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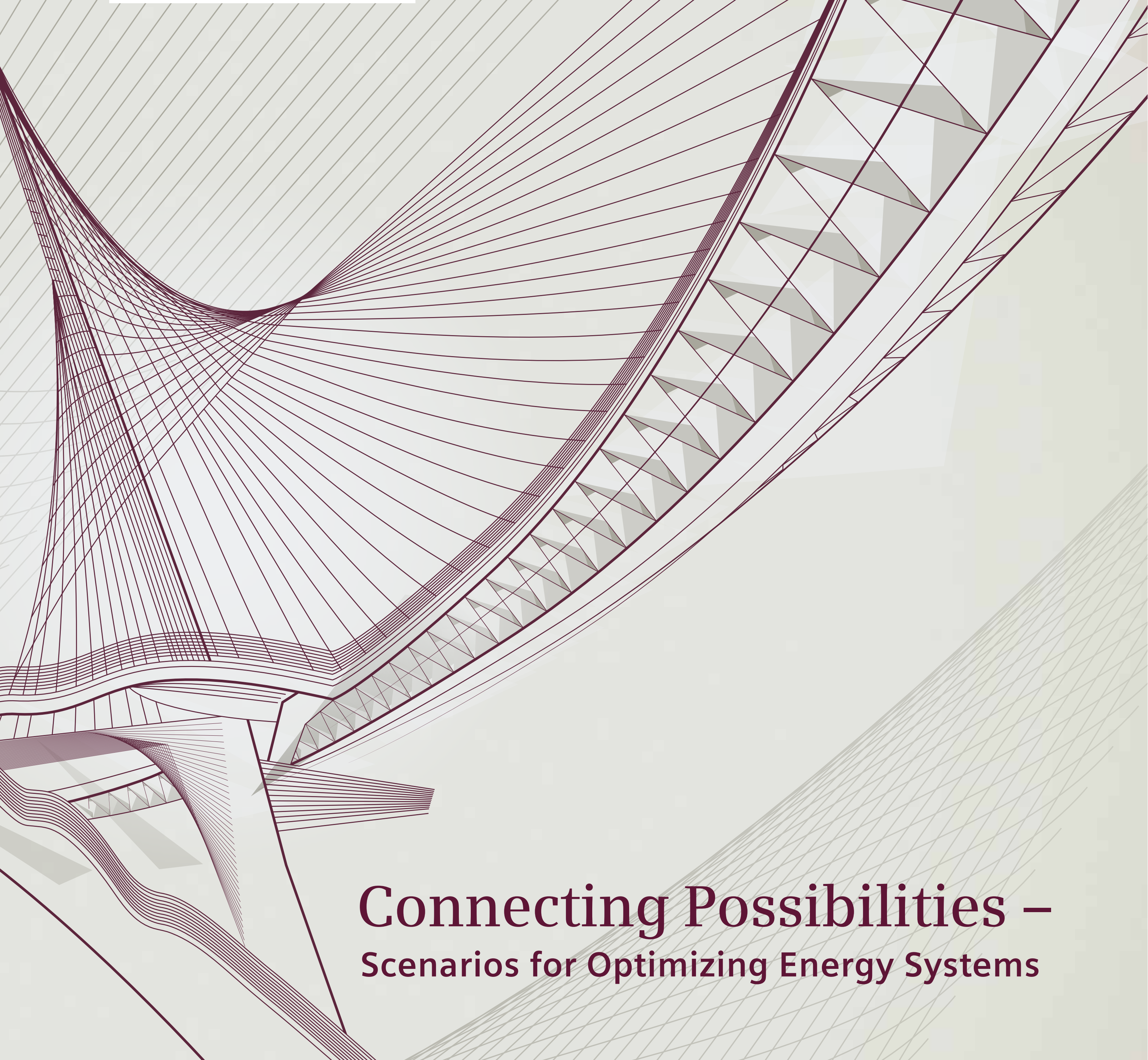


Connecting Possibilities –

Scenarios for Optimizing Energy Systems

Answers for energy.

Contents

Tomorrow's energy: Connecting possibilities

Energy is one of the fundamental requisites for the development of every society. Economic success and prosperity depend directly on the question of how reliably a society's energy system – in particular electricity – functions. The situation naturally varies from country to country and from region to region. While demand for electricity in the industrialized nations is expected to remain fairly constant over the medium term, the hunger for electricity in many emerging countries is soaring. Around 1.3 billion people on our planet still have no access to a regular supply of electricity.

To ensure the availability of electricity and make it both economical and climate friendly, many questions have to be answered. And definitive answers can be found only when the search for solutions doesn't end at a given country's or region's borders, but rather takes the larger contexts into account. One thing is clear: There certainly is plenty of potential for improvements.

Our Road to Daegu was a welcome opportunity to take a closer look at energy systems in regions throughout the world. Our goal wasn't to focus on minor possibilities for improvements here and there, but to think in larger terms. What overall possibilities does each energy system offer? What savings in resources and capital could be achieved with a major reconstruction of a country's power plant fleet?

In Europe, for example, many countries have plans to develop renewable energies, particularly wind and solar. And there is considerable room for optimizing these plans if priority is given to the choice of location. In a location-optimized scenario, savings of around 45 billion euros could be realized by 2030.

Or take the U.S.: In the study, a scenario shows that modernizing the country's power grid would save economic costs of up to 80 billion dollars a year resulting from power failures.

The study shows that China can maintain its CO_2 emissions at today's level despite a substantial increase in power generation. The levers for achieving this are the modernization of aging, inefficient power plants, the accelerated construction of highly efficient gas-fired power plants, and the further development of non-fossil fuels, such as renewables.

The individual scenarios presented in this study make it clear that there is huge savings potential when it comes to sustainable, secure and, above all, cost-efficient energy supplies. The study is intended to stimulate ideas and motivate. After all, calling attention to potential for improvements often sets creative powers in motion. I hope so in these cases.

Why? Because we need a framework setting that is often possible only with the concerted efforts of politics and society. This setting includes reliable investment conditions that send the right signals for developing the most sensible energy mix. Moreover, we need as much scope as possible for free competition so the best technologies can prevail economically in a market-oriented environment. And we also need a society that embraces new technologies.

If we all work together to promote and implement only a small share of all these possibilities, we would make substantial progress toward achieving energy systems with more innovative technologies, more effective climate and environmental protection, better supply security and greater efficiency.

Let's join together and pursue this path!

I wish you an interesting and motivating read!

Yours,

Michael Suess

Dr. Michael Suess

CEO Siemens Energy Sector
and member of the Managing Board of
Siemens AG

General introduction

»Securing Tomorrow's Energy Today« – the theme of the 22nd World Energy Congress (WEC) in Daegu, Republic of Korea – impressively introduces the challenges faced by energy markets today. As one of the world's most prestigious energy events, the WEC brings together the largest group of industry leaders and provides a platform for discussing challenges and proposing solutions for all aspects of the global energy markets. More than 5,000 government and business leaders and other delegates from 100 countries are expected to attend the Congress to discuss tomorrow's energy. The event provides a forum for up to 25,000 participants to learn about solutions for overcoming future challenges in the energy sector and to provide a business platform for networking with global players, exploring business opportunities and accessing new markets. The Congress was founded in 1924 by the World Energy Council, a United Nations-accredited global energy body representing energy-related stakeholders from more than 90 countries. Since then, the event has been staged in 20 cities throughout the world. The 22nd WEC is being held in East Asia, one of the world's most dynamic energy markets. Korea's green growth capital – Daegu – was symbolically chosen to give all participants an opportunity to see the country's initiatives for sustainable energy development. The theme »Securing Tomorrow's Energy, Today« has triggered a broad discussion about the ever-evolving quest to develop energy sources that provide affordable, sustainable and secure energy supplies in the future. The key questions of the 22nd WEC are: Will there be enough energy to meet growing demand? How can energy supplies be protected against disruptions? How will efforts to mitigate climate change affect access to future energy sources?

Siemens' contribution to this year's WEC has the theme »Think, talk, act energy.« In this spirit, Siemens, as one of the major energy solution providers, launched a global discussion on three different channels on its Road to Daegu.

The first channel featured six live discussions with local energy experts in different regions on challenges and possible solutions for certain regional energy markets. Dr. Michael Suess, CEO of the Energy Sector and member of the Managing Board of Siemens AG, invited customers, policymakers and experts from the energy industry to the roundtable discussions in six different regions – Europe, Russia, the United States, China, Saudi Arabia, and finally the Republic of Korea. Each roundtable discussion was held to identify individual responses to local challenges posed by the energy systems of tomorrow.

The themes of the roundtables were:

- **One integrated energy market for Europe: Idealistic experiment or future fact?**
- **Modernization of the Russian energy sector: Why the wait?**
- **Affordable and sustainable energy in America: A competitive advantage for the future?**
- **Increasing energy demand in China: How to achieve a sustainable future?**
- **Energy growth in the Gulf: Can we get more with less?**
- **Republic of Korea: Wrap-up for the Road to Daegu and future outlook**

This was also the basic idea behind the second channel: »The Energy Blog.« Two bloggers traveled from continent to continent, asking questions and searching for answers. They provided detailed insights of projects around the world on how one is coping with local challenges.

This publication is the third channel. It opens with a description of the situation of energy systems on all continents and provides detailed information and facts. The main section presents six archetype energy markets. In each of these chapters, a description of the energy market is followed by a presentation of various scenarios showing the optimization potential that would be available through technical changes in the energy supplies. »Connecting possibilities« means that one must think in broader dimensions in order to see what possibilities are available and how they can be connected to reconcile sustainability and economic benefits. A calculation at the end of each chapter then shows what positive effects realization of the scenarios would have on the economies of the respective country and region.

As a leading provider of innovative technologies, Siemens' efforts aim at initiating a dialog on further sustainable developments of the worldwide energy system. The scenarios shown in this publication should stimulate many interesting discussions.

Challeng

Reliable power supply

Resource efficiency

Economic efficiency

Climate protection

es

Introduction

1 Energy markets throughout the world face vast opportunities as well as distinct and enormous challenges. Growing energy demand in emerging and industrialized countries as well as high energy prices and CO_2 emissions require a rethinking of energy supplies. In line with the rising need for energy, demand for power is being fueled by growing economies and the accelerating trend toward electrification.[1] Energy's function as an enabler of the economy, in particular, is underscoring the importance of optimization measures for further economical and social development. Access to affordable energy promotes growth in all sectors of the economy such as industry, services and transport, and is thus a key prerequisite for ensuring competitiveness.[2] The discovery of vast conventional fuels, such as shale gas, has eased the fear of a near-term exhaustion of fossil resources. At the same time, the exploitation of primary energy resources is becoming more expensive. Sustainability targets could be satisfied by speeding the development of low-carbon power generation technologies such as gas-fired combined cycle power plants, improvements in efficiency and the further development of renewable energies such as wind and solar. Although the energy and technology mix varies from region to region, technologies for efficient, low-carbon power generation are already available for providing sustainable, reliable and affordable energy supplies.

Energy markets throughout the world present a variety of optimization potentials that will be analyzed in the following regional studies. Countries with similar challenges have been clustered into five archetypes. The regional- and country-specific deep-dives have been chosen to cover the challenges of the individual archetypes.

The idea behind this study is that each energy market could boost economic growth by developing an affordable, sustainable and secure energy supply.

Current energy supplies and global challenges

The global economy is growing and resilient against short-term local crises. Asia's GDP is robust, driven by rising consumption of primary energy. However, the limited availability of resources is forcing their more efficient use. As a result, the consumption of finite energy sources such as oil and gas is growing at a slower rate than GDP.

Key factors for each country's economic development are price and availability of energy. In the recent past, the prices for oil, gas and coal have increased rapidly. Nevertheless, a stabilization of the primary energy prices is expected due to the improving balance between energy supplies and demand. This stabilization will be supported by the economical exploitation of unconventional primary energy resources over the medium term.

The worldwide consumption of primary energy totaled around 12,730 Mtoe in 2010. This amount is steadily growing due to expanding economies and emerging countries, accelerating urbanization and the increasing demand for mobility and other energy-related services.[3] While the OECD countries consumed more than 40% of the worldwide energy supplies, demand in emerging countries is growing rapidly.[4] On a global scale, energy consumption is expected to increase at 1.3% a year from 2010 to 2030. In the face of this growing demand,[5] improving energy efficiency will be a major challenge for countries worldwide. Energy efficiency measures not only conserve primary energy but benefit the environment as well. Sustainability could be further improved with the help of renewable and low-carbon energy sources. Although approximately 13% of the world's energy demand is already being met with renewable sources and roughly 6% with nuclear, fossil primary energy carriers are expected to remain the dominant energy source at least until 2030.

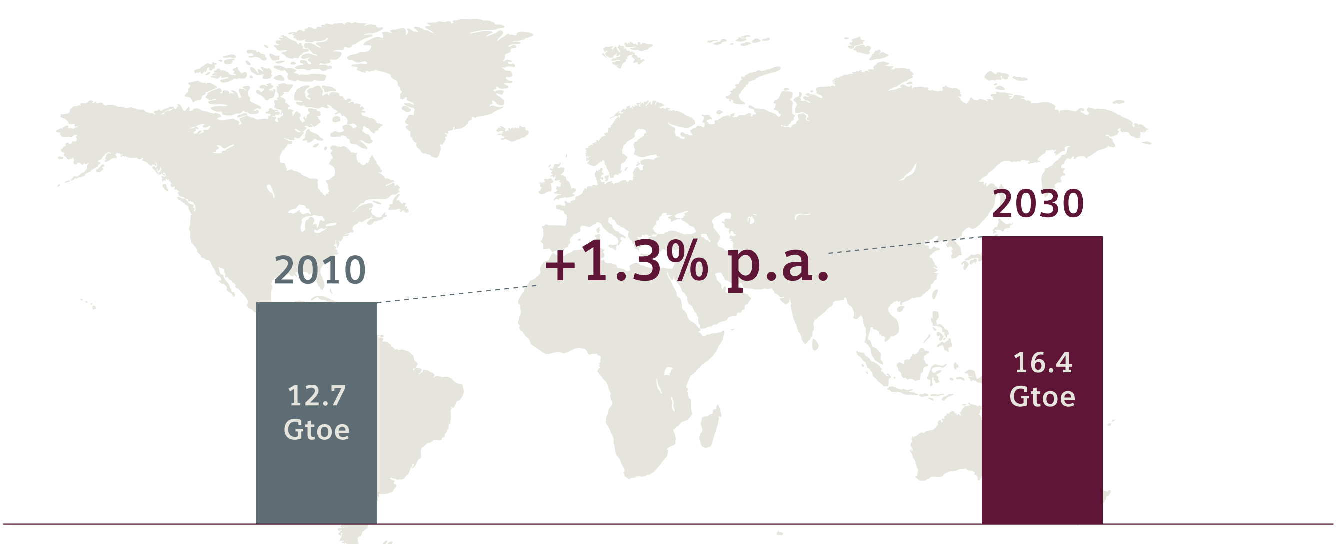
Climate policies are steadily gaining awareness and importance. Global energy-related CO_2 emissions increased in 2011 by more than 3%. This led to a new record level of more than 32 Gt CO_2 emissions, and this volume is expected to grow to 36 Gt CO_2 emissions by 2030.[6] Even the countries with the highest CO_2 emissions worldwide are now beginning to pay attention to the issue of climate protection.[7] To meet the international goal of limiting the rise in global temperatures, CO_2 emissions have to be reduced. As a result, low-carbon technologies must be implemented in all sectors of the world's economies. In addition, public awareness of harmful emissions is growing in more and more countries due to the increasingly visible consequences for the climate.

To meet these challenges, a total worldwide investment of approximately USD 37 trillion will be needed for developing energy infrastructure over the next two decades; this would account for approximately half of the current global GDP. These investments would expand supply capacity as well as replace aging energy infrastructure. On this basis, an average of more than USD 1.5 trillion would have to be invested year for year. The power generation sector will require nearly half of this total, while investment in gas supplies will add up to over USD 8.5 trillion, in oil to more than USD 10 trillion, and in coal to over USD 1 trillion by 2035.[8]

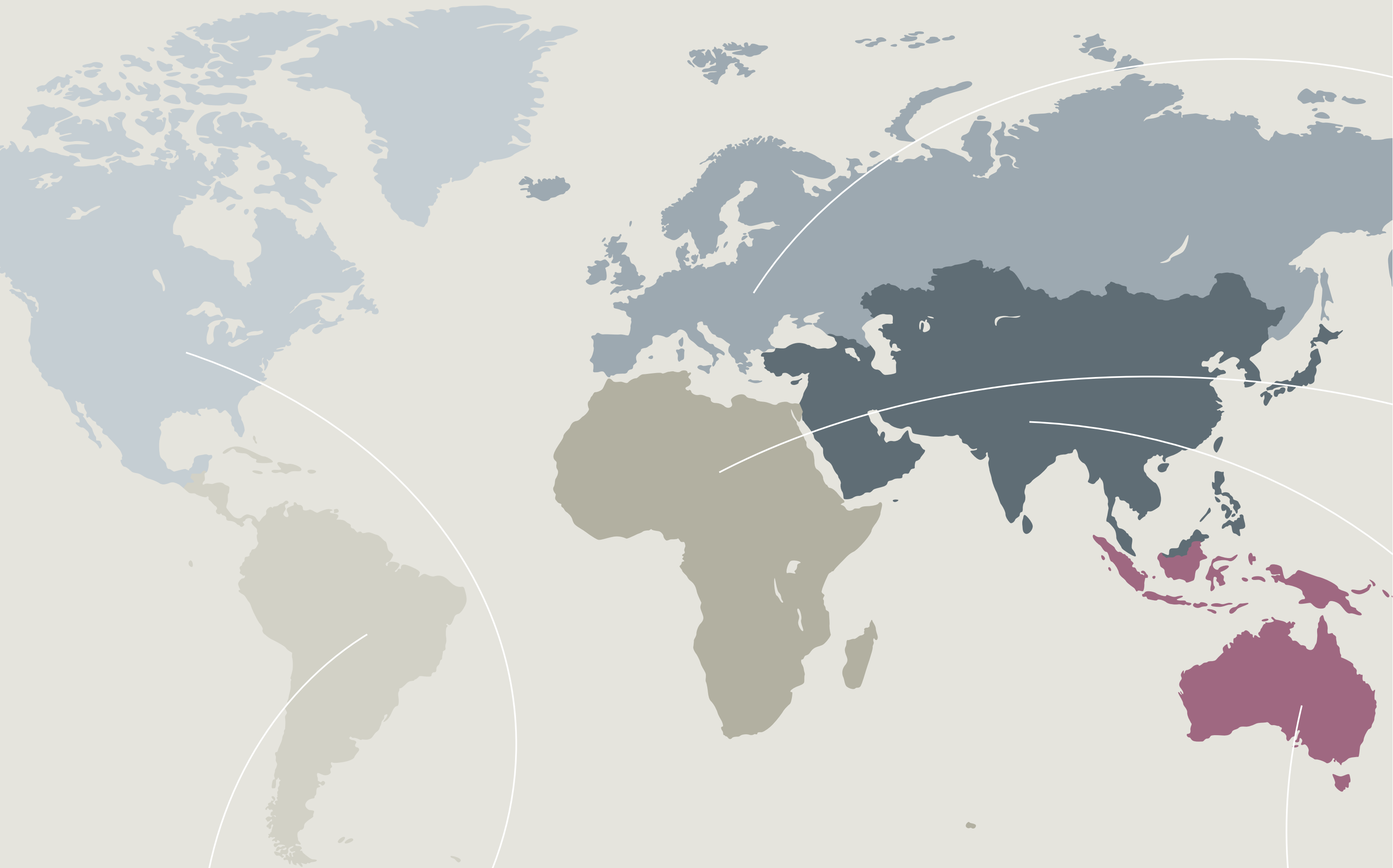
Emerging economies in particular face the challenge of providing sufficient energy supplies in rural areas. On average, nearly 20% of the world population did not have access to power in 2010.[9] This high percentage impressively indicates the huge potential that could be tapped by developing rural regions socially as well as economically. In fact, energy is a major prerequisite for reducing poverty[10] since it is a key prerequisite for a modern economy, industry and society. Approximately USD 1 trillion would have to be invested by 2030 to provide universal access to energy.[11] Renewable energies are considered to be a highly viable option for accelerating access to energy even in rural areas, and also have a positive impact on the climate.[12]

In short: The greatest global energy challenge ahead is to provide affordable, sustainable and reliable energy supplies for urban as well as rural areas. Yet each country faces its own specific challenges in this regard due to their specific infrastructure, economic maturity and available energy sources. The availability of primary energy resources as well as population growth determines the basic situation in each energy market. In the following section, the status quo is presented on a continent-specific basis to provide an overview of selected indicators.

Global energy consumption



Increase of global energy consumption from 2010 to 2030[3,4]



North America

In 2012, the population of North America exceeded 465 million and further growth to around 540 million is expected by 2030.[13] The proven energy resources of the North American continent are vast and total more than 220 billion barrels of oil, 10 trillion cubic meters of natural gas and approximately 250 billion tonnes of coal, which equals 211,300 Mtoe in total.[14] The energy demand of these countries, especially the United States, is enormous. The U.S. alone consumed more than 2,210 Mtoe in 2010, which accounted for nearly one-fifth of the world's annual primary energy demand.[15]

South America

South America had a population of approximately 400 million in 2012. This number is expected to increase to about 450 million by 2030.[16] While South America's conventional energy sources are enormous, some South American countries like Argentina and Venezuela are unable to provide sufficient energy security due to inadequate infrastructures and government regulations.[17] South America overall has proven conventional energy resources of approximately 8 trillion cubic meters of natural gas, roughly 330 billion barrels of oil and nearly 13 billion tonnes of coal, which equals 62,500 Mtoe.[18] The continent's annual energy consumption totals 590 Mtoe.[19]

Europe/Russia

Europe (including Russia) is the economic region with the world's second-highest GDP. Europe has a population of approximately 740 million, which is expected to stagnate in future. Europe is thus the only continent with a forecast population decline. By including Russia, with its enormous primary energy resources, the European continent's proven reserves total approximately 60 trillion cubic meters of natural gas, more than 140 billion barrels of oil and 305 billion tonnes of coal, which equals 287,100 Mtoe.[20] Most of the energy resources are located in Russia. The energy demand of the European continent totaled more than 2,400 Mtoe in 2010.[21]

Africa

More than one billion people currently live in Africa and this number is expected to grow rapidly to approximately 1.6 billion by 2030.[22] Yet the per-capita power consumption of only 620 kWh in 2010 was very low compared to other regions. One reason for this is insufficient power supplies on the continent, although Africa's proven primary energy reserves total roughly 15 trillion cubic meters of natural gas, approximately 130 billion barrels of oil and more than 30 billion tonnes of coal, which corresponds to a total of 52,700 Mtoe.[23] The continent's energy demand reached only 690 Mtoe in 2010.[24]

Asia/Middle East

Asia (including the Middle East), the world's biggest continent, is home to more than half of the world's population. The population reached nearly 4.3 billion in 2010 and is expected to grow by approximately 600 million to 4.9 billion by 2030.[25] The continent is characterized by major differences in population density, ranging from megacities to vast uninhabited regions. Natural gas reserves total over 90 trillion cubic meters, crude oil nearly 850 billion barrels and coal more than 190 billion tonnes, which equals a total of 333,000 Mtoe.[26] China, the dominant country in Asia, consumed approximately 2,400 Mtoe in 2010, which corresponds to nearly 20% of the world's annual energy demand, and its consumption is expected to continue growing rapidly.[27]

Oceania

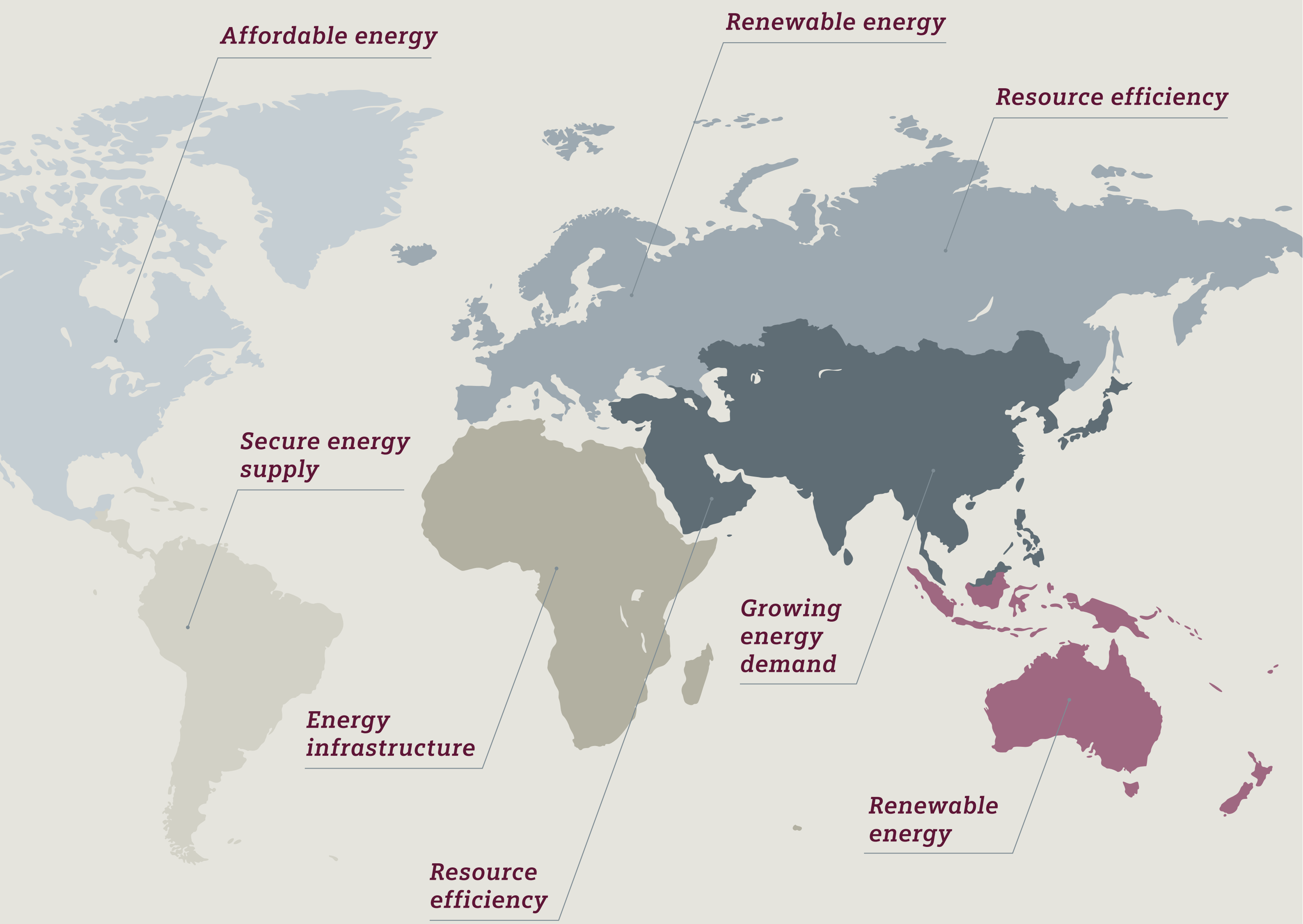
Oceania, the smallest of all continents, comprises Australia and New Zealand as well as the island nations in the South Pacific. The region's population totals only 37 million people and is expected to increase to 47 million by 2030.[28] Oceania's proven reserves are low compared to the other continents. Gas reserves amount to only about four trillion cubic meters, oil reserves to four billion barrels and coal reserves to 77 billion tonnes, which corresponds to 58,060 Mtoe.[29] Australia, the biggest country on the continent, has an energy demand of more than 130 Mtoe[30] and is an important exporter of coal.

