国家发展和改革委员会
能源研究所
Energy Reform Institute NDRC.P.R.C

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国家可再生能源中心
CHINA NATIONAL RENEWABLE ENERGY CENTRE

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CHILDREN'S INVESTMENT FUND FOUNDATION

Energy Transition Trends 2018

China, Europe, USA

Implementing Unit

国家发展和改革委员会 能源研究所 Energy Reform Institute NDRC.P.R.C

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Ea Energy Analyses

ENERGINET

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Foreword

China National Renewable Energy Centre, The Danish Energy Agency and Energinet in Denmark, GIZ, the German Energy Agency (dena) and Agora Energiewende in Germany, and the US National Renewable Energy Laboratory (NREL) cooperate in a large program "Boosting RE in China". The aim is to provide China with the most recent international experiences on energy transition and to develop long-term energy system scenarios for the transition to a low-carbon, clean and efficient energy system in China.

This report is developed by the program partners to give a snapshot of the energy transition trends for three of the largest energy consumers in the world: China, Europe and United States of America, to give the reader insight in the visions, possibilities and challenges in the on-going energy transition for the three regions.

The challenges associated with a transition to a low-carbon energy sector are becoming better defined, with solutions for many already identified. While economic, political and social differences exist among all nations, core technical, physical and business-based solutions appear to be consistent and broadly applicable. Institutional coordination among countries to share these innovations and lessons learned can bolster global progress in the energy transition.

More information about the Boosting RE in China program and the energy transition in China is available at the web site: www.boostre.cnrec.org.

International Trends in Energy Transition

Global warming affects all countries and can only be tackled in a conjoint international effort. The Paris agreement is considered to be a crucial milestone in the fight against climate change. For the first time, virtually all countries acknowledged that the threat of global warming is real and commonly agreed on "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels." More and more countries have published their national GHG reduction targets in order to reach this goal.

Figure 1: Overview of key countries' GHG reduction targets

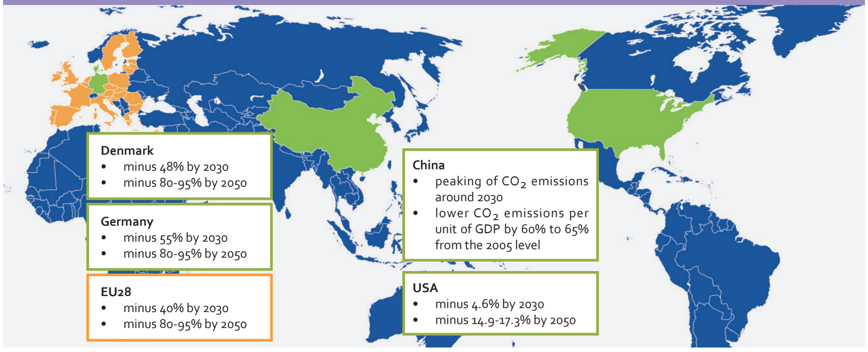


Figure 1
The data shown in the graphic are based on either Nationally Determined Contributions (NDCs) submitted to the United Nations (UN) or, in the case of Denmark and Germany, additional national targets. Unless stated otherwise, the base year for all targets is 1990. In order to allow for comparability, for the U.S., official NDC targets with base year 2005 have been converted to a base year 1990 using data from the Environmental Protection Agency (EPA). The Danish GHG reduction target for 2030 is based upon the preliminary Danish non-ETS reduction target of 39% compared to the 2005 level and is not an official Danish target.

Key Elements for A Successful Energy Transition Worldwide:

- International exchange of experiences and mutual learning
- Clear long-term vision, elaborated and regularly revised mid-term targets and flexible mind-sets for short-term adjustments

In addition, in the past years many countries have initiated a transition of their energy systems towards a more sustainable energy supply based on renewable energies (RE). The transition of the Chinese energy system should therefore be seen in the context of similar developments around the world. The paths all these countries have undertaken so far vary and depend on a number of variables, e.g. on their time and point of start, their geographical location or their political and societal setting. The following case studies shall illustrate this variety.

The European Union as the world's biggest market is a leading global player and a strong advocate for the fight against climate change. Denmark is widely considered a pioneer when it comes to RE, particularly wind energy, and the transition of its electricity and heating system. Germany, as Europe's biggest economy and most populous country, is a particularly good example of a highly industrialised nation that aims at decarbonising its economy. Last but not least, the United States of America (USA), being a vast territorial state with a complex political system, sets another example for the wide variety of the aforementioned variables.

What they all have in common is the experience to be acting in a highly dynamic and internationally intertwined context while transforming their energy systems from a rather centralised approach with continuous energy generation based on fossil fuels to a more decentralised system with fluctuating energy generation from thousands of energy production facilities (wind, solar, biomass etc.). This requires that politics and regulation are governed by a clear long-term vision, with elaborated and regularly revised mid-term targets and continuous concrete adjustment steps on a short-term basis.

1. China

Economic Development Link with Ecological Civilization

China continues to increase policy attention to environmental improvement and clean energy. During the 19th Party's Congress in October 2017, China announced a Two-Centenary-Goals, to finish building a moderately prosperous society in all aspects by 2035, and establish a Socialism Modernization Country which is prosperous, democratic, civilized and harmonious by 2050. The 13th Five-Year Plan for Economic and Social Development also emphasized a continued commitment to "the Four-Pronged-Comprehensive Strategy" and to promote balanced economic, political, cultural, social and ecological progress.

"Four-Pronged Comprehensive Strategy" refers to making comprehensive moves to finish building a moderately prosperous society in all aspects, deepen reform, advance the law-based governance of China, and strengthen Party self-governance.

In China, economic growth and energy development have been closely linked. Going forward, the country is shifting towards sustainable economic development patterns that include the concepts of energy system transformation and building an ecological civilization.

China's overall energy strategy includes several elements. For industrial policy, the Made in China 2025 plan emphasizes green technology such as renewable energy, electric vehicles, and advanced power system equipment. In the near-term, China National Energy Administration (NEA) recently issued Work Guidance of Energy Sector 2018, also emphasizing shifting towards low-carbon, clean energy and clean heating supply while restricting coal consumption. In addition, the National People's Congress just approved the Governmental Institutional Reform Plan this March, according to which 2 newly established Ministries-Ministry of Natural Resources (MNR) and Ministry of Ecological Environment (MEE)-would also strengthen central government policies in these areas.

