Gas Back-up Generation Update

23 Jan 19

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- Supports projects to inject biomethane into the gas grid
  - New RHI in place – estimated further 26 projects registered for completion by end Jan 2020
- Supports back-up gas generation projects
  - Pipelines for 20 – 50 MW gas engine plants
- Part owner of CNG Fuels Ltd, a company set up to build national network of CBM stations on the high pressure gas grid
  - Leyland CNG Station
  - 84% saving in GHG compared to diesel
- Developer of 'virtual pipeline' projects to take gas by road to off-grid customers including the distilleries and homes on Islay
  - Replacing oil with natural gas and then biomethane

Innovation in the New Gas Economy

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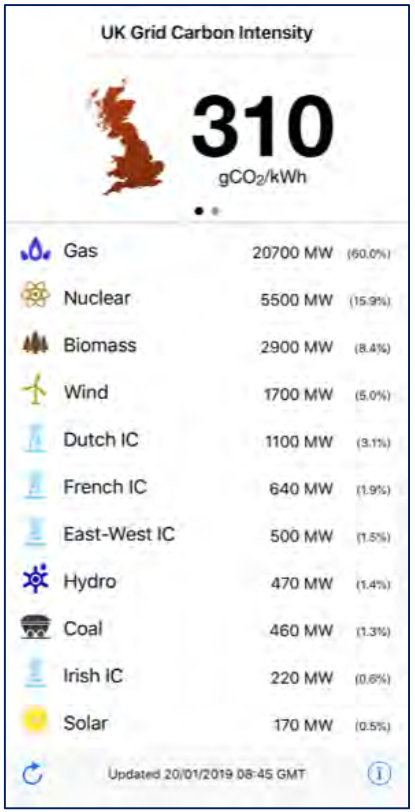
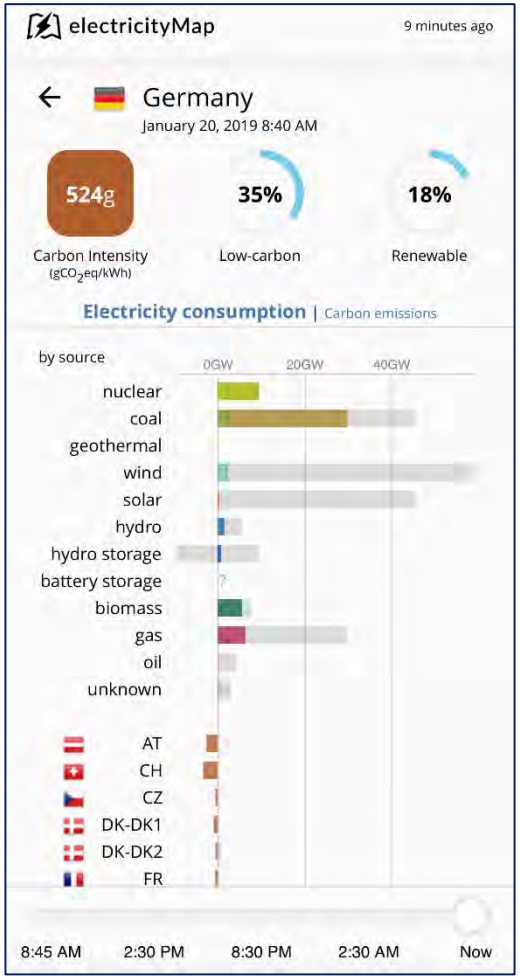
Back-up Generation

