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Energy Transformation and Solar Intermittency Issues in Power Design

PwC Advisory LLC
Infrastructure PPP
June 4, 2018



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About PwC

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About PwC Global

PwC is one of the largest professional services networks in the world.

At PwC *, our purpose is to build trust in society and solve important problems. We're a network of firms in 158 countries with more than 236,000 people who are committed to delivering quality in assurance, advisory and tax services. Find out more and tell us what matters to you by visiting us at www.pwc.com.

North & South America
70,982 people

Europe, Middle East & Africa
96,960 people

Asia Pacific
68,563 people

Locations

158 countries **736** locations

Revenue

US\$ **37.7** billion

People **

236,235 people



* "PwC" refers to the PwC network and/or one or more of its member firms, each of which is a separate legal entity.

** Incl. support staff (as of 30 June, 2017)

About PwC Japan Group

PwC network in Japan

- PwC Japan Group represents the member firms of the PwC global network in Japan and their subsidiaries. To address complex and diversified business challenges, PwC Japan Group consolidates expertise of assurance, consulting, deal advisory, tax and legal services as well as enhances its structure in order to cooperate organically.
- As a professional service network with a total number of about 6,300 partners and staff, PwC Japan Group provides quality client services to meet their needs and expectations.

PwC Japan Group

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Paris Accord and Renewable market

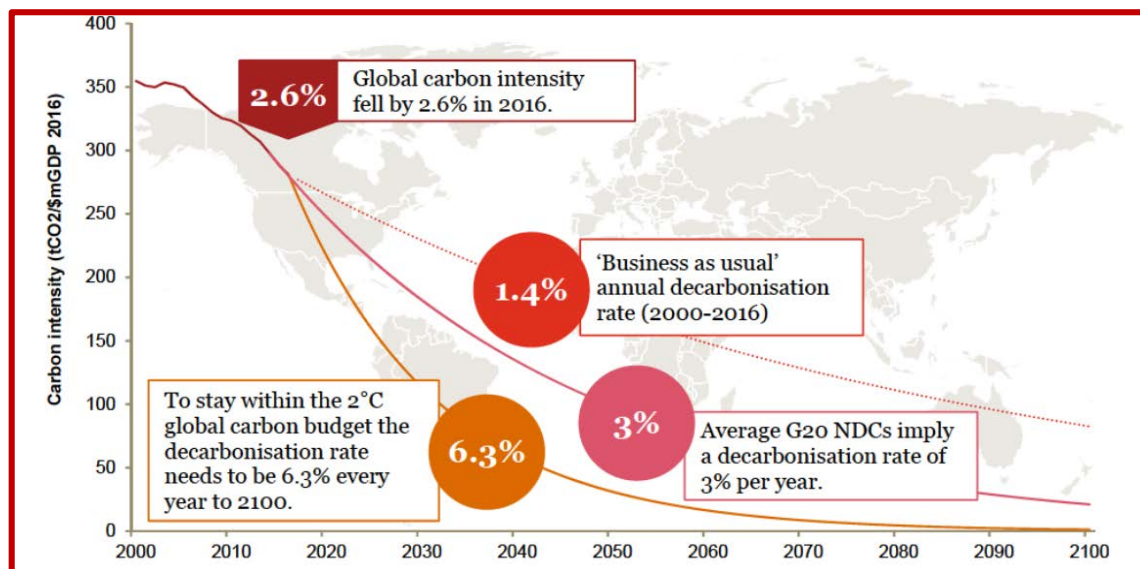
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Paris Accord:

Where are we now in the global challenge of decarbonisation?

- **Falling carbon intensity:** In 2016, global GDP growth was 3.1% but emissions grew by only 0.4%. This means carbon intensity – emissions per dollar of GDP – fell by 2.6% in 2016. In the future with projected global average economic growth of 2.1%, carbon emissions need to fall by over 4% every year average to hit the two degrees target.
- **Differences in each country's results:** Some countries leading the action: Some countries lead the decarbonisation by reducing the coal, but off-set by increase in coal consumption in others. Although renewable grew significantly, only accounted for smaller share.

