# Accelerating the Energy Transition – Opportunities for Western Australia

Henrik Stiesdal, 21.10.24

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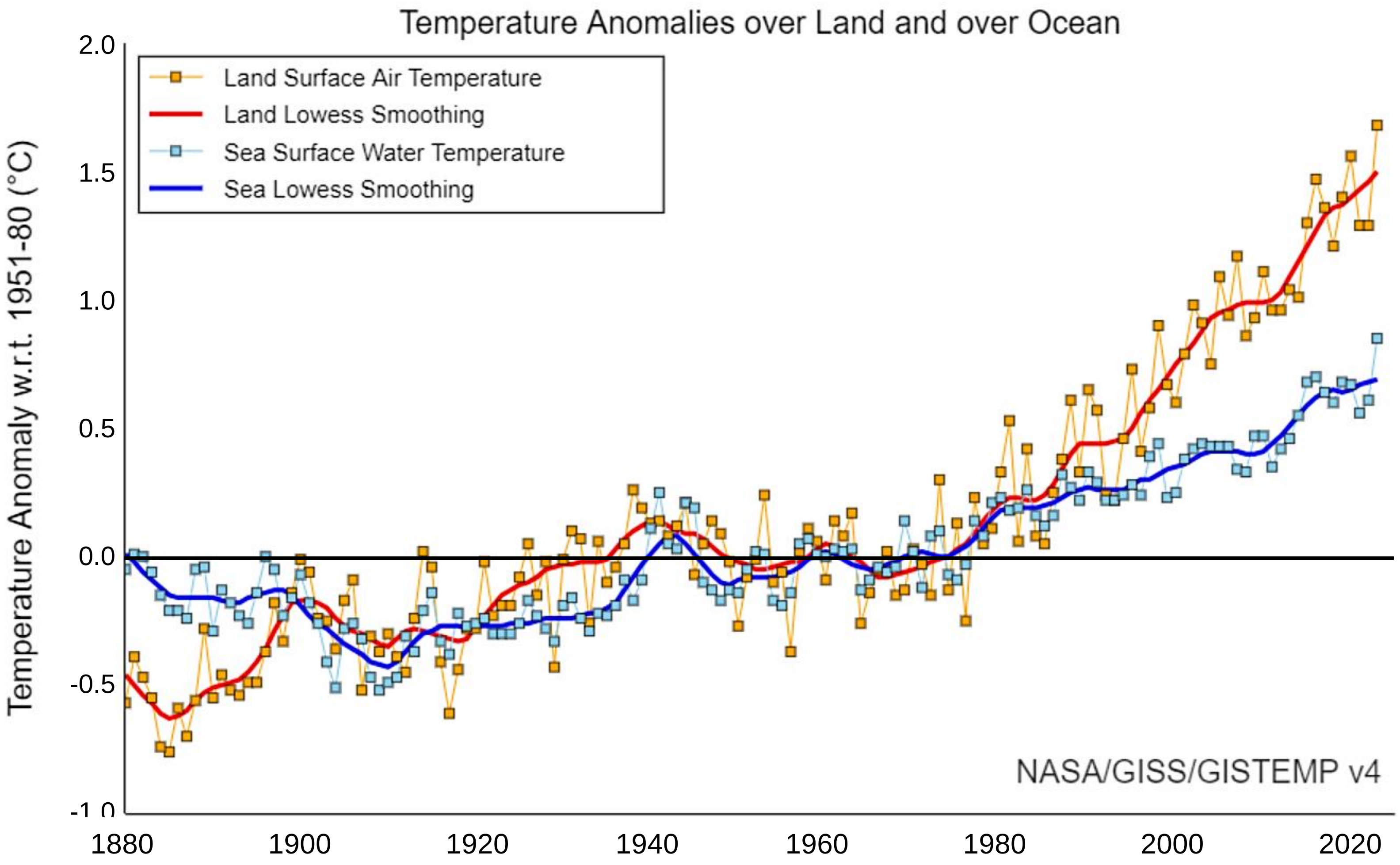
# Climate change is an essential threat to human society

2023 was the hottest year on record. And the consequences are disturbingly visible





 Source: NASA, Nature, BBC, Guardian

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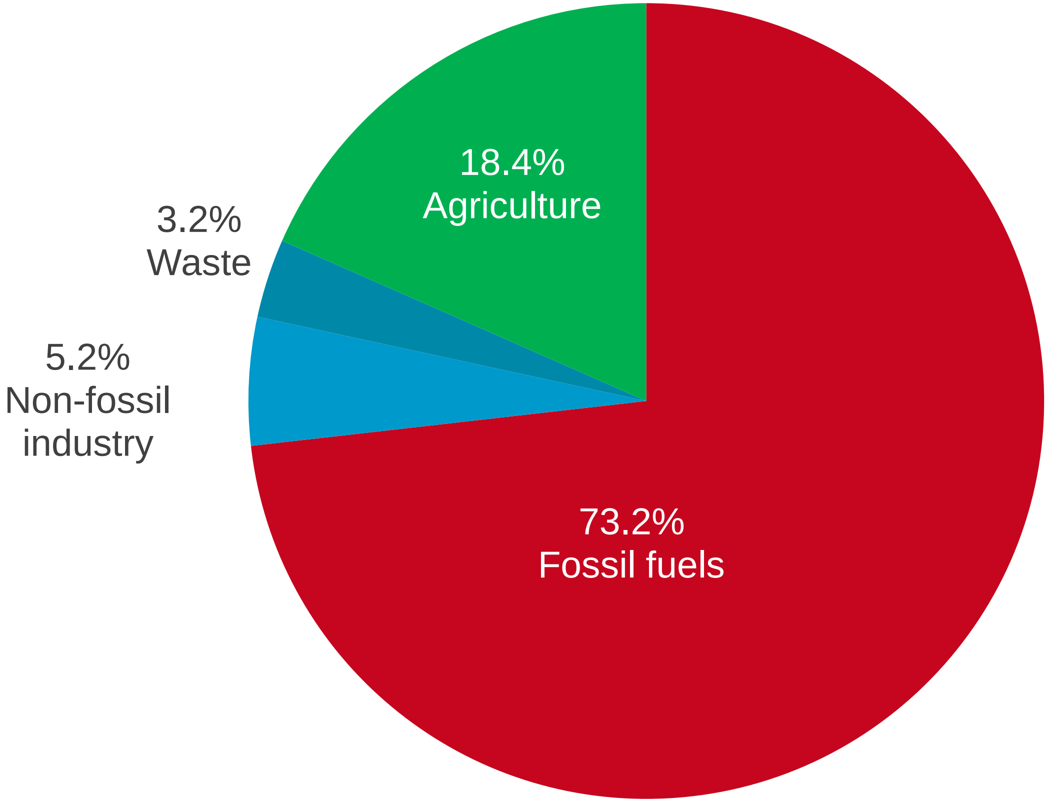
# Climate change is caused by man-made emissions

Fossil fuels account for the majority of climate-damaging emissions, agriculture is second

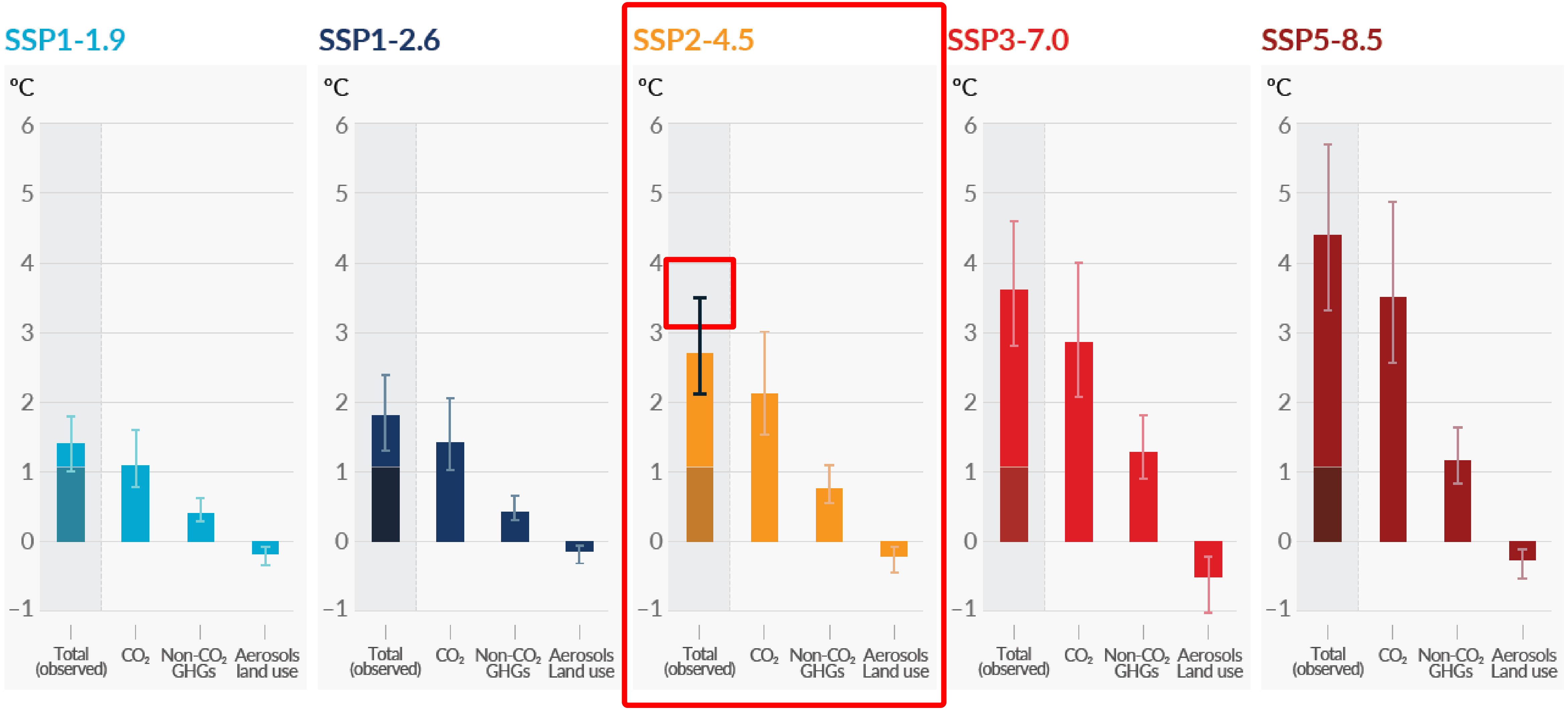





Source: IEA, IPCC, Statistia

# We are not on track

## Our emissions trajectory does not leave our children in a good position




 Source: IPCC

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# So – we are faced with a bizarre paradox

We do not act according to our knowledge

**We know the risk**

- Climate change is an existential threat to humanity.
- Large parts of the earth may become uninhabit-able, creating instability and displacing hundreds of million of people.

**We know what to do**

- Reduce emissions by phasing out fossil fuels as soon as possible.
- Replacing fossils with renewables that are often cheaper and have low volatility, leading to long-term societal stability.

**Yet, we don't do it**

- We delay the green transition due to technical, financial and political challenges.
- We still apply climate-damaging solutions, even building new gas- and coal-fired power plants.



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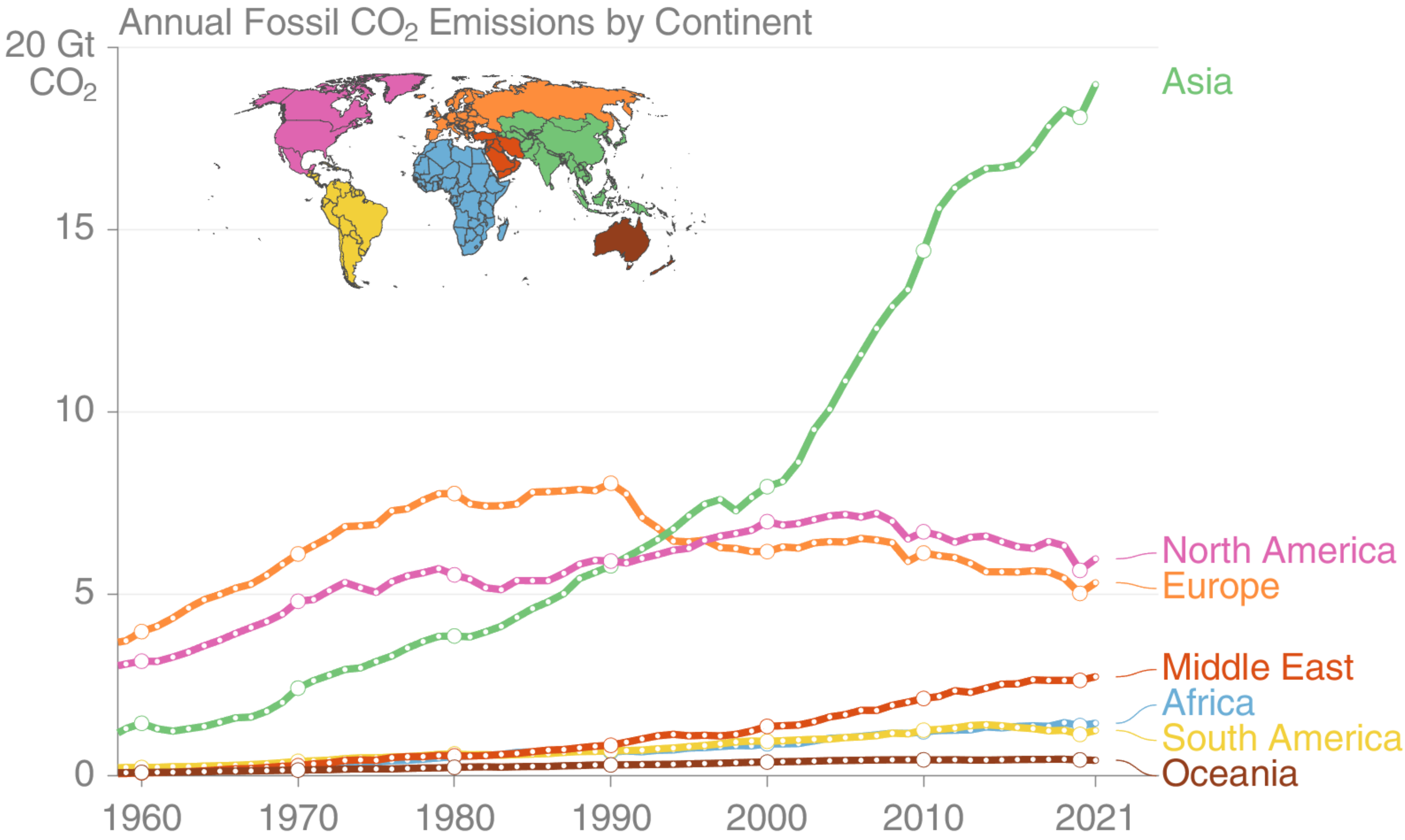
# Particularly in Asia, emissions are set to increase even further

Fossil emissions from Asia are 110% of the sum of emissions from the rest of the world






Source: Global Carbon Project

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# We are firmly settled on a burning platform

We need to act – but are often using or confronted with all sorts of arguments for not to act



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# Some specific challenges

Given that we know the solution, why are we too slow on the implementation of renewables?

