TETHYS 1st Webinar

Introduction to P2X

Kerem Gurdalli
Aarhus BSS

19 February 2025

Funded by the European Union

University of Cyprus

UNIVERSITÀ DEGLI STUDI FIRENZE

NEEST
NEW ENERGY & ENVIRONMENTAL SOLUTIONS AND TECHNOLOGIES

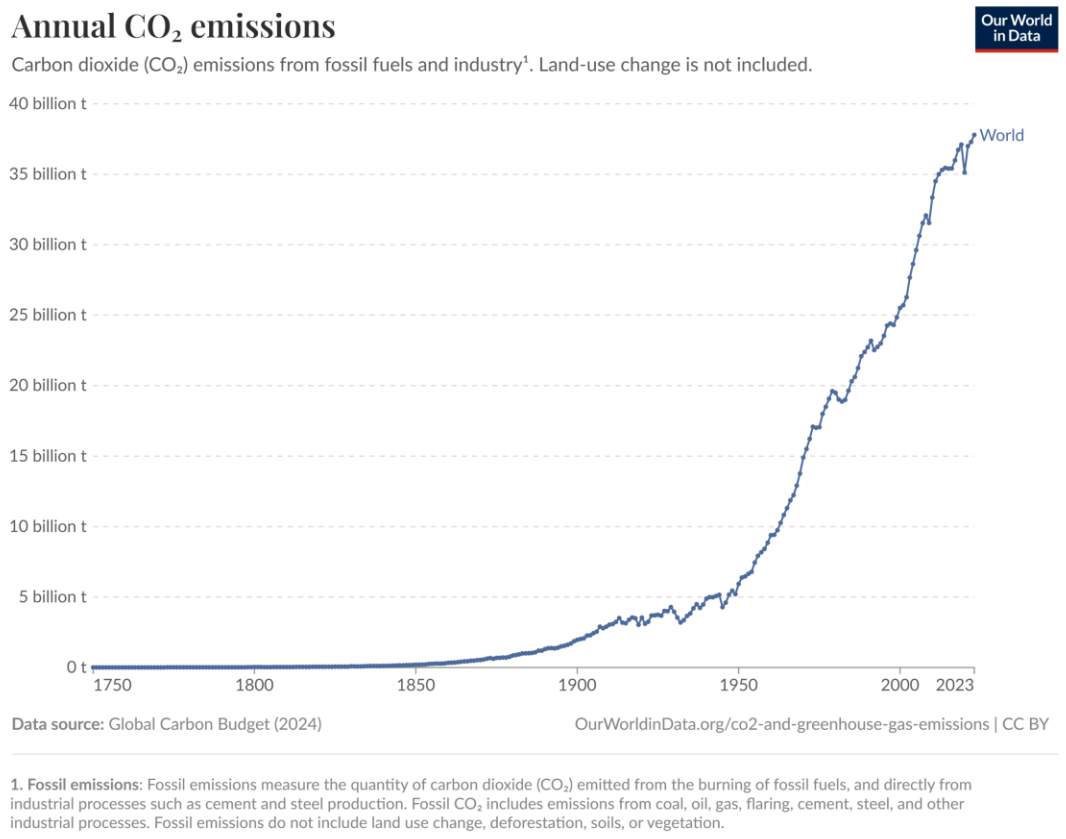
AARHUS BSS

Agenda

- Introduction
- Power-to-X
- Products of P2X
- Application of P2X
- Challenges
- Opportunities
- Real-life Examples
- Conclusion

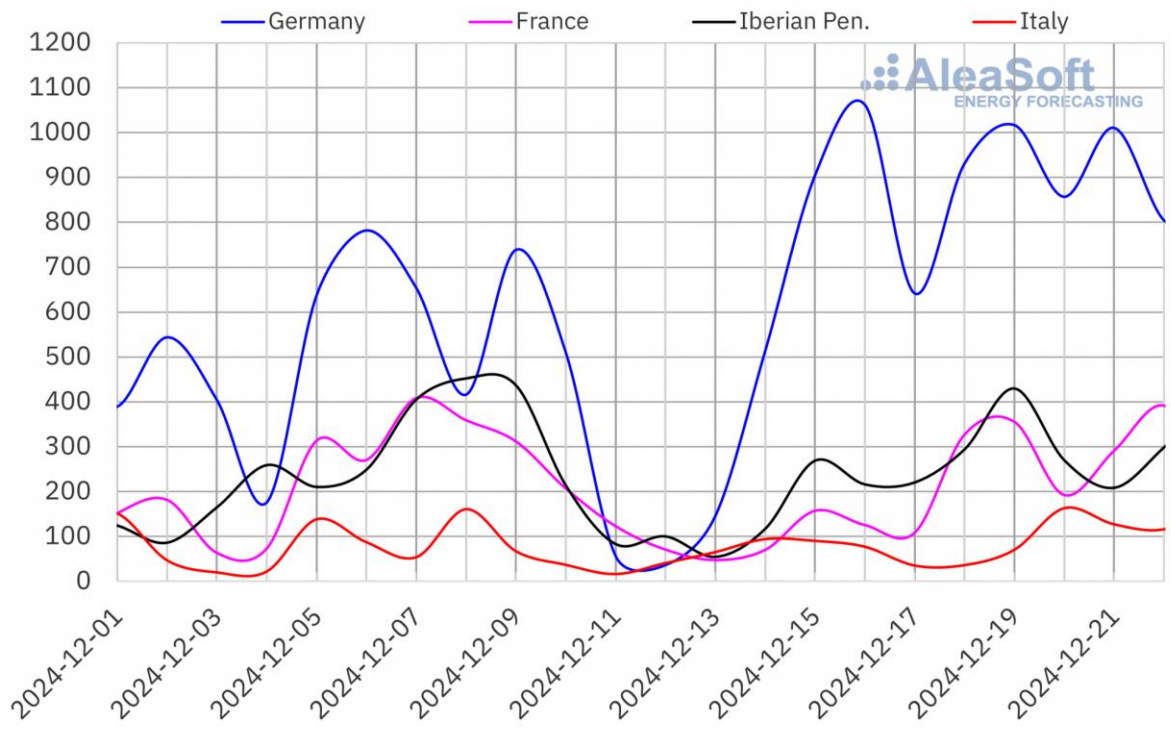
- Global Warming
- Ocean Acidification
- Climate Change
- Extreme Weather Events

DECARBONIZATION

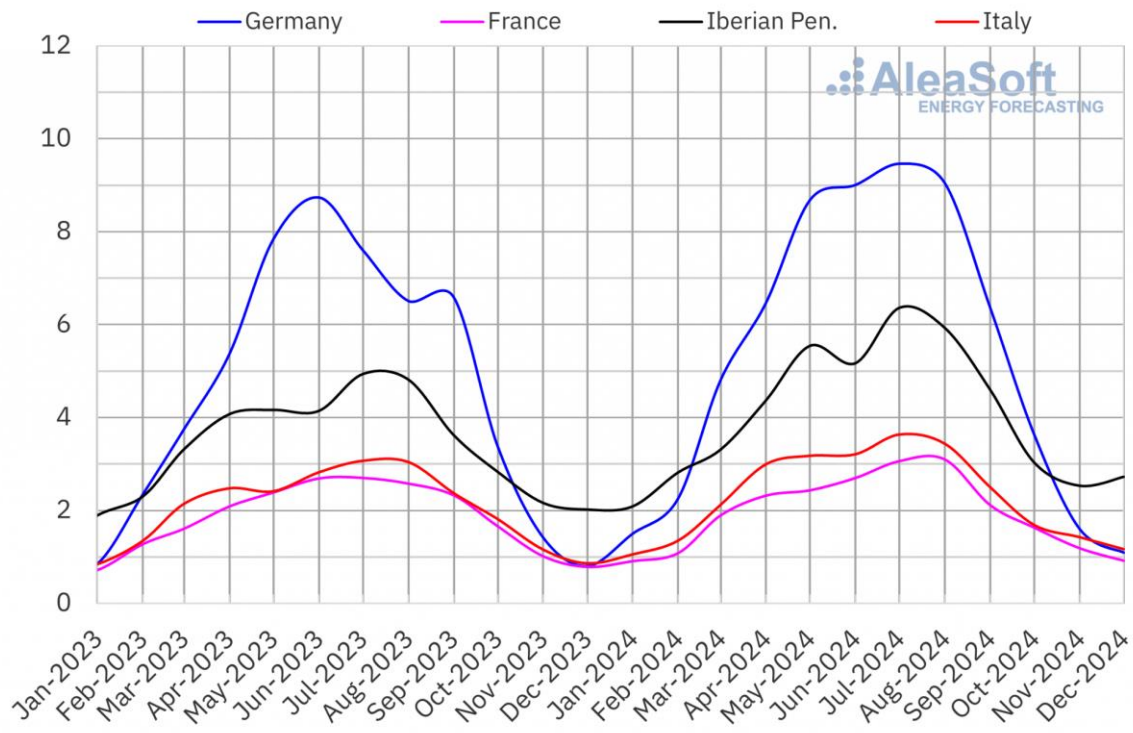


Why Power-to-X Matters?

European wind energy production [GWh]



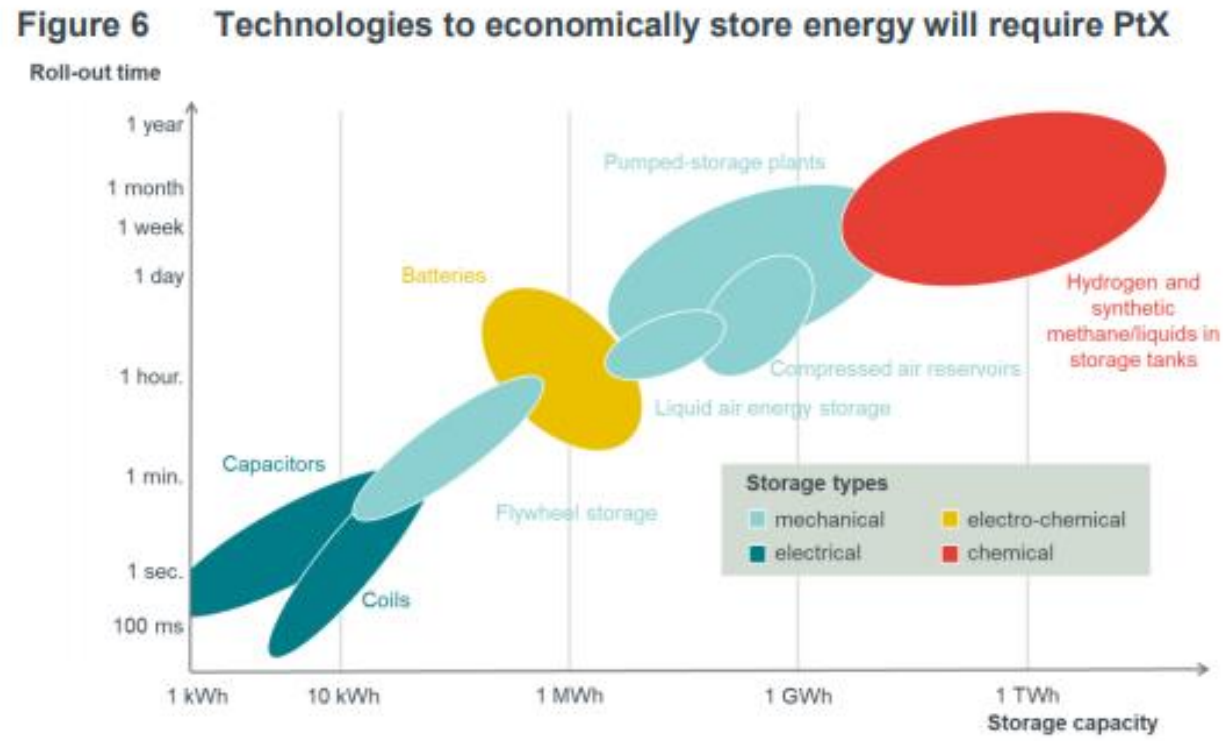
European solar photovoltaic energy production [TWh]