Figure 1: Low Carbon Economy Index 2017: Transition Pathways



*1: "Low Carbon Economy Index ("LCEI") 2017" (PwC-UK)

Decarbonisation: Pathways varies from one country to another

- ***Nationally Determined Contributions (“NDC”)*** determines the CO₂ reduction pathways to achieve Paris target for participating countries. In 2016, UK and China reduced their intensity exceeding the target.
- ***Paris accord with regional approach:*** Figure 2 and 3 shows historical and projected changes in carbon intensity to be on 2 degree pathway for Developed economies and Emerging economies respectively. The pathways varies from one countries from another due to its initial energy mix and the approach to decarbonisation.

Figure 2: Developed Economies NDC

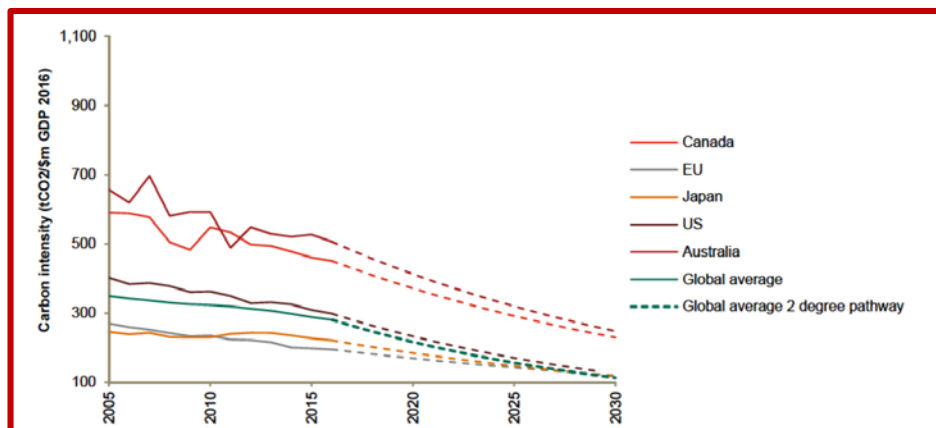


Figure 3: Emerging Economies NDC

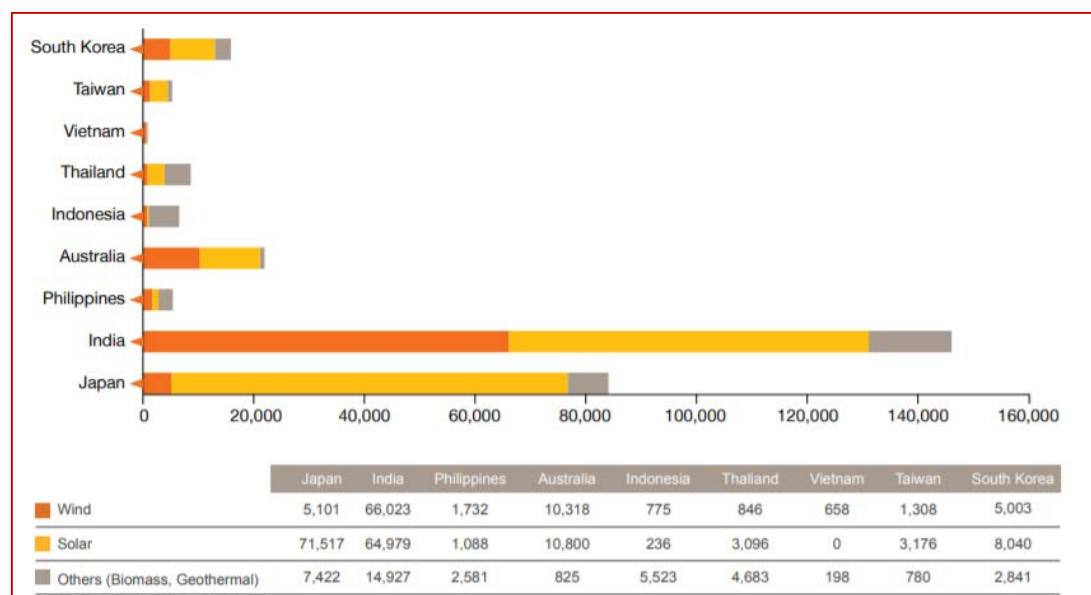


*1: “Low Carbon Economy Index (“LCEI”) 2017” (PwC-UK)

RE market potential for Asia Pacific Countries

- Many governments in Asia have ramped up their efforts increase RE in the energy mix, with RE targets being significantly higher in some countries when compared to existing capacity.
