Allianz SE | Group ESG Office
Allianz Climate Solutions GmbH

Energy Factsheets

2015

Executive Summary

The energy sector is an important driver and engine of the world economy. Due to the sector's importance, Allianz Group is directly and indirectly involved with various aspects of the global energy system as an investor, insurer, business partner and global corporate citizen.

Allianz is aware that the energy sector faces several significant risks, including environmental pollution issues, its significant contribution to climate change and its high dependency on finite fossil resources. While it remains in the foremost responsibility of energy sector companies and regulators to address these risks, Allianz acknowledges the responsibility it has as a financial services provider to work together with our clients and stakeholders to address and manage material Environmental, Social and Governance (ESG) risks and opportunities that are associated with today's energy sector.

The **Allianz Energy Factsheets** provide a factual overview of the key trends and associated ESG issues along the value chain of eight key energy sources (coal, natural gas, oil and oil products, nuclear energy, hydropower, wind, solar and bioenergy). This documentation is part of the overall Allianz Energy Framework and was used as the basis to inform and design Allianz' actions in the energy sector.

Chapter 1 gives an overview of the overall energy sector, explaining the different energy uses and displaying energy flows with figures for total energy production and consumption

Chapters 2-9 cover the factsheets per energy source. Each chapter/factsheet provides an overview of the most important supplier and consumer countries, the key ESG topics along the value chain, the most important climate/environmental impacts of the resource associated with its extraction and consumption, important regulatory developments and an outlook on potential future developments in the resource sector, including examples of more efficient or climate-friendly solutions

Information was collected from various internationally renowned sources such as for example the International Energy Agency, the US Energy Information Agency and the Intergovernmental Panel on Climate Change.

Key Findings

In 2012, fossil energy sources still made up 82% of the total energy supplied, with the remaining 18% coming from renewable energy sources. In the conversion, combustion, transformation and transmission of primary energy resources to final energy for consumption, 34% of the energy is lost as waste heat or due to other system inefficiencies.

Electricity generation is the most important use of energy resources (38%), however due to inefficiencies in power generation only one third of that energy is actually delivered as electricity and two thirds of the energy are wasted, used in the generation process or during transmission. Coal makes up almost half of the energy resources used for electricity generation, and natural gas almost one quarter. Oil and oil products only make up 5% of the energy used for electricity generation.

Heating is the second most important energy use (30%). Heating is also dominated by non-renewable energy resources: natural gas, coal and oil products are ranked first, third and fourth. It is notable that Bioenergy is the second most important providing almost one quarter of the energy for heating; this trend arises from the fact that large parts of the world continue to engage in traditional heating with woody (and other) biomass.

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1 Energy Overview

1.1 Energy Resources and Carriers

An energy resource is defined by the U.S. Energy Information Agency (EIA) and the International Energy Agency (IEA) as a resource that contains energy which can be converted to kinetic, potential, electrical and heat energy. These resources can be divided into two main categories (see also Table 1.1):

- Fossil Energy Resources, including non-renewable energy such as oil, coal, gas, nuclear
- Renewable Resources, including hydropower, wind, solar, geothermal, biomass

Primary energy is often converted to secondary energy before it is used for final consumption. Some energy resources are also used for their non-energy related properties.

Table 1.1. Overview of Energy Resources

Energy Category	Energy Resource	Factsheet Chapter
Primary Energy non-renewable	Coal	Chapter 2
	Natural Gas	Chapter 3
	Oil	Chapter 4
	Nuclear	Chapter 5
Primary Energy Renewable	Hydro	Chapter 6
	Wind	Chapter 7
	Solar	Chapter 8
	Bioenergy and Waste	Chapter 9
	Geothermal[1]	
Secondary Energy Energy Carriers	Oil Products	Chapter 4
	Electricity	Chapter 2-9
	Commercial Heat[2]	Chapter 2-9

1.2 Energy Uses

It can largely be differentiated between four energy-use groups (generation of electricity; production of heat covers all resources used to produce heat (in industrial and non-industrial applications); transport; non-energy use), however, only electricity and heat are of concern for the Allianz Energy Framework.

1.2.1 Electricity Generation

Globally, non-renewable resources such as coal, natural gas and nuclear make up almost three quarters of the energy used for power consumption. Other resources including renewables make up the other quarter.

[1] As geothermal energy has a minor role in the global energy sector, it is currently not part of Allianz Energy Framework.
[2] Commercial heat should be distinguished from heating, as they are fundamentally different concepts. While heating is an energy use, commercial heat is an energy carrier.
Commercial heat is heat that is created in combined heat and power (CHP) plants, heat plants, or in industrial processes, which is tracked and monitored and which is subsequently sold through heat distribution networks (often steam or hot water). Commercial heat makes up only 3.2% of total final energy-use, and 7.1% of final energy-use for heat (2012 data).

Most electricity is generated in central power stations (such as for example coal- and gas-fired power plants, combined heat and power (CHP) plants, nuclear power stations, photovoltaic (PV) facilities, wind turbines, hydro power plants, tidal power plants), where resources are converted to electricity and then delivered to end consumers through distribution networks.

1.2.2 Heating

Heating is the most important part of energy resource use globally (see Table 1.4), with 45 % of the energy available for consumption being used for heating. Non-renewables, like oil, coal and gas, are the main sources (two thirds) of energy for heat generation. Nevertheless, biomass is especially important for heating in non-OECD countries.

The IEA defines heating as "the consumption of energy sources (excluding electricity[3]) to produce heat in stationary applications. [...] the energy source is directly supplied[4] as a combustible fuel and transformed into heat in the industry, building and agricultural sectors".

1.2.2.1 Combined-Heat and Power Plants

CHP is a process by which electricity and heat are generated from the same energy source. Due to the double use (electricity and heat), such a system is considered to be more energy efficient than plants producing only heat or only electricity.

CHP has the further advantage that it can be done with almost any combustible energy resource (including for example coal, natural gas, biomass and waster).

The main system types are:

- Prime Movers: energy resources are combusted to generate steam which is then used to drive a turbine; the steam is regulated (temperature and pressure adjusted) and sold as commercial heat.
- Generators and waste heat recovery: traditional generators produce power and the heat is then recovered from the exhaust using a heat recovery system.
- Industrial CHP: industrial facilities requiring electricity and heat may have their own CHP plants for use in their facilities. Both the heat and electricity are then used on site.
- Residential, Institutional and Commercial CHP: Buildings, can use CHP systems to produce electricity and heat for the building.

Without any form of (heat) recovery, the conversion of energy resources to electricity would have an efficiency ratio of 3.18 PJ : 1 PJ (across all energy resources including coal), meaning that only 32 % of the energy would be recovered as electricity. The remaining 68 % would be released as waste heat. Efficient CHP plants can reach efficiencies ranging from depending on the technology used.

CHP plants make use of this waste heat by capturing and redistributing it to be sold by other consumers. This allows CHP to be 65 % to 80 % more efficient in recovering primary energy, such as that contained in coal, for final consumption. Furthermore, a CHP plant is more efficient that separate heat and power plants.

[3] Heat can also be generated using electricity. The IEA does not track this heat and thus excludes heat generated from electricity from heat energy figures. This is especially relevant for countries where low-cost electricity is used for heating such as for example Canada, France and Norway.
[4] Exceptions: commercial heat, solar and geothermal heat and heat from ambient energy.

1.2.3 Transportation

An important part of energy is also used for transportation of goods and people. Examples of energy uses are gasoline and diesel in internal combustion engines, biogas in busses, kerosene in aircraft, and fuel oil in ship engines.

A large part of the energy used in transportation currently comes from fossil fuel resources. Renewables such as ethanol additives are slowly gaining significance in the sector.

1.2.4 Non-Energy Use of Fuel Resources

Due to their chemical and/or physical properties, many energy resources may also be used for non-energy purposes. The chemical industry, for example, uses different refined oil products to produce cosmetics, fertilizers and pesticides. Another example of a non-energy use would also be motor oil, as it is not used as a fuel but as a lubricant in engines.

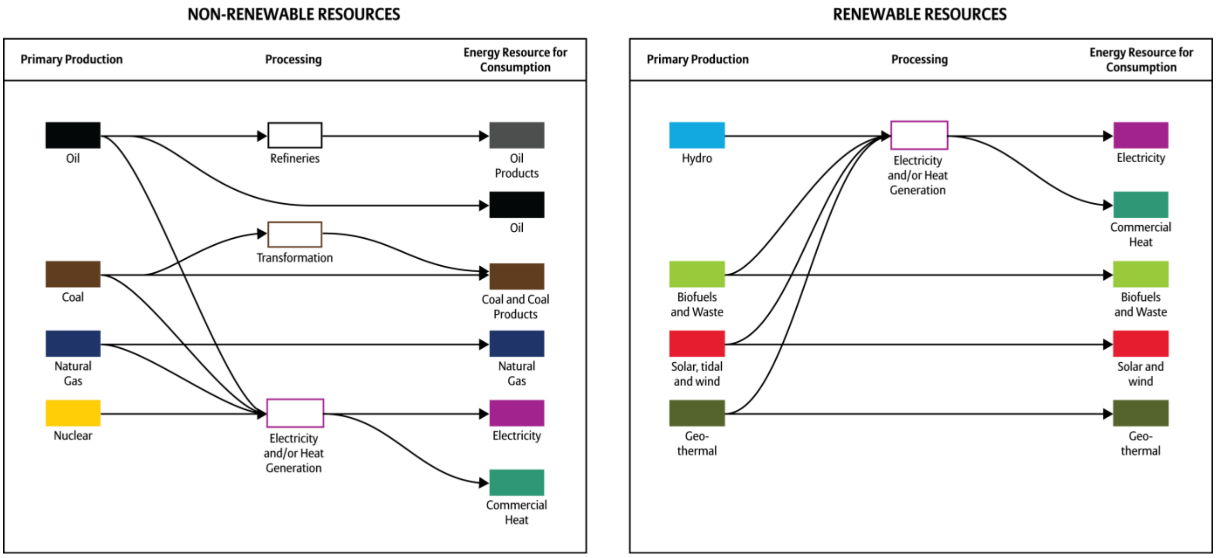
1.3 Key Energy Flows and Statistics[5]

According to data from the International Energy Agency, the global production of all types of energy resources equaled 563 590 PJ and the total consumption 375 937 PJ.

This number includes the following primary energy sources: Renewables (hydro, wind, tidal, solar, geothermal and biomass) and non-renewables (oil, coal, natural gas, uranium). The energy in these resources is mostly converted, transformed and/or refined into energy carriers for final energy consumption. During transformation, a significant share of the energy is lost in the form of heat released into the atmosphere or used for operating the transformation process.

Figure 1.2 (see page 10) visualizes the key energy flows from primary production to final consumption to help understand the different energy flows to the final uses of heating, transportation, electricity.

Figure 1.1. Simplified Overview of the Transformation of Primary Energy Sources to Final Energy Resources for Consumption



Source: Author's illustration according to IEA (2005).

1.3.1 Primary Energy Production

Oil, coal and natural gas are the three most important primary energy sources together making up 82% of the total primary energy supply (TPS). Nuclear and renewable resources provide the remaining

[5] In section 1 all energy quantities refer to 2012 IEA data, unless otherwise noted.

share of energy. Table 1.2 provides an overview of the global energy resource production by energy resource.

Table 1.2. Overview of Global Energy Resource Production

Primary Energy Source	Energy Resource Production 2012	
	PJ	% of total
Oil	176 059	31.24%
Coal	166 073	29.47%
Natural gas	119 238	21.16%
Biofuels and waste	56 133	9.96%
Nuclear	26 884	4.77%
Hydro	13 222	2.35%
Solar/tide/wind	3 149	0.56%
Geothermal	2 786	0.49%
Heat	46	0.01%
Grand Total	**563 590**	**100.00%**

Source: IEA (2014b) IEA Energy Sankey and IEA (2014c) Key World Energy Statistics 2014.

1.3.2 Energy Conversion

The primary energy is then converted into secondary energy through various processes. During these processes about 34 % of the energy produced is lost[6] or used in the process. Thus, of the 563 590 PJ produced, only 375 937 PJ are available for final consumption.

1.3.3 Energy Carriers for Final Consumption

The final energy for consumption is the total energy available for use in all sectors, net of any energy losses during conversion, transformation or transmission processes and own-use by the facilities executing these processes.

Table 1.3. Overview of Global Energy Carriers for Final Consumption

Energy Carrier for Final Consumption	Energy Carrier for Consumption 2012	
	PJ	% of total
Oil products	152 067 PJ	40,45%
Electricity	68 094 PJ	18,12%
Natural gas	57 187 PJ	15,21%
Biofuels and waste	46 497 PJ	12,37%
Coal	38 074 PJ	10,13%
Heat	12 000 PJ	3,19%
Oil	840 PJ	0,22%
Solar/tide/wind	836 PJ	0,22%
Geothermal	297 PJ	0,08%
Grand Total	**375 892 PJ**	**100,00%**

Source: IEA (2014b) IEA Energy Sankey and IEA (2014c) Key World Energy Statistics 2014.

[6] Energy losses also include statistical errors in the IEA data.

The total energy available for consumption (375 892 PJ) is used by different sectors as outlined in Table 1.4. The main final energy use is heat (45 %) followed by transport (28 %), electricity (18%) and non-energy uses (9 %).

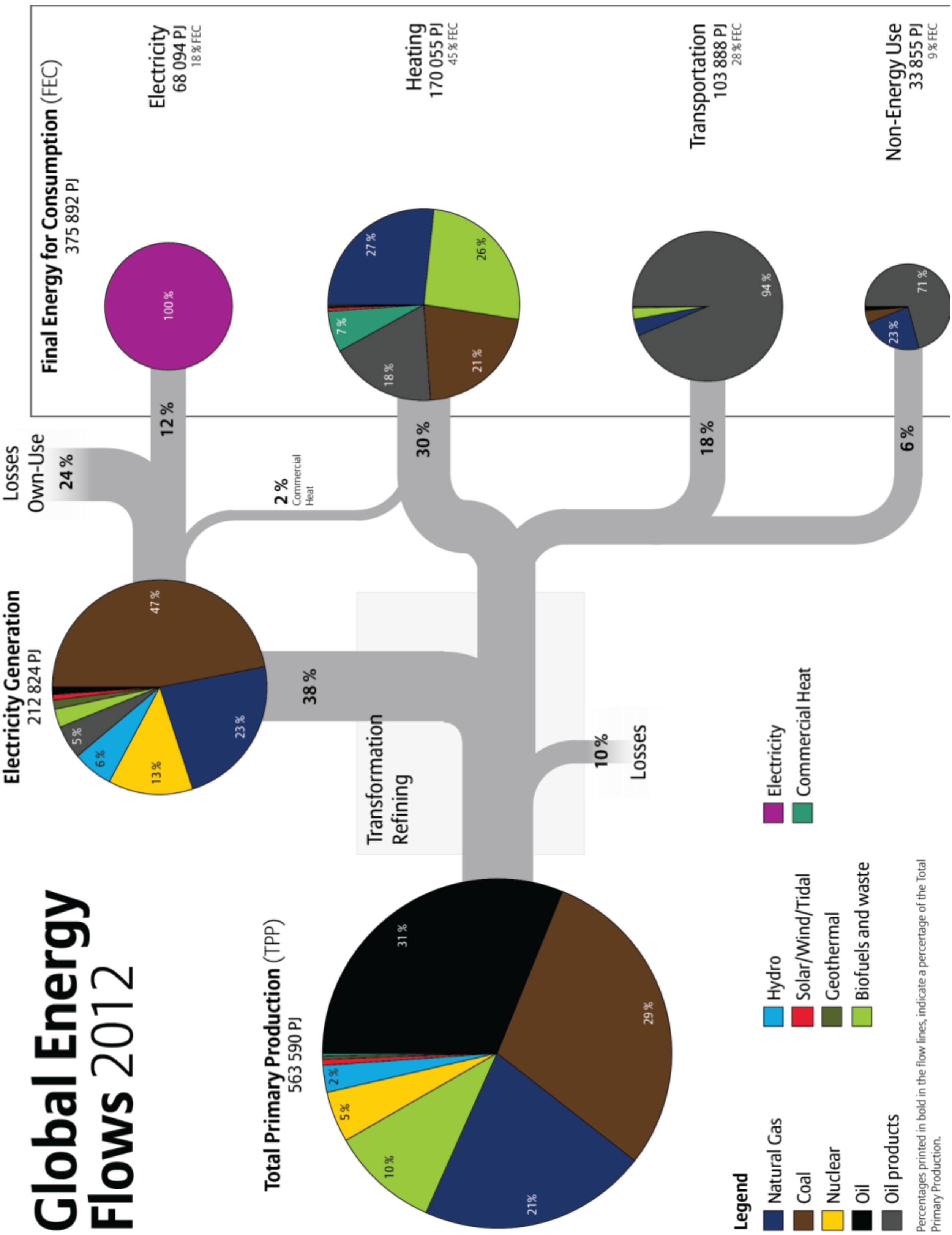
Table 1.4. World Energy Resource Consumption in 2012

Total Energy Consumption ...	Energy [PJ]	% of FEC	% of TPES
for heating	170 055 PJ	45 %	30 %
for transport	103 888 PJ	28 %	18 %
for electricity	68 094 PJ	18 %	12 %
for non-energy uses	33 855 PJ	9 %	6 %
Total Final Energy for Consumption (FEC)	375 776 PJ	100 %	66 %
Total Primary Energy Supply (TPES)	563 590 PJ		
Energy Losses[7]	187 814 PJ		34%

Source: IEA (2014b) IEA Energy Sankey and IEA (2014c) Key World Energy Statistics 2014.

