CAETS ENERGY COMMITTEE REPORT 2020

Solutions for High-Level Penetration of Intermittent Renewable Electricity

CAETS

INTERNATIONAL COUNCIL OF ACADEMIES
OF ENGINEERING AND TECHNOLOGICAL SCIENCES, INC.

CAETS Energy Report 2020

This report juxtaposes the contributing academies' views on development of new technologies to offset renewable energy intermittency and respective policy approaches to sustain growth in renewables generation, distribution, storage, and implementation.

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Executive Summary

By the end of 2018, the estimated share of renewable energy (RE) in global electricity generation was at 26%, an all-time high.[1] Electricity sourced from renewable capacity including wind, solar, and biomass reached a record 12.1% of total global electricity capacity in 2018.[2] In 2019, total global renewable energy generation capacity reached 2,351 GW – around a third of total installed electricity capacity. Hydropower accounts for the largest share with an installed capacity of 1,172 GW – around half of the total.[3]

Most surprisingly, however, the projected share of renewable electricity generation is projected to almost double from currently 26% to 44% by 2040, which would surpass coal by as early as 2026. Combined, solar PV and wind's global share of electricity generation could collectively surge from 7% to 26%. Technological innovation in solar and wind have driven renewable production to all-time highs, powering the move towards "all-electric energy systems" and independence from fossil fuel sources.

Despite this progress, the sector experiences growing pains. On the other side of the equation, electricity demand is set to increase 62% resulting in global generating capacity almost tripling between 2018 and 2050, or by 1.5% per year. "High-level" penetration, or proportion, of renewables in the grid is inevitably met with variability caused by weather and meteorological impacts on supply, and electricity intermittency occurs as supply-demand fall out of balance. The determination of "high" or "low-level" penetration can be quantitatively thought of as a breadth metric examining to what extent renewables are integrated into grid and account for a significant portion of its final energy consumption. High renewable penetration requires more flexible mechanisms to bolster resilience.

Developments in grid-scale battery storage, though ongoing, are currently technically inadequate and commercially unfeasible to overcome the intermittency problem. Without a breakthrough in long-duration battery technology to counteract the problem of controlling the load with fluctuating sources of variable renewable energy (VRE) like wind and solar, policymakers, utilities, and producers alike are faced with difficult considerations in determining sensible energy policy. This report summarizes the successful approaches taken by contributor countries and offers five viable solutions to intermittency, based on an assessment of the responses to the following questions:

- How is electricity distributed and stored, upon generation?
- What technologies must be improved to offset challenges in intermittency?
- Can targets be met, and by what year?
- Must existing fossil energies be phased out alongside this transition, or can they coexist?
- What policies best support systems with least resistance in intermittency?

This report compiled the contributions of 21 member organizations that serve on the CAETS Energy Committee: Argentina, Australia, Canada, China, Croatia, Czech Republic, France, Germany, Hungary, India, Japan, South Korea, Mexico, New Zealand, Nigeria, Pakistan, South Africa, Sweden, Switzerland, the United States, and Uruguay.

In order to gain some understanding of the respective country's solutions of the member representatives, similarly situated countries were analyzed as peer groups, and were then categorized based on their relative positions in

[1] REN21. Renewables 2019 Global Status Report; REN21 Secretariat: Paris, France, 2019; ISBN 978-3-9818911-7-1. http://www.ren21.net/gsr-2019/

[2] "International Energy Agency; International Renewable Energy Agency; United Nations Statistics Division; World Bank; World Health Organization. 2020. Tracking SDG 7 : The Energy Progress Report 2020. World Bank, Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/33822

[3] IRENA (2019), Renewable Capacity Statistics 2019, International Renewable Energy Agency, available at: www.irena.org/publications

the transition process. Peer-group analysis showed that implementation challenges and solutions for combatting intermittency are different across country archetypes.

This report assessed the performances of countries in several categories as follows as the basis for grouping for comparative review: energy mix portfolio, renewable electricity generation, climate policy and future milestones, and the presence of interconnected systems. The solutions proposed by contributing CAETS countries, given the wide breadth of their approaches, have been grouped into the following three categories:

Group A: Cross-Border Transmission Systems: Group A countries are characterized by their expansive distribution networks that transcends borders. Most countries have already accomplished high RE generation capacity, and now shift their focus to not only continue increasing generation efficiency, but also solving the intermittency issue by mass-scale energy trading via intercontinental distribution networks. While some countries have inherited infrastructural powerhouses from past investments, others have made deliberate modern investments to install high-capacity and long-distance transmission lines, with the goal of being resilient to intermittency. The result is a 'super grid', i.e. a single continental-scale, interlinked power market. This approach makes available benefits like congestion management, curbing of supply and demand imbalances, short-term storage as load-following reserve, and diversification of energy portfolios. Through integration, participating countries can dynamically align demand in the face of fluctuating supply. This flexibility reduces the need for costly individualized baseload generation.

Group B: Interregional Transmission & Distribution (TND) Systems: Group B countries are those with systems with varying degrees of renewable penetration that have dealt domestically with intermittency issues by installing nonintermittent power reserve systems that can quickly be dispatched to load-follow the fluctuations of VRE sources. Dispatchable power technologies such as pumped storage hydropower generation, gas-fired combined heat and power generation, biomass, geothermal, or to some extent, microgrid systems, can provide scalable amounts of electricity to cover demand immediately and independently of interruptions like adverse meteorological conditions. Due to individualized needs mostly in geographically isolated areas such as island chains have confronted and resolved supply-demand imbalance by developing innovative demand-response technologies.

Group C: Variable Renewable Energy (VRE) Growth Systems: Group C countries are those with low VRE penetration and/or high fossil-to-renewable ratio, and therefore experience few intermittency problems relating to VRE. These countries have focused on increasing renewable penetration as well as integration of solar PV and wind plants through investments in power transmission and distribution infrastructure. To realize these priorities, large investments in grid connection, generation capacity, and reinforcement of transmission lines between producing and consuming regions, are needed throughout the entire electrical grid. One challenge while expanding VRE production is the linking of variable renewables to the grid, which requires large up-front investments in AC/DC or HVDC transmission lines to connect new power plants located far from the load centers that they serve. Another concern is the transitioning out of fossil fuel reliance, which will slow the transition to green energy on account of its use as a ramping crutch.

The complex energy transition, which includes the interaction between different systems, has diverse challenges. A strategy to systemically shift to clean energy is not restricted to shifts in merely increasing renewable generation in a given nation's energy portfolio. Regardless of the level of mitigating technology, every country that confronts the issue of accelerating its nation's energy transition will require coordinated policy action to effect supply-side technological and demand-side solutions.

Introduction

The 'Renewable Problem': a need for clean, reliable power

The greatest problem inherent in mainstream renewable energy is intermittency because wind and solar generation are significantly affected by highly uncertain weather patterns. The variability of such renewables raises significant challenges and issues in attempting to precisely match supply and demand.

Grid frequency fluctuations is the direct result of an imbalance between generation and load: as generation exceeds load, the grid frequency increases, and vice versa. These imbalances are only predictable to an extent, but many unforeseeable factors stand in the way of precise knowledge that could track changes in demand and match these with exact supply of electric power. Any number of random events, such as the tripping of a transmission line, the sudden loss of a power plant, or an error in demand forecasting from wind and solar generators, could all lead to mismatch in output.

With demand for global energy consumption on the rise, the main challenge in the renewable revolution is in tackling the issue of the intermittent nature of solar and wind: how can countries organize the necessary flexibility into their electrical grids and distribution systems around renewables?

Caveats to two misleading solutions

At first blush, the ostensible cure-all solution seems to be to invest in a grid-scale battery that can be charged by excess energy during off-peak periods and hours later can dispatch the stored energy to respond to demand increases. Such grid-level storage would be considered a technological panacea to the intermittency problem; however, the current reality and that for the foreseeable future is that developments in battery technology are likely to remain too expensive to save, store, and dispatch on-demand at a scale that is commercially feasible.[4]

Furthermore, some advocates suggest that a lack of suitable storage technologies necessarily means that volatile influxes of VRE supply must be balanced by a stable baseload, such as nuclear. Though nuclear power plants are in operation in most OECD countries as a reliable and low-cost balancing mechanism to modulate output, the universal adoption of nuclear power even as an ancillary back-up system to renewable sources remains controversial. Following the Fukushima Daiichi nuclear disaster, the International Energy Agency halved its estimate of additional nuclear generating capacity to be built by 2035.[5] The nuclear power industry is experiencing a global downward trend, with many countries deciding to reduce or suspend their capital-intensive nuclear power development altogether.

For the purposes of this report, which aims to suggest feasible investments to combat intermittency with minimal disruption, the viability and adoption of nuclear power as a load stabilizer is not examined as an area of focus.[6] Nevertheless, continental European countries are utilizing nuclear as a solution to intermittency problems.

[4] Ponton, Jack (2018) 'Grid-scale storage. Can it solve the intermittency problem?' London: The Global Warming Policy Foundation.

[5] "Gauging the pressure". The Economist. 28 April 2011.

[6] Because the effectiveness of nuclear baseload is highly dependent on a number of specific conditions dependent on the load profile of the given country, such as penetration level of renewables, size of nuclear plant relative to local grid, and the potential for demand-side actions combined with grid and storage coordination, it would be unavailable as a universally appropriate solution. See NEA (2012) 'Nuclear Energy and Renewables: System Effects in Low-carbon Electricity Systems', Nuclear Energy Agency, OECD, Paris, France at *71 (recognizing that currently only few countries have the "economic incentive or operational necessity" to run nuclear power plants in a flexible way, and discussing systemic costs associated with a given country's ability to adopt a nuclear program).

Overcoming intermittency is essential to achieving renewable singularity

Whether to achieve its climate commitments or realize energy security goals, countries have committed to integrating renewables as a national priority. Catalyzed by market incentives and technological advances showing sharp declines in wind and solar investments, renewable penetration seems inevitable.

But the vital, unanswered questions remain: what methods will countries adopt to manage intermittency costs? How will old, rigid power systems be transformed or equipped to maximize new, flexible regimes of energy?

The answers will decide whether wind and solar can maintain their historical growth rates, or whether their penetration will soon be capped by the physics of intermittency. Intermittency is the greatest issue standing in the way of multiple sustainable development goals: limiting the global temperature rise in line with the Paris Agreement, addressing air pollution, and ensuring universal access to energy.

Countries attempting to meet energy goals must consider more novel methods to better integrate renewable resources. As such, the 21 countries were sorted into three focal groups based on their approach to intermittency:

A. Large geographic interconnections to absorb variability and modulate output;
B. The dispatch of secondary "spinning reserves" to quickly correct load fluctuations; and
C. Investment in transmission and distribution "smart grid" systems to efficiently deliver power without compromising quality.

Decisions as to which improvements to adopt for the electrical grid are an intricate lattice of production, transmission, storage, distribution and consumption. This requires detailed analysis taking into account of each country's respective generation portfolio, energy security directive, and zero carbon goals.

The nuanced nature of this problem is a decisive challenge for the great energy transition of our generation that can be distilled down to two questions examined in this report: what technologies do we have yet to innovate to meet mass-scale electricity demands with high-level penetration of renewable electricity, and what are the policies that are conducive to mass-scale accelerated growth of intermittent renewable electricity?

Purpose

This report was written with an advisory purpose of informing stakeholders in various decision-making capacities who are looking for expert technological insights, as well as providing a quick overview on the approaches of various member countries.

Given the scale and complexity of energy transition, and its interdependencies across different systems, no single solution can unilaterally achieve a complete transition. Therefore, the CAETS Energy Committee intends that this report should serve as a guide to policymakers by providing information on the specific approaches of various countries in addressing their energy transitions, which depend on the differences in their societies and economies.

Overview

The Current Status of Intermittency in Respective Countries

General country strategies and comments on resolving respective intermittency issues

Argentina

Argentina has not stated problems regarding the implementation of renewables related to intermittency and is still in the process of increasing renewable generation, but only after a comprehensive redevelopment of a new regulatory framework for electricity pricing mechanisms after 12 years of tariffs frozen and massive government subsidies.

Australia

The shift in electricity supply towards renewable resources is set to accelerate as the relative costs of large-scale wind and solar continue to fall in Australia. The more distributed nature of renewable energy generation coupled with other factors (such as behind the meter energy storage and energy management systems) will demand considerable agility in the way the electricity system is planned and operated, but new digital technologies have the potential to solve the optimisation and coordination challenges and deliver lower costs to consumers and high reliability.

Canada

Intermittency has not been an issue in Canada because of the large hydro generation capacity in most provinces that are ideal for backup of renewables. Also nuclear in Ontario and natural gas and coal in Alberta and Saskatchewan have made transmission intermittency a non-issue at current level of renewables. This may become an issue in the future, mainly in Alberta and Saskatchewan if the required shut down of coal plants by 2030 is extended to natural gas plants.

China

China is expanding on several investments towards its goal of achieving all-electric systems, including UHV AC-DC hybrid power grids, advanced grid technology, energy storage technology, and smart energy technologies. Their priority to stabilize demand consumption, as the largest demand area for energy on the South-East of China, CAE recommends building locally and nearby renewable energy system to improve the absorption capacity of intermittent renewable energy. Secondly, as the industry chain continues to migrate to inland provinces, it is encouraged that a system scheduling strategy for intermittent renewable energy generation is coordinated with on-site consumption and external transmission.

Croatia

One of the key measures for high uptake of RES is faster adoption of national strategic documents and creation of action plans, which should define the implementation of measures proposed by strategic documents. Role of local and regional governments should be emphasized through stronger role of local strategic documents such as Sustainable Energy and Climate Action Plans. Remaining barriers should be removed for the testing and implementation of demand response technologies, electrification of other sectors and strengthening of synergetic effects between decarbonization of energy production sector, heating sector and transport sector.

Czech Republic

Czech power grid was historically burdened with large-scale, unscheduled power flows from North-east Germany to Austria and back to Germany caused by wind parks generation located on north-east of Germany. After installation of phase-shifting transformers on cross-border connectors between Germany, Czech and Polish systems the risk of overloading was eliminated. Basic production provided in nuclear power plants, strengthening renewable generation sources, in particular photovoltaics and existing hydroelectric power plants, are solutions towards combatting intermittency.

France

France is well interconnected with its six neighbours, meeting the European goal of 10% of its installed capacity. Achieving 15% in 2030 as suggested by the European commission may prove to be difficult, as there are strong local oppositions to new transmission lines. However, the Academy notes that renewables generation is well correlated between European neighbouring countries and considers that interconnections can only be a small part of the solution to excess renewable energies.

Germany

The German power system is exceptionally reliable, with a SAIDI (System Average Interruption Duration Index) of 12 minutes per year. One of the biggest challenges is the necessary reinforcement of the transport grid over more than 5,000 km, which is inhibited by a pushback from public opinion. At DSO level the increasing number of heat pumps and electric vehicles already leads to bottle necks in the distribution grid. The solution is (expensive) reinforcement of existing lines and installation of variable local transformers.

Hungary

Hungary faces no major problems in relation to electric isolation, electric 'islands' or isolated grids, while it imports nearly one third of its annual electricity needs. Main cornerstones of the energy policy are the construction of new nuclear units to maintaining nuclear production for the long run as baseload and extensively develop PV capacities. Regarding the renewable sources, the currently installed capacity of renewable energy sources does not cause grid stability problems, but with the increasing number of PV plants and with the decreasing capacity of conventional fossil-based power plants it can be a major problem in the middle and long-term. Hungary is organically integrated into the EU electricity system and has interconnection to Ukraine and Serbia, too. The country has large cross-border capacities to its neighbouring countries: Hungary exceeds already significantly the 15% EU target relating to the interconnection of electricity systems, and the share of cross-border capacities relative to the nominal installed power plant capacities exceeds 47%. The further increase of cross-border capacities is, however, planned.

India

The Indian electricity grid operates as a single synchronous grid and there are no reliability issues at national, regional or state level. The availability of regional grids is consistently maintained at over 99%. The grids at distribution level are noted to have reliability issues in the areas with high growth of demand, exceeding the safe operational limits of distribution infrastructure.

Japan

The national grid in Japan has been very reliable. The national grid system is divided into 10 segments operated by independent and private electric power companies. Interconnection among the 10 segments is not broad, especially between the east (50 Hz) and west (60 Hz) sides. Installation of PV is concentrated to north (Hokkaido) and south (Kyushu) grid, which are relatively small in their capacity because of the smaller population. As a result, a Duck Curve problem has become severe in Kyushu grid, imposing a severe ceiling against the further installation of PV. 17% of the electricity generated in Kyushu grid was exported to neighbouring ones at 12:00-12:30 on Oct. 21, 2018, when 1.17 GW PV electricity (16% of the total renewable capacity) was forced to be disconnected from the grid. Metropolitan areas like Tokyo are currently free from an identifiable Duck Curve problem, but the land area available for PV installation is limited there.

Korea (South)

South Korea’s grid has scored highly in several reliance metrics: the frequency holding ratio: 99.9%, voltage holding ratio: 99.9%, and system average interruption duration index (SAIDI): 8.59 minutes. However, the power system near the metropolitan centres have suffered overload due to high load concentrations. Although the capital Seoul has extremely high population density and heavy load, generation is not sufficient to meet the demand. Korea Electric Power Corporation (KEPCO) is currently trying to expand its facilities, but it faces challenges due to opposition of residents near transmission systems. Recent solar power generation has rapidly increased, causing a Korean-style Duck Curve to occur, which shifts peak load time from previously 3 pm to now 5 pm.

Mexico

Mexico is interconnected to the north with the USA through several interconnection lines across the border from which it is exchanged similar amount of energy from both sides. To the south one interconnection with Guatemala and another one with Belize, mainly to export electricity. Pumping storage is one option for primary storage that is under study for Baja California and Norwest regions, while in general batteries are a more discussed option. Mexico has strong goals to promote clean energy codified in new legal mandates, and introduction of new intermittent capacity has been commissioned, raising potential challenges for the stability of the grid. Mexico looks to energy storage as a possible solution, along with the enhancement and expansion of the grid.

New Zealand

High-voltage transmission lines are publicly-owned. There are five major generation companies, three of which are partly publicly-owned. A central market regulator, *Transpower*, controls the transmission grid and system operation stability. There are 24 local electricity distribution companies taking power off the central grid and distributing it locally. Dry years can constrain hydro generation. As shares of solar and wind increase, this could become a stability problem for the grid. Grid reliability could be maintained through bioenergy plants, or gas-fired plants, on standby. Pumped hydro and hydrogen technologies are also being evaluated.

Nigeria

Nigeria currently experiences no renewables-related intermittency problems. The electricity regulatory agency is providing smart meters for use and the replacement of electrical appliances with more energy efficient appliances.

Pakistan

Pakistan experiences system losses in the grid due to inefficient transmission and distribution system. In addition, total power theft reached to 0.35 billion US dollars in 2017- 2018. Recent target assigned is 5% reduction over mean value of last five years data of SAIF1 and 10% reduction over mean value of last five years data of SAID1. Electricity short fall exceeded 6,000 MW in 2018 which is 18% of total power generation capacity equivalent to load shedding of 8 hours per day on average all over the country and particularly in summer. Reasons for high technical losses in Pakistan include haphazard expansion of power transmission and distribution systems, large scale use of 11 kV and LT lines in rural electrification, inadequate load management, use of poor quality equipment in agricultural pumping in rural areas and air-conditioners and industrial load in urban centres and large transformation stages which result in increases in iron and copper losses.

South Africa

Grid performance has been consistently good for many years in South Africa. Whilst the aim is to strengthen the transmission backbone to attain N–1 compliance as required by the Grid Code, and strengthen distribution networks to accommodate customer growth and ensure the ability to accommodate power from renewable IPPs, risks around transmission and distribution plant reliability still remain, due to ageing assets, system and resource constraints. To date the Duck Curve has not been experienced to any great extent in South Africa – although given the high growth planned for renewables, especially Privately solar PV, this is likely to be of concern in future. As such this has been factored into Transmission Planning.

Sweden

Sweden has a north-south flow with the major part of hydro and wind power in the north. But there is still a bottleneck in the south of Sweden that the grid development not yet has solved. No problems with isolated grids. Sweden is very well connected with the Nordic, Baltic and European systems by 16 interconnectors. Sweden is also a net-exporter over the years. Regarding Duck Curve issues, Sweden has a much flatter curve and hydro power technology is in place to balance the system. But with closing down more nuclear the demand for flexible demand or production response is needed.

Switzerland

Though Switzerland does not participate in EU-market coupling, it is part of the Continental European power system, with high integration with over 41 high-voltage tie lines, most notably linking the Northern markets with import-dependent Italy. Small electric "islands" are present in the distantly far mountain areas, but they are mostly of small size. Intermittency issues regarding loop flows are somewhat severe. Due to the mainly hydraulic based generation (encompassing about 60% of renewable) Switzerland faces during the summer time an export which could be between twice and three times the system load, and during winter time, the import can have ranges of more than 50% of the system load.

USA

Due to aggregate low penetration levels, renewables do not generally affect grid reliability or stability across large regions. Most outages result from physical damage in a local part of the distribution system. Nonetheless, select locations and feeders (e.g., in Hawaii and California) have relatively high, local deployment of variable renewables forcing utilities to take additional efforts to maintain stability and reliability. Some areas, specifically Texas and Hawaii, experience transmission congestion or oversupply of wind generation during low load periods, which is mitigated through curtailment. However, the levels of wind curtailment experienced in the United States differ substantially by region and utility service territory. In many regions, curtailment is very low and not even tracked. The U.S. transmission system is composed of three separate interconnected "synchronous" regions (western, eastern, and Texas) that operate with alternating current at 60 Hz. The three interconnections operate with only a few (asynchronous) direct current connections that allow transfer of energy between them. There is a strong synchronous connection with Canada for both the Eastern and Western interconnections, and the DC lines connecting the asynchronous Québec grid. While there is also a connection to a small portion of Mexico within the Western Interconnection, that dependency is less significant for either country as most of the Mexican grid is a separate system. Regarding Duck Curve phenomenon, select locations with large renewable penetration are seeing large ramp rates, specifically in California (CAISO) with large PV installations and in the Midwest (MISO) where large wind installations drive significant ramp rates and differences in locational marginal prices.

Uruguay

Uruguay experiences little electrical intermittency. The peak power in the Uruguayan electrical system is 2,100 MW and there are 2,000 MW in electrical interconnection with Argentina and 500 MW with Brazil. Installed wind power is 1,500 MW, solar is 250 MW, and hydro is 1,500 MW. Hydro is very flexible. There are also 1,000 MW in gas turbines. Uruguay is considering use of electric transport through batteries or hydrogen production is increased, as renewable energies (or persistent variables) grow.

Current Energy Mix Portfolios

Note: Some countries may source electricity from a fourth "other" category, such as waste incineration, such that these three categories do not total 100%.

	Fossil	Nuclear	Renewables
Argentina	63% share, increasingly displaced with gas, hydro, wind and solar power.	2% share of total electricity generation.	31.5% considering all hydro and renewables. (29.1% Hydro + 2.4% Renewables)
Australia	81% share of total electricity generation	0% share of total electricity generation	The shift in electricity supply towards renewable resources is set to accelerate as the relative costs of large-scale wind and solar continue to fall in Australia.
Canada	18.5%. By phasing out coal-fired electricity, Canada strives to have 90% of electricity from non-emitting sources by 2030. Currently, nuclear power in Canada is provided by 19 commercial reactors with a net capacity producing about 96,000 GWh.	14.5%. Modelling studies have estimated that electrification will require a two- to three-fold increase of electricity in Canada by 2050 and nuclear will be required to play a significant role in the major expansion of emissions free electricity.	67%
China	70.39% share of total electricity generation. However, share of non-fossil energy in total power generation will reach 50% by 2030.	4.20% share of total electricity generation, operates with base load and generally without load tracking, which can effectively improve the utilization rate of nuclear power and reduce the system power generation cost.	25.41%, with share of non-fossil energy in total power generation will reach 50% by 2030.
Croatia	27.63%	0	72.37%
Czech Republic	53.91%. In the long term, it is planned to shut down fossil coal power plants (by 2030). The concept is based on the requirement of self-sufficiency of electricity production. Basic production will be provided in nuclear power plants.	34%. Plans to build new nuclear power plants and update existing current units by 2035.	11.97%
France	9.7% total. From 2023 and on, the spinning reserve will be reduced with the decommissioning of all coal fired power plants which are presently used for grid stability only.	Nuclear electricity to be reduced from 72% to 50% by 2035. Decision on new plant construction by 2021.	19.7%
Germany	48% share, with a complete phase out of coal is planned in the year 2038 or even earlier.	12%, with plans to phase out completely by 2022, which may cause severe problems in electricity transport, because new transmission lines will not be erected in time.	35% share, with plans to expand to 50% by 2030, 65% by 2040, and 80% by 2050.

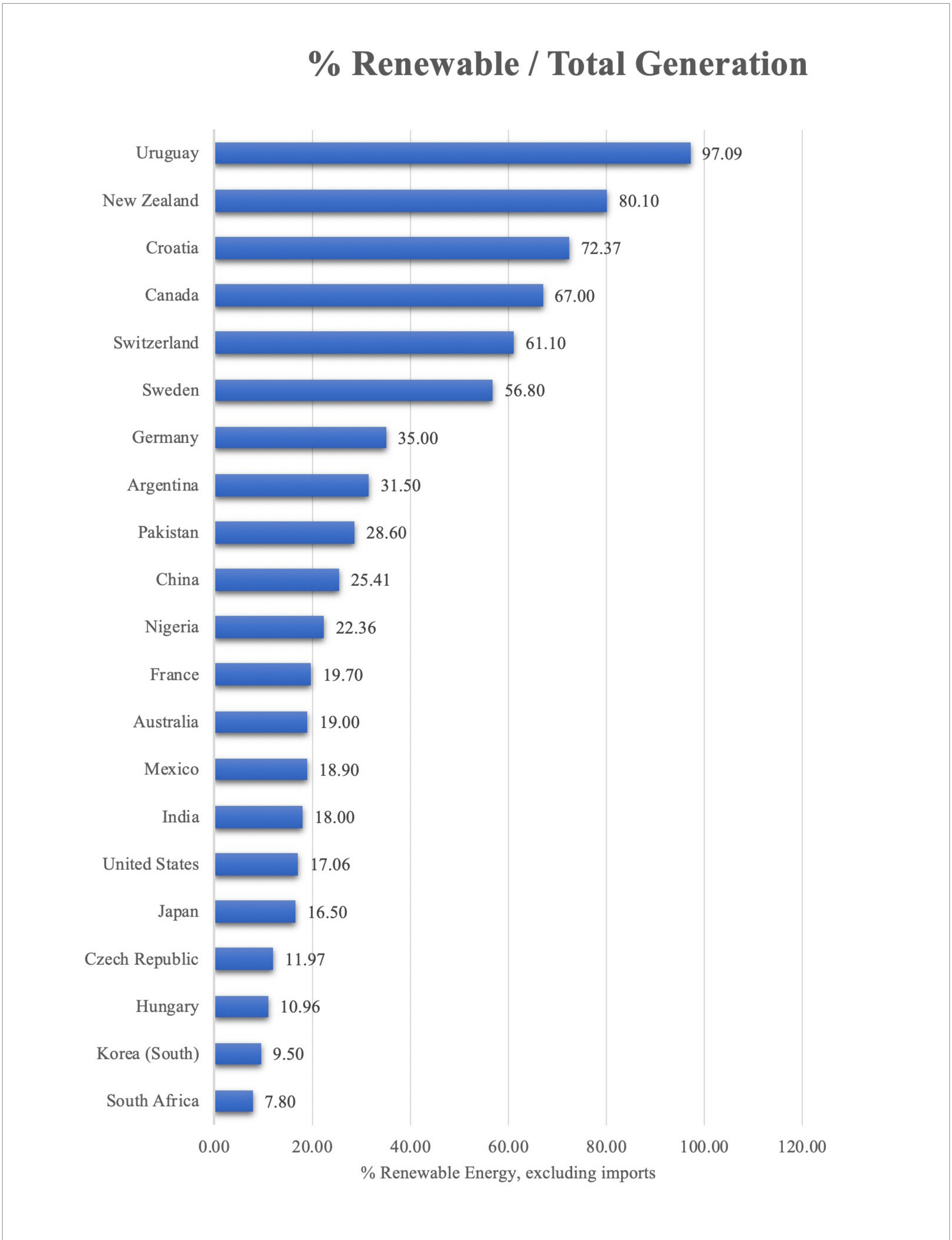
	Fossil	Nuclear	Renewables
Hungary	38.4%. There is a high level policy discussion on phase-out of coal in Hungary by 2030. The share of import is currently over 30%, which is based mainly on fossil production. The future role of import is not decided yet, could go back to 10-20%. (The above given percentages are calculated on the basis of the current domestic production, without import.)	50.64% in the domestic production, and approximately 36% in the domestic consumption (because of the high share of import). The construction of two new nuclear units is under preparation (currently in the licensing phase) which will replace the existing nuclear capacities. By 2040 the share of nuclear in the domestic consumption could be around 35-40%.	10.96%. Large scale development mainly in PV is underway.
India	79% total share	3% share	18%. Comment: India predicts to expect that the rate of deployment of variable renewables will no longer be determined by their per unit cost, which is already competitive with that of coal, but rather by the rate at which the electricity system can be adapted to support their integration and maintain security of supply and cost-effectiveness.
Japan	78.1%. Due to limited land area to devote to solar/wind farm production, Japan has chosen to invest in production of hydrogen (H_2), requiring Japan to import CO_2-free hydrogen from abroad as a substitute of imported fossil fuel which is currently the major energy source.	5.4%. All nuclear power plants were suspended in operation after the Fukushima accident in 2011. After 2015, some resumed operation and 9 plants are in operation as of 2019. The number of nuclear power plants operating in Kyushu grid increased from 2 in 2017 to 4 in 2018, which made the problem of the Duck Curve desperate and the cut-out of PV is recently very frequent. In Japan, temporal variation of nuclear power output is prohibited by law.	16.5%.
Korea (South)	68.0%. The 3rd Energy Master Plan announced in 2019 stated that South Korea will aggressively reduce coal-fired power plants, and expand PV and wind power capacities along with increasing gas-fired power plants.	22.5%. South Korea declared that no new nuclear power plants will be constructed, and existing reactors will be phased out after reaching their designed lifetimes.	9.5%. According to the 3rd Energy Master Plan, electricity generation by renewable sources will increase to 30-35% by 2040.

	Fossil	Nuclear	Renewables
Mexico	76.8%	4.3%	18.9%. The objectives set by the government in terms of clean energy and its degree of compliance: the energy generated in the country from clean sources must be 35% in 2024 and 50% in 2050. At the end of the first half of 2017, Mexico generated more than 20% of its electricity with clean sources, of which about 16% corresponded to renewable sources.
New Zealand	19.9%	0	80.1%. Note, there are no Government subsidies in place for renewable electricity. For example, with mean annual wind speed on good sites at around 10 m/s, the resources are very good. Hence a wind turbine in NZ can generate around three times as much electricity as the same model on the best 7 m/s sites in Germany, Denmark, etc. Currently wind and geothermal are the cheapest generation options with many additional sites consented but not yet constructed. So, the market can meet this target without government intervention. However, for the last few percent of the 100%, it may be cheaper to rely on gas plants to ensure grid reliability.
Nigeria	77.64%	0	22.36%. The Nationally determined contribution (NDC) to climate change mitigation envisages13 GW of off-grid solar by 2030, furthermore the sustainable energy for all, (SE4ALL) goal contribution of renewable energy excluding the large hydro power will be minimum 30% to the electricity mix.
Pakistan	65.9%. Furnace oil is being replaced by CNG, LNG and coal to achieve the objective of low-cost energy. Combined cycle power plants are mostly in use now.	7.3%	2.3%

	Fossil	Nuclear	Renewables
South Africa	86.2% total share. (Approximately 36% of coal produced in South Africa is used in the generation of electricity, which means that a relatively large proportion of South Africa's coal is exported or used by Sasol to be converted into liquid fuels.)	6%	13.8%
Sweden	1.9%	41.3%. Nuclear energy is phased out due to lack of profitability because of low electricity prices and need for renovations due to age, however no deadlines have yet been set in place.	56.8%, with the target is 100 percent renewable electricity production by 2040.
Switzer-land	2.8%	36.1%. Progressive nuclear energy decrease in the next decades (see energy strategy 2050). Nuclear phase out has already started, first nuclear power plant in CH will be disconnected end of 2019 and there is no new permission to build a new nuclear power station, however no deadline for shutdown as long as safe operation is guaranteed.	61.1%
USA	63.46%	19.32%	17.06%. There are no national goals for 2040. The current administration maintains an "all of the above" energy strategy that supports diverse fuel sources for electricity generation. Previous administrations have more aggressively pursued emissions reductions, for example former President Obama's Clean Power Plan, which called for more than 30 percent reductions in greenhouse gas emissions from the electricity sector by 2050. At the sub-national level, there is wide variability in the renewable energy goals (formalized in Renewable Portfolio Standards) of individual states, with some (e.g., Hawaii, CA) striving for 100 percent renewable energy production by 2045-2050, while others have no goals/mandates for renewable generation.
Uruguay	2.9%	0	97%

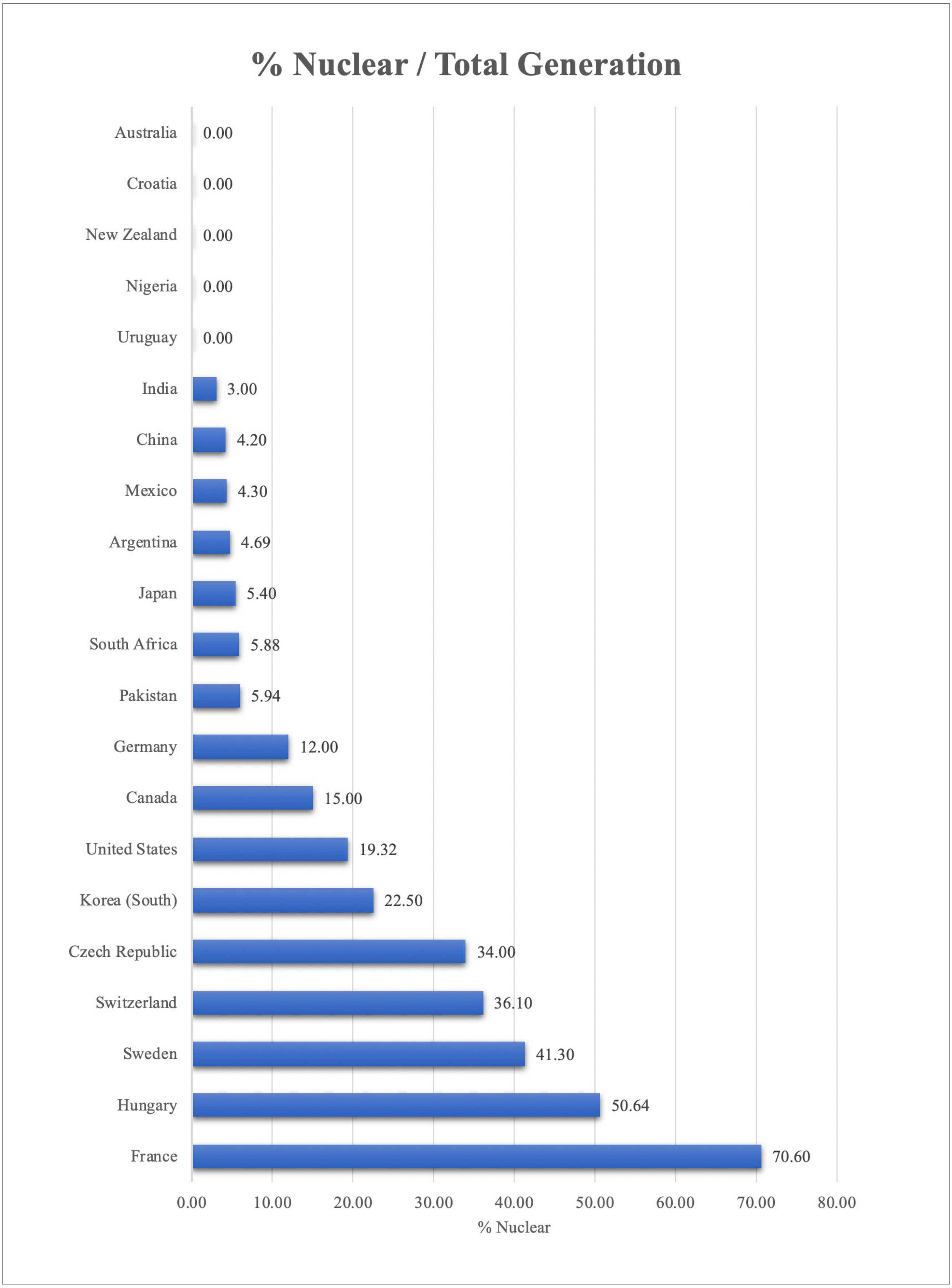
Graph 1:

