

Building a Local Renewable Energy System: The Electric Grid, Intermittency, and Algae

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Empowering Rural
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All electric grids must be perfectly “in balance” at all times, on all time scales

- Generation = Load
- Solved in different ways on different time scales
 - Decades: Long-term planning
 - Seasons: Seasonal “peakers”
 - Hours: Diurnal “generation stack”
 - Minutes: Spinning reserves, FCDM
 - Seconds: Frequency Response
 - Milliseconds: System inertia

How is this done?



Control room technicians schedule, call on, and adjust generators so that generation matches load

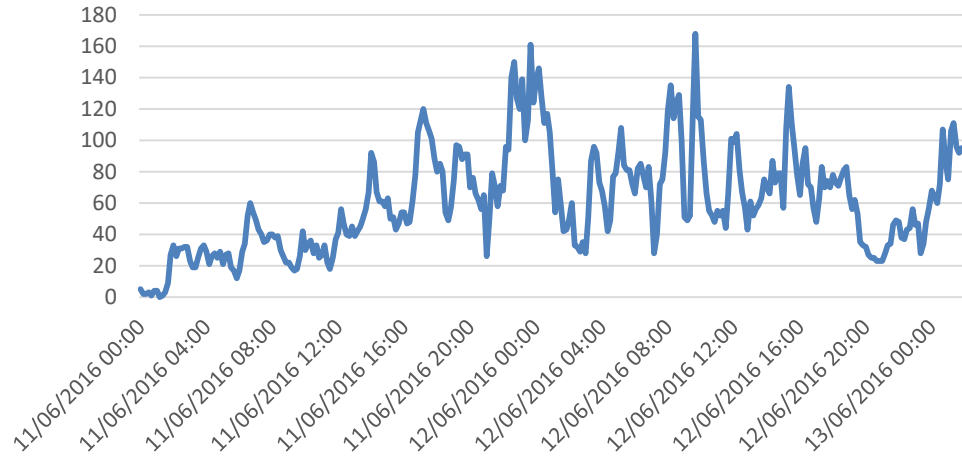
Most Renewable Energy Generation is Intermittent

- Wind
- Solar
- Tidal

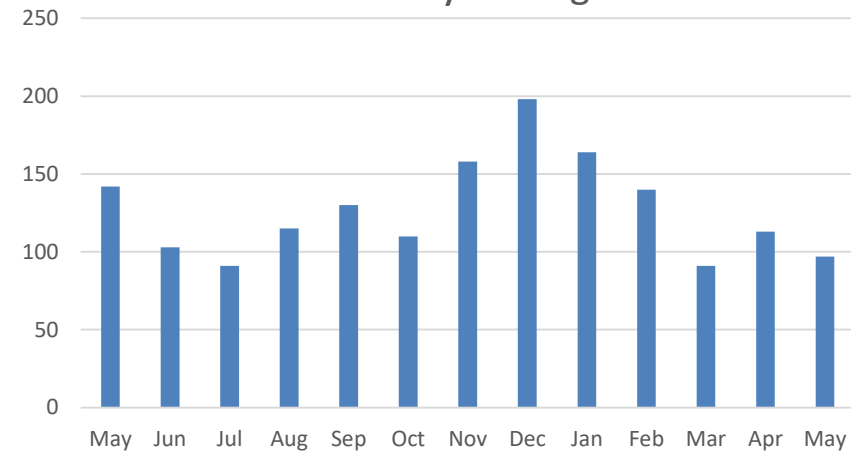
And wind and solar are intermittent on many different time scales