	North America	South America	Europe/ Russia	Africa	Asia/ Middle East	Oceania
GDP (USD)	18,690 bn	3,670 bn	20,120 bn	1,970 bn	24,540 bn	1,740 bn
Population (million)	465	400	740	1,070	4,260	37
Proven reserves (Mtoe)	211,300	62,500	287,100	52,700	333,000	58,060
Energy demand (Mtoe/a)	2,730	665	2,930	400	5,610	145

Key indicator per continent[31]

A precise assessment of energy market potentials in different regions is hardly possible on a continental basis. Since the characteristics of energy markets are highly diverse, even countries on the same continent can face different challenges. It is therefore more accurate to analyze energy markets by type than by continent. Five market archetypes have been identified by selected characteristics. These archetypes are used to identify key topics that will be examined in the regional studies.

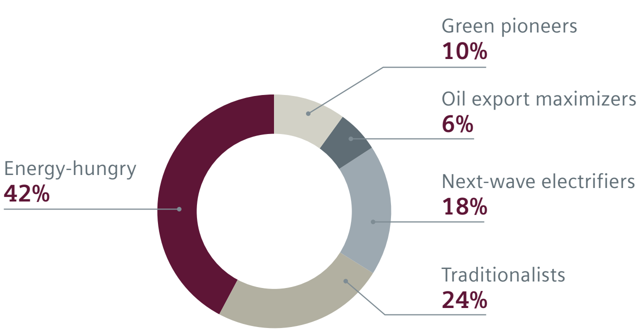
Challenges


Affordable energy
Renewable energy
Resource efficiency
Secure energy supply
Energy infrastructure
Growing energy demand
Resource efficiency
Renewable energy

The archetype classification

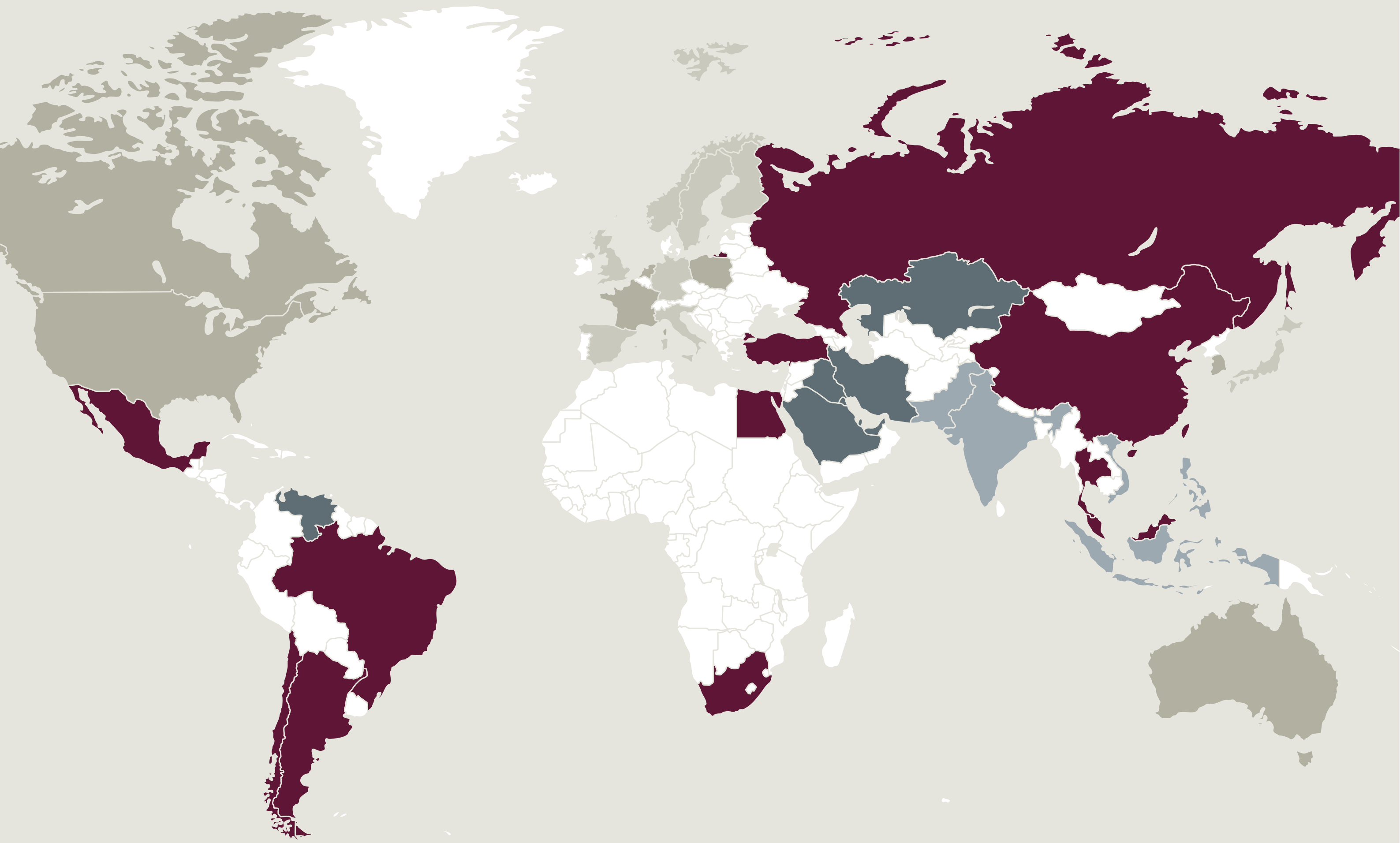
The archetype classification system assesses various criteria to characterize countries. The classification is primarily based on energy-related macroeconomic criteria, such as the share of oil exports in GDP, the annual growth rate of power generation, the share of renewable energies, and residential energy consumption. This assessment has resulted in five archetypes – the »Next-wave electrifier,« the »Energy-hungry,« the »Traditionalist,« the »Green pioneer« and the »Oil export maximizer.« Countries with major oil reserves are separated from the other regions by the share of oil exports in their GDP, to create a selective assessment.

Each of the archetypes faces its specific challenges. Each country has been assigned to the most appropriate archetype The characteristics of the archetypes are essential for identifying individual potential and solutions. These characteristics and challenges are described in detail below.



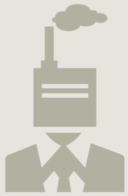
Energy-hungry countries have the biggest influence on the future energy landscape

Global power generation in 2030



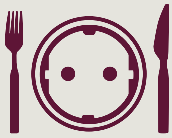
Green pioneers

- Germany
- Spain
- Great Britain
- Norway
- Sweden
- Italy
- Japan



Traditionalists

- Australia
- Canada
- France
- Republic of Korea
- Taiwan
- USA
- The Netherlands
- Poland

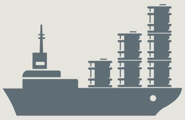


Energy-hungry

- Argentina
- Brazil
- Chile
- Turkey
- Malaysia
- Russia
- Thailand
- Ukraine
- China
- Egypt
- Mexico
- Republic of South Africa

Next-wave electrifiers

- Indonesia
- India
- Pakistan
- Vietnam
- Philippines



Oil export maximizers

- United Arab Emirates
- Iran
- Iraq
- Kazakhstan
- Saudi Arabia
- Venezuela
- Qatar
- Kuwait

The listed countries represent >90% of world power generation in 2030

Specific characteristics of the five archetypes

Green pioneers

Green-pioneer countries are reshaping their existing power market by accelerating the integration of renewable energy sources. Consequently, the share of renewables in power generation is comparably high. The energy policies of the Green-pioneer countries are strongly driven by »green« or »clean« concepts. The main focus therefore is on the reduction of carbon emissions.

Although Green-pioneer countries accept to some degree higher energy and power costs as the price for achieving sustainability, they nevertheless need to concentrate on remaining competitive. As a result, the integration of renewable energy sources in the generation mix is a key challenge. The intermittency of these sources presents technical difficulties such as a high degree and variance of grid capacity utilization, generation fluctuations and economic obstacles. Over the long term, however, Green-pioneer countries could benefit from an independent renewable energy supply that is not sensitive to fluctuations in primary energy prices. As a result, the environmental and economic potentials of Green-pioneer countries are vast and promising. Green-pioneer countries are primarily found in Europe, and include Germany, Spain and the United Kingdom. The European regional study will accordingly focus on renewable energy and efficiency in power generation.

Traditionalists

The predominant nature of all Traditionalist countries is their economic orientation. These countries are primarily cost-driven and therefore have to provide affordable energy and secure their energy supply. Traditionalist countries focus on a central energy infrastructure featuring large-scale and efficient power generation.

Nevertheless, Traditionalist countries should diversify their energy mix over the long term with renewable energy sources. Renewable sources combined with highly efficient gas-fired power plants, as well as other low-carbon technologies such as nuclear or carbon capture and storage could significantly reduce CO_2 emissions. Furthermore, investments in sustainable technology function as a multiplier and could enhance the economy overall as well as enable future developments. The key challenges here are modernizing the existing infrastructure to ensure efficiency on the consumption and generation sides, and the economical construction of new power plants. Exemplary countries in this category are the United States of America and the Republic of Korea. The regional studies of these countries consequently focus on the affordability and diversity of the energy mix.

Energy-hungry

Energy-hungry countries are on their way to satisfying the huge energy demands of their economies. These countries have already built an infrastructure to reach most stakeholders of their economy in contrast to Next-wave-electrifier countries. Nevertheless, due to their rapidly growing economy, the supply of a sufficient amount of energy is challenging. Energy-hungry countries need an affordable and available energy supply to ensure further economic growth.

The countries classified in this archetype are primarily rapidly emerging countries like China, which focus on the rapid expansion of energy supplies at competitive cost levels. Economies, especially those with high growth rates, are highly sensitive to the security of their energy supplies. In power generation, highly efficient, large-scale and centralized power plants can provide the necessary power. Consequently, the regional studies of China and Russia focus on the country's rapid growth in energy demand, the increase in efficiency, and the diversification of the energy mix with gas and renewable energies.

Next-wave electrifiers

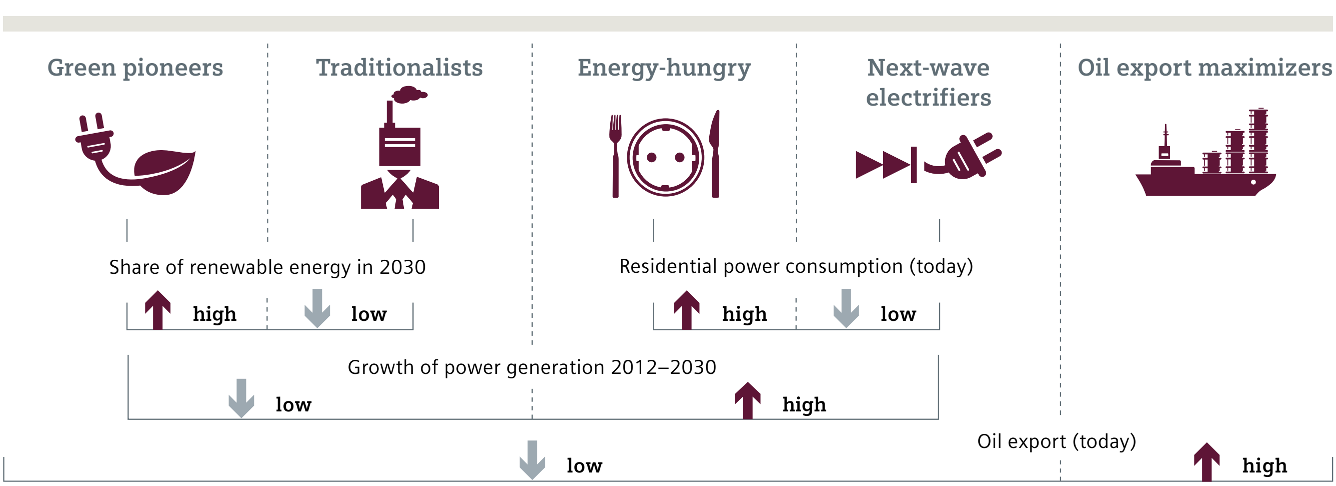
To develop their economies, Next-wave-electrifier countries have to provide an infrastructure that reaches all stakeholders in the economy in order to ensure further economic growth and prosperity. Due to lacking or inadequate energy infrastructure, the average residential power consumption is low. The main concern of this archetype is therefore to improve access to power. These countries, like India, are characterized both by large rural areas with low population densities and poor energy infrastructure standards, and by urban centers and megacities with enormous populations.

High growth in power generation and low per-capita energy consumption combined with underdeveloped energy infrastructure is prompting Next-wave-electrifier countries to focus on providing adequate energy supplies in urban and rural areas. In contrast to Energy-hungry countries, which already have a sufficient energy infrastructure, nationwide energy efficiency is not a priority for Next-wave electrifiers. These countries must first create a sufficient infrastructure before optimizing efficiency becomes an issue. Since optimization scenarios are a subordinate topic in this archetype, no deep-dive of a Next-wave electrifier country is foreseen in this study.

Oil export maximizers

Optimizing the profits from primary energy exports is a key focus of countries belonging to the Oil export maximizer archetype. Since they have vast primary energy reserves, their export is the biggest economic priority. Oil export maximizer countries are thus characterized by a high share of oil or gas exports in GDP. Saudi Arabia and Kuwait are two good examples of the Oil export maximizer archetype.

Oil export maximizer countries rely on their vast energy resources. Due to the extraordinary extent of their reserves, the sustainable use of energy resources has rarely been the focus of Oil export maximizer countries. Efficient energy use with best-in-class equipment should be the focus of a future-oriented strategy. Due to these characteristics and challenges, the regional study of Saudi Arabia will focus on limiting oil and gas consumption for power generation by implementing efficiency improvements to gain sustainability and to increase revenues from primary energy exports. An additional focus for oil export maximizers is the diversification of their power generation fuel mix towards non-fossil energy resources such as nuclear and renewables.



Résumé

Energy markets throughout the world offer numerous opportunities that could be used to improve national economies. All regions are being affected to some degree by global trends such as demographic change, accelerating urbanization, growing energy demand and rising carbon emissions.

Demographic developments are leading to a steady growth in energy demand.[32] Emerging countries in particular are experiencing accelerated population growth and face the challenge of satisfying soaring energy demand. Even the most advanced countries are seeing a growing demand for energy. In this situation, ensuring greater efficiency in power generation and consumption are vital measures for responding to this global trend and would promote economic growth.

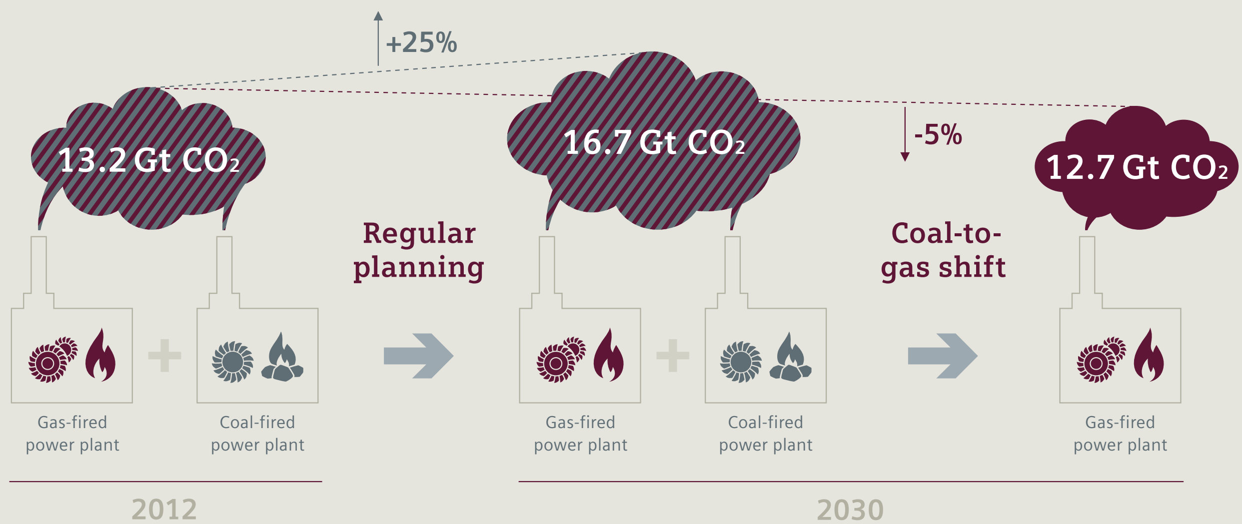
However, population growth is not evenly distributed worldwide. Existing centers of demand account for a major part of each region's energy consumption. It is therefore essential to provide all-encompassing energy supplies that simultaneously satisfy heavy and rising demand in population centers. The energy networks act partly as critical bottlenecks for these energy supplies. Power grids are essential in emerging countries for handling the expected increase in energy consumption, while industrialized countries are focusing on integrating renewable energies in their partly aging grid systems and on improving general grid reliability.[33]

Sustainability is increasingly the focus of both industrialized and emerging countries. In view of the high volume of CO_2 emissions worldwide, governments are setting more ambitious reduction targets. A combination of efficient state-of-the-art fossil power plants – particularly gas-fired combined cycle plants because of their low specific emissions – and renewable sources offer the most promising prospects for success in terms of sustainability, affordability and availability.

Great potential for improving efficiency and reducing environmental impact lies in a coal-to-gas shift. Currently, the most efficient fossil power generation is achieved with gas-fired combined cycle power plants. Therefore, a coal-to-gas shift is the most sensible path in terms of efficiency. If one assumes a worldwide power generation shift from coal-fired steam power plants to gas-fired combined cycle power plants by 2030 (with the exception of China and India, where a 30% shift is assumed, due to extensive regional coal resources, limited gas resources, and missing infrastructure such as pipelines), this shift would result in annual CO_2 savings of more than 4,000 Mt from 2030 onwards, which equals a 25% reduction in the power sector compared to the regular planning case. Technically recoverable conventional and unconventional global gas resources could cover the gas demand of a global coal-to-gas scenario for more than 250 years.

The calculated scenarios in this study show that investments in more efficient power generation and a heavier weighting of non-fossil energy sources like wind and solar in the energy mix would pay off in all energy markets. In short: The study concludes that economic behavior in terms of energy leads to environmental and social benefits.

Conclusion:
Economic behavior in terms of energy leads to environmental and social benefits.



A global coal-to-gas shift would lead to a reduction of CO_2 emission by 5% instead of the significant increase of more than 25% in the regular planning

Investments in …

… energy-efficient demand side technologies …

… efficient power-generation technologies …

… infrastructure modernization …

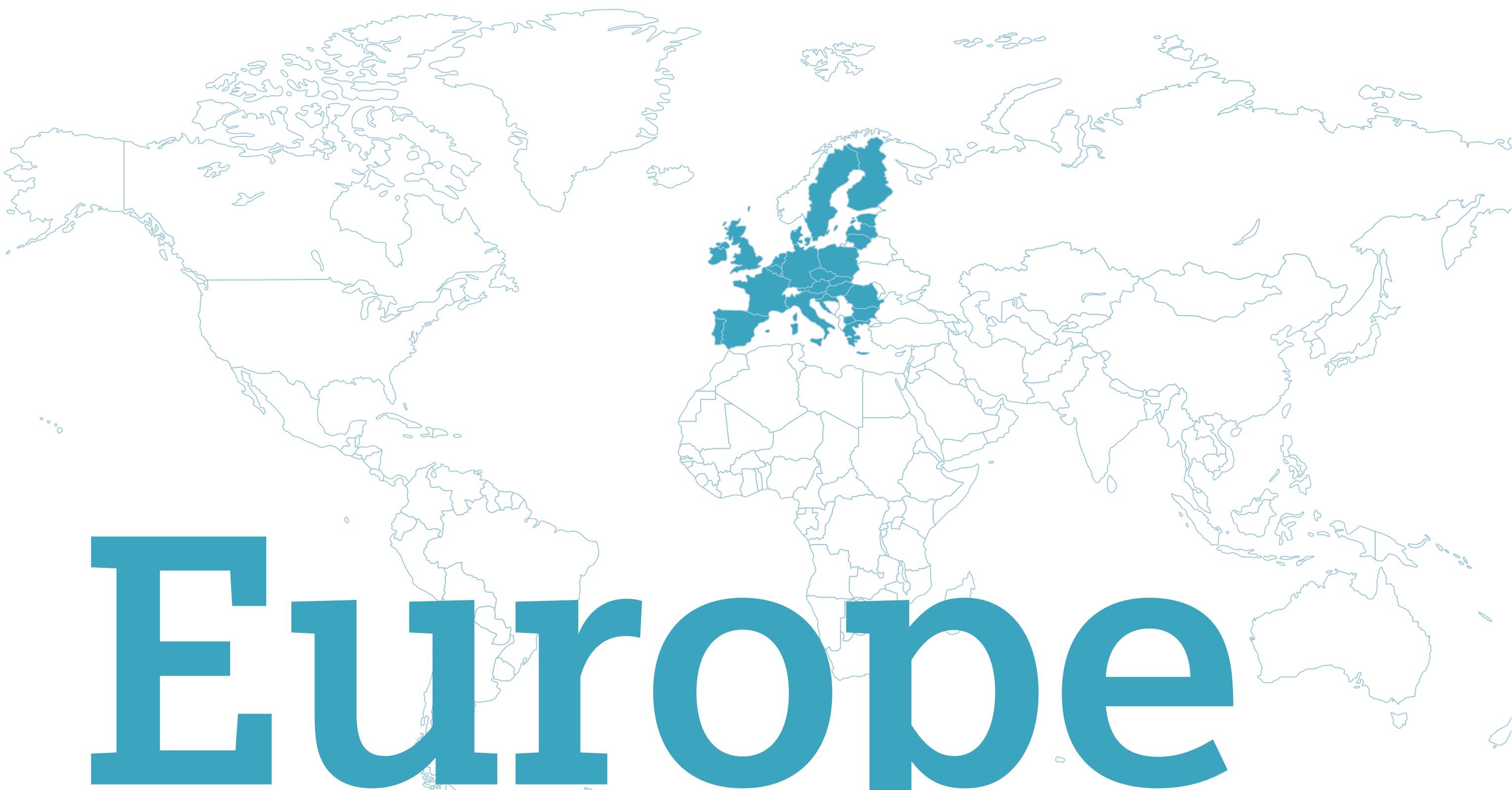
… security of energy supply …

… fuel diversification …

… combine economical and environmental advantages.

Footnotes

[1] Cf. IEA (2012 b), p. 23ff.
[2] Cf. Al-mulali, Binti Che Sab, Che Normee (2012), p. 4365.
[3] Cf. WEC (2013), p. 2.
[4] Cf. IEA (2012b), p. 552ff.
[5] Cf. IEA (2008), p. 10f.
[6] Cf. IEA (2012b), p. 241.
[7] Cf. DPA (2013).
[8] Cf. IEA (2012b).
[9] Cf. IEA (2012 b), p. 535.
[10] Cf. IEA (2012b), p. 321.
[11] Cf. IEA (2012b), p. 538.
[12] Cf. United Nations (2011).
[13] Cf. DSW (2012), p. 8ff.
[14] Cf. BP (2013).
[15] Cf. IEA (2012b), p. 552ff.
[16] Cf. DSW (2012), p. 8.
[17] Cf. IISD (2010), p. 1.
[18] Cf. BP (2013).
[19] Cf. IEA (2012b), p. 612.
[20] Cf. DSW (2012), p. 8.
[21] Cf. BP (2013).
[22] Cf. DSW (2012), p. 6.
[23] Cf. BP (2013).
[24] Cf. IEA (2012b), p. 608.
[25] Cf. DSW (2012), p. 12.
[26] Cf. BP (2013).
[27] Cf. IEA (2012b), p. 600.
[28] Cf. DSW (2012), p. 14.
[29] Cf. BP (2013).
[30] Cf. BREE (2012), p. 1.
[31] Cf. World Bank (2013a); DSW (2012); BP (2013).
[32] Cf. IEA (2012b).
[33] Cf. Yáñez et al. (2013), p. 1.



