WHEN TRUST MATTERS

Techno-economic overview of clean energy technologies

Clean Energy for EU Islands
Workshop series: Future-proofing electricity systems

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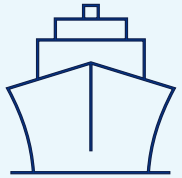
Outline

- Short Introduction to DNV
- Energy Transition Outlook 2023
- Levelized cost of energy (LCOE) of various technologies
- Island Examples

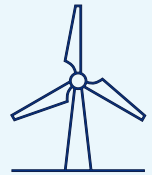
A global assurance and risk management company

159	~13,000	~100,000	100+	5%+
years	employees	customers	countries	of revenue in R&D

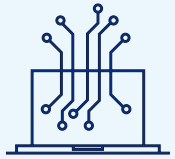
Ship and offshore classification and advisory



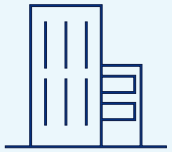
Energy advisory, certification, verification, inspection and monitoring



Software, cyber security, platforms and digital solutions



Management system certification, supply chain and product assurance



DNV

Energy Transition Outlook 2023: A global & regional forecast to 2050 - Highlights

The **energy transition is still in the starting blocks**, with energy emissions only peaking in 2024, but by 2030 emissions only fall 4% below present levels

Energy security has moved to the top of the agenda due to geopolitical developments. Protectionism is leading to reshoring and supply chain changes

Progressive policies are making impact, the Inflation Reduction Act in US and RePowerEU and Green Deal policies accelerate the transition

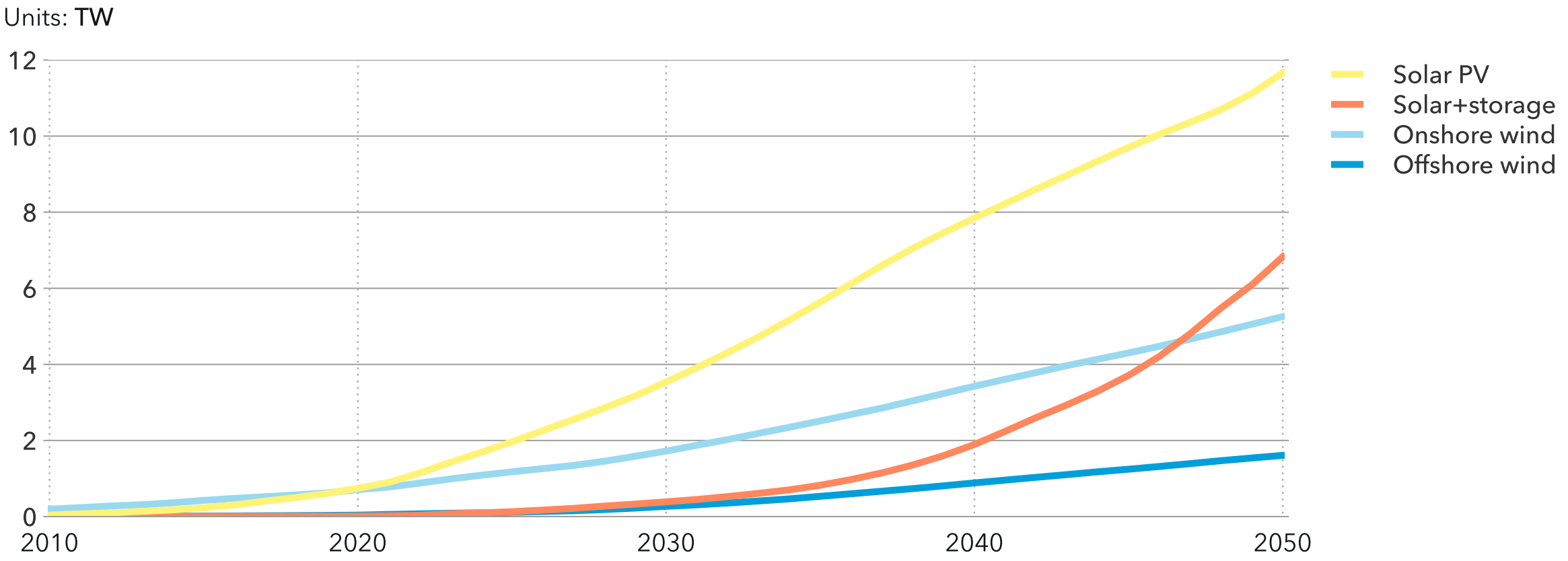
Solar PV and batteries are progressing fast, but **gridlocks** are impeding the near-term expansion of decarbonization technologies