Ardnamurchan Wind Turbine

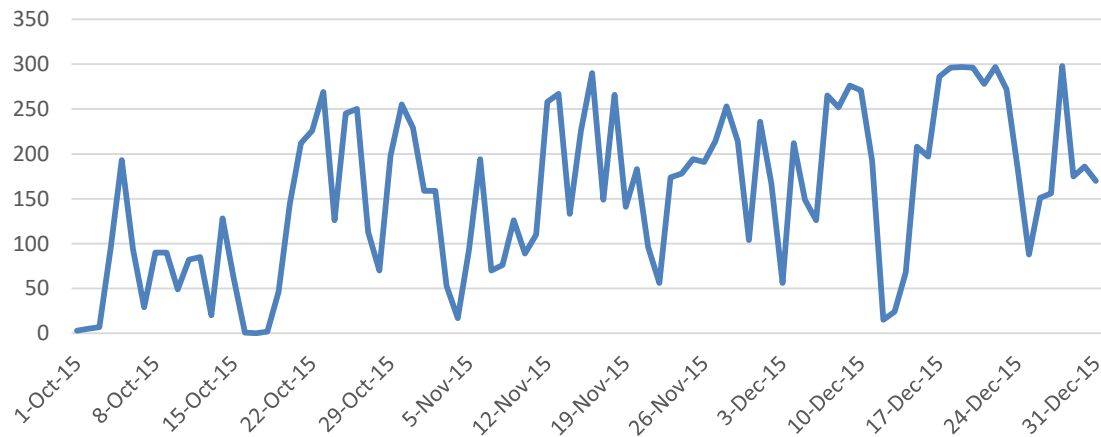
Ardnamurchan Turbine Output 10-Minute Average Power



Ardnamurchan Turbine Output Monthly Average Power

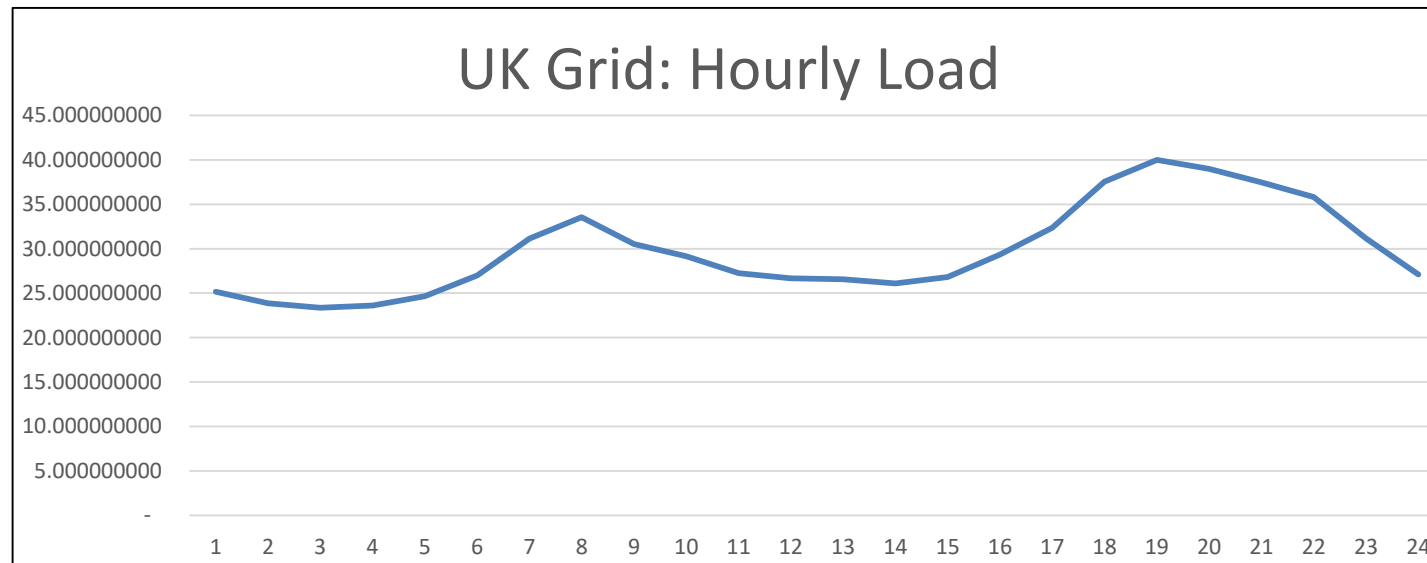


Ardnamurchan Turbine Output Daily Average Power



Renewable Integration: Load Variability

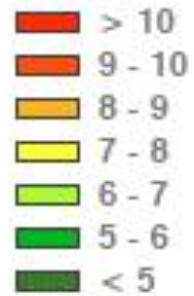
- Engineers adjust the output of power plants to follow (roughly) predictable variations in load