[7] The remaining 34 % are energy losses during the conversion, transformation and transmission.

Figure 1.2. Global Energy Flows from Total Primary Production to total Final Energy for Consumption



Source: Author's illustration based on IEA (2014b) IEA Energy Sankey.

2 Coal

2.1 Supply and Demand

In 2012, global coal supply reached 162 385 PJ (29 % of TPES). Coal is the second most important primary energy resource after oil.

Of these 162 385 PJ of coal supplied, 100 027 PJ are used in global electricity production, which makes it the number one primary resource for electricity production worldwide (47% of Final Energy Electricity(FEE)). 35 712 PJ are supplied to the heating sector (21 % of Final Energy Heat (FEH)).[8]

Furthermore it is the geographically most wide-spread fossil fuel with 75 countries having coal deposits, amongst them many developing countries, and over 50 countries actively mining coal with a global production of almost 8 billion tons (as of 2012).

Table 2.1. Overview of Coal Supply and Consumption

	Production (2012)		Consumption (2012)		Electricity production from coal (% share)	
1	China	3505 Mt	China	3785 Mt	China	3723 TWh, 79%
2	USA	851 Mt	USA	745 Mt	USA	1875 TWh, 38%
3	India	558 Mt	India	692 Mt	India	715 TWh, 68%
4	Indonesia	383 Mt	EU	319 Mt	Japan	281 TWh, 27%
5	Australia	374 Mt	South Africa	187 Mt	Germany	272 TWh, 45%[9]

Source: BGR (2013) Energiestudie 2013 and World Bank (2015) The World Bank Database.

As China's energy demand is rising rapidly, its coal consumption is currently almost as high as the consumption of the rest of the world combined. Despite abundant coal resources, China turned into a net importer in 2009 mainly due to lacking transportation infrastructure from mines located in the north west to consumption areas in the south. In addition, during recent consolidation efforts initiated by the Chinese government, many coal mines were closed because of poor health and safety standards. The second largest importer is the European Union (EU) (211 Mt), followed by Japan (185 Mt) and India (138 Mt), whose imports have doubled since 2008, and its demand is predicted to rise significantly within the next years. The three biggest exporters are Indonesia (384 Mt), Australia (316 Mt) and Russia (123 Mt), exporting the vast majority of their annual coal production.

2.2 Key Issues in the Value Chain

While coal quality can vary significantly by region and is determined by the level of moisture, ash, sulfur, volatile matter and other impurities, the IEA classifies coal according to its energy content as hard coal and brown coal.

Hard Coal (gross calorific value greater than 23 900 kJ/kg; on ash free basis): *anthracite*, used for industrial and residential applications; *coking coal* (approx. 15% of the global coal demand) used for

[8] The remaining difference to the TPES goes to non-energy uses of coal, the transport sector, transformation losses.
[9] As of 2011.

steel making; *steam coal*[10] (approx. 80% of the global coal demand) mainly used for steam-raising in power plants and heat production.

Brown coal (gross calorific value of less than 23 900 kJ/kg; on ash free basis): Brown coal with more than 31% volatile matter includes *sub-bituminous coal* and *lignite* and accounts for only 5% of the global demand. It is mainly used for domestic purposes as low energy content and high moisture levels make long-distance transport uneconomic.

2.2.1 Electricity Generation

Currently, the majority of electricity from coal is produced using these three methods:

- *"Pulverized coal-fired"* (PCF) plants account for 90% of all coal power production (steam-driven turbines).
- Far less common are *"circulating fluidized bed combustion"* (CFBC) plants where crushed coal is combusted at lower temperatures and submerged in fluidity bed of ash and other particulate materials (sand, limestone etc.). Compared to PCF, this method causes lower amounts of air pollutants.
- *"Integrated gasification combined cycle"* (IGCC) plants are still very limited in use. Coal is partially oxidized in air or oxygen at high pressure to produce a fuel gas and is then combusted to produce electricity and heat (combined cycle).

PCF plants as well as CFBC plants can be broken down into mainly three types of technology:

- Subcritical technology: water heat remains below the critical pressure of water (22.1 MPa) to generate steam.
- Supercritical technology: steam is generated above the critical point of water.
- Ultra-supercritical technology: temperatures and pressures exceed even supercritical technology.

Efficiency increases mainly with the degree of growing pressure and temperature from under 30% (sub-critical plants) to 45% (ultra-supercritical plants)[11]. Compared with the former technologies, IGCC is most efficient (efficiency can reach 50%).

Further efficiency improvements can be achieved by capturing the excess heat in a process called cogeneration or combined heat and power (compare with section 1.2.2.1).

2.2.2 Heating

Coal (21.4 % of total energy used for heat) is the most used resource for heating in the industrial sector and the fifth most used resource for heating in the non-industrial sectors. In industry, coal is mainly used by the iron, steel, non-metallic minerals and petrochemical industry.

Steel production for example requires the use of coal as an energy source as the reaction of coal with the iron ore has specific characteristics required to produce steel. Feasible alternatives have not yet been developed.

Coal or coal products such as for example peat, bituminous coal are also delivered to residential and commercial users where it is then transformed to heat in various processes (e.g. coal oven).

[10] Can also be indicated as "Other Bituminous Coal", including all bituminous coal, that is not included under Coking Coal.
[11] All efficiency notations in this document are based on the lower heating value of the fuel and net output.

As opposed to generating heat locally, where it is used, heat plants are facilities that take a primary energy resource, such as coal and convert the energy to commercial heat for distribution through local distribution networks.

Table 2.2. ESG Issues Related to Coal

Phase	Pro	Con

Extraction	• Wide geographic distribution & abundant availability.
	• A large share of global coal deposits relatively easy to access.
	• Relatively low extraction cost.
	• Reliable in terms of availability compared to renewables (sun/wind/water).
		• Significant differences in quality: e.g. high quality Australian reserves, high ash content reserves in India and China (requires washing, often associated with water stress/pollution), high levels of moisture and volatile matter in Indonesian coal (requires drying, often associated with water pollution).
		• Release of carbon monoxide and methane.
		• Emission of dust and coal particles.
		• Water impacts:
		  • Ground water is pumped out to dry out mining sites.
		  • Persistent industrial waste water disposal/drainage in rivers.
		• Land change and landscape destruction, (e.g. mountain top removal mining).
		• Deforestation (e.g. open pit mining in Indonesia).
		• Severe health impacts on local community (e.g. ground water pollution).
		• Lack of adequate safety standards in coal mines.
		• Inappropriate use of force against workers, local communities.
		• Child and forced labor in coal mines.
		• Resettlement of people-, land-, water-rights.
		• Bribery and corruption regarding licensing.

Transportation	• Quick, safe and easy transport by ship and rail. • Hard coal is convenient to transport (not economic for earthy brown coal due to low energy content).	• Environmental and social issues associated with transportation infrastructure (e.g. Australian coal harbors and impact on Great Barrier Reef; coal railways in environmentally sensitive areas; coal dust from uncovered coal lorries; noise and pollution).

Refining	• New coal conversion technologies can raise efficiency levels significantly.
	• Esp. China is looking into *coal gasification* (reduced pollution impacts but increased CO_2 emissions and water consumption)[12].
		• High water intensity
		  • Coal conversion (esp. to gas).
		  • Coal washing, incl. waste water discharge and spilling.

Combustion	• Efficiency and environmental performance gains through new technologies. • Modern plants with 40% less CO_2 emissions than conventional plants and efficiency levels up to approx. 45% (average worldwide is currently 33%).	• Energy payback[13] of coal significantly low compared to renewables. • Majority of new installed plants still with conventional and basic technology (emerging markets, high emission lock-in).

[12] Withouth CCS, coal gasification is said to produce more CO_2: synthetic natural gas emits seven times more greenhouse gases than natural gas, and almost twice as much carbon as a coal plant.
[13] Energy payback (also referred to as energy ratio) = Lifetime electricity output/total gross energy requirement for construction, operation and decommissioning.

Phase	Pro	Con
	• Easy integration into existing power systems.	• Inflexibility reg. sudden demand changes • High emissions of CO_2 and other GHG (i.e. methane, nitrous oxide). • Migration of released (toxic) pollutants (i.e. sulfur dioxide, nitrogen oxides, particulate matter, mercury) possible. • Emission-reducing technologies generally lower plant efficiency. • Carbon capture & storage technology still in pilot phase and very expensive. • Severe health impacts on local and regional communities and livestock due to air pollution.

2.3 Climate Effects in a Nutshell

Coal constitutes the fuel with the highest CO_2 emissions in relation to its energy content and with one of the lowest energy payback rates among all energy sources. Coal production is also related to many other environmental impacts that may secondarily impact the climate. Often, coal mining is conjoined with massive landscape destruction, leaving huge areas of fallow land which can hardly be restored when mines are no longer in use, due to a contamination of the soil with pollutants. Coal mining, especially in Asia, can also be associated with immense water stress and degradation due to coal washing.

2.4 Regulatory Instruments and Trends

As the number one source of GHG emissions, coal is especially sensitive to any kind of carbon pricing regulation. In 2014, about 40 national and 20 sub-national jurisdictions have implemented or plan to implement emissions trading schemes and/or carbon taxes. While some jurisdictions, like Australia, have also seen a dismantling of existing pricing schemes, the overall trend is overwhelmingly towards an increase in regulation targeting the reduction in CO_2 emissions and/or other effects associated with the burning of coal, e.g. local pollution and water spillage.

- **Cap-and-trade schemes:** Globally, carbon trading schemes are on the rise and have proven their effectiveness in-principle, although prices have remained subdued lately (driven both by economic and political factors): The European Union is the largest region with explicit carbon pricing, but CO_2 is heavily underpriced due to an oversupply of certificates. China, the U.S. and Canada have sub-national trading schemes (seven pilot zones in China, 10 states in the US and 2 provinces in Canada). Furthermore, there are carbon pricing schemes for specific sectors in place in Japan and planned in Korea for 2015.
- **Carbon taxes:** India has a carbon tax of USD 1.07 per ton of coal produced or imported into India since 2010. Australia had implemented a carbon tax in 2012, which was repealed by the government in July 2014 on the grounds that households and businesses needed relief from additional taxes. South Africa is planning to impose a tax on carbon starting 2016 and China has committed to do so however there are delays with implementation of the policy. Other taxes or incentives indirectly influence coal, such as tax credits for renewables or energy efficiency.
- **Cap schemes:** China has committed to reduce carbon intensity (number of tons of carbon emitted per dollar of GDP) by 40-45% from 2005- 2020 and plans to limit the share of coal in the domestic energy mix through a diversification of energy sources. The United States is

putting in place a regulation reducing carbon emission from the power sector – as the nation's largest source of GHG emissions - 30% below 2005 levels until 2030. The draft proposal of the Environmental Protection Agency (EPA) contains state-specific emission rate-based CO_2 goals, while the implementation approach, e.g. energy efficiency measures, shifting from coal to naturals gas, renewables is left to States. Under the draft rule, the EPA would let states and utilities meet the new standard with different approaches mixing four options including energy efficiency, shifting from coal to natural gas, investing in renewable energy and making power plant upgrades.

- **Financing restrictions**: Some international finance institutions implemented restrictions related to financing new coal power plants: The US Export-Import-Bank announced to stop financing coal plants overseas, the World Bank set up a new policy on coal power plant funding, the European Investment Bank links financial support to emissions (max. 500g CO_2/kWh) which excludes conventional coal power plants, and the European Bank for Reconstruction and Development set minimum standards for financing new coal power plants. For all these restrictions exceptions are made for very poor countries where the plant contributes to energy security, development or poverty restriction.
- **Emission standards**: In the UK the Energy Performance Act (passed in 2013) prescribes an annual emission budget for all new, retrofitted or extended fossil fuel-fired power plants. A base load power plant with an annual utilization rate of 85% is allowed to emit 450g CO_2/kWh. In case a power plant with the same capacity is only used 40% throughout the year, it is allowed to emit more than 900 gCO_2/kWh. Four US States (California, New York, Oregon, Washington) have enacted GHG emission standards imposing emission limits on new and/or expanded electric generating units. For example, since 2012, New York requires new or expanded base load plants that are bigger than 25 Megawatts to meet an emission rate of 462,5g CO_2/kWh and non-base load plants (> 25 MW) must meet an emission rate of 725g CO_2/kWh. On a national level, the Clean Power Plan proposal of the EPA is currently open for public comments and consultation until end of 2014. It includes nationwide emission standards of 499 gCO_2/kWh for any new coal-fired plants. Additionally, there are some voluntary standards: The OECD has published a list of recommendations for governments, primarily addressing China, to help accelerate clean technology diffusion by improving safety standards, promoting clean technologies.

Overall, coal still remains the cheapest option for generating electricity and heat in many regions, but policy interventions to improve efficiency, reduce air pollution and control emissions will be critical in determining its longer-term prospects. Under current regulations across the globe, low coal prices will continue to push gas out of the power sector (mainly in Asia and Europe). According to the IEA projections global coal demand will grow at 2.3% in average per year until 2017 mostly driven by non-OECD countries.

2.5 Technological Developments

Several rather new exploration, refining and combustion technologies aiming at making coal, or fossil fuels in-general, cleaner are increasingly reaching technical readiness or already being adopted:

2.5.1 Coal Gasification

Coal is transformed into synthetic natural gas. This helps to address pollution problems, but it produces actually more CO_2 (unless carbon capture storage (CCS) technology is applied) than traditional coal plants and is highly water intensive. This method is especially relevant for China, as it reduces its dependency on imported liquefied natural gas and allows it to exploit remote coal deposits, as gas is cheaper to transport than coal.

2.5.2 Coal-Bed Methane

Water is sucked from coal deposits that are currently too deep to mine conventionally, to free and collect the methane attached to the surface of the coal. Very little CO_2 is emitted, however there are concerns about water contamination. This method is especially relevant in Australia

2.5.3 Underground Gasification

Oxygen and steam are pumped into a coal seam to initiate small combustions converting the solid coal into gas. Hydrogen, methane, CO and CO_2 are then siphoned off through a second borehole. This process emits up to 80% less CO_2 than conventional coal extraction. This technology is currently not yet economically viable.

2.5.4 Carbon Capture and Storage

As long as fossil fuels and carbon-intensive industries play dominant roles in the world's economies, CCS will remain a potentially critical technology to prevent further GHG emissions to the atmosphere. CCS can be applied in electricity generation but also in emission intensive industrial processes (e.g. cement and chemical sectors). CCS can be divided in three general steps:

(1) separation of CO_2 from a mixture of gases (e.g. the flue gas from a power station or a stream of CO_2 rich natural gas) and the compression of this CO_2 to a liquid-like state,
(2) the transportation to a suitable storage site and
(3) the injection into a geological formation where it is kept in a natural (or engineered) trap.

CO_2 separation can happen *before the combustion*, where a syngas, a mixture of hydrogen, carbon monoxide and CO_2 is generated from fossil fuels, from which the CO_2 can then be removed leaving a combustible fuel. This method can be applied for e.g. coal based IGCC plants. A second approach is to separate the CO_2 *after the combustion* from the flue gases. A third method is called *oxy-fuel combustion*, where pure or nearly pure oxygen is used in the combustion process to yield a flue gas of high-concentrated CO_2, making the separation easier. Also, where the generation of concentrated CO_2 is already *an intrinsic part of the production process* (e.g. coal-to-liquids or SNG from coal), CO_2 can be captured. For the latter, CO_2 capture processes are commercially available and in common use, while for the other three methods, the separation processes are less advanced.