1. Building back-up gas generation plant that are needed when its not windy/sunny
2. E.g.: On 20th January 2019





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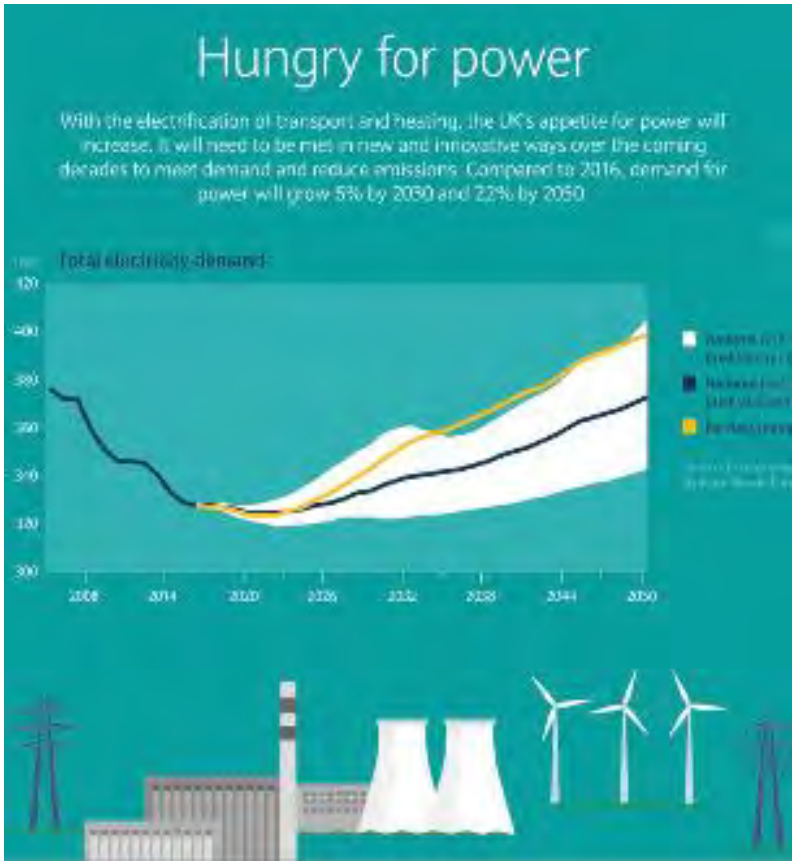
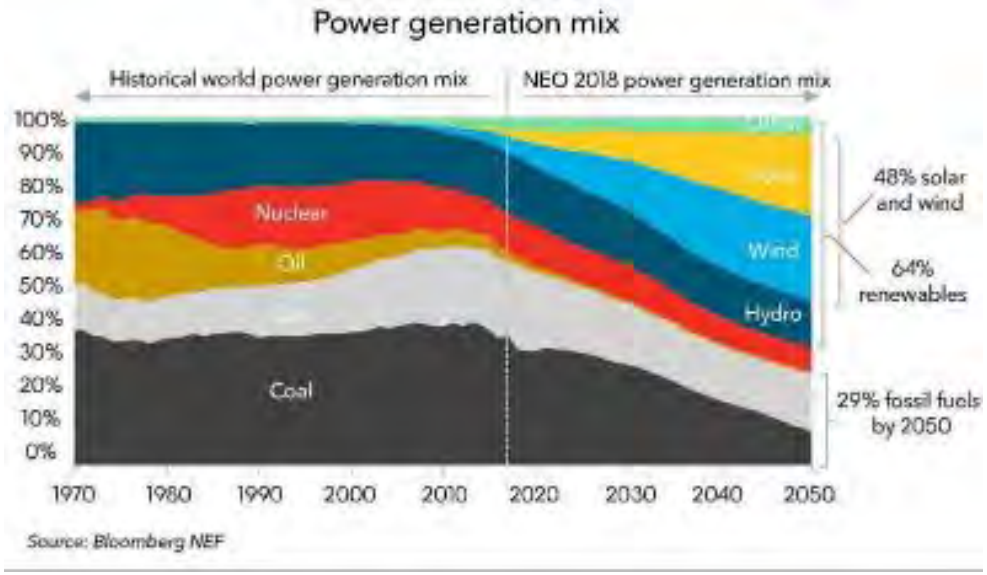
Building Back-up Gas Generation Plant that are Needed when it's not Windy

A new Bloomberg New Energy Finance report forecasts a big increase in gas generation as % market share stays flat but total market doubles in size.

https://about.bnef.com/new-energy-outlook/





UK electricity demand forecast to rise to 2050 due to electric vehicles (EVs) and some heating shifting to electric heat pumps.

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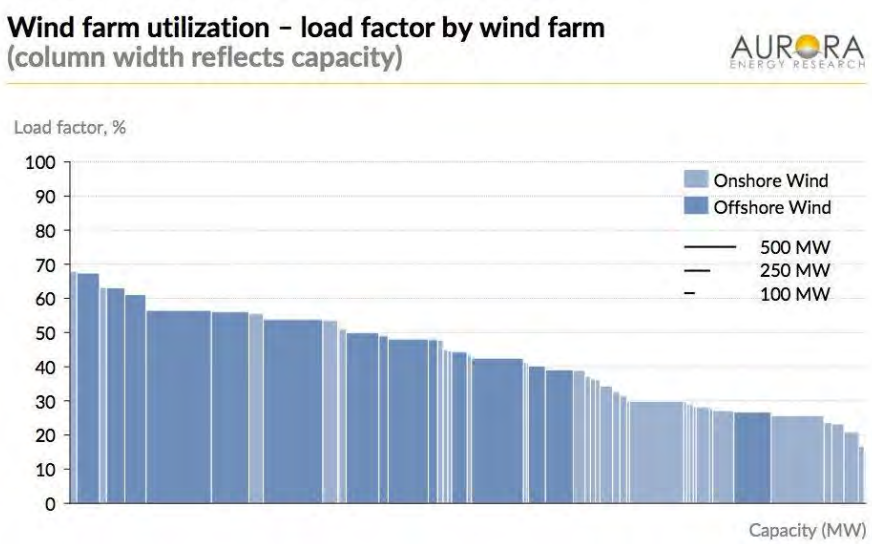
Subsidy-free Offshore Wind is Transformational

The latest offshore wind turbines are 10 MW each and expected to have a load factor of around 57% according to the latest CfD - these need much less gas back-up than onshore wind



Appendix 3 - Load Factors

Technology Type	Delivery Year	
	2023/24	2024/45
ACT	89.3%	89.3%
AD (>5MW)	90.3%	90.3%
Dedicated Biomass with CHP	87.0%	87.0%
Geothermal	91.0%	91.0%
Offshore Wind	58.4%	58.4%
Remote Island Wind (>5 MW)	47.8%	47.8%
Tidal stream	38.9%	38.9%
Wave	36.0%	36.0%

World's most powerful offshore wind turbines officially unveiled

07 September 2018 (0 Comments)
Posted by: Rob Norris
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RenewableUK is highlighting the innovative technology being used at Vattenfall's European Offshore Wind Deployment Centre offshore wind farm in Aberdeen Bay, which is officially opened today.

The 11 turbines include two 8.8 megawatt (MW) turbines standing 191 meters tall, which are the most powerful operating anywhere in the world. The project has a total capacity of 93.2MW – enough to meet the electricity needs of 70% of households in Aberdeen.

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What about Gas Generation?