Countries by % renewable / total electricity generation, descending

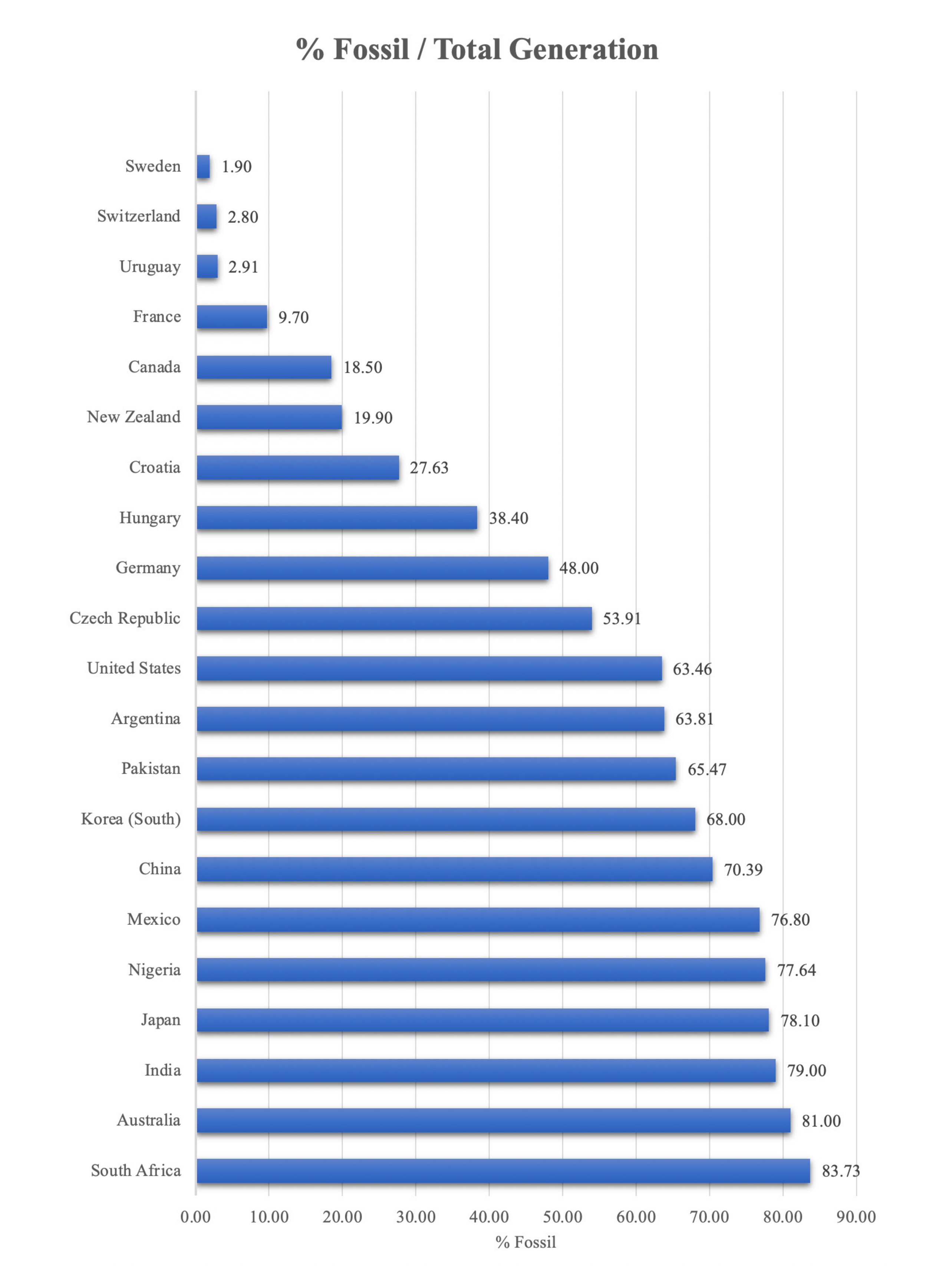


Graph 2:

Countries by % nuclear / total electricity generation, ascending



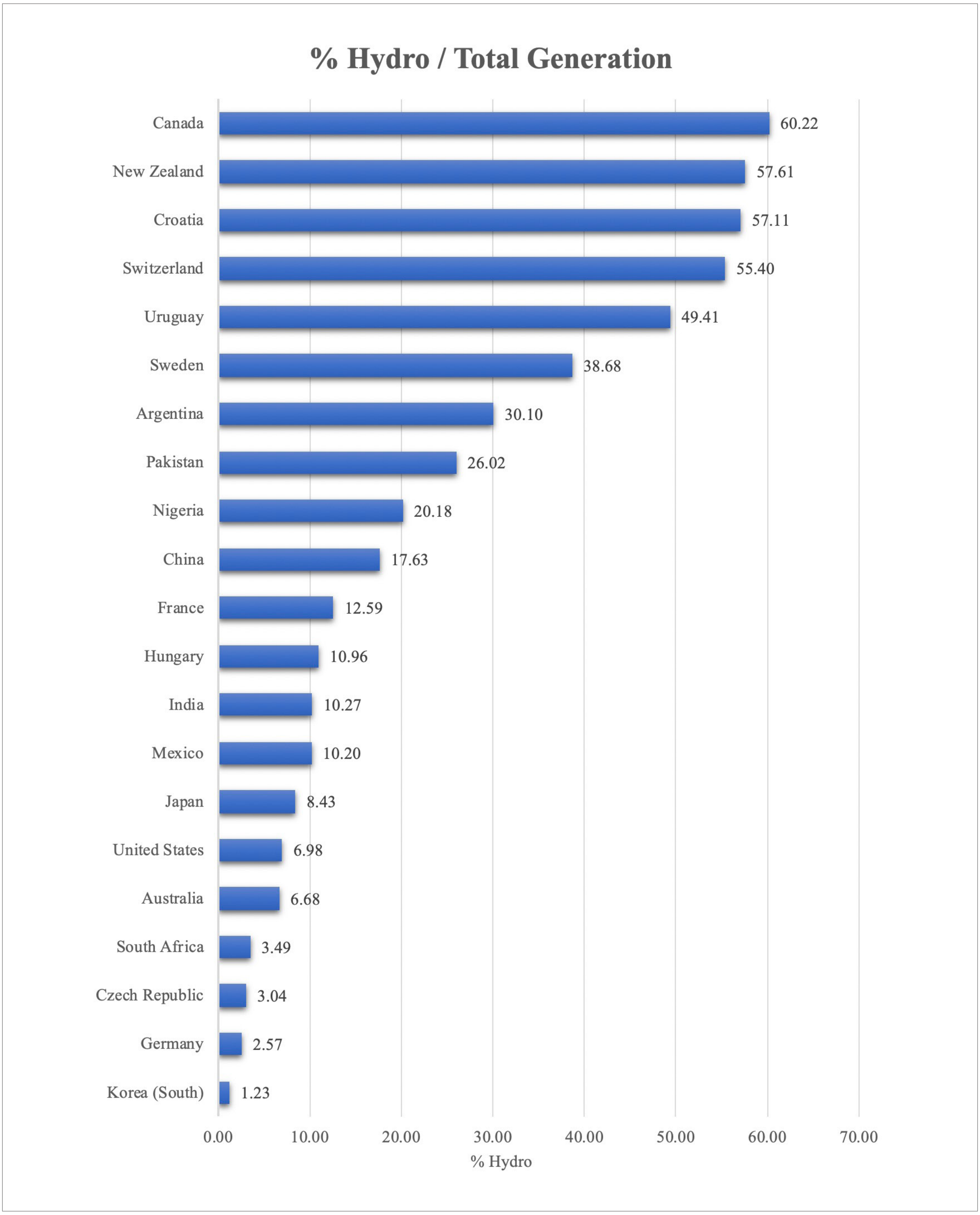
Graph 3:
Countries by % fossil / total electricity generation, ascending



Graph 4:

Countries by % hydroelectricity / total electricity generation, descending

Note: Some countries' use of hydroelectric power as a dispatchable storage solution to intermittent supply provided analysis into the quality of that country's renewable penetration.



Grouped Categories, and Breakdown of Countries' Renewable Portfolios

Note: "Hydro %" figures include generation from large and small hydro plants. "Biomass %" figures varies depending on respective countries' definition of renewable classification, and may include generation sources such as combustion of agricultural residues, byproducts, and bio-wastes.

Group A

Country	Hydro %	PV %	Wind %	Biomass %	Other %	Total RE (GWh)
Croatia	78.91	0.76	13.54	6.77	0.02	9,865.20
Czech Republic	25.43	22.21	5.78	40.59	1.71	10,534.00
France	56.00	9.00	23.00	11.00	1.00	125,000.00
Germany	7.50	20.00	49.00	20.00	3.50	226,400.00
Hungary	6.31	7.84	17.32	51.40	17.13	3,405.61
Sweden	68.10	0.40	18.30	13.10	0.10	90,600.00
Switzerland	90.60	4.70	0.30	1.60	2.80	41,305.00

Group B

Country	Hydro %	PV %	Wind %	Biomass %	Other %	Total RE (GWh)
Australia	35.38	24.49	32.97	7.17	0.00	49,339.80
Canada	89.72	0.75	6.56	2.68	0.30	437,626.00
China	66.91	7.87	19.68	3.94	1.60	1,777,000.00
India	58.70	11.35	23.10	6.69	0.16	227,961.00
Japan	51.10	38.70	4.80	4.00	1.40	150,000.00
Korea (South)	12.90	16.30	4.40	16.50	50.00	56,629.00
New Zealand	71.10	0.20	6.00	0.50	21.1	35,058.00
United States	40.93	9.34	38.57	8.81	2.34	712,773.00
Uruguay	49.41	3.14	37.98	6.58	0.00	12,064.00

Group C

Country	Hydro %	PV %	Wind %	Biomass %	Other %	Total RE (GWh)
Argentina	95.57	0.25	3.26	0.58	0.33	43,302.00
Mexico	53.97	3.7	20.63	1.06	20.63	59,965.50
Nigeria	87.76	6.44	1.29	4.51	0.00	6,801.75
South Africa	50.00	12.50	37.50	0.00	0.00	18,355.00
Pakistan	90.98	1.57	5.00	2.45	0.00	42,383.00

Solutions for Each Group Type

Group A: Cross-Border Transmission Systems

Countries include: Croatia, Czech Republic, France, Germany, Hungary, Sweden, Switzerland

Moving clean power across a continent?

Countries with relatively high levels of renewable penetration have found a novel way of addressing renewable-onset intermittency by trading across transnational interconnection systems. Continental interconnection presents several benefits, including enhanced electric reliability, supply security, affordability of wholesale power prices, resilience to increased demands resulting from unexpected events or emergency crises, and overall, bringing together a greater diversity of electricity sources.

The greatest benefit to continental interconnection is flexibility: balancing the irregular supply and demand of renewables by moving surplus and diversely generated renewable energy to neighboring countries. If a grid covers a wide enough geographical area, supply variations are evened out because electricity demand can draw from different sources. In connecting and fully integrating several regions, the average output will have a much smoother behavior. For example, European Union (EU) and electrically networked affiliate nations are, in effect, able to share a reliable baseload powered by nuclear power; 109 of the operating nuclear reactors in 15 EU member states account for over one-quarter of electricity generated in continental Europe[7].

Example: Interconnections between France and Germany, for instance, can provide Germany more capacity to fully utilize its variable renewables, supported by French nuclear baseload. In moments of high generation in which German wind and solar plants exceed demand, French nuclear plants can switch into load following mode to reduce their output and efficiently integrate lower-cost renewable energy.

The harmonization of energy markets and the development of cross-border grids have had different motivations, such as post-war infrastructure building, congestion management, competitive electricity pricing, treaties to encourage financial integration of key regions, or intentional implementation with the intent to offset intermittency issues. Regardless of these reasons, the transmission systems today face common issues such as informational problems stemming from network complexity, transmission congestion, and the lack of rapid diagnostic coordination.

The solution: Coordination, then, is the solution for these large networks' problems. **Smart grid technologies,** such as smart meters that can rapidly detect and respond quickly to imbalances. IoT-based connector technology can execute pre-programmed schemes to reroute, reduce load, or reduce generation in response to network disturbances. Countries with these such problems also make the observation that transmission capacities would need to be significantly higher than current transmission systems in order to promote unimpeded energy trading across distances unbounded by borders—however, the sharing of reserve services across the connected grids enables existing infrastructure to be used more efficiently and reduces the need for new capacity in individual countries. Since energy supply will have a larger proportion consisting of centralized baseload, further investments in grid reinforcement and installation of new transmission lines may be needed to meet sufficient transmission capacity.

[7] World Nuclear Association (2020); Nuclear Power in the European Union. https://www.world-nuclear.org/information-library/country-profiles/others/european-union.aspx

Group B: Interregional Transmission and Distribution (TND) Systems

Countries include: Australia, Canada, China, India, Japan, South Korea, New Zealand, Uruguay, United States

What are other forms of load-following solutions, to combat regional intermittency?

A few countries have looked at sources of intermittent power as a balancing mechanism or alternatively at short-term storage solutions to resolve intermittency issues. Intermittent power supplies are also frequently used for supplying power to remote urban centers which are not served via the ordinary grid. These remote urban areas can be a problem in countries with expansive land but low-density population centers, on islands physically isolated from main grids, or on account of other practical limitations that inhibit integration of their power systems must invest in independent, readily available reserves that can be dispatched instantaneously and with near certainty.

To meet day-to-day electricity demand, some utilities operate a main baseload that runs on conventional dispatchable sources like fossil and nuclear, but also renewable nonintermittent sources like biomass or geothermal energy. If unpredictable variations in load occur, these isolated systems have no other grid to divest from and must offset the imbalance using standby operating reserves that quickly "ramp-up" or "load-shed" production to correct the deviation. Investments in expensive distribution technology have also been installed in these countries to ensure that the power supply functions uninterrupted.

Most notable of these secondary reserves are pumped hydroelectric power supplies that can deploy output promptly and to buttress power shortages is a reliable model that can be deployed promptly.

Example: The Duck Curve phenomenon illustrates the problems of overgeneration of solar energy that results in an imbalance between electricity demand and supply. Overgeneration during the day, and the steepness of the load increase during the late afternoon and evening, presents a problem. Energy storage is a necessary solution to these problems by storing excess power production during the day and dispatching it at night, thereby eliminating overgeneration risk and consequentially allowing gatekeeping operators to effectively redistribute energy supply and demand at optimal times.

The solution: **improved distribution and storage technologies** are critical next steps to implement in these countries. Especially, the inherent storage capability of pumped storage can help isolated states integrate greater quantities of intermittent renewable power like solar and wind. The backup gas-fired power plants with quicker response times could also help balancing the demand and supply with intermittent inputs, although questions remain with the sustainability of gas-fired power plants. Countries utilizing pumped hydro, biomass, geothermal or other renewable sources as a zero-carbon storage solution is essentially converting renewable energy into a dispatchable, controllable energy source. Group B countries are also expanding micro-grids in their distribution systems to smooth out the supply and demand.

Group C: Variable Renewable Energy (VRE) Growth Systems

Countries include: Argentina, Mexico, Nigeria, South Africa, Pakistan

Building energy-efficient foundations in grid infrastructure, while simultaneously growing VRE penetration

These countries have few or no international connections to access other sources of dispatchable renewable energy and are highly reliant on fossil fuel as their primary energy source. Group C countries must overcome technological lock-ins from legacy systems, while redesigning electricity sourcing and pricing markets to increase renewable penetration.

For countries with high reliance on fossil fuel energy as their primary energy source, the transition towards renewable sources poses several difficulties, most notable is the need for peaking or load-following power plants and the coordination of high-voltage power links. Fragile or fragmented national grids cannot keep up with rising energy demands.

Network failures due to inadequate energy from fossil base loads, do not incentivize any shift to renewables because the problems associated with intermittency may exacerbate the current situation. The difficulty in integrating such volatile, decentralized renewable energy sources into old power grids designed around the old fossil fuel model poses incentive challenges to invest in energy transition at all.

For these countries to "leapfrog" past the initial intermittency problems experienced by high renewable penetration countries, their transition would be best served by investing in the installation of renewable-powered baseload plants.

The solution: **increase investments into optimized renewable load-following microgrids.** New renewable technologies, once proven feasible, should be scaled up and implemented to achieve long-term climate goals. However, alongside expansion and investments into renewable production, these countries can invest simultaneously in low-cost microgrid systems powered by renewable sources, especially in isolated regions where the main grid is unreliable, such as rural towns with low consumption or densely populated hubs of high consumption. Set up with multiple VRE loads that act as several sources of backup power, the microgrid provides communities with reliable energy without drastic overhaul to the existing grid infrastructure. By staggering the introduction of renewable, high efficiency VRE loads constrained to target areas can overcome intermittency pitfalls as well as streamline the market transition.

5 Proposed Solutions to Overcome Intermittency and Achieve Grid Stabilization

A non-exhaustive selection of ongoing developments in technology in select contributing countries, introduced here as recommended points of focal improvement in the near future.

Energy Storage

The state of distribution technology as they stand today, requires that electricity demand must be meticulously calculated to be in constant balance with electricity supply. In a grid without storage, fossil fuels must be scaled up or down to match the intermittent generation of wind and solar generation. Neither renewable, fossil, nor nuclear plants can respond quickly to imbalances in the network caused by changes in generation or demand.

However, mass grid-scale battery storage could. Large batteries are currently being developed and primarily utilizing lithium ion technology but also hydrogen and sodium-ion alternatives, could serve as enabling devices that allow renewable generation to be stored and accessed instantaneously to respond to uneven supply and demand. With the convenience of "saving" energy generated at peak, the battery can power the load during nonpeak PV/wind hours, and ultimately offset this variability to provide reliable power at all times of the day.

Such a battery would increase grid stability under day-to-day demand predictions, but also changes in demand caused by adverse weather events, tidal phases, and other unexpected circumstances.

Storage thus reduces peak generation or transmission capacity. Breakthroughs in energy storage efficiency as well as commercial application cannot be discussed without mentioning Tesla, the leading energy storage manufacturer and giant in utility-scale energy storage technology. In responding to the 2017 heat waves and electrical outages in southern Australia, Tesla built and installed the world's largest lithium-ion battery at its Hornsdale site using Powerpack batteries.[8]

Battery research led by Tesla and other startups is ongoing, but additional state-initiated research may be needed to supplement this fledgling industry for development into identifying the optimal energy storage for large-scale application, that is most suitable to a given city's geographic conditions and demand size. For example, consider Japan's position in leading hydrogen fuel cell research amidst a clear global market preference for lithium-ion batteries. Several Japanese joint government research projects, backed by domestic automakers and energy firms, have committed significant investments into hydrogen research. Though hydro-electrolysis technology has faced criticism for its comparative inefficiency relative to existing cheaper alternatives, Japan's bet on hydrogen is motivated in part by its need for a storage source that is better adapted to needs.[9] Conditions such as limited available land mass, mountainous terrain, susceptibility to earthquakes, and densely populated urban centers, seasonal variations are ill-suited to lithium storage sites or hydro plants, which could explain the intensive push towards hydrogen technology.[10]

[8] Tesla. (2017) "Tesla Powerpack to Enable Large Scale Sustainable Energy to South Australia" https://www.tesla.com/blog/tesla-powerpack-enable-large-scale-sustainable-energy-south-australia

[9] Shigeki Iida, Ko Sakata, Hydrogen technologies and developments in Japan, Clean Energy, Volume 3, Issue 2, June 2019, Pages 105–113, https://doi.org/10.1093/ce/zkz003

[10] Monica Nagashima. (Oct 2018) "Japan's Hydrogen Strategy and Its Economic and Geopolitical Implications", Etudes de l'Ifri, from https://www.ifri.org/sites/default/files/atoms/files/nagashima_japan_hydrogen_2018_.pdf

Demand Response

The most manual and potentially easily applicable solution that is already widely underway is demand response (DR): the planned discharge by power producers in response to fluctuating peak times. This strategy requires extensive coordination by DR administrators to respond to weak points in the grid by instantly discharging, which alleviates peaks in the system load.

In centrally planned economies or countries in which the state is the energy supplier itself, gathering data on peaking and employing energy demand measures will easily increase the efficiency of energy consumption easily.

However, in decentralized or horizontal systems, large-scale level focus on controlling demand produced from industrial or commercial actors requires much coordination. These clients contract in advance with government agencies to disclose regular use predictions as well as forthcoming events that may require unexpected draw. Mass users such as factories and retail shopping centers can schedule electricity consumption to supply less efficient “peaking” sources at lower cost. Delaying the draw from these large sources of energy consumption can considerably mitigate system instability.

On a residential level, some municipal and private utilities have offered testing and pilot programs engaging residential clients to participate in DR response in exchange for peak time nonuse rebates. If energy load is forecasted to be in top load hours, opted-in customers are directed to alternate direct load control programs with different rates. In Ontario, Canada, certain residential users can participate in a program called Peaksaver AC[11] whereby the utilities administrators of utilities plants can remotely control water heaters or air conditioning during peak demand periods, delaying the draw and pressure on the grid supply (allowing peaking plants time to cycle up or avoiding peak events), and the customers delayed consumption after high demand periods were over were rewarded with lower prices. At scale, these solutions have the potential to reduce peak demand considerably. The success of such programs depends on the development of appropriate technology, a suitable pricing system for electricity, and the cost of the underlying technology.

Another temporary solution to the intermittency problem of RE involves relying on combined cycle, or “flex”, power plants to mitigate the variability of wind and solar resources, also known as “smart ramping” or “smart gas”.

Ramping characteristics have been used as a secondary crutch for combined cycle plant design. Existing fossil plants can be fitted with technology to ramp up or down to accommodate shifting RE supply. However, this solution is not without inefficiencies. Long start times and slow ramping capabilities are largely a result of incorrect energy cycle modeling, lack of economic value, and/or an unaccounted-for event.

To be clear, operating and maintaining legacy fossil systems even as a “supporting net”, defeats the primary goals of transitioning to clean energy. Improvements in the ramping or rapid-response startup of gas-powered plants usually result in more GHG emissions.[12]

However, the combined cycle model provides a demand-side solution that is least disruptive. To mitigate issues in inefficiency, a technological response is needed, namely the addition of high-tech feed-forward controls. For example, Alstom, Mitsubishi and General Electric (GE) have all rolled out new flex facilities systems in recent years with an emphasis on flexibility.[13] All of them feature notable upgrades: ability to adjust internal controls, improve specific components, and rework architecture. By increasing such response technology, manufacturers are racing to develop fast-start turbines that can adjust output quickly without sacrificing performance.

[11] https://www.peaksaver.com/

[12] Rodw. (2020, April 09). Unlocking the Potential of Combined Cycle Plants, from https://www.power-eng.com/2018/04/01/unlocking-the-potential-of-combined-cycle-plants/

[13] Garthwaite, J. (2013, November 02). New "Flexible" Power Plants Sway to Keep Up with Renewables, from https://www.nationalgeographic.com/news/energy/2013/10/131031-flex-power-plants-california/

Financial Incentives & Strategic Curtailment

One of the main goals of DR is to be able to charge the consumer based on the most accurate price of the utilities at the time it is consumed. In states with high renewable penetration, sometimes the net load will exceed the forecasted load, causing excess amounts of electricity to be produced. If consumers had the option to pay less for using electricity during off-peak hours, and more during peak hours, the predictable supply and demand cycles could reliably offer incentives for consumers to change their behavior and offset use at strained grid hours.

In countries served primarily by vertically integrated utilities, power purchase agreements (PPAs) between the utilities increasingly contain financial provisions for curtailment contingencies. To increase accountability on part of the client to uphold the schedule, PPAs can also include minimum guarantees for generation and off-take, with penalties for not meeting those thresholds. There is a need to develop financial incentives to attract such users, mitigate the risk of under-performance, and achieve the desired curtailment. Institutional mechanisms, such as nationalized green fund, can be effective in bringing these innovative solutions to market.

The most salient criticism of demand-side management is that pilot programs have not been cost-effective, invasive towards consumer privacy rights, and resulted in minimal profit for utilities.[14] For DR programs to fully take effect, government actors must incentivize utilities to price demand accordingly attract enough customers to opt-in.

In addressing the curtailment issue on a regional or national level—namely, the discarding of the generated production from renewables when demand for electricity is less than supply—electricity governance and policing is needed to strictly monitor grid operators to prevent this mismatch from occurring. In 2014, China encountered an economic deceleration that drove down the demand for electric power. Other sources of power supply, namely fossil, became cheaper which resulted in an abandonment of electricity from wind. In 2015, the Chinese government pushed new policies that mandated grid companies to purchase renewable energy over fossil alternatives from generators.[15] In its subsequent NEA report, the Chinese government affirmed intentions to limit curtailment within five percent. The Chinese also streamlined their organizing agency structure to give authority to a centralized national government agency, previously provisional local government, the oversight in operational allocating and production planning. According to a report by the Brookings-Tsinghua institute, coordinated and integrated planning, expanding advance forecasting, and expanding operational accessibility were factors in governance that contributed to better system flexibility in the power sector.[16]

[14] NRDC. (2018, July 25). Using More Renewable Energy by Managing Curtailment, from https://www.nrdc.org/experts/sameer-kwatra/using-more-renewable-energy-managing-curtailment

[15] NDRC, Document 625, National Development and Reform Commission

[16] QI, Y., Lu, J., & Zhu, M. (2018, April 09). Wind curtailment in China and lessons from the United States, from https://www.brookings.edu/research/wind-curtailment-in-china-and-lessons-from-the-united-states/

Forecasting Tools

Technologies to automate the process of demand response can be implemented to streamline detection, target shortage, detect and signal load-shedding points in the grid to DR administers.

Software solutions that streamline this process can vastly reduce time and resources needed to supplement or discontinue a response in mismatched supply and demand. Building in IT communication technologies (Internet of Energy, IoE) is necessary for efficient compliance with DR programs.

In the Czech Republic, legacy systems of load control feature off-peak ripple signaling, in which rotating frequency generators emit high frequencies into the distribution network.[17] During peak times, a higher frequency signal is superimposed onto the main power signal, to shut down the load until a subsequent manual disabling of the signal. The receiver devices attached to residential or industrial loads are "telegrams" that can target specific regions.

Newer smart meter technology is also expanding. Smart grid systems deployed in Europe are implementing advanced mesh radio technology. European radio networks offer more bandwidth, shorter response times and improved security, combined with excellent coverage, even at difficult locations like cellars and rural areas, in comparison to PLC smart meters.[18] Mesh radio technology can be combined with existing cellular technology to create highly cost-efficient networks optimized for performance and security.

[17] EGC - EnerGoConsult ČB. (n.d.). Ripple Control, from https://www.egc-cb.cz/en/products-for-power-industry/ripple-control.html

[18] Andreadou, N.; Guardiola, M.O.; Fulli, G. Telecommunication technologies for smart grid projects with focus on smart metering applications. Energies 2016, 9, 375.

Microgrids

To meet small-scale needs or in isolated areas with limited mainland grid access, a microgrid can effectively integrate various sources of distributed energy as well as renewable electricity and can supply emergency power on reserve.

Microgrid systems are an applications of localized group of electricity sources and loads based on independent distributed power sources, that are, small-scale self-sufficient power systems, rather than relying on the traditional centralized power grid, is taken into account. In South Korea, the quasi-public utilities sector is working to develop microgrids that provide stable power supply by combining digital technologies such as blockchain and energy solutions with existing microgrid-related technologies such as small-scale PV, wind and energy storage devices. Recently, LVDC (Low-Voltage Direct Current) technology, an important component of the microgrid, is also being developed, and a test bed for core technologies of a LVDC smart grid is under construction at the Naju Innovation Industrial Complex.[19]

[19] See South Korea Questionnaire Report. Id. at 8.

Annex I

Questionnaire Template

The following form was sent to
each of the 21 centuries' academies to survey information on their respective country's energy portfolio, existing generation systems, and national strategy to meet clean energy goals.

Country Questionnaire: Survey Form

Overview

The focus of this paper is how various countries worldwide are each making the energy transition towards clean energy systems, whilst dealing with the inevitable problems of energy intermittency. This co-written paper from various countries will attempt to offer **two** suggestions to an audience of policymakers looking for expert advice: first, addressing what and how **technologies** are being implemented en masse to stabilize grid voltage and frequency, and second, discussing market-based **policy regulations** that attempt to mitigate problems caused by intermittency.

Please fill out the questionnaire by **September 20th, 2019,** regarding to your country's situation and your academy's view. Altogether, please limit your response to less than **5 pages,** and give short 2-3 sentence answers or bullet points. If possible, use charts, tables, references and other data measures.

Remember this data is to be juxtaposed against other countries policies. Pick and expand upon issue areas that are widely relevant, and not just niche markets. If applicable, you may indicate where scientific evidence or assessments by your academy differ from the official national policy. Also, clearly demarcate instances of where you think your country deviates from most other countries.

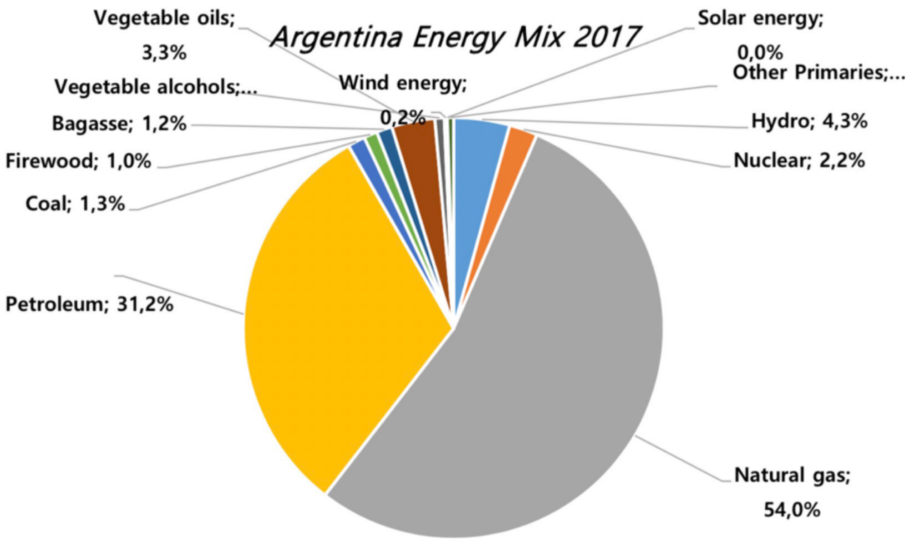
Target Audience

1) Members of international academies
2) International bodies such as United Nations SDG, Mission Innovation, etc.
3) Written for political advisory & policymakers

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

i.e. see Argentina example below



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh):
	Import-export ratio (%):
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %):
	Nuclear (GWh and %):
	Renewables (GWh and %):
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %):
	Wind (GWh & %):
	PV (GWh & %):
	Biomass (GWh & %)
	Other renewables (GWh & %)
Top 3 renewable energy sources	
Growth rate of total renewable generation (% per year) over the past five years	

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	
Ratio of fossil to non-fossil	Fossil (GWh and %):
	Non-Fossil*** (GWh and %):
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %):
	Hydro (GWh & %):
	Non-hydro Renewables (GWh & %):
Top 3 renewable energy sources	

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

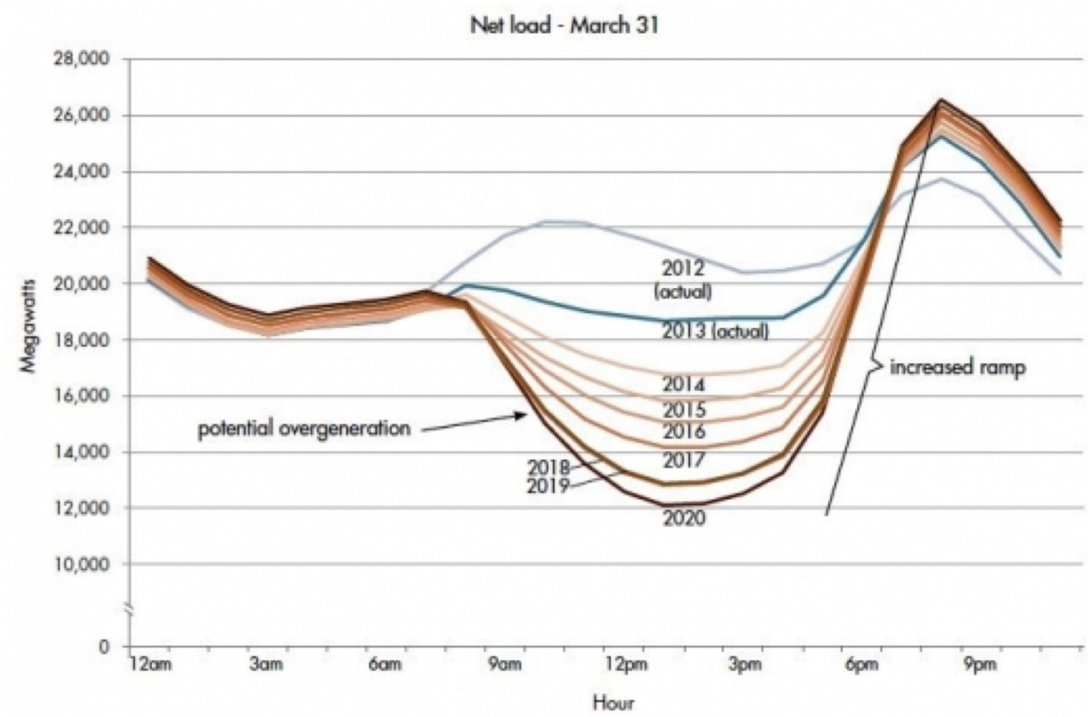
a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

b. What % of total electricity is imported compared to installed capacity in your country?

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

i.e. Denmark example below



b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

   1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   2. What technology is under development that attempts to implement smart meters and demand-side management?

   3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

Annex II

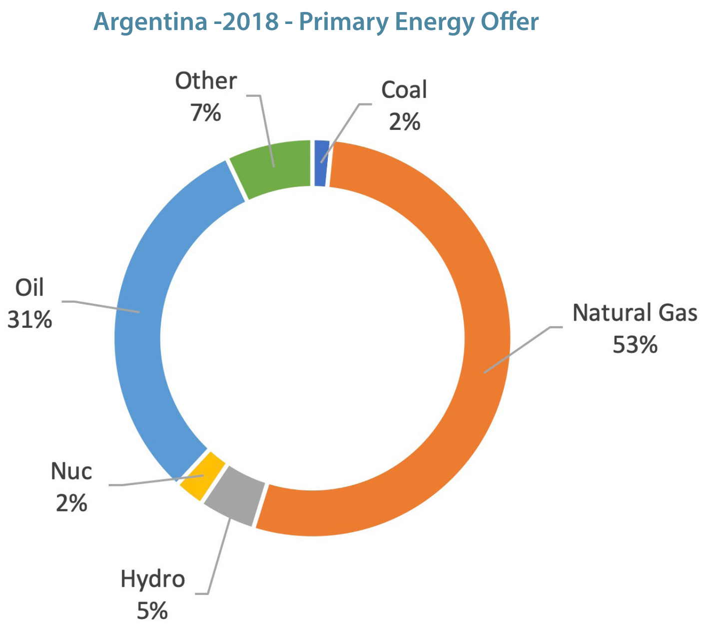
CAETS Energy Contributions (by Country)

Countries submitted their survey results, which served as basis for our group findings.
Below are their submissions as they were given by each academy's representative, of which contact can be found in Annex III.

Argentina

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 137,482 (without imports 344 GWh)
	Import-export ratio (%): Import 344 /Export 280– 122%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 87,727 – 63,81%
	Nuclear (GWh and %): 6,453 –4.69%
	Renewables (GWh and %): 43,302– 31.50%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 41,384 – 95.57%
	Wind (GWh & %): 1,413 – 3.26%
	PV (GWh & %): 108 – 0.25%
	Biomass (GWh & %): 252 – 0.58%
	Other renewables (GWh & %): 145 – 0.33%
Top 3 renewable energy sources	Hydro, Wind, Biomass
Growth rate of total renewable generation (% per year) over the past five years	2014: +1.15% 2015: 1.93% 2016: -8.94% 2017: +8.74% 2018: +2.57%

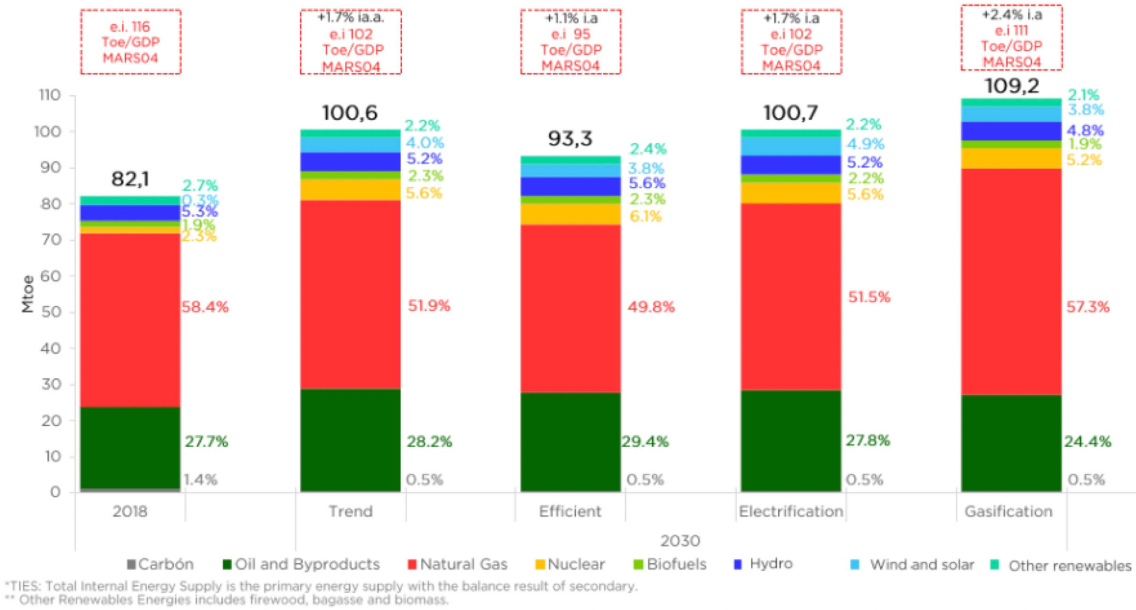
*Renewables include hydro and non-hydro renewables.

**Hydro includes large and small hydro.

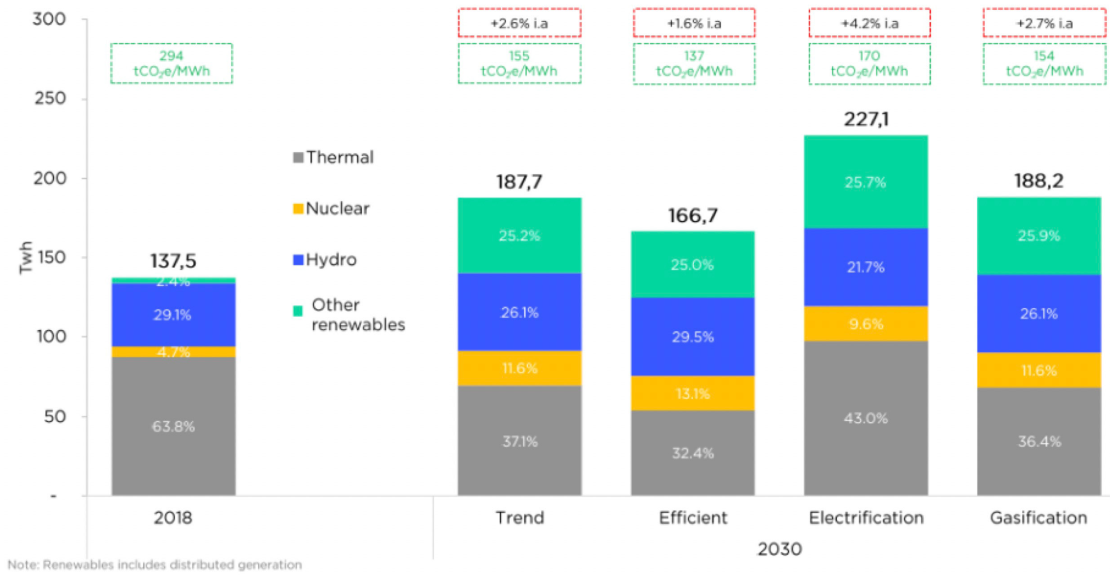
II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

Until 2025 there are quantitative objectives established by the National Government. (20% share of renewables). There is also an official forecast for 2030 based in four scenarios: Business as Usual (Trend), Efficient, Electrification and Gasification.[20] There aren't any official goals for 2040.