## Technical

**Statement**
- *We cannot rely on renewables for power supply. When there is no wind and no sun, everything would stop!*

**Underlying assumption**
- We have no technology available to store surplus electricity so it can be recovered as electricity when needed later.

**Reality**
- Electricity can be stored directly in batteries or converted into hydrogen and ammonia, stored, and regenerated when needed.

## Financial

**Statement**
- *We really would like to go green, but we cannot afford it!*

**Underlying assumption**
- Renewables are more expensive than fossils.

**Reality**
- In some markets renewables are or will become cheaper than fossils, and across the globe they will always be affordable.



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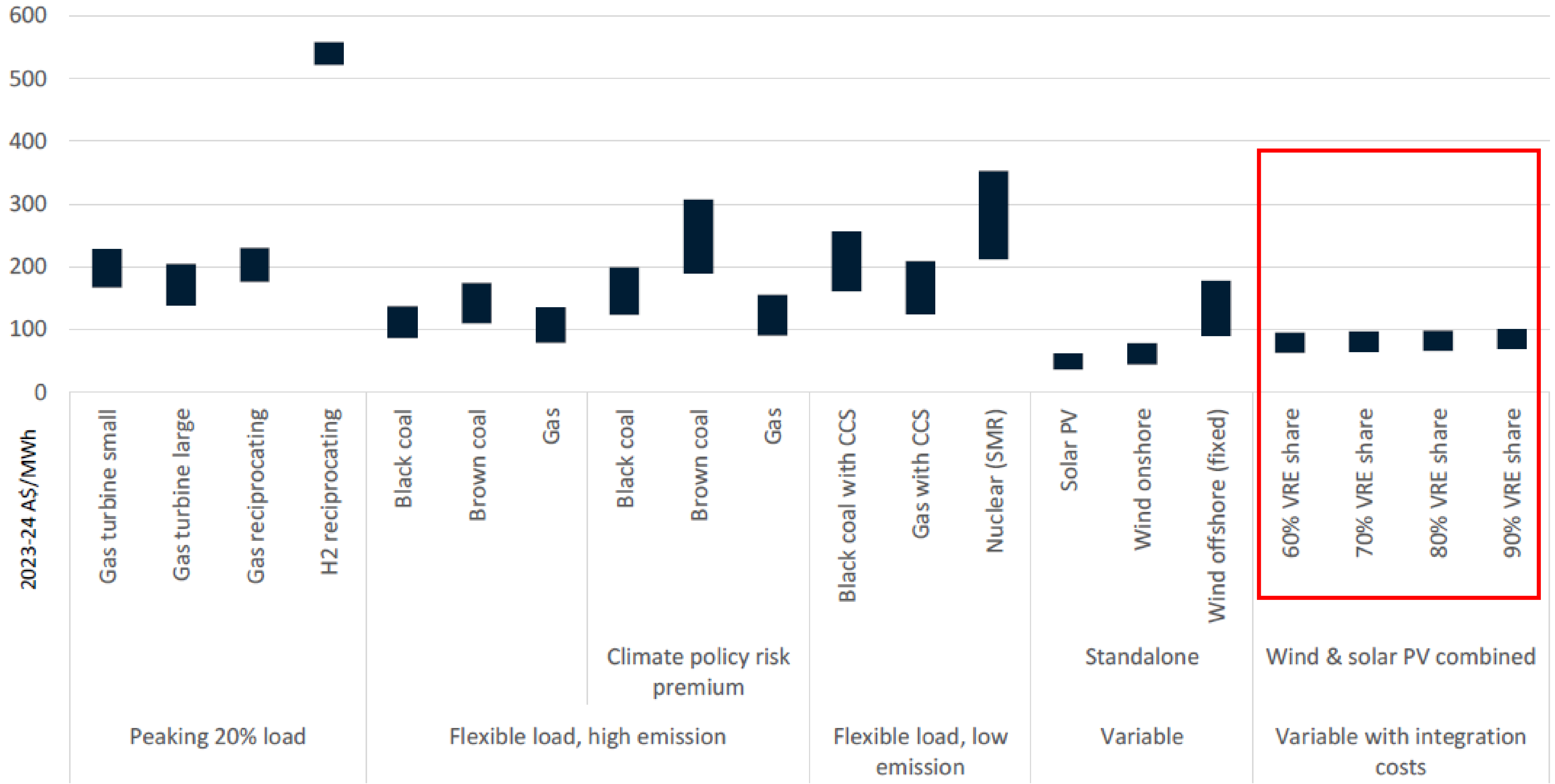
# Present cost of renewables vs. conventional energy

## CSIRO “GenCost” Consultation Draft






Source: CSIRO, 2023

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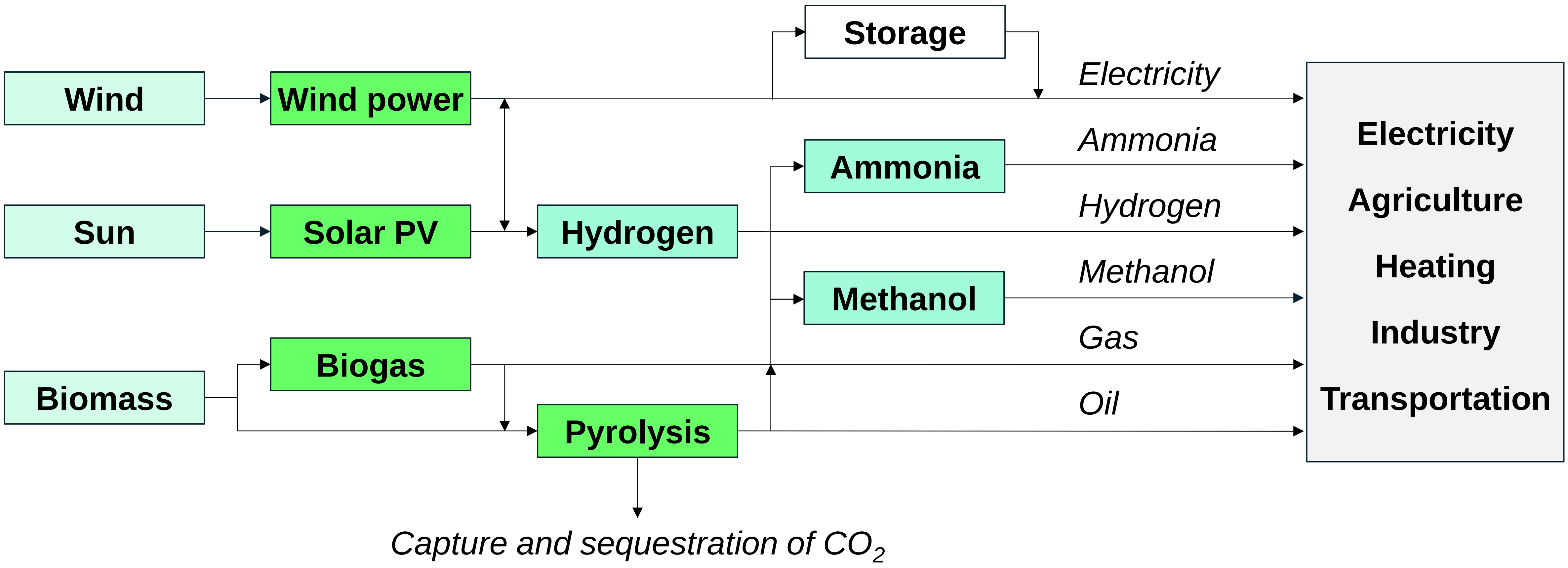
# A new energy system based on existing technologies

We can meet society's needs without new technologies; we just need scale



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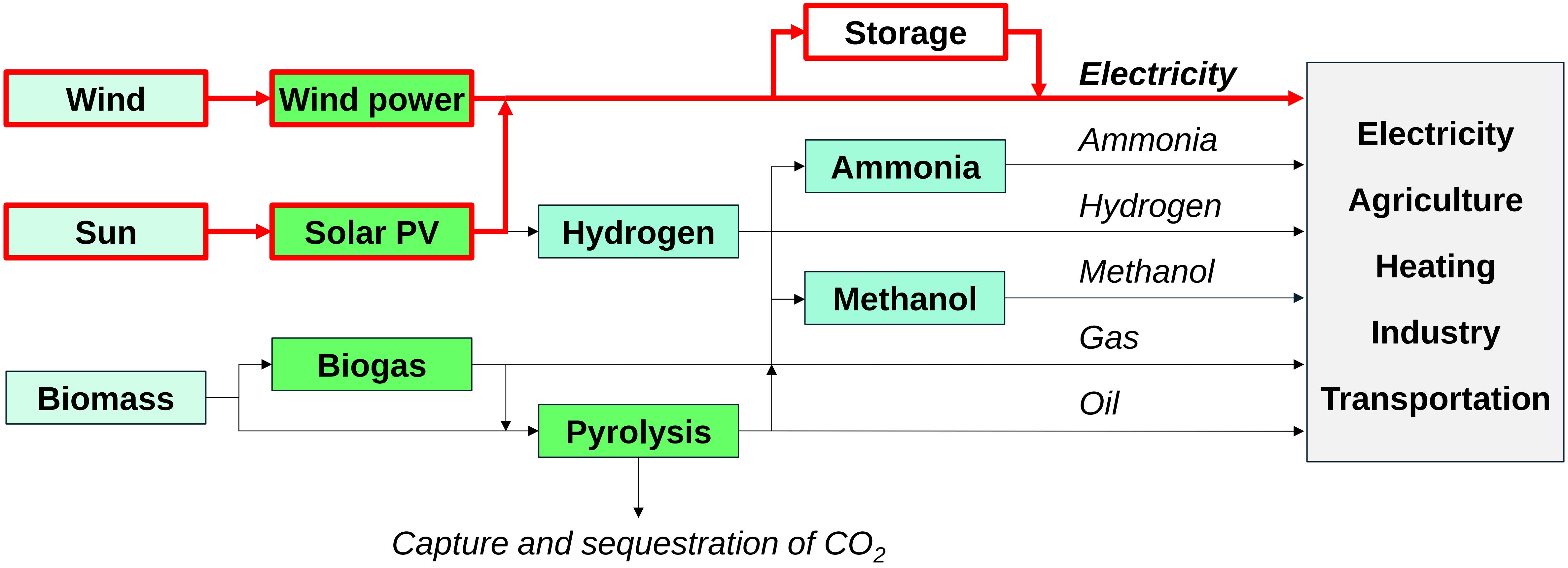
# A new energy system based on existing technologies

Everything that can be electrified must be electrified



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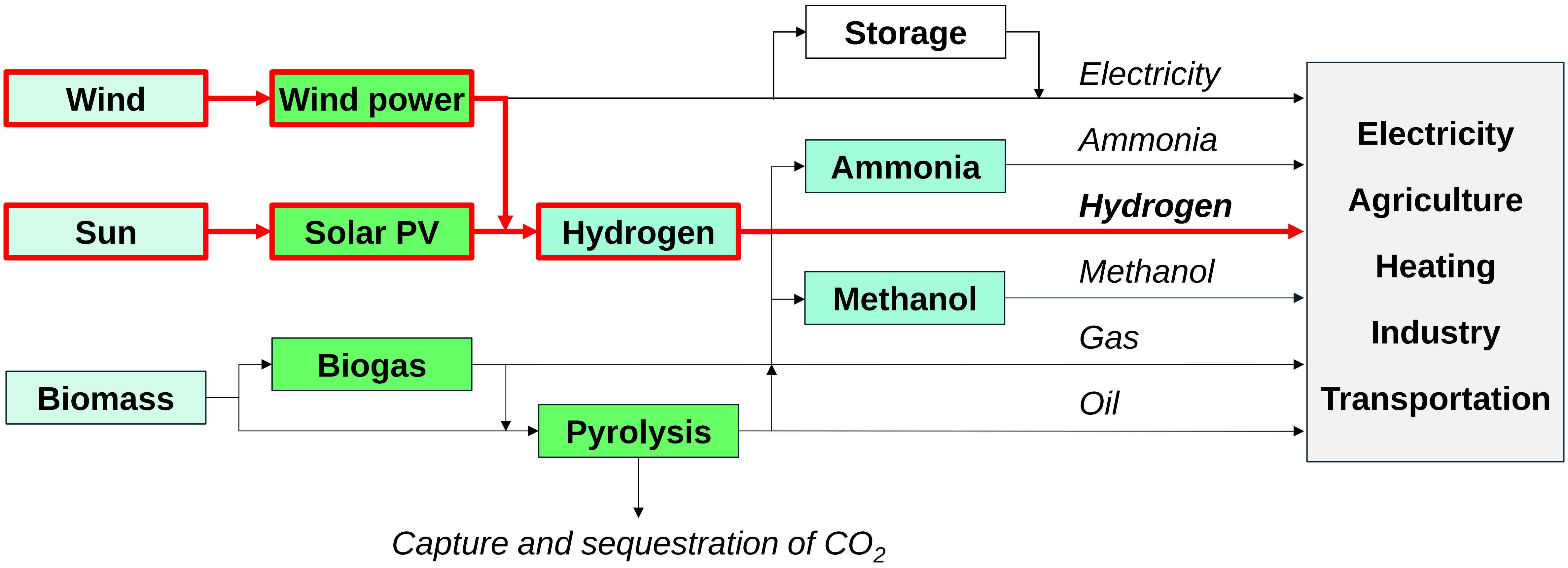
# A new energy system based on existing technologies

