ENVIRONMENTAL & ENERGY POLICIES & CO_2 EMISSIONS

GECF REPORT

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GAS EXPORTING COUNTRIES FORUM

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Report citation: Gas Exporting Countries Forum.
GECF report on environmental issues 2017

West Bay Towers view, Doha - Qatar

Gas Exporting Countries Forum

The Gas Exporting Countries Forum (GECF) is an international, governmental organization, established in 2001. It became a full-fledged organization in 2008 with its permanent secretariat based in Doha, Qatar.

The GECF provides the framework for exchanging experience and information among Member Countries. The GECF is a gathering of the world's leading gas producers whose objective is to increase the level of co-ordination and to strengthen collaboration among Member Countries.

In accordance with the GECF Statute, the organization aims to support the sovereign rights of its Member Countries over their natural gas resources and their abilities to develop, preserve and use such resources for the benefit of their peoples, through the exchange of experience, views, information and co-ordination in gas-related matters.

The Member Countries of the Forum are: Algeria, Bolivia, Egypt, Equatorial Guinea, Iran, Libya, Nigeria, Qatar, Russia, Trinidad and Tobago, the United Arab Emirates and Venezuela. Azerbaijan, Iraq, Kazakhstan, the Netherlands, Norway, Oman and Peru have the status of Observer Members.

Abbreviations

Bcm	Billion Cubic Metres
b/d	Barrels per day
BRICS Countries	Brazil, Russia, India, China and South Africa
BTU	British Thermal Unit
CAAGR	Compound Average Annual Growth Rate
CBM	Coalbed Methane
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power; the term co-generation is sometimes used
CIS countries	Commonwealth of Independent States
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
COP	Conference of Parties (UNFCCC)
EAU	Emission Allocation Unit
EIA	Energy Information Administration (US)
EOR	Enhanced Oil Recovery
ETS	European Emission Trading Scheme
EU	European Union
FID	Final Investment Decisions
FYP	Five Year Plan
GDP	Gross Domestic Product
GECF	Gas Exporting Countries Forum
GGM	Global Gas Model
GHG	Greenhouse Gas
Gtoe	Giga Tonne Equivalent
IEA	International Energy Agency
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
KBPD	Thousand Barrels per day
Km	Kilometer or Kilometers
LNG	Liquefied Natural Gas
Mboe/d	Million barrels of oil equivalent per day
MER	Market Exchange Rates
mmBtu or mBtu	Million British Thermal Unit
Mtoe	Million Tons of Oil Equivalent
Mtpa	Million Tons per Annum
NGLs	Natural Gas Liquids
NOCs	National Oil Companies
NPS	New Policies Scenario
OECD	Organization for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PPP	Purchasing Power Parity
PV	Photovoltaic
Tcm	Trillion Cubic Meter
TEC	Technical and Economic Council
UCV	Unconventional
UN	United Nations
US	United States
USGS	United States Geological Survey
WTI	West Texas Intermediate

Introduction

As a member of the world community, GECF recognizes its responsibility to the environment and strives to make it as green as possible by enhancement of gas share in the world energy basket and encouraging the world to further sustainable development of the global gas reserves. Part of this effort is regular studies and increasing awareness on environmental impact of natural gas conducted at the GECF.
These GECF series of brief reports on environmental issues are one of the results for such regular studies on environmental impact of natural gas.
The document explores the subject of environmental energy policies in the context of impact of combustion of fossil fuels on pollution and input from alternative sources of energy (mainly coal and renewables), as well as impact of technological developmentsıo Separately, energy efficiency, environmental policies and other regulations have been considered to study their impact on gas penetration in key markets/sectors and to allow developing GECF views on that matter.

This paper is structured as follows. Part I analyses contribution of fossil fuels' combustion to air pollution. Part II is dedicated to the role of switching from coal to gas as a main driver of recent CO2 emissions' reduction. Part III reviews energy efficiency policies in the post Paris Agreement era. Part IV presents a case study of renewables policy drivers and challenges for United States and China. Part V deals with recent renewable energy trends and role of natural gas. Part VI sums up the prospects of renewables and gas in power generation sector.

Content

I. Air pollution and the fossil fuels' combustion

There are several air polluting elements that have various effects on human health. Here the contribution of different fossil fuels to air pollution is examined along with these effects.

What are the air polluting elements and what are their main impacts?

There is a need to distinguish between two types of air pollutants: the primary pollutants which are directly emitted from the combustion of fossil fuels, industrial processes, and agriculture or also from natural processes, and the secondary pollutants such as ozone or secondary "particulate matters", which are created through a reaction of primary pollutants and other components in the atmosphere. The sunlight is a main catalyst for this reaction[1].

Among the main harmful air pollutants are:

- **Sulfur oxides (SOx)**, and especially sulfur dioxide (SO2), which contribute to the formation of acid rain and affect also health by causing respiratory illnesses;
- **Nitrogen oxides (NOx)** contribute to the formation of smog and also could cause respiratory illnesses;
- **Particulate matters (PM)** are composed of organic and inorganic elements and can include soot, ash, metals, and other particles. Particulate matters could be either primary particulates emitted directly to the atmosphere, or secondary particulates resulting from a reaction of primary pollutants with other components. It is worth noting that sulfur dioxide and nitrogen oxide contribute to the formation of these secondary particulate matters.
The negative effect of particulate matter on health depends on the size. The most harmful are the fine particles with less than 2.5 μm (micrometers) causing respiratory problems;
- **Heavy metals**, in particular mercury, have an important effect on human health; they can contribute to neurological damages as well as the development of cancers;
- **Carbon monoxide (CO)**, resulting from the incomplete combustion of transport fuels, coal or wood, is a toxic gas which can lead to death;
- **Smog**, which becomes a serious issue in big cities, can cause many health problems, in particular respiratory illness. It is mainly composed of ozone, resulting from a chemical reaction of carbon monoxide, nitrogen oxides, or particulate matters.

What is the contribution of different fossil fuels to air pollution?

The nature and amount of pollutants' emissions resulting from the combustion of fossil fuels are affected by many determinants:

- **The quality and specifications of the fossil fuels**, which mainly depend on the pollutants' content in fossil fuels. This content can vary significantly between regions, and through the lifetime of the field (for oil and gas) or the mine (for coal).
- **Combustion technology:** different combustion technologies are used in various sectors; these technologies can have different efficiencies which affect the level of pollutants' emissions. Energy efficient technologies consume less fuel and thus cause less pollution.
- **Emissions' reduction processes**: pollutants can be reduced or removed from fossil fuels at various supply chains and processing stages. This removal can be done before or after the combustion. (For instance: coal washing, desulphurization of oil and sour gas before combustion, or the use of catalytic converters in vehicles, pollutants chemical captures after combustion).

The main determinants highlighted above will determine variations of emissions factors for each pollutant by sector and also by region. As a benchmark, we can use the EIA estimation of the average emissions by fuels in power generation sector in United States. EIA did not consider the post combustion removal of pollutants in these estimations.