- India We see a large potential for better technologies in RE - such as more efficient photovoltaic (PV) cells, larger wind turbines and improvements in biomass and waste management, thus, leading to bigger and more scalable projects.

2025 RE forecast (MW) in Asia-Pacific



Source: The next frontier for infrastructure investments, PwC Singapore, 2018

India: Generation capacity to reach 640 GW by 2027 with RE leading the path to decarbonisation

Strong demand growth continues

- Currently, India has accumulated its generation capacity to meet its peak electricity demand.
- New demands for universal access, EVs, industrial corridors, public transport, etc. Central Electricity Authority (CEA) estimates to grow at **4-6%**

70% of new additions from RE

- In order to meet both the demand and energy transformation need, over next 10 years, cumulative generation capacity is likely to reach 640 GW by 2027.
- These additions will be contributed largely by renewable energy (70%)

Figure 6 : Power Demand Growth

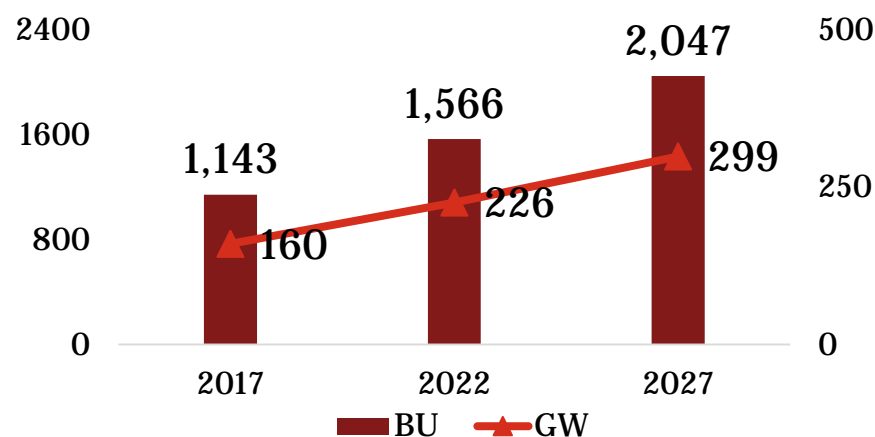
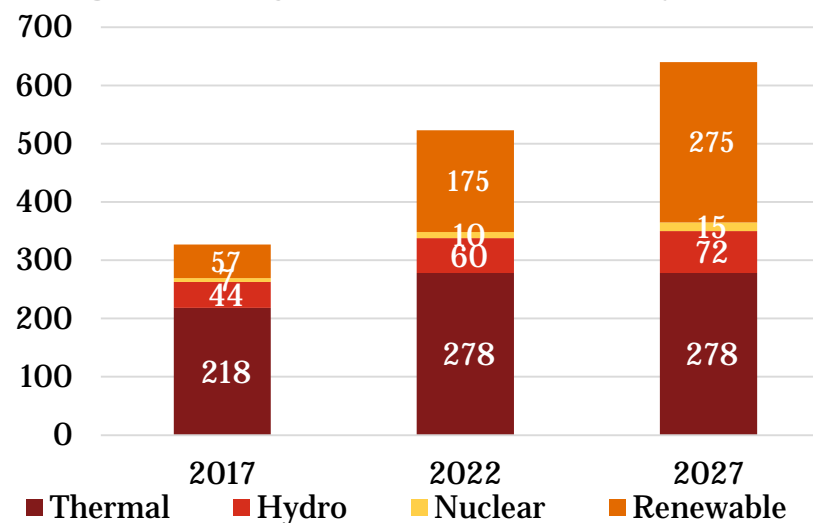