Europe

2 The European Union is one of the largest single economic areas in the world, which can be seen in the high share of imports of primary energy resources compared to local production.[1] Four of the 28 member states rank in the top ten largest national economies in the world by GDP. Yet the European Union is the economic region with the least primary energy resources in the world. Greater energy independence and better sustainability could be achieved by developing a higher share of renewable energy sources. Various incentives have been offered by European governments to promote more wind and solar power generation, and have resulted in a partly uncoordinated market growth. Since these incentives often fail to consider Europe's geographical diversity, they at times lead to inefficiency and unexploited potential, such as renewable power plants in suboptimal locations. The situation is further complicated by the complex structure of national regulations and the lack of an integrated European energy policy and market. In order to function as a single integrated energy market, the region's political, organizational and technical barriers must be overcome. The following regional study describes the current situation and challenges in the European energy market and shows potentials for improvements.

Energy Value Stream Europe

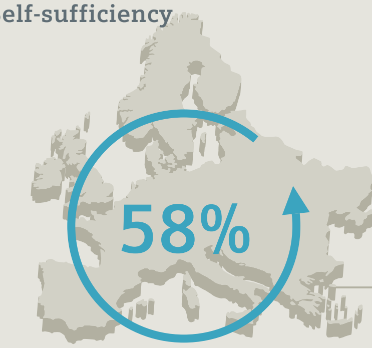
(2010) [2]

The EU faces complex challenges on the way towards an affordable, reliable and sustainable energy market. In order to understand the status quo and specific challenges of the OECD countries in the European Union energy market, the Energy Value Stream (EVS) is used in this study. To ensure the comparability of the Energy Value Streams in all subsequent chapters of the study, only OECD countries in the EU were included here.

Calculations based on: IEA – WEO 2012; IEA – Energy Balances 2012; The World Bank – World Data Bank; ABS Research – T&D Report; Global Insight; Siemens calculations

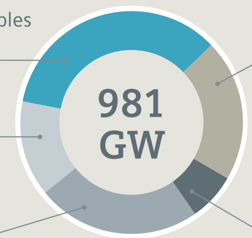
Primary energy

Self-sufficiency

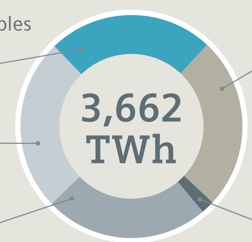


Power

Installed capacity



Power generation



Economy & sustainability

Economic indicator

GDP (USD current)

USD 17,869 bn

Indigenous production	Imports	Exports	Energy supply (TPES)
1,048 Mtoe	1,479 Mtoe	640 Mtoe	1,816 Mtoe

Transmission & distribution

T & D losses
6.5%

Grid length
11.1 million km

Grid density
2.2 km/km²

Reliability
SAIDI
65 min
p.a.

Consumption

Final consumption
3,107 TWh

Intensity
174 kWh per 1,000 USD GDP

Per capita consumption
5,631 kWh per capita

Sustainability

CO_2 emissions
3,873 Mt total
1,373 Mt share of power sector

CO_2 intensity of power sector
440 g per kWh

Three perspectives

The economy and sustainability perspective

The OECD countries in the European Union generated about USD 17,900 billion of gross domestic product in 2010. That year, a total of roughly 3,880 Mt of CO_2 gases were emitted. Power generation accounted for over one-third of these CO_2 emissions. The CO_2 emission intensity per consumed kWh of 440 g in the power generation sector in 2010 reflects the initial achievements of European efforts to foster sustainability in the power supply, when compared to the nearly 600 g per kWh recorded in 1990.[3]

The primary energy perspective

A massive dependency on imports can be observed when regarding the primary energy perspective of the European Energy Value Stream (EVS). Europe currently covers 60% of its energy consumption from domestic energy resources. The political wish to reduce dependency on imports and shift toward less CO_2-intensive energy sources can be observed in the power generation sector.[4]

The power perspective

The EU had around 980 GW of installed power generation capacity in 2010. Of that total, roughly 16% came from intermittent renewable energy sources and 16% from hydro power plants. The second largest share came from gas-fired power plants providing intermediate loads and serving as flexible backup capacity.

A total of approximately 3,660 TWh was produced in 2010 by these capacities, or three times the total produced in Russia that year. Yet even though the share of renewables in Europe is rising, power generation is still dominated by conventional power plants with coal and gas comprising together approximately half of the power generation.[5] Renewable power sources have steadily grown in recent years, and accounted for a share of 24% (10% without hydro power generation) in 2010. The overall growth rate for power generation in Europe is low. The exceptional 4% growth between 2009 and 2010 was precipitated by the recovery from the economic crisis, and is assumed to flatten toward the usual and steady annual rate of nearly 1%.[6]

Regarding power transmission, the EU has one of the most reliable and efficient transmission grids in the world. Losses while transferring and distributing power were approximately 6% in 2010, marking a decline from nearly 8% in 2000.[7] Nevertheless, compared to the especially efficient grid system in Germany, with losses of roughly 4%, there is still considerable overall potential to be realized in Europe. A high-efficiency grid system could also more effectively integrate intermittent power generation plants.[8]

Europe's net consumption was roughly 3,110 TWh in 2010. This equaled an annual power consumption rate, i.e. approximately 5,630 kWh per capita, which is an average value in international comparison.

The targets of the European governments are ambitious

The European governments have set ambitious targets for increasing the share of renewables and reducing CO_2 emissions.[9] The three main objectives defined by the EU's »20-20-20« targets are to provide clean, cheap and secure energy. By the year 2020, CO_2 emissions are to be reduced by 20% of the 1990 level, energy demand is to be cut by 20%, and renewables are to cover 20% of the total consumption.[10]

The primary energy demand growth rate of less than 1% for power generation combined with the 1.6% growth in power production between 1990 and 2010 shows initial progress toward reaching the »20-20-20« targets.[11] The fact that power consumption grew faster than the use of fossil primary energy sources indicates that the share of renewables in the generation mix is increasing along with the efficiency in generation, two key points in the EU's targets for 2020.

However, reducing the share of primary energy in the energy mix alone would not solve the overall European energy challenges. Important potential for improving energy efficiency and reducing CO_2 emissions is not being fully exploited. Ironically, the low prices for CO_2 emission certificates that were issued as part of the EU Emissions Trading System (ETS) have strengthened the economic position of coal-fired power plants. Nevertheless, a shift from coal to gas-fired power plants could reduce the relative CO_2 emissions by more than 50% including efficiency benefits.[12] But in the face of current emission allowance prices of USD 5 per ton of CO_2, incentives to invest in more efficient gas-fired plants are virtually ineffective.

Current challenges

The European Union is facing serious challenges to its goal of achieving the »20-20-20« targets while simultaneously remaining competitive in the global market. The right incentives need to be offered to stimulate investments in low-carbon fossil power generation. In fact, a shift towards more efficient power plants could be incentivized with the help of a stabilized CO_2 emission allowance price. Over the long run, this could reduce emissions dramatically.[13]

To provide a sustainable as well as affordable power supply, the market structure must be redesigned. Basic aspects, such as feed-in-tariff systems for renewables, need to be analyzed and restructured to prevent further record price increases and help secure Europe's industrial competitiveness.[14]
In addition, there is a need to improve the grid infrastructure due to the growing share of renewable power generation.

Primary goal: Reduce greenhouse gas emissions

One of the key challenges for the EU in regard to the »20-20-20« target is to build up the share of renewable energies. So far, this development is largely based on national plans. This is why wind and solar power plant, above all, are not being built at locations offering optimal resource condition. Yet this would be the most economical course to take, since the output of a wind power plant, for example, grows by the cube of the wind speed.[15] For photovoltaic plants, the rule is the more sun, the greater amount of produced electricity. National regulations – in particular in those countries with little sun or wind – currently offer ambivalent incentives that lead to building renewable power plants in suboptimal locations. There would therefore be major cost-reduction potential in an EU-wide regulation that would positively influence the competitiveness of the EU.

Scenarios for optimization

The upcoming analysis describes scenarios that would lead to significant saving potential in the future. The first scenario suggests a location-optimization of all additional renewable power plants across the EU up to 2030 in order to increase the load factor of the new installations. The second scenario assumes a complete consecutive coal-to-gas shift by 2030, which would increase the sustainability and stabilize the availability of power.

Scenario 1:

Optimized locations of renewables across the EU

As mentioned, national expansion targets are currently resulting in the disregard of the European potential of renewable power plant locations. In order to calculate the possible potential that could be realized with one integrated EU energy market and location-optimized renewable power plants, the following scenario is introduced:

»Renewable energy generation plants will be built at optimal geographic locations in the EU.«

In the year 2030, approximately 480 GW of intermittent renewable energy capacity is estimated to be installed in the EU, including roughly 200 GW of installed solar photovoltaic and 280 GW of installed wind capacity.[16] A new capacity of 100 GW for onshore wind, 80 GW for offshore wind, and 140 GW for photovoltaic plants is thereby estimated to be installed by 2030.[17] In the following scenario, the location of new renewable energy capacity is assumed to be optimized throughout the EU rather than on a country-specific basis. All renewables would be installed in the most efficient geographic locations, considering external factors such as wind speed and solar radiation intensity. According to this strategy, it is assumed that the same amount of power output would be generated in 2030 as is currently estimated. Yet due to the higher load factors, this power could be generated with less installed capacity and consequently with lower asset investments.[18] The renewable energy technologies considered here are solar photovoltaic, onshore wind and offshore wind.

The most ambitious scenario foresees a full shift of all renewable energy additions from 2013 up to 2030. The optimal location for solar photovoltaic is analog to the irradiation intensity in Spain, Portugal, Italy and Greece. The wind sites would be located in the North Sea and Baltic Sea, due to optimal conditions regarding wind speeds.[19] One basic assumption of the scenario is that the power generated with renewables will primarily be transmitted to areas of high demand and would not be consumed where it originates. As a result, the European power grid would have to be extended to transport the additional power to the consumers. In this scenario, the grid upgrade would be with 800-kV DC transmission lines to ensure long-distance transport with the lowest possible losses.

Savings up to USD 60 billion could be realized

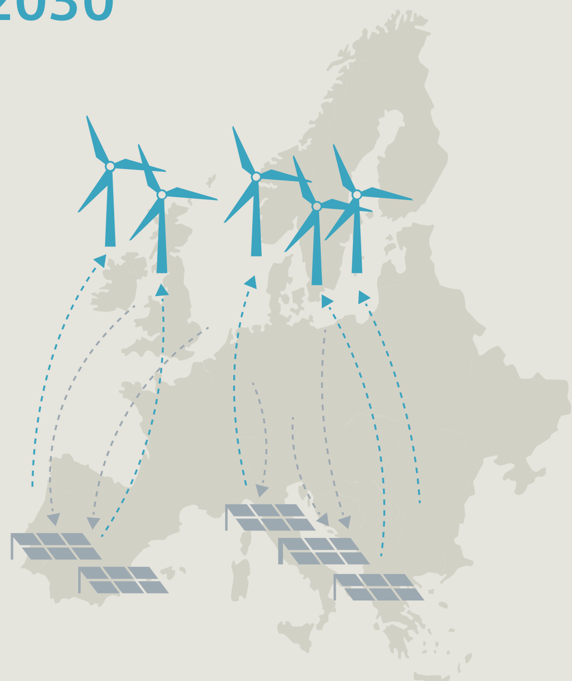
Taking the previously mentioned assumptions into account, a 100% shift of the additionally estimated renewable energy generation would lead to a 55 GW reduction in total capacity requirements. The shift of solar photovoltaic plants from the United Kingdom and Germany to Spain and Italy, and the shift of wind plants from Spain and Italy to the North and Baltic Seas would increase load factors dramatically compared to the current situation. Specifically, 39 GW of installed solar photovoltaic, 15 GW of onshore wind and one GW of offshore wind capacity could be saved. This would result in a total investment saving of approximately USD 80 billion due to the reduced total installed capacity. These savings would be reduced, however, by the investments needed for the transmission grid extension. The 800-kV DC transmission system would enable additional load-flows and would reduce the saving by approximately USD 20 billion by 2030. Consequently, a total net investment saving of approximately USD 60 billion could be realized. These savings could be used, for example, to reforest 100,000 km^2 of rain forest, which nearly equals the area of the Republic of Korea, host to the World Energy Congress.

An alternative scenario with a more conservative calculation, locating only 50% of the new solar photovoltaic and wind onshore capacity in optimal areas and placing offshore wind capacity fully in optimal locations, would also realize substantial unused potential. Even this conservative approach would result in a net benefit of nearly USD 40 billion from possibly saving 28 GW of installed capacity overall. In this scenario, it is assumed that the generated power will be consumed locally rather than transmitting it to distant consumption points. In this case, investments of approximately USD 3 billion would be required for expanding the grid, while savings in investments, due to reduced capacity requirements, would total USD 43 billion.

The saved investments realized by optimizing the location of additional renewable power plant capacity could lower the growth rate of power prices and improve the affordability of power. This aspect of the energy triangle could be improved. In order to maintain availability with a higher share of intermittent renewables, a flexible backup capacity of conventional power plants would be necessary. Since conventional gas-fired power plants have enormous advantages compared to coal-fired units in terms of flexibility and CO_2 emissions, a systematic coal-to-gas shift is considered beneficial.

Present
2012

Optimized
2030



The optimization of renewable power plant locations would lead to savings of up to USD 60 bn by 2030

Scenario 2:

Coal-to-gas shift

The primary energy carrier coal has the highest relative CO_2 emissions.[20] Compared to coal-fired power plants, gas-fired combined cycle plants are far more efficient in terms of specific CO_2 emissions. Depending on trends in coal and gas prices as well as the regulations of CO_2 emission certificates, a shift from coal to gas could be cost-neutral for investors. Moreover, regarding the dramatically lower initial investment for gas-fired plants, this solution could be favorable. An increase in the share of combined cycle power plants would influence all aspects of the energy triangle in a positive and comprehensive way. The possible effects will be calculated in the following scenario:

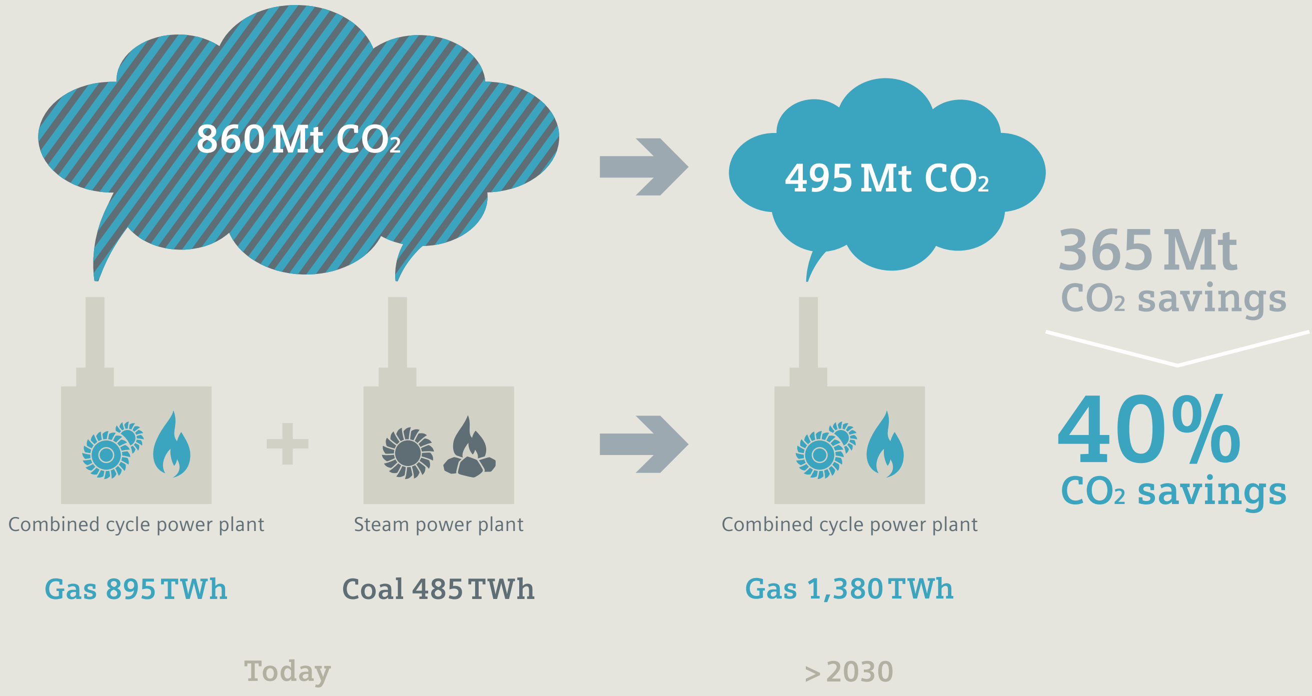
»All coal-fired power plants will consecutively be replaced by modern and flexible combined cycle gas-fired power plants by 2030.«

The scenario assumes that 100% of the coal for power generation will be substituted by gas by 2030. As a consequence, gas would be used to generate roughly 1,380 TWh in the EU, while the total power generation would remain constant at approximately 3,750 TWh, as planned.[21]

Nearly 365 million tonnes of CO_2 emissions could be saved

The suggested scenario would reduce CO_2 emissions by nearly 365 Mt in 2030. This amount is more than the total annual CO_2 emissions produced by Germany's power generation sector and would contribute 40% of the overall CO_2 emissions savings in the EU. The scenario would require about 100 GW of new combined cycle power plants. The investment needed here would total up to USD 90 billion. Nevertheless, a specific investment of USD 250 per ton of CO_2 emissions reduction by gas-fired power plants is more than six times lower than a comparable reduction achieved with solar photovoltaic technologies.[22]

A more conservative scenario, calculating with only a 50% shift of coal-to-gas would lead to a reduction of 165 Mt CO_2 emissions, or nearly 20% of the savings of power generation emissions in the European Union in 2030. The required investment would total approximately USD 40 billion.



The coal-to-gas shift would lead to 365 Mt CO_2 savings from 2030 onwards

Additional opportunity costs

The scenarios could have positive effects for most of the stakeholders, such as a lower growth rate of power prices and a reduction of harmful CO_2 emissions. Implementation of these scenarios should therefore be encouraged to avoid additional opportunity costs.

Energy-intensive industry could benefit from lower power prices

The first scenario, proposing the optimization of renewable power plant locations, reduces total investments for additional renewable power plant installations. This is the result of higher load factors, which reduces total installed capacity requirements. This scenario would therefore improve the overall affordability of power.

Energy-intensive industry depends on affordable power. These industries are highly sensitive to changes in the energy market, particularly power prices and additional regulatory interventions. Even though energy-intensive industry contributes only 1% of the European Union's GDP, it accounted for nearly USD 160 billion in 2010 and over 2.5 million jobs in the EU. High power prices could be a substantial disadvantage in view of the industry's strong international competition.[23] A certain percentage of the energy-intensive industry would therefore transfer their production to locations with better framework conditions.

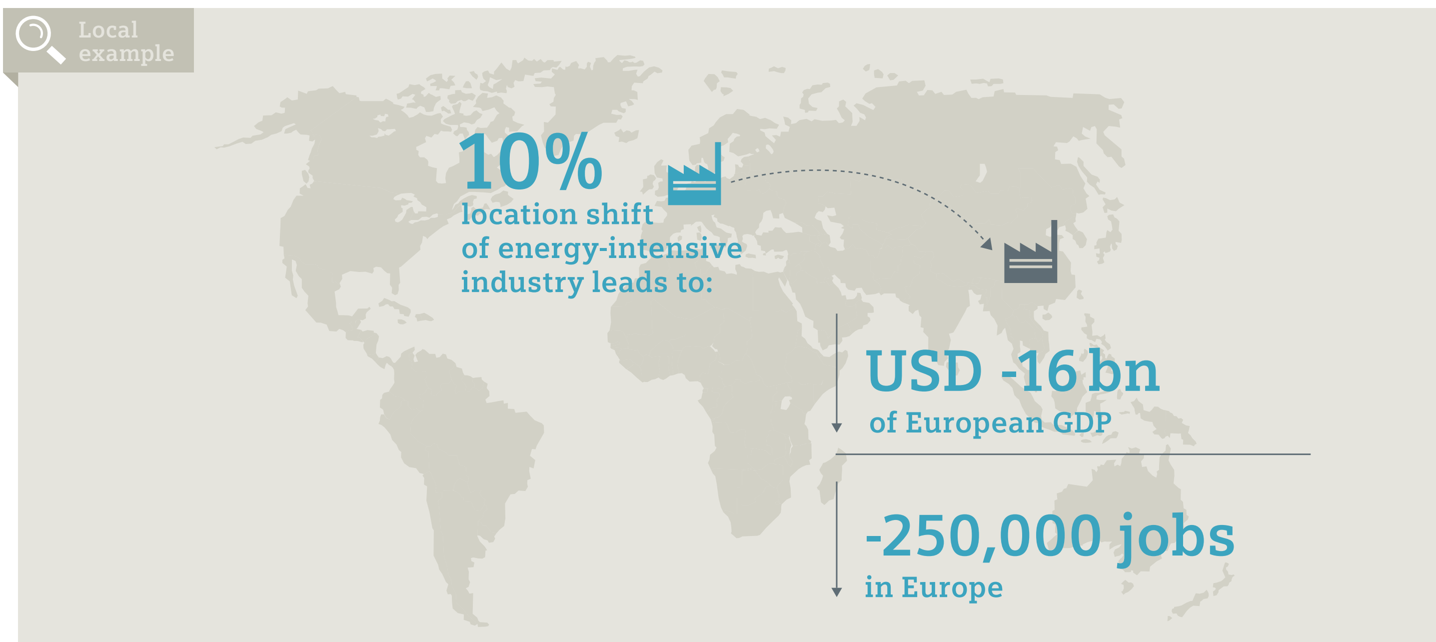
Due to their international setup, a location shift is a realistic option especially for global players.[24] The power costs for energy-intensive industry are typically between 5 and 6 US-ct per kWh in the United States, while the corresponding cost is between 9 and 11 US-ct per kWh in the EU. An industrial smelter in China with a capacity of 500,000 tonnes a year, for example, would save around USD 85 million a year in power costs, compared to average EU locations in 2015.[25] It can be assumed that over the medium and long term, dominant cost factors such as power price and labor costs will strongly influence decisions on whether to relocate a production site. Even a 10% relocation of energy-intensive industry would lead to a USD 16 billion decline in the European GDP. At the same time, this relocation would result in a loss of 250,000 jobs in the EU.[26]

The investment in green energy as an economic multiplier

Various independent studies show that investments in green energy and climate policy have positive side effects on the overall economy.[27] Even though the first scenario proposes optimizing total investment in renewables, the remaining high investments still offer huge potential for promoting economic growth by the multiplier effect. According to the multiplier principle, the entire EU industrial system could be affected positively especially by technologies with a high share of added value. Investments in renewables would support growth and the innovative strength of suppliers. By setting international technology standards, the renewables industry could profit from international exports. Looking at the supply chain for wind turbines, for example, there would be higher growth in the gear industry, blade industry and hydraulic industry.[28] This growth would lead to additional job growth. Furthermore, investments in green technology stimulate investments in research and development.

Success of the European economy depends on realizing unused potential

The economic and innovative strength of the EU could be increased by implementing the measures presented in the scenarios.[29] The opportunity costs combined with the huge benefits show the environmental and economical potential for the EU. Based on these scenarios, the best course for the EU is to pursue the optimal location of renewable energy resources, increase investments in extending the transmission grids and enforce the coal-to-gas shift. These actions would reinforce the idea and advantages of one integrated energy market for the EU.



A 10% shift of energy-intensive industry would lead to opportunity costs of USD 16 bn of the European GDP

Footnotes

1 Cf. IEA (2012 c).
2 Cf. IEA (2012a), (2012b), (2012c); Global Insight.
3 Cf. IEA (2012b).
4 Cf. IEA (2012b).
5 Cf. IEA (2012b).
6 Cf. Siemens Calculation, p. 78; EUC (2013a); World Bank (2013 a).
7 Cf. IEA (2012a).
8 Cf. World Bank (2013a).
9 Cf. EUC (2007).
10 Cf. EUC (2007).
11 Cf. IEA (2012b).
12 Cf. Siemens Calculation, p. 41.
13 Cf. Gründinger (2012), p. 86.
14 Cf. Garcia (2012), p. 333.
15 Cf. Bostan et al. (2013), p. 376.
16 Cf. IEA (2012b).
17 Cf. Siemens Calculation.
18 Cf. Heinrich-Böll-Stiftung (2013), p. 1.
19 Cf. Czisch (2001).
20 Cf. Umweltbundesamt (2012).
21 Cf. Siemens Calculation.
22 Cf. Siemens Calculation.
23 Cf. TGE Ltd. (2008).
24 Cf. Eikmeier et al. (2005).
25 Cf. Eikmeier et al. (2005).
26 Cf. CEPI (2013).
27 Cf. Gabriel, Steinmeier (2009).
28 Cf. BMU (2011), p. 19.
29 Cf. Eurelectric (2013).

