Potential and challenges of offshore renewables in the European Atlantic

Joannes Berque
Tecnalia

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Why offshore renewales?

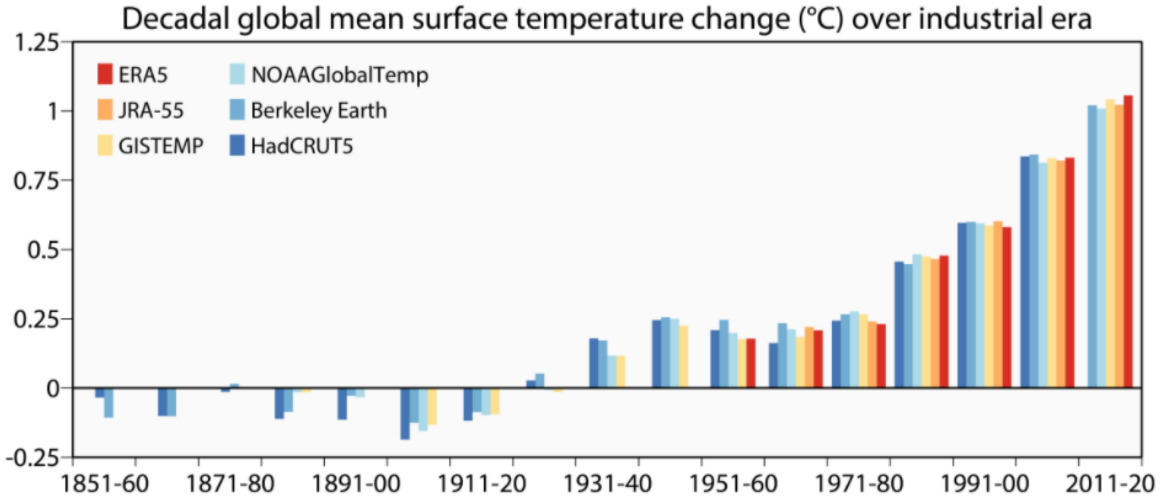
Which offshore renewables?

How to harvest it?

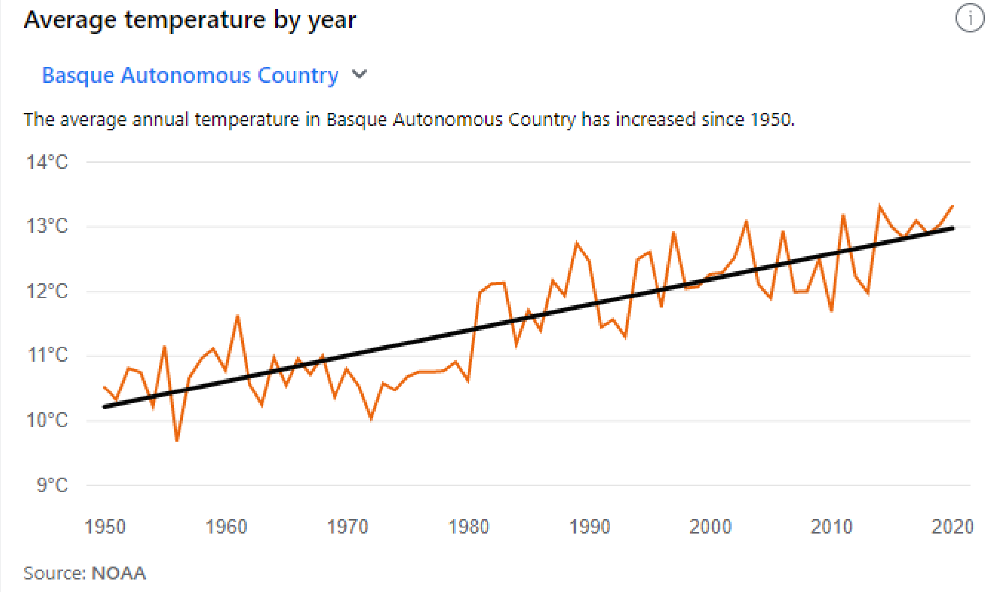
Image: Siemens Gamesa

Why offshore renewables?

- Robust technical, economical trends
- Space constraints onshore
- A good option – industrial, societal



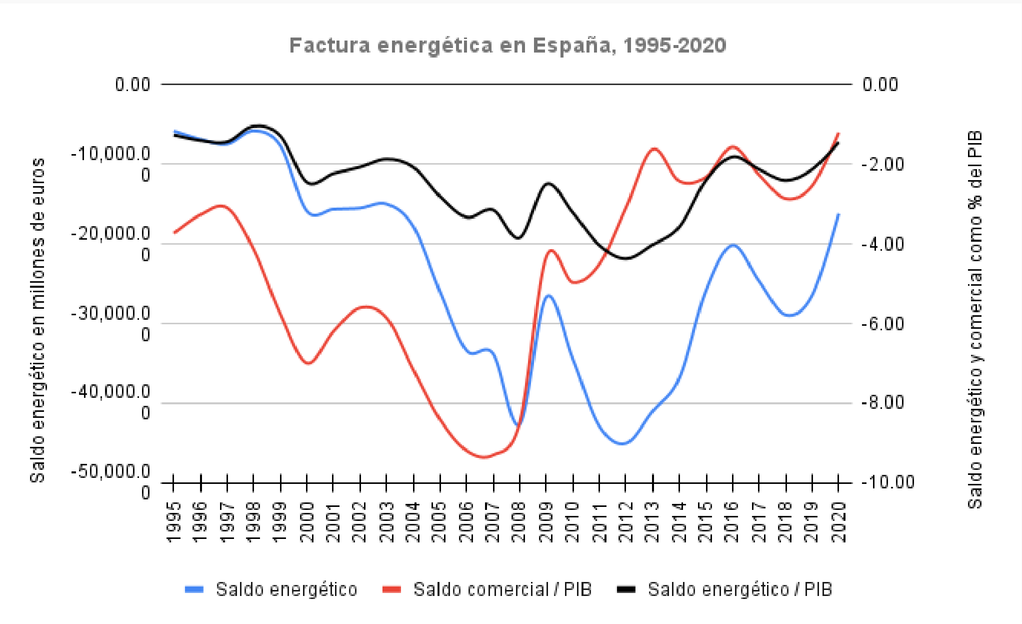
Decadal averages of global air temperature at a height of two metres estimated change since the pre-industrial period according to different datasets: ERA5 (ECMWF Copernicus Climate Change Service, C3S); GISTEMPv4 (NASA); HadCRUT5 (Met Office Hadley Centre); NOAAGlobalTempv5 (NOAA), JRA-55 (JMA); and Berkeley Earth. Credit: Copernicus Climate Change Service/ECMWF



Spain energy use and imports

	potencia/hab	%
Total	**3.6**	**100**
Petróleo y derivados	1.5	42
Gas natural	0.8	22
Renovables y biocombustibles	0.5	13
Energía nuclear	0.4	12
Combustibles fósiles sólidos	0.4	10
Residuos no renovables	0.0	0
Saldo imp-exp electricidad	0.0	1

Adaptado de INE 2019



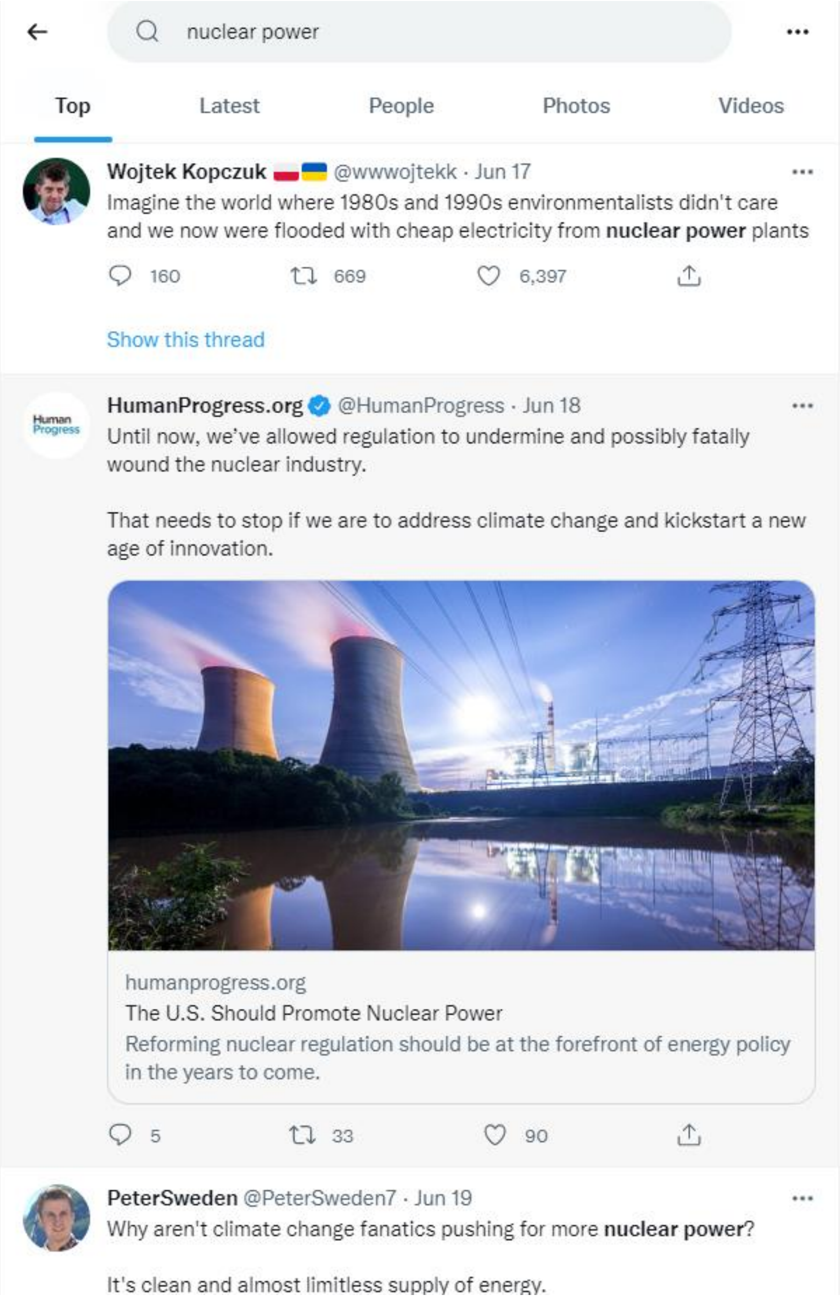
Jesús Ramos Martín (UAB)

