Tech Solutions for the Energy Transition

Henrik O. Madsen,

Danish Offshore Technology Conference, November 2022

Examples of tech solutions for the Energy Transition

1. Superconducting power cables
2. Floating offshore wind
3. Floating solar power plants
4. Aquaculture
5. CCS value chains
6. Molten Salt nuclear Reactors

The examples are characterized by cross disciplinary thinking and system integration

1. Superconducting power cables

Question: Can superconducting power cables do to cobber cables for power transmission as optical fibres have done to cobber cables for data transmission?

1. Landscape

Electrical energy demand will increase **2-3 fold by 2050**

More than **6.2 TW** of new solar power will be required

More than **1.6 TW** of offshore wind power will be needed

The best renewable resources are found at **Remote locations**

Current grid technology is **INEFFICIENT** for a renewables-based energy system

INSUFFICIENT TRANSMISSION CAPACITY to meet climate and energy targets

1. European supergrid landscape

1. NKT and partners Superlink in Munich

SuperLink is expected to become a 12 km link with a power rating of 500 MW and a voltage level of 110 kV

The superconducting cable is cooled to minus 200ºC in a closed circuit with the environmental harmless refrigerant nitrogen.

Cost cross over between cobber and super conductor happens around 3-4 GW for applications on land

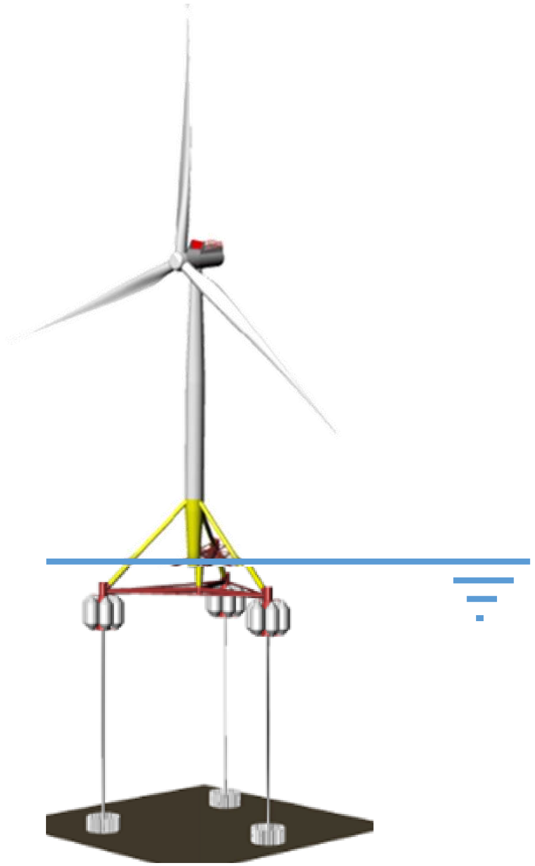
2. Floating Offshore Wind

- 80% of the offshore area suited for wind energy is in waters deeper than 60 meters and requires floating solutions
- Without subsidies floating offshore wind must aim for LCOE as for bottom fixed offshore wind
- The floating foundation and dynamic offshore cable are the main new elements in floating compared to bottom fixed offshore wind
- Floater solutions from the oil&gas industry are being promoted
- Floater solutions from port and bridge construction are also relevant
- The most critical issue is the productivity of the FACTORY

2. Floater solutions from the oil&gas industry

2. Survivability load cases

36-50 m/s



14 m Height

13 s Period

2. Hywind Tampen floating wind farm

2. Floating concrete buoy foundation solution

2. Caisson foundation

2. The floating factory

3. Floating solar power plants

Why floating solar?

- Floating solar photovoltaic (PV) installations open up new opportunities for scaling up solar generating capacity, especially in countries with high population density and competing uses for available land.
- They have certain advantages over land-based systems, including utilization of existing electricity transmission infrastructure at hydropower sites, close proximity to demand centers (in the case of water supply reservoirs), and improved energy yield thanks to the cooling effects of water and the decreased presence of dust.