- A May 2018 WWF report said that we need to keep existing gas capacity as there is no alternative to gas back-up for a windless week in January

"Despite impressive cost reductions in recent years, lithium batteries are unsuited to provide backup for multi-day wind lulls (attempting to do so would be inefficient and prohibitively expensive). Other new storage technologies show promise but are further away from full commercial deployment. Therefore, in 2025 we expect much of the backup capacity will be provided by existing gas. In the longer term to ensure the UK continues to meet its carbon budgets a low-carbon replacement will need to be found - this is one of the key challenges of the UK's energy transition".

See Page 26: https://s3-eu-central-1.amazonaws.com/centaur-wp/theengineer/prod/content/uploads/2018/05/14122525/Coal-To-Clean-May-2018.pdf

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How much existing Gas Generation?

- The Electricity Capacity Market is designed for the 'Windless Week in Winter' - with capacity shown below from latest auction in 2018

3: T-4 Breakdown of Awarded Capacity by Prima

ıary Fuel Type	Capacity (MW)
Bio-fuel	23
Biomass	61
Coal	2,565
Diesel	361
Distillate	225
DSR	1,201
Gas	29,611
Hydro	654
ıterconnector	4,558
Nuclear	7,926
orage - Battery	153
e - Compressed Air	3
ɔrage - Pumped	2,524
Waste	547

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CCGT Business Case (1)

- The direction of travel in the electricity market is for very low gas back-up generation load factors due to:
  - High load factor offshore wind
  - Onshore wind (though not so attractive due to low load factor)
  - Solar
  - Interconnectors
  - Demand side response
  - Electricity storage including vehicle-to-grid (V2G)
  - Possibility nuclear plants get further life extensions
- Biomass is likely to be gone by 2030 due to no subsidy.
- Given the above, it is realistic to expect <10% gas load factor by 2030
- It is possible one or two CCGTs could run at higher load factor but a lot of time the electricity commodity will not cover the cost of gas
- SSE/Siemens are building a smaller CCGT at Keadby with a claimed 63% efficiency
- RWE cancelled Tilbury
- Capacity market in 2020 likely to give low price again - not enough new demand, so who would build CCGT for 2024-5 if load factor is <10% by 2030? No Business Case

CCGT Business Case (2)

RWE Generation was looking to build the Tilbury Energy Centre on the site of the former power station, which is currently being demolished.

The centre would have featured various types of gas turbines and an energy storage facility, but the company has announced the development will not be progressing at this time.

A statement from the company reads: "RWE has decided to freeze the development of Tilbury Energy Centre.

"This decision was made based on current market conditions and project costs. As with any development project, options are continuously evaluated and only progressed if they become economically viable.

"The decision to freeze Tilbury Energy Centre has not been taken lightly, it will be a disappointment for those who have been working so hard to get us to the stage we have reached. We would like to sincerely thank the local authorities and community for their support during the past year.

"As always, RWE will constantly explore options for how best to develop our site in Tilbury, which remains a good location for future energy options."

- RWE Tilbury
  - Abandoned Nov 18

Work is officially underway to build what is claimed will be the most efficient combined cycle gas turbine (CCGT) power plant in the UK.

The £350 million Keadby 2 project – being developed by SSE and technology partner Siemens – will be capable of generating up to 840MW of electricity, with 63% efficiency.

It will sit alongside the energy supplier's existing gas-fired Keadby Power Station and help provide flexible energy capacity to the grid, with the turbine able to reach full power in 30 minutes.

Wesley Tivnen, Managing Director for Power and Gas at Siemens said: "This station will mean the UK can move away from coal-fired power and still have synchronous generating capacity on the grid to complement intermittent renewable generation. If the UK is to meet decarbonisation targets and keep the lights on, we'll ned to see a mix of technologies used to power the grid."

The plant is expected to enter commercial operational in 2022.

- SSE Keadby 2
  - In build by 2022

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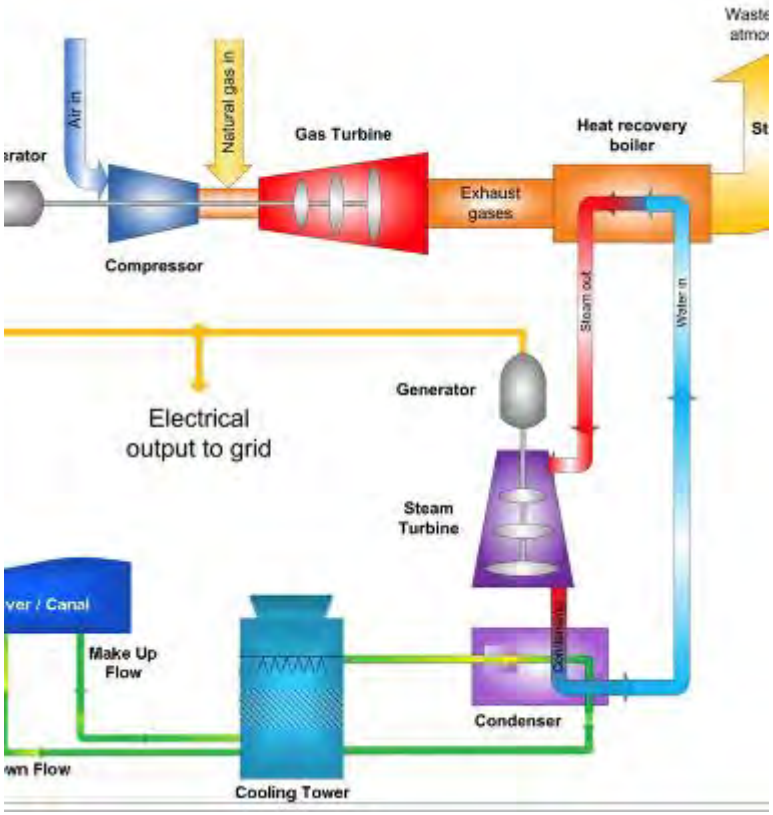
29,611 MW of Gas CCGT Received Capacity Payments