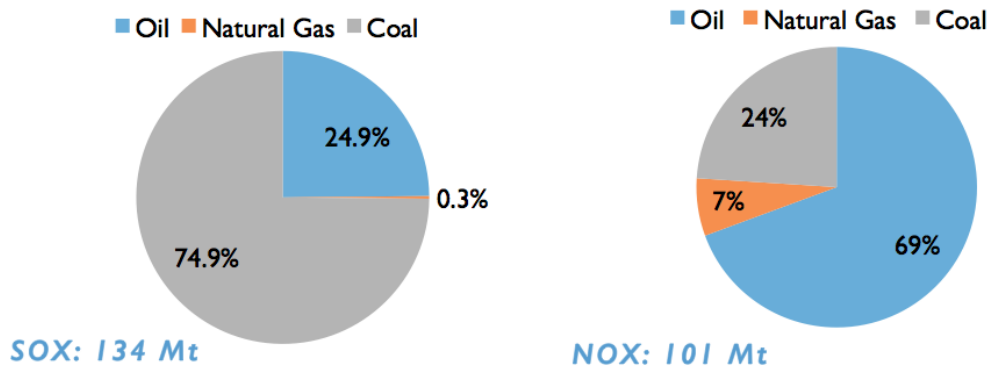
[1] World Energy Report 2016, Energy and Air Pollution
[2] Sandbag, 2017, "Energy Transition in the Power Sector in Europe: State of Affairs in 2016", Jan. 2017, Agrora, Sandbag
[3] Based on GECF communication at the 40th IAEE Conference held in Singapore between 18 and 21st of June 2017

Table 1. Fossil Fuel Emission Levels (lb per Mbtu of Energy Input)

Pollutants	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA

Figure 1: Emissions of sulphur oxide and nitrogen oxide by type of fossil fuel



Source: GECF Secretariat based on the data from GECF GGM

Natural gas is by far the cleanest fossil fuel, with oil and coal emitting around 5 times nitrogen oxides, and coal emitting nearly 2 times carbon dioxide which is the largest emitted greenhouse gas. Additionally, natural gas emits negligible amounts of sulfur oxides and particles, and therefore it does not contribute to the smog formation.

GECF estimates the sulfur oxides (SOx) and nitrogen oxides (NOx) emissions resulting from the combustion of fossil fuels at around 134 Mt and 101 Mt respectively for 2015.

Coal is the main source of SOx representing 75% of these combustion emissions followed by oil (nearly 25%). For NOx, oil is the largest source with 70% share, followed by coal (24%). Natural gas combustion accounted for negligible amount of SOx emissions and around 6% of global NOx emissions.

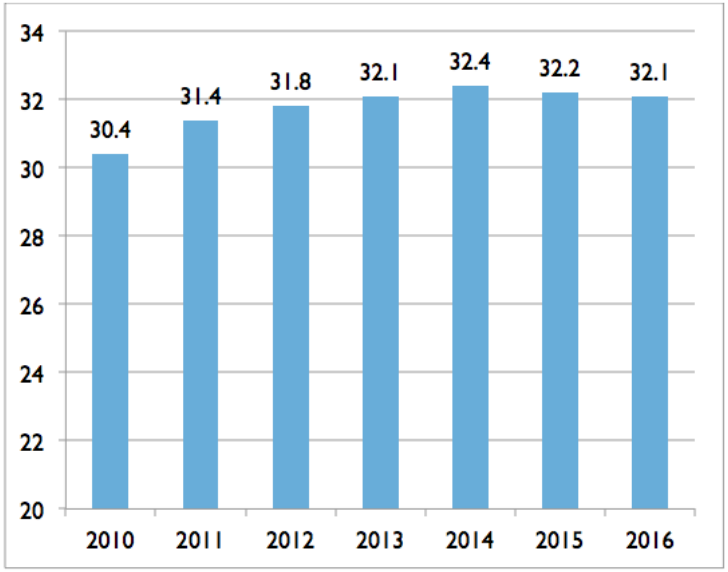
Concerning the harmful particulate matters (less than 2.5 μm), and according to the IEA estimates, global emissions from the combustion of fossil fuels and also biomass are around 35 Mt in 2015. More than half of these emissions are due to the combustion of biomass.

II. Switching from coal to gas as a main driver of recent CO_2 emissions' reduction

Recent evolution of CO2 emissions in the world showed clear evidence that the penetration of natural gas against coal is a key driver of emissions' decrease in many countries and regions.

According to IEA estimates, global emissions from the energy sector reached 32.1 GtCO2 in 2016, and have stabilized for three consecutive years. At the same time, global economy has continued its growth, achieving 3.1% increase in 2016 compared to last year. This is an indication of the decoupling of CO2 emissions from economic activity.

Figure 2: Global CO2 emissions (MtCO2)



Source: IEA 2016

The IEA CO2 emissions data showed also that energy related CO2 emissions decreased in the United States and China, the two largest energy consuming and CO2 emitting countries, and were relatively stable in the European Union. The above-mentioned three regions represent more than half of the CO2 emissions in the world.

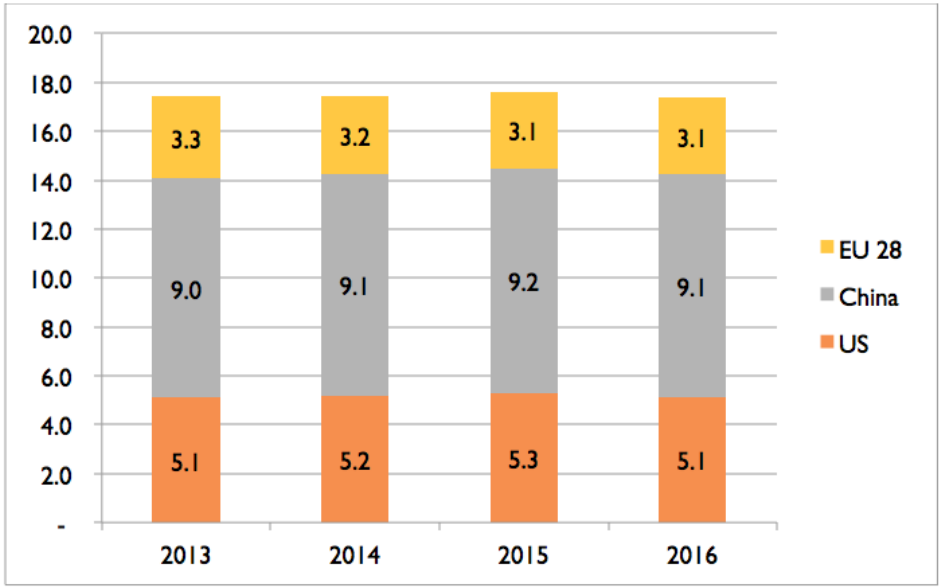
The decline of coal and its substitution by gas in these regions contributed significantly in the recently observed emissions trends.

In **The United States,** CO2 emissions decreased by 3%, or by 160 MtCO2 (this amount is equivalent to the global emissions of a country like Algeria). Coal consumption decrease was particularly important in United States, dropping by 11% in 2016 compared to 2015.

In the US power generation sector, substitution of coal with gas was significant, and the EIA recently released data showed that increase in the electricity generated from natural gas in 2016 is equivalent to around 38% of the observed decrease in electricity generated from coal.

For the first time, electricity generation from natural gas was higher than from coal in 2016 in United States.

