https://netzeroweek.com/event-agenda/

ENERGY STORAGE IS NOT WHISKEY –BLENDS ARE BEST!

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Why Medium Duration Energy Storage (MDES) really matters

A WIDE RANGE OF TIMES.

Energy storage (for supporting the electricity grid) matters over timescales ranging from ~1s to ~2.5years.

2.5 years $\cong$ ~80million s $\cong 2^{26}\ s$

Shorter than 1s … handled naturally (and locally) by *inertia*

Longer than 2.5 years … build more wind-turbines/PV-panels!

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over timescales ranging from ~1s to ~2.5years.
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A LOGARITHMIC SCALE FOR TIME …

In music, 1 “octave” corresponds to a factor of 2 in frequency

In music, 1 “semi-tone” … a factor of $2^{(1/12)}$ in frequency …

$2^{(1/12)}$=1.0595. $\log\left(2^{(1/12)}\right) = \log(2)/12 = 0.0578$

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The concept of a “semi-tone” can be related to log(time)

A LOGARITHMIC SCALE FOR TIME

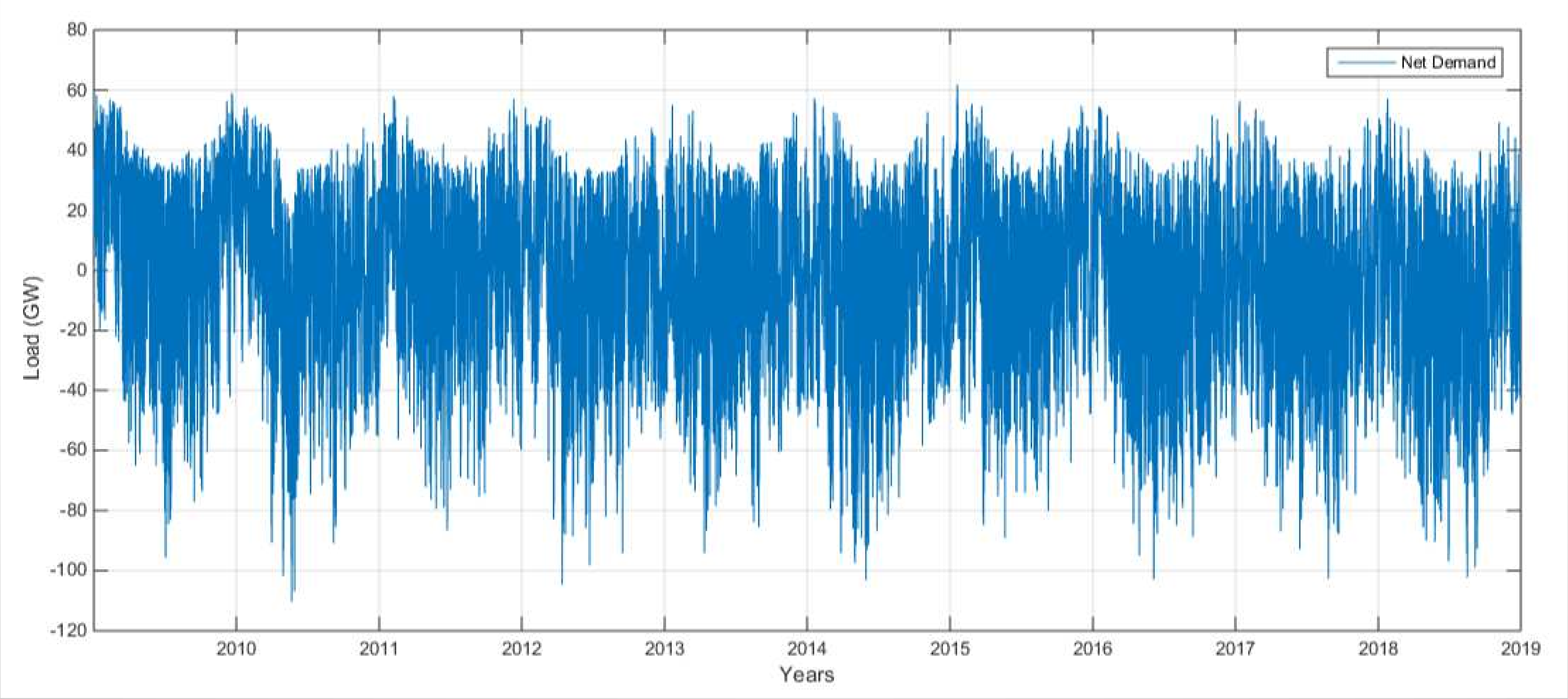
https://www.youtube.com/watch?v=ZY77zDzNmYw