Where direct electrification is not possible, hydrogen is the universal key



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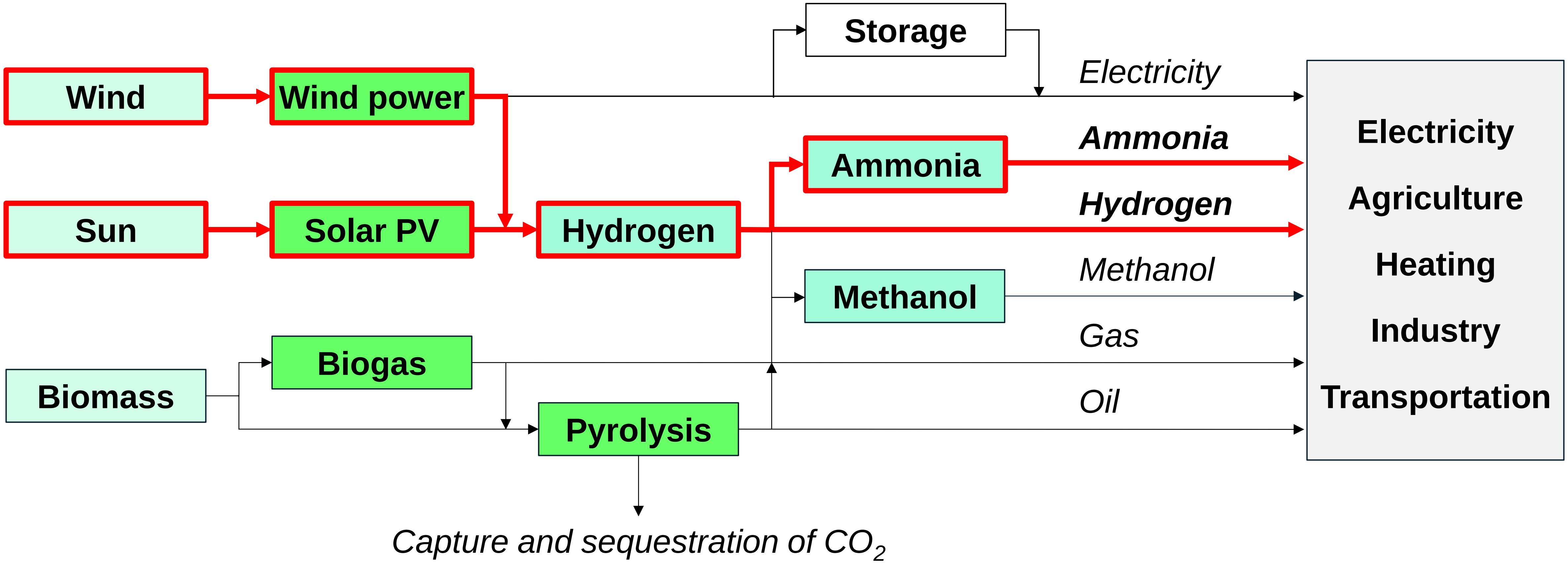
# A new energy system based on existing technologies

Hydrogen may be converted to ammonia for transportation and for fertilizer and chemical use



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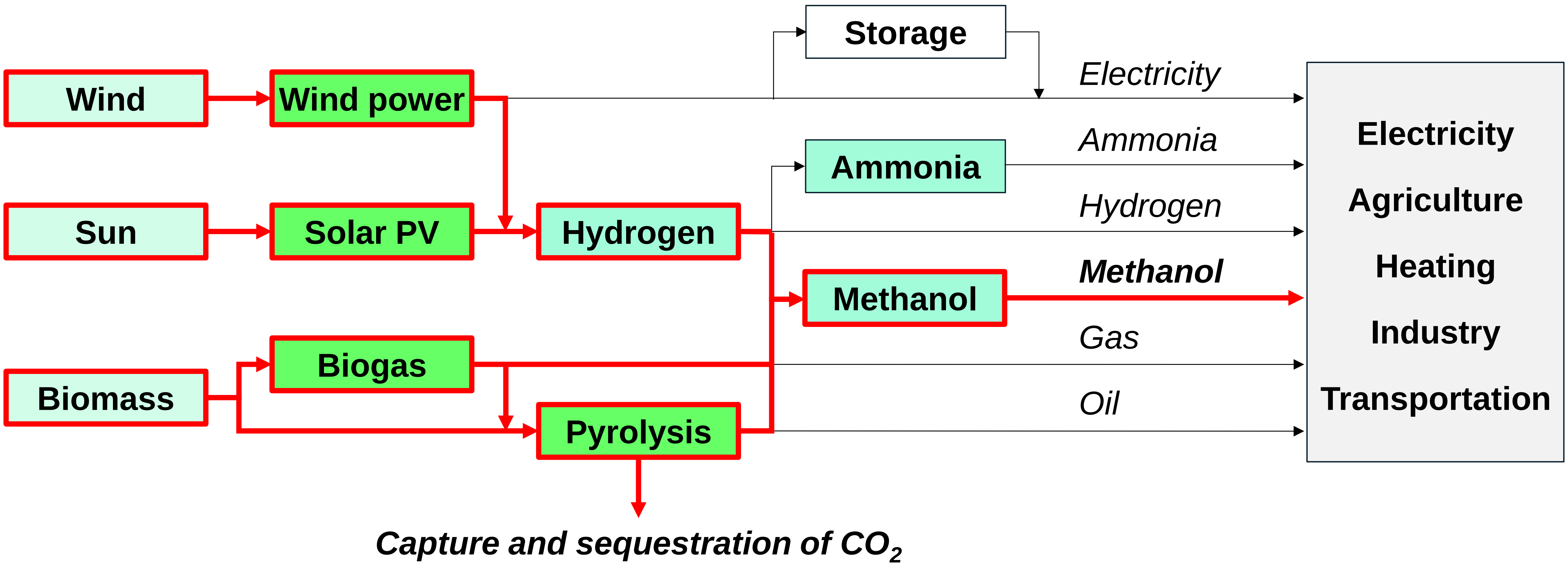
# A new energy system based on existing technologies

Hydrogen may also be combined with green carbon for methanol synthesis



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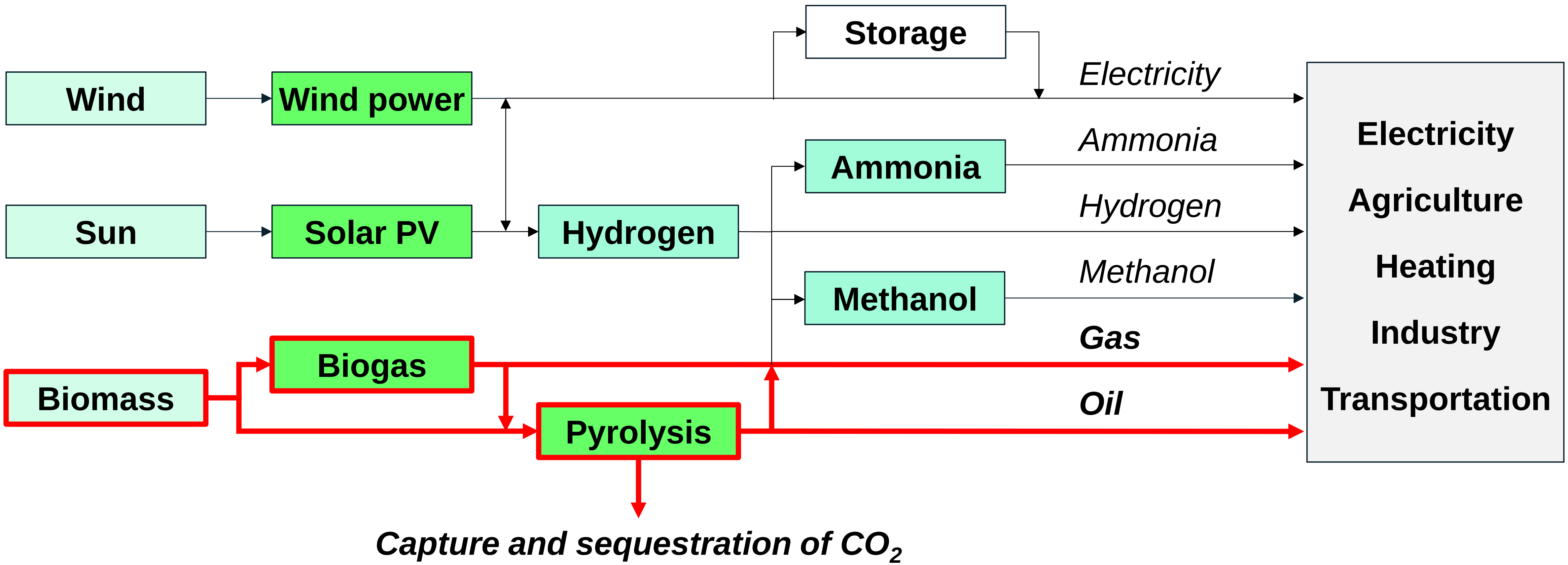
# A new energy system based on existing technologies

Green carbon fuels may be supplied directly where needed



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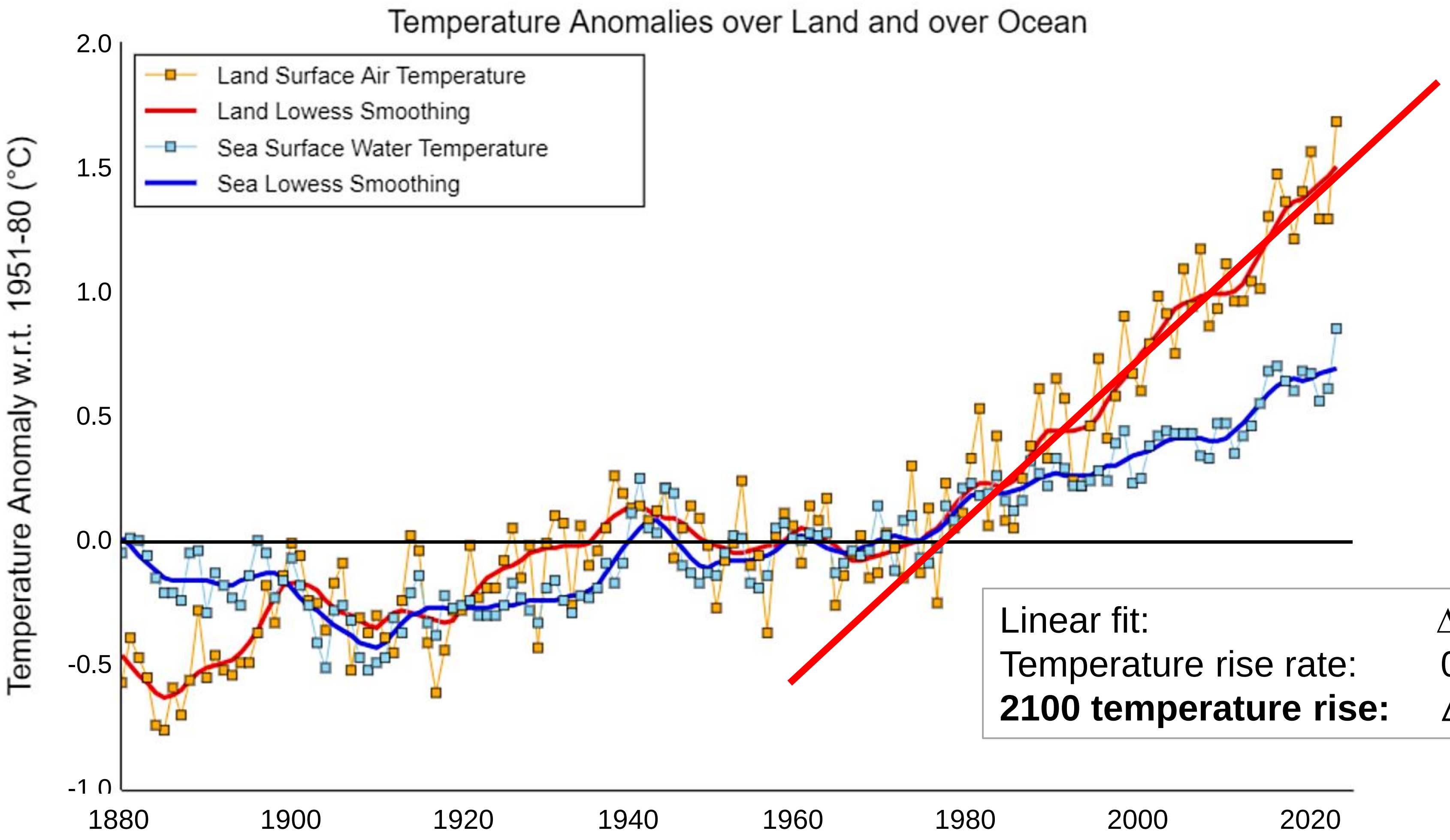
# We have everything we need, except for one thing: Time!

Getting to grips with climate change requires fast action and partnerships




Linear fit: ΔT = (Year – 1975) * 0.03 °C/year
Temperature rise rate: 0.3 °C/decade
**2100 temperature rise: ΔT = 3.75 °C**


Source: NASA, Nature, BBC, Guardian

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# Even small states can play a central role in the acceleration

The Danish wind industry is an example of impact way out of proportion with relative size of state

**Denmark played a key role in the modern wind industry development**

- The world now has more than 1000 GW of wind power installed, abating minimum 3.5% of global emissions.
- More than 99.9% of the world’s wind turbines are either Danish design or designed with inspiration from Danish turbines.