Development of Solar PV is Surging

In recent years China has begun to diversify its energy mix and turn to renewable energy. From 2005 to 2016, the share of renewable energy generation increased from 16% to 26%. The transition to a cleaner energy system is driven by the need to improve air quality, combat climate change, and eventually reduce the dependency on fossil fuels.

In recent years, the yearly added wind power installed capacity has declined while solar PV are surging. In 2017, on-grid wind additions amounted to 15.03 GW, down from a high of over 30 GW two years ago, whereas solar PV surged by over 53 GW which make acumulated capacity exceeds 24% of its 2020 minimum target of 105 GW.

Based on the results of the Below 2°C scenario in the China Renewable Energy Outlook 2017 (CREO2017), the annual flagship publication of China National Renewable Energy Centre, the share of wind in total primary energy supply is expected to rise from 0.7% in 2016 to 4% by 2020, 12.5% by 2035 and 21.8% in 2050. Solar PV is expected to rise from 0.3% in 2016 to 1% in 2020, 6.5% in 2035 and 13.4% in 2050.

Figure 2: Key Performance Indicators for the Energy System Transition in China

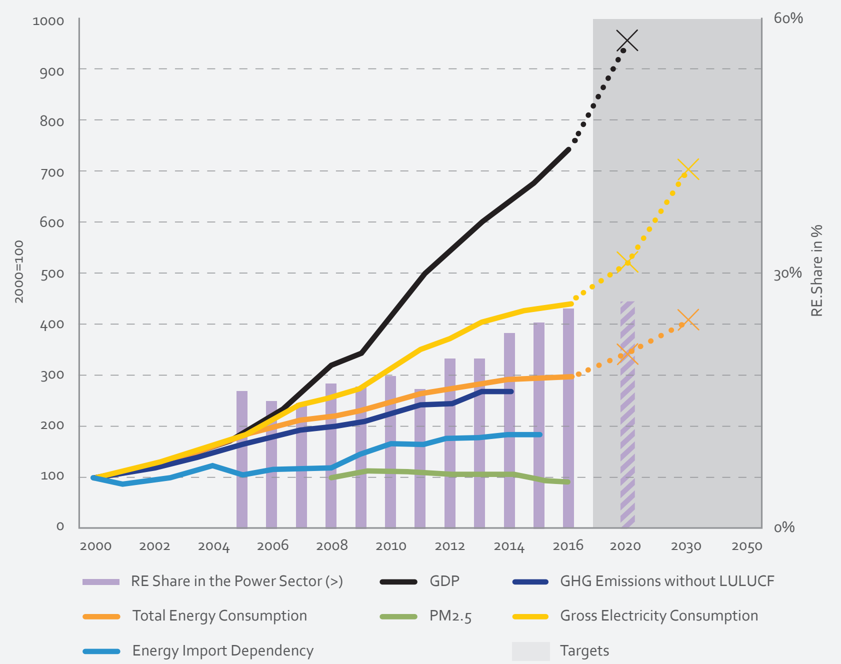


Figure 2 Data Source
GDP, Energy, Electricity: National Bureau of Statistics (NBS);
GHG Emission: Climate Watch data;
PM2.5: young-0;
Energy Import: China Statistical Yearbook: 2004-2017, China Energy Statistical Yearbook 2017;
Electricity: 13th- Five-Year Development Plan for Electricity;
RE Share in the Power Sector: China Electricity Council (CEC), NBS, National Energy Administration (NEA) and China National Renewable Energy Centre (CNREC).
2020 Target for GDP: based on annual growth rate 6.5%;
2020& 2030 target for energy: national strategy;
2020 target for electricity: 13th-Five-Year Development Plan for Electricity;
2030 Target: Outlook for the Development of Power Industry 2015-2030 by Jingru Wu.

Figure 3: 2050 China Total Primary Energy Supply Projection under Below 2°C Scenario of China Renewable Energy Outlook 2017

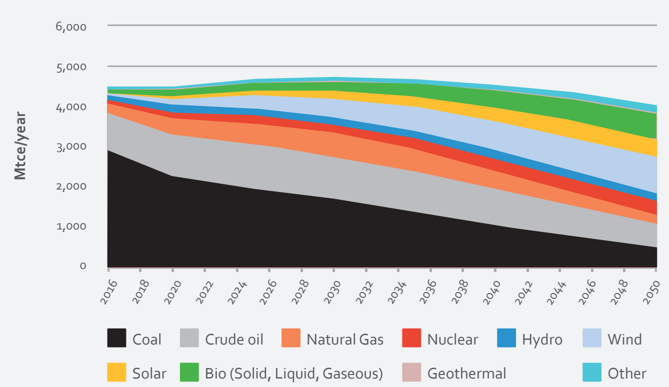


Figure 3 Data Source
"China Renewable Energy Outlook 2017," China National Renewable Energy Centre.

Table 1: Wind and Solar Power in Total Primary Energy Supply in 2025, 2030 ad 2050

	2020			2035			2050		
	TWh	Mtce	%	TWh	Mtce	%	TWh	Mtce	%
Wind	1451	178	4.0%	4679	575	12.5%	6963	855	21.8%
Solar	347	43	1.0%	2428	298	6.5%	4270	524	13.4%

Table 1
"China Renewable Energy Outlook 2017," China National Renewable Energy Centre.

