Wind Energy Forecasting for Distributed Generation

SmartCoDe Expert Cooperation Workshop 2011

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Dissemination Level: Public

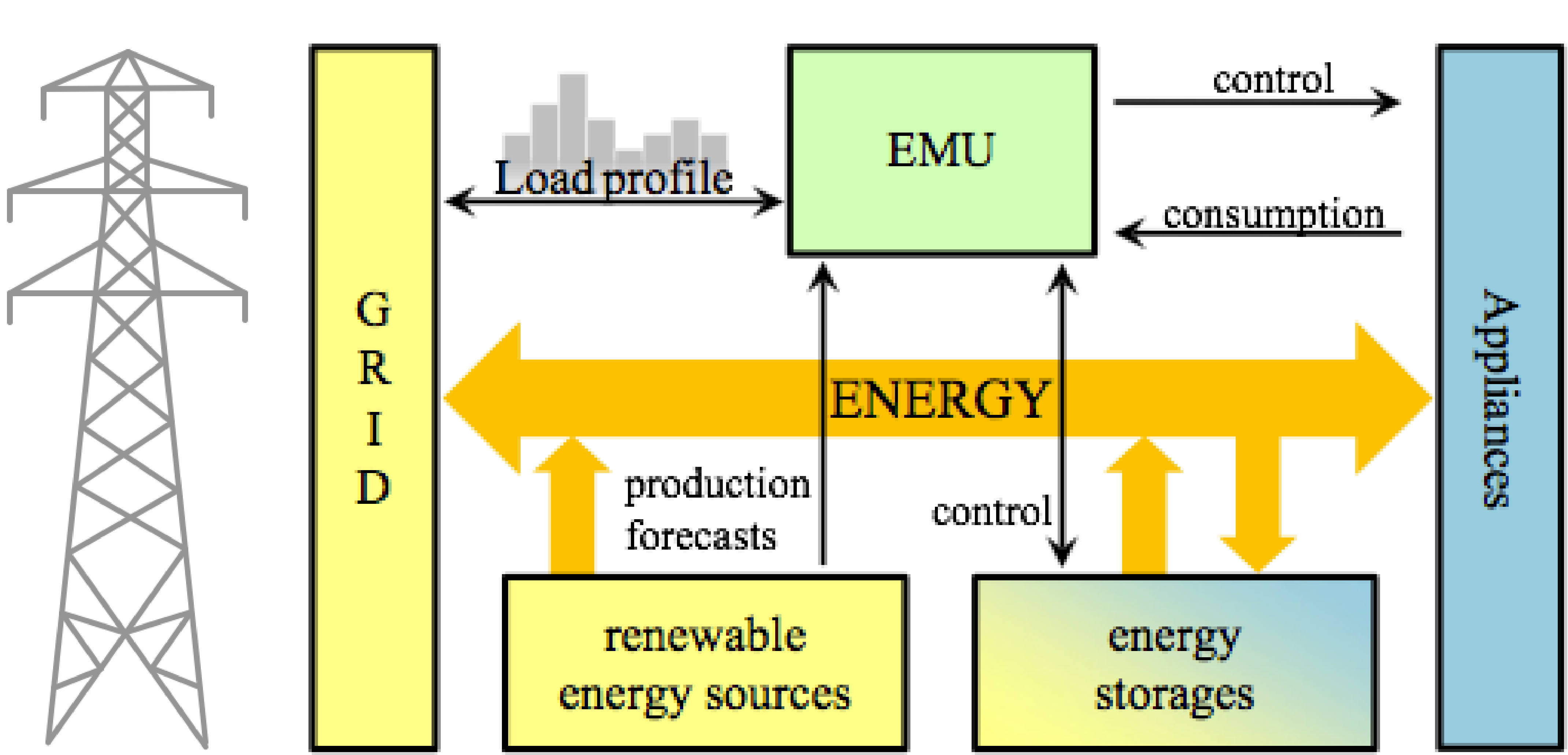
Energy Neighbourhood:

–Building with Energy Using Products (EUP)

–Daily energy use profile

–Local Energy Producer (LEP) in the form of a vertical axis wind turbine

–Energy Management strategy to optimise local energy use and local energy production