Electricity and renewables key findings

- Global electricity share in final energy demand doubles from 19% to 35% in 2050
- Variable renewables come to dominate the power mix - solar PV and wind have a 68% share in 2050
- Grid infrastructure needs significant improvements - with storage, connectivity and demand-response key to integrate variable renewables

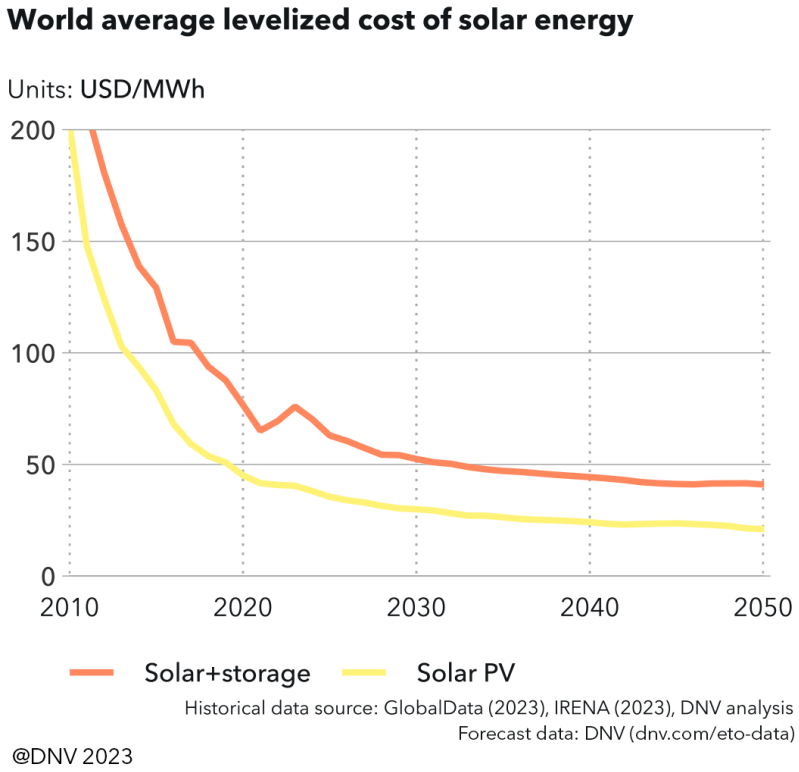
Rapid expansion of solar PV and wind, but starting from a low base

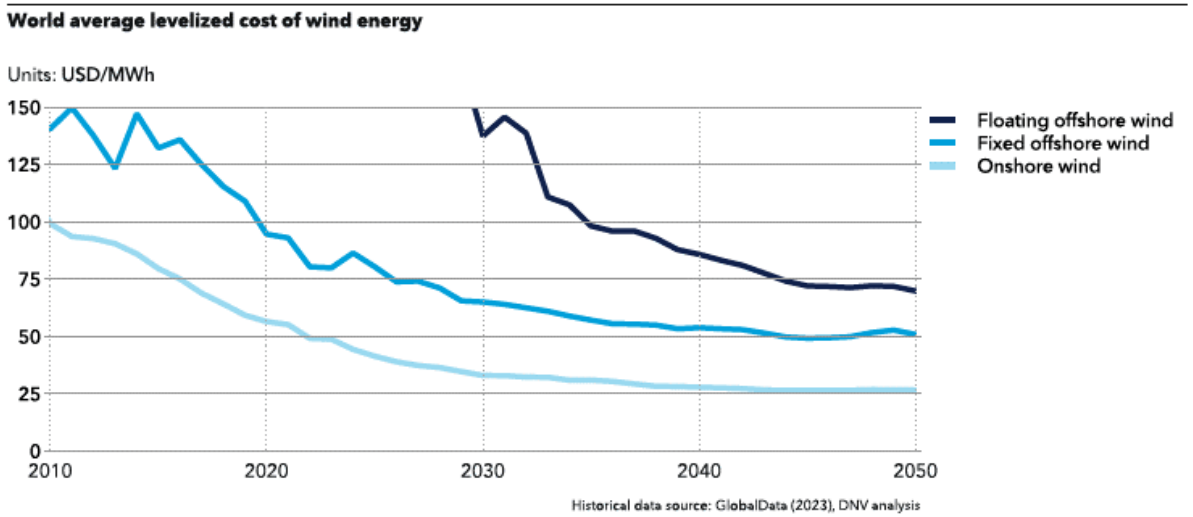
World grid-connected and off-grid installed capacity from solar and wind