Russia

3

Stretching 17,100,000 square kilometers across Northern Eurasia, Russia is the largest country in the world. Drawing on its vast energy resource reserves,[1] Russia produced approximately 1,300 Mtoe of primary energy in 2010. This equaled more than 10% of the total worldwide primary energy demand that year.[2] Only about half of the produced amount is consumed within the country itself; the rest is exported and thus a major driver for national GDP. Russia's decisions concerning its energy will therefore have an influence on the security of international energy supplies, environmental sustainability and the country's domestic economy.[3] The following regional study describes the current situation and challenges in the Russian energy market and possible solutions.

Energy Value Stream Russia

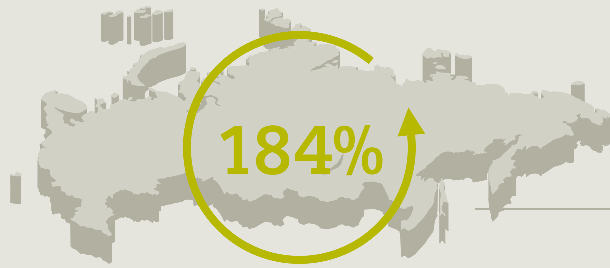
(2010) [4]

The Energy Value Stream illustrates the status quo of the Russian energy market, with regard to the country's primary energy, power and economy as well as sustainability indicators. These figures are the basis for identifying the current challenges.

Calculations based on: IEA – Energy Balance 2012; IEA – WEO 2012; IEA – Statistics 2012; ABS Research – T&D Report; The World Bank – World DataBank; Global Insight; Siemens calculations

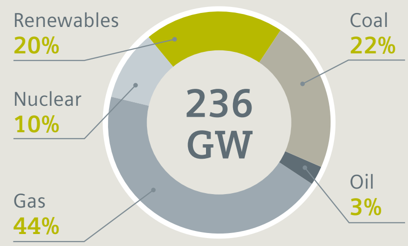
Primary energy

Self-sufficiency

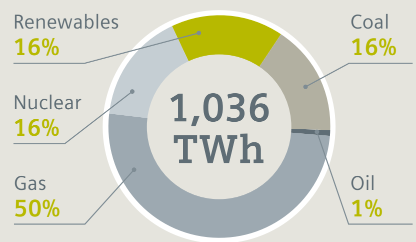


Power

Installed capacity



Power generation



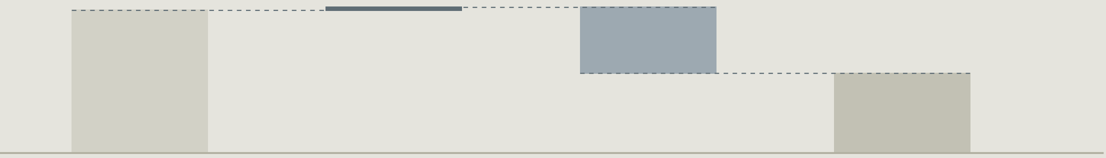
Economy & sustainability

Economic indicator

GDP
(USD current)

USD 1,867 bn

Indigenous production	Imports	Exports	Energy supply (TPES)
1,293 Mtoe	23 Mtoe	600 Mtoe	702 Mtoe



Transmission & distribution

T & D losses

12.4%

Grid length

2.7 million km

Grid density

0.2 km/km²

Consumption

Final consumption

727 TWh

Intensity

389 kWh per 1,000 USD GDP

Per capita consumption

5,179 kWh per capita

Sustainability

CO_2 emissions

1,624 Mt total

872 Mt share of power sector

CO_2 intensity of power sector

1,200 g per kWh

Three perspectives

The economy and sustainability perspective

Russia currently has a GDP of approximately USD 1,870 billion and is therewith ranked in the top ten of the world's biggest economies in terms of absolute numbers. However, the per capita GDP is less than half that of the EU. Regarding its sustainability perspective, Russia emitted over 1,620 Mt of CO_2 in 2010 and the country's power generation sector accounted for nearly half of this total. While Russia emits roughly 1.200 g of specific CO_2 emissions, the European average is only 440 g per kWh. This is the result of the comparatively low share of renewable energy sources in the country and inefficiencies in the power generation sector.[5] In view of Russia's huge existing resource capacities, efficiency in primary energy consumption has not been a priority issue for a long time.

The primary energy perspective

The primary energy resources of the Russian Federation, comprising natural gas, oil, coal and uranium, strengthen Russia's role as one of the biggest energy suppliers in the world.[6] In 2010, Russia produced a record amount of oil and gas and also exported the biggest share of natural gas in worldwide comparison.[7] Efficiency improvements on both the production and consumption sides – assuming a constant production rate – could increase exports as well as GDP. Due to inefficiencies, energy exports currently account for less than 50% of the primary energy production.

The power perspective

Power generation in Russia offers tremendous savings potential. By replacing inefficient gas-fired steam power plants with combined cycle power plants, the country could tap a high share of the overall potential. In addition to current generation inefficiencies, power is transmitted and distributed in the country with losses of roughly 12%. When compared to the average European loss rate of less than 7%, a modernization of the national grid system could obviously lead to substantial additional savings. Furthermore, power in Russia is subsequently consumed with inefficient and outdated equipment. Even though the per capita consumption of nearly 5,200 kWh per year is just slightly below the European level, one should consider that some rural areas in Russia do not have proper access to power. This means that the per capita consumption in urban areas is a lot higher.

In summary, Russia has one of the biggest efficiency improvement potentials in the world.[8] The Russian government is aware of this potential and has launched various programs to realize these savings.

Current challenges

Most of the country's power is generated in inefficient plants due to the lack of financial incentives for modernization. Tariff regulations in the power generation sector, for example, discourage market competition and there is no market mechanism for investments. Nevertheless, modernization of the country's plant fleet is necessary to tap benefits, such as increased competitiveness, reduced fossil fuel dependency and environmental improvements.[9]

In addition to the inefficiencies in power generation, only a small share of Russian industry has adopted energy efficiency programs. Most domestic companies are aware of energy efficiency potential, but suffer from the lack of capital for modernization investments.[10] Targeted incentives are therefore necessary to motivate Russian industry to focus on meeting the challenges of energy efficiency. In addition, energy efficiency in the building sector is especially deficient since consumers generally have no control over heating, there is a low share of private ownership of apartments, and there are heavy price subsidies. In the transport sector, efficiency is adversely impacted by major energy losses and outdated equipment.[11]

Savings potential is still tremendous

Aware of these challenges, the Russian government is already accelerating efforts to modernize the country's energy system. One dedicated goal of the Russian government is to reduce the energy intensity 40% by 2020 compared with the base year 2007.[12] To reach this target, the Russian government has launched various energy efficiency programs. Huge additional potential is still waiting to be tapped.[13] In summary, the challenges faced by the Russian energy market are to raise efficiency in energy generation, transmission, distribution and consumption.

Scenarios for optimization

The scenario analysis quantifies the efficiency potential in the Russian power generation and energy consumption sector. In terms of power generation, replacing gas-fired steam power plants would tap major potential for energy savings. The first scenario therefore assumes the complete replacement of all existing gas-fired steam power plants with combined cycle power plants by 2030. With regard to end consumption, the potential offered by modernizing the industry, building and transport sectors will be calculated in a second scenario.

Scenario 1:

Replacement of all gas-fired steam power plants

The first scenario presents an example for efficiency improvements in the Russian power generation sector. An ambitious case is calculated which assumes the consecutive replacement of all existing gas-fired steam power plants with combined cycle power plants by 2030. The scenario is introduced as follows:

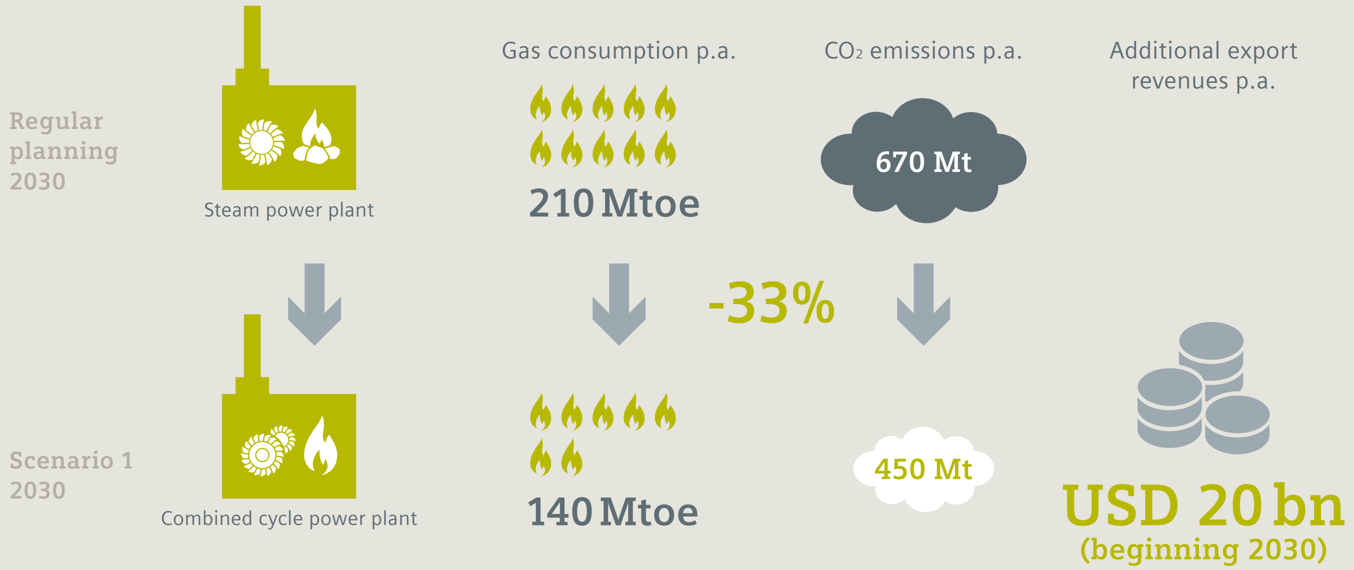
»All gas-fired steam power plants will be replaced with efficient combined cycle power plants by 2030.«

Currently, a capacity of 71 GW of gas-fired steam power plants is installed in Russia, while combined cycle and simple cycle power capacity is only 19 GW. This clearly highlights the efficiency potential of the Russian power generation sector, considering the low efficiency of the installed fleet. The efficiency of the fleet is below 40%, while state-of-the-art combined cycle power plants reach an efficiency of slightly over 60%. In this scenario, the installed combined cycle and simple cycle capacity in 2030 would be 145 GW comprising the replacement of existing gas-fired steam power plants as well as additional capacity to cover demand growth. As a consequence, gas-fired steam power plant capacity would be zero. A further assumption is that the generated power output with gas will remain constant at approximately 1,530 TWh in 2030.[14] Plants with increased efficiency need less primary energy input to produce the same amount of power output. Consequently, the saved gas resources could be exported at an approximate gas price of USD 8 per MBtu.

Over USD 160 billion could be realized by 2030

In this scenario, the country's gas consumption for power generation could be reduced 33% by replacing gas-fired steam power plants with efficient combined cycle plants. According to current forecasts, approximately 210 Mtoe of gas will be consumed in 2030. This amount could be reduced to 140 Mtoe in 2030 by exclusively using combined cycle plants. In this case, the annual demand for gas in power generation would decline by 70 Mtoe, equaling around USD 20 billion in additional revenue if the gas was exported. The replacement would also have an environmental impact: By reducing the consumption of the prime energy carrier, CO_2 emissions could be cut annually by 220 Mt. The cumulative benefits in the period from 2013 until 2030 would result in higher export revenues of nearly USD 240 billion and reduce CO_2 emissions by 2,400 Mt.

However, additional investments would be necessary to install approximately 66 GW of combined cycle plant capacity. Based on the overall costs of combined cycle power plants, the required investment would total roughly USD 80 billion. All in all, replacing inefficient gas-fired steam power plants with efficient combined cycle plants would lead to a cumulated net benefit of more than USD 160 billion by 2030. For comparison, this sum would have paid for all imports of the Russian Federation in 2009.[15]



A complete replacement of all gas-fired steam power plants by combined cycle power plants would lead to additional export revenues of USD 20 bn annually

In addition to its inefficiency in power generation, Russia also faces serious inefficiencies on the energy consumption side, shown in the following scenario.

Scenario 2:

Efficiency optimization in the industry, transport and building sectors

Roughly 30% of Russia's energy is consumed by industry, 35% in buildings and 20% by transport.[16] In the industry sector, a major redesign of existing manufacturing processes and specific machinery improvements are long overdue in order to meet the challenges of the Russian energy market.[17] In Russia's transport sector, energy consumption is mainly driven by pipeline, rail and aviation transport. Ship transport is negligible and will therefore not be considered.[18] Enormous savings potential exists in the transport sector due to the low energy efficiency in all transport fields.[19] As mentioned in the summary of challenges, the building sector also offers huge potential when it comes to energy efficiency. Overall, the biggest savings potential for Russia's energy consumption could be realized in this sector.[20] For an impression of the untapped potential, the following scenario has been created and calculated for this study:

»The Russian industry, transport and building sectors will be modernized toward an international level of efficiency.«

According to various studies, efficiency in the sectors could be improved to reach an international level. Efficiency improvements of nearly 25% could be realized in industry,[21] approximately 20% in transport and nearly 45% in the building sector. [22]

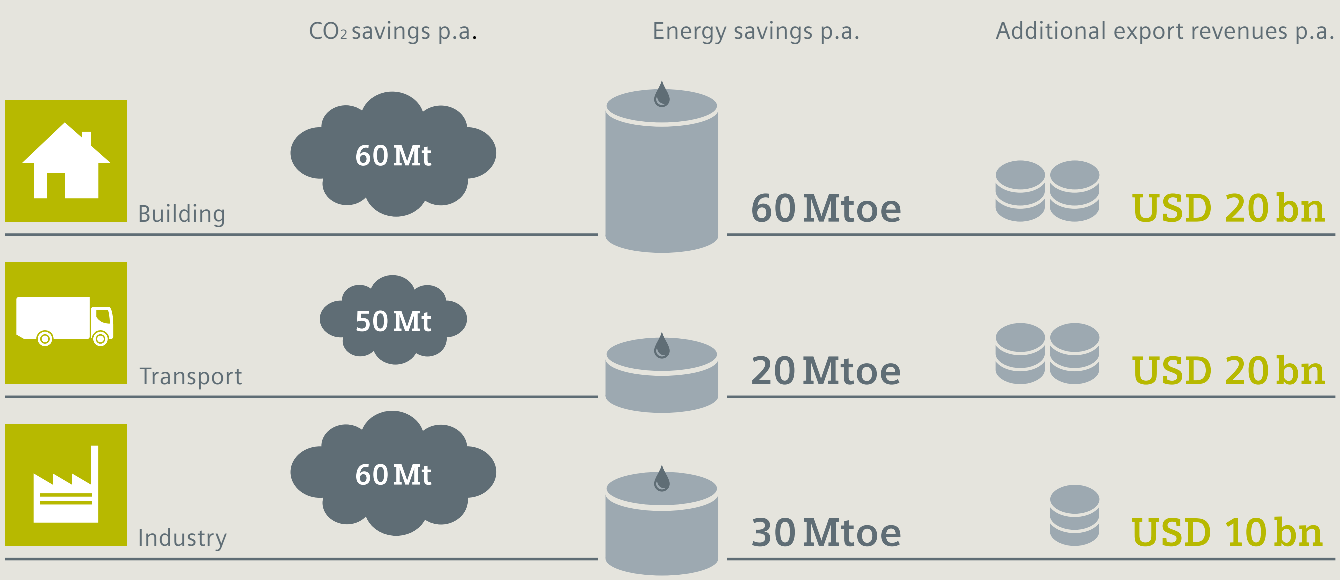
Up to 110 million tonnes of oil equivalent could be saved

In the industry sector, primary energy consumption could be reduced by nearly 25% from an absolute level of approximately 130 Mtoe to 100 Mtoe, assuming the complete implementation of all improvement measures. From a GDP perspective, the saved energy capacity of 30 Mtoe would allow the country to increase its energy exports by a total of nearly USD 10 billion a year, compared to the reference scenario without modernization. The calculated savings in CO_2 emissions would total 60 Mt a year.

In addition to the savings potential in industry, efficiency optimization could also be achieved in the transport sector. Possible savings of approximately 20 Mtoe could be achieved in this sector by using efficient equipment. The annual export benefit from the total saved energy would equal nearly USD 20 billion, while CO_2 emissions could be reduced by 50 Mt a year.

Finally, there is huge savings potential in Russia's building sector. The building scenario would provide total annual savings in energy consumption of more than 60 Mtoe. This potential could be realized by replacing existing, mostly outdated building technologies with new ones complying with international energy efficiency standards. The saved energy could be exported and would raise

Russia's export balance by USD 20 billion a year. In addition, there would be an absolute reduction of 60 Mt of CO_2 emissions, or nearly 4%. The relative economic outcome of the energy savings varies, due to the different input mix of primary energy in the three sectors. In the transport sector, for example, oil is the primary fuel, while gas is the dominant fuel in the industry sector. As a result, the financial savings per Mtoe have to be calculated on a sector-specific basis and are not directly proportional to Mtoe volumes.



A rise of the efficiency of energy consumption on a best practice level would lead to additional annual export revenues of nearly USD 50 bn

Additional opportunity costs

As described, there is huge potential for increasing energy efficiency in all sectors of the energy market. The potential calculated in the scenarios could dramatically improve the country's energy efficiency and would avoid additional opportunity costs.

Russian industry would benefit from lower power costs

The industry sector in Russia accounts for 36% of the country's GDP.[23] Low electricity prices are especially important for this sector. To maintain low electricity prices, improvements in the efficiency of the energy system are especially important. Even an assumed increase in growth rate of one percentage point would lead to nearly USD 7 billion in additional GDP.[24]

According to a World Bank survey, implementation of efficient energy consumption in Russia requires an investment of nearly USD 320 billion. The resulting efficiency measures could result in annual end user and investor cost savings of more than USD 80 billion.[25] Even though some of the potential has already been realized, the calculated scenarios comprise approximately 80% of the unused optimization potential.

Frequent blackouts have tremendous impact on the Russian economy

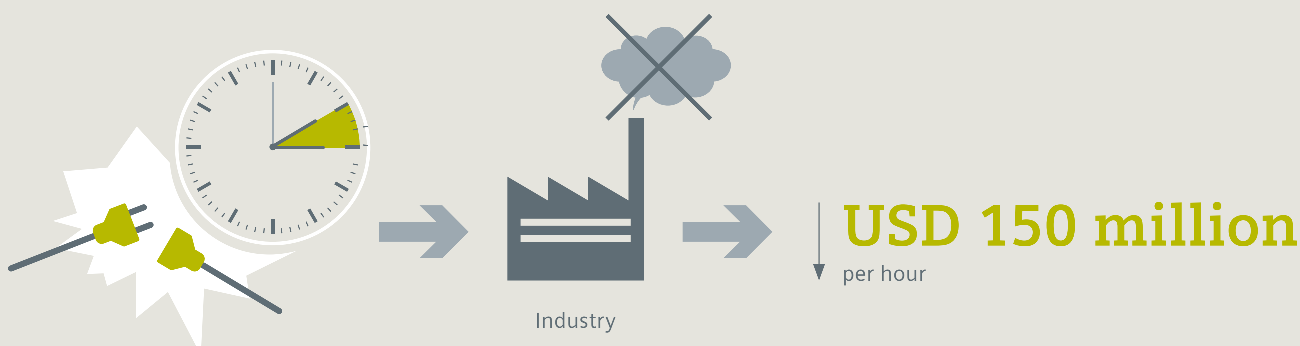
Beside ensuring better affordability, the assumed replacement of old power plants by new facilities would increase the availability of power. A rise in availability from the use of modernized technologies would allow Russia to increase its GDP dramatically. Every additional hour of production time without power blackouts is statistically responsible for approximately USD 100–150 million GDP in the industry sector.[26]

The costs of subsidies and the multiplier effect

In addition to the obvious advantages for the Russian economy, the government would also benefit from higher energy efficiency as a result of lower budget expenditures for subsidy-related costs. Studies show that the annual unused potential for paying energy bills of public institutions and private low-income households totals USD 5 billion.[27] By using energy more efficiently in those sectors, these costs could be dramatically reduced.

In addition to the mentioned opportunity costs, greater efficiency would also promote GDP production via the multiplier effect. By modernizing and thus investing in various technologies, Russia would be able to enhance its industrial know-how and competitive position in the production of modern technologies. A whole food chain of modernizing technologies could be built up and attract a comprehensive supplier network. This, in turn, would create huge potential for new investments, jobs, innovation and further GDP growth.[28]

Local example



Blackouts in Russia could cause opportunity costs of up to USD 150 million per hour

Footnotes

1 Cf. World Bank (2013a).
2 Cf. IEA (2012a), (2012e).
3 Cf. IEA (2011a), p. 245.
4 Cf. Global Insight; IEA (2012a), (2012b), (2012e).
5 Cf. IEA (2012b).
6 Cf. IEA (2013a).
7 Cf. World Bank (2013a).
8 Cf. Bashmakov (2008), p. 10.
9 Cf. IEA (2011a), p. 7.
10 Cf. IEA (2011a), p. 12.
11 Cf. Bashmakov (2008), p. 77ff.
12 Cf. Lychuk (2012), p. 1.
13 Cf. IEA (2002), p. 47.
14 Cf. Siemens Calculation.
15 Cf. BBRDM (2012), p. 11.
16 Cf. IEA (2012e).
17 Cf. IFC (2008), p. 48.
18 Cf. Bashmakov (2008), p. 33.
19 Cf. IFC (2008), p. 59.
20 Cf. Lychuk (2012), p. 2.
21 Cf. IFC (2008).
22 Cf. Bashmakov (2008), p. 78f.
23 Cf. CIA (2012).
24 Cf. McKinsey (2009), p. 6.
25 Cf. IFC (2008), p. 6.
26 Cf. World Bank (2013a).
27 Cf. Bashmakov (2008), p. 20; IFC (2008), p. 6.
28 Cf. Gabriel, Steinmeier (2009).

USA

4 The United States of America accounts for roughly one-sixth of the global energy consumption and has until now been dependent on energy imports.[1] Now that it is exploiting its vast reserves of unconventional fuels like shale gas to increase the affordability of its energy supplies, the U.S. is shifting from an energy importing to an energy exporting nation. The government's focus on affordability of energy might be one reason for the comparably low share of renewable energy sources to date. Nevertheless, the U.S. can provide a sustainable and affordable energy supply by using its domestic natural gas in efficient combined cycle power plants.[2] The reduction of CO_2 emissions in the past years has been a positive side effect of the economically driven development that has strengthened U.S. global competitiveness. This course has helped the U.S. government to achieve environmental improvements in its energy supply while keeping energy prices low. Nonetheless, there is still potential to be realized.
Most of the electricity in the U.S. is still generated by inefficient coal-fired power plants. These plants are economically viable due to the relatively low coal prices ensured by the country's huge coal reserves. In addition, the country's power transmission grid, with losses higher than the international average, is not adequate for today's market conditions and is plagued by frequent supply interruptions.

Energy Value Stream USA

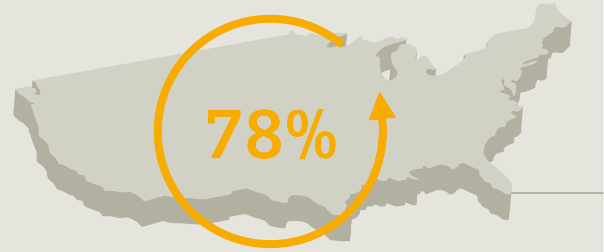
(2010) [3]

The Energy Value Stream presents the status quo of the U.S. energy market based on primary energy, power and economy as well as sustainability indicators, which are the basis for identifying the current challenges.

Calculations based on: IEA – WEO 2012; IEA – Energy Balance 2012; The World Bank – World DataBank; ABS Research – T&D Report; Global Insight; Siemens calculations

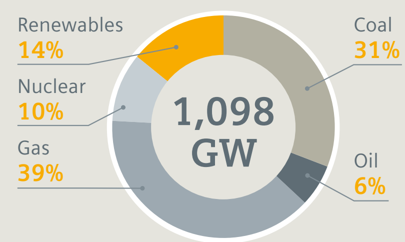
Primary energy

Self-sufficiency

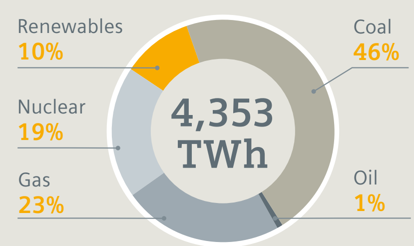


Power

Installed capacity



Power generation



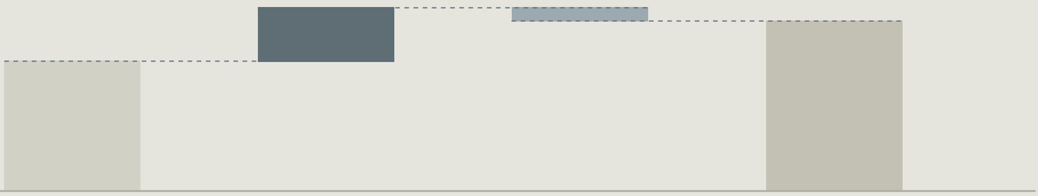
Economy & sustainability

Economic indicator

GDP (USD current)

USD 15,072 bn

Indigenous production	Imports	Exports	Energy supply (TPES)



1,725 Mtoe	721 Mtoe	190 Mtoe	2,216 Mtoe

Transmission & distribution

T & D losses
6.3%

Grid length
12 million km

Grid density
1.2 km/km²

Reliability
SAIDI
140 min
p.a.