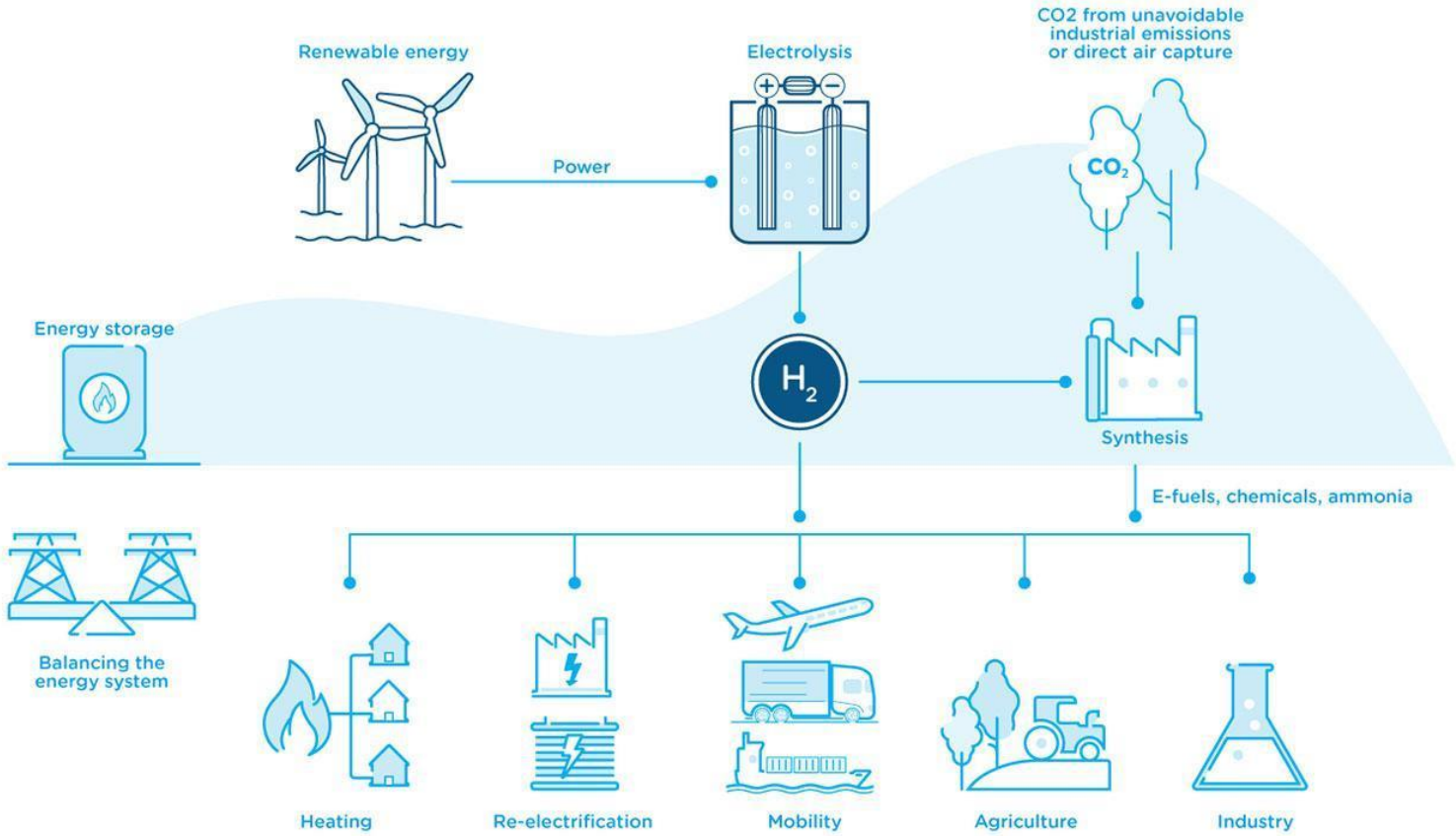
Source: Aleasoft 2025, IRENA 2024

Why Power-to-X Matters?

- **Energy Storage:** Stores excess renewable energy
- **Energy Transition:** Decarbonizes hard-to-electrify sectors
- **Grid Stability:** Balances supply and demand
- **Climate Goals:** Reduces greenhouse gas emissons

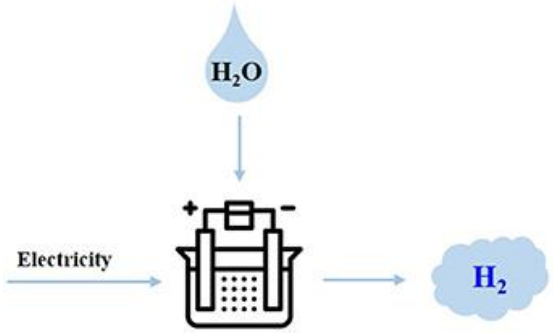


How Power-to-X Works?



Electrolysis (Power-to-Hydrogen)

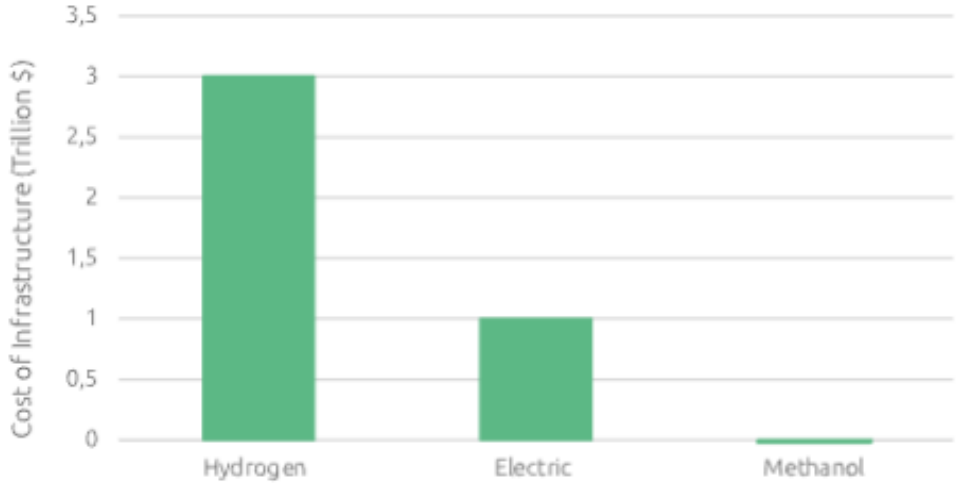
- $H_2O \longrightarrow H_2 + O_2$
- Green Hydrogen(H_2)
  - Core element of P2X
  - Fuel for vehicles
  - Industrial feedstock
  - Energy storage



Hydrogen Powered Bus - Aalborg

Methanation (Power-to-Gas)

- E-methane (CH_4)
- Residental Heating
- Feedstock for
  - Chemical production
  - Fertilizers
  - Synthetic Fuels

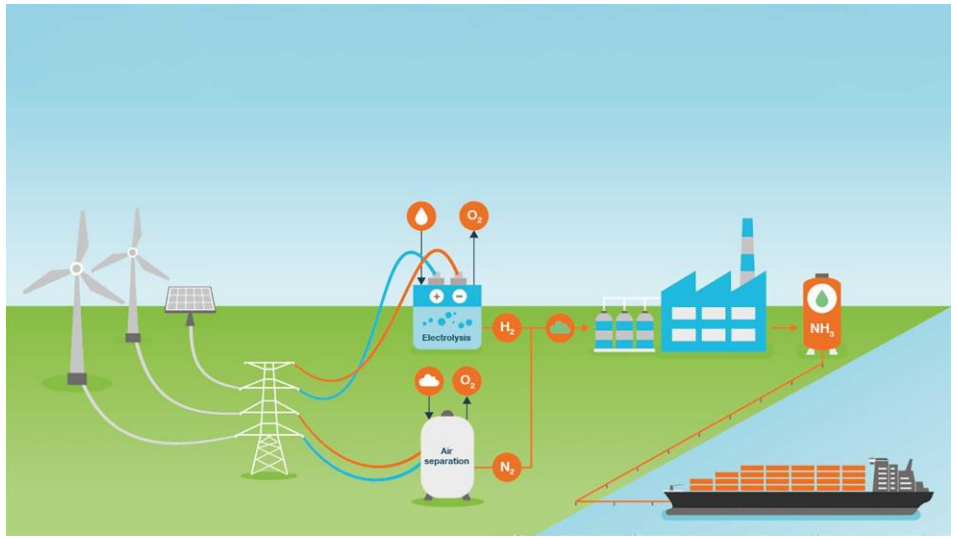


Fischer-Tropsch Synthesis (Power-to-Liquid)

- Liquid Hydrocarbons
  - E-Kerosene ($C_8 - C_{16}$)
    - Decorbonisation of aviation (2.5%)
    - Sustainable Aviation Fuel (SAF)
  - E-Diesel ($C_{17} - C_{20}$)

Power-to-Chemicals

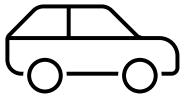
- E-Ammonia(NH_3)
  - Fertilizers
  - Industrial Chemical
  - Hydrogen Carrier
  - 1.8% of Global CO_2 emmisions
  - Fuel for Shipping
- Methanol (CH_3OH)
  - Fuel for transportation
  - High compatibility with existing infrastructure
  - Feedstock for chemicals
  - Safety is not a barrier