Global Average LCOE 2022

Technology	LCOE	Total Installed Costs
	(2022 USD/MWh)	(2022 USD/kW)
Bioenergy	61	2,162
Geothermal	56	3,478
Hydropower	61	2,881
Solar PV – utility scale	41	876
Solar PV – utility scale with storage	69	-
CSP	118	4,274
Wind onshore	49	1,274
Wind offshore	81	3,461





[Renewable Power Generation Costs in 2022 (irena.org)](#)
DNV ETO, ETO.DNV.COM

Average LCOE Europe 2022

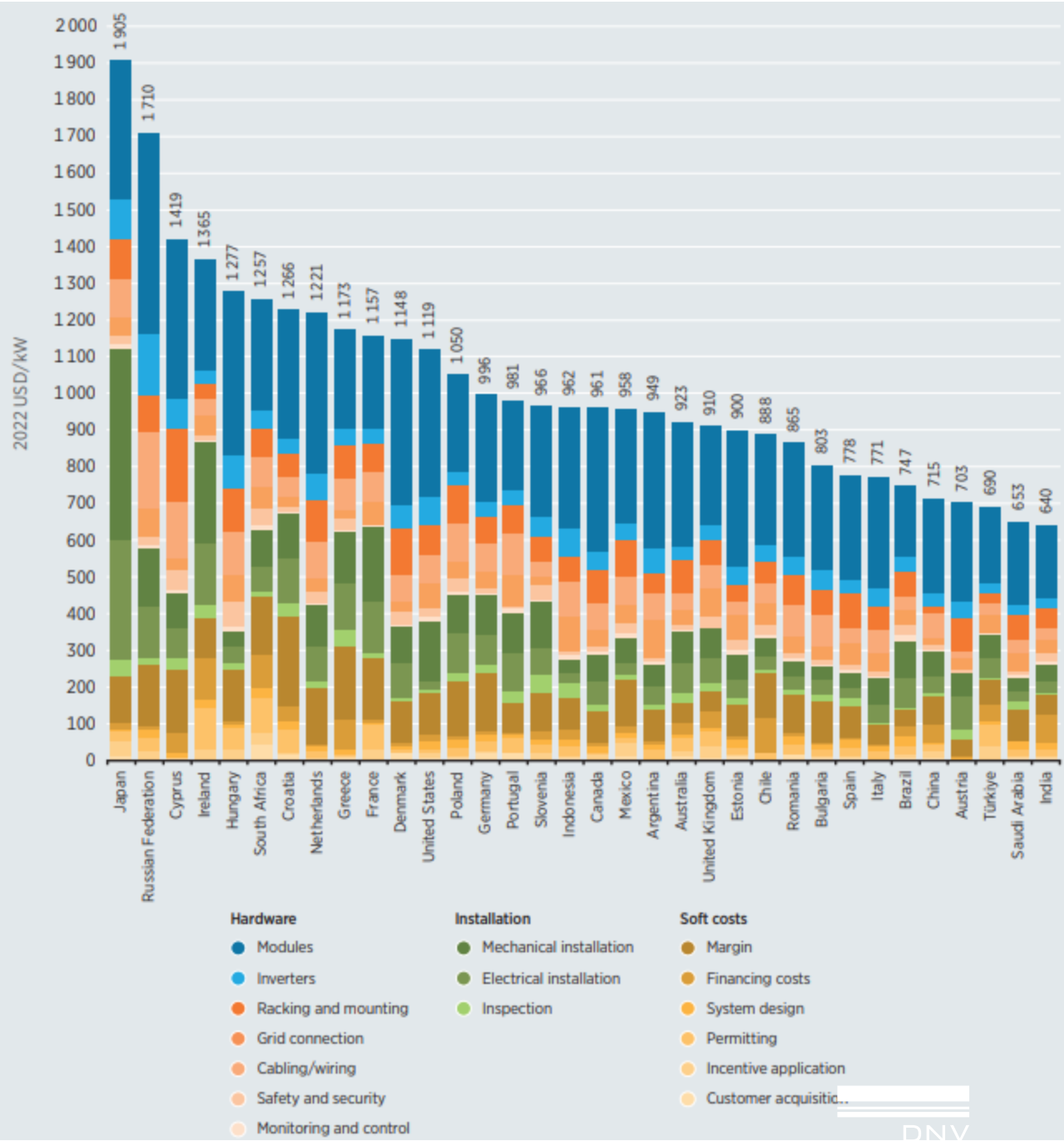
Technology	LCOE Europe USD/MWh 2022								
	Denmark	France	Germany	Greece	Italy	Netherlands	Spain	Sweden	UK
Wind onshore	42 (2020)	50	55	49	42	46	33	37	35
Wind offshore	43 (2021)	-	78	-	-	58	-	-	64
Solar PV utility scale	93	62	80	71	62	90	46	-	76
Bioenergy (all Europe)	92								
Hydro >10 MW (all Europe)	83								
Hydro <10 MW (all Europe)	92								

