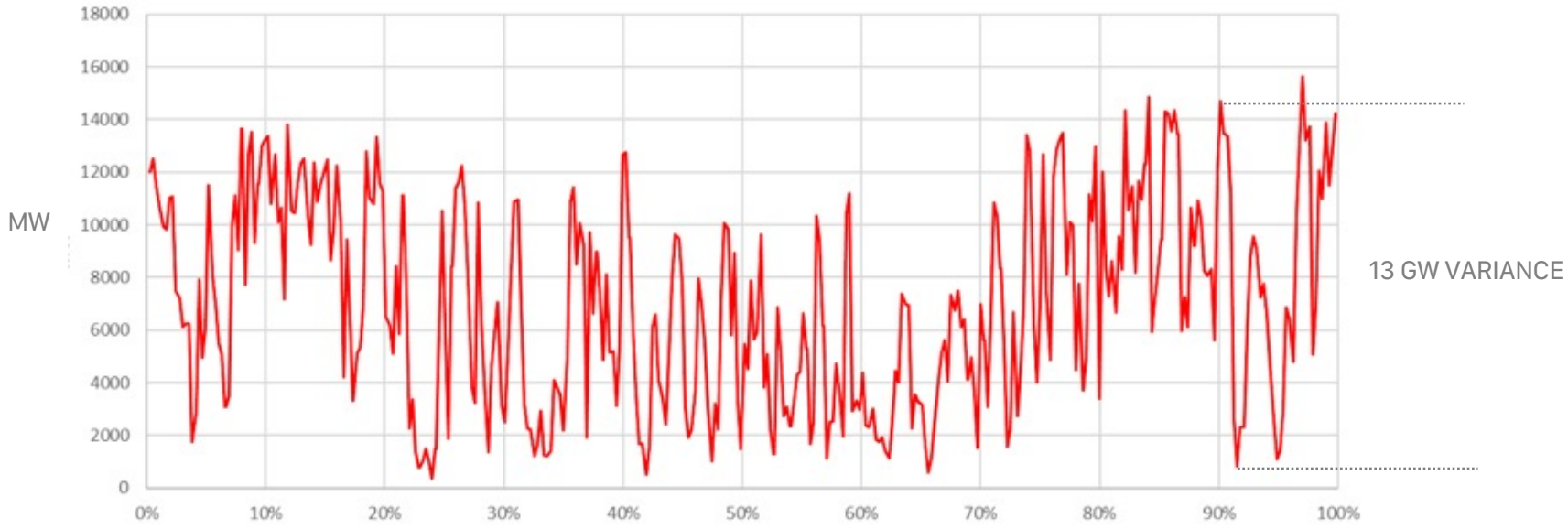
RENEWABLES WORK
EXCEPT WHEN THEY DON'T

DATA

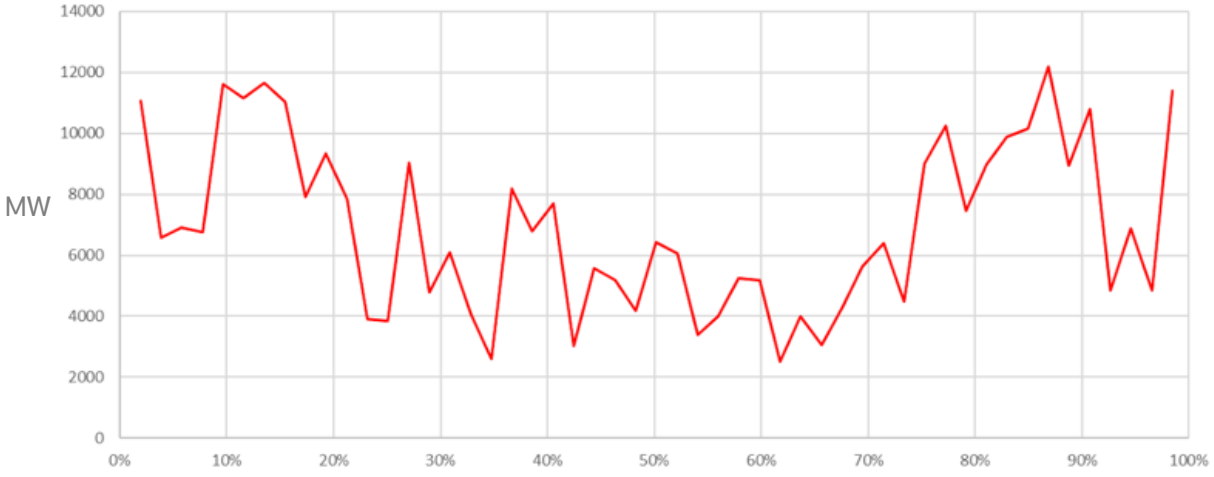
WIND INTERMITTENCY

THE HEAT VAULT
SECURING ENERGY . NATURALLY

24 HOUR DAY

