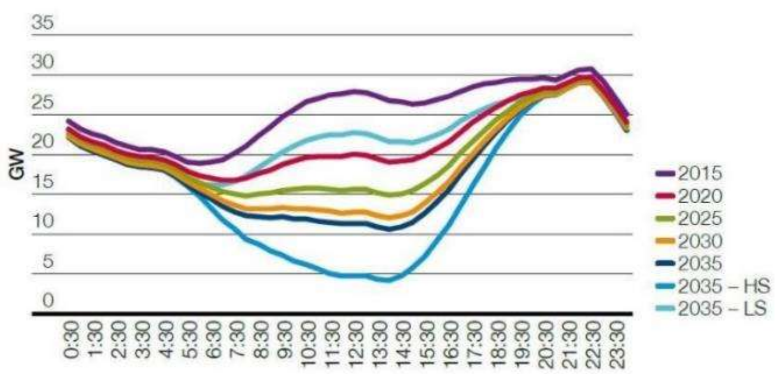
The Lockdown: A Partial Test of the 2030s Grid

The first UK lockdown (Spring 2020) provided a trial run of the "summer minimum" challenges of operating the grid as it will be in the 2030s and 2040s, with renewable generation as a high proportion of demand. Indeed, National Grid themselves state *"The conditions of summer 2020 will not be unique by 2025, they will be normal."* Demand was historically low and renewable generation historically high on both the distribution and the transmission grids. Not only did this mean that electricity flows through the transmission grid dropped severely, but also inertia dropped to levels that required extensive intervention.

This reinforces the need for Storelectric's CAES to provide not only absorption of renewable energy when it exceeds demand, but also the real inertia and other related grid stability services that are currently being provided by gas-fired power stations. Storelectric's plants not only provide more inertia than an equivalent-sized power station, but also provide it 24/7 if needed.

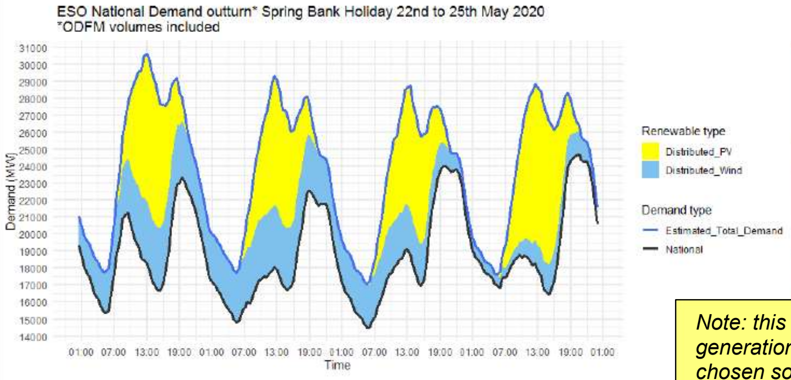
Minimum Energy Flows

Figure 96
Consumer Power summer transmission demand across years



In their Future Energy Scenarios 2015, National Grid declared that to keep the grid out of black-start conditions at least 5GW must flow through it. Based on then-known distributed solar generation, they believed that they risked dropping below this figure by 2035 in the worst-case scenario. However they had underestimated solar by 3GW and omitted to consider distribution-connected wind, so the first time they hit the 5GW threshold was actually in August that same year.

Bank Holiday Weekend (22nd to 25th May) | Demand Outturn



Date	Cardinal Point	Volume of ODFM enacted (increases ND) (MW)	National Demand inc ODFM (MW)	Dist. wind (MW)	Dist. PV (MW)
Fri 22nd May	1B	NONE	**15390**	2321	0
	3B	NONE	**16680**	3681	7330
Sat 23rd May	1B	999	**14813**	2909	31
	3B	1902	**16744**	3611	6530
Sun 24th May	1B	792	**14500**	2522	173
	3B	NONE	**16970**	2451	6340
Mon 25th May	1B	NONE	**16845**	622	254
	3B	1020	**16465**	1763	8170

Note: this is not the period of highest renewable generation during the pandemic. This period is chosen solely because National Grid evaluated the costs of their actions for it.

