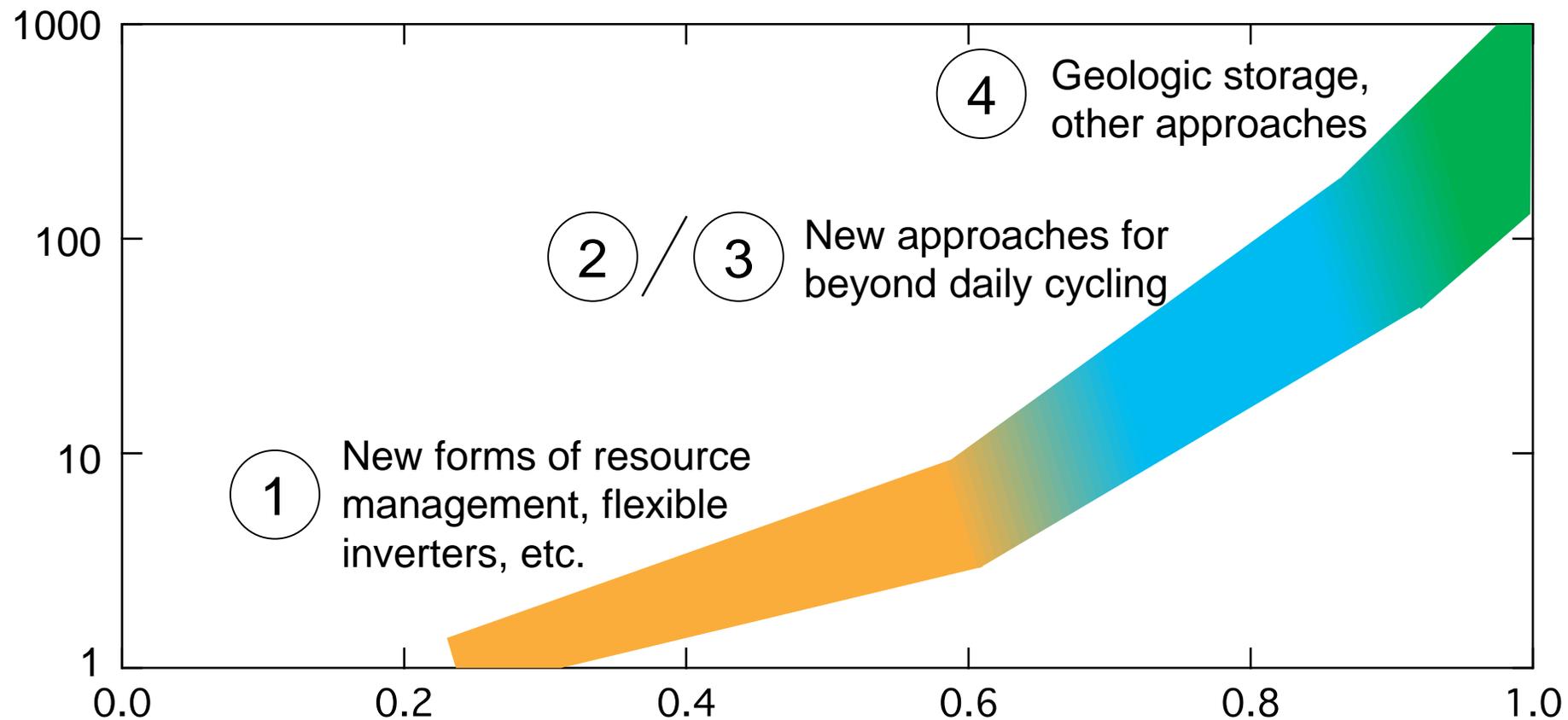


Beyond the hour and the day: cost effective long duration energy storage

Paul Albertus, Program Director

Several presentations cover challenges of adding wind and solar

Storage duration (hours at rated power)



Fraction of annual energy from wind and solar in a large grid

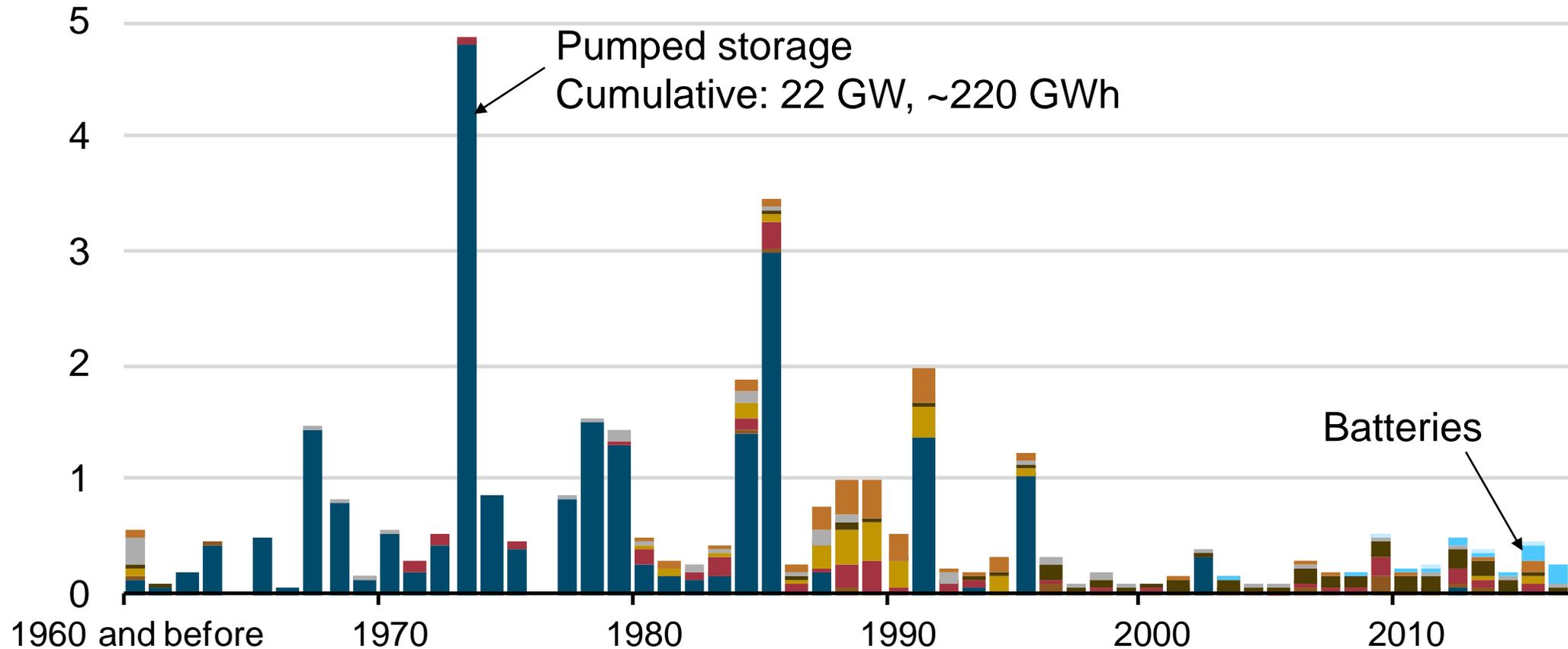


Pumped storage deployments have essentially stopped

Selected U.S. utility-scale electric generating capacity by initial operating year

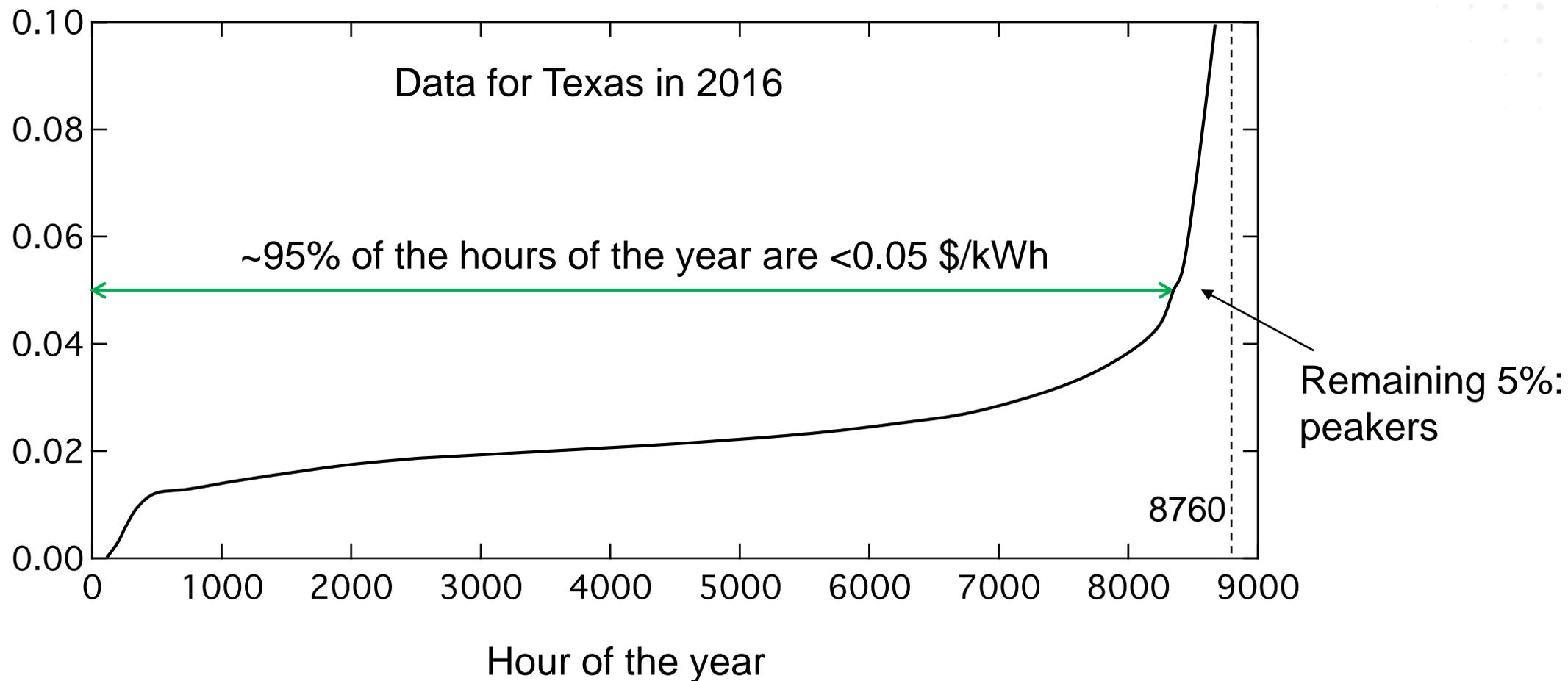
Pumped storage deployments have essentially stopped

