United Nations Framework Convention on Climate Change

Agenda item 4.a.ii

# Emerging climate technologies

## Technical paper

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# An assessment of emerging low greenhouse gas primary energy production, transformation & storage technologies in the energy supply sector, and policies to promote their adoption

Prepared for the
United Nation Framework Convention on Climate Change (UNFCCC)

Technology Executive Committee (TEC)

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# Organization of this presentation

- Review of the research questions applied for each technology
- Review of the energy supply and transformation technologies, their status and potentials
- Policy options to enhance their development and market uptake

# Research questions for each technology

- ***What is this technology, and where and how could it be useful?*** How does the technology work? Where and when is it likely to contribute to producing globally significant amounts of primary or transformed end-use energy? What markets could it fulfil? What are its co-benefits and costs?
- ***What is this technology's potential contribution to mitigating climate change?*** Given the latter question, what does this technology provide that other already commercialized and/or relatively less expensive low GHG technologies cannot in globally significant quantities?
- ***What are the initial and ongoing social, institutional, economic, and business conditions for successful uptake?*** Including but going beyond the simple upfront and lifecycle cost of bulk and firming electricity, what market structure characteristics, cultural preferences and objections, (missing) enabling institutions, and regulatory & liability issues may affect the ultimate penetration of this technology?

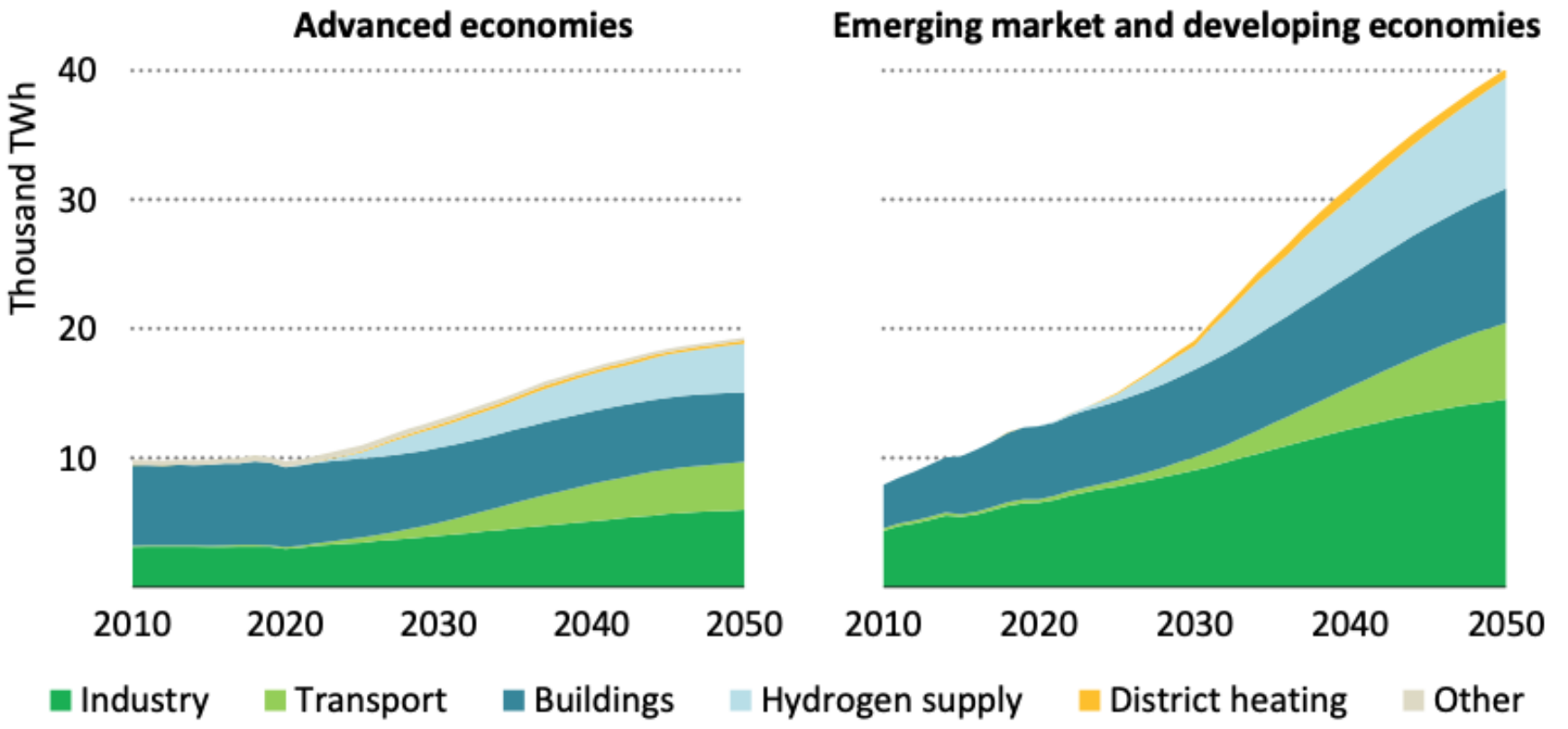
| Broad stage | TRL | Narrow stage | Policy & financial implications |
|---|---|---|---|
| Conceptual or research phase | 1 | Initial idea | At of scale of researcher, small company or individual. Broad R&D support sufficient. $ |
| | 2 | Technology concept formulated | " $ |
| | 3 | Experimental proof of concept | Moderate funds needed $$. |
| Development Phase | 4 | Early prototype, technology validated in lab | Funding needs increase. $$$ Early ARPA style realm |
| | 5 | Large prototype, technology validated in relevant environment | Moderate costs, no revenue, significant support needed. $$$$ ARPA |
| | 6 | Full prototype at scale, Technology demonstrated in relevant environment | Large costs, no revenue, significant support needed. ARPA $$$$$ |
| Deployment Phase | 7 | Pre-commercial demonstration, System prototype demonstration in operational environment | Very large costs, no revenue, significant support needed. Funding needed beyond ARPA funding, large firm, venture or state capital investment. $$$$$$$-? |
| | 8 | First-of-a-kind commercial, System complete and qualified | Funding plus strong natural or created lead market necessary $$$$$ |
| | 9 | Commercial operation in relevant environment, actual system proven in operational environment | Strong natural or created lead market necessary $$<->$$$$$ |

