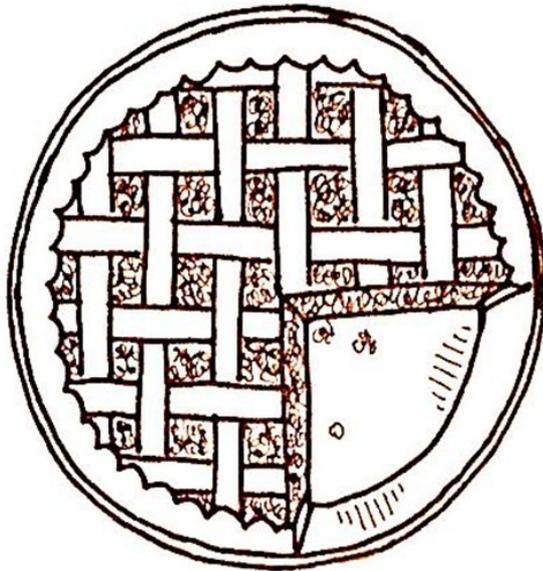


Can an island afford to meet its climate commitments?

David G Quirk, Ralph Peake, Adrian Cowin, Rebecca Keeley

Pie Chart



Pie that I have not
yet eaten.

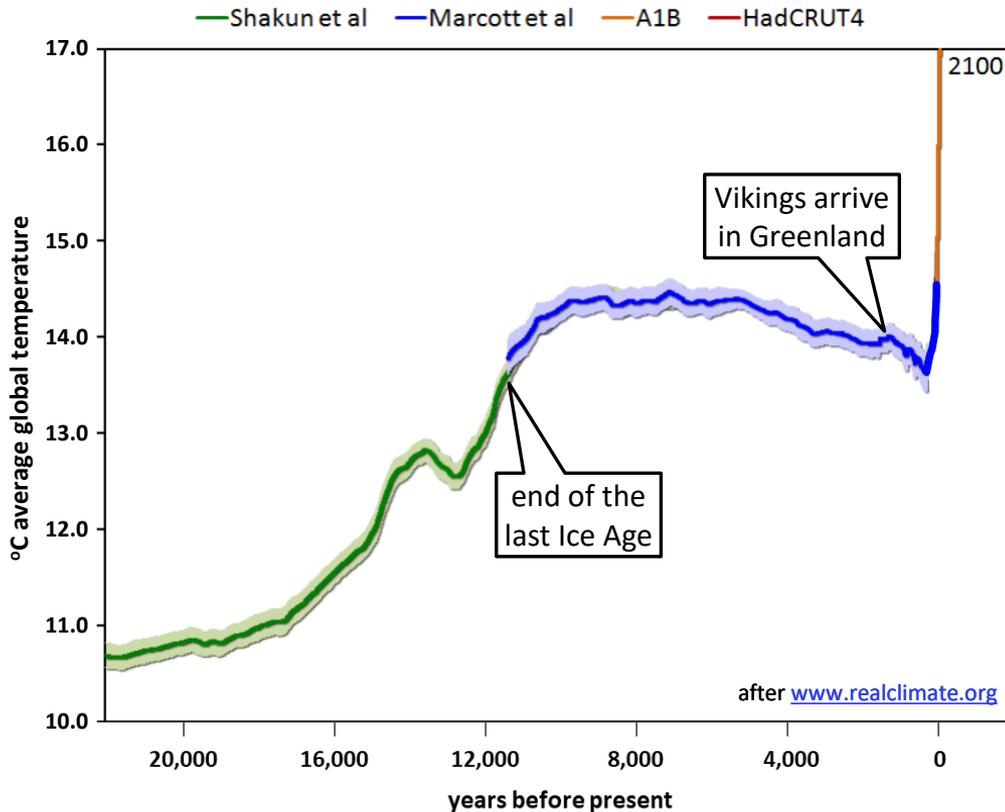


Pie that I have eaten

Amalie Quirk, 2018

- Climate Change Act 2021 commits IOM to achieving **net-zero emissions by 2050...**
 - But there has been **little tangible action to date**
- **IOM Government Conference 23-24 September 2025**
 - James Pomeroy: number 1 (of 3) **greatest opportunities for IOM is clean energy**
 - Chris Brannigan: IOM's future strengths are **clean air, clean finance, clean energy**
- IOM Chamber of Commerce: main call from the private sector is for a **secure supply of green energy** on the Isle of Man at an **affordable price**
- For the Island's economy & international standing, it is becoming increasingly **urgent to progress sustainable, affordable, secure, autonomous energy**
- So what's happening globally and what can we do here?
Climate Change → Other Islands → IOM Options → Energy Storage → Conclusions

Historical change in global temperature + future projections

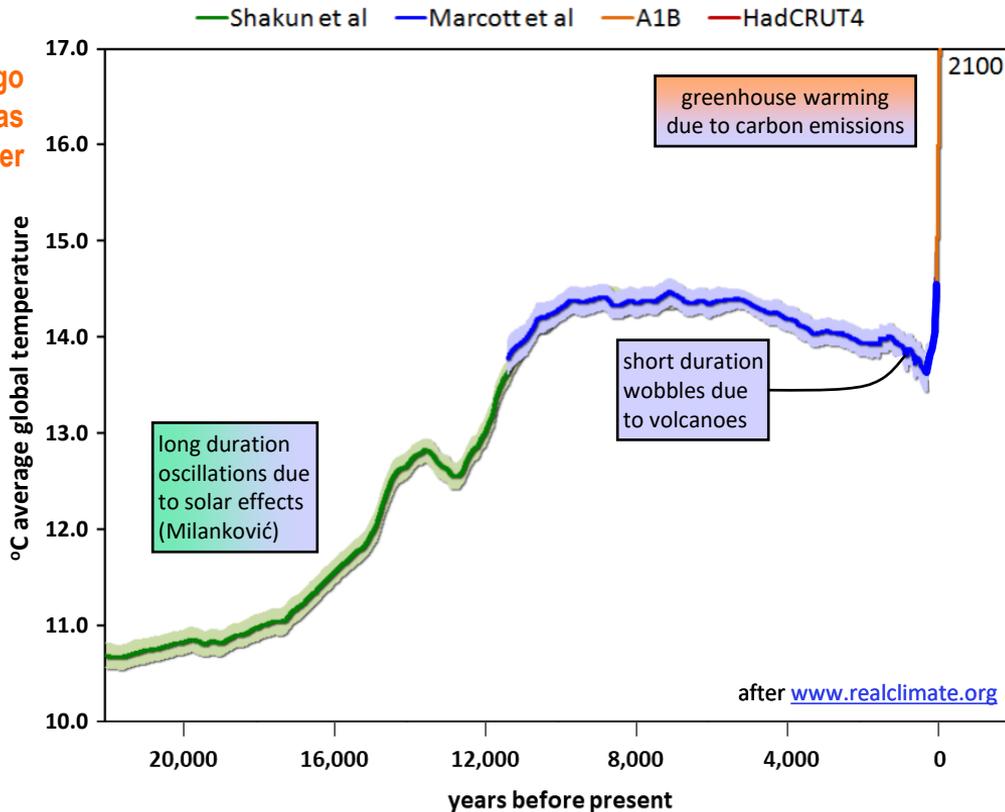


after www.realclimate.org

Quirk, D.G., 2021 (www.energysustainabilitycentre.im/knowledge-hub)

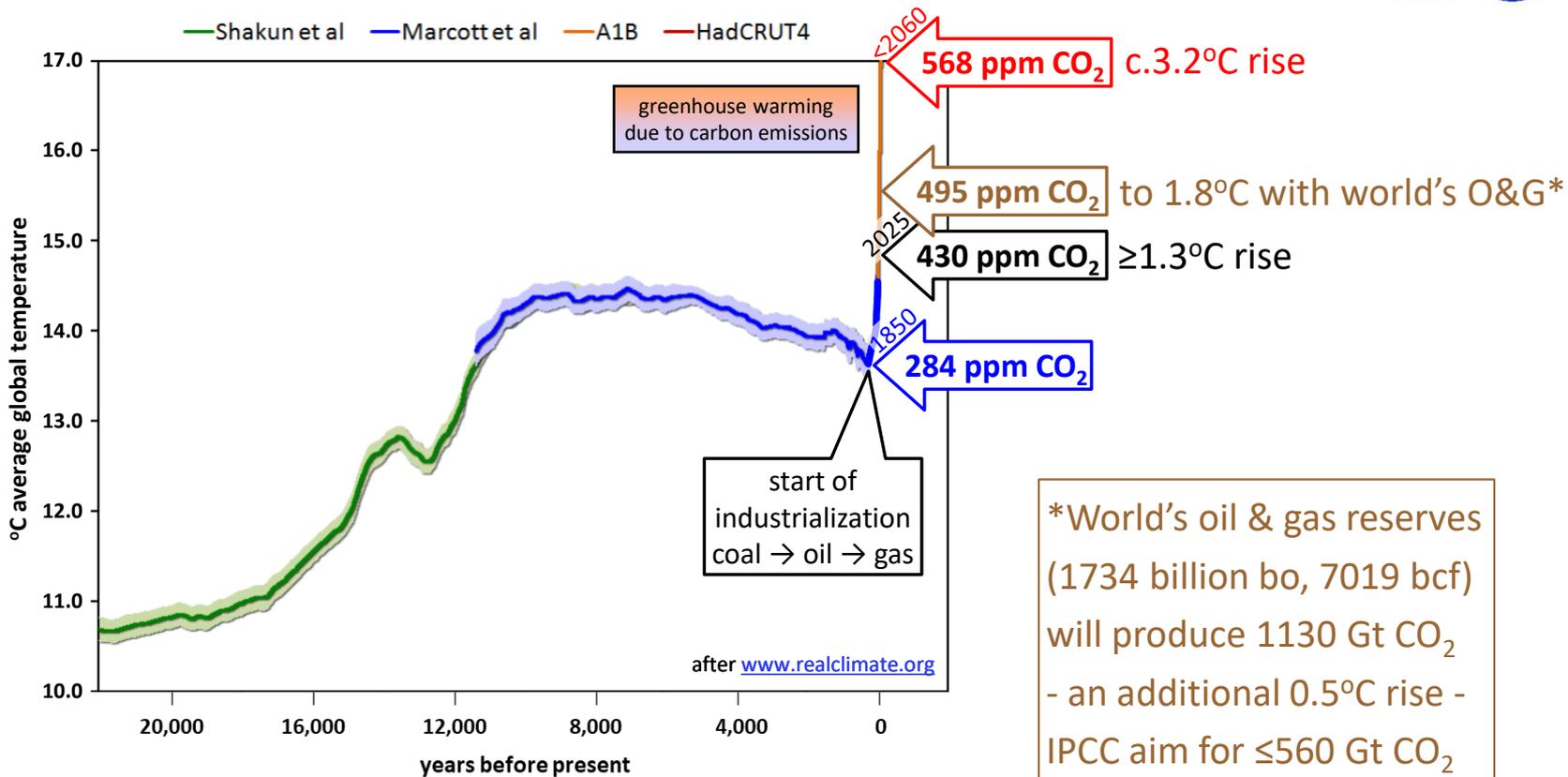
Historical change in global temperature + future projections

125,000 yrs ago
sea-level was
6-9 m higher



Quirk, D.G., 2021 (www.energysustainabilitycentre.im/knowledge-hub)

Historical change in global temperature + future projections



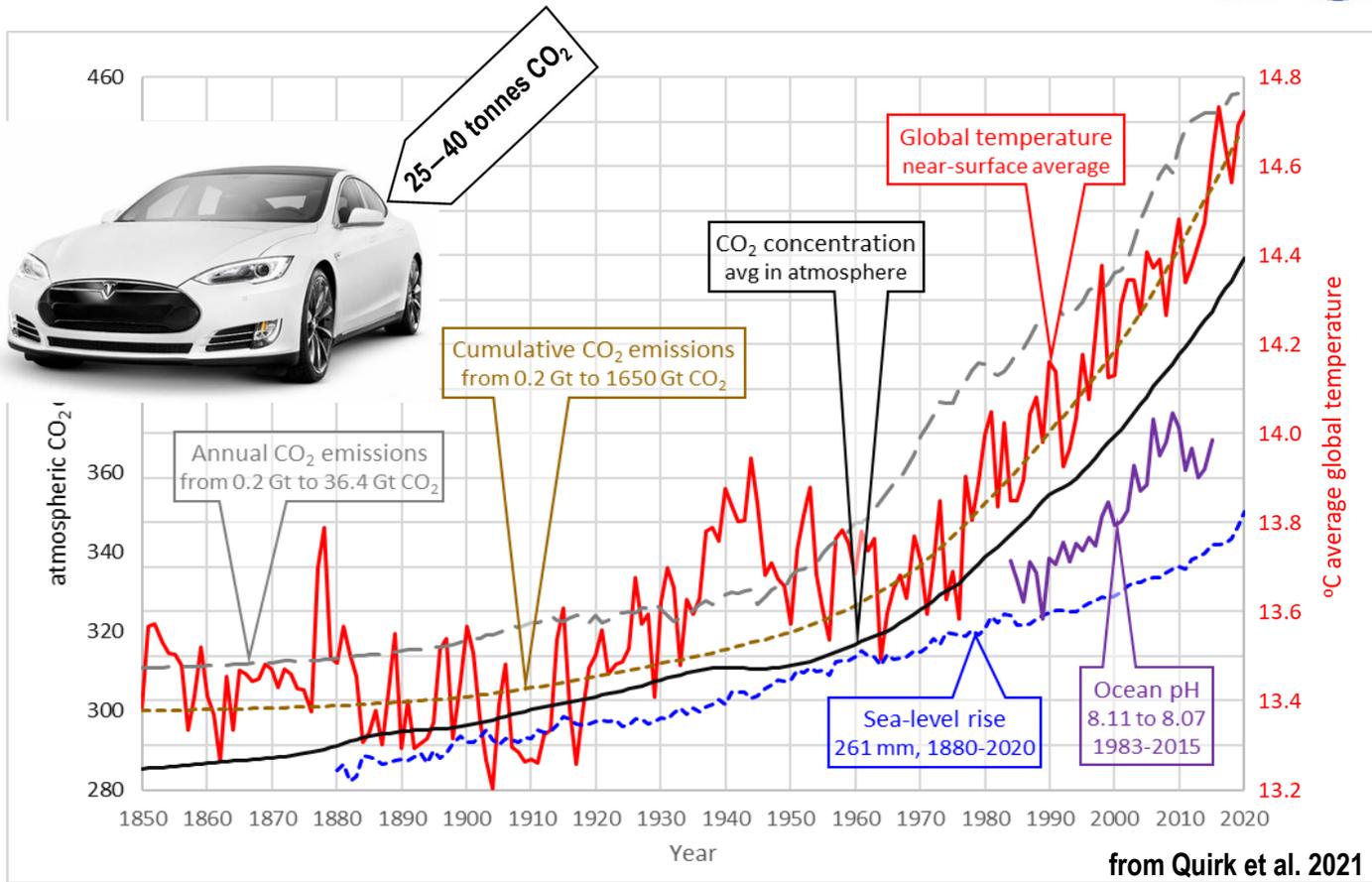
Quirk, D.G., 2021 (www.energysustainabilitycentre.im/knowledge-hub)

Avg N European emissions:
17 t CO₂/yr (direct + imports)
 largely related to oil & gas
Avg Chinese 9 t CO₂/yr