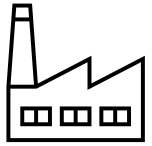
Source: MAN Energy Solutions

Source: Port of Aalborg

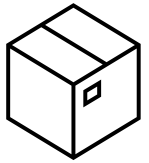
Application of Power-to-X



Transportation



Industry



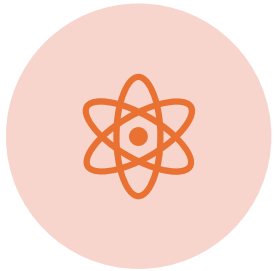
Energy Storage

Residential Use

Challenges

HIGH COSTS

ENERGY LOSSES



INFRASTRUCTURE

SCALABLILITY

Opportunities

- Falling Costs
- Policy Support
- Market Demand
- Job Creation

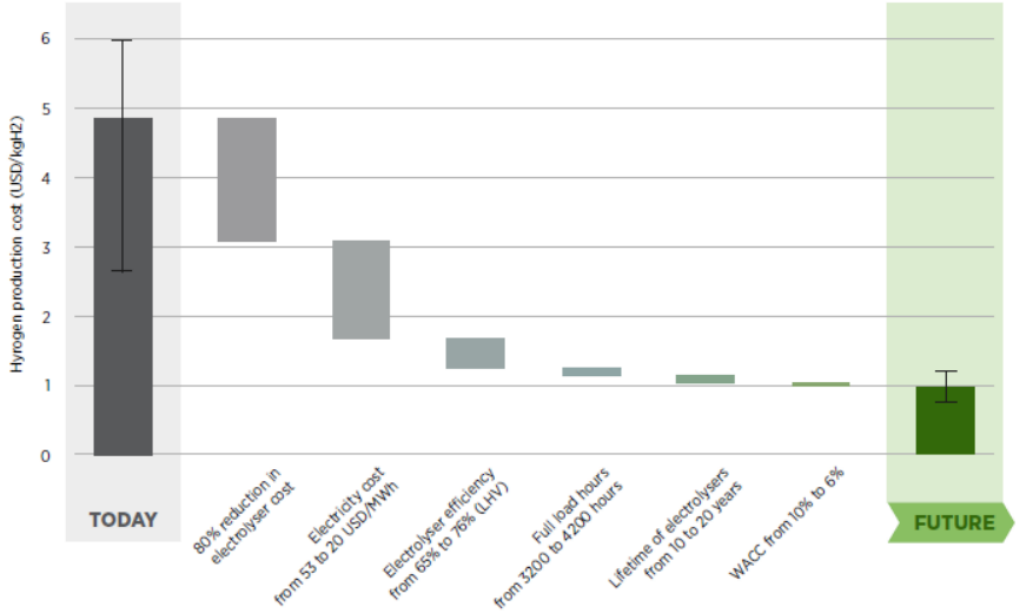
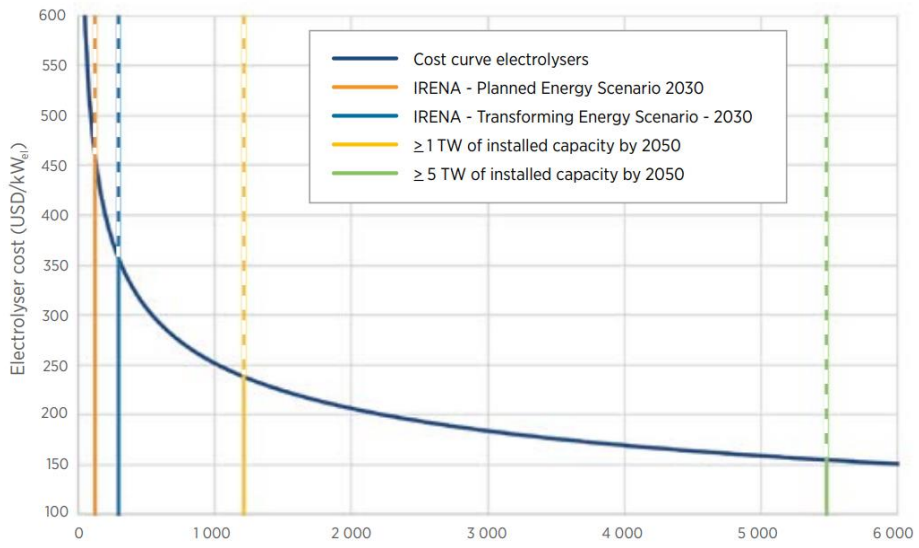
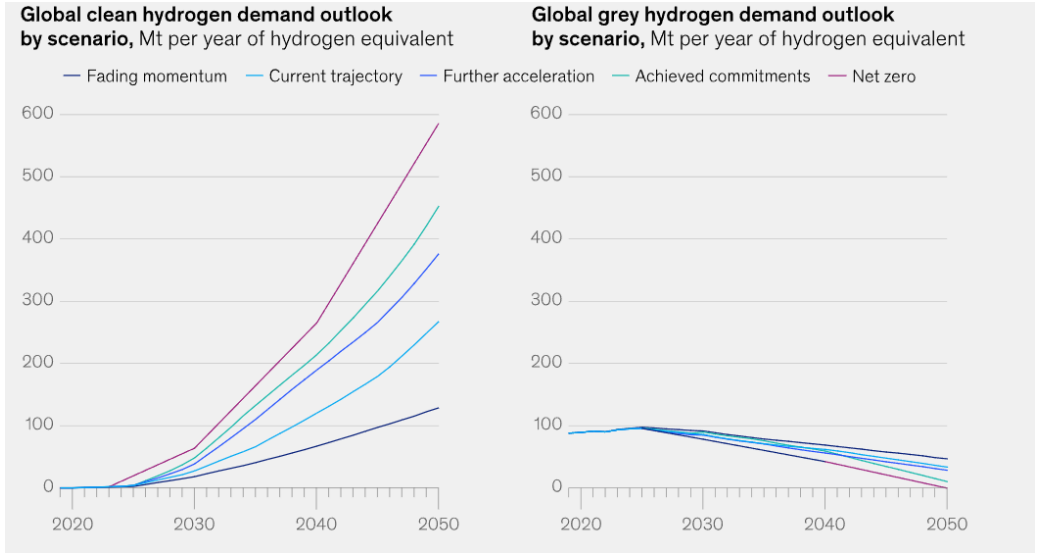


Figure 3 **Electrolyser cost reduction by 2030 and 2050, based on IRENA scenarios**

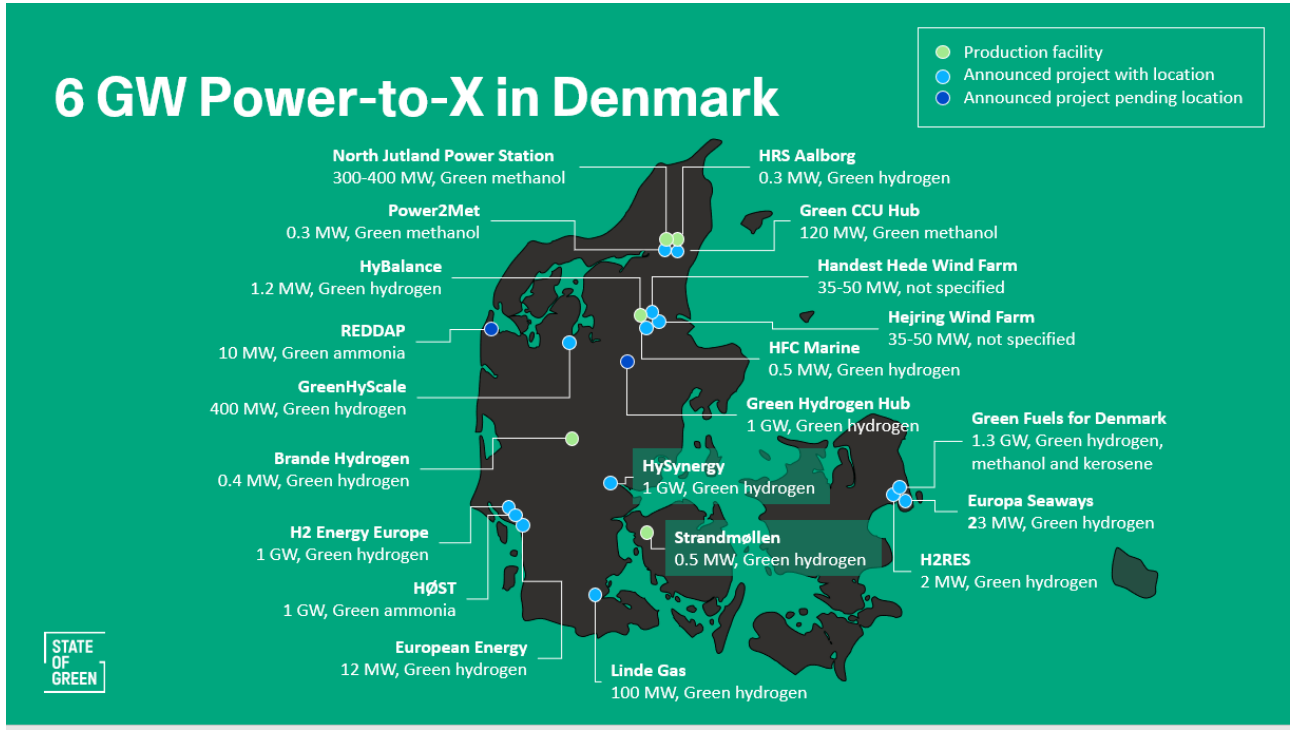


Source:IRENA



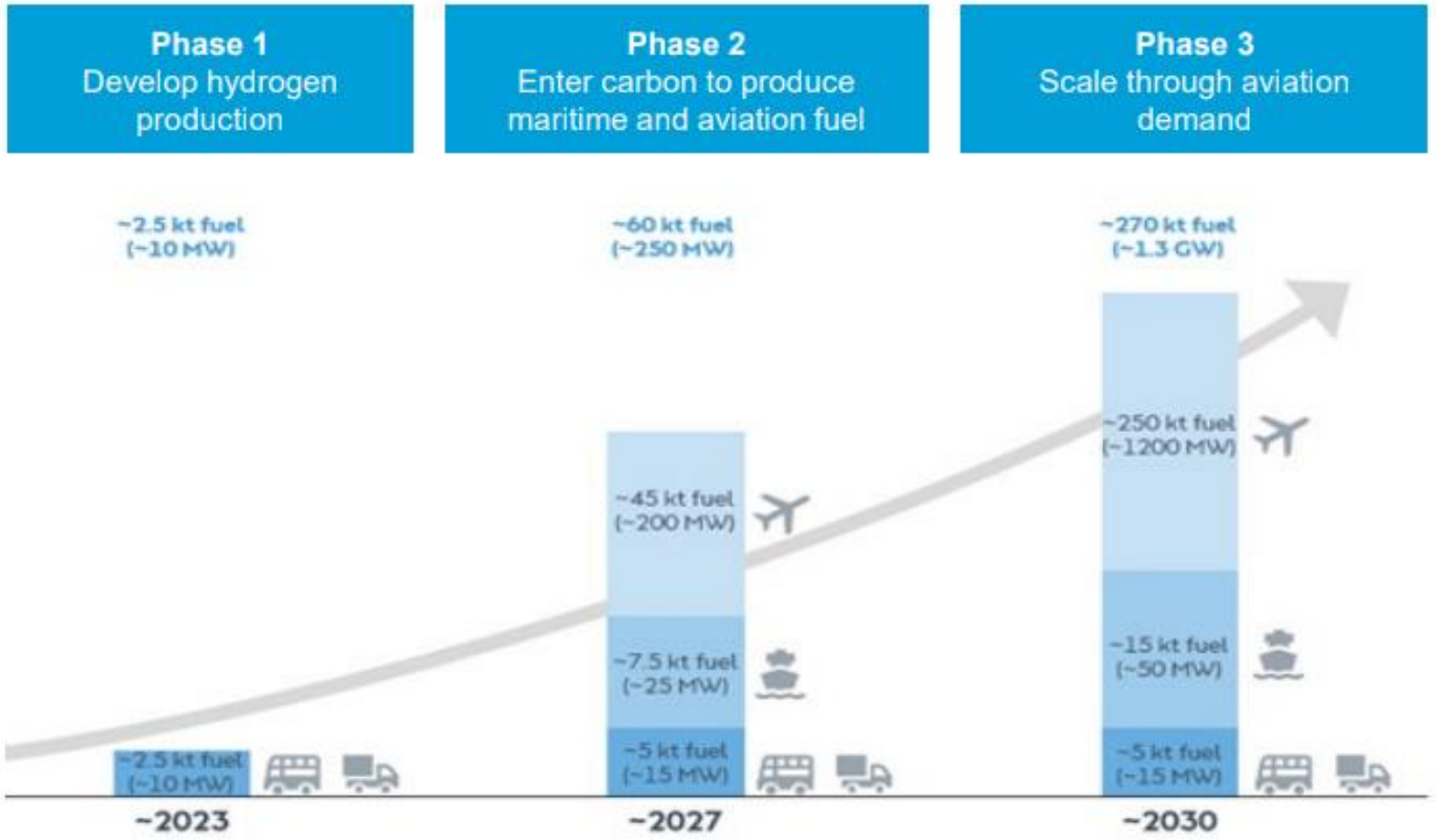
Source:McKinsey

Power-to-X Denmark



Source: Brintbrancen

Green Fuels Denmark



Hydrogen Island in Denmark

- 3 GW offshore wind – Up to 10 GW
- Artificial Island
- At full capacity 1 million tonnes of H_2

CIP
Copenhagen Infrastructure Partners

Green Steel in Sweden

- Green Hydrogen for steel production
- 700 MW Hydrogen plant
- Cutting CO_2 emissions in heavy industry
- By 2030 5 million tonnes of green steel
- 95% reduction in CO_2 emissions

Wind Energy: Debunking myths

1st TETHYS webinar - Day 3

George Xydis

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Agenda

- The four **W**

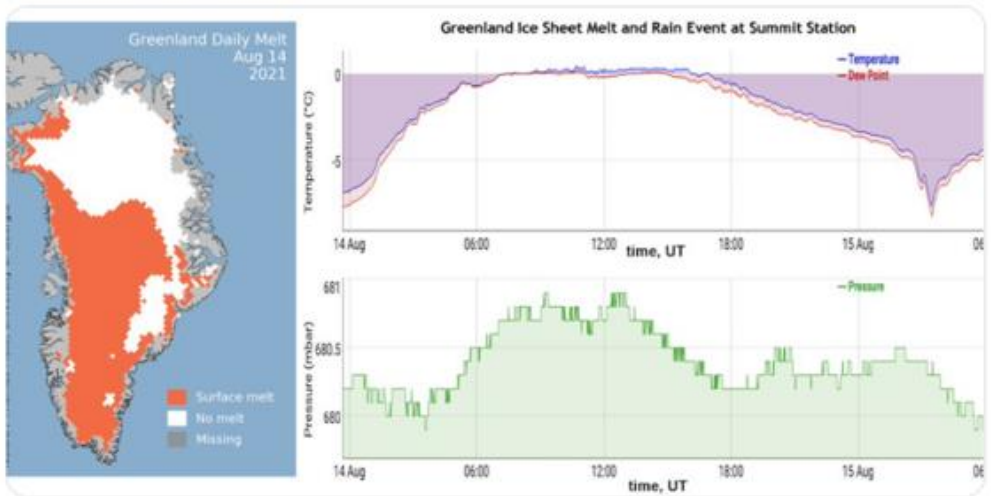
- **W**hy do we care?
- **W**e need to follow a different path
- **W**e have decided to do something about the whole problem
- **W**hy do people complain?