Consumption

Final consumption
3,801 TWh

Intensity
252 kWh per 1,000 USD GDP

Per capita consumption
12,257 kWh
per capita

Sustainability

CO_2 emissions
5,340 Mt
total
2,290 Mt
share of power sector

CO_2 intensity of power sector
530 g
per kWh

Three perspectives

The economy and sustainability perspective

In 2010, the U.S. generated GDP of about USD 15,000 billion and grew by nearly 3%.[4] Even though such economic growth would normally increase CO_2 emissions, the country actually lowered the level. As a result of the economically driven shift from coal-fired towards a higher share of gas-fired power plants, the U.S. was able to reduce its emissions. In 2010, power generation accounted for roughly 530 g of CO_2 emissions per kWh. This is nearly half the amount of the specific CO_2 emissions in Russia.

The primary energy perspective

Despite the reductions of CO_2 emissions, the U.S. is still one of the world's biggest energy consumers and strongly dependent on fossil energy sources. Yet by increasing its exploitation of unconventional energy sources, such as with fracking, the U.S. was able to reduce its dependency on primary energy imports. As a result, the U.S. was able to supply roughly 78% of its total primary energy consumption in 2010 from within its own borders. In 2011, this total moved toward 81%, further strengthening the country's independence from imports.[5] In addition, the spread of fracking also lowered the price of gas in the U.S. As a result, 1 MBtu in the U.S. costs about USD 4 today, less than half the price in Europe.[6]

The power perspective

The country's comparably low gas prices support the political target of ensuring affordable energy. As a result, the share of power generated by gas has already reached 23%. Although there is currently a slight decline in the share due to lightly rising gas prices, experts predict that gas-powered generation will grow continuously.[7] Coal-fired plants still account for 46% of the nation's power generation, while the share of renewable power generation is still low.

The country's installed generation capacity is already dominated by gas-fired power plants with a share of 39%. The installed capacity of coal-fired power plants accounts for a 31% share. Nuclear power plants held a 10% share of the total output in 2010. In order to diversify its energy supply over the long term, the U.S. introduced measures to promote the development of renewables. As a result, onshore wind power in particular is being installed in high wind locations. But since the incentives for renewables are mostly temporary, the total share of installed renewable capacity is currently still at a low 14% including hydropower plants.

Due to its outdated power grid infrastructure, the U.S. had frequent blackouts and power transmission losses above 6% in 2010. Compared to the 4% loss level in Germany, modernization investments need to be considered in the U.S. to avoid a negative impact on the country's economic development and to reliably serve its high power demand.[8] The annual per capita consumption of more than 12,200 kWh is nearly twice as high as in Russia. At the same time, the per capita GDP of nearly USD 50,000 in the U.S. is three times higher than the low per capita level of only USD 14,000 in Russia.[9] Consequently, the U.S. consumes roughly twice the kWh per capita but is able to generate more than three times the per capita GDP compared to Russia.

Current challenges

Fracking has already proven its value. Now an additional, accelerated development of production capacity is necessary in order to utilize the ecological and economic advantages of shale gas. The coal-to-gas shift scenario makes this especially clear. In addition, a further diversification of the energy mix – such as expanding the development of renewables – is also necessary. However, this requires a further optimization of the power grids.

Scenarios for optimization

The future scenarios define various measures for overcoming the specific challenges in the U.S. energy market. The scenarios describe the economic and environmental savings that could be achieved by implementing the suggested measures.

Scenario 1:

Coal-to-gas shift

The U.S. is already switching from the primary energy carrier coal to gas, due to the economic benefits. Nevertheless, an untapped potential exists that could be realized with a complete shift from coal to gas. To give an idea of this potential, this scenario assumes a complete shift from coal to gas by 2030:

»The primary energy carrier coal will be substituted completely by gas in power generation by 2030.«

According to current planning, power generation with gas is projected to be 1,970 TWh in 2030, while power generation with coal is projected to be 1,560 TWh in the same year. Since the scenario assumes a complete coal-to-gas shift, 3,530 TWh would be produced by gas in 2030.

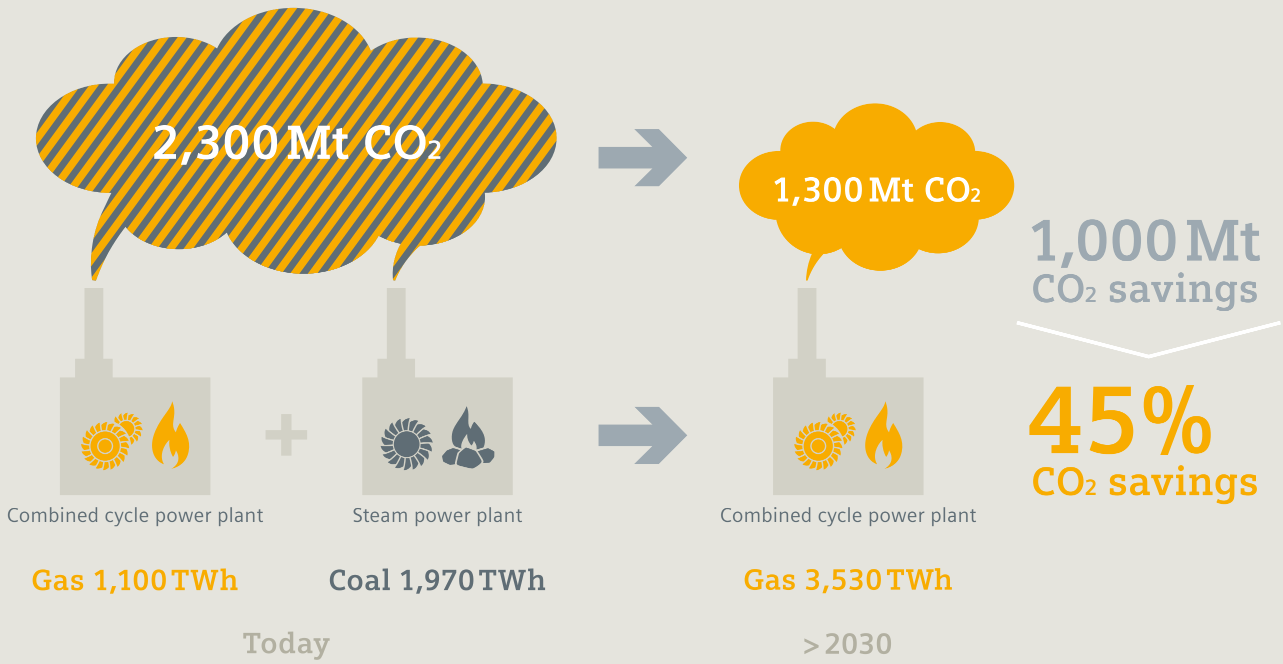
The projected increase in gas production using fracking technologies should be able to cover the increase in gas demand in a broad coal-to-gas shift.[10] Furthermore, due to the average 40% efficiency for coal-fired steam power plants and 60% for newly built combined cycle plants, total primary energy consumption could be reduced.

Instead of replacements with combined cycle power plants, CERA considered the idea of only fuel-converting coal-fired steam power plants into gas-fired ones.[11] Due to the much lower efficiency of steam power plants, the option for fuel conversion is economically viable only up to a gas price of USD 3 per MBtu. Assuming gas prices above this threshold, the construction of new gas-fired combined cycle power plants would be the favored option.

Roughly 1,000 million tonnes of CO_2 could be saved

A total coal-to-gas shift by building new combined cycle plants rather than coal-fired plants would have environmental benefits. Due to the lower specific CO_2 emissions of gas in comparison to coal and the higher efficiency of combined cycle power plants, a complete coal-to-gas shift would reduce CO_2 emissions in the U.S. by nearly 1,000 Mt by 2030 without raising power prices. This would correspond to a roughly 45% reduction of total CO_2 emissions of the power generation sector compared to 2012, even though total power demand is expected to grow rapidly up to 2030.

Even though the planning case already projects an additional installation of combined cycle capacity by 2030, the scenario is even more ambitious. An additional 340 GW capacity installation of high-efficiency combined cycle plants is estimated by 2030. The additional capacity would require a one-time investment of nearly USD 300 billion. Even though the suggested new installed capacity of 340 GW seems high, the scenario is feasible when compared to other projects in the past. For instance, new installations in the U.S. increased from 1999 to 2003 by 130 GW in only 5 years.



The coal-to-gas shift would lead to 1,000 Mt CO_2 savings from 2030 onwards

Scenario 2:

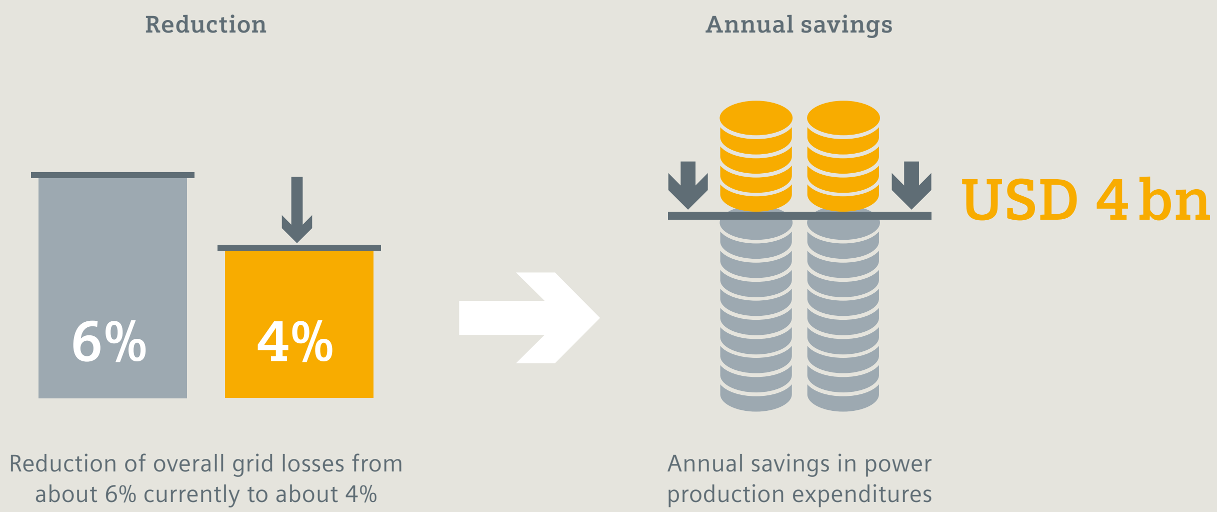
Modernization of the power grid to a state-of-the-art level

The second scenario suggests modernization and development of the outdated power grid system in the U.S. In this case, benefits would include reducing transmission and distribution losses and grid blackouts. In addition, the integration of wind power in the future would be facilitated by a modernized grid that can handle intermittent power feed-ins. Therefore, the following scenario is assumed:

»The power grid system in the U.S. will be modernized and developed towards an international state-of-the-art level.«

The grid system in the U.S. currently shows transmission losses of roughly 6%.[12] In this scenario, one assumes an improvement of 2 percentage points by modernizing the system. The system average interruption duration index (SAIDI) – an indicator of the transmission grid's reliability – would also be improved by the modernization scenario. The country's annual average blackout time per consumer of currently roughly 140 minutes[13] could be brought in line with the average European value of approximately 60 minutes.[14]

Grid modernization could save USD 4 billion in power production costs
Improvements to the grid system would reduce the total power generation requirements by roughly 85 TWh. Assuming an average 5 US-ct/kWh per kWh production cost, this would lead to annual financial savings of about USD 4 billion in total. The associated annual CO_2 emissions savings in the power generation sector would total over 50 Mt, equal to approximately 2% of the country's total annual emissions.[15] The corresponding investment for modernization is estimated to be USD 100 billion by 2030.[16] Modernization of the U.S. grid system would also reduce power blackouts, which will be described as additional opportunity costs below.



The modernization of the power grid system would lead to savings of USD 4 bn annually

Additional opportunity costs

Implementing the described scenarios could lead to stable power prices and lower power losses due to the modernized grid system and the extended coal-to-gas shift. These potentials need to be realized in order to avoid additional opportunity costs and economic disadvantages such as the lower competitiveness of U.S. industry.

Decreasing feedstock and energy costs in manufacturing industry

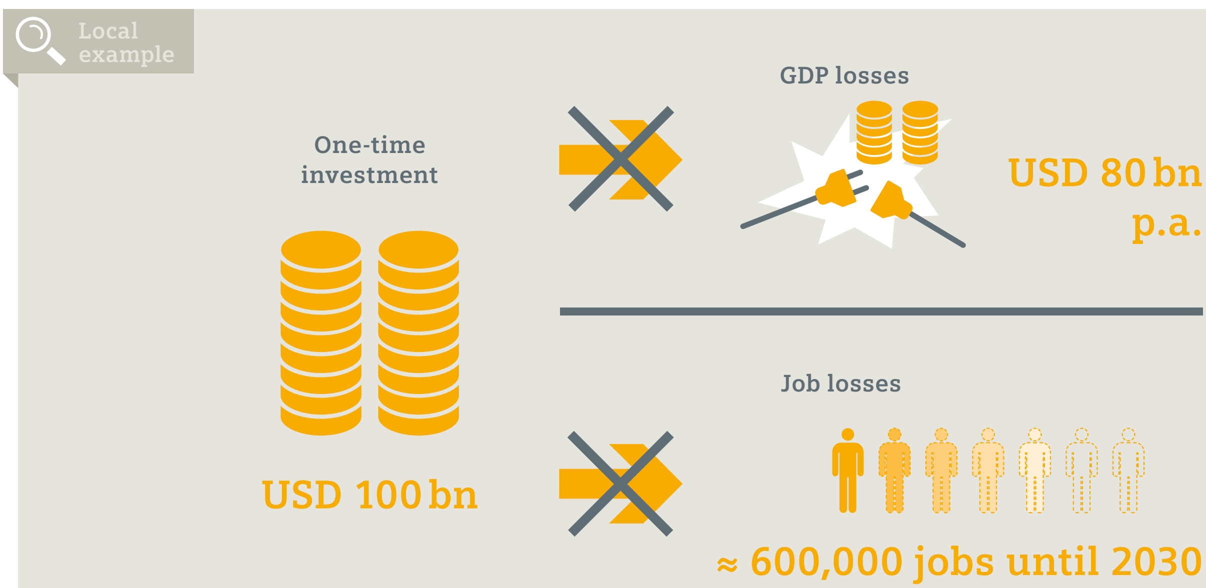
For new power plants, the coal-to-gas shift would be economically viable for gas prices below USD 7 per MBtu. Even though the price of gas slightly increased recently, it is still clearly below USD 5 per MBtu and therefore ensures the economic viability of combined cycle power plants. The extraction of unconventional gas resources, such as with horizontal drilling and hydraulic fracking, would keep gas prices low. These techniques reduce production costs and give access to resources which have been untouched so far. Furthermore, increases in power prices could be flattened due to the assumed extended shift from inefficient coal-to gas-fired power plants in the calculated scenario. U.S. manufacturers could realize substantial cost advantages if the increased shale gas supply and reduced power costs were exploited to their full potential. It can be assumed that the savings from lower feedstock and lower energy costs in the manufacturing industry would total more than USD 10 billion annually through 2030. Furthermore, U.S. companies could employ more than one million additional employees by 2030 as a result of affordable energy.[17] In addition to these benefits, realization of the grid modernization scenario would save further opportunity costs by reducing the frequency of blackouts.

Cost of power interruption

Energy is a major enabler of production in commercial as well as industrial sectors, and significantly affects the quality of life of private citizens. Thus, blackouts caused by over-aged equipment lead to huge opportunity costs for the U.S. economy. The country's power grid faces a high percentage of short-term interruptions due to the old equipment. But even these interruptions can have a devastating impact on power-sensitive customers, especially in computerized industries. Current studies estimate economic costs of power interruptions at USD 80 billion per year. These opportunity costs could be largely avoided by one-time investments of USD 100 billion to modernize the country's power grid.[18]

Effects of power blackouts for the economy

Neglecting future investments in the over-aged U.S. transmission and distribution system could lead to additional costs for households and businesses. Those costs would be even higher than the one-time investment needed for grid modernization. It can be assumed that the national costs would increase to a cumulated USD 1,400 billion by 2030. These costs would be passed on to the national economy in terms of decreased household spending, lost production and other disadvantages.[19] The lower economic growth rate, in turn, would result in a lower job growth rate. It is predicted that the U.S. economy would end up with an average of approximately 600,000 fewer jobs in 2030. This effect would be primarily driven by the diversion of household income and effects in consumer spending sectors.[20]



Investments in the U.S. grid would avoid GDP losses of USD 80 bn annually and the loss of 600,000 jobs until 2030

Footnotes

1 Cf. IEA (2012c).
2 Cf. Dixon (2010).
3 Cf. IEA (2012 a), (2012b), (2012 c); Global Insight.
4 Cf. World Bank (2013a).
5 Cf. World Bank (2013a).
6 Cf. Biggs (2012).
7 Cf. EIA (2013b).
8 Cf. World Bank (2013a).
9 Cf. IEA (2012c), (2012a); Global Insight.
10 Cf. Biggs (2012).
11 Cf. Biggs (2012).
12 Cf. IEA (2012c).
13 Cf. Eto, LaCommare (2008), p. 15.
14 Cf. BDEW (2013); Faltlhauser (2012), p. 15; IEA (2012c).
15 Cf. IEA (2012b).
16 Cf. LaCommare (2004).
17 Cf. EIA (2013a); PwC (2012), p. 4f.
18 Cf. LaCommare (2004).
19 Cf. LaCommare (2004).
20 Cf. ASCE (2011).

China

5

With over 1.3 billion inhabitants, China is the most populous country in the world.[1] This vast number of people and China's large economy make the country energy-hungry. In absolute numbers, it is the largest consumer of energy in the world and as the economy grows, demand for energy will continue to soar. In order to master this challenge, China needs uninterrupted access to affordable, bulk energy. Furthermore, in order to maintain energy security, this needs to be achieved without substantially increasing the country's dependence on energy imports. China currently has a high degree of self-sufficiency, primarily due to its extensive coal reserves.

At the same time, however, the country's focus on coal is a key driver behind high CO_2 emissions and has made China the world's largest emitter. The government is aware of this problem and is taking various measures to control emissions. The power sector is responsible for nearly half of the total emissions in China. Given this situation, the following options for reducing CO_2 emissions are feasible: modernization of aging, inefficient power plants, the accelerated construction of highly efficient gas-fired power plants, and the further development of non-fossil fuels, such as renewables.

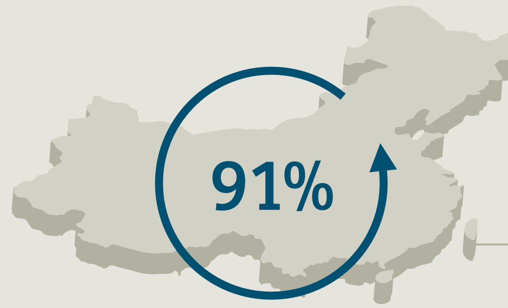
Energy Value Stream China

(2010)[2]

The Energy Value Stream illustrates the status quo of the Chinese energy market. This summary of selected indicators describes the country's primary energy, power, economy and sustainability aspects. These indicators are the basis for identifying current challenges.

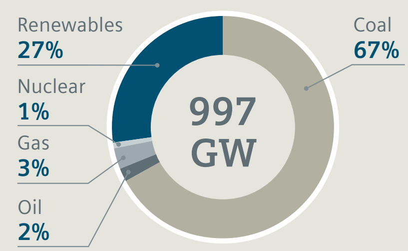
Primary energy

Self-sufficiency

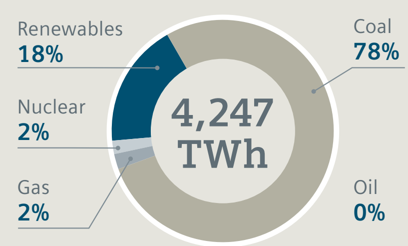


Power

Installed capacity



Power generation



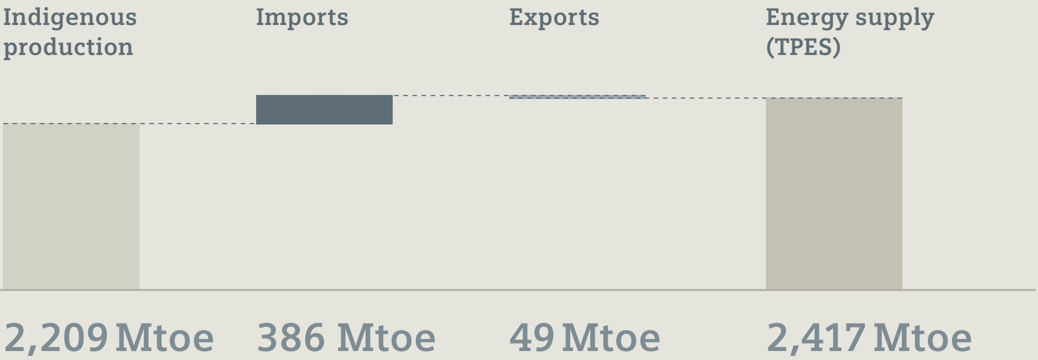
Economy & sustainability

Economic indicator

GDP
(USD current)

USD 6,985 bn

Calculations based on: IEA – Energy Balance 2012; IEA – WEO 2012; IEA – Statistics 2012; ABS Research – T&D Report; The World Bank – World DataBank; Global Insight; Siemens calculations



Transmission & distribution

T & D losses

6.9%

Grid length

10.5 million km

Grid density

1.1 km/km²

Consumption

Final consumption

3,452 TWh

Intensity

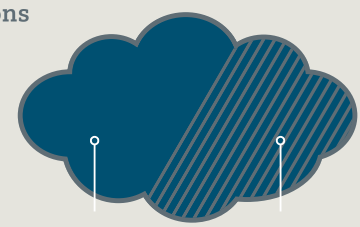
494 kWh per 1,000 USD GDP

Per capita consumption

2,581 kWh per capita

Sustainability

CO_2 emissions



7,214 Mt total

3,625 Mt share of power sector

CO_2 intensity of power sector

1,050 g per kWh

Three perspectives

The economy and sustainability perspective

China is the world's second-largest economy in terms of GDP.[3] From 1979 to 2012, inflation-adjusted GDP grew at an average annual rate of nearly 10%.[4] Until now, the corresponding growth in energy demand has been met primarily by coal, which has led to high levels of CO_2 emissions. In 2010, China emitted more than 7,210 Mt of CO_2.[5] Apart from the high CO_2 emissions in absolute terms, China also has a high CO_2 per GDP intensity. The CO_2 intensity of 1,050 g per kWh for the power sector is a key contributor to this factor and is significantly higher than in Europe.[6] The primary cause for this high level is the large percentage of small and comparatively inefficient coal-fired power plants in the country.[7]

Due to its high CO_2 intensity, China announced plans at the Copenhagen Climate Change Conference in 2009 to reduce its CO_2 emissions per unit of GDP by 40% to 45% relative to 2005 levels and increase the use of non-fossil-fuel-based energy to about 15% of its total energy use by 2020.[8] China is also a member of the Clean Air Asia initiative, which proposes that Asian countries adopt national ambient air quality standards in line with the World Health Organization interim target by 2016.[9] To meet these ambitious targets, China's current 12th Five-Year Plan aims for a 17% reduction in CO_2 emissions per unit of GDP and an increase in non-fossil-fuel-based energy from 8.4% to 11.4% by 2015.[10] These plans would involve investments of about USD 1.8 trillion in the power sector during this decade, including USD 850 billion in the current Five-Year Plan period (2011–2015).[11] However, in view of the country's growing energy demand, these targets might not be enough to meet the long-term goals set by Copenhagen and the Clean Air Asia initiative.

The primary energy perspective

China's actions are especially important for the world, since the country's energy demand accounted for 19% (2,420 Mtoe) of the global total in 2010, making it the world's biggest consumer of energy. Coal accounted for the largest share of 66%, oil for 17% and gas for just 4%.[12] The low share of gas in the energy mix stands in contrast to the fact that China has the world's largest technically recoverable shale gas reserves. Current studies estimate these to total more than 30 Tcm.[13] However, while gas might increasingly complement coal in China's energy mix, the latter is expected to remain the dominant primary energy source.

The power perspective

Coal is also the main energy source for generating power in China. Coal-fired power plants account for approximately 70% of the total installed capacity and generated about 80% of the total power in 2010.[14] To reduce its dependence on coal and lower the CO_2 intensity of its power sector, China is expected to reduce the share of coal power generation to about 60% by 2030. Accordingly, the share of other power sources, such as gas and renewables, would increase.

In 2010, gas accounted for only 2% of the power generation in China. Still, it is estimated that gas will account for 7% of the total by 2030.[15] Recent developments in the exploration of shale gas reserves in other countries have improved the prospects for a much larger share of gas-fueled power generation in China as well.

Apart from gas, China can also diversify its power mix with renewable sources due to its huge resource potential. China has already invested heavily in hydropower plants and is now tapping over 40% of its total potential for this energy source.[16] Since the hydro resources are located far from key consumption centers, the prerequisite for the development of this major potential is newly built high-voltage direct-current transmission lines.

Wind and solar power in China still only contribute a minor share of overall power generation. Nevertheless, renewable capacities have increased very dynamically in the past few years. The manufacture of wind turbines and solar panels has become a key industry in the Chinese economy, not only to meet domestic demand but also for export. Since the commissioning of wind power capacity suffered in the past due to the lack of suitable grid infrastructure, the expansion of grid infrastructure will have to be aligned with the development of renewables in the future. China has a track record of building such infrastructure with losses of less than 7%, which is comparable to the European grid.[17] This indicates that the country is well positioned to address infrastructure challenges.

