

Probabilistic forecasting:

Development of novel products for advanced operational needs

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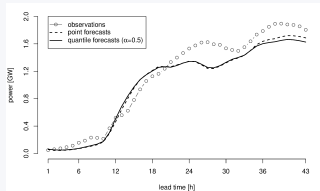
What makes a forecast probabilistic?



All forecasts actually are probabilistic!

Point forecasts

A single-value per lead time

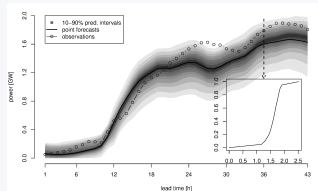


In practice:

- ▷ conditional expectation
- ▷ quantile forecasts

Interval forecasts

A range of potential outcomes with a given probability

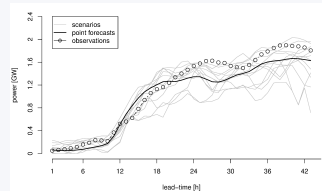


In practice:

- ▷ prediction intervals
- ▷ density forecasts

Scenarios

Alternative plausible realizations



In practice:

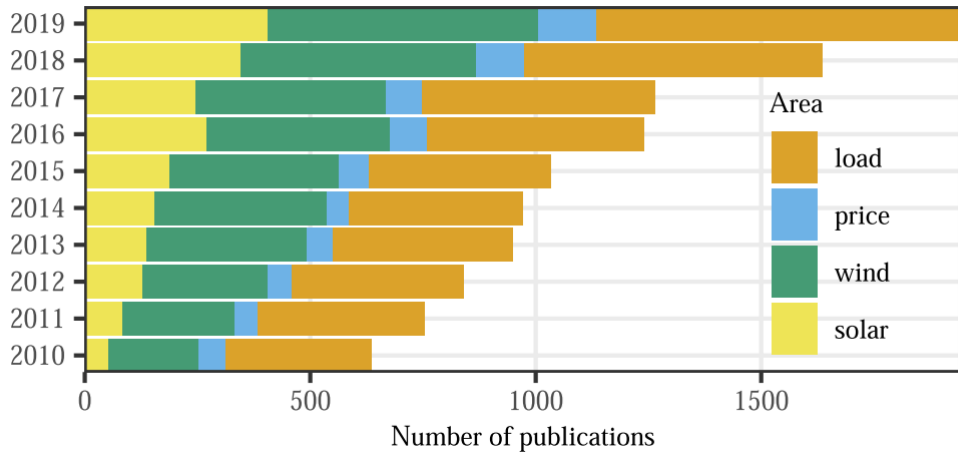
- ▷ statistical scenarios
- ▷ ensemble forecasts

And so... what is new with probabilistic forecasting?

- 1 Homogenizing the state of the art within energy forecasting
- 2 Adapting to operational needs
- 3 Going towards data monetization

- ➊ Homogenizing the state of the art within energy forecasting

They are catching up!



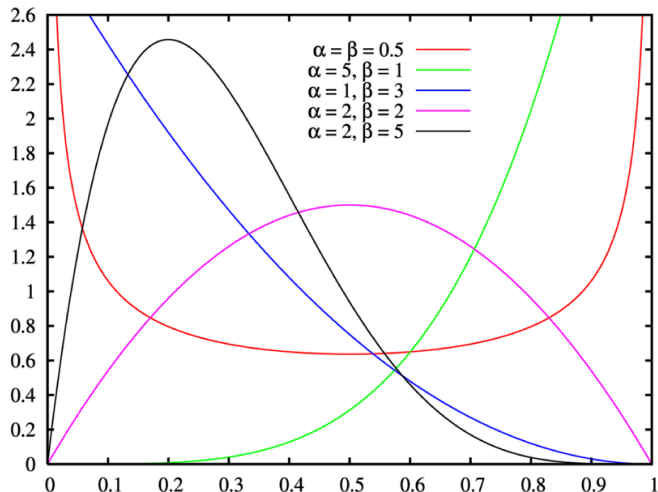
source: Hong *et al* 2020 - "Energy forecasting – A review and outlook"

Also with **new probabilistic forecasting problems** being looked at: DLR, flexibility, etc.