Source: Renewable Power Generation Costs in 2022 (irena.org)

Utility Scale Solar PV Total Installed Costs (2022)

- *Avg. soft cost ≈ 30% of total costs*
- *Avg. BoS hardware component costs (excl. inverters & modules) ≈ 23%*
- *Avg. module and inverter costs (non-BoS) ≈ 37%*
- *Avg. installation costs ≈ 19%*

	Soft Costs	Installation	Hardware	Modules & Inverters
	2022 USD/kW			
France	300	315	255	287
Greece	310	300	260	303
Italy	110	140	160	361
Netherlands	200	200	300	521
Portugal	160	245	295	281
Spain	155	125	170	328



Source: Renewable Power Generation Costs in 2022 (irena.org)

Grid-scale battery storage

Technology	LCOE	Total Installed Costs
	(2022 EUR/MWh)	(2022 EUR/kW)
Li-Ion	220	731

- Average LCOE component breakdown (2022)
  - Capital cost ≈ 42%
  - OPEX ≈ 12%
  - Charging Cost ≈ 43%
  - Taxes ≈ 3%

CAPEX

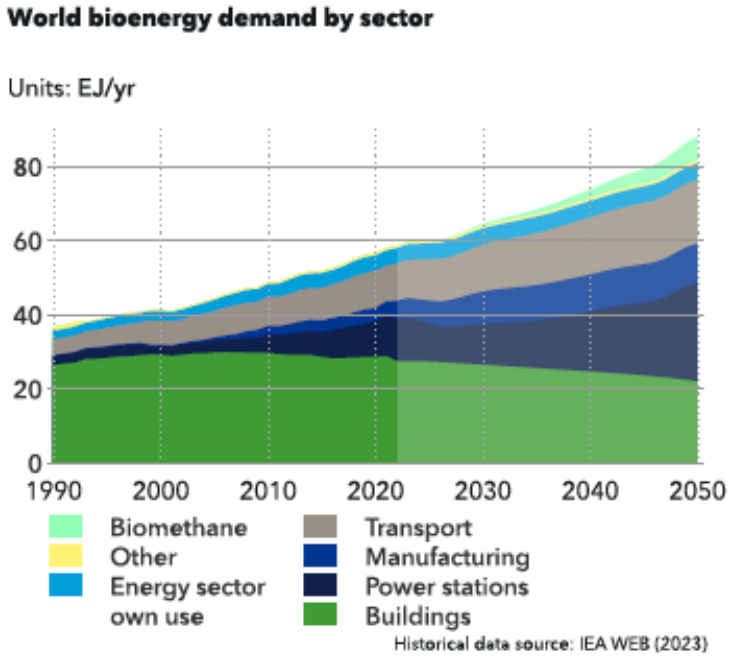
- Site preparation and EPC
  - Civils (foundations, buildings, roads)
  - Electrical (cables, equipment, grid)
- DC energy storage system / DC block
- Power conversion system hardware
- Communications and controls hardware
- Safety equipment
- Delivery, installation and commissioning

OPEX

- Insurance
- Land lease
- O&M service fee
- Warranties and performance guarantees
- Dispatch/ optimizer fee
- Auxiliary power and energy (dis)charging costs
- Recycling and disposal
- Future price risk
- [Augmentation]

Bioenergy

- Feedstocks
  - Bagasse
  - Landfill gas
  - Wood waste
  - Renewable municipal waste
  - Rice husks
  - Other vegetal & agricultural waste
- Technologies
  - Direct combustion
  - Co-firing
  - Anaerobic digestion
  - Municipal solid waste incineration
  - Landfill gas
  - Combined Heat and Power (CHP)



Installed costs and LCOE for bioenergy systems vary significantly between regions, technologies, and feedstock, with higher costs in Europe and North America (NA).