- A gas CCGT typically has 2 Open Cycle Gas Turbines (OCGTs) that burn gas to generate electricity, around 36% efficient
- There is also 1 Steam Turbine (ST) which makes electricity from steam made from the waste heat from the GTs, total efficiency around 55 – 60%



- In effect, we have around 20,000 MW of OCGT and 10,000MW of ST
- At a low load factor post-2030 there is unlikely to be sufficient waste heat from the OCGTs to run the STs for 2–4 hours
- So, in effect we need 10,000 MW of new gas generation to stand still
- This can be OCGT or gas engines

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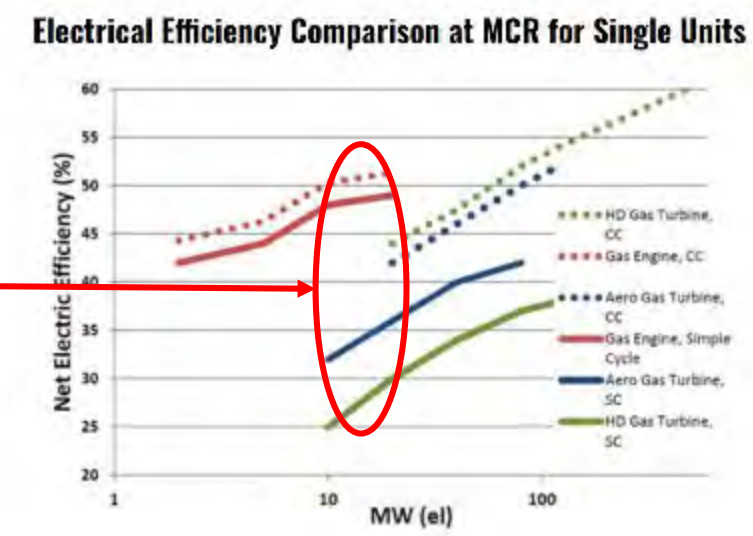
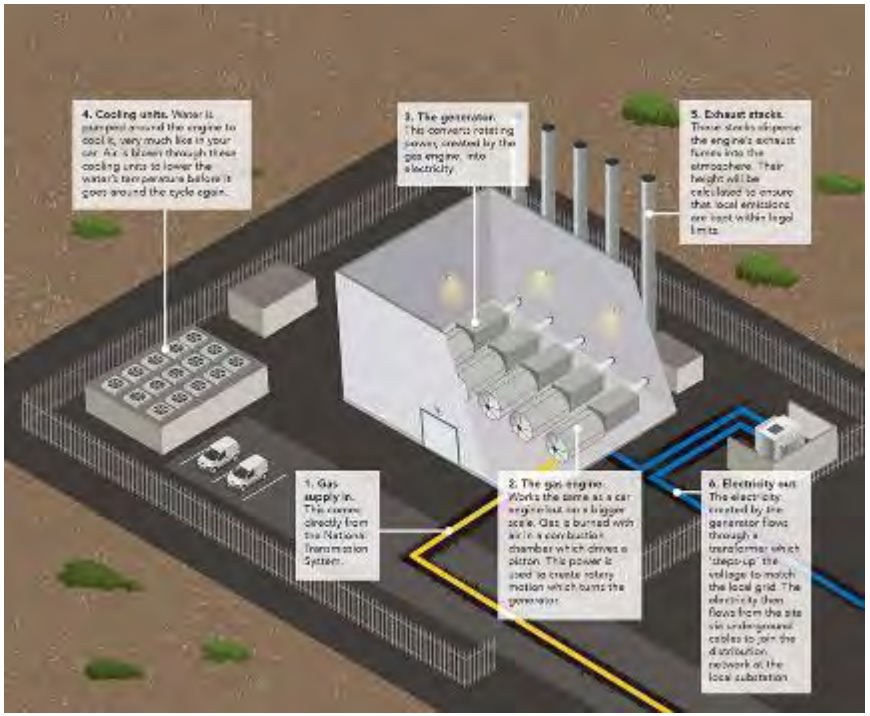
CCGT v OCGT v Gas Engines

- An advantage of gas engines is their flexibility and ability to ramp up very quickly
- Gas engines are also significantly more efficient that OCGTs for units of 20MW or less
- A 20 MW gas engine requires 20 – 50% less fuel than an OCGT
- These engines typically inject electricity into the 11KVA grid but Centrica are building on sites of CCGTs e.g. 50 MW at BRIGG *(below)*





Centrica Quote:

"Together, the engines will be operated as a highly flexible 'peaking plant' that will be able to go from a cold standstill up to full power in under two minutes. This is a feature that is becoming increasingly important as more intermittent renewable capacity such as wind and solar comes on line.

Our expectation is that the plant will typically run for only a few hours a day during the week when demand is at its highest."

