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Future challenges for a carbon neutral world
– what role can turbine technologies play?

The Future of Gas Turbine Technology,
ETN's 9th International Gas Turbine Conference,
10-11 October 2018, Brussels, Belgium

Shaun West

IGTC
International
Gas Turbine Conference

Introduction
The problem and the purpose of this presentation

Problem

... can turbine technologies support the transition to a carbon neutral world?

Purpose of this paper

…to understand the challenges of a carbon neutral world

…to provide insight into the implications for turbine technologies

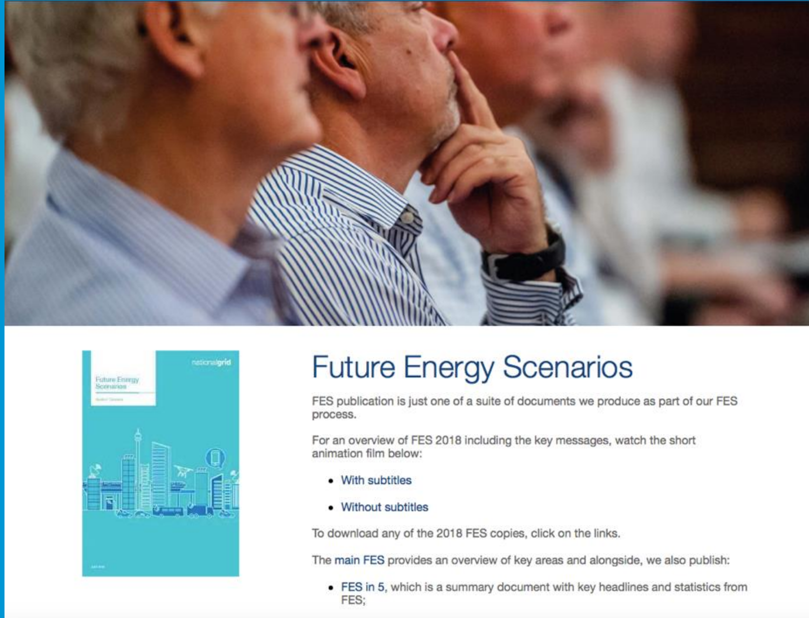
This presentation is based on a white paper written in 2017 based on published UK data from Nationalgrid used in this case

WARNING
I have (perhaps) too many graphs…

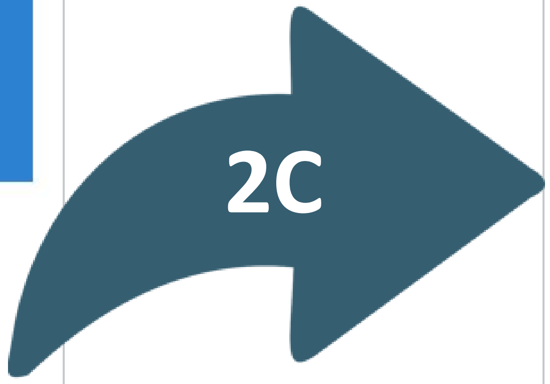
Future Energy Scenarios

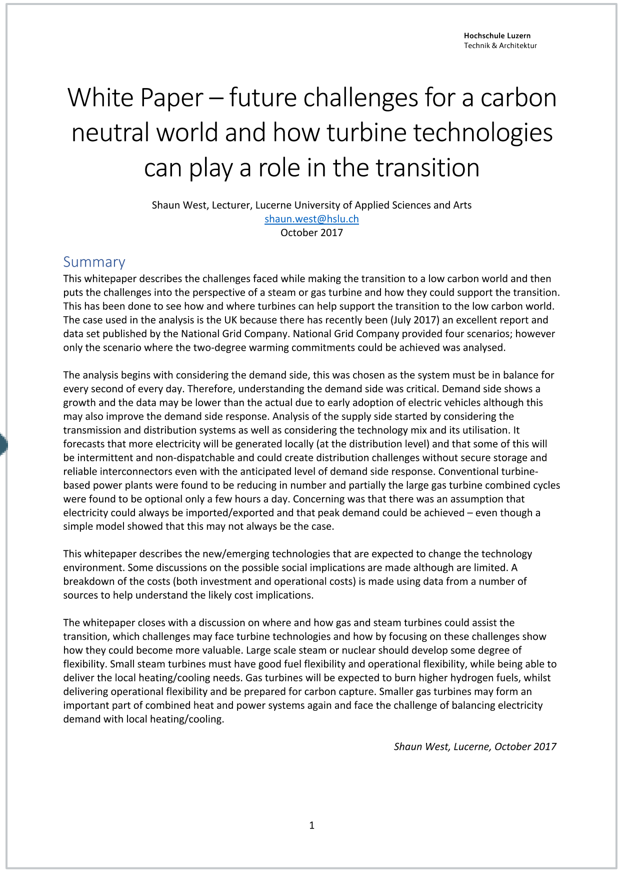
July 2017

nationalgrid



Where did the data
Published data forms the basis of the assessment





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White Paper – future challenges for a carbon neutral world and how turbine technologies can play a role in the transition

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October 2017

Summary

This whitepaper describes the challenges faced while making the transition to a low carbon world and then puts the challenges into the perspective of a steam or gas turbine and how they could support the transition. This has been done to see how and where turbines can help support the transition to the low carbon world. The case used in the analysis is the UK because there has recently been (July 2017) an excellent report and data set published by the National Grid Company. National Grid Company provided four scenarios; however only the scenario where the two-degree warming commitments could be achieved was analysed.

The analysis begins with considering the demand side, this was chosen as the system must be in balance for every second of every day. Therefore, understanding the demand side was critical. Demand side shows a growth and the data may be lower than the actual due to early adoption of electric vehicles although this may also improve the demand side response. Analysis of the supply side started by considering the transmission and distribution systems as well as considering the technology mix and its utilisation. It forecasts that more electricity will be generated locally (at the distribution level) and that some of this will be intermittent and non-dispatchable and could create distribution challenges without secure storage and reliable interconnectors even with the anticipated level of demand side response. Conventional turbine-based power plants were found to be reducing in number and partially the large gas turbine combined cycles were found to be optional only a few hours a day. Concerning was that there was an assumption that electricity could always be imported/exported and that peak demand could be achieved – even though a simple model showed that this may not always be the case.

This whitepaper describes the new/emerging technologies that are expected to change the technology environment. Some discussions on the possible social implications are made although are limited. A breakdown of the costs (both investment and operational costs) is made using data from a number of sources to help understand the likely cost implications.

The whitepaper closes with a discussion on where and how gas and steam turbines could assist the transition, which challenges may face turbine technologies and how by focusing on these challenges show how they could become more valuable. Large scale steam or nuclear should develop some degree of flexibility. Small steam turbines must have good fuel flexibility and operational flexibility, while being able to deliver the local heating/cooling needs. Gas turbines will be expected to burn higher hydrogen fuels, whilst delivering operational flexibility and be prepared for carbon capture. Smaller gas turbines may form an important part of combined heat and power systems again and face the challenge of balancing electricity demand with local heating/cooling.