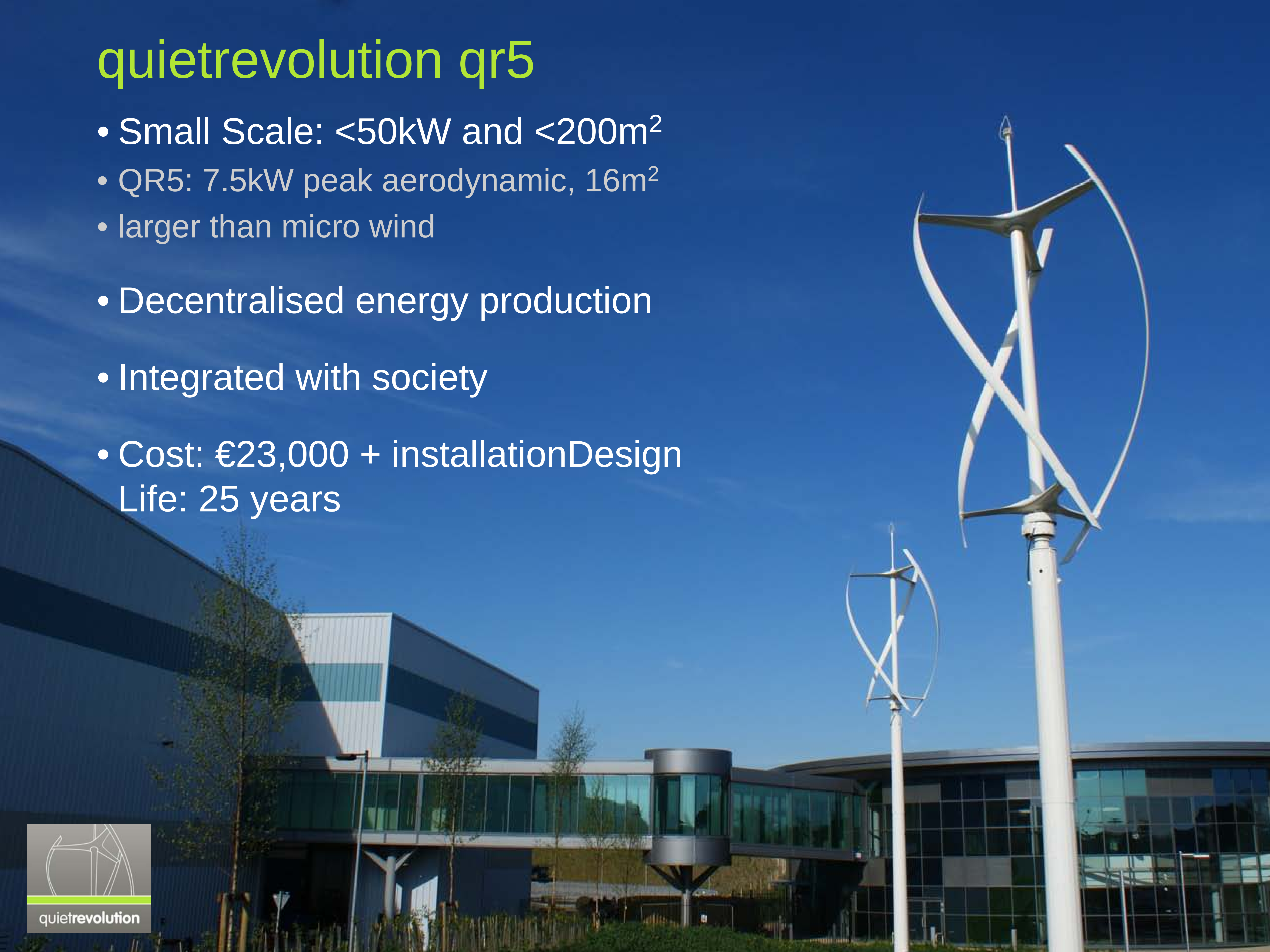


Energy Neighbourhood:

–Energy Management strategies become much more interesting when you integrate energy storage and local energy production

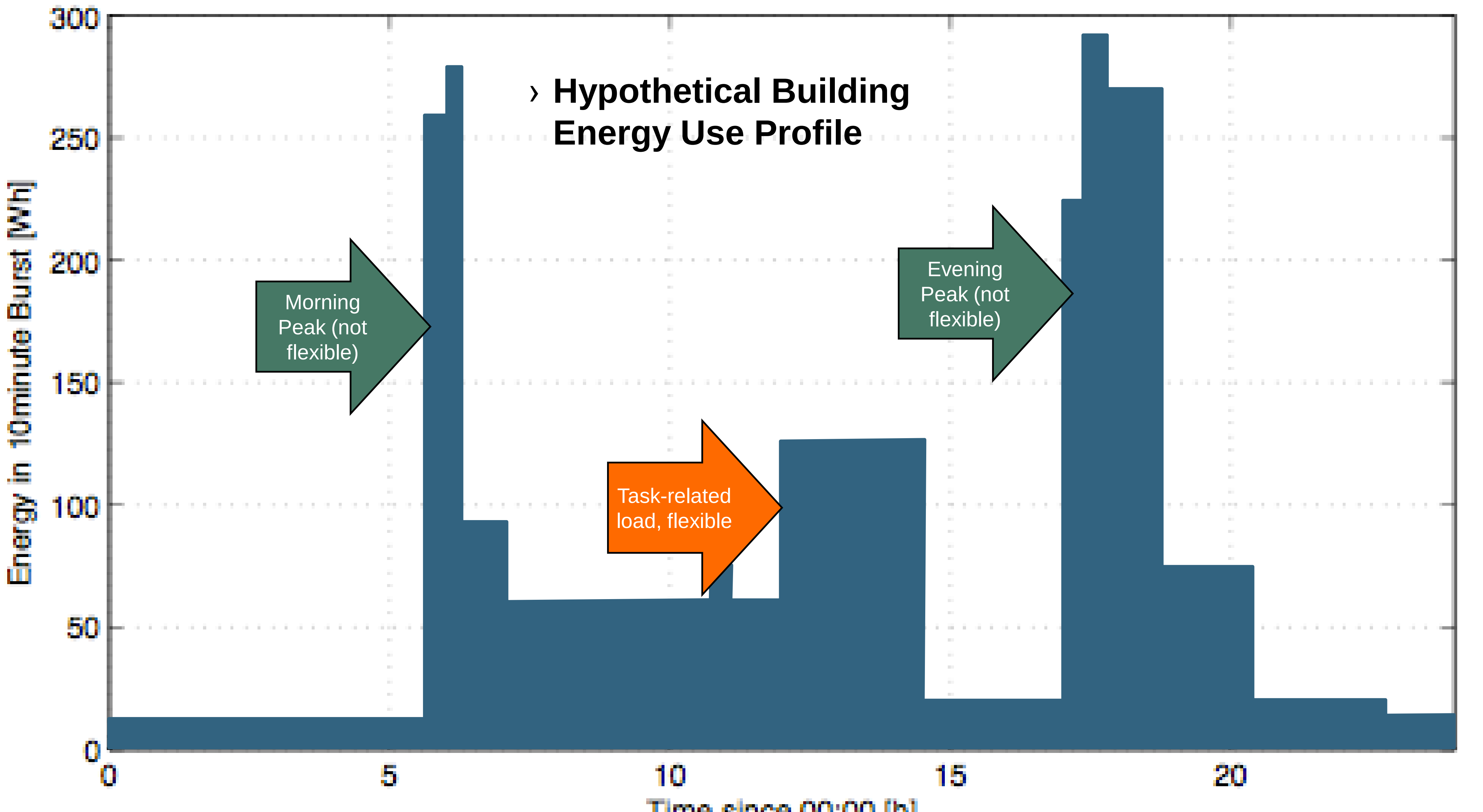
–Energy storage can be a variety of different “virtual storage” solutions. LEP is a qr5 vertical axis wind turbine

