Value and profitability metrics for wind and renewables

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(redacted to exclude unpublished information)

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Talk Outline

- Power of LCOE
- Problems of LCOE
- Cost of Valued Energy (COVE)
- Redesigning Turbines for High Market Share

Standardized Cost Metric for Energy System Design: Levelized Cost of Energy (LCOE)

$$\mathrm{LCOE} = \frac{\text{Annual Costs}}{\text{Annual Energy Production}} = \frac{\left(\mathrm{CAPEX}_{\text{turbine}} + \mathrm{BOS}\right)\mathrm{FCR} + \mathrm{OPEX}}{\int G\,dt}$$

- CAPEX: Capital expenditures
- BOS: Balance of Station (Installation, Grid, Financing)
- FCR: Fixed Cost Return (about 5%-6% for 25-year systems)
- OPEX: Annual Operating Expenditures
- *G*: Power generation as a function of time (t)

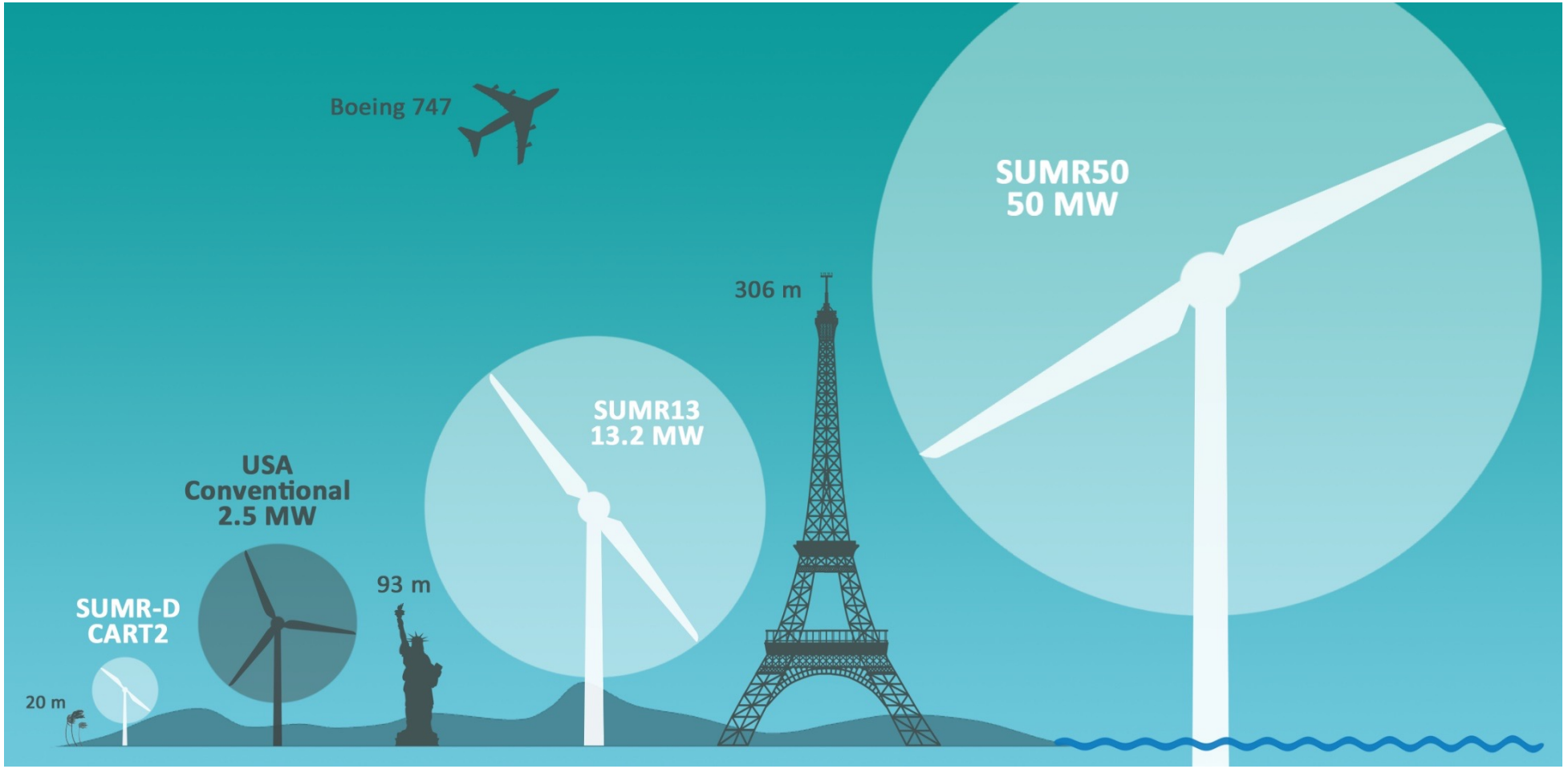
LCOE in Google scholar: **35** in 2000 → **372** in 2010 → **5,250** in 2020