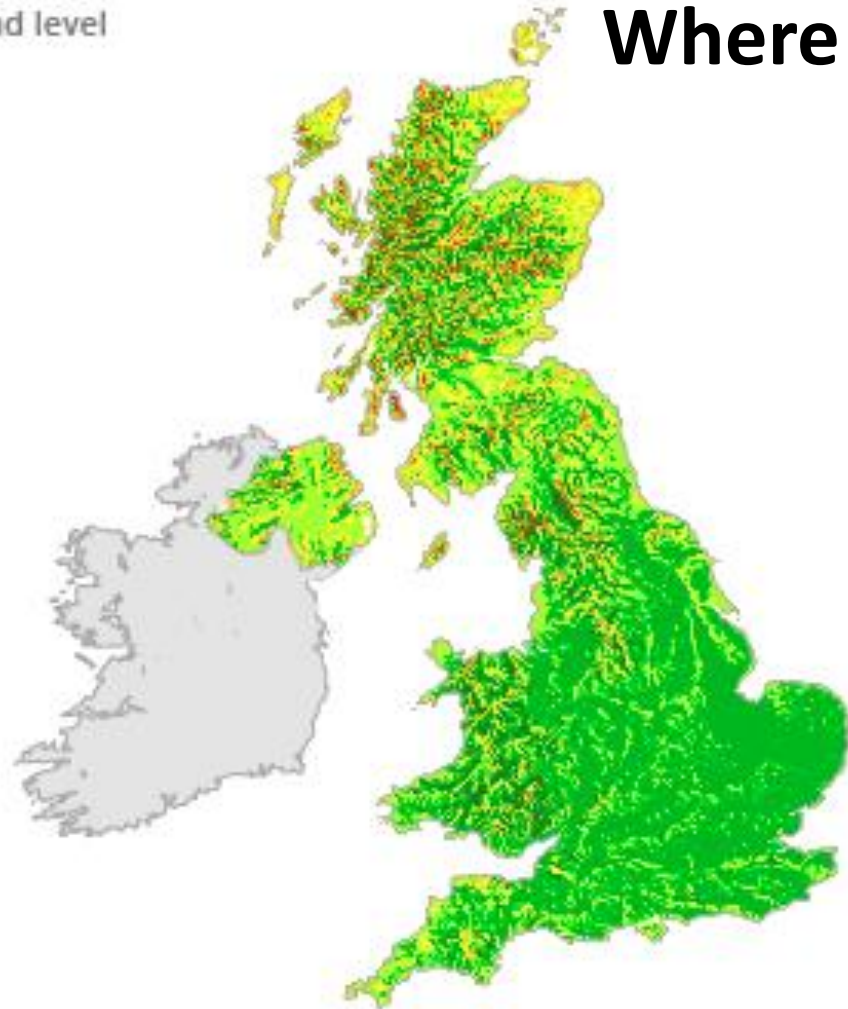
- Additional (unpredictable) variability poses serious technical and economic challenges to the operation of the grid