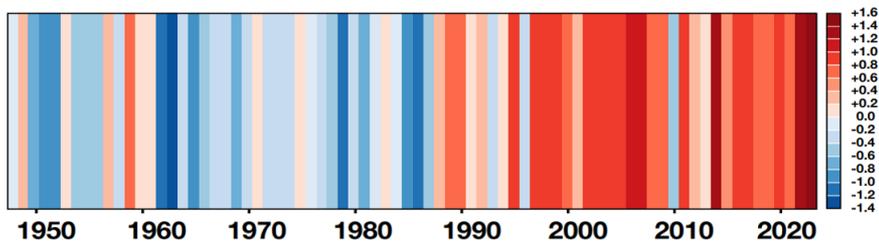
1 t CO₂ = 10,000 bin bags
≡ burning 1.4 large trees

Each of us is responsible
for putting the equivalent
CO₂ into the atmosphere as
burning 24 trees each year
to fuel our lifestyle...
... ≥170,000 bin bags CO₂/yr

Carbon-free energy reduces
this by 80% → 4 t CO₂/yr left

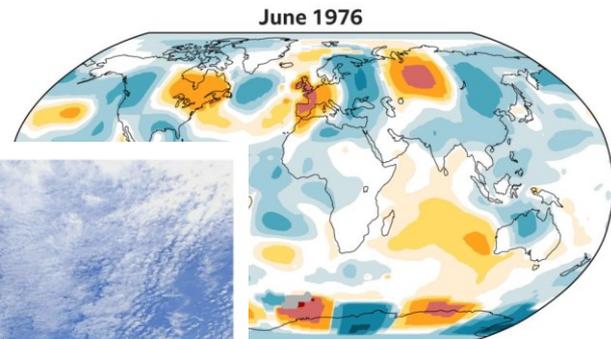


Climate change on & around Isle of Man

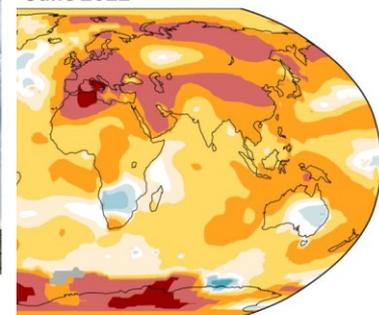


How global temperatures have changed

Temperatures (°C) compared with 1951-80 global averages



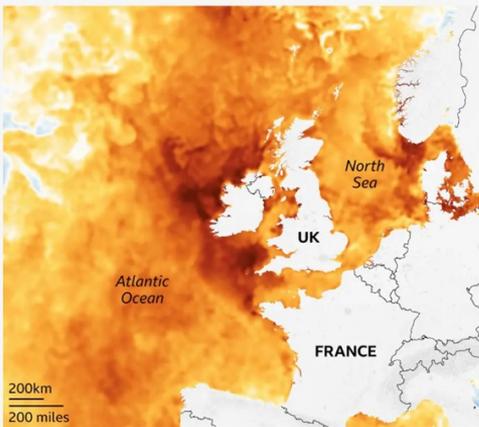
June 1976



June 2022

Sea around the UK much warmer than usual

Sea surface temperature on 20 May 2025, compared with 1982-2011 average for that day



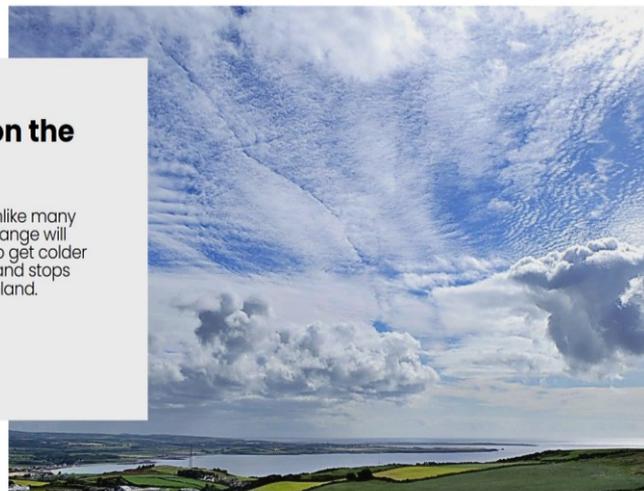
Source: Met Office OSTIA, ESA CCI



Future climate on the Isle of Man

This animation shows that, unlike many parts of the world, climate change will probably cause NW Europe to get colder as the Gulf Stream slows up and stops due to meltwater from Greenland.

Watch Now



www.energysustainabilitycentre.im/knowledge-hub

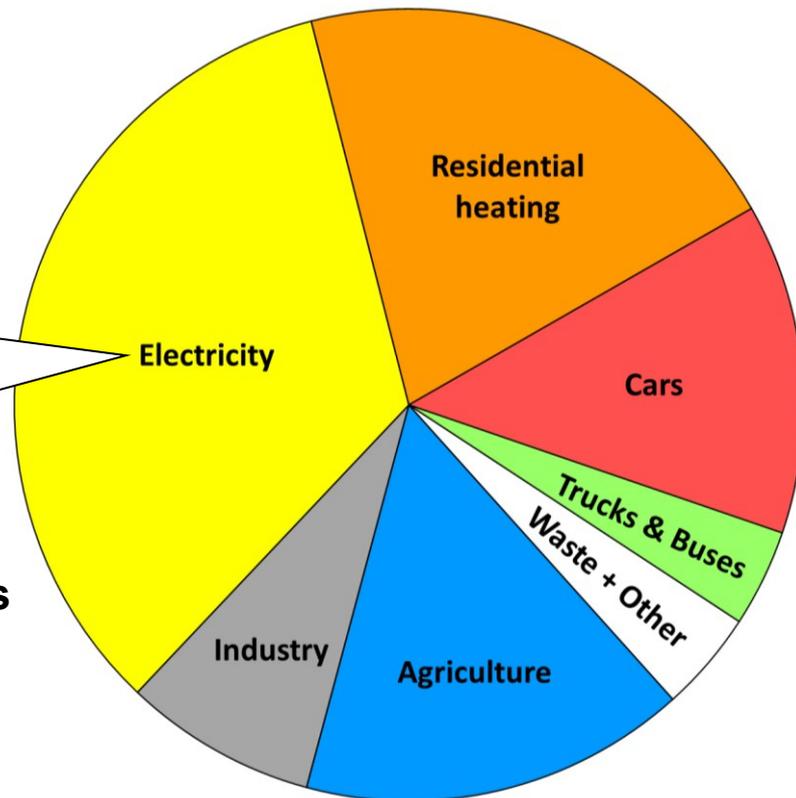


80% of IoM emissions are from oil & gas - 550,000 tonnes CO₂e per year

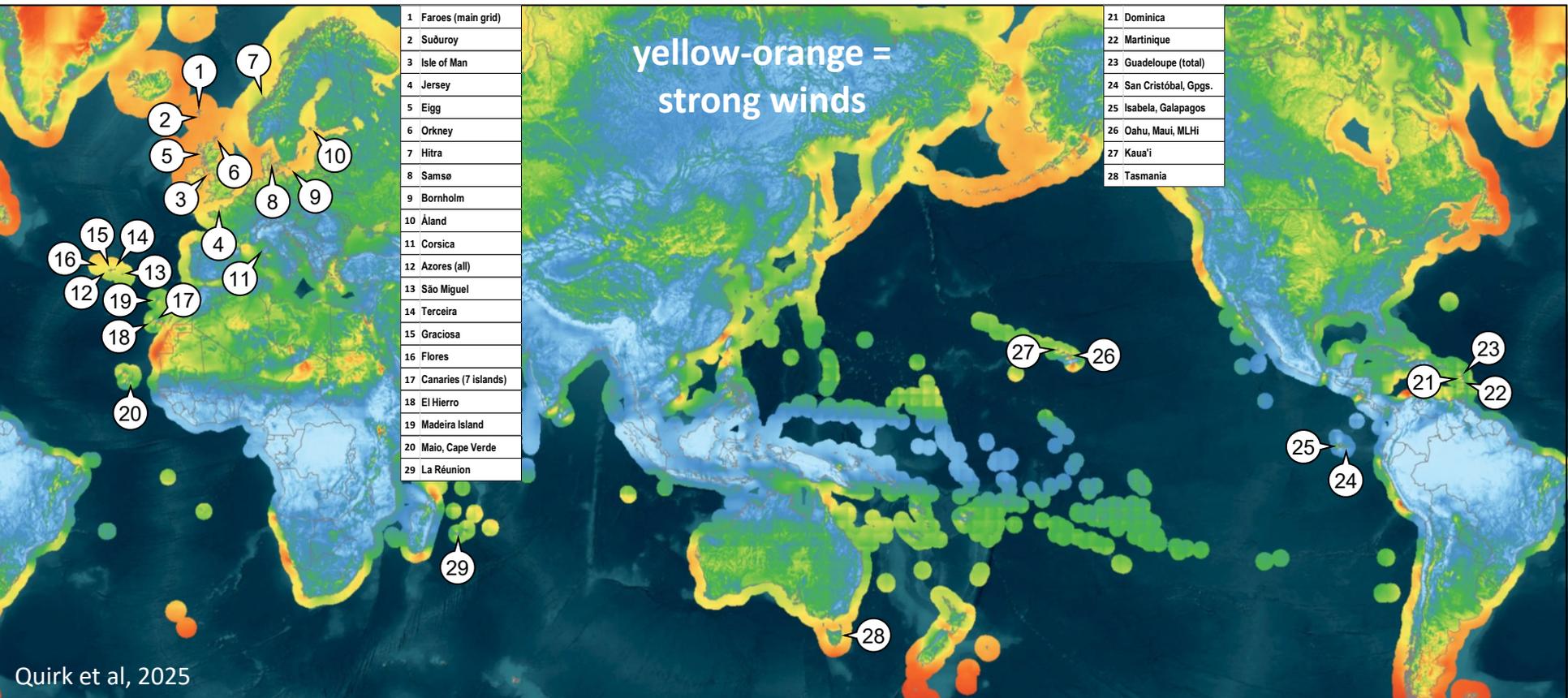
360 GWh per year =
 12 kWh/day per person (£3.50)
 10 MWh/year per household
£105 million/yr at 29.1p/kWh
 Consumption will double with heating & transport electrification
227,000 tonnes CO₂/year emitted from Pulrose

Import dependency = high & volatile costs

Isle of Man 2019 Emissions, Aether
 (residential halved, air travel & sea transport not fully accounted for)



Islands in energy transition league

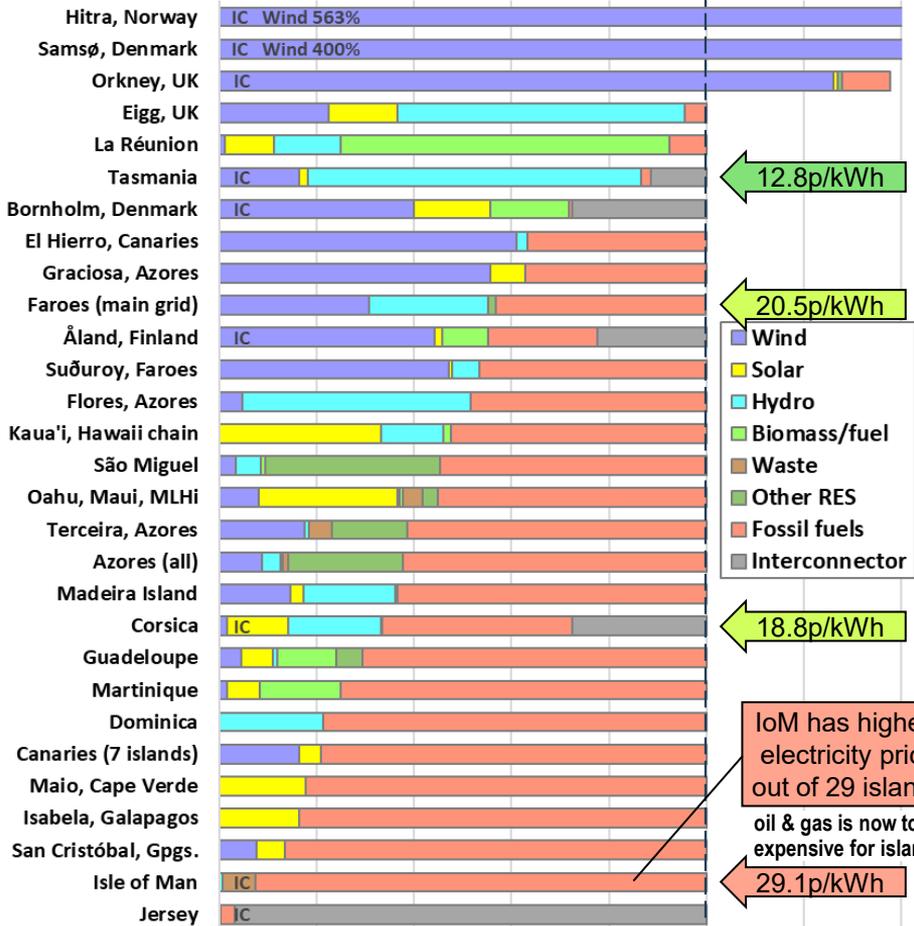


Islands' energy mix, ranked for progress in transition to renewables

Quirk et al. 2025

local & imported power supply relative to electricity demand

0% 20% 40% 60% 80% 100% 120% 140%



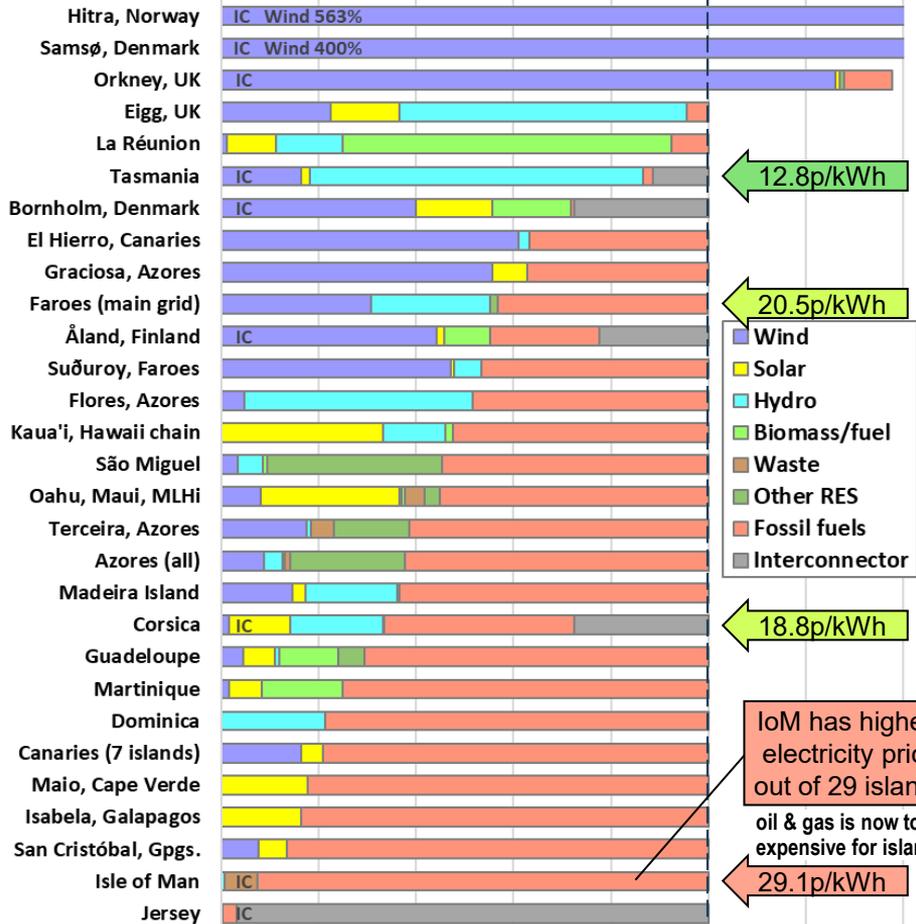
IoM has highest electricity price out of 29 islands
oil & gas is now too expensive for islands