A lot of R&D concentrates on basic problems over which we might have gone too fast in the past, e.g.

- the **bound problem** – power generation and consumption is necessarily double-bounded
- **parametric approaches** – which distributions are most appropriate, and why?
- forecast verification... it is not that easy!
- etc.

Those challenges are common to nearly all energy forecasting problems

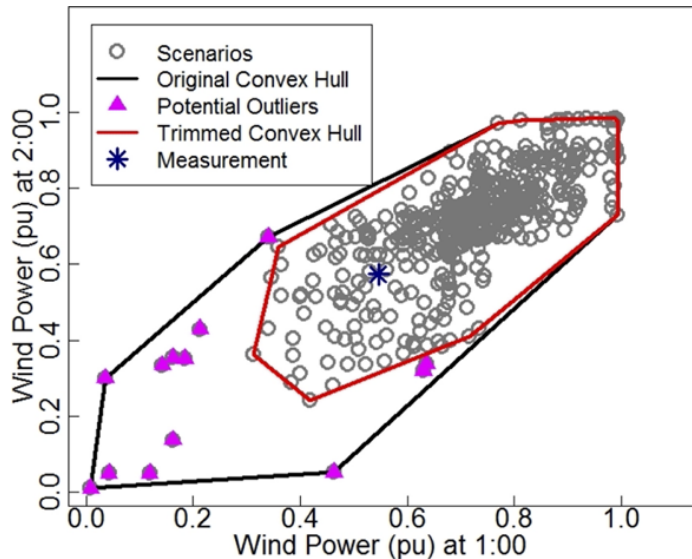


source: wikipedia

2 **Adapting to operational needs**

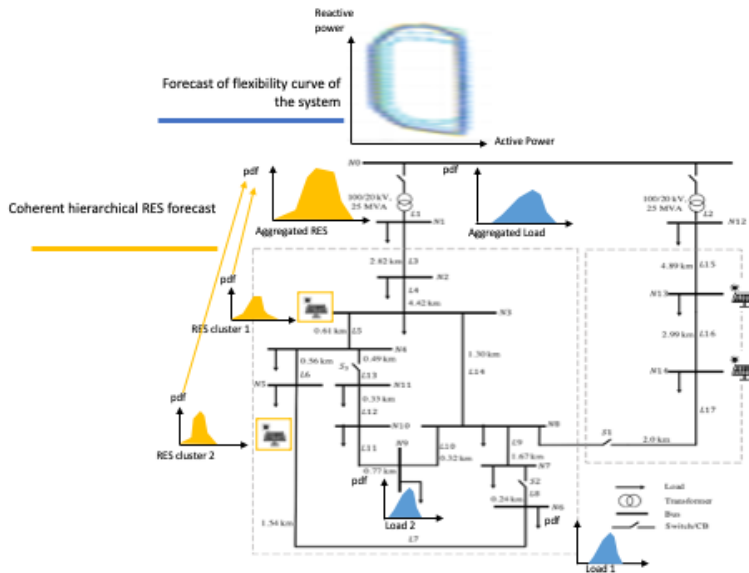
(some of the following talks will look into that extensively!)

- Today we are used to predictive densities and trajectories...
- That does not mean they are the best input to many modern-days operational problems...
- For some problems (e.g. robust and chance-constrained optimization), it makes sense to have forecasts in the form of ellipsoids and polyhedra.