Turbine Size Continued Growth

25 MW turbines can reduce LOCE (Qin *et al.* 2020 Renew Energy; Qin *et al.* 2020 Torque)

50 MW Turbines are technical feasible

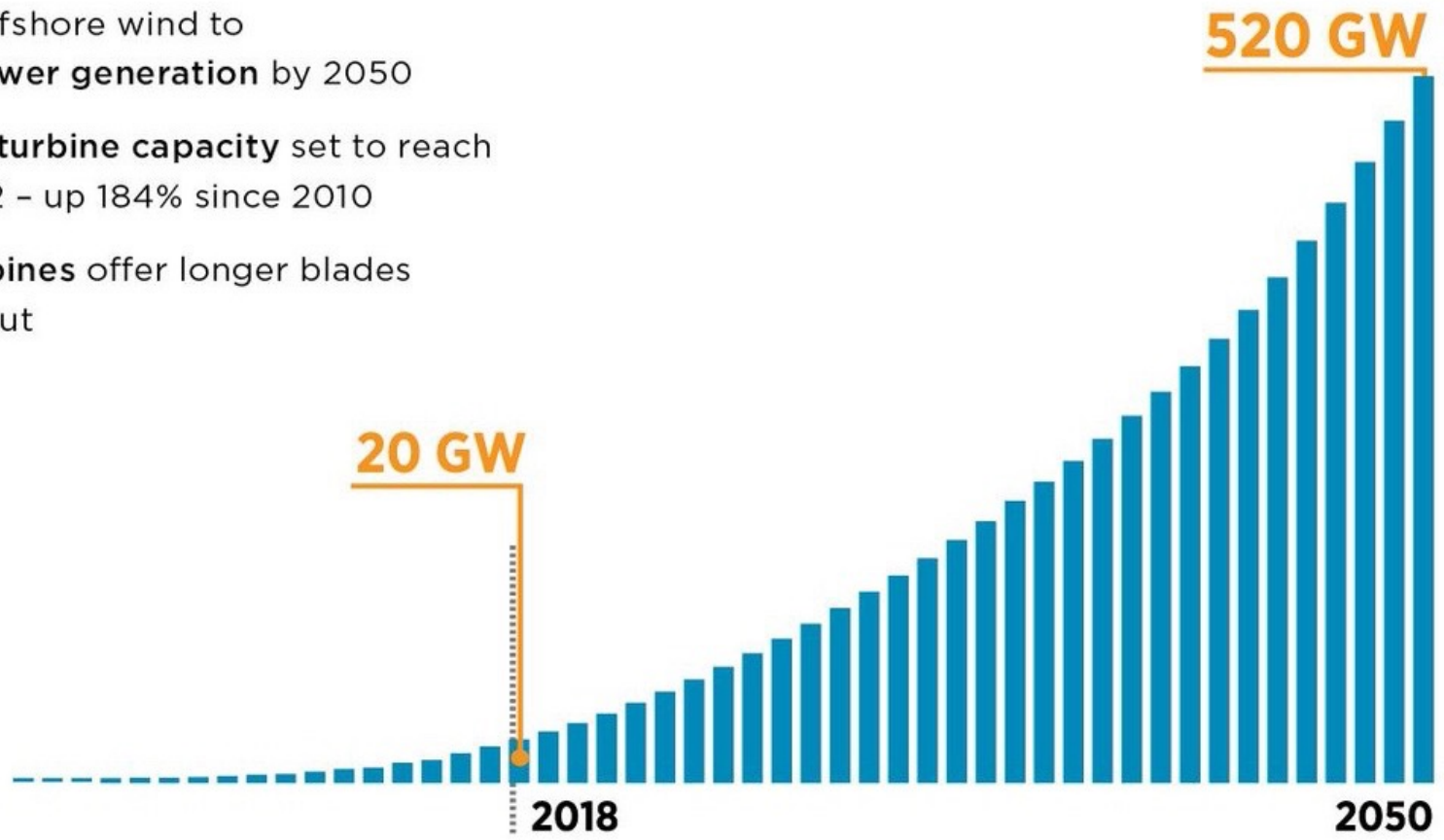
(Yao *et al.* 2022 Wind Engr; Kianbakht *et al.* 2022 Wind Energy; and sumrwind.com)