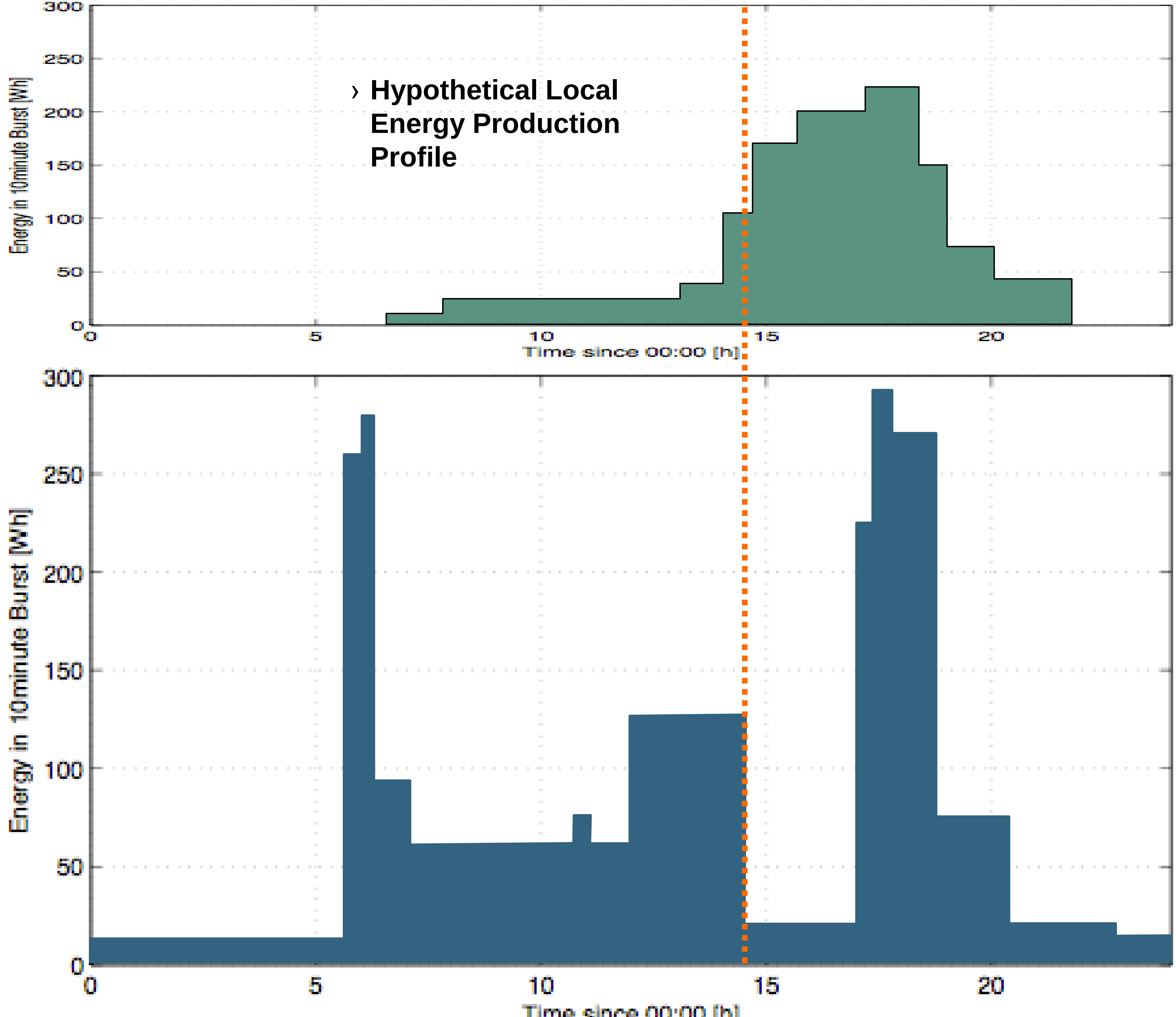
–Objective is to optimise the local energy consumption


quietrevolution qr5
• Small Scale: <50kW and <200m²
• QR5: 7.5kW peak aerodynamic, 16m²
• larger than micro wind
• Decentralised energy production
• Integrated with society
• Cost: €23,000 + installationDesign Life: 25 years
quietrevolution

Why do we need Energy Forecasting?