The song *It's too late* by David Bowie in this 1976 album uses a nice simple repeating pattern of semi-tone up-down-up-down

(Play from 1:10 – 1:30)

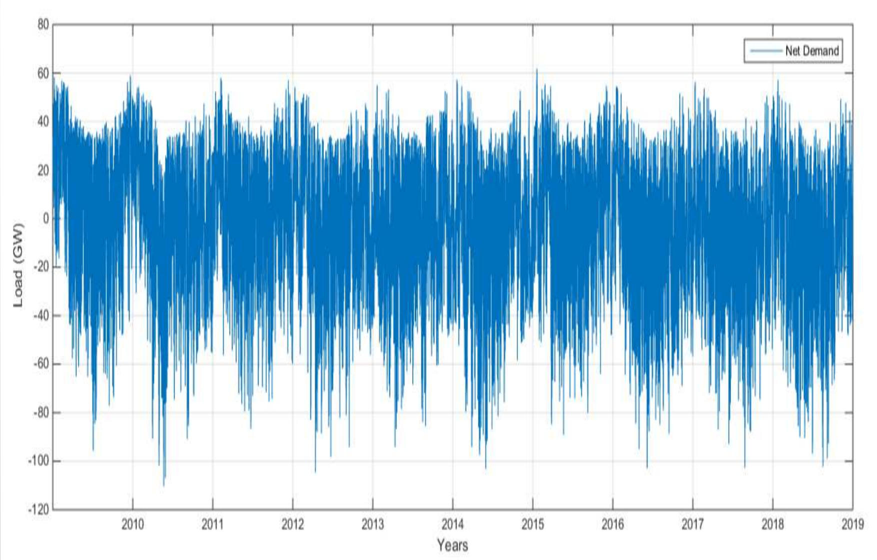
In case a "semi-tone" means nothing to you …

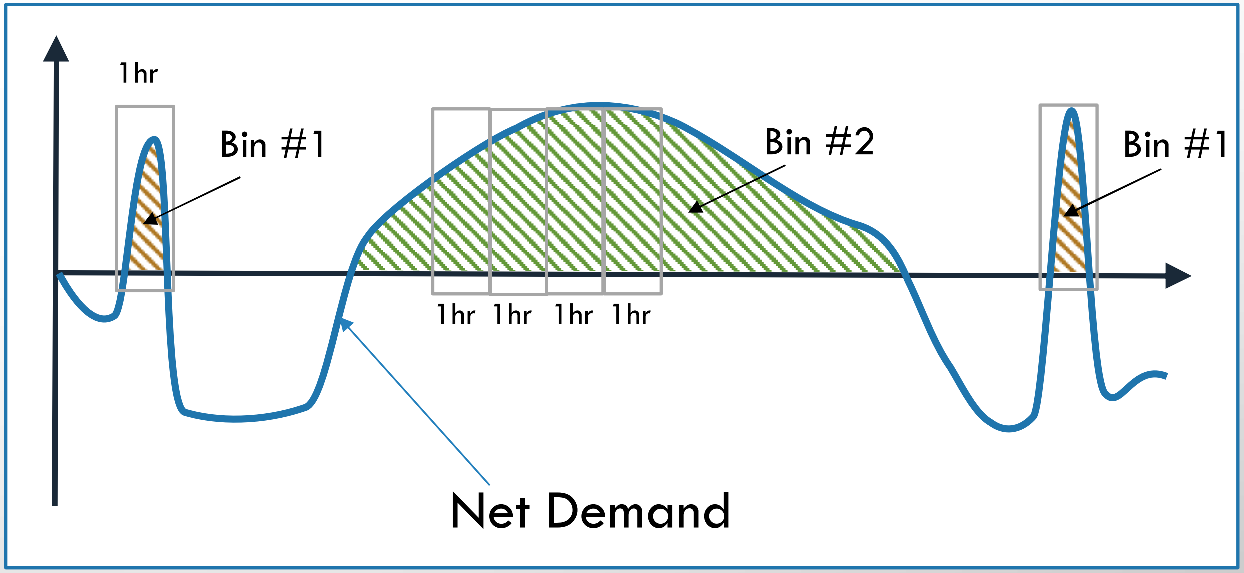
THE RELATIVE IMPORTANCE OF DIFF. DISCHG. DUR<u>NS</u>.