Figure 3: CO2 emissions in US, China and EU 28 (MtCO2)



Source: IEA 2016

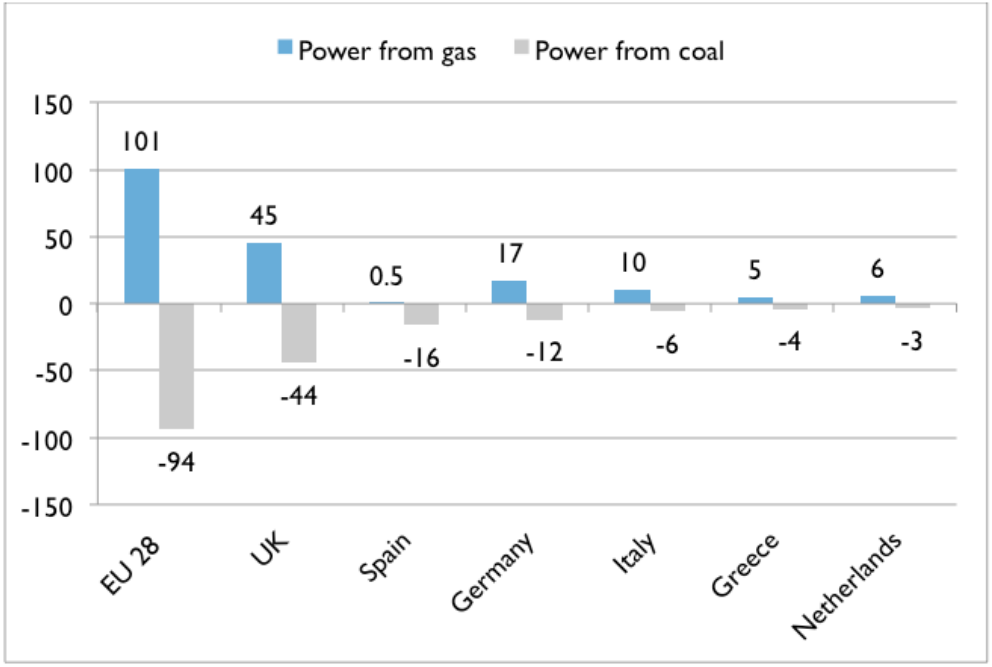
In **China**, total CO2 emissions decreased by 1% last year, driven by decline in coal demand for the third consecutive year. According to preliminary data from China's National Bureau of Statistics (NBS), coal consumption dropped by 4.7% in 2016 compared to 2015, while natural gas demand increased by around 8%. Chinese global energy demand however, increased by 1.4% in 2016 over 2015.

Switching from coal to gas in power generation, industrial and residential sectors is a key determinant of CO2 reduction in China, and this has been mainly driven by aggressive policies aimedg at reducing pollution and greenhouse gas emissions. This move is clearly observed in big cities, particularly Beijing, where the reduction of coal use is considered as an urgent issue. The city has recently closed the last big coal power plant, and is taking measures to reduce the coal in residential sector, particularly for heating.

In **Europe**, total CO2 emissions were relatively stable, but the power generation emission observed a decrease by more than 4% in 2016 over 2015. Substitution between gas and coal in this sector is a key driver of this CO2 emission reduction, despite some disparities between European countries.

European coal-fired power generation fell by 94 TWh in 2016 compared to 2015, while gas-fired generation grew by around 100 TWh.

Figure 4: Variation in electricity generated from coal and from natural gas between 2015 and 2016 (TWh)



Source: Agora Energiewende and Sandbag, 2017

The decrease in coal power plant emissions in 2016 over 2015 was driven by United Kingdom (-58%), Spain (-27%), Greece (-21%) and Italy (-17%). However, Germany and Poland, the biggest European CO2 emitters and coal users, have recorded smaller decrease of coal power plant emissions with respectively 4% and 1% drop in 2016 over 2015[2].

Substitution of gas to coal power generation was clear in most of the countries experiencing a drop of coal use in this sector, and this has been driven by increasing competitiveness of gas power plants, and also by environmental regulation. Even in Germany, the increase of natural gas in power generation has been at the expense of coal.

United Kingdom has seen the most important substitution effect in Europe, with power generation from gas increasing by 45 TWh. One of the key drivers of this increase is the higher level of carbon prices compared to European ETS system, due to the application of Carbon Price Floor by the UK government as part of its climate change policy. UK carbon floor prices reached more than 20 Euros/tonne in 2015 and 2016, compared to EU ETS prices staying around 5 Euros/t.

[2] Sandbag, 2017, "Energy Transition in the Power Sector in Europe: State of Affairs in 2016", Jan. 2017, Agrora, Sandbag

III. Renewables policy drivers and challenges: The case of United States and China

Policies that promote renewable energy have significantly contributed to their recent expansion in the global energy mix, particularly for solar and wind power. Without policy support and government intervention, renewable energy would not have been able to make such progress, because of its technical and economic characteristics and barriers mainly: the relatively high costs; low energy content; need of large areas for project deployment; intermittency and difficulties associated with the integration in the power systems.

The promotion of renewables is considered a priority area in the global effort to deal with climate change, and we can see the role of renewable policies in the countries' INDCs, submitted in the framework of the Paris Agreement.

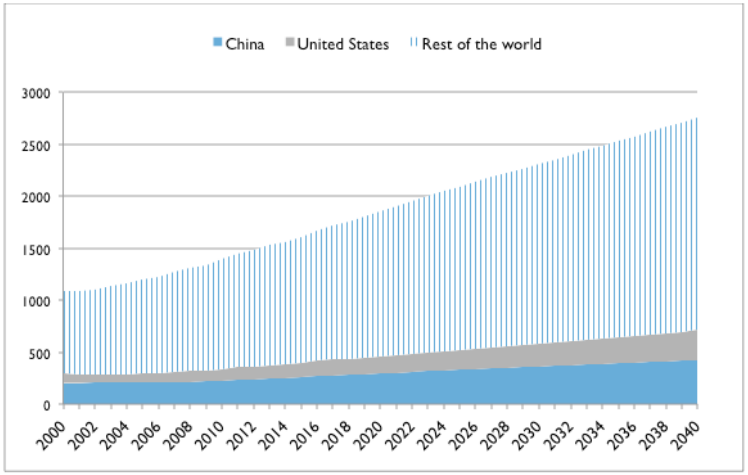
Many countries have considered ambitious targets for renewables, particularly for power generation, where several mechanisms and support schemes are used to achieve these targets, such as subsidies (mainly in the form of feed-in tariffs or tax exemptions); application of priority schemes for electricity supply, renewable electricity supply standards and purchase obligations, or the establishment of renewable investment funds.

In this report, we will investigate the post Paris Agreement policy drivers and challenges in China and United States. These two countries are expected to be the drivers of future renewable development.

Prospects of non-hydro renewables in United States and China

GECF Global Gas Outlook forecasts, in the base case scenario, that renewables (excluding hydro) in the Unites States and China would grow annually by 3% and 2% respectively, between 2015 and 2040. The share of these two countries in global renewable consumption is expected to reach 25% by 2040

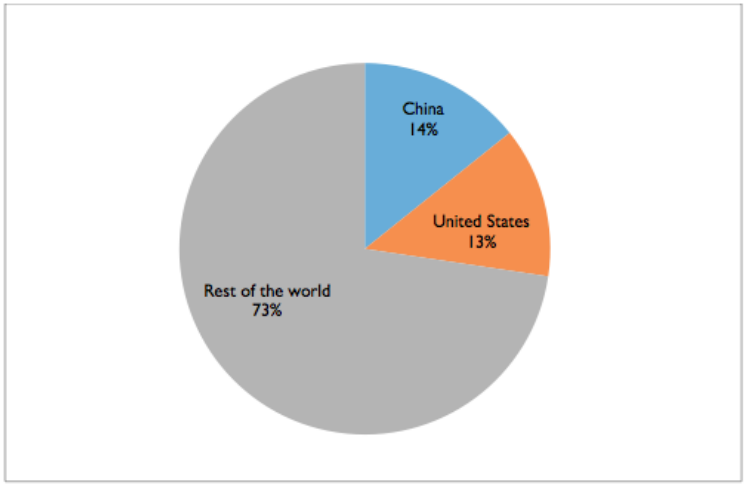
Figure 5: Perspectives of renewables development (Mtoe)



Source: GECF Secretariat based on the data from GECF GGM

Moreover, United States and China are forecast to increase their renewable consumption by nearly 316 Mtoe between 2015 and 2040, which represent around 27% of the world incremental renewables consumption in this forecast period.