Between 2000-2022 costs ranged from a low end USD 701/KW for landfill gas projects in NA and to a high of USD 5,481/kW for renewable municipal waste in Europe.

Biomass / Biogas CHP

- CHP biomass installations have higher capital costs.
- CHP has higher overall efficiency (around 80% to 85%).
- Produces heat, steam, DHW, and cooling for industrial processes, space and water heating/cooling through district heating.

- CHP Market Sectors
  - Commercial office buildings
  - Greenhouses
  - Hospitals
  - Hotels
  - Wastewater treatment plants

Low-cost feedstocks – such as agricultural or forestry residues or the residues from processing agricultural or forestry products and opportunity fuels can significantly reduce LCOE for electricity to as low as USD $30/MWh

Hybrid Power System Case S4S TILOS - Greece (2020)

- Technical characteristics :
  - Batteries: 2 nickel-chloride batteries, totalling 800kW/2.8MWh.
  - Wind turbine: 800 kW
  - Solar PV: 160 kW
  - Inverters: 8x20kW PV inverters & 2x450kW battery inverters
- Overall, the guaranteed power of the Hybrid Station is 400kW
- Control & Management System:
  - The monitoring and control unit has daily and per-second contact with the operating platform of the non-interconnected island administrator.
  - The system can satisfy voltage support conditions at the level of a second and at shorter intervals, and support the network frequency by injecting nominal active power during these periods
- Installed cost: EUR €13.7M

https://eunice-group.com/projects/tilos-project/

El Hierro Wind and Pumped Hydro - Canary Islands (2014)

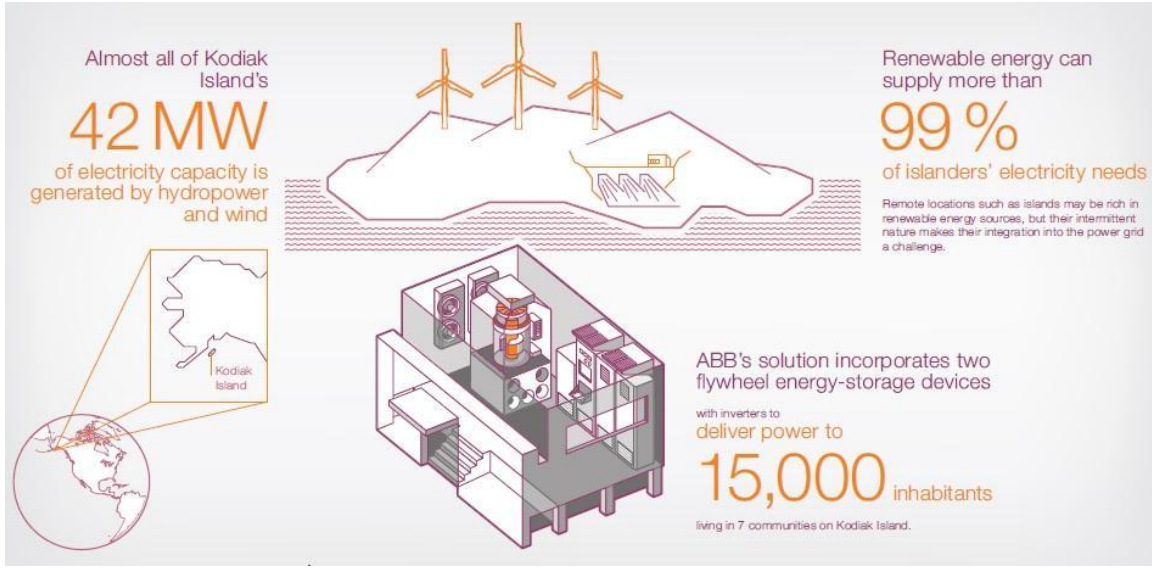
- Technical Characteristics:
  - 11.5 MW wind (5x2.3 MW)
  - 11.32 MW hydro (4x 2.830 MW)
  - 6 MW pumping station (2x1.5 MW & 6x0.5 MW)
  - Future: 5 MW PV and 5 MW storage (stage 1) & 7 MW PV and 5 MW storage (stage 1)
- Installed Cost: €82 - €94 Million (depending on source)

https://www.endesa.com/en/projects/all-projects/energy-transition/renewable-energies/el-hierro-renewable-sustainability

Kodiak Island Microgrid – US (2009-2015)

- 30 MW Hydro (20 MW in 1984)
- 9 MW Wind (3x1.5 MW in 2009, 3x 1.5 in 2012)
- 3 MW battery storage (2012)
- 2 MW grid stabilization generators (2x1MW flywheels in 2015)