Figure 4: 2017 Newly Added Power Capacity (GW)

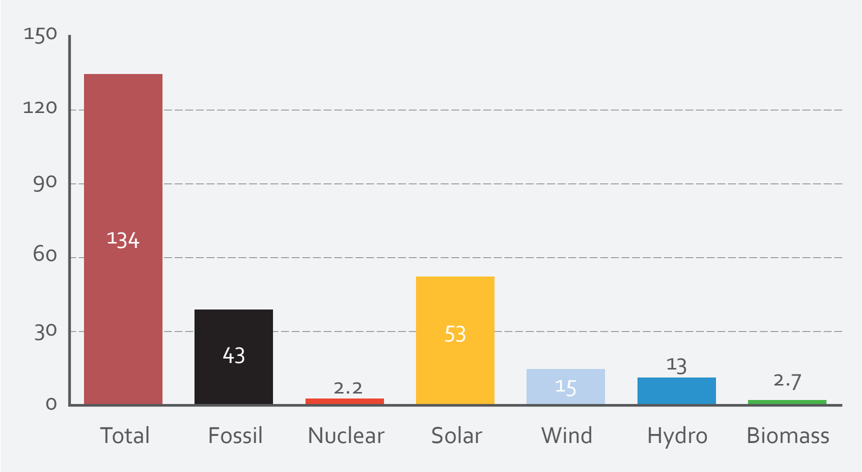


Figure 4
Figures of total, thermal, nuclear and hydro power are based on China Electricity Council's statistic data. Figures of wind, solar and biomass are based on China National Renewable Energy Centre's statistic data.

Figure 5: 2017 Newly Added Solar and Wind Capacity and Increase in Electricity Production

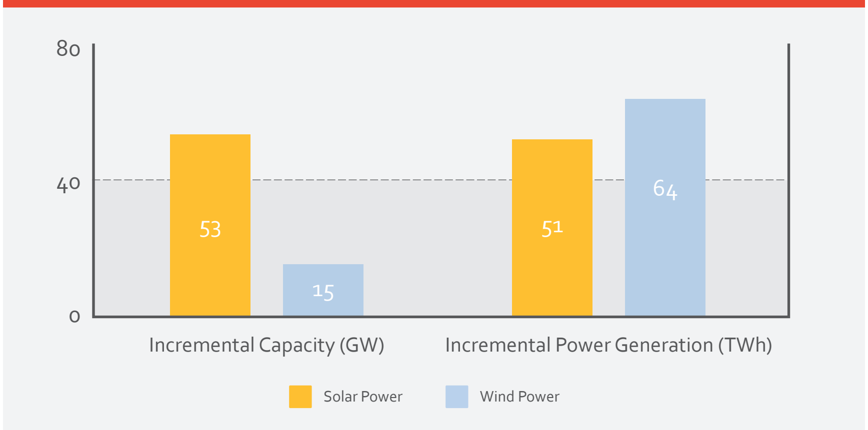


Figure 5
China National Renewable Energy Centre

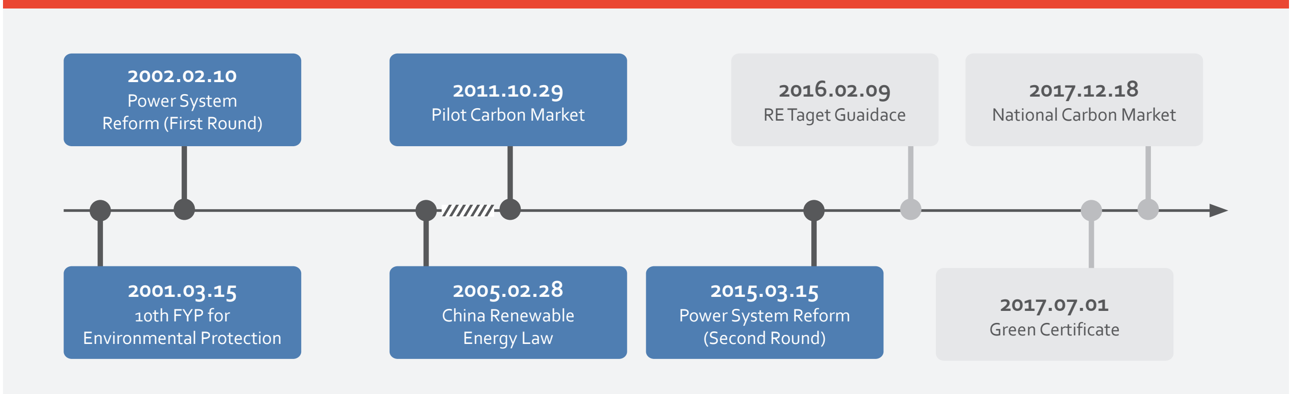
Policy Framework for Emission Reduction and Power System Reform Established

Emission reduction and institutional reform are two of the focal points in energy sector development in the last two decades. Since the 10th Five-Year Plan for Environmental Protection in 2001, China established strict targets on environmental protection and set out practical measures to combat pollution.

During the 12th Five-Year-Plan period (2011-2015), China established a 2020 greenhouse gas (GHG) emission intensity target, and proposed to reduce emissions intensity by a combination of market and administrative tools. China National Development and Reform Commission (NDRC) announced to launch carbon market pilots in 2011.

In institutional reform, in 2015 China began a major effort to reform the power sector, which will eventually include bilateral power trading, spot power markets, and ancillary services markets. Since the overall reform began, six supporting polices have been issued covering transmission and distribution (T&D) price reform, establishing spot market pilots, building electricity trading exchanges, forming bilateral markets for generation and efficiency, opening electricity retail markets, and regulating so-called captive coal power plants used by industry. Linked to the power sector reform, NEA has launched pilots for making coal fired power plants more flexible in response to the need for integration of the variable production from wind and solar power plants.

Figure 6: Timeline of Policies



Transforming from Subsidy Based to Marketised Alternatives

China is committed to deploying market mechanisms to accomplish its green and low-carbon energy transition. Whereas China from 2009 has relied on a feed-in tariff to boost wind and solar power, the country may shift towards a renewable energy quota mechanism as well as voluntary green certificates launched in 2017. By 2020, the national non-hydro renewable energy power consumption should reach 9% in total and all electricity generation companies are to produce 9% of energy from non-hydro renewables. In March 2018, the government started to collect opinions on a mandatory renewable power quota mechanism. The main responsible bodies proposed to include power grid enterprises, power distribution and electricity marketing enterprises, and

Figure 6
Timeline of policies for key energy transition policies in China 2000-2017

owners of captive power plants.