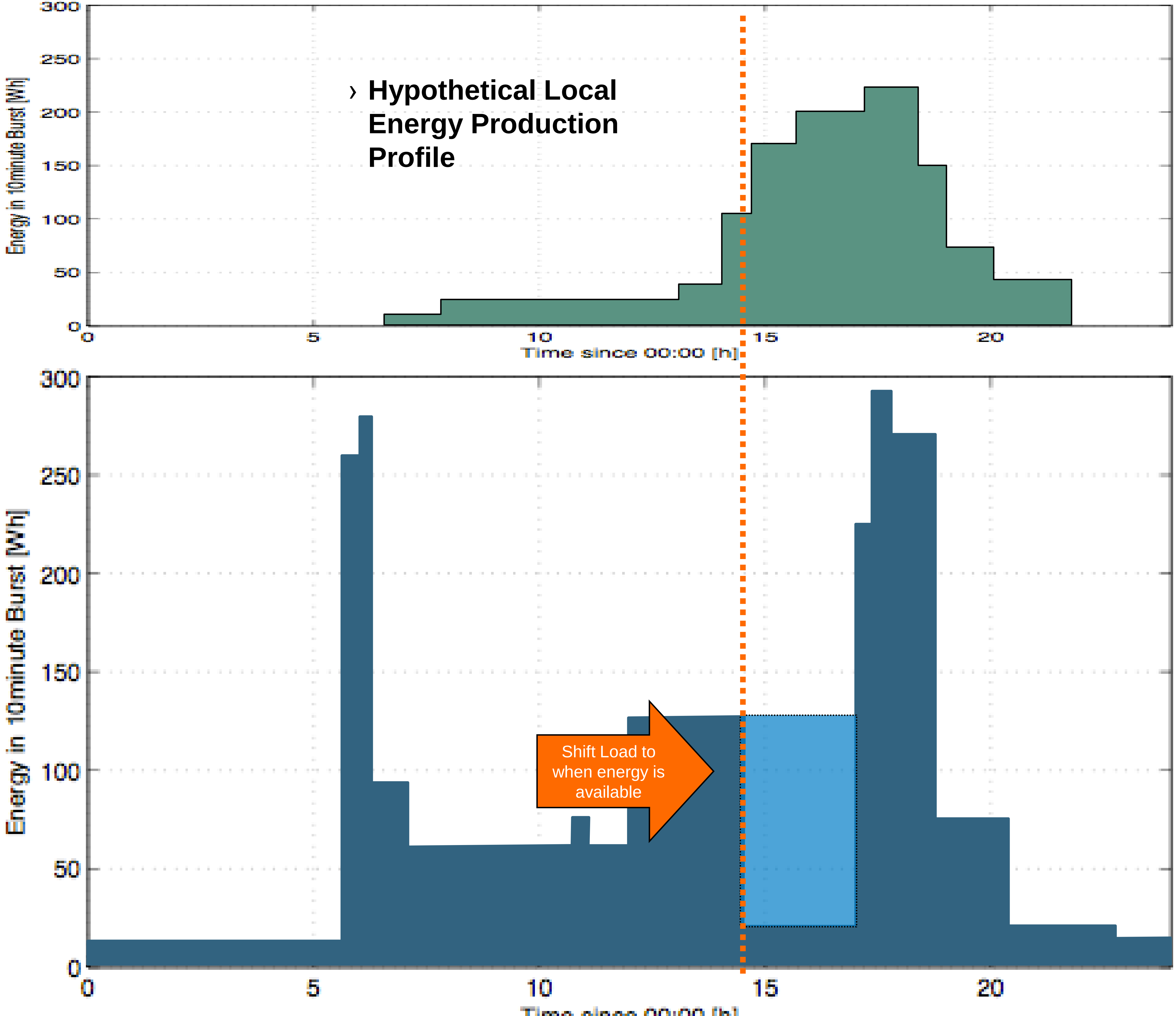
- DSM and SmartCoDe project becomes a lot more interesting if there is a **Local Energy Producer**
- Provides end user with options:
  - use locally generated energy (offset local consumption); coordinate demand with forecast supply
  - or sell back to grid (export) when tariff is high
  - potential to engage in spot energy market (strategically timed export)



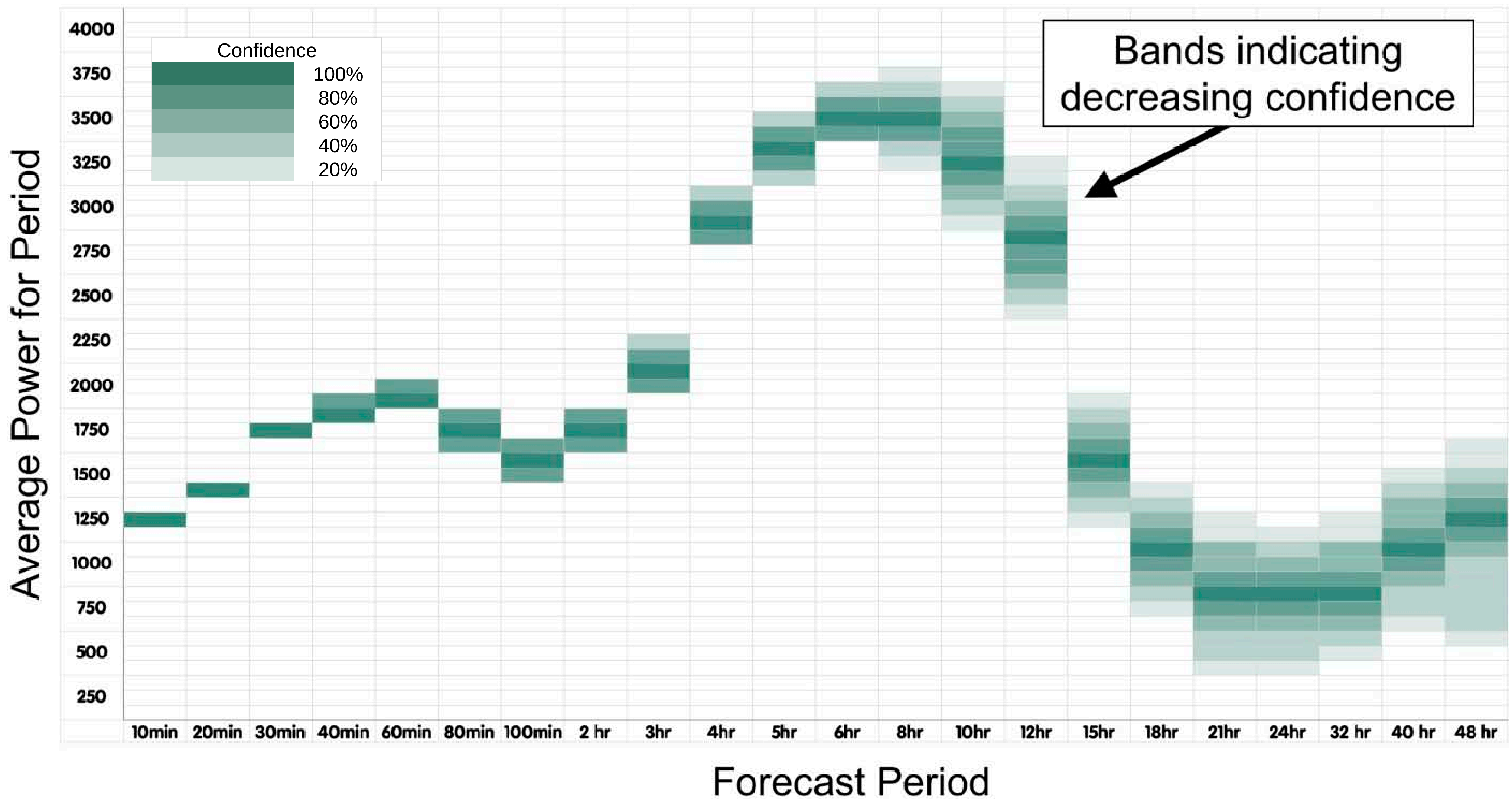


› Hypothetical Local Energy Production Profile
Energy in 10minute Burst [Wh]
Time since 00:00 [h]
0
50
100
150
200
250
300
5
10
15
20