Current challenges

China's ongoing and rapid economic growth poses a major challenge to the domestic power sector to provide enough electricity to the main consumption centers economically. Experts estimate that the total power generation capacity in China will reach 2,230 GW by 2030, which is over twice the installed power plant capacity of about 1,000 GW in 2010.[18] Since this is to be achieved without increasing the dependency on imports and while meeting the announced CO_2 intensity targets, China needs to use its existing resources more efficiently and increase the share of other conventional and non-conventional resources.

Development of shale gas resources

China has set an ambitious goal of doubling its use of natural gas from 2011 levels by 2015. To put this into perspective: It corresponds to 30% of the expected growth of global gas demand. In this case, China would absorb the entire production increase from Central Asia and around 30% of the global increase in liquefied natural gas (LNG) supplies.[19] While China has made impressive progress on domestic conventional gas production, this would only allow for a marginal increase in the total share of power generation.

Exploitation of the country's vast shale gas reserves would enable a more ambitious shift towards gas. This would require further research to adapt the current international drilling techniques to China's specific geological conditions. The China National Petroleum Company is moving quickly to explore domestic shale gas reserves in partnership with international gas producers such as Royal Dutch Shell and Chevron. However, China is still likely to be five to ten years away from commercial shale gas production. As a result, to increase sustainability, the replacement of coal by gas in power generation has to be supported over the short-term by efficiency improvements in coal-fired plants.[20]

Huge potential for efficiency

The average generation efficiency of power plants in China is just 33%, which is low compared to Europe's 38% average.[21] This can largely be attributed to the fact that more than 60% of the country's coal-fired power plants have capacities below 600 MW and still use subcritical technology with an efficiency of only 27–37%, compared to the 45% efficiency of supercritical large power plants.[22] To increase the fleet's average efficiency, China needs to retire its smaller, less efficient power plants and invest into more efficient technologies. Yet this still might not be sufficient to meet the country's CO_2 intensity reduction targets. Consequently, to further reduce emissions and to diversify its power generation mix, China needs to increase its share of renewables, gas-fired and nuclear power plants.

Demand-supply mismatch between resource-rich areas and demand centers

To realize its renewable potential, additional investment in the development of transmission infrastructure is required. There is a lack of infrastructure connecting resource-rich areas with key demand centers. China's main power consumption centers are in the east, while most of the wind potential is in the northern part of the country.

Although the 12th five-year plan already defines ambitious targets for the development of renewables, the enormous growth of power demand would exceed those efforts. To really make a major step towards higher sustainability, even more measures need to be implemented. The following scenarios demonstrate the potentials for the power sector.

Scenarios for optimization

The following scenarios for China's power sector can enhance sustainability while maintaining affordability and security of supply, which are the respective goals in the energy politics triangle. The scenarios describe the economic as well as environmental benefits that could be realized by implementing the suggested measures. The first scenario examines improvements in the efficiency of coal-fired power plants, the second examines a coal-to-gas shift for inefficient coal-fired power plants, and the third examines an expansion of renewables.

Scenario 1:

Replacement of existing small coal-fired power plants by supercritical large coal-fired power plants

Since the demand for power is expected to increase substantially over the coming decades, increasing the efficiency of coal-fired power plants would play a significant role in positively influencing the aspects of the energy triangle. This could be achieved by replacing existing inefficient coal-fired power plants by more efficient supercritical large power plants. Hence, the following scenario is calculated:

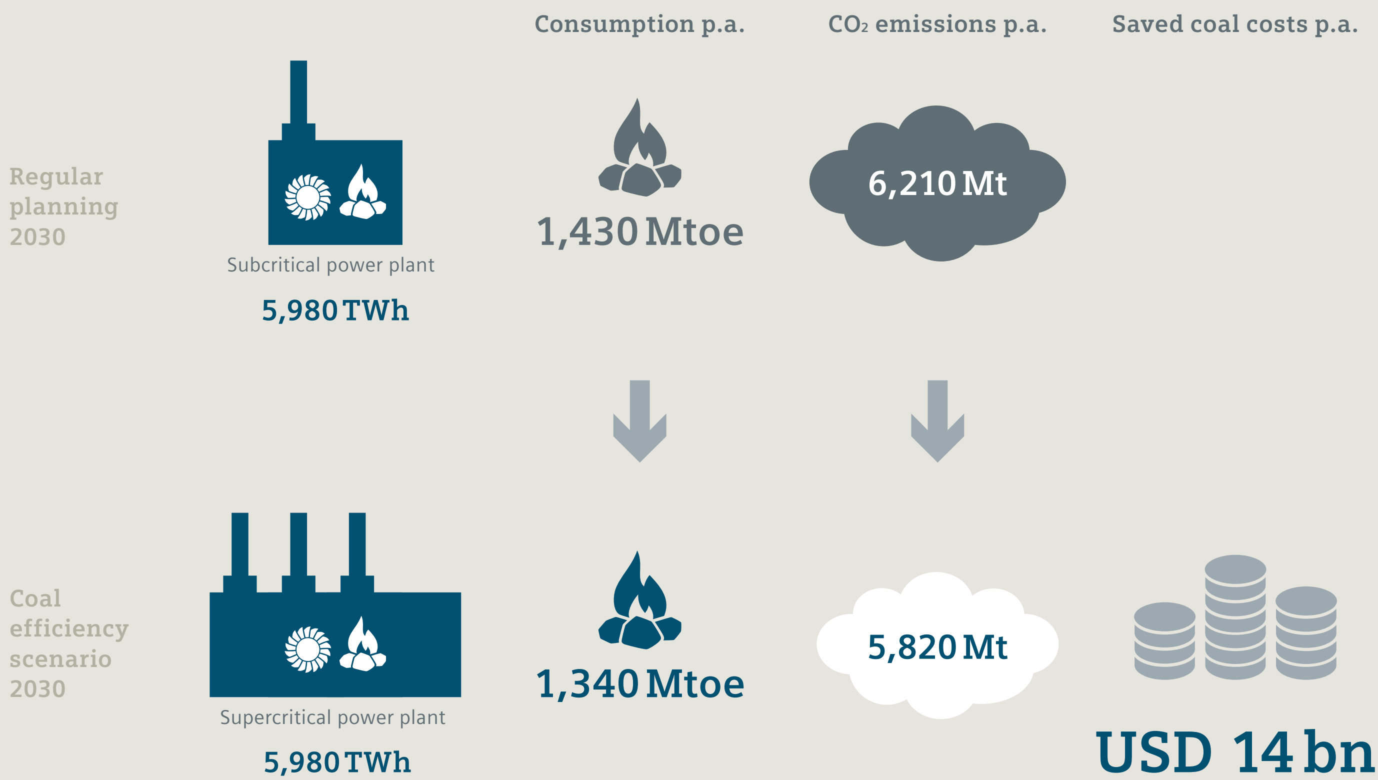
»Accelerated replacement of inefficient coal-fired power plants (about 30% of installed coal capacity) by efficient supercritical large coal-fired power plants by 2030.«

In 2012, the share of supercritical large power plants in China was less than 10% of the total coal-fired capacity, whereas the share of less efficient power plants with capacities lower than 600 MW was more than 60%.[23] The power generation of this low-efficient power plants leads to consuming excess energy resources on the one hand and relatively high emissions of CO_2 on the other. As a basis, this scenario assumes the accelerated shut-down of the most inefficient coal-fired power plants – which would be about 30% of the installed coal capacity – and their replacement with more efficient coal-fired power plants. This would improve overall efficiency on the generation side, lower the price of power, reduce coal consumption and consequently lead to lower CO_2 emissions.

CO_2 emissions would be reduced by 390 million tonnes

The proposed measures would reduce CO_2 emissions by about 390 Mt in 2030, leading to a reduction in CO_2 intensity as well. While this scenario would involve initial additional investments of around USD 40 billion for the new coal-fired power plants, there would be significant savings since coal consumption would decline by about 90 Mtoe annually. This would lead to an annual reduction of roughly USD 14 billion in fuel costs. Implementing this scenario would offer a fast payback period and could be the easiest way to reduce the CO_2 intensity of the power sector. However, it might not be sufficient to meet the CO_2 intensity targets.

As an alternative to this scenario, an even more significant decline in CO_2 intensity would be possible by converting inefficient coal-fired power plants to more efficient gas-fired power plants.



A conversion of subcritical power plants to supercritical power plants would save USD 14 bn coal costs annually from 2030 onwards

Scenario 2:

Coal-to-gas shift

In this scenario, it is assumed that an increase in shale gas extraction in China would enable the country to shift from inefficient coal-fired power plants to gas-fired combined cycle power plants that are up to 25 percentage points more efficient. The scenario is therefore presented as follows:

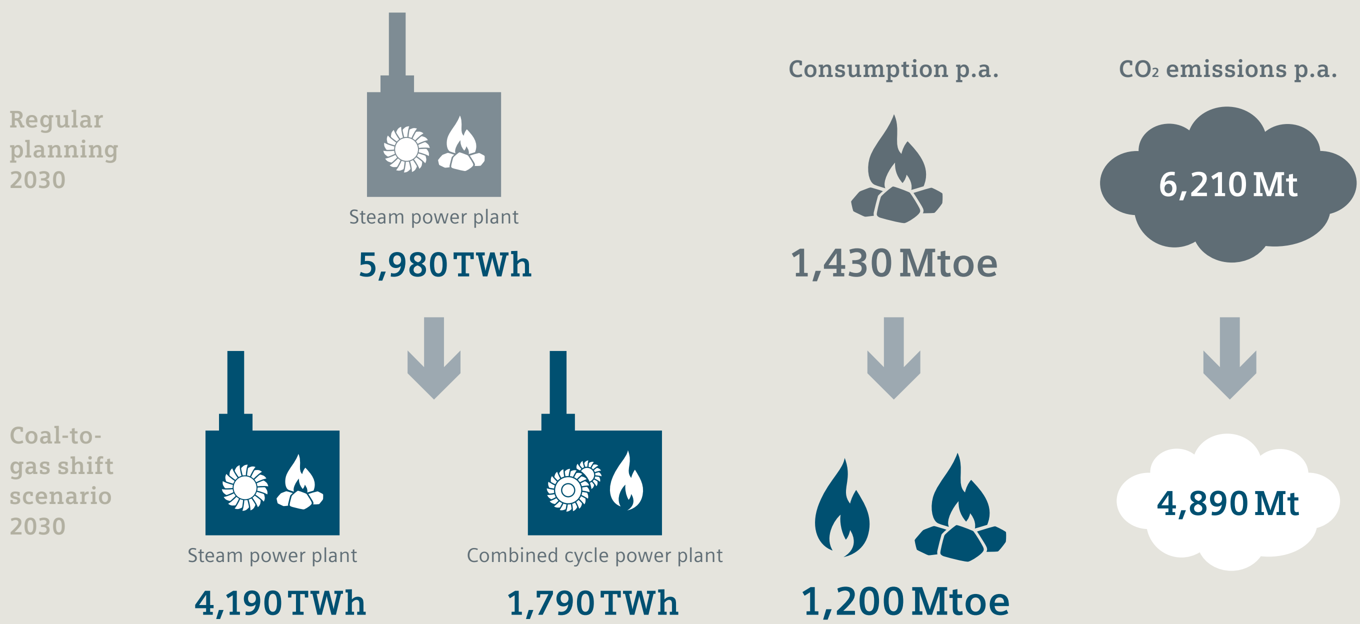
»Replacement of inefficient coal-fired power plants (about 30% of the installed coal capacity) by efficient gas-fired combined cycle power plants by 2030.«

Replacing 30% of the inefficient coal-fired power plants with gas-fired power plants is expected to result in a decrease of 1,790 TWh of coal-generated power. This amount of power would have to be generated by gas rather than coal. Supplying the required gas for this purpose would not be an issue if shale gas production would mature. Consequently, benefits of the lower CO_2 emissions of gas-fired plants could be leveraged while supply security would be maintained.

CO_2 emissions would be reduced by 1,320 million tonnes

The increased share of power generated by gas-fired power plants would reduce CO_2 emission by 1,320 Mt in 2030, nearly 20% of the estimated CO_2 emissions of the country's power sector in 2030. To achieve this, about 340 GW capacity of additional combined cycle power plants would be needed compared to the baseline scenario. Since gas-fired power plants have a lower initial investment cost than coal-fired power plants, this scenario would reduce initial power plant investments by roughly USD 120 billion compared to the baseline scenario. The coal-to-gas shift would cut coal consumption by around 230 Mtoe annually, which nearly equals the primary energy demand of the Republic of Korea. Although annual fuel costs for gas are roughly USD 26 billion higher than the planning case, a CO_2 price of USD 20 per ton emissions would make this scenario economically viable.

If China wants to reduce coal consumption and CO_2 emissions even further, either of the first two scenarios could be complemented by an enhanced expansion of the country's renewables capacity.



A 30% coal-to-gas shift would lead to 1,300 Mt CO_2 savings from 2030 onwards

Scenario 3:

Expansion of renewable power generation up to 30% of the power generation

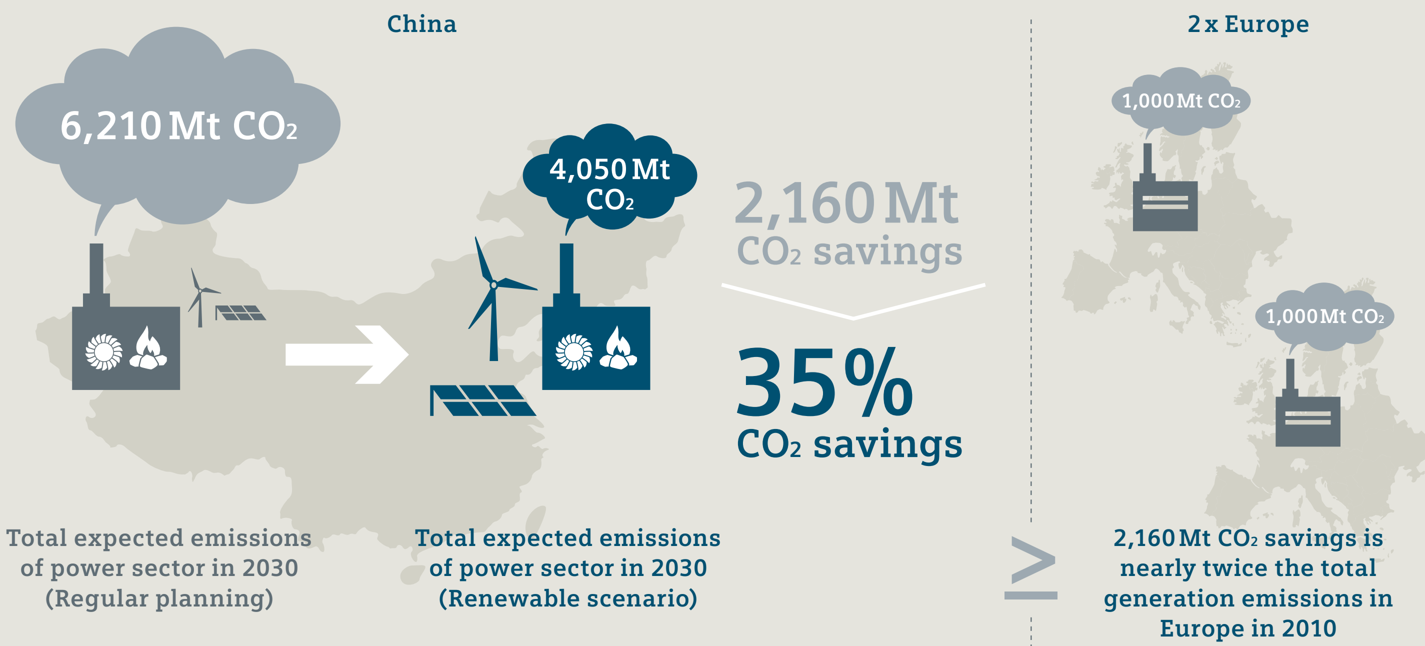
On its current trajectory, China is expected to have an 11% share of renewables (without hydro) in its power generation mix by 2030.[24] However, the country could achieve a significantly higher generation share with renewables, particularly with wind and solar technologies. By 2020, the price of onshore wind power is projected to be on a par with the price of coal power in China (not considering transmission costs).[25] This scenario therefore focuses on the development of wind and solar. However, the share of other renewables in the mix is also expected to grow. The scenario is therefore presented as follows:

»Increasing the share of renewables without hydro in the power generation mix to 30% by 2030.«

Under this scenario, it is expected that coal-generated power would be reduced by around 2,200 TWh and its share in the country's total power generation would decline to about 40% in 2030. This would require an estimated additional capacity of 570 GW for wind and about 500 GW for solar PV. Nearly 1,840 TWh of power would be generated by wind and 1,060 TWh by other renewables other than hydro.

CO_2 emissions would be reduced by 2,160 million tonnes

The larger share of renewables would reduce CO_2 emissions by 35% or about 2,160 Mt in 2030. This reduction in CO_2 emissions is nearly twice the total generation emissions in Europe in 2010. Even though this scenario would require additional investments of about USD 1,290 billion, the decline in coal consumption would reduce costs by about USD 80 billion annually. In addition, with a CO_2 price of USD 20 per ton emissions, there could be additional annual CO_2 emissions tax savings of about USD 40 billion, leading to a faster payback.



A share of 30% intermittent renewables in power generation would reduce CO_2 emissions by roughly 2,200 Mt

Additional opportunity costs

Apart from the benefits described above, the realization of these scenarios would also create more jobs and raise GDP. Not implementing the scenarios would incur corresponding opportunity costs.

The power generation industry would consume less coal, resulting in reduced pollution and associated costs

In all three scenarios, emissions and pollution levels would be reduced. Air and water pollution have a severe impact on healthcare expenditure, agriculture output and water treatment costs. The cost of pollution in China currently totals about 5.8% of GDP.[26] This could be reduced by adopting the scenarios. China's GDP (purchasing power parity) is expected to reach USD 30 trillion by 2030.[27] Every 1% decrease in the cost of pollution in 2030 would add USD 18 billion to GDP.

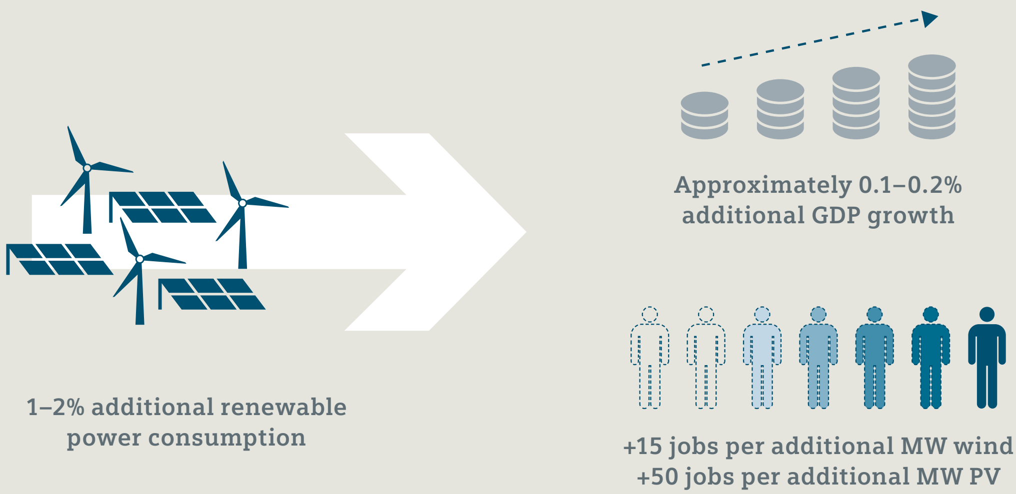
»Investments in renewables would create jobs«

Investments in renewables would not only reduce pollution, but would also have an impact on GDP by increasing manufacturing capabilities. This, in turn, would result in more exports, increase capital formation and fuel job growth. It is estimated that 15 jobs are currently created for every MW of installed wind power, and approximately 50 jobs are created for every MW of installed solar PV power.[28] Furthermore, a strong domestic renewables industry would improve China's trade balance and reduce its energy imports, resulting in higher GDP. The annual growth of renewables by 1–2%, which is assumed in the scenario, would lead to additional annual GDP growth of 0.1–0.2 percentage points.[29]

Sustainable growth while reducing CO_2 intensity would be possible

Given the many benefits in terms of CO_2 emissions, energy security and GDP impact, China could achieve much more than its existing CO_2 intensity targets by adopting the scenarios. The first scenario, in which inefficient power plants are replaced with more efficient ones, involves low investments and is the easiest to implement. However, the coal-to-gas shift scenario offers a higher reduction in emissions. Independently of these two scenarios, the share of renewable power generation should be increased. Implementing these scenarios would help China develop a more efficient and cleaner power sector as well as support its continuing economic growth.

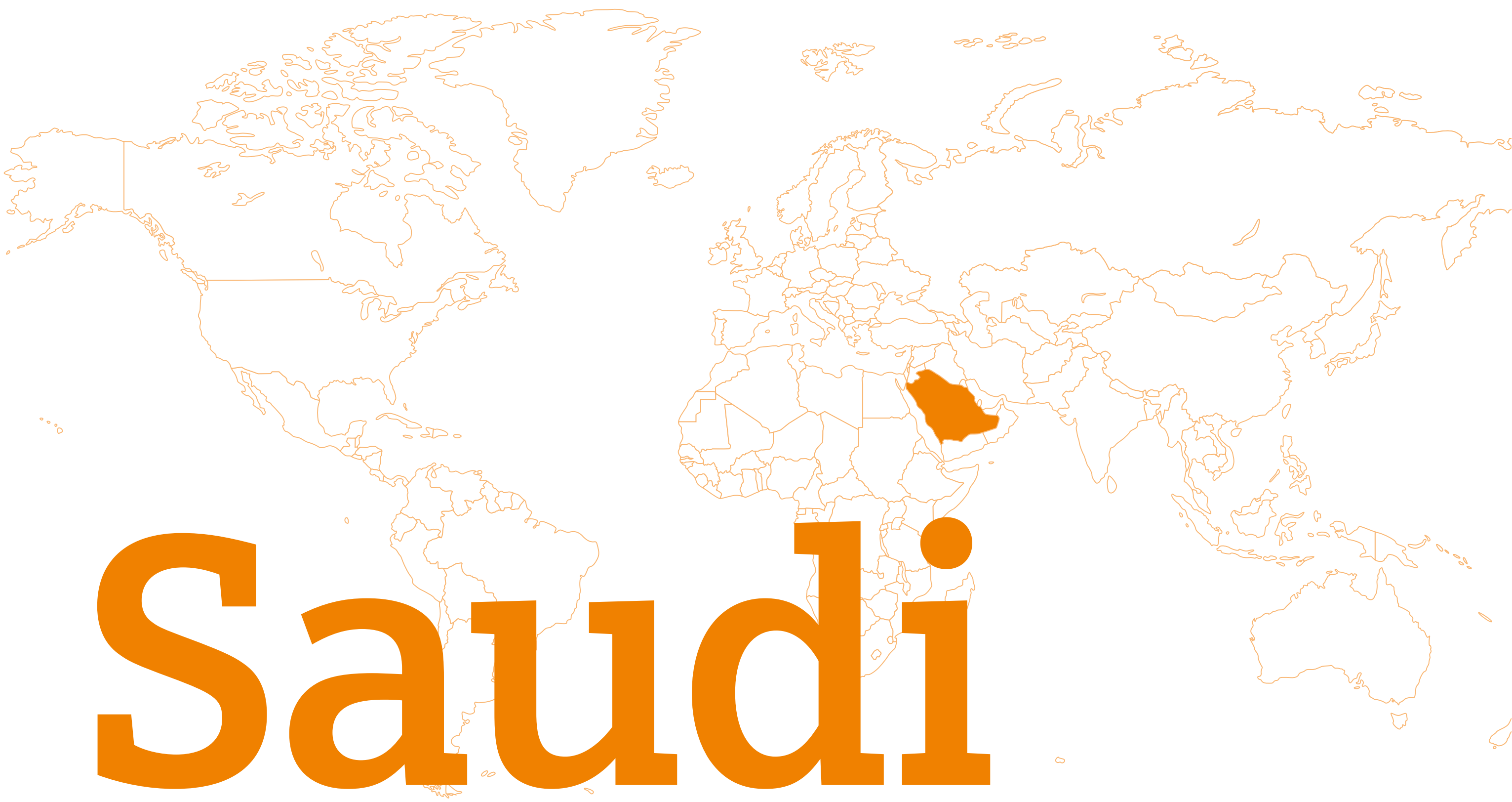
Local example



A 1% increase of renewable power consumption would create additional GDP growth of 0.1%

Footnotes

1 Cf. World Bank (2013b).
2 Cf. IEA (2012 a), (2012b), (2012 c); Global Insight.
3 Cf. World Bank (2013b).
4 Cf. Morrison (2013), p. 1.
5 Cf. IEA (2012b).
6 Cf. IEA (2012b).
7 Cf. Siemens AG (2008).
8 Cf. Tanugi (2010), p. 1f.
9 Cf. Clean Air Asia (2013), p. 3.
10 Cf. KPMG (2011), p. 1f.; Dent (2012), p. 8.
11 Cf. KPMG (2011). (Note: Conversation rate: 1 RMB = 0.16 USD)
12 Cf. IEA (2012b).
13 Cf. EIA (2013e), p. 22.
14 Cf. IEA (2012b).
15 Cf. IEA (2012b).
16 Cf. IEA (2012b); Meisen, Hawkins, p. 4.
17 Cf. IEA (2012e), p. II. 101.
18 Cf. IEA (2012b).
19 Cf. IEA (2013b).
20 Cf. EIA (201 e); IEA (2013b); Worldwatch Institute (2011).
21 Cf. Siemens AG (2008).
22 Cf. Fridley et al. (2012), p. 60f.
23 Cf. Fridley et al. (2012), p. 60.
24 Cf. Siemens Calculation.
25 Cf. IEA (2011a), p. 23.
26 Cf. World Bank (2007), p. XXVII.
27 Cf. PwC (2013), p. 2.
28 Cf. IEA (2011b), p. 27; Renner et al. (2008), p. 114.
29 Cf. Fang (2011).