Total Internal Energy Supply



Electricity Generation

[20] http://www.energia.gob.ar/contenidos/archivos/Reorganizacion/planeamiento/2019-12-09_Energy_scenarios_2030_English_dist_ext.pdf

b. What are the benchmarks of progress for improvement metrics?

(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	160,000 GWh
Ratio of fossil to non-fossil	Fossil (GWh and %): 90,000 – 28%
	Non-Fossil*** (GWh and %): 230,000 – 72%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 70,000 – 30.43%
	Hydro (GWh & %): 50,000 – 21.74%
	Non-hydro Renewables (GWh & %): 110,000 – 47.83%
Top 3 renewable energy sources	Hydro, Wind & Solar

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

We do not have that problem in relation to non-hydroelectric renewable energy. Argentina has almost 3 MM km2 of surface, 14,000 km of overhead lines in 500 kV, 50 % of the electrical demand is in a 20% of surface located more than 1000 km away from the main renewable generation (hydro, wind or solar).

Given the low density of power lines, failures in the transmission system have challenged major outages in the past (general blackout in June 2019). It is necessary to expand the transport network to make it more reliable and allow a better insertion of renewable resources.

Patagonia Region presents high wind power penetration. In the event of the 500 kV Madryn - Choele Choel line tripping, the Patagonian system would be isolated. Under circumstances of high wind and low load, the region could operate with mainly low inertia generation.

b. What % of total electricity is imported compared to installed capacity in your country?

Not more than 10% and only in relation to circumstantial shortages or the possibility of reducing generation costs. Generally, imports and exports are balanced.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

That problem is not significant yet in relation to solar or wind energy.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

With a maximum demand of 27,000 MW and installed capacity of 40,000 MW, Argentina has small interconnections with neighboring countries, with the exception of Brazil and Uruguay, with capacities of 2,000 MW and 1,000 MW respectively.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

This phenomenon is not currently visible with renewables at only 5 a 6% of total power generation, and solar energy even a smaller percentage of renewables.

There are generation restrictions based on transient stability that could curtail renewable generation.

Considering the renewables projects under operation and those under construction, the system capacity is at its limit of supporting additional generation without restrictions.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Technologies designed to reduce the cost of the economic externalities caused by these randomly interruptible technologies are not being developed. Specialists in regulation see it as natural to move quickly in the development of DERs (Distributed Energy Resources), defined as the set of resources (especially IT), services and technologies aimed at solving and optimization the issues of supply, long term private and public planning and management in the Distribution system in low and medium voltage.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

In addition to more than 4,000 MW of Hydro plants with little storage capacity but with the possibility of regulation, there are approximately another 4,000 MW of Hydro plants with a large hydroelectric accumulation capacity that allow reserves for Intermittent Renewables. The joint operation Hydro - Wind allows to increase the productivity of the Hydroelectric Plants. Also, Argentina has a pumping station of 1000 MW. Regarding the increase energy efficiency of family homes and offices, federal legislation has been developed to improve energy efficiency and has to be regulated and implemented at local levels.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

   15% of thermal power plants have old technologies and are only kept as a reserve for periods of drought or serious accidents in the Transmission system. It should be noted that, already in 2002, 100% of thermal energy was produced with state-of-the-art combined cycles.

   Argentina has 3 nuclear power plants in operation. We don´t see any role for these plants in mitigating the intermittency problem of renewables energies, as they are dispatched in base conditions, with constant production, and avoiding modulations

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

   1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

      Primary and secondary frequency regulation is performed with conventional generation for the Argentinean and Uruguayan system. PFR is performed with gas turbines and SFR with Hydro. Additionally, over frequency regulation could be required for renewable power plants.

      PMU implementation in the Argentinean Power System is a current subject of research.

      The main restriction that exists today to face a scenario with a high Percentage of Renewables (> 20 to 30% and strong slopes of unforeseen reduction of Renewable power, is the lack of sufficient Transportation Capacity

   2. What technology is under development that attempts to implement smart meters and demand-side management?

      Distribution companies operating in Argentina are bringing smart meters and studying alternatives to take advantage of the large amount of hydro power in the country. The use of telecontrol or remote command in medium and even low voltage is also expanding to protect and quickly restore the service in a scenario of future increased volume of intermittent technologies.

   3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

      There are discussions to have a law regarding cyber security after a recent black out.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

Argentina is still in the process of redefining an Energy pricing mechanism after 17 years of frozen prices and government subsidies. An international consulting company had been hired in 2019 that, associated with an Argentine consultancy, prepared and proposed a new Regulatory Framework and a series of recommendations. But until now, the new government in power since December 2019 has not expressed itself so far.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

There is not a carbon market or tax in Argentina.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Argentina had between 2002 and 2015 a period of strong disinvestment due to political reasons. In the past 5 years energy companies started to invest again in renewable power generation and in distribution and transmission lines. A big expansion of the Transmission System is necessary for the future integration of additional renewables and hydro power plants. HVAC projects are under public tender auction for their construction.

The load factor of the cables in Medium and Low Voltage increased in the last 2 decades by more than 50%, making it impossible to transfer loads and reshape immediately the grid and the Service in the event of a failure.

At current time there are no projects for storage in distribution or transmission systems. For now, the reserve of Hydro power plants with great storage capacity and the thermal power plants of reserve are sufficient.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion strongly supports the installation of renewable energies. Political parties have aligned with public opinion. The difficulties to obtain financing and the shortage of transport capacities until new lines are built, slows down many projects.

VII. Suggestions

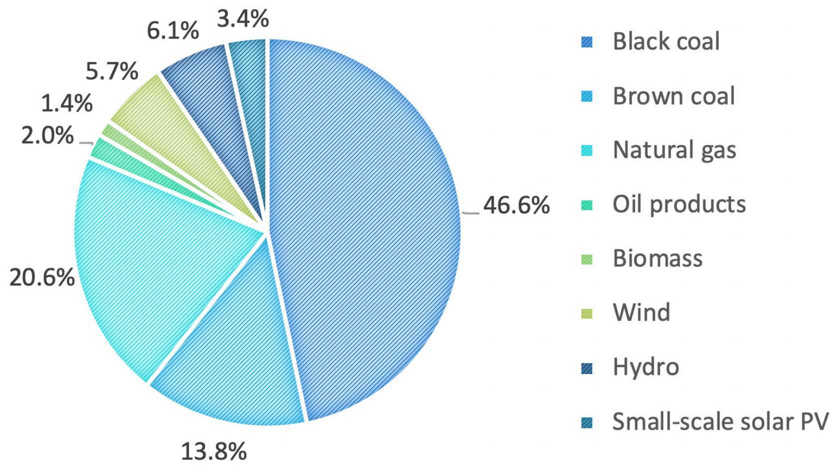
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

Our experience of almost 30 years of operating a vertical disintegrated system with mandatory competition in the Electricity Generation and Gas Production or other fuel markets, show us that it is possible to take into account simultaneously the environmental theme, achieve the minimum costs and distribute them with equity among all customers, ensuring the international competitiveness of the country and finally assure the supply of energy to the market. The regulations to be developed have to take into account the defined targets of renewable energies defined for each country and the issues that arises from the peculiarities of these energies.

Australia

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country,[21] along with total electricity generation data in this table format (below):



2018* Data	Measure[22]
Power generation total amount and import-export ratio	Power generation total (GWh): 261405.1
	Import-export ratio (%): 16.46%
Renewables*, fossil and nuclear electricity generation Must add up to "Power generation total (GWh and 100%)"	Fossil (GWh and %): 212066.3 (81%), majority of which was coal at 60%
	Nuclear (GWh and %): Nil
	Renewables (GWh and %): 49339.8 GWh (19%)
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables) Must add up to "Renewables (GWh and %)"	Hydro** (GWh & %): 17451.9
	Wind (GWh & %): 16266.5
	PV (GWh & %): 2139.2 (large-scale PV) 9,941.9 (small-scale PV)
	Biomass (GWh & %): 3539.3
	Other renewables (GWh & %):
Top 3 renewable energy sources	hydro (7% of total generation); wind (6%) and solar (5%)
Growth rate of total renewable generation (% per year) over the past five years	+12% in 2013-14 -7% in 2014-15 +12% in 2015-16 +6% in 2016-17 +10% in 2017–18

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

[21] australian_energy_update_2018

[22] Department of the Environment and Energy, Australian Energy Statistics, Table O, March 2019

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

The Australian Government has committed to meeting Australia's target for carbon emissions reduction under the Paris Agreement of 26-28 per cent reduction on 2005 levels by 2030. There are no specific policies to implement this target in the energy or electricity systems.

2040 Goals	Measure
Renewable power generation total amount (GWh)	Australia's current Renewable Energy Target is due to expire in 2020, with capacity currently approved sufficient to meet the target of 33,000 GWh. The Government has not announced any replacement for the RET, although various renewable energy targets exist at the state and territory level[23] The Australian Energy Market Operator, which operates the National Electricity Market (NEM), has made a series of projections for the electricity generation mix out to 2040 or 2050.[24] However, these forecasts are generated for use in system planning and are not government or national targets.
Ratio of fossil to non-fossil	Fossil (GWh and %):
	Non-Fossil*** (GWh and %):
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %):
	Hydro (GWh & %):
	Non-hydro Renewables (GWh & %):
Top 3 renewable energy sources	Hydro, Wind & Solar

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Following the System Black event in the South Australian region of the National Electricity Market (NEM) in September 2016, there has been sustained focus on grid reliability and security. The Independent Review of the Future Security of the NEM (otherwise known as the Finkel Review), led to a series of reforms designed to improve system security and reliability, including the creation of an Energy Security Board to oversee implementation.[25]

b. What % of total electricity is imported compared to installed capacity in your country?

Not applicable

[23] https://www.climatecouncil.org.au/resources/states-renewable-energy/

[24] Australian Energy Market Operator Integrated System Plan 2019-20

[25] Independent Review of the Future Security of the National Electricity Market, 2017

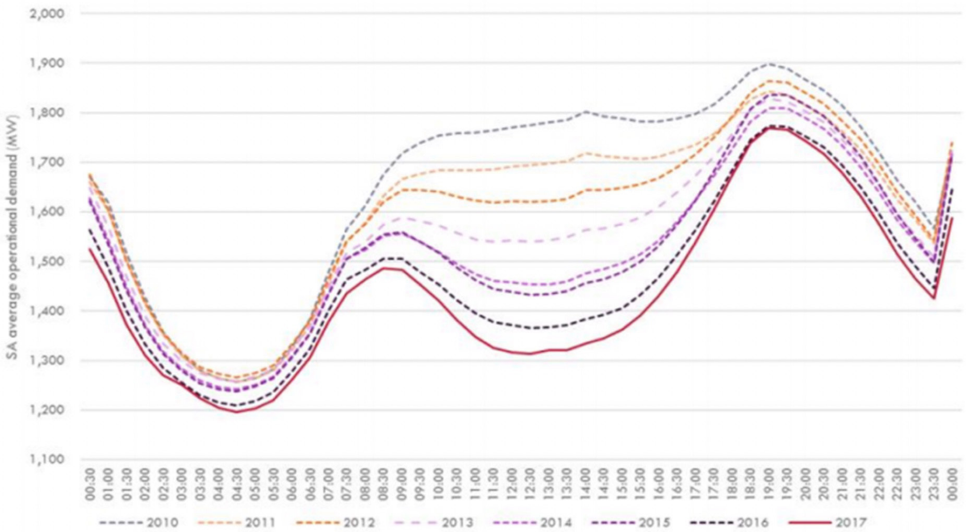
IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation

Rooftop solar has had a fundamental impact on usage and the system demand profile in recent years. The unprecedented growth of rooftop solar PV units – from approximately 14,000 units in 2008 to 1,700,000 units (with an estimated output of 4,917 megawatts [MW]) in 2017in the NEM regions.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

The graph below shows the average operational demand of rooftop solar in South Australia. Similar trends are also emerging in other NEM regions and Western Australia.



c. What are some steps that have been taken to mitigate this phenomenon?

The South Australian government's policy for 2019 has a focus on creating a more flexible grid- with more flexibility in demand and load (such as batteries and electric cars) to soak up and embrace the growing share of wind and solar power supply. Other measures to future-proof the network include installation of fast-start gas generators, pumped hydro storage technology and planned interest-free loan scheme for batteries.[26]

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

The National Energy Market (NEM) is a wholesale market through which generators and retailers trade electricity in six eastern and southern states and territories, except Western Australia and the Northern Territory which have their own electricity systems and separate regulatory arrangements. The power system is not connected to any other country or international system for demand-supply control, although there have been proposals to link renewable energy installations in northern Australia to south east Asia via high voltage DV cables.

The power system is not connected to any other country or international system.

[26] https://reneweconomy.com.au/agl-gets-ready-for-duck-curve-and-high-renewables-with-new-gas-plant-15012

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

While energy storage comes in many forms, including pumped hydro, hydrogen and flywheels, batteries (such as the 100 MW Tesla battery in South Australia) are the most common solution to renewable intermittency. There are a range of batteries that are currently in use and many more under development that could be combined with renewable generation. Australia has pioneered co-located developments with the Gullen wind and solar project. It combines a 10 megawatt (MW) solar farm with 73 wind turbines. The wind and solar plants complement one another, with solar producing more electricity during the summer and wind generating more in the winter. Furthermore, the generation profile of solar and wind are complementary, with solar peaking in the middle of the day and wind generation generally peaking in the afternoon. The complementary generation profile of wind and solar enables projects to produce electricity almost continuously. Similarly, the Hornsdale Power Reserve (see below) is providing system strengthening and FCAS services.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

The uptake of rooftop solar continues to impact operational and peak demand, accelerating a paradigm shift for the energy industry, according to an Australian Energy Market Operator (AEMO) analysis. The 'duck curve' is a factor that may contribute to a shifting market paradigm where thermal generators are facing higher operational costs alongside reduced demand. Market and system reforms will need to be put in place to maintain system security and enable this transition at the lowest cost to consumers.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

- Solar thermal
- Battery storage projects: Batteries are supporting the increased uptake of renewable energy while also delivering increased reliability and security to the grid. By the end of 2018, the 100 MW (129 MWh) Hornsdale Power Reserve was still the largest in the world, and a growing number of industrial-sized batteries were completed across Australia. These included the 30 MWh Ballarat Energy Storage System funded by the Victorian Government and the Australian Renewable Energy Agency (ARENA); the 30 MW/8 MWh Dalrymple Energy Storage for Commercial Renewable Integration in South Australia; the 25 MW/50 MWh Gannawarra Energy Storage System, which was retrofitted to an existing solar farm; and the 5 MW Alice Springs Battery Energy Storage System funded through government-owned corporation Territory Generation. These projects continue to grow across Australia as technologies develop and the availability, functionality and cost of many forms of energy storage technology improves.

  Benefits: In 2018, the Hornsdale Power Reserve served to reduce the frequency control ancillary services costs by up to $50 million. The role of batteries in reducing network demand and lowering costs for residential consumers was also backed by governments in 2018. The South Australian Government was the first to introduce a $100 million home battery scheme. The scheme includes a rebate and a low interest loan option, financed by the Clean Energy Finance Corporation, to help households pay for the balance of the battery and new solar panels if required.

- Hydro and pumped Hydro: Hydro remained the largest generator of renewable electricity in 2018, providing 35.2 per cent (17,002 GWh). New investment by Australian government and private investors in pumped hydro along with plans to expand and modernise the Snowy and Tasmanian hydro schemes are making progress.
- Snowy Hydro already plays a critical role in ensuring system stability and at times of peak demand, and security to the energy market well into the future. It is proposed to add 2,000 megawatts of energy generation and provide 175 hours of storage for the National Electricity Market (NEM). In Tasmania, the Battery of the Nation project continues to progress with 14 sites examined by Hydro Tasmania for pumped hydro capability. The pumped hydro developments would run in conjunction with wind power, which would see water pumped uphill at times when demand is low and then released to produce electricity at peak periods. ARENA has supported the initiative with up to $5 million funding for feasibility studies, which is being matched by Hydro Tasmania.[27]
- Hydrogen and fuel cell innovation: The Australian Federal government is providing significant support for hydrogen and has proposed a national hydrogen strategy in February 2019. Industry leaders are taking strides to develop Australia's hydrogen infrastructure for both fuel cell vehicles (FCVs) and stationary applications. ARENA announced the formation of a new fuel cell and hydrogen association in Australia that aims to foster industry and government cooperation for regulations, codes, and standards to support the Australian transition to a hydrogen economy.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes))

A mix of distributed renewable energy generation and firming technologies including battery storage and pumped hydro are being considered for Australia's future grid. The Australian Government's Solar Communities Program provides funding for community groups in selected regions across Australia to install rooftop solar photovoltaic, solar hot water and solar-connected battery systems at their facility to reduce emissions, reduce their electricity costs and support renewable energy.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Several Australian Government agencies are working on climate change to reduce emissions, adapt to the changing climate and meet international commitments. At the core of these policies is the Emissions Reduction Fund and Safeguard Mechanism. This is complemented by the Renewable Energy Target (RET), energy efficiency improvement, phasing out very potent synthetic greenhouse gases, and direct support for investment in low emissions technologies and practices. In February 2019 the Australian Government announced the Climate Solutions Fund, providing an additional funding to continue the momentum towards reaching Australia's 2030 emissions reduction target of five per cent below 2000 levels by 2020 and 26-28 per cent below 2005 emissions by 2030. The RET is an Australian Government scheme designed to reduce emissions of greenhouse gases in the electricity sector and encourage the additional generation of electricity from sustainable and renewable sources. The Solar Towns Programme will provide Australian communities with an opportunity to engage at a local level with clean renewable energy, improve local environments, generate a sense of community ownership and self-reliance, and improve local community outcomes. Several Australian best-known businesses- including banks,

[27] https://www.snowyhydro.com.au/our-scheme/snowy20/

legal firms, airlines, councils, property groups and other small businesses are carbon neutral certified.[28]

ARENA and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) are aiming to capitalise on the enormous opportunities for domestic hydrogen production and export. CSIRO developed and successfully tested a membrane technology which allows hydrogen to be transported in the form of liquid ammonia, making it possible to handle hydrogen in bulk using existing infrastructure, linking production, distribution, and delivery. The National Hydrogen Strategy (currently under development) aims to include up to 10% hydrogen in the domestic gas network, to build hydrogen refueling stations in every state and territory, and to replace natural gas with hydrogen to power heavy-duty fuel cell vehicles (FCVs). By harnessing Australia's significant renewable energy potential and existing infrastructure, this national strategy will integrate hydrogen into the country's energy mix as a clean power source.

Though nuclear energy generation is prohibited in Australia, the Parliament has recently commenced an inquiry to investigate new and emerging forms of nuclear energy technology that may be beneficial for any future consideration.

The Barker Inlet Power Station (under construction in South Australia) also demonstrates an orderly transition to a carbon-constrained future by helping phase out some of the old generation at the nearby Torrens A Power Station and replacing it with new more efficient technology producing less greenhouse gas per unit of electricity generated.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Australia's electricity grid requires regular small adjustments to keep the supply and demand of electricity in balance and keep the system operating at the required frequency, a tight band around 50 Hertz. The Hornsdale Tesla battery is registered to provide these frequency control ancillary services (FCAS).

   In the Australian Capital Territory (ACT), the Volt Amps Reactive (VAR) control is a smart grid solutions the seeks to stabilise fluctuations in the network by discharging residential batteries at varying power factors, creating either an inductive or a capacitive generation source.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Developments in communications technology have helped advanced energy-metering systems link into control technologies to provide flexible, sophisticated control of energy-using systems according to varying conditions. Continuing and future developments include:

   - data collection, intelligent control and communication capabilities being increasingly devolved to intelligent energy-using equipment, appliances, and other distributed intelligent devices
   - increased communication among energy-using devices, meters, sensors and controllers, and sharing of data among systems
   - wireless sub-metering, including self-powered modules

[28] https://www.environment.gov.au/climate-change/publications/factsheet-actions-australia-is-taking

- more open-source data formats and communication protocols
- movement of electronic data and applications to the internet (cloud storage)
- real-time energy efficiency benchmarking and model validation and calibration

These developments and trends, combined with higher energy prices and network charges, and the increasing focus on greenhouse gas emissions, will increase the already rapid uptake of energy metering, monitoring and control systems.

Leveraging the expertise in network planning, field construction, network control and data analytics advanced metering infrastructure (AMI) smart meters in the state of Victoria, CitiPower Powercor was able to get near-real time information of the voltages of all the customers on its low voltage (LV) network. With this live data, they were able to monitor and optimise system voltages by lowering or raising voltages at the zone substation level with little to no effect to our customers while generating significant power reductions throughout the network.

A joint venture between Pacific Equity Partners and global smart meter leader Landis+Gyr is the intelliHUB. The Clean Energy Finance Corporation (CEFC) has committed up to $60 million in debt finance to support the continued growth of intelliHUB, and the increased availability of smart meters to benefit homes and businesses.

Demand-side management: ARENA is currently undertaking ten Demand Response (DR) projects in three states (Victoria, New South Wales and South Australia) over a three year period (2017-2020). The projects aim to deliver 200 megawatts (MW) of capacity by 2020, covering both residential, commercial and industrial energy users, and using a range of technologies and innovative behavioural change ideas to help deliver this capacity.[29]

Some technologies in use are:

- Remote-controlled voltage reduction through network control centre: smart meters deployed across the distribution network provide information on voltage at the meters of all its customers. This allows the electricity distributer to ensure that the level of voltage reduction it undertakes remains above the minimum level required. This use of smart meter data is an important innovation because it ensures that voltage is maintained at the customer connection point, avoiding the potential for a voltage reduction to damage customers' end use equipment.
- DR enabling equipment, such as Frigbots, which provide remote control of refrigeration loads and a centralised energy control system for multi-site businesses that combines smart thermostats and lighting controls with a cloud software solution to provide a simple and effective building management system.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   - The Australian Cyber Security Centre (ACSC) has been actively working with energy sector organisations and government agencies to strengthen their resilience to cyber security threats. In November 2018, the ACSC commenced a nationwide program of cyber security resilience and response activities for Australia's electricity industry. Information exchange and training activities will enable technical, operational, communications and business continuity professionals from Australian-based electricity

[29] https://arena.gov.au/knowledge-bank/demand-response-rert-trial-year-1-report/

organisations to share experiences, information and techniques to better prevent, detect, respond to and recover from cyber security incidents.

- Drone technology is under trial to undertake visual inspections of faults around electricity grid.
- Artificial intelligence (AI) and machine learning are set to transform the energy industry, by digitising its asset inspection and asset management.
- Internet of Things (IoT): An IoT Hub was developed in June 2018 to integrate two key tools for network control: the virtual power plant (VPP) fleet and the Advanced Distribution Management System (ADMS). The selected systems under the Reposit fleet are integrated with the ADMS portal to provide a real time representation of solar generation, current battery storage levels, and node level low voltage (LV) network data and utilise the stored energy to help protect the grid.
- Blockchain: Australian start-up PowerLedger uses blockchain technology that offers mechanism for the sale of excess renewable energy. The energy is produced onsite at multi-unit residential and commercial developments and at businesses and homes connected to the distribution network. It uses a peer-to-peer (P2P) energy trading platform that enables these sites to monetize their excess solar energy for the first time.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

There are only state run schemes for solar feed in tariffs in Australia.

Incentive programs that support home battery storage system uptake in Australia have been introduced in the states of Victoria, South Australia, New South Wales, Queensland and the Australian Capital Territory. These programs will help to expand the market for home batteries in the states to capture & discharge solar energy.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Carbon emissions trading or taxing is not currently applicable in Australia. A Carbon Pricing Mechanism operated in Australia from 2012 to 2013.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

The changing generation mix increases the intermittency of supply from end users back into the grid. Encouraging investment in new fuels in efficiently developed new fuel precincts – called Renewable Energy Zones (REZ) offer to optimise investment in networks to support this transformation.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Community surveys in Australia show widespread support of large scale solar.[30] There is also a perception that solar projects may not face the same community opposition that has been associated with wind developments, such as noise and visual. Genuine community engagement is critical the energy market transition and to ensure that communities across Australia benefit from this transition, they are engaged from the early stages of project planning. Community engagement and benefit sharing are increasingly important to securing financing and power purchasing arrangements regardless of the technology as is evident from the experience of Uriarra Solar Farm(below). For example, the community engagement principles for renewable energy projects suggested by the Victorian Government are:[31]

- mutual benefit
- mutual respect
- relationship building
- authenticity
- appropriateness
- ongoing engagement
- transparency and responsiveness

[30] ARENA/IPSOS (2015), Report: Establishing the social licence to operate large scale solar facilities in Australia: insights from social research for industry, Australian Renewable Energy Agency, Australian Government, Canberra, Australia.

[31] Lane, T. and J. Hicks (2017) Community Engagement and Benefit Sharing in Renewable Energy Development: A Guide for Applicants to the Victorian Renewable Energy Target Auction. Department of Environment, Land, Water and Planning, Victorian Government, Melbourne.

Case study in Wind:

Neoen's Hornsdale Wind Farm is a 309MW project consisting of 99 wind turbines located in South Australia. Great care and efforts were taken to tailor the project to the local context, especially through the developer's engagement with local Aboriginal people and the creation of a wildlife conservation reserve. As a result of their engagement and benefit sharing approach, Hornsdale Wind Farm has broad and deep community support from traditional owners of the land, neighbours, construction contractors, local council, and community groups.

Case studies in Solar:

Uriarra solar farm, Australian Capital Territory: The local community initially opposed proposed development for being too close to residences and significantly changing the rural landscape. Consequently, the solar farm was successfully relocated to an area that had fewer residents near the proposed facility.

The Moree Solar Farm, New South Wales: Operated by Fotowatio Renewable Ventures (FRV), it is a 56MW facility in northern New South Wales that began generating in 2016. FRV helped to integrate the project into the local community and with a high level of involvement and outreach including:

- developing a whole of project life Community Consultation Plan
- establishing a Community Reference Group to develop criteria to measure the project's success based on the key themes relevant to the community. The minutes for each meeting were made publicly available.
- the development and implementation of an effective complaints' management process
- using a diverse range of engagement activities to engage with the local community, such as stalls at local markets, presentations, site tours and a public display.

The project delivered significant benefits to Moree and the wider community with five permanent local employees operating the solar farm. More than three quarters of the total construction jobs were awarded to local workers. In addition to employment opportunities in subsequent solar projects, the benefit sharing program will deliver a portion of project revenue back to the community as grants to support local initiatives.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

The shift in electricity supply towards renewable resources is set to accelerate as the relative costs of large-scale wind and solar continue to fall in Australia. The more distributed nature of renewable energy generation coupled with other factors (such as behind the meter energy storage and energy management systems) will demand considerable agility in the way the electricity system is planned and operated, but new digital technologies have the potential to solve the optimisation and coordination challenges and deliver lower costs to consumers and high reliability.

Coherent and ambitious policies, programs and regulatory mechanisms are essential to support the development of new technologies and their integration into existing supply chains to foster the transition to low-emission energy technologies. Equally, investors, consumers and communities must be confident that market design and regulation will meet their needs in both the short and the long term.

An investment environment that encourages replacement of ageing infrastructure with new, efficient, low-emission technologies is therefore essential. Australia's abundant renewable resources could be the foundation of new export industries to meet the world demand for clean fuels such as hydrogen.

Submitted by the Australian Academy of Technology and Engineering
Contact Matt Wenham
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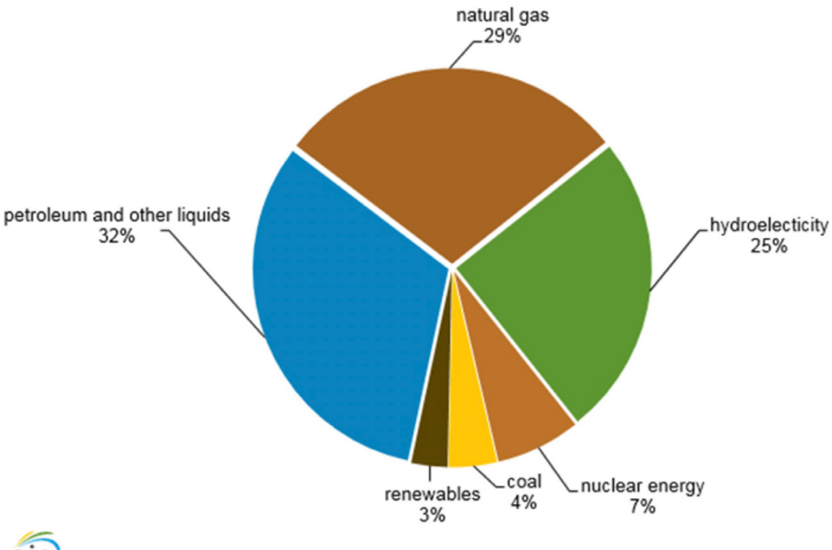
Canada

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



Source: *BP Statistical Review of Energy, 2019*

2017* Data	Measure[23]
Power generation total amount and import-export ratio	Power generation total (GWh): 652,000
	Import-export ratio (%): 0.21 (2018 Imports=12,500; 2018 Exports=60,200 GWh)
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 120,657; 18.5%
	Nuclear (GWh and %): 94,570; 14.5%
	Renewables (GWh and %): 437,626; 67%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 392,624; 60.22%
	Wind (GWh & %): 28,697; 4.4%
	PV (GWh & %): 3,261; 0.5%
	Biomass (GWh & %): 11,740; 1.8%
	Other renewables (GWh & %): 1,304: 0.2% *includes ethanol and municipal waste and landfill gas
Top 3 renewable energy sources	Hydro, wind, biomass
Growth rate of total renewable generation (% per year) over the past five years	1.6% (over past 10 years)

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2050 Goals[32]		Measure
Renewable power generation total amount (GWh)	1,734,480 GWh (non-fossil) (for comparison: 1,305,556 GWh)[33]
Ratio of fossil to non-fossil	Fossil (GWh and %): 192,720 GWh; 10%
	Non-Fossil*** (GWh and %): 1,734,480 GWh; 90%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 564,657 GWh; 29%
	Hydro (GWh & %): 920,637 GWh; 48%
	Non-hydro Renewables (GWh & %): 250,536 GWh; 13%
Top 3 renewable energy sources	Hydro, nuclear, wind

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Intermittency has not been an issue in Canada because of the large hydro generation capacity in most provinces that are ideal for backup of renewables. Also nuclear in Ontario and natural gas and coal in Alberta and Saskatchewan have made transmission intermittency a non-issue at current level of renewables. This may become an issue in the future, mainly in Alberta and Saskatchewan if the required shut down of coal plants by 2030 is extended to natural gas plants.

b. What % of total electricity is imported compared to installed capacity in your country?

About 1%

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

No

[32] "Canada's Challenge & Opportunity", Trottier Energy Futures Report, April 2016. Available from https://www.cae-acg.ca/projects/trottier-energy-futures-project/. For simplicity an average capacity factor of 50% was used.

[33] Based on "High Ambition Scenario" in "Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy", Environment and Climate Change Canada, 2016.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

This is currently not an issue in Canada (see above).

c. What are some steps that have been taken to mitigate this phenomenon?

Not applicable.

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Generally, Canada's interconnections are north-south (between the U.S. and Canada) rather than east-west. The structure of the electricity sector has been evolving over the past decade. In most provinces, there has been a shift from vertically integrated electric utilities (often provincial Crown corporations) to various degrees of market liberalization and/or unbundling of generation, transmission and distribution services.

Power lines currently connect Canada to the U.S. East (Maine, New Hampshire, Vermont, New York, and Massachusetts), the U.S. West (Washington and Montana), and the U.S. Midwest (North Dakota, Minnesota, and Michigan.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

New projects under development include the Lake Erie Connector, the Manitoba-Minnesota Transmission Project and the Quebec–New Hampshire Interconnection.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

The main drivers of additional Canada- US interconnections are renewable portfolio standards and renewable electricity targets in many U.S. states. These mandate minimum levels of renewable power in each state's electricity mix as a result, exports of Canadian power are well positioned to grow.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Canada is a world leader in hydro electricity production and there is a great deal of flexibility to grow renewables especially wind and solar but also, in the long term, tidal and geothermal.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Primary storage/backup systems include hydro and natural gas. Pump hydro, battery storage and heat pump geothermal are developed or being developed at local community scale.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

   In 2018, final regulations to phase-out traditional coal-fired electricity in Canada by 2030 were proclaimed. Canada's electricity generation mix is already one of the cleanest in the world. By phasing out coal-fired electricity, Canada strives to have 90 % of electricity from non-emitting sources by 2030. Currently, nuclear power in Canada is provided by 19 commercial reactors with a net capacity producing about 96,000 GWh. Modelling studies have estimated that electrification will require a two- to three-fold increase of electricity in Canada by 2050 and nuclear will be required to play a significant role in the major expansion of emissions free electricity.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

   1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

      Not relevant except in localized examples

   2. What technology is under development that attempts to implement smart meters and demand-side management?

      In recent years, utility companies in several provinces have started installing wireless smart meters in Canadian businesses and residences. Concerns about possible health effects from exposure to the radiofrequency fields that these devices emit has slowed down installations. Demand-side management by provincial governments and utilities which includes subsidies for energy efficiency plays a prominent role in current efforts to reduce GHG emissions. The effectiveness of this policy approach has been difficult to analyze and is in dispute.

   3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

Pricing is done at the provincial level. Provinces have differing regulations for addition of renewables into their grid. Ontario, Canada's largest province, has developed a Feed-In Tariff (FIT) Program to promote greater use of renewable energy sources. This has resulted in a relatively high residential electricity bill.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The Canadian government has imposed a nation-wide carbon levy (tax) on fuel combustion. The charge began at $20 in 2019 and will rise to $50 per tonne of CO_2 by 2022. Provinces could create their own system of carbon pricing or equivalent cap and trade based on their needs. For Provinces that did not create their own plans, the Federal Government imposed the tax to be redistributed to the Provinces in a revenue-neutral manner. There are exemptions for a certain period for energy-intensive, trade-exposed industries.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Canada's provinces and their regulators have jurisdiction over investments in electricity infrastructure and innovation, which are funded on a user-pay basis that is passed on to ratepayers. In general, provincial regulators tend to focus on immediate costs and keeping consumer rates as low as possible, However, there are a few energy storage demonstration projects both on a grid scale and in northern communities (not tied to the grid) to replace diesel generators.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

The Canadian Electricity Association has proposed a national plan to increase the electricity sector R&D to increase the commercial deployment of technology to decarbonize the economy including:

- Carbon capture and storage
- Grid integration of distributed energy resources
- Grid scale storage
- Grid integration of electric vehicles
- Demand response
- Optimization of asset use
- Fault detection and mitigation

There are also concepts for building a modern east-west grid across Canada bringing together government decision makers, electricity companies, and innovative suppliers.

Submitted by Canadian Academy of Engineering
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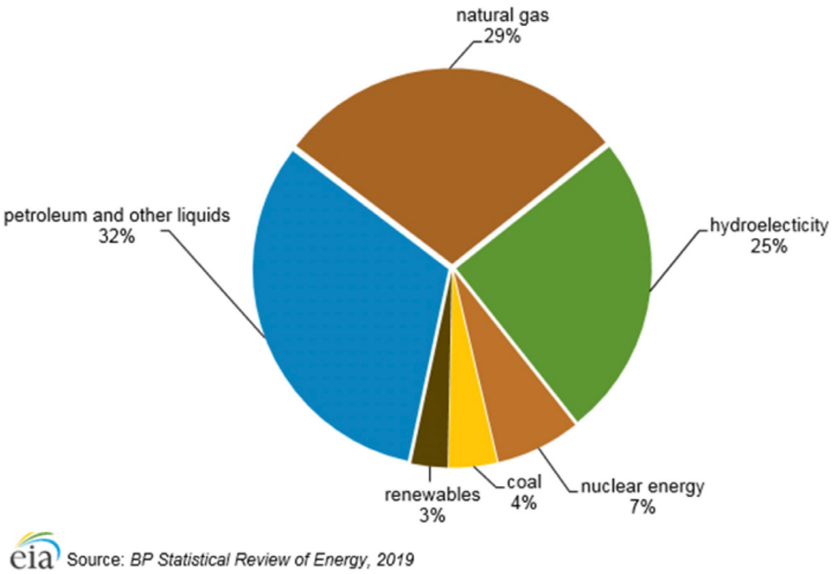
China

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 6.994E6 GWh
	Import-export ratio (%): (568.8 GWh /2090.6 GWh) – 27.21%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 4.923E6 GWh, 70.39%
	Nuclear (GWh and %): 0.294E6 GWh, 4.20%
	Renewables (GWh and %): 1.777E6 GWh, 25.41%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 1.233E6 GWh,17%
	Wind (GWh & %): 0.366E6 GWh,5%
	PV (GWh & %): 0.177E6 GWh,2%
	Biomass (GWh & %): 0.090E6 GWh, 1%
	Other renewables (GWh & %): 0.007E6 GWh, 0.1%
Top 3 renewable energy sources	Hydropower, Wind power, and Solar power.
Growth rate of total renewable generation (% per year) over the past five years	installed capacity ofrenewable: 2018: 728.96 GW ↑ 11.7% 2017: 652.52 GW

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

The supervising energy agency's stance is that in 2020, 2035 and 2050, the nationwide electricity consumption will reach 7.7E6 GWh, 12.1E6 GWh and 13.9E6 GWh (7.7 trillion, 12.1 trillion and 13.9 trillion kWh) respectively. And by 2020 and 2030, the share of non-fossil energy in primary energy consumption will reach 15% and 20%, respectively. Specially, the share of non-fossil energy in total power generation will reach 50% by 2030.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

Firstly, total energy consumption, within 2020 and 2030, will be controlled within 5 and 6 billion tons of standard coal respectively. And the total amount will be basically stable in 2050. Secondly, non-fossil energy accounts for the proportion of primary energy consumption will be not less than 15% in 2020 and 20% in 2030, and more than 50% in 2050.Thirdly, total carbon emissions will be peaked before 2030. Fourthly, carbon emissions per unit of GDP will be down 40%-45% in 2020, and 60%-65% in 2030compared with that of 2005. At last, energy efficiency indicators (the energy consumption per unit of GDP) will be 15% lower than in 2020, and reaching the world average in 2030 and reaching the world advanced level in 2050.