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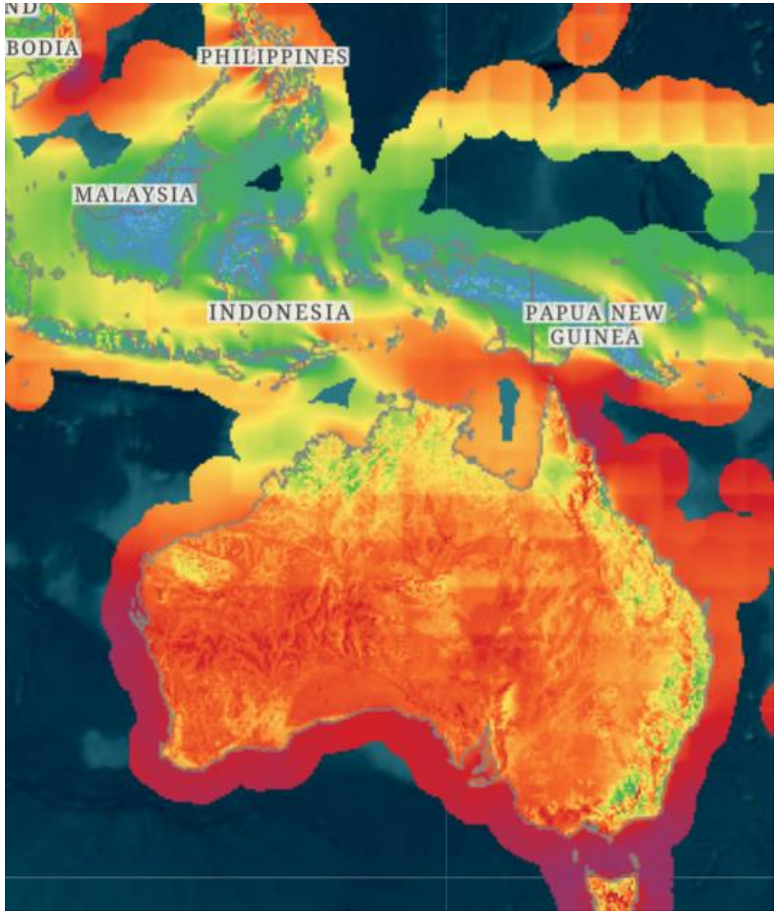
# WA could become a key player in renewables

Due to its excellent resource WA could be a central export hub for electricity-based products

**WA has an extraordinary combination of size and resources**

- The wind resource (left) is on par with the upper 10% in the world.
- The solar resource (right) is on par with the upper 5% of the world.







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# The solar PV opportunities in WA are staggering

On a global scale few if any administrative regions compare with WA

**The simple numbers**

- The world currently uses about 27,000 TWh of electricity annually.
- In WA, solar PV can be expected to have a capacity factor higher than 25%.
- Consequently, the installed soler PV capacity needed to deliver the world's consumption of electricity is

  P = 27,000 TWh / 8760 h / 25% = 12.3 TW
  = 12.3 million MW

- One MW of solar PV takes up one hectare. 20% additional are could be added for roads, infrastructure, etc.
- Consequently, the land area needed to cover the whole world's consumption of electricity is

  A = 12.3 million Ha * 1.2 = 14.8 million Ha
  = 148,000 sq.km
  **= 6% of WA land area**

## Western Australian solar farm leads way in performance stakes

SUN Energy's 100 MW Merredin Solar Farm in Western Australia has emerged as the country's best performing utility-scale PV project in 2021. International consultancy Rystad Energy says it has delivered an average capacity factor of 29.6% for the calendar year.

JANUARY 27, 2022 DAVID CARROLL

UTILITY SCALE PV   AUSTRALIA

*Image: Risen*

 Source: PV Magazine

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# Hybrid solar and wind can deliver ammonia at attractive cost

WA benefits from it  excellent resources in both solar and vind

**Optimizing the ratio**

- A combination of 70% solar PV and 30% onshore wind in WA can deliver hydrogen at 2.75 USD/kg.
- Using hydrogen at this price in ammonia synthesis leads to an ex-plant price of ~650 USD/ton for ammonia.
- The current world market price for green ammonia is ~900 USD/ton.



Picture credit: Regen Power

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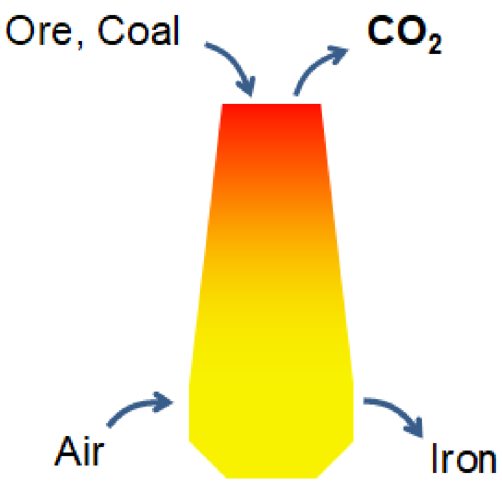
# WA could reap the benefits of value add on iron exports

Transitioning from export of iron ore to export of iron

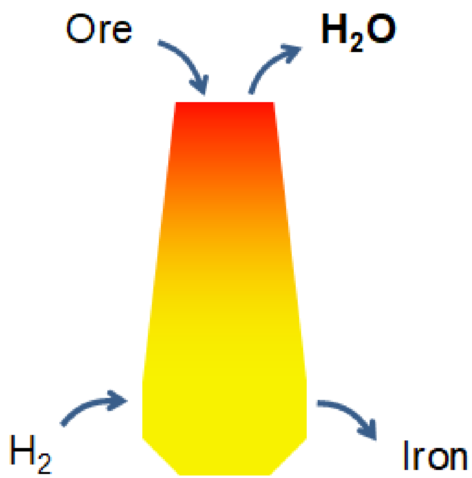
### Traditional iron making furnaces




$2\,Fe_2O_3 + 3\,\mathbf{C} \rightarrow 4\,Fe + 3\,\mathbf{CO_2}$

Iron ore + Coal → Iron + lots of $CO_2$

### Hydrogen based iron furnace



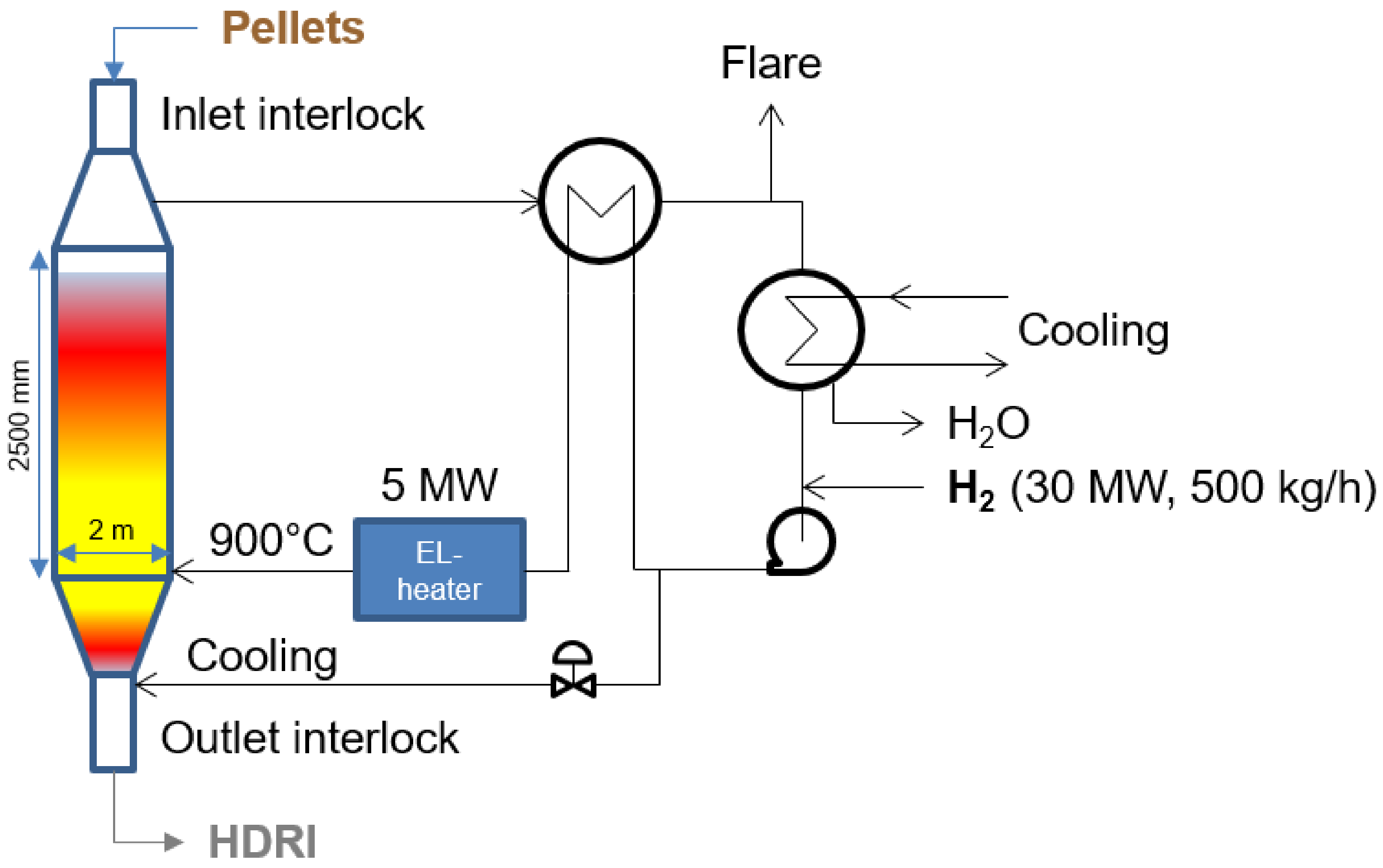

$Fe_2O_3 + 3\,\mathbf{H_2} \rightarrow 2\,Fe + 3\,\mathbf{H_2O}$

Iron ore + hydrogen → Iron + water

World steel production corresponds to 2-4000 GW of electrolysis, 10-20 x India's current power production

# WA could reap the benefits of value add on iron exports

A 30 MW unit suited for testing



# WA could reap the benefits of value add on iron exports

The scale would suit well to a state that has abundant renewable resources


Typical blast furnace:
10.000 t iron pr. day
~ 3 GW of electrolysis

Typical iron ore mine:
20 mio. t/y
~ 10 GW of electrolysis

Australian iron ore export:
900 mio. t/y
~ 240 GW of electrolysis



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# WA could also contribute to $CO_2$ removal fron the atmosphere

Using crop residues WA could extract millions of tons of $CO_2$

**A significant resource**

- WA currently has an annual output of 7.5 million tonnes of agricultural residues, mainly straw.
- Using the typical 1-1 ratio, WA could extract 5 million tons of $CO_2$ from the atmosphere annually and abate an additional 2.5 million tons of $CO_2$ through the supply of green fuels replacing fossil fuels.



Picture credit: Department of Primary Industries and Regional Development

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# How does one make big things happen?

## The history of the Danish wind industry is a good example

**The Danish "wind adventure" had four key driving elements**

**1. The government wanted it to happen**

- Since the late 1970s, the wind industry has enjoyed the support of a strong political majority.

**2. A demand was created by the establishment of long-term frame conditions**

- A 30% investment subsidy was implemented.
- The government imposed a grid connection mandate on the utilities.
- Electricity supply rates offered customers decent project economies.

**3. Selected demonstration projects received subsidies**

- The world's first offshore wind farms received specific subsidies

**4. Strong links were established between industry and research**

- The interaction was a side effect of the investment subsidy

# Can this be done?

## A possibility or a pipe dream?

**The simple facts**

- We have all the technologies. Nothing new needs to be invented.
- It is entirely affordable.

**How could we make it happen?**

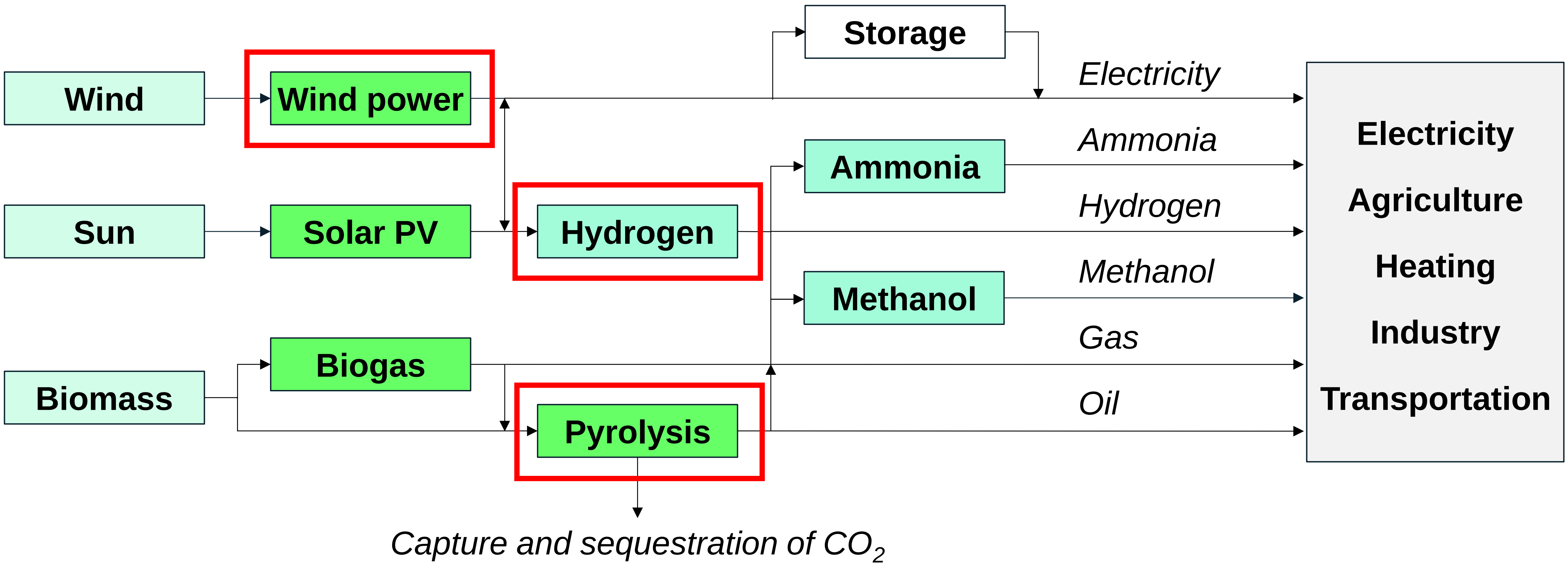
- We could take our bearings from the simple success story of the Danish wind industry.
- In Wester Australis, we could set the example and demonstrate the new energy system.