Saudi Arabia

6

The Kingdom of Saudi Arabia, as a part of the Middle East region, is among the most energy resource-rich countries in the world. With proven oil reserves comprising about one-fifth of the world's total, Saudi Arabia is among the major producers as well as exporters of petroleum liquids.[1] Consequently, the Saudi Arabian economy strongly depends on this industry. Furthermore, the size of proven natural gas reserves in the country is the fifth-largest in a worldwide comparison.[2] Nevertheless, broad gas extraction for export purposes has not yet been a primary national target.[3]

But in line with the growing Saudi Arabian economy and population, domestic energy consumption is sharply increasing. If no optimization measures are taken, experts predict that by 2030, two-thirds of the country's oil production would be required for domestic consumption and export revenues would be hurt significantly.[4] Therefore, optimizing the efficiency of the existing equipment structure and diversifying toward more sustainable alternative non-fossil sources needs to be considered. Even though the Saudi Arabian government is already introducing plans to overcome these challenges, there are still untapped potentials to be realized.

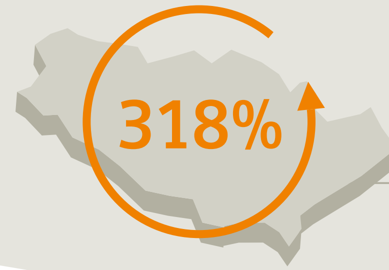
Energy Value Stream Saudi Arabia

(2010) [5]

The Saudi Arabian status quo in terms of the energy market is summarized in the Energy Value Stream. To provide a more detailed insight, the specific perspectives are described below.

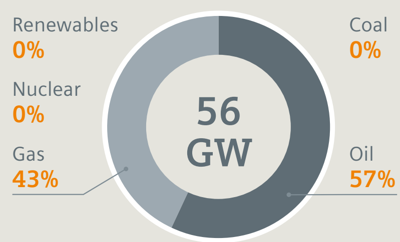
Primary energy

Self-sufficiency

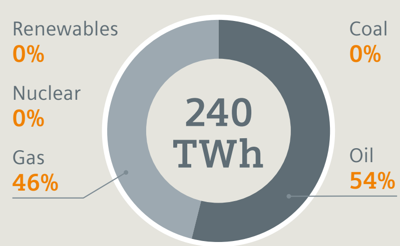


Power

Installed capacity



Power generation



Economy & sustainability

Economic indicator

GDP
(USD current)

USD 628 bn

Calculations based on IEA – WEO 2012; IEA – Energy Balances 2012; The World Bank – World DataBank; ABS Research – T&D Report; Global Insight; Siemens calculations

Indigenous production	Imports	Exports	Energy supply (TPES)
538 Mtoe	10 Mtoe	401 Mtoe	169 Mtoe

Transmission & distribution

T & D losses

9.0%

Grid length

353,000 km

Grid density

0.2 km/km^2

Consumption

Final consumption

196 TWh

Intensity

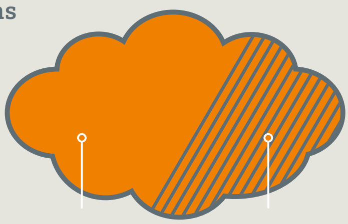
312 kWh per 1,000 USD GDP

Per capita consumption

7,140 kWh per capita

Sustainability

CO_2 emissions



447 Mt
total

183 Mt
share of power sector

CO_2 intensity of power sector

940 g
per kWh

Three perspectives

The economy and sustainability perspective

Due to its abundance of primary energy reserves combined with the growing global demand for energy, Saudi Arabia is experiencing steady economic growth and rising social wealth. In 2010, GDP was roughly USD 630 billion, which translates to a per capita value of approximately USD 30,000. This falls roughly between the Russian and the U.S. levels. The country's GDP grew by more than 5% annually in recent years and growth is expected to continue at this level. Since energy consumption is strongly linked to GDP development, efficiency and sustainability measures are being undertaken by the government. As a result of actions taken so far, the CO_2 intensity of the power generation mix has been steadily lowered toward an specific value of 940 g per kWh consumed.[6]

The primary energy perspective

In 2010, a total of roughly 530 Mtoe in primary energy was produced, with oil and gas accounting for 470 Mtoe and 60 Mtoe, respectively. Gas was produced largely as a byproduct of oil exploration in the past and was sometimes used to maintain the pressure of oil fields through direct re-injections of the gas flow.[7] Solitary gas exploration has only recently been initiated, and gas is now used to partly cover growing domestic demand. Saudi Arabia has a self-sufficiency rate of nearly 320% so far, but as domestic energy consumption escalates, the optimization of oil export volumes will be a major factor in the government strategy to secure export revenues. Along with efficiency improvements, a shift from oil to gas in domestic supply offers potential for this purpose.

The power perspective

One lever for enhancing efficiency is to optimize the energy mix in the power sector and the condition of the country's power plant fleet. So far, power generation is dominated by oil-fired low efficiency steam power plants. These plants account for nearly 60% of Saudi Arabia's total installed capacity. Spurred by efficiency and sustainability targets, the share of gas-fired power plants is already growing. In 2010, over 40% of the country's capacity – which translates to about 24 GW – was fueled with gas, yet not more than 5 GW of that total was generated by combined cycle power plants with a state-of-the-art efficiency level.[8] Altogether, this improved efficiency in power generation to more than 30% in 2010[9], starting from an average of 27% in 1990. The share of oil and gas in power generation, 54% and 46%, respectively, nearly match the share of installed capacity. All in all, roughly 240 TWh were generated by an installed capacity of nearly 60 GW in 2010. When this value is compared to the 180 TWh generated in 2006, the extent of the growing domestic demand is obvious.[10]

Although Saudi Arabia has achieved initial improvements in its power generation efficiency, the country's power grid system – with transmission and distribution losses of roughly 9% or nearly 15 TWh in 2010 – lies below the international efficiency standard. Thus, after deducting grid losses as well as the energy industry's own power use, the total final power consumption is approximately 200 TWh. In a per capita perspective, the amount of more than 7,000 kWh lies roughly one-third above a mid-range value as in Europe.

Current challenges

This situation is leading to Saudi Arabia's energy market challenges. The country's population is growing steadily and some 80% of the approximately 27 million citizens – more than 21 million – already live in urban areas[11] and are accelerating the demand for energy. As a consequence, energy consumption is growing faster than both the population and GDP, pushing up energy intensity. Economic growth is being accompanied by a rising need for energy-intensive air-conditioning as well as water desalination. In addition, the highly subsidized fossil energy and electricity prices in Saudi Arabia encourage wasteful practices and investment decisions that hinder more efficient energy use overall.[12] As a result, Saudi Arabia is the major consumer of petroleum products in the Middle East, particularly regarding use in the power generation and transmission sector. The country's total domestic energy demand is expected to increase from 3.4 million barrels per day of oil equivalent at present to roughly 8.3 million barrels per day of oil equivalent in 2028.[13]

Together with its primary energy consumption, Saudi Arabia's power consumption has also grown sharply over the last five years and is estimated to increase at a similar rate in the future. Roughly half of the produced power is consumed by the growing residential sector.[14]

Diversification by shifting towards non-fossil energy sources

In order to address the rising demand for power generation and preserve oil reserves for economically lucrative export, one challenge is to diversify the country's power generation mix. Most of the power is currently produced by inefficient oil-fired power plants. Well aware of this problem, various Saudi Arabian institutions have introduced plans aimed at increasing the share of non-fossil power generation plants. For example, the scientific think-tank K.A.CARE has set the goal of meeting nearly half of the country's power needs with non-fossil sources within this decade. K.A.CARE intends to more than double its installed capacity by adding approximately 50 GW from renewables by 2020 and 20 GW from nuclear power plants by 2032.[15] In order to integrate these additional capacities, the country's regionally separated power grids need to be connected to one another by expanding the transmission grid infrastructure.[16]

Raising efficiency and tapping vast domestic gas resources

By diversifying towards a larger share of non-fossil power generation fuels, the growing rate of domestic oil consumption could be flattened. This is necessary in view of estimates that, by maintaining its current course, Saudi Arabia could turn from an oil-exporting to a net oil-importing nation within the next decades.[17] In order to maintain its oil exporting status, the country must reduce its current rate of oil consumption. To achieve this, the efficiency of the existing oil-fired power plant fleet needs to be improved. An even more sensible measure would be to use domestic gas resources to produce power more efficiently and sustainably in gas-fired combined cycle power plants.[18] Saudi Arabia's conventional gas reserves of 8.2 Tcm equal roughly 7,400 Mtoe and would provide fuel for operating 100 GW of gas-fired combined cycle power plants for about 100 years.[19]

In summary, Saudi Arabia faces the challenge of covering its growing energy demand while simultaneously being economically dependent on exporting its fossil energy sources. It is therefore necessary to increase the country's energy efficiency and diversify the energy mix in power generation.

Scenarios for optimization

The future scenarios define various measures for the specific challenges in the Saudi Arabian energy market. They describe the economic and environmental savings that could be achieved by increasing the efficiency of the existing power plant fleet or shifting from oil to gas and towards non-fossil energy.

Scenario 1:

Increasing the efficiency of oil-fired power plants

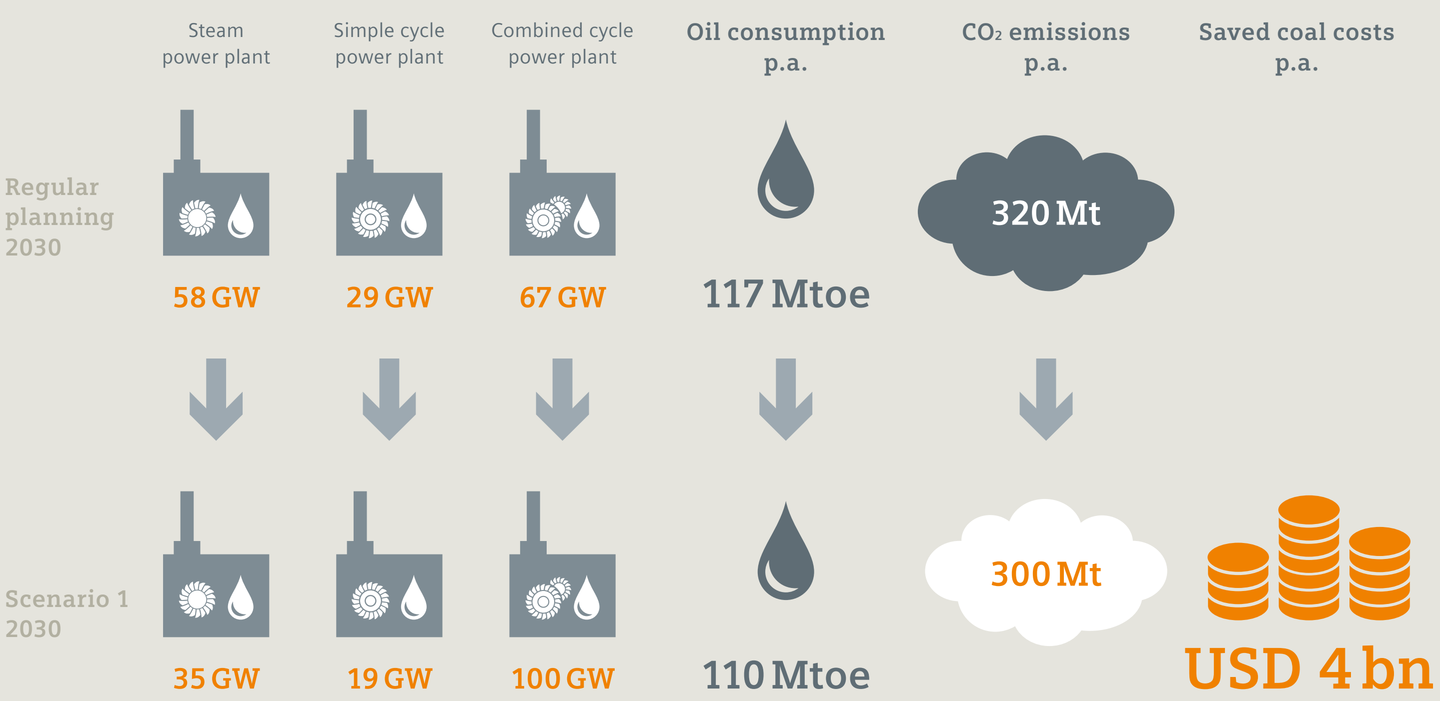
As mentioned in the challenges above, oil is highly valued as a Saudi Arabian export. The first scenario therefore addresses the power plant efficiency challenge by assuming a modernization of the existing oil-fired power plant fleet:

»Replacement of steam power plants by efficient combined cycle power plants and conversion of existing simple cycle power plants to combined cycle power plants in the oil-fired power generation sector by 2030.«

In this scenario, compared with regular planning estimates, roughly 23 GW of planned low efficiency oil-fired steam power plants are assumed to be replaced by more efficient combined cycle plants. As a result, the total remaining capacity of steam power plants would be 35 GW instead of the originally planned 58 GW in 2030. In addition, a capacity of 10 GW of inefficient oil-fired simple cycle power plants ought to be converted to highly efficient combined cycle plants. This would reduce the installed simple cycle capacity from 29 GW in the baseline scenario to roughly 19 GW. Due to the higher efficiency of combined cycle technologies, the following potentials could be realized, compared to the regular planning case.[20]

7 million tonnes of oil equivalent could be saved annually from 2030 onwards

The assumed scenario would offer huge potentials in terms of the domestic energy demand. By shifting the generation mix to more efficient power plants in the oil-fired sector, roughly 7 Mtoe of oil could be saved annually from 2030 onwards. From an exporting price perspective, this would be worth about USD 4 billion in annual fuel savings compared to the planning case. In addition, the initial investments would be roughly USD 17 billion lower than the alternative planning case solution, due to the lower specific investments for combined cycle rather than steam power plants.[21] As a positive side effect, the increase in power plant efficiency would also allow the country to realize potentials regarding sustainability. The suggested solution would reduce CO_2 emissions by more than 20 Mt annually. And although this scenario already offers significant improvements, Saudi Arabia could realize even higher potentials by shifting its power generation mix towards a higher share of gas-fired technologies.



The improvement of inefficient oil-fired power plants would save USD 4 bn in oil costs annually

Scenario 2:

Oil-to-gas shift

In this scenario, a shift towards a more efficient and sustainable primary energy carrier for power generation is assumed. In contrast to the first scenario, this one assumes a replacement of all inefficient oil-fired power plants by highly efficient gas-fired plants:

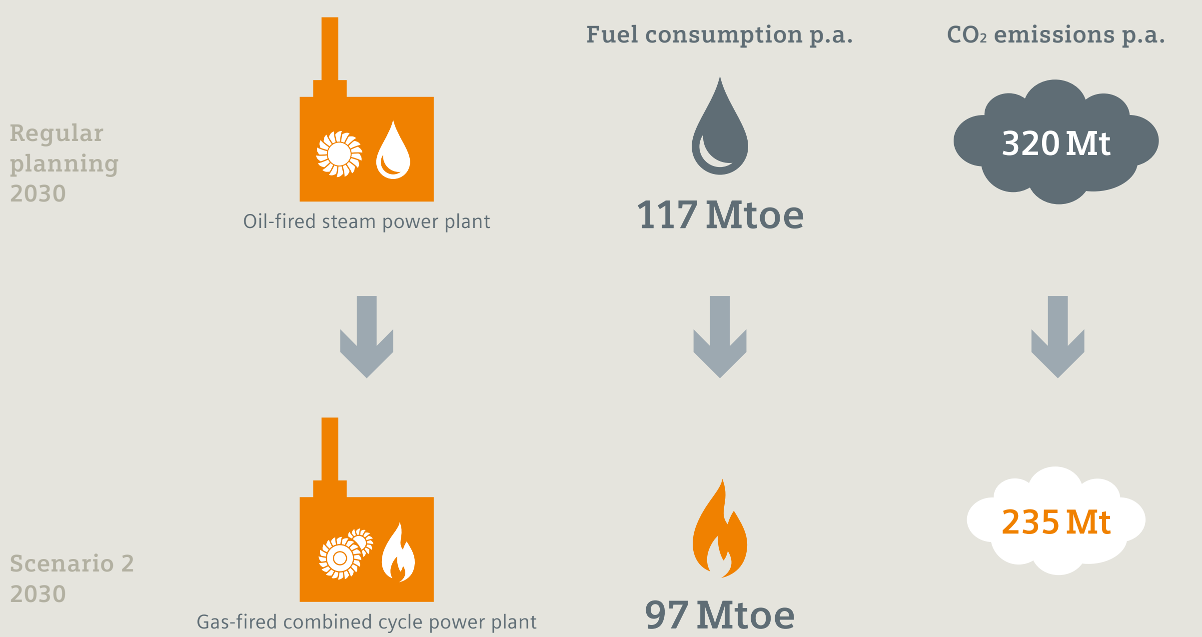
»Shift of all oil-fired steam power plants to gas-fired combined cycle power plants by 2030.«

Compared to the planning case, roughly 40 GW of steam power plants would be replaced by more efficient gas-fired combined cycle plants. In this scenario, the amount of generated power would remain constant at roughly 630 TWh in 2030. The total installed capacity, however, would decline by nearly 10 GW to a total of approximately 180 GW in 2030, due to the higher availability and load factors of the installed combined cycle plants. The scenario would allow the country to realize potentials in sustainability as well as in efficiency.

20 million tonnes of oil equivalent could be saved annually from 2030 onwards

The oil-to-gas shift scenario could be a very efficient path in terms of a future energy mix. It would enable the country to achieve oil savings of more than 42 Mtoe while gas consumption would increase by roughly 22 Mtoe, due to the higher efficiency of combined cycle power plants. The annual net savings of approximately 20 Mtoe could thus increase Saudi Arabia's export balance by roughly USD 18 billion each year, starting from 2030. Compared to the regular planning, initial capital expenditures could be reduced by roughly USD 18 billion, which is even better than in the first scenario. In addition, annual savings for fuel costs are more than four times higher. Besides providing economic benefits, the scenario would also achieve vast CO_2 emission savings that would total more than 85 Mt annually in 2030, compared to the planning case.

Due to the comparable low share of non-fossil power generation in Saudi Arabia, there are still untapped potentials within this sector. Those will be considered in the third scenario.



The oil-to-gas shift would lead to 85 Mt CO_2 savings from 2030 onwards

Scenario 3:

Increasing the share of non-fossil power generation

In regard to saving fossil fuels while satisfying the country's growing total power demand, the third scenario assumes an increased installation of renewable and nuclear capacities.

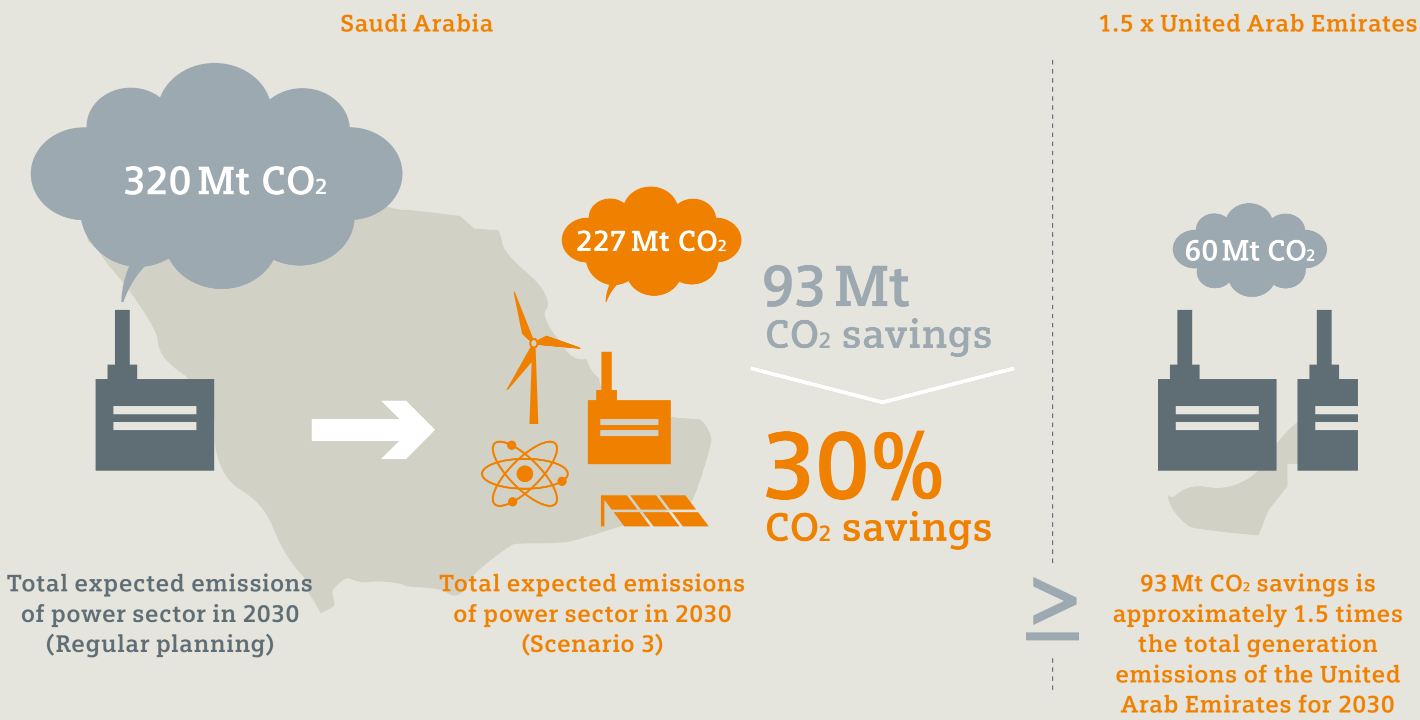
»Shift towards non-fossil energy by increasing the share of renewable and nuclear power plants by 2030.«

Compared to the general plans of the various Saudi Arabian energy market stakeholders, this scenario assumes an extensive expansion of renewable and nuclear power generation capacity by 2030. Compared to the planning case, the share of renewable power generation is assumed to nearly double from 10% to 20%, while the share of nuclear power generation is assumed to increase from 8% to 16% by 2030. This would require additional capacities of solar plants (photovoltaic and concentrated solar power) of about 13 GW and of wind plants of roughly 9 GW compared to the reference case. For nuclear power, an installed capacity of 15 GW instead of 7.5 GW in the regular planning case is assumed to be commissioned by 2030.[22]

30 million tonnes of oil equivalent could be saved annually from 2030 onwards

Reducing the use of fossil primary energy carriers by implementing the assumed scenario would diversify Saudi Arabia's energy mix and increase the country's oil export balance by roughly 30 Mtoe in 2030, compared to the planning case. These exports would account for approximately USD 16 billion a year. Due to the considerably lower specific emissions in this scenario, more than 90 Mt of CO_2 emissions would be saved annually from 2030 onwards. This value is approximately 1.5 times the estimated total of CO_2 emissions for power generation in the neighboring country of the United Arab Emirates for 2030.[23]

Even though the annual financial as well as environmental savings are high compared to the first two scenarios, this scenario would require a higher initial investment of roughly USD 46 billion in order to be realized. Saudi Arabia's policymakers therefore need to carefully consider these scenarios and decide on the country's future energy mix in the power sector based on an overall energy perspective.



The increased share of non-fossil power generation would reduce CO_2 emissions by roughly 93 Mt from 2030 onwards

Additional opportunity costs

To handle the country's challenges, the above-mentioned scenarios are possible solutions for the energy market. In addition to the direct potentials, such as lower CO_2 emissions, reduced primary energy input and other financial savings, the assumed measures would also prevent additional opportunity costs.

Missed industry development

By investing in alternative renewable technologies, Saudi Arabia could diversify its risk of being strongly dependent on the oil industry. This would not only save primary energy but also build up a comprehensive service industry for renewables. Even though it is likely that most of the power generation technology would be imported, there would still be positive effects on GDP, such as from a growing maintenance industry. This, in turn, would develop human capital value through know-how transfers to Saudi Arabia, and generate additional jobs and higher GDP.