Figure 6: Incremental renewable development between 2015 and 2014 (Mtoe)



Source: GECF Secretariat based on the data from GECF GGM

The previous forecasts highlight the key role of the United States and China in future renewable development. However many challenges and uncertainties are characterizing these prospects, particularly the role of policies in supporting renewable development in these countries.

Renewable policies drivers and challenges in United States and China

The case of China:

China has announced its ambition to increase the share of non-fossil fuels, including renewables, to around 20% in primary energy mix by 2030. The country has also considered renewable penetration targets by 2020, especially for power generation. The recently released 13th energy mid-term plan has revised upward these 2020 targets for solar, wind and hydro capacities by more than 50 GW (The new posted target is to reach more than 700 GW by 2020 for solar, wind and hydro power).

China has developed many supporting schemes to meet its renewable targets and commitments such as: feeds in tariffs, renewable purchase obligations. However, the country is facing three main challenges to sustain renewables growth.

• **Funding issues and cost of policy support:** we can note in this regard that China has recently reduced the level of feed in tariffs for renewables; this reduction is driven by the decrease in renewable development costs and also by the need to reduce the costs of policy support. Chinese policymakers are also looking to introduce more market based mechanisms as a way to improve efficiency of renewable policy support and to reduce its cost.

• **Renewables integration:** renewable integration challenge in China is related to the ability of power system to deal with intermittency, particularly with the increasing share of renewables. Indeed, the Chinese power system has experienced some congestion issues, as well as a lack of flexibility to deal with renewable intermittency, and this has led to large renewable curtailments, especially wind power which was not able to reach the consumers.

In order to improve renewable integration, China is considering developing renewable projects close to the large consuming areas. This will allow for better management of intermittency and bottlenecks in power networks.

• **Power generation over capacities:** one of the main issues in China is related to the existing power generation over capacities, particularly in the context of the slowdown of energy consumption. This over capacities could challenge the development of new power plants, including new renewable capacities.

However, in order to reduce these over capacities and also to deal with its environmental commitments, China has considered large phasing out of coal fired capacities, and has ordered the cancellation of many planned coal power plants

The case of United States:

For the United States, the renewable penetration targets are considered at state levels. The most ambitious target is displayed by California State with 50% of renewable share in power mix by 2030. There is no official national target for renewables in United States, but some announcements have been made by president Obama such as the doubling of non-hydro renewables in power generation compared to 2013 level (equivalent to around 10% share of renewables by 2020).

There are mainly two renewable policy drivers in the United States:

• **The State level initiatives,** especially with the Renewable Portfolio Standards, adopted by 30 American states and districts. In the context of these mechanisms, States consider renewable penetration targets, and develop supporting schemes to meet these targets.

• **Federal taxes' credit for the renewable projects (ITC and PTC mechanisms):** They include production tax credit, especially for wind, and investment tax credit, especially for solar. These federal tax exemptions have been extended in December 2015 for a period of 5 years.

The main challenge for the renewable supporting policies is related to the direction of federal energy policy under President Donald Trump. Indeed, the Trump administration has recently taken some steps aimed at dismantle the federal support to various climate actions and programs, with the signing of an executive order in this regard last March. Particularly, the Trump administration has considered stopping the Clean Power Plan which is a main lever proposed by Obama to meet American Paris Agreement commitments.

Trump has also proposed important budget cuts for some federal agencies involved in clean energy and climate change initiatives.

To what extent this move of American energy policy can affect renewables development is still very ambiguous: For instance, there is no clear reference in Trump's executive order and budget proposal to the revision of federal taxes credit for renewable projects (ITC and PTC mechanisms). These supporting mechanisms are likely to be kept, because they are compatible with the job creation objective displayed by Trump (Renewable create more job in United States than coal industry which Trump wants to revive).

In addition, many opposing forces and legal issues can challenge the implementation of the Trump policy.

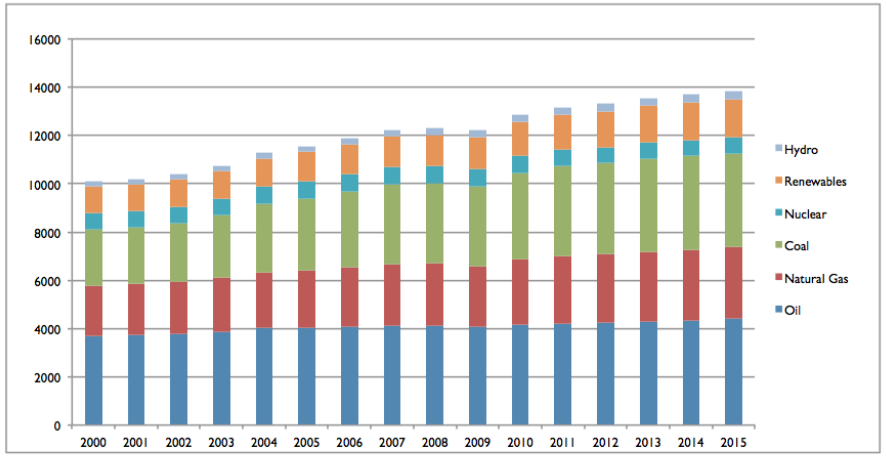
There is a signal that American renewable momentum is likely to be sustained, and driven by state level initiatives and also by the efforts and willingness of the civil society and businesses.

IV. Recent renewable energy trends and role of natural gas[3]

Renewable energy carriers (excluding hydro power) has experienced a significant progress in the primary energy consumption, achieving an average annual growth rate of 3% between 2005 and 2015. This growth rate showed that renewables have been the highest growing energy sources, preceding coal (2.7% average growth) and natural gas (2.3% average growth).

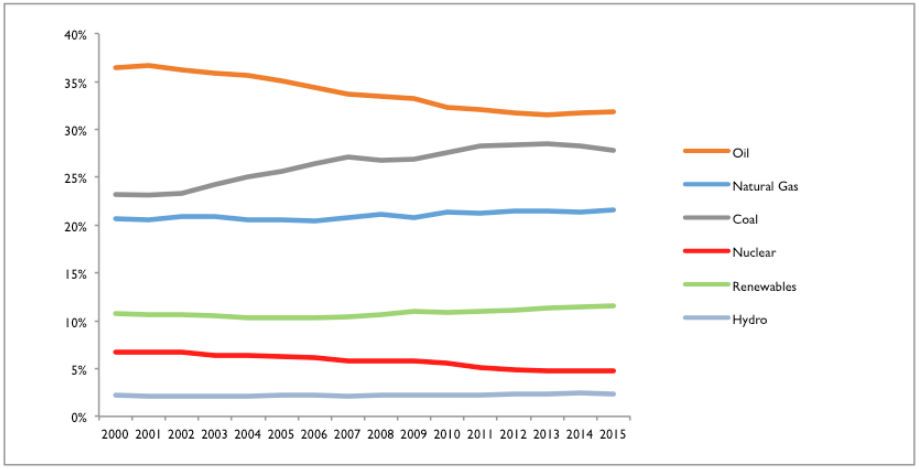
Despite strong progress, the share of renewables in primary energy mix reached 11.6% in 2015, which remains far below natural gas 22% and coal 28%; indicating that the large part of energy needs is still supplied by fossil fuels