- Installed cost: $16 Million in grants + $39.6 Million in clean renewable energy bonds

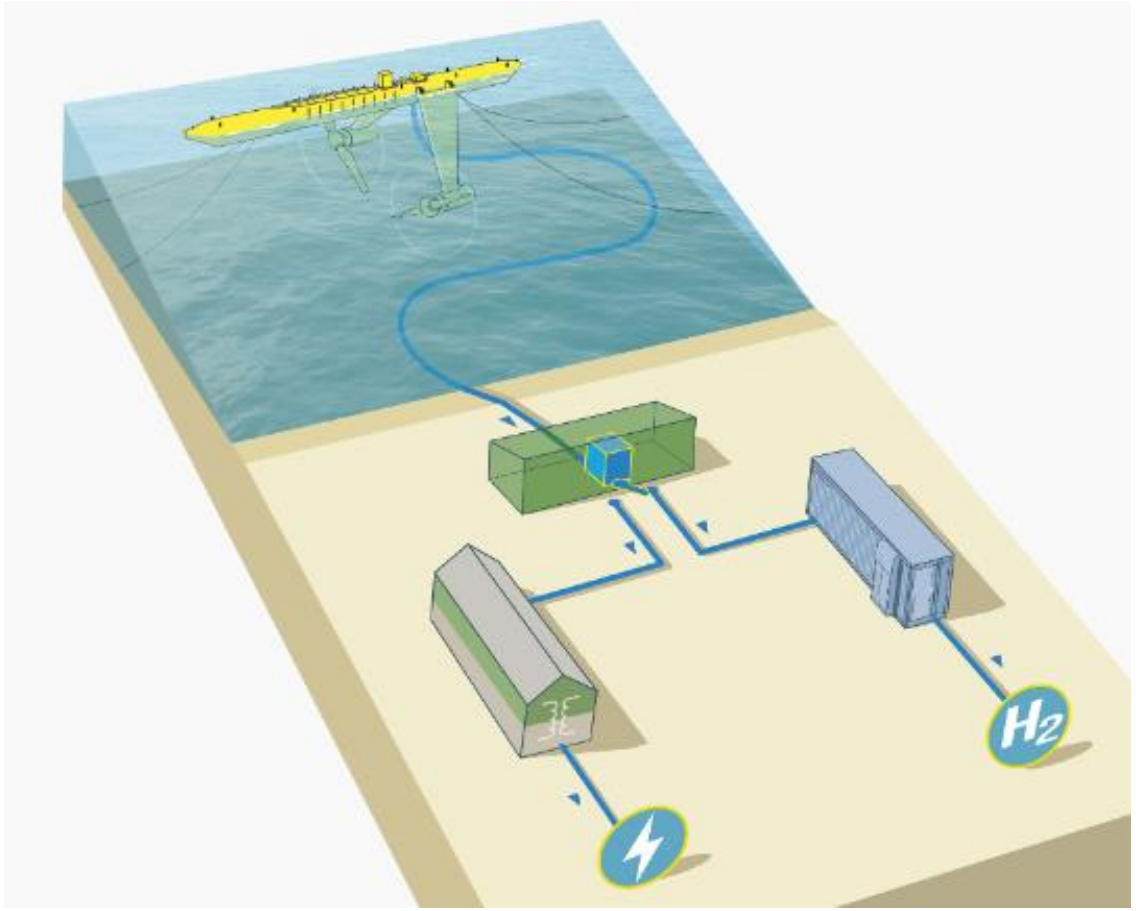


https://new.abb.com/power-generation/in-control/02-2014/integrating-renewables-in-an-alaskan-island-microgrid
https://www.hitachienergy.com/about-us/customer-success-stories/kodiak-island#

Orkney Islands Hydrogen Case – Scotland (2017-2023)

- ITEG - Integrating Tidal energy into the European Grid (2017-2023)
  - 2 MW floating tidal energy converter
  - 670 kW electrolyzer
  - onshore energy management system
  - A vanadium flow battery

  - EU Funding: € 6.46 m
  - Total Budget: € 11.79 m



https://vb.nweurope.eu/projects/project-search/iteg-integrating-tidal-energy-into-the-european-grid/#:~:text=ITEG%20will%20develop%20and%20validate,limitations%20faced%20in%20remote%20communities
https://www.orkney.gov.uk/Files/Strategic_Projects/Hydrogen%20projects/Hydrogen%20strategy.pdf .

Thank you

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