PART 1: WHY DO WE CARE?

"A picture is worth a thousand words"

National Snow and Ice Data Center
@NSIDC

On August 14, 2021, temperatures rose above freezing on the summit of Greenland, fueling a rain event that dumped 7 billion tons of water—the heaviest since records began in 1950.



10:14 PM · Aug 18, 2021

299 7 Share this Tweet

Massive crack in Antarctica ice shelf spanning 11 miles

That damn squirrel

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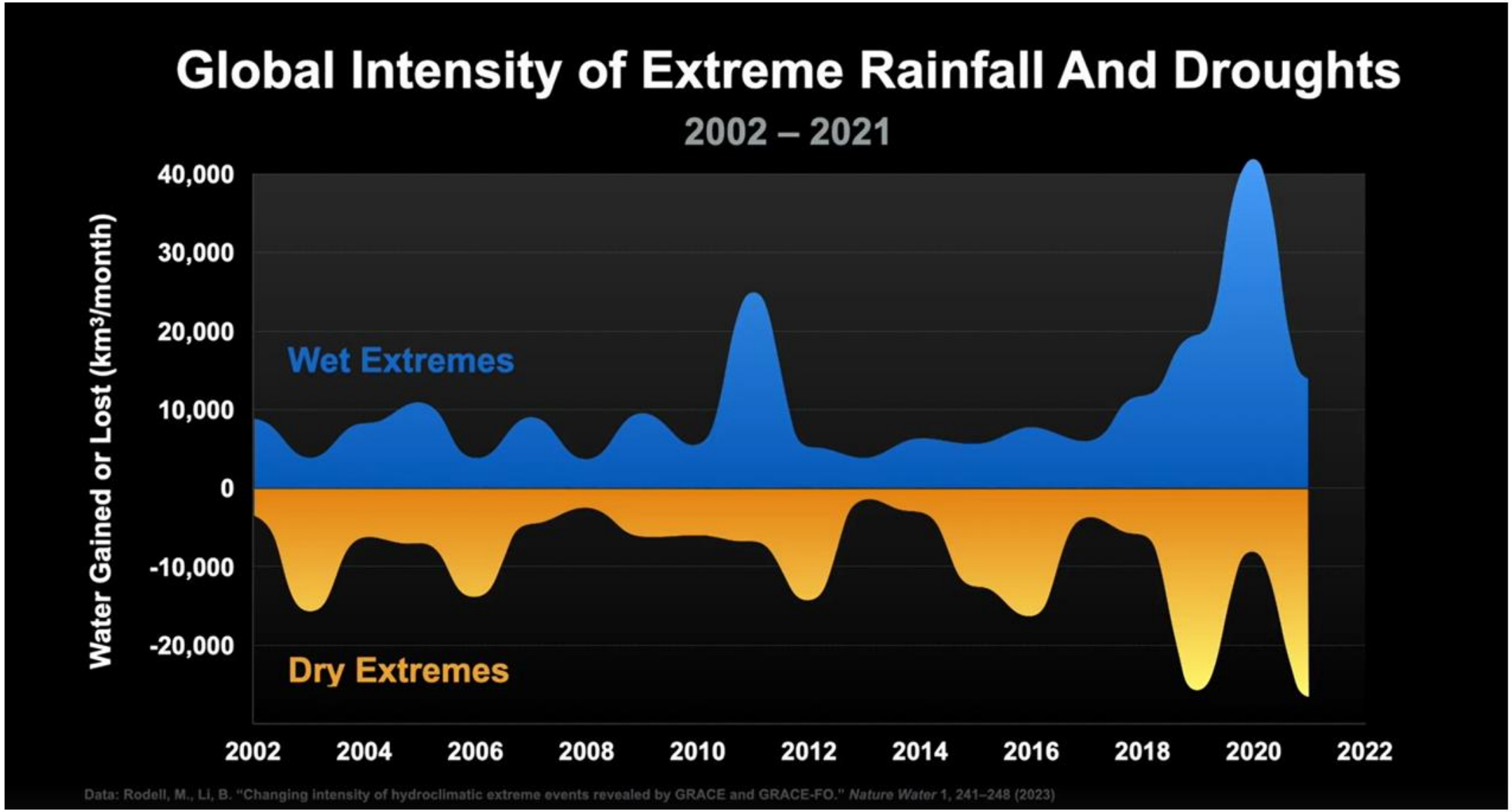
WHY DO WE CARE?



WHY DO WE CARE?

TED Speaker | TED Attendee

David Christian

Historian

Website: Big History

TED Speaker

Personal profile

David Christian teaches an ambitious world history course that tells the tale of the entire universe — from the Big Bang 13 billion years ago to present day.

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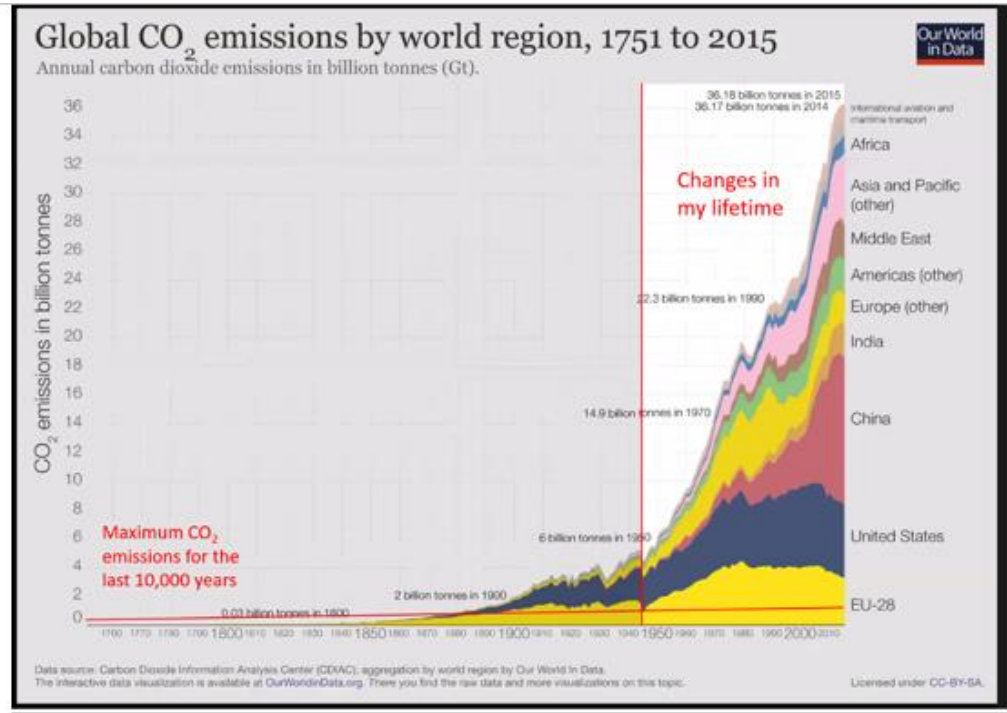

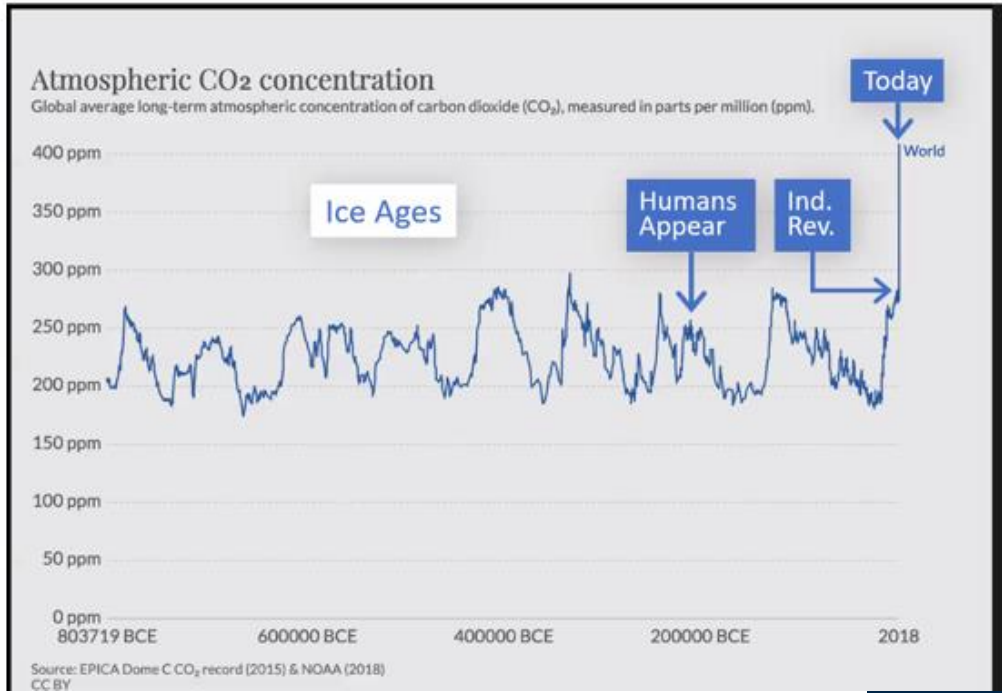

Trains carrying coal, Virginia, USA

The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

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Mark Jacobson • 2nd

Professor-Civil & Environ Eng, Director-Atmos/Energy Progra...

2w •

So long as we keep getting fooled by fossil fuel circus tricks - carbon capture, direct air capture, blue hydrogen, and electrofuels, subsidies to the fossil-fuel industry will only increase.

Globally, fossil fuel direct+indirect subsidies were $7 trillion in 2022 or 7.1 percent of world GDP

https://lnkd.in/gG4E4bs6 International Monetary Fund

IMF Fossil Fuel Subsidies Data: 2023 Update

imf.org • 1 min read

Mark Z. Jacobson

Engineer

Overview | Books

YouTube • Climate Chat

Can We Rapidly Move to 100% Renewables? - Interview with ...

In this Climate Chat episode, we interview Stanford professor Mark Z. Jacobson ab...

Jul 15, 2024

Age

59 years

Sep 26, 1965

Education

University of California, Los...

Stanford University

Stanford University Professor - Mark Z. Jacobson

Jacobson has been a professor at Stanford University since 1994. His research cross...

Stanford University

https://web.stanford.edu › group › efmh › jacobson

Stanford University Professor - Mark Z. Jacobson

Jacobson has been a professor at Stanford University since 1994. His research crosses two fields: Atmospheric Sciences and Energy. To date, he has published 185 ...

Wikipedia

https://en.wikipedia.org › wiki › Mark_Z._Jacobson

Mark Z. Jacobson

Mark Zachary **Jacobson** (born 1965) is a professor of civil and environmental engineering at Stanford University and director of its Atmosphere/Energy Program.