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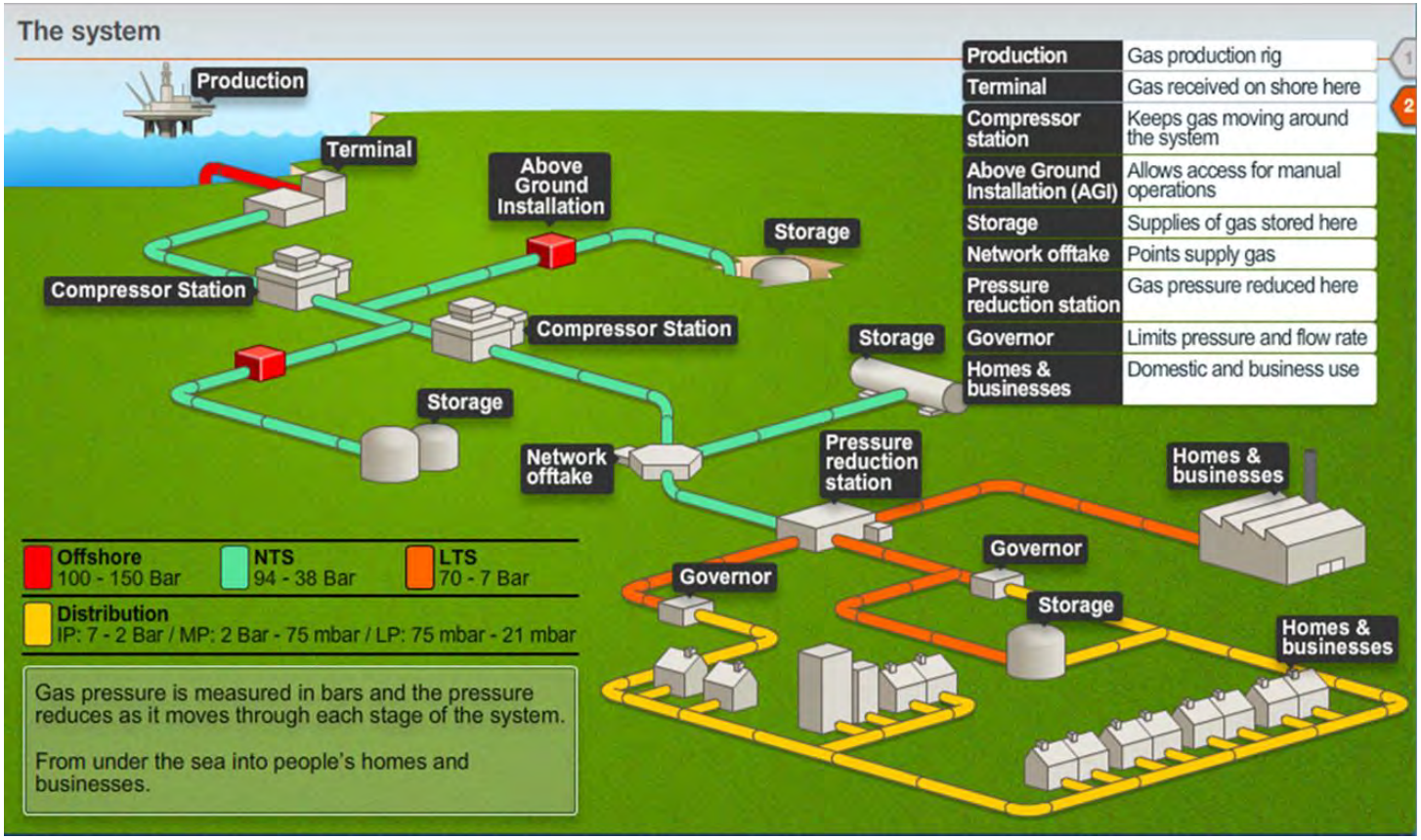
UK Gas Network



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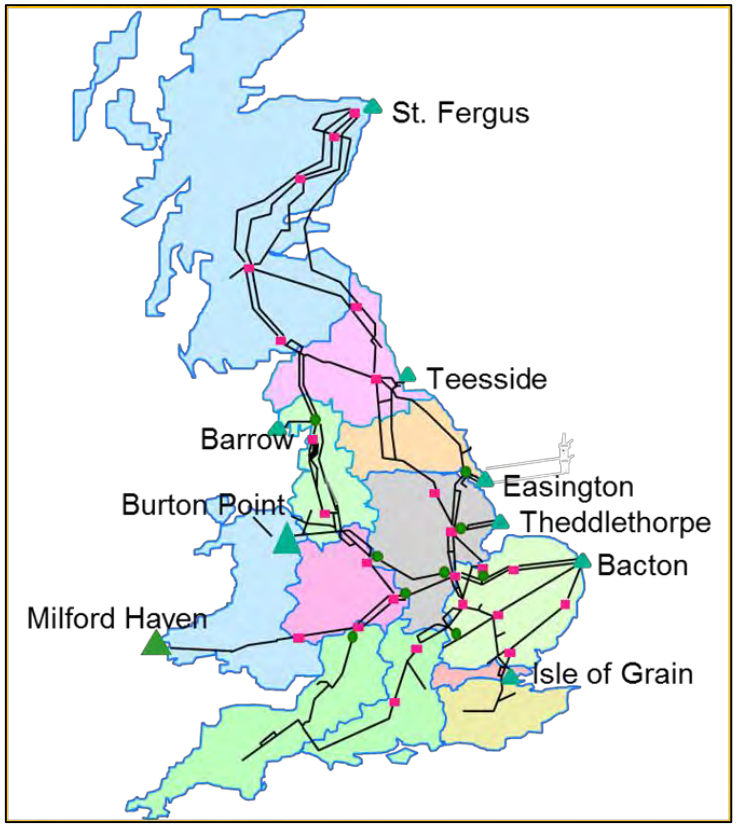
Gas Systems / Networks