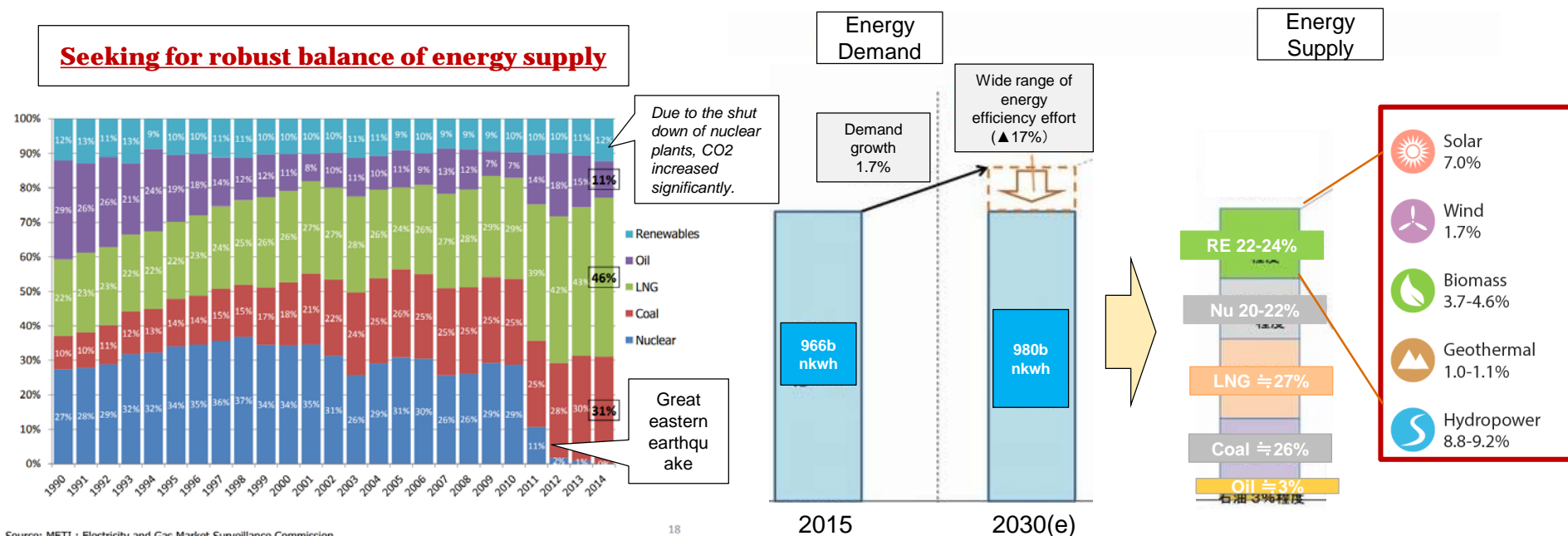
Figure 7 : Projected Installed Capacity (GW)



*3: Indian power sector - overview, challenges and opportunities (PwC India)

Robust energy mix with the shift for renewable energy

- Japan has experienced ,multiple external and internal energy shocks, such as oil shock in 70's, great eastern earthquake. However, its energy policy of “balanced power source” always saved the energy security of the country. Currently, the energy policy seek the balanced sources of supply with nuclear, coal, LNG, oil hydro and other renewables.
- From 2015 to 2030, Japan foresee the growth of the power demand of 1.7% to be off-set by energy efficiency. Major shift of the composition of the power supply with around 22 to 24% of renewable sources with percentage of “Base load” to be around 56%.