› **Hypothetical Local Energy Production Profile**



Wind energy forecast can be critical input for effective demand side management



› Energy forecast is supplied to Energy Management Algorithm

› Represents forecast energy for period

› Duration of period gets longer the further into the future we look

› Band of confidence to aid decision making

Why is quietrevolution **interested in SmartCoDe?**

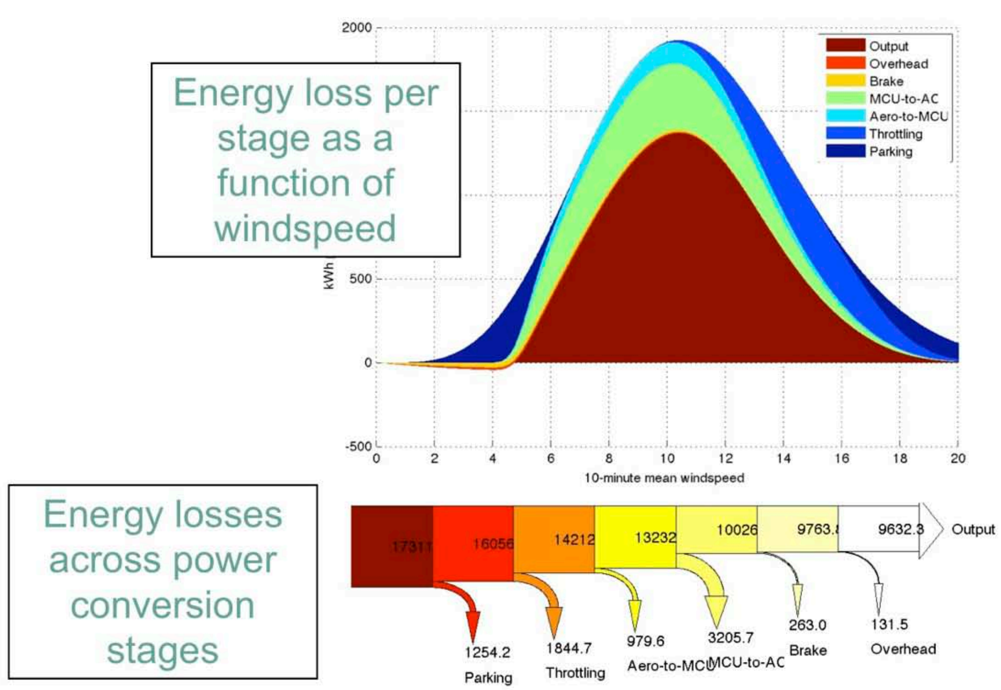
› Effective integration of Local Energy Producer (such as a small-scale wind turbine) into energy neighbourhoods can:

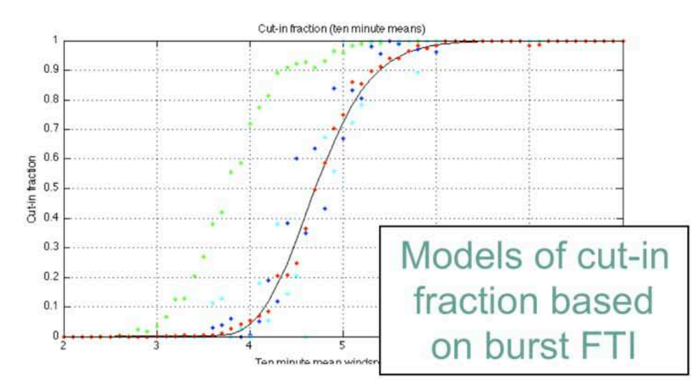
  – **Increase the value of the energy produced by the turbine**
  – **Decrease the volatility of the renewable energy source to the overall electrical network**