Imports from…

	Country/Region	Oil exports (bbl/day)
1	Saudi Arabia (OPEC)	6,658,642
2	Russia	4,653,500
3	Iraq (OPEC)	3,428,379
4	Canada	3,037,668
5	Iran (OPEC)	2,700,000
6	United Arab Emirates (OPEC)	2,418,388
7	Nigeria (OPEC)	1,879,288
8	Kuwait (OPEC)	1,826,331
9	Norway	1,501,768
10	Kazakhstan	1,410,917

Wikipedia

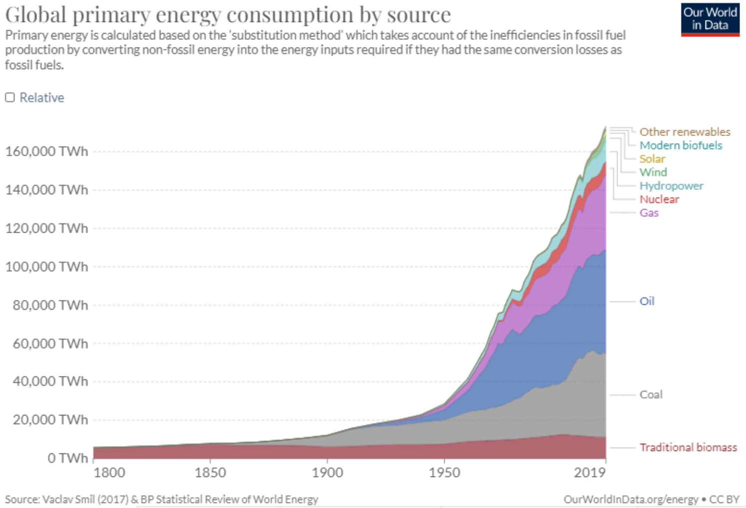
Media: an alternative for energy independence?

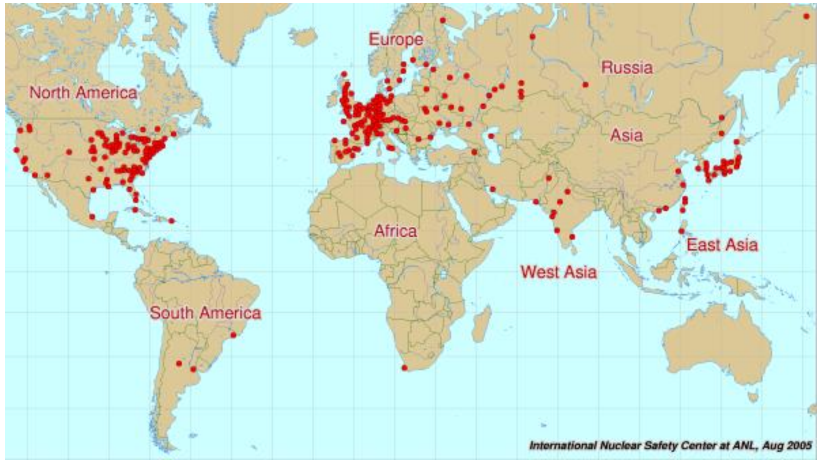


But actually…

World Nuclear Association (2018) [edit]

Rank	Country/Region	Uranium production (2018) (tonnes U)[1]	Percentage of World Production (2018)
	World	53,498	100.00%
1	Kazakhstan	21,705	40.57%
2	Canada	7,001	13.09%
3	Australia	6,517	12.18%
4	Namibia	5,525	10.33%
5	Niger	2,911	5.44%
6	Russia	2,904	5.43%
7	Uzbekistan	2,404[2]	4.49%
8	China	1,885[2]	3.52%
9	Ukraine	1,180[2]	2.21%
10	United States	582	1.09%





Element	£/MWh	Percent of price
Construction risk premium	35	38%
Other financing costs	26	29%
Operation & maintenance costs	19.5	21%
Capital cost	11	12%
Total electricity price	**92.5**	

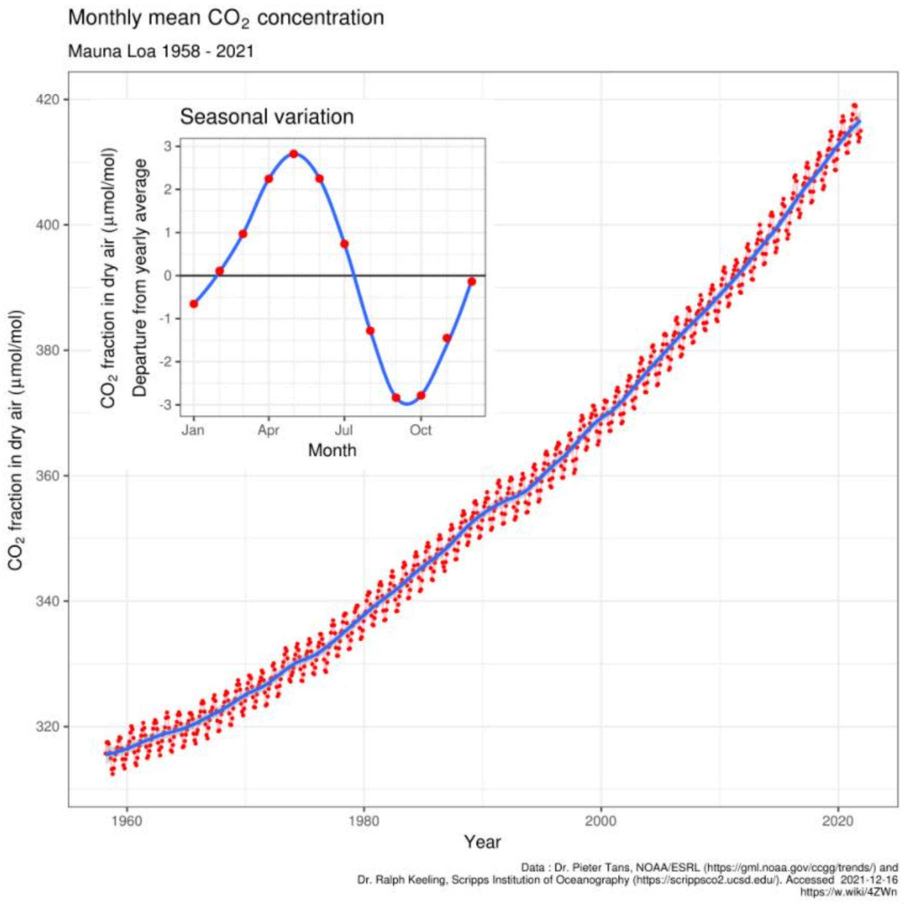
Optimizing risk management

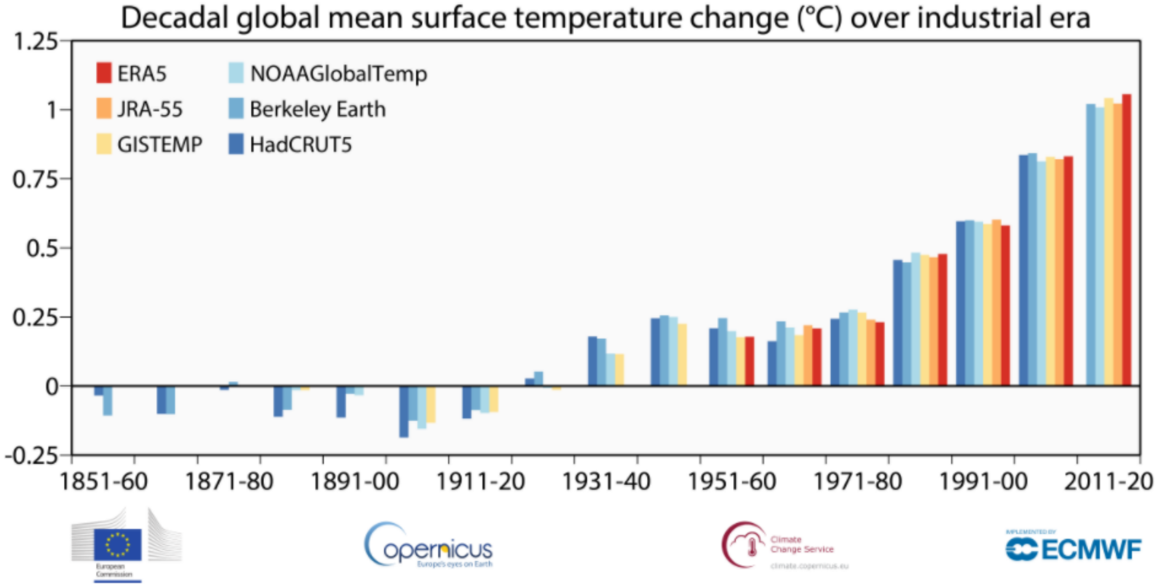
Shale?

Largest oil shale deposits (over 1 billion metric tons) (Dyni 2006)[7]

Deposit	Country	Period	In-place shale oil resources (million barrels)	In-place oil shale resources (million metric tons)
Green River Formation	United States	Paleogene	1,466,000	213,000
Phosphoria Formation	United States	Permian	250,000	35,775
Eastern Devonian	United States	Devonian	189,000	27,000
Heath Formation	United States	Early Carboniferous	180,000	25,578
Olenyok Basin	Russia	Cambrian	167,715	24,000
Congo	Democratic Republic of Congo	?	100,000	14,310
Irati Formation	Brazil	Permian	80,000	11,448
Sicily	Italy	?	63,000	9,015
Tarfaya	Morocco	Cretaceous	42,145	6,448
Volga Basin	Russia	?	31,447	4,500
Leningrad deposit, Baltic Oil Shale Basin	Russia	Ordovician	25,157	3,600
Vychegodsk Basin	Russia	Jurassic	19,580	2,800
Wadi Maghar	Jordan	Cretaceous	14,009	2,149
Graptolitic argillite	Estonia	Ordovician	12,386	1,900
Timahdit	Morocco	Cretaceous	11,236	1,719
Collingwood Shale	Canada	Ordovician	12,300	1,717
Italy	Italy	Triassic	10,000	1,431

Another fossil fuel problem…





Decadal averages of global air temperature at a height of two metres estimated change since the pre-industrial period according to different datasets: ERA5 (ECMWF Copernicus Climate Change Service, C3S); GISTEMPv4 (NASA); HadCRUT5 (Met Office Hadley Centre); NOAAGlobalTempv5 (NOAA), JRA-55 (JMA); and Berkeley Earth. Credit: Copernicus Climate Change Service/ECMWF