Wind and Solar Energy Arise

Unprecedented increase in wind energy → now the largest globally growing energy source
The world added wind capacity: 61 GW of in 2019 → 93 GW in 2020, a 53% increase!
Offshore wind is the fastest rising component of wind energy driven by reductions in LCOE

- Could raise offshore wind to **4% of global power generation** by 2050
- Average **new turbine capacity** set to reach **8.3 MW** by 2022 – up 184% since 2010
- **Next-gen turbines** offer longer blades and higher output



The Problems of LCOE

LCOE does not care when or where power is generated

$$\text{LCOE} = \frac{\text{Annual Costs}}{\text{Annual Energy Production}} = \frac{\left(\text{CAPEX}_{\text{turbine}} + \text{BOS}\right)\text{FCR} + \text{OPEX}}{\int G\,dt}$$

LCOE is same if energy delivered at all one or spread out

LCOE is the same if energy is generated intermittently or dispatched on demand

LCOE is the same for grids with very low or very high renewable shares

Value is Related to Supply and Demand

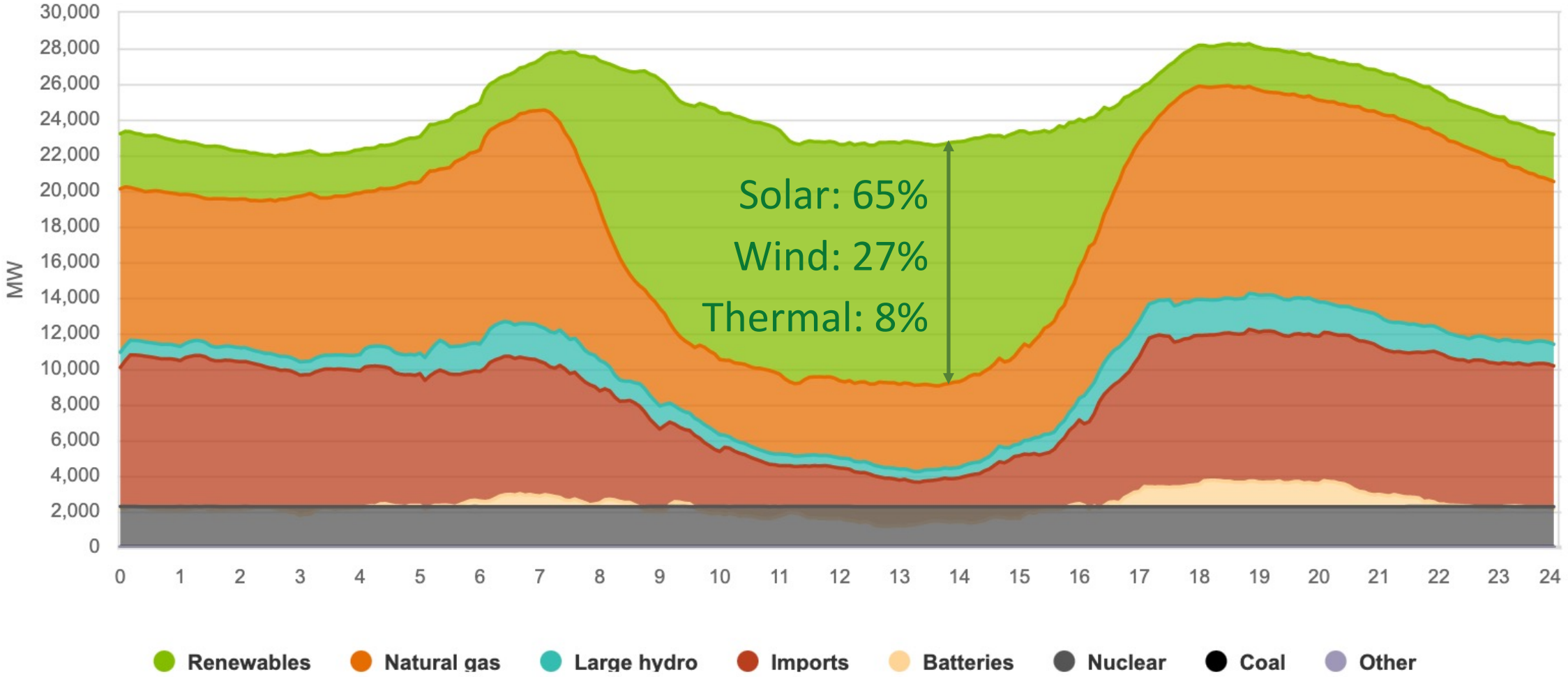
Value of parka depends on when and where