National Transmission System

Owned and operated by National Grid



Gas Distribution Networks

Various owners / operators

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Pressure Tiers

National Grid National Transmission System

- **NTS – 50 – 100 bar**
  - Un-odorised network, no CV target
  - CCGTs supplied from this
  - Avoids LDZ charges (see next slide)

Gas Distribution Networks

- **LTS 12 bar to 70 bar, but most at 19 or 42 bar**
  - Very rarely have capacity issues
  - All metal – however new high pressure PE at 19bar now possible
- **IP (4 – 6.9 bar)**
  - Good coverage across UK
  - Usually have good capacity
  - PE or metal construction
- **MP (75 mbar to 2 bar)**
  - Very high coverage across UK
  - PE or metal construction
  - Pressure likely to need 'boosting' to match engine requirements

Transportation Charging

Benefit of NTS Direct

		Load Factor						
		5%	10%	15%	20%	25%	30%	35%
Indicative Network Transportation Charge (£/annum)	1MW	£11,100	£18,800	£26,250	£33,300	£34,900	£40,700	£43,000
2	MW	£18,800	£33,300	£40,700	£52,000	£62,750	£64,500	£73,700
3	MW	£26,250	£40,700	£57,300	£64,600	£78,250	£91,500	£104,600
4	MW	£33,300	£52,000	£64,500	£82,700	£100,000	£118,000	£135,000
5	MW	£34,900	£62,750	£78,200	£100,000	£122,500	£144,000	£164,000
10	MW	£62,750	£100,250	£143,500	£184,250	£270,000	£285,000	£300,000
20	MW	£100,200	£184,250	£440,000	£470,000	£500,000	£525,000	£550,000
50	MW (DN)	£825,000	£850,000	**£875,000**	£900,000	£930,000	£960,000	£985,000
50	MW (NTS)	£150,000	£175,000	**£200,000**	£225,000	£245,000	£270,000	£295,000
				saves £675 k a year				

- NTS connection avoids LDZ charges paid for connections to the DN (Distribution Network)
- Good option for >20MW
- Savings increase as load factor falls

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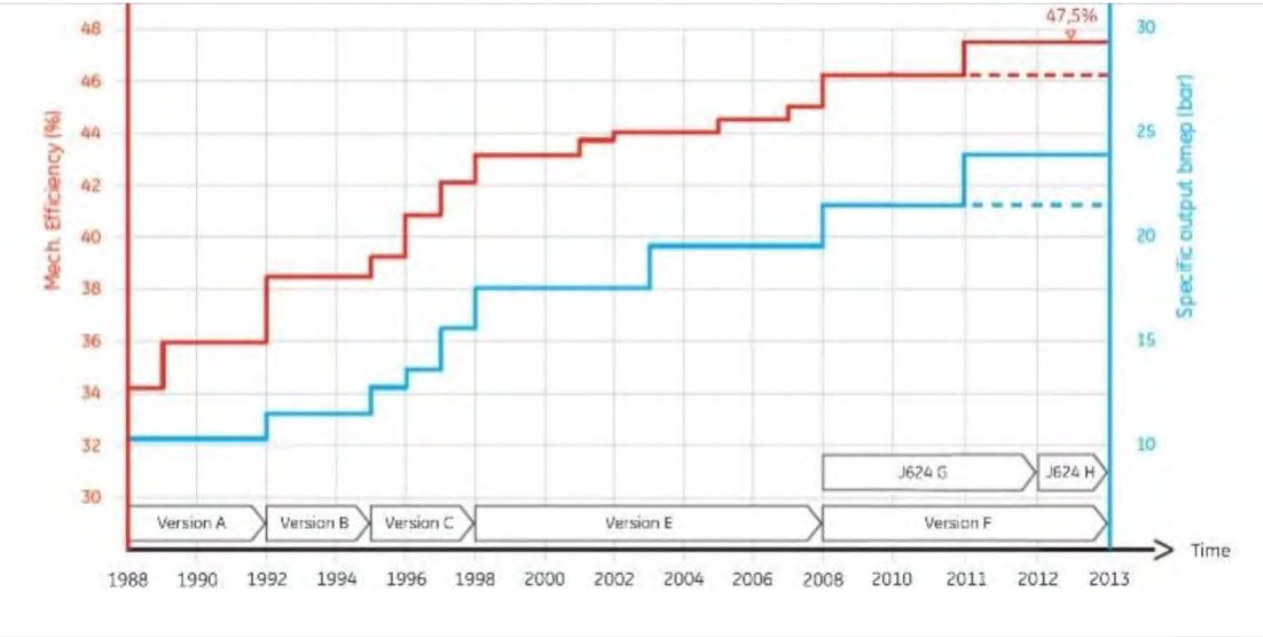
Efficiency of Gas Engines

- This graph shows that spark ignition gas engines have become much more efficient in the last 30 years
- Sales historically based on CHP with >90% load factor



- It may be that the <10% load factor gas engines are not so efficient as the above - capex is a key driver with low running hours (for 95% load factor CHP efficiency is more important)
- Large back-up gas engine plants are being installed in US (next slides)

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225MW Denton Energy Centre in Texas

- 225MW plant with 12 gas-powered engines
- Each 18.75 MW
- 100% renewable over the year but not on daily basis – gas back-up

6/1/2018 12:00:00 AM

The City of Denton and Denton Municipal Electric (DME) have announced that the Denton Energy Center (DEC) power plant will begin commercial operation on July 1. While the DEC has been going through testing throughout the spring, the commercial operation of the DEC will allow DME to begin providing wholesale power to the Texas grid.