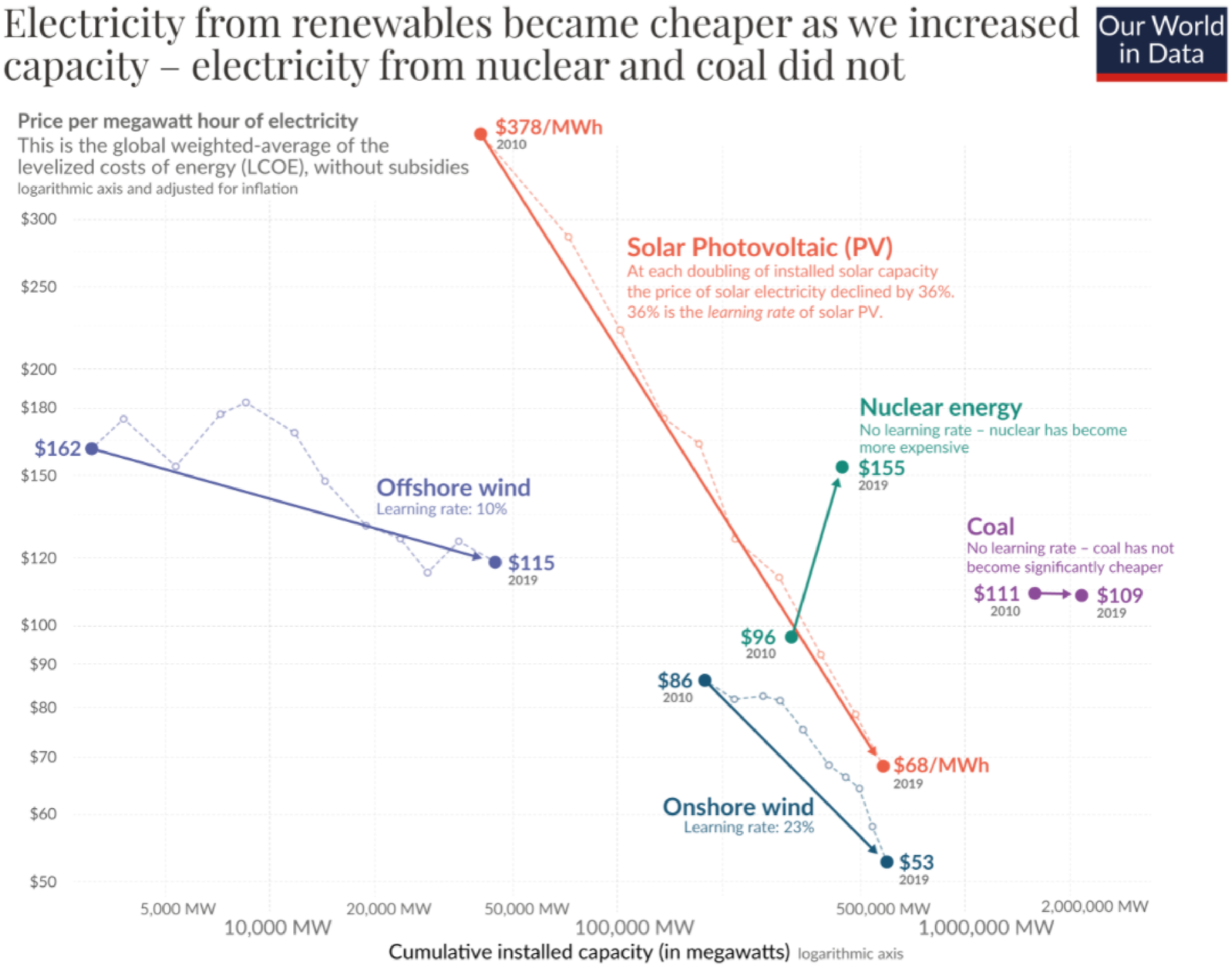
Why renewables

Oil and gas: environmental, economical, and geopolitical issues

No good alternatives to renewables – proliferation, no shale

Are renewables really a solution?

Can we pay for renewables?



Source: IRENA 2020 for all data on renewable sources; Lazard for the price of electricity from nuclear and coal – IAEA for nuclear capacity and Global Energy Monitor for coal capacity. Gas is not shown because the price between gas peaker and combined cycles differs signficantly, and global data on the capacity of each of these sources is not available. The price of electricity from gas has fallen over this decade, but over the longer run it is not following a learning curve.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Are there enough of them?

Wind: 1000 TW

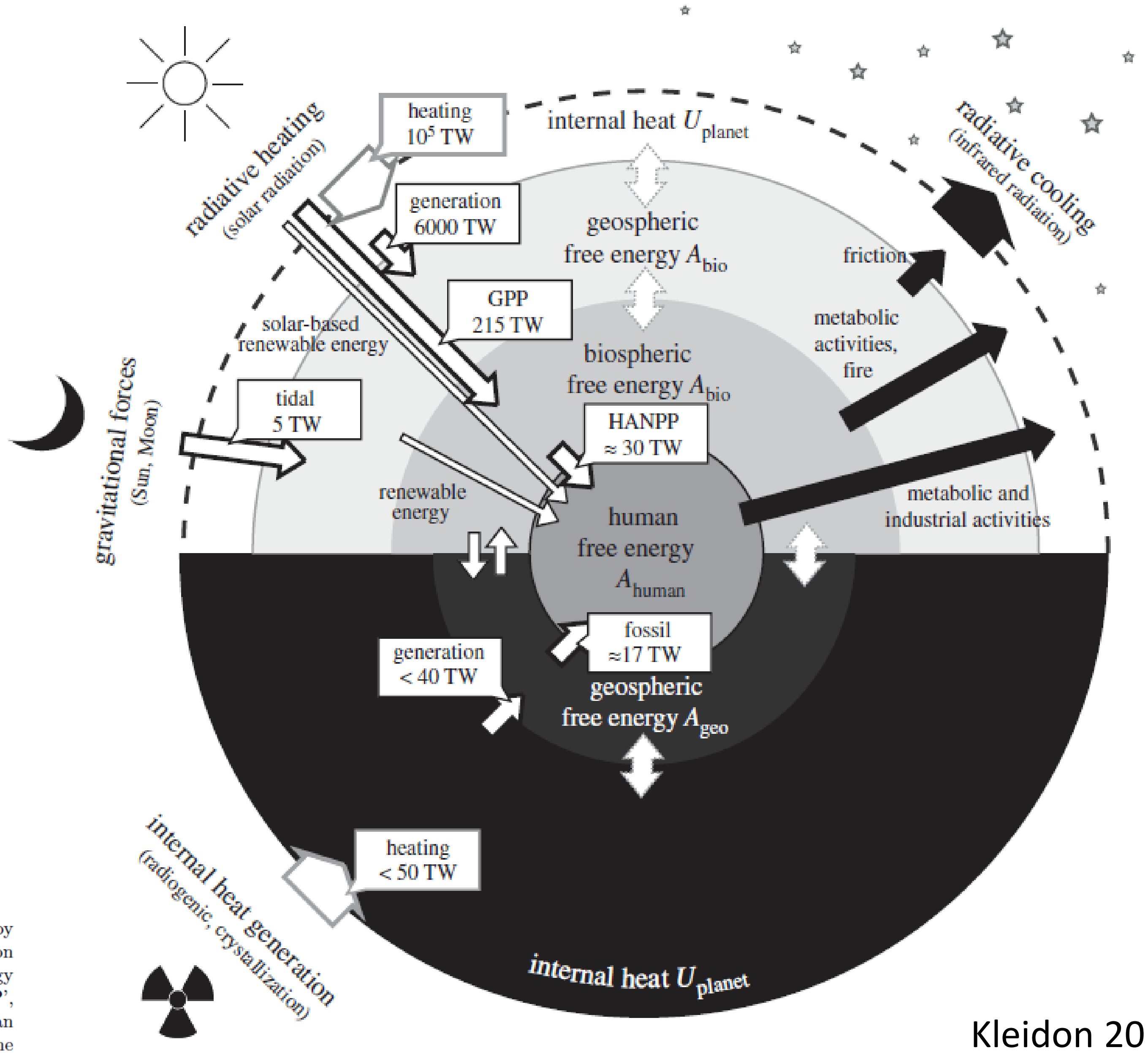
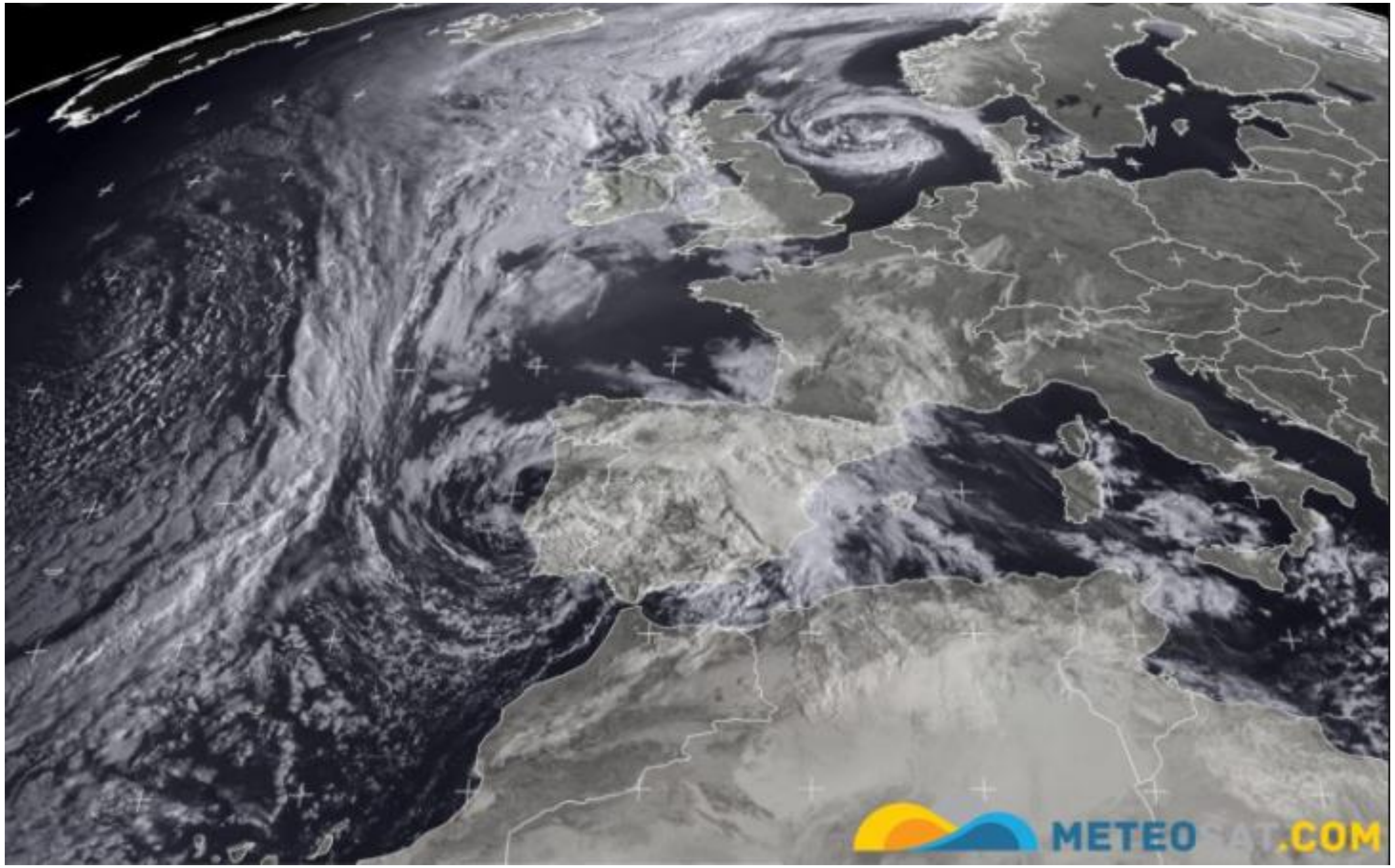


Figure 4. Estimates for global free energy generation rates at the planetary scale. Heating rates by solar radiation and interior processes are shown in boxes with grey borders. Free energy generation processes are shown by white boxes and arrows with black borders ('tidal', free energy generation by tidal forces; 'generation', free energy generation by heat engine processes; 'GPP', gross primary productivity, i.e. chemical free energy generation by photosynthesis). Human activity is driven by about 30 TW of human appropriation of net primary productivity of the biosphere ('HANPP') and the consumption of fossil fuels ('fossil'). 1 TW = 10^{12} W. Adapted from Kleidon [17].