Islands' energy mix, ranked for progress in transition to renewables

Quirk et al. 2025

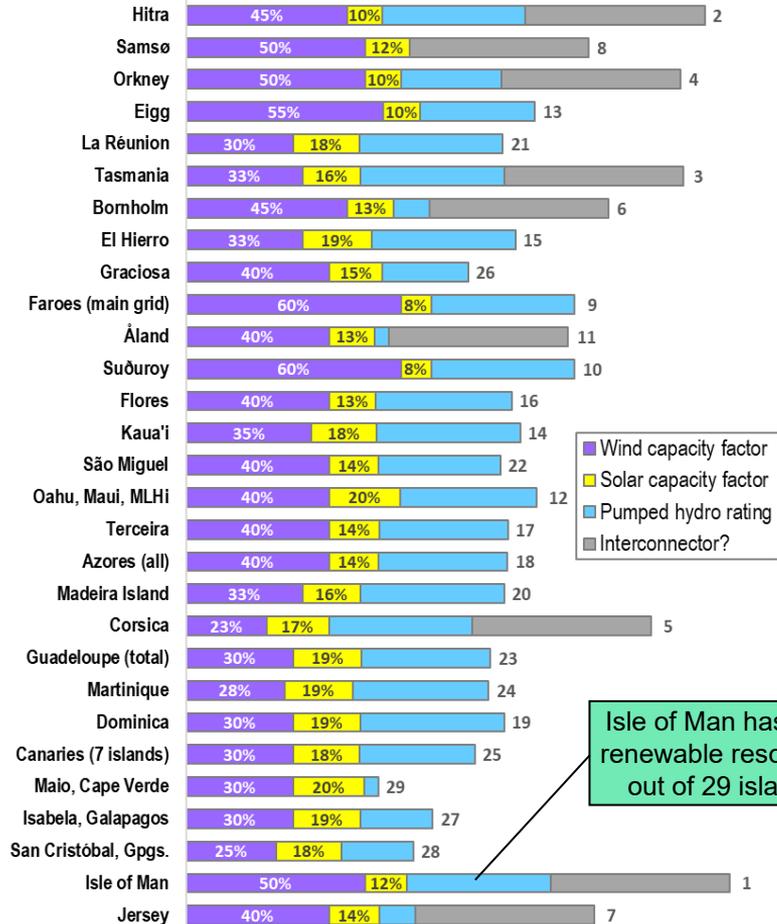
local & imported power supply relative to electricity demand

0% 20% 40% 60% 80% 100% 120% 140%



Potential for energy self sufficiency (Isle of Man ranks no. 1)

Resource strength for a secure, affordable, green energy system
Low Moderate High Very High

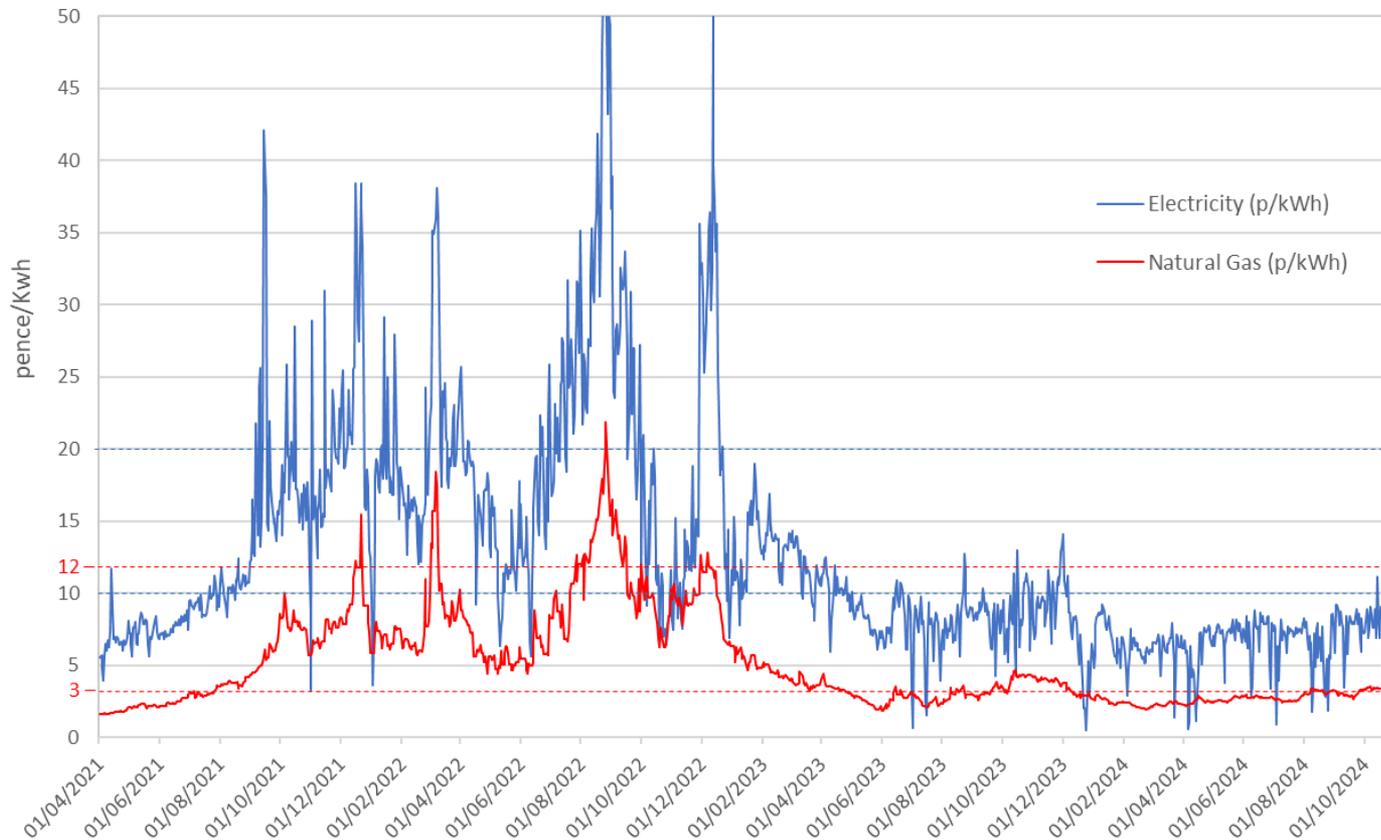


IoM has highest electricity price out of 29 islands
oil & gas is now too expensive for islands

Isle of Man has best renewable resources out of 29 islands

Fossil fuel prices are volatile, unpredictable & insecure

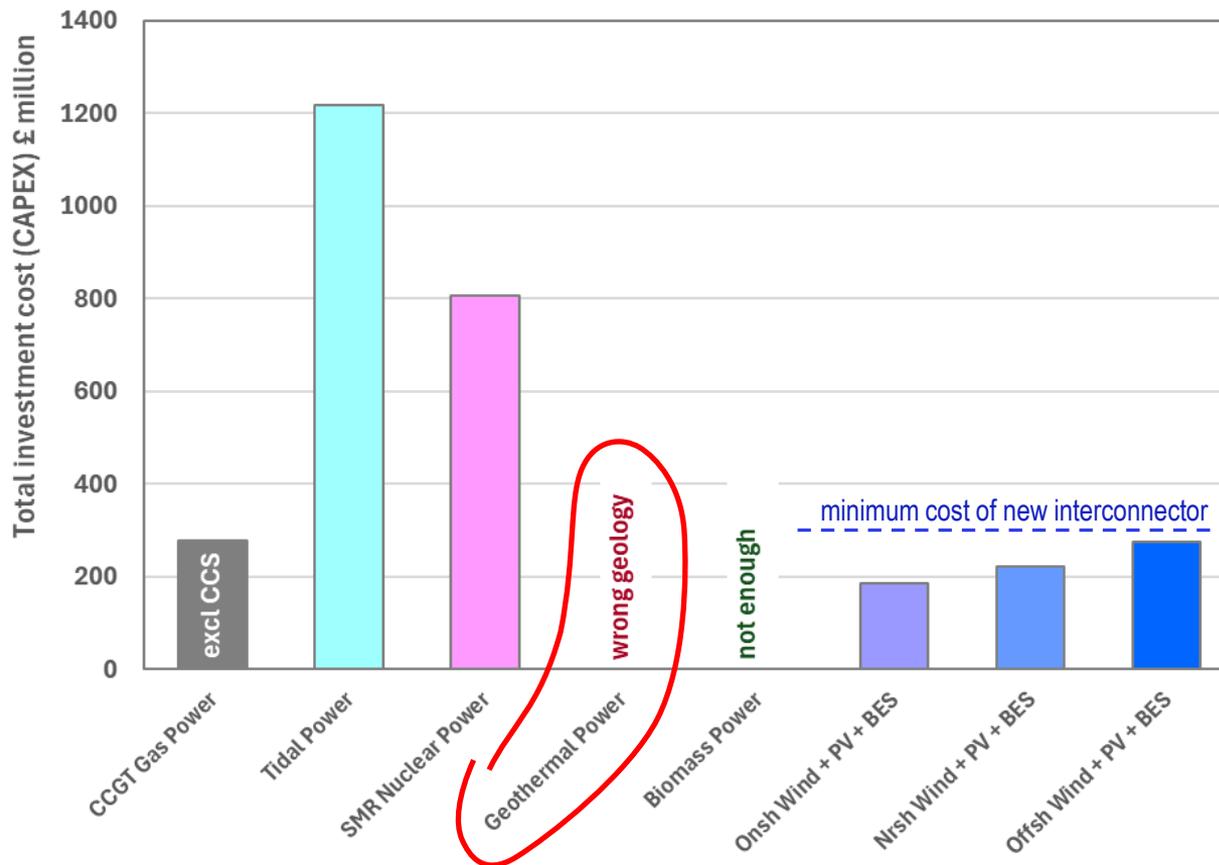
Wholesale gas & wholesale electricity prices, April 2021 - October 2024



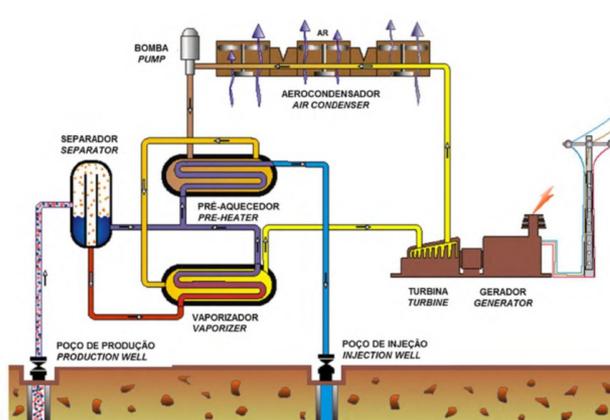
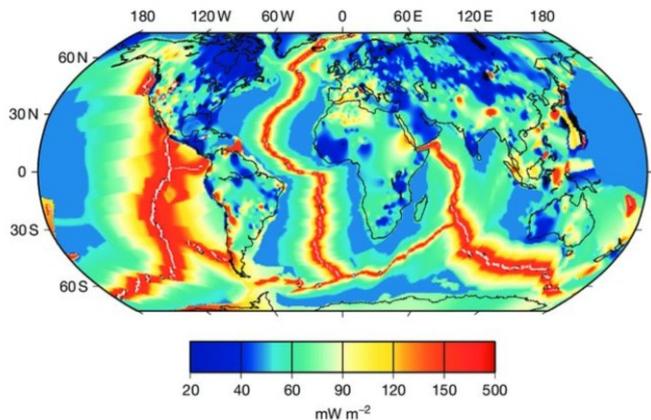
- Denmark started wind industry after 2nd oil crisis



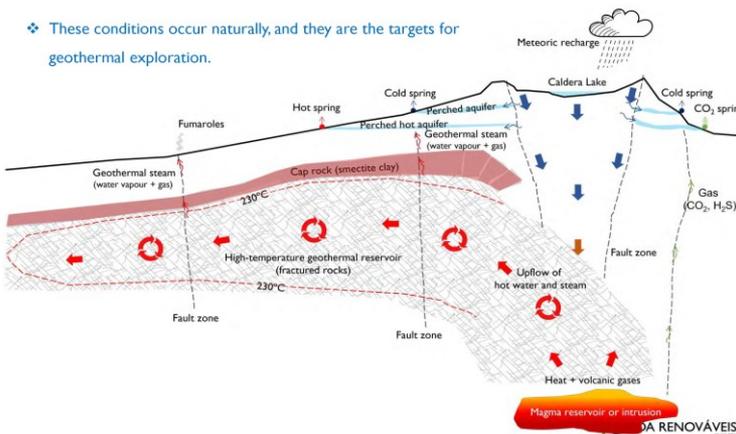
Manx electricity options – total investment, incl storage



Geothermal energy needs high heat &/or warm water aquifers



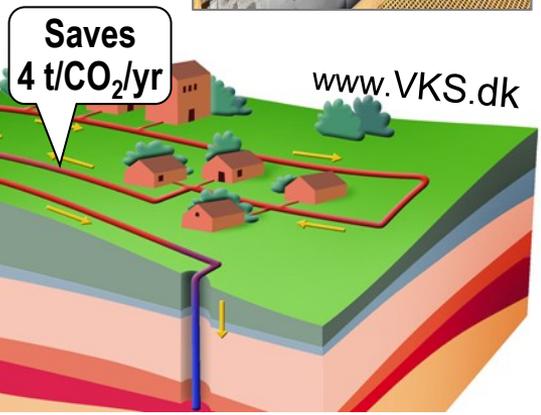
❖ These conditions occur naturally, and they are the targets for geothermal exploration.