The transportation of CO_2 in pipelines is already a known and mature technology, comparatively little experience exists with using offshore pipelines or transportation via ship.

In a last step, the CO_2 is injected into appropriate geological formations e.g. saline aquifers, depleted oil and gas field. While the physical processes and engineering aspects of the storage are well understood, the identification of suitable storage sites poses several challenges, as it must provide sufficient capacity and injectivity, must prevent the CO_2 leaking to the atmosphere or potable groundwater and the interaction with any other operations (e.g. oil and gas drilling) must be considered.

A power plant equipped with a CCS system would need roughly 10-40% (11-22% for Natural Gas Combined Cycle Plants, while 24-40% for Pulverized Coal Plants) more energy than a plant of equivalent output without CCS, thereby reducing plant efficiency by 7-10%. Thus the deployment of CCS technology for coal-fired electricity generation is more viable for plants operating under advanced technologies and with efficiencies of 40% already. In such cases CCS can prevent CO_2 emissions to the atmosphere by 80 to 90%, bringing CO_2 intensity down to less than 100 g/kWh.

Currently, about 20 large-scale CCS projects are in operation or advanced planning stage. Most of them are industrial applications, such as oil and gas processing or chemical production, while the utilization of CCS for large-scale power plants still remains to be implemented. The widespread application of CCS depends very much on technical maturity, costs, diffusion and transfer of technology to developing countries, regulatory aspects, environmental issues and public perception.

2.6 Outlook

The IEA expects the world-wide coal use to rise by between 15% (*New Policies Scenario*[14]) and more than 50% (*Current Policies Scenario*[15]) from 2012 to 2040 driven almost entirely by increasing demand in developing countries, while coal demand in OECD countries is estimated to decline. Based on the *New Policies Scenario* coal's share in global primary energy demand will fall from 29% in 2012 to 24% in 2040, which makes it the second most important energy source after oil. Coal will continue to be the most important fossil fuel for electricity generation with a share between 30% (*New Policies Scenario*) and 40% in the *Current Policies Scenario* of the global electricity generation in 2040. The *450 Scenario*[16] draws a very different pathway for coal: coal demand will peak in the current decade and then drop rapidly, thus by 2040 the share of coal in the global energy demand will just be 17% making it the number four behind oil and gas and renewables.

Regardless of these differing projections for the future coal demand, one challenge will be how to harness coal's energy content while producing lower levels of pollution and GHG emissions.

Existing energy generation technologies hold further improvement potential with regards to efficiency and reduction of CO_2, but also NO_x, SO_2 and particulates. The average efficiency of coal-fired power plants globally is currently 33% (EU average 38%), whereas modern, high efficient plants reach 45% and emit up to 40% less CO_2. About three-quarters of operating plants use no "High Efficiency – Low Emission" technology; more than 50% are over 25 years old and have less than 300MW capacity. An improvement of 1% in the efficiency of a conventional pulverized coal combustion plant leads to a reduction of 2-3% in CO_2 emissions. Improving the efficiency of the oldest (> 25 years) and most inefficient coal-fired plants would lead to a CO_2 emissions reduction from coal use by over 25%, representing a 6% reduction in global CO_2 emissions. Some countries have made it a priority to improve the efficiency of their coal fleet (e.g. Japan and Korea, with average efficiencies in excess of 40%), but the number of "High Efficiency – Low Emission" plants in the world remains low. Moreover, almost 50% of new plants under construction or in planning - primarily in developing countries – are built with conventional technologies. To overcome this hurdle, more effort needs to be made to set-up adequate financing mechanism and enable technological support for developing countries.

Efficiencies of coal-fired plant could also be increased if the heat is captured and used as commercial heat.

[14] For definitions of IEA scenarios please see appendix.
[15] For definitions of IEA scenarios please see appendix.
[16] For definitions of IEA scenarios please see appendix.

3 Natural Gas

3.1 Supply and Demand

In 2012, global natural supply reached 119 238 PJ (21 % of TPES). Natural gas is the third most important primary energy resource after oil and coal.

Natural gas has a current share of 48 949 PJ (23 % of FEE) in global electricity production, which makes it the number two primary resource for electricity production worldwide. Natural gas used for heating, represents 45 675 PJ (27% of FEH) of the total final energy used for heating.

Globally proven reserves are constantly growing and are sufficient to meet conceivable levels of demand for several decades to come. Estimated and proven reserves (conventional and unconventional) primarily lie in Russia and Central Asia, China, North America and the Middle East, with a tendency to more off-shore and remote areas.

Table 3.1. Overview of Natural Gas Supply and Consumption

	Production (2013)		Consumption[17] (2013)		Gas electricity and heat production (2011)		Electricity production from gas (% share)	
1	USA	682 bcm	USA	722 bcm	Russia	2,876 TWh	USA	1,045 TWh, 24.2%
2	Russia	610 bcm	Russia	460 bcm	USA	2,392 TWh	Russia	519 TWh, 49.3%
3	Iran	158 bcm	Iran	156 bcm	Japan	702 TWh	Japan	374 TWh, 35.9%
4	Qatar	157 bcm	China	142 bcm	Iran	491 TWh	Iran	160 TWh, 66.8%
5	Canada	157 bcm	Japan	119 bcm	China	229 TWh	China	84 TWh, 1.8%[18]

Source: BGR (2013) Energiestudie 2013, IEA (2013a) Key World Energy Statistics 2013 and World Bank (2015) The World Bank Database.

Main exporting nations are Russia, Qatar and Norway. Russia and the United States have a 40% share of global natural gas production (together 35% of consumption). The largest conventional reserves lie in Russia, while most unconventional reserves are in the US, which began heavily tapping their unconventional deposits (currently more than 60% of US production) in the last decade. The United States thereby reduced import needs significantly and might soon become a net gas exporter. European gas production already peaked, increasing its dependency on imports from the Commonwealth of Independent States[19], Africa and the Middle East. Currently, Europe (excluding Russia) is the only region where demand exceeds production, with a factor of two. For the time being, there are several relatively independent regional gas markets with highly diverging price levels.[20] Vessel-based liquid natural gas (LNG) transport is expected to lead to more integration of these markets.

[17] 12,4% of natural gas is used for non-energy purposes, e.g. chemicals. (IEA Key World Energy Statistics 2013, p34).
[18] As of 2011.
[19] The Commonwealth of Independent States consists of Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.
[20] For instance, the US price level is a third of the European and a quarter of the Asian.

Table 3.2. Natural Gas Resources and Reserves

Natural Gas Source	Estimated resources	Proven reserves
Conventional gas	310	191
Unconventional gas	526	5.5
Shale gas	205[21]	3.7 only US
Tight gas	63	-
Coal bed methane	50	1.8
Aquifer gas	24	-
Gas hydrates	184	-

Source: BGR (2013) Energiestudie 2013.

3.2 Key Issues in the Value Chain

The recent hype for unconventional gas (and oil) roots mostly in technological advances over the last two decades – particularly fracking – and soaring conventional gas prices in the early 2000's[22]. The potential of unconventional gas deposits is much debated. Although their global availability seems quite high, estimates are highly diverging and actually proven (and currently economical) reserves are much lower.[23] Currently, the US accounts for 80% of unconventional gas production.[24] A replication of US fracking rates in other world regions is not likely in the next decades.[25] China is expected to supply 11% of global shale gas production by 2035. Aquifer gas and gas hydrates are currently not commercially recoverable and will remain so for the foreseeable future.

The main difference between conventional and unconventional gas is rooted in the geological features of the deposit, extracting methods and/or the costs for exploration and production:

Conventional gas occurs in geological formations, that are easy to access (e.g. above oil deposits, "gas traps"). After drilling, the gas flow is normally maintained for an economically sufficient period without further technical measures.

Unconventional gas is either not gaseous or trapped in an impermeable carrier rock:

- Tight gas is trapped in thick sandstones, generally in depths between 3,000-5,000m.
- Coal bed methane is absorbed in coal particles, normally 300 to 2,000m below the surface.
- Aquifer gas is dissolved in ground water.
- Gas hydrates are frozen compounds of water and methane, mostly occurring in permafrost and deep-water sediments.

Combustion of natural gas (i.e. mainly methane) relies on two different technologies, the first being *gas turbines* with an efficiency factor of 30 to 40%. The second are *gas-powered steam turbines*, which

[21] All values in tcm.
[22] The recent advances in technologies have been achieved largely by a combination of horizontal drilling with hydraulic fracturing ("fracking") and the injection (and partial reflux enriched with the natural gas) of huge amounts of a compound of water combined with sand and chemicals.
[23] For a comparison of estimates see Bundesanstalt für Geowissenschaften und Rohstoffe (BGR): Energiestudie 2013.
[24] 98% of shale gas production, 58% of tight gas production (Canada 2nd with 28%), 63% of coal bed methane production (China 2nd with 13%).
[25] Reasons: less mature technology and industry, smaller and deeper deposits, tougher standards, population density, public scrutiny.

are only slightly more efficient. These technologies are more and more used together to form "*combined cycle gas turbines*" with an enhanced efficiency of up to 60%[26].

Furthermore, natural gas may be burned in combined heat and power plants to recover parts of the waste heat as commercial heat. CHP plants thus have a higher efficiency factor.

Natural gas is the most important heating resource especially for non-industrial use and for industrial use globally. The main activities using natural gas for heating include residential heating, the petrochemical industry, and commercial building heating. It represents 26,87 % of total energy used for heating globally. Just as oil and oil products, natural gas is delivered to consumers where it is converted to heat energy locally.

Table 3.3. ESG Issues Related to Natural Gas

Phase	Pro	Con
Extraction/ Production	• Many conventional gas deposits comparatively easy to access, while the majority of new proven reserves are in unconventional or remote areas. • Amount of proven gas reserves constantly increasing, though economic viability relies on gas price levels. • Unconventional gas and LNG increases political options to diversify suppliers or even reduce dependencies on foreign gas supply, sometimes overruling economic considerations. • Proven technology, especially for conventional gas. Easy to deploy in different regions (given sufficient geophysical mapping). • Production infrastructure can easily be modified to process both gas and oil (conventional and unconventional). • So-called associated gas is an almost free by-product of oil extraction.	• Very capital-intensive upfront with relatively low returns, therefore high dependency on market price, most new deposits are either unconventional and/or in remote (e.g. Arctic) or deep sea areas. • High-cost extraction first to be mothballed in case of insufficient price level or tightening regulation (stranded assets). • High land-use and eco-system impact, especially for unconventional gas. • Water impacts: • ground and surface water pollution (toxic chemicals and biocides); • high water demand, especially problematic in arid regions. • Pollution impacts: • air emissions (e.g. lead, benzene, hydrosulfides, methane); • GHG emissions (deforestation, venting, leakage, flaring), but lower than other fossil fuels; • Often uncontrolled leakage/ emissions of radioactive solid residuals (radon). • Ongoing economic loss due to gas leakage. • Gas reserves often situated in regions with ongoing human right violations, posing additional non-financial project risks.
		• Additional issues in unconventional production • Production methods believed to increase probability and intensity of earthquakes and tremors. • Public scrutiny and opposing regulation in several European countries. • Economic viability probably only given for the US and in the future China and Canada (other regions: less mature technology and industry, smaller and

[26] This is reached by using excess heat from the gas generation to drive the steam-powered turbine.

Phase	Pro	Con
		deeper deposits, tougher standards, population density, public scrutiny). • Coal bed methane production is currently only economic where gas and coal infrastructure is nearby. • Hydrate production is very immature (uneconomical and explosion danger).
Refinery	• Proven processes with apparently no major issues.	
Transport-ation	• Limited environmental pollution, except GHG / air emissions (i.e. no toxic spills). • Well established pipeline technology, with capacity for multipurpose use (city gas, wind gas and similar). • LNG infrastructure reliefs from pipeline dependence (marine and road energy transport possible).	• Cost-intensive construction and maintenance of specific infrastructure (pipelines or liquefaction / regasification terminals and vessels); ongoing debate on necessity of individual projects. • Increasing off-shore or remote production areas raise length of necessary transportation infrastructure and costs. • Infringement of sensitive ecosystems. • Air pollutants and GHG emissions (leakage). • Safety of infrastructure: explosion dangers, terrorist attacks, political leverage.
Combustion	• No competition with feedstock (compared to first generation biofuels). • Relatively low upfront Capital Expenditure, established practices for construction of plants. • Proven technology: Technological efficiency and flexibility, best available fossil-based residual capacity. • Increasing potential for small-scale, decentralized generation • Long operational lifespan of 40 to 50 years. • Relatively low GHG emissions and other pollutants compared to other fossil fuels.	• Air pollutants / GHG emissions. • Current global power markets favor renewable energies and coal- over gas-fired plants (lack of stringent carbon pricing).[27]

3.3 Climate Effects in a Nutshell

Generally, natural gas is regarded as the *cleanest* fossil fuel. Its combustion is 50% less GHG emission-intensive compared to coal (median best available technologies). The majority of life cycle GHG emissions from natural gas occur at combustion (mostly CO_2), but there is also no scientific consensus about associated upstream GHG emissions (mostly methane). There are estimates that methane leakage (mismanaged wells, transmission, processing) constrains the emissions performance of natural gas to a degree, where it equals best available technology coal-fired generation.[28] On average,

[27] e.g.: In Europe, 60 percent of the gas-fired capacity is not recovering fixed costs. http://www.smithschool.ox.ac.uk/research/stranded-assets/.

[28] Mismanagement at wells, especially fracking sites: no emissions control, frequent unloading of liquids from well, poor practices. http://www.epa.gov/airquality/oilandgas/pdfs/20140415leaks.pdf. A thorough multi-stakeholder analysis of supply chain leakage is currently undergoing. http://www.edf.org/methaneleakage.

life cycle GHG emissions from unconventional shale gas are up to 10 % higher than from conventional gas.[29]

Nevertheless, sustained energy production from natural gas is seen as compatible[30] with 2°C global warming scenarios, as it is the best fossil-based residual capacity. Though, switching all fossil fuel combustion to natural gas alone cannot avoid as many GHG emissions as needed. For instance, by 2030 the power plant fleet would require a carbon-intensity of less than one-third the level that can be delivered by the most efficient gas-fired plant today, in the absence of CCS technology.[31]

3.4 Regulatory Framework

Regarding exploration and production, regulatory changes have tended to tighten the requirements related to well construction and protection of groundwater, especially regarding unconventional gas.

- Most regulatory instruments address emission intensity (carbon and pollutants) and do not specifically address a specific fossil fuel type. In many cases gas is indirectly affected, as technical efficiency and emission thresholds aim to crowd out certain coal types, advantaging gas.
- Despite the lower carbon characteristics, natural gas plants are still subject to carbon (and other emissions') regulation. For instance in Germany, the simultaneous phase-out of nuclear power, low coal price levels and low carbon prices led to a re-rise in domestic lignite combustion, at the expense of natural gas. Any stringent carbon pricing will directly impact the business case for gas plants (comparative advantage of natural gas over more carbon-intensive fossil fuels, comparative disadvantage to renewables and nuclear).
- Furthermore, minimum standards for efficiency, carbon intensity or technical flexibility of new plants are applied for approval or financing. For instance, EPA proposed emission limits for new coal and gas power plants and is also planning to expand limitation of carbon emissions to existing plants. Moreover, in Europe, the Large Combustion Plant Directive and the Industrial Emissions Directive are upcoming. All this might support gas if the tightening regulation does crowd out coal.
- As the estimated gas demand increase is mainly rooted in the power sector, the upcoming power market design changes in many countries will heavily influence the business case for gas power plants.[32]

3.5 Other Current Trends

LNG enables gas trade via shipping or road transport and is expected to become as important as pipelines in terms of international delivery of natural gas. Currently, 10% of global gas consumption are transported via LNG (one third of global gas trade), mostly to China and Japan and to a minor degree to Europe. The main exporting nations are Qatar, Malaysia and Australia. Globally LNG demand has been growing over the past two decades, however in recent years has seen a stagnation as capacity expansion (liquefaction terminals and vessels) leveled and domestic gas consumption in

[29] Natural gas is composed primarily of methane, a greenhouse gas with a high global warming potential: 72x that of CO2 (averaged over 20 years) or 25 times that of carbon dioxide (averaged over 100 years), according to the Intergovernmental Panel on Climate change http://onlinelibrary.wiley.com/enhanced/doi/10.1002/ese3.35, http://www.pnas.org/content/early/2014/07/16/1309334111.full.pdf.