About

Mark Zachary Jacobson is a professor of civil and environmental engineering at Stanford University and director of its Atmosphere/Energy Program. He is also a co-founder of the non-profit, Solutions Project. Wikipedia

Born: September 26, 1965 (age 59 years)

Education: University of California, Los Angeles (1994)

See more

Academic advisor: Richard P. Turco

Feedback

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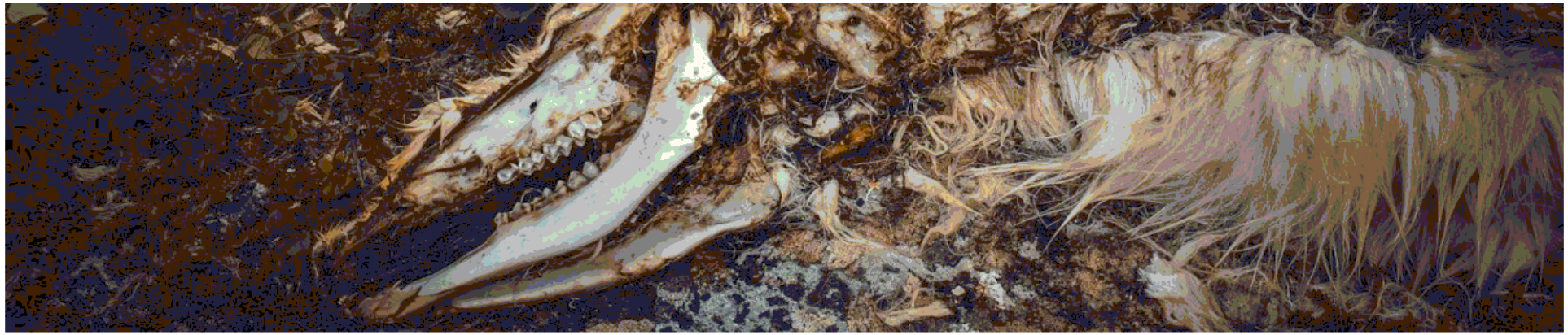
Three things to know about the latest IPCC Report:

1. Climate emissions are still rising—current government plans aren't ambitious enough. The report details what's needed to address this.

2. It's no longer enough to just cut emissions—**we also need to remove some of the carbon** that's already in the atmosphere.

3. If we're going to do this, **we must leverage nature**. Investing in natural climate solutions could provide up to 1/3 of the emission reductions we need–one of our most powerful tools to tackle climate change that is available to us ***right now***.



(Image credit: Shutterstock)

This summer, researchers found more than 200 dead reindeer on the island of Svalbard in Norway. The animals starved to death because climate change disrupted their access to the plants that they typically eat.

Climate change brings warmer temperatures to Svalbard, which results in more rain. After the heavy December rain hit the ground, the precipitation froze, creating "tundra ice caps," a thick layer of ice that prevented reindeer from reaching vegetation in their usual winter grazing pastures, and the reindeer eventually starved to death.

(Image credit: CDC/Janice Haney Carr)

This year, scientists released a report describing how "flesh-eating" bacteria that live in the ocean may be spreading to previously unaffected beach waters, thanks to climate change.

The report authors described five cases of severe flesh-eating bacterial infections in people who were exposed to water or seafood from the Delaware Bay, which sits between Delaware and New Jersey. Such infections have historically been rare in the Delaware Bay, as the bacterium responsible for the disease, called *Vibrio vulnificus*, prefers warmer waters, such as those in the Gulf of Mexico.

But with rising ocean temperatures due to climate change, *V. vulnificus* may be moving farther north, making these infections more common in areas that were previously off limits, the authors said.

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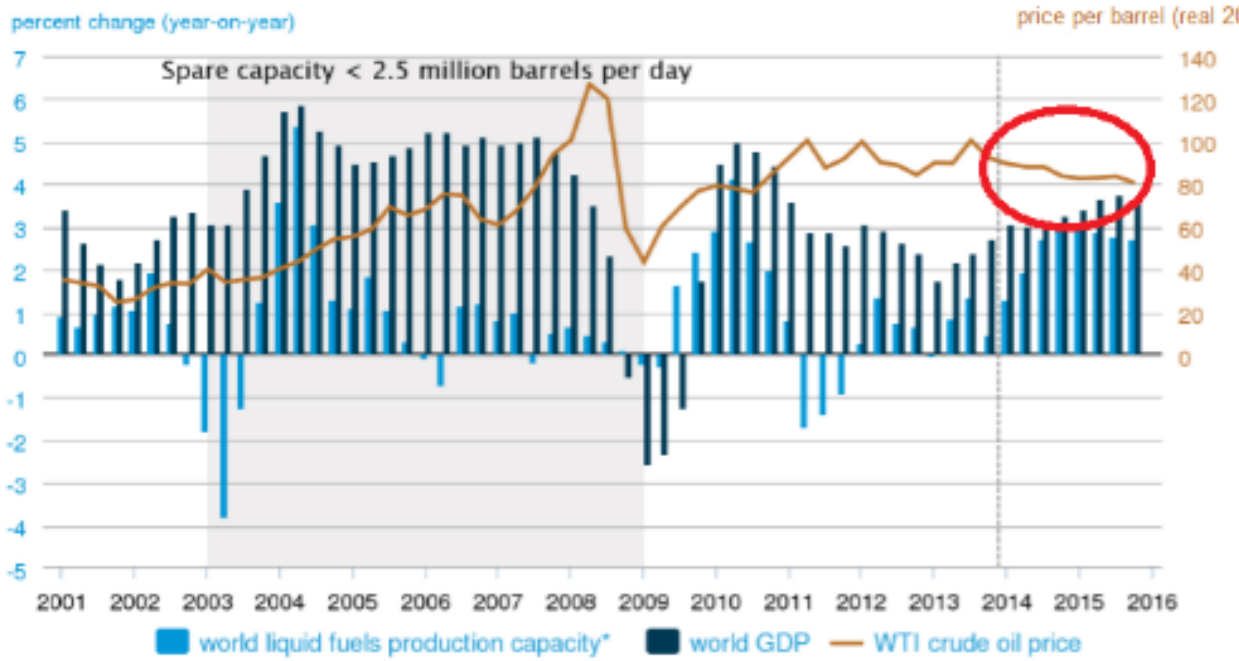
LUNG FROM TEENAGER (NON-SMOKER) IN LOS ANGELES IN 1970

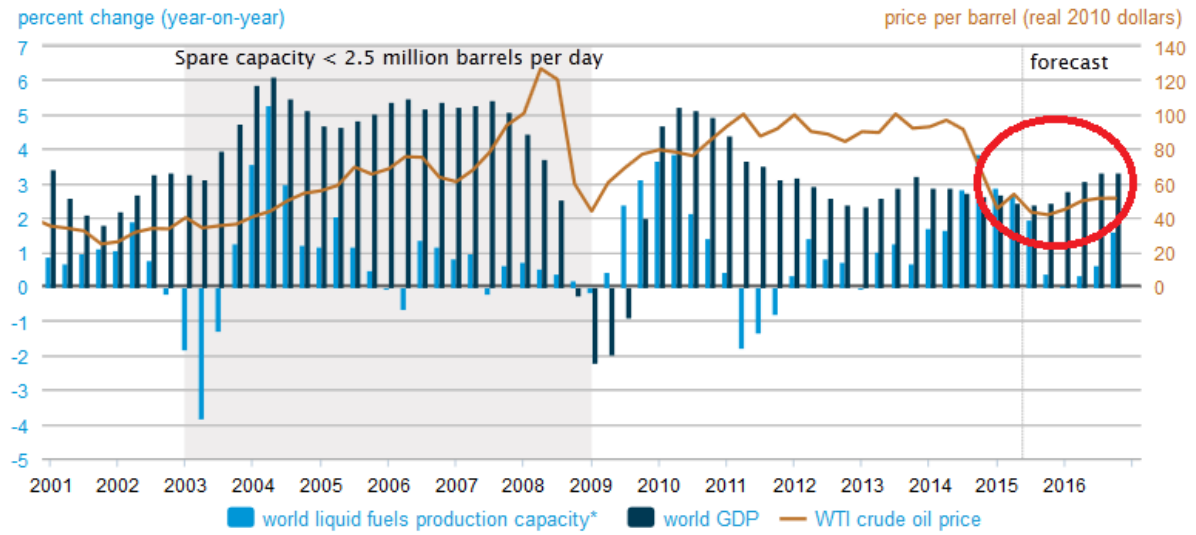
Changes in world liquid fuels production capacity and GDP, price of WTI crude oil



*World capacity = OPEC capacity plus non-OPEC production
Source: U.S. Energy Information Administration, Thomson Reuters
Updated: Monthly | Last Updated: 1/7/2014

The years 2003-2008 experienced periods of very strong economic and oil demand growth, slow supply growth and tight spare capacity

Changes in world liquid fuels production capacity and GDP, price of WTI crude oil



*World capacity = OPEC capacity plus non-OPEC production
Source: U.S. Energy Information Administration, Thomson Reuters
Updated: Monthly | Last Updated: 08/11/2015

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WE NEED TO FOLLOW A DIFFERENT PATH

FROM RUSSIA WITH LOVE...

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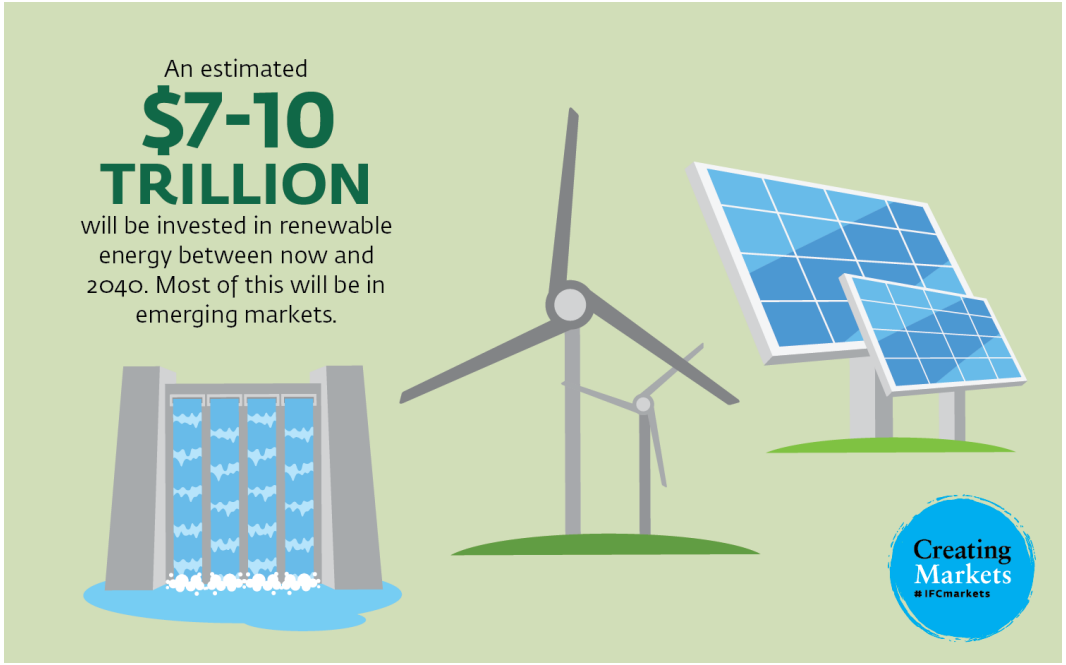
WE HAVE DECIDED TO DO SOMETHING ABOUT THE WHOLE PROBLEM!



Bloomberg Green

Energy & Science

Denmark Secures Backing for $34 Billion Clean Energy Island

By Morten Buttler
February 4, 2021, 12:00 PM GMT+1 *Updated on February 4, 2021, 2:34 PM GMT+1*

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The Commission said in March it wanted to reduce dependence on Russian gas by two-thirds this year, and completely by 2030. It also unveiled a target to increase its share of renewable energy from 40 to 45% by 2030.

The EU also aims to reduce greenhouse gases by 55% by 2030 and to be carbon neutral by 2050.

On Monday, Denmark said it would increase its wind capacity off the Baltic Sea island of Bornholm from two to three gigawatts, and link this production to Germany's electricity grid.

In May, Germany, Denmark, the Netherlands and Belgium announced a similar agreement to increase the North Sea's wind power capacity tenfold to 150 gigawatts by 2050 to help the EU achieve climate goals and avoid Russian hydrocarbons.

Germany, Denmark, Netherlands and Belgium sign €135 billion offshore wind pact

Heads of government from the North Sea countries gathered in Esbjerg to sign a cooperation agreement on offshore wind development and "green" hydrogen. They will target at least 65 GW by 2030 and 150 GW by 2050.