Most Renewable Energy Generation is Far Away

AVERAGE WIND SPEED
25 metres above ground level
m/s



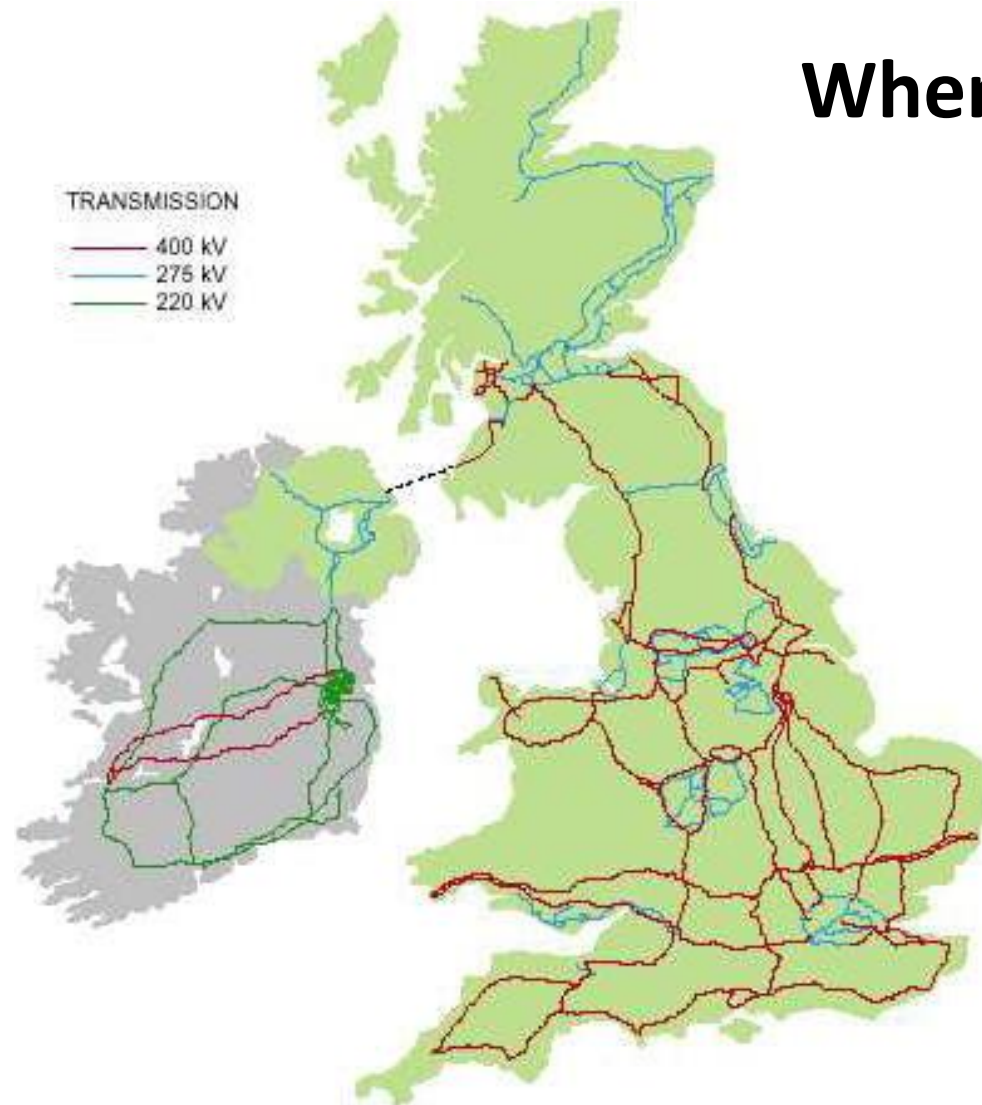
Where the Wind Blows



SOURCE: DTI

Most Renewable Energy Generation is Far Away

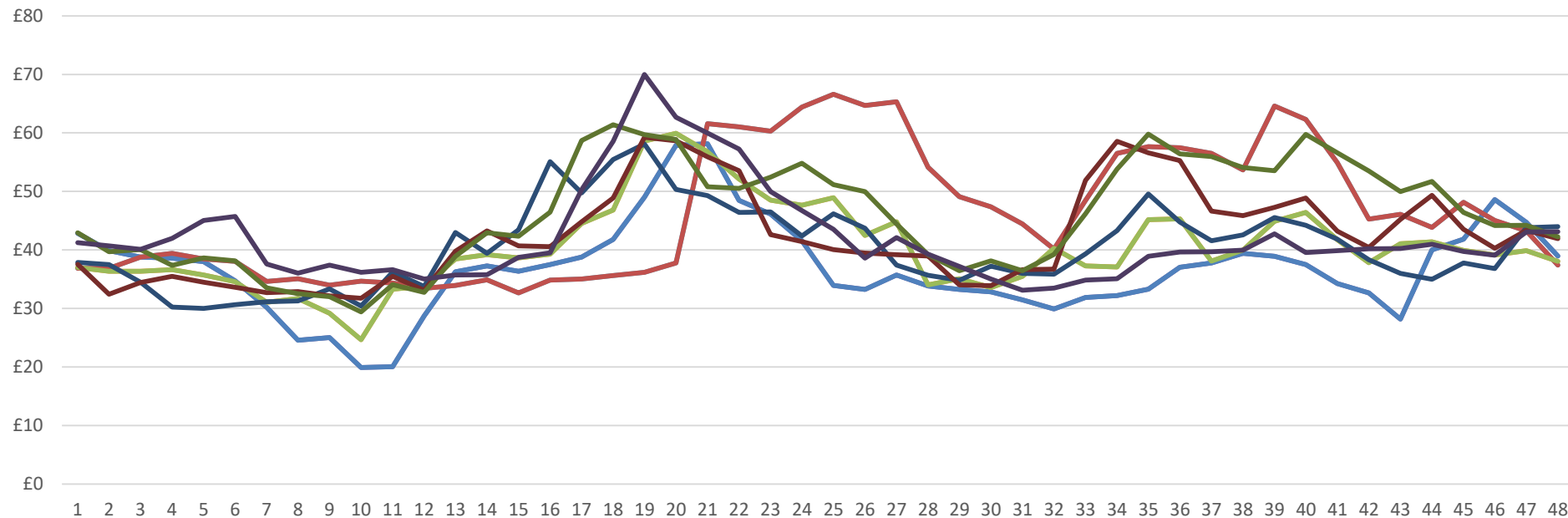
Where the Wires Are



Loads that can use intermittent generation, especially in places that are poorly interconnected, can be very valuable to the local grid