Highly subsidized energy prices

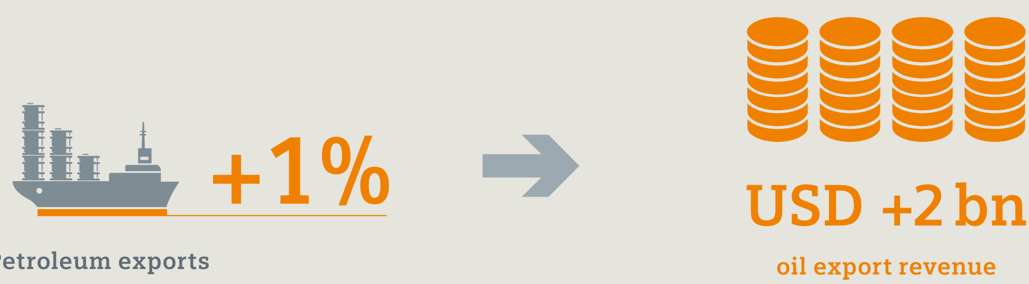
Besides the possible effects from building up an alternative energy sector, positive effects could also be derived from savings in terms of subsidized energy in Saudi Arabia. The rapid growth in domestic energy consumption with highly subsidized end-user prices, which are much lower than world energy prices, implies growth in the cost of subsidizing domestic consumption. This equals opportunity costs in terms of the difference between domestic sale prices and average export prices.[24] In 2010, Saudi Arabia spent roughly USD 45 billion for oil as well as power subsidization. This equals roughly 10% of the country's GDP.[25] With domestic energy prices being significantly lower than the international level, prevention of wasteful consumption is not sufficiently incentivized. This is one reason for Saudi Arabia consuming more oil than Germany, even though its population is only one-third as big.[26] If domestic consumption could be reduced by 1%, this would result in annual savings of USD 450 million through reduced annual subsidies spendings.

Due to its strong dependency on oil exports and rising domestic energy consumption, Saudi Arabia needs to focus on handling its energy resources in a more efficient manner. This regional study therefore suggests three possible solutions for overcoming these challenges: modernizing the existing inefficient oil-fired power generation fleet, shifting the country's power generation mix towards a larger share of gas-fired plants, and increasing the share of renewable power generation. All three scenarios would allow the country to realize considerable economic and ecologic potentials as well as prevent additional opportunity costs. In order to realize these potentials, Saudi Arabia's policymakers need to coordinate their efforts and act in time.

Local example

A reduction of 1% in the domestic primary energy consumption would lead to roughly USD 450 million reduced annual subsidies spendings

Local example



An increase of 1% in today's Saudi Arabian petroleum exports would increase oil export revenue by more than USD 2 bn

Footnotes

[1] Cf. EIA (2013c).
[2] Cf. EIA (2013c), p. 10.
[3] Cf. EIA (2013c), p. 10.
[4] Cf. Lahn, Stevens (2011), p. 2.
[5] Cf. IEA (2012a), (2012b), (2012 e); Global Insight; World Bank (2013a).
[6] Cf. ABB (2011), p. 3; IEA (2012e).
[7] Cf. EIA (2013c), p. 10.
[8] Cf. Siemens Calculation.
[9] Cf. Alyousef, Abu-ebid (2012).
[10] Cf. EIA (2013c), p. 13; World Bank (2013 a).
[11] Cf. Siemens Calculation; Sharif (2013).
[12] Cf. IEA (2012d); Belschner (2012), p. 52; Lahn, Stevens (2011).
[13] Cf. Khalid A. Al-Falih (2010).
[14] Cf. IEA (2012e).
[15] Cf. EIA (2013c), p. 13; KACARE (2013).
[16] Cf. Moussa (2010).
[17] Cf. Lahn, Stevens (2011), p. 2.
[18] Cf. Alyousef, Abu-ebid (2012), p. 304.
[19] Cf. BP (2013).
[20] Cf. Siemens Calculation.
[21] Cf. Siemens Calculation.
[22] Cf. Siemens Calculation.
[23] Cf. Siemens Calculation.
[24] Cf. IEA (2012d); Belschner (2012).
[25] Cf. IEA (2012d).
[26] Cf. Belschner (2012), p. 56.

Republic of Korea

7 Due to its limited domestic energy resources, the country is heavily dependent on primary energy imports. The country consumed more than 680 million barrels of oil and 43.2 billion cubic meters of gas in 2011,[1] partly due to its huge and advanced refinery industries. More than 85% of the country's primary energy imports come from the Middle East,[2] and this dependency is the major challenge faced by the Korean energy market.[3] Greater independence of imports could be achieved by intensifying the development and integration of renewable energy sources and further expanding nuclear sources. However, the country's share of renewable sources in its overall primary energy supply is the lowest of all OECD countries, while its nuclear share lies above the OECD average.[4] Consequently, improvement potentials exist that should be tapped to strengthen the economy overall and secure the country's energy supply for the future.

Energy Value Stream Republic of Korea

(2010) [5]

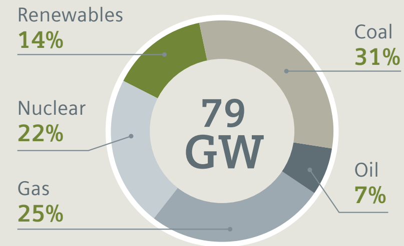
The EVS illustrates the status quo of the Korean energy market, concerning primary energy, power and economy as well as sustainability indicators, which are the basis for identifying the current challenges.

Primary energy

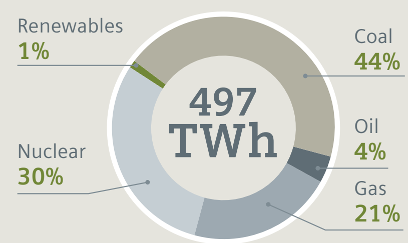
Self-sufficiency

Power

Installed capacity



Power generation



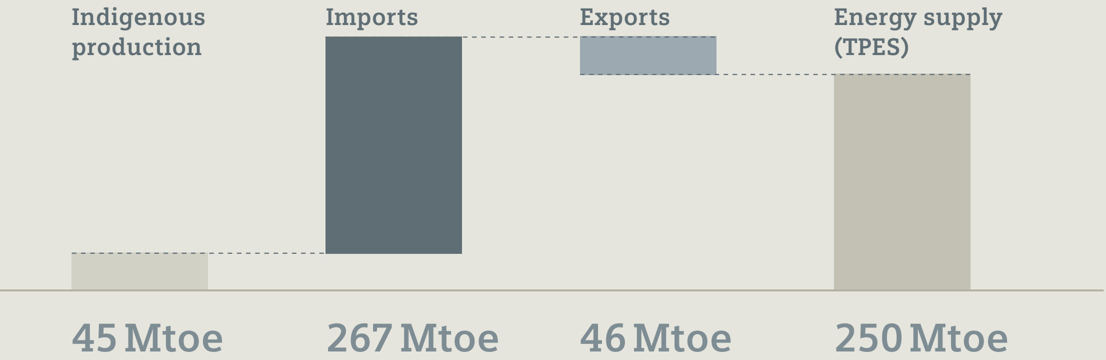
Economy & sustainability

Economic indicator

GDP (USD current)

USD 1,067 bn

Calculations based on: IEA – The Republic of Korea 2012; ABS Research – T&D Report; Global Insight; Siemens calculations



Transmission & distribution

T & D losses

3.6%

Grid length

1.7 million km

Grid density

17.0 km/km²

Consumption

Final consumption

449 TWh

Intensity

421 kWh per 1,000 USD GDP

Per capita consumption

9,186 kWh per capita

Sustainability

CO_2 emissions

563 Mt total

279 Mt share of power sector

CO_2 intensity of power sector

620 g per kWh

Three perspectives

The economy and sustainability perspective

In 2010 the Republic of Korea generated a nominal GDP of over USD 1,000 billion,[6] which translated to a per capita GDP of more than USD 21,800. This was roughly only 10% lower than the OECD average in 2010.[7] The CO_2 intensity in power generation is comparably high. In fact, the CO_2 emissions rate of 620 g per kWh is higher than the U.S. rate. However, the Korean government is committed to cutting CO_2 emissions and is therefore aiming to reduce all greenhouse gas emissions by 30% by 2020, compared to its business-as-usual case, and has included this target in its strategy for »Green Growth.«[8]

The primary energy perspective

The Republic of Korea is highly dependent on energy imports, which is reflected by the country's low energy self-sufficiency rate of less than 20%. In 2010, domestic primary energy production of less than 45 Mtoe provided only a small share of the total primary energy supply of 250 Mtoe. Furthermore, primary energy imports account for more than 90% of the primary energy consumption in the Republic of Korea. This high percentage is due to the negligible domestic resources, the high energy demand of the country's refinery industry, and the minimal contribution of renewable sources. To secure its energy supply, the Republic of Korea is ambitiously seeking overseas production as well as exploring opportunities for primary energy, and is planning to increase the share of nuclear power in the near future.[9]

The power perspective

The most basic way to secure the country's energy supply is to increase the efficiency and productivity of the power industry.[10] However, Korean power generation already had a high efficiency of approximately 38% in 2010.[11] The country's power grid, which is comparably modern, has losses of less than 4%, which is better than the average loss rate of the European grid.[12] Nevertheless, due to the continuously growing demand for power, further improvement in the efficiency of power generation and power consumption would improve Korea's independency.[13]

In 2010, a total capacity of 79 GW was installed in the Republic of Korea, consisting mainly of coal-fired, gas-fired and nuclear power plants. The high share of nuclear capacity in the country's generation mix supports the aim of providing affordable power, due to efficient operation and low-cost construction.[14] Although the installed capacity of renewable energy corresponds to roughly 15% of the total capacity, the government plans to invest more than USD 8 billion in offshore wind farms in order to reach a wind capacity of 2.5 GW by 2019, up from a mere 0.3 GW in 2008.[15]

Currently only 1% of the country's power is generated by renewable sources. The biggest contributors to the power supply are gas, nuclear and coal, in that order. To further secure the energy supply and to become more independent from primary energy imports, power generation has to become even more efficient and renewable and nuclear sources have to be integrated in the power generation mix. The Korean government has initiated several projects for energy independency, showing that this target can be realized in the future. Songdo (Incheon) Eco-City – an integrated residential and industrial »Free Economic Zone« north of Seoul – is the most famous project in this regard. The project is a model of self-sufficient sustainability and serves as a center for the development of green technologies.[16]

Current challenges

To foster its energy independency, the first goal of the national strategy for »Green Growth« is to develop the extensive use of alternative energy technologies. The integration of renewable energies in the existing mix is a key challenge for the Korean energy market, and is the result of a trade-off between the need for independence and the need for flexibility and reliability. Aggravating the situation, the country's power stability over the long term remains a major concern in the Republic of Korea. Due to its low system reserves, the Republic of Korea faces possible shortages and potential blackouts.[17]

Liberalization of the energy market

To avoid blackouts and increase energy independence, private investments in the energy market are necessary. However, power prices are currently frozen by the government to protect consumers and support ongoing economic growth. The tariff system does not reflect the true costs of generation and distribution and also does not provide incentives for private investments in the infrastructure or for efficient electricity consumption. Centralized government control of the energy market and direct intervention in operation and investment decisions can often lead to competitive distortions of prices, inefficient operations and an inadequate generation infrastructure. New private investors would stimulate competition in the energy market, which in turn would benefit households and industry.[18]

Market liberalization is a key goal of the Korean government. Nevertheless, efforts in this direction are currently halted and there has been no commitment to a timeline as yet.[19] A change in the power and energy markets will require considerable commitment on the part of the Korean government, and strong support with a clear legislative framework. Accordingly, the Korean government should prepare a detailed program for an energy market reform, including a clear timeline and milestones.[20]

In summary, the country's energy market has to be liberalized and must reduce its dependency on primary energy imports by increasing the share of renewables and nuclear power generation. At the same time, the flexibility, availability and sustainability of the country's power generation must be improved.

Scenarios for optimization

Optimization scenarios have been calculated to address the specific Korean challenges and present options for the country's energy market. In the first scenario, a coal-to-gas shift is assumed, while in the second scenario the share of renewable and nuclear power generation is assumed to increase up to 2030.

Scenario 1:

Coal-to-gas shift

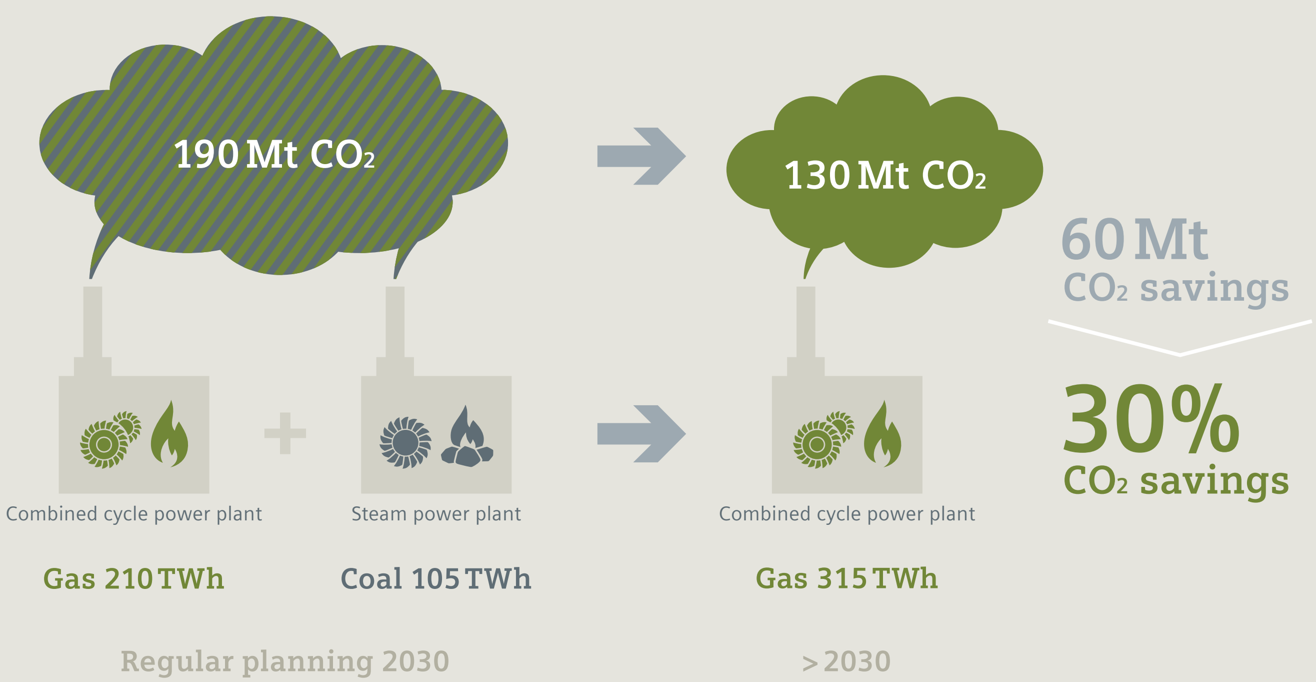
The first scenario assumes an improvement of the country's power generation sustainability, according to Korean strategy, by shifting the primary energy carrier from coal to gas. Therefore, a consecutive and complete coal-to-gas shift is assumed in the following scenario:

»All coal-fired power plants will consecutively be replaced by modern and flexible combined cycle gas-fired power plants by 2030.«

According to current estimations, approximately 50 GW of combined cycle capacity will be installed in 2030, while the capacity of steam power plants, mainly fired by coal, is estimated at 25 GW. Assuming a constant power generation of approximately 670 TWh in 2030, roughly 315 TWh of the total would be generated by gas in 2030, while coal would no longer be used for generation.[21]

60 million tonnes CO_2 could be saved annually from 2030 onwards

The lower specific emissions of gas and the higher efficiency of combined cycle power plants compared to steam power plants would reduce CO_2 emissions in power generation by 60 Mt CO_2 annually from 2030 onwards. The regular planning case estimates the total CO_2 emissions of the power sector in 2030 to be roughly 190 Mt. In contrast, a consequent coal-to-gas shift would reduce this total to approximately 130 Mt. Furthermore, due to the higher efficiency of combined cycle power plants, the country's power could be generated with approximately 10 Mtoe less primary energy input annually, compared to the regular planning. Installation of new combined cycle power plants would lead to higher investments of USD 18 billion by 2030 compared to the baseline scenario.



The coal-to-gas shift would lead to 60 Mt CO_2 savings from 2030 onwards

Scenario 2:

Increase renewable and nuclear power generation

The second scenario assumes an increased share of renewable and nuclear power plants in the country's power generation. The scenario can be summarized as follows:

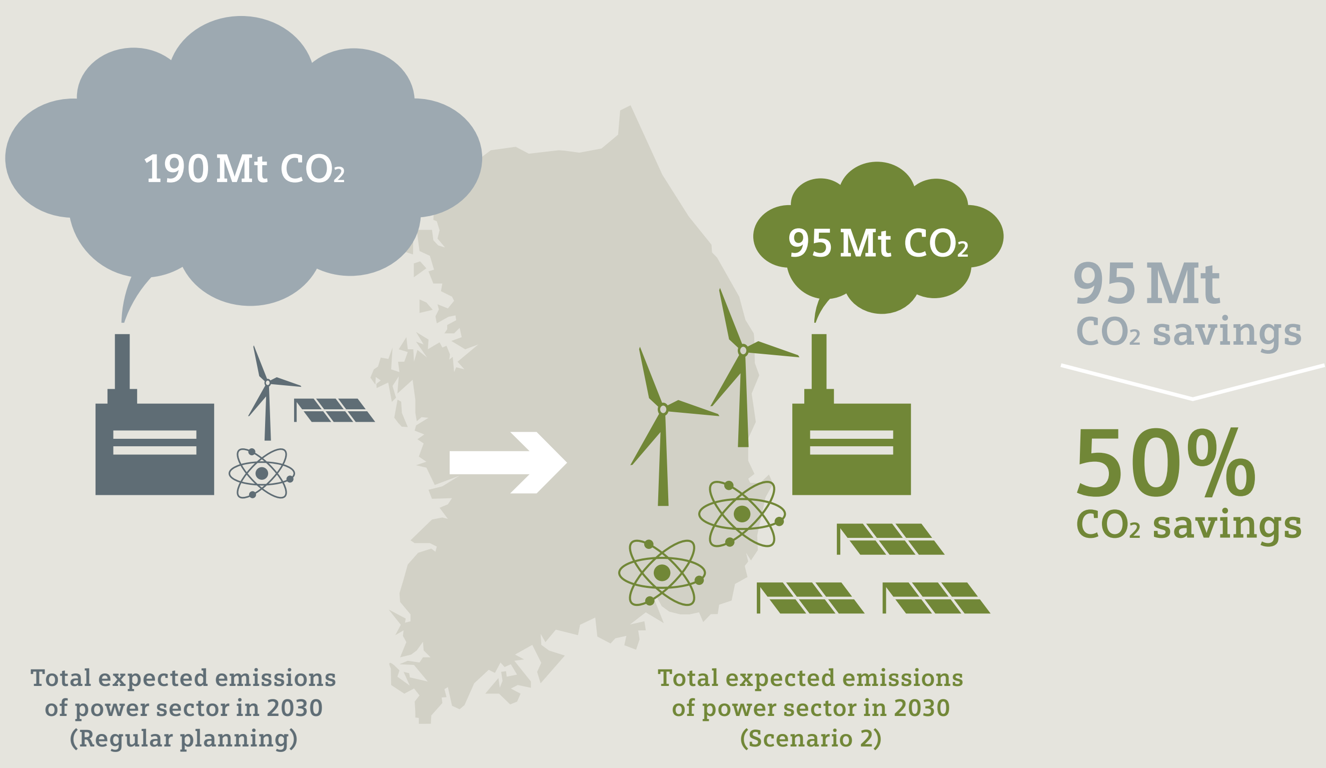
»Shift towards non-fossil energy by increasing the share of renewable and nuclear power plants by 2030.«

By 2030, regular planning assumes over 30 GW of nuclear capacity and more than 20 GW of renewable capacity, without hydro in the Republic of Korea. Analog to the first scenario, the main assumption is that the generated power in 2030 will remain constant. Thereby, the assumed enhanced development of renewable and nuclear power plants would replace inefficient coal-fired steam power plants, while gas-fired combined cycle power plants would remain as estimated in the regular planning. Therefore, the installed capacity in this second scenario would mainly consist of 38 GW of renewables excluding hydro, 40 GW of nuclear power, and 48 GW from combined cycle power plants.

95 million tonnes CO_2 could be saved annually from 2030 onwards

Realizing this scenario would reduce the primary energy demand for power generation by more than 20 Mtoe annually. Due to Korea's high dependency on primary energy imports, reducing the country's primary energy input is imperative. Furthermore, the enhanced installation of carbon-free power generation technologies in the Republic of Korea would slash CO_2 emissions by roughly 95 Mt. This would equal nearly one-sixth of energy-related CO_2 emissions in the Republic of Korea in 2030 and would support the government's CO_2 emission targets.

To realize this ambitious scenario, investments in new renewable capacities and nuclear power plants would be necessary. The cumulative investments for new plant construction are approximately USD 65 billion higher than in the regular planning case. Nevertheless, these additional investments would have a fast payback time due to reduced dependency and import balances.



The enhanced installation of renewables and nuclear power plants would lead to 95 Mt CO_2 savings annually from 2030 onwards, compared to the regular planning

Additional opportunity costs

Summarizing the results of the calculation, the scenarios would have a positive impact on the country's energy independency and on economical as well as environmental indicators. These scenarios should therefore be supported, otherwise opportunity costs could accrue.

The Republic of Korea as the world leader in the green global market

The Republic of Korea plans to increase its share of renewables and is promoting the following technologies to encourage ecofriendly energy consumption: high-efficiency photovoltaic cells, fuel cells, advanced nuclear power, green cars, smart grid, advanced carbon capture and storage, water treatment, rechargeable batteries, light emitting diodes as well as green IT. These goods and services are intended to become the basis for making the country a world leader in the green market. This would generate additional job growth, export revenues and economic growth.[22] In addition, this expansion in the green industry would fuel further growth in other industry sectors due to the multiplier effect. The initial successes here are already visible. Since 2008, the sales of green technologies have increased more than six-fold, while exports and investments by private investors have grown roughly five-fold.[23] As a result of these developments, the »Industry Food Chain« and domestic value-added of Korean businesses was affected positively. Employment in the green industry is expected to grow by an additional 110,000 jobs by 2015, while export revenues are anticipated to reach over USD 35 billion by 2015.[24]

The Republic of Korea has also been very effective in developing a strong nuclear industry, with high levels of availability and reliability, making it one of the world leaders in efficient operation and low-cost construction. This excellent performance has led to the first nuclear power plant sales to the United Arab Emirates and the sale of a research reactor to Jordan. This development would be strengthened by an increased domestic use of these technologies, and further stimulate industry growth.[25] The Republic of Korea could therefore benefit from an increased use of renewables and nuclear energy through the multiplier effect.

»Efficiency is essential in regard of the high import dependency«

Energy efficiency measures could increase the country's energy independency, which is one focus of the national strategy. If efficiency is not promoted, the costs for energy would increase due to the economy's growing energy demand and the lack of connections with an international pipeline grid. The huge Korean refinery industry, in particular, would suffer from rising prices for primary energy, and may lose its competitiveness. At present, this industry is among the most competitive players in the global petroleum processing market.[26] In 2011, Korea's refinery industry processed approximately 1,000 million barrels of crude oil, making it the sixth-largest refinery industry in the world.[27] In the same year, exports from this sector accounted for nearly 10% of the total by the Republic of Korea. Inefficiencies in the use of energy could lead to disadvantages for the refinery industry.[28] If the export revenues of the refinery sector decline by 1%, this would equal about USD 500 million.

Independency and affordability of energy as an enabler for the economy

The main target of the Korean government's energy policy is to achieve greater independency from energy imports. As a consequence, the strategy for »Green Growth« supports the utilization of new and renewable energy sources. Nevertheless, these changes have to be realized without adversely impacting energy affordability. To provide affordable energy, the Republic of Korea should additionally focus on efficiency measures throughout the economy and especially in power generation. This would strengthen the Korean economy over the long term.

Footnotes

1 Cf. IEA (2012f), p. 51ff.
2 Cf. EIA (2013d), p. 1ff.
3 Cf. Heshmati (2013), p. 58.
4 Cf. IEA (2012f), p. 10.
5 Cf. IEA (2012f).
6 Cf. Tanugi (2010), p. 1f.
7 Cf. OECD (2013), p. 21.
8 Cf. IEA (2012f), p. 9.
9 Cf. IEA (2012f), p. 10.
10 Cf. Heshmati (2013), p. 58.
11 Cf. ABB (2012), p. 4.
12 Cf. IEA (2012f), p. 82.
13 Cf. Heshmati et al. (2013), p. 3.
14 Cf. IEA (2012f), p. 10.
15 Cf. EIA (2013d), p. 11.
16 Cf. Songdo IBD (2013).
17 Cf. IEA (2012f), p. 25.
18 Cf. IEA (2012f), p. 12.
19 Cf. Heshmati (2013), p. 60.
20 Cf. IEA (2012f), p. 12.
21 Cf. Siemens Calculation
22 Cf. Zelenovskaya (2012), p. 4.
23 Cf. Zelenovskaya (2012), p. 5.
24 Cf. Zelenovskaya (2012), p. 5.
25 Cf. IEA (2012f), p. 11.
26 Cf. Kang, Bae (2012), p. 1.
27 Cf. IEA (2012f), p. 69.
28 Cf. Kang, Bae (2012), p. 2.

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Abbreviations

bn	billion
CERA	Cambridge Energy Research Association
CO_2	Carbon dioxide
DC	Direct current
EU	European Union
EVS	Energy Value Stream
GDP	Gross Domestic Product
Gt	gigatonnes
GW	gigawatt
IEA	International Energy Agency
K.A.CARE	King Abdullah City for Atomic and Renewable Energy
kW	kilowatt
kWh	kilowatt-hour
MBtu	million British thermal units
Mt	million tonnes
Mtoe	milion tonnes of oil equivalent
MWh	megawatt-hour
OECD	Organisation for Economic Co-operation and Development
p.a.	per annum
PV	Photovoltaic
SAIDI	System Average Interruption Duration Index
T&D	Transmission and Distribution
Tcm	trillion cubic metres
TPES	total primary energy supply
TW	terrawatt
TWh	terrawatt-hour
WEO	World Energy Outlook