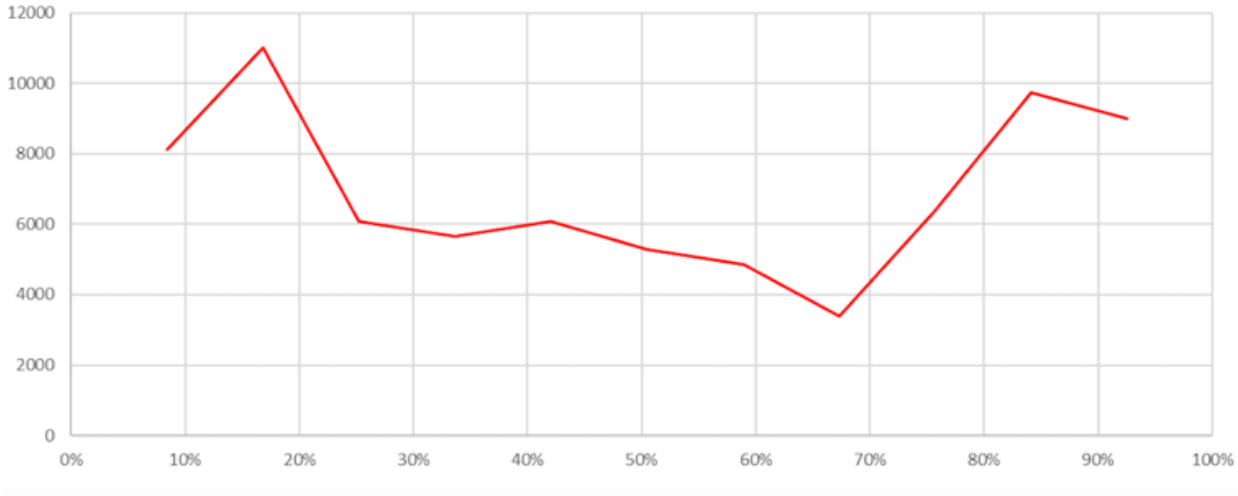


WEEK



TIME

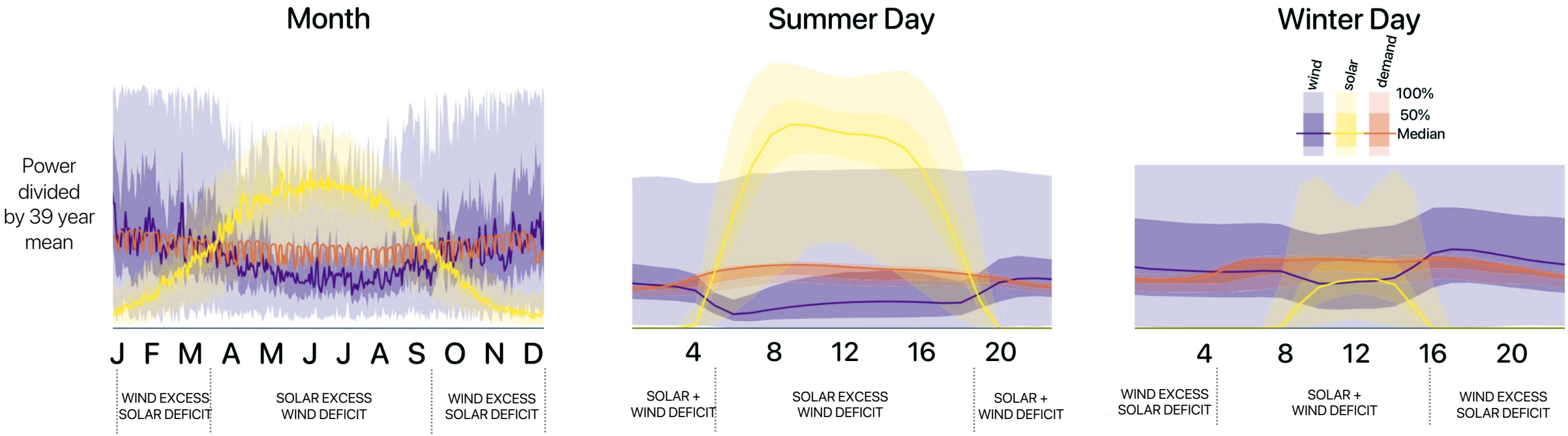
MONTH



UK EXAMPLE

WIND & SOLAR INTERMITTENCY

THE HEAT VAULT
SECURING ENERGY . NATURALLY

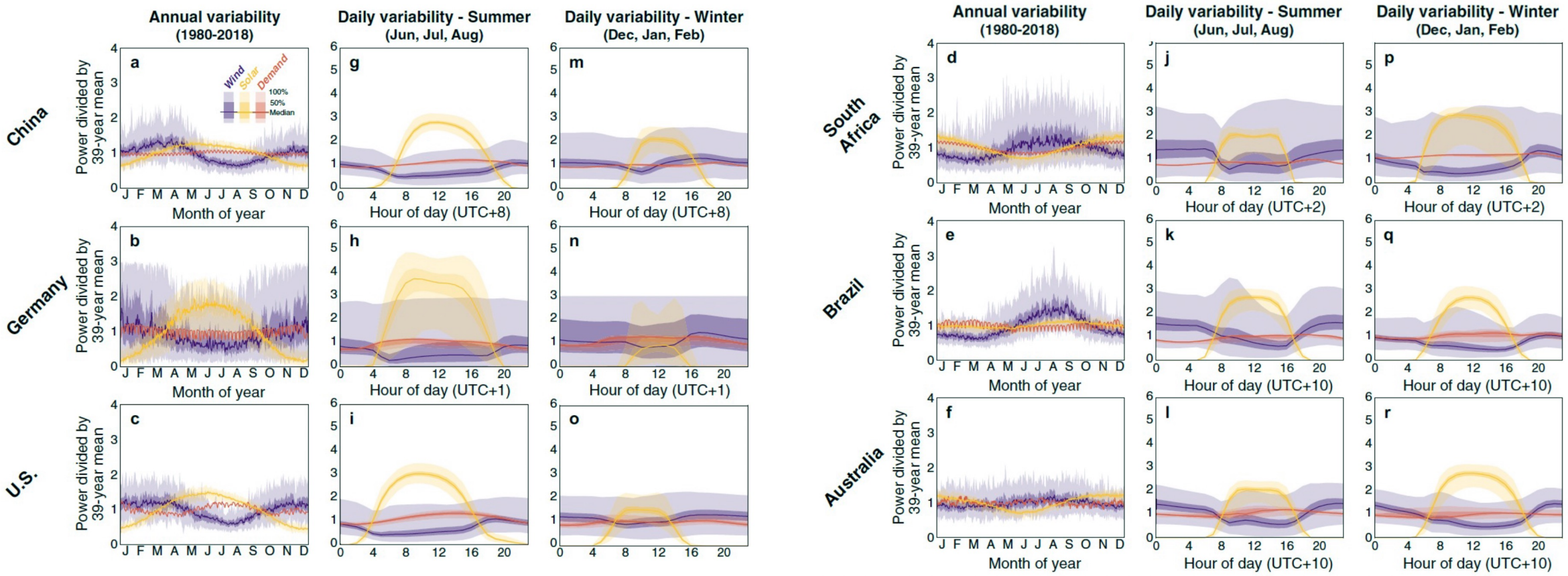