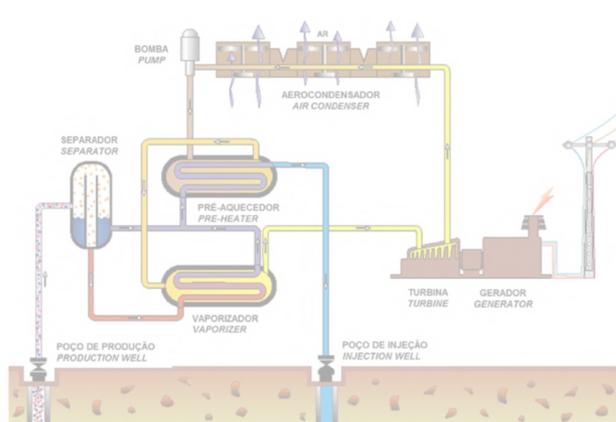
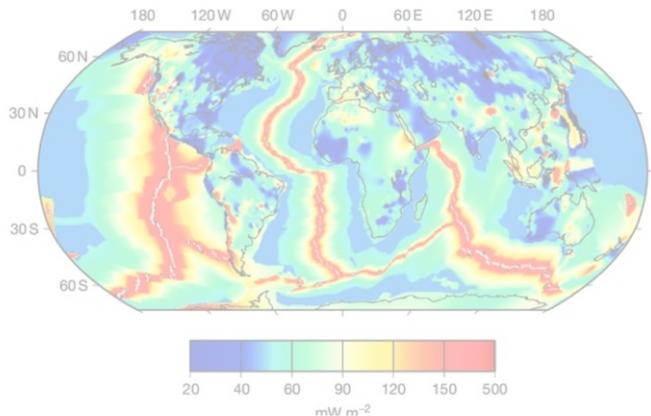
wrong geology

Geothermal Power

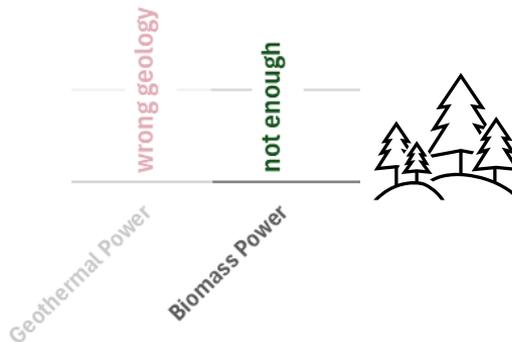
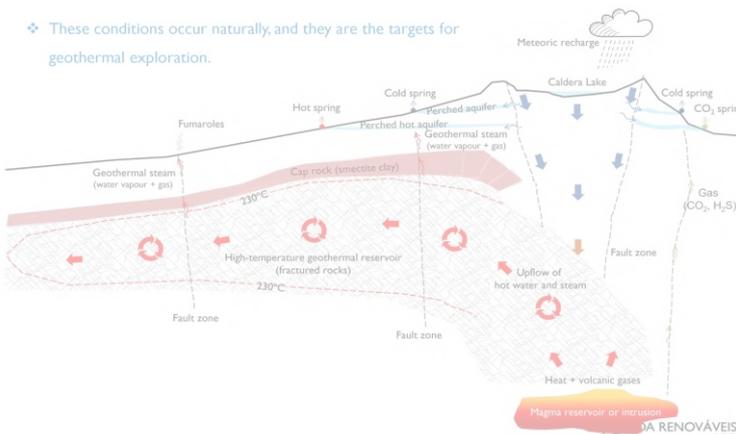
District heating from hot water aquifer



Biomass energy needs a huge source of recyclable vegetation

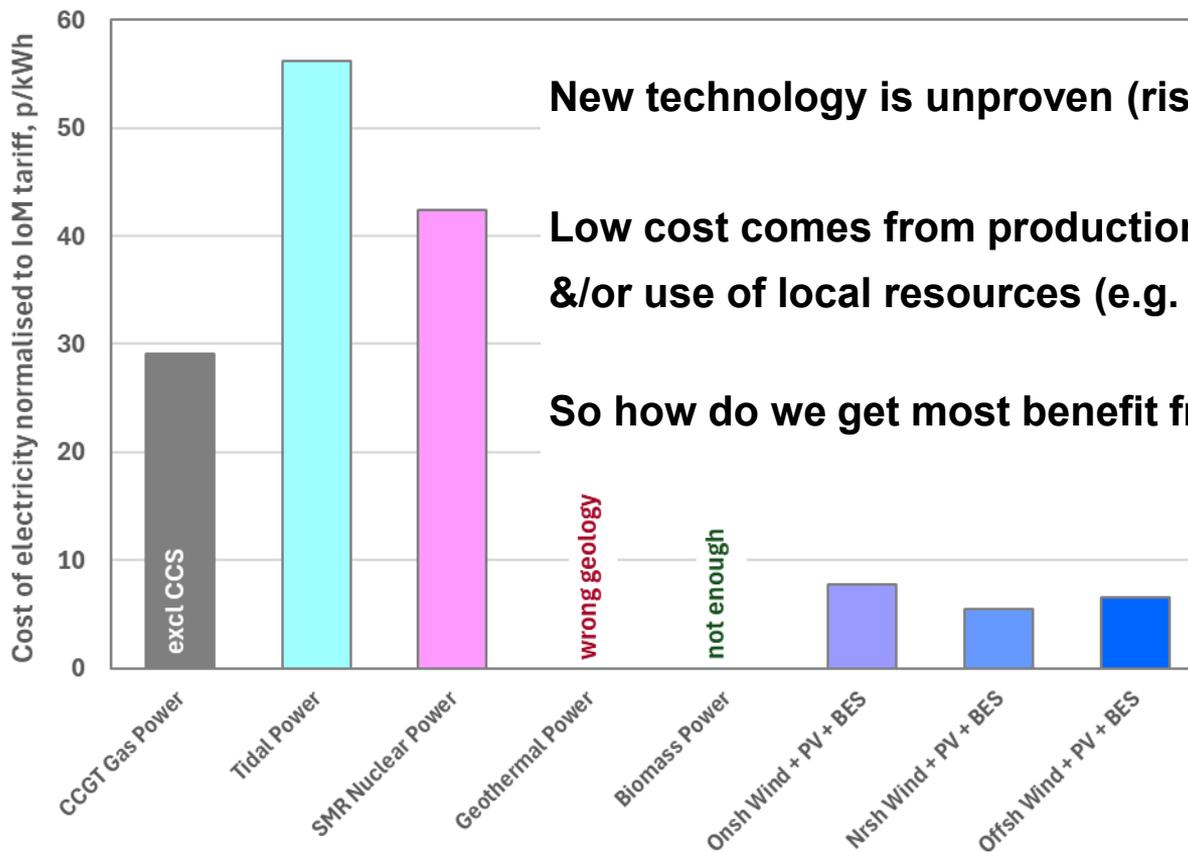


❖ These conditions occur naturally, and they are the targets for geothermal exploration.



To provide enough power from a wood-fired power plant requires a forest five times larger than the total area of the Isle of Man

Manx electricity options – cost per kWh, incl energy storage

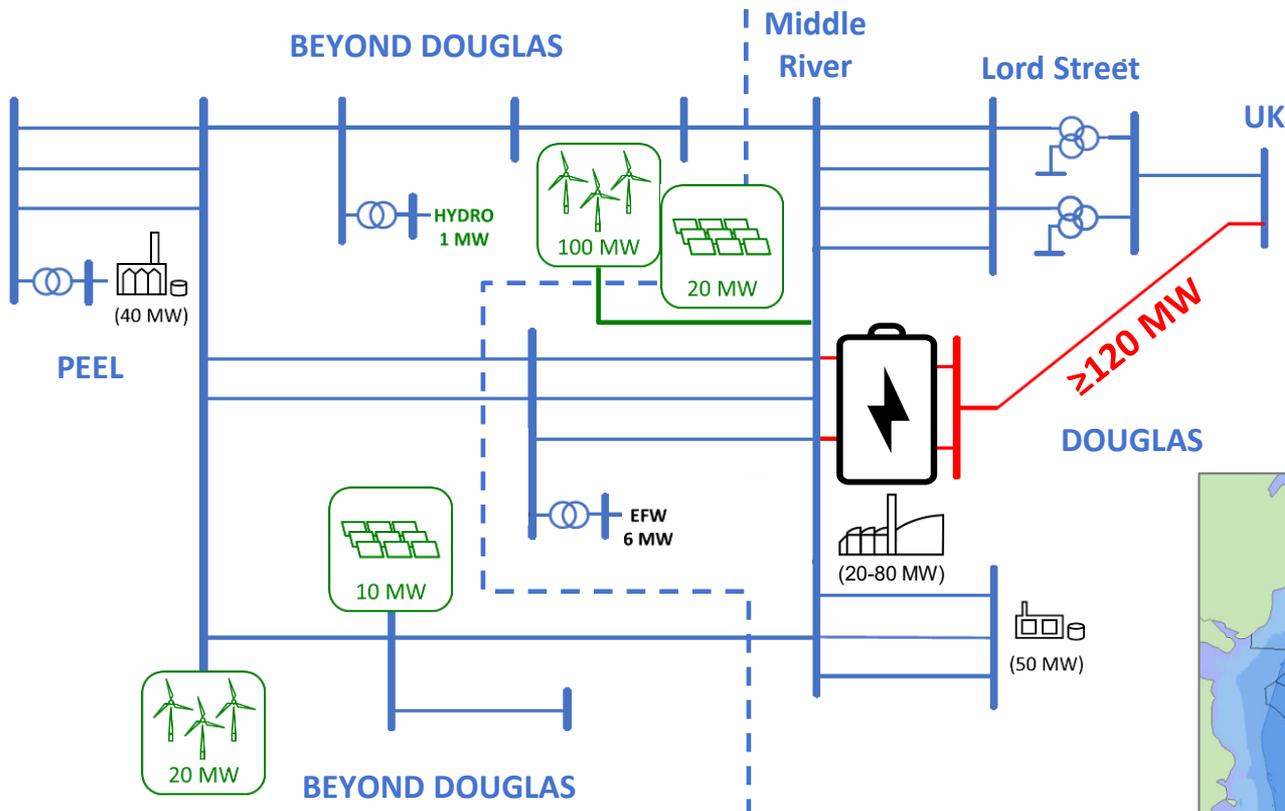


New technology is unproven (risky) & expensive

Low cost comes from production line efficiencies &/or use of local resources (e.g. hydro electricity)

So how do we get most benefit from wind & solar?

Example of IoM electricity grid running on emissions-free power

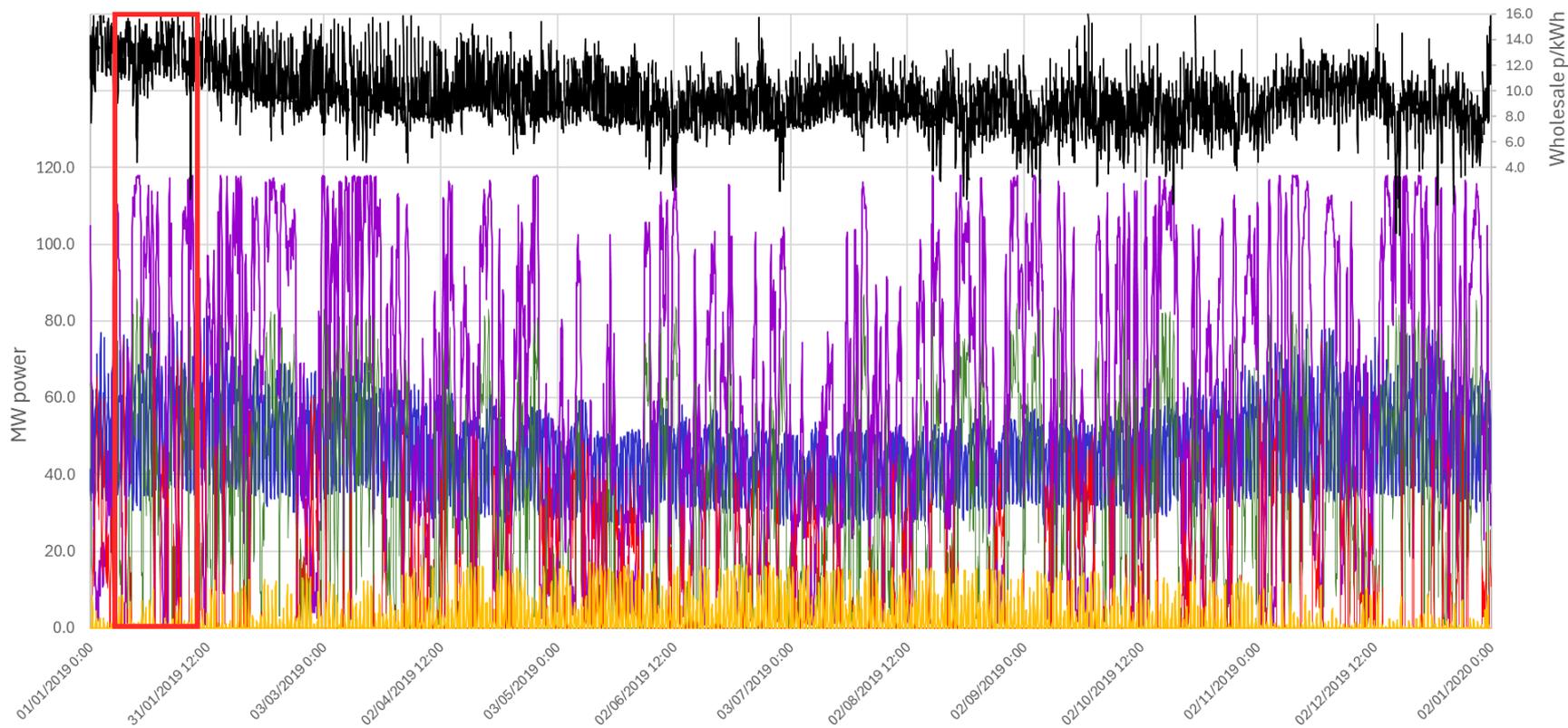


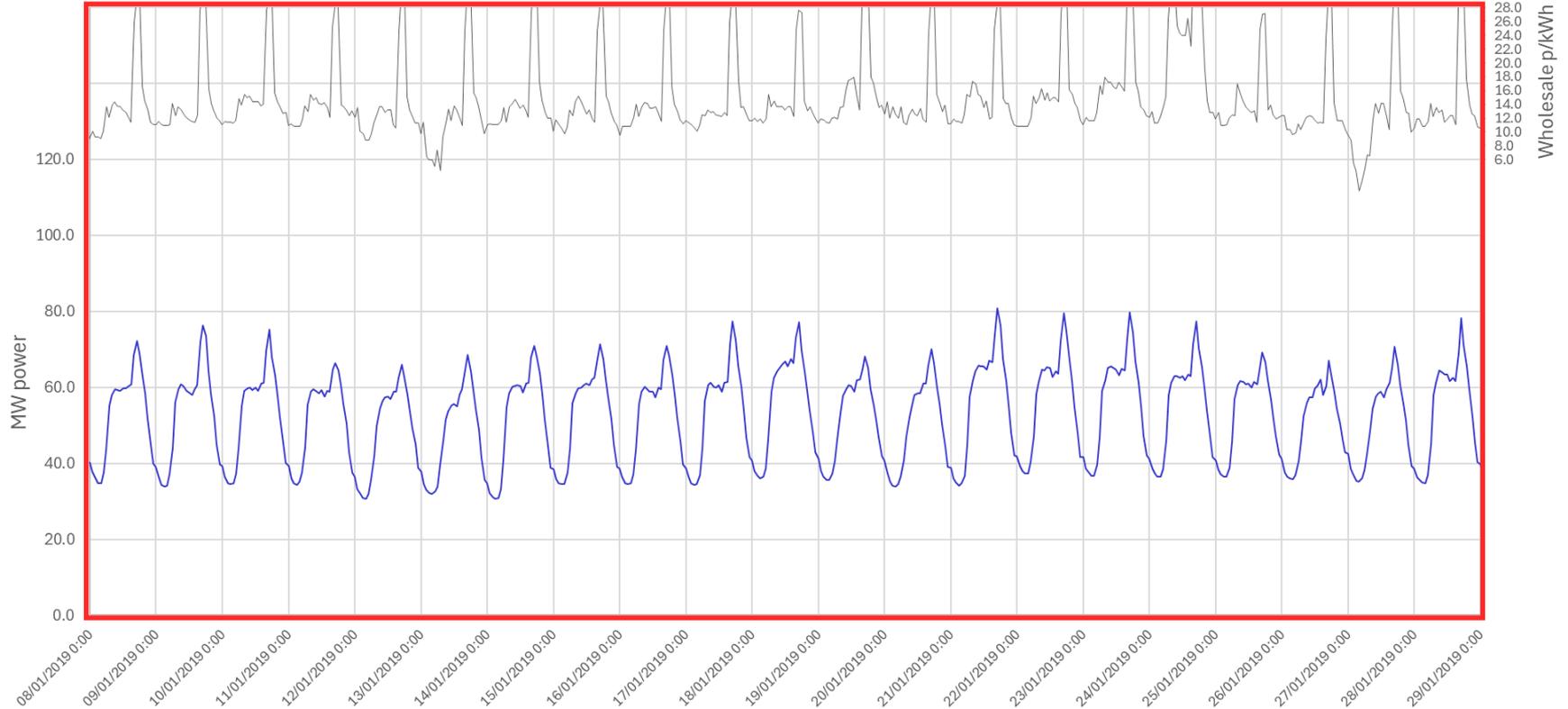
With interconnection can come vulnerability

How to build a secure energy system?