**Really … that easy?**

- No. Nothing in this is easy.
- Western Australia will have its own challenges relating to vested interests.
- The interests of First Nations, biodiversity and ecology, etc. also need to be respected

# A new energy system based on existing technologies

Fields requiring support for cost reduction



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# Industrialization is the key lever to cost reduction

The Ford Model T

1909


1923

 Source: Ford Motor Co.

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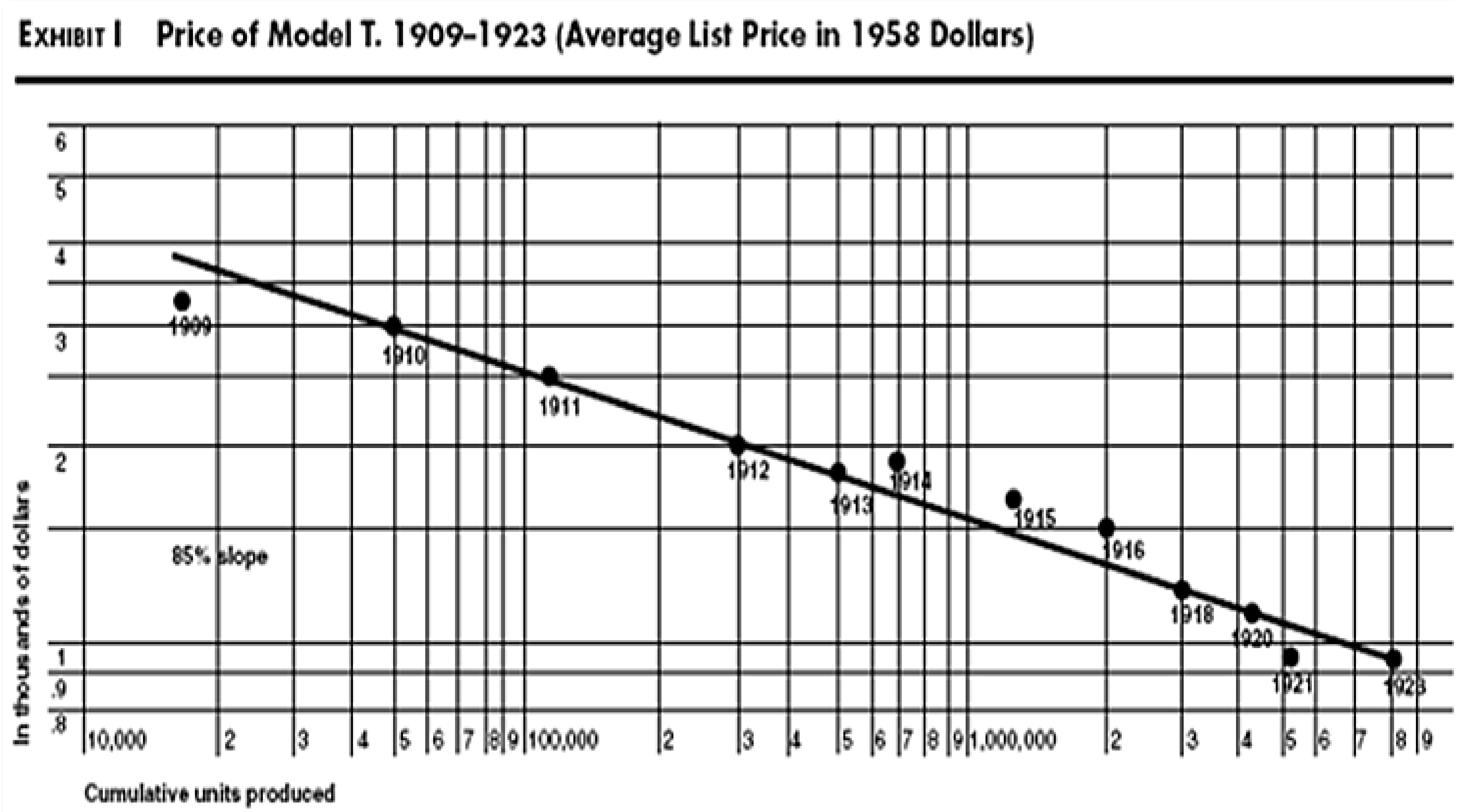
# Industrialization is the key lever to cost reduction

## The Ford Model T cost trajectory




 Source: Ford Motor Co.

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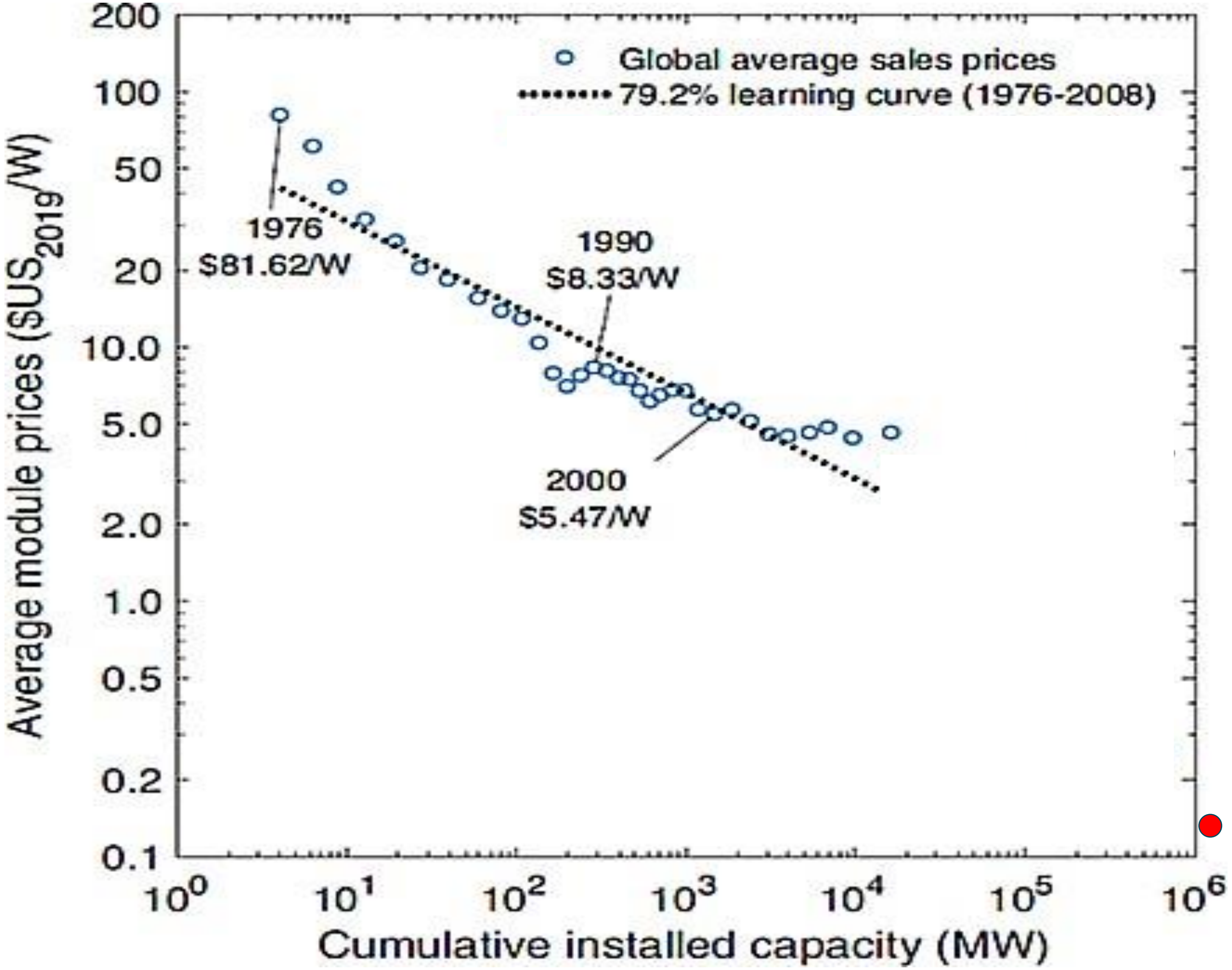
# Industrialization is the key lever to cost reduction

The solar PV cost trajectory




 Source: Schmalenbach Journal of Business Research (2021) 73:179–206

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# Stiesdal fields of activity

The Company develops climate solutions within three distinct fields of the energy transition


## Hydrogen

HydroGen industrialized electrolyzers


## SkyClean

SkyClean pyrolysis plants combining $CO_2$ capture and storage with green fuel production

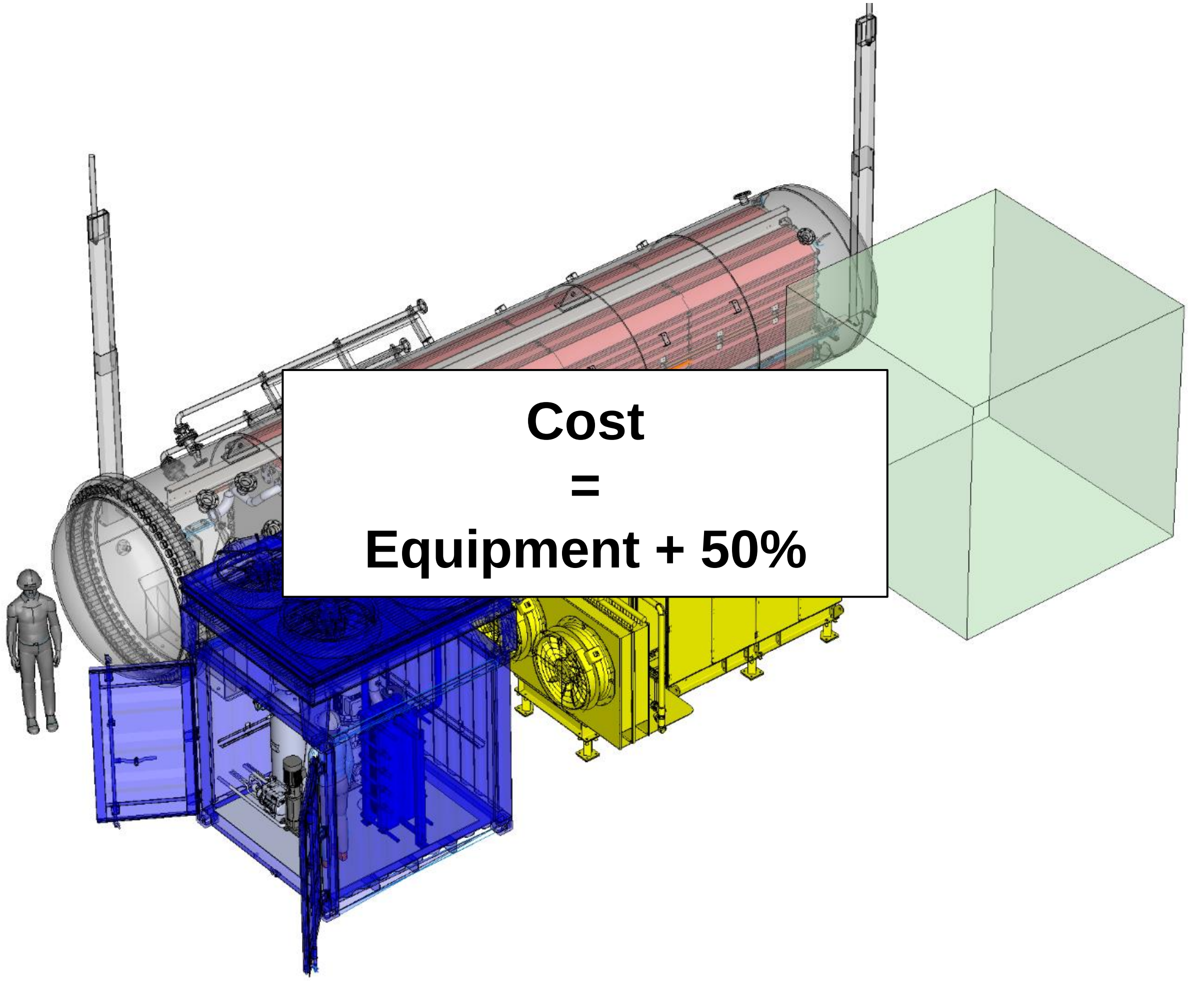
## Offshore

Tetra industrialized floating offshore wind systems

# Industrializing hydrogen electrolyzers

Traditional electrolyzers are complex and expensive. The modular HydroGen concept is different