Example 2: network-aware flexibility forecasts

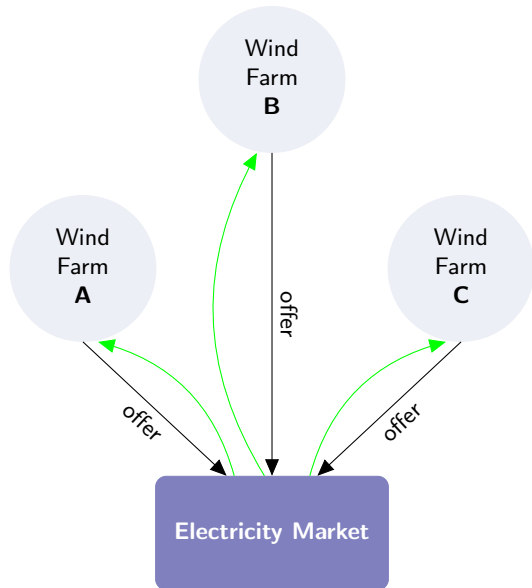
With distributed RES at distribution grid level, one may need additively consistent forecasts, and projected in the flexibility space...



3 Collaborative and market-based analytics

Context:

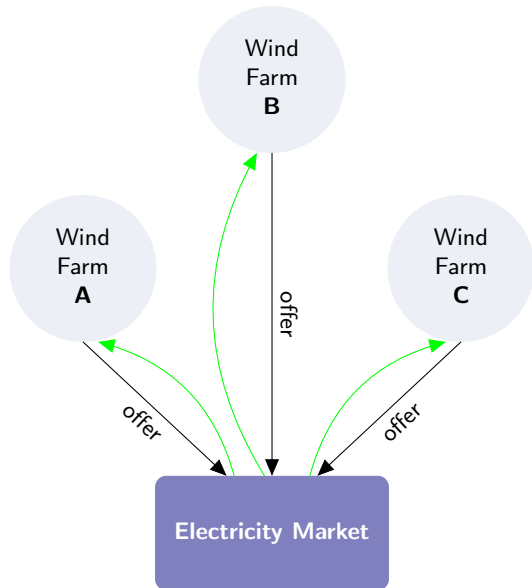
- Wind farms offer in electricity markets based on their individual (probabilistic) forecasts and private information
- Their revenue is affected by their (lack of) forecast accuracy



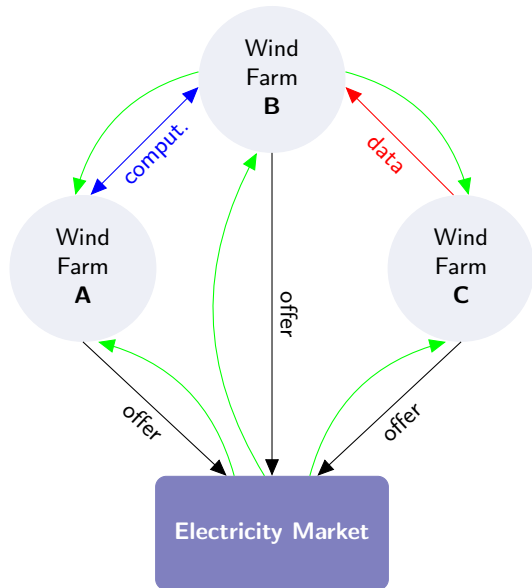
A motivating real-world example

Opportunity: All *could* benefit from some form of collaboration (e.g., information sharing)

Challenge: They have no interest in doing so



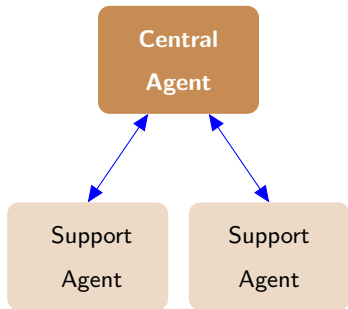
A motivating real-world example



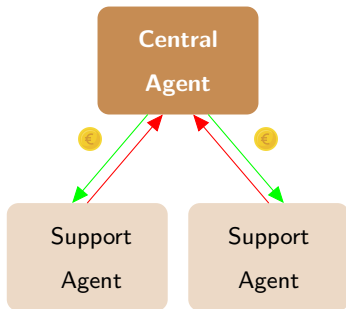
Proposal: Design a framework allowing for all agents to collaborate and benefit from it

Agents meet through **analytics platforms** supporting collaborative and market-based analytics