Wind Resource Forecast -> Wind Energy Forecast

› In year 1 of the SmartCoDe project we developed an Advanced Energy Yield Model

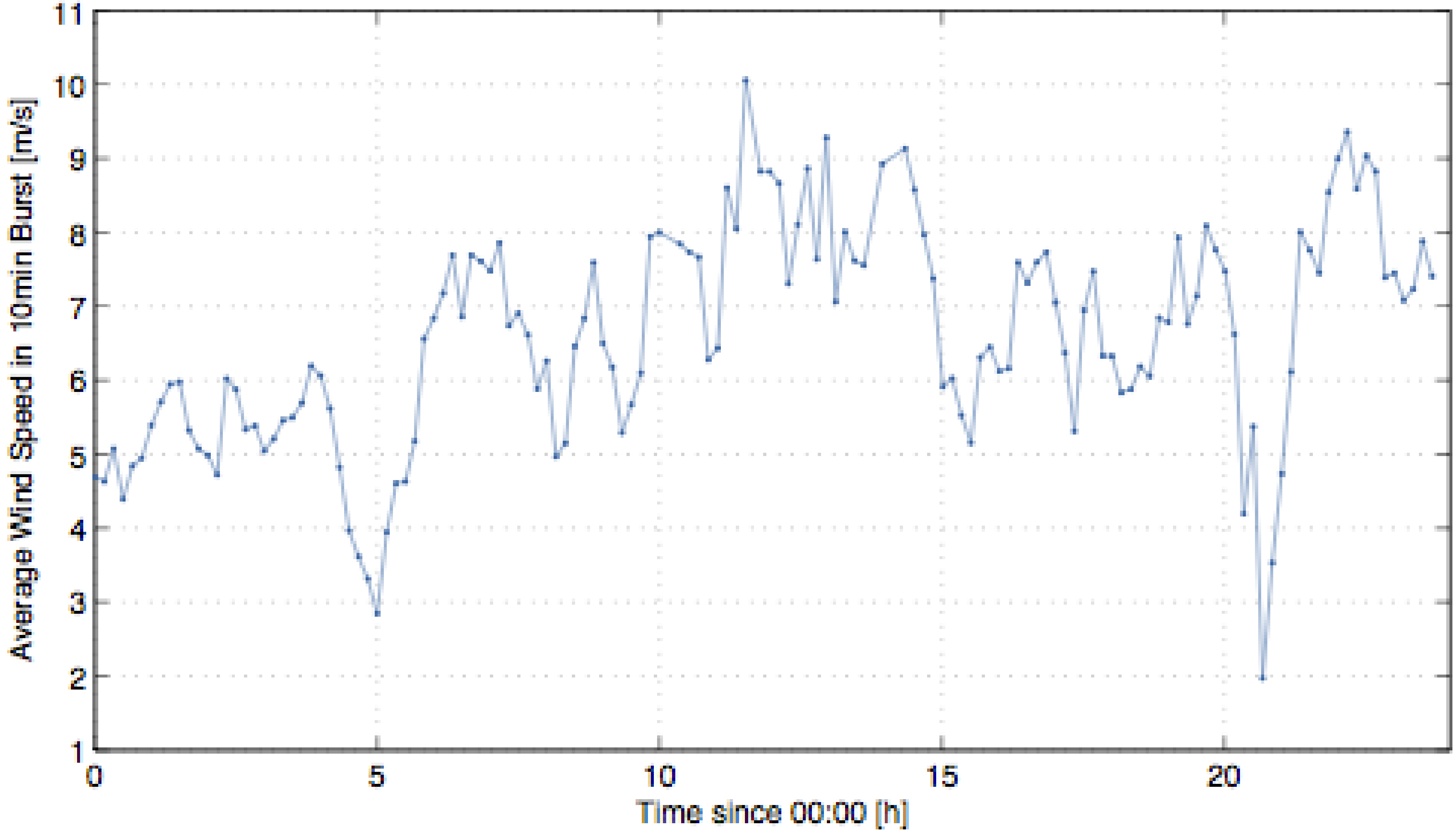
› Allows us to accurately predict energy output of the wind turbine based on the available wind resource, even for very short periods





The challenge of wind resource forecasting

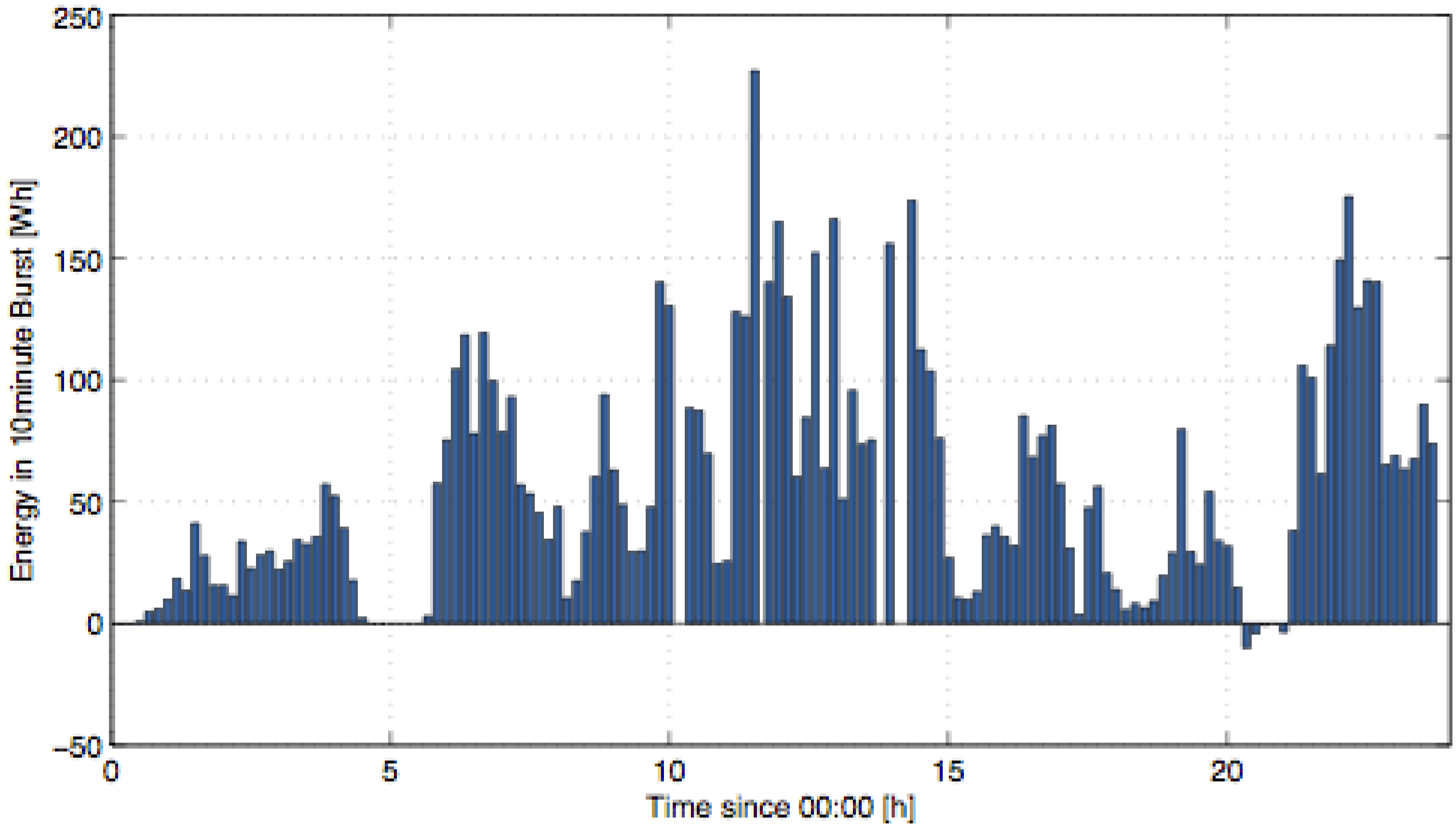
› Wind speed is very variable or "volatile"