**Cost**
**=**
**Equipment + 200%**



**Cost**
**=**
**Equipment + 50%**



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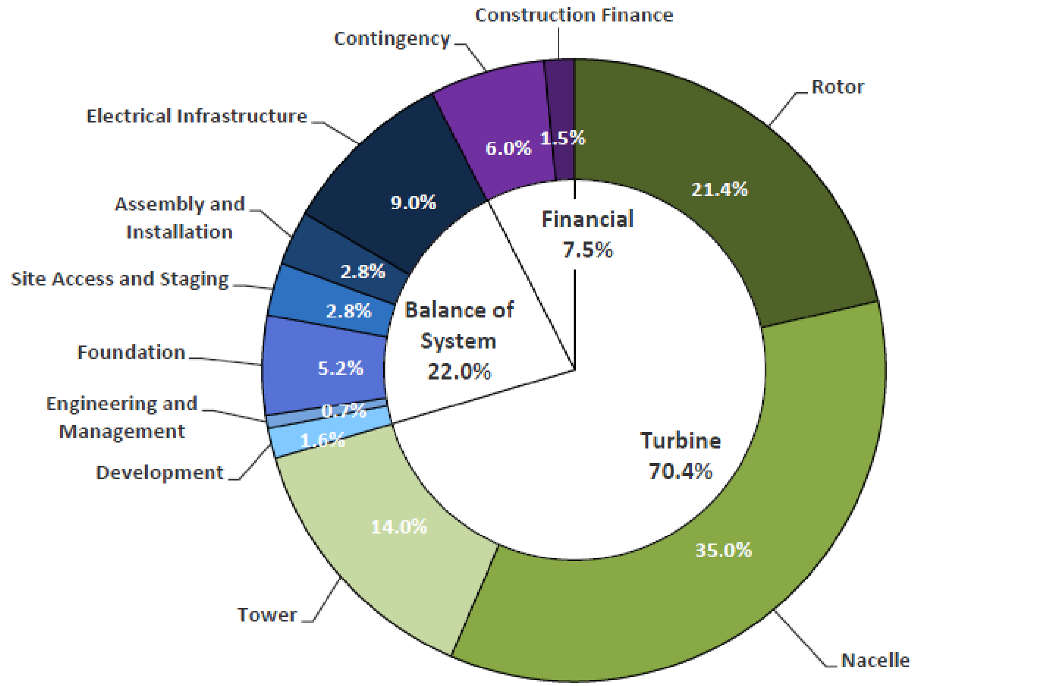
# The reference case: Onshore wind power

Wind farms comprise modular, factory-manufactured machines with standardized infrastructure

## Land-Based Wind Project Component Cost Breakdown




- Turbine component cost estimates are derived from the 2015 Cost and Scaling Model, used as an internal reference and not publicly available.
- BOS component cost estimates are obtained from the Land-based Balance of System Systems Engineering (LandBOSSE) model (Eberle et al. 2019).
- Construction financing was estimated assuming a 3-year construction duration and distributing the capital and interest over the 3 years.
- Project contingency assumes 6% of total CapEx.
- Total installed project CapEx for U.S. projects in 2021 averaged $1,501/kW (Wiser and Bolinger 2022).

| Parameter | Value ($/kW) |
|---|---|
| **Wind Turbine CapEx** | **100%** |
| Rotor | $313 |
| Nacelle | 512 |
| Tower | 204 |
| **BOS CapEx** | **31%** |
| Engineering | 23 |
| Project management | 10 |
| Foundation | 75 |
| Site access, staging, and facilities | 40 |
| Assembly and installation | 41 |
| Electrical infrastructure | 132 |
| **Financial CapEx** | **11%** |
| Construction finance | 23 |
| Contingency | 90 |
| **Total CapEx** | **142%** |

All costs reported in 2021 USD

26

 Source: NREL

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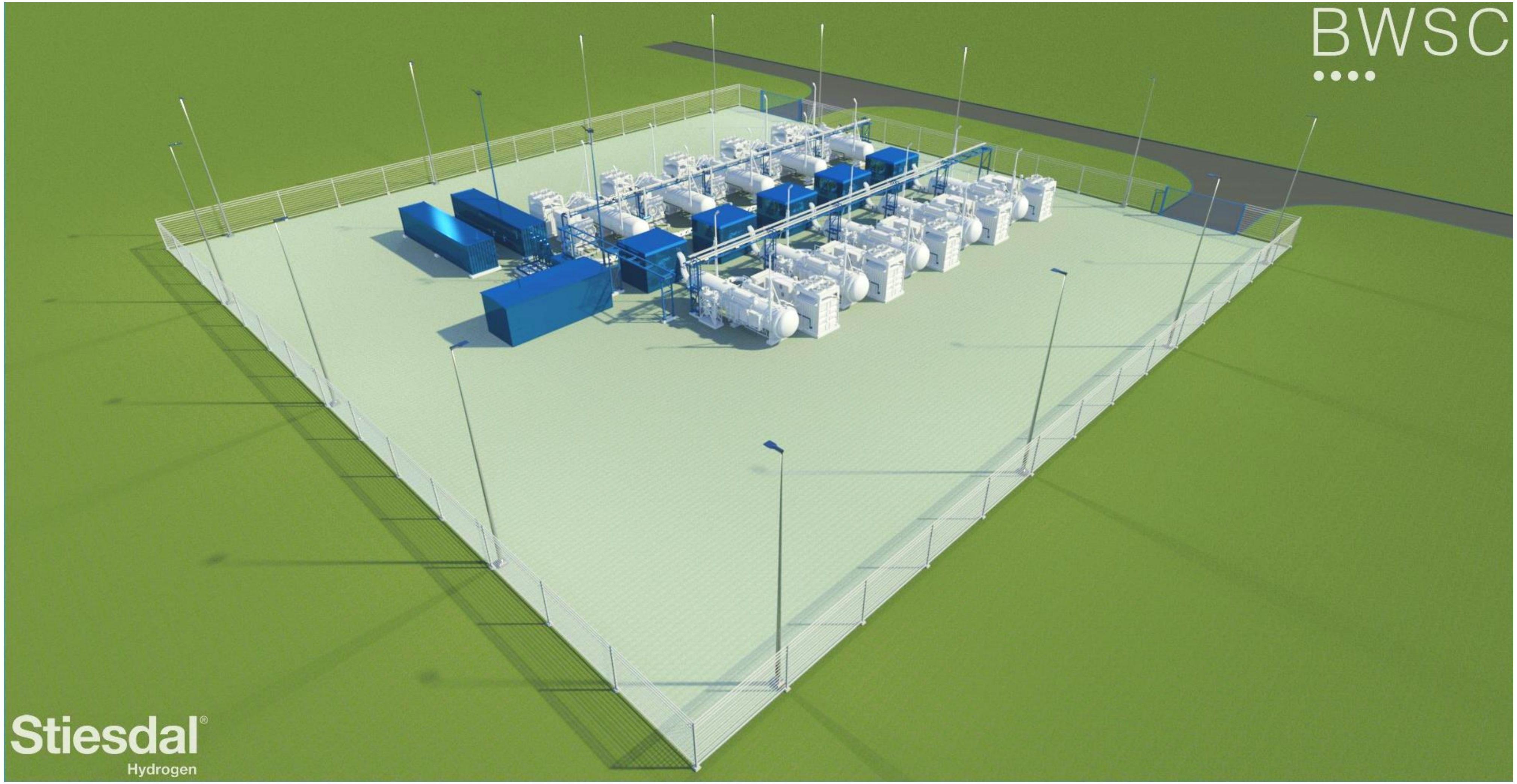
# Applying the wind power approach to hydrogen

A 30 MW modular and standardized hydrogen plant – MVAC and water in, hydrogen out @ 35 bar



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White Dream
Mobilkraner
Lastbilkraner
Maskinflytning
Specialtransport
Larvebåndskraner
Baksning - Sværgods
BMS
BMS
ICOU 107105

# Stiesdal fields of activity

The Company develops climate solutions within three distinct fields of the energy transition


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## SkyClean

SkyClean pyrolysis plants combining $CO_2$ capture and storage with green fuel production

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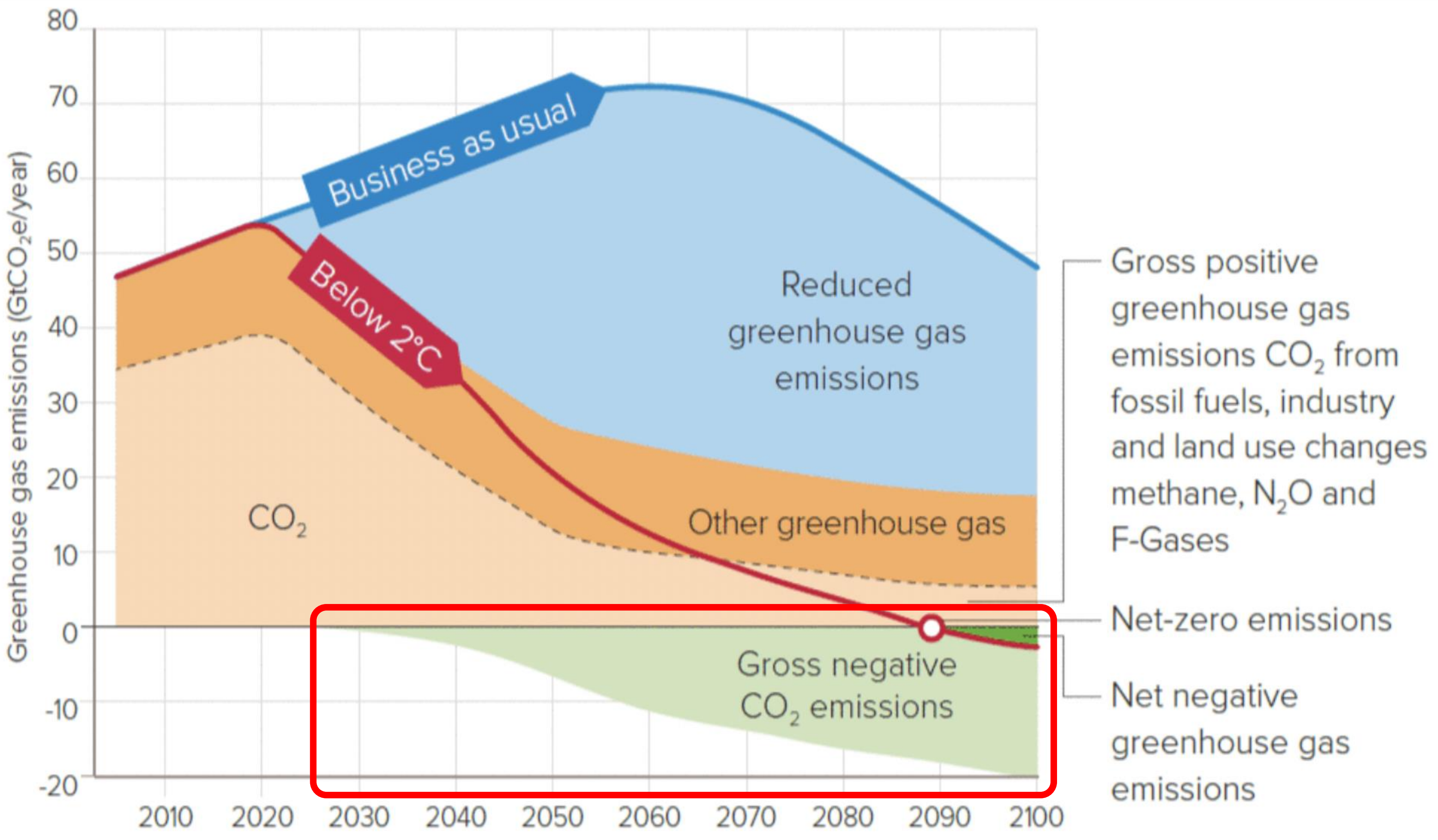
# The world is going to need negative emissions

Staying below 2°C will require that we start removing $CO_2$ from the atmosphere




Source:UNEP Emission Gap Report 2018.



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# There are different ways to extract $CO_2$ from the atmosphere

We can extract the $CO_2$ mechanically – or we can let nature do the job

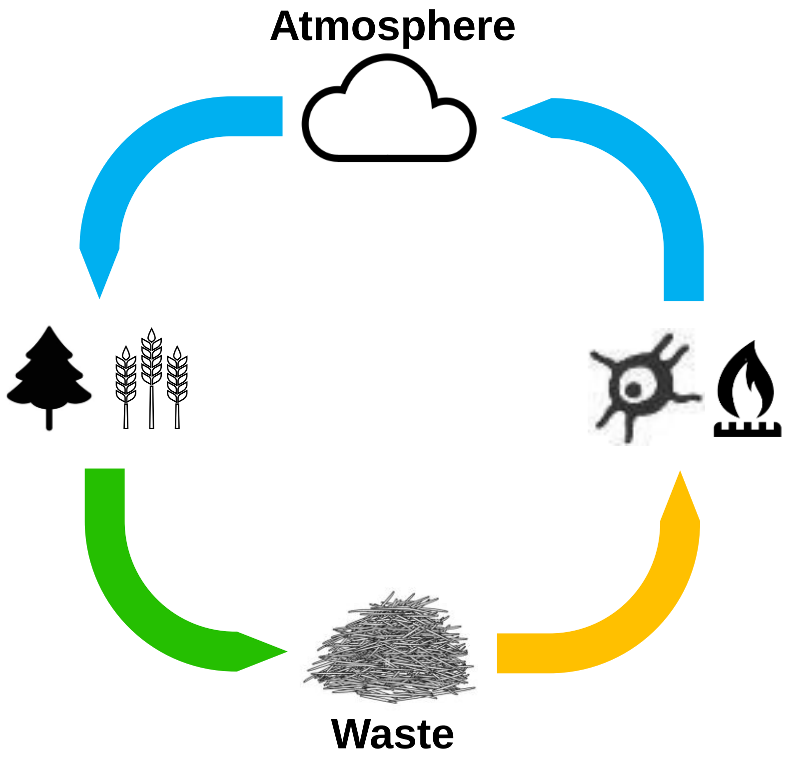
# The carbon cycle in nature, agriculture and forestry

## The carbon cycle has an annual flow with strong uptake of $CO_2$ in the growth season

100% of plant carbon captured as $CO_2$ through photosynthesis

100% of plant waste carbon emitted to atmosphere as $CO_2$ by metabolism or combustion

