measures on the structure of future power sector and the achieved annual reduction of GHG emission during the study period (Figure 17). The results indicate that the impact of proposed measure will be effective after 2010. The GHG reduction will arrive 8 Mton CO_2 in 2020 and will grow to 17 Mton in 2020 and arrive 23 Mton in 2030 corresponding to an average annual reduction rate of 13% for the period 2015-2030. Compared to RS the achieved GHG reduction will amount to 11% in 2015 and 27% in 2030.

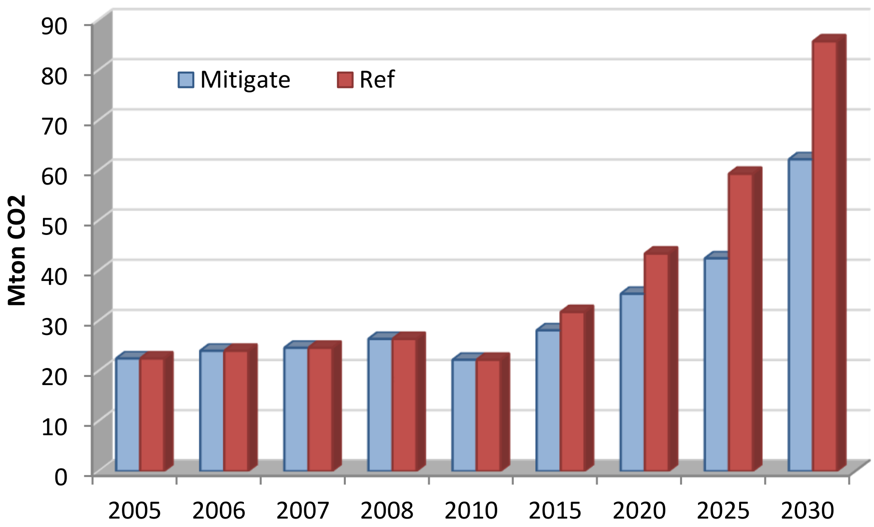


Figure 17. Comparison of CO2 Emissions for RS and MS

Figure 18 presents the relative development of CO2 emissions by fuel type for MS. Starting from the present situation where HFO is dominating, the increased share of NG will substitute HFO up to the year 2020 for which the highest NG availability is expected. After that the NG decrease will be compensated by renewables and nuclear.

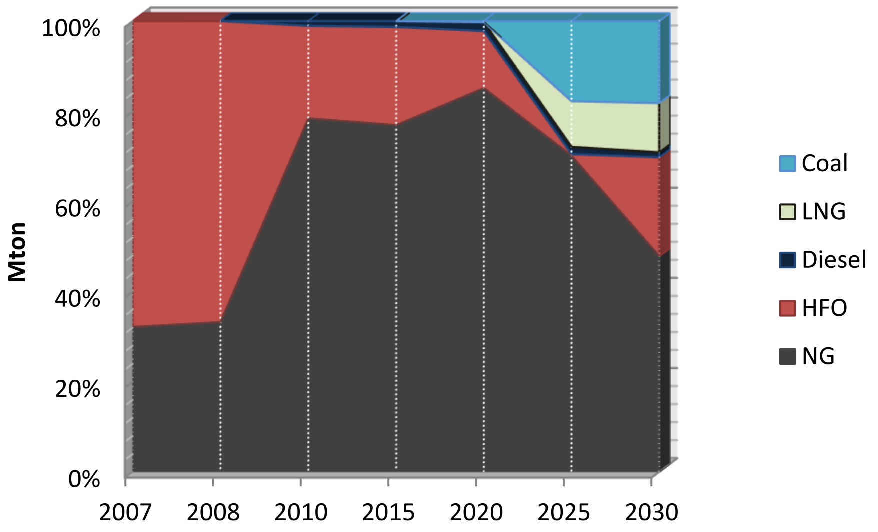


Figure 18. Development of CO2 emission of power sector by fuel type (MS)

The evaluation of the achieved emission reduction by type of measure show that the emission reduction arise mainly from the proposed increase of NG and CC in the future generation system, followed by the increased contribution of renewables their share will arrive 11% in MS compared to 3% in RS, and the last is the role of the expected reduction of technical losses in electric grid. Figure 19 presents the GHG reduction results by type of mitigation measure for the year 2030. It can be concluded that the shift to use NG and CC instead of HFO fired steam turbines will contribute by 62% of total GHG reduction, followed by substitution of fossil fuel by renewables with 26% and the reduction of technical loses and efficiency improvement by 12%. The achieved results confirm the importance of increasing NG share in the generation process for reducing GHG emission and fulfilling the requirements of sustainability development of energy sector in environmental dimension.