– The above is a 24 hour period (September 8, 2011) measured wind data from the SmartCoDe demonstrator site presented as ten minute averages

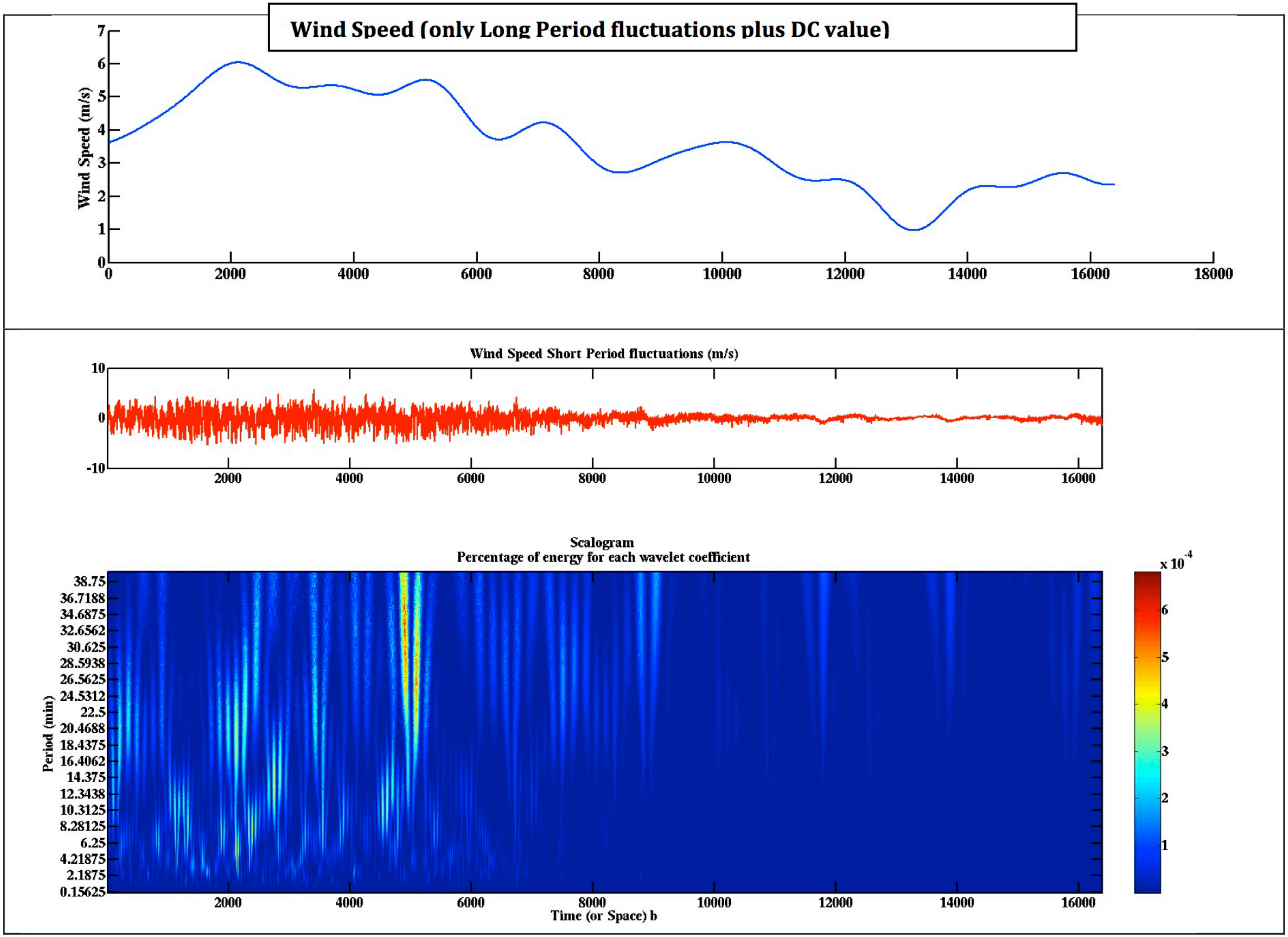
The challenge of wind resource forecasting

› And worse, energy is proportional to the **cubic** power of wind speed!



– The 10 minute average energy produced by the SmartCoDe demonstrator turbine for the same 24 hour period.

Fluctuations exist in both frequency and time



How do we do wind energy forecasting?

- We are **not re-inventing** weather forecasting!
- Use weather forecasting of wind resource from a nearby weather station(s) as **input** to energy model
- But forecast information is given at coarse **macro scale**, far away from wind turbine, and usually at wrong height
- Need to **correct** macro scale forecast to **local micro-scale**

How do we “correct” the weather forecast?

One Option: physical model

› Need to **correct** macro scale forecast **to local micro-scale**

–Local terrain roughness

–Local turbine height

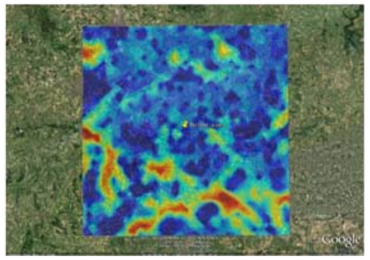
› Need to understand atmospheric boundary layer physics

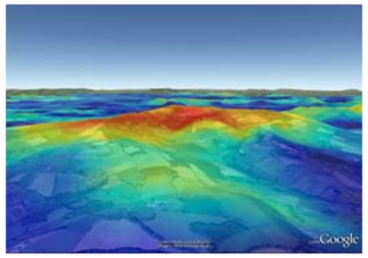
› **Not a practical solution**

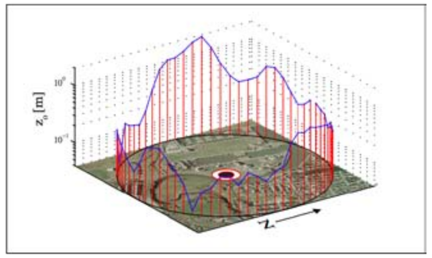
–requires too much detail

–too much subjective “tuning” required

–expensive and not robust







z_o [m]	Classification	Landscape description
0.0002	Sea	Water surface: Open sea or lake, tidal flat, snow-covered plain.
0.005	Smooth	Featureless land surface: Beaches, marsh and fallow open country.
0.03	Open	Level open country: Heather, moor and tundra.
0.10	Roughly open	Open agricultural: Cultivated or natural area, low crops or plant cover.
0.25	Rough	Built agricultural: Cultivated or natural area, high crops and buildings.
0.5	Very rough	Suburban: Intensely cultivated landscape
1.0	Skimming	Towns: Densely built-up area.
⩾ 2	Chaotic	High-rise: City centres with a mixture of