And if there are many more parkas than people, parka value diminishes

LCOE ignores when, where, and how much energy is needed

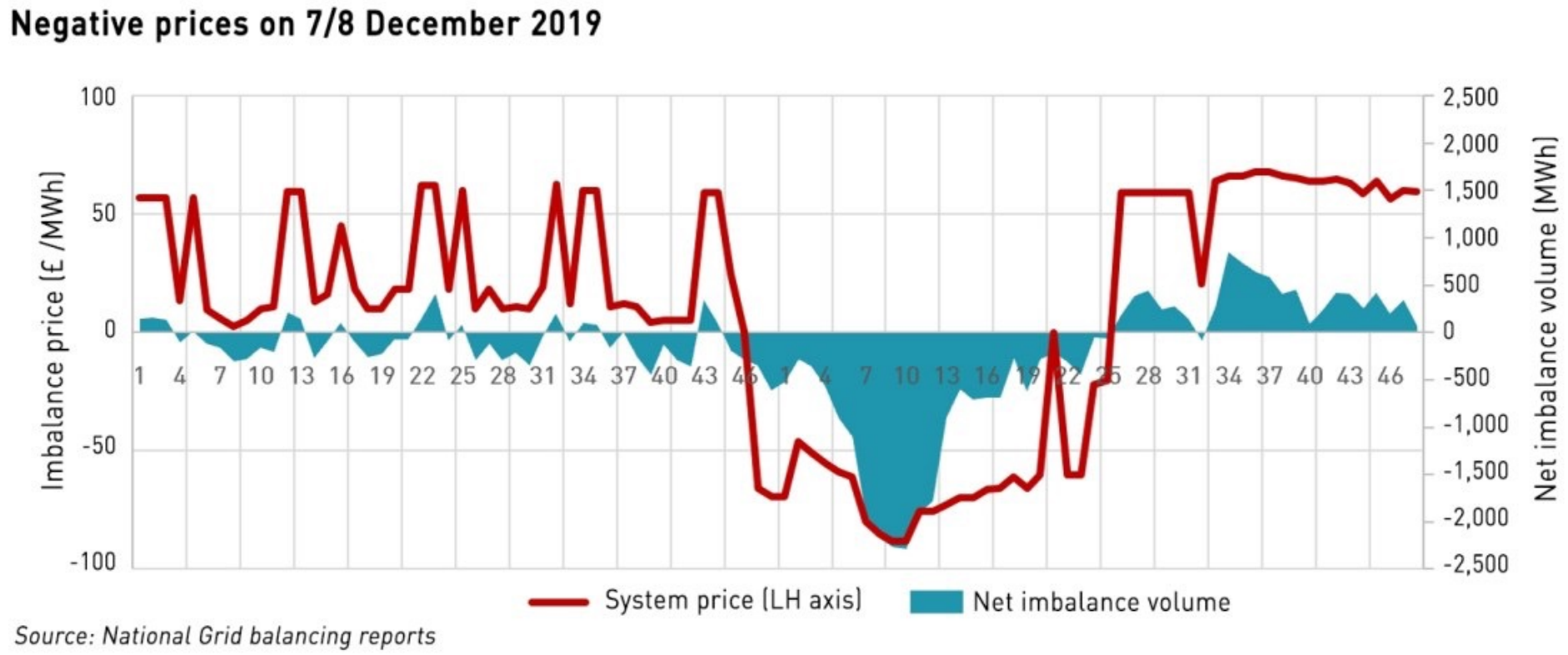
Renewable Shares are Increasing

Renewable penetration now averaging more than 30% in CAISO (California)
and momentarily reaching up to 80% of all generation (e.g., below reaching 60%)



Energy price variability is increasing

When wind energy creates a surplus (on grids with high renewables shares), results in curtailment (not considered by LCOE) and even negative energy prices!



Is there a cost metric that considers energy price with generation?

Cost of Valued Energy (COVE)

Normalized Price for Cost of Valued Energy (COVE)

J. Simpson *et al.* 2020
Renewable Energy

$$p \equiv \frac{P}{P_{avg}} = \frac{P}{\int_{\text{year}} P\,dt} \qquad p_{\text{avg}} = 1$$

To avoid currency & inflation issues

$$\text{COVE} = \frac{\text{Annualized Costs}}{\text{Annual Energy Production } weighted\ by\ price} = \frac{\Sigma costs}{\int p * g\ dt}$$