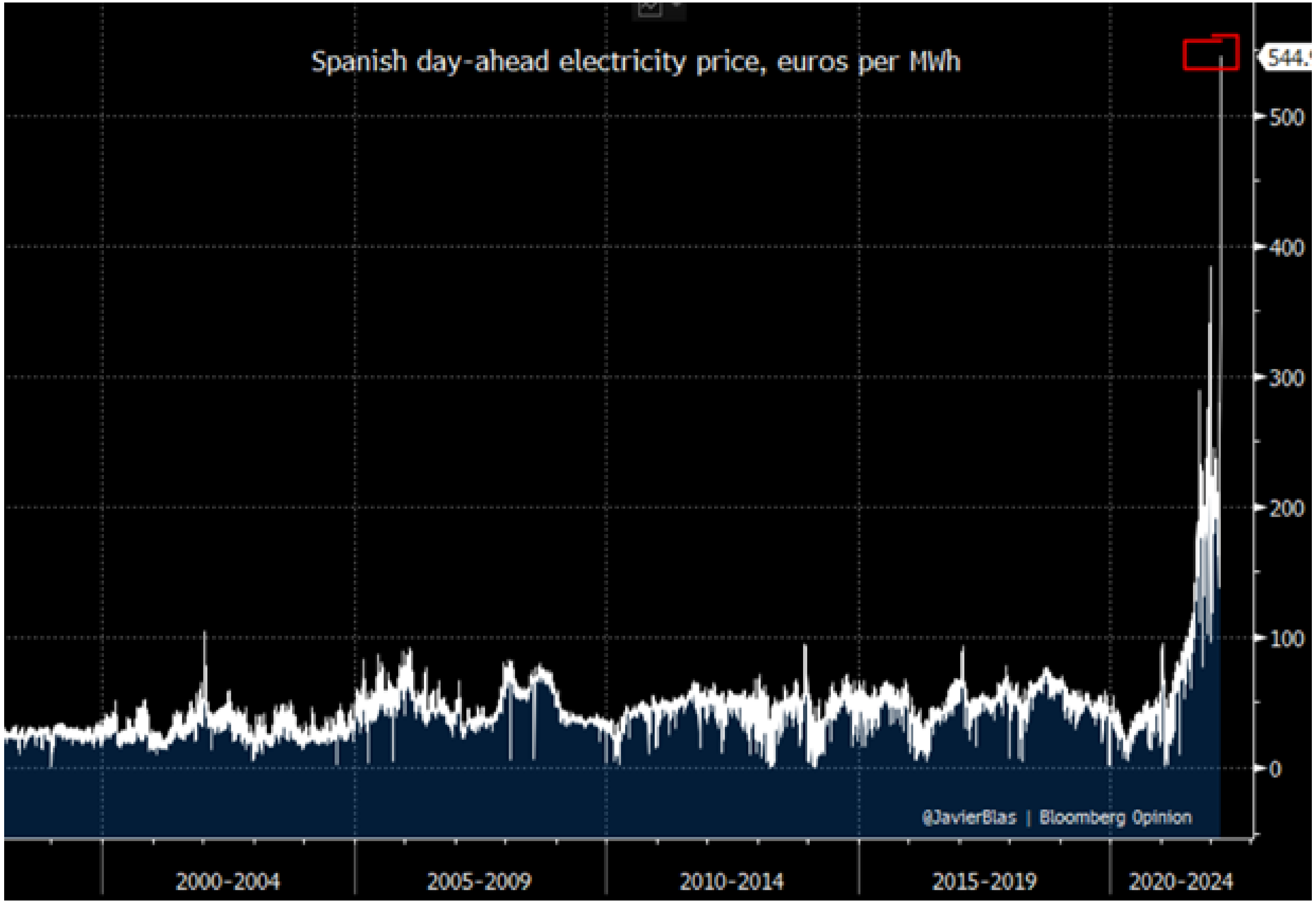
Kleidon 2012

What about intermittence?

- Grid interconnection
- Hydropower?



Intermittence vs. volatility



Why OFFSHORE renewables?

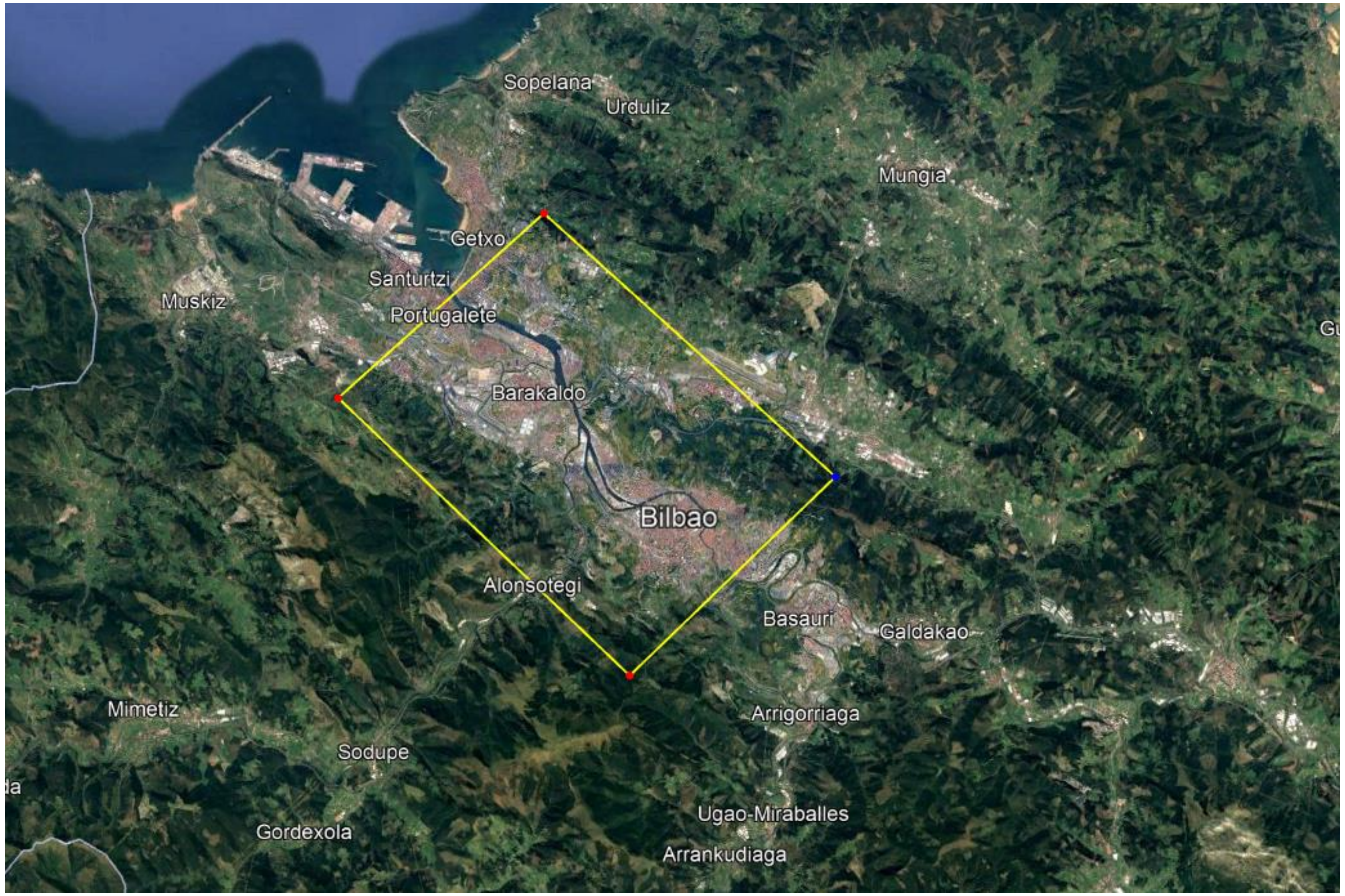
No good alternatives to renewables

Renewables offer a true solution

But why offshore?

Land use

Solar farm~ 15 W/m2 (annual average)



100 km2 de planta solar

340 km2 de planta solar

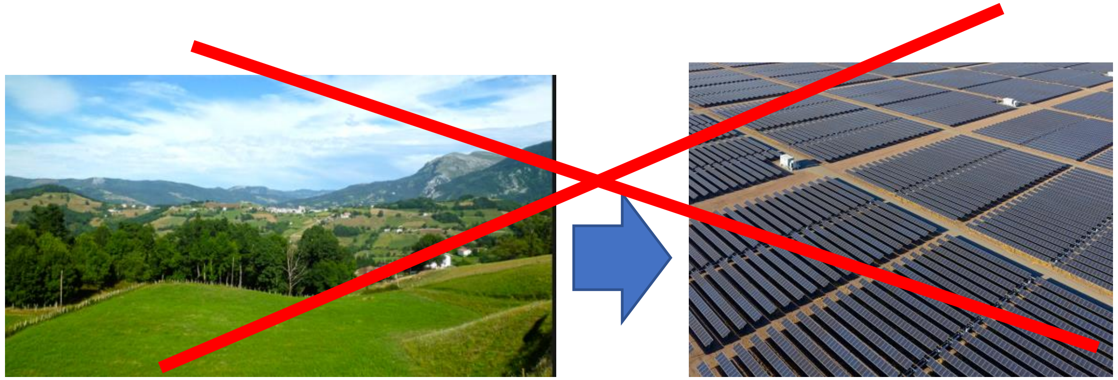
Where do we put the farms?

