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The Global Outlook

An active transformation of the energy system is essential to meet long-term goals.

Energy Technology Perspectives 2014 *(*ETP 2014*) charts a course by which policy and technology together become driving forces in transforming the energy sector over the next 40 years. Recent technology developments, markets and energy-related events have asserted their capacity to influence global energy systems. They have also reinforced policy's central role in the increasingly urgent need to meet growing energy demand while addressing related concerns for security, costs and environmental impacts. Radical action is needed to transform energy supply and end use.*

- The carbon intensity of the energy system has held steady – less than 1% change – for the past 40 years. To meet long-term climate targets in the face of rapidly increasing energy demand, radical action is needed to decarbonise both generation and end-use.
- The USD 44 trillion additional cost to decarbonise the energy system in the 2 Degree Scenario (2DS) by 2050 is more than offset by over USD 115 trillion in fuel savings – resulting in net savings of USD 71 trillion. Even with a 10% discount rate, the net savings top USD 5 trillion.
    - The latest cost estimate compares with USD 36 trillion in *ETP 2012.* Some of the increase is due to accounting changes, but the calculations show that the cost of decarbonising the energy system – in real terms – is about 10% higher than it was two years ago. In part, this illustrates something the IEA has been saying for some time: the longer we wait, the more expensive it becomes to transform our energy system.
- *ETP 2014* confirms that global population and economic growth can be decoupled from energy demand. Under identical population and gross domestic product projections, global energy demand grows by 70% in the 6 Degree Scenario (6DS) but by just over 25% in the 2DS.
- Slower progress in carbon capture and storage and persistent increased costs of nuclear technology are decreasing deployments over the 2050 horizon compared with *ETP 2012* analysis. Low costs in some regions are driving up near-term natural gas demand in the 6DS and 4 Degree Scenario (4DS), but 2DS gas demand falls as renewable technologies quickly become more cost-competitive – especially in the power sector.
- In the 2DS, the share of fossil fuels in global primary energy supply drops by almost half – from 80% in 2011 to just over 40% in 2050. Because fossil fuel use remains sizeable, CCS plays a significant role in limiting related emissions in the power sector; both transport and industry require significantly more decarbonisation beyond 2050.
- Energy efficiency, renewables and CCS make the largest contributions to global emissions reductions in the 2DS. Respectively, they account for 38%, 30% and 14% cumulative emissions reductions to 2050. Nuclear, end-use fuel switching, and power generation efficiency and fuel switching are essential to reach the 2DS target cost-effectively.
- Industrial energy efficiency improvements will not suffice to decouple increasing materials demand and energy consumption. Development and deployment of new low-carbon technologies such as enhanced performance catalysts and separation systems, technologies that can use low-quality raw materials with limited energy requirements, bio-based process routes, and CCS are also needed to meet 2DS targets.
- Large, cost-effective energy saving potential that reduces emissions exists in the buildings sector and can provide net wealth to economies. Difficult market conditions and non-technical barriers are stifling advancement. Policy maker resolve and funding will be needed to overcome these first hurdles, after which realising savings will become less policy-intensive.
- Improved fuel economy, advanced vehicles and fuels, and demand-side management strategies are critical to mitigating transport emissions. Despite improving fuel economy (partially through hybridisation) of the passenger light-duty vehicle fleet and increasing deployment of electric vehicles, both are progressing too slowly to achieve 2DS.

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Electrification of the Global Energy System

Electricity will increasingly power the world's economies this century

Rapid evolution in the character of supply, coupled with the fact that growth in electricity demand is outpacing all other final energy carriers, requires increasingly strategic approaches to balance supply and demand. Power generation is responsible for roughly 40% of global CO_2 emissions. Decarbonising the sector impacts the entire energy system and is crucial for achieving deep emissions cuts in a relatively short time, as required by 2050 in the 2DS. If achieved, the 2DS gives the world at least a 50% chance of keeping average global temperature rise from pre-industrial levels below 2°C.