Carbon markets are another trend. From 2011 to 2016, China has launched seven carbon market pilots in Beijing, Tianjin, Shenzhen, Shanghai, Hubei, and Guangdong. So far, allowances in these markets have been allocated mainly through grandfathering and benchmarking, with only small-scale auctions. A national carbon market was officially announced in December 2017, covering the power and heating sectors, which are responsible for a large fraction of coal use. The market will only start official trading in next several years, and the carbon allowance mechanism design will be promoted continuously. Policy-makers hope that carbon prices play a increasingly important role in promoting the low carbon transition.

Obstacles to Low-carbon Development

While China is undoubtedly committed to a low-carbon energy transition over the long term, there are numerous near-term obstacles. Energy demand continues to grow rapidly, and fossil fuels remain essential for meeting near-term needs.

Moreover, conflict between provincial and national objectives is urgent to address. Most provinces have overcapacity of coal power, and provincial officials remain wary of reforms that could threaten the financial viability of state-owned power groups. This means that bilateral contracts, inter-provincial power trades, and spot market pilots are not necessarily designed to promote economic dispatch. There is a consensus that reforms to date have yet to breach what Chinese analysts call "provincial fortresses" that prevent competition and economic dispatch.

China has also struggled to implement policies prioritizing dispatch of renewable energy. For example, although the central government has established numerous policies to mandate minimum dispatch hours for wind and solar and for elimination of wind and solar curtailment and in 2017 both curtailment rate and curtailment power quantity of wind and solar power decreased, the integration of these resources remains a severe problem in several provinces. Provinces like Gansu have developed large amounts of wind and solar that cannot be absorbed by demand inside the province, yet transmission capacity and broader dispatch areas for clean energy have lagged.

Centralized Power of Policy Makers in the Future

In 2018, NEA work priorities include green, low-carbon, and innovation-driven development, improving energy supply quality and system efficiency, curing poverty alleviation and providing good quality energy services, strengthening energy sector governance, and widening international cooperation. As wind and solar PV fall in price, price parity for wind may arrive in 2020 and solar PV before 2025. Power market reforms should play a major role in improving the economics of clean energy. In particular, spot markets, ancillary services markets, increased inter-provincial and inter-regional transmission, and distributed energy should help eliminate the barriers to low carbon energy.

Significant change is also continuing at the administrative levels. Two new ministries, Ministry of Ecological Environment (MEE) and Ministry of Natural Resources (MNR), were established in March 2018. The Ministries responsible for environmental tax and carbon emissions trading mechanisms are to be incorporated into MEE, helping integrate these policies with other environmental policies. Similarly, departments responsible for water, grassland, forestry and wetland resources will now be integrated into MNR, helping calibrate natural resource policies in these areas. Centralization of similar departments could simplify policy-making, oversight, and implementation.

2. European Union

The EU's Long-term Energy Targets for 2030/2050

The European Union (EU) has ambitions to be the leading force in the fight against climate change. It has agreed to spend at least 20% of its budget for 2014-2020 – as much as €180 billion – on climate change-related actions. An EU-wide energy system transition, i.e. implementing common targeted policies and advancing the structural integration of the EU are seen as key drivers for the decarbonisation of the economy.

The long-term goal of reducing GHG emissions by 80-95% by 2050 compared to 1990 levels was set in October 2009 by the European Council. In October 2014, the European Council agreed to more concrete, EU-wide targets and policy objectives for 2030 (see table below). These targets aim to achieve a more competitive, secure and sustainable energy system and to meet its long-term 2050 greenhouse gas reductions target. They do not prevent Member States from pursuing their own, more ambitious targets.

Table 2: EU Energy Targets for 2030 and 2050

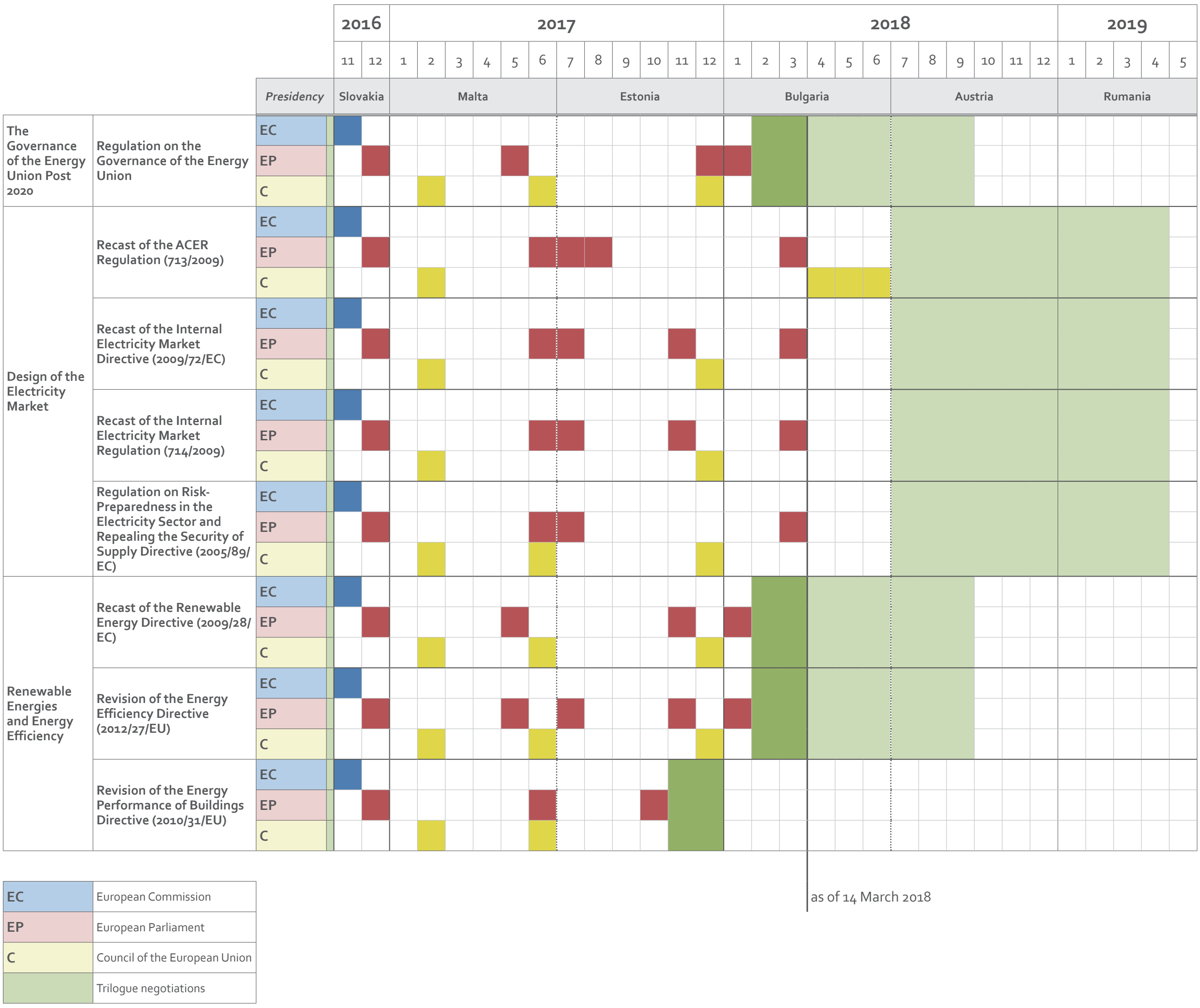
	2030	2050
GHG Emissions Compared to 1990 Levels	>40%	80-95%
Energy Efficiency Compared to "Business-as-usual"-Projections	>27%	--
Share of Renewable Energy of Total Energy Consumed	>27%	--