Shaun West, Lucerne, October 2017

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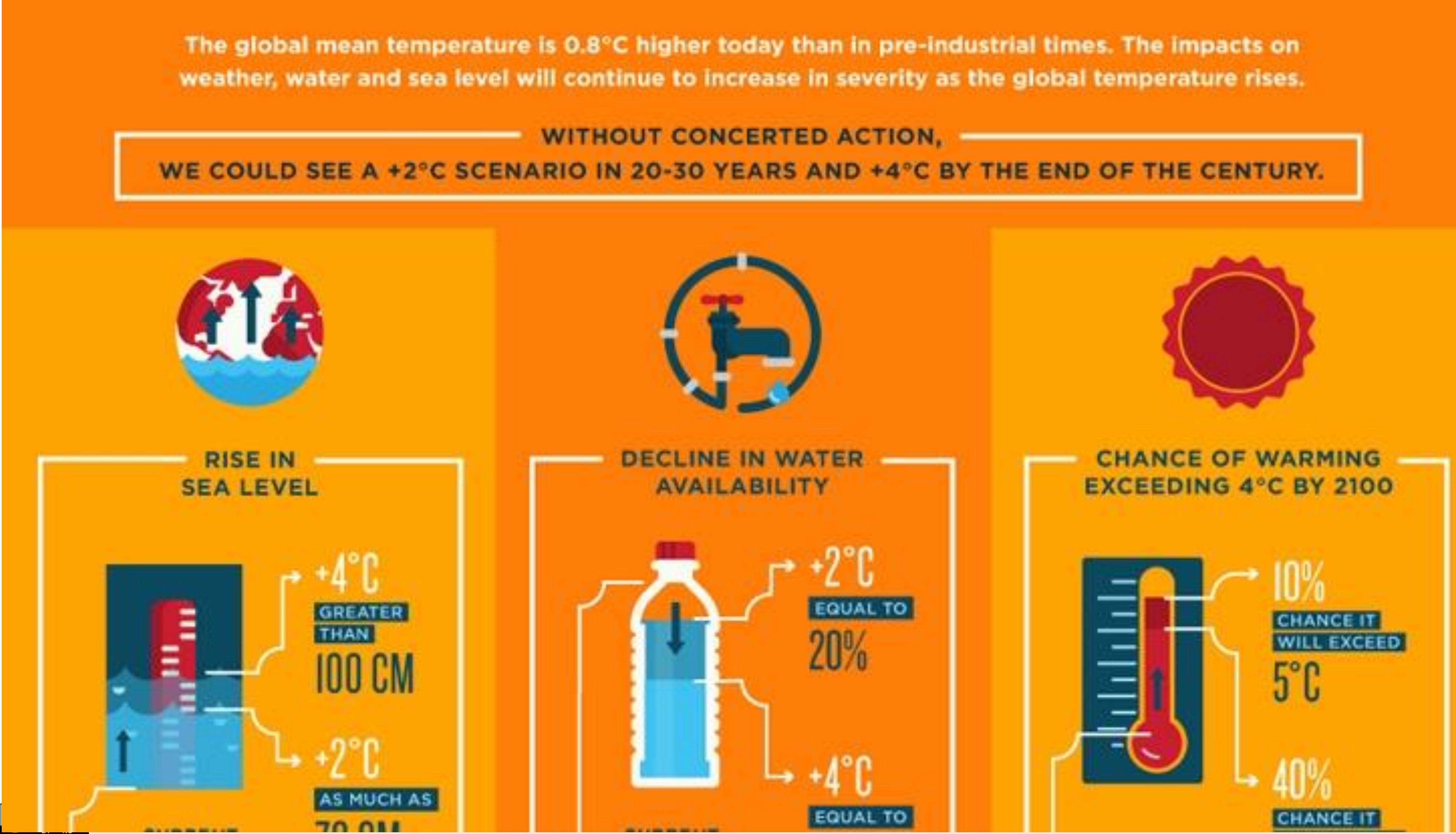
UK data from Nationalgrid was used (google “*Future Energy Scenarios*”)



http://www.worldbank.org/en/topic/climatechange/publication/turn-down-the-heat

Climate change

Huge risk if global warming passes 1.5C, warns landmark UN report

Urgent changes needed to cut risk of extreme heat, drought, floods and poverty, says IPCC

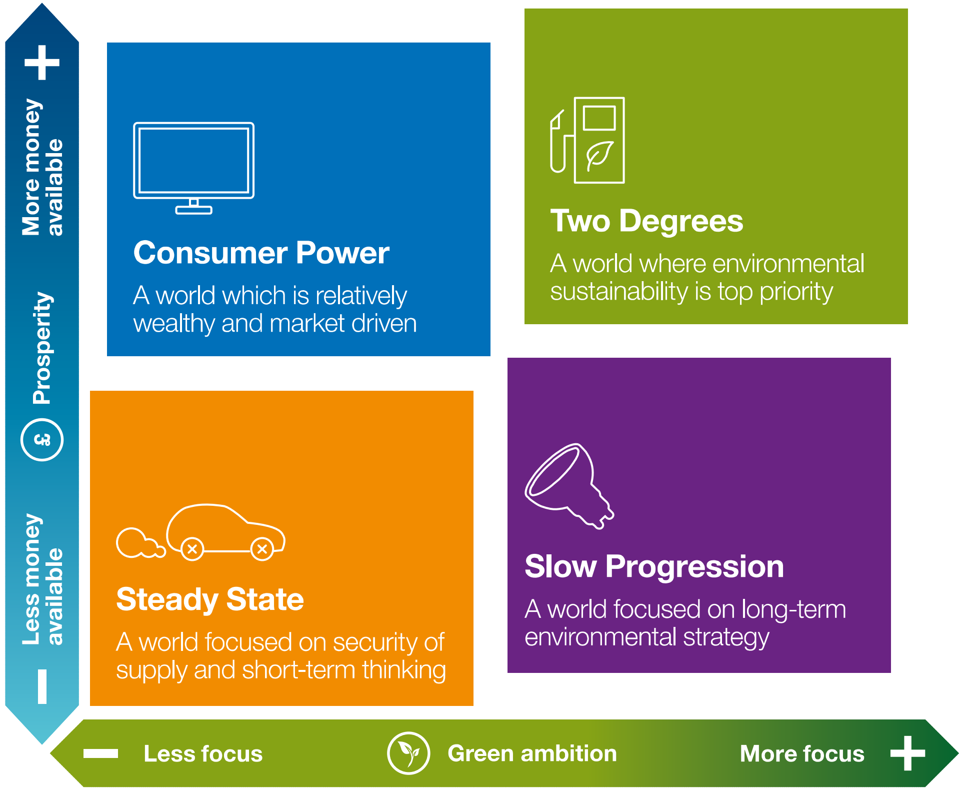
- IPCC climate change report – live updates and reaction

Jonathan Watts
Global environment editor

Mon 8 Oct 2018
02.00 BST

theguardian.com

Underlying assumptions
The two-degree scenario was selected

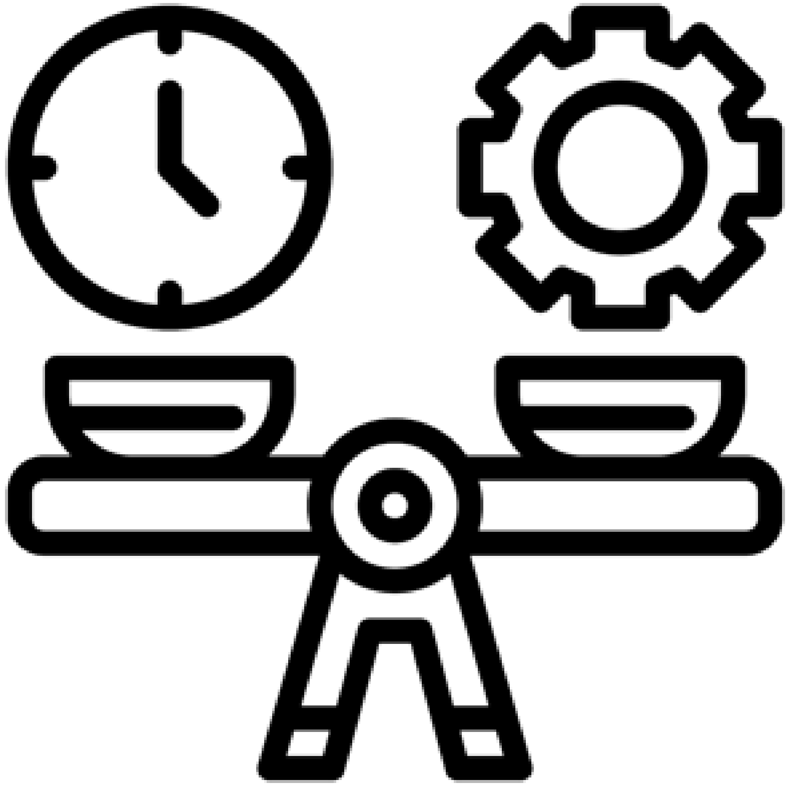


Two Degrees has the highest level of prosperity. Increased investment ensures the delivery of high levels of low carbon energy. Consumers make conscious choices to be greener and can afford technology to support it. With highly effective policy interventions in place, this is the only scenario where all UK carbon reduction targets are achieved.