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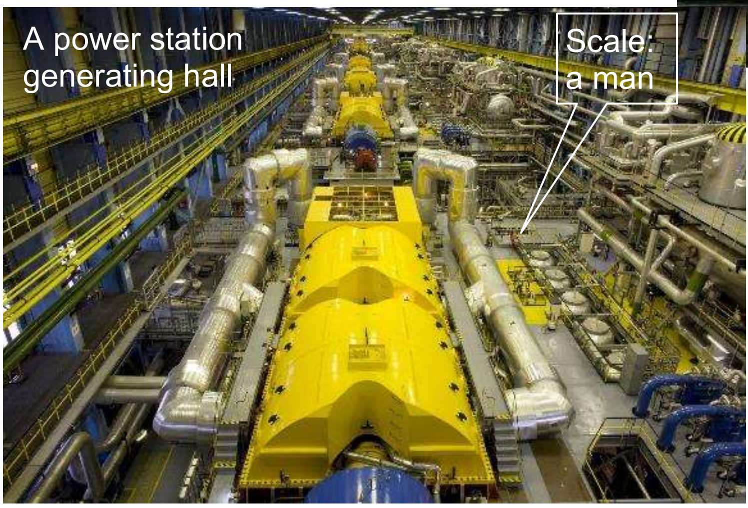
During the COVID-19 Lockdown, demand has plummeted as a small increase in domestic consumption has fallen far short of a huge decrease in industrial and infrastructure (e.g. trains) consumption. Simultaneously the weather was perfect for renewable generation for weeks on end, with unseasonably strong sunshine combining with persistently strong winds. As a result, afternoon minima dropped below overnight minima on the transmission grid.

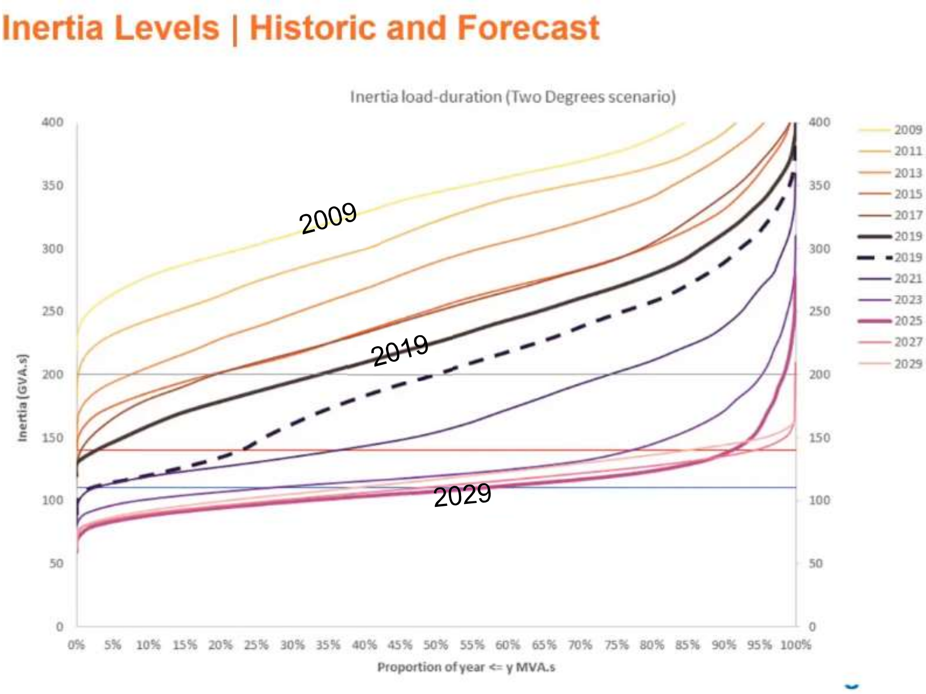
Inertia and Grid Stability

As fossil fuelled power stations continued closing during the last decade, it became apparent that they were providing many more services than just energy. Prime among these was inertia, with related capabilities such as real reactive power / load, ROCOF (Rate Of Change Of Frequency) and Phase Locked Loops – and many that are still more esoteric.