Solution required is stability of >12 hours to whole seasons. Increasing supply exaggerates problem

GERMANY EXAMPLE

GLOBAL WIND & SOLAR INTERMITTENCY

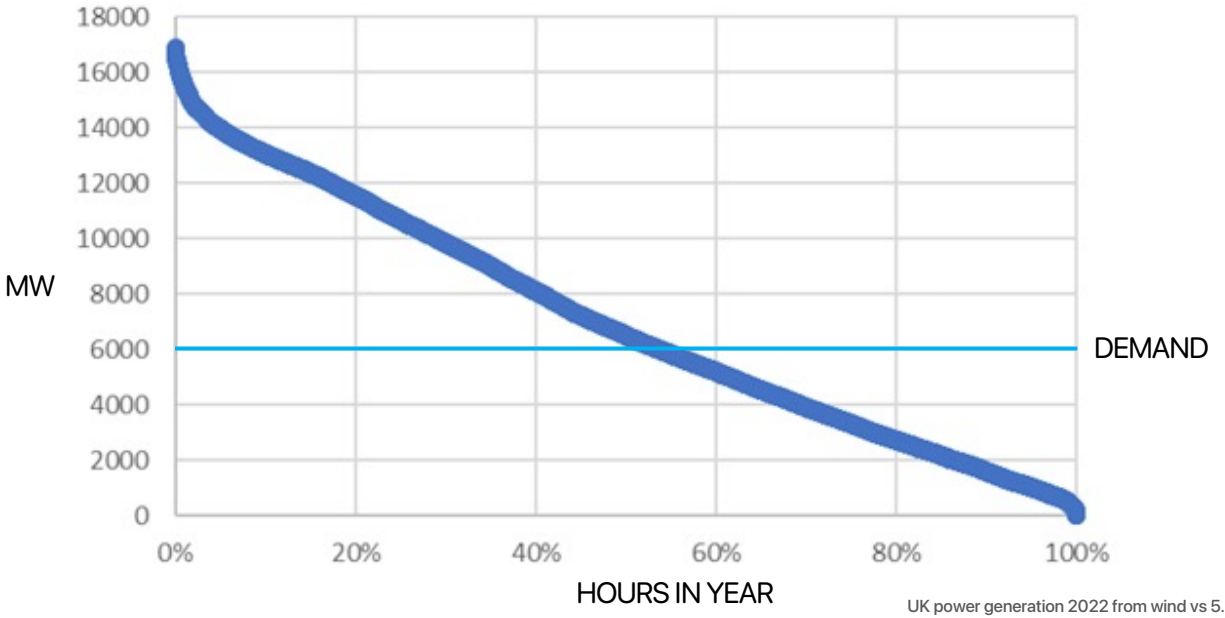
THE HEAT VAULT
SECURING ENERGY . NATURALLY