3. Why floating solar (2)

- The possibility of adding floating solar capacity to existing hydropower plants is of particular interest, especially in the case of large hydropower sites that can be flexibly operated
- The solar capacity can be used to boost the energy yield of such assets and may also help to manage periods of low water availability by allowing the hydropower plant to operate in “peaking” rather than “baseload” mode,
- And the benefits go both ways: hydropower can smooth variable solar output by operating in a “load-following” mode.
- Floating solar may be of particular interest where grids are weak, such as in Sub-Saharan Africa and parts of developing Asia.

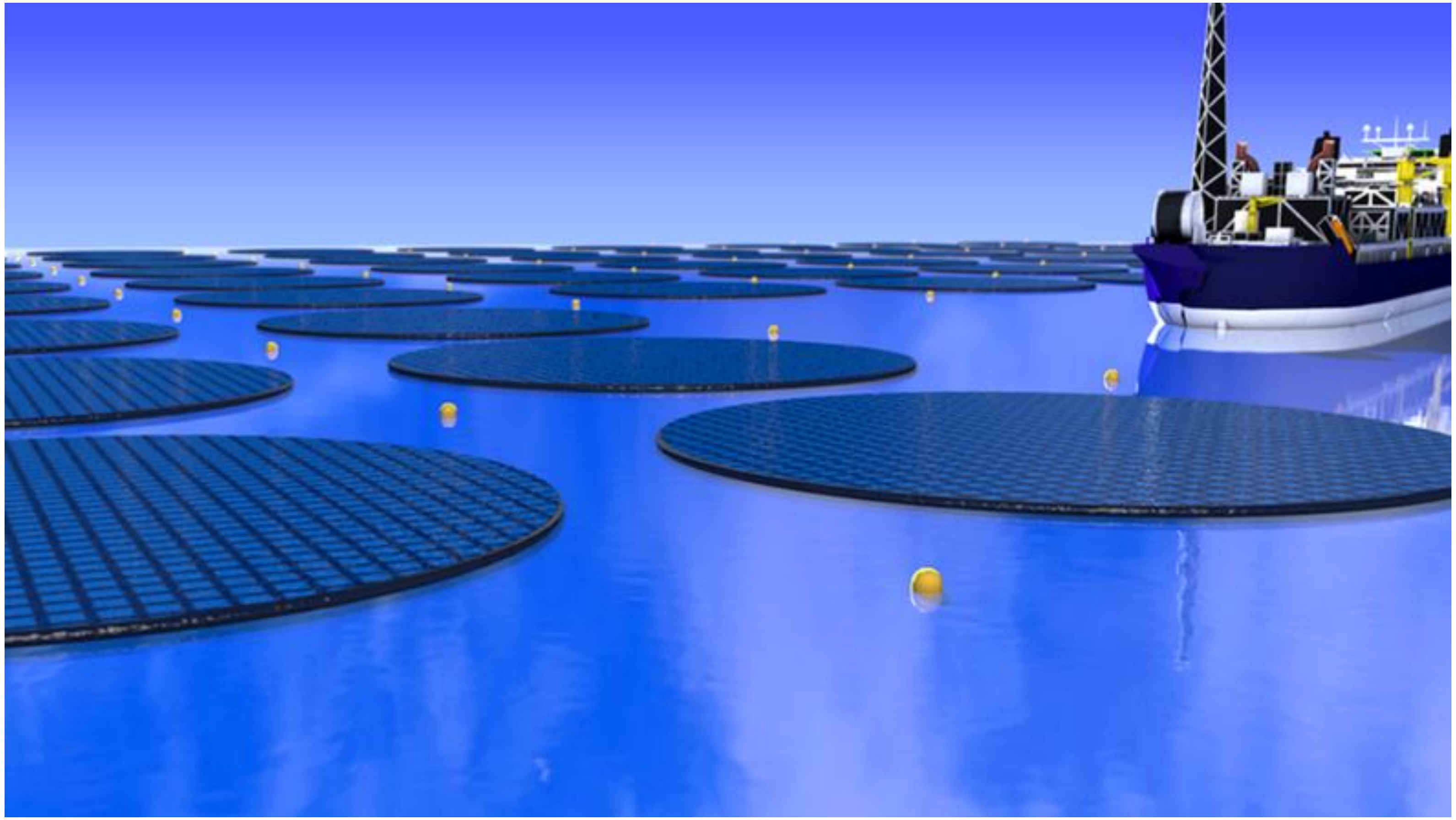
3. Why floating solar (3)