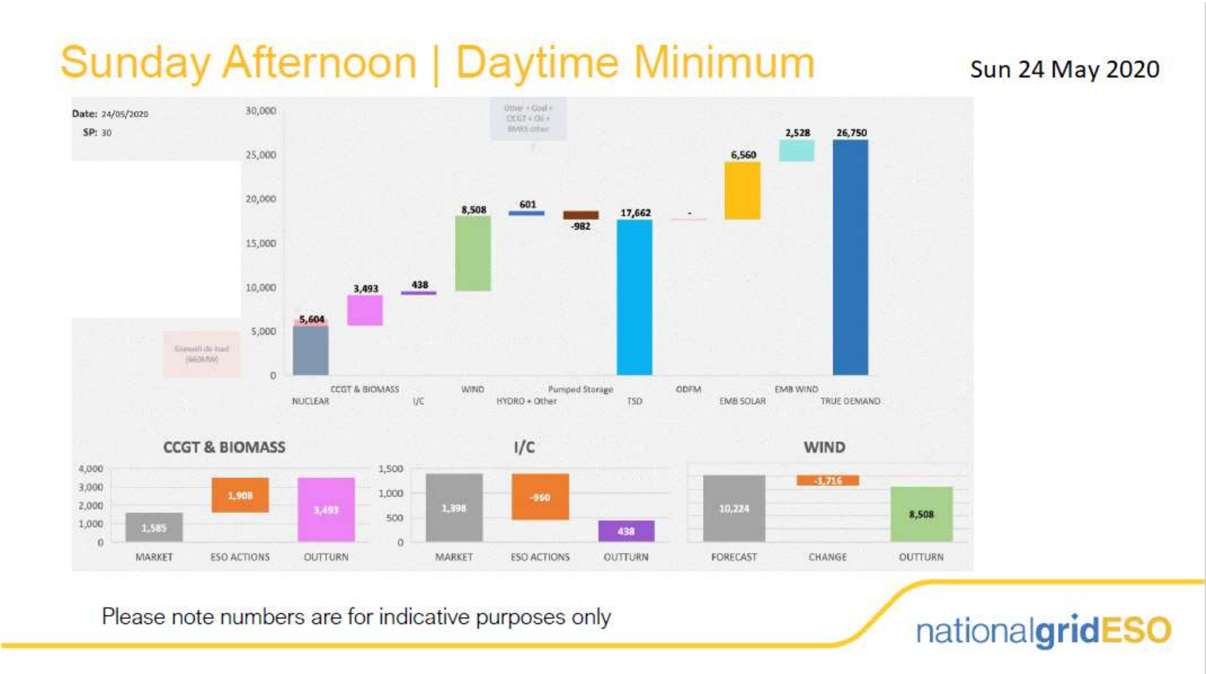
What is inertia? In a car, if the engine fails the weight of the car provides the momentum that means that it slows gently, enabling it to come to a save halt. Those in the car are protected. Without that momentum, the slow-down following the engine fault would be like hitting a brick wall. Inertia is momentum for rotating machines: power stations, being large rotating machines, have it in abundance whereas DC connected systems (including solar and wind generation, and interconnectors) don't.

Therefore as power stations close, replaced by DC-connected generation, inertia drops alarmingly. The fundamental cause of the black-outs across the UK on 9th August 2019 was that two initial trips, one in a power station and the other in a wind farm, turned into a cascade of subsequent trips around the country because there was insufficient inertia on the grid.



And inertia is dropping very fast: this graph shows how it's decreased over the last decade 2009-19, and is expected to continue to decrease 2020-29. National Grid has initiated many [investigations and activities] into these, including a number of [new contract types] and pathfinder activities (in the yellow box on the right of the first link) in order to contract for these stability services. All versions of Storelectric's CAES can provide all these services 24/7, regardless of whether charging, discharging or neither.

Consequences for Grids



Therefore National Grid had to undertake a number of actions to preserve grid stability. These include:

1. Pay to increase 1.9GW contracted interconnector imports to 3.2GW
2. Pay for 5.0GW curtailment of wind
3. Pay to turn down nuclear ~0.7GW
4. Pay to turn on 3.4GW power station generation
5. Various other actions

The total cost of these, over a bank holiday weekend, was £51m:

Costs of Managing the Bank Holiday Weekend

22-25 May 2020

Very low demands with low synchronous generation mix

	Friday 22nd May	Saturday 23rd May	Sunday 24th May	Monday 25th May	Total
Overnight Minimum Demand*	15.4 GW	14.8 GW	14.5 GW	16.8 GW	-
Daytime Minimum Demand*	16.7 GW	16.7 GW	17.0 GW	16.5 GW	-
Overnight ODFM Instructed Volume	-	999 MW	792 MW	-	-
Daytime ODFM instructed Volume	-	1,902 MW	-	1,020 MW	-
Balancing Mechanism Costs	£16,000k**	£14,249k	£7,073k	£2,152k	£39,474k
Trading Costs	£600k	£1,420k	£1,624k	£466k	£4,110k
ODFM Costs	-	£4,700k	£1,400k	£1,200k	£7,300k
Total	£16,600k	£20,369k	£10,096k	£3,818k	£50,833k

These costs represent the impact low synchronous generation mix during a normal low demand weekend combined with the suppression of demand brought about by COVID-19. The demands this weekend were some of the lowest expected this year.

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*These demands include the additional demand from the ODFM service, **Constraint costs higher on Friday due to fire under a Transmission line
Please note that these numbers are subject to change.

And this was not the weekend with and greatest actions, as solar was not very high. *And these costs exclude increased imbalance costs and trading price volatility*, the total of which are likely to be considerably higher. Not only is all of this activity exceedingly expensive, but also it increases the grid's emissions. All of this would be completely unnecessary if there were sufficient of Storelectric's CAES on the grid.

And in the 2030s and 2040s?
By the 2030s and 2040s, more power stations will have closed – they may not even be available to be turned on if needed. Interconnectors and DC connected generation will have at least doubled in importance. this situation will be much more frequent – indeed, it is likely to be the normal state of affairs in summer, and quite usual in spring and autumn.