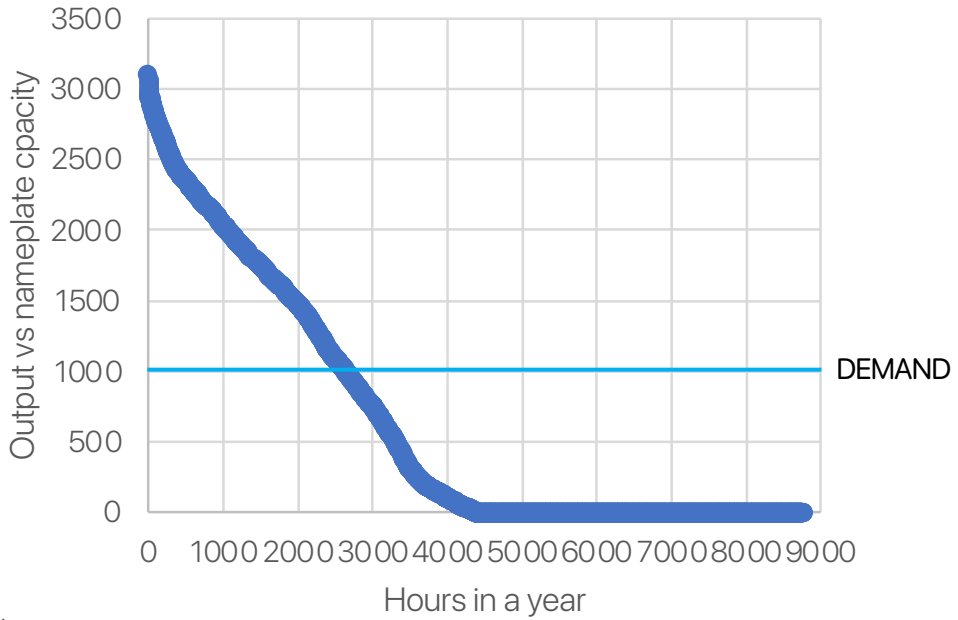
WIND & SOLAR POWER PRODUCTION

THE HEAT VAULT
SECURING ENERGY . NATURALLY

WIND LOAD DURATION

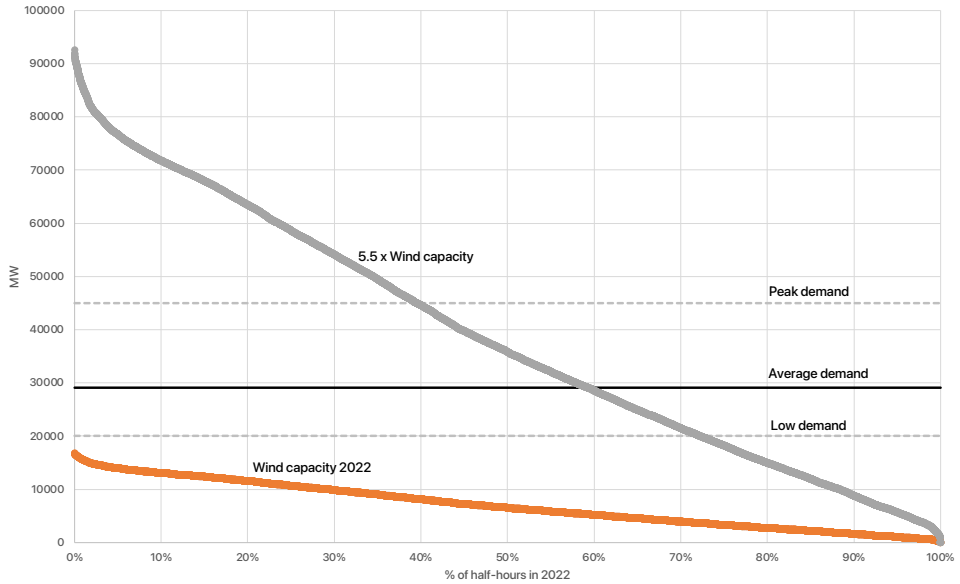


PV LOAD DURATION



- Excess production of non dispatchable electricity occurs in least time (15-50%) and deficit in most time available each year.
- Expanding capacity simply exaggerates this imbalance.
- This requires a whole season solution to store electricity when in excess to carry forward excess to future period of deficit