Figure 7: Evolution of Primary Energy consumption by source (Mtoe)



Source: GECF Secretariat based on the data from GECF GGM

Figure 8: Fuels' shares in primary energy consumption (%)



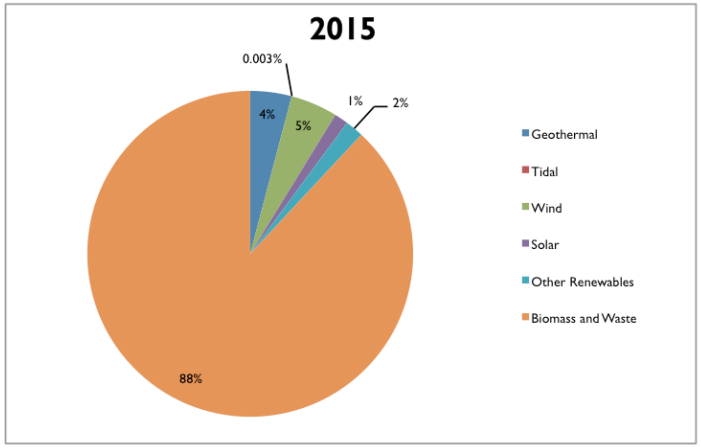
Source: GECF Secretariat based on the data from GECF GGM

[3] Based on GECF communication at the 40th IAEE Conference held in Singapore between 18 and 21st of June 2017

In GECF estimation, renewable energies including biomass and waste, represent 88% of the total non-hydro renewables consumed in 2015, of which a significant share is related to the consumption of traditional biomass (representing around 2/3 of total biomass and waste in 2015)[4]. Despite a relative decrease of its share in the last ten years, traditional biomass still accounted for more than half of non-hydro renewable energy consumed in the world.

The share of solar and wind has reached 6% of the global renewable consumption. This share is still low, but it has increased from less than 1% in 2005 to 6% in 2015, witnessing an accelerated progress particularly during the last 5 years.

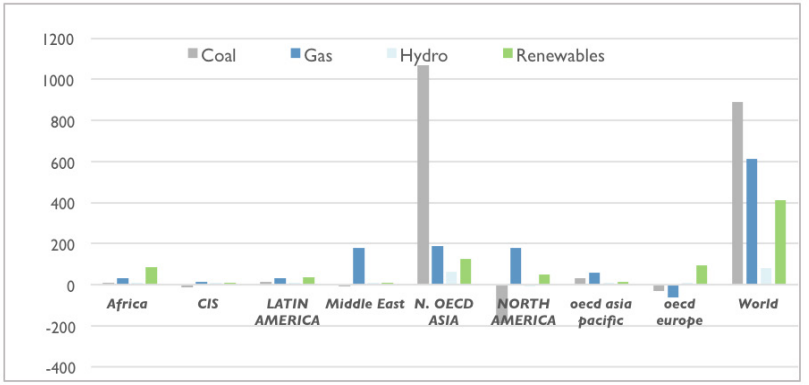
Figure 9: Renewables' consumption by source (2015)



Source: GECF Secretariat based on the data from GECF GGM

In order to assess the dynamics of renewables and natural gas, the incremental consumption of renewables and natural gas by region between 2005 and 2015 is highlighted in the chart below. Also the chart indicates that demand for coal remains an important determinant of gas penetration in many countries and regions.

Figure 10: Incremental primary energy consumption by sources and regions (between 2005 and 2015), (Mtoe)



Source: GECF Secretariat based on the data from GECF GGM

[4] The remaining is due to the consumption of biofuels in the transportation sector and in incinerators producing power and heat

According to the chart, the following evolutions can be observed during the last decade:

• **Non OECD Asia** is showing the most important non-hydro renewables increase compared to other regions (around 30% of global incremental renewables demand between 2005 and 2015), followed by OECD Europe. However, coal has been the main driver in this region playing a key role in meeting the large growing energy needs. Natural gas has increased significantly by more than 180 Mtoe (200 bcm) between 2005 and 2015, but this growth has been driven mainly by industrial and residential sectors. Power generation represents less than 25% of the incremental gas demand in non OECD Asia[5].

• **OECD Europe** displays two main evolutions. On one side, important progress in renewables development, and on the other side, a decrease in conventional energy consumption, including natural gas nearly 60 Mtoe (67 bcm) between 2005 and 2015. These evolutions have been mainly driven by strong policy support to the development of renewables, slowdown in global energy consumption affected by low economic growth (particularly in the context of European economic crisis) and by progress in energy efficiency.

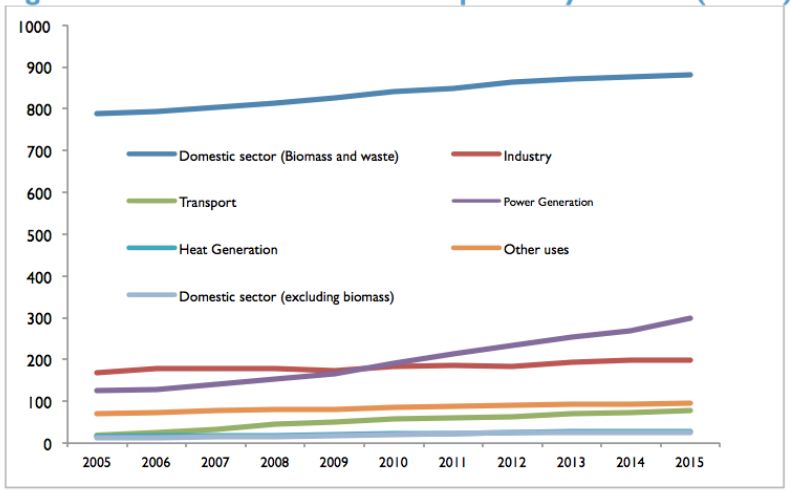
• **North America** highlights significant renewables growth, but natural gas has observed larger increase in this region. We can see a large substitution of gas for coal in North America, especially in United States. This substitution has occurred essentially in the power generation sector.

• In other regions, we can see progress of both renewables and natural gas consumption in order to satisfy the growing energy demand. In Africa, the significant increase of renewables has been driven by biomass used to satisfy the energy needs of growing population (average biomass growth rate is estimated at 2.5% between 2005 and 2015).

Renewables and gas in power generation sector

Power generation has been the most important driver of renewables demand increase, with a 10% average growth rate between 2005 and 2015, followed by waste and biomass consumed in the domestic sector. Renewables in the transportation sector have also registered an increase, despite a relative slowdown observed in the last 2 years, owing to oil price downturn which affected the competitiveness of renewables against oil.