In early June 2020, demand suppression was 11.9%, yielding a carbon intensity of 46g CO_2e/kWh. The annual cost of National Grid actions May-September (5 months) is forecast to be £831m for 10% demand suppression. If similar proportions of renewable energy were to be delivered without demand suppression, the cost would be £831m divided by 90% = £923m. Extrapolating, the balancing costs of a 2040 grid would be £1bn p.a. for those five months alone – assuming (rashly) that sufficient gas-fired power stations will still be available and will remain as cheap by then. This is a rash assumption as they will generate much less electricity per annum than today, so all their annual running costs and amortisation etc. will need to be recovered over such services alone, increasing the price of those services. And note that these costs are for only the peak 5 months in the year. For such services, it can therefore be predicted that ***year-round costs will exceed £1bn p.a. by 2030.***

To the above "summer minimum" issues can be added the lack of electricity on the grid when renewables are not generating sufficient for demand and interconnectors cannot make up the shortfall, such as after sunset on a windless winter evening, or during weather patterns that extend such low-generation period to days or weeks – which will also be a frequent occurrence by the 2040s according to most European countries' energy transition plans. These are the subject of a separate brief.

National Grid provided the following estimates of the costs of summer flexibility with 5, 10 and 15% demand suppression – probably best considered as renewables being a much greater percentage of demand to those degrees. This falls far short of the costs that would arise in a 100% renewable grid. Just for these low levels of renewable penetration, costs are forecast in the range £592m – £725m for the 4 months (£742m – £911m including September).

Month	Outturn 2019 (£m)	Pre-Covid Forecast Baseline (£m)	15th May Forecast (15% -20% suppression) (£m)	5% Demand Suppression (£m)	10% Demand Suppression (£m)	15% Demand Suppression (£m)
May	64.4	121.3	166	[163]	[163]	[163]
June	89	103.8	207.7	129.8	147.2	166.5
July	71.7	110.4	214.9	139.7	160.0	183.1
August	108.7	120.2	217.7	160.1	185.3	212.3
Total	333.2	455.7	826.3	592.6	655.5	724.9
Sept		115.1		149.6	165.6	185.8

Is there a cheaper way?
Yes. And much more effective.

- The maximum requirement for inertia during this period was about 4GW. This could be produced by 2GW of Storelectric's CAES (any technology).
- The requirement for combined extra actions on export, renewables curtailment and storage absorption on Sunday 24th May (close to the maximum) was 1.8GW, again achievable by 2GW Storelectric CAES.
- Not coincidentally, the 9th August 2019 blackouts (see this analysis) and its enormous consequential costs for the economy could have been prevented with 1.43GW natural inertia and back-up electricity.

2GW TES CAES can be built for an estimated £1.4bn (though the first few plants will be a little dearer); CCGT CAES and hybrid will be substantially cheaper per GW output but have less absorptive power (as a majority of input energy is gas, whether methane or hydrogen), so 3-4GW would need to be built. But all these plants would operate commercially, spreading their costs over not only the above services but also many other services too, thereby providing a much cheaper and more cost-effective solution.

And because the technologies are naturally inertial 24/7 (whether charging, discharging or neither, assuming a contract for provision of such services), and would deliver numerous balancing, ancillary and stability services with a single dispatch, grid management and control would be greatly simplified.

About Storelectric
Storelectric (www.storelectric.com) is developing transmission and distribution grid-scale energy storage to enable renewables to power grids reliably and cost-effectively: the world's most cost-effective and widely implementable large-scale energy storage technology, turning locally generated renewable energy into dispatchable electricity.

- Innovative adiabatic Compressed Air Energy Storage (Green CAES ™) will have zero / low emissions, operate at 68-70% round trip efficiency, levelised cost significantly below that of gas-fired peaking plants, and use existing, off-the-shelf equipment.
- Hydrogen CAES ™ technology converts & gives new economic life to gas-fired power stations, reducing emissions and adding storage revenues; hydrogen compatible.

Both technologies will operate at scales of 20MW to multi-GW and durations from 4 hours to multi-day. With the potential to store the entire continent's energy requirements for over a week, global potential is greater still. In the future, Storelectric will further develop both these and hybrid technologies, and other geologies for CAES, all of which will greatly improve storage cost, duration, efficiency and global potential.

About the Author
Mark Howitt is Chief Technical Officer, a founding director of Storelectric. He is also a United Nations expert advisor in energy transition technologies, economics, regulation and politics – invitation here.

A graduate in Physics with Electronics, he has 12 years' management and innovation consultancy experience world-wide. In a rail multinational, Mark transformed processes and developed 3 profitable and successful businesses: in commercialising a non-destructive technology he had innovated, in logistics (innovating services) and in equipment overhaul. In electronics manufacturing, he developed and introduced to the markets 5 product ranges and helped 2 businesses expand into new markets.