Techos: 15-30%?

Transporte: 15-25%

Agri-PV positiva

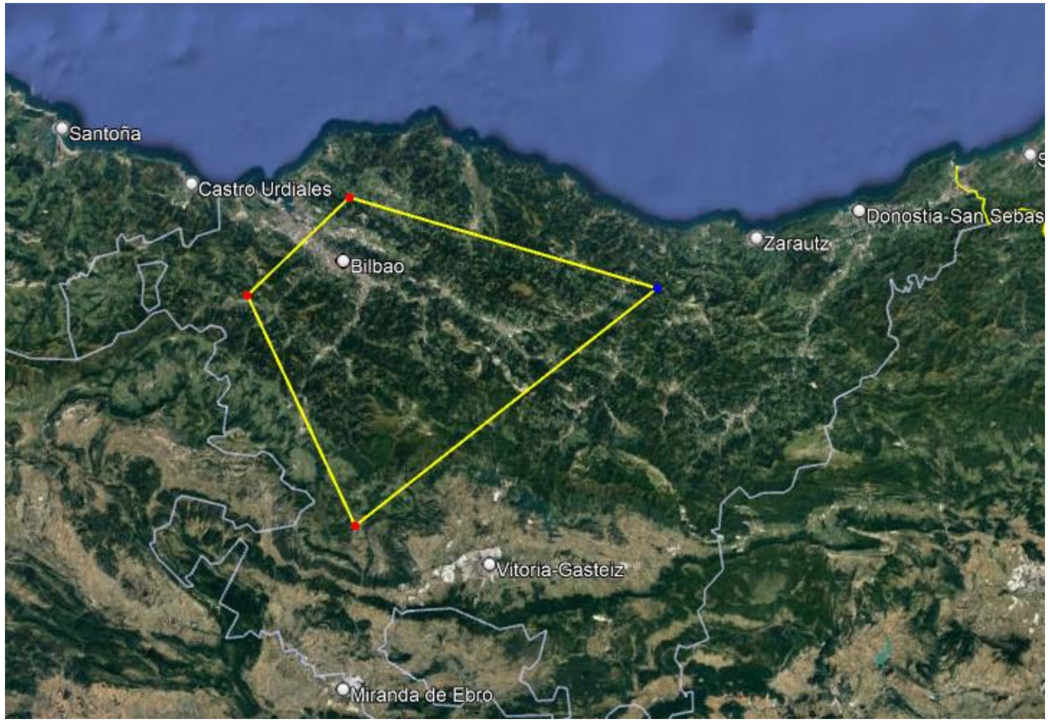
Contribución positiva al medio ambiente local



What about wind farms?

Annual average 2 W/m2 onshore, 3 W/m2 offshore

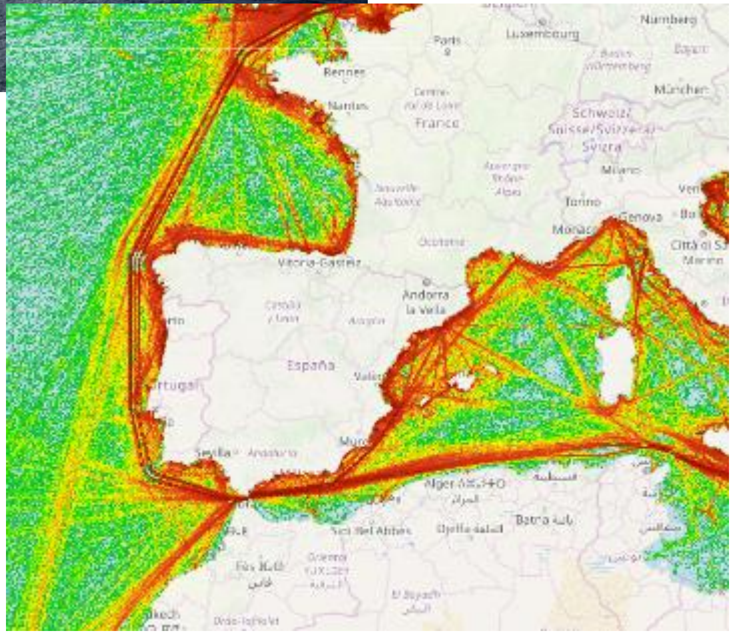
1500 km2



Marine space

Parque offshore ~3 W/m2

1200 km2



Summary to here

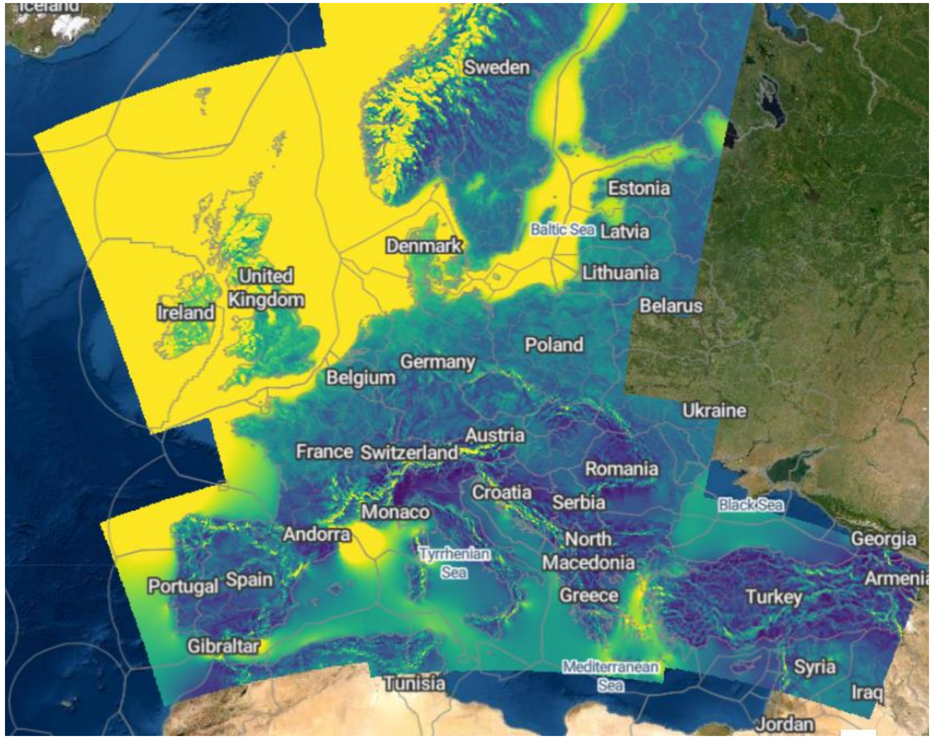
- Robust trends
  - Renewables are the best bet for sustainability and energy independence
  - Most competitive source
  - Space needed → a good future for competitive offshore solutions

Which offshore renewables?