Current Developments in European Energy Policy: The Winter Package

The EU is striving for a European Internal Energy Market that sets the general framework for energy to flow freely across the EU – without technical or regulatory barriers. This intends to allow for more competition, to pool the different capacities of all Member States and to improve energy security and system stability.

The EU's approach to follow the principle of subsidiarity in its effort for an energy transition can be used as example and comparison for the challenges in China. The EU as central entity focuses on setting and monitoring clear common targets and on making sure that the general framework (market structures, regulations, infrastructure etc.) allows for a dynamic development towards a new energy system. The Member States on the other hand have both the right and the duty to implement such policies that contribute to the common targets while at the same time taking into account their respective regional conditions.

Figure 7: Time Schedule for the Winter Package Following the Ordinary Legislative Procedure



In November 2016, the European Commission published a number of legislative proposals summed up as "The Clean Energy for All Europeans" package. This so-called "Winter Package" aims at specifying the strategic implementation of the EU energy targets 2030 and at advancing the Energy Union. On more than a thousand pages it primarily covers the following topics:

- Governance of the Energy Union,
- Design of the electricity market,
- Renewable energies and energy efficiency.

The package is currently being consulted by the European Parliament and the Council of the European Union, i.e. by the respective national ministers, following the so-called ordinary legislative procedure of the EU (see also the overview of the legislative process below). The common goal is to pass the package before the election of a new European Parliament in May 2019.

Figure 7
Own graphic based primarily on official information by the European Parliament (http://www.europarl.europa.eu/legislative-train/theme-resilient-energy-union-with-a-climate-change-policy).

Figure 8: Key Performance Indicators for the Energy System Transition in the EU

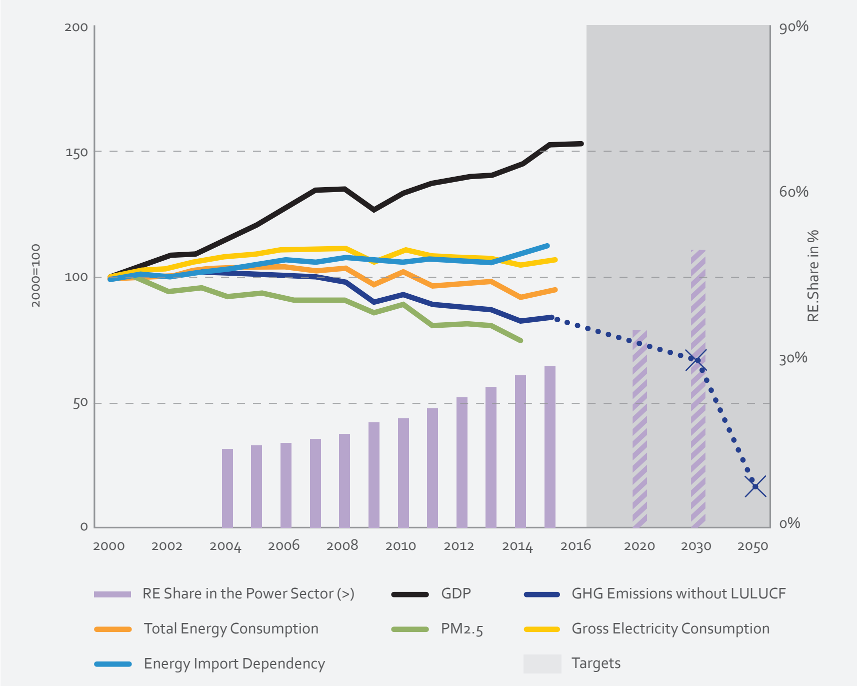


Figure 8
Targets for the RE Share in the Power Sector are based on PRIMES projections.

Achievements and Challenges: Measuring the Progress in the EU and A Look Ahead

The chart on the key performance indicators for the three interlinked goals of the EU's energy policy (reducing greenhouse gas emissions, reducing the EU's dependency on energy imports, ensuring growth and employment) shows that progress has been made since 2000 concerning each of these goals. The chart also highlights the effective decoupling of greenhouse gases on the one hand and economic growth on the other.

However, considering the ambitious targets set for 2030 and 2050, efforts have to be increased both on EU and Member State level. This does not only imply additional support for technological development for more energy efficiency, but also a thorough check of all emission relevant policy fields, i.e. transport and mobility.

Excursus: ENTSO-E and the European Grid Planning Process:

With the establishment of the European Network of Transmission System Operators for Electricity (ENTSO-E) in 2009 the European TSOs have been given important tasks and thereby substantial influence on the development of the European power market and transmission system. The main product of the TSO's planning is the (non-binding) Ten Year Network Development Plan (TYNDP) which is carried out under EU regulation 714/2009 on a biennial basis.