***Net Demand** for the UK over 10 years with if 75% of generation was from wind and 25% generation from PV and 10% over-capacity (i.e. the average value here is slightly negative).*

THE RELATIVE IMPORTANCE OF DIFF. DISCHG. DUR^{NS}.



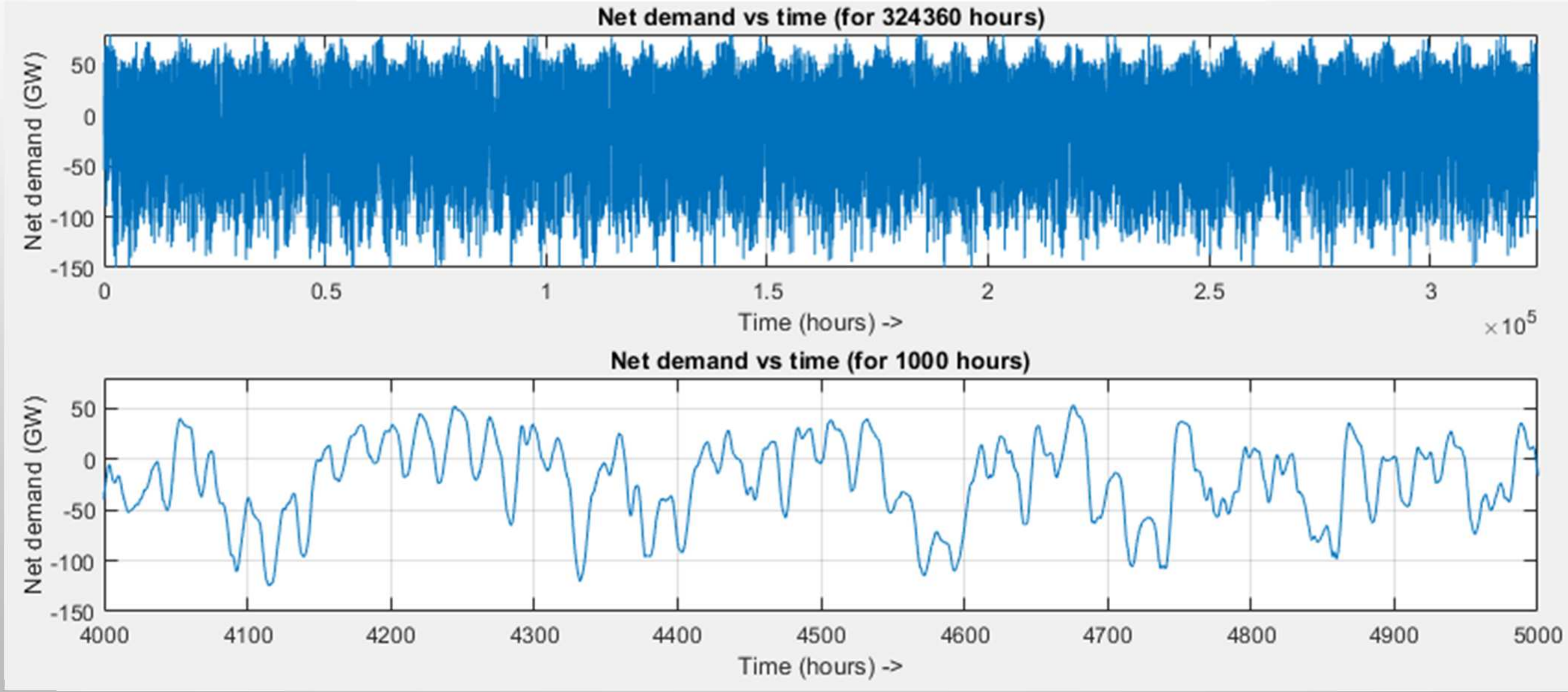


Examine each continuously-positive section in turn and sort these into 3 different "Bins"…

$T_{Discharge}$ <4hrs:	SDES.	(Batteries)	<1% of energy from storage
4hrs < $T_{Discharge}$ < 200 hrs:	MDES.	(CAES, LAES, PTES. …)	~92% of energy from storage
$T_{Discharge}$ > 200 hrs:	LDES.	(Hydrogen , Ammonia, …)	~7% of energy from storage