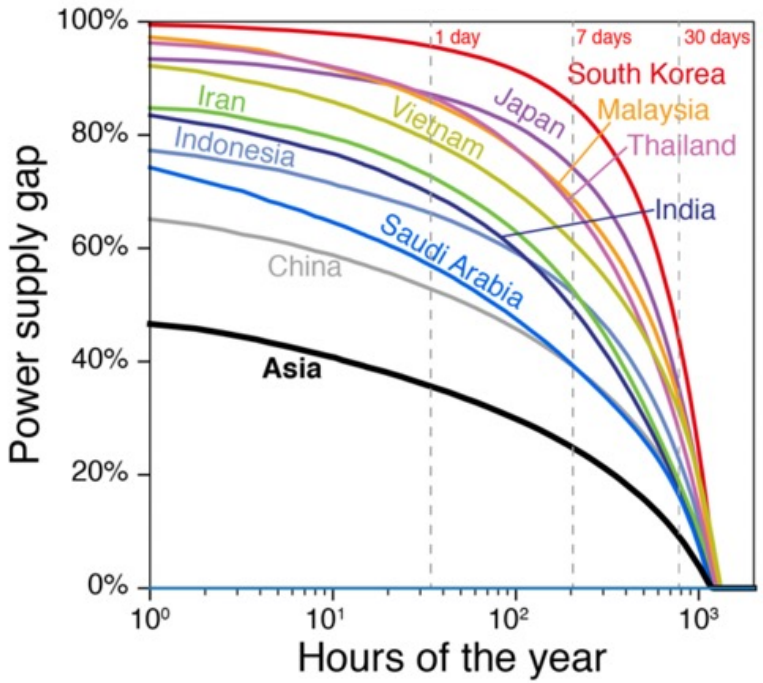
UK power generation 2022 from wind vs 5.5X increase in generation



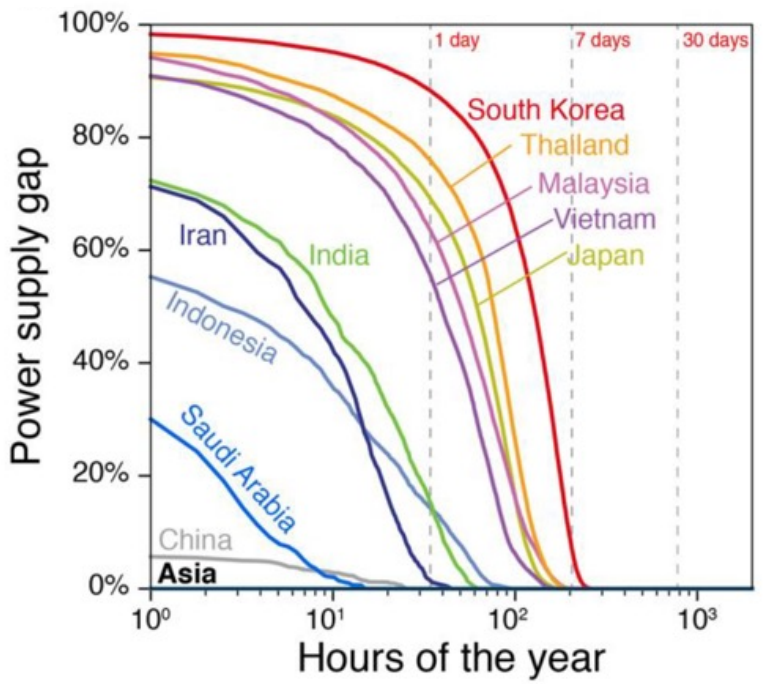
THE HEAT VAULT
SECURING ENERGY . NATURALLY