2050 Goals	Measure
Renewable power generation total amount (GWh)	Our academy recommendsabout the nationwide installed capacity: 2020: 2110 GW, including non-fossil 920 GW,44%; 2035: 3590 GW, including non-fossil2200 GW, 61%; 2050: 4860 GW, including non-fossil3900GW, 80%.
Ratio of fossil to non-fossil	Fossil (GWh and %): 20%
	Non-Fossil*** (GWh and %): 80%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 10%
	Hydro (GWh & %): -
	Non-hydro Renewables (GWh & %): -
Top 3 renewable energy sources	Hydropower, Wind power, and Solar power.

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

At present, the supervising energy agency's stance about the China's electric island problem is not prominent. While reducing the operating costs and improving energy efficiency, there are still some problems in the operation of isolated grids. In addition, with the construction of nationwide renewable energy, as well as the promotion of energy conservation and environmental protection policies and power sales policies, more and more industrial and mining enterprises with relatively low power consumption will operate on isolated grids.

b. What % of total electricity is imported compared to installed capacity in your country?

There is no data showing that China's power system is connected to large overseas systems. In 2018, the import and export data of electricity respectively were 568.8GWh and 2090.6GWh. That was too small percentage to have influence to the national grid.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

China's "Duck Curve phenomenon" is not very prominent. Domestic academic papers on the graph are relatively rare. However, in the eastern provinces with peak consumption, large-scale wind farms and centralized photovoltaic power plants have been newly built and put into operation in recent years. As a consequence, intermittent energy generation has affected the transient stability of the power grid, power quality, dispatching operation and peak regulation to a certain extent.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

First, Ultra-High Voltage (UHV) lines had been established to guarantee long-distance transmission of electric power, so as to mitigate the intermittent problem in a single region. Second, to encourage distributed industrial and commercial renewable energy projects. Third, energy storage in situ. Fourth, a time-of-use tax strategy is implementing to encourage time-sharing electricity for industrial and residential users from the management perspective.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

The supervising energy agency's traditional and mainstream solution is to connect more and more grid systems to grid-connected power generation and ensure effective scheduling and switching between traditional power generation modes and new energy generation modes. Interconnection strategy would broaden and disperse the load and availability of solar and wind across a larger area, although actual operational data are still needed to further study for output characteristics of intermittent energy sources.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

The government is developing variable-speed pumped storage technology; promoting the research and development of physical energy storage technologies such as flywheel, high-parameter high-temperature heat storage, phase change energy storage and new type compressed air; and developing chemical energy storage technologiessuch as high-performance fuel cells and supercapacitors.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

China's renewable energy development has a significant late-mover advantage, and a number of technologies have been ranked among the world's first-class, there is no active elimination of old technology related reports.

Under normal circumstances, China's nuclear power plants generally maintain rated power operation. Our academy recommendsnuclear power units should not perform frequent load adjustments and all stay in the base load position.Nuclear power operates with base load and generally without load tracking, which can effectively improve the utilization rate of nuclear power and reduce the system power generation cost.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   First, UHV AC-DC hybrid power grids. These kinds of grids have been initially established, in order to meet the needs of large-scale long-distance multi-point acquisition, transmission and distribution of renewable energy. Second, advanced grid technology. To strengthen the research and development of smart grid technologies such as new energy grid-connected and micro-grid, and promote the development and demonstration of information and communication technologies and control interactive technologies. Third, energy storage technology. And the fourth,smart energy technologies. To promote deep integration of grid with distributed energy.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The supervising energy agency's stance is toimprove and promote the application of demand-side interactive technology, power virtualization and power trading platform technology to improve the power grid system regulation capacity.Meanwhile, based on the energy Internet, smart customization of various energy sources would be promoted, electricity demand wouldbe appropriately guided, peak regulation would be encouragedvia users are participate in, and new models of smart energy usewould be fostered.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   First, to accelerate the deep integration of electrification and informatization. Second, to build "Internet +" smart energy comprehensively. Third, to strengthen the intelligent construction of the power system, to build the Energy Internet, and to promote the interconnection of multiple types of energy flow networks and the coordinated transformation of multiple energy forms.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

China's Renewable Energy Act stipulates that "the on-grid price of renewable energy power generation projects can be determined according to the characteristics of different types and the circumstances of different regions, and in accordance with the principle of promoting the development and utilization of renewable energy and economic rationality." Hence, a fixed electricity price policy has been adopted. Meanwhile, the government has established a renewable energy development fund to provide financial support for the development and utilization of renewable energy.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The supervising energy agency is cultivating an Internet-based energy consumption trading market; promoting networked transactions such as energy use rights, carbon emission rights, and renewable energy quotas; and developing an energy-sharing economy.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

From 2020 to 2035, in order to meet the needs of large-scale long-distance multi-point acquisition, transmission and distribution of renewable energy in western and northern China, the government intends to establish a UHV AC-DC hybrid power grid. Meanwhile, the development of energy storage technology and industry is encouragedby the government in the next decade.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Chinese citizens have been firmly supporting the government to increase the proportion of renewable energy with less pollution and higher safety in the entire energy supply system.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

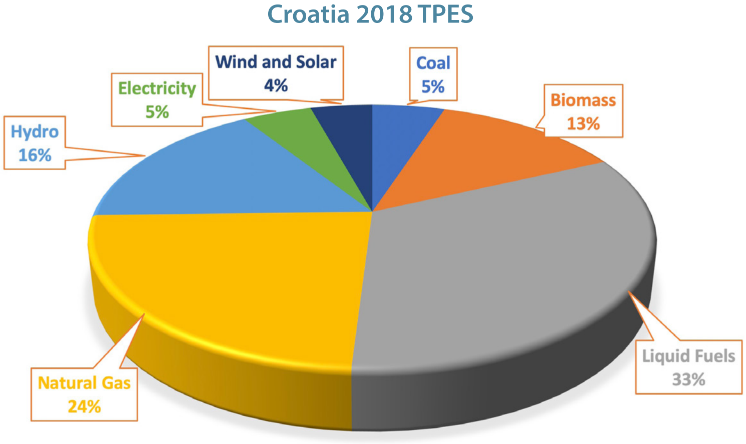
Firstly, as the largest demand area for energy on the South-East of China, our academy recommends to build locally and nearby renewable energy system to improve the absorption capacity of intermittent renewable energy. Secondly, as the industry chain continues to migrate to inland provinces, it is encouraged that a system scheduling strategy for intermittent renewable energy generation is coordinated with on-site consumption and external transmission.

Croatia

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

Croatia Total Primary Energy Supply in 2018



In total in 2018, 408,85 PJ of energy was supplied and 286,28 PJ of energy was used in final energy consumption.[34]

2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 13 631.7 GWh
	Import-export ratio (%): Import 12 692 /Export 6532 (194.30 %)
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 3 766.5 – 27.63%
	Nuclear (GWh and %): 0
	Renewables (GWh and %): 9 865.20 – 72.37%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 7 784.9 – 78.91%
	Wind (GWh & %): 1 335.4 – 13.54%
	PV (GWh & %): 74.9 – 0.759%
	Biomass (GWh & %): 668,0 – 6.77%
	Other renewables (GWh & %): 2 – 0%
Top 3 renewable energy sources	Hydro, Wind, Biomass
Growth rate of total renewable generation (% per year) over the past five years	2013: +73.64% 2014: 6.85% 2015: -25.08% 2016: +9.83% 2017: -16.55% 2018: + 35.41%

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

[34] Energy in Croatia 2018 – Annual energy report; http://www.eihp.hr/wp-content/uploads/2019/12/Energija2018.pdf

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

Official goals for 2040 can be derived from the Energy Strategy of the Republic of Croatia for 2030, with the view on 2050, which was adopted in March 2020. In the Table below, goals from the newly adopted Energy Strategy are listed.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

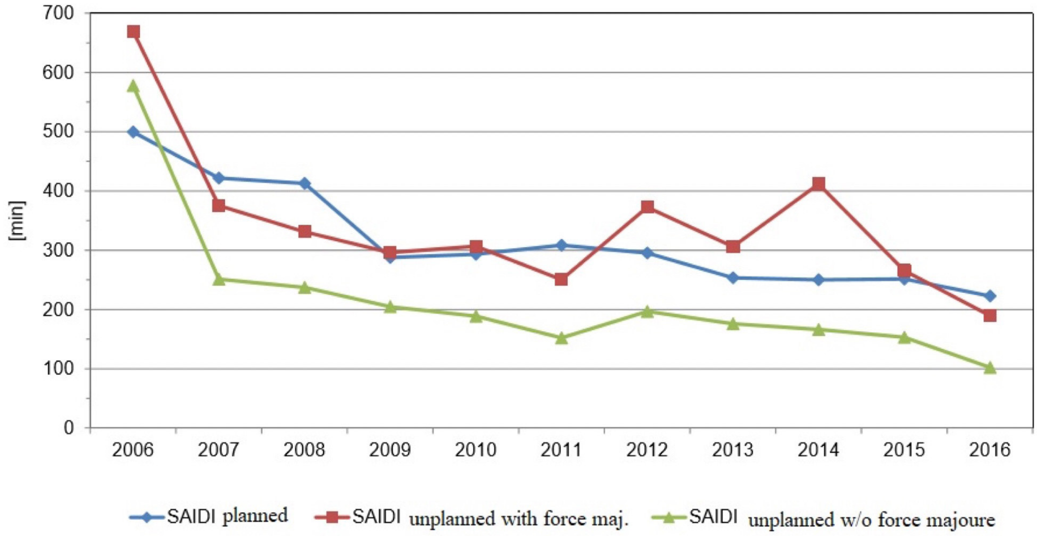
2040 Goals	Measure
Renewable power generation total amount (GWh)	18 500 (S1 fast transition scenario) – 16 000 (S2 moderate transition scenario) GWh
Ratio of fossil to non-fossil	Fossil (GWh and %): 2 600 – 13% (S1) 4 400 – 21.6%
	Non-Fossil*** (GWh and %): 18 500 – 87% (S1) 16 000 – 78.4%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 0
	Hydro (GWh & %): 7 700 – 41% (S1), 48% (S2)
	Non-hydro Renewables (GWh & %): 10 800 – 59% (S1) 8 300 – 52% (S2)
Top 3 renewable energy sources	Hydro, Wind & Solar

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

We do not have that problem in relation to renewable energy sources. This can be observed through the SAIDI coefficient,[35] which is in decline during the last decade, including the last years with increased integration of variable RES in Croatian energy system.



b. What % of total electricity is imported compared to installed capacity in your country?

Imports amount for 20-40% of electricity demand, depending on the hydrology.

[35] Plan of development of the distribution grid 2018-2027, HEP ODS, Zagreb 2017.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

In Croatia, the Duck Curve phenomenon cannot be observed yet, due to still low share of RES, in particular, of Solar energy.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

With a maximum demand of 3 100 MW and installed capacity of 4 700 MW, Croatia has very good interconnections with neighboring countries, enabling enough transmission capacities to cover the whole demand, if necessary.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

This phenomenon is not currently visible with variable renewables at only 13% of total power generation, and solar energy even a smaller percentage of renewables (1%).

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Most typical technology that would be used for mitigation of the intermittency issues that might emerge in the future would be dammed hydro and pump hydro technology, being available and operational in Croatia. Power-to-heat technology and demand response technologies for households are yet to be implemented on a larger scale.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Apart from additional pump hydro facilities being planned, power-to-heat technology on the largest CHP units in Croatia is being developed, with TE-TO Zagreb, the largest CHP unit in the country already having heat storage installed.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Old technologies are not actively phased out, but are no longer in focus of national policy documents, such as proposed drafts of Strategy of Low-Carbon Development and Energy Strategy. Such technologies include coal and oil power plants. Nuclear energy is present in the system, since half of the NPP Krško in the neighboring Slovenia is owned by HEP (National Power company). However, although not dismissed, nuclear power is also not regarded as part of solution in the energy transition of Croatia, due to high cost.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Flexible gas power plants are kept in reserve, in case hydro capacities are not sufficient to stabilize the operation. Novel transformation and storage technologies, such as power-to-heat, could be used when implemented.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Numerous options for demand response systems are being investigated by private companies (Končar d.d., Ericsson Nikola Tesla d.d.), involved in EU funded projects (H2020 project INSULAE – which uses the smart island concept for living laboratories), establishing cooperation with academia and development agencies through Horizon 2020 and similar programmes. Smart metering, prosumer concepts (which is also recognized in legislation) and smart applications are being investigated by energy cooperatives, as well as business models for such applications.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Blockchain technology is being investigated and concepts based on blockchain are being implemented through nationally funded projects (HrZZ project IMPACT) with cooperation from private companies and energy cooperatives, but also public institutions such as HROTE and distribution system operator.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The country has liberalized the electricity retail market, as an important step towards enabling transparent trade, decentralized trade in future smart grids and demand response technologies implementation, which can lead to new markets, enabling final users participation.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The Emissions Trading System, based on the Directive 2003/87/EZ, was implemented in Croatia through three phases, starting with testing phase (2005.-2007.), implementation phase since 2009. and the present phase 2013.-2020. ETS Directive was transposed in the Croatian legislation in the form of the Regulation on greenhouse gas emission quotas and the method of trading with emission units (Official Gazette 142/08). In addition to plant operators, aircraft operators are involved in the ETS. Obligations in the aviation sector relate to monitoring and reporting CO_2 emissions and tonne-kilometers from aircraft. The revenue from the ETS is used to fund energy efficiency and RES projects through the Environmental Protection and Energy Efficiency Fund (EPEEF).

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

The Distribution system operator HEP DSO prepared the Plan of development of distribution grid in 2017, planning for years 2018-2027 the network expansions and maintenance. Also, losses in distribution network are being reduced, while in the Draft of Energy Strategy the emphasis is given to advanced and smart network development. However, these measures are not yet implemented.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion is inclined to renewable energy, which is also recognized in the legislation as the issue of interest for the Republic of Croatia. Some myths are still present in the public sphere regarding energy transition and renewable energy, but academia and civil society, such as energy cooperatives, are working on spreading the up-to-date information regarding RES development. Programmes of co-funding of energy efficiency measures and RES implementation provided by EPEEF are an important factor of fostering the acceptance of RES in the general public. Regional involvement is mostly orchestrated by the regional development agencies.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

One of the key measures for high uptake of RES is faster adoption of national strategic documents and creation of action plans, which should define the implementation of measures proposed by strategic documents. Role of local and regional governments should be emphasized through stronger role of local strategic documents such as Sustainable Energy and Climate Action Plans. Remaining barriers should be removed for the testing and implementation of demand response technologies, electrification of other sectors and strengthening of synergetic effects between decarbonization of energy production sector, heating sector and transport sector.

Czech Republic

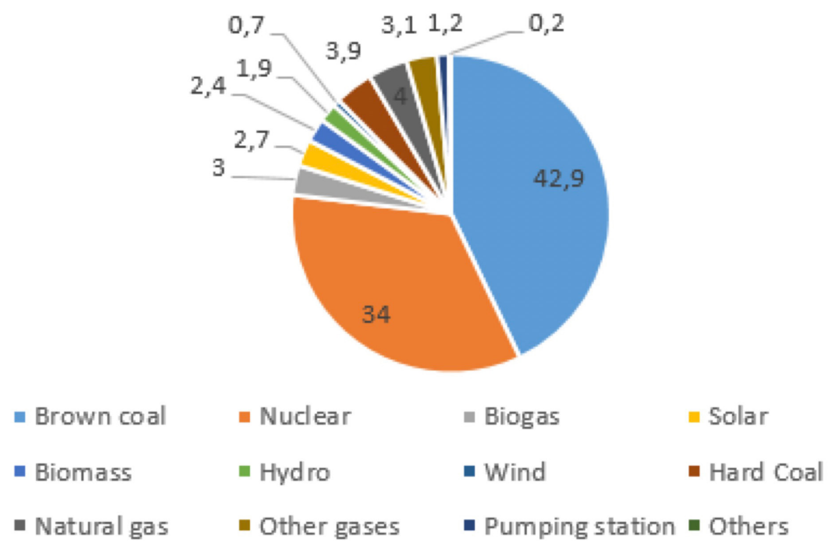
I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

The majority of electricity production in the Czech Republic takes place in coal-fired power plants (40%), nuclear power plants (32%), renewable sources (hydro, solar, wind, biomass) (18%)

Electricity is produced in the Czech Republic 85.9 TWh per year, 9.9 TWh was imported and 25.7 TWh was exported. The output balance was thus in surplus with almost 20% of the electricity produced.

Czech republic Energy Mix 2018



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 87,997
	Import-export ratio (%): 9 900 GWh was imported and 25 700 GWh was exported , saldo 16 800 GWh . I/E 38%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 47,435 (53.91%)
	Nuclear (GWh and %): 29,921 (34.0%)
	Renewables (GWh and %): 10,534 (11.97%)
	Other (GWh and %): 107 (0.12%)
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 2,679 (3.04%)
	Wind (GWh & %): 609 (0.69%)
	Solar PV (GWh & %): 2,340 (2.66%)
	Biomass (GWh & %): 4,726 (5.37%)
	Other renewables (GWh & %): 180 (0.2%)
Top 3 renewable energy sources	PVE, wind, biogas, pumping hydrostations
Growth rate of total renewable generation (% per year) over the past five years	0,3%

Reference: IEA Electricity generation by source, Czech Republic
**Renewables include hydro and non-hydro renewables.*
***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

2040 Goals	Measure
Renewable power generation total amount (GWh)	20000 GWh
Ratio of fossil to non-fossil	Fossil (GWh and %): 30000 GWh, 38%
	Non-Fossil*** (GWh and %): 50000 GWh, 52%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 30000 GWh, 38%
	Hydro (GWh & %): 2000 GWh, 2%
	Non-hydro Renewables (GWh & %): 18000 GWh, 22,5%
Top 3 renewable energy sources	Biomass incl. biogas, Solar, Hydro

****Non-fossil includes nuclear and renewables.*

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

Reductions	2020	2040
Primary energy resources PJ	1800	1700
Final energy consumption PJ	1000	950
CO_2 mil. ton	100	75

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Czech power grid was in the past burden with huge unscheduled power flows from North-east Germany to Austria and back to Germany caused by wind parks generation located on north-east of Germany. After installation of phase-shifting transformers on cross-border connectors between Germany, Czech and Polish systems the risk of overloading was eliminated.

b. What % of total electricity is imported compared to installed capacity in your country?

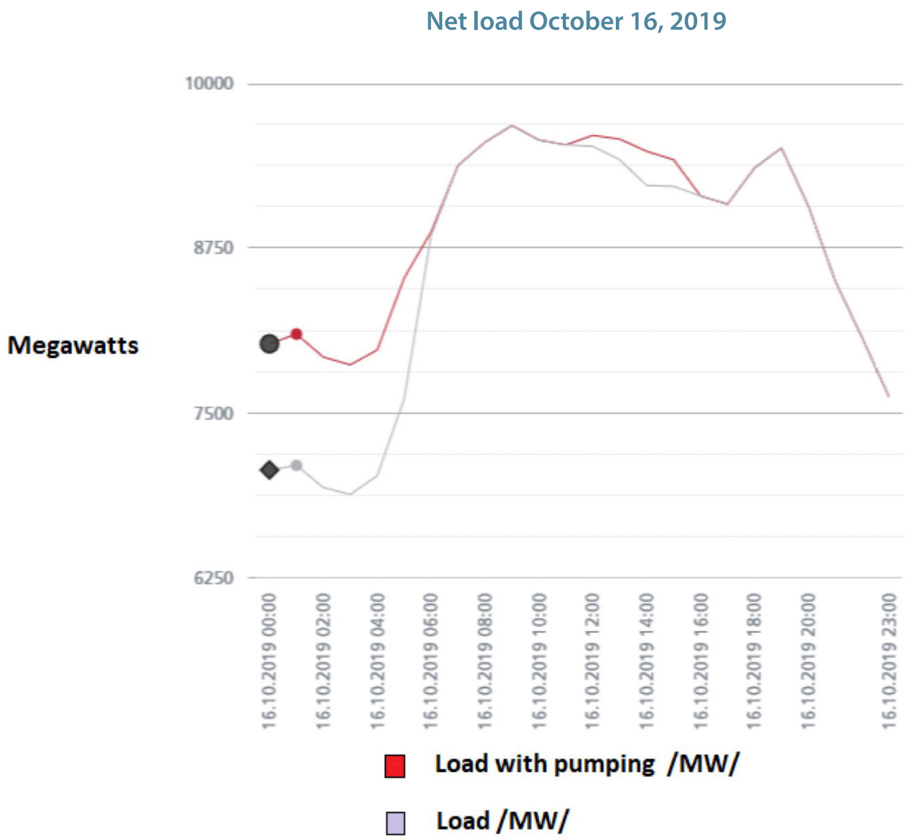
The Czech Republic exports aprox. 20 - 25 % of domestic electricity consumption. Similar amount of electricity (11-15 TWh/year) is physically transited across the Czech power system.

Czech power grid was in the past burdened with huge unscheduled power flows from North-east Germany to Austria and back to Germany caused by wind parks generation located on north-east of Germany. After installation of phase-shifting transformers on cross-border connectors between Germany, Czech and Polish systems the risk of overloading was eliminated.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

Not yet, but it is a challenge for decades after 2030



b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

There are no internal bottlenecks within the Czech power network. Main bottlenecks causing unintended power flows via neighboring Czech, Polish and Austrian transmission systems are between North and South part of Germany.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Long distance DC underground lines to transport wind electricity from North to South part of Germany. But projects are extremely expensive and delayed.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Primary pumped storage power plants but with limited capacity of artificial upper reservoirs. Some potential of flexibility is "hidden" in ripple-controlled electricity consumption, esp. electrical boilers and heaters.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Old, esp. lignite fired power plants will be phased out in tune with depletion of domestic brown coal reserves. Nuclear energy is the only option for replacing phased out coal-fired base load power plants. However, new nuclear units have to more contribute to system regulation.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The potential of load management and flexibility on consumption side is now "captured" by ripple controlled demand motivated by tariff system. Cost-benefit analyses of smart meter roll-out work out negative because of only costs and no real benefits.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The project New tariff structure focused on new challenges like prosumers, demand side response, electricity storage, aggregators, etc. was canceled few years ago for political reasons, because it could lead to increasing bills for some customers with very low consumption but with standard or high capacity of connection to the grid

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The Czech Republic is the party of European emission trading system (EU ETS). Revenues from selling allowances serve to finance energy efficiency and environment protection projects.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Generally, investments to distribution networks are focused on improvement of grid resilience, reliability, capacity and intelligence (remote observability and control, preparedness for roll-out of smart meters, e-mobility, active customers like prosumers, demand response providers, aggregators, use of flexibility and non-frequency ancillary services on distribution level, etc.)

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

The public opinion towards renewable energy sources, esp. large photovoltaic plants is negatively influenced by photovoltaic boom around 2010 driven by subsidies burden to final customers and partly to state budget later on. Wind convertors are matter of resistance of local inhabitants and lack of convenient windy territories.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

None

France

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

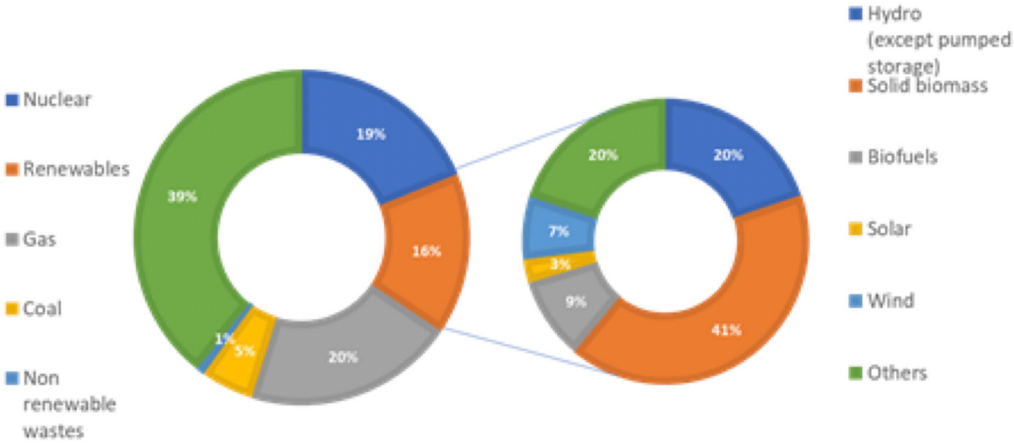


Figure 1- France – Primary energy - Ministry of Energy (nuclear being counted as the electrical output) – 2018

In 2018, a total of 257.5 Mtoe primary energy was supplied, and 157.7 Mtoe final energy was consumed. The transportation sector (29.6%) consumed the most followed by the residential sector (26%), industrial sector (17%), commercial (15.5 %), agricultural sector (2.8%) with 9.1% non-energetic usages

2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 556,000
	Import-export ratio (%): Import 13.58 Export 76.50 ratio 18%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 54.21 – 9.7%
	Nuclear (GWh and %): 393.15 – 70.6%
	Renewables (GWh and %): 109.44 – 19.7%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (TWh & %): 393.15 & 74% Hydro (TWh & %): 74.38 & 14% Non-hydro Renewables (TWh & %): 63.75 & 12%
Top 3 renewable energy sources	Hydroelectric, Wind, solar
Growth rate of total renewable generation (% per year) over the past five years	2014: -4.8% 2015: -3.92% 2016: +6.83% 2017: -6.37% 2018: +21.57%

**Renewables include hydro and non-hydro renewables.*
***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

There are no official targets set neither for the entire system nor for electricity generation in 2040 or 2050. Scenarios will essentially depend on a decision to be taken in 2022 to replace part of the existing nuclear fleet by new reactors at their end of life, or to phase out nuclear. The table is based on the "new nuclear" scenario of the French agency for energy savings (Ademe – 2018 – "trajectoires d'évolution du mix électrique 2020-2060" – in French only). It assumes that the share of nuclear will remain close to 50% of total generation.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

France is bound to meet its commitment included in the "European directive on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030" (Regulation (EU) 2018/842 of the European parliament and of the council of 30 May 2018). It calls for a reduction of its non-ETS emissions of 37% in 2030 compared to the 1990 level. Non-ETS emissions (European Trading Scheme including transport, buildings, agriculture, non-ETS industry and waste), account for roughly 60% of French emissions.

The French parliament is presently setting the more challenging targets of 1) Carbon neutrality and 2) division by a factor of six of greenhouse gas emissions in 2050 compared to 1990.

The same law will provide for nuclear not to exceed 50% of the electricity generation mix in 2035 (this goal was previously set for 2025).

2040 Goals	Measure
Renewable power generation total amount (GWh)	350,000 GWh
Ratio of fossil to non-fossil	Fossil (GWh and %): 12,000 GWh & 3%
	Non-Fossil*** (GWh and %): %): 383 GWh & 97%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 260 GWh
	Hydro (GWh & %): 77 GWh
	Non-hydro Renewables (GWh & %): 223 GWh
Top 3 renewable energy sources	Wind, Hydroelectric, solar

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

So far, and with a relatively small amount of Wind and Solar, there are no reliability issues on the grid. In years 2023 and later, the spinning reserve will be reduced with the decommissioning of all coal fired power plants which are presently used for grid stability only.

b. What % of total electricity is imported compared to installed capacity in your country?

In 2018, 26.1 TWh were imported and 86.3 TWh were exported to be compared to an annual generation of 548,6 TWh.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

This issue is handled by the European Union. Our Academy calls for load shedding of excess Wind or Solar energy when not needed, but it is not on the agenda of the European Union yet.

c. What are some steps that have been taken to mitigate this phenomenon?

Demand side management (DSM) is at an early stage, and should be facilitated by the generalization of smart meters. France is a deregulated market, and it is expected that the market will optimize DSM.

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Our country is well interconnected with its six neighbors, meeting the European goal of 10% of its installed capacity. Achieving 15% in 2030 as suggested by the European commission may prove to be difficult, as there are strong local oppositions to new transmission lines.

However, our Academy notes that renewables generation is well correlated between European neighboring countries, and considers that interconnexions can only be a small part of the solution to excess renewable energies.

Until now, penetration level of solar energy in France is relatively low, and France is not facing a duck curve yet (meaning the demand of dispatchable sources is quickly decreasing after the morning peak, or increasing before the evening peak)

However, the French grid experiences more and more hours of very low or negative prices, when there are excess supplies of non-dispatchable energies (solar and wind) from Germany and Northern Europe. It is presently an economical, not a technical issue.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

Idem.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

This question does not apply to France, which import surplus electricity from neighboring countries.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

- So far France has not been confronted to stability problems due to intermittency, but only to low or negative prices. The present policy is for the market to mitigate the problem. In addition, the French TSO starts to develop a capacity market.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

- The installed pumped storage power is ~4,900 MW with approximately a 5 hours mean capacity. There are no plans for extension.
- Hot water cylinders are widely used, and provide a secondary storage.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

- The last five coal units should be decommissioned in the next ~5 years; presently they are used as spinning reserve only (3100 MW, but practically no electricity generation).
- The law calls for reducing the share of nuclear to 50% of the electrical mix in 2035, but no decision is taken yet beyond this threshold (either replacing aging units, or not). All French units have a load-follow capability equivalent to Open Cycle Gas Turbines. But an increased share of nondispatchable renewables creates a substantial economic challenge to nuclear. Our Academy considers that there is no tangible argument for motivating an early shutdown of nuclear units.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?
    - There is presently no stabilization issue, due to the large inertia provided by nuclear units and hydraulic units
    - Long term wise, active discussions are underway to develop a Hydrogen economy. In the meantime, our Academy considers that Battery Electricity storage (BESS) will be needed, to the detriment of the Hydrogen economy.
    - Our Academy considers that a system cost analysis of the system should be made, to value the merits of nuclear with respect to system stability (Refer to "System Costs with High Shares of Nuclear and Renewables - © OECD 2019 NEA No. 7299).

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Smart meters are systematically implemented (all France covered in 2021). As the market is deregulated, DSM should develop. It is already enforced for large industrial consumers.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Except cybersecurity, these technologies are presently not part of the agenda.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

   France is deregulated, and it is to the market to set up new mechanisms. The French

   TSO (RTE) is in charge of balancing the grid. A capacity market is in place since 2016. In 2019, the TSO launched a call for tender of capacity until 2030.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

   France is part of the European Trading Scheme, which covers 40% of its emissions; it generates no revenue.

   There is a taxation system on all hydrocarbon products, correlated to their CO_2 content (with exemptions (agriculture, fisheries, etc.). The revenue falls into the Treasury.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

   The French DSO (Enedis) invests roughly 4.2 B€ per year. Its program is not public, nor approved by the French regulator.

   To our knowledge, there are no investments in storage facilities beyond demonstrators and R&D.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

   Public opinion is very open to the energy transition although there are some resistance to wind farms based on the NIMBY principle. Regional and local authorities are actively participating in the process, supporting local investments which are generally popular, but not economically optimized.

VII. Suggestions

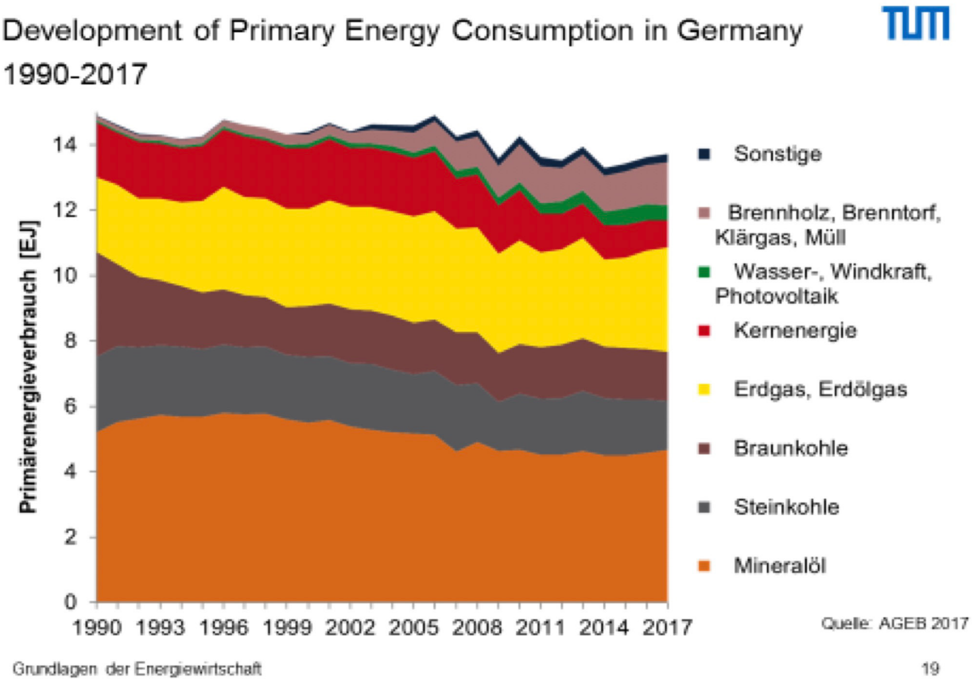
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

- Place economy at the core of the system, and measure any long-term decision against the cost of abated CO_2.
- For any country, don't do more than the competing economies.
- Beware of the free riders, ie those countries which do not take their part of the burden sharing but benefit of the worldwide reduction of CO_2 emissions resulting of costly efforts made by more virtuous countries.
- Collectively accept a high CO_2 price. Our Academy supports the recommendations of the French economical advisory body to the Government (France Stratégie). It determined that achieving Carbon neutrality in 2050 requires a CO_2 price of 250 €/t in 2030; with a steady but sharp increase beyond this date. The present price of CO_2 on the EU-ETS market is 26 €.

Germany

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



In 2018, a total of 13,600 PJ primary energy was supplied, and 9,300 PJ final energy was consumed. The industrial sector and the transportation sector consumed 29% each, the residential sector 26% and the tertiary including the public sector 16%.

2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 647,000
	Import-export ratio (%): 31,500 / 82,700 = 38%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 312,100, 48%
	Nuclear (GWh and %): 76,000, 12%
	Renewables (GWh and %): 226,400, 35%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 16,600, 7.5%
	Wind (GWh & %): 111,500, 49%
	PV (GWh & %): 46,200, 20%
	Biomass (GWh & %): 45,700, 20%
	Other renewables (GWh & %): 6,500, 3.5%
Top 3 renewable energy sources	Wind, PV = Biomass
Growth rate of total renewable generation (% per year) over the past five years	2014: +6.5% 2015: +14.8% 2016: +0.7% (weak wind year) 2017: +13.8% 2018: +4.7%

**Renewables include hydro and non-hydro renewables.*
***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

- Reduction of greenhouse gases at least 70%, in 2050 80 to 95% (1990). In the wake of the IPCC 1,5°C report and rising public awareness of the climate crisis, several leading politicians have publically announced a goal of greenhouse gas neutrality by 2050, but this is not yet official.
- Share of renewable primary energy consumption 45%, 60% in 2050
- Share of renewable electricity 65%, in 2050 minimum 80%

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

i. Reduction of primary energy consumption 50% by 2050 (2008)

ii. reduction of traffic energy consumption of 40% by 2050 (2005)

iii. Reduction of energy use in buildings of 80% by 2050 (2008)

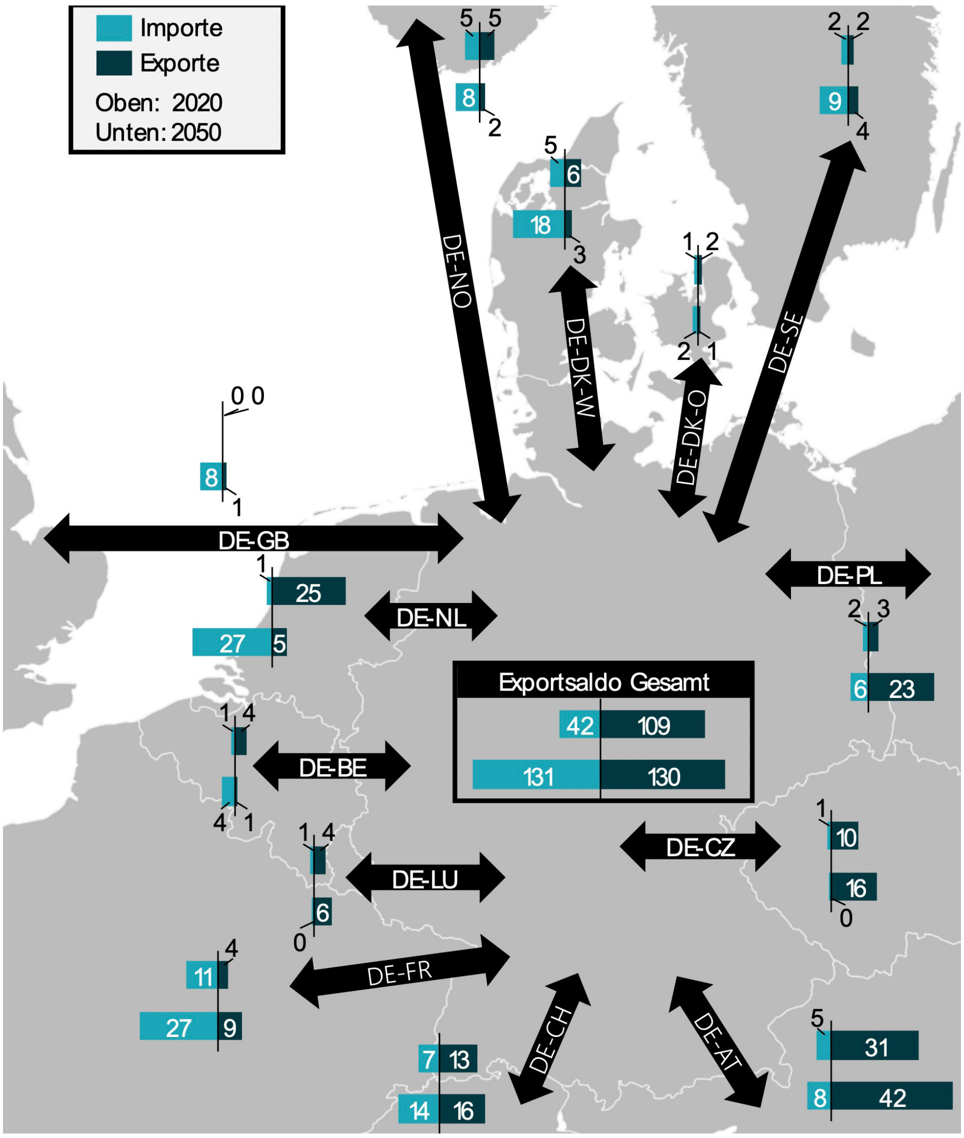
iv. Reduction of electricity consumption for existing appliances 25% (2008)

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

The German power system is one of the most reliant worldwide, with a SAIDI (System Average Interruption Duration Index) of 12 minutes per year. One of the biggest challenge is the necessary enforcement of the transport grid over more than 5.000 km, which is actually inhibited by missing public acceptance. At DSO level the increasing number of heat pumps and electric vehicles already leads to bottle necks in the distribution grid. The solution is (expensive) enforcement of existing lines and installation of variable local transformers.

b. What % of total electricity is imported compared to installed capacity in your country?



IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

In special situations a negative residual load could be observed over some hours, partly in combination with negative electricity prices. These events will gain on relevance when looking forward to more than 200 GW of fluctuating renewable electricity. A negative residual load in about 50% of the time in 2050 could be the consequence, if not compensated by storage or load shift.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

The German power system of Germany is interconnected to 12 neighbour countries: Austria, Switzerland, France, Luxemburg, Belgium, Netherlands, Denmark, Great Britain, Norway, Sweden, Polanda and Czech Republic.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

The main electricity consumers are located in the south of Germany. The most effective locations for wind energy converters are situated 1000 km away at the Northern and Baltic Sea. Additional transportation capacity is necessary. The south has more effective locations for PV generation, which shows a higher fluctuation than wind energy. This is a challenge for keeping up the reliability of the electricity system, especially for industry consumers.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Pumped-storage hydroelectricity power generation has reached its capacity limits in Germany for reason of ambient protection. Gas fired power plants are the economically most interesting option to provide short and long term reserve power. Therefore big scale battery systems cannot yet be economically operated on a midterm timescale, the same goes for hydrogen storage.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

There are demonstration projects with batteries (large and small scale) as well as with hydrogen electrolysers using renewable electricity, combined with cavern storage systems using former salt caverns.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Germany will phase out of nuclear energy in 2022, which may cause severe problems in electricity transport, because new transmission lines will not be erected in time. Furthermore a complete phase out of coal is planned in the year 2038 or even earlier. The decision for the coal exit is based on a report by a commission created by the government. Besides the exit plan, it recommends measures on social and structural development and financial aids for States in which economically depend on lignite mining.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Large (distribution grid level) and small stationary battery systems (in combination with PV) are entering the market. In short term future traction battery systems will support the distribution grid (vehicle to grid).

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The roll out of smart meters is delayed since more than 5 years, due to data security aspects, it will hopefully start next years, beginning with large consumers.

   Several projects (Reallabore) with micro grids analyze small scale demand side management systems, operated by aggregators in cooperation with the local DSO.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Blockchain energy markets are discussed and demonstrated, especially for peer tp peer trading and labeling renewable electricity.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

Beside the already known and established market instruments, new platforms for flexibility trading are developed in demonstration projects, as a substitute for former discussions on capacity markets, instead of energy only markets.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The European Emission Trading System ETS is applicable for the energy sector and parts of large industry. Actually the German government discusses plans of applying ETS on households and traffic, alternatively rising a new tax on greenhouse gases. The revenues shall be used as a bonus for emission reduction or for new measures in climate protection.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

For the moment being, most DSO´s invest in retrofitting variable transformers in the distribution grid or enhance the grid capacity by building up meshed networks.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion toward the green energy transition has been largely favorable. However, there have been recent increasing concerns about damage to natural scenery (wind, PV and biomass) economic efficiency (PV), conflicts among residents (new transportation lines), land shortage (wind, PV, biomass), etc. The Energy Transition based on the German Energiekonzept includes a public dialogue to keep up and increase public acceptance. An increasing criticism on the expected costs of the Energiewende and the failure of interim goals, like for 2030, can be noted. Since late 2018, there is a growing climate movement predominantly by young people including school strikes, framing climate protection as an intergenerational justice issue and demanding immediate and ambitious political action to reach the goals of the Paris agreement. As a consequence, public awareness of the climate emergency has much risen and may lead to increasing public pressure for a more ambitious energy transition.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

- Flexibility platforms in order to assign a value to flexible capacity and demand side management
- Smart distribution grids, in order to enable distribution grids to provide more system services
- Participation of small scale renewable electricity generation on the infrastructure costs (distribution grid, storage systems)
- Investment in power to gas and power to liquid systems
- More electrification of traffic and heat application in industry and household
- Coordinated integration of electric mobility (vehicle to grid)
- Expansion of district heating grids in combination with heat storage and power-to-heat
- A critical review and concretization of the fuzzy goal of 80 to 95% reduction goal is strongly advised.

Hungary

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

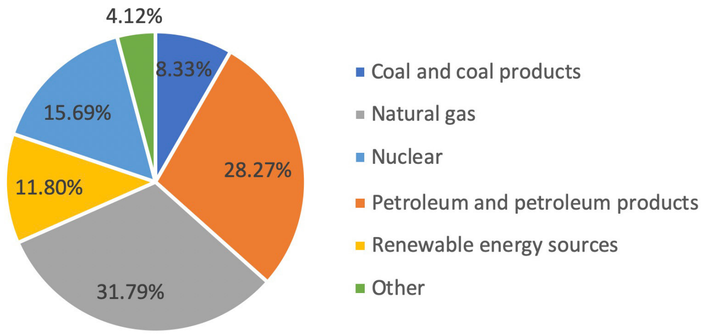


Fig1: The share of different energy sources in the primary energy supply (in total 1125 PJ) of Hungary in 2017 (detailed data for 2018 is not available yet)[36]

In 2018, a total of 462.3 Peta Joule primary energy was domestically produced, 1028 PJ imported, and in total 1,126.5 PJ primary energy was consumed.[37]

2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 31 069 GWh[38]
	Import-export ratio (%): (Import 18 613 GWh / Export 4 265 GWh) = 436% Net import 14 348.2 GWh Share of import in the electricity supply: 31.59%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 11 930.94 GWh, 38.4 %
	Nuclear (GWh and %): 15 733.2 GWh, 50.64%
	Renewables (GWh and %): 3 405.61 GWh, 10.96%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 215.00 GWh, 0.69%
	Wind (GWh & %): 589.86 GWh, 1.9%
	PV (GWh & %): 267.10 GWh, 0.86%
	Biomass (GWh & %): 1 750.43 GWh, 5.63%
	Other renewables (GWh & %): 583.22 GWh, 1.88% (includes biogas (186.15 GWh / 0.6%), waste (390.71 GWh / 1.26%) and geothermal (6.36 GWh / 0.02%))
Top 3 renewable energy sources	Biomass, Wind and Waste
Growth rate of total renewable generation (% per year) over the past five years	2014: 2 980,4 ktoe -332.8 ktoe 2015: 3 248,8 ktoe +268.4 ktoe 2016: 3 199,9 ktoe -48.9 ktoe 2017: 3 177,8 ktoe -22.1 ktoe[39] (nearly 80% is biomass)

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

[36] https://www.ksh.hu/thm/3/indi3_1_2.html

[37] https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_qe001.html

[38] Preliminary data for the year 2018 from the following link: http://mavir.hu/documents/10258/229275463/Előzetes+Termelésmegoszlás++2018+MavirHonlapra+HU+20190131.pdf/c7c5165f-9332-ddc1-93d9-f0bef4b08a3d

[39] https://www.ksh.hu/thm/3/indi3_1_2.html

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

The current official energy policy of the Government, accepted by the Parliament covers the period 2011-2030. New energy policy is under development, which will be publically discussed and finally adopted later this year / next year.

Due to the global changes, there is a need for integrated strategic planning, which is able to efficiently support the clean-energy based transformation in Hungary.

The concept of the New Energy Strategy will be the „clean, smart and affordable energy", as communicated by the Government.

i. Clean: increases the low or zero emission technologies within the domestic energy consumption, urges the increase of energy efficiency and strengthen energy independency.

ii. Smart: is based on the latest innovation projects to be able to provide high-level energy services on the lowest cost

iii. Affordable: diversified supply portfolio and legislative environment in order to domestic energy prices can support the competitiveness of Hungarian economy.

For the CAETS report national contribution we have collected forecast from the MAVIR Ltd. (Hungarian Independent Electricity Transmission Operator Company Ltd.) and the optimistic scenario results of MAVIR reported in the below TABLE. The forecast represents the prognosis data of the year 2033.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

According to Hungary's National Energy and Climate Plan the total gross CO_2 emission will be 56276 kt in 2030. Further forecasts are not yet available. (Fig. 2)

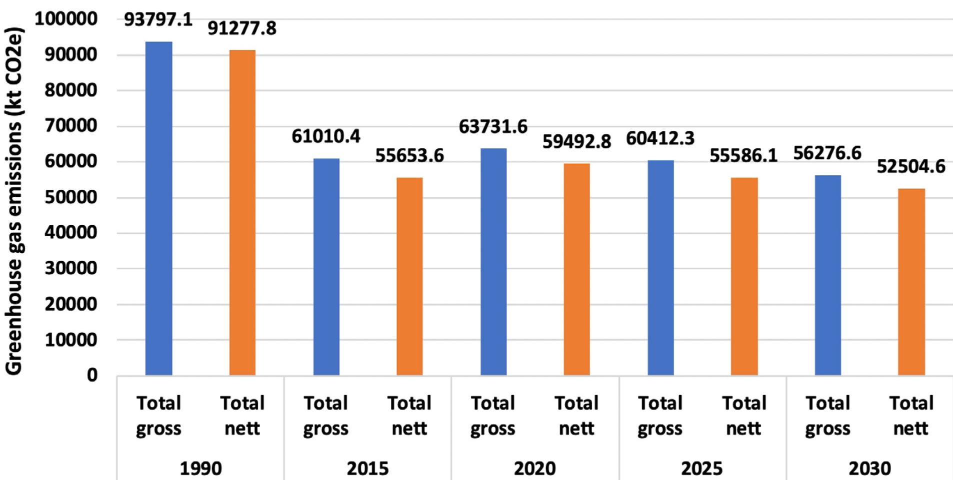


Fig2: Greenhouse gas emissions through complementary policies and measures 1990-2030.[40]

[40] https://ec.europa.eu/energy/sites/ener/files/documents/hungary_draftnecp.pdf

2033 Forecast	Measure
Renewable power generation total amount (GWh)	7 638.1 GWh[41]
Ratio of fossil to non-fossil	Fossil (GWh and %): 7 169.6 GWh 17.2 %
	Non-Fossil*** (GWh and %): %): 35 332.3GWh 84.52%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables) Must add up to "Non-fossil (GWh and %)"	Nuclear (GWh & %): 27 694.4 GWh 66.25%7 This high share of nuclear will be present only for few years in a period when old and new nuclear units will be in operation. This share will most probably drop by 2040 to appr. 35-40%.
	Hydro (GWh & %): 215.00 GWh 0.51%
	Non-hydro Renewables (GWh & %): 7423.1 GWh 17.75%
Top 3 renewable energy sources	Solar (PV), Wind and Biomass

****Non-fossil includes nuclear and renewables.*

Comment: The share of import is currently over 30%. The future role of import is not decided yet. The above given percentages are calculated on the basis of the current domestic production, without import.

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

We do not have that problem in relation to electric isolation, electric 'islands' or isolated grids. The Hungarian electricity system is organically integrated into the European electricity grid, and the country has large cross-border capacities to its neighboring countries. Regarding the renewable sources, the currently installed capacity of renewable energy sources does not cause grid stability problems, but with the increasing number of PV plants and with the decreasing capacity of conventional power plants it can be a major problem in middle and long-term.

b. What % of total electricity is imported compared to installed capacity in your country?

In 2018 the share of imported electricity in the total electricity supply was 31.59% (67,007 TJ or 1600 ktoe[42]), which is one of the highest values in the European Union.

[41] https://www.mavir.hu/documents/10258/15461/Forr%C3%A1selemz%C3%A9s_2018_IG.pdf/fc043982-a8ea-e49f-6061-418b254a6391

[42] http://mekh.hu/download/f/99/a0000/7_2_orszagos_eves_energiamerleg%202014_2018e.xlsx

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

Hungary do not have such a problem yet. The Hungarian capacities of the installed renewable energy sources are in the level of controllability. The experienced imbalances in the grid are compensated partially with imported electricity, partially with domestic conventional power plants.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Hungary is well integrated to the EU electricity system and has interconnection to Ukraine and Serbia, too. Hungary exceeds already significantly the 15% EU target relating to the interconnection of electricity systems; the share of cross-border capacities relative to the nominal installed power plant capacities exceeds 47%. The further increase of cross-border capacities is, however, planned. In the recent years major infrastructure investments have been launched in Hungary.[43]

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

[43] Hungarian NECP 2018, p. 31-34.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

The main focus is currently on the promotion of R&D. One particular example is the development of battery solutions. A good example is that at the end of summer 2018 ALTEO's battery energy storage facility, which is unique not only in Hungary but also in Central and Eastern Europe, started its test run.[44] The battery technology used is lithium ion. The installation will enable ALTEO to participate in the electricity market by providing frequency and secondary regulation to the national grid operating in virtual power plant mode.[45]

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Hungary does not have storage capacity yet. There are many arguments in favor of and against the construction of pumped storage hydro power plant facilities in Hungary, and no such facility has yet been built. There is no policy and no public discussion on that topic at all. There are research projects in the private sector on the so-called grid scale batteries, as mentioned in the previous paragraph.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

There is a high level policy discussion on phase-out of coal in Hungary by 2030. This would result to shut-down the second largest baseload power plant (with 960 MW capacity).

Hungary has four VVER-440 type nuclear power plant units with 2000 MW total capacity. They were commissioned between 1982 and 1987 with the original lifetime of 30 years. Their lifetime has been extended by 20 years, so these capacities will be shut-down between 2032 and 2037. For the replacement of the nuclear units two VVER-1200 units with 2400 MW total capacity are being prepared with the planned start of commercial operation before 2030.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

It is essential to have available the widest possible range of means to ensure flexibility, due to the rising number of inflexible, weather-dependent renewable producers. As part of developing the new National Energy Strategy, the Government puts emphasis on the following: System integration of RES production; Advancement and facilitation of demand response; Improved use of regulatory capabilities (e.g. demand response) available in the distribution networks; Improvement of innovative technologies; Spread of digitalization and smart equipment; Development of additional means of electricity interconnection and strengthening of market integration.

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[44] https://bcsdh.hu/alteos-battery-energy-storage-facility-has-started-its-test-run-in-the-name-of-sustainability/

[45] https://www.pv-magazine.com/2018/08/23/wartsila-completes-its-first-european-energy-storage-project/

2. What technology is under development that attempts to implement smart meters and demand-side management?

   As a strategic objective, the development of smart metering systems, a shift to digitalization in consumer administration and the creation of possibilities for simplification. The Hungarian Government promotes the installations of smart meters regarding public utility services, i.e. natural gas, electricity and water consumption.[46]

   Taking into account Hungary's geographical and climate characteristics, among renewable energy sources, a high priority is assigned to the use and spread of photovoltaic power production. In parallel, Hungary places emphasis on improving regulatory measures on the demand side in line with the EU regulations. Hungary encourages the consumer-side smart grids and smart metering solutions, which can significantly contribute to optimizing power consumption. There are already available on demand-side smart meters, which allows the integration of solar PVs in housing and small industries to the grid.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   There is no specific policy known for these topics. Although in 2018, with the involvement of government actors, representatives of industry, science and Academia the Energy Innovation Council was established, which has the goal to develop and implement energy system related research projects.

[46] Government Decree no. 26/2016. (II.25.)

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The residential sector is under price regulation, and just a small number of households enter the competitive market.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

In order to achieve the global GHG reduction targets set by international conventions and in line with EU climate goals the EU introduced the so called ETS (emission trading scheme), which is considered as a financial mean to reduce pollution. The ETS scheme has been implemented in Hungary and the rules apply outlined in the ETS Directive.

Energy taxes in Hungary are levied within the framework of the 2003 EU Energy Tax Directive, which sets minimum rates for the taxation of energy products in member states.[47]

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

The Hungarian power transmission network is undergoing continuous modernization and is scaled to meet performance requirements.[48] Electricity projects with Hungarian involvement on the (third) list of PCIs[49] is in effect: interconnection of Žerjavenec (HR)/Hévíz (HU) and Cirkovce (SI); increase of the electricity interconnection capacity of Hungary and Slovakia between Gabčíkovo (SK) and Gönyű (HU) and Veľký Ďur (SK); interconnection of Sajóvánka (HU) and Rimavská Sobota (SK). The so called 'Grid Development Plan of the Hungarian Electricity System – 2017' sets out other investments planned in the future.[50]

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion strongly supports the installation of renewable energies. Political parties have aligned with public opinion. The application of nuclear energy is also accepted by the majority of the public.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

[47] https://www.oecd.org/tax/tax-policy/taxing-energy-use-2018-hungary.pdf

[48] https://www.mavir.hu/documents/10258/27582228/Halozatfejlesztes+project+statusz+2009_2017_V0.pdf/27aec42b-d764-46bf-814e-e873d6b65a8d

[49] 'Projects of Common Interest' - in accordance with Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans- European energy infrastructure and repealing Decision No 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No 714/2009 and (EC) No 715/2009 (OJ L 115, 25.4.2013, p. 39).

[50] Hungarian NECP 2018, p. 31-33.

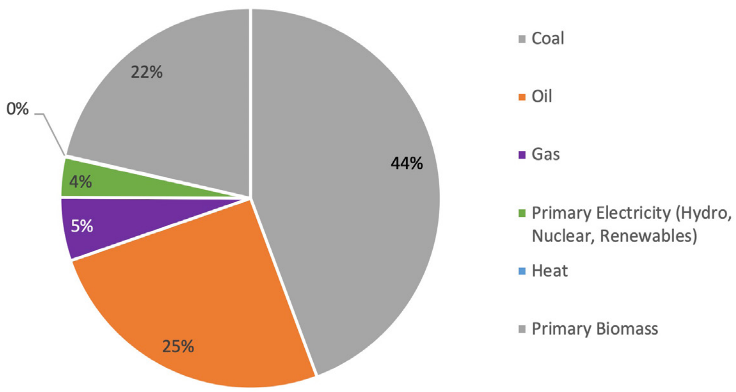
India

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

India Energy Mix 2018

Source: IEA



2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 1,303, 367 GWh (without imports : 5611 GWh'
	Import-export ratio (%): Import (5611 /Export (P) 7,203 – 66.26%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 1,037,059 – 79%
	Nuclear (GWh and %): 38,346-3%
	Renewables (GWh and %): 227961-18%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Large Hydro (Renewable) (GWh & %): 126,122 – 55.33%
	Wind (GWh & %): 52,666 – 23.10%
	PV (GWh & %): 25,871- 11.35%
	Biomass (GWh & %): 3,404 - 1.49%
	Bagasse - (GWh & %): 11,847 – 5.20%
	Small hydro – (GWh & %): 7691 – 3.37%
	Other renewables (GWh & %): 358 – 0.16%
Top 3 renewable energy sources	Hydro, Wind, Solar
Growth rate of total renewable generation# (% YoY) over the past four years	2015: +2% 2016 : -2% (mainly due to the declined electricity generation from large hydro resources) 2017: +9% 2018: +12%

Source: CEA, 2018, Energy statistics, 2019

(P) – Provisional

** RES (Renewable Energy Sources) include Large & Small Hydro resources, Biomass Gasifier, Biomass Power, Urban & Industrial Waste Power, Solar and Wind Energy*

 # includes generation from large hydro other than RES

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

- Government of India has, in June 2015, set a target of achieving renewable energy capacity of 175GW (Solar – 100 GW, Wind – 60 GW) by 2022.
- Central Electricity Authority has, in the National Electricity Plan (2018), considered RE capacity target of 275 GW (Solar – 160 GW, Wind – 100 GW, Others – 15GW) by 2027.
- Central Electricity Authority has in the draft report on optimal Energy mix in 2030 assessed RE capacity of 455 GW (Solar -300 GW, Wind –140 GW).

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

Goals	Measure
Increase in the capacity of renewable energy generation	Solar PV - 100 GW , Wind - 60 GW, Bio-power – 10 GW, Small hydro – 5 GW by 2022 Solar PV - 160 GW, Wind - 100 GW, Bio-power – 10 GW, Small hydro – 5 GW by 2027
Reduction in the GHG intensity of GDP by 2030	Reduction by 33-35% by 2030 from 2005 level
Increase in the share of non-fossil fuel generating capacity in total capacity by 2030	Achieving 40% non-fossil fuel generating capacity by 2030
Renewable purchase obligation (RPO)	RPO target of 21% (10.5% each from solar and renewable non-solar sources) set by Government of India for all states by 2022
Reduce specific energy consumption in energy intensive industries.	Specific energy saving targets assigned to certain categories of energy intensive industries under Perform Achieve and Trade (PAT) scheme

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

The Indian electricity grid operates as a single synchronous grid and there are no reliability issues at national, regional or state level. The availability of regional grids is consistently maintained at over 99%. The grids at distribution level are noted to have reliability issues in the areas with high growth of demand, exceeding the safe operational limits of distribution infrastructure.

b. What % of total electricity is imported compared to installed capacity in your country?

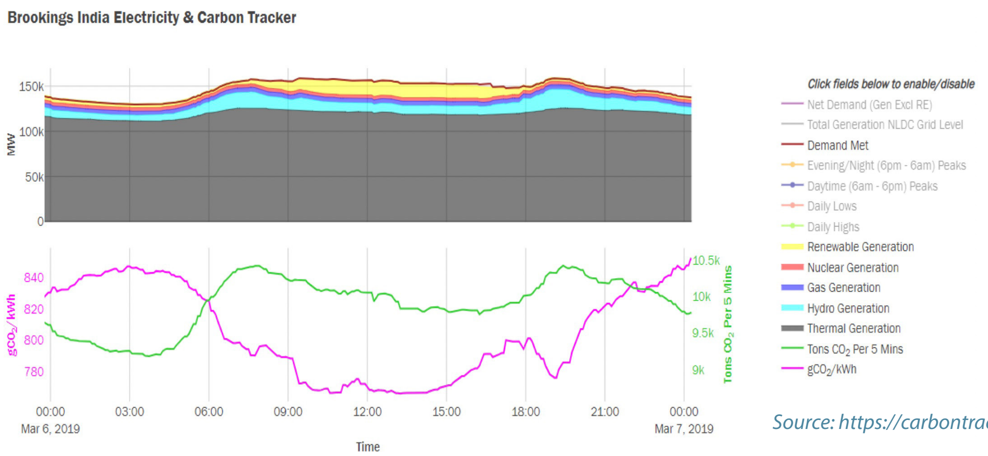
Less than one percent. Currently, India has surplus electricity generation capacity IV. Imbalances in Supply & Demand

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

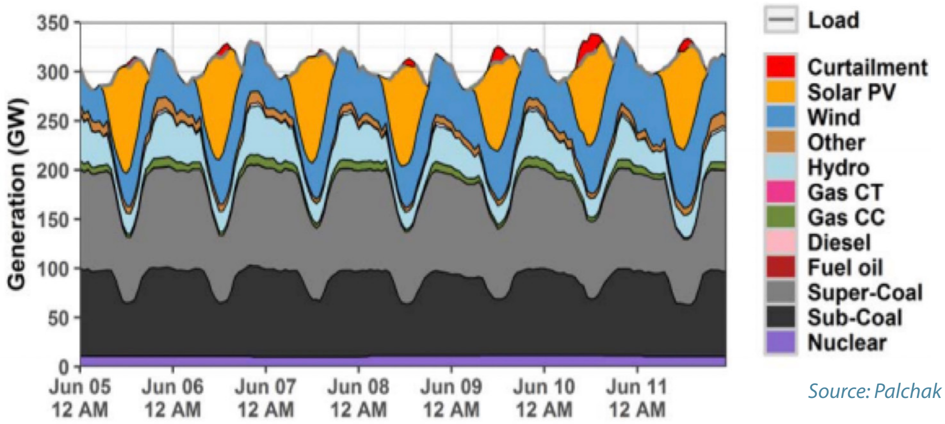
b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

India currently displays a mild version of the duck-curve phenomenon, due to the still relatively low level of installed solar PV relative to peak demand. Installed solar PV is about 28 GW relative to peak demand of about 177 GW (2019). The figure below shows the typical dispatch profile for a high solar day, low demand day (in this case, March 7 2019). It can be seen that the level of solar generation (in the figure labelled as renewable generation, but at this time of year it is largely solar) is relatively small, and can be easily be accommodated by cycling the hydro and thermal generation.



Source: https://carbontracker.in/

However, in the longer-term, i.e. by 2030, it is expected that the duck-curve phenomenon could become much more severe, as the share of solar capacity in total generation capacity increases significantly. The figure below shows the simulated one-week dispatch of the power system in 2030, under a scenario with relatively high renewables penetration. Although high, the level of renewables penetration is well within the levels foreseen in government planning documents. It can be seen that the duck-curve phenomenon is much more severe than at present. Instantaneous solar penetration can reach up to 25-40% (the latter figure being on low demand days) of instantaneous demand.



Source: Palchak et al (2019)

c. What are some steps that have been taken to mitigate this phenomenon?

As yet, the duck-curve phenomenon is not severe for India.

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Broadly speaking, the government is pursuing three efforts in order to mitigate the future severity of the duck curve phenomenon. These are:

Flexibilization of the existing thermal and hydro fleet: The government has issued regulations to mandate lower technical minimum generation thresholds for the coal based power plants falling under the jurisdiction of central commission (technical minimum of 55%), as well as encouraging states to implement lower technical minimum.

Demand shifting: The government of India is encouraging the shift of demand to high renewables generation times of day, in particular the encouragement of agricultural pumping during the daytime instead of the nighttime, through the Kisan Urja Suraksha evem Utthan. Mahabhiyan (KUSUM) scheme. Also, electricity regulatory commissions are trying to explore the time of day pricing to give price signals to change the electricity consumption behavior especially during the peak times.

Building new flexibility procurement options such as battery storage and pumped hydro storage: The government of India has ambitious plans to deploy storage technologies to facilitate the uptake of renewables. For example, large-scale tenders have been launched for the procurement of stationary battery storage capacities.

All of these objectives are underpinned by cross-cutting measures to create the right regulatory and price signals, for example through reforms to India's electricity markets.

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Indian electricity grid with an installed capacity of 344 GW as on 31 March, 2018 and peak demand of 160 GW is interconnected with Bhutan (about 1.4 GW), Bangladesh (about 1.2 GW) and Nepal (about 1.5 GW). While India imports hydro power form Bhutan, it exports power to Bangladesh, Nepal and Myanmar.

Power exchanges during FY 18 are given below:

Import from/ Export (-) to	Million kWh
Bhutan	5611
Bangladesh	(-) 4809
Nepal	(-) 2389
Myanmar	(-) 5

Source: POSOCO, March, 2018

It may be noted that these interconnection capacities and the energy exchanges are very small relative to the size of the Indian grid and the challenge of integrating variable renewables in India.

India is a massive, continental scale synchronous electricity grid. The physically neighboring countries with whom electricity trade is envisaged happens at present are Bhutan, Nepal and Bangladesh. Compared to Bhutan, Nepal, and Bangladesh taken as a group, India's grid measured in terms of installed capacity is 23 times larger. Thus, trade with these countries will always remain very marginal in terms of balancing India's grid. Put simply, India is too large, its neighbors too small, and can make only miniscule impact on the balancing of the Indian grid.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

As mentioned in aforementioned statements, the efficiency of India's system will largely be determined by measures within India.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

See above

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Two key technologies for India will be battery storage and retrofit of coal plants to make them more flexible. Pilots have been conducted to bring Indian plants down to world-best technical minimum of 40%, although much of the existing capacity remains very far from such technical performance.

Regarding storage, the government of India has recently tendered 1.2 GW of 'dispatchable renewable' capacity (e.g. renewable plus some battery storage capacity), with a specific tariff covering energy produced at peak time. This kind of tender will be extremely important in terms of assessing the cost and feasibility of bringing to scale battery storage as a technology in India, and assessing its system value.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

There is substantial potential for low cost peak demand shifting options which could explore first along with deployment of cutting-edge new technologies. For example, it is estimated that 60 GW of agricultural pumping load could be shifted from nighttime to daytime largely as a regulatory measure. Regarding new technologies, thermal storage for cooling and 'smart-cooling' with a time of day component could be crucial to ensure that India's growing cooling demand can be met without increasing the evening/nighttime peak demand. Just as important as technologies, however, is the thermal efficiency of new buildings which could dramatically lower future cooling demand and nighttime energy demand which cannot be met from solar.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Majority of the coal-based generation plants have entered in long term PPA with electricity distribution companies. Hence, there is no forceful phase-out of old coal-based generation plants. However, to improve the efficiency of the plant and thereby to reduce emissions from the combustion of coal, CEA has recommended replacing the inefficient & retired units with more efficient supercritical /ultra-super critical units. Retirement of ~ 22 GW of such coal-based capacity has been considered in the National Electricity Plan, 2018. By and large all new coal-fired generating capacity addition during last 5 years is based on super-critical technology. Advanced ultra-super critical technology is also under implementation. The role of nuclear based power plants is limited in mitigating problem of intermittency as the technology is mainly designed for meeting base load requirement.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Technologies such as battery energy storage technology, pumped hydro, solar thermal, Automatic generation control (AGC) in large hydro, and coal-based power plants are under development/implementation for contributing to the flexibility needs in the grid and for frequency stabilization

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The government of India under the UDAY scheme has targeted to distribute about 50 million prepaid smart meters/ prepaid meters by 2020. The Bureau of Energy Efficiency under the Ministry of Power is also working together with the DISCOMs to implement Demand side management measures across various consumer categories.

   Further, Energy Efficiency Services Limited (EESL) launched Smart Meter National Programme (SMNP) to replace 25 crore conventional meters with smart meters across India. EESL model of bulk procurement, aggregation of demand, and monetization of savings will be the approach to roll out smart meters. Moreover, EESL schemes such as UJALA (Unnat Jyoti by Affordable LEDs), PAVAN (Energy Efficient ceiling fan), SLNP (Street Light National Programme), Energy Efficient Building and e-Vehicle are helping to promote energy efficiency. To increase demand side management many utilities are planning to do introduce Demand response programs on pilot scale.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   While synchrophasor based Wide Area Management System (WAMS) using Phasor Measurement Units and pilot Smart Grid projects are under implementation; big data analytics and P2P trading using block chain are being planned in a bid to provide reliable, 24*7 electricity and emerging customer centric services.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

During 2018-19, about 88% of DISCOM's power procurement was in the form of long-term contracts (Power Purchase Agreements), which are typically structured into a two-part tariff, consisting of a generation-based variable cost component and an availability-based fixed cost component. Only about 4% of generation is traded on power exchanges, and about 5% bilaterally between DISCOMS and through traders. The government is moving forward with a quite ambitious agenda of electricity market reform, which has a number of objectives. Firstly, it wants to introduce real-time energy balancing and ancillary services markets, which can lead to better forecasting and scheduling on both the demand and the supply side, while at the same time creating incentives for the introduction of new resources to balance the real-time (i.e. unscheduled) intermittency of renewable generators (but also, of course, unscheduled imbalances of demand, or conventional generation). The government is also aiming at introducing a day-ahead market, which would preserve the fixed-cost component of existing PPAs, but schedule and dispatch all generation based on a single national pool. The exchange-based market would determine the market clearing price based on submitted bids for supply and demand, on the basis of marginal variable costs. The day ahead market has a number of objectives, viz: optimizing the scheduling and dispatch of the fleet; ensuring better sharing of generation resources across distribution companies (DISCOMS) and states; and creating temporal and locational price signals for power system operation and investment.

In summary: the government of India has an ambitious market reform agenda, although it is expected that this will take time to roll-out.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

There is no carbon trading mechanism in the country. However, an environment cess was applied on production & import of coal (known as clean energy cess. The collection from clean energy cess generated revenues around USD 12 billion between 2010 and 2018 (Source: CCAC).

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Currently, distribution companies are investing massively for expanding their electricity grid network to more and more areas in order to achieve the governments' policy objectives of universal electrification of households, 24*7 reliable power etc. Companies are also investing in energy efficient technologies such as star labeled distribution transformers, ABC insulation materials, in demand side management measures (rooftop solar expansion, star labeled home appliances such as ACs, fans, LEDs) and that reduce losses and increase accountability such as smart meters/prepaid meters. They are also investing in advanced technologies such as Battery Energy Storage for grid balancing and smart technologies to better forecast the demand, study behavioral analytics and thus to improve consumer centric services.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public strongly supports the energy transition but are sensitive to the costs.

VII. Suggestions

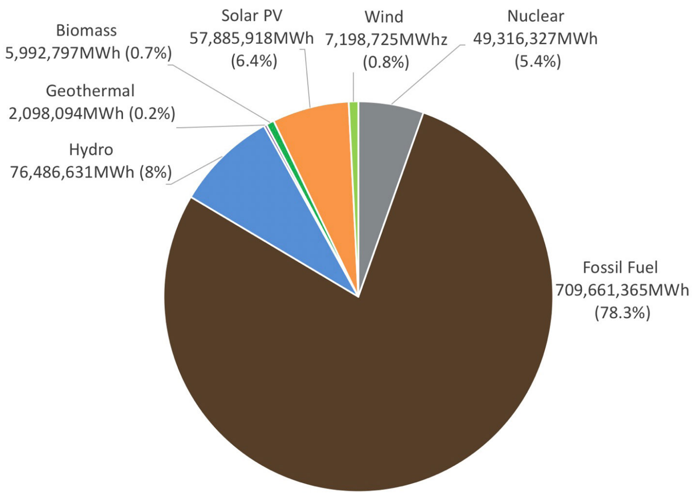
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

The future of renewables (wind and solar) is bright in India. We expect that the rate of deployment of variable renewables will no longer be determined by their per unit cost, which is already competitive with that of coal, but rather by the rate at which the electricity system can be adapted to support their integration and maintain security of supply and cost-effectiveness. According to TERI's analysis, there is no 'silver bullet' to the challenge of renewable energy integration in India. It will require a comprehensive portfolio, encompassing more flexible operation of the dispatchable fleet, demand response, and storage, underpinned by strong market and regulatory signals. Achieving this in the context of a fast-growing electricity demand, and a power sector that is still struggling with financial issues & in-efficiency, will be a big challenge. Key turning points for India could be the cost of battery energy storage, thermal storage in cooling, and efforts to shift load to times of high renewables availability.

Japan

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



https://isep-energychart.com/en/1105/

2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 908,000 GWh
	Import-export ratio (%): 0%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 710,000 GWh (78.1%)
	Nuclear (GWh and %): 49,000 GWh (5.4%)
	Renewables (GWh and %): 150,000 GWh (16.5%)
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 76,500 GWh (51.1%)
	Wind (GWh & %): 7,200 GWh (4.8%)
	PV (GWh & %): 57,900 GWh (38.7%)
	Biomass (GWh & %): 6,000 GWh (4.0%)
	Other renewables (GWh & %): 2.0 GWh (1.4%)
Top 3 renewable energy sources	1) Hydro, 2) PV, 3) Wind
Growth rate of total renewable generation (% per year) over the past five years	24.3% 7.4 GW/year

**Renewables include hydro and non-hydro renewables.*
***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	2040 goal has not been presented by government. In 2030 goal, 234,000 – 256,000 GWh renewable is targeted.
Ratio of fossil to non-fossil	Fossil (GWh and %): 820,000 GWh (77%) as of 2030
	Non-Fossil*** (GWh and %): %): 245,000 GWh (23%) as of 2030
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 224,000 GWh (21%) as of 2030
	Hydro (GWh & %): 96,000 GWh (9%) as of 2030
	Non-hydro Renewables (GWh & %): 149,000 GWh (14%) as of 2030
Top 3 renewable energy sources	1) Hydro, 2) PV, 3) Biomass

****Non-fossil includes nuclear and renewables.*

Japanese government presented its commitment for 80% reduction of CO_2 emission by 2050. However, no practical policy is presented to bridge the 2030 energy mix, which is rather conservative and will be satisfied, and this aggressive 2050 goal.

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

The national grid in Japan has been very reliable. National grid system is divided into 10 segments operated by independent and private electric power companies. Interconnection among the 10 segments is not broad, especially between the east (50 Hz) and west (60 Hz) sides. Installation of PV is concentrated to north (Hokkaido) and south (Kyushu) grid, which are relatively small in their capacity because of the smaller population. As a result, a Duck Curve problem has become severe in Kyushu grid, imposing a severe ceiling against the further installation of PV. The grid containing large cities like Tokyo is free from a Duck Curve problem, but the land area available for PV installation is limited there.

b. What % of total electricity is imported compared to installed capacity in your country?

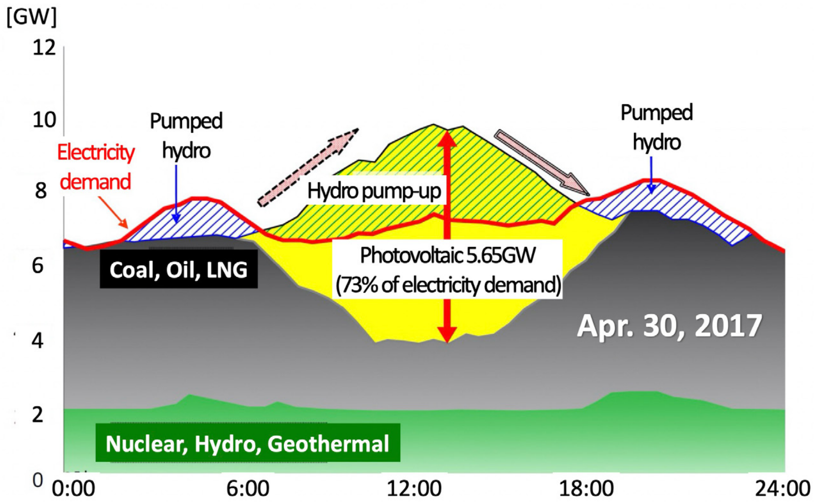
Due to geographical isolation, there is no grid interconnection to neighboring countries. Domestically, interconnection among 10 local grids is narrow, resulting in the lack of tolerance for the installation on intermittent power generation sources. As an example, 17% of the electricity generated in Kyushu grid was exported to neighboring ones at 12:00-12:30 on Oct. 21, 2018, when 1.17 GW PV electricity (16% of the total renewable capacity) was forced to be disconnected from the grid.