**Agriculture Forestry**




**Rot or burn**

100% of plant carbon in waste products captured as $CO_2$ through photosynthesis

100% of plant carbon left in waste or absorbed by soil microorganisms



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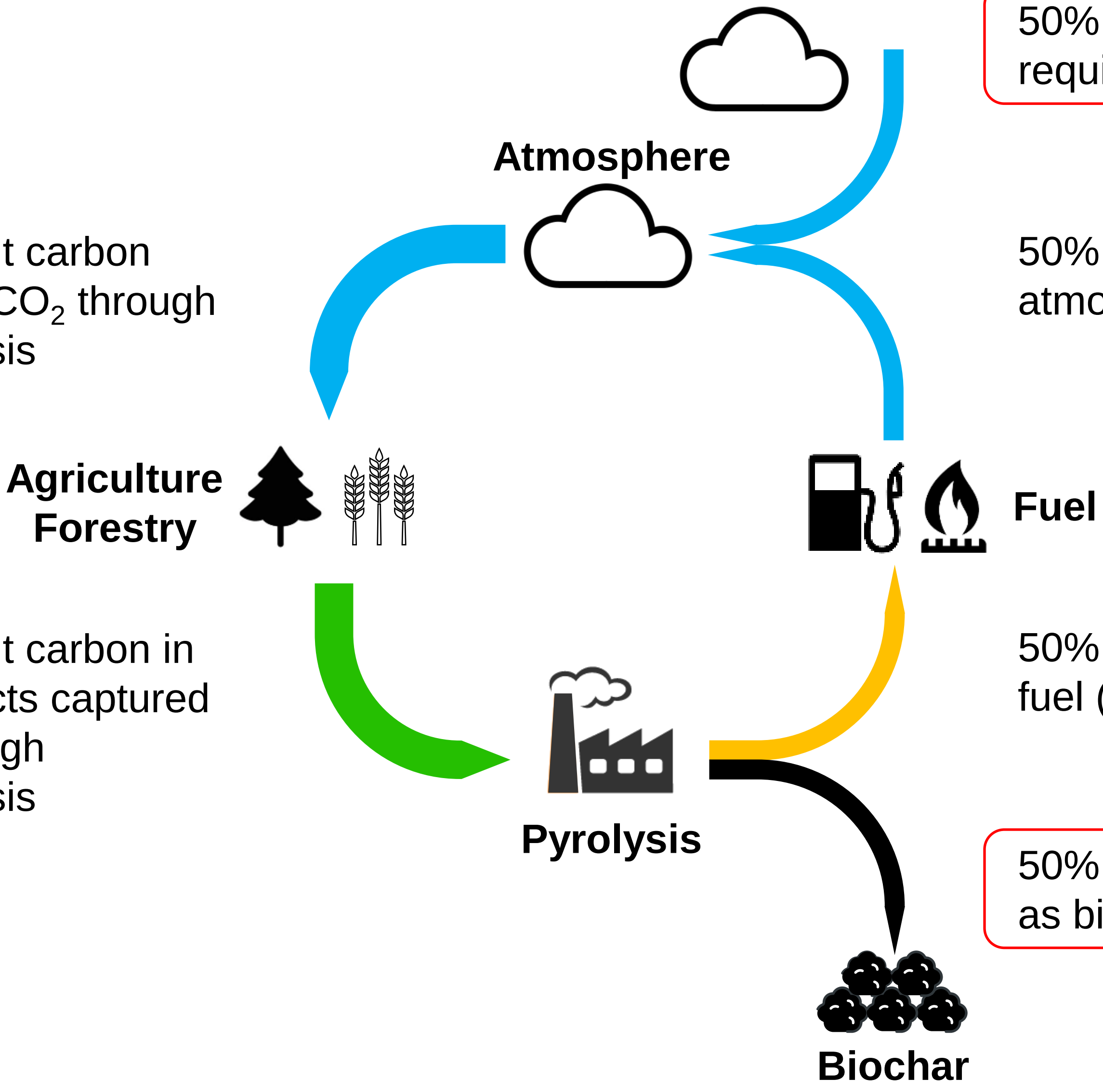
# Changing the carbon cycle with pyrolysis of residues

Producing biochar has radical effect

100% of plant carbon captured as $CO_2$ through photosynthesis

100% of plant carbon in waste products captured as $CO_2$ through photosynthesis




**Source**

50% of additional carbon in the form of $CO_2$ required to run cycle again

50% of plant waste carbon emitted to atmosphere as $CO_2$ by combustion

50% of plant waste carbon supplied as fuel (gas and oil)

**Sink**

50% of plant waste carbon sequestered as biochar



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# All types of green feedstock are suitable for pyrolysis

Cereal residues, biogas digestate, manure, wood chips, oil palm plantation residues ….



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SkyClean

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# Floating offshore wind

Leveraging floating wind's technical potential will unlock global access to offshore wind

**IEA Offshore Outlook**

- Global offshore wind power capacity is set to increase 15-fold over the next two decades, creating a $1 trillion business
- Offshore wind can deliver 1.5 times the world's current electricity consumption, but the commercially available resource is very unevenly distributed due to water depth limitations
- Introducing floating offshore technologies will expand the commercially available resource by a factor of 10



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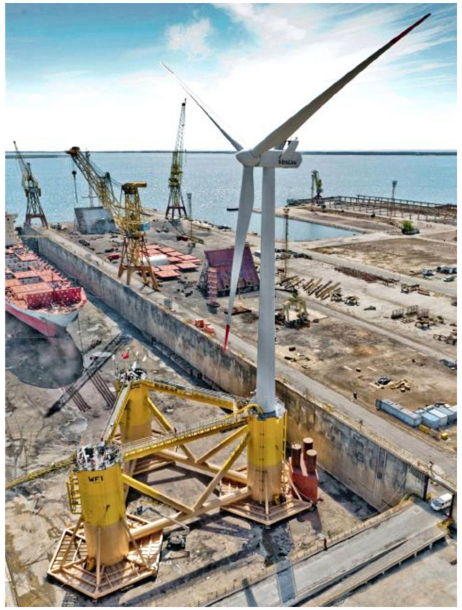
# Industrializing floating offshore wind

Traditional shipyard fabrication is slow and expensive. Stiesdal's modular Tetra concept is the solution





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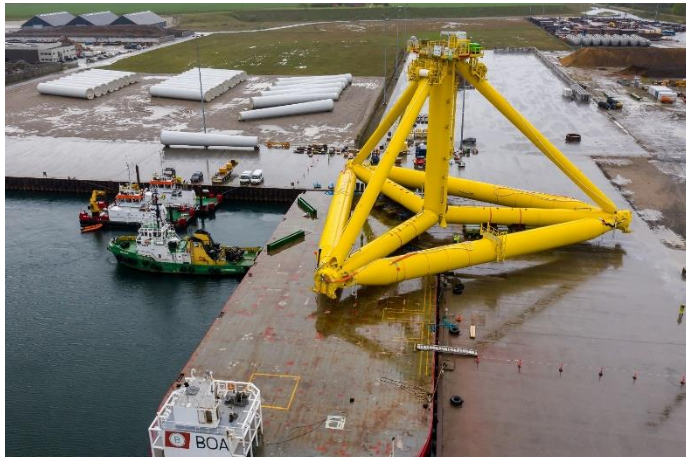
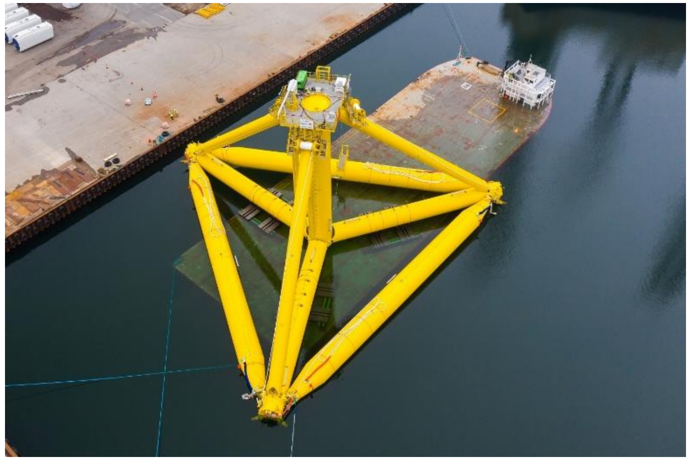
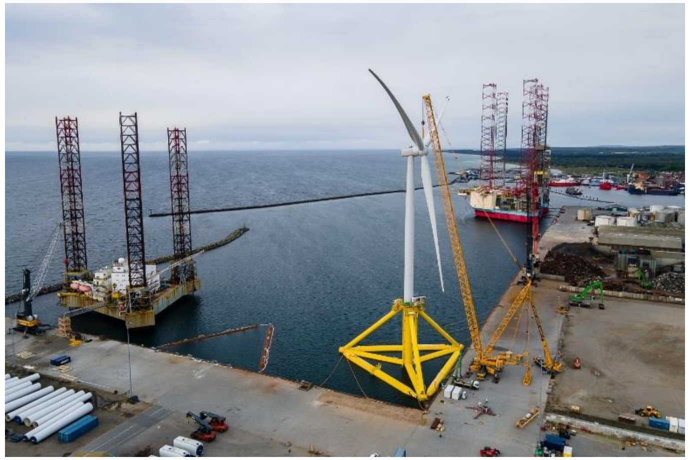
# Industrialization in practice

The TetraSpar Demonstrator Project was developed in collaboration with Shell, RWE and TEPCO



# From demonstrator to full scale

## The TetraSub variant will be Stiesdal's mainstream product



Picture credit: Maersk Supply Services

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# We could work together to accelerate the energy transition

Jointly Denmark, Australia and WA have all the competences to accelerate the change needed

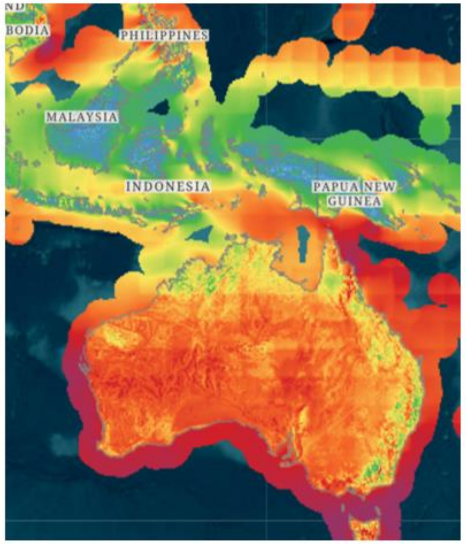
**An attractive example of complementary potentials**

**Western Australia has**

- Abundant renewable resources
- Size
- Raw materials that could benefit from local value add
- Well-established infrastructure

**Denmark has**

- Long experience in renewable energy innovation
- Technologies suited for localization
- Good structures for in global technology dissemination









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# Wanting to make big changes, we are facing a lot of inertia

Middle-aged men have too much power!





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# Tuning the mindset for tackling the world's largest problem