Selected U.S. utility-scale electric generating capacity by initial operating year
gigawatts



Future grid should provide low-cost electricity >90% of the year

Electricity price (\$/kWh)



The problem to be solved

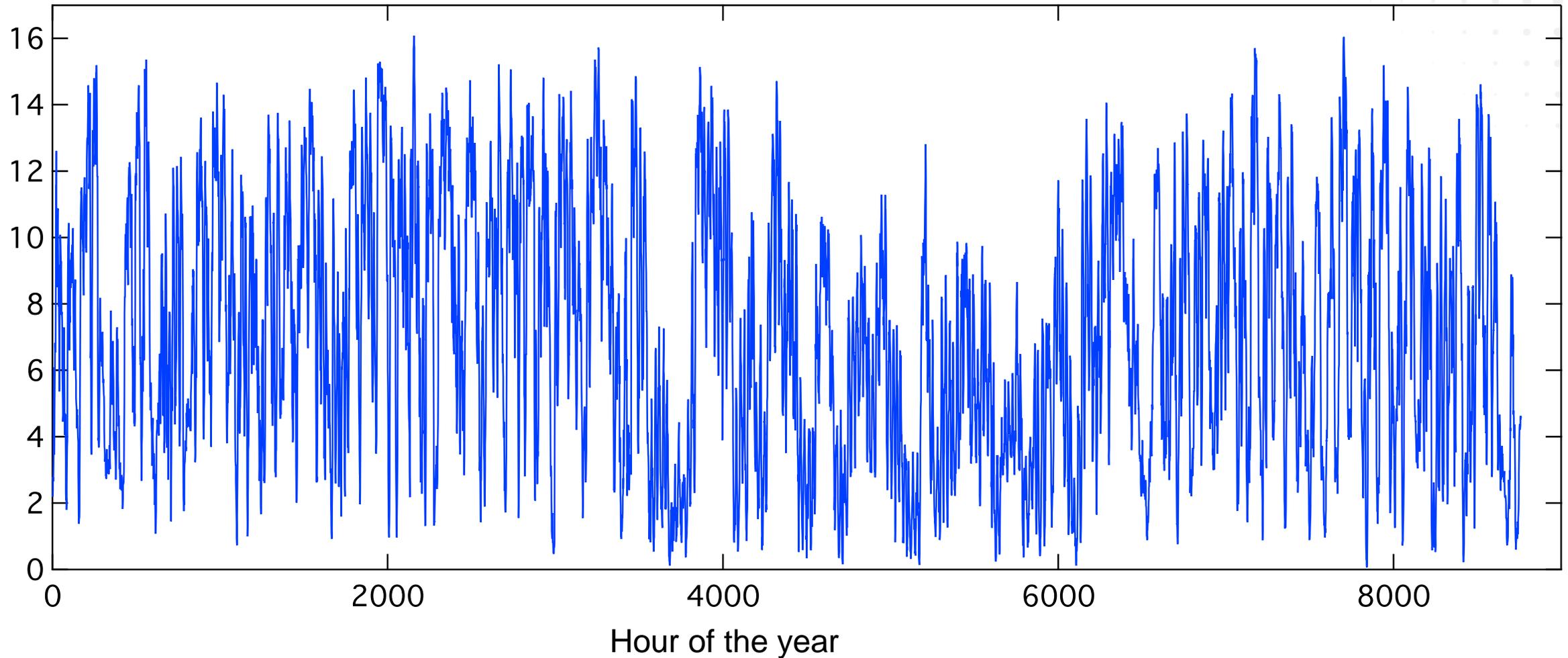
- ▶ Can we build a future wind and solar + storage generation system with a cost profile like that of today's grid?
- ▶ Yes! If we have:
 - (1) Storage systems with tens of hours of duration.
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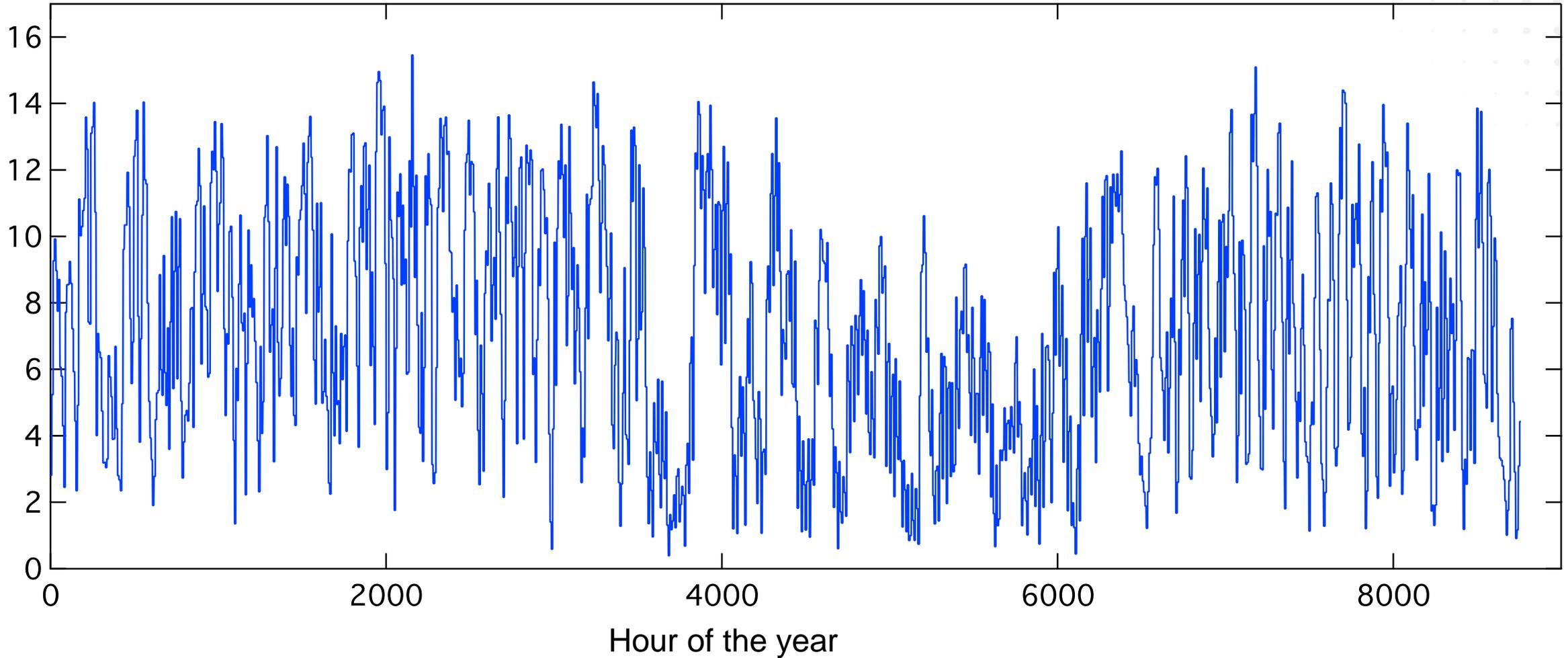
1-hour time blocks for Texas wind

2016 wind output in Texas (GW)



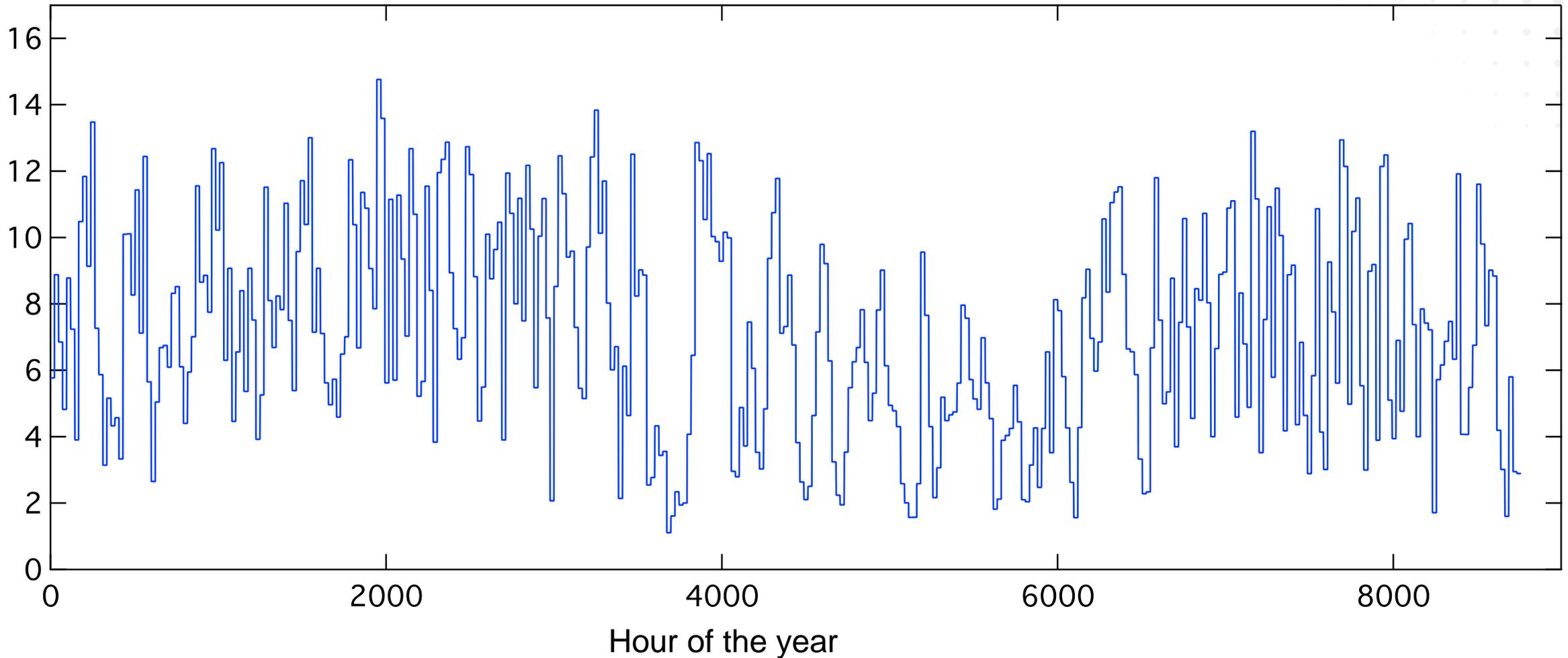
8-hour time blocks for Texas wind

2016 wind output in Texas (GW)