Trilemma of Market design

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Trilemma of Market design: Different jurisdictions faces common challenges

Trilemma of reliability, affordability and sustainability

- In a changing energy world, power systems are becoming more decentralised and, with that, comes volatility. The need to balance energy resilience with flexibility is adding a new tension to the central trilemma of reliability, affordability and sustainability.
- Energy systems need to deliver flexibility whilst also ensuring reliability and regulators, policy makers and companies are able to combine to create good energy market outcomes.. is as central as ever.

We can learn from global experiences

- The contrast between the similarity of the challenges and the difference in market design approaches offers a great opportunity. There should be no need to invent market design solutions from scratch. Different parts of the world have followed different evolutionary paths and have adopted different policy frameworks. There are things that are done well and things that are done badly everywhere and we can learn from them.

“What you’re seeing is a massive change that has led to the security of the national electricity market being called into question. There’s always been a debate about balancing sustainability, security and affordability, the so called trilemma, but there’s no doubt that the questions of price and security are now front and central in the national debate.”

*Dr Peter Davis, Board Member, The Australian Energy Market Operator (AEMO), from a blackout that left South Australia, in September 2016,

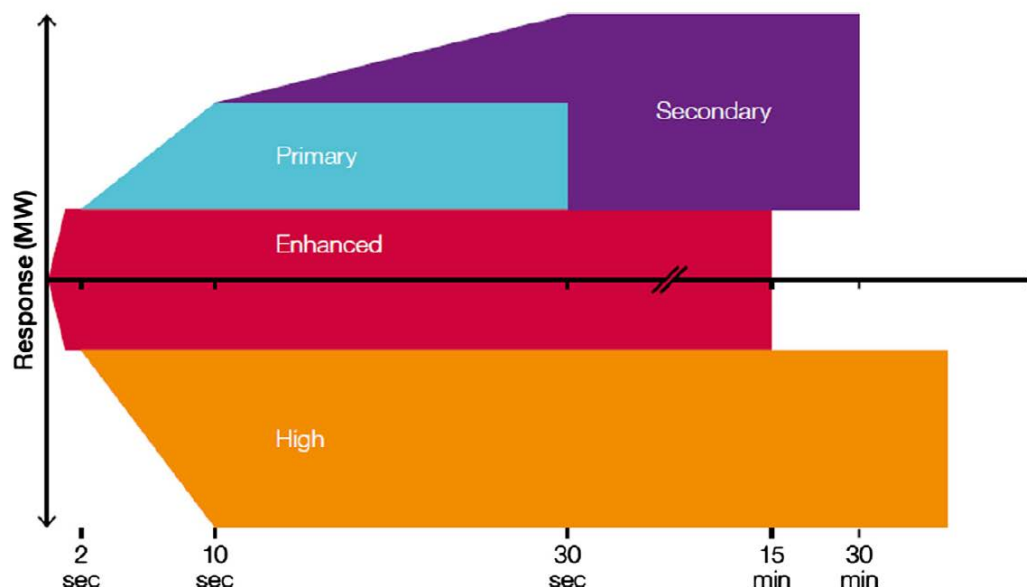
*5: “Market design in a world of energy transformation, PwC-Global EU&R

Design to achieve the reliable power market

Ancillary service market design

- Ancillary services help balance the transmission system as it moves electricity from generating sources to ultimate consumers.
- TSOs operates several markets for ancillary services from primary, secondary markets.