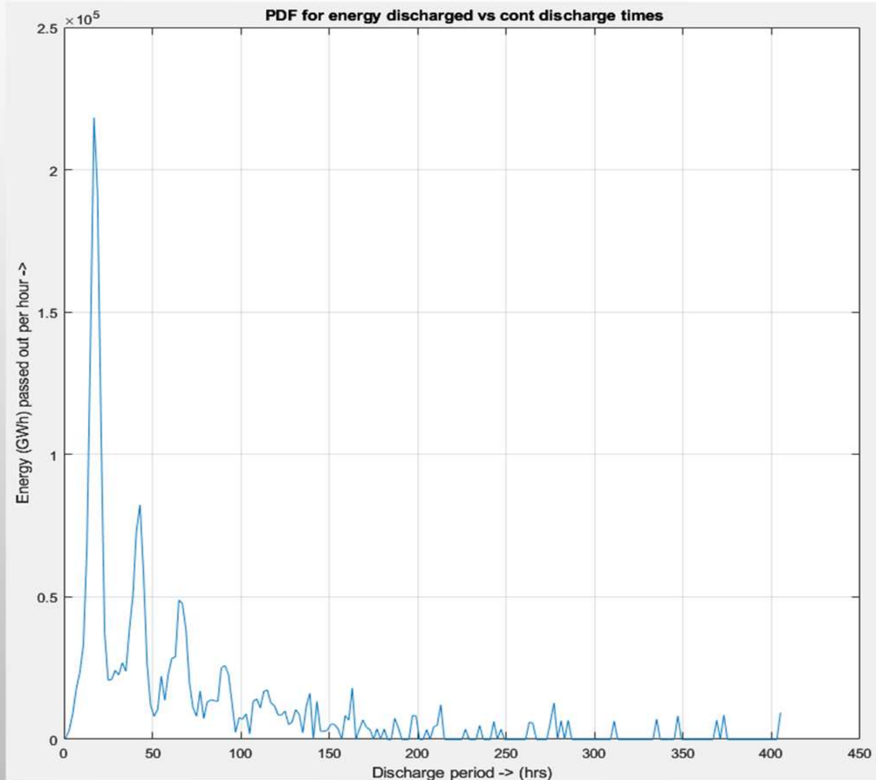
MORE INSIGHT INTO DISCHARGE DURATIONS

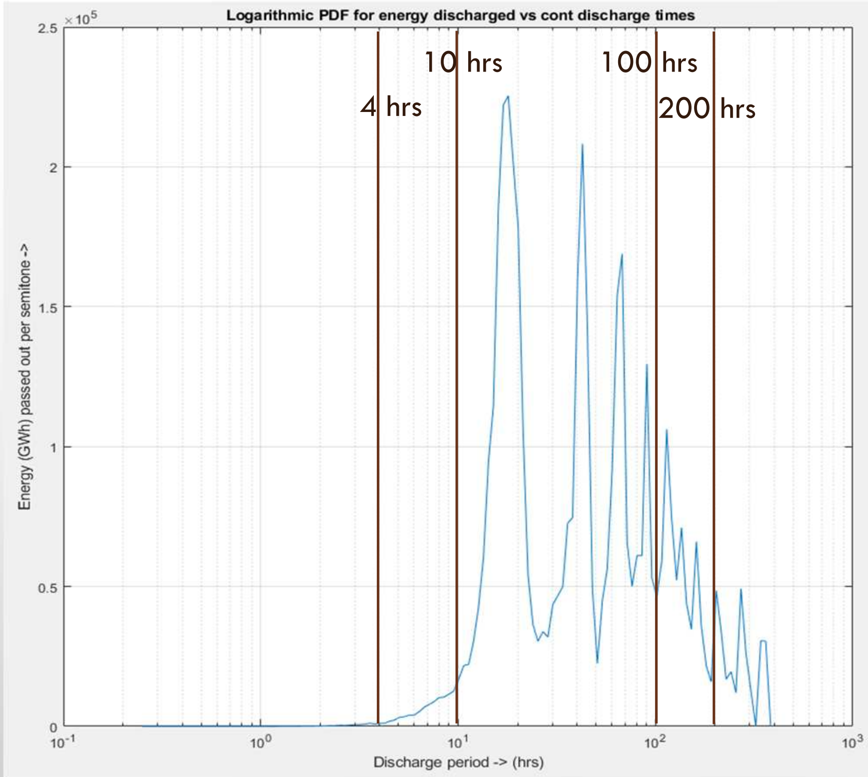
You can analyse *Net Demand* for any future energy scenario to discover how the energy that would be discharged from storage is distributed over various different discharge times. The data below is that used in the Royal Society report.



MORE INSIGHT INTO DISCHARGE DURATIONS:

Splitting the data into many more divisions yields a *probability density function* (PDF) showing how storage output energy is distributed over periods of continuous discharge. 'Can use either linear or logarithmic scale for discharge time.