"Since 1905, DME has maintained high quality, reliable electric service for Denton," said DME General Manager George Morrow. "Achieving commercial operation is a major milestone for the DEC project, DME, and the City of Denton as we continue our focus on providing exceptional service for our customers."

The DEC is a 225-megawatt, quick-start, natural gas-fired power plant comprised of 12 reciprocating internal combustion engines and generators. Individually, each "gen set" weighs 416 tons and can generate up to 18.75 megawatts of electricity. The DEC includes advanced supervisory, safety, and emissions control systems; additional exhaust gas reduction equipment and noise reduction upgrades to the power blocks, and exhaust, fuel, and cooling water systems. The DEC took 423,000 man hours to construct, with up to 255 individuals working on site. The project was constructed with a focus on safety, which resulted in zero reportable safety incidents.

Home > Government > Departments > Denton Municipal Electric > Renewable Energy

RENEWABLE ENERGY

The City of Denton is a national leader in renewable energy adoption, setting a goal to achieve 100 percent renewable energy for all customers by 2020. Learn more below about how Denton is leading the way in renewable energy.

DENTON RENEWABLE RESOURCE PLAN

On Feb. 6, 2018, the City Council adopted the Denton Renewable Resource Plan (DRRP), which set a goal to have 100 percent of Denton's energy load under renewable energy contracts by 2020. While Denton had already made a commitment to increase the City's renewable portfolio, the DRRP represented an actionable plan to help Denton in our efforts to reach 100 percent renewable.

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128MW Plant - New Orleans

- 128MW plant with 7 gas-powered engines
- Each 18.75 MW

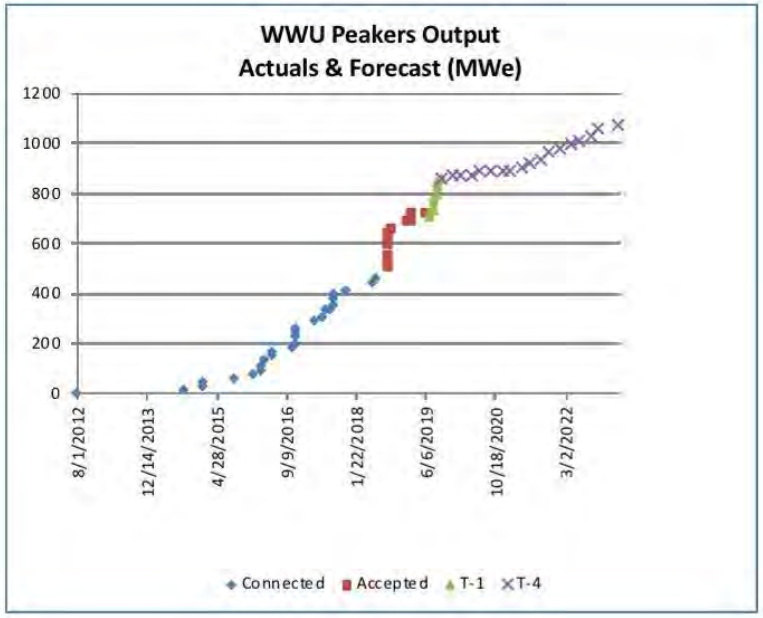
New Orleans chooses Wärtsilä Smart Power Generation solution for new power plant

Wärtsilä Corporation, Press release, 21 March 2018 at 2:00 PM E. Europe Standard Time

The technology group Wärtsilä's Smart Power Generation solution has been selected to power the New Orleans Power Station, a 128 MW plant to be constructed at the retired Michoud power plant site in New Orleans, Louisiana, USA. The retired plant, which was the only power generating facility within the city's borders, was shut down due to economic and operational considerations. The New Orleans City Council recently approved the new 128 MW plant, which will be powered by seven Wärtsilä 50SG reciprocating gas engines.

The Growth of the Gas Engine Market in GB

- This graph shows growth in Wales and West Utilities area (Wales and SW of England)
- Electricity was more valuable in this region with premium embedded benefits payments, but the 11 KVA grid is now saturated due to solar and back-up gas engine plant development is moving north



- E.g.: Yorkshire - in 2017, the Planning Inspectorate said that a 14 MW gas back-up plant was necessary for renewables and could be built on land reserved for renewables as without gas, you cannot have wind/solar

Source: https://acp.planninginspectorate.gov.uk/ViewDocument.aspx?fileid=22737684

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2 New 49MW Gas Power Plants from Centrica

- 49MW plant with 5 gas-powered engines
- 9.8MW each
- Built next to existing CCGT
- NTS

Centrica completes two 50MW fast-response plants in Brigg and Peterborough

Distributed Energy

08 OCTOBER 2018

Share

Centrica plc has completed construction of two new fast response power plants in Brigg, North East Lincolnshire, and Peterborough. Capable of producing enough power to meet the needs of 100,000 homes, the 50MW* facilities have been designed to respond to peaks in demand within two minutes.

The new plants have been built on land adjacent to Centrica's existing gas-fired power plants and each consist of five reciprocating gas engines that will typically run for a few hours a day. The facilities will be operated from Centrica's new Energy Control Centre in Peterborough and maintained by local teams.

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Back-up Gas Engine Plant Operators

UK Power Reserve

Sembcorp Industries has agreed to buy flexible generation company UK Power Reserve (UKPR) from the private equity firms Inflexion and Equistone for £216 million.