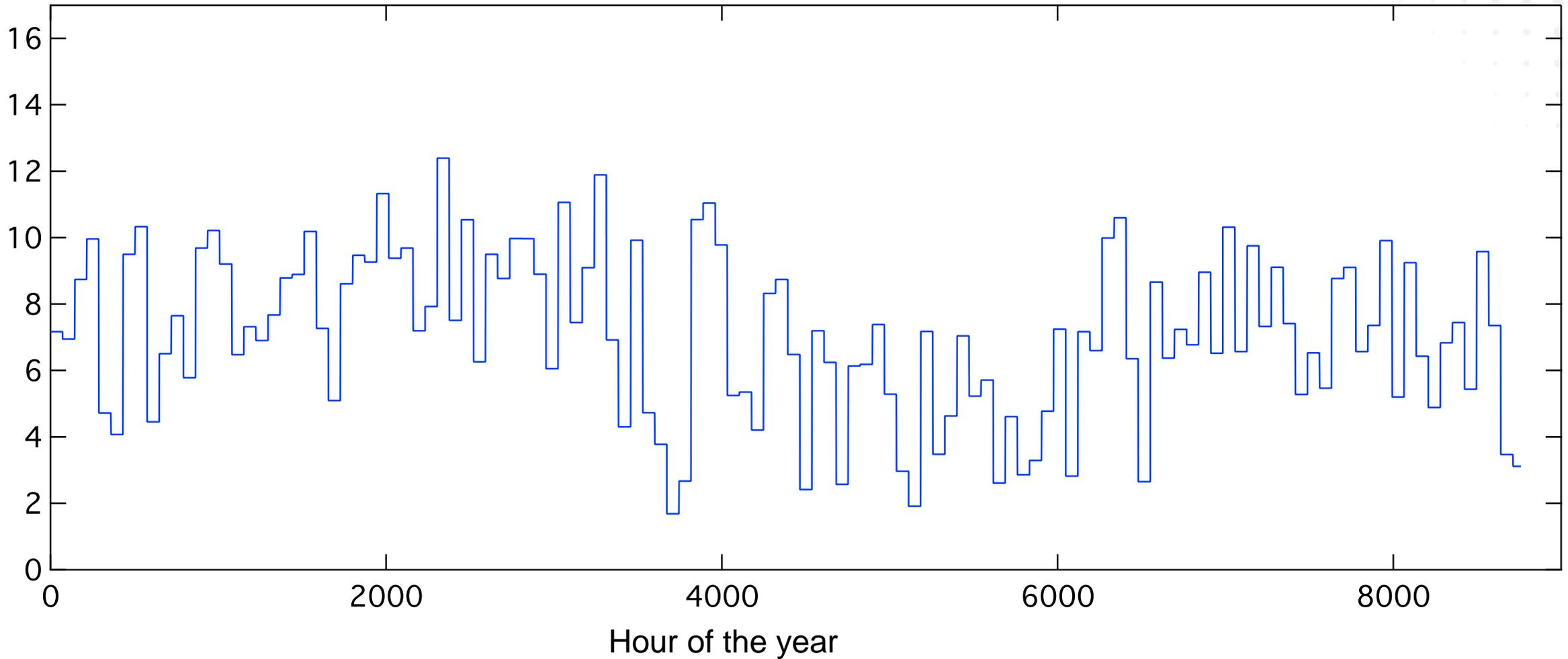
24-hour time blocks for Texas wind

2016 wind output in Texas (GW)



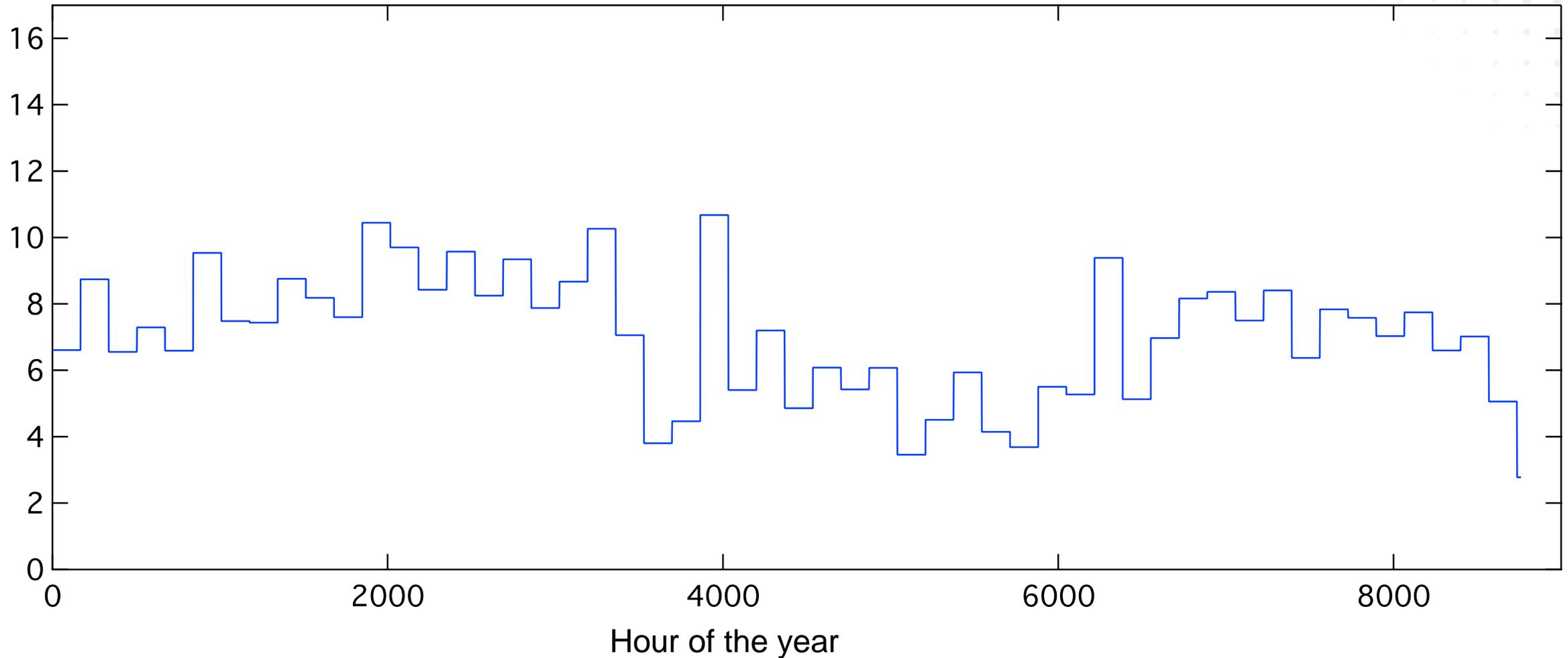
72-hour time blocks for Texas wind

2016 wind output in Texas (GW)



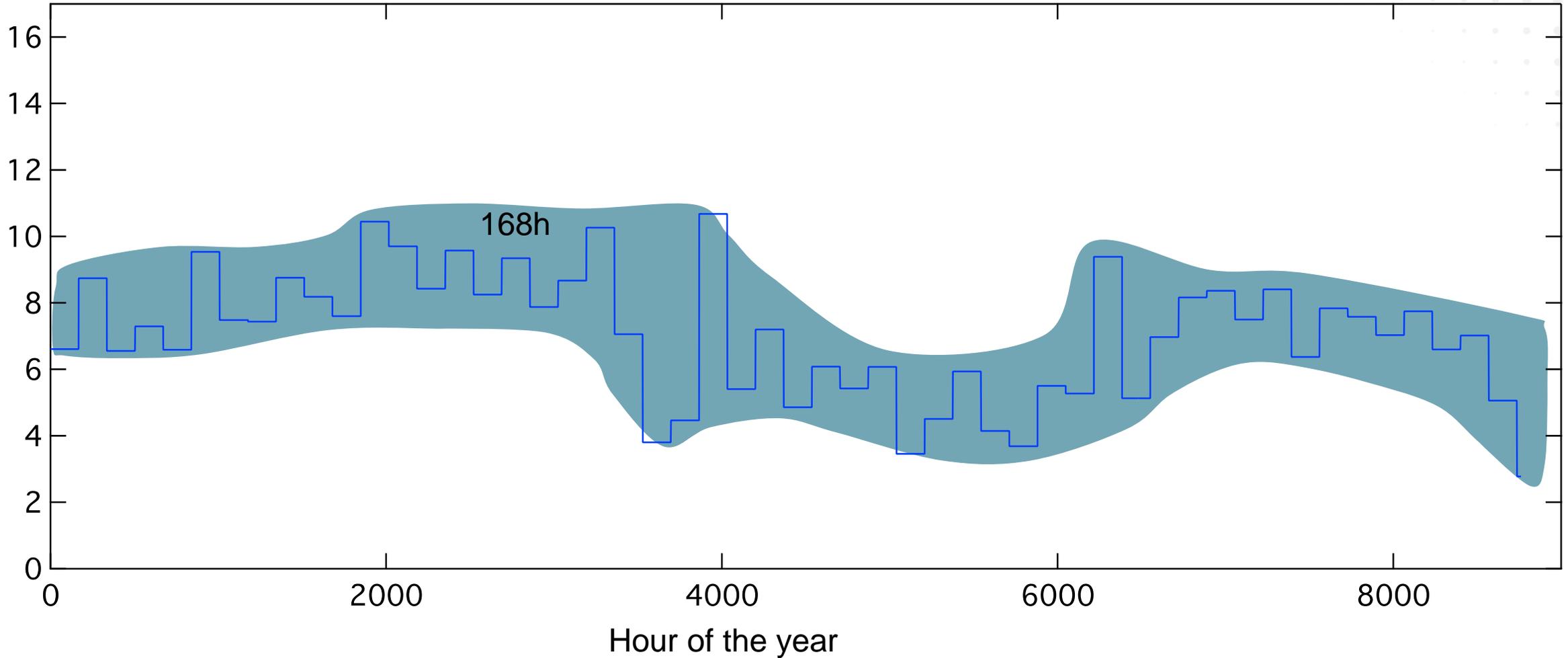
168-hour time blocks for Texas wind

2016 wind output in Texas (GW)