The available frequency response services in GB, their response times, and their durations



Applied Energy 203 (2017) 115–127, Frequency response services designed for energy storage

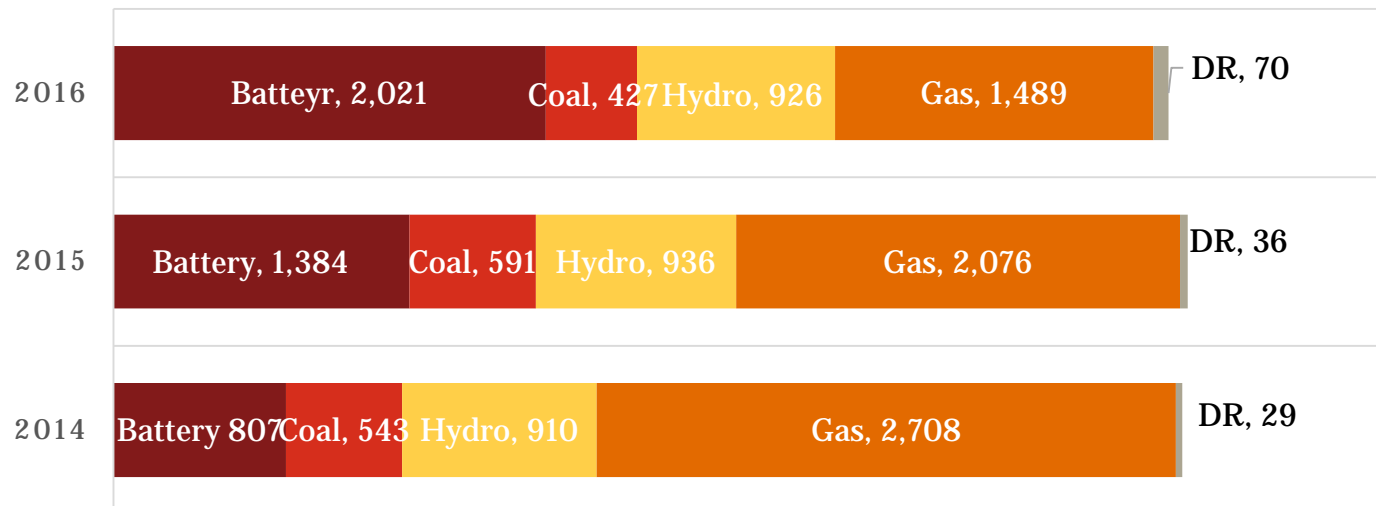
New Technology:

Design of the new market leads to the introduction of new technology

Multiple technologies used in emerging power market

- PJM Interconnection LLC (PJM) is a regional transmission organization (RTO) in the United States, one of the largest and innovative electricity market and Ancillary service market is one of power market contributing to the market stabilization in energy transformation era.
- The market contracts multiple technologies and in the last three years, proportion of **battery** has grown significantly exceeding Gas. In addition to the large introduction of RE technologies, the importance of new technologies such as battery in the new market design shall upsurge.

Figure 8: Technology mix in PJM Ancillary market

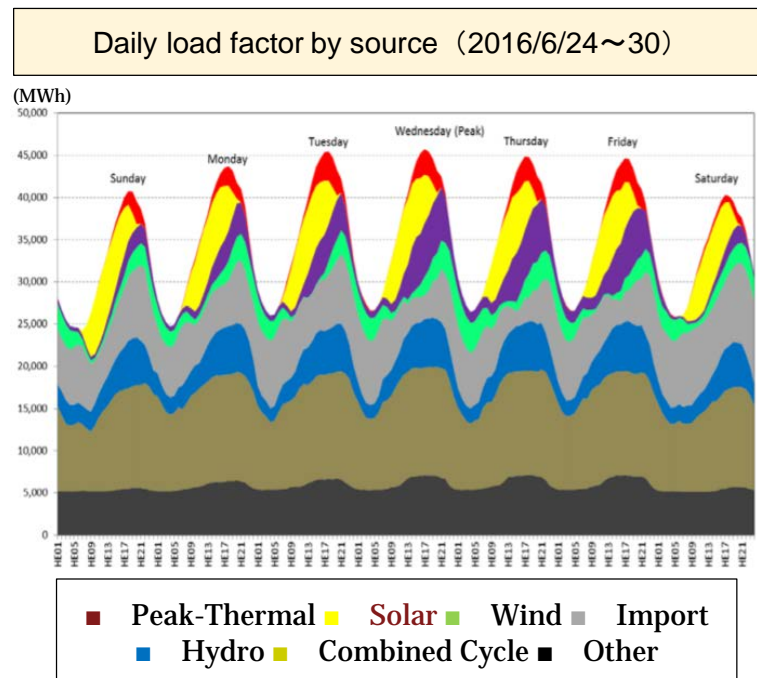


Source: PJM "State of the Market Report"