UKPR currently has a portfolio of more than 1GW of distributed generation assets spread across 32 sites in England and Wales, with 533MW already in operation and a further 480MW in development and construction expected to come online by 2019.

The portfolio largely consists of gas-fuelled reciprocating engines, but also includes 120MW of battery storage as well as a limited number of diesel engines.

Welsh Power

Welsh Power currently has 25 sites across the UK. Click on the map markers to see our sites and their energy capabilities.

Green Frog Power

Our first gas-powered balancing plant was built in just three months in 2015. With new software and new engineering, it was the blueprint for the next generation of balancing plant operated by Green Frog. Over the past two years we have built over £150 million worth of new gas plants across the UK. These natural gas plants can start and be online in 30 seconds, which is unique in the global market. Just as importantly, they can be started and stopped repeatedly without an impact on the equipment.

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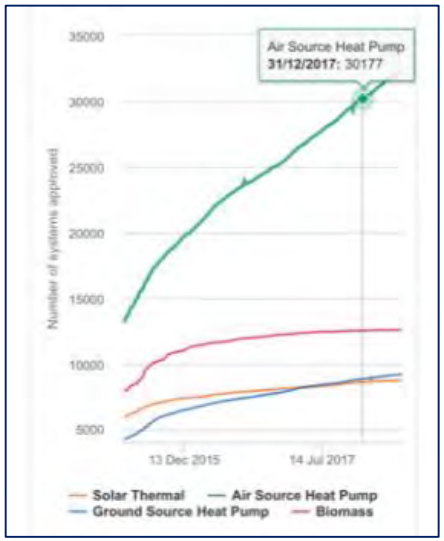
De-carbonisation of Heat by 2050

- By 2050, it's likely that there will be a significant number of heat pumps
- Market growing due to RHI but <10,000 new ones per annum



- Imperial report for the CCC indicated scenarios with as much as 150,000 MW of back up gas
- There is still likely to be increased electricity demand due to EVs and heat pumps
- Windless week in January is a fundamental issue regarding back-up generation capacity (and availability of gas but that's a separate issue)

Imperial College London

Impact of heat decarbonisation strategies on the electricity generation portfolio

Different decarbonisation pathways require substantially different electricity generation portfolios, as the choice of heating pathway will have significant implications for gas and electricity systems. Optimal generation portfolios for the core decarbonisation scenarios are presented in Figure E. 3. Coordination of the design and operation of gas, heat and electricity systems is important for minimising the whole-system costs of decarbonisation.

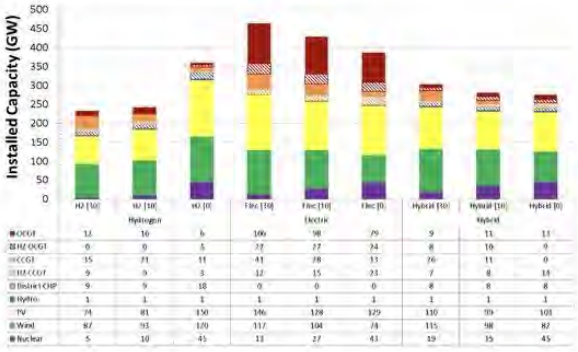


Figure E. 3 Optimal generation portfolio in the core decarbonisation pathways

From the optimal generation portfolio proposed by the model, a number of conclusions can be derived:

1. **Maximum capacity of low-carbon generation that is assumed to be available by 2050 is sufficient to reach the zero-carbon target[18].**

Across all scenarios a significant capacity of low carbon electricity generation PV, wind and nuclear is required, representing an increase of 130-450% of electricity generation capacity on today's levels (of around 100 GW). The optimal generation portfolio also includes hydrogen based CCGT and OCGT plant. There is only one case, i.e. 0Mt H2 pathway, where the capacity of PV, wind and nuclear hit the upper limits of UK deployment potential by 2050[19]. This increase in electricity generation capacity

[18] The CCC defined the upper UK deployment limit for low-carbon electricity generation technologies as wind, PV, CCS and nuclear is 120 GW, 150 GW, 45 GW and 45 GW for wind, PV, CCS and nuclear respectively.

[19] Due to insufficient capacity of low-carbon electricity generation, this case cannot meet the zero-carbon target and the annual carbon emissions were 2 Mt/year.

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Nuclear Lifetimes

- Out of the 15 operational nuclear reactors in the UK, the last is scheduled to close in 2035
- Currently only 1 new power nuclear station, Hinkley C, is being constructed – with a planned capacity of 3,260MWe
- Uncertainty in relation to whether lifetimes of plants can be extended

Power Station	Net MWe Output	Closure Date
Dungeness B	1040	2028
Hinkley Point B	840	2023
Hunterston B	830	2023
Hartlepool	1190	2024
Heysham 1	1160	2024
Heysham 2	1240	2030
Torness	1205	2030
Sizewell B	1195	2035

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Conclusions

- 57% load factor offshore wind with close to no subsidy, combined with interconnectors and DSR and existing nuclear (will lives be extended?) is a killer for:
  - Nuclear
  - Onshore Wind
  - Old CCGTs (definitely the Steam Turbine part)

- Gas load factors are heading to be very low - new CCGTs seem to be the wrong technology for new plants operating from 2024-25

- It may merit keeping the OCGT part of CCGTs alive until 2030 if the capacity payments justify it

- Building gas engines on the NTS makes sense due to avoided LDZ Charges which are highly significant for low load factors
  - So, the CCGTs can replace the Steam Turbine with gas engines and have a more flexible plant

- There appears to be an inevitable boom in gas engines on the way

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