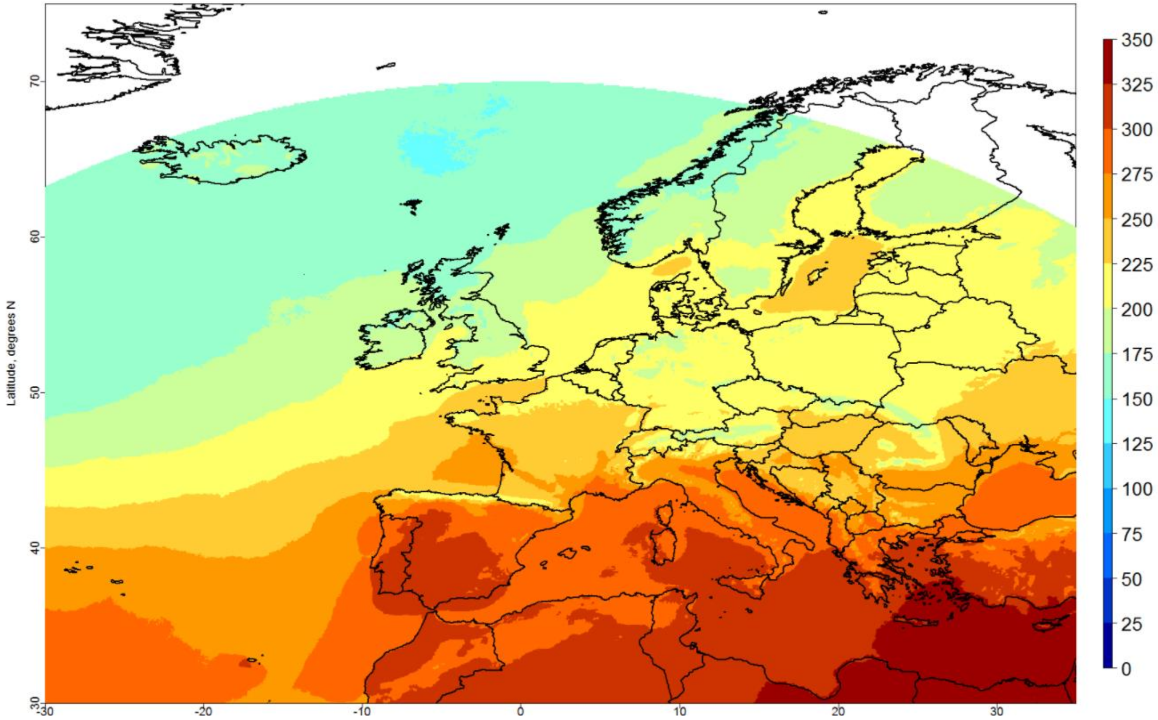
Most advanced is wind

Most potential is solar – but technical and environmental issues

Wave, tides, bio also interesting



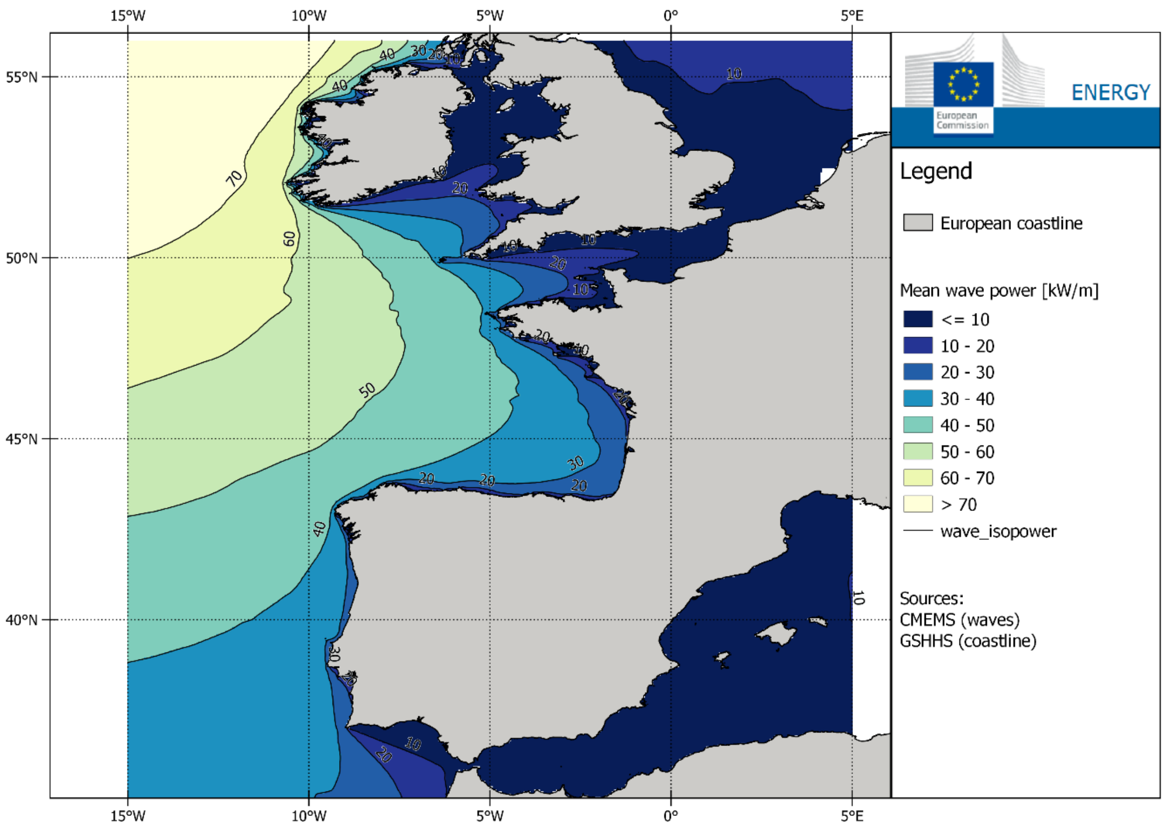
https://map.neweuropeanwindatlas.eu/



Eumetsat – mean surface shortwave radiation

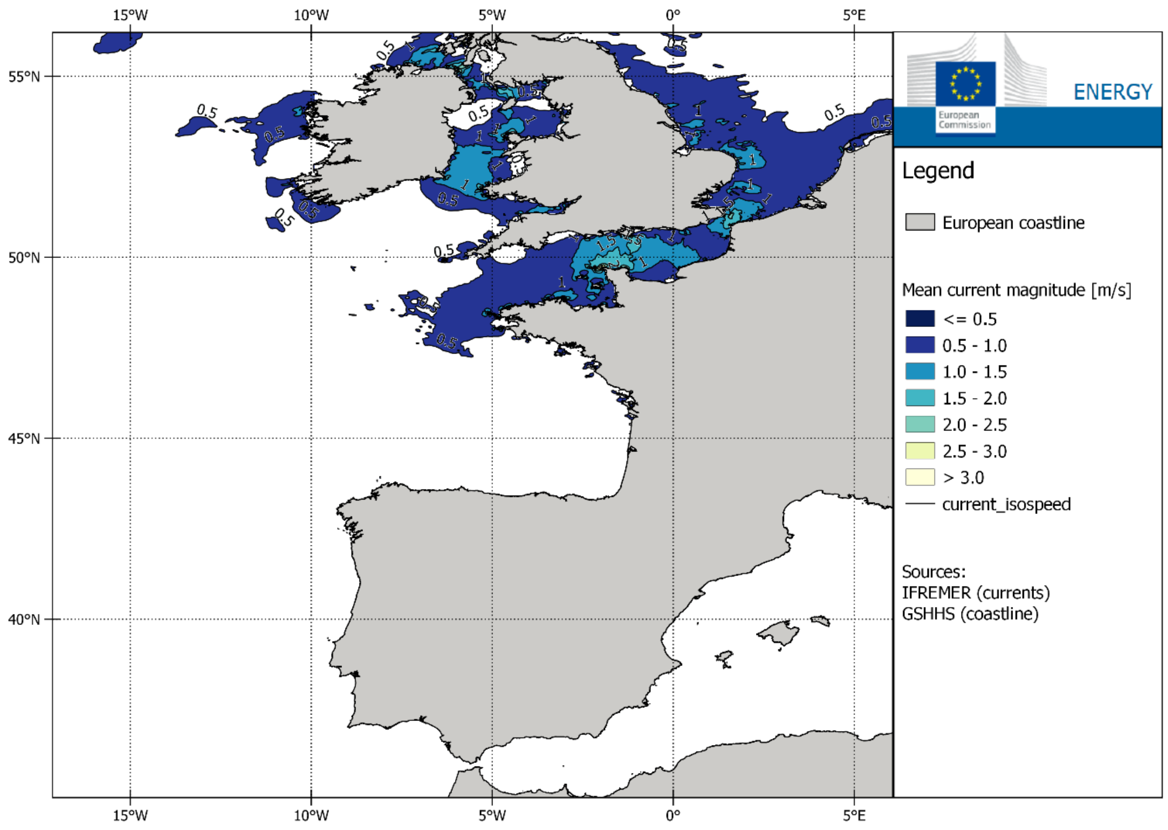
https://www.mapaeolicoiberico.com/

WAVES – 2-3 MW/km



France énergies marines – for DG ENER

TIDAL



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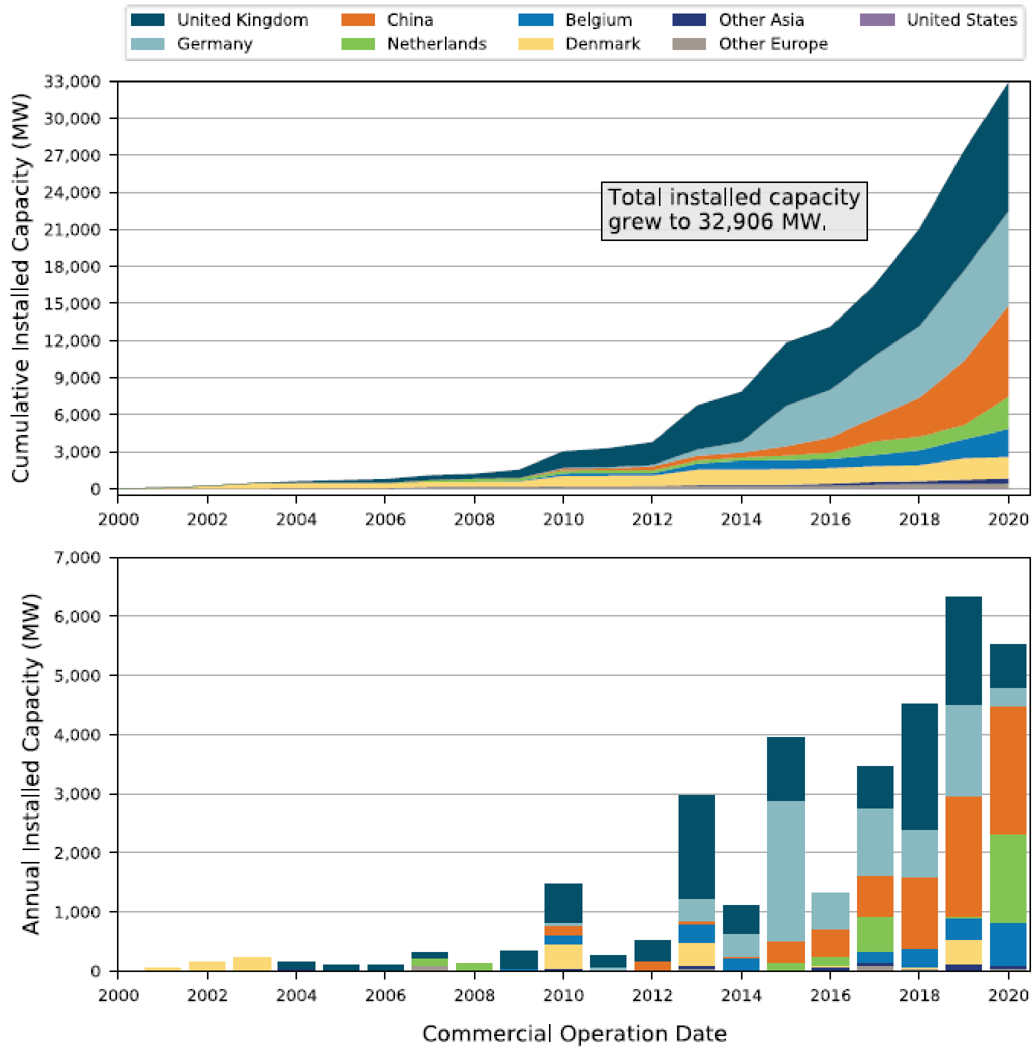
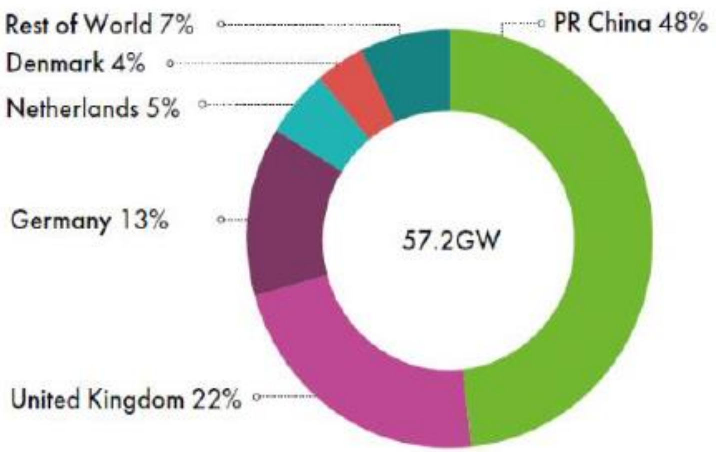