[30] This does not mean that switching all fossil fuel combustion to natural gas alone could avoid as many GHG emissions as needed for a 2° warming scenario.

[31] IEA WEO Energy Climate Map 2013.

[32] Many power markets currently feature a large amount of "energy only markets". The rapid entry of RE in many markets are changing the system characteristics, leading to ongoing discussions about other forms of refinancing, e.g. capacity mechanisms. Gas power plants will be heavily affected by this.

formerly exporting LNG countries rose. Nevertheless, in the long run, a more globalized LNG market is expected to overcome regional gas markets, thereby narrowing price spreads and pipeline dependencies that exist today.[33] China, India and Asia Pacific are expected to increase their LNG-demand significantly by 2035, compensated by the surge in Australian LNG production. The European demand-trend for LNG remains ambiguous as energy regulations have a huge impact and LNG primarily goes to high-price markets (mainly Asia).

Arctic drilling: While 25% of global gas is already being produced at Arctic Russian onshore gas sites, there are new estimates on significant conventional and unconventional off-shore Arctic resources: 30% of global undiscovered conventional gas resources are assumed in this area.[34] Currently, exploration of such reserves faces unsolved challenges, such as: gaps in technological capabilities, economic non-viability of production, immature emergency infrastructure, need for significant capital expenditures (e.g. for exploration, liquefaction, and transportation infrastructure), potential insurability, protection of sensitive ecosystems.[35] Most activities in the near term are expected to be in Northern Alaska, the Norwegian and Russian Barents Sea and Western Siberia. Economic feasibility also depends on the development of unconventional (onshore) production, e.g. in the US.

3.6 Outlook

The global picture of natural gas development shows steady growth rates in production and consumption. While conventional production stagnates at a high level, tapping unconventional resources could diversify the supply and transport of natural gas.

The business case for natural gas is highly dependent on the development of a) coal markets and b) energy market design, climate and environmental regulation. While the Northern American market already tilted towards gas, emerging markets (including Asia) are expected to continue with large-scale coal combustion despite air pollution concerns. Europe's development relies on regulatory decisions in the next years, which will decide if coal will be phased out in favor of gas and renewable energy, and if gas contracts stay linked to oil prices.

Generally, upstream costs in gas production are rising because remaining deposits get more difficult to exploit, leading to questions about future revenues. Many projects rely on notable gas price levels, which may be impeded by oversupply and a diversity of regulatory issues, especially regarding climate change and the remaining burnable carbon budget. On the demand side, the IEA expects global gas demand to grow at a rate of approximately 1 to 2% p.a. until 2040 in the different carbon policy scenarios; in all scenarios natural gas is growing faster than coal and oil. Gas is expected to overtake oil by 2030 in OECD countries, while in non-OECD countries gas will remain the third most important fuel behind coal and oil. Gas' share in global primary energy demand is expected to increase slightly from 21% today to between 22% (*450 Scenario*) and 24% (*Current Policies* and *New Policies Scenario*) by 2040. The power sector is set to remain the main driver of increased gas demand worldwide, with its share in global electricity production remaining at 23 % (*Current* and *New Policies Scenarios*), while in the *450 Scenario* gas' share drops to 17% by 2040. Actual gas consumption is highly sensitive to

[33] Similar to the oil industry, where supertankers advented in the 1960s.
[34] 22% of global undiscovered conventional oil and gas resources.
[35] Natural gas spills normally don't harm the environment as heavy / widespread as oil spills; however, methane leakage impacts climate and risks poisoning and explosions. Furthermore, oil is often associated with gas deposits; hence, oil spills may also be possible during a gas spill.

regional price levels, competitiveness with other fuels, notably coal and renewable energy (RE), carbon regulation, development of gas-based road transport, etc.[36]

[36] The competitiveness with coal is especially tight as a global or regional adequate price for carbon is missing.

4 Oil and Oil Products

4.1 Supply and Demand

In 2012, global oil supply of oil reached 176 059 PJ (31 % of TPES), making oil the most important energy supplier.

Nevertheless, in the electricity and heat sectors, oil play a less important role than in the transport sector. Oil and secondary oil products have a combined share of 12 543 PJ (6 % of FEE) in global electricity production, which makes them the fifth most important resources for electricity production worldwide. Oil and oil products used for heating, are more important: they represent 30 547 PJ (21% of FEH) of the total final energy used for heating.

For electricity generation, the share of oil and refined products is expected to continue to decline, as its use for electricity generation is inefficient.

Oil and oil products only play an important (but nevertheless decreasing) role in electricity generation in some large oil producing economies or as an emergency or back-up fuel in economies with low grid reliability. Apart from the power sector, oil demand is rising, with the major amounts of oil being used for transport (62% of the total worldwide oil production), followed by petrochemicals (17%), others (including agriculture, public services, residential: 12%) and industry (9%).

Table 4.1. Overview of Oil Supply and Oil Product Production and Consumption

	Production (% of world total)		Consumption[37] (% of world total)		Electricity production from Oil (% share)	
1	Saudi Arabia	544 Mt, 13%	USA	800 Mt, 19%	Japan	105 TWh, 10.1%
2	Russia	520 Mt, 12%	EU	597 Mt, 15%	Saudi Arabia	66 TWh, 26.5%
3	USA	387 Mt, 9%	China	484 Mt, 12%	Iran	67 TWh, 27.8%
4	China	206 Mt, 5%	Japan	235 Mt, 6%	Mexico	48 TWh, 16.4%
5	Iran	186 Mt, 4%	India	172 Mt, 4%	Indonesia	42 TWh, 23.2%[38]

Source: IEA (2013a) Key World Energy Statistics 2013, World Bank (2015) The World Bank Database, BGR (2013) Energiestudie 2013 and BP (2013) Statistical Review of World Energy June 2013.

Besides Middle Eastern countries, Russia and Canada are major exporters of oil and have large reserves. The EU, which does not have significant oil reserves, is the number one importer worldwide, accounting for over a quarter of global oil imports, followed by the USA, China, Japan and India.

4.2 Key Issues in the Value Chain

Conventional and unconventional oil differ in terms of viscosity and density of the oil as well as in the type of its deposit.

- **Conventional oil**: Crude oil and natural gas liquids occur as a by-product of natural gas production. The highest proven reserves exist in Saudi Arabia, Iran, Iraq, Kuwait and the United Arab Emirates.

[37] For all final uses.
[38] As of 2011.

- **Unconventional oil**: Extra heavy oil, bitumen (bound in tar sands), shale oil (extracted from oil shale) and light tight oil . The highest proven reserves can be found in Canada (tar sands) and Venezuela (extra-heavy oil). In addition, Russia and Kazakhstan are suspected to have significant resources of extra-heavy oil and bitumen, and modest amounts are believed to exist in China, the Middle East, the UK and the US.

Oil can be refined into a variety of fuel products, depending on its purpose of use. Refined products include gasoline, kerosene, liquefied petroleum gases, gas/diesel oil and residual fuel oil. The main oil-based fuel in electricity generation is fuel oil, which accounts for nearly 50%, followed by gas oil and crude oil. For heating, heating oil is the most important petroleum-based source of energy.

4.2.1 Oil and Oil Product Use for Power Generation

Currently, the majority of power from oil is produced using these three methods:

- **Combustion turbines**: The most common technology is to burn oil in a combustion turbine, similar to a jet engine, to produce mechanical power which is converted into electricity by generators.
- **Steam boilers**: The oil is burned in a boiler to create steam, which then drives a steam turbine to produce electricity through a generator.
- **Combined cycle**: This technology combines the two above and is most efficient as the same fuel source is used twofold. The oil is burned in a combustion turbine which produces electricity and the exhaust heat is used to produce steam, driving a steam turbine and thereby producing additional electricity.

The second and third methods can also be done in a CHP plant, thereby creating commercial heat.

4.2.2 Oil and Oil Product Use for Heating

Crude oil as an energy resource for heating is only of marginal importance: only 0.24 % of the total energy for heating is from crude oil. Nevertheless, secondary oil products (17,97 % of the total energy for heating) such as heating oil, play an important role in the energy mix for heating. Secondary oil products[39] is derived from oil through refining, mixing and/or other chemical transformation processes.

In order to be used for heating, oil and secondary oil products are delivered (for example through pipelines, by truck, by rail) to the consumer (industrial or non-industrial) where the resource is then locally transformed to heat (for example through a heating system, in a boiler, or in a furnace creating hot air or hot water which is then circulated in the building.).

Table 4.2. ESG Issues Related to Oil and Oil Products

Phase	Pro	Con
Extraction/ Production	• Large proven reserves of oil which may last for several decades depending on price for oil and technological developments. • Technical potential for increasing output in extraction processes. • New technologies unlock new types of resources (e.g. light tight oil) that were	• High sensitivity of supply, as 70% of global oil (and gas) reserves are concentrated in a few countries that are politically unstable (e.g. Iraq, Libya, Syria, Sudan). • High price volatility. • Drilling of most types of conventional and unconventional oil in remote areas is a technological challenge and cost-

[39] For a list of secondary oil products that are included in the statistical definition of oil products by the IEA please see the IEA Glossary: http://www.iea.org/stats/defs/sources/petrol.asp.

	considered unrecoverable in the past.	intensive. • High-cost extraction first to be mothballed in case of insufficient price level or tightening regulation (stranded assets). • Water use and water impacts: • Water demand to clear wells. • Underground water contamination. • Runoff from exploration process impacts surface waters. • Water pollution through oil spills. • Flaring of gas as a by-product of oil exploration causes further CO_2 emissions without any energy benefits. • Tar sand mining is highly carbon-intensive, releases cancer-causing hydrocarbons and leaves huge areas of wasteland leading to severe land change and landscape destruction.
Transportation	• Several means of transport available: marine, pipeline, road, rail. • Easy to transport.	• Increasing off-shore and remote production sites raise length, costs and potential harm on environment of necessary infrastructure. • Water pollution: oil spills through marine accidents with high and long-term impact. • Pipeline spills and continued leakage harm the environment significantly.

Refining	• Technical potential for increased energy efficiency in oil transformation processes (Smelting reduction , separation membranes or black liquor gasification).
	• Potential of CCS during refining.
		• Water use and water impacts:
		  ◦ Various processes to refine crude oil require water.
		  ◦ Release of treated/polluted water during refining.
		• Refining produces sludge and other solid waste that can contain high levels of heavy metals and toxic compounds that require special handling, treatment and disposal.

Combustion	• High flexibility of oil-fired power plants, giving the opportunity to respond to sudden changes in the power demand. • No competition with feedstock (compared to first generation biofuels).	• Electricity generation from oil mostly uneconomic. • Air emissions: Oil combustion causes vast amounts of carbon dioxide and other greenhouse gases. • Water use and water impacts: • Oil-fired power plants use large amounts of water for cooling and steam production. • Power plants release waste water which can contain pollutants. • Residues that are not burned completely can accumulate and form toxic solid waste which requires special disposal: • Oil spills on land can degrade soils.

4.3 Climate Effects in a Nutshell

The combustion of oil and oil products releases large amounts of CO_2 and other greenhouse gases and produces toxic waste. The exploration of oil, which often takes place in remote and sensitive areas, can significantly harm the environment through the destruction of land and habitats as well as the emission of air pollutants and greenhouse gases. Additionally, the long transportation ways (from extraction areas to refinery sites and later on to locations of use) further increase life-cycle greenhouse gas emissions. Regulatory instruments and trends

4.4 Regulatory Framework

As energy production from oil only accounts for a minor share, whilst the majority of oil is used for transport, most regulatory instruments regarding oil do not directly address electricity generation or heating. However, any carbon regulations such as carbon taxes or cap and trade schemes also have effects on the use of oil for the power and heat sectors.[40]

Oil and gas exploration and drilling regulations: Oil and natural gas are extracted on private and public lands as well as in offshore operations. Drilling in each of these areas falls under specific regulatory jurisdictions (on a local or state level if onshore or offshore within 200 nautical mile border). Protecting the environment and human health is the main goal of all drilling regulations. Across the world, there is a trend towards stricter regulations: in the US for example, new oil and gas drilling regulations require the capture of emissions, such as volatile organic compounds and methane, along with air toxics such as benzene, ethylbenzene and n-hexane, starting 2015 as federal standard. Regulations also exist for the exploration process.

NOTE: Some aspects mentioned in this factsheet, especially with regards to regulation, are also relevant/applicable to natural gas.

4.5 Outlook

Until 2040, global oil demand is expected to rise slightly (in the IEA *Current* and *New Policies Scenario*), mainly due to increasing demand for transport fuels. In the *450 Scenario*, however, global oil demand is projected to fall by 20% between 2013 and 2040. In all IEA scenarios oil's share in global primary energy demand is expected to drop from 31% in 2012 to 27% in the *Current Policies Scenario*, respectively 26% in the *New Policies Scenario* and 17% in the *450 Scenario*.

Currently, less than half of remaining proven oil reserves can be recovered by conventional technology. Advanced technology offers further potentials to recover significantly more oil from existing fields, but the application of any such new technologies also depends on their cost-efficiency.

As it is expected that the future oil demand cannot be met by conventional crude oil, the role of natural gas liquids and unconventional oil will increase. The share of conventional crude oil is predicted to fall from 80% in 2013 to about 64% of total oil production worldwide in 2040, whilst the share of natural gas liquids will rise from 14.5% in 2013 to almost 20% in 2040 and unconventional oil from 7% in 2013 to about 16% in 2040. Today, the most common substitute product for conventional oil is oil derived from highly controversial tar sands, that occur mostly in Canada's west. Further types of unconventional oil are Orimulsion®[41], an oil product derived from extra heavy oil, which is drilled mostly in Venezuela, and light tight oil, a shale oil derived from kerogen-rich shales which requires special technologies to be produced economically and therefore is – at the moment – uncommon outside the US. In addition, new drilling areas, especially within the Arctic circle are increasingly developed; an estimated 13% of the world's remaining oil reserves are located within the Arctic circle.

[40] For details on carbon regulations please see chapter 2.

[41] Orimulsion® is a registered trademark for a bitumen-based fuel developed by the Research and Development Affiliate of Petroleos de Venezuela SA (PDVSA).

5 Nuclear Energy

5.1 Supply and Demand

In 2012, global production of nuclear energy totaled 26 884 PJ (5 % of TPES). As all nuclear resources were used for electricity generation, nuclear energy ranked third globally, with a share of 12 % of energy converted to electricity (FEE).

The use of nuclear energy is generally in decline since 2006; in non-OECD countries growth figures only reached average 2.8 % p.a., and in the OECD countries even decreased by 12.9 % p.a. Most of the reduction is related to (temporary) shut-downs of nuclear capacity in Japan post-Fukushima and the German nuclear exit. In August 2014, 388 reactors with a combined capacity of 333 GW were operating in 31 countries worldwide, while 46 reactors were mothballed. Nevertheless, as of August 2014 18 countries are considering or introducing nuclear power programs, 72 nuclear power plants (NPP) are currently under construction, 174 more NPP are planned, with increases mainly in Asia and the Middle East.[42]

Table 5.1. Overview of Nuclear Energy Production and Capacity

	Electricity production & share of total electricity production (2013)		Installed capacity (2014)		Capacity under construction, share of global construction (2014)	
1	USA	790 TWh, 19%	USA	99 GW	China	33 GW, 43%
2	France	406 TWh, 73%	France	63 GW	Russia	9 GW, 12%
3	Russia	162 TWh, 18%	Japan	43 GW	South Korea	7 GW, 9%
4	South Korea	133 TWh, 28%	Russia	24 GW	USA	6 GW, 8%
5	China	105 TWh, 2%	South Korea	21 GW	India	4 GW, 6%

Source: World Nuclear Association (2014a) World Nuclear Power Reactors & Uranium Requirements.

5.2 Key Issues in the Value Chain

Uranium Reserves: Uranium is mined in 20 countries, but 84% of the resources are concentrated in five countries: Australia, Canada, Kazakhstan, Brazil, and China.[43] Despite the decline in nuclear power production, global uranium ore extraction increased by over 25% between 2008 and 2010 because especially Kazakhstan, as the biggest producer, has extended its mining activities due to price advantages of fresh uranium over recycled uranium or plutonium. Depending on future policies and nuclear reactor efficiency developments, proven uranium resources are predicted to last for another 80 years, assuming constant demand at current levels; soaring prices might increase economic recovery though.

Nuclear Power: The use of nuclear power can potentially have major negative environmental and social impacts: catastrophic accidents, proliferation of material that can be used for the production of nuclear weapons, and chemical as well as nuclear waste.