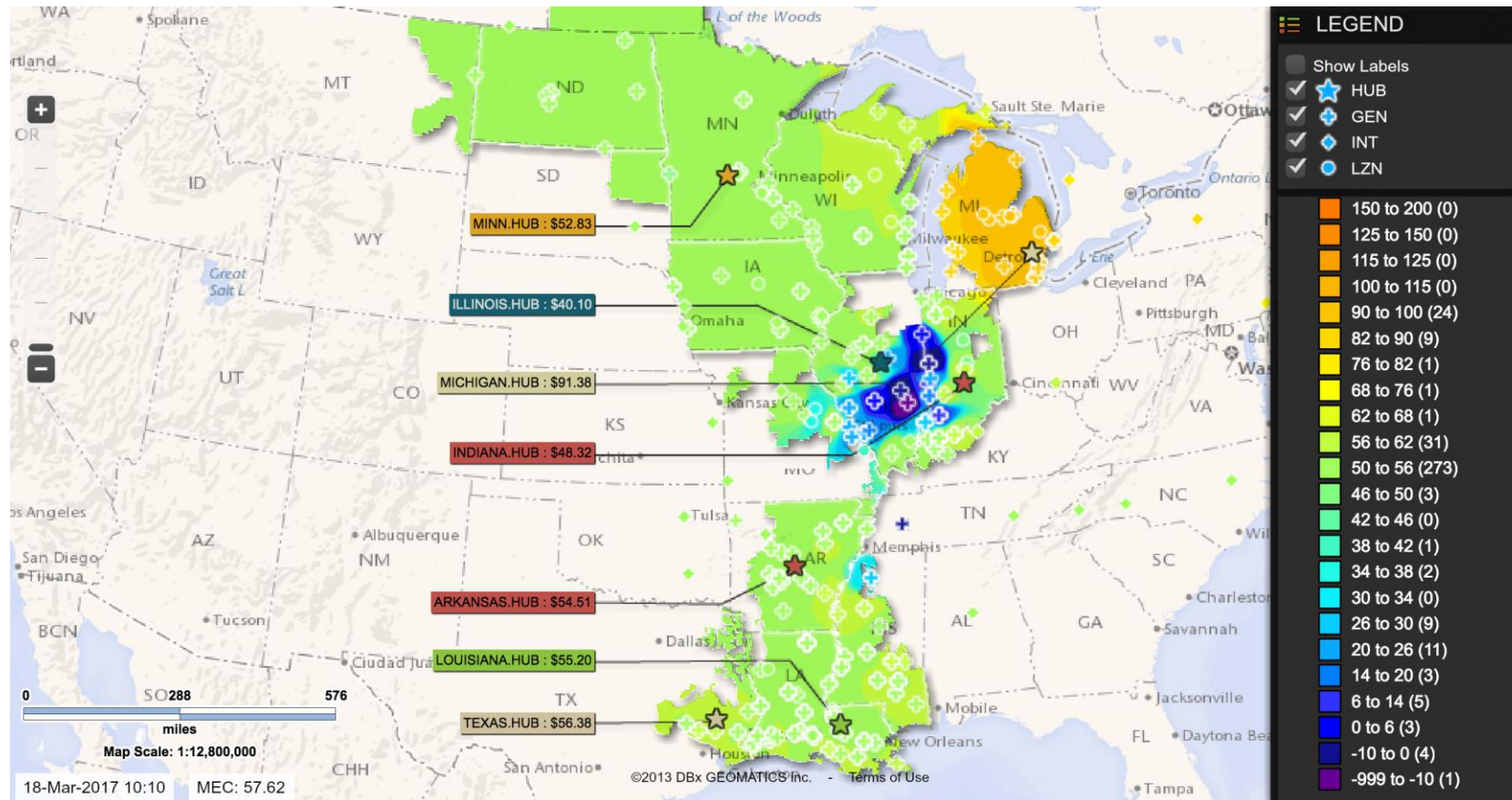
➤ Wholesale energy prices are volatile

UK Half-Hourly Wholesale Energy Prices



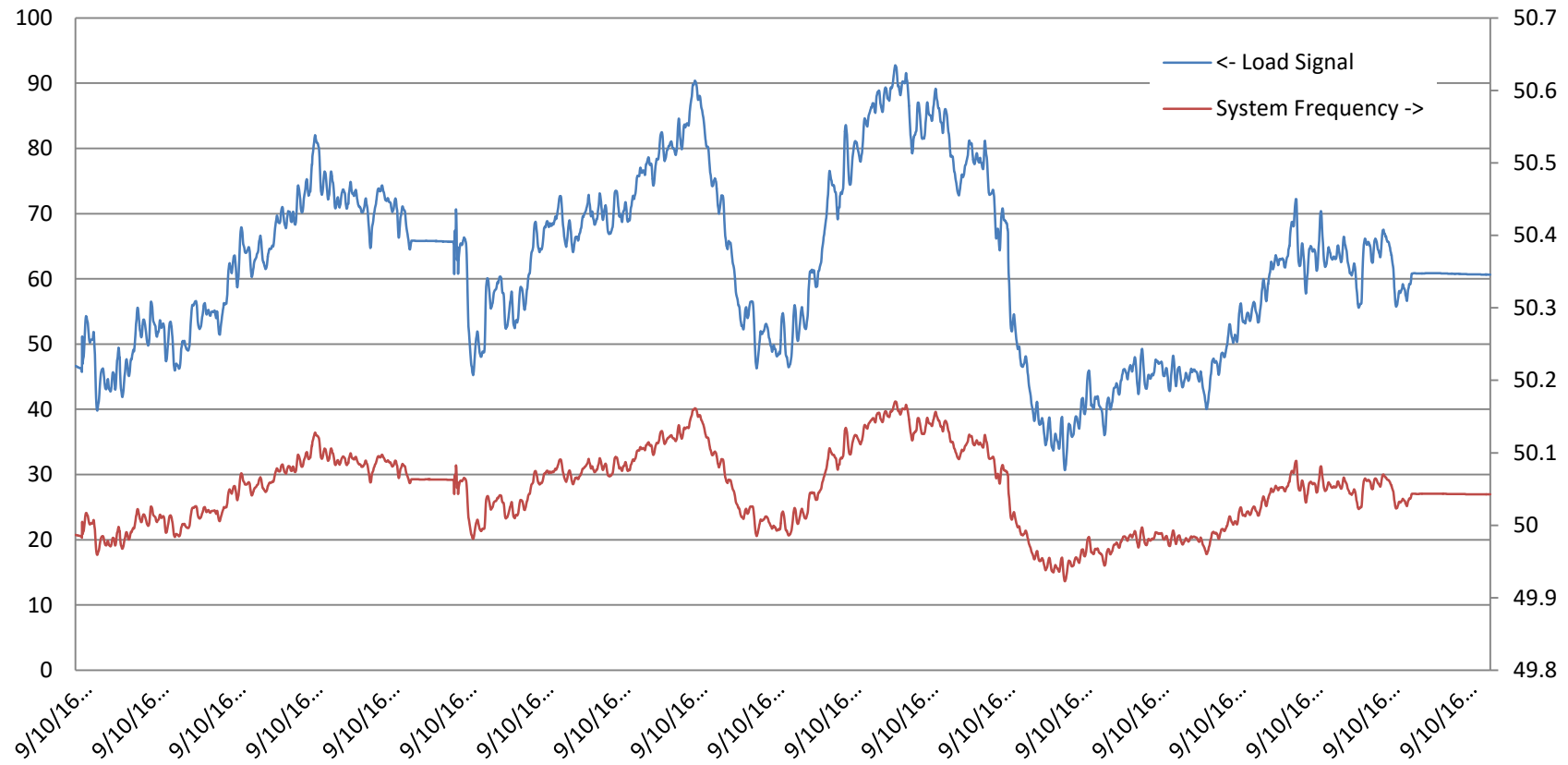
Loads that can use intermittent generation, especially in places that are poorly interconnected, can be very valuable to the local grid