- By 2050, electricity overtakes oil products to become the dominant final energy carrier in the 2DS. The share of electricity rises to between 23% and 26% of overall energy demand across all scenarios. This reflects an acceleration of the growth trend that saw electricity's overall share rise from 9% to over 17% from 1970 to 2011.
- While the share of electricity in total energy demand progresses towards 30% across all regions, growth rates to 2050 differ vastly. In the 2DS, average electricity demand in OECD countries grows by 16% from 2011 to 2050; in non-OECD regions, the growth rate averages 145% over the same period.
- CO_2 emissions per unit of electricity must be drastically decreased to meet 2DS targets. Deployment of low-carbon technologies can cut average emissions globally from about 500g/kWh in 2011 to 30g/kWh in 2050, a reduction of more than 90%. This is a massive reversal of recent trends, which saw overall emissions from the electricity sector increase by almost 75% from 1990 to 2011, amid rising demand but little change in emissions intensity.
- Shares of fossil fuels and renewables reverse in the 2DS. In 2011, fossil fuels constituted more than 65% of the global electricity generation mix while all renewables combined made up 20%; the opposite share breakdown will be needed by 2050, with renewables surpassing 65% and fossils dropping to just over 20%, while nuclear grows to a 17% share in 2050 from 12% in 2011.
- Decarbonising the electricity sector can deliver the spillover effect of reducing emissions from end-use sectors, without needing further end-use investments. Yet to fully leverage the benefits of increased shares of decarbonised electricity, including reaching 2DS emissions targets, comprehensive approaches are needed to combine electrification with end-use initiatives. If the electricity sector remains dependent on fossil fuels, electrification of end-use sectors is unlikely to achieve the necessary CO_2 emissions reductions.
- Cumulative power sector investments in the 2DS are 30% higher than in the 6DS. The average cost of generating electricity will rise by 30% to 50% by 2050 in all three *ETP 2014* scenarios. But the cost differences between scenarios will be modest: global average electricity generation costs in the 2DS in 2050 are actually on a similar level to those in the 6DS. Only in the transition period from today to 2050 will global average electricity costs increase by up to 15% compared with the 6DS. Reduced demand, lower technology costs and lower fossil fuel prices are the three most important parameters that keep electricity costs from rising at a much faster rate in the 2DS.

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ETP 2014 Electricity by the Numbers

Recent trends and current statistics

- Almost 40% of global primary energy is currently used to generate electricity, and electricity generation produces nearly 40% of global energy-related CO_2 emissions.
- But final energy demand exhibits a different trend: oil products continue to dominate, accounting globally for 40% of final energy demand in 2011 (particularly for transport). Electricity comes second, with a share of just 17% in the final energy demand mix, but is rapidly increasing.
- Worldwide, per capita electricity consumption more than doubled from 1 263 kilowatt hours in 1974 to 2 933 kWh in 2011.
- Despite impressive growth rates and encouraging trends in the deployment of renewable power technologies, fossil fuels covered more than three-quarters of the demand increase from 2001 to 2011. Coal represented 47% of the increase, and gas 30%.
- Failure to implement "best-in-class" technologies for new coal electricity generation capacity is making it more difficult to meet 2DS targets. Sixty percent (434 gigawatts [GW] of 734 GW) of new coal capacity built in the past decade uses least-efficient subcritical technology.
- As a result, little progress has been made in decarbonising electricity generation. Actually, the average global CO_2 intensity of electricity generation was 536 g CO_2/kWh in 2011 – the same as in 2001.

The future of the electricity system globally

- The share of electricity rises to around 25% of overall energy demand across all *ETP 2014* scenarios to 2050. Growth in electricity production is between 80% and 130% (2DS and 6DS, respectively) from 2011 to 2050.
- The 6DS requires a large increase in power-sector investment that averages USD 760 billion annually, driven by increasing electricity demand in emerging economies and replacement of ageing infrastructure in OECD countries.
- In the 2DS, cumulative absolute investments of USD 40 trillion are required by 2050 in global electricity systems (generation as well as transmission and distribution), or an annual average of USD 990 billion. This represents more than a doubling of current average investment levels of USD 420 billion from 2000 to 2012.
- Average annual capacity additions to 2050 of low-carbon electricity generation technologies in the 2DS:
  - Solar PV: 92 GW, more than triple the 30 GW added in 2012.
  - Onshore wind: almost 80 GW, a 70% increase to the build-rate of 46 GW in 2012.
  - Coal with CCS: 15 GW; gas with CCS: 13 GW; nuclear: 22 GW; offshore wind: 16 GW; concentrated solar power: 18 GW.
- In the 2DS, renewables are responsible for almost half (46%) of the CO_2 reductions in the power sector to 2050, with wind accounting for 18% and solar for 13%. CCS and nuclear provide 14% and 13%, respectively, of the cumulative reductions.

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Electricity Storage as a Game Changer?