This reflects the Paris Agreement on climate change

QUANTIFICATION OF THE CHALLENGES AHEAD

Quantification of the challenges ahead
Supply side must always balance demand



supply (+ imports) = demand (+ storage + exports)

The system must balance for every second of every day

Quantification of the challenges ahead
Supply must balance demand

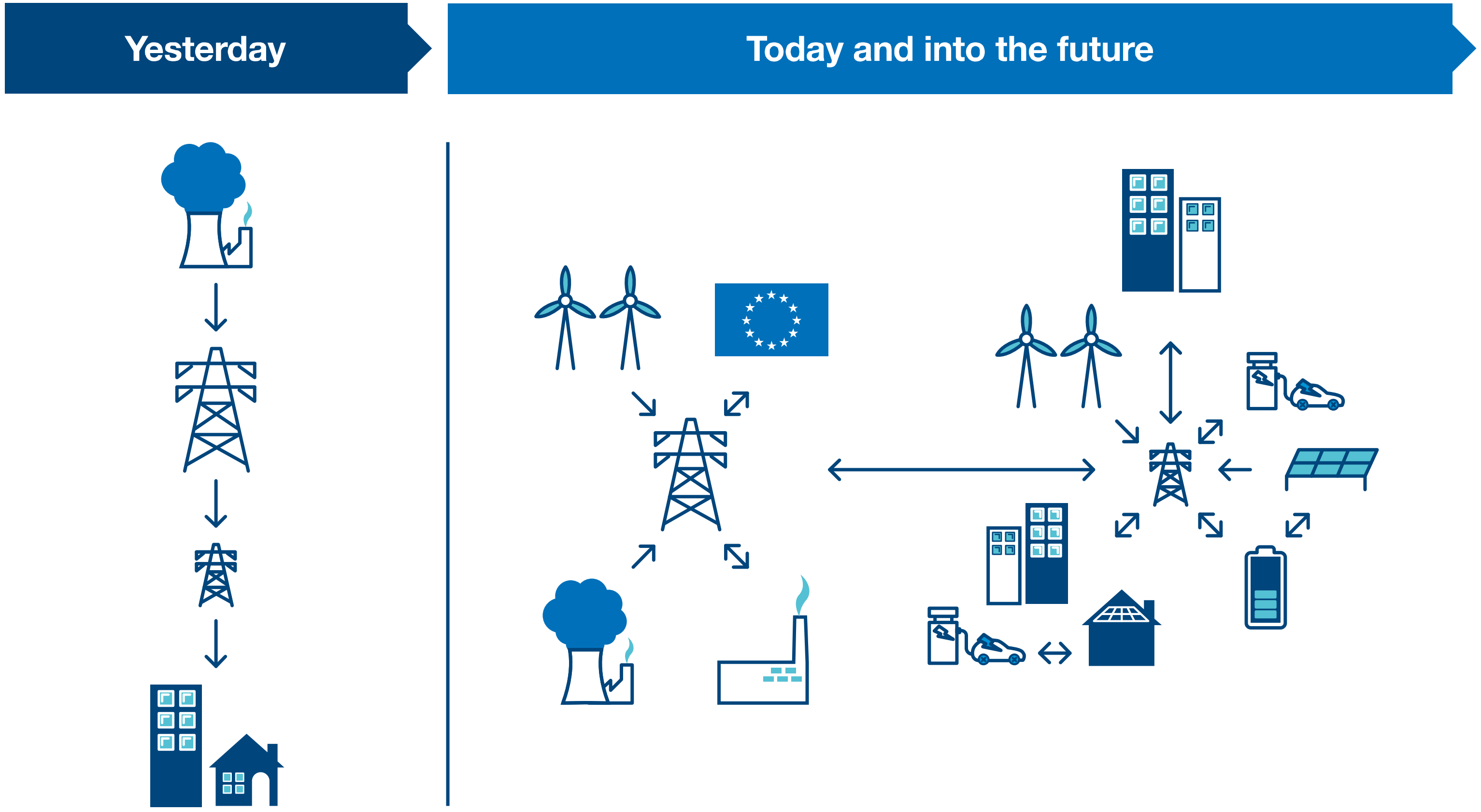
GW

We **must** have sufficient installed **capacity** to meet the **peak demand**

If not the lights **will** go out

Annual production (in TWh) does not provide sufficient insight

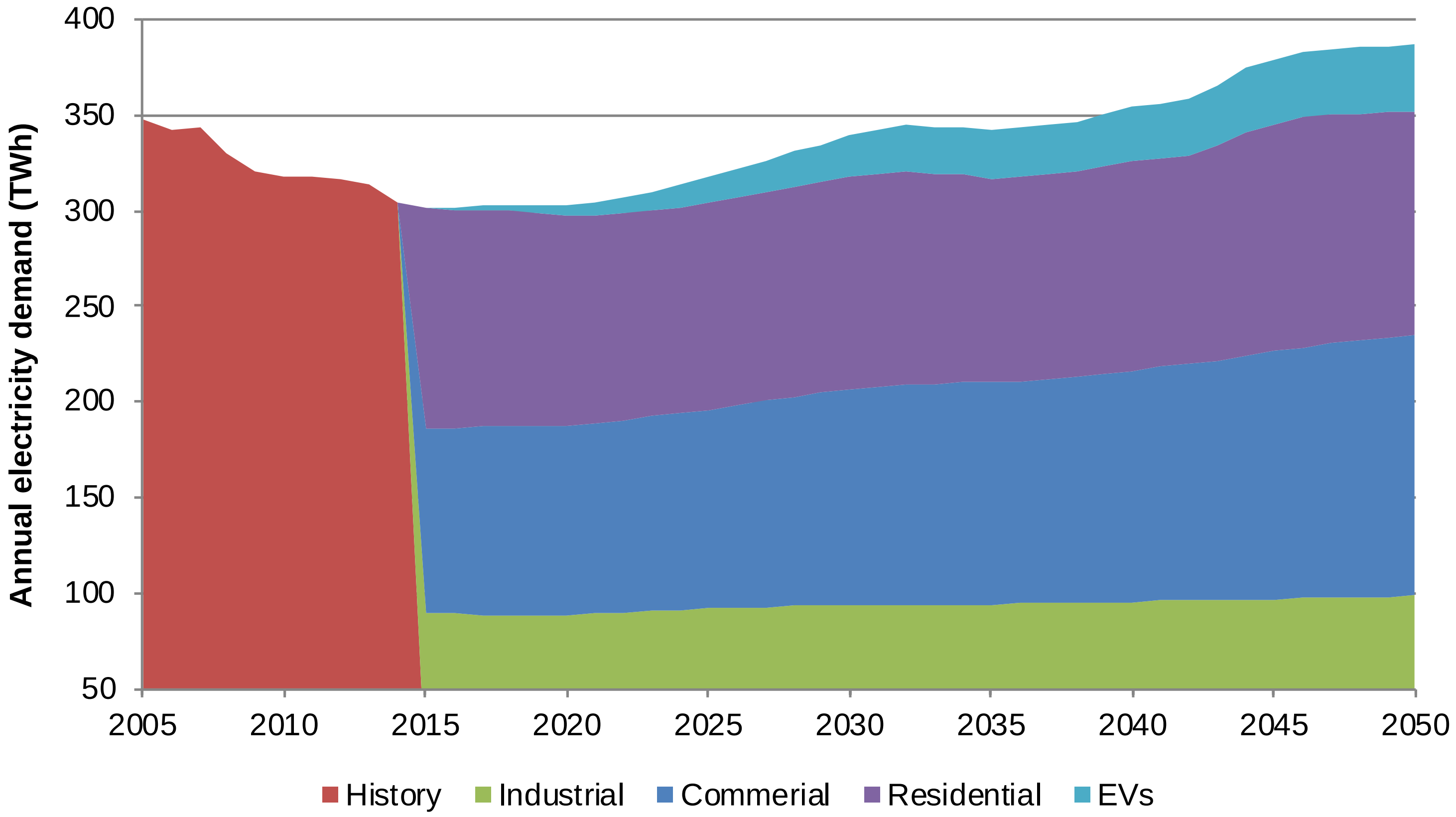
Quantification of the challenges ahead
Generation, transmission and distribution is becoming ever more complex



We need to learn to balance locally, regionally, nationally and internationally

System balancing becomes every more important to ensure reliable electricity

Quantification of the challenges ahead
Demand side – annual demand



Demand for electricity will increase, much of this is driven by the switch to electricity