➤ “Local” energy prices are *very* volatile

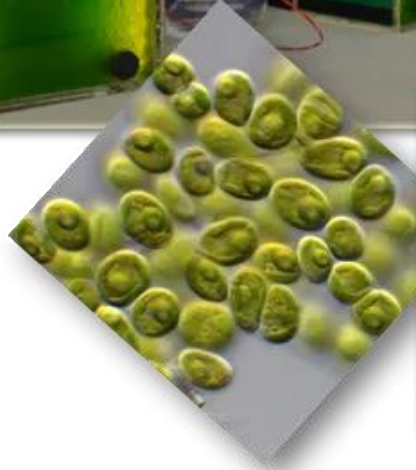
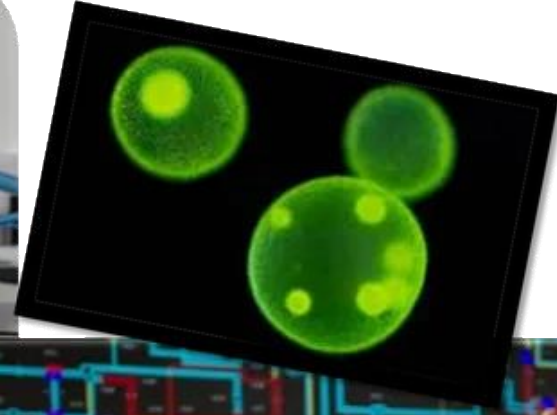


Loads that can “sell” variability to the grid can earn significant revenue

System Frequency and Frequency Response



What does this have to do with Algae?