Figure 11: Renewables' consumption by sector (Mtoe)

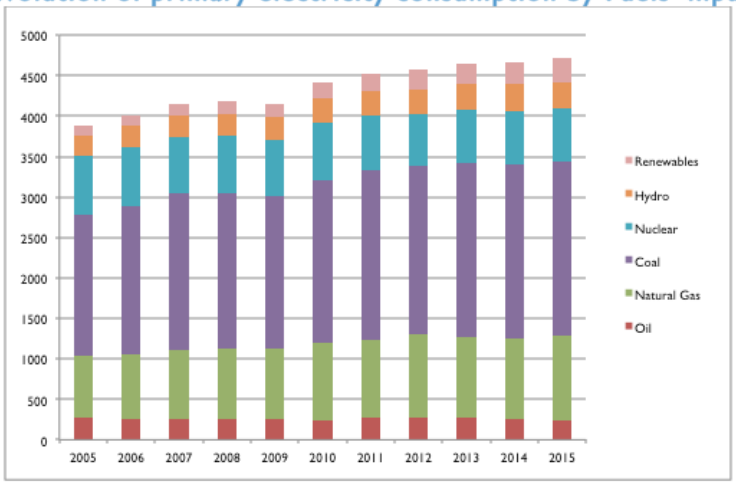


Source: GECF Secretariat based on the data from GECF GGM

[5] [GECF GGO, 2016], GECF Global Gas Outlook 2016, GECF Secretariat, January 2016.

The pace of growth of energy inputs in power generation during the last decade has been largely higher for renewables compared to natural gas and coal.This growth has allowed renewables to reach 14% of the primary electricity consumed.

Figure 12: Evolution of primary electricity consumption by Fuels' inputs (M. Toe)



Source: GECF Secretariat based on the data from GECF GGM

Although the share of renewables has doubled in less than ten years, it remains far below the share of natural gas and coal in power generation mix (estimated respectively at 22% and 45% in 2015).

Many drivers have contributed to the observed accelerated development of renewables in power generation sector:

- Renewable policy supports implemented in many countries. Renewables are promoted as clean source of energy and as a lever to improve security of supply in many important energy-consuming markets.
- Progress in renewable power technologies, particularly solar and wind, which have achieved significant decrease in costs and improvement in efficiency.
- Progress in the execution of renewables projects, particularly the reduction in projects' lead-times. Wind farms can be built in nine months and solar parks in three-to-six months[6].
- Development of renewable equipment industry, particularly in the emerging countries, which has allowed cost improvement and development of scale economies. Renewable industry along the entire renewable value chain is also promoted by many countries to stimulate economic growth and exports.

Taking into account the increasing penetration of renewables in power generation, what could be the effect on natural gas?

Renewables penetration can have two opposing effects on natural gas in the power sector:

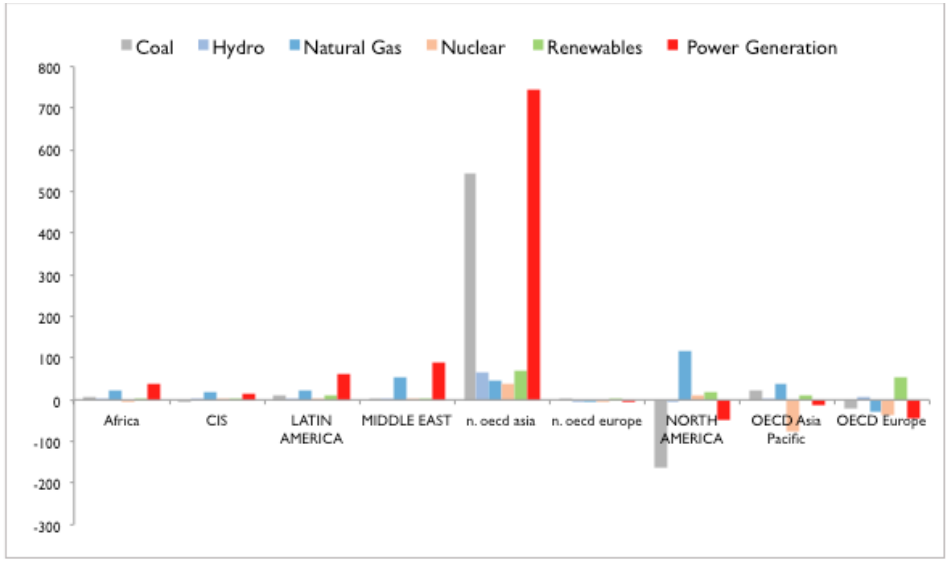
- A positive effect related to the fact that gas fired power plants can play a key role in integrating and in managing the intermittency of renewable electricity, because of their flexibility and ability to balance supply and demand in cost efficient way. Gas power plants enjoy technical and economic advantages that allow them to work in baseload, intermediate load and peak load regimes, and to provide efficient back up for renewables.
- However, renewables can have negative effect on gas power plants and more generally on thermal power plants. Indeed, renewables are often prioritized in the merit order to supply electricity to the power systems, because they are benefiting from support schemes (subsidies, privileged regimes and renewables obligations) and they have very low marginal costs.

[6] [FS-UNEP/ BNEF, 2016], "Global trends in renewable energy investment 2016", Frankfurt School- United Nations Environment Program Collaborating Centre for Climate & Sustainable Energy Finance, 2016

In this context, thermal dispatchable power plants are often used to satisfy the residual electricity demand, which is the remaining electricity after supplying intermittent and prioritized renewables. Increasing renewable penetration contributes to reduce the residual electricity demand and can therefore lead to reducing the operating hours of thermal power plants, especially in the markets with stagnating electricity demand. Renewable penetration can also lead to increase the competition between the traditional thermal sources, particularly between natural gas and coal to meet the residual electricity demand.

The combination of the positive and negative effects of renewables on natural gas is bringing uncertainties on gas demand in power generation sector, but it is expected that environmental concerns and policy supports to natural gas, especially after the adoption and ratification of the Paris Agreement, would give momentum to natural gas as a clean and environmental friendly fuel.

Figure 13: Incremental Power generation by fuels' inputs and regions Mtoe), (between 2005 and 2015)



Source: GECF Secretariat based on the data from GECF GGM

Regional dynamics of renewables and natural gas in power generation

In order to assess more accurately the dynamics of renewables and natural gas in power generation sector, there is a need to consider this dynamic on regional basis and to distinguish between the regions observing high electricity demand growth and other regions having more mature power markets. Furthermore, we need to consider the various sources of energy in power generation.

The chart below highlights the incremental power produced by fuels' input between 2005 and 2015.

In Non OECD Asia, the high growth of electricity demand has driven the demand for all energy sources in power generation. But, coal remains predominant in this region, and represents the most important share in the additional primary electricity demand between 2005 and 2015. Coal is still the fuel of choice in many Asian countries, because of its availability and relatively lower prices. Furthermore, the tightening of domestic supply in traditional gas producing countries in the region, namely Indonesia and Malaysia, has supported the growth of coal in these countries.

We can note a significant increase in renewables driven by solar and wind, especially in China (Chinese solar and wind capacities have grown from 30 GW in 2010 to 170 GW in 2015). The increase of renewables in power generation between 2005 and 2015 in Non OECD Asia is estimated at around 68 Mtoe.

Natural gas use in power generation has also experienced an increase in the region (around 46 Mtoe between 2005 and 2015), stimulated by measures and initiatives aiming to reduce pollutants' emissions in India and China and more recently by gas prices' slowdown. Nevertheless, natural gas is still facing competition from coal, and is often more attractive for other sectors, particularly the petrochemical industry.

In the mature regions like OECD Europe, North America and OECD Pacific Asia, the increase of renewables between 2005 and 2015 (estimated at around 86 Mtoe) has been associated with reduction in electricity demand and power generation outputs. This has put some pressure on traditional energy sources in producing electricity and has led to raising competition, especially between gas and coal

In Europe for instance, between 2005 and 2015, all the traditional energy sources witnessed a decrease of their usage in power generation. In addition, intensive competition has been observed between natural gas and coal in many countries; but recent drop in gas prices and also policy supports to cleaner power, like in United Kingdom with carbon floor prices, have led to large substitution of coal by natural gas.