Decarbonization will lead to an increase in electricity demand

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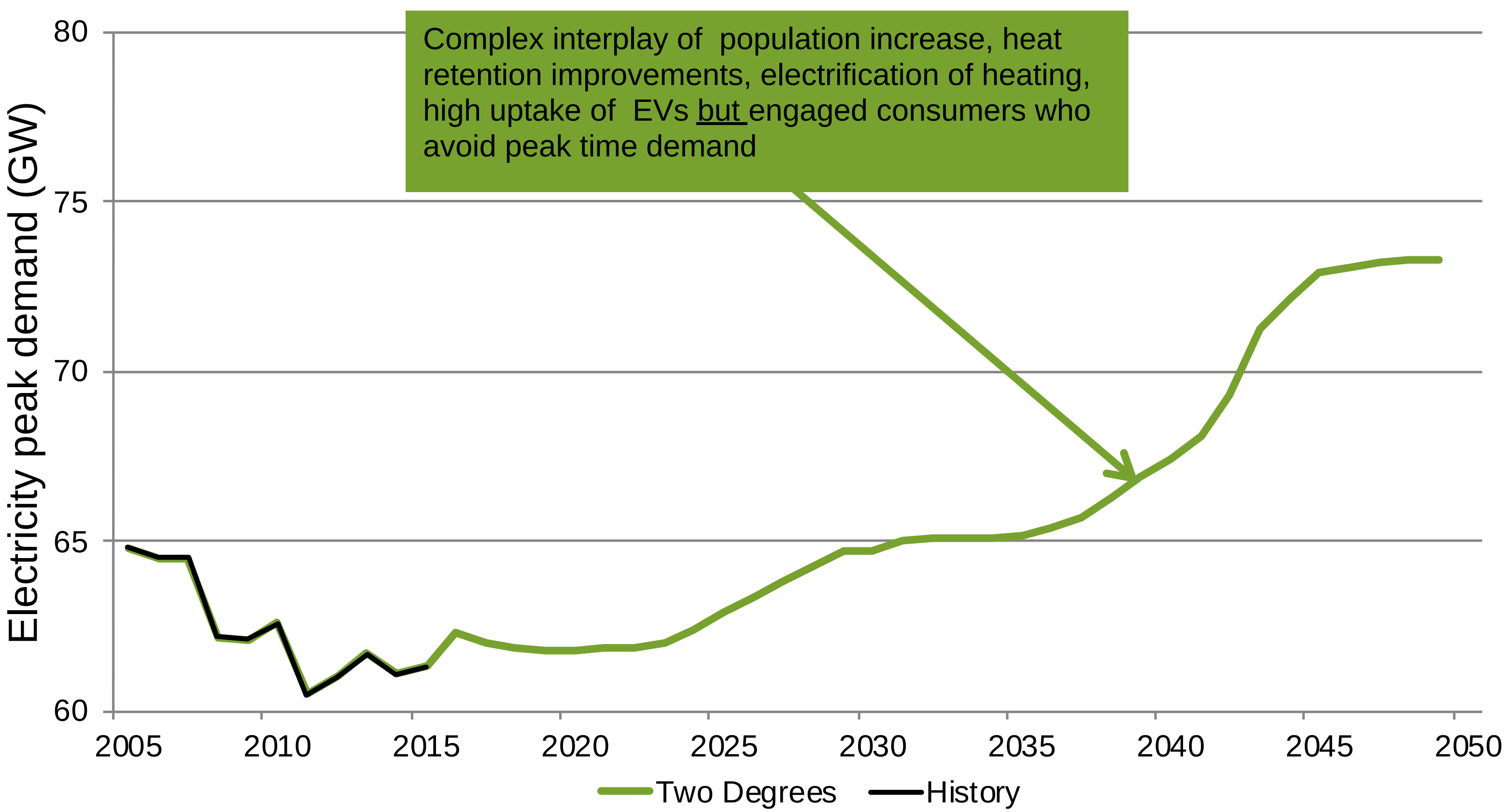
Quantification of the challenges ahead
Demand side – peak electricity demand

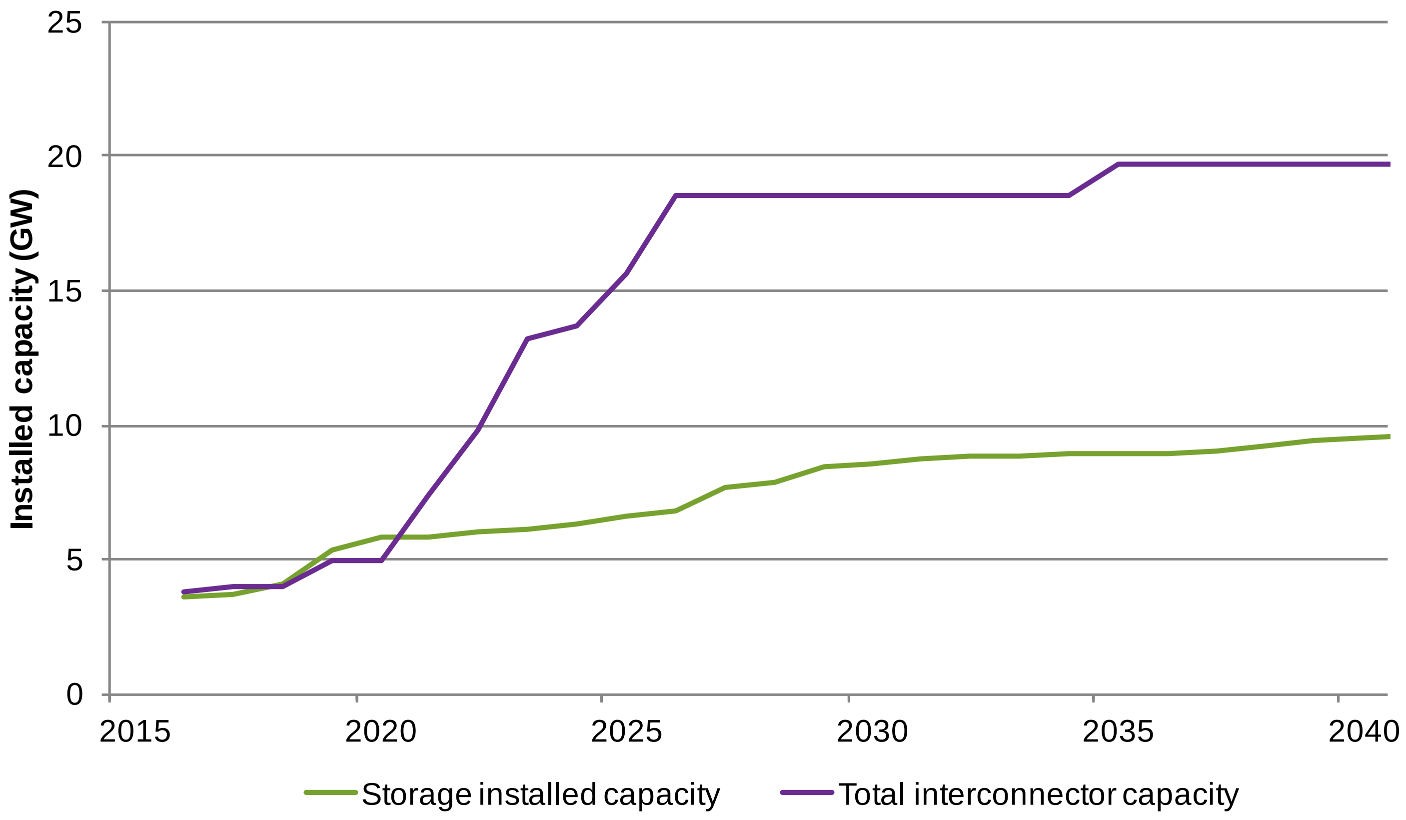


Annual demand grows slowly yet **peaks** are high

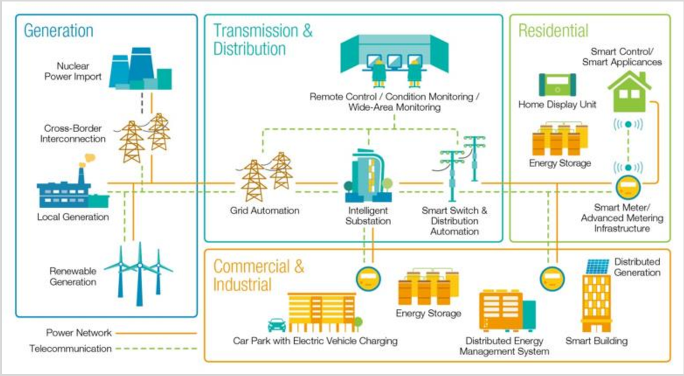
Decarbonization will leads to a change in the daily demand profile

Quantification of the challenges ahead

Electricity storage and interconnector capacity both grow



Smarter Grids and Smart Appliances can help



There is increased buffering from storage, interconnection and smart appliances

Quantification of the challenges ahead
Supply side – Overview of the supply side by type