Scope of study

## The size of the prize

The global electricity system must go from delivering ~23k TWh per year of mostly dirty electricity, to ~60k TWh per year of mostly clean electricity by 2050

**Figure 3.9 ▷ Electricity demand by sector and regional grouping in the NZE**

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*Electrification of end-uses and hydrogen production raise electricity demand worldwide, with a further boost to expand services in emerging market and developing economies*

| Primary Energy Supply Technologies | TRL | Current & estimated eventual levelized cost of energy for supply 2019 USD $/kWh | Size and generality of resource if available | Key co-benefits and other considerations |
|---|---|---|---|---|
| Airborne wind energy | 3-5 | Unknown | Large but vague | Can potentially be used for remote sites far from grid with poor solar |
| Floating solar PV | 8+ | 0.35 historic, current low auction bids at 0.05, projected 2030 ~0.05, ~0.04 2050 | Very large and broadly geographically spread: 4,251 to 10,616 TWh per year | When tied with existing hydropower frees water resource for use as firm power, utilizes existing transmission, and reduces evaporation losses |
| Floating wind | 8+ | Current auctions at 0.13-0.15 | Very large and confined to large lakes & ocean EEZs: Conservatively up to 83,229 TWh per year | When placed in deep ocean very large resource with low siting conflicts |
| Wave power | 5-8 | Current 0.30-0.55. 0.22 by 2025 & $0.165 by 2030 | Moderate: 2 TW globally, but highly regional. | Highly regional. No convergence on design. |

| Primary Energy Supply Technologies | TRL | Current & estimated eventual levelized cost of energy for supply 2019 USD $/kWh | Size and generality of resource if available | Key co-benefits and other considerations |
|---|---|---|---|---|
| Tidal power | 3-8 | Current 0.20-0.45. 0.11 by 2022-2030. | Moderate: Very regional, can be locally large. | Highly regional. Tidal barrages are unlikely to be approved, in stream floating axial turbines showing most promise. |
| Ocean thermal energy conversion | 5-6 | Current 0.20-0.67 for 10 MW units falling to 0.04-0.29 for 100 MW units | Very large but localized: 4,000-13,000 TWh/yr | Can be located anywhere between 30° north and south with reasonable access to 1km+ ocean depth. Can provide water desalinization. |
| Bioenergy with carbon capture and storage (BECCS) | 6-8 | Variable with application. Fossil unit cost plus CCS cost minus carbon revenue benefit. | Very large. | Net-neutrality is highly vulnerable to what biomass feedstock is used and how it extracted. CCS should be ~$50-$100/t, but is only proven with ethanol production. |

| Transformation or Storage Technology | TRL | Cost 2019 USD | Key applications |
|---|---|---|---|
| Green hydrogen | 8+ | $4.5-6/kg, could fall to less than $2 by 2030 with economies of scale and innovation | Storage of variable renewable electricity; high process heat; steel reduction; ammonia fertilizers; heavy transport |
| Next generation batteries | 3-8+ | Lithium ion batteries are now $150-300/kWh, an expected to fall to <$75 by 2030. Multiple other chemistries and construction at the low TRL level | Small and large vehicles; supply and end-use in electricity grids; portable electronic and motor devices |
| Thermal energy storage | 3-8+ | Highly variable. | As a supplement to residential heating, electricity firm power, |
| Heat pumps | 8+ | At least double the cost of boilers, usually more. | Residential & commercial heating and cooling; industrial steam |

# Policy options for development and market uptake (1)

- Given the need for net-zero $CO_2$ by 2050-‘70, economy wide scenario planning, done with input from all key stakeholders, is required
- Based on the planning exercises above, specific social & sectoral goals must be defined that allow technological agnosticism and measurable performance standards
- Standard sets of co-benefits, ideally corresponding to the Sustainable Development Goals, should be defined, and their pursuit included in support policy.
- Expanded research, development and small-scale piloting funding for emerging primary energy supply and enabling technologies. Countries and regions need to assess their potential competitive advantages and seek partnerships with others in the same situation where necessary.
- Based on all the above, establish targeted innovation and early commercialization programs as needed to identify and break commercialization blockages, e.g., the UK Offshore Wind Accelerator or the US ARPA-E

# Policy options for market uptake (2)

- Lead markets are needed to support economies of innovation and production, followed by full carbon pricing to support commercialized technologies. This can be done through renewables obligations or feed-in-tariffs with carve outs for early-stage technologies.
- Removal of fossil fuel subsidies and full carbon pricing once the technologies are commercialized.
- Phase outs of high emitting, not retrofittable technologies to reduce emissions and make room for new, lower emitting technologies.
- A systemic innovation and market uptake approach is needed, that includes technology development, needed transmission, and market design that values energy, capacity and co-benefits in the business model

*Thank you!*

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