In North America, renewables and natural gas have seen a significant increase despite the reduction of power generation outputs. In the United States, gas increase has been driven by the relatively low gas prices and also by environmental policy restrictions (Federal restrictions against atmospheric pollutants, state level environmental restrictions). Natural gas increase has reached more than 100 Mtoe between 2005 and 2015.

In the other markets experiencing a growth of electricity demand (Middle East, Latin America and Africa), the increase of renewables remains less important than natural gas, and the recent gas price decrease has even encouraged local use of natural gas, both in gas exporting and in gas importing countries.

Gas importers have recently increased their gas import capacities, particularly LNG in the Middle East and Latin America. However, natural gas consumption in these regions remains sensitive to the evolution of domestic supply of natural gas and to the climate conditions (such as drought affecting hydropower in Brazil).

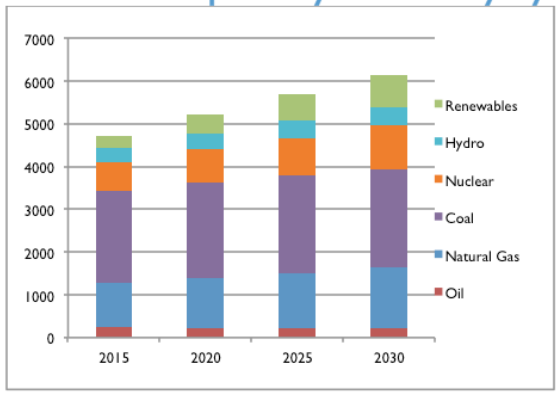
V. Prospects of renewables and gas in power generation sector

Power generation is the sector which will drive renewable growth over the long term; it is also the sector which is the most exposed to competition between renewables and the other energy sources. GECF assessment and forecsats of renewables and natural gas in power genration sector is based on the power module in GECF Global Gas Model.

This power model is based on two interlinked submodels : an investment model which determines the capacity required (including a reserve margin) and which builds capacity based on the power plants long-run marginal costs, and a dispatch model which determines the generated power from different installed capacities to meet the demand of electricity.
In the power generation sector, GECF projections foresee renewable growth at an average rate of more than 6% between 2015 and 2030, compared to 2% growth for natural gas on the same forecasting period.

The increase of renewables will lead to increase in the share of this source of energy in power generation mix (expressed in primary electricity by fuel inputs) to reach 12% in 2030 (around 7% in 2015). Gas also will expand its share in electricity generation reaching 23% in 2030 (around 22% in 2015).

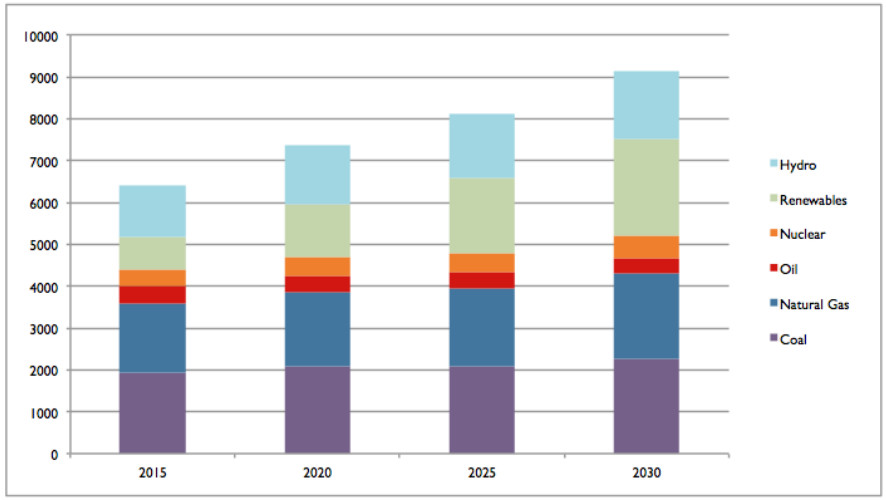
Figure 14: Forecasts of primary electricity by fuels inputs



Source: GECF Secretariat based on the data from GECF GGM

The difference between the rate of growth of renewables and gas in the power sector (expressed in primary electricity by input fuels) is mainly driven by the projected development of renewables and natural gas fired capacities. Indeed, renewable capacity is expected to raise at a much faster pace than natural gas (7% growth for renewables vs. 1.5% for natural gas between 2015 and 2030).

Figure 15: Forecasts of power generation capacities by source

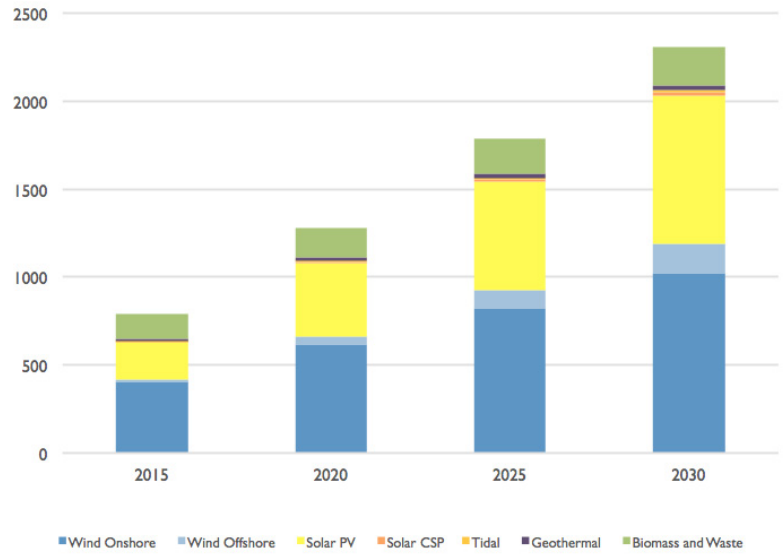


Source: GECF Secretariat based on the data from GECF GGM

Non hydro renewable capacity is projected to increase from 790 GW in 2015 (12% of total installed capacity in 2015) to approximately 2300 GW in 2030 (25% of total installed capacity in 2030), while gas power generation capacity would increase from 1600 GW in 2015 to 2000 GW in 2030.

Non-hydro renewable capacity is projected to increase from 790 GW in 2015 (12% of total installed capacity in 2015) to approximately 2300 GW in 2030 (25% of total installed capacity in 2030), while gas power generation capacity would increase from 1600 GW in 2015 to 2000 GW in 2030.

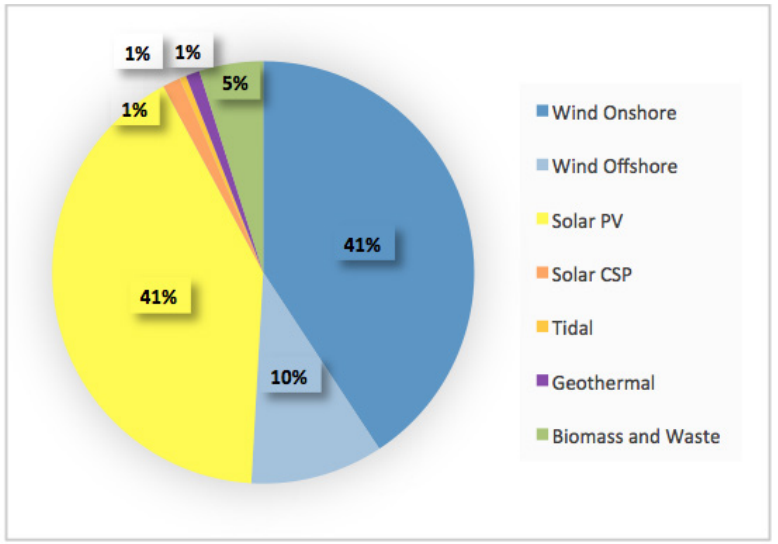
Figure 16: Forecasts of non-hydro renewable power generation capacities by technology



Source: GECF Secretariat based on the data from GECF GGM

Renewables are forecast to represent more than 55% of the total power capacity addition between 2015 and 2030.