The ENTSO-E planning process consists of three steps: First, different scenarios for the future are developed in order to frame uncertainties and to identify what Europe needs in terms of electricity transmission infrastructure. Based on these scenarios experts of 41 TSOs in 34 European countries carry out common planning studies. The results of the planning studies are a series of infrastructure projects. As a last step, these projects are assessed following a European approved methodology to assess the costs and benefits of projects. This assessment is not just a purely economic assessment. Instead, it also takes into account how projects support the environment, the European welfare, the security of supply etc.

Each year the EC updates a list of projects of high European importance, the so-called list of "projects of common interest" or "PCI-list". This list takes its point of departure in the last TYNDP. PCIs must comply with certain rules regarding transparency and involvement of stakeholders and can in turn achieve both faster permission and financial support from the EU.

3. Denmark

Decoupling Economic Growth, Energy Consumption and GHG Emissions

The overall trends of the Danish economy and the energy sector show that Denmark has been able to grow its economy and at the same time reduce the absolute energy consumption and GHG emissions (see graphic below). Analysis shows that the impact of manufacturing industries moving out of Denmark have only had a marginal impact on both energy consumption and GHG emissions. Energy efficiency including combined heat and power generation (CHP) and expansion of district heating and a sharp increase in the use of RE are the most important factors in decoupling economic growth from energy consumption and GHG emissions.

Figure 9: Key Performance Indicators for the Energy System Transition in Denmark

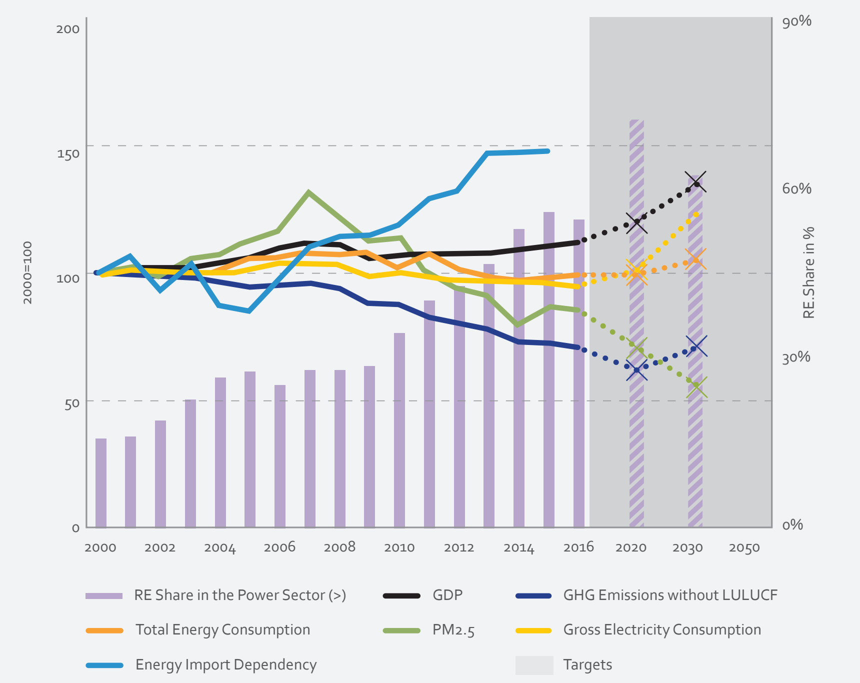


Figure 9
GHG emission targets based upon the preliminary Danish non-ETS reduction target compared to 2005 level. Data do not illustrate official Danish targets.

The most dramatic changes in the Danish energy sector have been going on in RE generation which provided for 31% of the gross energy consumption in 2016. In the early 1990s, RE sources accounted for less than 5% of the Danish power generation. In 2016 that number was 60% due to a significant exploration of Denmark's wind power potential both onshore and offshore (42%) and a fuel transformation from coal and natural gas toward biomass (14%).

RE Integration The Danish Way – Flexibility and Open Energy Markets

In order to cope with almost 50% of all Danish power generation being fluctuating (wind and solar), a number of initiatives and system solutions have been implemented by the Danish transmission system operator (TSO) Energinet.dk. The main elements have been:

- **Planning and Forecasting:**
  The Danish TSO has developed an advanced system for forecasting expected production from power sources like wind and solar in order to improve planning of generation up until the hour of production and thereby reducing the need for standby capacity.

- **Power Plant Flexibility and Back-up Capacity:**
  Back-up capacity combined with a technical ability of most conventional power plants to adjust generation to significantly less than 50% of their rated capacity means that RE becomes a base load power source in the Danish system.

- **Effective and Transparent Power Markets (NordPool):**
  The integration of wind and solar has been supported by the Nordic day-ahead power market. Very low marginal cost for wind and solar power means that they are "dispatched" by the market ahead of conventional power sources in the "merit order".

- **Strong Domestic Transmission Grid and Cross-border Interconnectors:**
  For balancing and market purposes, strong power interconnectors to Denmark's neighbouring countries both in the North (Norway and Sweden) and in the South (Germany and soon Netherlands) enable Denmark to balance under- or surplus production with its neighbours. Especially the hydro based power generation in Norway and Sweden is ideal to balance fluctuations in wind and solar. This happens through coupled electricity markets, nowadays stretching from Finland to Southern Europe.

- **TSO Buying Flexibility in the RE Sector:**
  Large wind power projects have shown to be very effective as balancing capacity in windy conditions. A wind park has a very short response time and very low start-up costs. With the help of proper incentives and "virtual power plant control systems", large wind projects can participate in the specific balancing power market getting attractive power prices when the general power market prices are low.

Going forward, with the goal of even more fluctuating power in the Danish energy system, further planning of infrastructure (grid) and market is vital to preserve the high level of system stability and competitive power prices. Further integration and interconnection with neighbouring countries and the EU power system is part of the answer. In addition, the ability to store and use electricity in other sectors like heat through heat converters is being explored. Furthermore, the future electrification of transportation is part of this plan. The Danish energy planning is closely aligned with the EU plans for a more deeply integrated Energy Union.