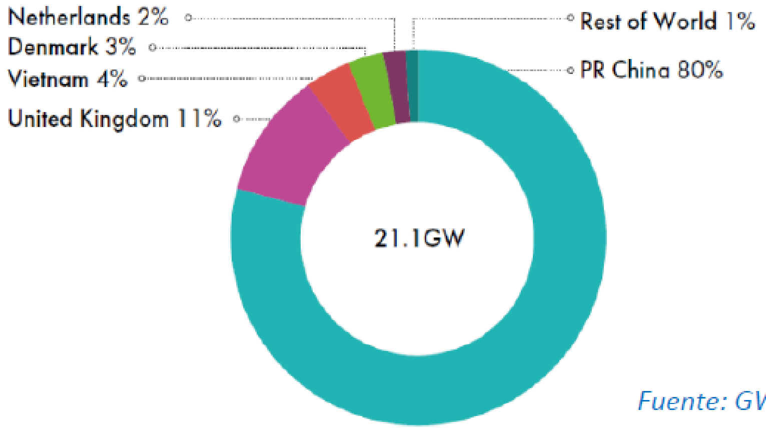
Figure 10. Global cumulative offshore wind energy deployment (top) and annual capacity additions (bottom) through 2020

NREL 2021

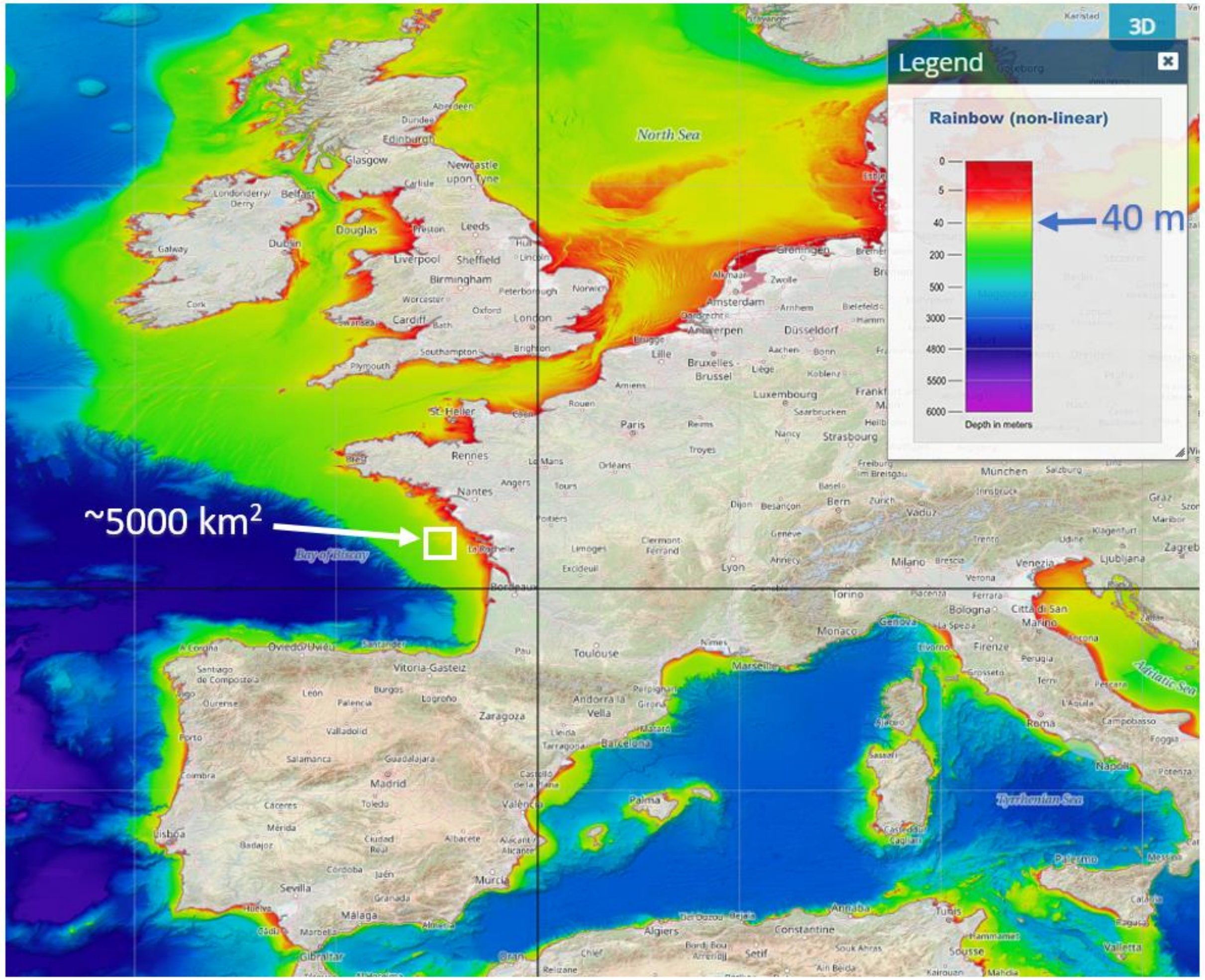
Total installations offshore (%)



New installations offshore (%)



Fuente: GWEC



Bathymetry of Western Europe *(from: EMODNet)*

Illustrative spatial requirements for offshore wind power generation

EU electricity generation	2800	TWh
Mean power	319	GW
5% of European power	16	GW
Offshore wind mean power per farm area	3	W/m2
Required area for 5% generation	5324	km2

Extending bottom-fixed solutions beyond 60 m

beyond XXL” monopile for the Yunlin offshore wind farm (image: Steelwind Nordenham, FHI corporation, via offshorewind.biz)

The Seagreen wind farm, offshore Scotland, uses jacket foundations in 40-60 m depth range *(image: Seagreen Wind Energy)*

Offshore wind cost breakdown

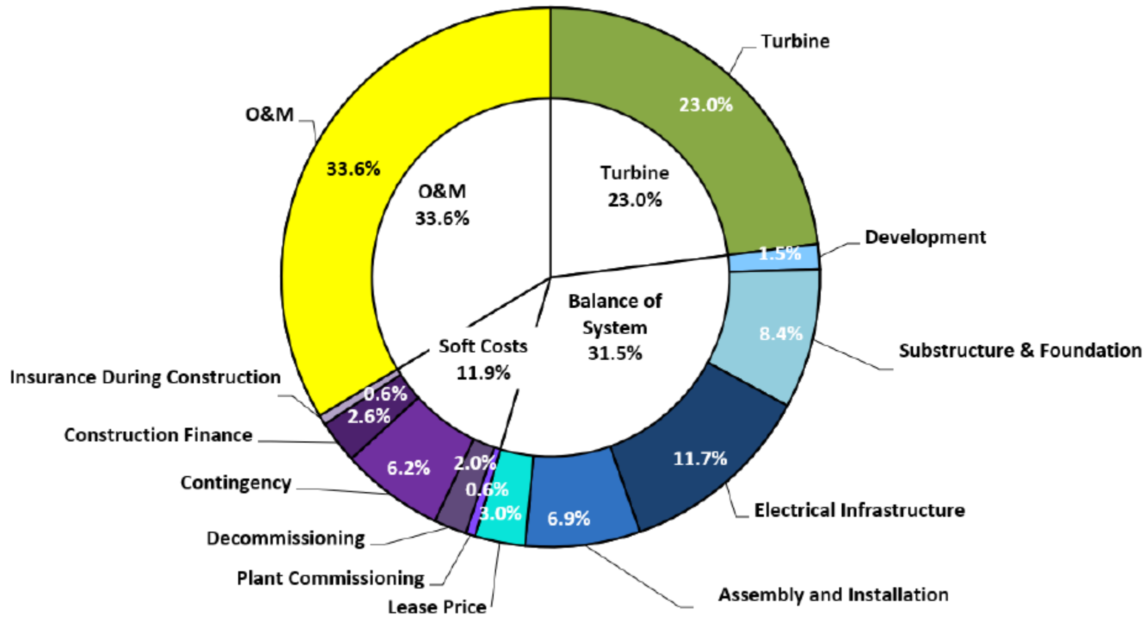
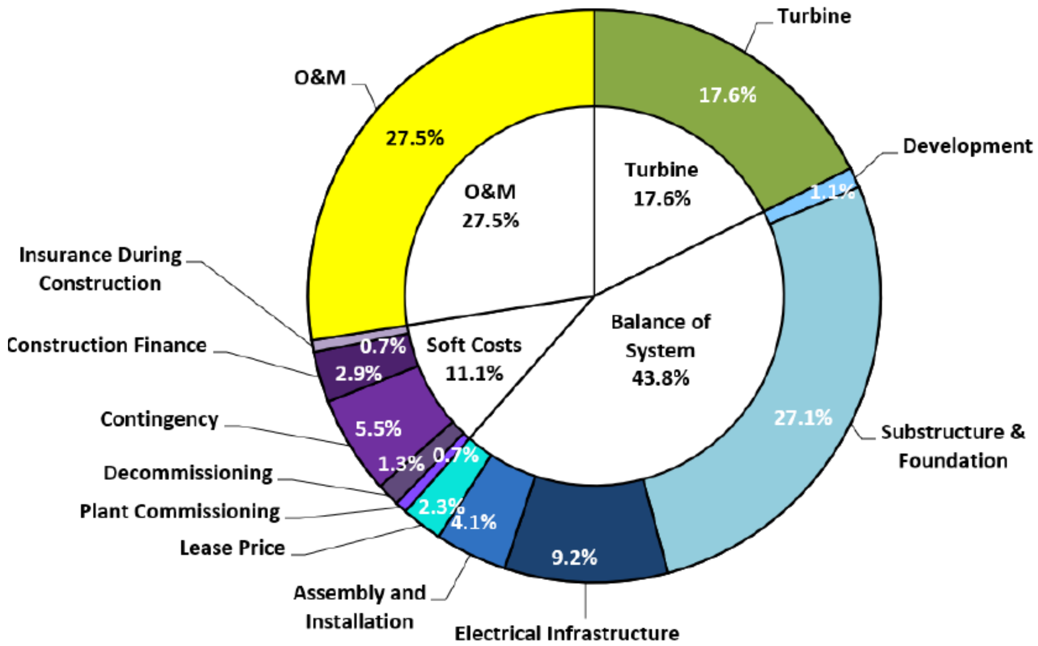