Figure 17: Renewable power generation capacities addition (2015-2030)



Source: GECF Secretariat based on the data from GECF GGM

However, we need to be careful when appreciating the dynamic of renewables capacities and its effects on power generation mix. Indeed, large increase in renewable capacity is offset by low capacity factors of renewables technologies and this can lead to much lower increase in renewable energy outputs.

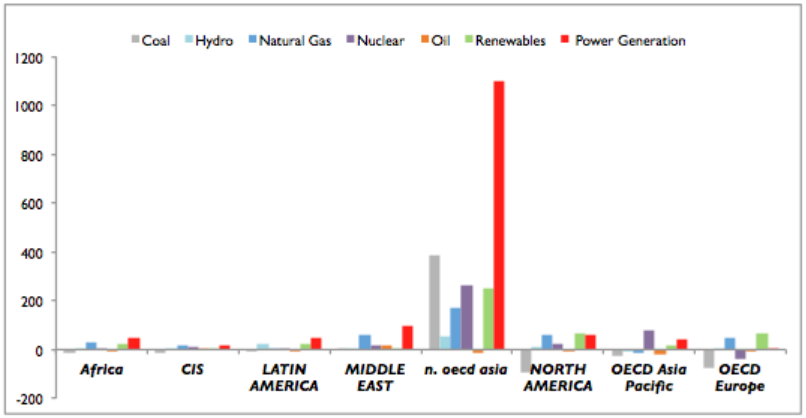
In terms of renewable capacities' increase by type of technology, it is projected that around 90% of the 2015 – 2030 renewable capacity addition will come from wind and solar, particularly wind onshore and solar PV. These two technologies are expected to represent more that 2000 GW by 2030 (80% pf the total non hydro renewables).

Regional prospects for renewables Vs. Natural Gas in power generation sector

The chart below illustrates the projections of incremental power generation by fuels' inputs in different regions, over the period 2015-2030.

These projections highlight the expected evolutions of renewables and gas for power in different regions, and we can distinguish (see red color) regions with strong power generation growth such as non-OECD Asia, those with moderate growth (North America) and regions for which a relative stagnation of power generation needs is expected, especially Europe.

Figure 18: Incremental Power generation by fuels' inputs and regions (between 2015 and 2030)



Source: GECF Secretariat based on the data from GECF GGM

Non-OECD Asia: GECF projections foresee that all energy sources would increase to meet the expected growing electricity demand in the region, which is driven by economic and population increase (non OECD Asia represents nearly 55% of the world incremental power generation between 2015 and 2030).

It is worth noting in this region, that the pace of growth of China electricity demand is expected to slow down compared to previous period, because of Chinese economic growth moderation and structural change of the economy ("New Normal" economic development model).

Renewable energies are expected to rise significantly in non-OECD Asia benefiting from policies' supports and lower costs for solar and wind power, especially with the increase of locally manufactured renewables' equipment. Local equipment industry (solar in particular) is making significant progress and is strongly supporting the renewable development effort in the region.

On the other hand, coal is expected to remain the driver of growth in electricity generation, representing around one third of incremental power generation, particularly in India. Asia is still investing heavily in coal-fired capacity development ($ 65 billion in 2015 according to IEA estimation).

According to GECF forecasts, Non-OECD Asia would also experience high increase of nuclear driven by the ambitious goals of China and India (China's objective is to reach 58 GW by 2020 and India to reach 63 GW by 2032).

For natural gas, despite that this source of energy is expected to see the most important increase in power generation compared to other regions in the world (representing nearly 44% of world incremental gas in power generation between 2015 and 2030); the potential of gas for power generation in the region is affected by the strong competition from other sources, particularly coal, and also by the attractiveness of other gas consuming sectors, especially the industry.

North America: GECF projections foresee the continuity of renewables and natural gas progress at the expense of coal in power generation, to satisfy a relatively growing electricity demand. The growth of electricity demand is mainly due to the expected relative economic growth in this region.

Increase of renewables in North America is estimated at 69 Mtoe between 2015 and 2030. For the United States, extension for a period of 5 years of the federal tax credits (mainly Production Tax credit for wind and Investment Tax Credit for solar), in addition to the state level renewable promotion programs, will be important drivers of American renewable growth.

President Trump's policy can affect this renewable prospects, but at the time of writing, it remains not clear if the tax credit support to renewables, one of the main supporting mechanism, will be amended. Indeed, renewables is an important economic sector creating large job opportunities which is is in line with America first policy objective promoted by the Trump administration.

Natural gas is expected to increase in the American power generation sector, benefiting from competitive prices, environmental restrications at the state level and also regulation promoting the development of extensive gas supply

Renewables and natural gas are expected to see progress at the expense of coal, but federal policy uncertainties in the United States after the Trump election would affect these prospects and could be more favorable to fossil fuels. Nevertheless, evironmental restrictions at the state level and intitiatives from American businesses to supply clean power can be key drivers in sustaining renewable development in the country.

OECD Europe: Considering the projected stagnation of electricity demand in OECD Europe, the rise of renewables is expected to occur at the expense of coal and nuclear power. Natural gas, however, is forecast to grow by nearly 50 Mtoe in Power Generation between 2015 and 2030; this increase is mainly driven by environmental restrictions (such as industrial emissions directive and expected rise of carbon prices). Natural gas will also benefit from its flexibility advantage to ensure an efficient back up of renewables and will therefore play a key role in balancing electricity supply and demand in this region.

On the other hand, renewables are expected to continue their increase in power generation despite a marked slowdown in the rate of deployment compared to the last decade (Average annual renewable growth is forecasted around 3.6% next ten years compared to more than 10% for the last decade). This relativel slowdown is driven by the maturation of renewable deployment in certain markets such as Germany, and also by the expected revisions in subsidies and adjustments of renewable supporting policies (implementation of the new renewable directive) to deal with renewables integration issues[7].

For the other regions, renewables would see an important increase **in OECD Asia Pacific and Latin America** with Japan and Brazil respectively as key drivers of renewable development. Gas in power generation is however expected to play less role in the above two regions, particularly with the forecastdecrease in Japan owing to nuclear restarting.
Gas would see however, an important progress **in Africa, Middle east and CIS region** to support growing power generation needs in these regions. The additionnal gas for power demand between 2015 and 2030 for these three regions is estimated at around 110 Mtoe (more than 120 bcm).

As a conclusion, we can say that power generation is the main driver of renewables growth, which is supported by strong power generation capacity development totaling more than half of the additionnal power generation capacities between 2015 and 2030. Solar photo voltaic and wind onshore are anticipated to represent 80% of this renewables additionnal capacity
Renewables and gas in power generation will see different dynamics between the growing electricity markets and the more mature ones.

[7] Large renewable integration challenge is reflected in the technical and economic difficulties to ensure efficient back up for variable and intermittent renewables, and to control the over capacities in power generation and infrastructure owing to low utilization effect brought by variable renewables outputs

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