New Energy Agreement in the Making

Based upon the EU energy targets for 2030, the political negotiations on a new energy agreement that will set the course and targets for the period beyond 2020 for the Danish energy sector have begun. High on the agenda will be a further transformation away from fossil fuel based energy sources, a further improvement of energy efficiency and creating a market based energy sector securing a cost effective transformation and thus competitive energy prices for consumers and enterprises. The government is working for an RE target of 50% of the gross energy consumption in Denmark by 2030. For the support of RE sources both EU regulation and recommendations by Danish experts point at more competition based support schemes like the tender system used for the deployment of offshore wind.

4. Germany

The "Energiewende" – Energy Transition Made in Germany

The German energy transition (so called Energiewende) is a long-term energy and climate strategy towards a low-carbon energy system based on developing RE and improving energy efficiency. It is considered an ambitious industrial project and requires technical and societal transformation within Germany and within the whole of Europe. The energy transition is based on four main objectives: combatting climate change, avoiding nuclear risks, improving energy security, and guaranteeing economic competitiveness and growth. The Energiewende is an integrated policy framework, covering all sectors of energy and economy. It includes targets and policy measures for CO_2 emission reduction, RE development, phasing out nuclear energy by 2022, and improvement of energy efficiency (see table below).

Table 3: Key German Energiewende Targets

		Status Quo	2020	2025	2030	2035	2040	2050
Greenhouse Gas Emissions	Reduction of GHG emissions in all sectors compared to 1990 levels	-27.6% (2017)*	-40%		-55%		-70%	-80-95%
Nuclear Phase-out	Gradual shut down of all nuclear power plants by 2022	12 units shut down (2017)	Gradual shut down of remaining 8 reactors					
Renewable Energies	Share in final energy consumption	13.1% (2017)*	18%		30%		45%	min. 60%
	Share in gross electricity consumption	36.1% (2017)*			65%			min. 80%
Energy Efficiency	Reduction of primary energy consumption compared to 2008 levels	-5.9% (2017)*	-20%					-50%
	Reduction of gross electricity consumption compared to 2008 levels	-2.9% (2017)*	-10%					-25%

Table 3
Data with an * are preliminary data.

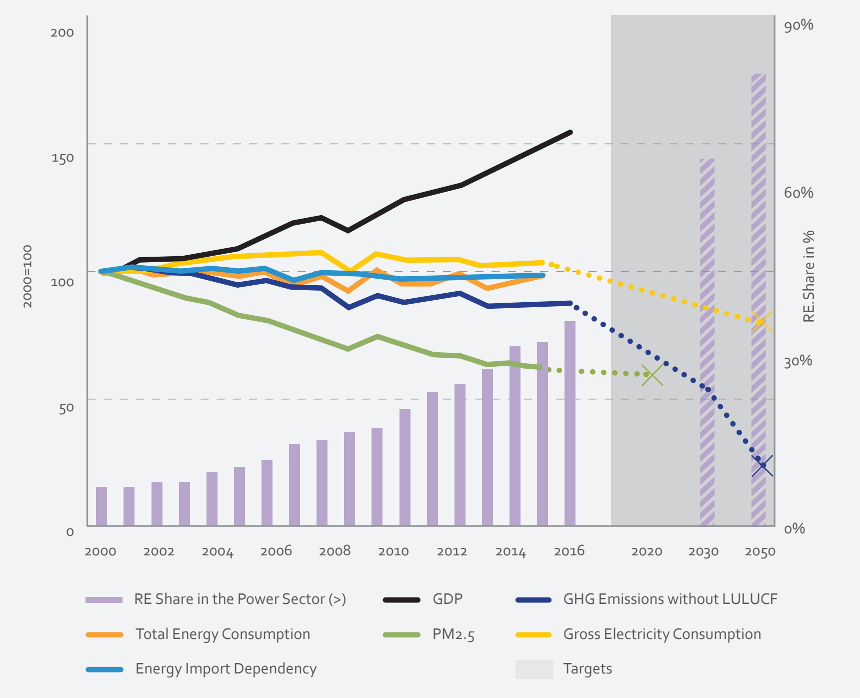
Some Progress Made and Still Some Way to Go

In recent decades, Germany has significantly diversified its electricity mix toward RE (which grew from 4 percent in 1990 to above 35 percent in 2017), including a sharp increase in citizen-owned projects between 2000 and 2010. However, the share of RE in other sectors (transport and heating/cooling) has not increased proportionally.

Since the necessary expansion of the transmission grids is a lengthy process with a lot of legal, political and regulatory challenges, there are relevant delays which are becoming more and more obvious in the overall system management: grid congestions increased and the further development of RE plants is more and more exposed to the risk of insufficient grid structures. In addition to the expansion of the transmission grid, increased system flexibility is pursued by encouraging new technologies and processes (e.g. demand side management, storage technologies, Power-to-X technologies, digitization of system management processes).

While the FIT degression scheme has already led to a reduction in prices from above 50 ct/kWh for PV in 2004 to roughly 10 ct/kWh nowadays, auctions for RE have delivered promising price projections for the future: recent auctions resulted in an average price of 4.91 ct/kWh. The recent auction for onshore wind has resulted in an average price of 3.82 ct/kWh and the recent auction for offshore wind (to be built by the mid 2020s) resulted in prices from 0 to 6 ct/kWh (average weighted price 0.44 ct/kWh, additionally 1.5 ct/kWh for grid connection are paid). Overall, prices for RE have decreased tremendously and are expected to decrease further.