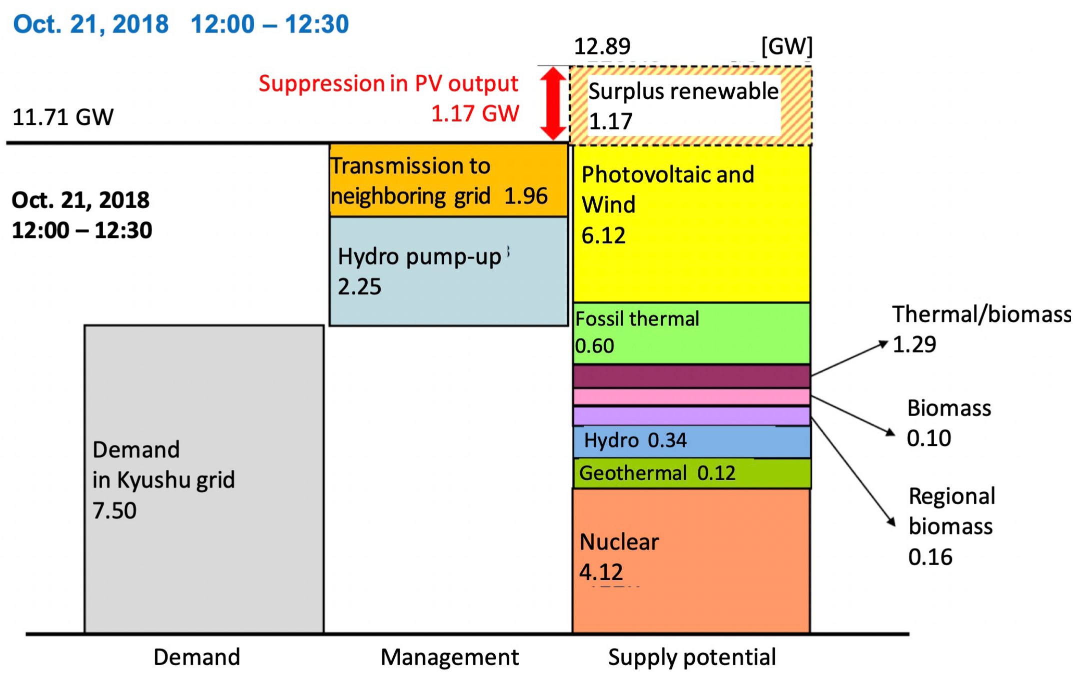
IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

A Duck curve problem is severe in Kyushu grid as below.





c. What are some steps that have been taken to mitigate this phenomenon?

Intensive use of pump-up hydro power generation

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Japanese grid is not connected to other countries.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

Some efforts are ongoing to increase the capacity of interconnection among 10 domestic grids, but it is accompanied by the issue of investment.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

The primary bottleneck to cause the Duck Curve problem is the segmentation of domestic grids accompanied by the site mismatch between electricity demand and the suitable place for PV and wind installation. Gird interconnection with other countries have not been discussed in the policy level.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Just the disconnection of PV electricity to the grid.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

So far, pump-up hydro power generation has been the only technology that has been used to mitigate intermittency. However, the increase in its capacity is limited. Heat pump is already spread for air-conditioning, and recently some subsidizations exist for pushing energy-efficient buildings. As for novel technology, hydrogen generation via water electrolysis using surplus electricity is focused, but low capacity factor due to the use of only surplus electricity imposes the bottleneck of its realization. As a technological benchmark, 10 MW alkaline water electrolyzer coupled with 20 MW PV will be in operation in 2020.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

All the nuclear power plants were suspended in operation after the Fukushima accident in 2011. After 2015, some resumed operation and 9 plants are in operation as of 2019. The number of nuclear power plants operating in Kyushu grid increased from 2 in 2017 to 4 in 2018, which made the problem of the Duck Curve desperate and the cut-out of PV is recently very frequent. In Japan, temporal variation of nuclear power output is prohibited by law.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?
2. What technology is under development that attempts to implement smart meters and demand-side management?
3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

Japan is in preparation for new electricity pricing mechanism. So far, 10 local grid company has been in charge of generation and distribution exclusively. Now, power generation and distribution were split into different companies and each consumer can choose a power generation company for their electricity purchase. This scheme is under development and dynamic pricing of electricity is still a future issue.

For pushing the installation of renewable power generation, a feed-in tariff (FIT) scheme has been introduced since 2012. Extra purchase price is set for renewable electricity, which price is determined by the government and is gradually reduced until now. The levy drastically increased with the dissemination of renewable power generation and is currently 2.95 yen/kWh, which is ca. 11% of the electricity price for residential consumers.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Japanese government imposes Global Warming Countermeasure Tax, which is currently 289yen/t-CO_2. The total revenue is ca. 260 billion yen, which used for the program to invest for the actions in private sector to reduce CO_2 emission.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Mostly for boosting the capacity of the interconnection among 10 local grids. Except for some R&D project, there is no commercial electricity storage for grid stabilization.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Japan experienced the accident of Fukushima nuclear power plant and there is very strong public opposition against nuclear power plant, even though the government never changed the nuclear fraction of 21% in 2030 energy mix. The only choice for the decarbonization is the use of renewable energy. This is why public opinion is affirmative towards the levy of electricity price due to FIT, at the present level. The major public conception is that electricity suppliers block the increase of renewable power generation, which is not always the case. Policy makers have never decided to make substantial investment for strengthening domestic grid interconnection.

VII. Suggestions

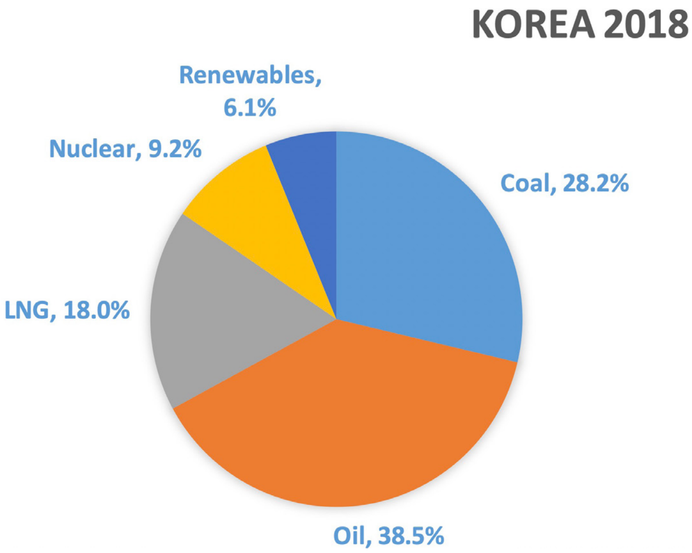
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

It is very difficult for Japanese grid system to be connected with other countries due to geographical constraint. It is not easy to increase the capacity of pump-up hydro in Japan because most of the suitable sites are already used. For Japan, the only possibility of realizing the acceptance of intermittent renewable power generation and decarbonization of energy system at the same time is the use of CO_2-free fuel for power generation. At this moment, H2 is the only possible CO_2-free fuel. Due to the limitation of land area and solar/wind resources, it is difficult to produce CO_2-free hydrogen domestically by an amount which satisfies an entire energy demand in Japan. Therefore, Japan have to import CO_2-free hydrogen from abroad as a substitute of imported fossil fuel which is currently the major energy source.

Korea (South)

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



In 2018, a total of 307.5 Mtoe primary energy was supplied, and 232.7 Mtoe final energy was consumed. The industrial sector consumed the most (61.4%), followed by the transportation sector (18.5%), residential/commercial sector (17.8%), and public sector (2.4%).

2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 593,639
	Import-export ratio (%): No import or exports
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 403,504 – 68.0%
	Nuclear (GWh and %): 133,506 – 22.5%
	Renewables (GWh and %): 56,629 – 9.5%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 7,285 – 12.9%
	Wind (GWh & %): 2,465 – 4.4%
	PV (GWh & %): 9,208 – 16.3%
	Biomass (GWh & %): 9,363 – 16.5%
	Other renewables (GWh & %): 28,308 – 50.0%***
Top 3 renewable energy sources	Biomass, PV, Hydro (excluding waste energy in other renewables)
Growth rate of total renewable generation (% per year) over the past five years	2014: +25.39% 2015: +37.93% 2016: +9.65 2017: +14.68% 2018: +13.07%

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro, as well as pumped hydro.*

****Other renewables include waste energy (24,355 GWh), some of which is not a renewable energy by the international standards.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

In June 2019, Korean government announced the 'Third Energy Master Plan' which mandated that electricity generation by renewable sources will increase to account for 30-35% in the electricity mix by 2040. In terms of cumulative generation capacity, an increase of 103-129 GW (mostly PV and wind) will be necessary to achieve the goal. Nuclear and fossil-powered sources will decrease due to Korean government's commitment to the greenhouse gas reduction and cleaner & safer energy policy. The detailed breakdown for the 2040 power generation mix goals will be available in 2020.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

By 'Third Energy Master Plan' Korea aims at reducing 18.6% in the final energy consumption (BAU) by 2035, and in particular, 19.6% reduction in electricity consumption (BAU) by reducing electricity consumption from industry and commercial sectors. Various policy measures will be introduced to achieve 38% (BAU) improvement in energy efficiency to reach the goals. Korea also plans to fulfill its CO_2 reduction commitment of 37% (BAU) by 2030 and continues its efforts towards 2040. Also, more than 30% in electricity generation will be from distributed energy sources by 2040.

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

The power system in Korea is well-known for its high quality. Indicators such as the frequency holding ratio of 99.9%, voltage holding ratio of 99.9%, and system average interruption duration index (SAIDI) of 8.59 minutes, all verify the high reliability of the power grids in Korea. However, the power systems near the metropolitan area have suffered from overload due to high load concentration in these areas. Since Seoul, the largest city in Korea, has extremely high population density and heavy load, power generation in the region is not sufficient to meet the demand. This area receives imported electricity from other places such as the West Coast, and transmission lines are overloaded frequently. Such transmission line congestion problems affect the reliability of power grid in a negative fashion. Korea Electric Power Corporation (KEPCO) is trying to expand its facilities, but currently facing challenges due to opposition of residents nearby the transmission systems.

In Korea, main peninsula is connected with Korea's largest island, Jeju, via two HVDC lines. 2,272 GWh of electricity is delivered from mainland to Jeju in 2018, but on the other hand, power transfer from Jeju to mainland is technically impossible. Although two HVDC lines (submarine) are connecting the Korea's largest island, Jeju, with the main peninsula, Korea is completely isolated in electricity from neighbouring countries (China, Japan, and North Korea). Therefore, the security and reliability of electricity supply has been the upmost policy priority in Korea in the last 70 years.

In low voltage system, smart grid technologies regarding isolating the system from main network and enhancing power system resilience are significantly developed in Korea. Specifically, KEPCO and companies have developed several island microgrids and grid-connected microgrid systems. However, because renewable management in distribution network is very important on grid reliability, technical development is further required.

b. What % of total electricity is imported compared to installed capacity in your country?

Korea is an isolated country in terms of electric connection with neighboring countries, thus there is no import or export of electricity into or out of Korea.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

Until now, penetration level of renewable electricity in Korea has been extremely low. But recently, solar power generation has rapidly increased. Although this situation is desirable for the environment, it can be harmful for the existing power system through shifting the load curve and causing the peak load time imbalance. It is so-called Duck Curve phenomenon. In Korea, increased solar power started to cause Korean-style Duck Curve to occur, which shifts the peak load time from 3 pm to 5 pm.

Date	Maximum Demand (Increase Ratio)		Temperature		
	Before Demand Management	Actual Demand	Minimum	Average	Maximum
2011 Aug 31 (3 pm)	72.19 GW (3.3%)	72.19 GW (3.3%)	22.1 °C	26 °C	31.8 °C
2012 Aug 06 (3 pm)	77.60 GW (7.5%)	74.29 GW (2.9%)	24.4 °C	29 °C	34.5 °C
2013 Aug 19 (3 pm)	80.08 GW (3.2%)	74.02 GW (-0.4%)	23.9 °C	28.4 °C	34.1 °C
2014 Jul 25 (3 pm)	76.05 GW (-5.0%)	76.05 GW (2.7%)	24.2 °C	27.9 °C	32.6 °C
2015 Aug 07 (3 pm)	77.05 GW (1.3%)	76.92 GW (1.1%)	23.4 °C	28.5 °C	34.8 °C
2016 Aug 12 (5 pm)	85.30 GW (10.7%)	85.18 GW (10.7%)	24.4 °C	29.5 °C	35.6 °C
2017 Jul 21 (5 pm)	86.26 GW (1.1%)	84.59 GW (-0.7%)	25.5 °C	29.4 °C	34.1 °C

In a conventional power system consisting of residential and industrial loads, the load is primarily concentrated during the day and lightly loaded at night. Suppose a large number of photovoltaic power generators are installed in such a system, solar power sources produce the maximum power around 12 pm to 1 pm when the solar radiation is the most intense. Considering this fact, the total load is rather large at 5 pm, and the load profile looks like the shape of duck.

c. What are some steps that have been taken to mitigate this phenomenon?

There are a variety of solutions to mitigate the duck curve, and the most common method is using energy storage systems and the way in which the system is connected to other systems to increase system inertia. There have been no specific actions to mitigate this phenomenon yet due to still a low level of renewable penetration in the power system. Aggressive deployment of ESS systems with government subsidies and support for R&D to modernize the grids are on the way.

Jeju Island is planning to use 100% renewable energy and electric vehicles by 2030 (Carbo-free Island 2030 Project). Current power generation capacity of Jeju Island is 1,350 MW, of which the renewable energy generation capacity is 436 MW. By weight, it is about 32%. Wind power is 266 MW, solar power is 160 MW, others are 8.8 MW, and solar PV capacity was increased by 16 MW compared to last year. As of 1 pm on the day of 2018-11-22, out of total 610 MWh of Jeju Island, the amount of renewable energy generation was 309 MWh, accounting for

49%. Due to the high fluctuations in the output of renewable power generation, if the power generation is too much more than the load, the curtailment operation is required. Consequently, the number of curtailments in renewable power generation on Jeju Island has been gradually increased recently: 6 times in 2016, 16 times in 2017, 17 times in 2018 and 19 times in 2019.

Date	Number of curtailments	Amount of curtailments (MWh)
'15	3	152
'16	6	252
'17	16	1,301
'18	17	1,366
'19 (~6.3)	19	3,975

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
'15								1		2			3
'16				1	1					1	3		6
'17			1	2	1				4	6	2		16
'18		1		4	2			1	4	3	1	1	17
'19		1	9	1	8								19

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

As mentioned above, the power system of Korea is not interconnected to other countries at all. A research project to construct the Northeast Asia Super Grid is underway. The final goal is to interconnect HVDC transmission lines among South Korea, Japan, China, Russia, and even North Korea. However, not only geographical, environmental and technical problems exists, but political problems are also the hurdles to overcome.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

Even though Korea is not practically working on any international level energy interconnection, some steps are being taken within the Korean territory. Jeju island is a good example of energy isolation, and technology innovation is being made to overcome the isolation problems. Jeju Island is preparing for the era of energy transformation, constructing VSC-HVCD which ables surplus energy reverse power transmission, installing Energy Storage Systems (ESSs) to save surplus energy, and working on an electric vehicle (EV) dissemination policy that can serve as ESS.

At present, two types of HVDCs (LCC-HVDC, Line-commutated HVDC) are installed in Jeju Island to operate as the base power source of Jeju Island system. The capacity of Unit 1 LCC-HVDC is 300 MW and Unit 2 LCC-HVDC is 400 MW. These two HVDC only receive power from interior and adjust the amount of power received according to the amount of renewable energy produced. The third (Unit 3) HVDC which is Multi-level Converter (MMC) based Voltage Source Converter HVDC (VSC-HVDC) is under construction (to be completed by 2020) to cope with the influx of more renewable energy.

	Unit 1 HVDC	Unit 2 HVDC	Unit 3 HVDC
Operating Status	O	O	X (On construction)
Capacity	300MW	400MW	200MW
Reverse transmission	X	O (Not use)	O
Systems	LCC	LCC	VSC

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Renewable electricity is being rapidly deployed in Korea recently. However, law and infrastructure for hosting renewable electricity are not prepared adequately and sufficiently. For example, due to ambiguous legal definition of renewable energy sources, 1/3 of solar power generation is considered as generation resource, and other 2/3 is considered as reduction of load. Korean government needs to constantly perform the research and analysis to upgrade the power system with great care to overcome these technicalities.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

- Pumped-hydro power generation was introduced to handle the problem of intermittency for existing power grids. Construction of new pumped-hydro power stations is underway to handle output volatility due to renewable electricity expansion. To realize the 'Renewable Energy 3020 Implementation Plan ("RE3020" – to produce 20% of electricity from renewable sources by 2030), construction of three new pumped-hydro facilities (2,000 MW) is planned according to the '8th Basic Plan for Long-Term Electricity Supply and Demand.' KHNP (Korea Hydro & Nuclear Power Co. Ltd.) recently selected Youngdong, Hongcheon, and Pocheon cities as candidates for the new pumped-hydro power facility construction sites.
- ESS (Li-battery) and super-grid are also being considered as options to mitigate intermittency problems, and thus Government is providing subsidies for ESS installed with PV or wind (REC weighting factor of 4).
- Policy-driven measures such as demand response programs are also being implemented to mitigate problems. Within demand response programs, there are 28 aggregators, 4,168 resources companies, which provide about 4.3 GW resources in Korea. Government has changed the program to enlarge the amount of voluntary bidding and shrink the mandatory reduction. Furthermore, it introduced two new programs, the peak demand DR and the fine dust DR.
- Also, forecasting of renewable electricity and green hydrogen production technologies are being developed in Korea.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Pumped-hydro storage as well as ESS (Li-battery) is used primarily and further developed to create more flexibility.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Korea is trying to actively phase out coal-fired power generation to improve air quality and to expand renewable power generation. Nuclear power is hard to coexist with renewable electricity in the future in terms of intermittency, because it is also a rigid power load.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Currently, controlling the generation of thermal power plants and nuclear power plants has been implemented, and wind power generation control system is also under development. Korea is also developing the integrated control technology for wind plant farm to control the total amount of generation. Energy Storage System (ESS) is used for frequency control and stabilizing the intermittent power, output correction and operating instruction.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   KEPCO and the Korean government are deploying smart meters all over the nation and gathering the metered data in real-time. KEPCO started the Korean Green Button Initiative in the second half of 2019. The plan is to deploy 22,500 smart meters for thousand customers until 2020. Currently, 6,800 thousand customers are equipped with smart meters as of June 2018. Also, demand response (DR) has been in operation since 2014. Twenty-five aggregators are currently in operation, and 3,536 demand resources (4,139 MW) have been in control since April 2019.

   Korean government released the KIEE (Korea Initiative on Energy Efficiency) Plan in 2019 to reduce 14.4% of final energy consumption and create 69 thousand jobs until 2030. It includes strategies to increase the energy efficiency in each sector. For industry, it will drive to use FEMS (Factory Energy Management System) and pay an incentive for small and medium sized companies. Furthermore, government will make a microgrid industry complex model in which distributed energy resources, FEMS, and TOC (Total Operation Center) are integrated to enable energy trading and increase self-consumption in overall complex. For commercial buildings, this would create an Energy Star-compliant standard that evaluates and compares the efficiency of old builds, that then forces non-compliant, energy-poor buildings to make changes.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Renewable Energy Monitoring Service (REMS) is being installed with the renewable system and even ESS in Korea since 2019. It consists of Remote Terminal Unit (RTU) and server system. Korea Energy Agency (KEA) has developed and operated REMS center in which 10,000 renewable energy sites are monitored in 2019, and 15,000 sites including buildings and renewables are connected to it every year. Also, block chain-based energy prosumer and virtual power plants are in development at selected sites like the new smart city in Sejong.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

New electricity pricing mechanisms are being considered and discussed in public. Especially, the progressive billing system for residential use is controversial. Korea has redesigned this package to introduce the Time-Of-Use (TOU) option. Also, Korean government started allowing a small power brokerage market in 2018. The electricity less than 1 MWh from the renewables, ESS, and electrical vehicles can be traded.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

In order to achieve the GHG reduction targets, the emission trading system has been implemented since 2015, but the effectiveness of the system is constantly questioned due to industry disputes and the issue of appropriate carbon pricing.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

376 MW ESS for frequency regulation is installed and operated in Korea until 2017. It has the potential to be the biggest volume of ESS in the world. New distribution infrastructure is being invested in continuously. High Voltage Direct Current (HVDC) 300 MW, 400 MW are installed on Jeju island. Also, Low Voltage Direct Current (LVDC) infrastructure is built in a few places, such as Jeollanam-do, Gochang, and other islands. In the near future, Korea has a plan to build a Medium Voltage Direct Current (MVDC) microgrid system to enhance the acceptance rate of the renewable energy.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion toward the green energy transition has been largely favorable. However, there have been increasing concerns recently about damage to natural scenery, economic efficiency, conflicts among residents, land shortage, etc. The Energy Transition towards clean energy is based on the "RE3020" plan, in particular, focusing on creating and disseminating a variety of public community participation models for renewable energy, in which residents or citizens can participate to take collective actions. Each municipality carries forward regional policies for energy transition based on regional energy plans.

VII. Suggestions

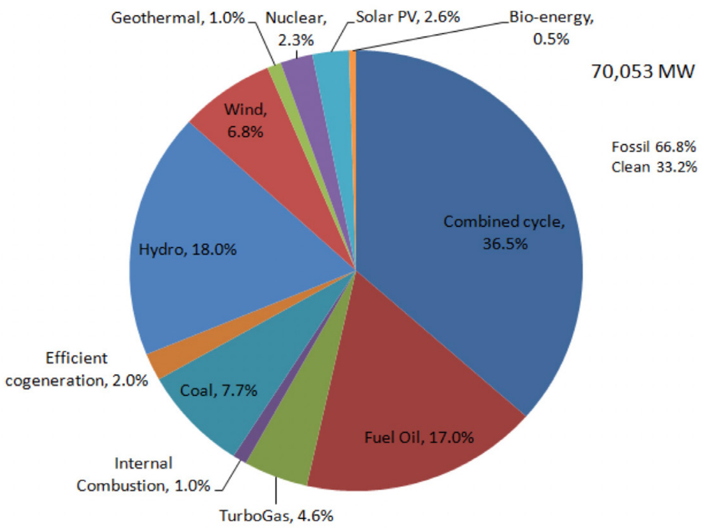
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

Since Korean economy relies heavily on energy-intensive industries, there is only a small room to accommodate intermittent energy, and the reliability of electricity system must be well maintained. Korean electricity grid is a single large grid with precise quality control, too. Numerous efforts have to be made in all the sectors from electricity generation, transmission and distribution. Increased R&D investment and extended-term field tests (including living labs) are required in the area of grid modernization, power prediction and two-way control, power to X technology, etc to help increase deployment of variable generation. Public acceptance on expansion of renewable energy sources should also be further improved.

Mexico

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 317,278 GWh
	Import-export ratio (%):
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 243,669.5 GWh , 76.8%
	Nuclear (GWh and %): 13,643.0 GWh , 4.3%
	Renewables (GWh and %): 59,965.5 GWh , 18.9%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 32,362.4 GWh , 10.2%
	Wind (GWh & %): 12,373.8 GWh , 3.9%
	PV (GWh & %): 2,220.9 GWh , 0.7%
	Biomass (GWh & %): 634.5 GWh, 0.2%
	Other renewables (GWh & %): 12,373.8 GWh, 3.9%
Top 3 renewable energy sources	Hydro, Wind and Geothermal
Growth rate of total renewable generation (% per year) over the past five years	There is no significant generation growth 2014: 52,488 GWh; 2015: 46,588 GWh; 2016: 47,852 GWh; 2017: 49,331 GWh; 2018: 53,019 GWh

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro, as well as pumped hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

The objectives set by the government in terms of clean energy and its degree of compliance: the energy generated in the country from clean sources must be 35% in 2024 and 50% in 2050. At the end of the first half of 2017, Mexico generated more than 20% of its electricity with clean sources, of which about 16% corresponded to renewable sources.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	By 2050 clean energy will provide 50% of total generation, however the forecast is only for 15 years
Ratio of fossil to non-fossil	Fossil (GWh and %): 294,731 GWh, 60.1% by 2033
	Non-Fossil*** (GWh and %): %): 195,316, 39.9% by 2033
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %):
	Hydro (GWh & %): 32,362.4 GWh , 6.6%
	Non-hydro Renewables (GWh & %): 162,953.6 GWh, 33.3%
Top 3 renewable energy sources	Wind, solar and nuclear

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

In Mexico three systems are not connected to the National Interconnected System, Baja California, Mulegé and Baja California Sur. While Baja California is interconnected to the Western Electricity Coordinating Council (WEEC) of the United States of America, the las two systems (Mulegé and Baja California Sur) are isolated and treated as islands.

b. What % of total electricity is imported compared to installed capacity in your country?

Mexico is a net exporter of electricity.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

The wind and solar penetration is still low, at this moment there is not such a problem identified.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Mexico is interconnected to the north with the USA through several interconnection lines across the border from which it is exchanged similar amount of energy from both sides. To the south one interconnection with Guatemala and another one with Belize, mainly to export electricity.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Mexico is studying energy storage to mitigate problems of intermittency and flexibility.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Pumping storage is one option for primary storage that is under study for Baja California and Norwest regions, while in general batteries are a more discussed option.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Fuel oil technology is being replaced by combined cycles mainly, and there is intention to be completely phase out.

Up to 2018 there was a planning to add three new 1400 MW nuclear reactors by 2029, 2030 and 2031 respectively. With the new government this option has been halted.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   A couple of high voltage direct current projects where intended to be awarded through a bidding process last year (2018), which were intended to stabilize, interconnect new regions and expand the grid; never the less, both bidding processes where canceled.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Main cities in Mexico are starting to introduce smart meters due to a large promotion of solar PVs in housing and small industry. However, it is necessary to enhance the distribution grids to be able to support the increased new flow exchanged with the grids, to control intermittency and stability, and to set clear rules of net billing.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Smart grid projects and smart metering are under definition, both in the transmission and distribution grids.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The new electricity pricing mechanism in Mexico is based on Marginal Local Price (MLP), which are defined for a specific period, calculated in accordance with the Market Rules and applicable to electricity transactions conducted on the Wholesale Electricity Market. MLP reflect its energy, grid congestion and loss components.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Within the Mexican Electricity Market, the instrument used to cap carbon emissions and to promote new clean energy plants are the Clean Energy Certificates (CEC). The Electricity Industry Law defines the Clean Energy Certificates (CEL) as that title issued by the Energy Regulatory Commission which endorses the production of a certain amount of clean energy electricity and which serves to meet the requirements associated with the consumption of the consumption centers.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Within the 2019 National Electricity System planning cycle there were identified 31 projects to address and strengthen the General Distribution Grids. These projects are located in different regions of the country and ate intended to be developed in the following three years. Investment in distribution projects is estimated in 173 billion pesos including expansion, modernization, smart power grids and new substations to provide the service and meet demand in the short and medium term with efficiency, quality and reliability.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

In December 2014 due to the Energy Reform, it was established an obligation to carry out social impact assessments (EVIS) on all energy sector projects, whether from state industries or private companies, including renewable energy projects. The purpose of this provision accompanying the environmental impact assessment is to know the social potential impacts so that solutions can be designed adequate for social mitigation and management. The assessment must contain "the identification, characterization and assessment of the social impacts that could arise from its activities, as well as mitigation measures, measures to expand positive impacts and the corresponding social management plan". The EVIS aims to ensure that projects have a beneficial and productive relationship between impacted communities and businesses.

VII. Suggestions

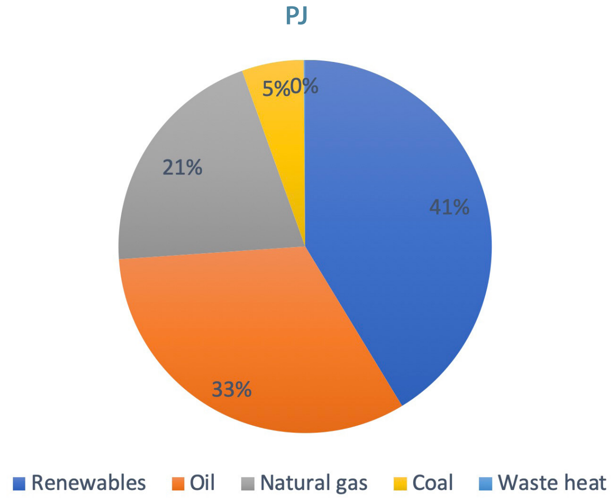
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

There are a number of efforts that have to be done in the Mexican National Electricity System. Since Mexico already have a strong clean energy promotion legal framework, introduction of new intermittent capacity has been commissioned, raising challenges for the stability of the grid. In this regard, energy storage could provide a solution, along with the enhancement and expansion of the grid. Regulatory provisions and technology development must be foreseen in order to make those solutions economically affordable.

New Zealand

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

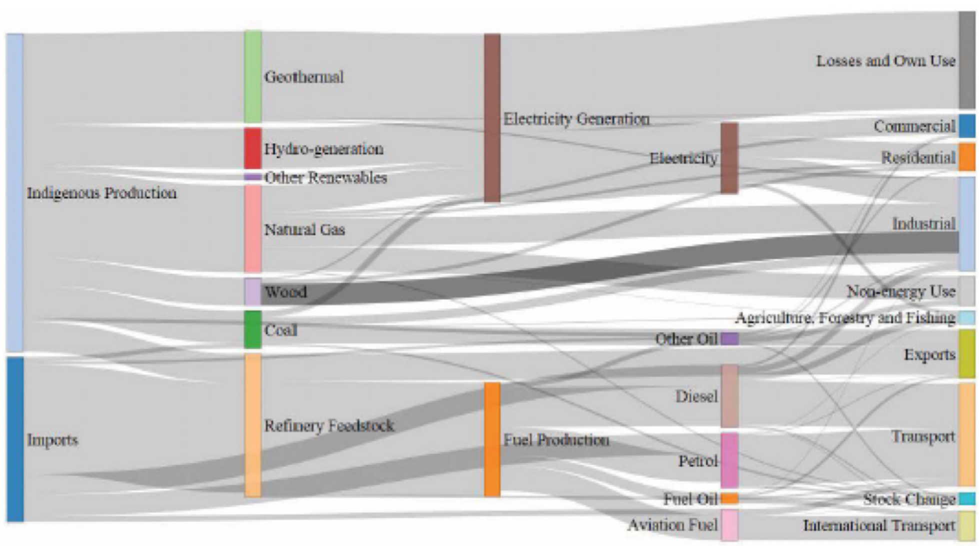


Primary energy shares in 2018

New Zealand's population is approaching 5 million. The electricity system is around 10 GW of installed generation. Electricity demand has not increased over the past decade (partly due to improved energy efficiency) but is now likely to increase due to the growing population together with more electric vehicles (currently around 15,000).

Around 3000 MW of wind, geothermal and other electricity generation options have been identified and are available for immediate development with a significant share of them already received a building consent.

Note: renewable energy includes geothermal energy that shows up as high shares of primary energy (compared with end-use energy shares) due to its low conversion efficiency (as shown in the figure below).



2017 data: https://www.mbie.govt.nz/assets/d7c93162b8/energy-in-nz-18.pdf

2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 43,280 (year to end March 2019)
	Import-export ratio (%): 0%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 8222 GWh (including co-generation); 19.9%
	Nuclear (GWh and %): 0%
	Renewables (GWh and %): 35,058 GWh; 80.1%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 24,934 GWh; 71.1%
	Wind (GWh & %): 2120 GWh; 6.0%
	PV (GWh & %): 74 GWh; 0.2%
	Biomass (GWh & %): 177 GWh; 0.5%
	Other renewables (GWh & %): Geothermal 7,392 GWh; 21.1%
Top 3 renewable energy sources	Hydro, geothermal, wind
Growth rate of total renewable generation (% per year) over the past five years	1.7% (varies in dry years when hydro gives less generation)

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro, as well as pumped hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

<table>
<tr><th>2040 Goals</th><th>Measure</th></tr>
<tr><td>Renewable power generation total amount (GWh)</td><td>Current targets:
100% renewable electricity by 2035.
NDC greenhouse gas emissions: 11.2% below 1990 levels by 2030 and Net zero emissions by 2050
Note, there are no Government subsidies in place for renewable electricity. For example, with mean annual wind speed on good sites at around 10m/s, the resources are very good. Hence a wind turbine in NZ can generate around three times as much electricity as the same model on the best 7m/s sites in Germany, Denmark etc. Currently wind and geothermal are the cheapest generation options with many additional sites consented but not yet constructed. So the market can meet this target without government intervention. However, for the last few per cent of the 100%, it may be cheaper to rely on gas plants to ensure grid reliability.</td></tr>
<tr><td rowspan="2">Ratio of fossil to non-fossil</td><td>Fossil (GWh and %): 1500 GWh; 3%
Coal is to be phased out by 2025 under normal operating conditions or by 2030 if dry years prevail.</td></tr>
<tr><td>Non-Fossil*** (GWh and %): 48,500 GWh; 97%</td></tr>
<tr><td rowspan="3">Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)</td><td>Nuclear (GWh & %): 0%</td></tr>
<tr><td>Hydro (GWh & %): 30,000 GWh; 60%</td></tr>
<tr><td>Non-hydro Renewables (GWh & %): 18,500 GWh; 37%</td></tr>
<tr><td>Top 3 renewable energy sources</td><td>Hydro, geothermal, wind</td></tr>
</table>

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

High-voltage transmission lines are publicly-owned. There are five major generation companies, three of which are partly publicly-owned. A central market regulator, Transpower, controls the transmission grid and system operation stability. There are 24 local electricity distribution companies taking power off the central grid and distributing it locally.

Dry years can constrain hydro generation. As shares of solar and wind increase, this could become a stability problem for the grid. Grid reliability could be maintained though bioenergy plants, or gas-fired plants, on standby.

b. What % of total electricity is imported compared to installed capacity in your country?

0%

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

Seasonal peak power demand occurs in winter due to heating demand, but summer peaks are growing in some warmer regions due to air-conditioning demands. Daily peaks have been satisfactorily met by peaking plants using gas-fired generation but dispatchable hydro and bioenergy are also options available to the system operator. (Geothermal is base load).

Chapter 8 in the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2011) on Integration of renewable energy into present and future energy systems, discusses this issue.[51]

The growing electric vehicle fleet could impact on peak power levels in the future due to recharging demands. The concept of "vehicle to grid" to offset peak demands is being evaluated as are further demand side management options. For peak load management, there is already an early industry of "interruptible load" (around 300 MW), especially using refrigerated cold-stores which can go off-line for a few hours without detrimental effects. The cold-store owners are compensated for withdrawing their demand. More generally, gas-fired plants are dispatched to meet daily peaks. An interruptible supply for heating domestic water, known as ripple control, operated successfully for decades, but following privatisation of the industry, has largely been closed down

The key to overcoming peak demand is having a more flexible grid, possibly with some energy storage (though this tends to be a costly solution). Pumped hydro storage is being assessed in NZ.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

[51] Sims, R (New Zealand)., P. Mercado, W. Krewitt, G. Bhuyan, D. Flynn, H. Holttinen, G. Jannuzzi, S. Khennas, Y. Liu, M. O'Malley, L. J. Nilsson, J. Ogden, K. Ogimoto, H. Outhred, O. Ulleberg, F. van Hulle, 2011: Integration of Renewable Energy into Present and Future Energy Systems. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlomer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Several large hydro plants are located in the south of the South Island (giving 98% of total S Island generation with wind the rest). Other hydro plants (including run-of-river) in the central North Island meet around 25% of N Island demand, with gas 25-30%, geothermal 25-30% and wind about 8%.

An HVDC cable (around 1.2 GW capacity) links the two islands with power being transmitted either north or south on a daily basis as needed. Wind farms are widely dispersed as is solar PV with around 21,000 grid-connected systems in place and solar farms being planned by private investors in association with line companies (of which there are 24 some private companies and some owned by local trusts).

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

As the share increases, the variability of wind generation is managed by running it in association with hydro to give system stability and control. The hydro is modulated around whatever level wind turbines are generating. Hence as wind generation increases there is the potential for under-utilisation of some hydro plants. Hydro cannot be fully shut down as the rivers have minimum flow requirements under their resource consents. So sometimes water by-passes the turbines as "spillage".

Time-of-use charging and installation of smart meters is slowly growing.[52] It is expected that the biggest future load management will be a result of charging of electric vehicles during low demand periods (so no water has to be spilt past turbines) and vehicle-to-grid options. Hence electric vehicles are seen as a major load management device for the future.

There is a slowly growing micro-grid industry, primarily around solar panels (with some off-grid schemes also using small-wind and/or micro-hydro systems. This remains a small industry, but is important in some isolated rural and island communities. (Note that many South Pacific island countries like Tuvalu, Tonga, Niue and the Cook Islands have around 30% of their generation coming from solar and the remainder from small hydro or diesel generators. So there is growing interest in renewable electricity and mini-grids in this region).

Ocean energy options have been evaluated with some technologies tested, particularly ocean current turbines. Wave power has potential given New Zealand's long coastline but the tidal range is too small.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Heat pumps are a very popular heating option in many houses and commercial buildings mainly for space, but also for water heating. Domestic log burners are also common as is gas heating in the North Island (gas is not reticulated in the South Island other than some limited LPG grids). Heat pumps are generally replacing direct use of electricity in resistance heaters (with a substantial efficiency gain) and sometimes wood or natural gas burning. Very little coal or oil is used for space heating domestically or commercially.

The current hydro dams have limited storage capacity of only around 6 weeks. In a low precipitation (dry) year, particularly in the South Island, then the hydro plants have to be run part-loaded, including during winter, once the storage reserves become depleted. To compensate, gas-fired plant is run more often and power may need to be transmitted from north to south to compensate for lower hydro electricity generation in the South. In extreme dry years, then an under-utilised gas/coal plant located in the North Island can be more fully utilised. A dry-year standby plant might need to operate about one year in 20, often for a period of around three months continuously. Hence in a normal year, renewable electricity can be above 85%, but in a very dry year this can decline to 75%. Pumped hydro storage is being assessed but has limited potential.