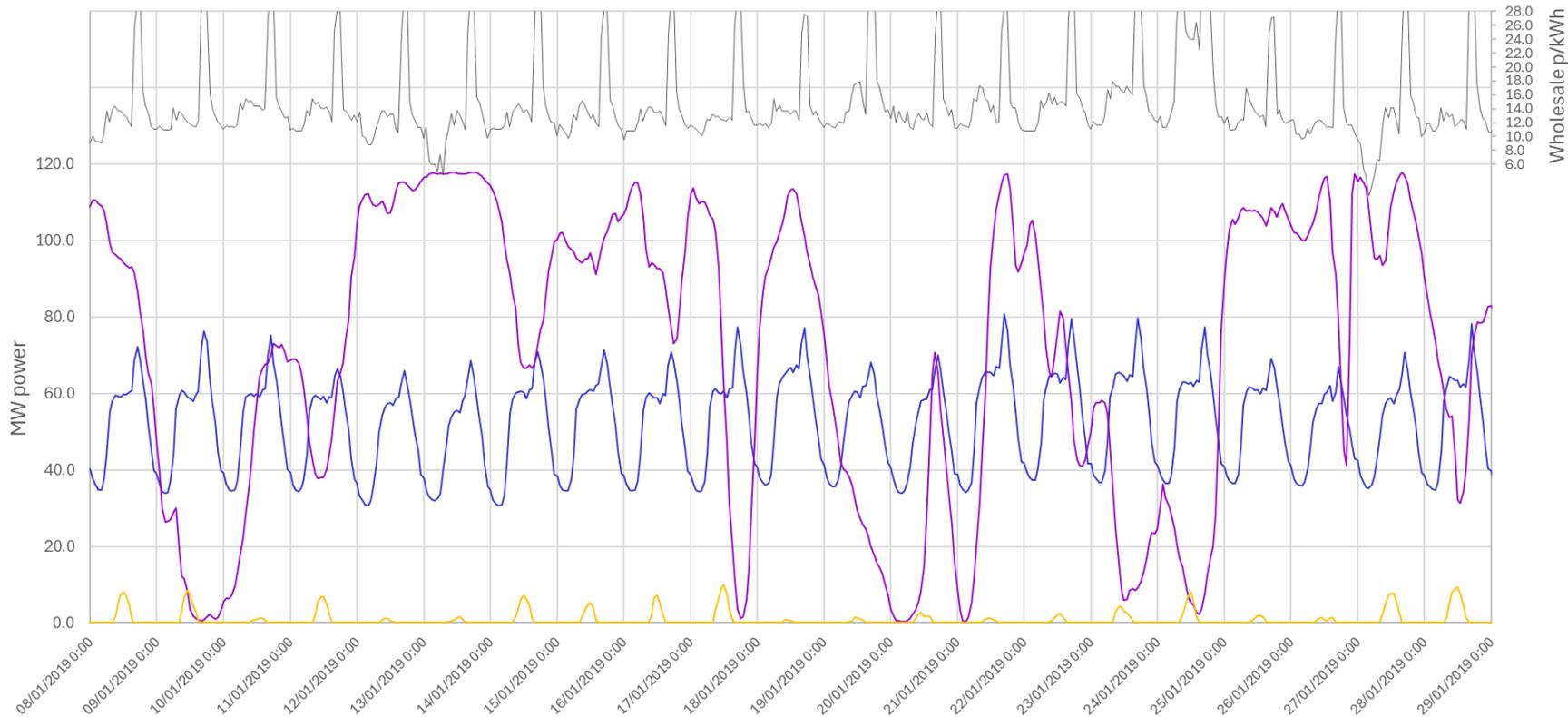
Energy system model: electricity demand, prices, wind & solar strengths, generator & infrastructure capacities & costs, CO₂, storage strategies, etc.





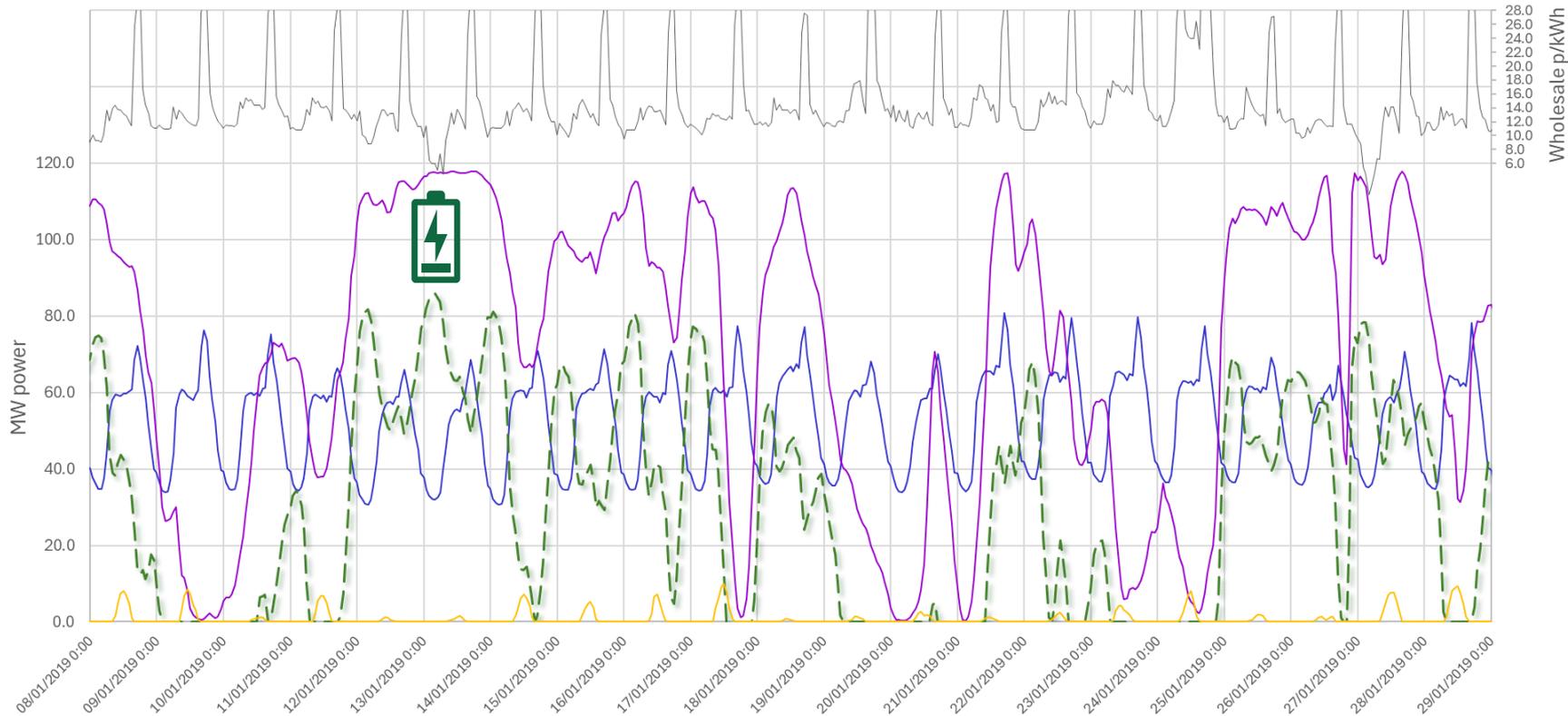
3 weeks, January 2019

Demand + price + 120 MW wind (50%) + 20 MW solar (12%)



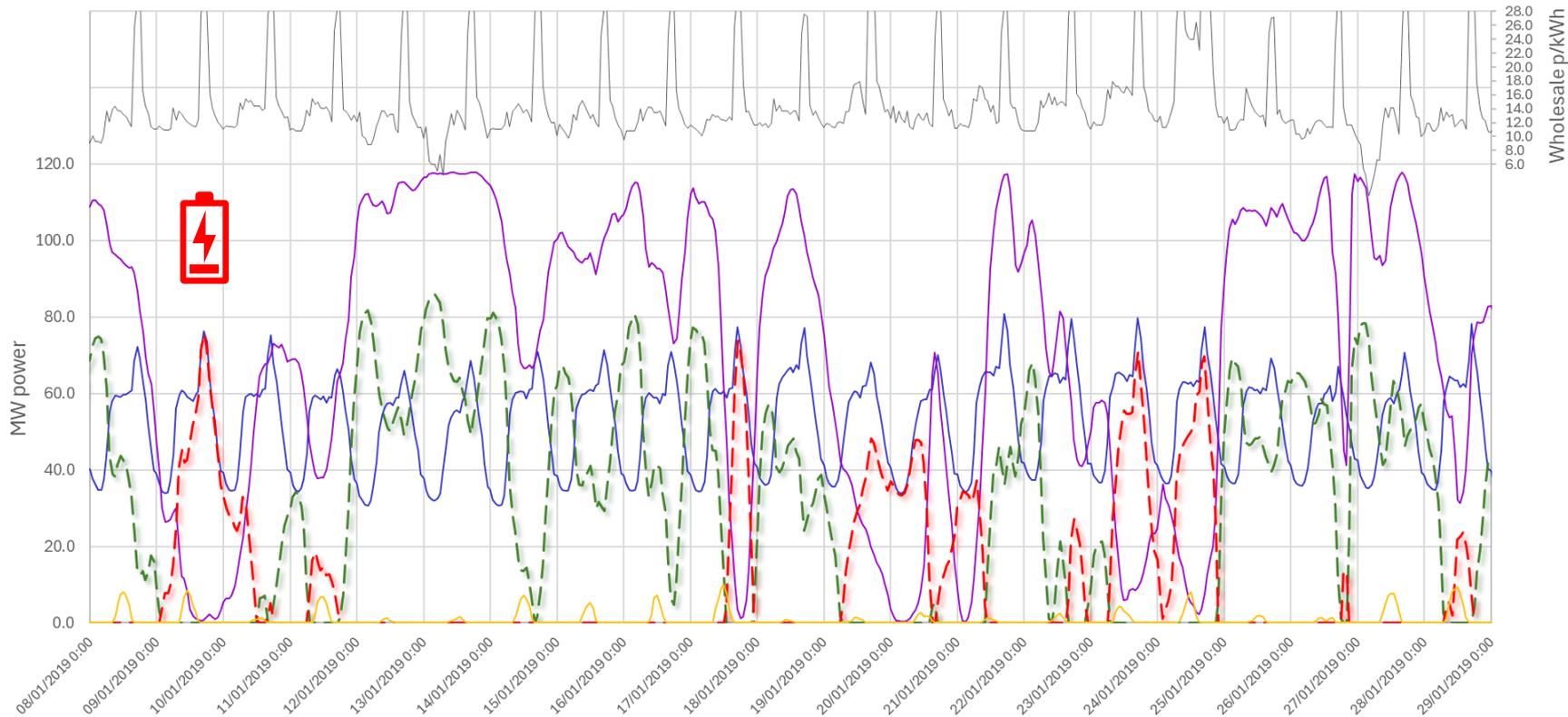
3 weeks, January 2019

Demand + price + wind + solar + energy surplus (=> storage)



3 weeks, January 2019

Demand + price + wind + solar + surplus + deficit (discharge)

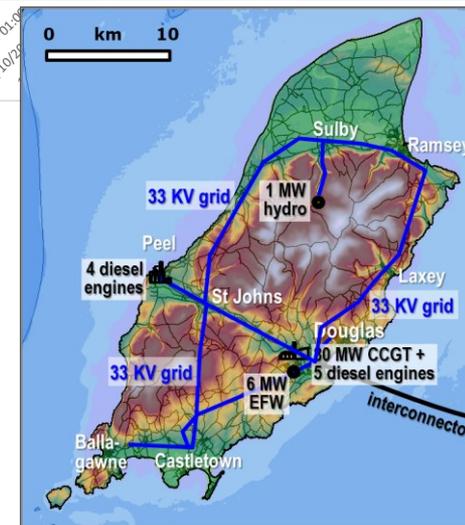


3 weeks, January 2019

Exported electricity & imported electricity: Step 1D IoM EnergyPLAN model - 100 MW wind, 40 MW solar



Only 65% of renewable energy can be used when generated...
 if 120 GWh surplus is exported, 120 GWh has to be imported...