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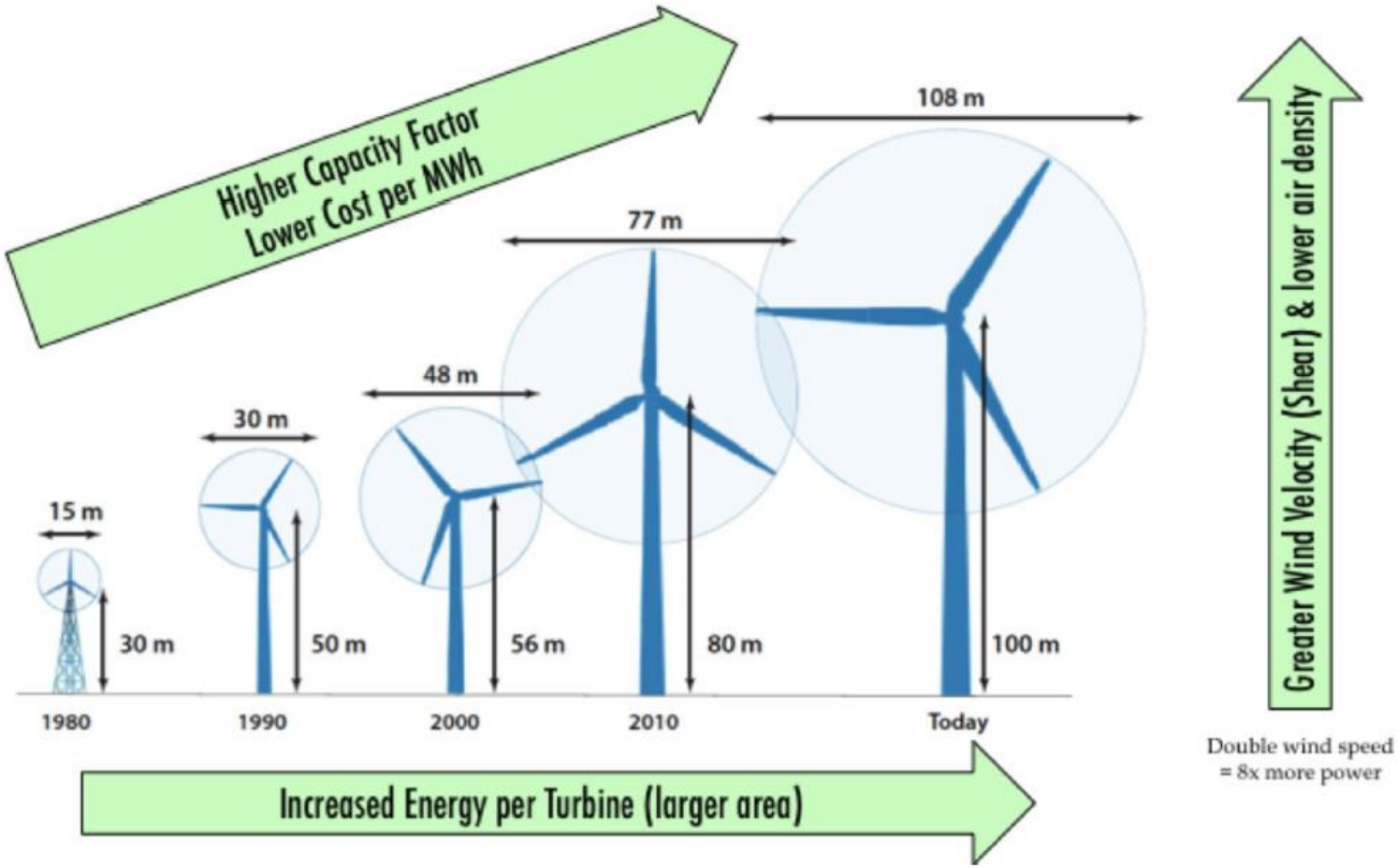
$P_w = ½ \rho A v^3$ Means Turbine Height and Rotor Diameter Matter



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Sany reaches full power with 15MW onshore wind turbine

Sany has achieved full power from its record-breaking 15MW onshore wind turbine at a pilot project in the north-east of China.

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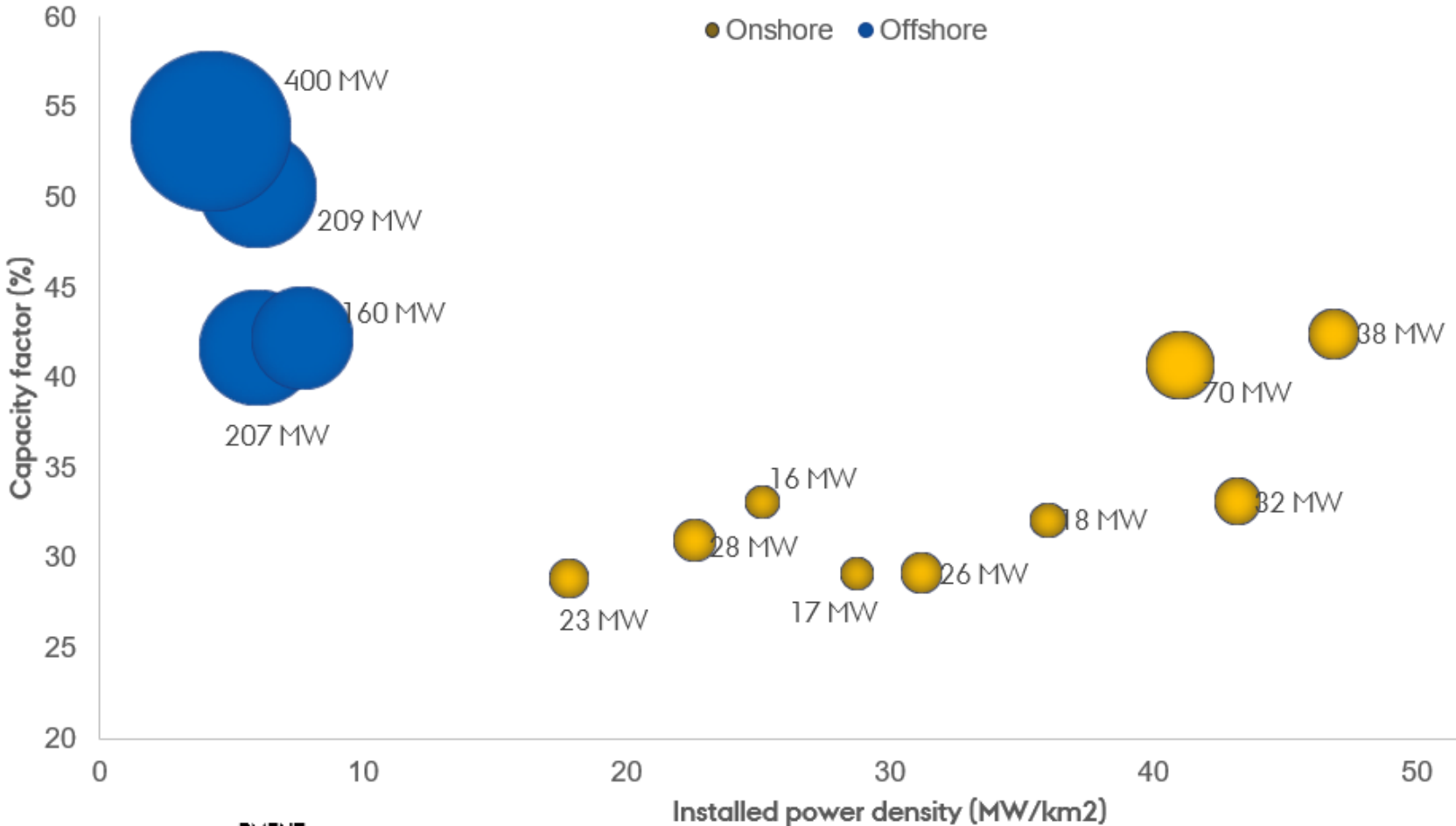
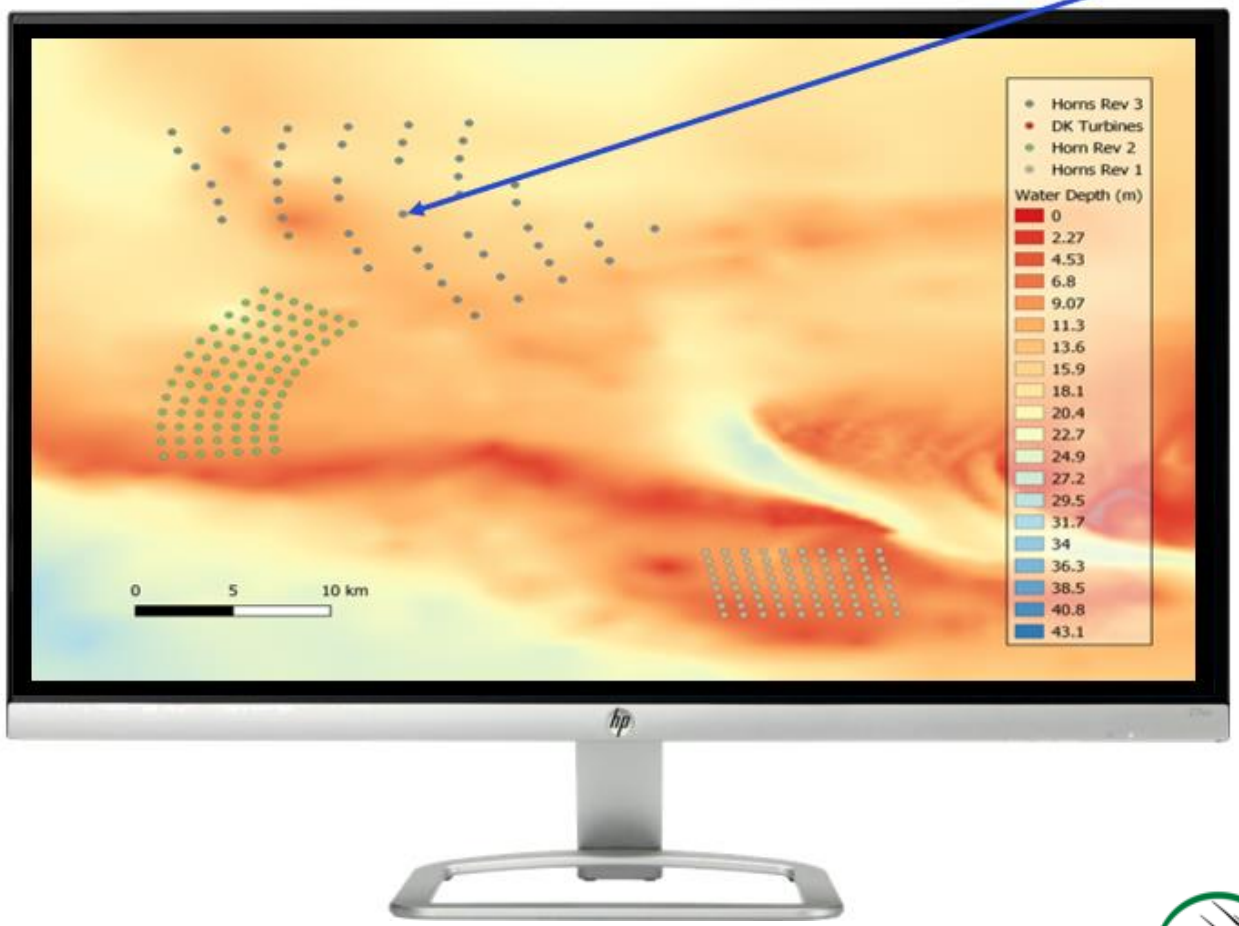
REVEALING THE PATTERNS: SPACING DENSITY

That cannot be? 0.9 to 8.8 wind turbine per km2 would result in massive wake losses. Maybe? The relationship between wind farm capacity factors (%) and installed power densities (MW/km2) are presented in the figure below. The size of the bubbles represent the installed nameplate capacity of the wind farm (MW).



WE HAVE DECIDED TO DO SOMETHING ABOUT THE WHOLE PROBLEM!