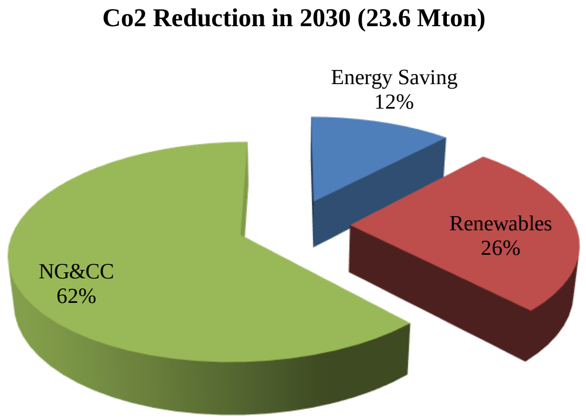


Figure19.: Expected CO2 Reduction by Type of Mitigation Measure in 2030

(NG&CC: substituting HFO by NG and shifting to CC, Renewables: increasing the share of renewable energies, Energy Saving: reduction of electric grid losses and efficiency improvements)

Figure 20 presents a comparison of the expected development of specific GHG emission per generated kWh for RS and MS. It can be seen that the proposed mitigation measures given by HFO replacing by NG in steam turbines and the increase CC share in addition to the further adopted measures will help to reduce the specific GHG emission from 0.64 kgCO2/kWh in 2007 to about 0.4 kgCO2/kWh in 2030 for MS compared to 0.58 kgCO2/kWh for RS showing a relative reduction of specific Co2 emission of Syrian generation system of about 25%.

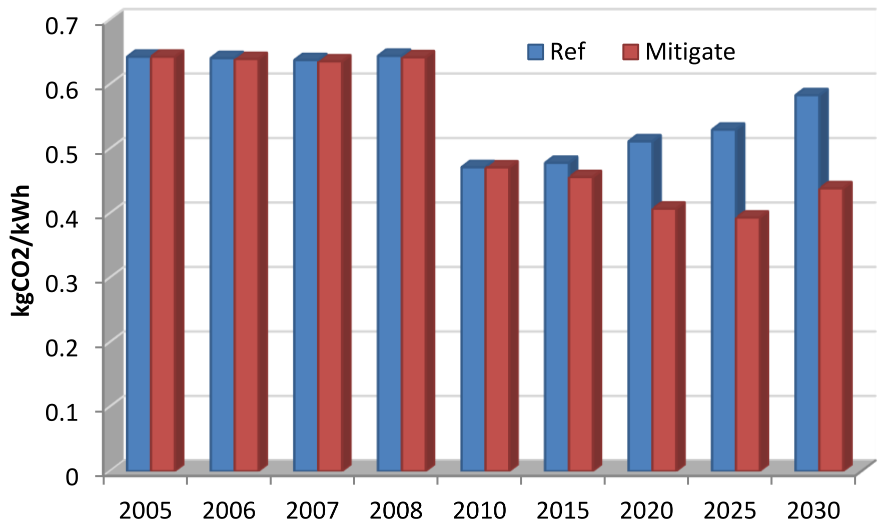


Figure 20. Comparison of the future development of specific GHG emission for RS and MS

4. Conclusion

Over the study period 2007-2030 The CO_2 emission will grow from 24.6 Mton in to about 86 Mton for RS and 62 Mton for MS showing a reduction of about 14 Mton in the year 2030. The cumulative amount of the expected GHG reduction over the study period will amount to 200 Mton of CO_2. Thus, the adopted mitigation measures given by increasing the share of clean technologies represented by CC and renewables in addition to the further adopted conservation measures will help in achieving significant mitigation of GHG emissions. to reduce the specific GHG emission from 0.64 kgCO_2/kWh in 2007 to about 0.4 kgCO_2/kWh in 2030 for MS compared to 0.58 kgCO_2/kWh for RS showing a relative reduction of specific CO_2 emission of Syrian generation system of about 25%.

The evaluation of the achieved emission reduction by type of measure show that the emission reduction arise mainly from the proposed increase of NG and CC in the future generation system, followed by the increased contribution of renewables their share will arrive 11% in MS compared to 3% in RS, and the last is the role of the expected reduction of technical losses in electric grid. The evaluation of the achieved results of GHG reduction by type of mitigation measure for the year 2030 indicates that the shifting from using HFO in steam turbines to NG and CC will contribute by 62% of total GHG reduction, followed by substitution of fossil fuel by renewables with 26% and the reduction of technical loses and efficiency improvement by 12%. This observation confirms the importance of increasing NG share in the generation process for reducing GHG emission and fulfilling the requirements of sustainability development of energy sector in environmental dimension.

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