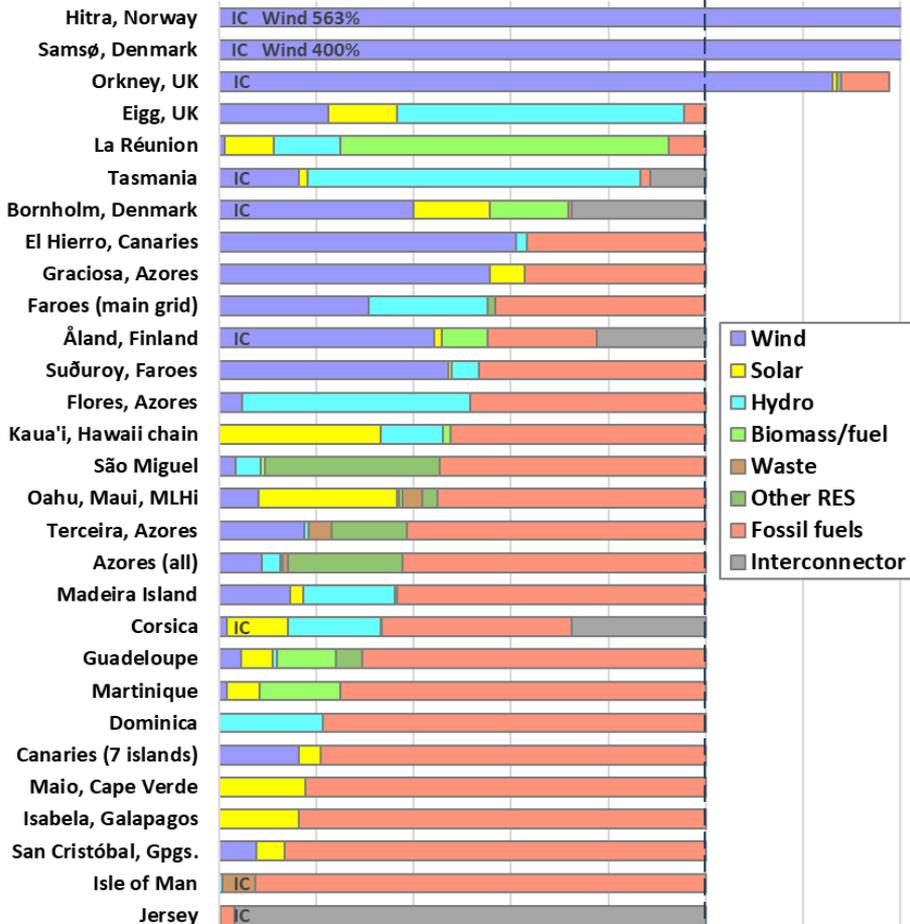
www.energysustainabilitycentre.im/ipa

Start with *Quick Start Guide*

Goal: $\geq 100\%$ self-sufficiency, $< 22\text{p/kWh}$, $< 15,000\text{ t CO}_2/\text{year}$

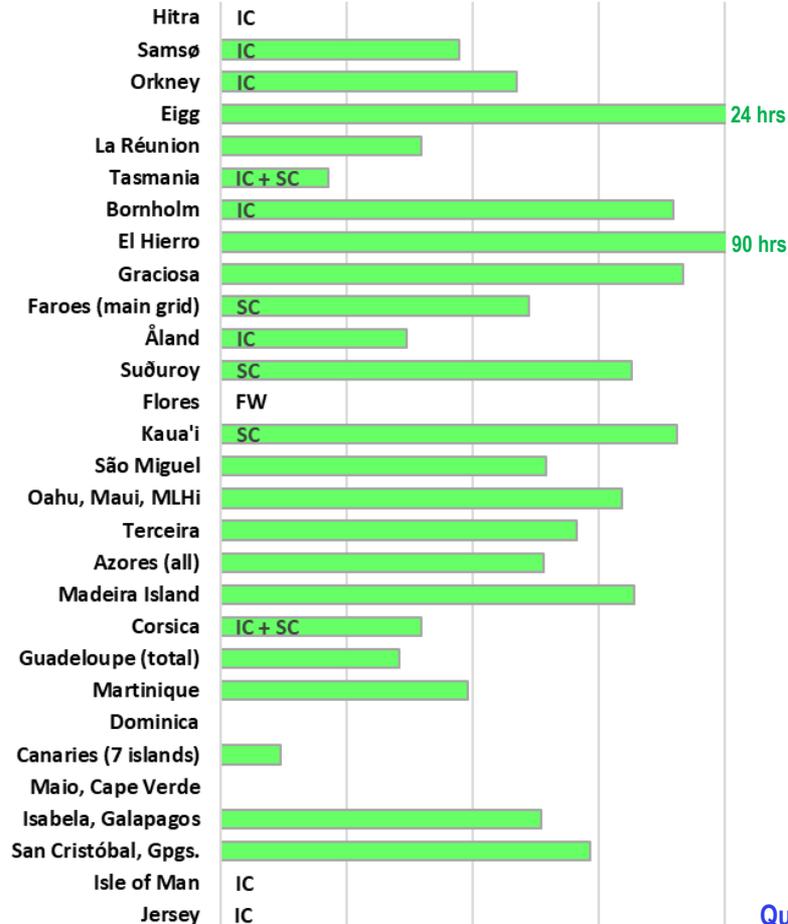
Islands' energy mix, ranked for renewable energy %

0% 20% 40% 60% 80% 100% 120% 140%



Storage capacity – hours demand covered

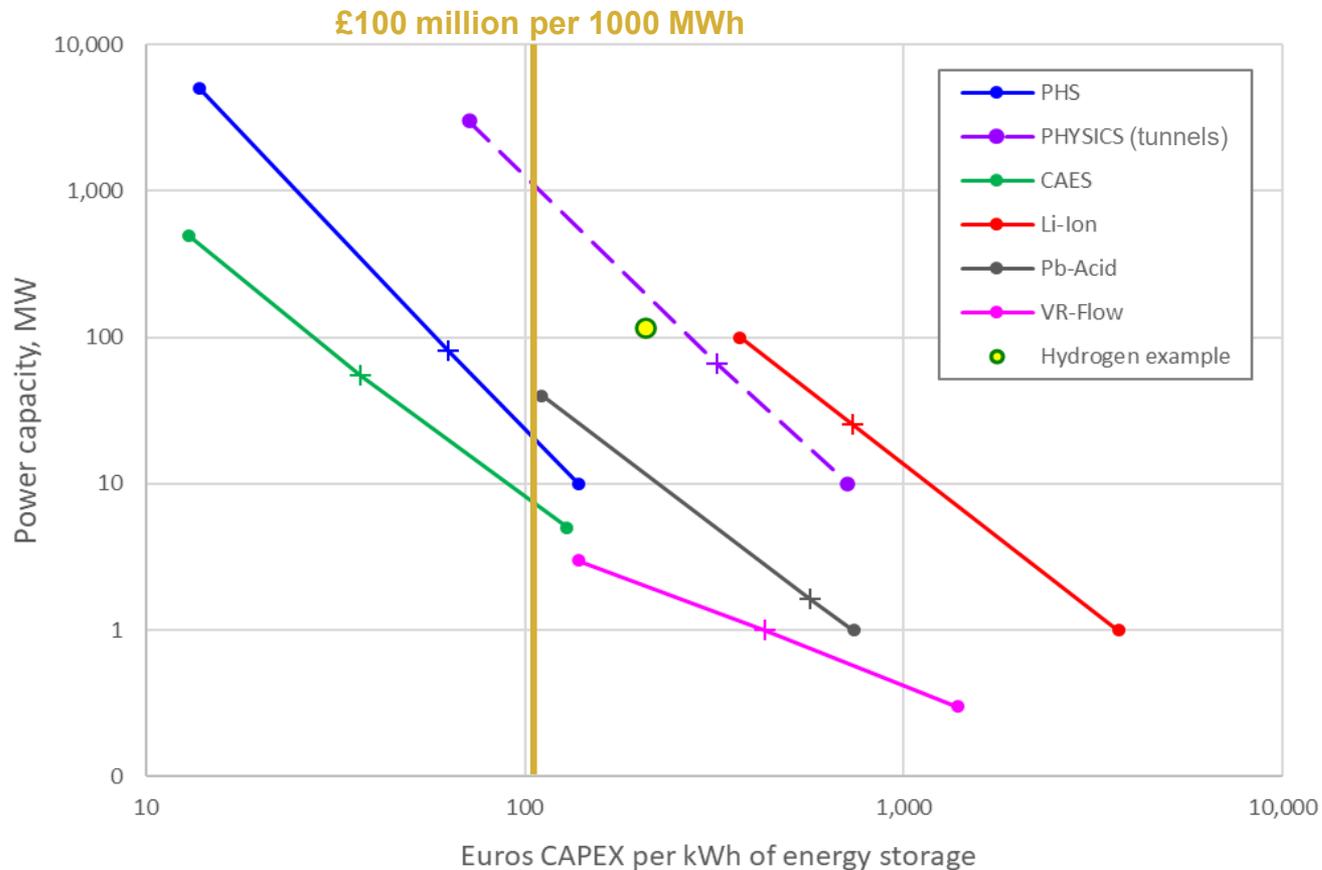
0.00 0.01 0.10 1.00 10.00



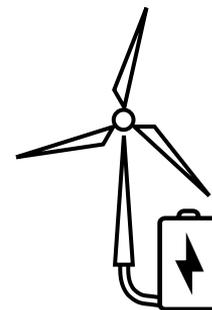
Stabilised with batteries + electronics (+/- synchronous machine)



Energy storage options – ranges in power vs CAPEX cost/kWh



- Pumped Hydro Storage
- Underground PHS ± SW
- Compressed Air Storage
- Lithium Ion Batteries
- Lead Acid Batteries
- Flow Batteries
- Hydrogen





Pumped hydro is the most sustainable energy storage solution



Turlough Hill – Ireland’s main energy storage since 1974

292 MW for 6 hrs (1700 MWh)

286m head, 6 turbines

2.6 million m³ water

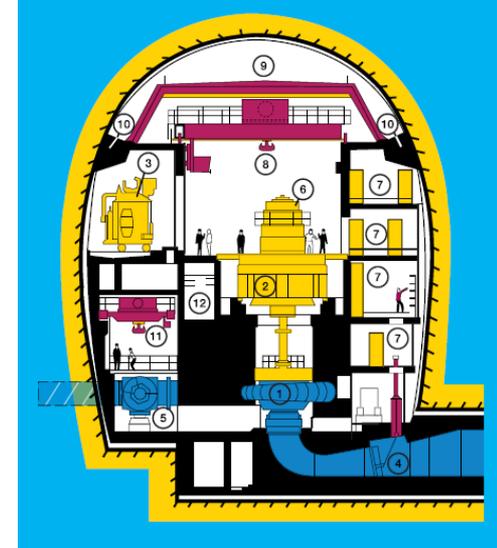
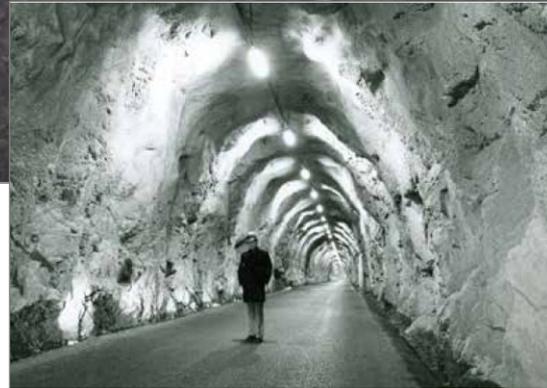
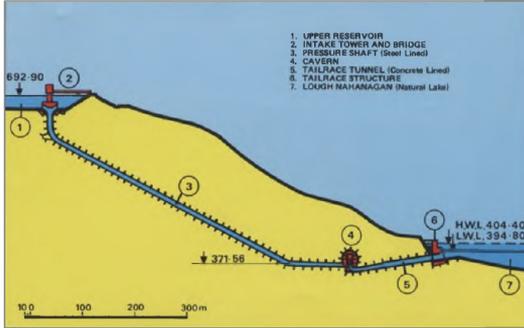
75% roundtrip efficiency

£240 million motoday

- **Reduces price fluctuations, improves energy security**, relieves grid congestion
- **Revenue** from arbitrage (buy low, sell high) & ancillary services (grid stabilisation)
- **Uses local resources**, including construction companies



Turlough Hill – Ireland’s main energy storage facility since 1974



Cross-section view of cavern

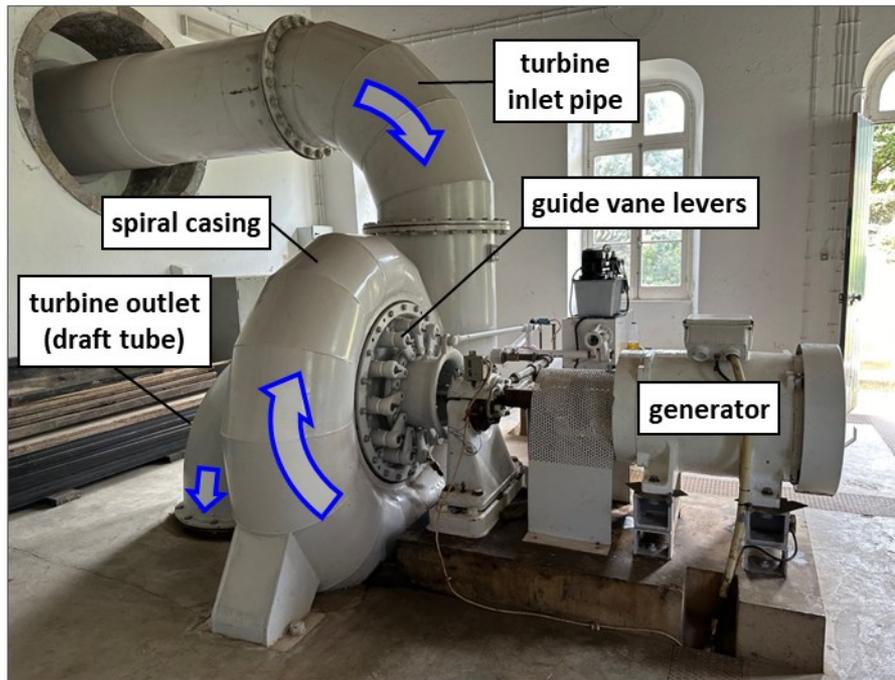
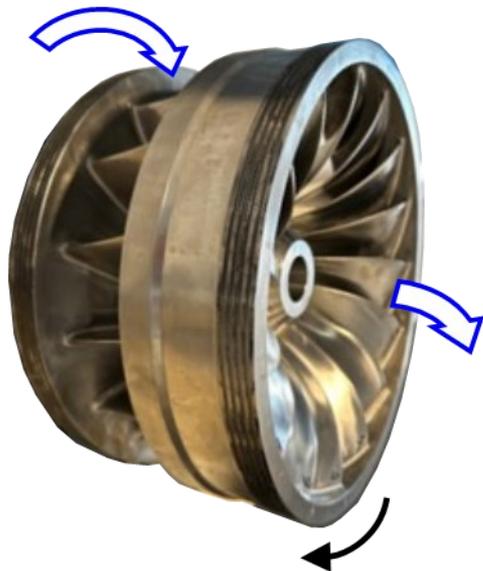
1. Pump Turbine
2. Motor/Generator
3. Main Unit Transformer
4. Flap Gate
5. Turbine Inlet Valve
6. Pony Motor/Generator
7. 10 kV Switchgear, Control Panels and Relays.
8. 2 x 70 ton Bridge Cranes
9. False Roof with Soundproofing
10. Haunch Beams
11. 50 ton Bridge Crane
12. Cable Gallery for 220 kV Cables

DTU Offshore is working on pumped hydro with turkey nest, underground, seawater & quarry reservoirs

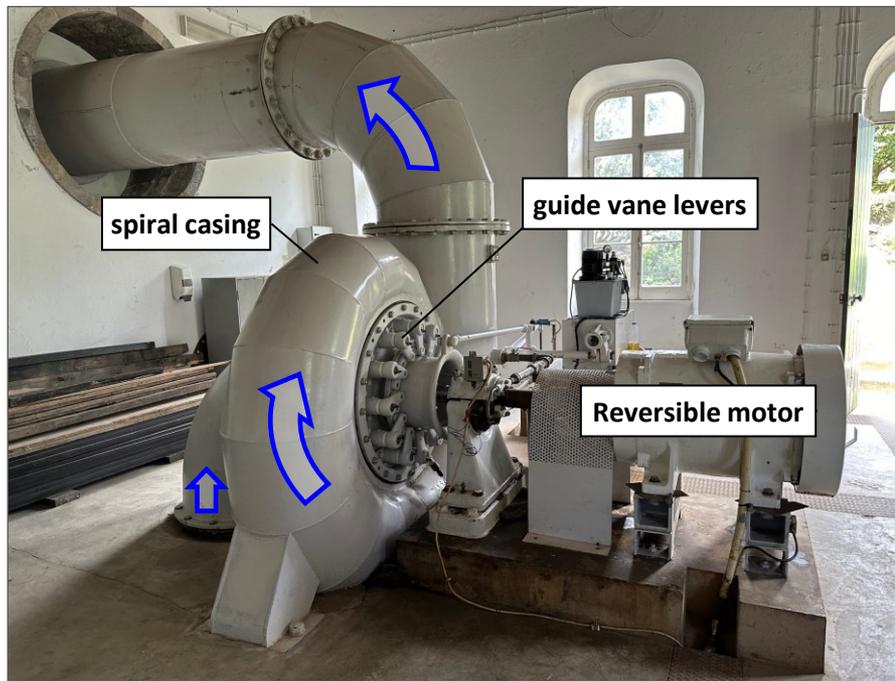
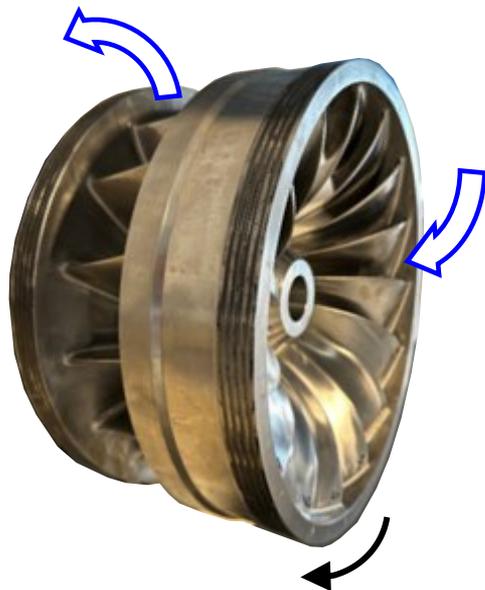
Example layout for two hydro power units