EXAMPLE 1



Coordinate	
WTG	V164-8 (8.3MW)
Hub Height (m)	105
Commercialization date (ddmmyyyy)	23-12-2018
Wind speed (m/s)	9.44
Water depth (m)	15.9
Wave height (m)	1.34
Air density (kg/m^3)	1.24
Temperature (C)	283.5
Distance to shore (km)	54
Power Curve	*Link*
AEP for 2019 (MWh)	27,523

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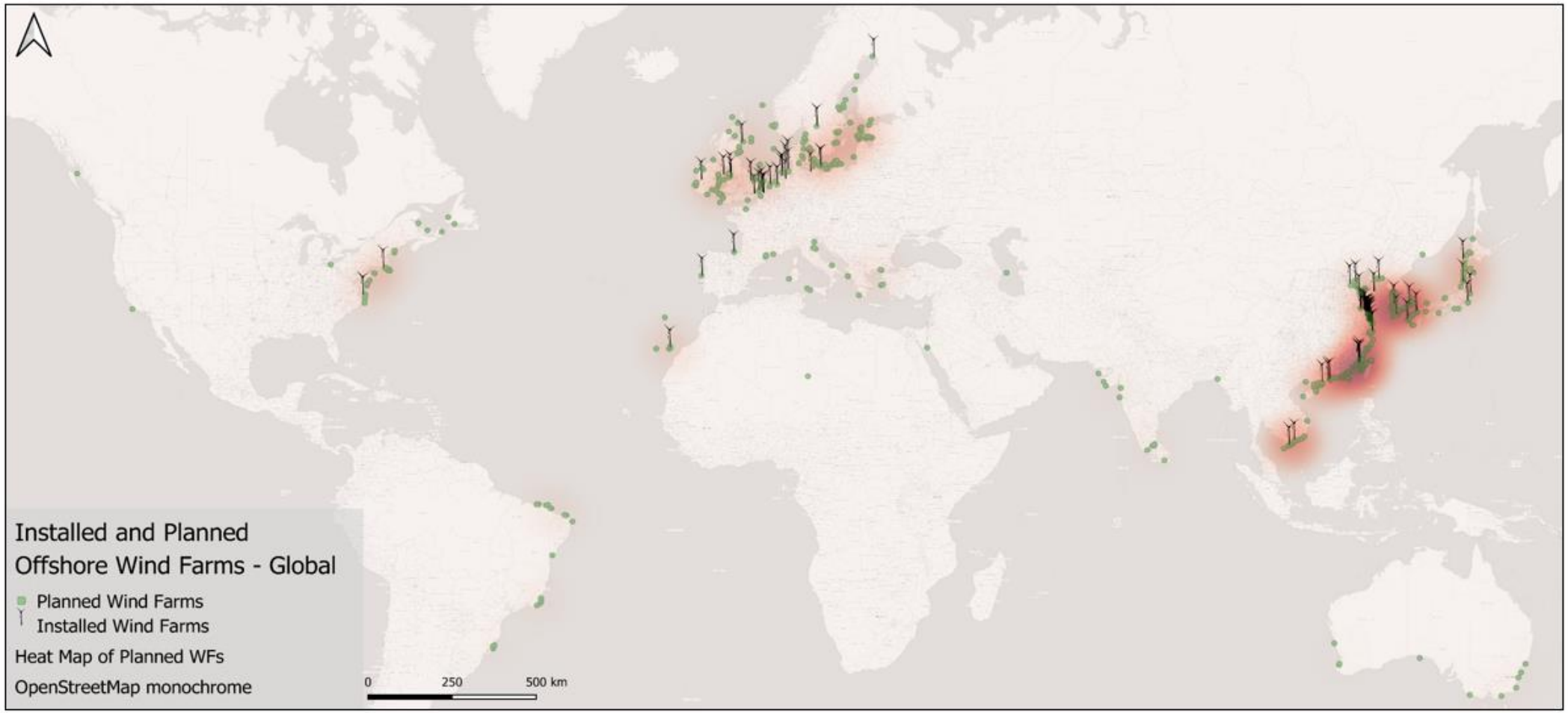
WE HAVE DECIDED TO DO SOMETHING ABOUT THE WHOLE PROBLEM!

OFFSHORE WIND

REVEALING THE PATTERNS: LOCATION

The current offshore wind projects in different stages



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WE HAVE DECIDED TO DO SOMETHING ABOUT THE WHOLE PROBLEM!

GLOBALink Xinhua Global Service

GLOBALink | 26MW offshore wind turbine rolls off production line in SE China's Fujian

Source: Xinhua Editor: huaxia 2024-10-13 21:14:31

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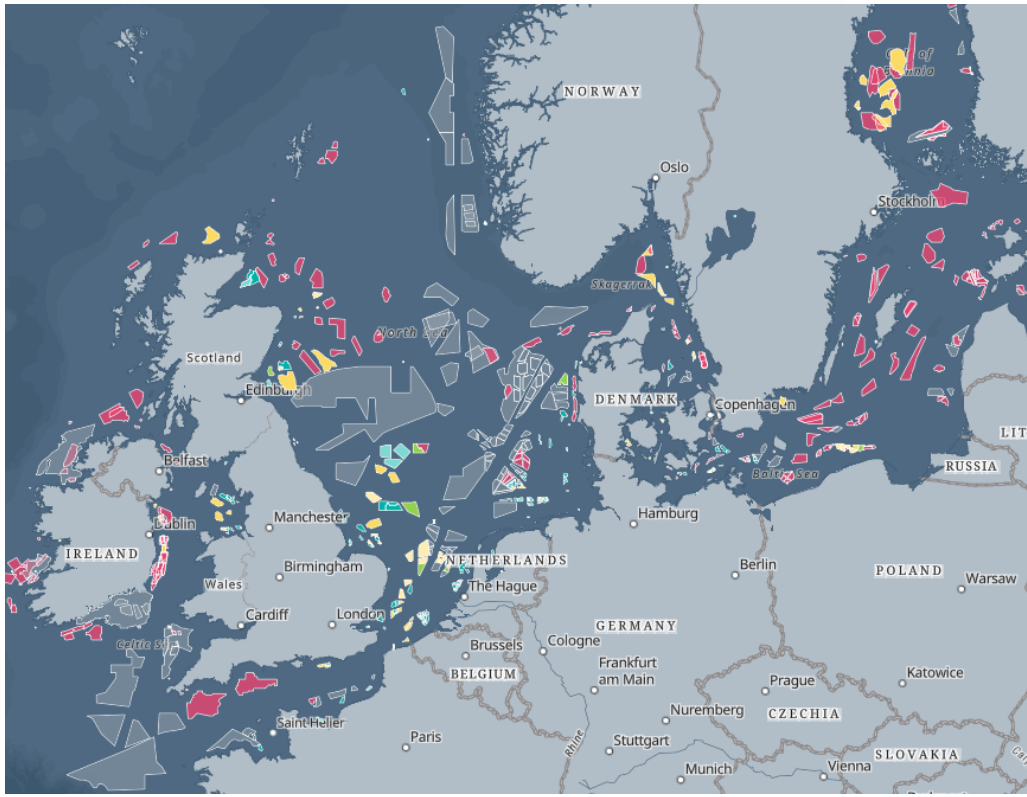
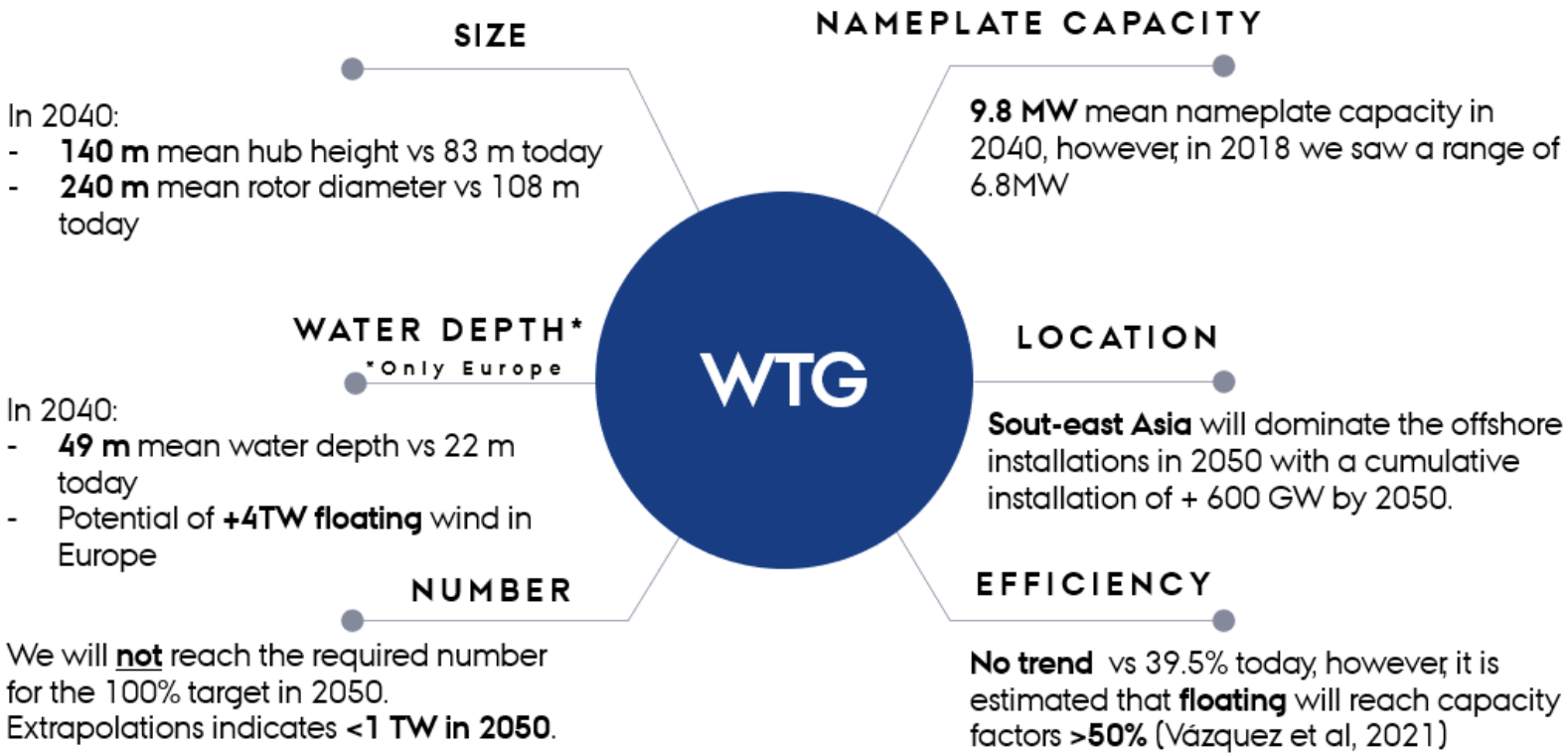


WE HAVE DECIDED TO DO SOMETHING ABOUT THE WHOLE PROBLEM!

OFFSHORE WIND

THE FUTURE OFFSHORE WIND TURBINE

The future wind turbine can be derived entirely from statistics, which neglects market developments and energy policies. Thereby, such also comes with significant uncertainties.



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Why do people complain about wind turbines?