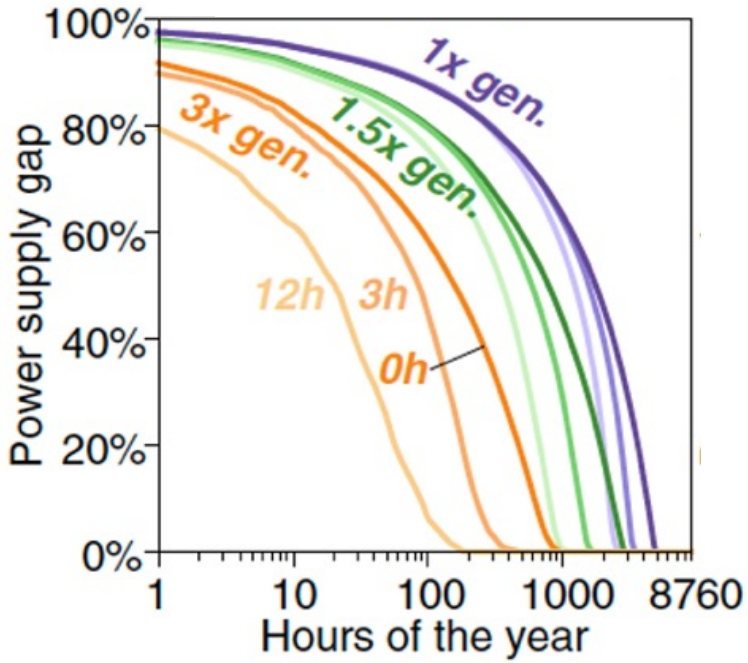
POWER SUPPLY GAP VS. CAPACITY

No energy storage and no excess generation



12 hours energy storage and 1.5X generation

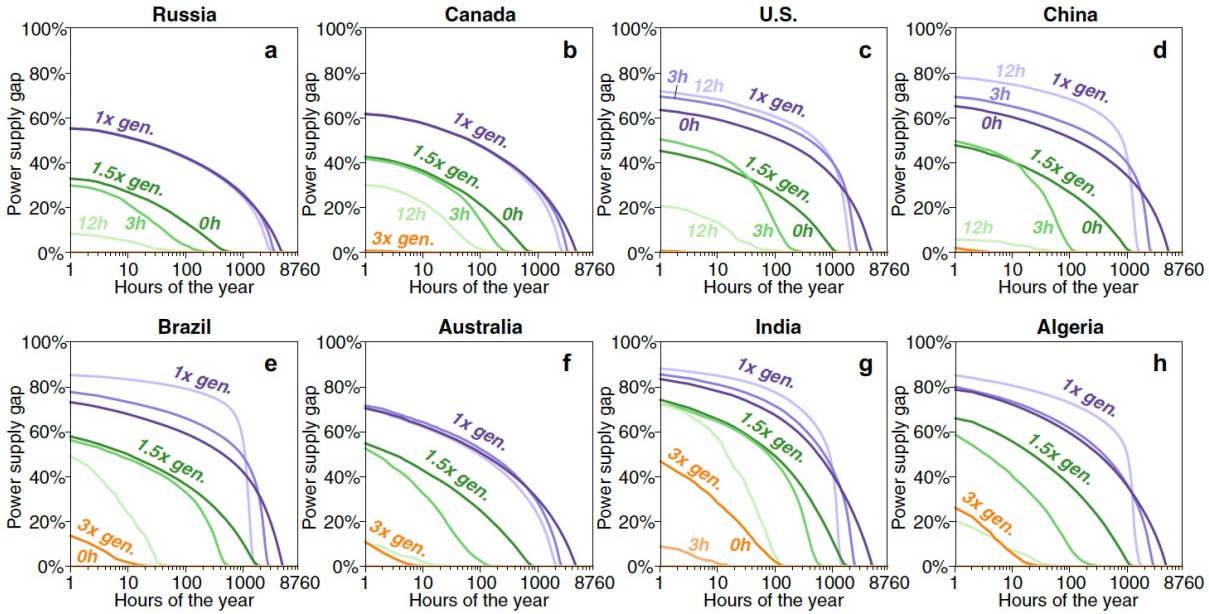


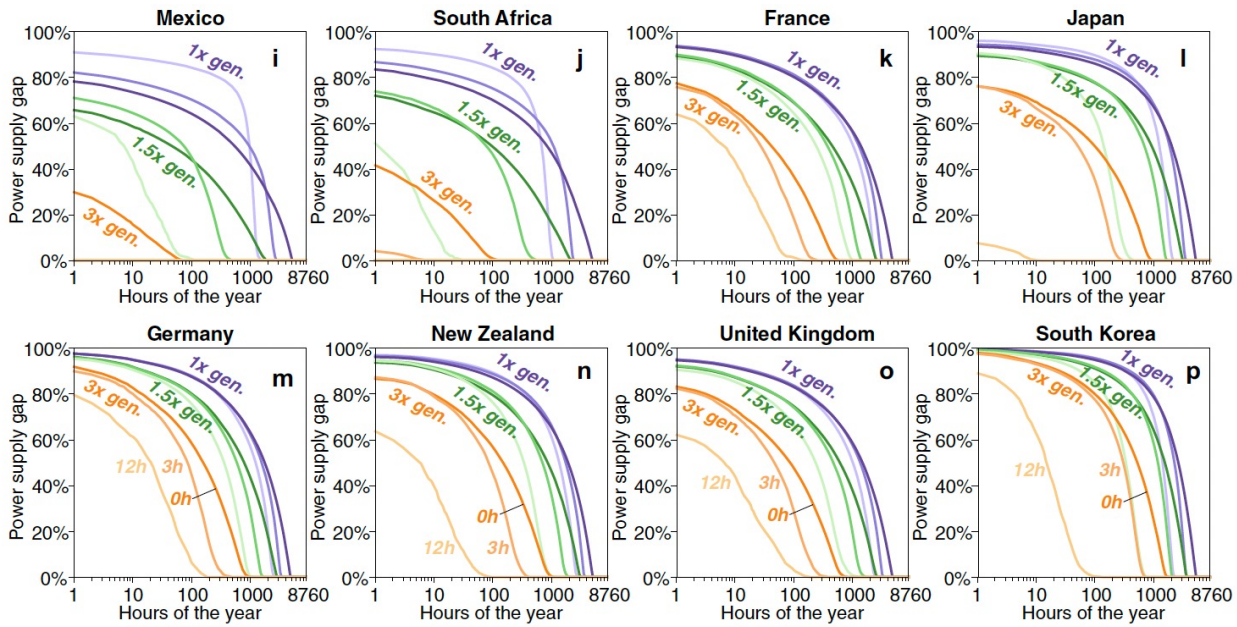


Areas under each curve show the share and hours of unmet electricity demand of the most reliable solar-wind systems
in selected countries assuming specified storage and generation quantities. Even at 3X build there will be serious unmet demand without long duration energy storage.