Nuclear waste occur at different levels of radioactivity: low-level waste produced at all stages of the fuel-cycle; intermediate-level waste produced during reactor operation and by reprocessing; high-

[42] e.g. United Arab Emirates, Saudi Arabia, Jordan, Belarus, Nigeria, Poland, Turkey, Bangladesh, Vietnam.
[43] Hence, mining focuses on few companies and mining sites: Kazatomprom (15%), Areva (15%), Cameco (14%), ARMZ/Uranium One (13%), McArthur River (13%), Olympic Dam (6%), Ranger (5%), Arlit (5%).

level waste through fission products and used fuel. The majority of chemical and low-level radioactive waste products occur during the mining and milling of uranium ore. All stages and types of mining, processing and enrichment use leaching methods, where large amounts of water are diluted with chemicals, e.g. sulfuric acid, some of them endangering groundwater aquifers.[44] While the transport of the unburned nuclear fuel from the mines to the operation plant poses no particular radiation risk, the transportation of used uranium to either the reprocessing facilities or the final disposal site requires high safety measures and can be associated with civil unrest (esp. in Europe). This applies to longer-term storage as well, especially since there is no dedicated end deposit for intermediate and high-level radioactive nuclear waste worldwide.

Globally, five different types of reactors are currently used for commercial power production: Light-water (354 reactors), heavy-water (48), gas-cooled (15), graphite-moderated (15), fast breeders (2). New reactors are mainly light-water (61), with heavy-water only amounting to 5, 2 fast breeders and 1 gas-cooled reactor. Whereas in past decades Western and Soviet countries used differing plant designs, current generation plants apparently will have no major differences regarding safety issues. Next generation plants are said to be significantly more efficient and to reduce waste with high half-life. Nuclear fusion does not seem to be commercially deployable in the foreseeable future.

Table 5.2. ESG Issues Related to Nuclear Energy

Phase	Pro	Con
Extraction/ Processing/ Enrichment	• Proven uranium reserves increased in recent years. At the current rates of exploration and consumption, proven reserves to last for eight more decades.[45] • Open pit and shaft mining of uranium is similar to conventional metalliferous mining; uranium often extracted as by-product in other mining activities.	• Radioactive and toxic contamination of air, water and soil in the greater mining area if engineering and safety measures are insufficient.[46] • Water impacts: High water consumption for mining and leaching processes. Some leaching methods contaminate aquifers.[47] • Safety regulation: No globally binding principles for management of radioactive wastes from extraction, processing and enrichment of uranium.[48] Emerging uranium producing and nuclear energy countries often lack adequate (execution of) environmental health and safety legislation. • Radioactive wastes of processing and enrichment often insufficiently isolated nor protected from mishandling in the long-term.
Construction	• Electricity generation capacity of existing NPP can be increased by equipment upgrades, e.g. generators or turbines. • Current and next-generation plants share common global standards.	• High upfront costs (EUR 3 to 8bn per reactor) • Construction times generally rising (current average 10 years) due to legal cases and regulatory changes. • Estimated construction costs have

[44] Most mining methods are applied to other metalliferous mining products. The so-called in-situ leaching is on the rise, especially in Central Asia, and has more severe environmental impacts than conventional methods.
[45] Please note that certain deposits require rising price levels to be economically viable.
[46] e.g. fortified waste water ponds to avoid percolation, ventilation against radon contamination etc. Contamination of local water supplies around uranium mines and processing plants has been documented in Brazil, Colorado, Texas, Australia, Namibia and many other sites. Toxic radon emissions remain though health impacts were reduced significantly in the last decades through a variety of measures.
[47] For instance, there are severely contaminated sites in Bulgaria, Czech Republic, Commonwealth of Independent States and Germany.
[48] World Nuclear Associations' Charter of Ethics and International Atomic Energy Agency's safety guide are not legally binding on operators.

Phase	Pro	Con
		increased eightfold in the past decade. Many projects were significantly delayed and over budget, thereby also increasing the risk of financial project failure.
Operation	• Widespread accepted safety guidelines and safety networks. But regulation remains national responsibility, with no globally binding agreement.[49] • No GHG or other emissions during operation. • Comparatively little land use (e.g. vs. renewable energies). • Without considering externalities, relatively moderate and predictable costs of electricity over service life, as fuel costs (uranium) account for only 5% of total generating costs. • Age of shut down reactors since 2000 is 35-40 years; increasing tendency for lifetime extensions as long as consequently rising OPEX remain economically viable. Operational lifespan of new reactors said to reach at least 40 and up to 60 years.	• Safety regulation: Lack of implementation, execution of stringent safety regulations, insufficient adherence international standards in some countries in Eastern Europe and in market-entering Asian countries. • Ongoing discussions in several OECD countries on prolonging operation life of NPPs, potentially conflicting with safety regulation. • Irrespective of stringent safety-measures, substantial risks for environment and humans remain (e.g. technical failure, human errors, natural catastrophes, shortages in cooling water, civil unrest, terrorist attacks, nuclear proliferation). • Externalities: Several cost factors not priced in (nuclear accidents, waste disposal, decommissioning). No insurability of major incidents, major stake of liabilities often remain with the state and exceed financial capabilities of operators.[50] • Public scrutiny on operation and disposal risks. • A significant share of NPP needs replacement in the coming two decades (average age of global NPP is 28 years, 42% with operating life of more than 30 years. 7% for longer than 40 years). • Older plants experience rising maintenance costs, leading to occasional final shutdowns due to lack of economic viability. • Electricity generation characteristics might not be flexible enough for systems with high intermittent renewable energy. • Costs of new NPPs tend to have relatively high remuneration for electricity generation (e.g. Hinkley Point in UK).
Decommis-sioning / Disposal	• Complete decommissioning and site restoration technically feasible.	• Dismantling of a NPP takes approx. 10-20 years with associated cost of EUR 500-1000mn. • Half-life period of nuclear waste requires end deposit to be safe against geological events, technical failures, and human impacts for tens of thousands of years. • Currently, there is no end deposit for intermediate and high-level radioactive nuclear waste worldwide.

[49] e.g. Global Nuclear Safety and Security Network or European Nuclear Safety Regulators Group. IAEA offers non-binding guidelines and self-assessment tools, e.g. Review of Infrastructure for Safety.
[50] The European Commission quotes estimations that the damage costs from the Fukushima accident amount to EUR 187bn, while Chernobyl lies at EUR 450bn.

5.3 Climate Effects in a Nutshell

During the electricity generation process, no GHG emissions occur. However, in the whole life-cycle, emissions are released mainly due to the use of fossil fuels in all phases, e.g. for transport or refinery plants. With relatively low overall life-cycle emissions NPP are considered to be an effective climate mitigation option by the Intergovernmental Panel on Climate Change . Further, the IEA suggests that for the achievement of the 2°C scenario an increase of nuclear energy by a factor of 2.25 is necessary. However, the development of the costs of low-carbon alternatives like renewables will determine the potential of nuclear. In addition, the physical impacts of climate change – gradual warming and acidification, increase in natural catastrophes, and already today increased risk of heat waves with resulting (cooling) water shortages – threaten the security of NPPs and could require more shut-downs.

5.4 Regulatory Framework

On a global scale, the International Atomic Energy Agency (IAEA) is the key actor in terms of technical and procedural standards. States with a nuclear power program in place can subscribe to IAEA benchmarks and are then committed to comply with the IAEA safeguard standards. Most national regulation builds on IAEA's standards, which are often directly transferred into national regulation.[51] However, some countries lack stringent implementation and execution of regulations and practices, mainly in Eastern Europe and Asia.

While states have the principle right to peacefully use nuclear technology, the political will to embrace nuclear energy seems to vain and/or be conditional to increased regulatory requirements:

- Germany decided in 1998 to phase out all NPPs due to the risks and the (costly) unsolved waste issue. This decision was cancelled in 2009 and reintroduced in 2011, after the nuclear accident in Fukushima. In 2011 eight reactors were shut down immediately and the government has agreed to shut down the remaining nine NPP until 2022.
- France, who has the highest percentage of nuclear power in the electricity mix worldwide, decided after Fukushima to upgrade the safety standards of its NPPs; in 2012 France decided to extend the life of the existing plants to over 40 years to avoid building new NPP. The new government announced plans to shut down 33% of its NPPs in favor of renewable energy. Hence, only one NPP is currently under construction.
- In Japan, the Fukushima accident triggered a shutdown of all 48 NPP for regulatory clearance. Before, nuclear power had a 30% share in Japanese electricity production. Since the temporary shutdown the country imports 88% of its fuels for electricity supply. Despite public reluctance, 19 NPPs have requested permission to fire up in 2015.
- In the US, the renewed interest in nuclear power at the turn of the century ("Nuclear Power 2010 Program") faded due to economic challenges and the Fukushima accident; hence most of the planned projects have been canceled. Furthermore, the Nuclear Regulatory Commission suspended the (re-)licensing of plants in 2012 until autumn 2014 due to non-compliance of its Waste Confidence Rule with the National Environmental Policy Act.

5.5 Outlook

The majority of the 400+ existing reactors are operating since more than 28 years. Hence, the majority of nuclear capacity will be decommissioned within the next two decades. The current status of NPP being planned and under construction does not match this offtake. Furthermore, without government

[51] In the European Union, the Nuclear Safety Directive enshrines the IEAE's conventions into EU law but the primary responsibility still lies with the national regulator.

support, currently investments in new NPP are generally not economically attractive within liberalized markets, that have access to relatively cheap coal and/or gas.

The actual development will depend on

a) the uncertainties about financial and cost development of nuclear energy and its competitors, especially renewable energies, and
b) the risks stemming from waste and of accidents: besides the possibilities of nuclear accidents and proliferation, temporary and final storage of radioactive residuals (waste and material) still poses major concerns.

Hence, implementing and executing stringent safety and monitoring schemes in emerging nuclear countries will be as important as maintaining high safety standards for existing and decommissioned NPPs and their waste and gearing on full costs without major externalities.

Despite the significant uncertainties regarding national nuclear policy development and at times substantial concerns from societal stakeholders, the IEA projects a more than doubling in nuclear energy generation capacity in its *450 Scenario*. This increase would lead to a share of 25% in overall electricity generation of nuclear power by 2040.

6 Hydropower

6.1 Supply and Demand

In 2012, on a global scale, hydro is the sixth most important energy source with a share of 13 222 PJ (2 % of TPES). All energy supplied from hydro is converted to electricity making it the fourth most important (6 % of FEE) energy source for electricity production after coal, gas, and nuclear. Hydro is the most important renewable energy source used for electricity production.

On a global scale, hydropower is an important electricity source – its current share in global electricity generation amounts to around 15% (2013) with an installed capacity of 1,067 GW (2011).

Table 6.1. Overview of hydropower capacity and generation

	Highest installed capacity (2011)		Highest Generation (2011)		Share in electricity production (2010)	
1	China	249 GW	China	714,000 GWh	Norway	99%
2	Brazil	82.5 GW	Brazil	429,000 GWh	Brazil	83.9%
3	USA	77.5 GW	Canada	348,000 GWh	Venezuela	73.4%
4	Canada	75.1 GW	USA	268,000 GWh	Canada	59%
5	Russia	49.7 GW	Russia	180,000 GWh	Sweden	48.8%

Source: WEC (2013) World Energy Resources 2013 and IPCC (2012) Renewable Energy Sources and Climate Change Mitigation.

6.2 Key Issues in the Value Chain

There are generally three types of hydropower, all of which require elevation changes in the water surface.

- **Storage hydropower** generate electricity by impounding large quantities of water through the use of reservoirs and dams. Due to its high land consumption, storage hydropower has a far higher environmental and social impact than both pumped storage facilities and run-of-river hydropower.
- **Run-of-river** plants generate electricity from the available flow of the river.
- **Pumped storage** power stations act as energy storage devices which can be used when grids face energy shortages or surpluses.

Table 6.2. ESG Issues Related to Hydropower

Phase	Pro	Con
Construction	• Hydroelectric dams can both provide energy and water management services (e.g. electrification of rural areas, assurance/stabilization of water supply, flood control, etc.). • Most efficient energy technology in terms of energy yield with energy payback[52] up to 280 • Proven, reliable technology. • Vast untapped potentials in Asia (e.g. Tibet, China), Latin America (e.g.	• Very high capital expenditures. • Lengthy planning and construction processes. • Projects often exposed to disruptions due to corruption, mismanagement and legal challenges. • Dependency on topographical conditions (e.g. water availability, elevation differences). • Loss of biodiversity and irreversible alterations of landscapes and

[52] Lifetime electricity output divided by total gross energy requirement for construction, operation and decommissioning.

Phase	Pro	Con
	Patagonia, Argentina) and Africa (e.g. Congo/East Africa).	ecosystems. • GHG leakage through deforestation and flooding of reservoirs (some estimations that 4% of global GHG emissions by reservoirs). • Often associated with high social costs; in case of large projects resettlement of local communities, community/ water right impacts). • Without sufficient grid-infrastructure, big hydro projects can fail to provide energy to local communities. • Often, it might be more effective to build small-scale renewable energy plants that more easily provide people with electricity.
Operation	• Low operating costs & long lifespan (40-80 years). • Low GHG[53] emissions over whole lifecycle. • Both base-load supply as well as flexible operation for peak demand possible. • Generally suitable for centralized and de-centralized grid systems.	• Cross-border impacts, e.g. possible changes in flow regimes and water supply potentially leading to political conflicts. • Silting-up of dams may lead to alteration of parameters for electricity generation and downstream agriculture. • Increasing drought risk due to climate change might hamper efficiency.

6.3 Climate Effects in a Nutshell

Generally, hydropower is a comparatively climate-friendly way of electricity generation though there is some controversy on the amount of GHG released through the decay of biomass that sets in when large areas are flooded (methane leakage).

6.4 Regulatory Framework

As hydropower is at little risk from any climate regulation, local or national environmental regulation matters most. Though there are no global regulation schemes, voluntary standards have evolved. Since the 1980s, impact assessments increasingly focus on integrated management plans that not only address technical but also social and environmental concerns. When large hydropower projects are considered a top political priority, however, environmental or social impacts are often insufficiently accounted for.

Regulatory attempts: In 1998, the World Commission on Dams has arguably issued to most comprehensive set of voluntary best-practice criteria and standards for the hydro-sector. International Development Finance Institutions such as the World Bank, the Asian Development Bank, the African Development Bank and the European Bank for Reconstruction and Development have also developed own guidelines, best-practice recommendations and quality criteria. Trying to establish more broadly accepted standards, the International Hydropower Association recently introduced a comprehensive and rigorous assessment tool[54] in cooperation with nongovernmental organizations, governments, Development Finance Institutions and commercial organizations that evaluates sustainability aspects of the whole lifecycle of a project (early stage, preparation, implementation and operation). In many cases, however, such tools and best-practice recommendations are not implemented properly (for

[53] Greenhouse gases.
[54] Hydropower Sustainability Assessment Protocol.

example in the case of the Belo Monte hydroelectric dam in Brazil currently under construction), leading to project disruptions and public scrutiny.

Promotion: In Germany, hydropower receives remuneration within the framework of the German Renewable Energy Act (EEG). Large-scale hydro plants are allocated lower feed-in-tariffs than small-scale plants (e.g. pumped storage) whose operating costs are relatively but are necessary to meet flexible energy-demands.

Globally, public tenders serve as the main method to promote hydropower expansion. International Development Finance Institutions often provide project loans, predominantly for projects in developing countries.

6.5 Current Trends

Globally, a tendency towards more cross-border hydropower projects can be observed. For example, Latin American and African countries increasingly combine resources to develop joint projects. While being traditionally led by the public sector, in recent years, hydropower projects have drawn more (transnational) private sector investment.

Expansion of capacity in emerging economies: There has been a rapid increase in hydropower capacity predominantly in Asia and Latin America over the last 10 years which is predicted to continue in the near term. E.g., Brazil plans on almost doubling its hydropower capacity to 164 GW by 2030. Also China is expected to more than double its annual generation to 1,500 TWh by 2035. In the medium term, Africa is likely to be a key growth market as improving interconnection between countries and larger energy markets reduce the risks for private sector involvement.. Currently, the biggest cross-border hydropower project worldwide (planned capacity of 40GW), the Grand Inga Dam, is planned in DRC as multi-stakeholder project of South Africa and DRC.