Other potential advantages of floating solar include:

- Reduced evaporation from water reservoirs, as the solar panels provide shade and limit the evaporative effect of wind
- Improvement in water quality, through decreased algae growth
- Reduction or elimination of the shading of panels by their surrounding
- Elimination of the need for major site preparation
- Easy installation and deployment in sites with low anchoring and mooring requirements, with a high degree of modularity, leading to faster installations

3. Offshore floating solar power plant

3. Floating Solar Plants powering FPSO



4. Acquaculture

- An installation as shown contains a biomass similar to a farm with more than 4500 cows
- By moving installations further offshore it is possible to reduce negative environmental impacts
- Closed installations can significantly reduce the sea lice problems

4. Example of installed concept – Nordlaks

4. Ocean Farm 1 under transport from China

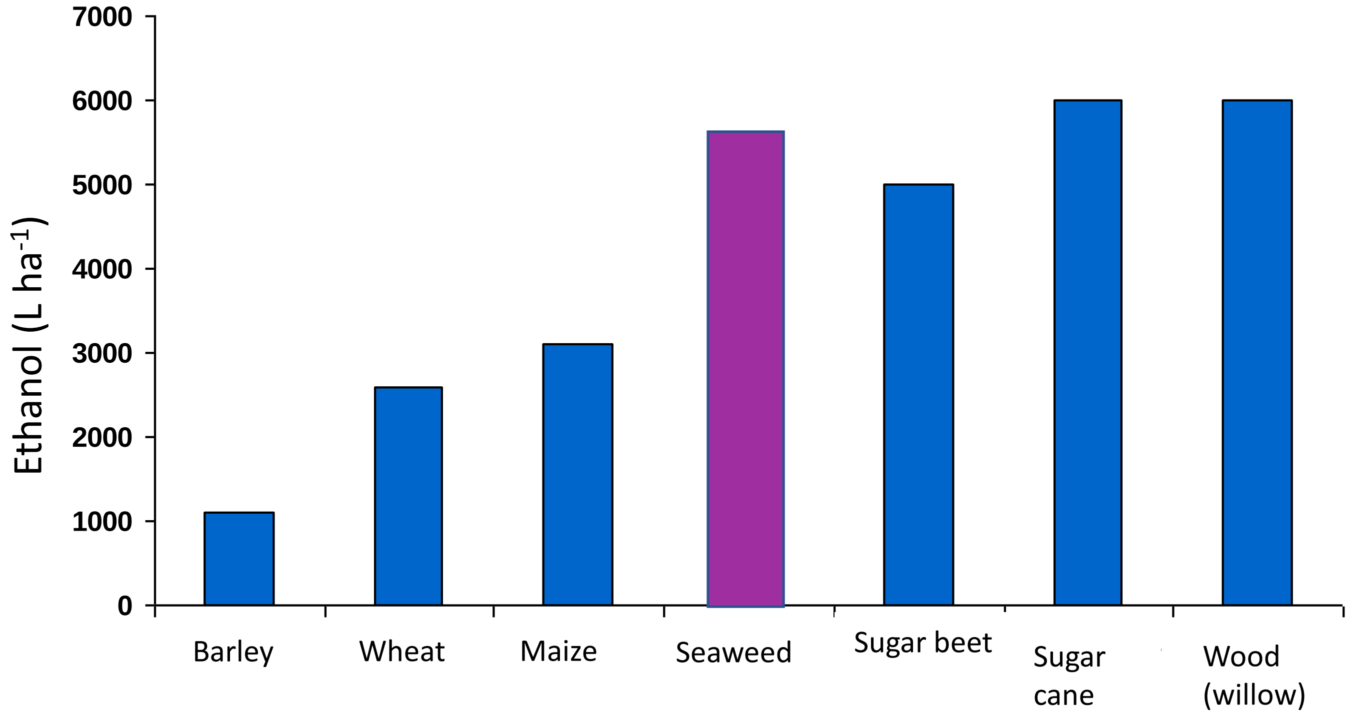
4. Seaweed opportunities

- Many forms of seaweed have rapid growth and only use the nutrients and minerals in the ocean
- Seaweed has applications for food, feed, energy, …
- Automation must be introduced to achieve scale

- Photosynthesis from a 17.000 km^2 seaweed production area west of Norway can make Norway carbon neutral

4. Seaweed cultivation

4. Seaweed compared with other energy crops – comparable production per area in 4-5 months



(Source: Fulton et al.; willow: Zero; seaweed: SINTEF Fisheries and Aquaculture)

(Handå et al., 2009, modified 2012)