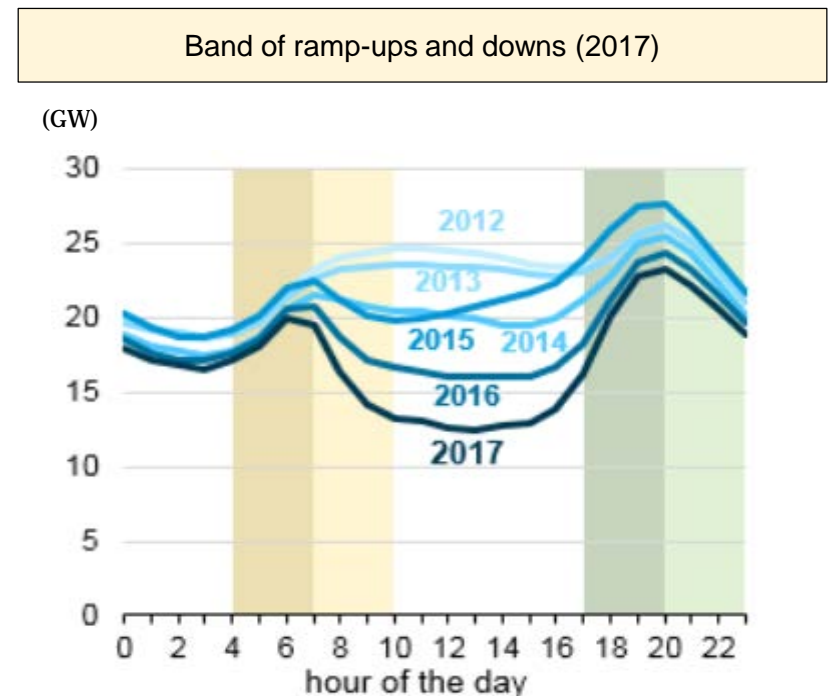
Rising role of solar power in the power market

Effect of ramp-up and ramp-down

- Under the most aggressive environmental regulation, California promotes the expansion of renewable energy. As a result, ramp-up and downs increased in the morning time and late afternoon time and grid stabilization is one of the key issue in the power market design
- In 2017, the band of ramp ups and downs increased to 10GW.



Source : California Energy Commission "Thermal Efficiency of Natural Gas-Fired Generation in California: 2017 Update"