Responding to the demand for more flexible energy provision: With the advent of more renewable energy, hydropower plays in some countries an increasingly flexible role (mainly in the form of pumped storage plants) by providing energy when there is a shortage in the power system and by consuming excess energy in case of surpluses. For example, cross-border cooperation enables Denmark to store some excess electricity in Norway’s pumped storage plants.

Challenges: Permitting, planning and construction can be extensively hindered if projects fail to sufficiently manage social impacts and build social consensus (e.g., lost livelihoods due to inundated pastures or lacking waters supply, resettlements without/against the will of local communities, cross-border conflict potential because of altered flow regimes).

Technological progress: The use of new materials shield equipment from abrasion through sediments, fish-friendly turbines reduce hydropower’s environmental impact and other dam materials such as dryer concrete significantly lower building costs. New technologies such as hydrokinetic turbines hold potential particularly in saturated markets such as the EU or the US. Hydrokinetic energy generation captures energy from moving water requiring less pronounced elevation changes than conventional turbines and no dams or diversion. Furthermore, they can be deployed underwater, for example in rivers or streams. Once fully developed, hydrokinetic energy might greatly increase electricity supply from small-scale hydropower.

6.6 Outlook

Globally, hydropower offers significant potential for expansion of capacity, especially in emerging and developing countries. The technical potential is not a limiting factor since the current installed capacity of 1,067 GW (equaling a production of 3,550TWh) as of 2011 could be quadrupled to 3,721 GW. The underdeveloped capacity varies between 47% in Europe and 61% North America and 92% in Africa; 80% in Asia and 74% in Latin America. While in Europe and Northern America mainly modernization, refurbishment, and upgrading of existing stations as well as small hydropower (e.g., hydrokinetic turbines) will take a major role, large-scale new capacity will be predominantly developed in Asia, Latin America and Africa. Absolute hydropower capacities are expected to rise significantly within the next 20 years. Even so, a slightly decreasing share in total energy generation is likely, although the IEA estimates that global hydropower capacity would have to almost double from current levels to stay within the two-degree target range.

All in all, hydropower is still the most important and most efficient renewable energy source at present and will very likely remain so in the medium term.

7 Wind Energy

7.1 Supply and Demand

In 2012, solar, tidal and wind energy[55] made up 3 149 PJ (0.56 % of TPES) of the total primary production. The largest portion (2 299 PJ; ‹ 1 % of FEE) of these renewable energy sources was converted to electricity.

After years of strong growth, the globally installed capacity of wind power amounted to 318 GW at the end of 2013 which could generate 4% of the world's electricity demand. During the year 2013, 35 GW were added which is 10 GW less than during the record year of 2012. Almost 50% of all wind capacity was brought online since 2009 and almost 90% since 2004.

Table 7.1. Overview of Wind Energy Capacity and Generation

	Highest installed capacity (2013)		Share in electricity generation (2013)[56]		New capacity added (2013)	
1	China	91.4 GW	Denmark	33.2%	China	16.1 GW
2	USA	61.1 GW	Portugal	23.0%	Germany	3.2 GW
3	Germany	34.3 GW	Spain	21%	UK	1.9 GW
4	Spain	23.0 GW	Ireland	18%	India	1.7 GW
5	India	20.2 GW	Germany	8.4%	Canada	1.6 GW

Source: GWEC (2014a) Global Wind Report, GWEC (2014b) Global Wind Statistics 2013, Associação Nacional de Conservação da Natureza (2014), Wind Power Monthly (2013), Irish Wind Energy Association (2014) Wind Statistics and AEE (2014) Strommix in Deutschland 2013.

2013 saw the strongest growth in China. Propelled forward by feed-in premiums, 16.1 GW of new capacity were installed, up from around 12 GW in 2012. This market momentum is likely to continue with a capacity target set of 150 GW by 2017 which requires total capacity expansion of another 60 GW until then. Except for India that added 1.7 GW to the grid, other Asian countries played a marginal role only. In 2014, Asia is set to replace Europe as market leader in terms of cumulative installed capacity.

With additional 12 GW of wind power installed in 2013, Europe's markets proved to be stronger than expected as average remuneration declined and policy uncertainty increased. Germany and the UK accounted for 46% of all new European installations adding 3.2 and 1.8 GW respectively. Even though market prospects for Europe in the near-term are subdued because of cut-back support schemes (Spain) or policy uncertainty (Italy and France), the EU 2020-legislation[57] and sustained commitment of important markets such as Germany will provide some market stability; off-shore installations are expected to pick up pace in the medium term.

In Northern America (the third largest market), US growth figures dropped by 92%, installing only 1 GW, after regulatory uncertainties; an important extension of a production tax credit created a pipeline of 12 GW of projects under construction, long-term prospects are uncertain as support mechanisms are tightly coupled with the fiscal development.

[55] In the IEA dataset solar, tidal and wind energy are only presented as a combined category of renewable energy sources.
[56] Estimate based on cumulative installed capacity.
[57] If EU proposals anticipating a 27% share or renewables by 2030 are going to beadopted as binding targets, wind power capacity growth in Europe could be stabilized or even accelerated.

7.2 Key Issues in the Value Chain

Wind turbines transform kinetic wind energy into electricity through an induction generator. Wind turbines can operate both on- and off-shore and on- as well as off-grid. As of 2012, off-shore wind energy still plays a minor role representing only 2% (thereof more than 90% situated in Northern Europe) of the total installed wind power capacity.

Table 7.2. ESG Issues Related to Wind

Phase	Pro	Con
Manufacture/ construction/ installation	• Few environmental impacts: No emissions except noise, small land-take (on-shore), stations are 80-90% recyclable. • Generally, long-term constraints to materials supply seem unlikely. • Easy and cheap installation and dismantling of on-shore wind turbines compared to thermal or nuclear plants. • Compared to on-shore, off-shore wind features higher average wind speeds, more full load hours, fewer environmental and planning concerns and facilitates large-scale developments. • Small-scale wind power allows decentralized grid-structure (interesting for off-grid deployment, e.g. for rural electrification in vast countries without extensive grid infrastructure).[58]	• ESG issues in mining activities: Rare earth mining and processing toxicity and social concerns. • Rare earths (esp. in off-shore wind turbines) fosters resource dependencies as they are almost exclusively exploited in China at present.[59] • Construction of off-shore wind parks requires large amounts of steel and is 50 to 100% more expensive than onshore plants. • Public scrutiny due to aesthetical and noise pollution concerns. • Dependency on wind conditions.
Operation	• No GHG[60] emissions during operation. • No fuel or carbon costs, no water consumption and no waste production. • Energy payback of up to 40.[61] • Lifespan: 20-25 years with 4000-7000 hours/year of operation. • Possibility of repowering existing sites with more efficient plants.	• Wildlife impact through bird and bat collisions. • Visual impact/land scape alteration, possible radar interference (as ever larger turbines are built, such concerns become more acute). • Intermittency of electricity generation. • Off-shore grid-connection and maintenance currently still technically difficult and expensive (not commercially viable without public support). • High share of wind energy in energy mix (approx. > 50%) will require back-up and energy storage facilities as well as sufficient grid structure.[62]

7.3 Climate Effects in a Nutshell

Wind energy is very climate friendly. Some GHG emissions are caused by sourcing and transporting the necessary raw materials, the manufacturing of the turbines and their installation; lifecycle GHG

[58] Currently, India has the largest share of off-grid deployment with almost 20%, followed by Australia with 11% of national installations.
[59] Research efforts are underway to reduce the use of rare earths or find alternatives – electrical ceramic magnets for off-shore turbines might offer a solution in the longer term.
[60] Greenhouse gases
[61] Lifetime electricity output divided by total gross energy requirement for construction, operation and decommissioning.
[62] Relying on interconnectors with Germany and hydropower storage plants in Norway assisted the country with significantly increasing the share of wind power in total electricity generation.

emissions amount to 8-20gr CO_{2eq} /KWh.[63] If turbines were manufactured using renewable power, wind would be an almost completely GHG-free electricity source.

7.4 Regulatory Instruments and Trends

Due to continued policy support and technological advances, wind has reached the status of the most mature renewable energy technology apart from hydropower. Over the course of the last decades, increasing wind promotion measures have led to tremendous capacity growth and resulting economies of scale which triggered a rapid decline in investment costs (by a factor of three between 1980 and 1999). Between 1996 and the end of 2012, the cumulative average growth rate has been around 25% per year making wind energy very likely the fastest-expanding power source during that period. In some regions that feature good wind conditions (across Europe and the US) wind is already cost competitive with electricity market prices. Increasing technological maturity will further decrease dependency of support mechanisms, as seen for instance in Germany. Though, the electricity market design must reflect the characteristics of renewable energies with almost no marginal costs. As wind energy becomes increasingly competitive in a growing number of countries, the next policy challenge will be to change energy market designs when phasing out state support.

Currently, various **regulatory instruments** are used to support wind energy:

- **Feed-in tariffs**: For details on feed-in tariffs see PV factsheet.
- **Tendering mechanisms**: In line with EU guidelines on state-aid for renewables, the 2014 reform of the EEG introduces tendering mechanisms to determine the level of remuneration for new wind energy capacities from 2017 onwards. The reform will also regulate the volume of expansion for on-shore capacities through the adoption of an expansion corridor that limits expansion to between 2.4 and 2.6 GW/year net. Capacity growth of off-shore wind energy, however, will be supported by fixed targets (6.5 GW by 2020; 15GW by 2030).
- **Financing mechanisms/fiscal policies and other approaches** employed to foster wind energy installations comprise quota-driven frameworks with renewable portfolio standards for utilities (in place in 79 countries as of late 2013 including some states in the US) or investment or production tax credits (common in many states in the US). As in the US incentive schemes are mostly state-based lacking long-term federal support and often depend on the fiscal cycle, investors are faced with a very short time horizon which leads to considerable market volatility and boom-bust dynamics.

7.4.1 On-Shore Technological Trends and Cost Developments

In recent years, capital costs of wind power fell mainly through fierce competition, standardization and technological advances. Larger wind turbines featuring larger towers and longer blades as well as smaller generators that operate also under lower wind speeds have led to improving capacity factors. Moreover, installation costs have been decreasing for a long time due to learning effects. This has somewhat mitigated the problem of intermittent electricity generation and considerably contributed to reduce wind power's levelized cost of electricity (LCOE) which has declined by around 15% between 2009 and 2014. In the medium term, continued incremental improvements in turbine design, more efficient material usage, increased reliability, less maintenance and operation costs and longer component lifetimes will likely further decrease technology costs.

[63] The amount of CO_2 emission that would cause the same radiative forcing as an emitted amount of a greenhouse gas or of a mixture of greenhouse gases, all multiplied by their respective global warming potentials, which take into account the differing times they remain in the atmosphere.

Repowering of existing wind turbines has been increasing, too. Replacing old plants with fewer, taller, more efficient and more reliable turbines improves power output and grid compliance while tackling noise and bird mortality. Furthermore, small-scale turbines are increasingly deployed in remote areas, for example to power telecommunication infrastructure or to foster rural electrification in off-grid areas in developing countries. Another trend to watch are recently developed new turbine designs that might enable wind farms to operate in areas with lower wind speeds in the near future. Wind farms consequently could be erected closer to cities, reducing the need of expensive grid connections from remote areas.

7.4.2 Off-Shore Technological Trends and Cost Developments

Although off-shore wind has recently become more expensive due to greater depth, increasing distance from the shore, and delays in construction and grid connection, it is growing rapidly. In 2013 a record 1.6 GW of new capacity were added and overall off-shores capacities climbed to 7 GW (93% thereof situated in Europe). Pursuant to ambitious estimates, a total of 80 GW (three-quarters in Europe) could be reached by 2020 worldwide. During the same period, off-shore LCOE is projected to decline by 10 to 40% from 2009-levels.

7.5 Outlook

Globally, wind energy has enormous potential for future expansion. Even if accounting for lower load factors of wind turbines compared to thermal plants, deploying wind on one percent of the world's land areas would approximately equal the worldwide capacity of power plants. With global electricity demand continuing to grow in the coming years, and with LCOE of wind energy further decreasing, competitiveness of wind is bound to further gain ground. By 2035 global wind capacity could reach 1,130 GW according to IEA's new policies scenario (318 GW in 2012). The IEA estimates that wind power costs could be lowered by up to another one third by 2030. In the longer term, wind might deliver up to 18% of global electricity by 2050. Due to its low GHG emissions, wind technology generally is capable of greatly decarbonizing energy production, as long as challenges arising from high wind shares such as electricity generation intermittency and the design of electricity markets are solved.

8 Solar Energy

8.1 Supply and Demand

In 2012, solar, tidal and wind energy[64] made up 3 149 PJ (0.56 % of TPES) of the total primary production. The largest portion (2 299 PJ; ‹ 1 % of FEE) of these renewable energy sources was converted to electricity. The remainder of the solar, tidal and wind energy (836 PJ; ‹ 1 % of FEH) is used for solar heating[65].

Starting from a low level, the market for photovoltaics (PV) has expanded dramatically in recent years. PV’s future growth potential is huge, but in 2014 it still only accounted for a share of around 1% in the global electricity consumption.

8.1.1 Solar Energy Used for Heating

Solar energy consists of only 0.5 % of total energy available for heating. Solar energy technologies are used mainly for non-industrial purposes, especially for the on-site production of heat for warm water and space heating. IEA Two main technologies for heat generation from solar energy are currently used (OECD & IEA, 2012):

- thermal collectors (creating low-temperature heat of up to 80 °C), which are mostly used in residential and commercial applications; and
- concentrating technologies, which can be used to create higher temperature heat necessary for many industrial applications.

The IEA funds the “Solar Heating and Cooling Programme” that researches solar energy as a heat source. Their research and development efforts are also focusing on readying solar heating technologies for industrial applications (IEA SHC, 2015). The US government also funds solar thermal research through the National Renewable Energy Laboratory (NREL, 2015).

Table 8.1. Overview of Solar Energy Supply and Consumption

	Highest installed capacity (2013)		Share in electricity production (2013)[66]		New capacity added (2013)	
1	Germany	35.6 GW	Italy	7.8%	China	11.3 GW
2	China	19.8 GW	Germany	6.2%	Japan	6.9 GW
3	Italy	18.4 GW	Greece	5.8%	USA	4.8 GW
4	Japan	13.6 GW	Bulgaria	3.8%	Germany	3.3 GW
5	USA	12.1 GW	Belgium	3.3%	Italy	1.5 GW

Source: EPIA (2014) Global Market Outlook for PV 2014-2018 and IEA (2014b) Snapshot of Global PV.

8.2 Key Issues in the Value Chain

PV has to be differentiated from concentrated solar power which generates electricity through concentrating light to drive a heat engine connected to an electrical power generator. Especially in countries with high insolation, concentrated solar power is deemed to yield a high future potential. Currently, however, it plays a marginal role only with globally around 2.5 GW installed capacity as of 2012.

[64] In the IEA dataset solar, tidal and wind energy are only presented as a combined category of renewable energy sources.
[65] Solar thermal heating in buildings; wind and tidal energy are likely not used for heating.
[66] Estimate based on cumulative installed capacity.

PV relies on solar cells that generate electricity by converting sunlight into a flow of electrons. At present, wafer-based crystalline silicon cells (~ 90% market share) and thin-film solar cells (~ 10% market share) are the most important technologies in use. While the former mainly rely on silicon and silver as raw materials, some of the thin-film cells require metals such as indium or tellurium whose long-term availabilities are subject to debate.

Table 8.2. ESG Issues Related to Solar Energy

Phase	Pro	Con
Manufacturing of PV modules	• Long-term availability of raw materials for wafer-based modules. • Wafer-based modules can be manufactured without toxic components (small amounts of lead currently used during production can be replaced inexpensively). • 95% of solar modules are recyclable.	• Supply of metals such as tellurium or indium used for thin-film solar cells is largely dependent on mining as by-products of other metals. • ESG issues in mining activities.
Operation	• Lifespan: 25 - 40 years[67]. • No GHG[68] emissions. • No air/noise emissions nor waste production. • Low environmental impact; (use of solar exposure of buildings to save land, easy dismantling). • Future – though yet to be quantified - potential for vertical application. • No fuel or carbon costs. • Energy payback of up to 47[69]. • Easily scalable technology: Both small-scale deployment for self-consumption (distributed Solar PV) or large-scale deployment on utility-scale possible. • Dependent on insolation, PV can be used both on- and off-grid which makes it a suitable and cheap option for remote areas (In many rural areas without grid availability, e.g. sub-Saharan Africa, PV is already often cheaper than conventional power). • Convenient installation, maintenance and dismantling.	• Volatility of electricity generation due to intermittent sunlight exposure. • High share of PV in energy mix (> 50-80%) will require energy storage and/ or back-up and more decentralized grid structure.