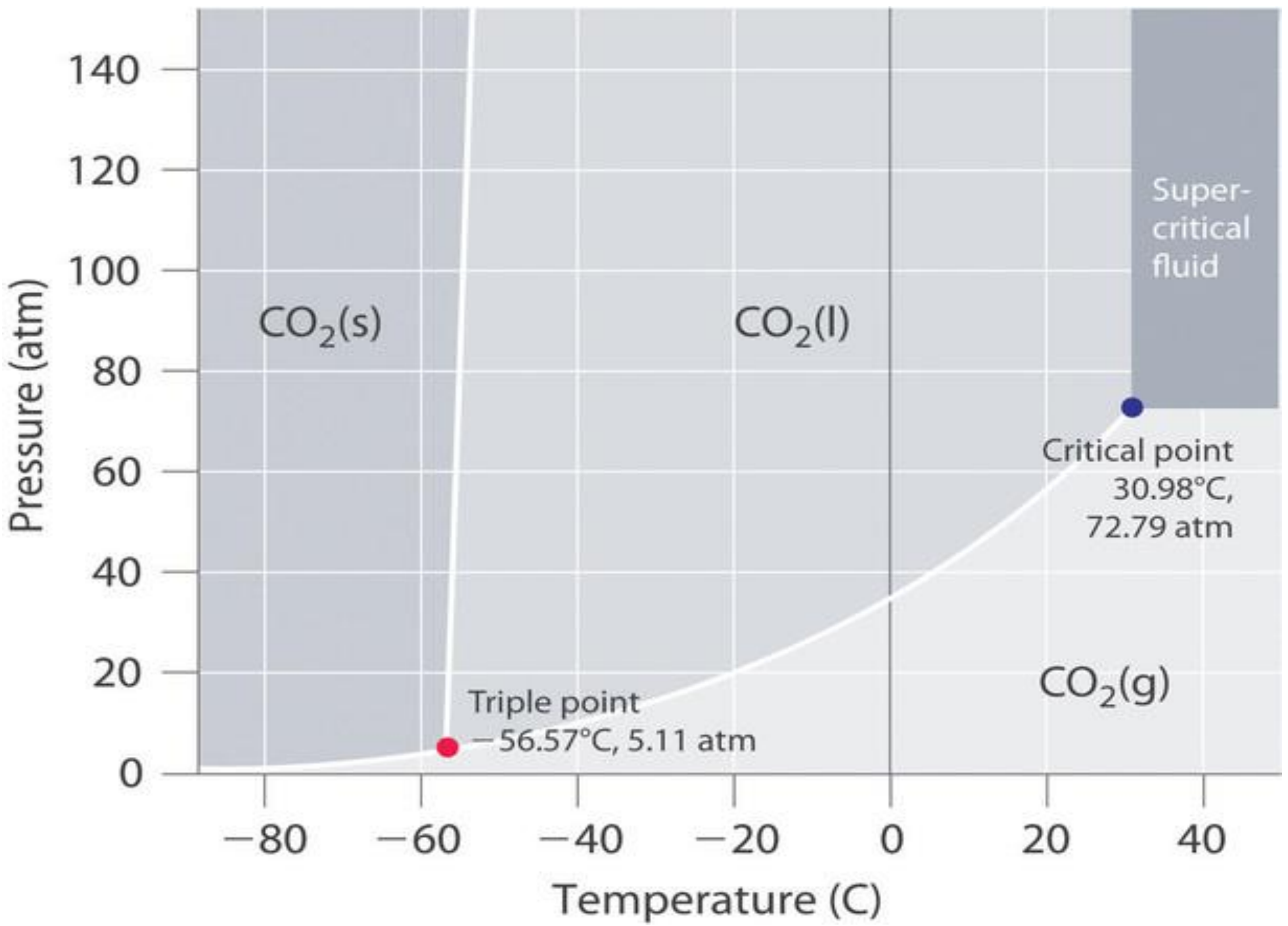
4. Algae opportunities

- Only a very small fraction of the ocean's algae have had their DNA mapped
- The potential of finding algae for new medicines is very high
- Algae can be cultivated and grow fast by adding CO_2 from emitters
- Algae admitting light penetration beyond 6 meters have been discovered
- Algae can also be used to produce biofuels

5. CCS value chain

- The value chain is very young and there is significant room for research and innovation
- Capture, transport and storage all have the potential for R&I
- Capture methods include: chemical (amines), membrane, cryogenic, fuel cells (MCFC and SOFC), …
- Transport can be in gas, (cryogenic) liquid or solid form (dry ice)
- Storage opportunities in deep geological reservoirs or depleted oil and gas reservoir under a cap rock are relevant in Denmark
- CARBFIX turns CO_2 into rock through injection into subsurface basalts

5. Phase diagram for CO_2



5. CCS in Denmark

- Denmark is moving very fast for CCS to give a significant contribution to the “70% target” by 2030
- Denmark will allow storage of CO_2 in land based and near shore geological reservoirs in addition to two depleted oil&gas fields
- Denmark will allow for storage of CO_2 imported from abroad
- The Danish authorities have come very far in developing the framework for capture and storage – transport is next.
- Transport by pipeline or in (cryogenic) liquid form has been proposed up to now – *some of us here believe more in transport in solid form*