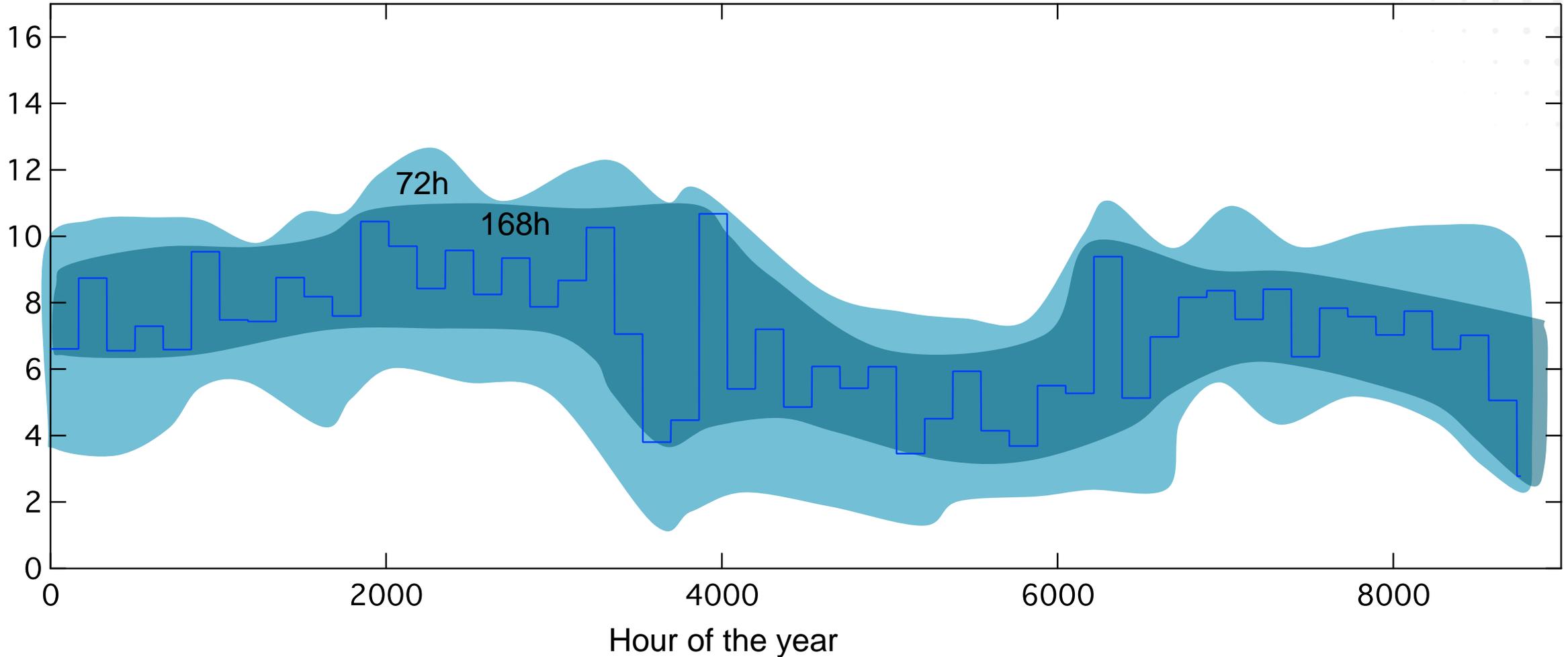
Time scales and variability of Texas wind

2016 wind output in Texas (GW)



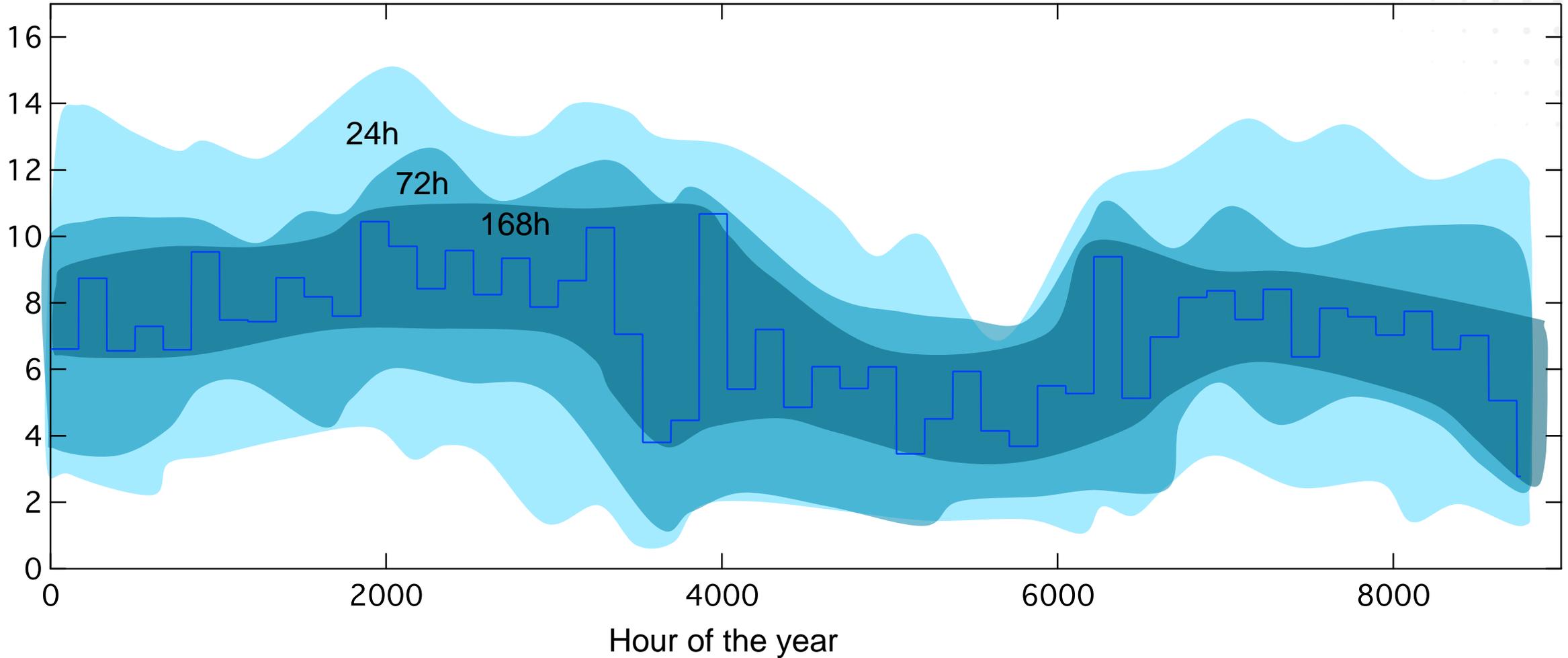
Time scales and variability of Texas wind

2016 wind output in Texas (GW)



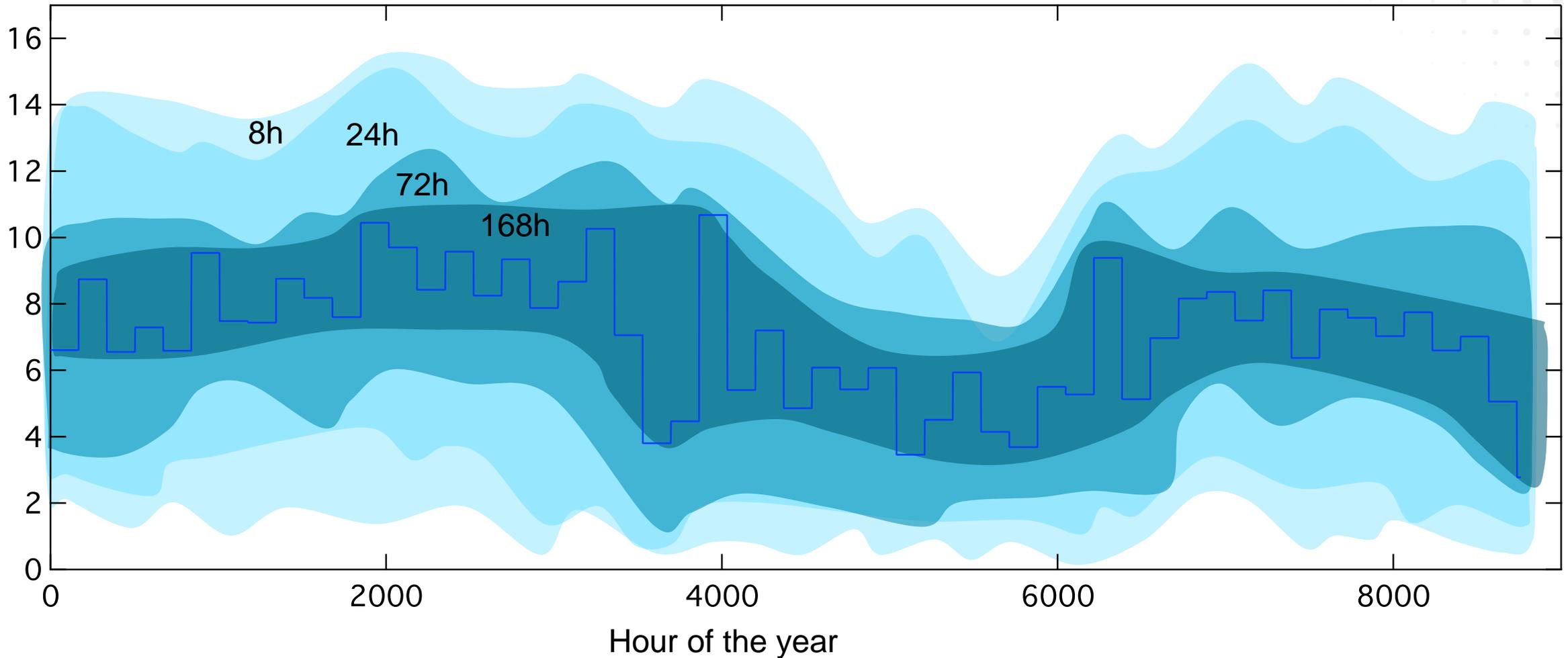
Time scales and variability of Texas wind