Dispatchable

Non-dispatchable

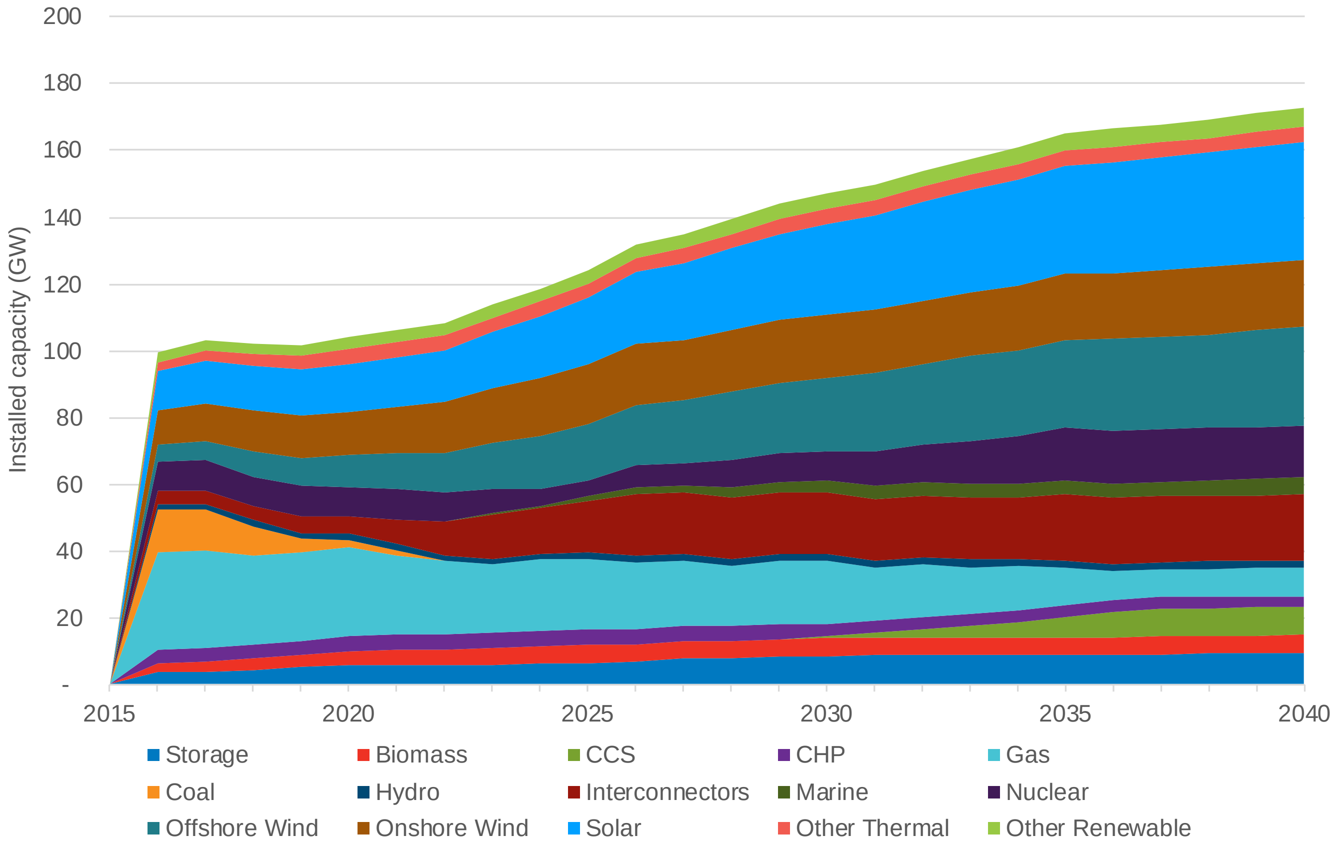
Intermittent

There are different rules for each type of electricity producer on the system…

Remember that some of the new capacity is at the distribution level

The market rules and dynamics are getting very complex

Matching demand with Installed capacity
Supply side – the installed capacity grows faster than demand



More local heat and power, more wind, more solar.

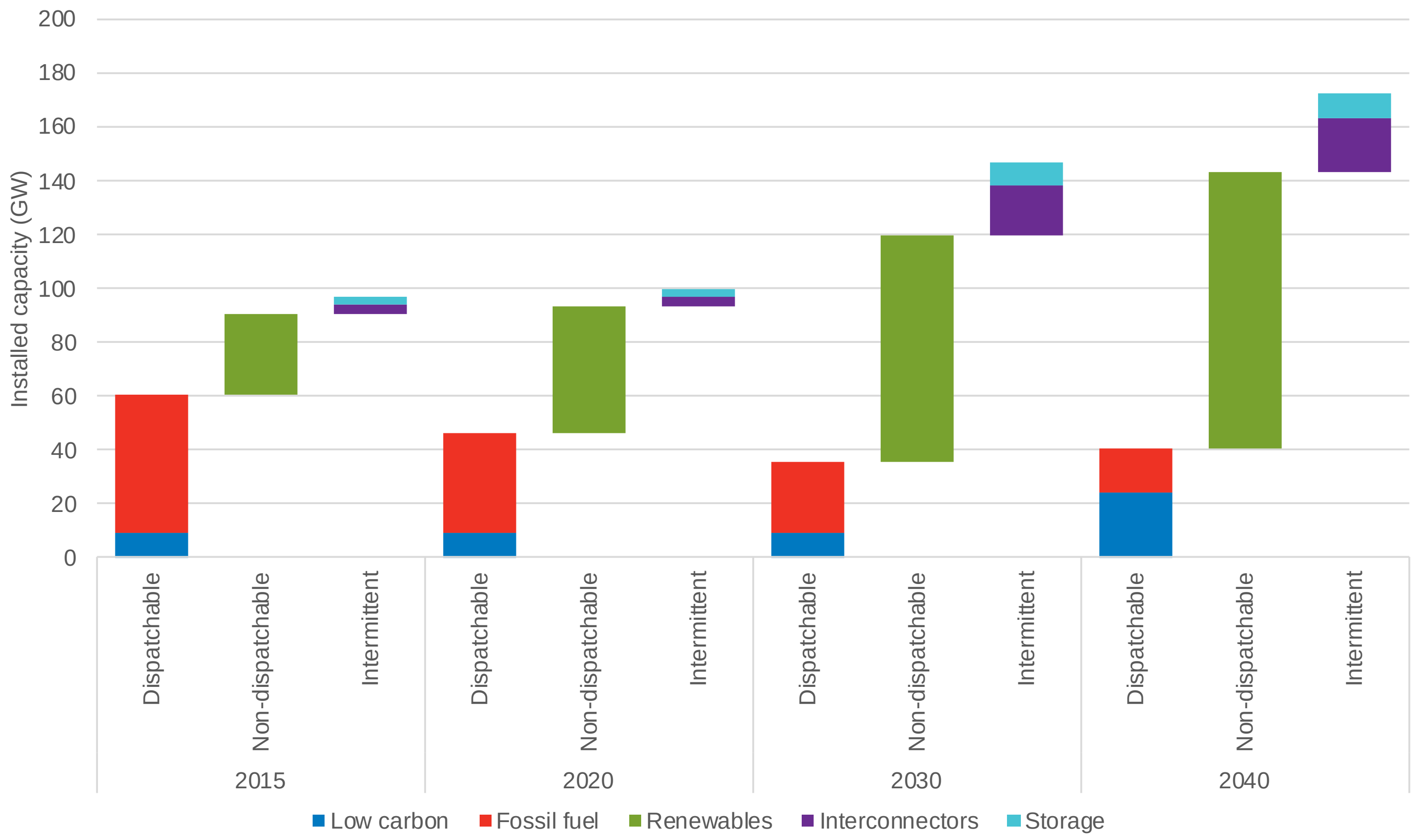
Less conventional power generation.

The utilization factor changes massively and is technology specific.

The generational mix changes dramatically over the next 20 years

Quantification of the challenges ahead

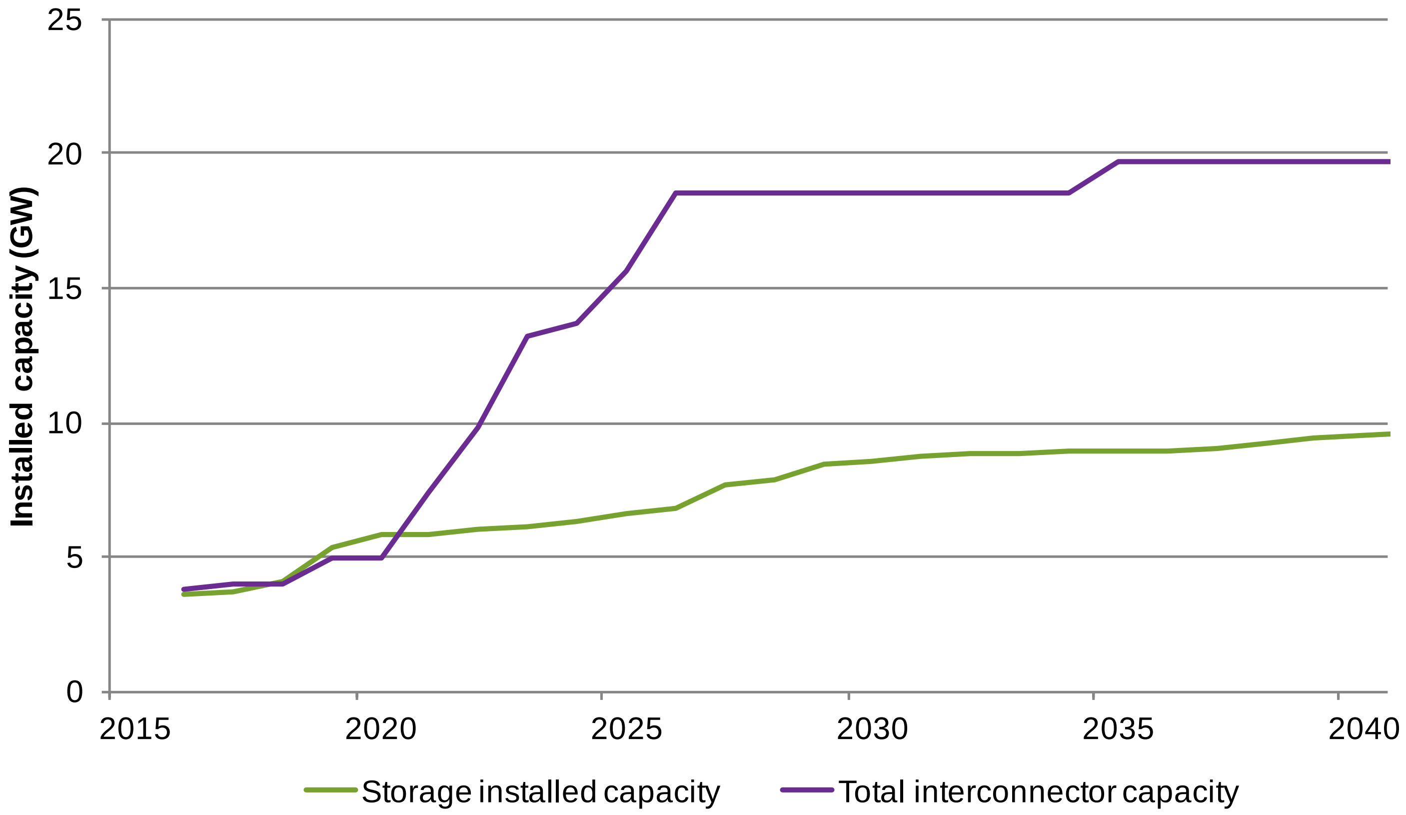
Supply side – overview of the supply side by type