6. Molten Salt Reactors for Marine Transport

- A second atomic era is coming powered by Molten Salt Reactors?
- If so, this will change transport and industry forever
- The fundamentals for this technology were developed in the 1960's at the Oak Ridge National Laboratory, but the technology was never completed
- The production can be industrialised and factories developed for mass production
- Danish company Seaborg is one of the leading developers and promoters

6. The difference between Nuclear and the MSR

First atomic era is the Pressurized Water Reactor – PWR

- Solid fuel Uranium < 1% efficient
- Produces long lived nuclear waste
- Operation under high pressure
- Relies on active cooling and huge containment structures
- Not viable for marine transport

Second atomic era is the Molten Salt Reactor - MSR

- Liquid fuel >90% efficient
- Minimal residuals; zero long-lived transuranic waste
- Operation under ambient pressure and high temperature
- Naturally and walk-away safe in “containerized” structure
- Perfect for marine transport

6. Molten salt reactors – potential for marine transport

- The MSR in intended to operate without refuelling during its 30-year life – it can be compared with a nuclear “battery”
- The MSR can easily fit in a traditional engine room
- With inexpensive fuel the operating speed can increase
- A new leasing model for the propulsion system is likely

- 60-100 MW installation

Thank you for your attention

For more information please contact at

henrikomadsen@gmail.com