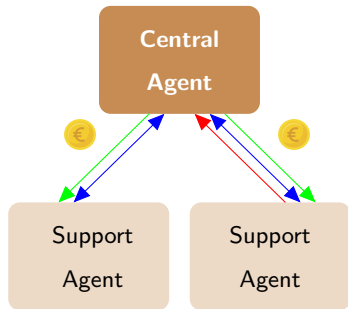
Collaborative Analytics:



Data Markets:



Analytics Markets:



( computing interaction  data exchange  payment)

Substantial **methodological research** is needed to obtain such analytics platforms! (e.g. blending mechanism design and statistical/machine learning)

A quantile regression market example

- **Rogue Trading** is a *central agent* that has a quantile regression problem (for generation y_{t+k}), since optimal renewable energy offers generally are quantiles of predictive distributions
- **Rogue Trading** owns a set ω of m features, $\omega = \{x_1, \dots, x_m\}$

The following (linear) regression problem could be used as basis for eventual prediction,

$$y_{t+k} = \beta_0 + \sum_{i=1}^m \beta_i x_{i,t} + \varepsilon_t, \quad t = 1, \dots, T$$

where the vector of coefficients $[\beta_0 \dots \beta_m]^\top$ can easily be learned using a pinball loss function ρ_α (for nominal level α)

$$S_\omega = \frac{1}{T} \sum_{i=1}^m \rho_\alpha \left(y_t - \left(\beta_0 + \sum_{i=1}^m \beta_i x_{i,t} \right) \right)$$

Based on the data available, the minimum loss function value is S_ω^*

- **Rogue Trading** could post the regression task on an analytics platform, to improve model fit
- It declares a willingness to pay of $\phi = 100\text{€}$ per percent-point improvement in S

- Two support agents **Good Data** and **Useful Features** may bring in additional features z_1 and z_2 , to be remunerated

The regression problem can then be augmented, as

$$y_{t+k} = \underbrace{\beta_0 + \sum_{i=1}^m \beta_i x_{i,t}}_{\text{Rogue Trading}} + \underbrace{\gamma_1 z_{1,t}}_{\text{Good Data}} + \underbrace{\gamma_2 z_{2,t}}_{\text{Useful Features}} + \varepsilon_t, \quad t = 1, \dots, T$$

where the augmented vector of coefficients $[\beta_0 \dots \beta_m \gamma_1 \gamma_2]^\top$ can be learned similarly, yielding a lower value of the loss function

$$S_\Omega = \frac{1}{T} \sum_{i=1}^m \rho_\alpha \left(y_t - \left(\beta_0 + \sum_{i=1}^m \beta_i x_{i,t} + \gamma_1 z_{1,t} + \gamma_2 z_{2,t} \right) \right)$$

which we denote S_Ω^*

- If z_1 and/or z_2 are informative features, one expects $S_\Omega^* < S_\omega^*$

- How to define **revenues** and **payments** in such a regression market?

For each support agent j ($j = 1, 2$), the revenue is given by

$$\pi_j = \phi(S_\omega^* - S_\Omega^*)\psi_j, \quad j = 1, 2$$

where ψ_j is an allocation policy based on feature valuation (can be obtained with, e.g., leave-one-out or Shapley-based allocation), such that $\sum_j \psi_j = 1$

For **Rogue Trading**, the payment is

$$\pi_c = \phi(S_\omega^* - S_\Omega^*)$$

Such a simple approach actually yields a well-behaving market with a wealth of good properties, i.e.,

- budget balance
- symmetry (or anonymity)
- zero element
- incentive compatibility (and group-strategy-proof)
- truthfulness and normality, etc.

- Probabilistic forecasting is a very active field of R&D
- Many developments are oriented towards the needs of forecast users and bringing them optimal value
- Novel approaches are under development to incentivize data sharing, in both collaborative and market-based environments
- Ultimately, the biggest challenge may still be supporting adoption of probabilistic forecasting by forecast users!

Thanks for your attention!