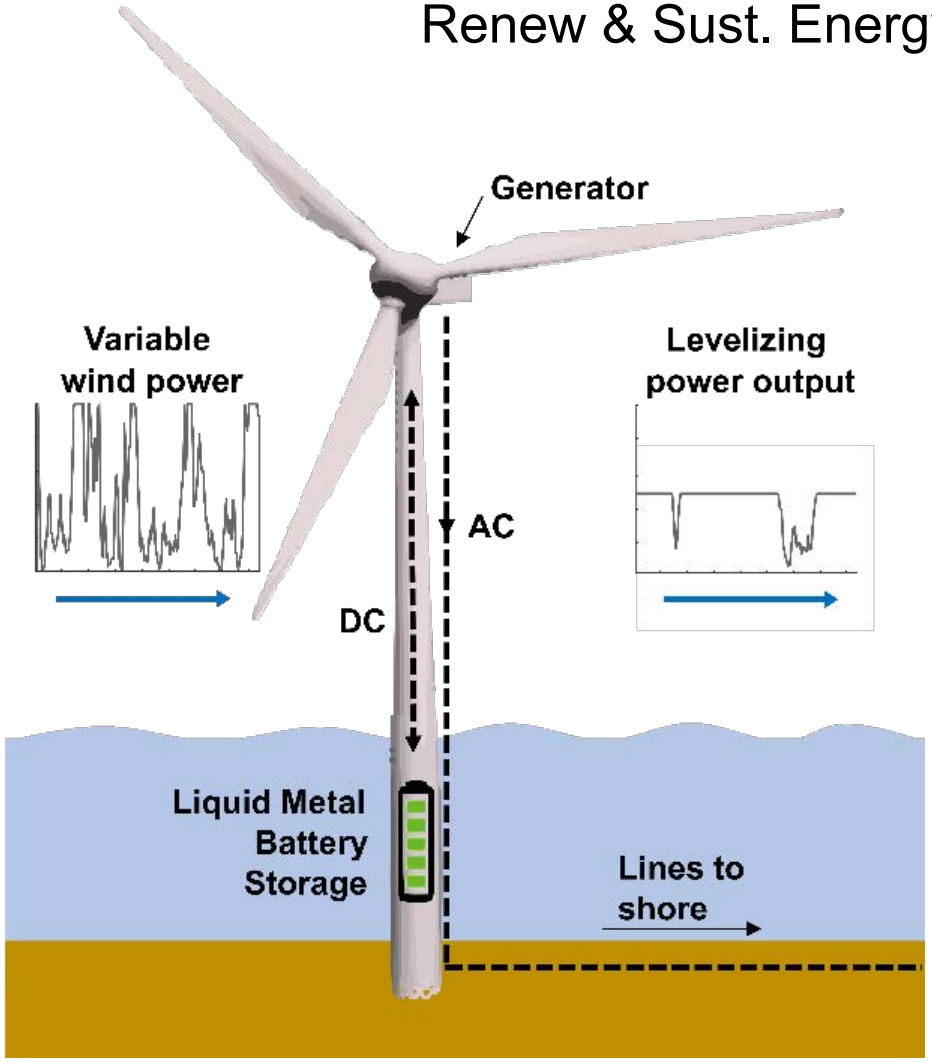
COVE can incorporate:

- dynamic grid characteristics (hourly demand & spot price variations)
- regional and annually changes as grid decarbonizes
- Simpler to use than LCOE+LACE, SLCOE, LCD
- Uses (requires) a model for price as function of time …