GLOBAL POWER SUPPLY GAP VS. CAPACITY

THE HEAT VAULT
SECURING ENERGY . NATURALLY





Areas under each curve show the share and hours of unmet electricity demand of the most reliable solar-wind systems
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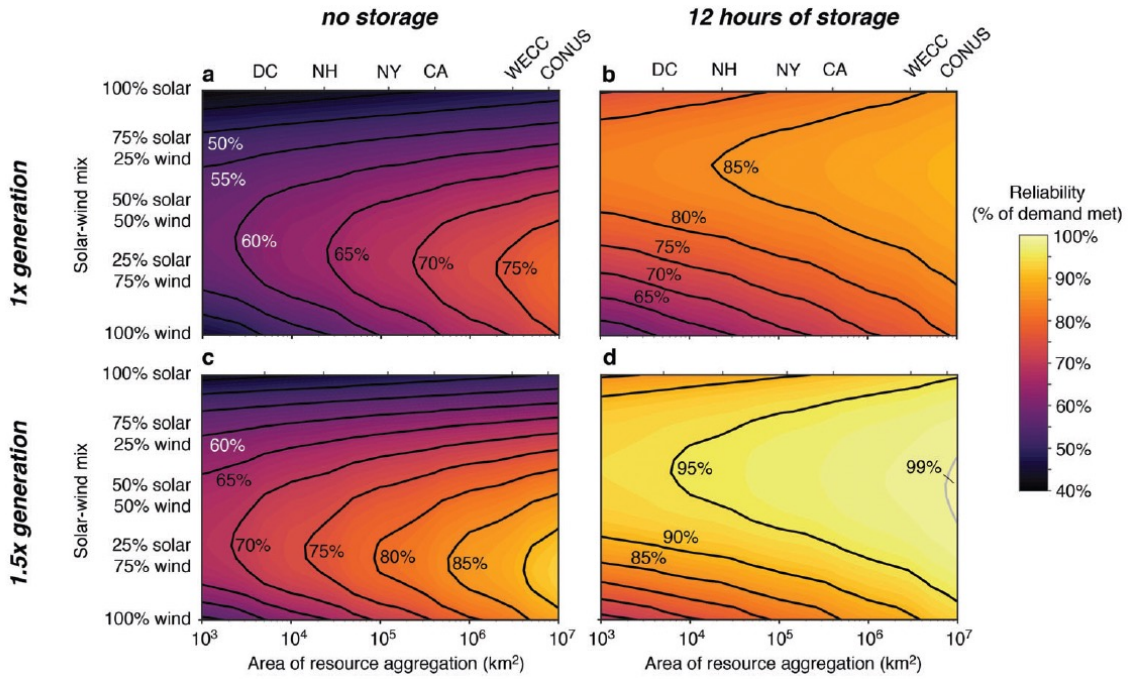
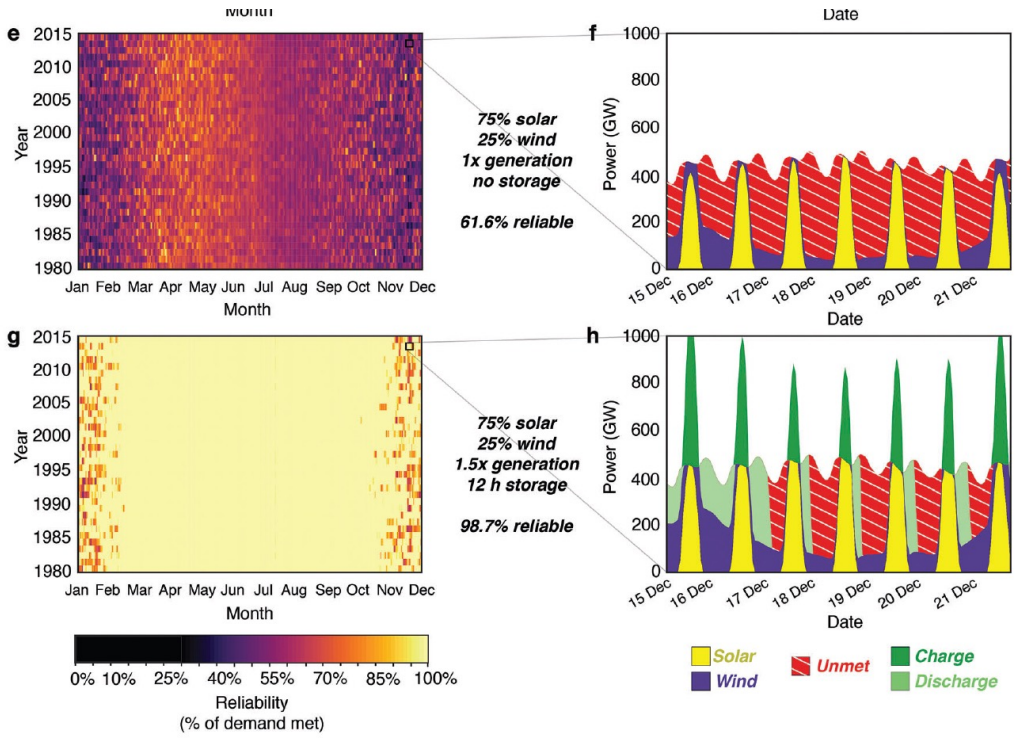
SOLAR & WIND RELIABILITY