2016 wind output in Texas (GW)



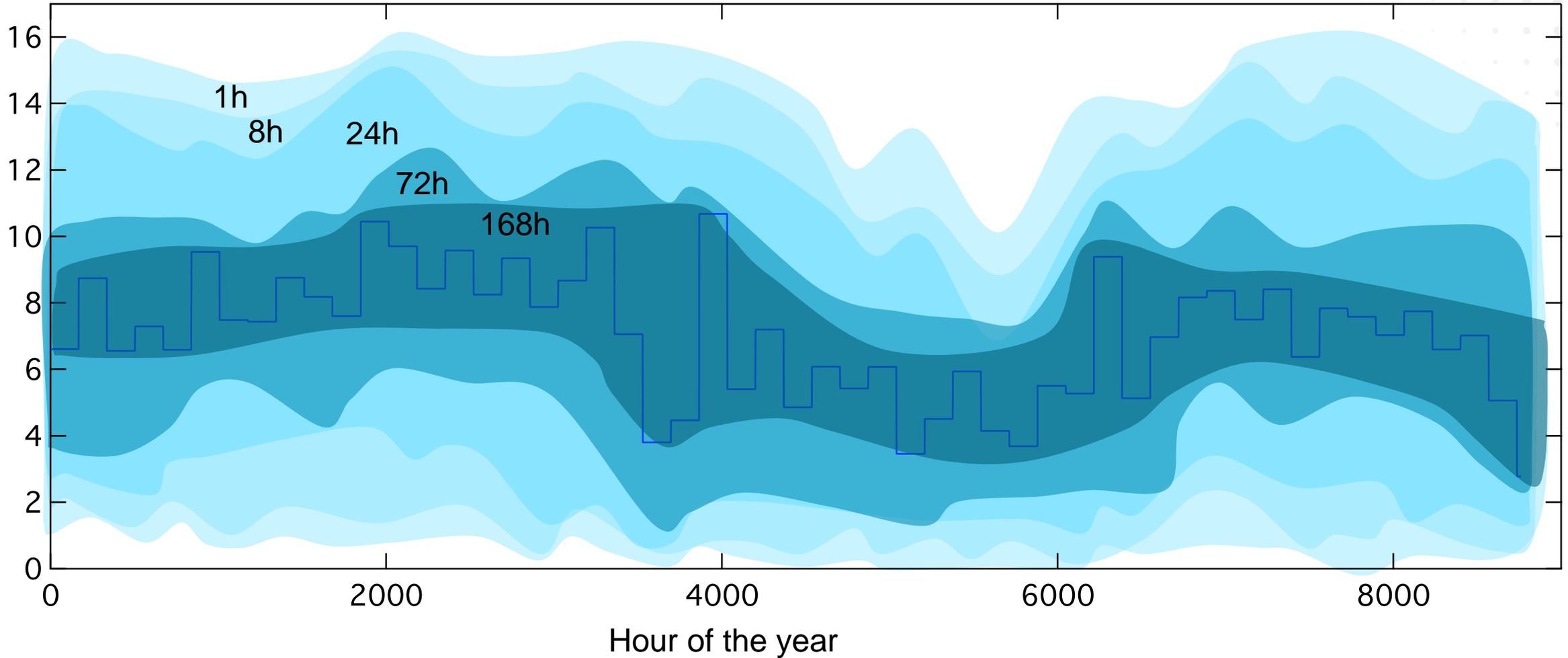
Time scales and variability of Texas wind

2016 wind output in Texas (GW)



Time scales and variability of Texas wind

2016 wind output in Texas (GW)



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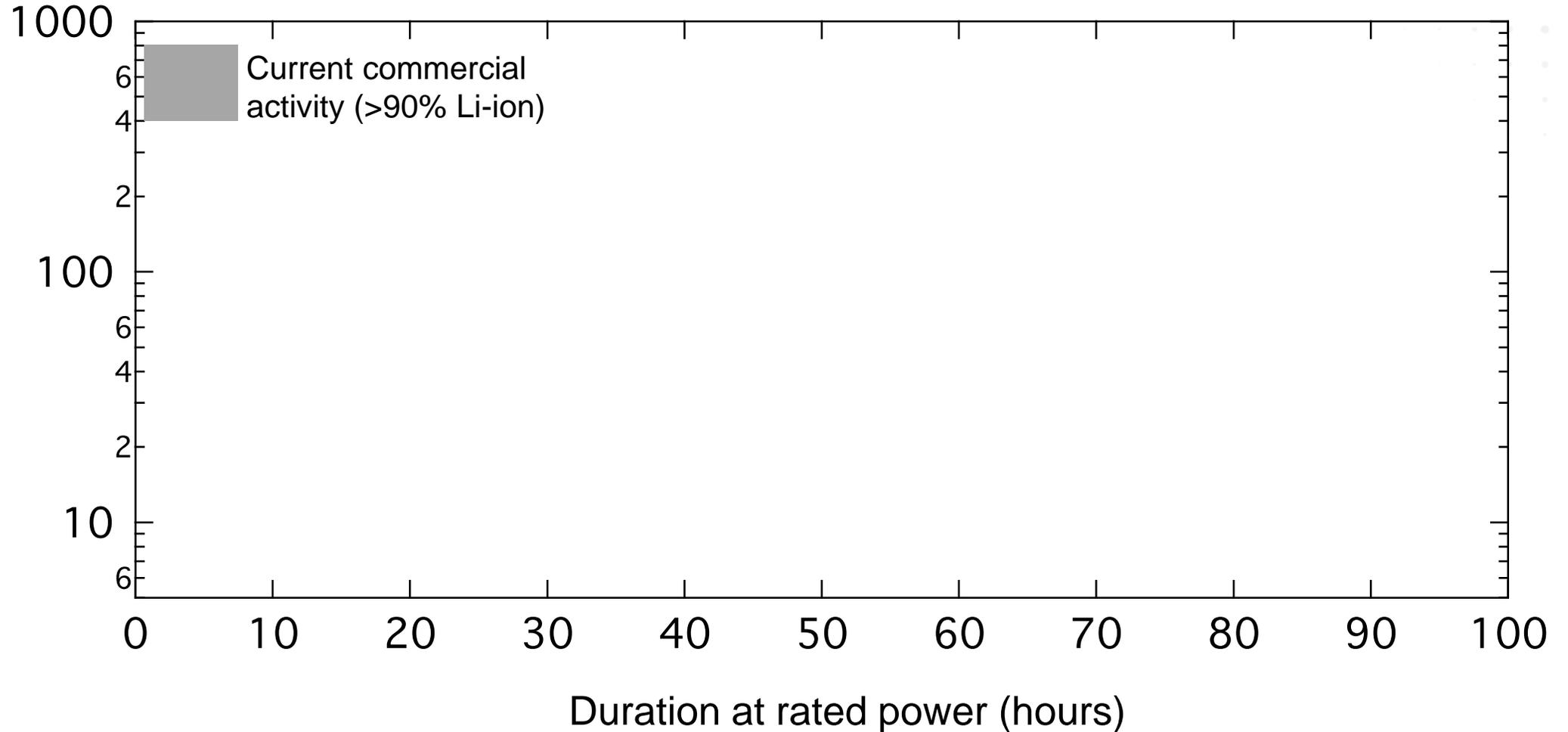


Power (Watts)