- Wind power must compete with other low-cost energy sources
- Ideal wind sites are often in remote locations.
- Turbines produce noise and alter visual aesthetics.
- Wind plants can impact local wildlife
- You can’t run a country with a high share of Renewables

Trump Calls Wind Turbines Bird Killers. New AI Tech Saves Them From The Blades

ENVIRONMENT MINISTRY LICENSES WIND PARKS IN EVROS BURNED FOREST

September 25, 2023 environment, FEATURED 7 Comments

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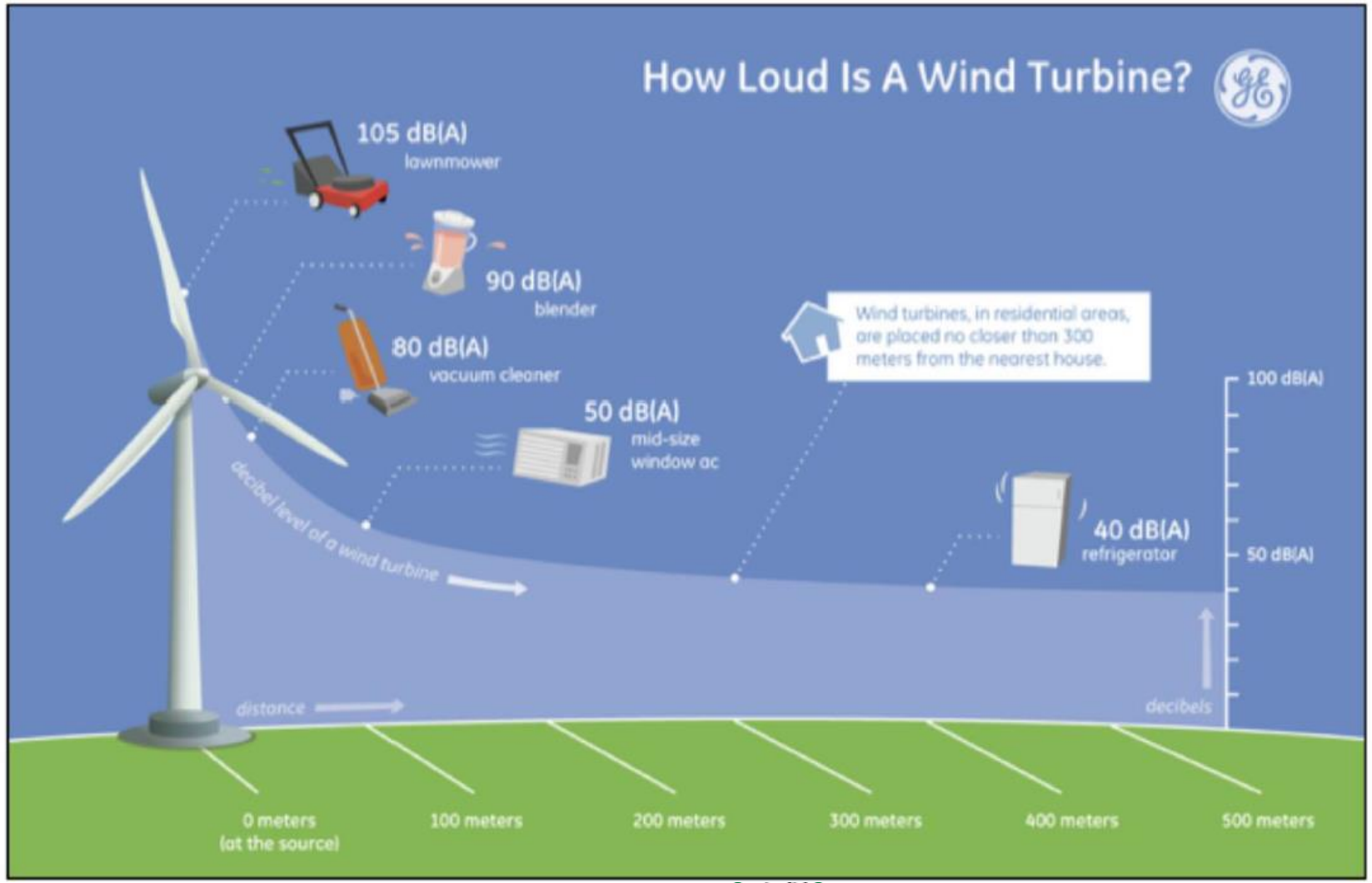
Wind Turbines and Birds

	U.S. Bird deaths/yr
Wind turbines	76,000-990,000
Communication towers	7 million
Transmission/distribution lines	8-57 million
Windows/buildings	1 billion
Cats	2.4 billion
Coal + natural gas electricity	13.2 million
Nuclear electricity	100,000

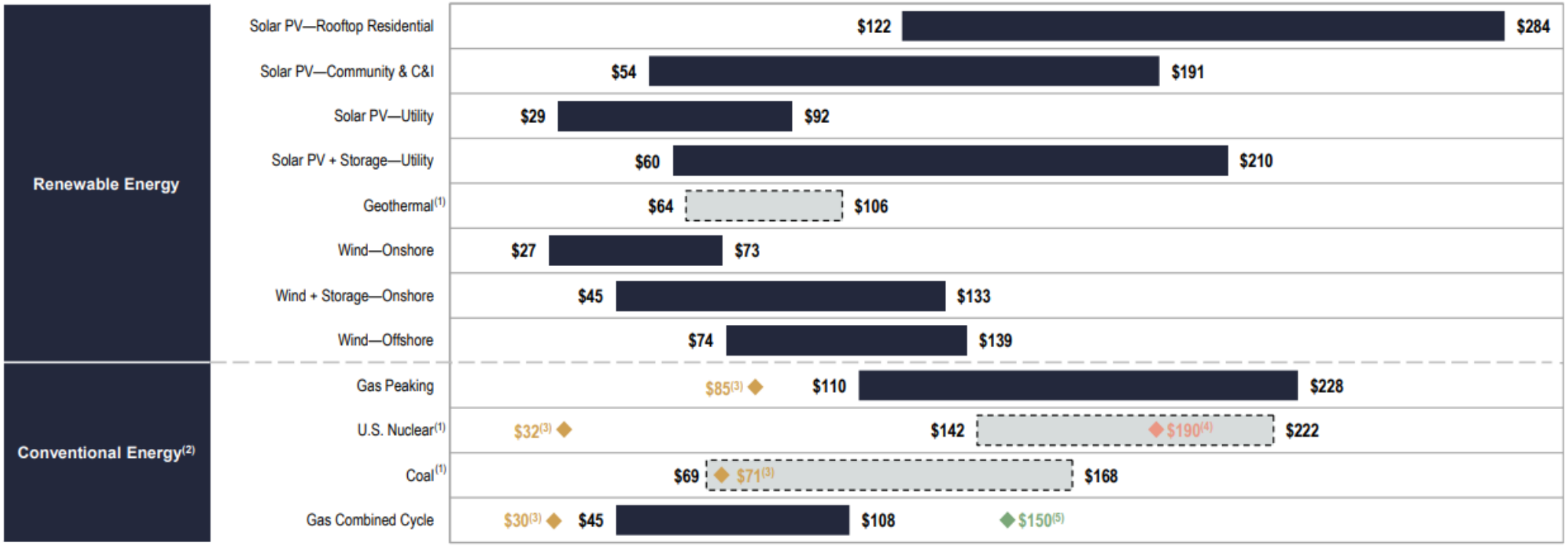
https://www.sustainabilitybynumbers.com/p/wind-power-bird-deaths

Wind Turbine Sound Level is Comparable to a Refrigerator (When you can hear it at all)



Levelized Cost of Energy Comparison—Version 17.0

Selected renewable energy generation technologies remain cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard and Roland Berger estimates and publicly available information.*

Note: Here and throughout this analysis, unless otherwise indicated, the analysis assumes 60% debt at an 8% interest rate and 40% equity at a 12% cost. See page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities.

(1) Given the limited public and/or observable data available for new-build geothermal, coal and nuclear projects the LCOE presented herein reflects Lazard's LCOE v14.0 results adjusted for inflation and, for nuclear, are based on then-estimated costs of the Vogtle Plant. Coal LCOE does not include cost of transportation and storage.

(2) The fuel cost assumptions for Lazard's LCOE analysis of gas-fired generation, coal-fired generation and nuclear generation resources are $3.45/MMBTU, $1.47/MMBTU and $0.85/MMBTU respectively, for year-over-year comparison

https://www.lazard.com/research-insights/levelized-cost-of-energyplus/

Iberdrola

How long does it take to build an offshore wind farm?

While the construction of an onshore wind farm can take between 4 and 8 years, taking into account all phases of the process, **the construction of an offshore wind farm is estimated to take between 7 and 11 years**. Three to five years are dedicated to the development phase, one to three to the pre-construction phase and two to four years to construction.

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https://greenagenda.gr › ν-σ-υπεν-ά... · Translate this page

Ν/σ: Άδεια για αιολικό σε 14 μήνες, αντί 5 χρόνια – Πιλότος ...

Jun 20, 2022 — · Τα στάδια της αδειοδοτικής διαδικασίας μειώνονται από 7 σε 5 και **ο χρόνος αδειοδότησης των έργων μειώνεται σε 14 μήνες**, από 5 χρόνια που είναι ...

ΕΛΛΑΔΑ 10 Αυγούστου 2021 | 17:50

Αναδασωτέες όλες οι καμένες εκτάσεις εντός 30 ημερών

Μέτρα στήριξης και άμεσες παρεμβάσεις στις πυρόπληκτες περιοχές

Σύνταξη in

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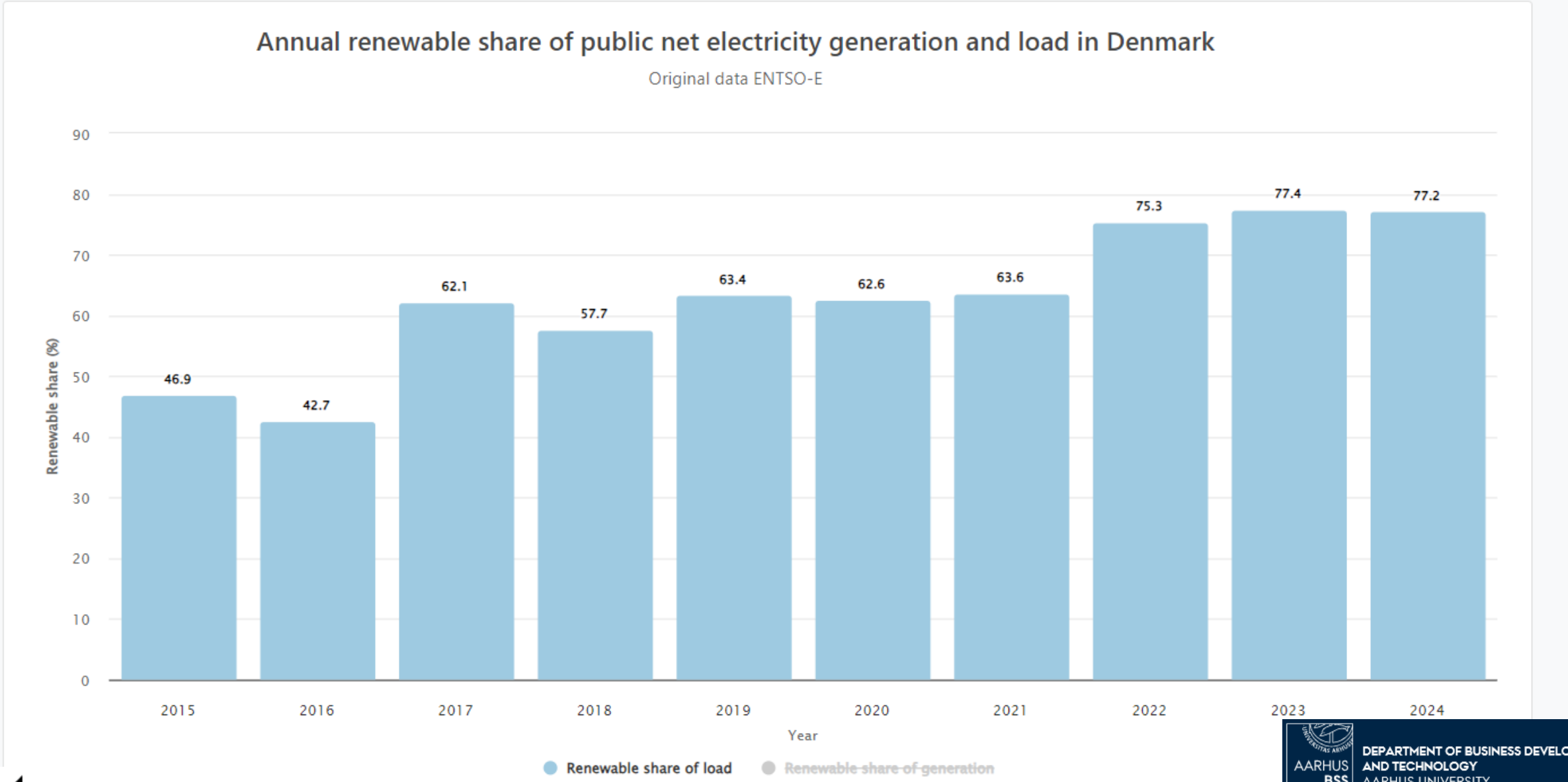

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THANK YOU

George Xydis

Aarhus University, Denmark

E: gxydis@go.uop.gr; gxydis@btech.au.dk

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