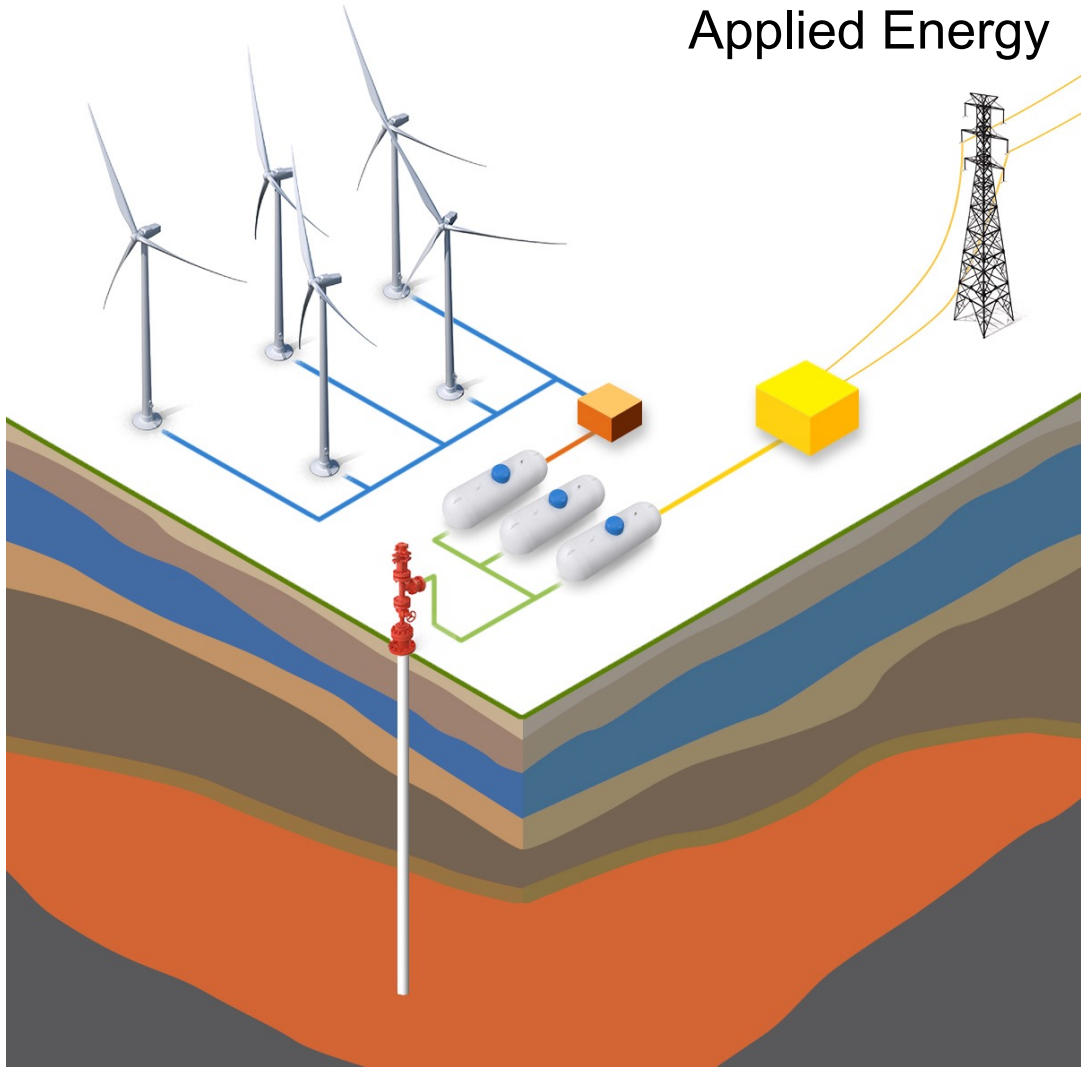
Redesigning Wind Turbines for High Market Share?