Figure 10: Key Performance Indicators for the Energy System Transition in Germany



Outlook: Increasing Flexibility and Digitization of the Energy System

The current political debates in the energy sector involve several topics. Among them are discussions about RE capacity additions, especially with respect to the acceptance among citizens. However, capacity additions, mainly for wind onshore, remain high. In the focus is also the self-consumption of solar power, which is attractive for households and business consumers. In this context, the development and installation of energy storage systems has seen increasing importance as they allow a maximisation of self-consumption and increase system flexibility. An important part of the current debate is also the issue of digitization which is a key element of a successful energy transition. Fluctuating RE (PV, wind) require a communication network which combines generation, consumers and grids. The energy system needs to always provide flexibility to balance variable RE generation. This is only possible when generation and (flexible) demand can use safe and digital communication channels. In 2016, the German Government hence approved a law on the "Digitization of the Energy Transition". Last but not least the integrated energy transition that makes use of synergy effects which come from the connection of all sectors (energy, transport, building, industry) is high on the agenda. With the 2018 coalition treaty, Energiewende issues remain a priority of the government's political agenda. The emission reduction targets for 2020 are unlikely to be met. However, the coalition of Christian democrats (CDU/CSU) and the social democratic party (SPD) aims to meet them and is committed to the 2030 targets. To do so, it has increased the RE target in the power sector for 2030 to 65 percent.

Market-based RE Integration as Cost-efficient Way to Deal with the Complexities of the Energy Transition

Germany's Energiewende is one example of how a highly industrialised economy can transition its power system towards a climate-friendly, economically competitive system while ensuring energy security. Experiences with market and system integration measures for variable RE show that a market-based integration with the regulator as a coordinative actor taking into account all relevant stakeholders significantly reduces the costs. Furthermore, long- and medium-term targets have proven helpful to align policies that have short-term effects with long-term goals. Taking into account the lessons learned in Germany, China has the chance to tackle air pollution and create a climate-friendly energy system which equally allows for economic growth.

5. United States of America

Dynamics of Energy Sector Evolution

In the United States (U.S.), energy sector evolution has been driven primarily by technological innovation, market competition, and standards and policies—particularly at the state and local levels.

Technical standards and policies have supported the competitive space for RE technologies, seeing them through early periods of market adoption as prices decreased markedly. For example, one source assesses that state and local renewable portfolio standard (RPS) policies stimulated 60% of RE deployment between 2000 and 2015 and drove costs down through cumulative installed capacity. Corporate Average Fuel Economy (CAFE) standards for vehicle fuel efficiency drove innovations such as start-stop internal combustion engines. Incentives ease the cost and uncertainty burden for early adopters in these transitions. And targeted investments in R&D can address specific concerns of investors and technology limitations.

Market forces have had a leading impact in the U.S. energy transition and associated reduction in carbon intensity. Governments considering adoption of RE face a much less costly decision than those deploying RE technologies a decade ago, although there remain important impacts on utility and regulator planning for new infrastructure, such as transmission, and on operations. The advances in wind, solar and storage are shared globally, resulting in significant leap-frogging potential. The relatively turbulent market adoption pathway experienced by early adopters may not be faced by those deploying these technologies today. The pace of this energy transition, with the unexpected role of natural gas, was difficult to foresee. Nevertheless, the government has had a role in ensuring fair, enabling, functional market platforms capable of reliably integrating all forms of energy, thus increasing security, reducing costs and helping to achieve stated social and environmental goals.

Figure 11: Key Performance Indicators for the Energy System Transition in the U.S.

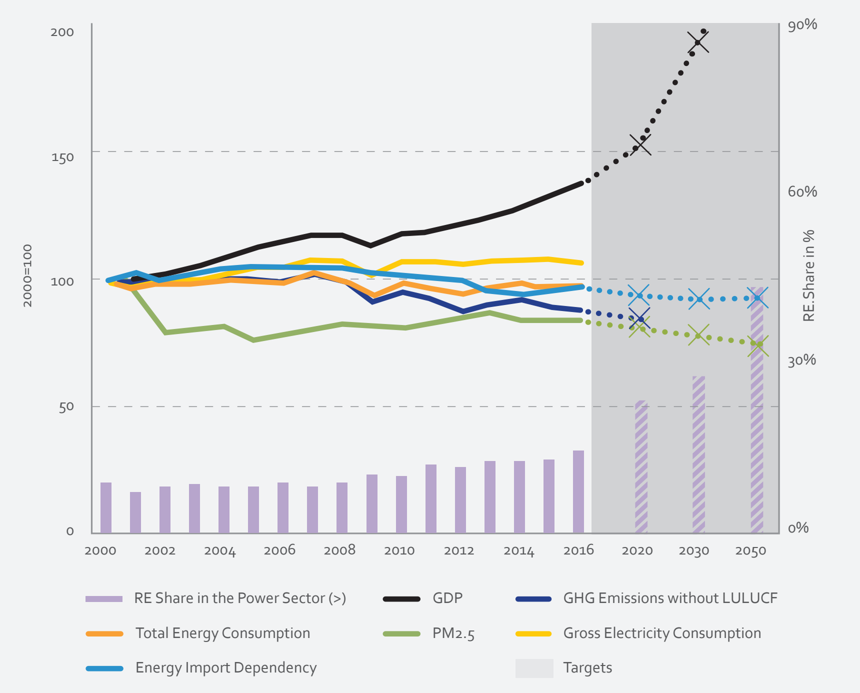


Figure 11
The 2020 target value for GHG Emissions without LULUCF is based on the U.S. Nationally Determined Contribution (NDC), which the Trump administration confirmed will not be implemented. The NDC included a 2020 target of 17% below the 2005 value. There was also a 2025 target of 26-28% below the 2005 level, and no targets beyond that date.

Outlook: Energy Systems Integration and Market Modes

As RE technologies improve and become less costly, the new focus for energy transition in the U.S. will emphasize reliability, resilience, and power system flexibility. This includes the capability of integrating all forms of generation; transmitting power through reliable, physical infrastructure; and managing load, all in a secure and affordable way. The mass deployment of sensors and advanced metering provides significant new opportunities with big data not previously available. This digitization of the energy sector could create pathways for enhancements from artificial intelligence and machine learning that improve central power system management reducing losses for utilities and costs for consumers.

Conversely, these advances may also have a significant impact on distributed energy systems for those customers who choose to take more control over their own energy production and consumption. Regulators and utilities have an important role to play in maintaining the technical and economic viability of the grid while enabling consumer choice and engagement as adoption of distributed generation and storage continues to grow.

Energy Transition Trends 2018

China, Europe, USA