[52] The 2 year work programme of the Smart-Grid Forum, instigated by the government in 2014, can be found here: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-generation-and-markets/electricity-market/new-zealand-smart-grid-forum/

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

The NZ Emissions Trading Scheme has put a price on carbon (currently around NZD $34/t CO_2) which is encouraging the phasing out of coal-fired power plants (and also heating plants). The current gas reserves are declining but no further exploration for offshore oil/gas supplies is permitted. Existing exploration permits are being honoured but there is current debate on whether a gas find should be developed given the global carbon budget, and the risk that more relatively cheap gas would diminish the rate of renewable energy developments and constrain the Government's target for net zero greenhouse gas emissions by 2050.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Hydro-wind links, the hydro dams acting as a "battery".

2. What technology is under development that attempts to implement smart meters and demand-side management?

   As above, both demand side management and smart meters are in place and could be expanded.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Electric vehicle-to-grid systems

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

Largely left to the market, though a recent electricity pricing review has been undertaken with 30 recommendations for government to consider: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-consultations-and-reviews/electricity-price/

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

The Emissions Trading Scheme (ETS) has been in place for several years but for various reason has largely failed to reduce greenhouse gas emissions. The electricity sector has reduced emissions due to more renewable electricity generation systems being developed that are very competitive with new fossil fuel generation, even without a C price. Some of the revenue goes to landowners for growing plantation forests as offsets. The ETS is currently being reviewed, including introducing auctioning, a floor price, reviewing free allocations to avoid potential leakage through industries at risk, and bringing in the agricultural sector.[53]

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Transpower, responsible for the high voltage transmission system and the system operator, has produced several recent reports on the future for the electricity sector and infrastructure that can be found here: https://www.transpower.co.nz/

Pumped hydro storage is being evaluated.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Generally there is much support for renewable energy. There is pride in having 85% renewable generation and without the need for subsidies. Concerns are whether the future tariffs will rise as the share of renewables approaches 100% of total generation.

Several cities generate their own renewable electricity – such as from landfill gas, sewage gas, hydro in the water supply, solar PV investments, wind farm ownership.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

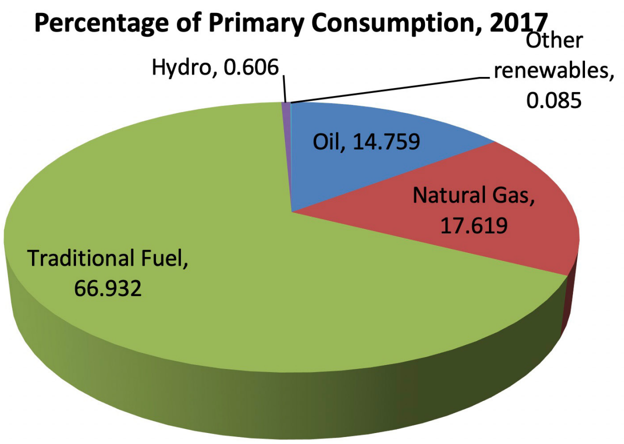
The current share of variable electricity generation systems can increase significantly without there being a grid reliability risk with the exceptions of dry years. More bioenergy plants can be deployed (as in Scandinavia) to avoid having to depend on coal or gas in future decades.

[53] https://www.mfe.govt.nz/climate-change/new-zealand-emissions-trading-scheme/about-nz-ets

Nigeria

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 29,588.26 (without imports)
	Import-export ratio (%): Import /Export 2006.57– 0%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 23,618.70 - 77.64%
	Nuclear (GWh and %): 0
	Renewables (GWh and %): 6,801.75 – 22.36%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 5,969.55 - 19.62%
	Wind (GWh & %): 87.60 - 0.29%
	PV (GWh & %): 438.00 - 1.44%
	Biomass (GWh & %): 306.60 - 1.01%
	Other renewables (GWh & %): 0
Top 3 renewable energy sources	Hydro, Wind, Biomass
Growth rate of total renewable generation (% per year) over the past five years	2014: +5.47% 2015: +5.42% 2016: +3.99% 2017: +2.41% 2018: +1.88%

**Renewables include hydro and non-hydro renewables.*
***Hydro includes large and small hydro, as well as pumped hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

The Nationally determined contribution (NDC) to climate change mitigation envisages13GW of off-grid solar by 2030, further more the sustainable energy for all, (SE4ALL) goal contribution of renewable energy excluding the large hydro power will be minimum of 30% to the electricity mix.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	403,390.03 GWh
Ratio of fossil to non-fossil	Fossil (GWh and %): 964,782.13 – 68%
	Non-Fossil*** (GWh and %): 453,180.91 – 32%
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 49,790.88 – 4%
	Hydro (GWh & %): 56,165.26 - 12%
	Non-hydro Renewables (GWh & %): 397,015.65 - 88%
Top 3 renewable energy sources	Hydro, Wind & Solar

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

No.

b. What % of total electricity is imported compared to installed capacity in your country?

None.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

No.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Not applicable.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Not applicable.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Not applicable.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

No.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Hydro plants and thermal plant are used as the base load while captive power augments the deficit due to inadequate power supply by the grid.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The electricity regulatory agency is providing smart meters for use and the replacement of electrical appliances with more energy efficient appliances.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The country has developed a Multi Year Tariff Order (MYTO) with a periodic review.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

There is not a carbon market or tax in Nigeria.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

With privatization of power sector, successor companies are investing towards more access to electricity and the use of solar PV for the rural areas.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion strongly supports the installation of renewable energies. Political parties have aligned with public opinion. The difficulties to obtain financing and the shortage of transport capacities until new lines are built, slows down many projects.

VII. Suggestions

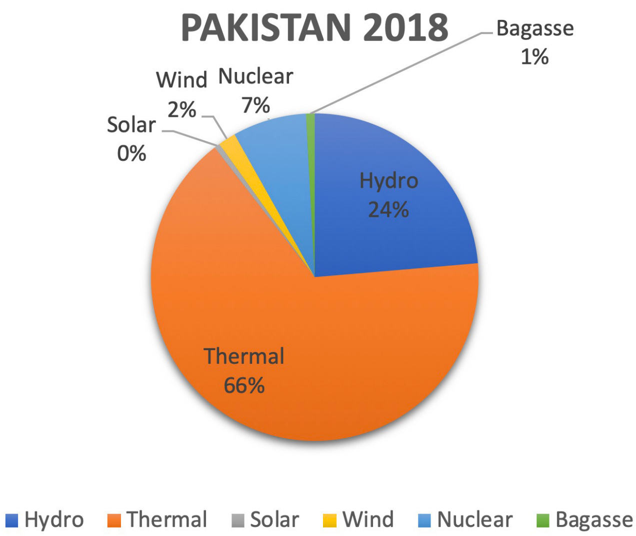
a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

With the privatization of the power sector that brings competition in the Electricity Generation and distributions, there is need to take into account simultaneously the environmental issues to achieve the minimum costs and distribution of renewable energies source.

Pakistan

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 148,210
	Import-export ratio (%): No Import or Export
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 97,027 – 65.5%
	Nuclear (GWh and %): 8,800 – 5.9%
	Renewables (GWh and %): 42,383 – 28.6%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 38,562 – 26.0%
	Wind (GWh & %): 2,118 – 1.4%
	PV (GWh & %): 664 – 0.5%
	Biomass (GWh & %): 1,039 – 0.7%
	Other renewables (GWh & %): None
Top 3 renewable energy sources	Hydel, Wind, Bagasse
Growth rate of total renewable generation (% per year) over the past five years	2016: + 5.7% 2017: - 25% 2018: + 36%

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro, as well as pumped hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	
Ratio of fossil to non-fossil	Fossil (GWh and %):
	Non-Fossil*** (GWh and %):
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %):
	Hydro (GWh & %):
	Non-hydro Renewables (GWh & %):
Top 3 renewable energy sources	

** Pakistan has not yet set goals for 2040*
****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

1 billion dollars is drained per annum in system losses in the grid due to inefficient transmission and distribution system. In addition, total power theft reached to 0.35 billion dollar in 2017- 2018. National Electric Power Regularly Authority – NEPRA has recently started using System Average Interruption Frequency Index –SAIFI in addition to System Average Interruption Duration Index–SAID1 because of frequent reporting errors from power plants.

Recent target assigned is 5% reduction over mean value of last five years data of SAIF1 and 10% reduction over mean value of last five years data of SAID1. Electricity short fall exceeded 6000MW in 2018 which is 18% of total power generation capacity equivalent to load shedding of 8 hours per day on average all over the country and particularly in summer.

Reasons for high technical losses in Pakistan include haphazard expansion of power transmission and distribution systems, large scale use of 11kV and LT lines in rural electrification, inadequate load management, use of poor quality equipment in agricultural pumping in rural areas and air-conditioners and industrial load in urban centers and large transformation stages which result in increases in iron and copper losses.

b. What % of total electricity is imported compared to installed capacity in your country?

Pakistan used to import 39MW of electricity from Iran two decades ago at five cents per unit. Import of 4000MW electricity from India and 1300MW from CIS was under discussion until recent past but none of the option materialized till date.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

Government has started focusing on solar power very recently. Currently only 0.6% of total power is solar. Study like Duck Curve has not been conducted so far in Pakistan. However, data about "number of hours of sunlight availability" for different cities is available.

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Total installed solar electricity in Pakistan is 518MW out of which 400 MW solar power is installed in a solar park in Punjab province. PV cells are mostly imported from China and solar is mostly used as an alternative source. Solar thermal turbines are not in use in Pakistan. With a net electricity shortfall of 32% at peak in summer and 26% of population not having access to grid electricity, the question of mitigating the intermittency problem doesn't arise. UPS and standby generators are in common use among household, industry and commercial organizations as an alternative solution for load-shedding.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

60% of the population use either UPS or standby generators or both to ensure availability of minimum power supply during electricity load-shedding hours.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Furnace oil is being replaced by CNG, LNG and Coal to achieve the objective of low-cost energy. Combined cycle plants are mostly in use now.

With total estimated coal reserves of over 186bn tonnes, Pakistan ranks sixth among coal-rich countries. Pakistan didn't initiate plans to exploit this huge coal reserve in Lakhra until recently. 330MW plant started operation in 2019. At the same time efforts are underway to utilize wind corridor in Sindh province. 1200 MW of wind turbine has been installed so far whereas installed capacity of solar is 518 MW. In addition to that 340 MW in 2017 and 349 MW in 2018 nuclear power plants were added in 2017 and 2018 respectively. Current policy is to encourage FDI in this sector and meeting energy shortfall is more important than cleaner energy.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Technology development is a low priority area for the government.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Imported smart meters from China will be installed in Karachi to curb electricity theft and gradually all over the country.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   None

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

The determination of tariff for electric power services is one of the primary responsibilities of National Electric Power Regulatory Authority – NEPRA. NEPRA determines electricity tariffs, keeping in view the principles of economic efficiency and service quality, according to the prescribed tariff standards and procedure rules 1998. In most cases under long term Power Purchase Agreements – PPAs, Generation Company's tariff is determined on cost plus basis. Distribution companies are given a multi-year performance tariff and transmission companies tariff is determined on annual cost plus basis.

The tariff in power sector has been envisaged under a two part tariff scheme i.e. Power Purchase Price and Capacity Purchase Price. Power Purchase Price , including fuel expense and variable operational and maintenance cost, is primarily paid to the company for producing and delivering electricity to the national grid. On the other hand, Capacity Purchase Price is a fixed cost (debt servicing, insurance, fixed operational and maintenance costs, and working capital financing cost) reimbursed to the company for establishing and maintaining the power plant facility.

1. The formula for the determination of the power purchase cost is:

PPP = PP(EC)*Q(p) + PP(CC) + TC

Where

PPP is the power purchase price

PP(EC) is the energy charge part of PPP

Q(p) is quantity purchased by the company

PP(CC) is the capacity charge part of PPP

TC is the transmission cost

2. The formula for the determination of the distribution margin for the distribution company is:

DMD = RBD*RORBD + DD + ED + tD ± ORCD

Where

DMD is the eligible distribution company's Distribution Margin

RBD is the eligible distribution company's rate base

RORBD is the eligible distribution company's cost of capital

DD is the eligible distribution company's depreciation expense

ED is the eligible distribution company's expenses including but not limited to operation, maintenance and human resources

tD is the eligible distribution company's federal and provincial taxes (allowed as pass through)

ORCD is the eligible distribution company's other regulatory costs including other income

3. The formula for the determination of the revenue requirement for the distribution company is:

RRD = PPPD + DMD ± PYAD

Where

RRD is the eligible distribution company's revenue requirement

PPPD is the power purchase cost for an eligible distribution company

DMD is the distribution margin for an eligible distribution company

PYAD is the prior year adjustment for an eligible distribution company

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

18 small Alternative & Renewable Energy – ARE projects of 644 MW total were completed till 2016 with 1,368,287 approved Carbon Emission Reductions – CERs under Clean Development Mechanism – CDM.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

According to a recent estimation, Pakistan requires approximately $40 billion investment in the transmission and distribution system to completely end load-shedding. Matiari-Lahore transmission line, a project of 878 kilometer of $2 billion, is the highest ever investment in the transmission line which would carry 4,950MW of electricity from Tharparkar, Hub and Karachi to Punjab. One more instance of investment is the transmission line from Port Qasim to Faisalabad with 4,000MW capacity.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public is generally in favor of renewable energy but because of extreme political stances a long pending Hydel project of 4000MW is pending since last fifty years.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

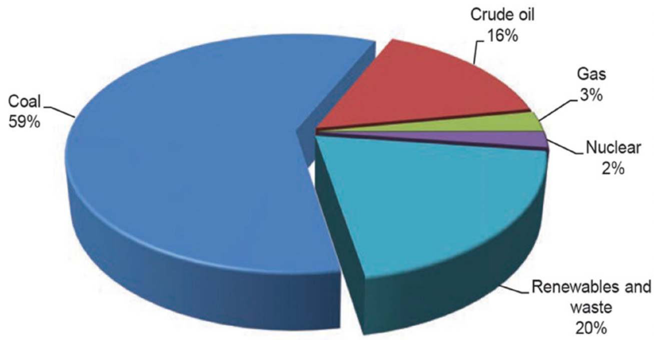
- Alternative Energy Development Board which was established by the government to promote clean energy should provide proactive support to investors.
- Issues related to long pending 4000MW Hydel power project should be resolved through political process.
- Old transmission system needs replacement to avoid losses. National Transmission and Dispatch Company should actively look for the development of smart grid and meters.
- Monopolies created by Independent Power Producers in cities should be addressed by bringing in fair competition among multiple producers.
- Small dams' projects should be encouraged.
- Electricity thefts should be controlled strictly.
- Country energy-mix policy and targets should be made for 2040 and 2050.

South Africa

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

In the early 1990's only 35% of South Africans had access to electricity. Since then South Africa has had a major programme aimed at providing access to electricity to those without. This has been the priority in moving the economy to an all-electric society. To date the access figure has increased to just over 86% however full electrification remains an elusive target.[54] South Africa's total energy supply is as reflected in the diagram below:[55]



Approximately 36% of coal produced in South Africa is used in the generation of electricity, which means that a relatively small proportion of South Africa's total energy needs are met by electricity, with coal, oil and biomass meeting the largest share of energy needs.

2018* Data[56]	Measure
Power generation total amount (GWh)	241 517
Ratio of Fossil to Non-Fossil	Fossil (GWh and %): 202 224 (86.2%)
	Non-Fossil (GWh and %): 32 548 (13.8%)
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewable)	Nuclear (GWh & %): 14 193 (6%)
	Hydro* (GWh & %): 8 440 (3.6%)
	Non-Hydro Renewables (GWh & %): 9 915 (4.2%)
Top 3 renewable** energy sources	Hydro, Wind. Solar PV
Growth rate of total renewable generation (% per year) over the past five years	2014 = 14 134 2018 = 18 355 Percentage growth over 5 years = 30%

**Hydro includes large and small hydro, as well as pumped hydro.*

***Renewables include hydro and other non-hydro renewables.*

[54] http://www.energy.gov.za/

[55] South African Energy Sector Report 2018 – Department of Energy

[56] Eskom Integrated Report 2018

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Data[57]	Measure
Renewable power generation total amount (GWh)	362 000
Ratio of fossil to non-fossil	Fossil (GWh and %): 137 560 (38%)
	Non-Fossil*** (GWh and %): 224 440 (62%)
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 14 480 (4%)
	Hydro (GWh & %): 10 860 (3%)
	Non-hydro Renewables (GWh & %): 199 100 (55%)
Top 3 renewable energy sources	Wind (36%), Solar PV (15%), Hydro (3%)

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Grid performance has been consistently good for many years in South Africa. Whilst the aim is to strengthen the transmission backbone to attain N–1 compliance as required by the Grid Code, and strengthen distribution networks to accommodate customer growth and ensure the ability to accommodate power from renewable IPPs, risks around transmission and distribution plant reliability still remain, due to ageing assets, system and resource constraints.

b. What % of total electricity is imported compared to installed capacity in your country?

3.3% of South Africa's electricity is imported – mostly from the Cahora Bassa hydro power station in Mozambique. South Africa in turn exports approximately 7% of its electricity to neighbouring states. (2018 figures)

[57] Draft Integrated Resource plan 2018

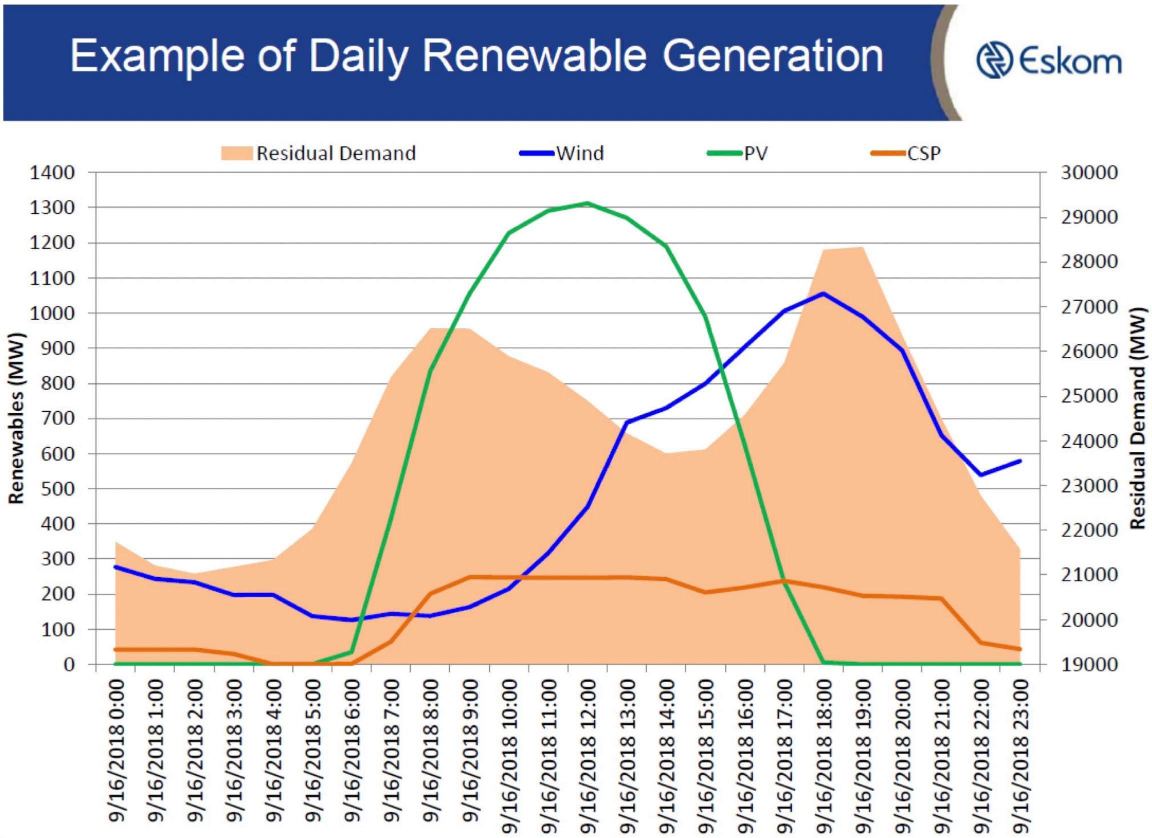
IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

To date the Duck Curve has not been experienced to any great extent in South Africa – although given the high growth planned for renewables, especially privately installed Solar PV, this is likely to be of concern in future. As such this has been factored into Transmission Planning.

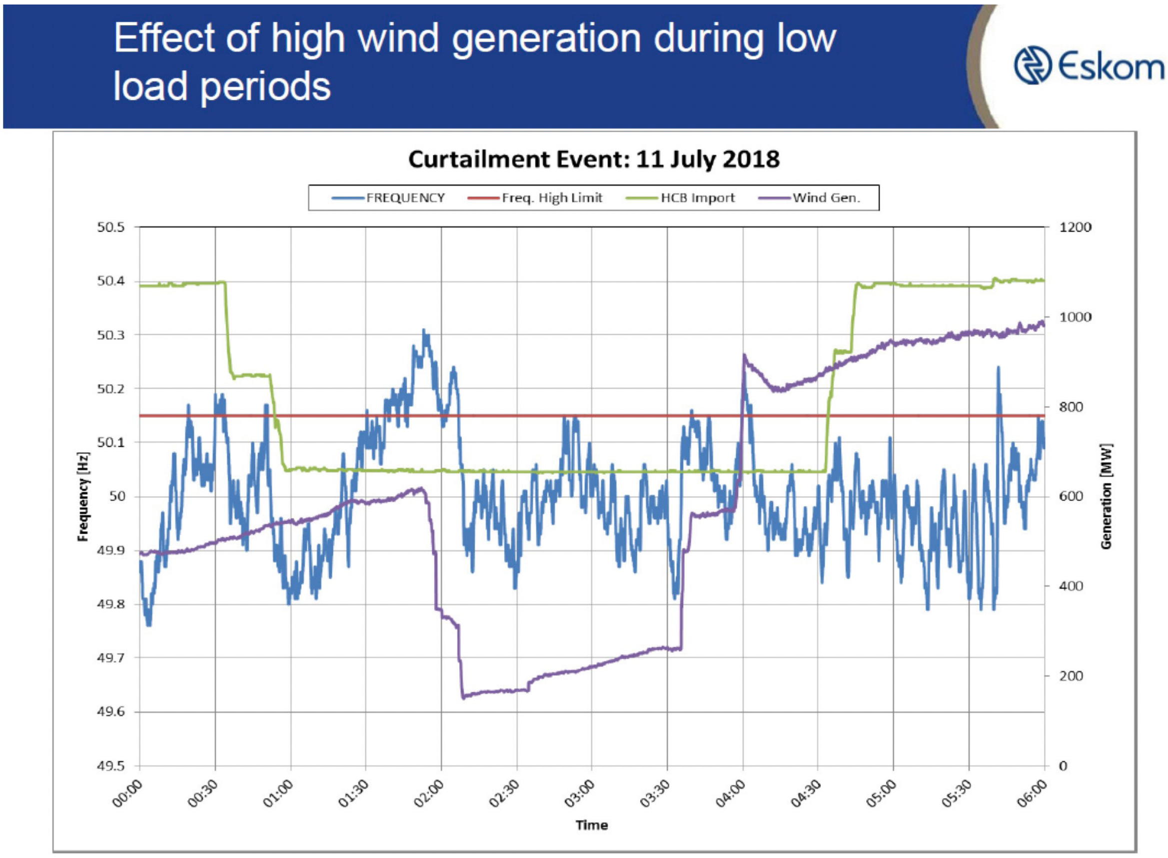
b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

To date variable renewables, roll-out has been limited. As such the current variability has been catered for with current flexible generation which includes open cycle gas turbines, pumped storage and hydro plant. Additional demand side measures such as interruptible load and demand side management initiatives are available in the event of demand-supply unbalances. A typical example of daily renewable generation is provided below:



[Source: Eskom TDP2018 Public Forum – October 2018]

There have been isolated cases of excess generation at times of high wind generation during low load periods – for example such an event on 11 July 2018 resulted in the curtailment of in excess of 500 MW of wind generation. This is shown graphically below:



[Source: Eskom TDP2018 Public Forum – October 2018]

c. What are some steps that have been taken to mitigate this phenomenon?

South Africa has two important planning processes which inform the future of the electricity system in the Country. These are the Integrated Resource Plan (IRP) which models and plans future generation capacity over a 20 – 30-year period, and the Transmission Development Plan(TDP),[58] which caters for the IRP in the transmission system over a 10 year period. The current TDP includes a variety of grid strengthening projects as well as additional flexible generation capacity to cater for the increased levels of renewable energy planning in the IRP. In addition, the IRP recommends "Detailed analysis of the appropriate level of penetration of [Renewable Energy] in the South African national grid to better understand the technical risks and mitigations required to ensure security of supply is maintained during the transition to a low-carbon future. Some work has been done on the impact of increasing shares of variable generation on system operations in South Africa (Flexibility Study). There is a need to expand this work to include an in-depth analysis of technical options such as reduced inertia, reduced synchronizing torque, reduced voltage support and reduced contribution to short-circuit currents to overcome stability issues resulting from non-synchronous generation and distributed generation. There is also a need to determine whether the stability issues will become relevant in the near, mid and long term. The above-mentioned technical options are most suitable to overcome the challenge."[59]

[58] Eskom Transmission Development Plan 2019 - 2028

[59] South African Draft IRP 2019

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

The South African transmission system is interconnected to the majority of Southern African Countries and forms part of the Southern African Power pool.

Whilst the South African system is interconnected as part of the Southern African Power Pool, all other networks are much smaller than the South African network and as such can offer minimal support in balancing supply and demand in the country.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

See response to 2 above.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

A detailed transmission development plan exists for the entire country. This plan includes indications as to where system constraints are being experienced and are likely to be experienced under various demand and supply scenarios. In all cases transmission projects are recommended to address these current and potential constraints. In addition, future flexible generation (and/or additional storage) is planned to cater for greater variability in supply.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

- Pumped storage – existing and well-established technology including the recently completed 1333 MW Ingula Project, however there is limited scope for new projects in the future.
- Smart metering – in roll-out phase in a few municipalities.
- Large scale battery storage – in pilot stage by the national utility, Eskom.
- Open cycle gas turbines – existing and well-established technology with additional capacity planned for in the proposed 2018 IRP.
- Demand side management initiatives – some existing and some which are under development.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

The primary storage systems in use in South Africa are pumped storage – with a total capacity of 2 732MW currently available. Secondary systems include interruptible load in large aluminium smelters and other demand side measures. Demand aggregation is being considered for future application.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

The current draft 2018 IRP plans the phasing out of the many older coal plants - typically as these reach end of life. For example, coal capacity is planned to reduce from just over 39 000 MW in 2018 to below 34 000 MW by 2030. Given that there is still 9 600 MW of new coal capacity under construction and plans for a further 1 000 MW, it is anticipated that the transition to a cleaner power sector will take place over several decades. It is however recognised that there are numerous uncertainties and variables in the technology, and in the economic and environmental areas which could change this view considerably. Therefore, the South African Government has adopted a flexible approach which will be regularly reviewed.

The current draft 2018 IRP does not include any further expansion of nuclear capacity. The increase in intermittency is catered for by the construction of considerable gas/diesel capacity (an additional 8 GW by 2030) with a very low capacity factor. This could be replaced by battery storage as the business case for battery storage improves.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   The ability for the grid to handle higher levels of variable renewables supply has been addressed in the draft 2018 IRP which recommends that a study of measures be undertaken to ensure that security of supply is maintained during the transition to a low-carbon future. This will include an in-depth analysis of technical options such as reduced inertia, reduced synchronizing torque, reduced voltage support and reduced contribution to short-circuit currents to overcome stability issues resulting from non-synchronous generation and distributed generation.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Smart meters are being rolled out in several municipalities, private housing estates and other similar applications. Demand side management has been widely used in South Africa to manage capacity constraints and as such is well stablished.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Research is underway at a number of universities and research organisations to develop and implement technology to advance energy efficiency and renewable energy. Some of these systems are specifically aimed at low-income consumers and prepaid systems.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

   Whilst there are no plans to change the regulatory and pricing methodology in South Africa, the unbundling of Eskom will inevitably result in the requirement to create a local electricity market and hence a revised pricing regime. In addition, domestic time of use tariffs have been considered for several years now, however implementation is hampered by resource constraints.

   A new development is that municipalities are including a fixed "service fee" charge in response to their customers installing solar PV systems. In South Africa most municipalities cross-subsidise other expenses from the surplus they gain by selling electricity with a significant mark-up. When existing customers install own-generation this source of income decreases, and the fixed charges enable the municipalities to retain the surplus they are used to. One of the outcomes of this is that customers do not register own generation systems, or completely disconnect from the supply grid.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Carbon taxes were introduced this year. The revenue from the carbon tax goes into the general fiscus.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Eskom has applied for a capital allocation of just under USD 700m for investment in Transmission and Distribution infrastructure.[60]

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion has been mixed historically, with the majority focusing on energy access and not on the source of generation. This is however changing, and public opinion is moving towards renewable energy as a low cost and sustainable supply of electricity. There is growing interest in stand-alone and distributed systems. Many municipalities are claiming to encourage rooftop solar systems – albeit reluctantly due to the impact this will have on their revenues. The regulatory environment is responding very slowly to the market drive for more distributed self-generation systems.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

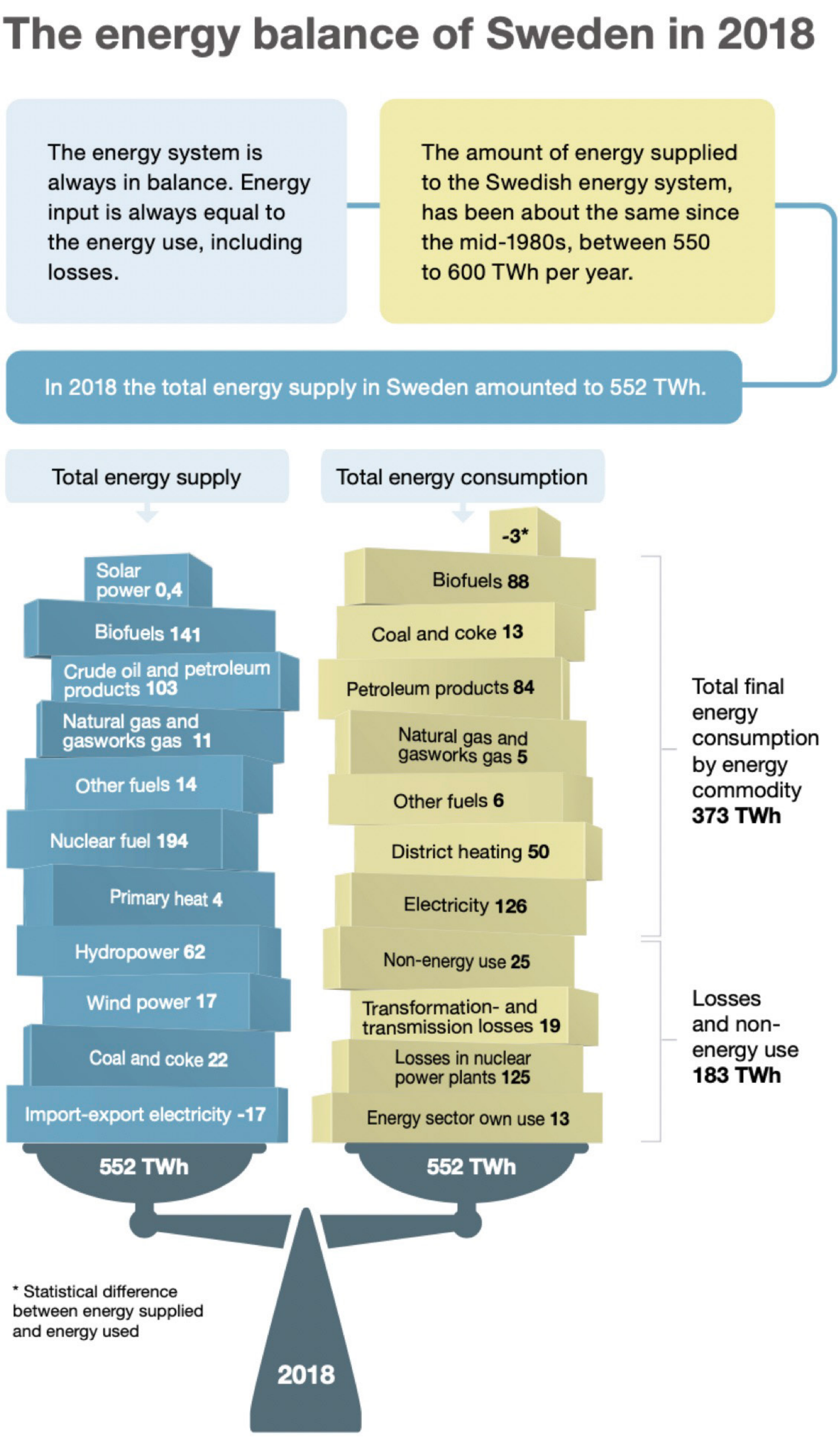
Modelling from a variety of sources suggest that there is major potential for the roll-out of far more intermittent energy in South Africa than is included in the current plans. This can be affected at minimal risk to the state through private sector funding and can be readily factored into the existing Transmission Planning processes. It does however require changes to the policy and regulatory environment in South Africa, as well as the restructuring of the Power Sector. There are indications that there is some appetite for these changes, however implementation is slow and inadequate.

[60] Eskom MYPD4 Application 2018

Sweden

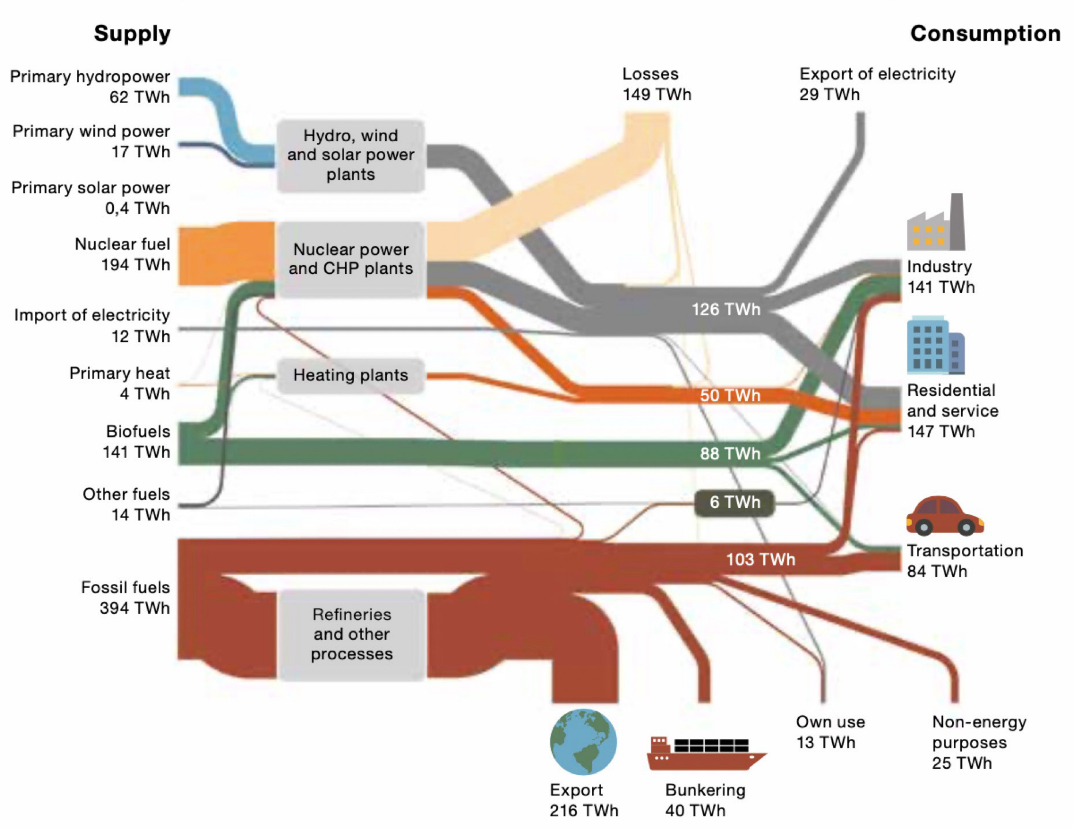
I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



Source: Energy balance of Sweden in 2018 (Sweden Energy Agency 2020)

Energy system 2018



Source: Energy balance of Sweden in 2018 (Sweden Energy Agency 2020)

2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 159,500 GWh
	Import-export ratio (%): Import 12,000 GWh, export – 29.200 GWh
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 3,000 GWh and 1,9 %
	Nuclear (GWh and %): 65,800 GWh and 41,3 %
	Renewables (GWh and %): 90.600 GWh and 56,8 %
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 61,700 GWh and 68,1 %
	Wind (GWh & %): 16,600 GWh and 18,3 %
	PV (GWh & %): 400GWh and 0,4 %
	Biomass (GWh & %) 11,900 GWh 13,1 %
	Other renewables (GWh & %)
Top 3 renewable energy sources	Hydro, wind and biomass
Growth rate of total renewable generation (% per year) over the past five years	Large yearly variations due to hydrological situations. Year Total renewable Wind solely 2014 + 2,6 % + 8,2 % 2015 + 19,2 % + 45,6 % 2016 - 12,2 % -5,0 % 2017 + 6,0 % + 13,5 % 2018 - 4,8 % + 16,7 %

Source: Swedenergy – Preliminary figures 2018

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 158,500 GWh
	Import-export ratio (%): Import 12,000 GWh, export – 29.200 GWh
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 3,000 GWh and 1,9 %
	Nuclear (GWh and %): 65,800 GWh and 41,5 %
	Renewables (GWh and %): 89,700 GWh and 56,6 %
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 60,900 GWh and 67,9 %
	Wind (GWh & %): 16,700 GWh and 18,6 %
	PV (GWh & %): 200 GWh and 0,2 %
	Biomass (GWh & %) 11,900 GWh 13,3 %
	Other renewables (GWh & %)
Top 3 renewable energy sources	Hydro, wind and biomass
Growth rate of total renewable generation (% per year) over the past five years	Large yearly variations due to hydrological situations. Year Total renewable Wind solely 2014 + 2,6 % + 8,2 % 2015 + 19,2 % + 45,6 % 2016 - 12,2 % -5,0 % 2017 + 6,0 % + 13,5 % 2018 - 4,8 % + 16,7 %

Source: Swedenergy – Preliminary figures 2018

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

The 12th of April 2018 the government decided on an energy bill based on the framework agreement (Government Bill 2017/18:228) "Sweden's energy policy". The framework is adopted by the Parliament.