8.3 Climate Effects in a Nutshell

Considering the whole life cycle, PV produces few GHG (30-80 gCO_2 equivalent/kWh) and therefore contributes to decarbonization of electricity generation. During electricity generation, no GHG are emitted. As soon as modules would be manufactured using renewable power, PV would be an almost completely GHG-free electricity source.

8.4 Regulatory Instruments and Trends

Albeit their steady decline, costs of PV electricity are often still comparatively high. Rising PV competitiveness has led to a decrease in volume of fiscal support in mature markets such as Germany, while at the same time more and more countries are adopting support schemes (such as China, Japan, etc.). PV-support policies are mostly embedded in wider schemes to increase the share of renewable

[67] Manufacturers mostly warrant 25 years during which power output does not fall below 80% rated power but especially newer modules are expected to last much longer.
[68] Greenhouse gases.
[69] Lifetime electricity output divided by total gross energy requirement for construction, operation and decommissioning.

energy in the energy mix for climate-saving purposes. The EU, for instance, supports PV indirectly by the EU targets to reach a minimum renewable energy share of 20% of final energy consumption by 2020[70]. In the course of the last decade, increasing PV promotion measures have led to important capacity growth which triggered a rapid decline in module prices having decreased 80% between 2008 and 2012. Falling prices in turn further contributed to accelerating PV capacity growth in the last years. While Europe and in particular Germany had long been the most important driver of new PV installations, 2013 has seen the market shifting towards China, Japan and the US. With support schemes being cut in Europe and extended in Asia, markets demonstrate that they still remain largely policy-driven; as of end 2013 cost-competitiveness has been reached in 19 markets such as China (industrial), Germany (both residential and industrial) and Italy (residential).

- **Feed-in tariffs**: With the Renewable Energy Act (EEG) in 2000, Germany took the lead promoting PV by paying a fixed premium for every kWh of PV-generated electricity that is fed into the grid over a period of 20 years. This long-term security has attracted many investors. Due to its remarkable success in enlarging and lowering the costs for new PV capacity, the EEG served as a blueprint for many other countries that enacted similar legislation, making feed-in tariffs the most favored and most important driver of PV-capacity growth. (98 countries as of late 2013 including most European countries, China and Japan have feed-in tariffs).
- **Tendering mechanisms**: The 2014 reform of EEG plans to introduce tendering mechanisms to determine the level of remuneration for new PV capacities by 2017. PV promotion through the EEG will be capped as soon as a threshold of 52 GW (currently 36 GW) capacity is reached.
- **Financing mechanisms/fiscal policies and other approaches** employed to foster PV installations comprise quota-driven frameworks with renewable portfolio standards for utilities (in place in 79 countries as of late 2013 including some states in the US), net-metering[71] or tax credits (common in many states in the US). As in the US incentive schemes often depend on the fiscal cycle, investors are faced with a very short time horizon which can a challenge. Tax rebates, soft loans, power purchase agreements and grants (many of which are common in China) are also frequently used to boost deployment of PV modules. In 2013, for instance, China introduced a 50% value-added tax refund for operators of PV plants that will last through 2015.
- **Production of modules**: In 2013, over 90% of PV modules were manufactured in Asia, thereof 70% in China.
- **Market development:** During the record year 2013, 39 GW were added with global capacity reaching around 139 GW. Approximately half of all PV capacity was taken on line in the last two years and 98% have been developed since 2004.
- In 2013, growth was mainly driven by Asia. By also implementing feed-in tariffs, China has become the biggest PV market. In 2013, 11.8 GW new capacity was installed, up from just around 3 GW in 2012. In 2014, China has revised its PV targets for 2017 upwards, now aiming to triple the amount of installed PV capacity from currently 20 GW to 70 GW by 2017. Japan, which implemented a feed-in tariff for PV after the Fukushima disaster, experienced strong capacity growth, too, with new installations reaching 6.9 GW in 2013. Capacity growth has also been picking up in the US with new installations rising to 4.8 GW.

In Germany, however, declining feed-in tariffs led to only 3.3 GW of new installations in 2013 after three consecutive years of around 7.5 GW capacity expansion. Due to caps on feed-in tariffs (in Italy), retroactive cuts (in Spain) and policy uncertainty (in France and Italy) other big European PV markets

[70] New EU proposals that have yet to be enacted as binding targets anticipate a 27% share or renewables by 2030.
[71] Consumer-produced PV electricity fed in to the grid can be employed to offset energy provided by utility during billig period which lowers the household's electricity bill.

likewise lost momentum last year while new feed-in tariffs saw the installation of capacity soar in the UK. In general, the European market development points downward.

8.5 Outlook

Globally, solar energy in the form of PV has enormous potential for future expansion of capacity as solar energy is the most abundant energy resource on earth. With global demand continuing to grow in the coming years, module prices and LCOE are projected to further decrease (based on proven learning rates, costs could be further reduced by up to 50% by 2035) while solar cell efficiencies will keep rising. Even though the market currently still remains heavily dependent on support policies, unsubsidized PV electricity is already competitive in a growing number of countries. Until 2018, global solar PV capacity is likely to reach at least 308 GW (139 GW in 2013). Due to its low GHG emissions, PV technology is capable of contributing to greatly decarbonizing energy production. To limit global warming, the IEA estimates that PV capacity would have to reach almost 1 TW by 2035. Assuming current expansion rates of around 40 GW/year, this target would be attained in 2035. In the near future, it is even likely that PV growth rises to more than 50 GW/year.

9 Bioenergy and Waste

Bioenergy and Waste needs to be differentiated into two broad categories (traditional uses and modern uses) for the purpose of this factsheet.

Most bioenergy is consumed in developing countries for *traditional uses*: these includes using biomass such as wood, charcoal, agricultural residues and animal dung, mainly for cooking and water heating. In colder climates, traditional biomass is also used for residential space heating. According to the IEA, these traditional uses are very inefficient as only 10 to 20% of the energy are actually utilized, while the remainder is wasted in combustion.

Modern bioenergy, as opposed to traditional bioenergy, is mostly used in OECD countries and is produced industrially. It includes solid biomass (wood pellets and chips, municipal solid waste), liquid biofuels (ethanol, biodiesel, aviation biofuels) and biogases (bio-methane), which all have or need sophisticated production, trade and distribution systems. Bioenergy in OECD countries is mainly used to produce bio-heat (sold as commercial heat to industrial, commercial and residential consumers) to produce electricity and transportation fuels. In OECD countries, the traditional use of bioenergy is less prevalent.

9.1 Supply and Demand

In 2012, global production of bioenergy totaled 10 % of TPES[72] (56 240 PJ). Globally, 26% (43 986 PJ) of available energy for heating comes from bioenergy, while in electricity production, only 3 % of FEE (6 086 PJ) come from bioenergy.

In large parts of the developing world, traditional use of wood remains the most important resource for residential heating. On a global scale, 50 % of residential heating uses biofuels and waste.

9.2 Key Issues in the Value Chain

Table 9.1. ESG Issues Related to Biomass and Waste

Phase	Pro	Con
Production	• Biomass energy sources are considered renewable when used at a sustainable rate. • Waste: Through various processes (such as anaerobic digestion, gasification) household and industrial waste can be used to create bioenergy. • Wood: Proper forest management can improve local biodiversity (e.g. by removing invasive or infected trees), while producing additional biomass. • Biofuels: Second-generation biofuels[73] are able to make use of agricultural wastes or	• Some bioenergy sources (e.g. certain crops) are only available seasonally, which can have reliability issues • Traditional Biomass: low efficiency, potentially high environmental and social impacts (example: respiratory health impacts, unsustainable sources, deforestation, soil degradation) • Competition between first generation biofuels[74] and food systems, as food crops may be allocated to energy purposes. • Competition between bioenergy production and biodiversity as energy

[72] The IEA notes that there are significant uncertainties regarding this number as the traditional bioenergy sector is not captured by national energy statistics. The IPCC estimated, in 2011, that the true number could be approximately 6 000 to 12 000 PJ greater than published by the IEA.

[73] IEA Definition: "Second generation biofuels are those biofuels produced from cellulose, hemicellulose or lignin [i.e. they do not use parts of crops used for its nutritional value]. 2nd generation biofuel can either be blended with petroleum-based fuels combusted in existing internal combustion engines, and distributed through existing infrastructure or is dedicated for the use in slightly adapted vehicles with internal combustion engines [...]. Examples of 2nd generation biofuels are cellulosic ethanol and Fischer-Tropsch fuels." (IEA, 2010, p. 22).

[74] IEA Definition: "First generation biofuels are biofuels which are on the market in considerable amounts today. Typical 1st generation biofuels are sugarcane ethanol, starch-based or 'corn' ethanol, biodiesel and Pure Plant Oil (PPO). The

Phase	Pro	Con
	crops grown on marginal agricultural lands. Furthermore biofuels can be created from algae. • For the agriculture industry and producers the biomass sector provides new economic opportunities, if policies are well designed to mitigate adverse effects such replacing food with energy crops	crops encroach on high biodiversity value areas. • Potential impact on local communities (illegal expropriation, displacement, loss of traditional lifestyles). • While wood is considered a renewable resource, unsustainable or uncontrolled harvesting and burning can have significant land-use change and air pollution impacts[75].
Combustion	• Biomass/-fuels are versatile and can be used for electricity and/or heat generation as well as transport and for non-energy uses. • Combustion of biomass/-fuel is considered carbon neutral because only the carbon accumulated during growth is released". • Waste: Resources such as sewage, used cooking oil, municipal solid waste etc. can be combusted directly. • In rural areas of developing countries bioenergy is often the only available energy source; this makes it even more important to improve efficiency and establish processes to use the resource sustainably • Bio-ethanol and biogas could provide clean alternatives for rural communities currently dependent on wood as their source of heat, as these fuels burn more cleanly, this reducing the potential health impacts.	• Various bioenergy sources have different qualities and calorific values: equipment used for conversion and combustion must be specifically designed to be compatible with the specific biofuels. • Wood: Unfit equipment (wood burning stoves without proper chimneys or ventilation) can cause severe health impacts[76]. • Wood smoke can contain potent drivers of anthropogenic climate change.

9.3 Climate Effects in a Nutshell

The increased use of bioenergy is an important part of the IEA ETP 2012 2°C Scenario[77] (ETP 2DS). The scenario would require an increase of the proportion of TPES of bioenergy from the current 10% to 24% until 2050 and it would require large improvements in conversion-efficiencies of bioenergy technologies as well as increased use of such technologies.

Burning of biomass and waste generates CO_2 and other GHG emissions, like any other combustion process. Furthermore there are GHG emissions and GHG lifecycle emissions attached to bio energy resources through production and delivery (e.g. use of machines during harvest and processing). It is therefore essential to take a lifecycle approach, comparing the GHG emissions over the complete lifecycle of the bioenergy resource compared to its fossil alternative, in order to understand the relative lifecycle greenhouse gas reductions and to understand the true sustainability impacts of the bioenergy resource.

feedstock for producing 1st generation biofuels either consists of sugar, starch and oil bearing crops or animal fats that in most cases can also be used as food and feed or consists of food residues." (IEA, 2010, p. 22).

[75] This point not only relates to the way forest resources are used for bioenergy but all forestry mangement practices.

[76] For example pneumonia, stroke, heart disease, lung cancer, tuberculosis, and cataracts.

[77] The scenario aims at reducing GHG emissions in the energy sector by 50%[77] by 2050 to limit the atmospheric GHG concentration to 450 ppm or warming to 2°C.

While the life cycle approach includes all the impacts in the processes before and after combustion, it also disregards the impacts of land use change specifically to produce bioenergy sources. When lands (especially forests) are converted for bioenergy source production, additional carbon may be released into the atmosphere, from for example clearcutting, while this initial carbon *expense* should in theory be balanced with other GHG savings from bioenergy.[78] Furthermore, the impacts on biodiversity, water, soil pollution, etc. should be addresses separately.

Using municipal solid waste as a bioenergy resource reduces the demand for landfill capacities, therefore there are no land use change impacts on the climate. Furthermore, combustion of waste can be considered a form of final recycling of the energy contained in the material; this reduces the demand for fossil resources to generate electricity and/or heat. Depending on the type of waste burned, a life-cycle assessment can show the efficiencies thereof compared to fossil fuels.

9.4 Standards and Regulatory Instruments and Trends

Most standards and regulatory trends are focused on liquid biofuels (ethanol, biodiesel, bio aviation fuel, etc.) and less on solid or gaseous bioenergy sources. The IEA suggests that current agricultural and forestry certification systems could be used starting grounds for biomass certifications, as they provide a framework for sustainable agricultural or forestry management, cultivation and harvest.

This section will list some of the frameworks that are in force. Many of the regulations disregard solid and gaseous energy sources, focusing on liquid biofuels.

9.4.1 EU Renewable Energy Directive (Directive 2009/28/EC)

EU description: “The Renewable Energy Directive establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.”.

Updates to this directive will be brought soon by the EU: there may (based on March 2015 information) include new policies on the sustainability of bioenergy resources, regional cooperation within the EU to develop bioenergy more effectively, early coordination of national bioenergy policies, electricity market redesign and integration (distribution, transmission and production).

9.4.2 EU Emissions Trading Schemes

Bioenergy sources are zero-rated under the EU Emissions Trading Scheme, meaning that no emission certificates are needed for the emissions created by burning biomass. For liquid biofuels, zero-rating can only take place if the energy source abides by EU regulated sustainability criteria, such as impact on food, biodiversity, etc.

9.4.3 German *Biomassestrom-Nachhaltigkeitsverordnung*

The German Biomass-Electricity-Sustainability Regulation outlines certain sustainability criteria applicable to liquid biofuels. These include protection of biodiversity, of areas with high conservation value, of areas of high carbon storage, and of peat bogs. Furthermore, the bioenergy resources must be produced in sustainable managed agriculture and must respect certain GHG goals of the German government.

[78] This topic is still subject to scientific debate, therefore no established reference values for emissions from land-use change exist.

9.4.4 United States Policies

Bioenergy policies in the United States have a strong focus on transportation biofuels. The Energy Independence and Security Act of 2007 outlined strong requirements to move away from fossil fuels and, by extension, for GHG emissions reductions. Nevertheless, the act focuses mostly on transportation bioenergy and reducing energy consumption for electricity and heating through improved efficiency. For biomass used for heating, cooling or power generation, there are no specific requirements in place yet on the federal level.

On state level, action on bioenergy is also moving forward. The State of California, adopted a Bioenergy Action Plan in 2012, encompassing all types of bioenergy resources. The plan has several points to promote and increase the development of bioenergy in the state.

9.5 Outlook

9.5.1 General Outlook

- Over the past years, there has been an increase in trade in bioenergy resources. This trend will likely to continue as regulations encourage the use of bioenergy. In the IEA New Policy Scenario, bioenergy demand will increase by almost 50% by 2040.
- Largest growth sectors are expected to be power generation, and industrial use of bioenergy. An important part will also be the reduction of traditional use of bioenergy (as it is replaced by modern uses).
- Heat generation from bio-energy sources has been growing 1-2% per year globally over the past years. The largest gains have been seen in Europe and US.
- Continued research and development is increasing the conversion efficiency (reducing the losses) of bioenergy heat and electricity plants.
- Combined heat and power (CHP) plants will play an increasingly important role. Such plants currently have efficiencies of up to 90%. Biomass and biogas can be used in these types of plants to produce commercial heat and electricity.
- Cooling, which is increasing in importance globally is an issue that will come up in the future as it is related to the heating debate, however up until now has not yet been addressed systematically.

9.5.2 Liquid Biofuels and Biogases

- Since the peak in biofuels investment in 2007, investments in biofuel production have declined overall, however investments in 2nd generation production continues to increase.
- Biogas is likely to continue increasing in importance, as technologies to convert biomass and waste to gas are reaching maturity.

9.5.3 Solid Biomass

- Europe has the most important modern biomass heating sector.
- Growth in China has slowed due to lack in biomass availability.
- CHP and heat generation using biomass is gaining importance globally; networks both for electricity and heat transport are continuously developed (for example in Denmark) to use heat and electrical energy more efficiently.
- Many heat and power plants are being converted to allow co-firing of bioenergy resources alongside conventional fuels.