Francis turbine – inflow & power is adjusted with vanes



Francis turbine – can be reversed, pumping water to the upper reservoir to store energy



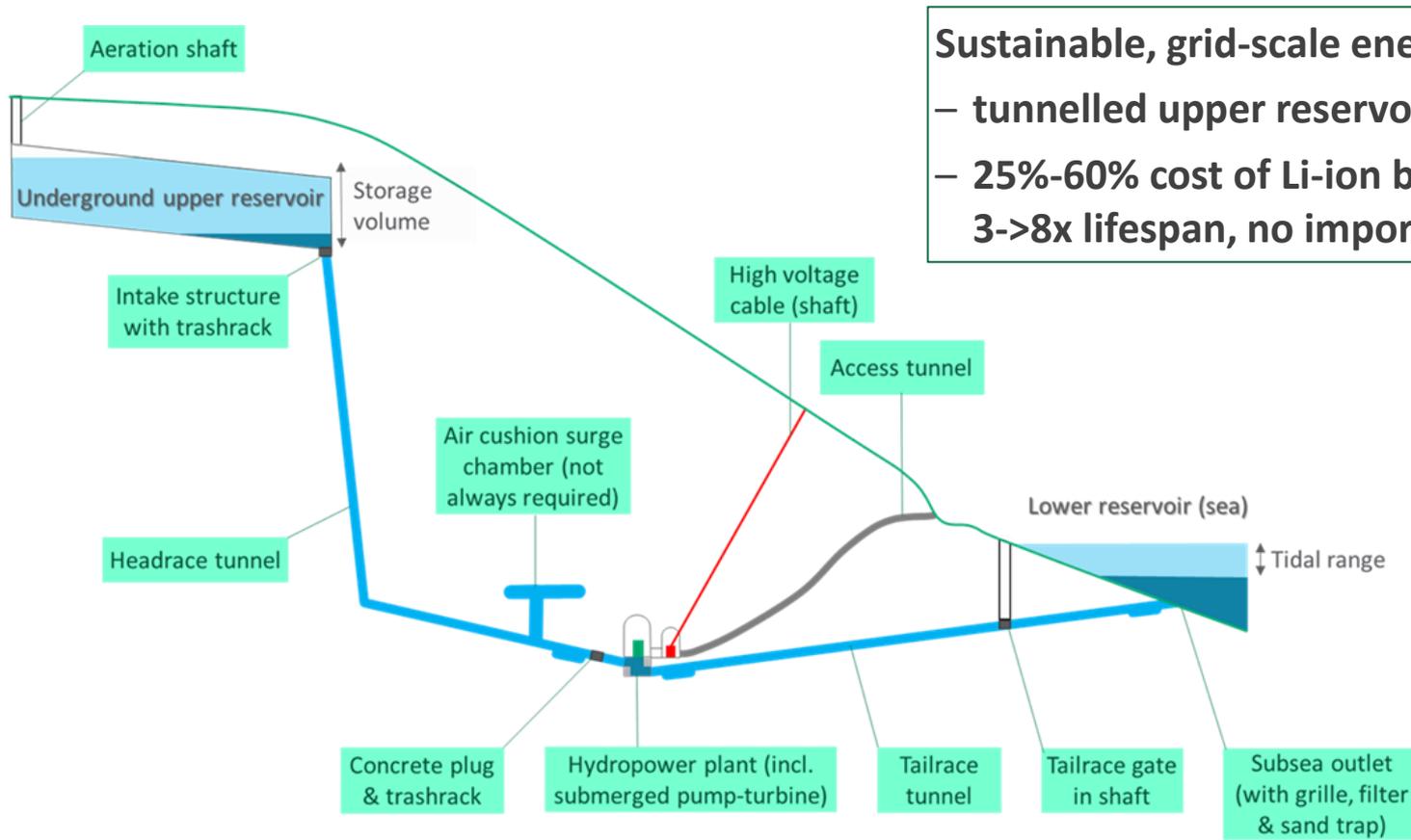
Conventional pumped hydro scheme, medium scale (2700 MWh)

Dispatchable power from combining wind & solar with grid-scale storage

How can local communities gain most benefit from renewables?

Elevation difference (head)	265 m	
Headrace construction	tunnel (drill & blast)	
Horizontal distance	1.8 km	1 in 6.8
Upper reservoir volume	5,000,000 m ³	
Nominal storage capacity	2700 MWh	48 hrs max power
Nominal power generation	60 MW	tbd (40-240 MW)
Indicative cost, NOK million	650 (2000)	calculated (generic)
assuming 1 reversible Francis turbine, no hydraulic short-circuit		

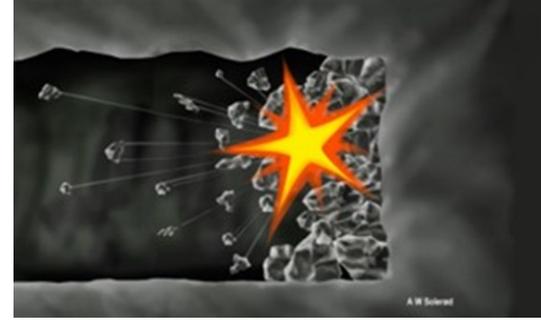
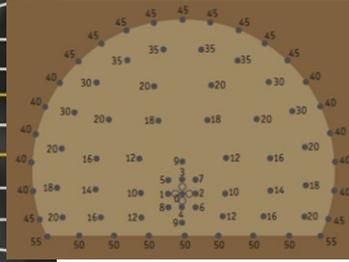
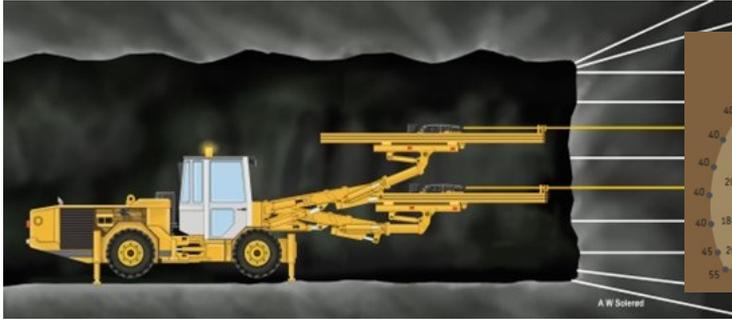
Underground pumped hydro – no surface footprint, scaleable



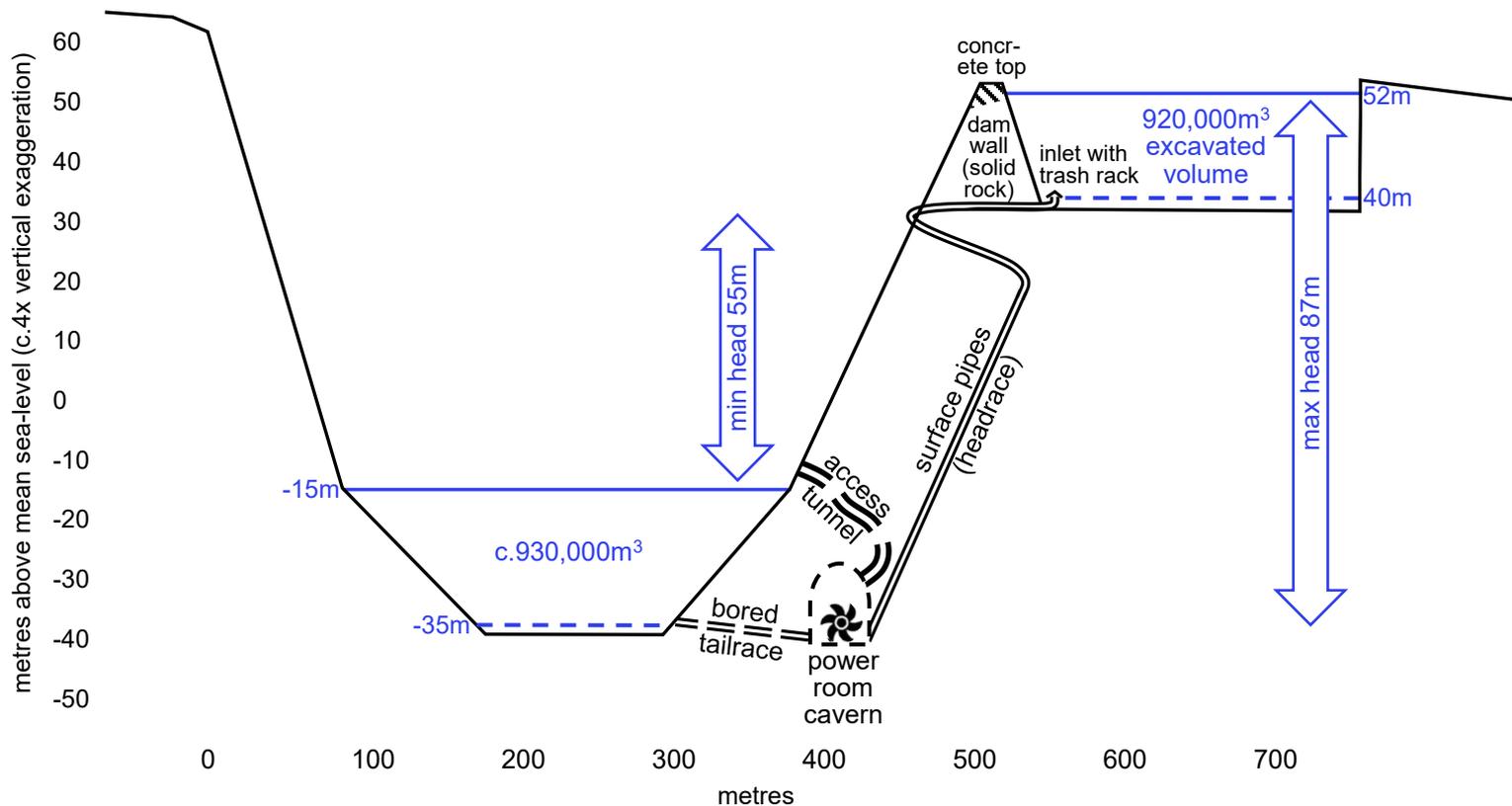
Sustainable, grid-scale energy storage

- **tunnelled upper reservoir**
- **25%-60% cost of Li-ion batteries,**
- **3->8x lifespan, no imports**

Norwegian tunnelling factory for roads & (now) hydro power



Schematic section through quarry pumped hydro scheme – 149 MWh



Small-scale pumped hydro scheme – 29 MWh



Elevation difference (head)	108 m	103-113 m
Headrace construction	surface pipe (or inclined bore)	
Horizontal distance	450 m	1 in 4.5
Upper reservoir volume	117,000 m ³	5x 19,500 tanks
Nominal storage capacity	29 MWh	tbd
Nominal power generation	5 MW	tbd
Indicative cost	NOK c.130 mill (early estimate) excl roofs & cables to Industripark	
assuming 1 reversible Francis turbine, no hydraulic short-circuit		

Conclusions

- We can not only pay for the transition but it will earn us money
- 80% of Manx emissions are related to oil & gas and this is solveable
- Electricity is relatively easy, transport & heating need more thought

Conclusions

- We can not only pay for the transition but it will earn us money
- 80% of Manx emissions are related to oil & gas and this is solveable
- Electricity is relatively easy, transport & heating need more thought
- Wind pays for itself on islands – energy companies will invest (e.g. Middle East) ...
 - ... But wind does not make sense without grid-scale storage
 - ... Then wind (+ solar) can replace Pulrose Power Station
 - ... And we can trade on the UK & Irish markets

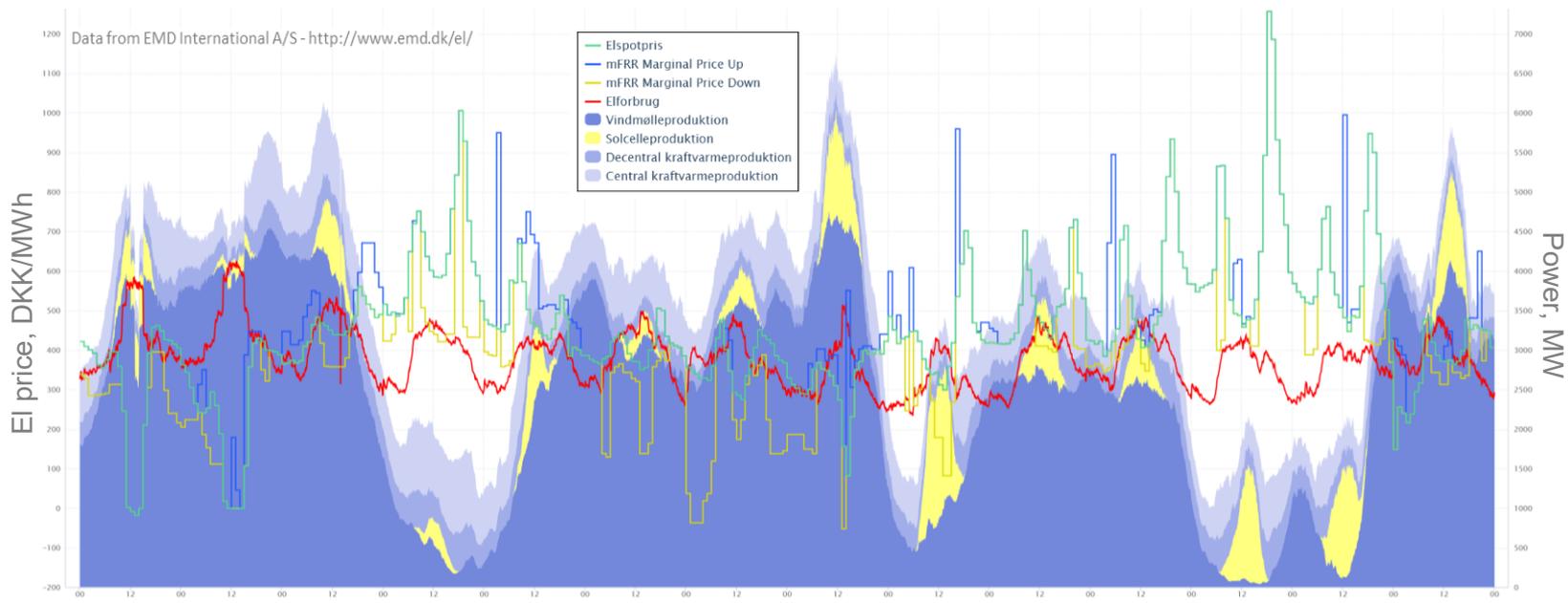
Conclusions

- We can not only pay for the transition but it will earn us money
- 80% of Manx emissions are related to oil & gas and this is solveable
- Electricity is relatively cheap
- Wind pays for itself on **Gura mie ayd** thought
... But wind does not make sense without grid-scale storage
... Thereafter, wind (+ solar) can replace Pulrose
... And we can trade on the UK & Irish markets
- Clean energy will attract new industry & skills and will make us proud
- Pumped hydro storage offers local construction jobs
- We can learn from & collaborate with other islands
- Isle of Man can innovate again, assuming public support
- Lots of info & videos at www.energysustainabilitycentre.im