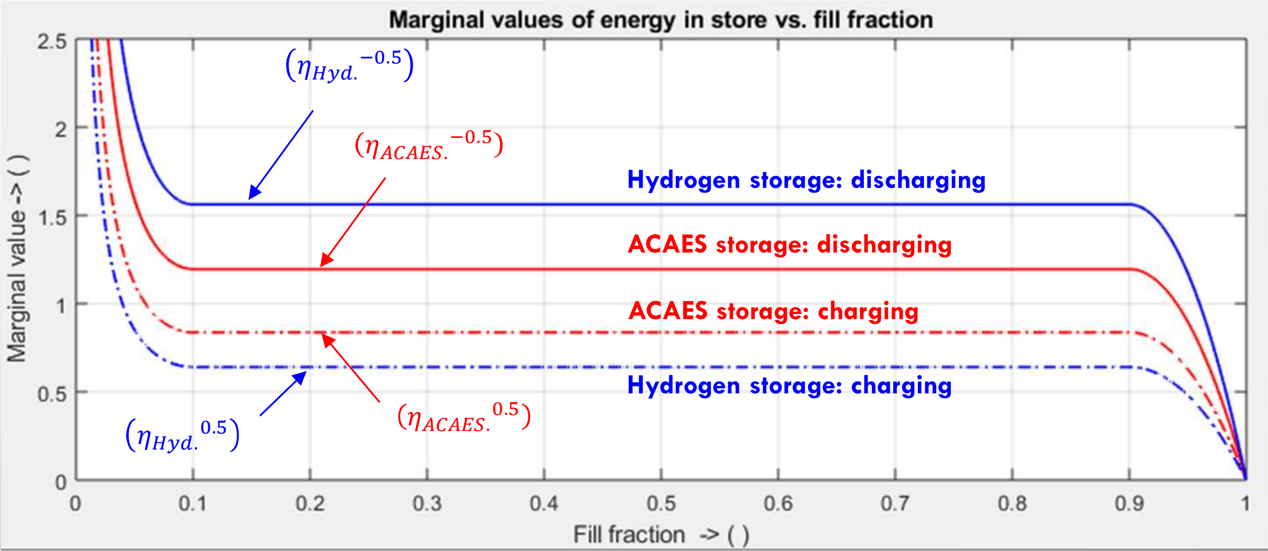
The "periodicity" on the linear scale of discharge times reflects the fact that if storage is discharging for 17 hrs (first peak) it is quite likely to continue discharging for (17+24) hrs or (17+48) hrs.

A TOOL FOR SYSTEMS WITH *N* STORES.

With 2 or more stores in the system, we must address *scheduling*.

A good scheduling approach for the operation of multiple stores in a system is described by Zachary *et al*. [1]

This is implemented in …
www.era.ac.uk/resources/NStore_sim

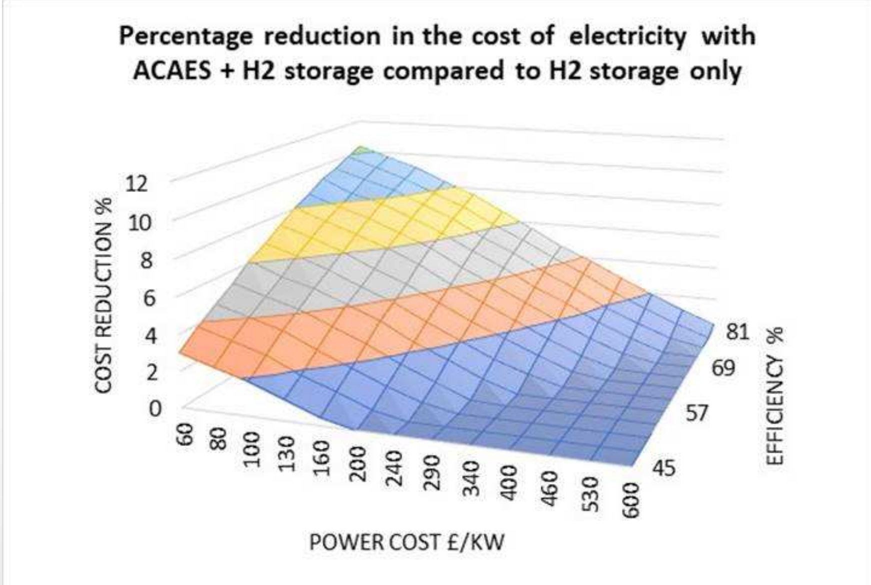


[1] Zachary, S. *Scheduling and dimensioning of heterogeneous energy stores with application to future GB storage needs*. In review. https://arxiv.org/abs/2112.00102.