Chinese Mandarin language

**Crisis**

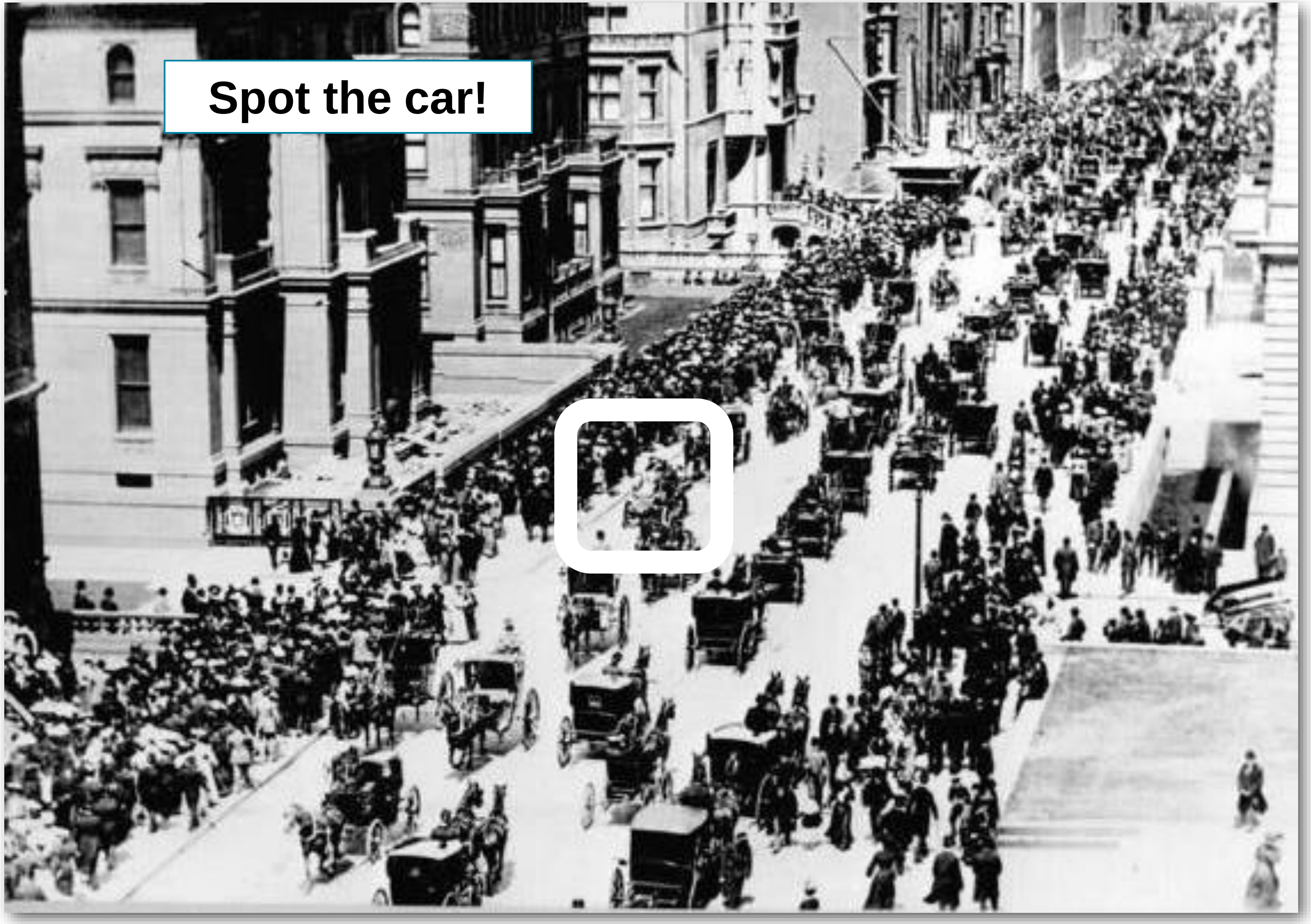
**Weijī**

危 机

**Danger** **Opportunity**

# Transformation has happened before

5th Avenue, New York City, Easter Sunday, 1900




 Picture credit: New York City Library

# Transformation has happened before

5th Avenue, New York City, Easter Sunday, 1913


 Picture credit: New York City Library

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# Thanks for your attention


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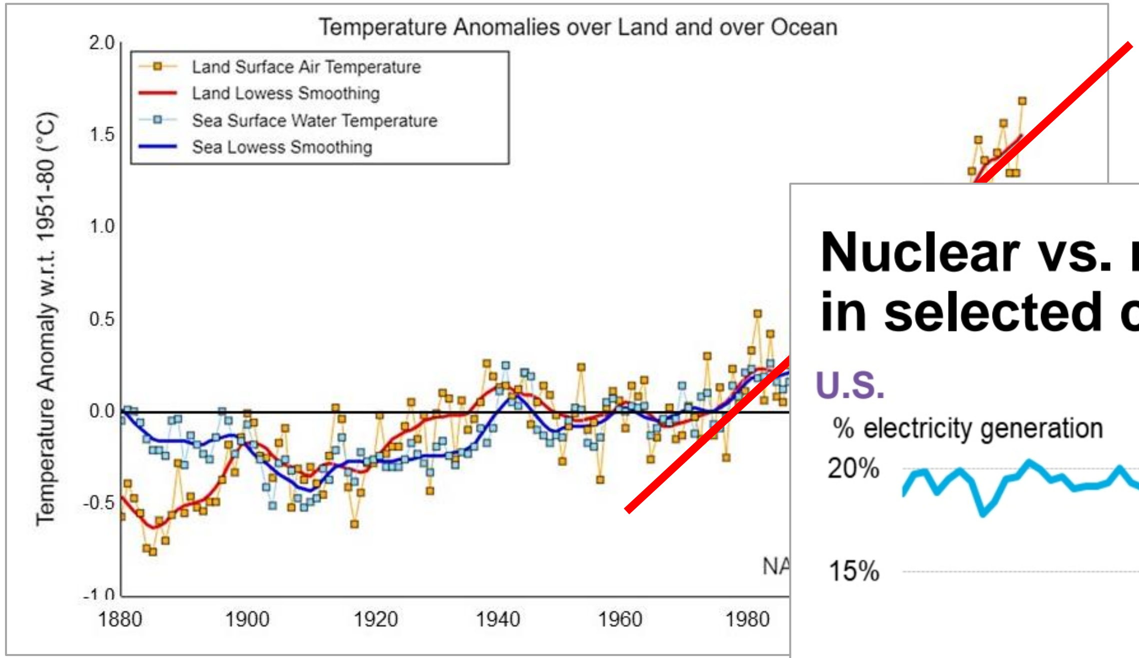
SAFETY SYSTEM CERTIFICATION DNV ISO 45001

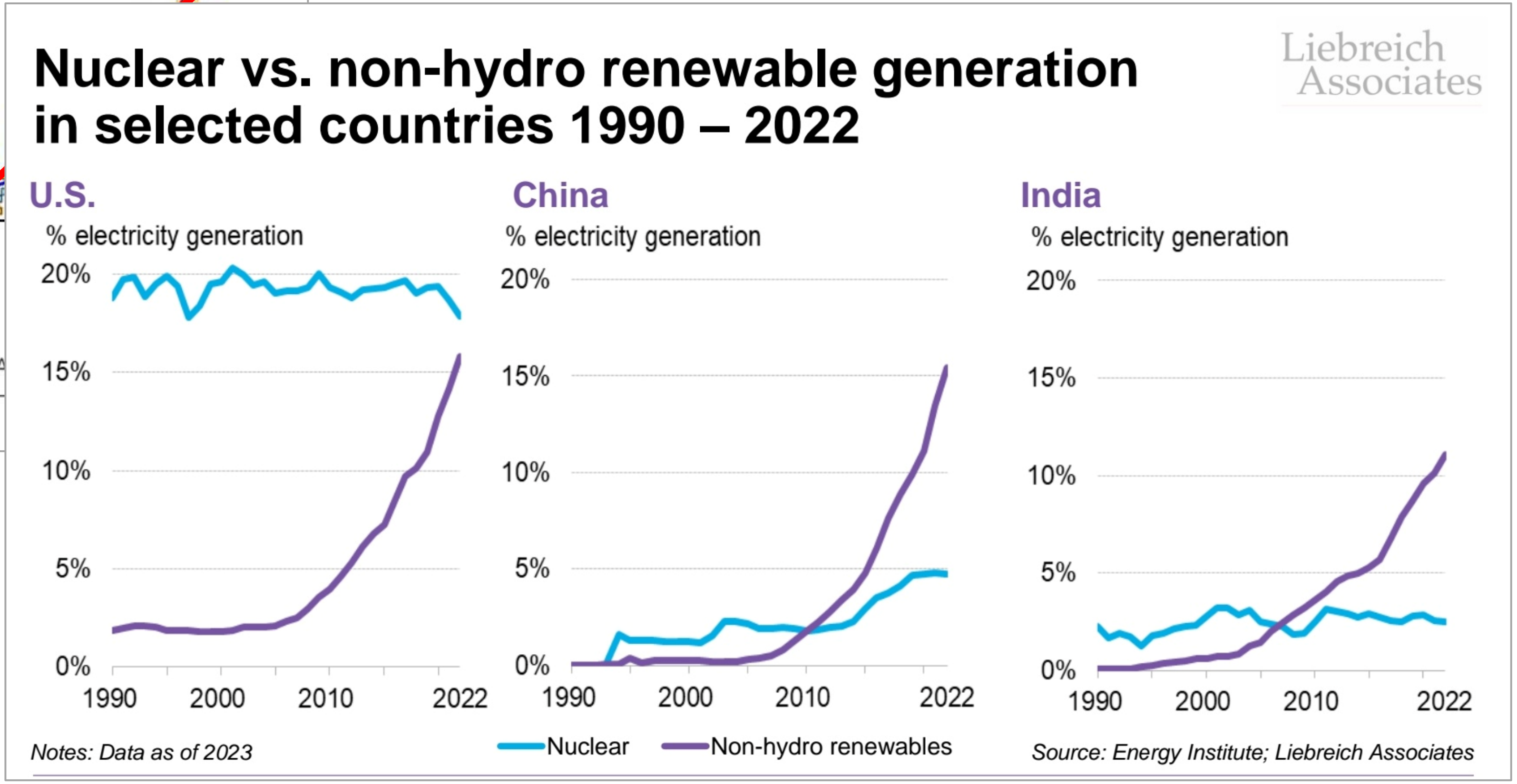
QUALITY SYSTEM CERTIFICATION DNV·GL ISO 9001

# Backup

# But why not nuclear?

We have neither the time nor the money for a nuclear build-out that really matters



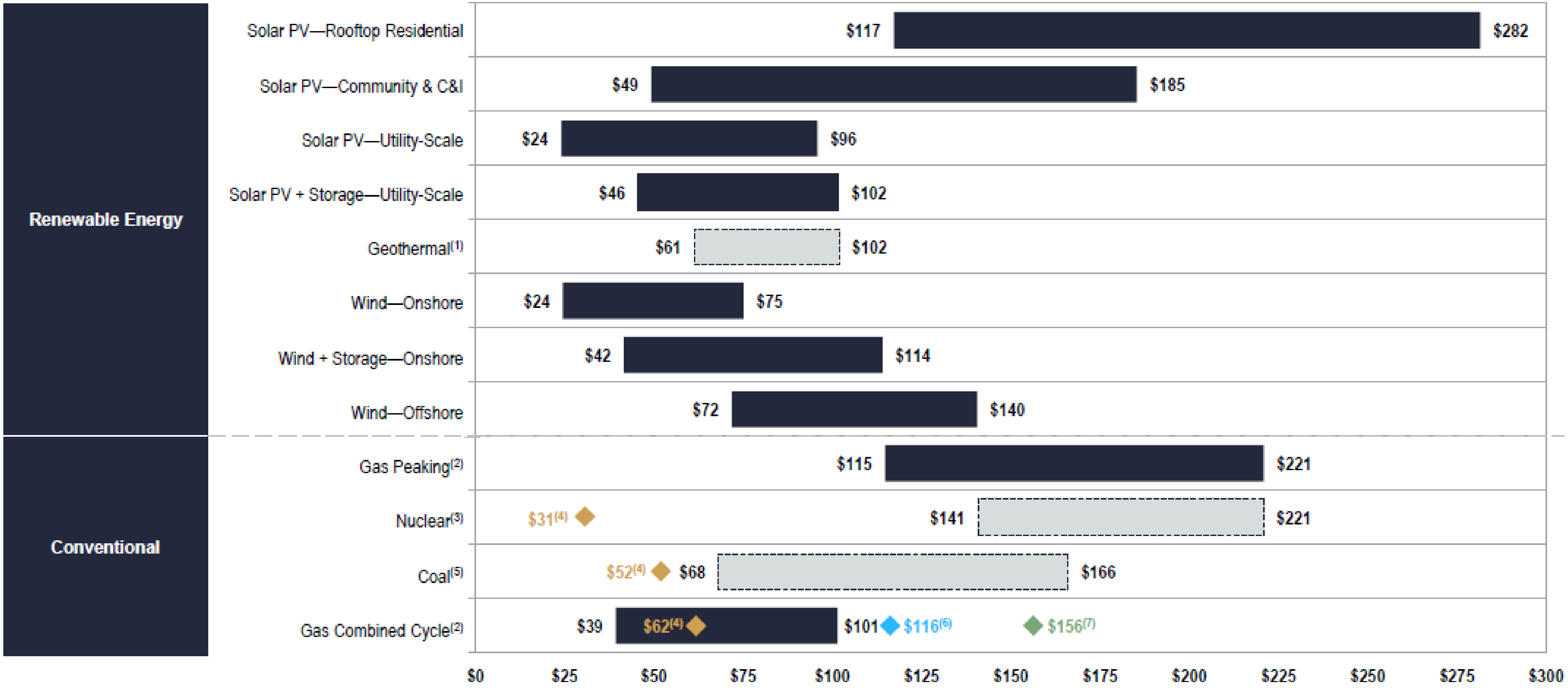




**Global Capacity additions 2023:**

Renewables: 507 GW
Nuclear: -2 GW

# Present cost of nuclear vs. renewables

## Lazard LCOE, ver. 16.0




 Source: Lazard

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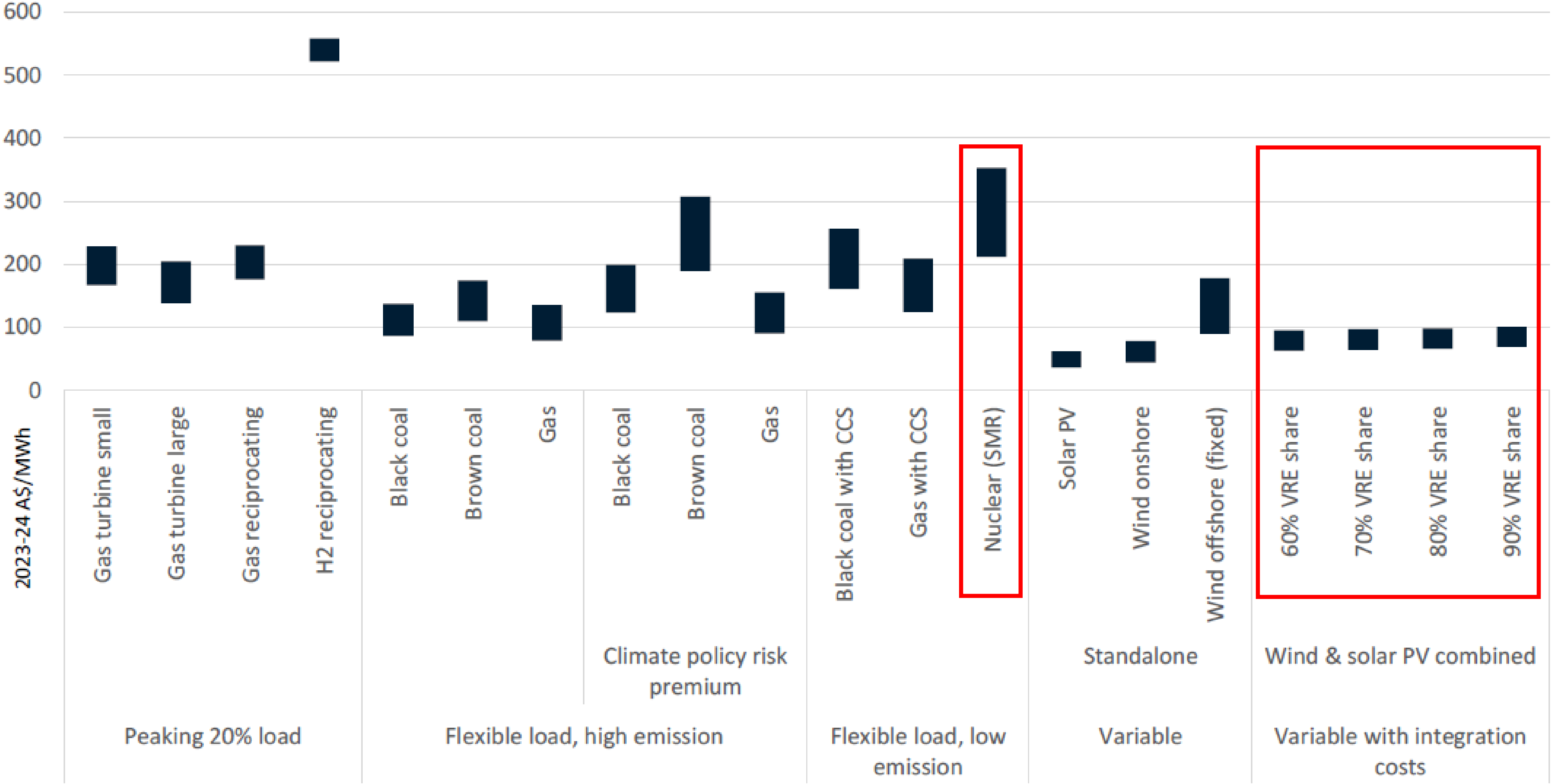
# Present cost of nuclear vs. renewables

## CSIRO “GenCost” Consultation Draft






Source: CSIRO, 202

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