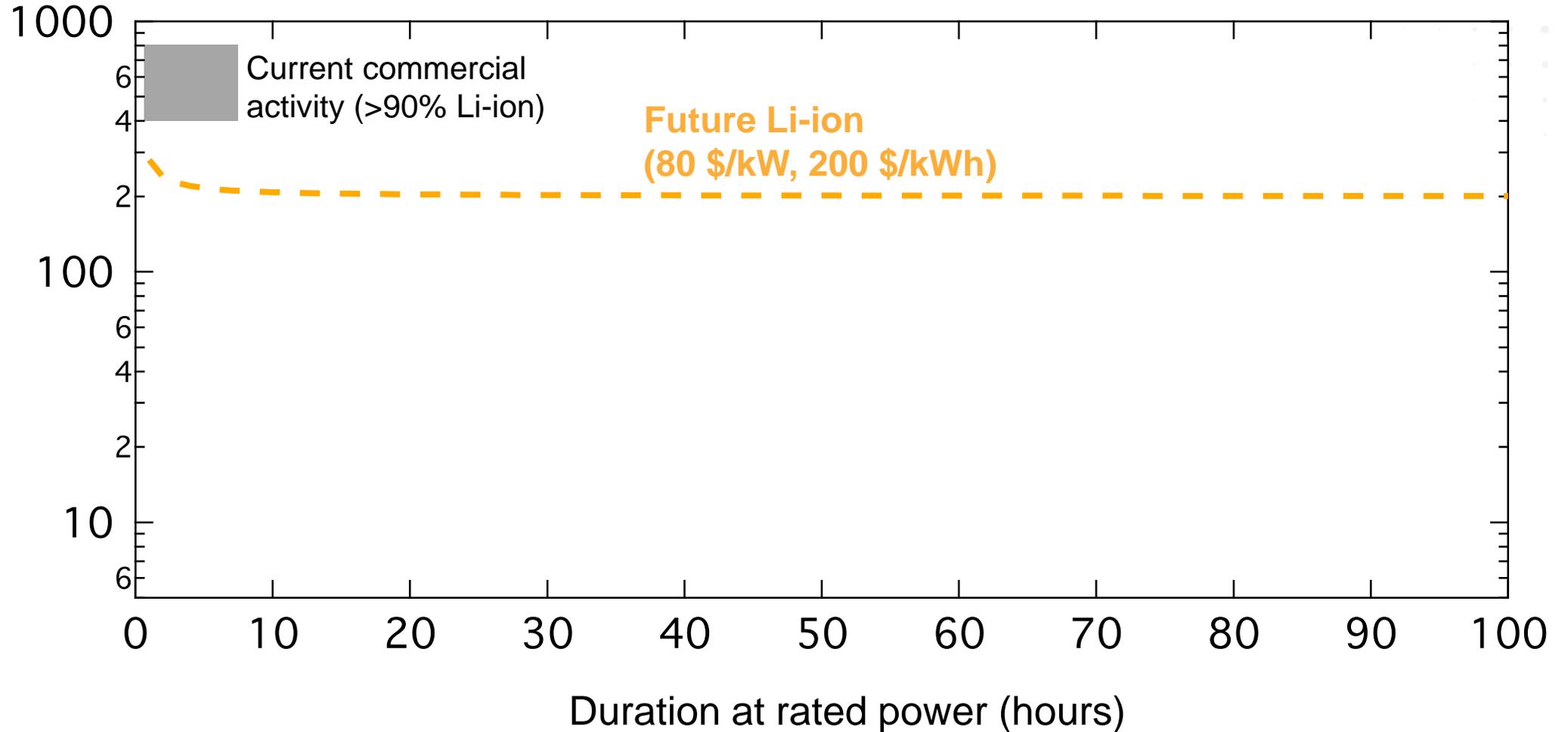
Low cost at long durations is needed

Complete system cost (\$/kWh)



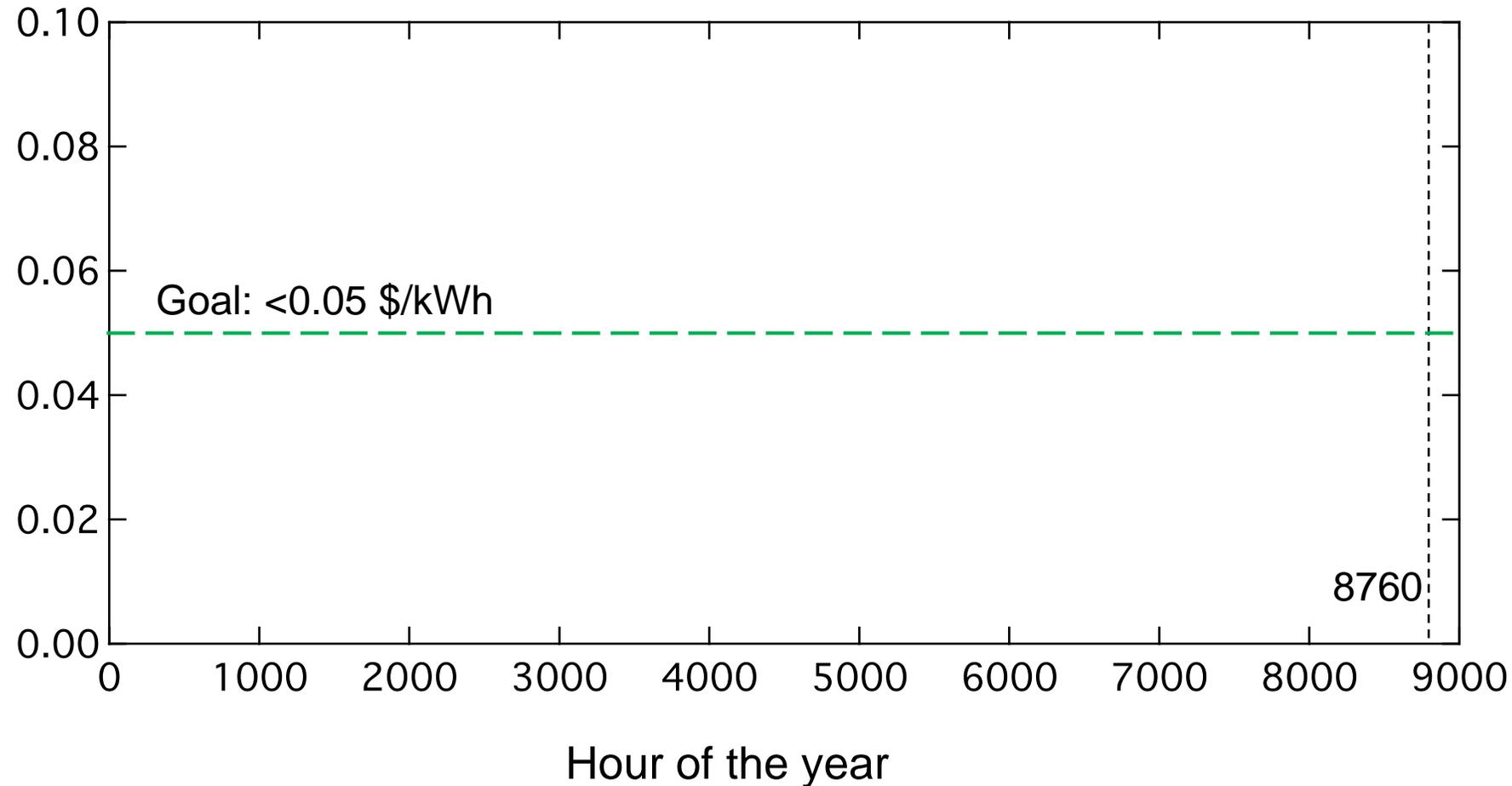
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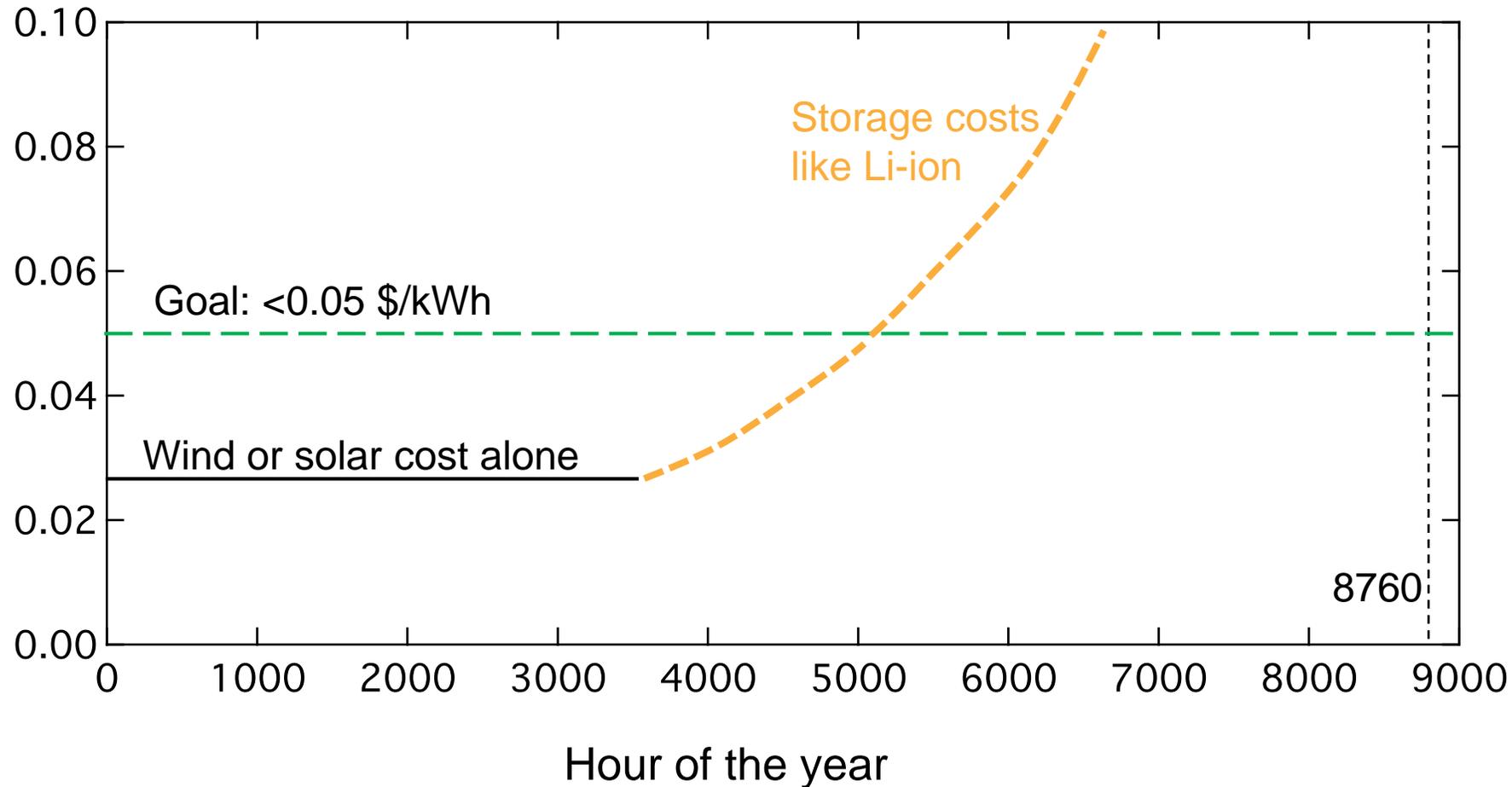
Li-ion storage costs don't work