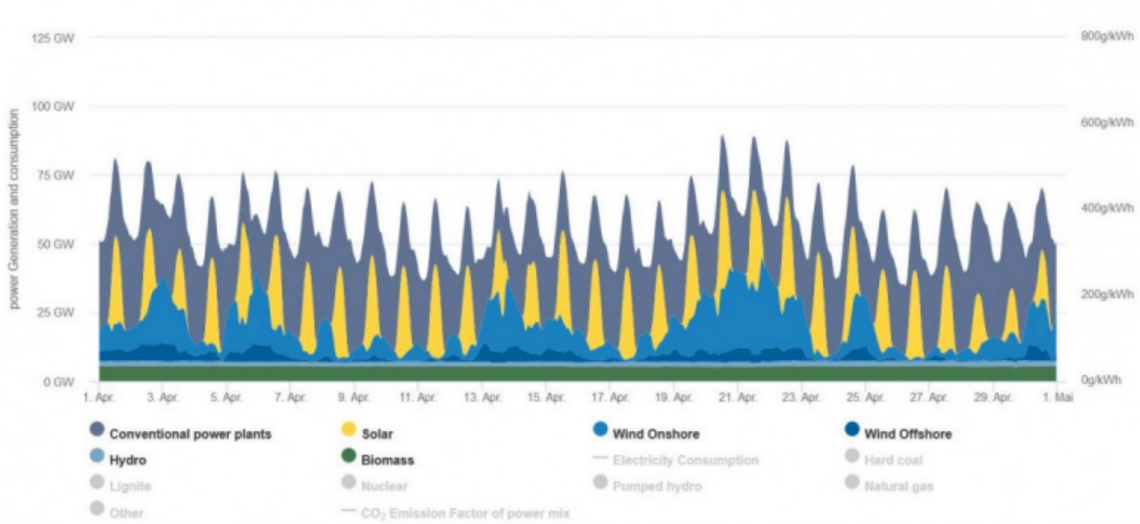




- Reliability of solar and wind generation as a function of area and resource mix.
- Contours and shading in each panel represent the average calculated reliability (% of total annual electrical demand met) by a mix of solar and wind resources ranging from 100% solar to 100% wind (y-axes) and aggregated over progressively larger areas of the contiguous U.S.
- Daily demand met as a function of resource mix, generation and energy storage.
- Temporal characterization of daily demand met by solar, wind and energy storage (if present) for every day in the simulation period and aggregated over the contiguous U.S. under different scenarios

RENEWABLES GROWTH AND NEGATIVE PRICING

THE HEAT VAULT
SECURING ENERGY . NATURALLY



- Expansion of assets for wind and solar with simultaneous use of existing fossil fuel-based assets leads to periods of excess production which in turn creates extreme volatility in energy pricing, including periodic negative pricing to as low as -€80/MWh.
- Renewable asset owners suffer losses in these periods or continue to be subsidised by taxpayers to curtail power and stop production.
- These effects are particularly acute when demand drops in periods of warm weather.
- Building or overbuilding renewable assets to satisfy increased peak demand will only exacerbate this problem and dampen the pace for renewables growth.

GERMANY EXAMPLE

REFERENCES

THE HEAT VAULT
SECURING ENERGY . NATURALLY

- Geophysical constraints on the reliability of solar and wind power worldwide. Dan Tong, David J. Farnham, Lei Duan, Qiang Zhang, Nathan S. Lewis, Ken Caldeira & Steven J. Davis NATURE COMMUNICATIONS | (2021) 12:6146 | https://doi.org/10.1038/s41467-021-26355-z
- Geophysical constraints on the reliability of solar and wind power in the United States. Matthew R. Shaner, Steven J. Davis, Nathan S. Lewis and Ken Caldeira. Energy & Environmental Science DOI: 10.1039/c7ee03029k