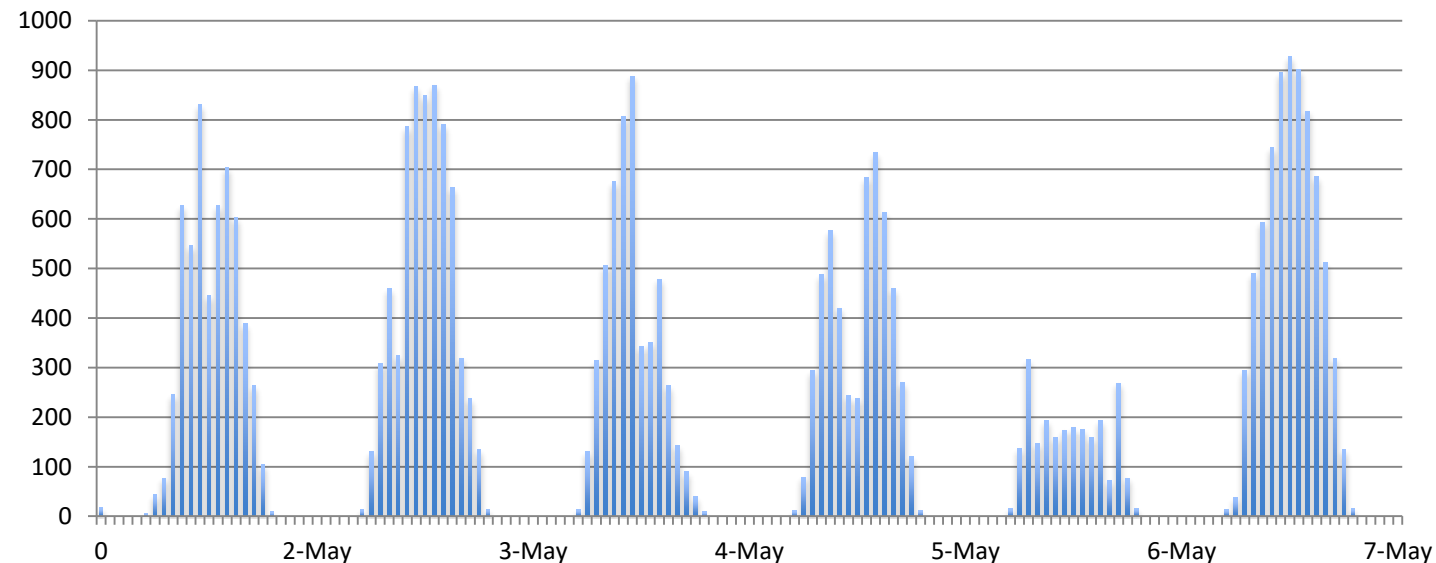


What does this have to do with Algae?

- The main cost of algae production is the cost of energy
- Algae can evidently survive, and thrive, with intermittent energy input

North Atlantic Insolation in Wh/m²

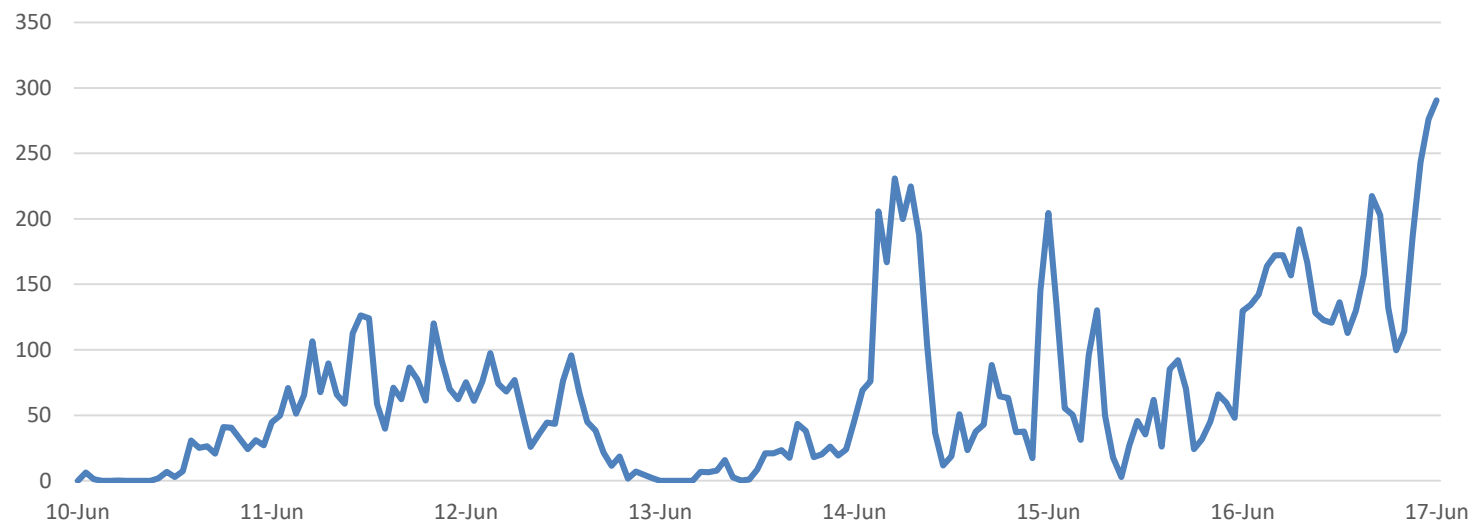
May 1- May 7 2010



What does this have to do with Algae?

- We have been running experiments to understand how various patterns of intermittence, valuable to the grid, affect algal production
- The economics of intermittent energy use look very attractive

Weekly Power Output of Ardnamurchan Wind Turbine



What does this have to do with Algae?

- Photo Bio Reactors will be able to:
 - Buy energy during the cheapest half hours in each day, potentially making “last minute” decisions, reacting to volatile electricity prices
 - Adjust load very quickly to offer Frequency Response services to National Grid
 - Make use of what would otherwise be curtailed-off wind generation, lowering the cost of algae production and allowing for the fuller development of Western Scotland’s abundant renewable energy resource



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