Storage Integrated in Wind Turbines

J. Simpson *et al.* 2021
Renew & Sust. Energy



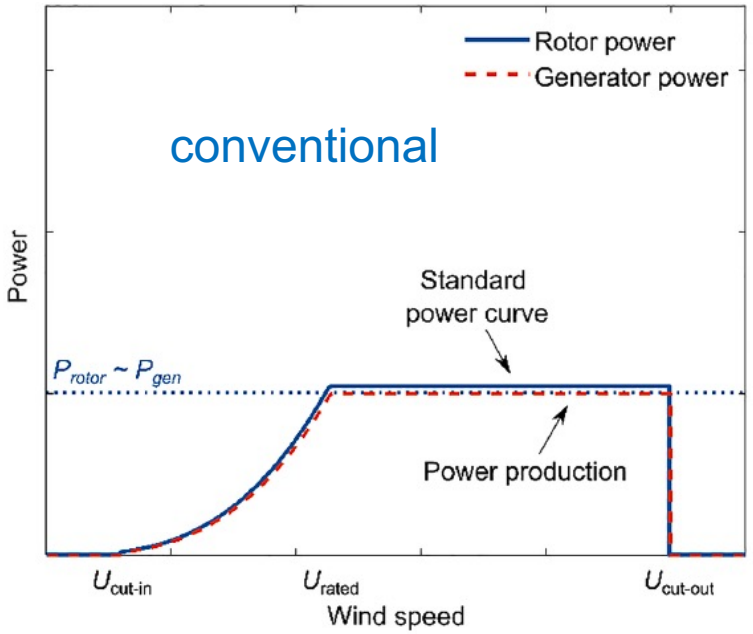
C. Qin *et al.* 2021
Applied Energy

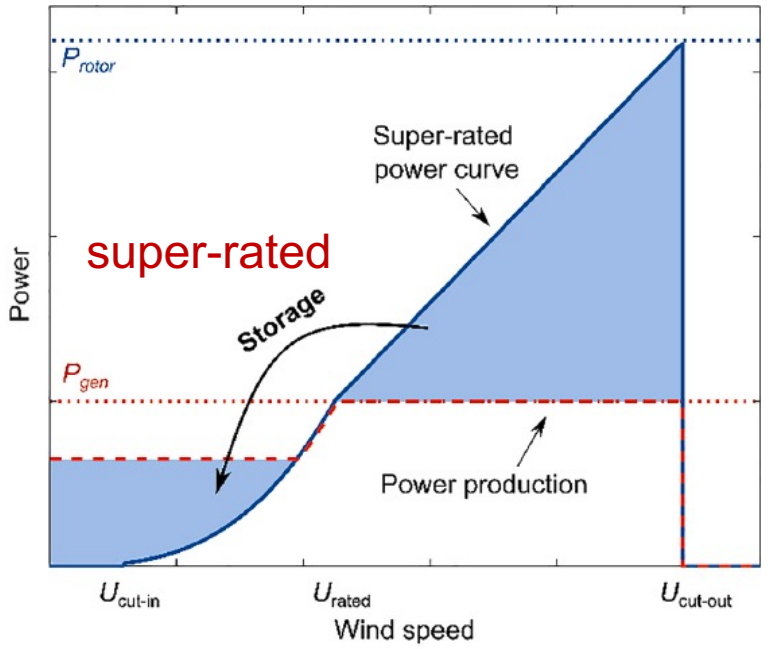


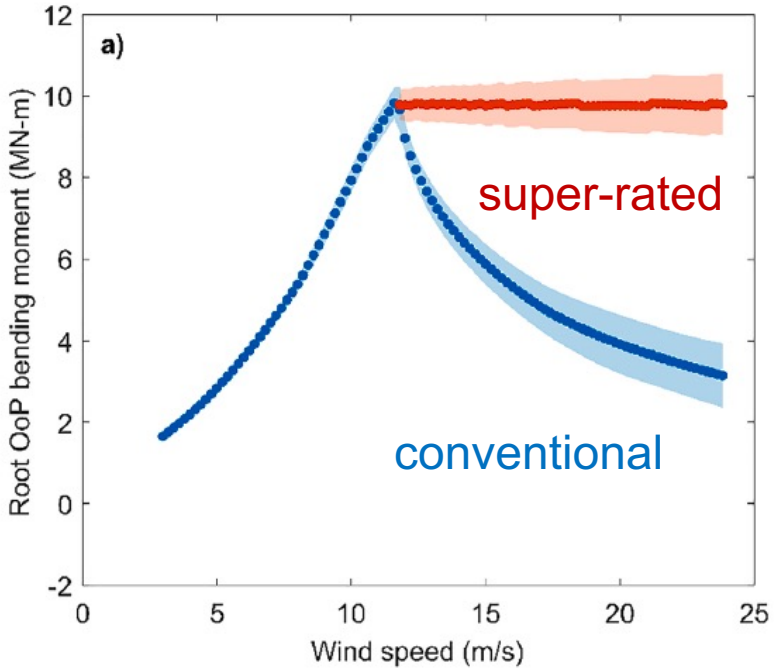
Re-Design Turbine Operation for Storage?

Super-rated

J. Simpson *et al.* 2022
Energy Conv & Mngmt. X







Can increase AEP & capacity factor by ~20% for same rotor, generator, cable
And can reduce delivered power variations by ~40%

Conclusions

- Rapidly increasing wind driven by LCOE reductions
- LCOE is the world-wide standard for renewable energy design

- Periods of high (vs. low) wind and/or solar generation lead to periods of low (vs. high) hourly energy spot prices for grids with high renewables
- COVE is an alternative to LCOE to consider such energy supply and demand aspects for turbine/system design
- Integration of energy storage can allow wind turbines to be levelized and even dispatchable, but should consider COVE minimization

- Turbine capacity factor, storage, conversion & price-based metrics likely to be much more important as renewable penetration increases