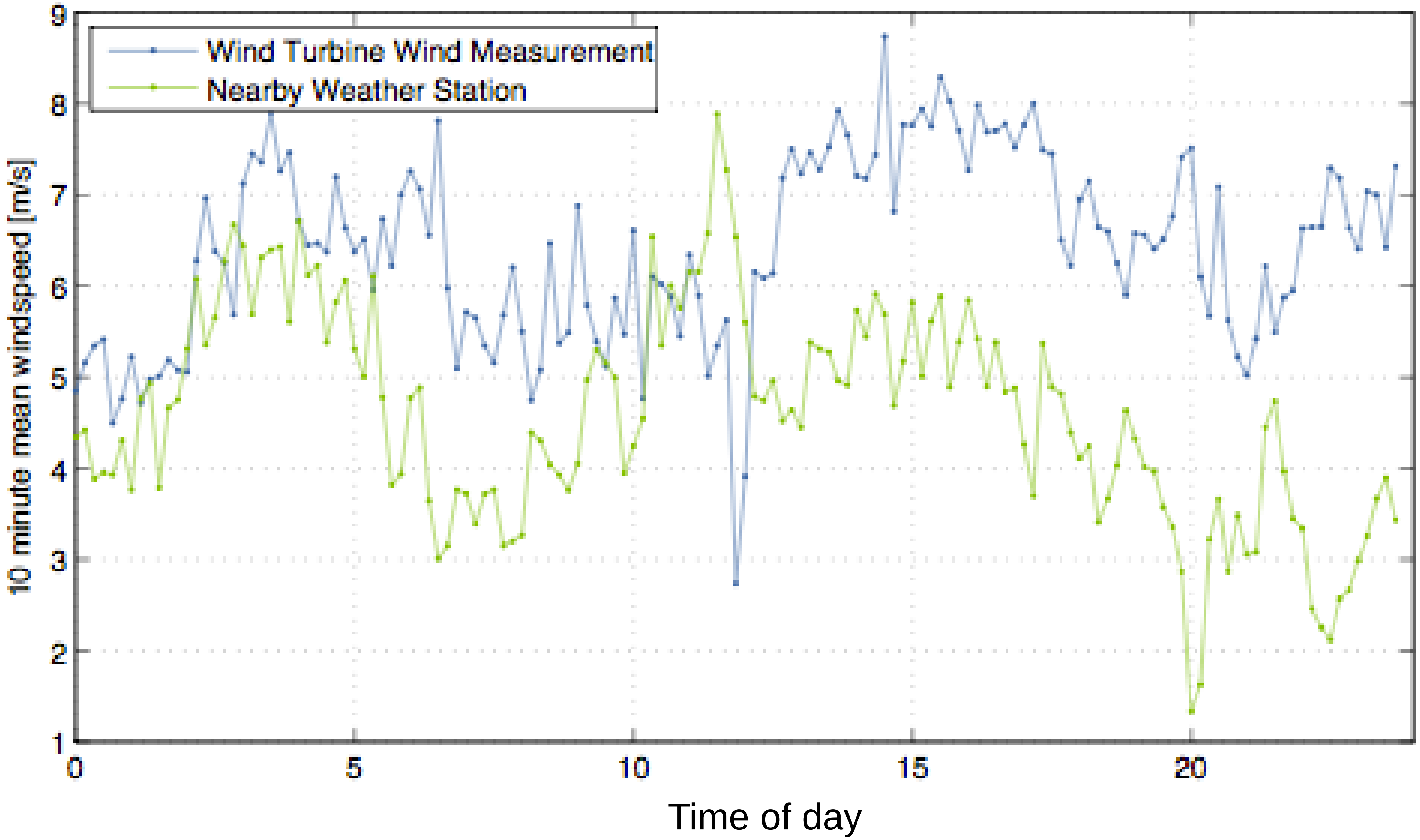
Existing classification of Z_0 is very subjective and prone to significant error

How do we “correct” the weather forecast?

Better Option: fit empirical model using “machine learning” (such as ANNs and variations)

- Identify key variables: wind speed, turbulence, wind direction
- Start by **training** the model
  - provide a data set of **historical** data from nearby weather station
  - local wind data from turbine for the same period of time
  - need to judiciously select training data to provide a **complete** set of statistics but at same time avoid over-learning
- Once model has learnt how to correct weather station to local turbine based on historical data, can apply to future wind forecast
- In parallel, continue machine learning
  - continue to compare current conditions at local site to current conditions at weather station. Model adapts to longer-term variations, such as seasonal changes or local topographical changes (growth of trees, new buildings)
- Inconsistency in mapping weather forecast can provide input to confidence weighting

Correct nearby weather station to local turbine



– Real-world data is presented from qr5 wind turbine and a weather station located 21 km away
– Correlation is not simply scaling absolute data - need to understand underlying physics
– Additional inputs are turbulence in each 10 minute burst and average wind direction

Wind Energy Forecasting for Distributed Generation

- Integrating Local Energy Production into an energy neighbourhood opens up many more opportunities for effective Energy Management
- Knowledge of future energy production (i.e. wind energy forecast) needs to be matched with expected energy demand profile for best results
- Wind energy forecast is challenging due to volatility of wind
- Use existing nearby weather station forecasts as input - don't reinvent the wheel!
- Develop machine-learning algorithms to correct weather station wind forecast to local wind turbine location
- Model is continuously adapted with time

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