Electricity price (\$/kWh)



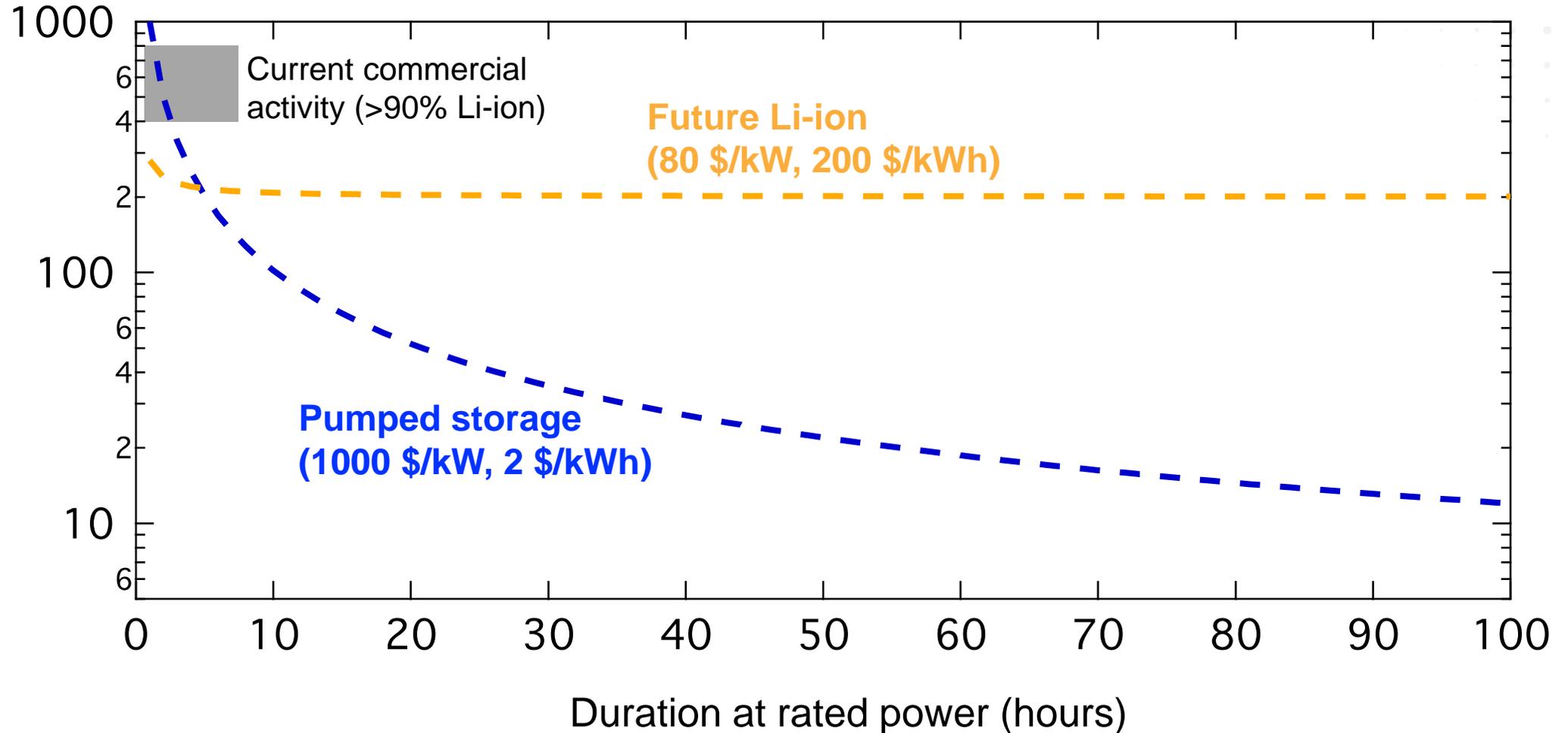
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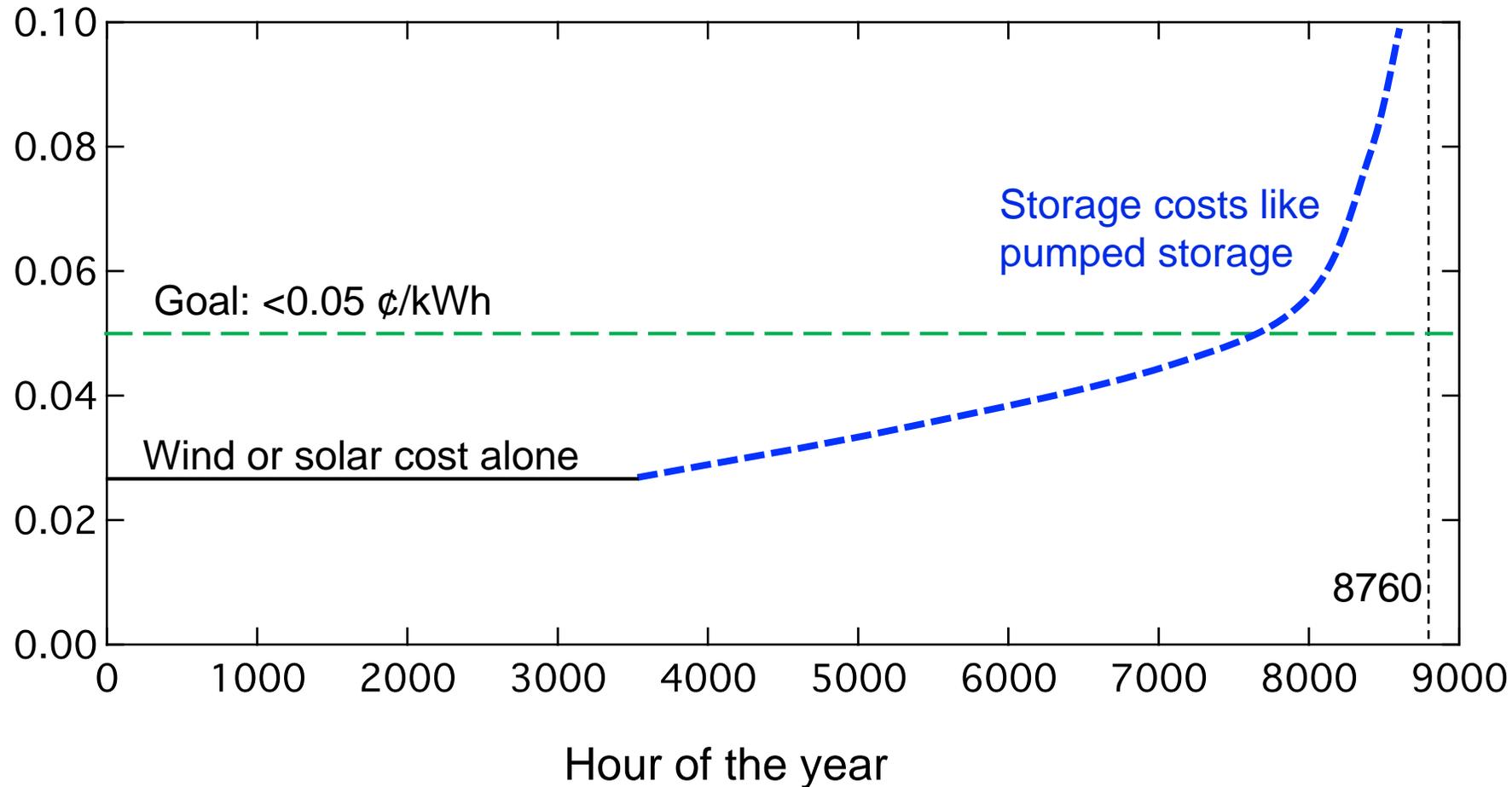
Low cost at long durations is needed

Complete system cost (\$/kWh)