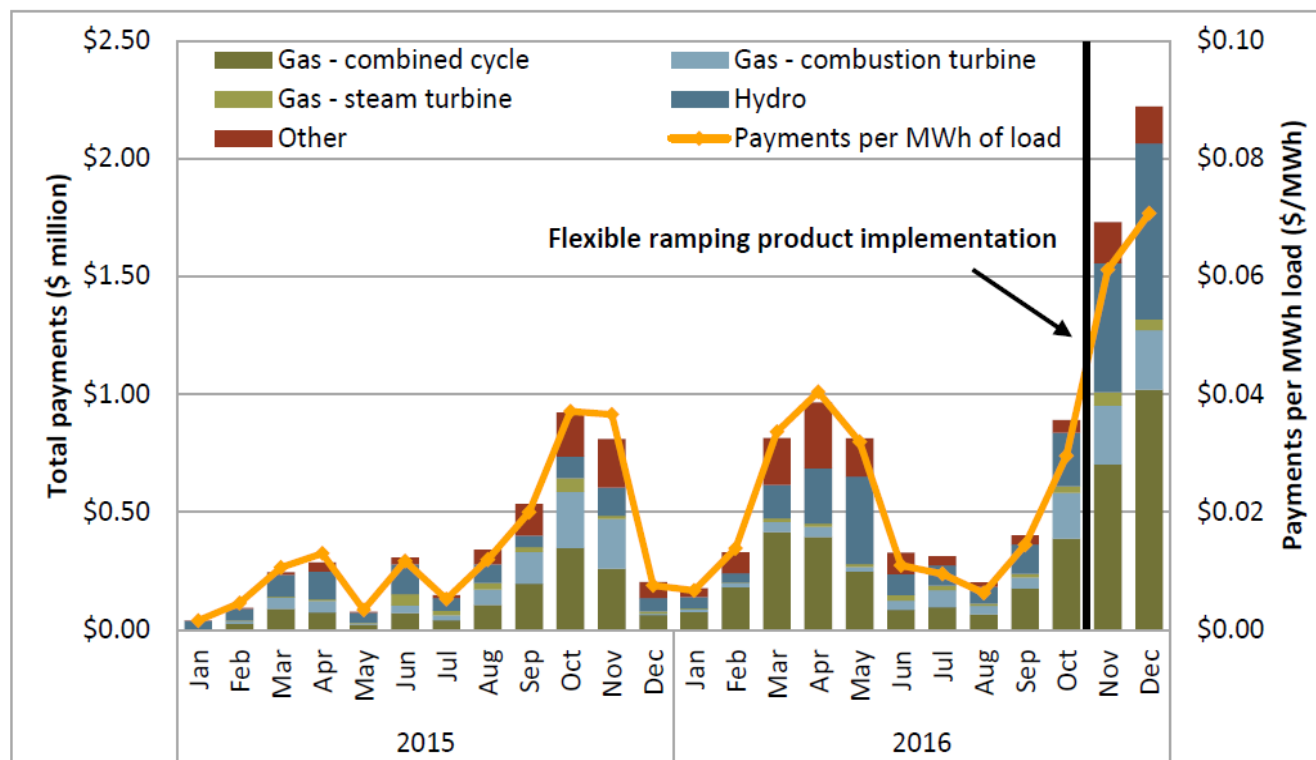


Source : EIA

New market product to control ramp-ups and downs ***“Flexible Ramping Product”***

Flexible Ramping Product (FRP) is the new product introduced in CAISO (California and other) from November, 2016 to control the real time ramping in the area. FRP is served mainly by gas, combined cycle.

FRP: by source



Source : CAISO “Q3 2017 Report on Market Issues and Performance”

Text list table

Information from PwC Global Network

	Title	Contents
*1	“Low Carbon Economy Index (“LCEI”) 2017” (PwC-UK)	LCEI tracks the progress G20 countries have made to decarbonise their economies
	https://www.pwc.co.uk/services/sustainability-climate-change/insights/low-carbon-economy-index.html	
*2	“The next frontier for infrastructure investments, PwC Singapore, 2018	With total renewable energy investments of USD 241.6 billion in 2016, this report provides our view on how renewable energy continues to have a strong economic case in Asia-Pacific, key considerations for investors and emerging trends/technology in the sector
	https://www.pwc.com/sg/en/publications/assets/renewable-energy-in-asia-pacific-2018.pdf	
*3	Indian power sector - overview, challenges and opportunities (PwC India)	Workshop for Japan Smart Community Alliance, October 31, 2017.
	https://www.smart-japan.org/english/index.html	
*4	“Market design in a world of energy transformation”	Senior executives and experts from 12 countries and four continents gathered for a PwC roundtable on market design in Brussels. The event brought together leading players with substantial experience from both the regulatory and corporate spheres to discuss how market design can best evolve to meet the challenges of new energy systems.
	https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/market-design-in-a-world-of-energy-transformation.html	