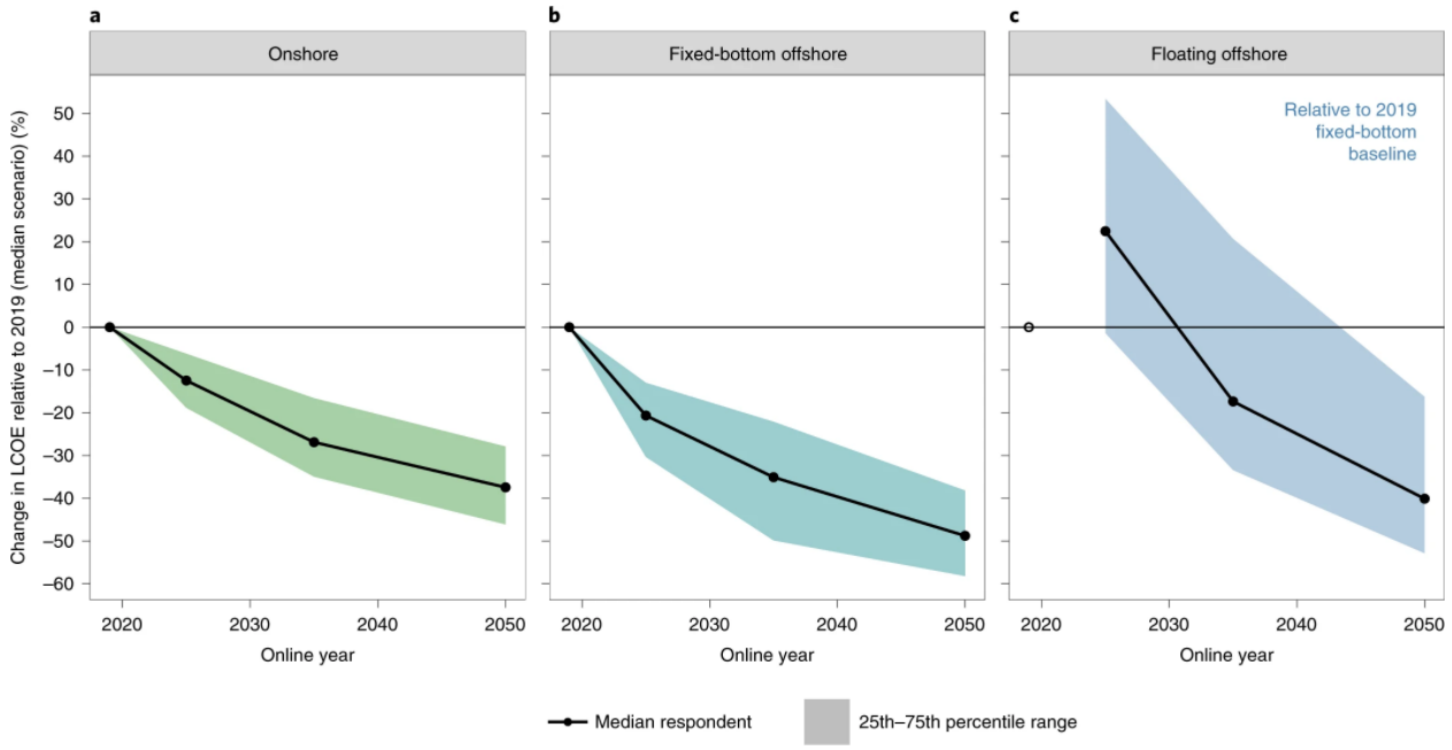
Figure ES2. Component-level LCOE contribution for the 2020 fixed-bottom offshore wind reference project operating for 25 years



re ES3. Component-level LCOE contribution for the 2020 floating offshore wind reference project operating for 25 years

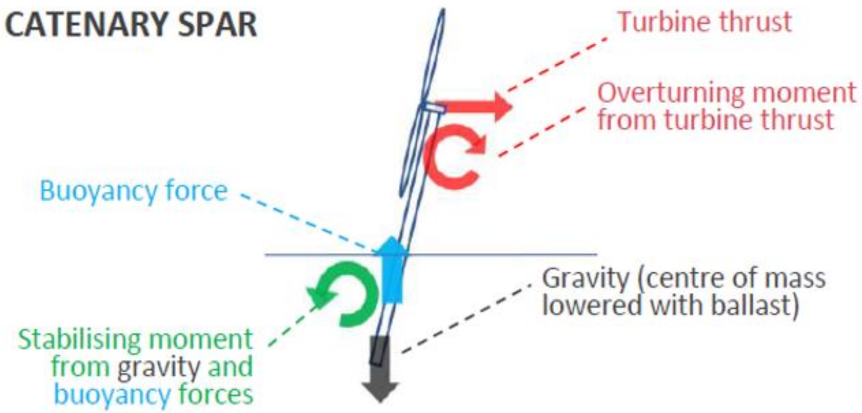
NREL 2020

Learning rates and cost reduction

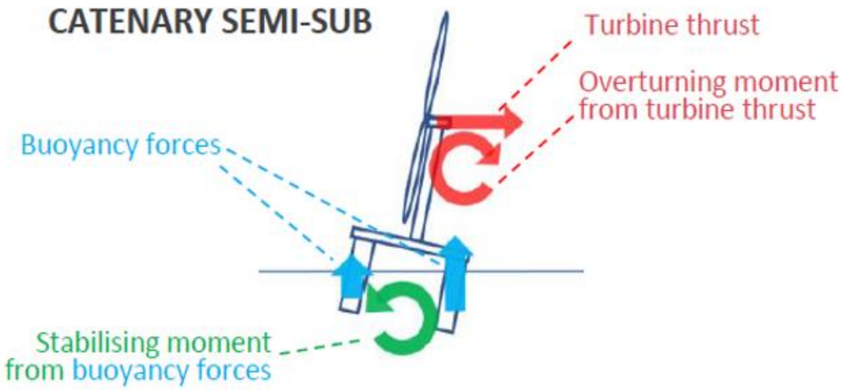


a–**c**, From the 2020 elicitation, the medians of expert responses in terms of percentage LCOE reductions are shown by the lines/markers, and the shaded areas represent the 25th–75th percentile ranges of all responses for the median scenario. Panels show results for onshore (**a**), fixed-bottom offshore (**b**) and floating offshore (**c**) wind. Floating offshore wind changes are compared with expert-specific 2019 baselines for fixed-bottom offshore wind, depicted in the figure as the empty circle; given the nascent state of floating offshore wind, experts predict that LCOE in 2025 will be higher than 2019 fixed-bottom costs.

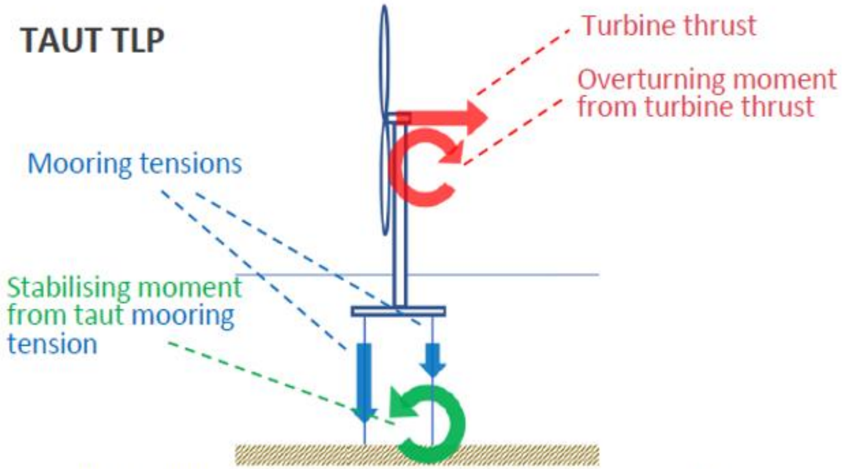
Stabilisation mechanisms for floaters



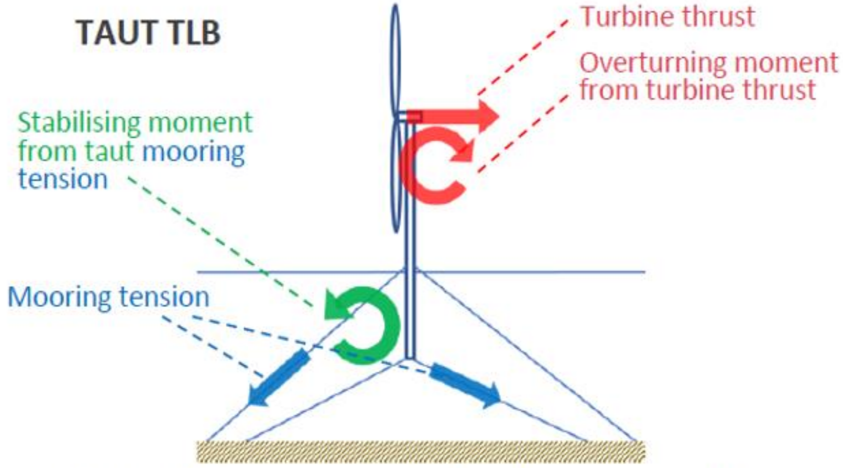
Spar stability: moment of gravity and buoyancy



Semi-submersible stability: moment of buoyancy forces



TLP stability: moment of vertical taut mooring lines



TLB stability: moment of inclined taut mooring lines

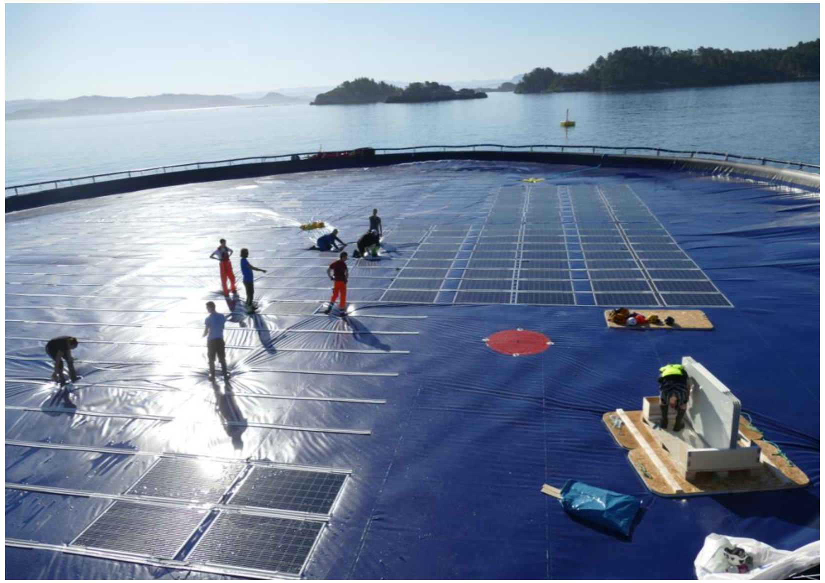
Hywind Scotland – Spars

Floatgen – Barge

Windfloat Atlantic – Semi-submersible

EDF Usine Marémotrice de la Rance, 240 MW

Oceantec (now IDOM) Marmok at BiMEP, 2017



Installation of Ocean Sun's 100 kW offshore demonstrator in Kyrholmen (image: Ocean Sun)

Kelp forest (image: Douglas Klug via phys.org)

Wrapping up

- Offshore renewables are here to stay
  - Only realistic alternative to fossil fuels
  - Sustainability, economics, geopolitical drivers
  - Already cost-competitive
  - Land-use pressure

- In the European Atlantic the main challenge is depth
  - Wind: R&D for floaters, offshore operations
  - Solar: R&D for floaters, mooring, biodiversity