FOR AN AFFORDABLE NET ZERO UK …

Blending MDES with H_2 storage

(Significant uncertainty exists about future costs of power conversion machinery for ACAES and roundtrip efficiency so optimise many different cases …



Storage	R.E. £35/MWh	R.E. £40/MWh	R.E. £45/MWh
Hydrogen in Caverns only	£57.83 /MWh	£64.48 /MWh	£71.10 /MWh
Hydrogen + ACAES	£56.24 /MWh	£62.00 /MWh	£68.77 /MWh
Hydrogen + ACAES + WIS	£55.49 /MWh	£61.22 /MWh	£67.83 /MWh
ACAES Only	£65.40 /MWh	£72.24 /MWh	£78.57 /MWh

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FEATURES OF A SYSTEM INCLUDING LDES&MDES

- Most energy from storage will pass out from MDES, not from LDES
- With MDES, the over-generation factor reduces from ~1.3 to ~1.2
- The spend on MDES is similar to that on H_2 – although the MDES stores are much smaller.

```
Store #1:  Total energy (in,out)=(2975.91,2022.24) (TWh)
Store #2:  Total energy (in,out)=(3463.36,1402.59) (TWh)
```

Storage cost components (NPV) listed here

Store #	Element	Value	Cost (£bn)
1	IP Power	43.54 (GW)	16.18
1	OP Power	32.31 (GW)	15.28
1	Energy Cap.	5.07 (TWh)	18.53
1	Enrgy Dfct.	-1.09 (TWh)	-0.07
2	IP Power	36.24 (GW)	19.21
2	OP Power	60.84 (GW)	30.50
2	Energy Cap.	47.21 (TWh)	37.55
2	Enrgy Dfct.	6.84 (TWh)	0.45

Generation costs given now

Element	Value	Cost (£bn)
Genn. to meet demand	21090.00 (TWh)	391.91
Losses & Curtailment	4748.87 (TWh)	88.25

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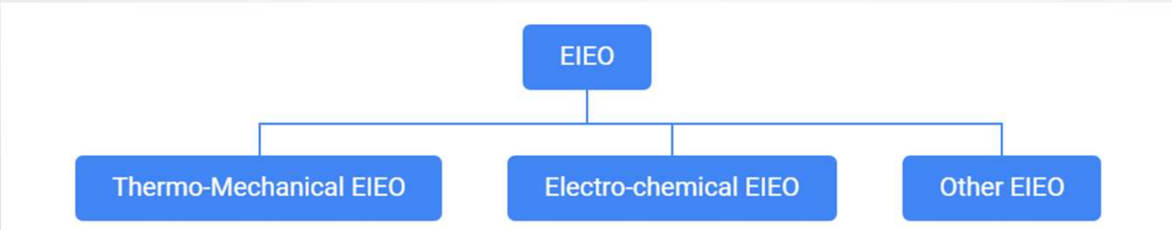
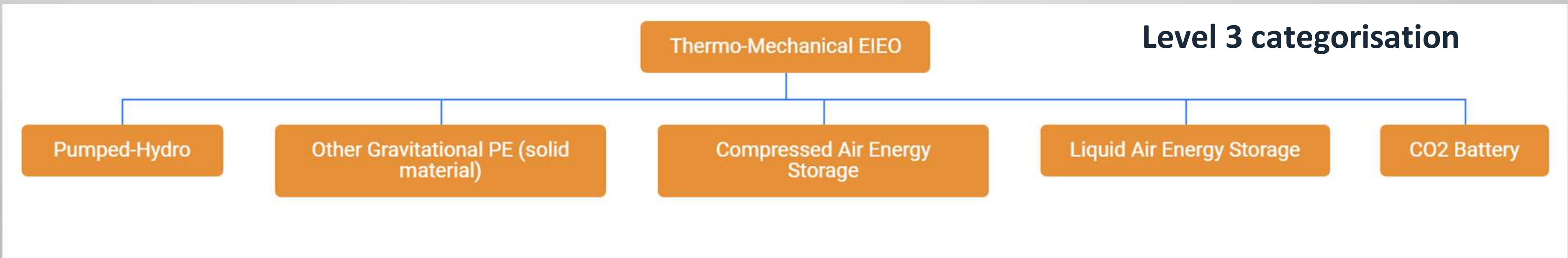
TECHNOLOGIES FOR MDES