Appendix

Abbreviations

CCS	Carbon Capture and Storage
CFBC	Circulating Fluidized Bed Combustion
CHP	Combined Heat and Power
EEG	*Erneuerbare Energien Gesetz* (German Renewable Energy Act)
EPA	Environmental Protection Agency
ESG	Environmental, Social and (Corporate) Governance
EU	European Union
FEC	Total Final Energy for Consumption
FEE	Final Energy for Electricity
FEH	Final Energy for Heat
GHG	Greenhouse Gas
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
LCOE	Levelized Cost of Electricity
LNG	Liquid Natural Gas
NPP	Nuclear Power Plant
OECD	Organization for Economic Cooperation and Development
PCF	Pulverized Coal Fired
TPES	Total Primary Energy Supply
US	United States
USA	United States of America

Units	
bcm	Billion Cubic Meters
kJ	Kilojoule
kg	Kilogram
kWh	Kilowatt hour
MPa	Megapascal
Mtoe	Million Tons
MW	Megawatt
PJ	Petajoule
ppm	Parts per Million
TWh	Terawatt Hour

Definition of IEA Energy Scenarios

The *Current Policies Scenario* is based on those government policies and implementing measures that had been formally adopted as of mid-2014.

The *New Policies Scenario* takes into account the policies and implementing measures affecting energy markets that had been adopted as of mid-2014, together with relevant policy proposals, even if specific measures needed to put them into effect have yet to be fully developed. It assumes only cautious implementation of such commitments plans.

The *450 Scenario* sets out an energy pathway that is consistent with a 50% chance of meeting the goal of limiting the long-term increase in average global temperature to 2 degree Celsius compared with pre-industrial levels. In this scenario the concentration of GHG in the atmosphere peaks by around the middle of this century at a level above 450 parts per million (ppm) and stabilizes after 2100 at around 450 ppm making the 2 degree objective still attainable.

Tables and Figures

Figures

Tables

Sources

Overview

DESTATIS (2013). Energy Production: Balance sheet of heat supply, total. https://www.destatis.de/EN/FactsFigures/EconomicSectors/Energy/Production/Tables/BalanceSheetHeat.html (19/01/2015).

United States Energy Information Administration (EIA) (2012). Combined heat and power technology fills an important energy niche. http://www.eia.gov/todayinenergy/detail.cfm?id=8250 (19/01/2015).

EIA (2015). Glossary. http://www.eia.gov/tools/glossary/index.cfm?id=C (21/01/2015).

European Commission (2012). Biomass issues in the EU ETS.

European Commission (2013). Energy Efficiency. http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/2367-ee-18-2015.html (12/12/2015).

European Commission (2014). EU Energy in Figures: Statistical Pocketbook 2014.

International Energy Agency (IEA) (2005). Energy Statistics Manual.

IEA (2012). Technology Roadmap: Bioenergy for Heat and Power.

IEA (2014a). Heating without Global Warming.

IEA (2014b). IEA Energy Sankey. http://www.iea.org/sankey/ (21/01/2015).

IEA (2014c). Key World Energy Statistics 2014.

IEA (2014d). World Energy Outlook 2014.

OECD & IEA (2012). Policies for renewable heat.

OECD, IEA & Eurostat. (2004). Energy Statistics Manual. Paris: International Energy Agency.

Renewable Energy Policy Network for the 21st Century (REN21) (2014). Renewables 2014: Global Status Report.

UK Houses of Parliament (2012). POSTNOTE 410: Bioenergy.

UN ESA Statistics Division (2008). International Standard Industrial Classification for All Economic Activities.

United Nations Development Program (UNDP) (2007). Human Development Report 2007/2008: Access to Energy and Human Development.

Coal

Bloomberg (2013). Obama's Overseas Coal Pledge to Curb Ex-Im Bank Financing. http://www.bloomberg.com/news/articles/2013-06-25/obama-s-overseas-coal-pledge-to-curb-ex-im-bank-financing (08/08/2014).

Breaking Energy (2013). US Won't Finance Overseas Coal Plants, But Will Still Sell the Fuel.

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) (2013). Energiestudie 2013. Reserven, Ressourcen und Verfügbarkeit von Energierohstoffen.

European Bank for Reconstruction and Development (2013). Energy Sector Strategy.

European Investment Bank (n.d.). Emission Performance Standard.

Environmental Protection Agency (EPA) (2014). Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units.

Greenpeace (2010). Power station technologies.

IEA (2011) World Energy Outlook 2011.

IEA (2012). Technology Roadmap 2012 – High efficiency, low-emissions coal-fired power generation.

IEA (2013). Medium Term Coal Market Report 2013.

IEA (2013). Technology Roadmap – Carbon Capture and Storage.

IEA (2013). World Energy Outlook 2013.

Institute for Advanced Sustainability Studies (2014). Working Paper: CO2 Emissionsgrenzwerte für Kraftwerke – Ausgestaltungsansätze und Bewertung einer möglichen Einführung auf nationaler Ebene.

Intergovernmental Panel on Climate Change (IPCC) (2005). Special Report on Carbon Dioxide Capture and Storage.

KPMG (2013). Green Tax Index 2013.

U.S. Energy Information Administration (EIA) (2013). International Energy Outlook 2013.

VGB PowerTech e.V. (2013). Electricity Generation 2013/14: Facts and Figures.

World Bank (2014). Statement: Putting a price on carbon.

World Bank (2015). The World Bank Database. http://data.worldbank.org/ (27/05/2015).

World Coal Association (WCA) (2013a). Climate Policy Paper II.

WCA (2013b). Coal Facts 2013.

World Energy Council (WEC) (2013). World Energy Resources 2013.

Natural Gas

Allianz Global Corporate & Specialty (2010). Siemens combined cycle gas turbine in Irsching. http://www.agcs.allianz.com/insights/expert-risk-articles/generating-electricity-on-a-grand-scale/ (16/06/2015).
BGR (2013). Energiestudie 2013.
Bloomberg (2012). New EPA Rules Could Prevent 'Fracking' Backlash. http://www.businessweek.com/articles/2012-04-18/new-epa-rules-could-prevent-fracking-backlash (16/06/2015).
BP (2014). Energy Outlook.
EPA (2013). 2013 Proposed Carbon Pollution Standard for New Power Plants. http://www2.epa.gov/carbon-pollution-standards/2013-proposed-carbon-pollution-standard-new-power-plants (16/06/2015).
EPA (2014a). EPA Fact Sheet: Reducing Carbon Pollution from Power Plants.
EPA (2014b). Clean Power Plan Proposed Rule. http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule (16/06/2015).
EIA (2013). International Energy Outlook 2013.
Howarth, R. W. (2014). A bridge to nowhere: methane emissions & the greenhouse gas footprint of natural gas.
IEA (2014). Medium-Term Gas Market Report 2014.
IEA (2012). Natural Gas Information 2012.
IEA. (2013a). Key World Energy Statistics 2013.
IEA (2013b). World Energy Outlook 2013.
IPCC (2011). Special Report Renewable Energy Sources 2011.
Kepler Cheuvreux (2014). Stranded assets, fossilised revenues.
National Renewable Energy Laboratory (2000). Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System.
Netzentwicklungsplan (2012). Netzentwicklungsplan Strom 2012.
Proceedings of the National Academy of Science (2014). Harmonization of initial estimates of shale gas life cycle greenhouse gas emissions for electric power generation.
WEC (2013). World Energy Resources 2013.
World Bank (2015). The World Bank Database. http://data.worldbank.org/ (27/05/2015).

Oil and Oil Products

BGR (2013). Energiestudie 2013.
BP (2013). Statistical Review of World Energy 2013.
EPA (2013). Oil.
Greenpeace (2013). Point of no Return. The massive climate threats we must avoid.
CNN Money (2012). Obama tightens oil and gas drilling regulations. http://money.cnn.com/2012/04/18/news/economy/drilling-regulations/ (21/08/2014).
IEA (2013a). Key World Energy Statistics 2013.
IEA (2013b). Medium Term Oil Market Report 2013.
IEA (2013c). World Energy Outlook 2013.
World Bank (2015). The World Bank Database. http://data.worldbank.org/ (27/05/2015).

Nuclear Energy

BP (2013). Statistical Review of world energy 2013.
BGR (2013). Energiestudie 2013.
Die Zeit (2014). Energiewende à la française. http://www.zeit.de/2014/27/energiewende-frankreich-segolene-royal-atomlobby (16/06/2015).
Energy Watch Group (2013). Fossil and Nuclear Fuels – the Supply Outlook.
European Commission (2015). Nuclear Safety. http://ec.europa.eu/energy/en/topics/nuclear-energy/nuclear-safety (16/06/2015).
Hansen, J. (2009). Strategies to address global warming.
International Atomic Energy Agency IAEA (2014). Nuclear Safety Review 2014.
IEA (2013a). Key World Energy Statistics 2013.
IEA (2013b). World Energy Outlook 2013.
IPCC (2014). Energy Systems.
IPCC (2014). Summary for Policymakers: Mitigation.
The Guardian (2008). Extracting a disaster. http://www.theguardian.com/commentisfree/2008/dec/05/nuclear-greenpolitics (16/06/2015).

The Wall Street Journal (2014). France to Dim Its Reliance on Nuclear Power. http://www.wsj.com/articles/france-to-dim-its-reliance-on-nuclear-power-1403113287 (16/06/2015).
The Washington Post (2014). After the Fukushima meltdown, Japan's nuclear restart is stalled. http://www.washingtonpost.com/blogs/monkey-cage/wp/2014/08/15/after-the-fukushima-meltdown-japans-nuclear-restart-is-stalled/ (16/06/2015).
Thomson Reuters (2011). Decommissioning a Nuclear Plant can cost $1 Billion and Take Decades. http://www.reuters.com/article/2011/06/13/idUS178883596820110613 (16/06/2015).
Thomson Reuters (2012a). U.S. approves first new nuclear plant in a generation. http://www.reuters.com/article/2012/02/09/us-usa-nuclear-nrc-idUSTRE8182J720120209 (16/06/2015).
Thomson Reuters (2012b). France to extend life of nuclear plants. http://www.reuters.com/article/2012/02/12/france-nuclear-idUSL5E8DC2UU20120212 (16/06/2015).
United States Nuclear Regulatory Commission (n.d.). Continued Storage of Spent Nuclear Fuel. http://www.nrc.gov/waste/spent-fuel-storage/wcd.html (21/08/2015).
University of Michigan (2008). MRS Bulletin. Nuclear Fuel Cycle: Environmental Impact.
World Bank (2015). The World Bank Database. http://data.worldbank.org/ (27/05/2015).
WEC (2013a). Cost of Energy Technologies.
WEC (2013b). World Energy Resources.
World Nuclear Association (WNA) (2014a). World Nuclear Power Reactors & Uranium Requirements. http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-Archive/Reactor-Archive-December-2014/ (16/06/2015).
WNA (2014b). Supply of Uranium. http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/ (16/06/2015).
WNA (2015a). The Economics of Nuclear Power. http://www.world-nuclear.org/info/Economic-Aspects/Economics-of-Nuclear-Power/ (16/06/2015).
WNA (2015b). The Nuclear Fuel Cycle. http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Introduction/Nuclear-Fuel-Cycle-Overview/ (16/06/2015).
WNA (n.d.). Nuclear Regulations & Regulators. http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Appendices/Nuclear-regulation---regulators/ (16/06/2015).

Hydropower

Barros, N., Cole, J. J., Tranvik et al. (2011). Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude.
IPCC (2012). Renewable Energy Sources and Climate Change Mitigation.
IEA (2010). Projected Costs of Generating Electricity.
IEA (2012a). Energy Technology Perspectives 2012.
IEA (2012b). Technology Roadmap Hydropower.
WEC (2013). World Energy Resources 2013.

Wind Energy

Agentur für Erneuerbare Energien (AEE) (2014) Strommix in Deutschland 2013. http://www.unendlich-viel-energie.de/mediathek/grafiken/strommix-in-deutschland-2013 (27/05/2015).
Associação Nacional de Conservação da Natureza (2014). Portugal atingiu valor recorde do século na produção de eletricidade renovável e de emissões de CO2 evitadas. http://www.quercus.pt/comunicados/2014/janeiro/3297-portugal-atingiu-valor-recorde-do-seculo-na-producao-de-eletricidade-renovavel-e-de-emissoes-de-co2-evitadas (27/05/2015).
Bloomberg (2014). China Targets 70 Gigawatts of Solar Power to Cut Coal Reliance. http://www.bloomberg.com/news/2014-05-16/china-targets-70-gigawatts-of-solar-power-to-cut-coal-reliance.html (16/06/2015).
Frankfurt School- UNEP Centre/BNEF (2014). Global Trends in Renewable Energy Investment 2014.
Fraunhofer-Institut für Solare Energiesysteme (ISE) (2013). Stromgestehungskosten Erneuerbare Energien.
Fraunhofer ISE (2014). Aktuelle Fakten zur Photovoltaik in Deutschland.
Fraunhofer-Institut für Chemische Technologie (2013). Recycling von Windkraft-Anlagen.
Global Wind Energy Council (2014a). Global Wind Report Annual Market Update 2013.
Global Wind Energy Council (2014b) Global Wind Statistics 2013.
IPCC (2012). Renewable Energy Sources and Climate Change Mitigation.

IEA (2013). Wind seen generating up to 18% of world's global power by 2050.
IEA (2013). World Energy Outlook 2013.
Irish Wind Energy Association (2014). Wind Statistics.
http://www.iwea.com/_windenergy_onshore (16/06/2015).
Knoll, A. (2012). Windenergie: Zu Lande oder zu Wasser?
National Renewable Energy Laboratory (2012). IEA Wind Task 26: The past and future cost of wind energy.
REN21 (2014). Renewables 2014 Global Status Report.
The Guardian (2014). Rare earth mining in China: the bleak social and environmental costs.
http://www.theguardian.com/sustainable-business/rare-earth-mining-china-social-environmental-costs (08/08/ 2014).
The World Wind Energy Association (2013). Half-year report 2013.
Wind Power Monthly (2013). Wind is Spain's biggest power generator in 2013.
http://www.windpowermonthly.com/article/1225725/wind-spains-biggest-power-generator-2013 (27/05/2015).
WEC (2013). World Energy Resources 2013.
WEC (2013). Cost of Energy Technologies.

Solar Energy

Bloomberg (2013). New Energy Finance Summit 2013.
Deutsche Bank Research (2014). Outlook: Let the Second Gold Rush Begin (Industry outlook solar).
European Commission (2013). PV Status Report 2013.
European Photovoltaik Industry Association (EPIA) (2014). Global Market Outlook for PV 2014-18.
EPIA (2014) Market Report 2013.
IPCC (2012). Renewable Energy Sources and Climate Change Mitigation.
IEA (2013a). World Energy Outlook 2013.
IEA (2013b). Medium-Term Market Report 2013.
IEA (2014a). Energy Technology Perspectives.
IEA (2014b). PVPS Report Snapshot of Global PV.
REN21 (2014). Renewables 2014: Global Status Report.
Solar Business Services (2013). National Feed-in-Tariff for Photovoltaic Revised and Effective since September 1, 2013. http://solarbusiness.com.au/china-solar-market-update-september-2013/ (16/06/2015).

Biomass

Ares, E. (2013). Biomass. Science and Environment.
EIA (2012). Combined heat and power technology fills an important energy niche.
http://www.eia.gov/todayinenergy/detail.cfm?id=8250 (16/06/2015).
EIA (2015). Combined Heat and Power Partnership - Efficiency Benefits.
http://www.epa.gov/chp/basic/efficiency.html (16/06/2015).
European Commission (2012). Biomass issues in the EU ETS.
Health Canada (2012). Avoid wood smoke.
http://healthycanadians.gc.ca/healthy-living-vie-saine/environment-environnement/home-maison/wood-smoke-fumee-bois-eng.php (16/06/2015).
IEA (2012). Technology Roadmap: Bioenergy for Heat and Power.
IEA (2014a). Heating without Global Warming.
IEA (2014b). IEA Energy Sankey. http://www.iea.org/sankey/ (21/01/2015).
IEA (2014c). Topic: Heat. http://www.iea.org/topics/heat/ (19/01/2015).
IEA (2014d). Key World Energy Statistics 2014.
IEA (2014e). World Energy Outlook 2014.
OECD & IEA. (2012). Policies for renewable heat.
REN21 (2014). Renewables 2014: Global Status Report.
UNDP (2007). Human Development Report 2007/2008: Access to Energy and Human Development.
Zuk, M., Rojas, L., et al. (2006). The impact of improved wood-burning stoves on fine particulate matter concentrations in rural Mexican homes.

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