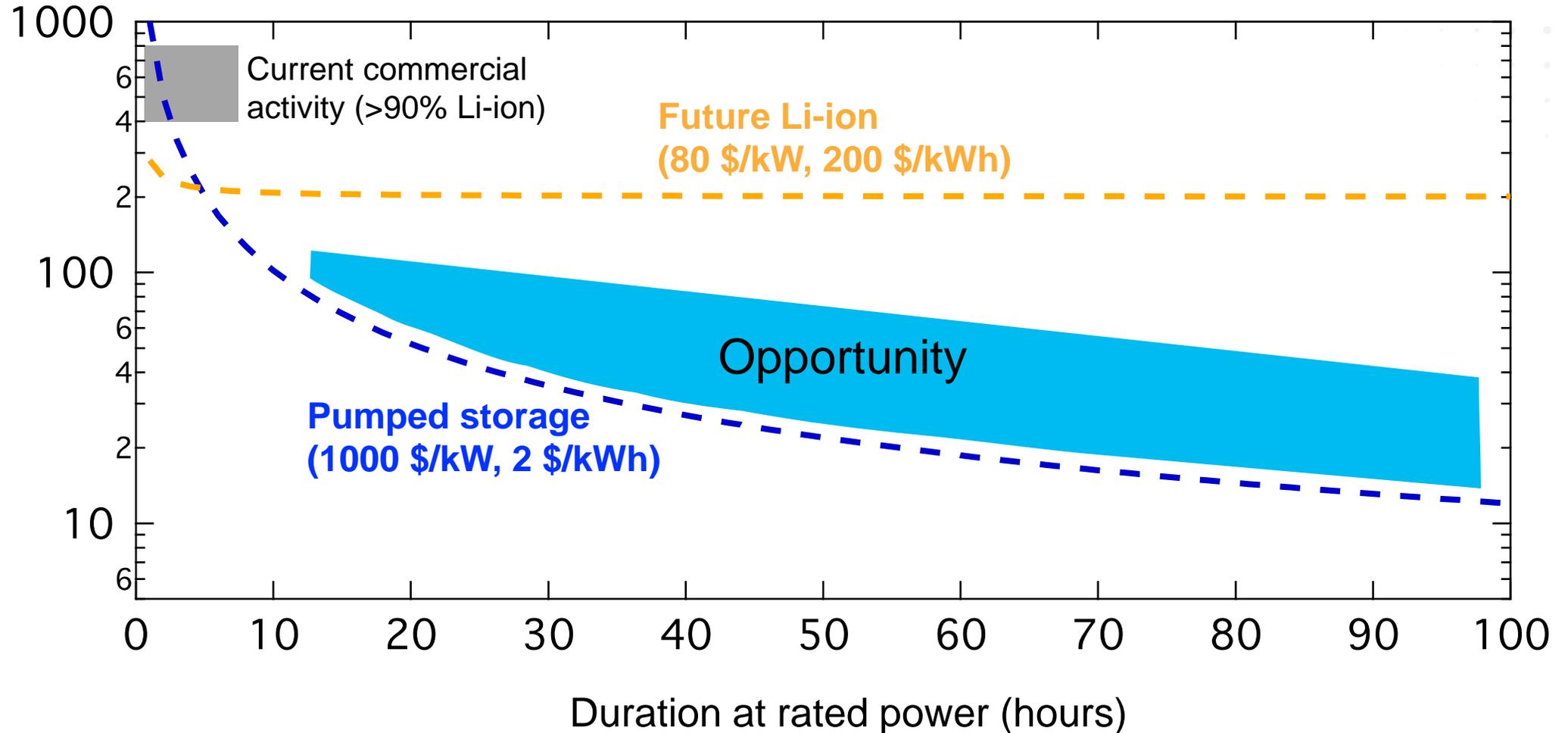
Pumped storage costs do work

Electricity price (\$/kWh)



Low cost at long durations is needed

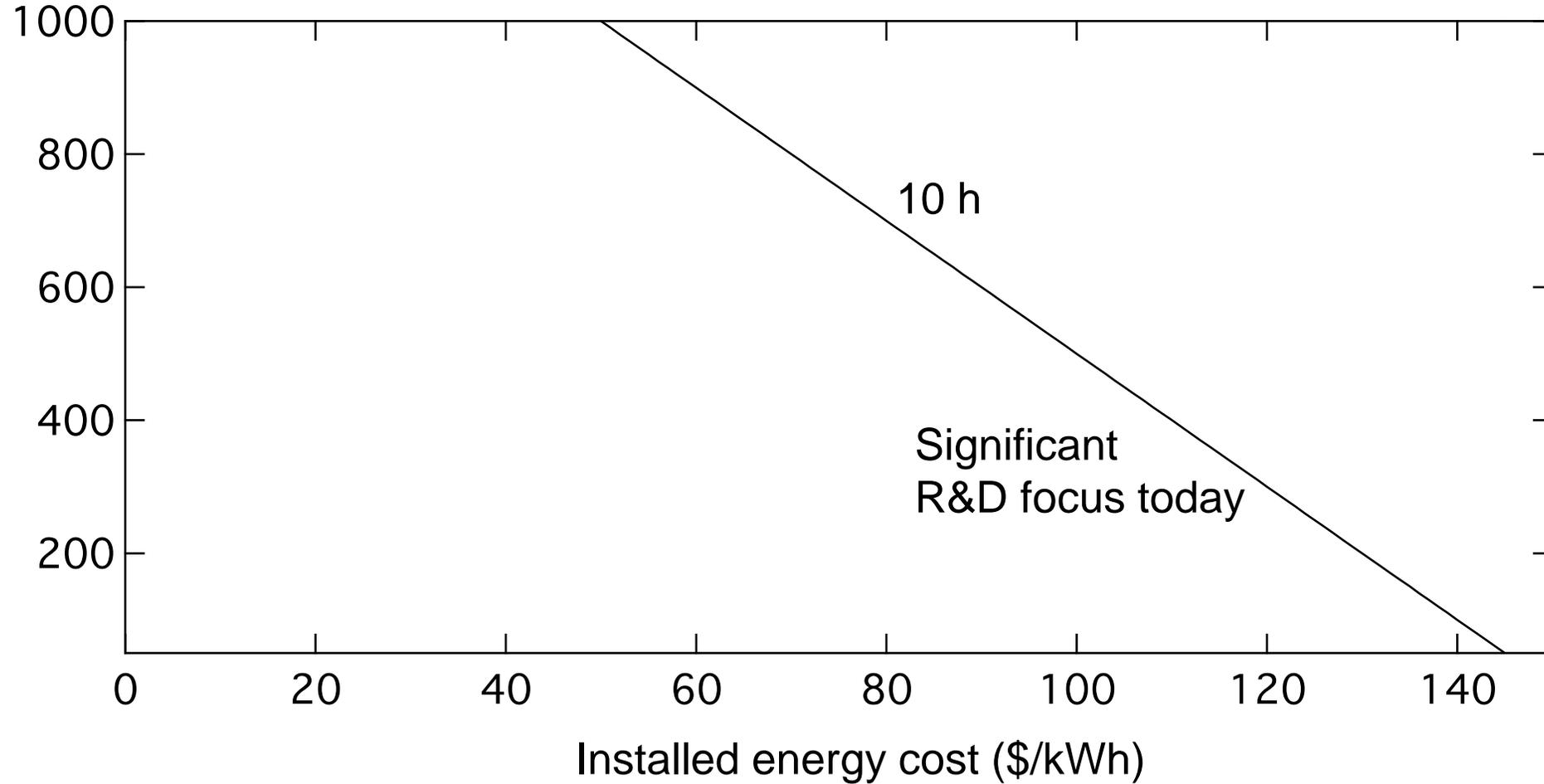
Complete system cost (\$/kWh)



Low energy costs are required

Installed power cost (\$/kW)

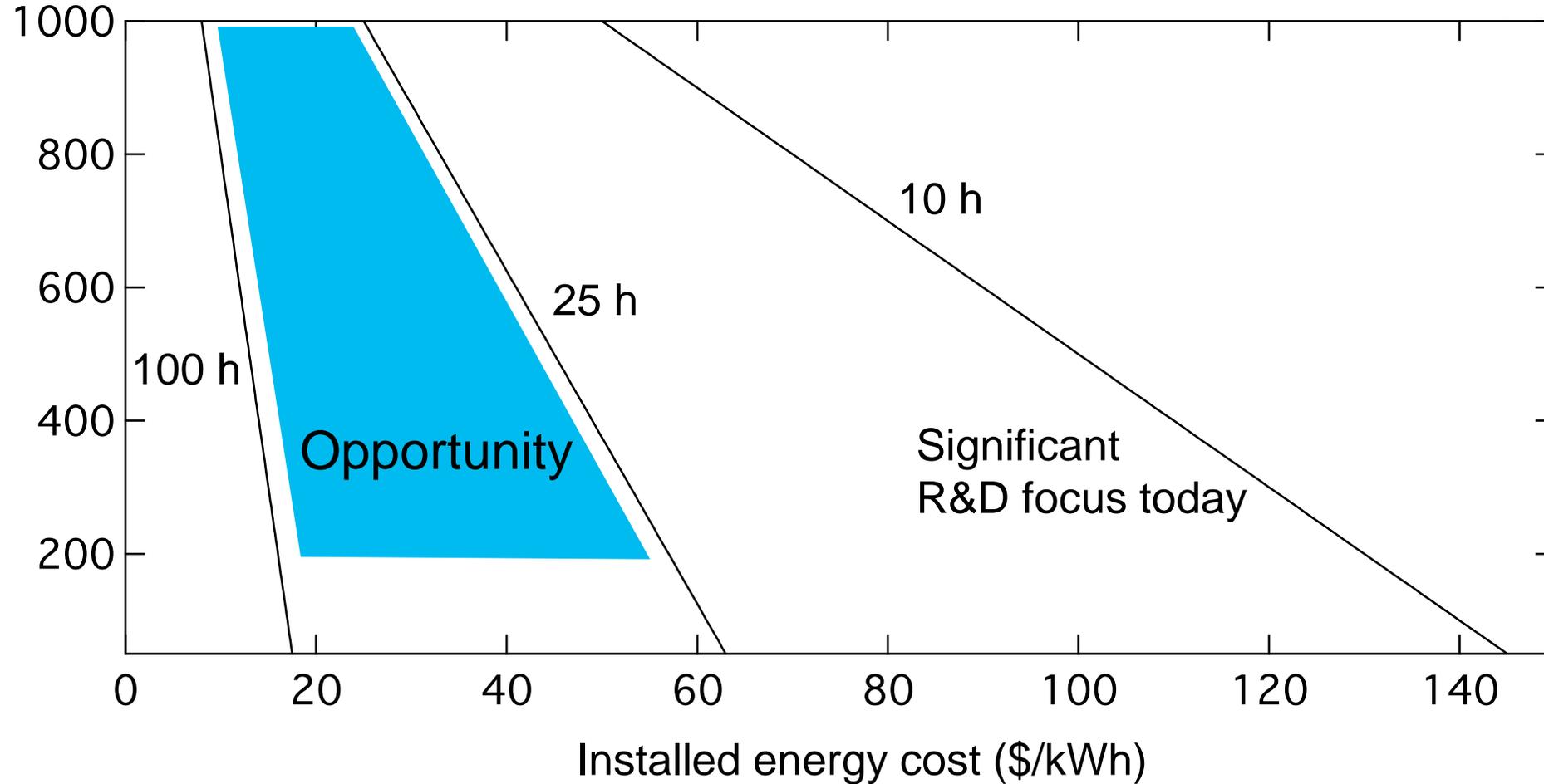
For a fixed 0.05 \$/kWh-cycle



Low energy costs are required

Installed power cost (\$/kW)

For a fixed 0.05 \$/kWh-cycle





What are some technical ideas for building long duration storage systems?