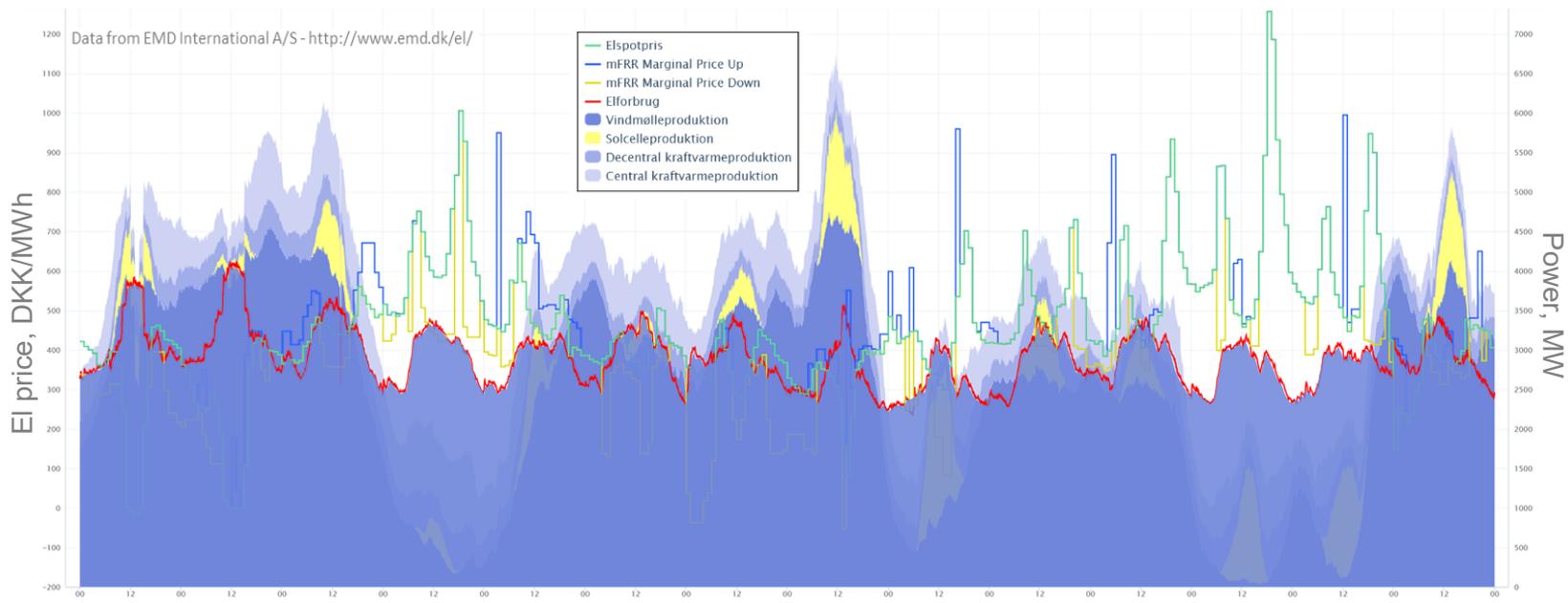
Reserve slides

Too little storage to balance Europe's wind & solar generation regional supply-demand mismatch: high & unpredictable prices

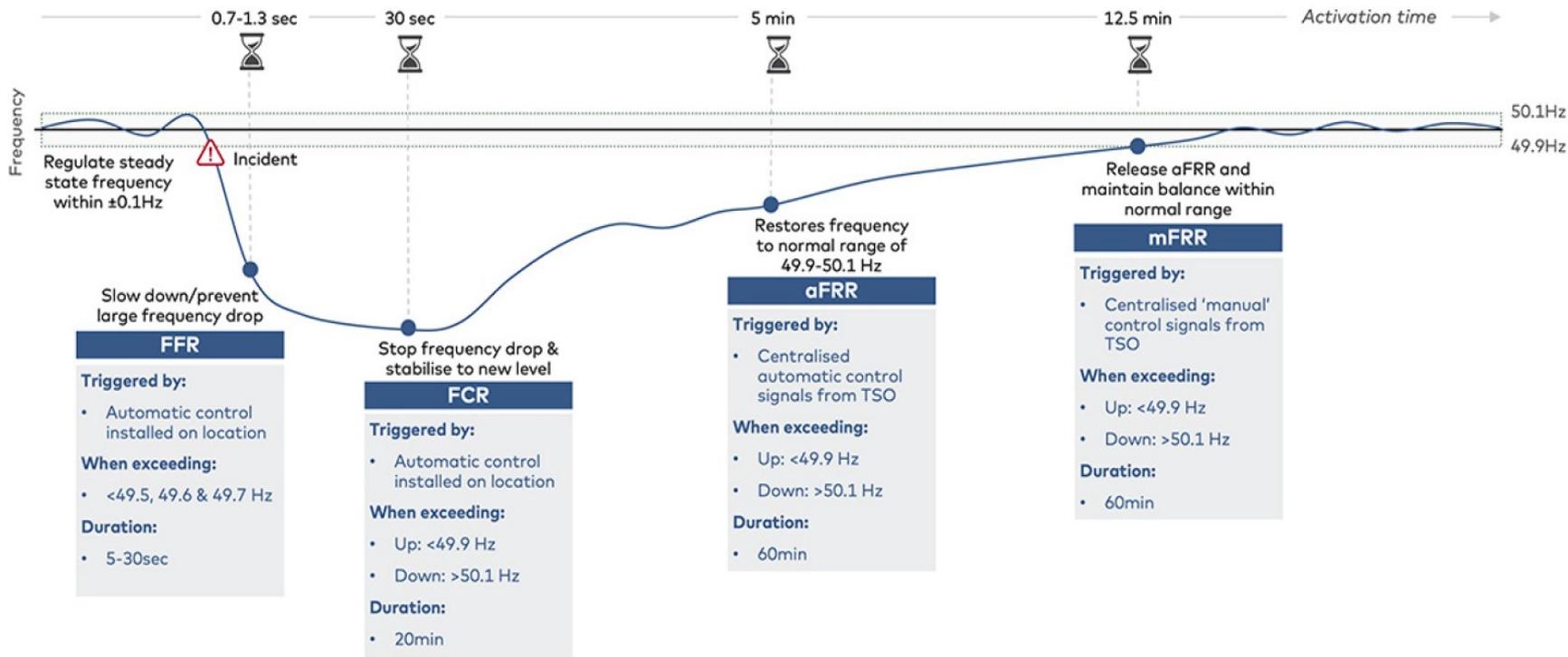


Can we convert wind energy to a dispatchable form of power?

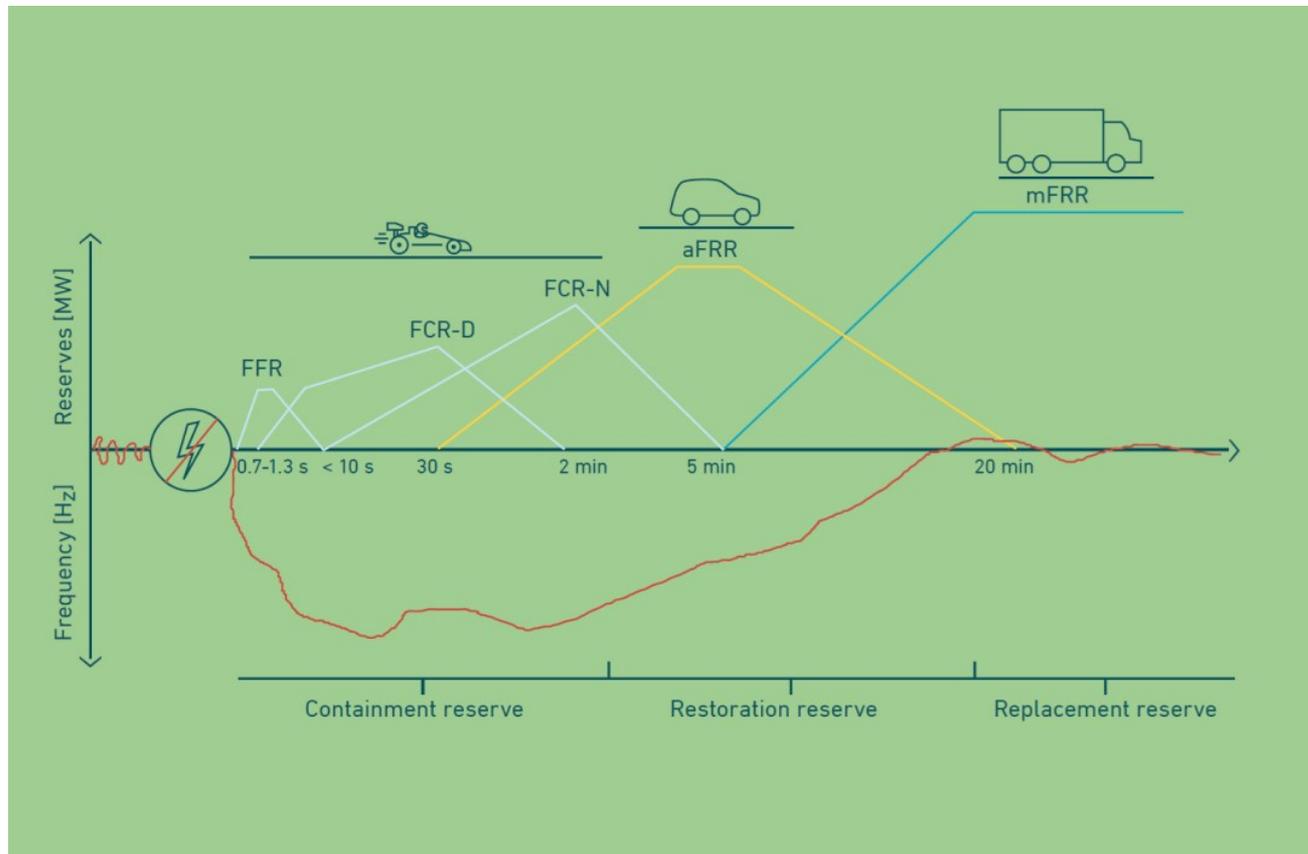
Cost of solar + storage is <50% of electricity from gas power plants



Balancing reserves markets in DK-NO-SE-FI to regulate frequency



Energinet DK2 ancillary service activation times



Who is the Energy & Sustainability Centre Isle of Man?

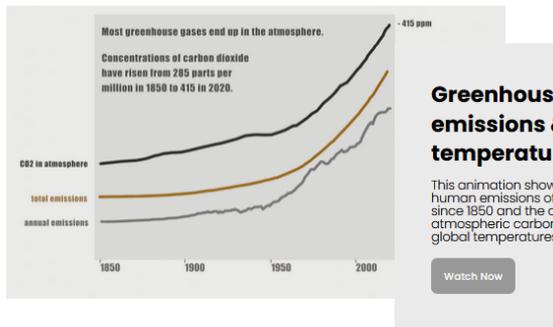
Our mission is to advance the green transition by providing knowledge to communities, businesses and the public sector through independent research, verifiable data, practical training and strategic advice. On the Isle of Man, we champion local renewable energy, affordable heating solutions and a low-carbon economy for a secure, sustainable future.

<https://www.energysustainabilitycentre.im/knowledge-hub> [/news](#)

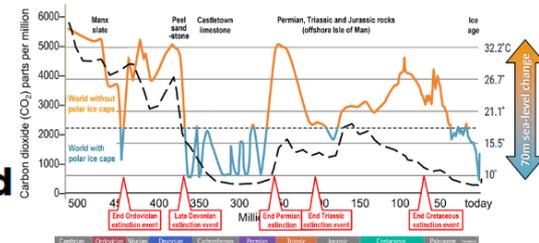


A huge thanks to all participants at the Low-Carbon Island conference on 27 Oct 2022. This was truly a landmark event in the Isle of Man's journey to net zero emissions.

- Links to the presentations are available here:
- Hon Jane Poole-Wilson MHK opens proceedings (Film)
 - Hon Jane Poole-Wilson MHK sums up the day (Film)
 - Terji Nielsen & Helma Trondheim (SEV) - Faroes plan for 100% renewable electricity by 2030 (Slides) (Film)
 - Henrik Lund (Aalborg University) - Denmark's experience in the energy transition (Slides)
 - Poul Østergaard (Aalborg University) - The benefits of district heating to island communities (Slides)
 - Dave Quirk (ESC IOM) - Options for self-sufficiency in low-carbon power on the Isle of Man (Slides) (Film)
 - James Curran - Investing in ecosystems & nature-based solutions (Slides)
 - Simon Nicholas (KPMG) - Green business, community-supported projects & the IOM economy (Slides)
 - Two-slide summary Highlights from the talks (Slides)



Green Energy Island videos released



500 million years of climate change on the Isle of Man

Find out about follow-up courses & workshops here - www.greenfutureisland.im

DENMARK'S NATIONAL R&D CENTRE FOR OFFSHORE TECHNOLOGIES

DTU Offshore – Danish Offshore Technology Centre – Denmark's national R&D centre for offshore technologies with a central position in the energy transition, developing commercial, research-based energy & sub-surface solutions for marine & coastal environments.

- Offshore CO₂ storage
- **Energy transition solutions for islands**
- Sub-surface energy storage, including H₂
- Wastewater management & green chemicals
- Environmental impact of offshore energy operations
- Responsible abandonment of wells & depleted oil & gas fields
- Maintenance of offshore structures, incl. corrosion management

Since the Centre opened in 2014, we have delivered more than 100 solutions for companies worth DKK 2.3 billion & involving around 700 researchers, incl. 200 PhD students. We are currently working on 90 industrial projects.

Technical University of Denmark* - global expertise in the green transition

- [DTU Offshore](#) (Danish Offshore Technology Centre)
 - expertise in island energy systems, energy storage, green hydrogen, CO₂ storage, offshore licencing, economics, risk & uncertainty, district heating, geothermal energy, waste water, public engagement
- [DTU Wind](#) – including the [Global Wind Atlas](#) and [Centre for Clean Energy](#)
- [DTU Elektro](#) – including [Solar PV Systems](#) and [Solar DTU](#)
- [DTU Energy](#) (Department of Energy Conversion and Storage)
- [DTU Sustain](#) – including [Centre for Absolute Sustainability](#)
- [DTU Aqua](#) - National Institute of Aquatic Resources
- [VILLUM Center for Sustainable Fuels and Chemicals](#)
- [Climate Challenge Laboratory](#)
- https://issuu.com/dtudk/docs/dtu_facts_and_figures_2025