Energy targets:

- By 2030, Sweden's energy use is to be 50 percent more efficient than in 2005. The target is expressed in terms of primary energy use in relation to gross domestic product (GDP).
- The target by 2040 is 100 per cent renewable electricity production. This is a target, not a deadline for banning nuclear power, nor does mean closing nuclear power plants through political decisions.

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

Following table is an overview with key climate and energy policy objectives extracted from "Sweden's Integrated National Energy and Climate Plan" published by Ministry of Infrastructure and reported to European Parliament 16.1.2020.

Target	Target year	Base year
Sweden must cut its net greenhouse gas emissions to zero and then achieve negative emissions. A maximum of 15% of emission reductions should come from additional measures.	2045	1990
75% reduction in emissions from sectors outside the European Union's Emission Trading System (EU ETS). A maximum of 2% from additional measures.	2040	1990
63% reduction in emissions from sectors outside the EU ETS. A maximum of 8% from additional measures.	2030	1990
70% reduction in emissions in the transport sector	2030	2010
40% reduction in emissions from sectors outside the EU ETS. A maximum of 13% from additional measures	2020	1990
50% of final consumption of energy to be covered by renewable sources	2020	
100% renewable electricity generation (this is a target not a deadline for nuclear energy)	2040	
50% improvement in energy efficiency	2030	2005

There aren´t any official metric goals concerning energy use and electricity generation. The Sweden Energy Agency performed and published in 2019 a report of long-term scenarios of the energy system ("Scenarier över Sveriges energisystem 2018"). Following numbers are taken from the scenario "Reference EU" in the report.

2040 Goals	Measure
Renewable power generation total amount (GWh)	149,000 GWh (excl nuclear)
Ratio of fossil to non-fossil	Fossil (GWh and %): 3,000 GWh and 1,7 %
	Non-Fossil*** (GWh and %): 174,000 GWh and 98,3 %
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 25,000 GWh and 14,4 %
	Hydro (GWh & %): 69,000 GWh and 39,6 %
	Non-hydro Renewables (GWh & %): 80,000 GWh 46,0 %
Top 3 renewable energy sources	Hydro, wind and biomass

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Sweden has a north-south flow with the major part of hydro and wind power in the north. But there is still a bottleneck in the south of Sweden that the grid development not yet has solved. No problems with isolated grids.

b. What % of total electricity is imported compared to installed capacity in your country

25 % of installed capacity or 38 % of available capacity can be imported or exported. Sweden is a net-exporter over the years.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

Sweden is very well connected with the Nordic, Baltic and European systems by 16 interconnectors.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Sweden has a much flatter curve and hydro power is there to balance the system. But with closing down more nuclear the demand for flexible demand or production response is needed.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Sweden has 4 bidding zones and a new balancing model is under implementation and each bidding zone should have power to be in balance within every 15 minutes timeframe.

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Waterbeds for hydropower is the main storage.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Nuclear energy is phased out due to lack of profitability because of low electricity prices and need for renovations due to age. New taxation is used as a tool to make fossil combustion less profitable. In June 2016, a framework agreement was reached between five political parties (representing a majority in the Parliament). The framework contains actions promoting renewables but there is not a deadline for banning nuclear power, nor does mean closing nuclear power plants through political decisions.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   A new balancing model and more automatic reserves. Implementing 15-minutes resolution for the balance responsible parties.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   The next generation of meters are decided to be implemented by 1 January 2025. The meters shall have hourly resolution and have a clear accessible interface for the consumers.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   By funding from the EU Horizon 2020 program a national project CoordiNet is ongoing to explore local marketplaces for trading. The aim is to use the grid more efficient.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

There is an energy-only market so far. Some companies are using capacity tariffs for the grid.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Within EU there is an ETS trading system since 2005. Buyers buy from companies that are lowering their emissions. The government is issuing the maximum level for emissions.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

The national grid, mainly 400 and 200 kV, have a plan for approximately 1.5 billion € 2019-2022. The total investments for other grids are increasing by 3 % 2020-2023 compared to 2016-2019. During 2016-2019 the investments has been approximately 4.5 billion €. (The academy´s report "Sweden´s future grid" from 2016)

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

There is a public opinion against windmills and power lines in the local areas. The current windmills are mainly built in areas with few inhabitants. Local environmental resistance is sometime huge and the decision making for permits then goes to the government.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

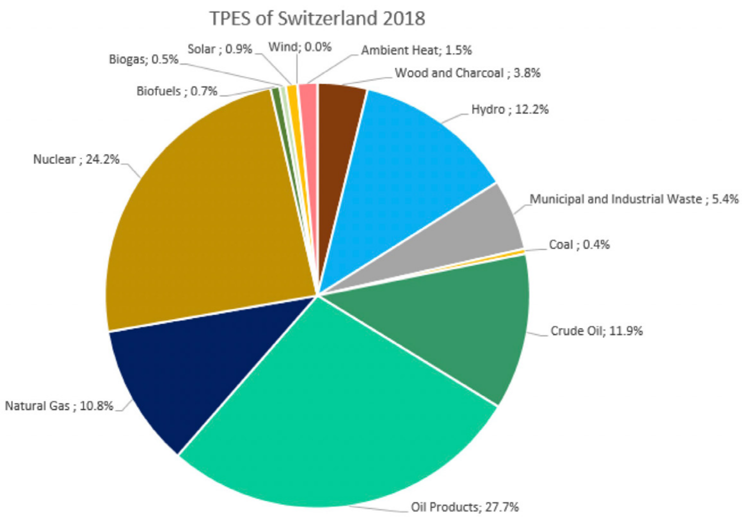
The academy suggests that a goal is defined and decided for delivery reliability.

The academy also suggests that the process for permits for new investments in renewables and grid must be faster than today.

Switzerland

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):



Data Source: Overall Energy Statistics of Switzerland (Gesamtenergiestatistik) 2018

2018 Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 67’558 GWh
	Import-export ratio (%): 95.1%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 1'839 GWh and 2.8 %
	Nuclear (GWh and %): 24’414 GWh and 36.1 %
	Renewables (GWh and %): 41'305 GWh and 61.1 %
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 37'428 GWh and 90.6 % of Renewables
	Wind (GWh & %): 122 GWh and 0.3 %
	PV (GWh & %): 1'944 GWh and 4.7 %
	Biomass (GWh & %): 642 GWh and 1.6 %
	Other renewables (GWh & %): 1'169 GWh and 2.8 %
Top 3 renewable energy sources	For Electricity Generation: Hydro, PV, Biomass
Growth rate of total renewable generation (% per year) over the past five years	Growth rates of total renewable electricity generation: 2014: -0.2 % 2015: +1.4 % 2016: -8.6 % 2017: -1.1 % 2018: +3.2 % Growth rate mainly affected by hydro production.

Data Source: Overall Energy Statistics of Switzerland (Gesamtenergiestatistik) 2018

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

Binding targets are fixed in law for 2020 und 2035 (see table below)

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	Renewable electricity production (without hydropower) 2020 4’400 GWh, 2035: 11’400 GWh Electricity production of hydro 2035: 37’400 GWh (no target for 2020)
Ratio of fossil to non-fossil	Fossil (GWh and %):
	Non-Fossil*** (GWh and %):
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %):
	Hydro (GWh & %):
	Non-hydro Renewables (GWh & %): see above
Top 3 renewable energy sources	For electricity production: hydro power, no specific goal for other renewable electricity production technologies

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric ‘islands’ or isolated grids?

No problems for the national grid yet.

Only loop flows are actually severe, Switzerland doesn’t participate in EU-market coupling yet.

On distribution level there is an increase of new renewable infeed, mainly PV roof-top installations.

b. What % of total electricity is imported compared to installed capacity in your country?

44% (2019), TSO Swissgrid Data. The TSO Swissgrid AG publishes every year an electricity overview for Switzerland: Aggregated energy data of the control block Switzerland (2009 to 2019) https://www.swissgrid.ch/en/home/customers/topics/energy-data-ch.html

Due to the main hydraulic based generation (60%) we face during summer time an export which could be between twice and three times the system load, and during winter time the import can have ranges of more than 50% of the system load!

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

We are part of the Continental European power system well-interconnected over 41 tie-lines on the highest voltage level of 220 kV and 380 kV. For Information: Principality of Liechtenstein (110 kV, Axpo, 4 electric lines).

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

Due to the currently quite low percentage of new renewable energy this effect is not yet visible. However, based on the flexibility of hydro production we see a similar behavior quite well in our import/export timely-dependent curves.

Photovoltaics have until now no major negative impact; regulation of too high photovoltaic electricity production.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

All kind of storage is one of the solutions

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

Switzerland has up to 3 GW of pumped hydro storage available.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Energy Strategy 2050

https://www.bfe.admin.ch/bfe/en/home/policy/energy-strategy-2050.html

What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Progressive nuclear energy decrease in the next decades (see energy strategy 2050). Nuclear phase out has already started, first nuclear power plant in CH will be disconnected end of 2019 and there is no new permission to build a new nuclear power station, however no deadline for shutdown as long a safe operation is guaranteed.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Batteries, participation of loads within the ancillary system market

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Rollout of 80% smart meter until the end of 2027. DSM in the framework of the energy strategy 2050.

   See 1.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   Only in discussion.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

In discussion in the framework of the energy strategy 2050. Careful support for new technologies – time limitation etc.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

Yes, a CO_2 levy. The CO_2 levy is a key instrument to achieving statutory CO_2 emission targets. This incentive tax on fossil combustible fuels, such as heating oil and natural gas, has been levied since 2008. In making fossil fuels more expensive, it creates an incentive to use them more economically and choose more carbon-neutral or low carbon energy sources.

Two-thirds of the revenue from the levy is redistributed annually to the public and the economy independently of consumption. One-third (max. CHF 450 million) is invested in the buildings programme to promote CO_2-reduction measures such as, e.g., energy-efficient renovations or renewable energies. Another CHF 25 million is provided to the technology fund.

For more information,

Link: https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-policy/co2-levy.html

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

Battery energy storage systems. In Volketswil (Canton of Zürich) the electricity distribution operator (EKZ, Elektrizitätswerk des Kantons Zürich) implemented a battery energy storage system with a capacity of 18 MW.

https://www.ekz.ch/de/ueber-ekz/newsroom/medienmitteilungen-2018/EKZ-nehmen-groesste-Batterie-in-Betrieb.html

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

The energy strategy 2050 was approved by the Swiss citizens through active participation with 58.2% yes on the 21th May 2017.

https://www.srf.ch/news/schweiz/abstimmungen/abstimmungen/energiestrategie/stimmvolk-heisst-energiegesetz-mit-58-prozent-gut

e. How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

“Energie Schweiz” is a Swiss federal action program with a very large diversity of measures in the domain of energy. All energy issues are in the focus of the measures of the Confederation and the 26 cantons. The 26 cantons have their own action programs. Even the local communities are engaged in improving their energy efficiency, to promote renewable energy end electrical vehicles and to reduce CO_2 emissions (Label “Energiestadt”, meaning “energy town”).

https://www.energieschweiz.ch/home.aspx

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

The finals storage challenge is still unsolved. Here is where most of the efforts are required. Otherwise The energy strategy 2050 is our official guide line.

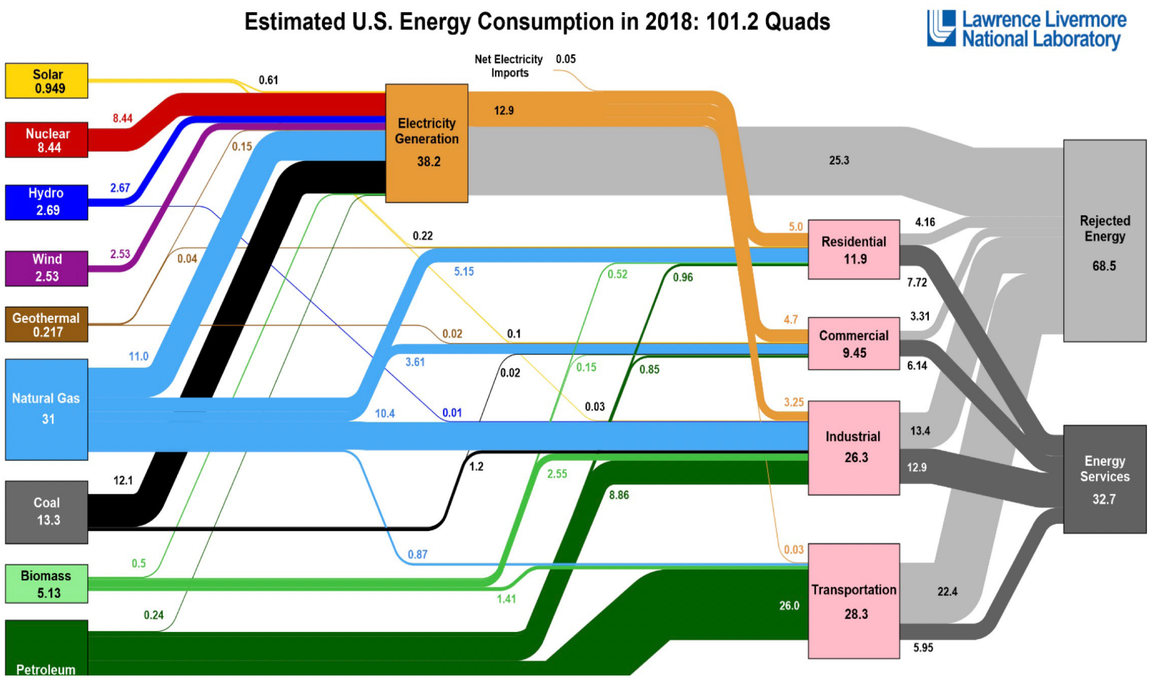
https://www.uvek.admin.ch/uvek/en/home/energy/energy-strategy-2050.html

United States of America

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

In 2018, about 101.2 quadrillion BTU energy were generated in the United States.



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 4,177,810 GWh
	Import-export ratio (%): 58274GWh/13805GWh, 422%
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 2,651,169 GWh, 63.46%
	Nuclear (GWh and %): 807,078 GWh, 19.32%
	Renewables (GWh and %): 712,773 GWh, 17.06%
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 291,724 GWh, 40.93%
	Wind (GWh & %): 274,962 GWh, 38.57%
	PV (GWh & %): 66,604 GWh, 9.34%
	Biomass (GWh & %): 62,765 GWh, 8.81%
	Other renewables (GWh & %): 16,728 GWh, 2.34%
Top 3 renewable energy sources	Hydro, Wind, PV
Growth rate of total renewable generation (% per year) over the past five years	2014: +3.16% 2015: +1.05% 2016: +11.98% 2017: +12.66% 2018: +3.81%

**Renewables include hydro and non-hydro renewables.*

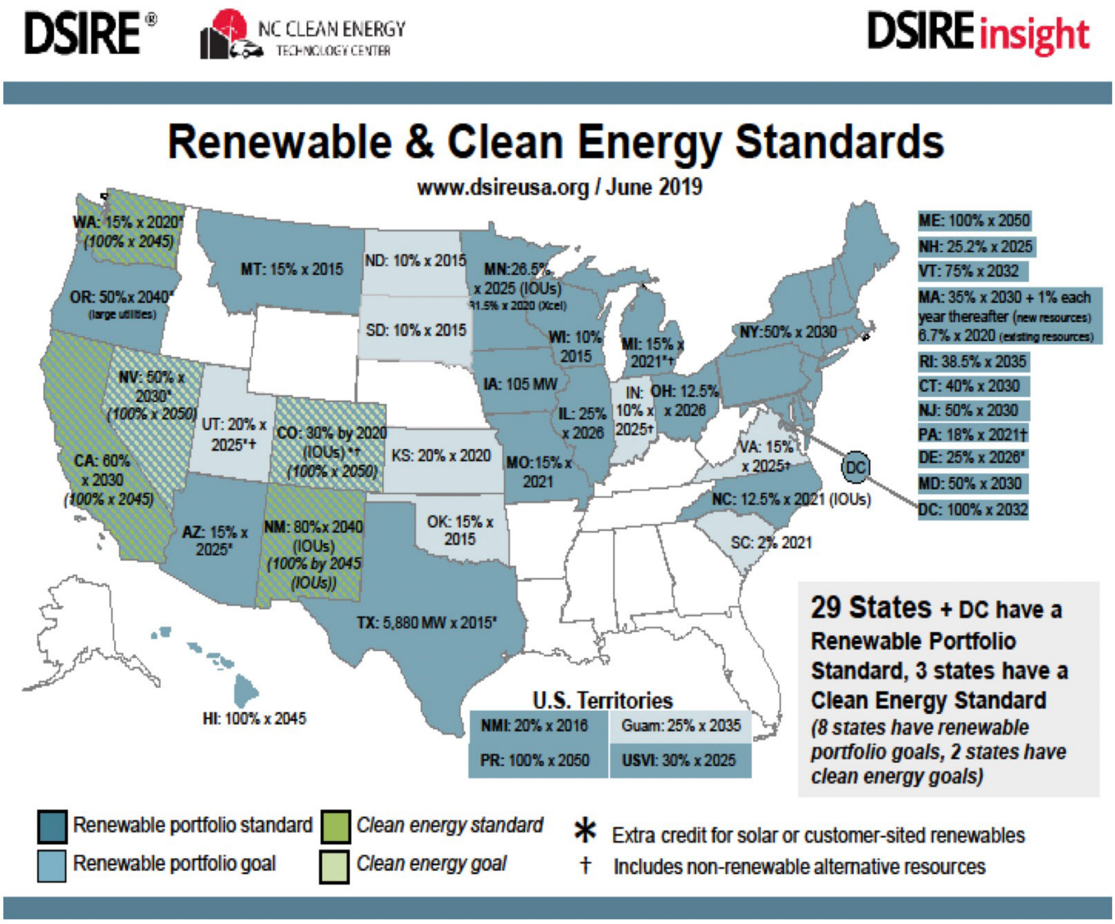
***Hydro includes large and small hydro.*

****Hydro-electric pumped storage & other account for remaining 6,790 GWh*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

There are no national goals for 2040. The current administration maintains an "all of the above" energy strategy that supports diverse fuel sources for electricity generation. Previous administrations have more aggressively pursued emissions reductions, for example former President Obama's Clean Power Plan, which called for more than 30 percent reductions in greenhouse gas emissions from the electricity sector by 2050. At the sub-national level, there is wide variability in the renewable energy goals (formalized in Renewable Portfolio Standards) of individual states as shown in Figure 2, with some (e.g., Hawaii, CA) striving for 100 percent renewable energy production by 2045-2050, while others have no goals/mandates for renewable generation.



b. What are the benchmarks of progress for improvement metrics?

(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

Some states have Renewable Portfolio Standards (RPS) that specify desired penetration levels while others measure progress in net CO_2 reductions relative to a benchmark year.

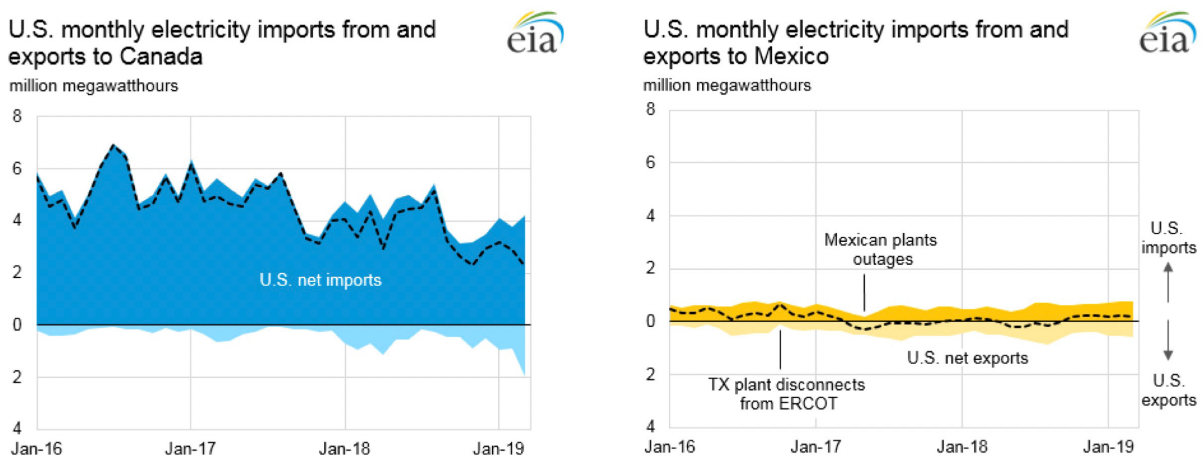
III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

Due to aggregate low penetration levels, renewables do not generally affect grid reliability or stability across large regions. Most outages result from physical damage in a local part of the distribution system. Nonetheless, select locations and feeders (e.g., in Hawaii and California) have relatively high, local deployment of variable renewables forcing utilities to take additional efforts to maintain stability and reliability. There have been just a few cases of renewables causing outages larger issues, for example from many inverters tripping off in response to fault conditions resulting in larger loss of load (see for example, https://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf). Some areas, specifically Texas and Hawaii, experience transmission congestion or oversupply of wind generation during low load periods, which is mitigated through curtailment. However, the levels of wind curtailment experienced in the United States differ substantially by region and utility service territory. In many regions, curtailment is very low and not even tracked

b. What % of total electricity is imported compared to installed capacity in your country?

In 2018, US total generator nameplate capacity was 1,186,943.9 MW. Net electricity imports from Mexico and Canada was 44,469,160 MWh.

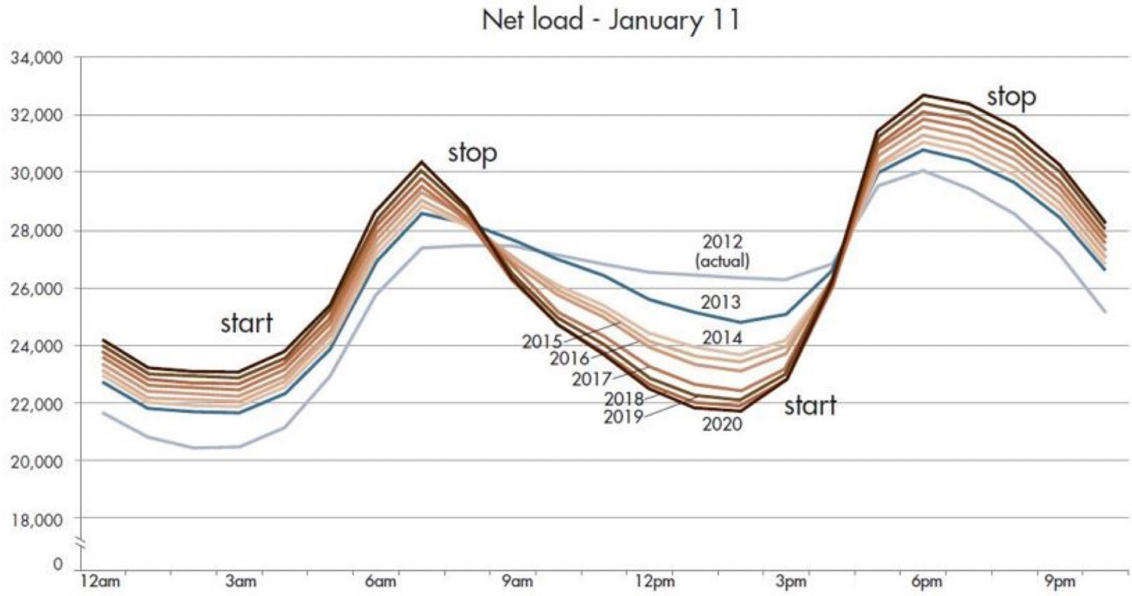


Source: U.S. Energy Information Administration, Form EIA-111, Quarterly Electricity Imports and Exports Report.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.



Net load curve on January 11 for years 2012 through 2020. Source: California Independent System Operator

Select locations with large renewable penetration are seeing large ramp rates, specifically in California (CAISO) with large PV installations and in the Midwest (MISO) where large wind installations drive significant ramp rates and differences in locational marginal prices.

c. What are some steps that have been taken to mitigate this phenomenon?

During periods of surplus energy, system operators decrease the output from wind or PV plants to "curtail" generation or use market pricing mechanisms to incent beneficial behavior (i.e., load shifting). While curtailment is an acceptable operational tool, as increasing amounts of renewable resources, oversupply conditions are expected to occur more often. System operators are seeking solutions to avoid or reduce the amount of curtailment of renewable power to maximize the use of renewable sources, including: changing operational practices to enable more frequent power plant cycling; installing utility-scale battery storage to shift load; implementing demand response markets and TOU rates.

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

The U.S. transmission system is composed of three separate interconnected "synchronous" regions (western, eastern, and Texas) that operate with alternating current at 60 Hz. The three interconnections operate with only a few (asynchronous) direct current connections that allow transfer of energy between them. There is a strong synchronous connection with Canada for both the Eastern and Western interconnections, and the DC lines connecting the asynchronous Québec grid. While there is also a connection to a small portion of Mexico within the Western Interconnection, that dependency is less significant for either country as most of the Mexican grid is a separate system.

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

Some areas have expanded energy trading markets over larger geographical areas (e.g., CA Energy Imbalance Market) to allow selling of renewables over larger geographic areas to avoid curtailment.

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Most curtailment occurs when the construction of necessary transmission lags behind the pace of wind farm development, resulting in infrastructure that is insufficient for the amount of wind generation on line. In ERCOT (Electric Reliability Council of Texas) and SPP (Southwest Power Pool), for example, substantial amounts of wind generation were brought online before the necessary transmission could be built and energized, leading to wind curtailments. ERCOT's reported wind curtailments rose from about 1% in 2007 to a peak of more than 17% in 2009. Since the construction of new transmission and the adoption of new transmission operating procedures that increased the transfer capacity on existing transmission, curtailments fell to 4% in2012 and further to 1.6% in 2013, although some of the reduction could be attributed to market redesign to LMP pricing and faster schedules that improved overall system operations.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

Pumped hydro and utility-scale battery storage, demand response programs, time of use rates, and advanced metering infrastructure ("smart meters").

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

The majority of storage available is through pumped hydroelectric energy storage; however, few viable sites remain for further expansion of this alternative. Battery storage has grown substantially over the past decade, largely concentrated in PJM (mid-Atlantic), ERCOT (Texas), CAISO (California) regions. The majority of utility-scale battery storage is Li ion chemistry. Some markets have large, organized demand response programs and distribution utilities have programs designed to create flexible loads including dispatchable hot water and home heating.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

There are currently no official programs to phase out specific technologies or fuels in generation. Liquid fuels, however, have largely been phased out of the generation mix due to cost and environmental concerns, and are only used rarely for electricity generation, with exceptions being islands such as Puerto Rico and Hawaii and remote areas such as Alaska. The primary driver of change in the generation resource mix in the U.S. is the relative cost (including both capital expenditure and operational costs) of different generation facilities and fuels. Renewables, and particularly large wind power, have benefitted from federal and state policies to encourage development of low carbon resources (e.g., Federal Production Tax Credit, State Renewable Portfolio Standards), and are increasingly cost competitive with conventional generation sources. Although not driven by a coordinated national policy, the higher cost of coal and nuclear generation has led to numerous retirements.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   A variety of hardware/sensors (e.g., synchrophasors, fault locating/isolating relays), operational (e.g., EMS, data visualizations) are used in normal operations to maintain situational awareness and stability. New technologies under development include power electronics such as hybrid and solid state transformers that allow precise control of power flows on both the transmission and distribution systems.

2. What technology is under development that attempts to implement smart meters and demand-side management?

   Advanced metering infrastructure has been deployed in many areas of the U.S., predominantly in the residential sector (total deployed ~78 million). However these are used primarily for billing and benefit utilities through reduced meter reading expenses and are not typically used for demand side management. Transactive controls and pricing to retail customers is being research and modeled but is not expected to be deployed widely.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   There are numerous technologies in development that have potential to impact electric sector planning and operation, with significant R&D investment now occurring outside of traditional vendors and utilities. Much of this research investment is seemingly focused on algorithms, computing, and communications technologies as opposed to hardware or new devices. Priority areas include: large scale data collection and analytics (e.g., asset management, real time optimization, drones for rapid damage assessment and recovery); new control systems and architectures; as well as advanced power electronic devices.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

There is no singular national strategy guiding the evolution of the electric generation portfolio, and there is wide heterogeneity across the U.S. in terms of market structures and mechanisms (e.g., some competitive markets, some regulated). An array of federal and state policy tools are used to incent changes in the bulk power systems, including the federal production and investment tax credits that helped drive large expansions of renewables. Individual state renewable portfolio standards also have encouraged more renewable electricity generation, and some states also provide tax credits for installation of solar and other renewable electricity. The current administration has demonstrated concern regarding closure of coal and nuclear generators and have explored mechanisms to provide higher prices for electricity from "fuel secure" coal and nuclear plants operating in competitive markets. Currently regions of the U.S. operating in competitive wholesale generation are evaluating strategies including minimum price floors and firm capacity markets to maintain adequate resource availability while integrating variable renewables often driven by state level policies.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

There is no national carbon tax nor greenhouse gas emissions trading scheme in the United States. Several states have created sub-national cap-and-trade programs. The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort among the northeastern and mid-Atlantic states. States sell nearly all emission allowances through auctions and invest proceeds in energy efficiency, renewable energy, and other consumer benefit programs. California has a cap-and-trade program under which emission allowances are distributed by a mix of free allocation and quarterly auctions. State law requires that the auction revenue be spent for environmental purposes, with an emphasis on improving air quality. At least 25% of the revenue must be spent on programs that benefit disadvantaged communities.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

There is no coordinated national plan or roadmap for electricity transmission and distribution system improvements from the U.S. government, as distribution systems are regulated by states and local municipalities and are outside of federal regulation. The most common technologies are traditional relays, fault detecting relays, advanced metering infrastructure, and a few early applications of volt/var control. Some areas concerned about electricity system resilience (e.g., Manhattan following Superstorm Sandy) have encouraged development of microgrids with local generation attached to distribution systems.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

Public opinion is divided and heterogeneous across the U.S. regarding a transition to renewable power. While there is general support (particularly among younger residents) for increased deployment of wind and solar generation, similarly there are areas with strong support for coal and natural gas and potential anti-environmental backlash. The current administration advocates an "all of the above" strategy that does not prioritize renewables over fossil fuels.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

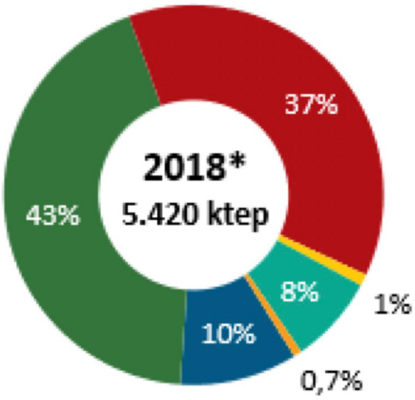
There are numerous areas that require increased RD&D investment including improvements in modeling capability, increasing flexibility in planning and operations, and improvements in large-scale long-duration energy storage, each of which can help increase deployment of variable generation. In the market-driven context of U.S. electric systems, it will be critical for variable renewables to continue to decline in cost and to be combined with storage to make more firm and "dispatchable".

Uruguay

I. Energy Status Quo

a. What is the current national energy portfolio, as of 2018? Please include any data graphics describing the primary energy mix in your country, along with total electricity generation data in this table format (below):

URUGUAY 2018



2018* Data	Measure
Power generation total amount and import-export ratio	Power generation total (GWh): 12,425
	Import-export ratio (%): 1.32 %
Renewables*, fossil and nuclear electricity generation	Fossil (GWh and %): 361 2.9 %
	Nuclear (GWh and %): 0 0 %
	Renewables (GWh and %): 12,064 97.0 %
Of Renewable production, breakdown of the following (hydro, wind, PV, biomass, other renewables)	Hydro** (GWh & %): 6,139 49,41 %
	Wind (GWh & %): 4,719 37.98 %
	PV (GWh & %): 390 3.14 %
	Biomass (GWh & %): 817 6.58 %
	Other renewables (GWh & %): 0 0 %
Top 3 renewable energy sources	Hydro, Windpower, Biomass
Growth rate of total renewable generation (% per year) over the past five years	2014 +26.35 % 2015 -0.78 % 2016 +5.45 % 2017 +4.53 % 2018 0,00 %

**Renewables include hydro and non-hydro renewables.*

***Hydro includes large and small hydro.*

II. Future Milestones of Entire Energy System

a. Looking ahead to 2040 (or if unavailable, other milestone target years), what are the future goals of your country's energy strategy?

b. What are the benchmarks of progress for improvement metrics?
(including, but not limited to: total primary and/or CO_2 reduction goals, total final energy reduction, renewable electricity generation, and conventional and renewable generation capacity)

2040 Goals	Measure
Renewable power generation total amount (GWh)	18,000
Ratio of fossil to non-fossil	Fossil (GWh and %): 0 0 %
	Non-Fossil*** (GWh and %): 18000 0 %
Of Non-Fossil production, breakdown of the following (nuclear, hydro, non-hydro renewables)	Nuclear (GWh & %): 0 0 %
	Hydro (GWh & %): 9000 50%
	Non-hydro Renewables (GWh & %): 0 0%, 9000 50%, 9000 50%
Top 3 renewable energy sources	Windpower, hydropower, FV

****Non-fossil includes nuclear and renewables.*

III. Problems in Intermittency of the Power Grid

a. Are there issues regarding grid reliability on a national, regional, or local level? If yes, how severe is the problem of electric isolation, electric 'islands' or isolated grids?

No, there are no problems. The peak power in the Uruguayan electrical system is 2100 MW and there are 2000 MW in electrical interconnection with Argentina and 500 MW with Brazil.

Installed wind power is 1500 MW, solar is 250 MW and hydro is 1500 MW. Hydro is very flexible. There are also 1000 MW in gas turbine.

b. What % of total electricity is imported compared to installed capacity in your country?

Electricity is normally exported.

IV. Imbalances in Supply & Demand

a. Is your country experiencing a Duck Curve phenomenon, or an imbalanced residual load curve? (i.e., time dependent variation in renewable energy output with time-dependent variable solar and/or wind generation)

b. If yes, discuss well-known or severe case studies and include a duck curve chart that captures generation data from over the past 5-10 years (example below). If no, please discuss effective grid management techniques (or others) that prevented this phenomenon from occurring.

c. What are some steps that have been taken to mitigate this phenomenon?

d. In efforts to mitigate, is the power system of your country interconnected to the system of another large body, such as another country or international system to increase control of supply-demand?

e. What steps are being taken to correct the level of energy isolation to bring it to greater efficiency?

f. Where are the locations of the bottlenecks (that lead to this phenomenon)? Discuss case studies that have been implemented to mitigate this problem.

Wind power in Uruguay increases production at night, therefore there is no phenomenon of duck curve, if it appears, hydro and gas turbines are used.

V. The Solution Part 1: Technologies That Streamline Implementation

a. What are some typical latest technologies that attempt to mitigate problems of intermittency that your country or region is making strides in?

b. What are some primary or secondary storage system that being used or is being developed that attempts to create more flexibility? (i.e. primary: pumped hydro storage; secondary: heat pump in energy-efficient residential homes)

The strategy of pumping storage installation has been analyzed, technical feasibility studies have been carried out for up to 400 MW and 12 hours of storage, they will be economically feasible by 2040.

c. Are there attempts to actively phase out old technologies? If yes, please describe the national strategy motivating this transition. If no, briefly discuss how this will affect the energy transition in the context of promoting clean energy. What is the current or future role of nuclear energy in mitigating the problem of intermittency?

Steam plants have been deactivated; nuclear power is not expected in the future.

d. In the following subject areas, please pick and discuss whether this category of technology is relevant to your country. If not applicable, please indicate (1-2 sentences) the status of this technology as whether or not it is being pursued at this time.

1. What technology is under development (or implementation) that attempts to stabilize normal grid operations?

   Primary regulation is first used with Hydro plants. Additionally, any possible thermal reserve with fast start, (open cycle turbines).

2. What technology is under development that attempts to implement smart meters and demand-side management?

   To manage demand, energy price information is provided per hour.

3. Any other new smart tech in development? Examples include, but not limited to, block chain, risk management, anti-cyber threat security, etc.

   In the transmission networks Uruguay uses the concept of dynamic chargeability. The thermal load limit is used instead of the design capacity.

VI. The Solution Part 2: Market-Regulating Policies that Promote Seamless Energy Systems

a. How is your country approaching new electricity pricing mechanisms, and retaining the economic sustainability of your grid?

   The price mechanism is that of marginal (spot price) with contracts.

   The remuneration of the transmission and distribution is regulated.

b. Is there a system of carbon emissions trading or taxing? To what fund does revenue from this program go towards?

   No, there is not.

c. What are new distribution infrastructure investments, including storage, that your country or region is currently spending?

   The investments in transmission and distribution are currently to improve the network.

d. How has the public opinion towards the energy transition to renewable energy been in the past? How is the current administration or regional/local municipalities approaching campaigns to affect public opinion on renewable energy systems?

   Public opinion strongly supports the installation of renewable energies. Energy policy is a "state policy" with the support of all parties.

VII. Suggestions

a. What suggestions do you have to offer in deciding the future of intermittent energy in your respective country?

   The suggestion is that when intermittent energies (or rather persistent variables) grow, the use of electric transport through batteries or hydrogen production is increased.

Annex III

Author Acknowledgements

List of contributing experts to the 2020 CAETS report

21 countries' energy experts contributed to this year's edition of the CAETS Energy Report, providing evaluation of national energy technologies and academy recommendations. The following experts agreed to be mentioned as contributors to 2020 CAETS Energy Report:

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Endorsement

This 「CAETS energy committee report 2020: solutions for high-level penetration of intermittent renewable electricity was endorsed by the following CAETS Member Academies

Argentina's Academia Naciaonal de Ingeniería

Australian Academy of Technology and Engineering

Royal Belgian Academy Council of Applied Sciences

Canadian Academy of Engineering

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Croatian Academy of Engineering

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