How can the system be balanced when the ratio of dispatchable to non-dispatchable capacity changes so dramatically?

The system must be balanced yet the volume of dispatchable generation reduces

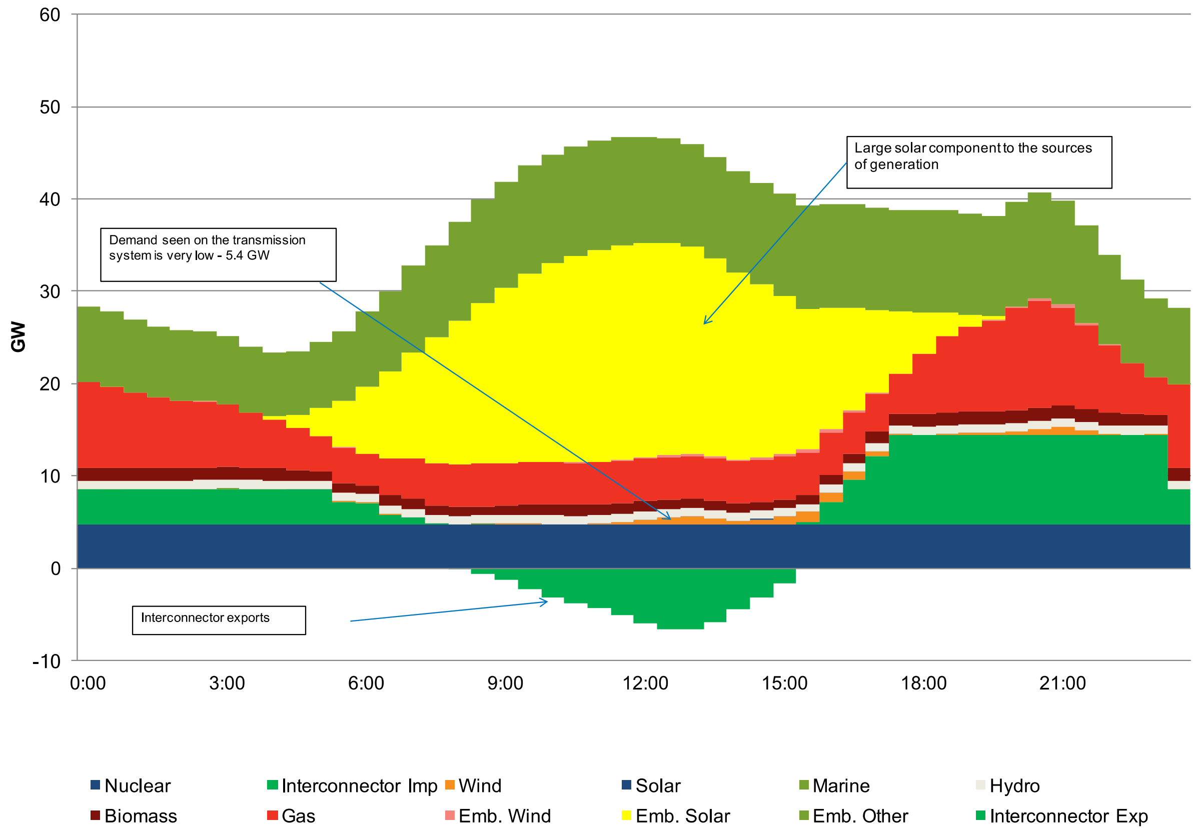
Quantification of the challenges ahead
Supply side – electricity storage and interconnector capacity both grow



Both storage and interconnectors can absorb and provide power. They have different capabilities to fully-dispatchable power plants.

Over the period storage doubles and interconnector capacity in creases by a factor of four

Quantification of the challenges ahead
Supply side – electricity production and transmission on a typical summer day in 2014



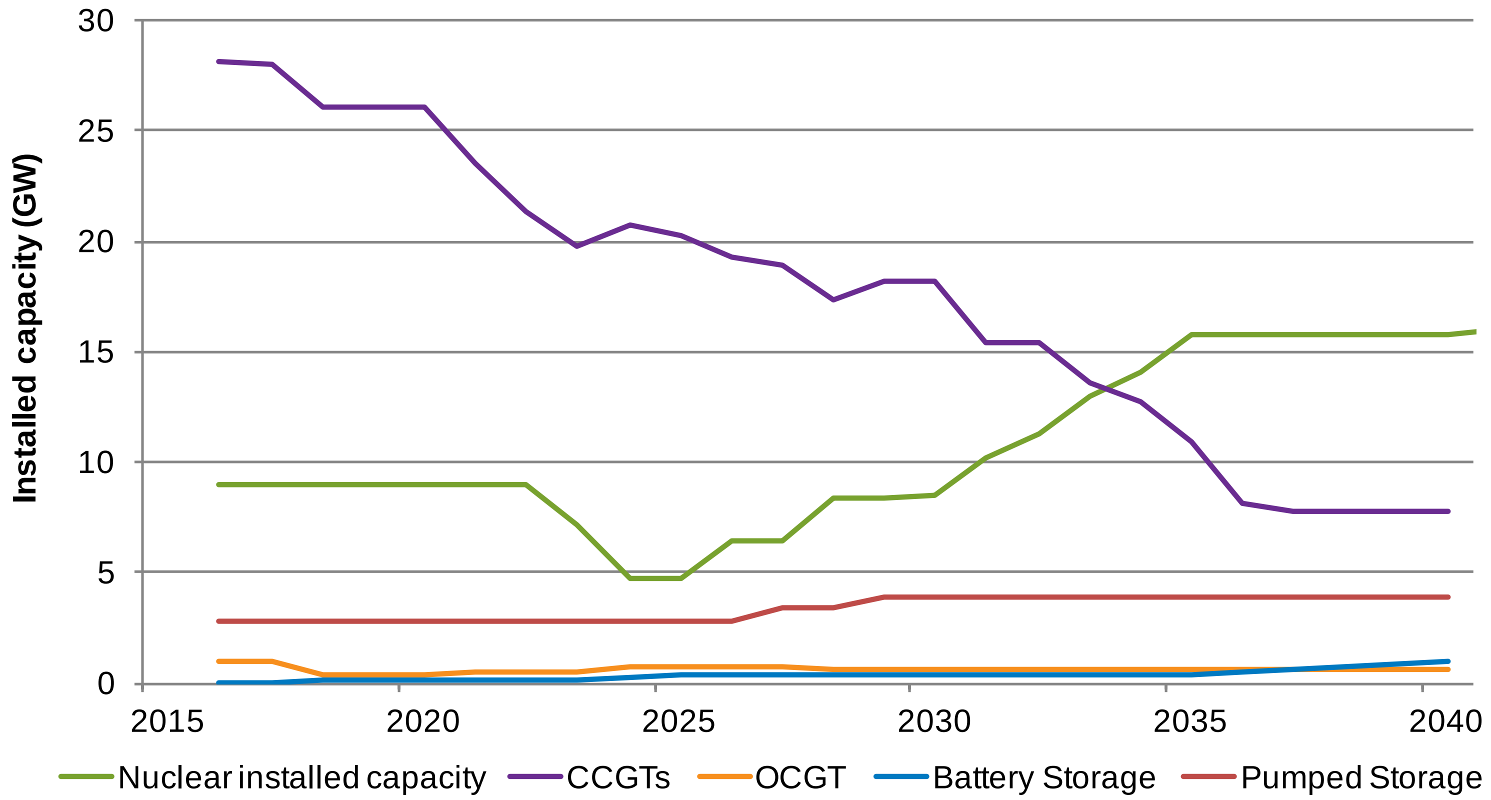
Solar provides a major component of the power production during the day. The grid is reliant on the interconnectors to balance the system.