These are many and varied – but mostly *thermo-mechanical.*

Level 1 categorisation



Level 2 categorisation



Level 3 categorisation

CONCLUSIONS

- You may have learned a new unit here –the ***per-semitone*** **!**
- We have seen PDFs (Probability Distribution Functions) showing how the energy that comes out of energy storage will be distributed over different discharge durations.
- Tools exist to elucidate the role of MDES … **www.era.ac.uk/resources/NStore_Sim**

energy storage
IEA Technology Collaboration Programme

www.TinyURL.com/LS-MDES-task

MDES matters – a lot!

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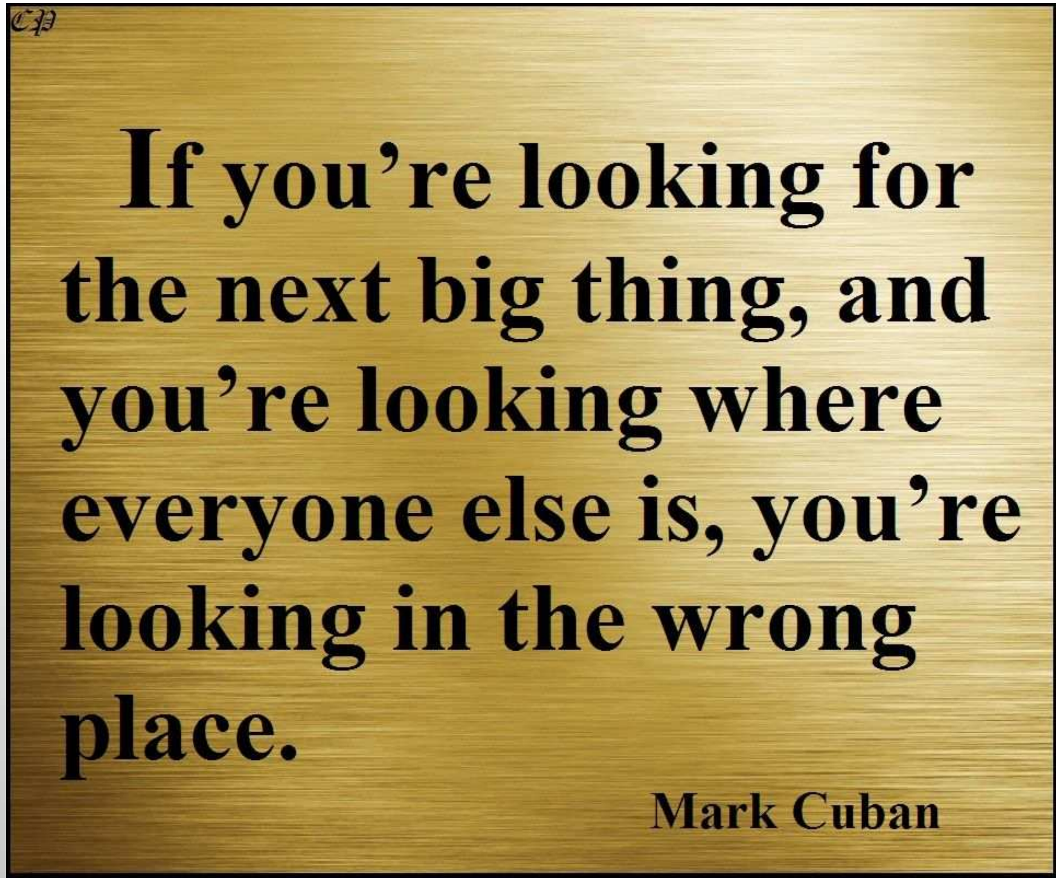
Thanks for listening. **Seamus.Garvey@Nottingham.ac.uk**



https://www.pinterest.co.uk/pin/450782243930694637/