Costs, value and competiveness challenge the technology in electricity systems

ETP 2014 *analysis casts doubt on recent claims that electricity storage will be a game changer, yet confirms its widespread value as a versatile tool. As a flexibility resource, storage can support grid balancing and facilitate access to electricity using renewable energy. However, the significant cost of many technologies for high-power and high-energy applications currently undermines the conceptual flexibility potential of storage compared with competing options. But storage is uniquely capable of delivering modularity, controllability and responsiveness.*

- Electricity storage is expected to play multiple roles in future energy systems, but it is unlikely to be a transformative force itself. At current costs and performance levels, particularly for high-power and high-energy applications, it falls short of delivering the conceptual flexibility potential when compared with competing options.
- The role of electricity storage in a given power system will depend on system-wide development. Competitors of storage are at different levels of maturity and cost-competitiveness: thermal dispatchable generation is the incumbent technology; demand response can provide excellent reserve capacity at minimal cost; and although less mature, smart grids provide increased interconnectivity to shift loads in time and space.
- The true asset of battery storage for power systems might lie in modularity, controllability and responsiveness. No other asset in the sector can combine these characteristics.
- Arbitrage opportunities have driven most global electricity storage deployments over the last 40 years. Current drivers for electricity storage, including variable renewable integration, operational support, system planning and end-use applications, are highly system-specific and complex and are likely to require changes to regulatory and market frameworks.
- Pumped hydro storage (PHS) currently represents 99% of all deployed electricity storage, and remains well-suited for many storage applications. Although a broad range of other technologies exist at varying stages of development, none has yet been deployed at a significant scale compared with existing PHS capacity.
- Frequency regulation, load following and off-grid applications represent the most attractive deployment opportunities for electricity storage in the short to medium term. Because these applications have the highest value, they offer more latitude for the high cost of electricity storage to be competitive.
- Solar photovoltaic panels combined with small-scale electricity storage are a powerful resource for off-grid applications and can provide access to electricity in remote areas. These applications can benefit from lessons learned from battery technology in electronics and electric vehicles.
- Energy systems integration that strategically positions storage can create an economic, flexible and resilient low-carbon energy system. Diverse system-wide opportunities exist, such as power-to-heat, power-to-gas or co-generation with thermal storage.
- Governments should develop policy measures to support application-driven R&D strategies for grid balancing, including electricity storage and other flexibility resources that contribute to delivering a low-cost trajectory to low-carbon power systems.
- All energy stakeholders should encourage and engage in "systems thinking" that capitalises on synergies among thermal, electrical and fuel pathways within the energy system.

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Power Generation in India

Addressing the challenges of growth, access and environmental factors

Very few countries have faced challenges of the magnitude that confront India in its quest to maintain strong economic growth while providing electricity to its 300 million citizens who now lack access. The country will need to tap all energy sources and technologies to meet the scale of energy demand projected over the next few decades. In establishing the framework for its low-carbon growth strategy, and with fossil fuels currently providing more than three-quarters of electricity generated, India will need to be mindful of environmental and social factors.

- India is increasing both power capacity and generation. Progress is being made to address the institutional and structural barriers that hamper the much-needed expansion of the power sector.
- 68% of India's electricity comes from coal. As the country pursues a low-carbon growth strategy in the power sector, this share is expected to fall. Coal capacity, however, will continue to rise.
- At 33.1%, the average efficiency of India's coal-fired power plants is low. Specific emissions from its coal fleet, at over 1 100 gCO_2/kWh, are well above the global state-of-the-art level of around 750 gCO_2/kWh. Policies in place to eventually halt the construction of subcritical units and encourage use of more efficient technology will gradually bring down specific CO_2 emissions.
- Continued reliance on fossil fuels for a large share of generation will require that India heavily supplement domestic supplies of coal and gas with imports. This will have an impact on power plant design, technology and operation, and will require addressing issues such as regulation of power tariffs.
- Expanding nuclear and large-scale hydropower capacity is increasing the share of non-fossil generation. More large-scale hydropower will assist in managing congested grids and integrating the growing variable renewable generation capacity. While nuclear provides just 3% of power generation, India has long declared its ambition to increase the share of nuclear generation.
- India is abundantly endowed with potential for generation from other renewable sources, including wind, solar, geothermal, biomass and small hydropower. Wind power capacity additions, for example, have exceeded targets.
- Complex bureaucratic processes and the high cost of financing new projects result in significant perceived risks that could slow India's ambitious plans in solar and wind power. To facilitate capacity expansion, more effective procedures must be developed to resolve in a timely manner issues related to land acquisition and building on or near protected areas.
- Further expansion of the transmission and distribution system and effective operation of the newly created national grid will be important to enhance the efficiency of delivering power to the consumer and the potential to expand generation.
- Power tariffs could be set at levels that prompt utilities to improve the performance of power generation plants while also allowing for reasonable profits on generation. The practice of providing free or heavily subsidised electricity, which can lead to wasteful use of energy, should be reviewed.
- Greater emphasis on increasing generation from renewable sources, and installing the infrastructure to distribute that electricity, would allow an expanded renewables portfolio to contribute more effectively to satisfying India's power demand.