Can the Continental Synchronous Area support this level of import/export?

What happens if the interconnectors cannot balance supply and demand?

Quantification of the challenges ahead

Supply side – forecast installed capacities for dispatchable technologies

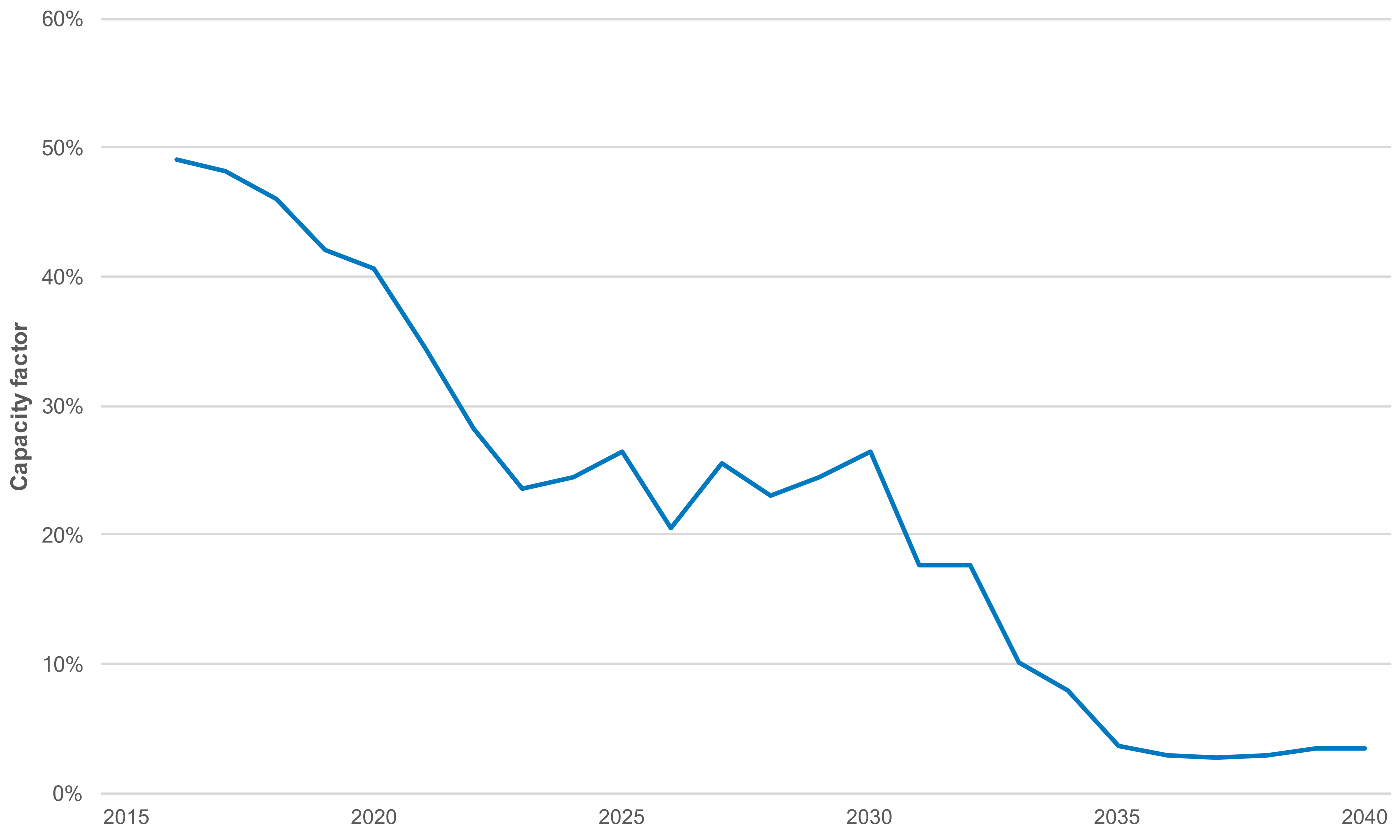


The report considers all of these technologies 'dispatchable'.

Nuclear has limited flexibility and storage has limited capabilities.

Most of the flexibility will have to be provided by the gas turbine based plants

Quantification of the challenges ahead
Supply side – utilization of the gas turbine is dropping



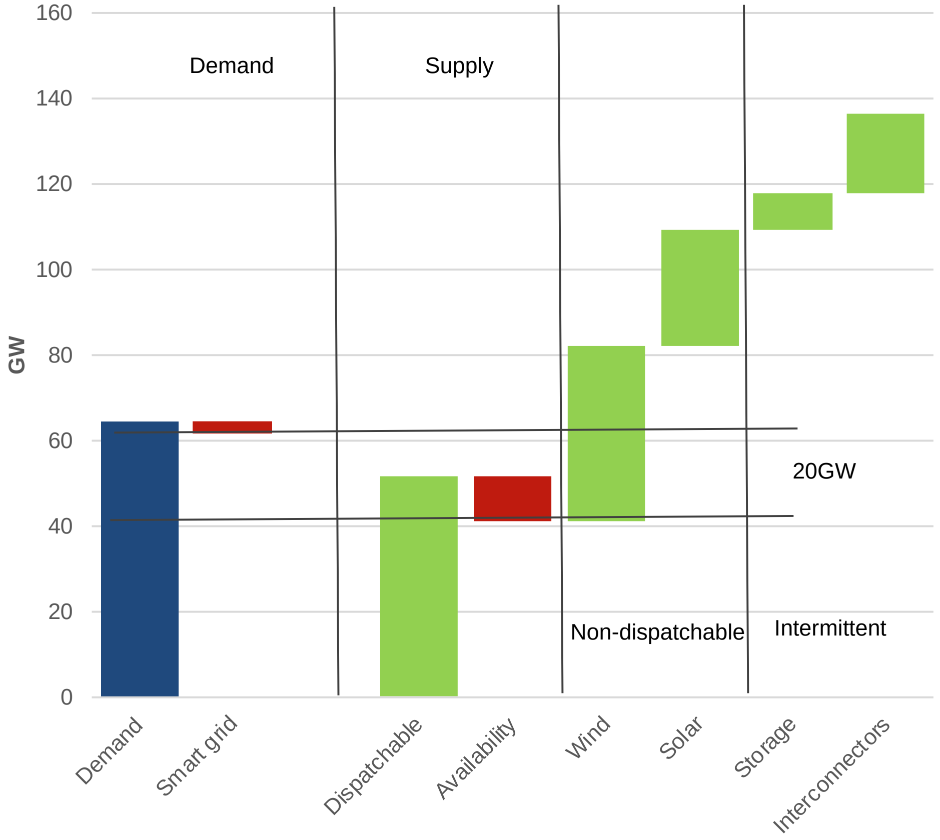
Capacity factors of less than 25% mean the gas turbines will be providing grid support services.

How do we work to improve the capacity factor?

The grid system must provide an availably incentive otherwise there will be no new plants built

Quantification of the challenges ahead

Supply side – there is a potential shortfall of 20GW between demand and supply



With high levels of non-dispatchable generation there is a 20GW shortfall.

What happens in winter when it is cloudy and there is no wind?

There is a risk that the interconnectors and the storage are unable to bridge the shortfall

Quantification of the challenges ahead
The analysis of the data, based on the two-degree scenario shows

Demand side… a build-up of…

- … demand supply response – this is generally unproven and assumes a change in behaviour
- …electric vehicles – this is anticipated to be sooner/faster than expected provide increases in demand and options for demand-side management

Supply side… a build-up of…

- …intermittent and non-dispatchable generation in the system
- …new nuclear plant (limited flexibility?)
- …supply at the distribution level – this is new and will require new management approaches
- ….prosumers at the distribution level

We are about to enter challenging times…

Quantification of the challenges ahead
The analysis of the data, based on the two-degree scenario shows

Interconnectors, storage and prosumer

- New interconnector and storage capacity – need to balance the system but contingent on others
- Prosumers – locally imbedded heat/cooling technologies coupled with electricity generation

Fuel issues

- A general phase out of carbon producing technologies
- Pre-combustion reformation
- A slow switch to a hydrogen (blue and green)

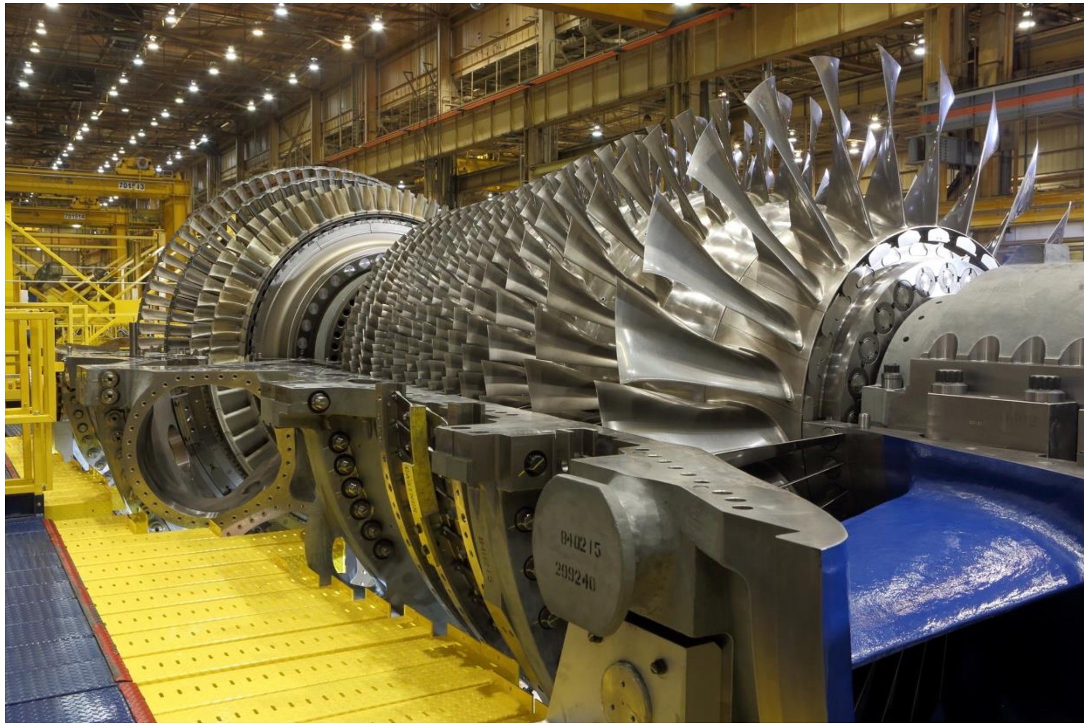
We are about to enter challenging times…

TURBINE TECHNOLOGIES AND THEIR APPLICATION IN THE NEW WORLD

Turbine technologies and their application in the new world
Implications for large gas turbines

The number of new combined cycle power plants expected to be built is low and the operation of these units is expected to fall as they become more important for system balancing.

- Increased flexibility to capture value in the capacity or system balancing markets.
- Increased efficiency to continue to drive cost out and reduce specific carbon emissions.
- Could be required to have carbon capture installed, either post- or pre-combustion.



http://s3.amazonaws.com/dsg.files.app.content.prod/gereports/wp-content/uploads/2015/12/07224603/7HA.01-in-Greenville-factory_1.jpg

Does this mean the end of large CCGTs?

Turbine technologies and their application in the new world
Implications smaller gas turbines

These would form part of an integrated combined heat and power system and would be running on natural gas or hydrogen/natural gas fuels.

- Improvements in system integration of district heating systems.
- Decoupling of the electricity from the heating/cooling.
- Simple/standalone operation to allow flexible operations on smaller scales (e.g., micro-turbines).

https://assets-turbomachinerymag-com.s3.amazonaws.com/uploads/2016/08/MAN’s-MGT-series.jpg

Does the ‘industrial gas turbine’ become a preferred technology?

Turbine technologies and their application in the new world
Implications large steam turbines

The model assumes that all large steam turbines are associated with nuclear power plants.

- Operational flexibility needs to be improved.
- Grid support services during periods of low load.
- Construction periods must be reduced (non-operational demand).

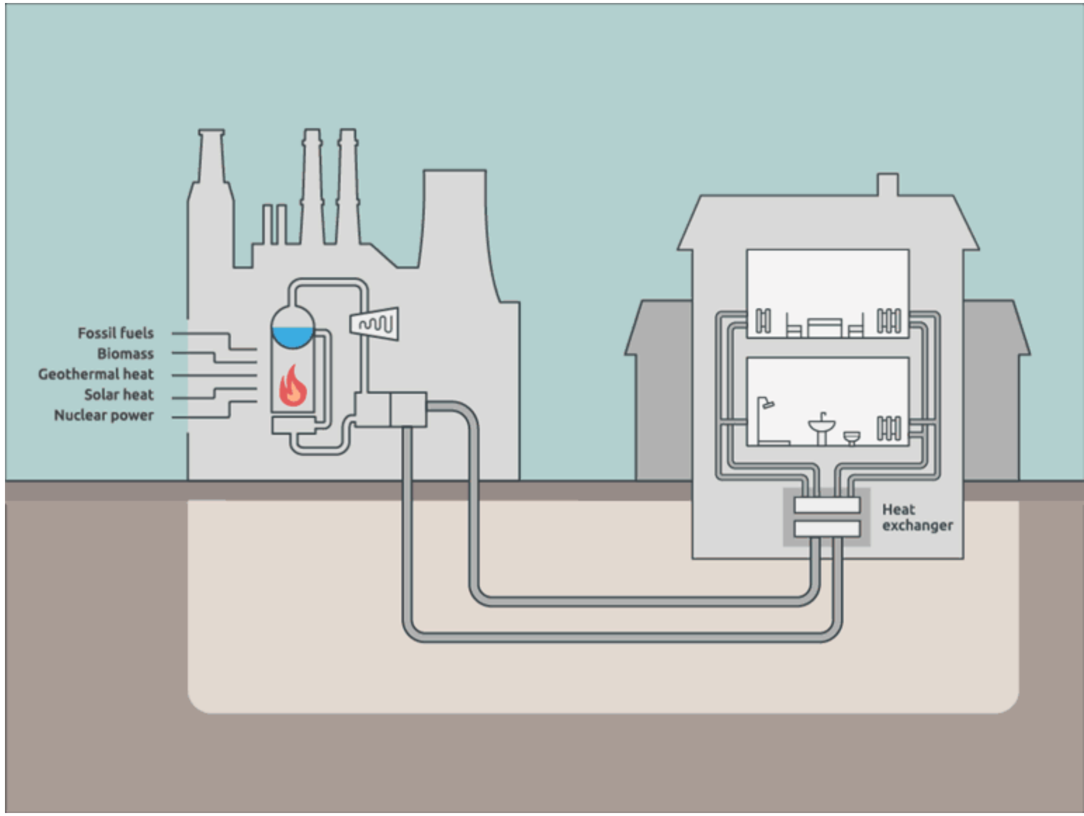
http://chinaplus.cri.cn/news/business/12/20171117/53205.html

The challenges are not with the steam turbine

Turbine technologies and their application in the new world
Implications smaller steam turbines

Overall level of CHP remains with the fuel changes (e.g., more biomass or hydrogen enrichment of natural gas). Integration of wider heating and cooling systems to use the low-grade 'waste' heat from these systems.

- Closer system integration with local heating/cooling systems.
- Increased remote control to ensure system stability.
- Increased flexibility (already in place to a greater degree).



Laura Toffetti, DensityDesign Research Lab.
https://upload.wikimedia.org/wikipedia/commons/0/0d/District_heating.gif

The turbine technology is mature

Closing

The main challenges to reach the carbon neutral world

- Demand for electricity will grow
- There will be more imbedded generation and proconsumers
- System balancing will become more challenging
- There will be a switch to natural gas/hydrogen as a fuel

System integration issues will become major challenges in the **carbon neutral world**.

Turbines **could** have a valuable role to play to help with **deliver the carbon neutral world**.

Final thoughts…

"To improve the market share for turbomachinery during the energy transition we have to support the energy and climate policy targets (emission reduction, security of supply, affordability/cost efficient). We (the OEMs, suppliers, and users) then need to establish a long-term vision that would meet these targets and meet the needs and requirements of the users. The community then needs to widely disseminate the vision to politicians, future students, and the general public.

Gas turbine technology is a technology that has the capacity, supported by further investment and research, to deliver both low carbon and carbon neutral solutions with the required security of supply at cost competitive prices. Investments today will both enable broader contributions to the energy targets in the transition, and it will also bring us closer to cost-competitive carbon neutral solutions for the future."

Shaun West,
10 October 2018

Shaun West
Expert in Product-Service System
Business Model Innovation

werkbox

Thanks for your time!
Questions over coffee…

Slides posted on SlideShare.com