Sub-Seasonal and Seasonal Dunkelflaute Forecasting and a Cost analysis.

Projects: WinDTwin & LongCast

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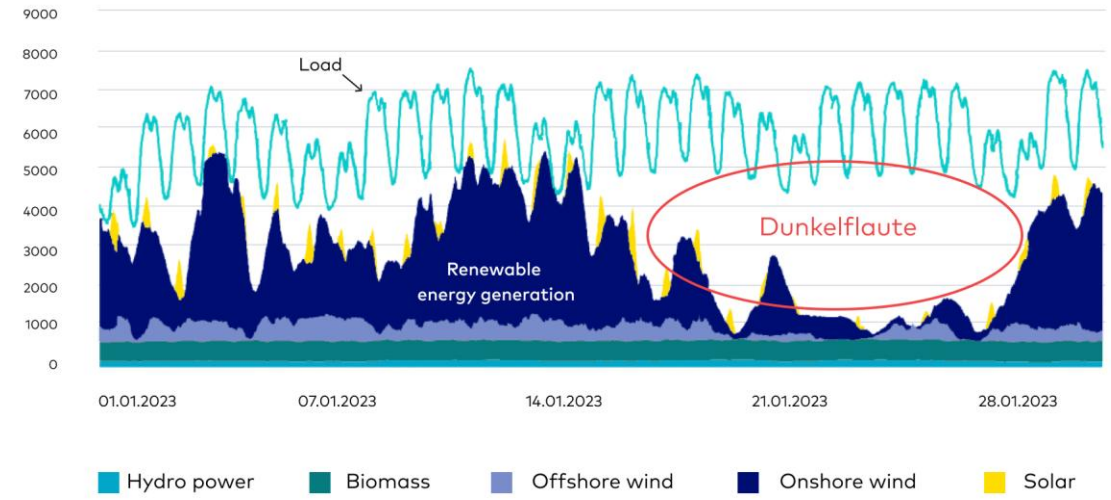
Dunkelflaute forecasting

For increased Grid stability

Dunkelflaute: Average input energy is lower than a pre-determined threshold over a rolling window of 48 hours [Mockert et. al. 2023]

Dunkelflaute in Germany in January 2023



https://energiewende.eu/blackout-bei-dunkelflaute/

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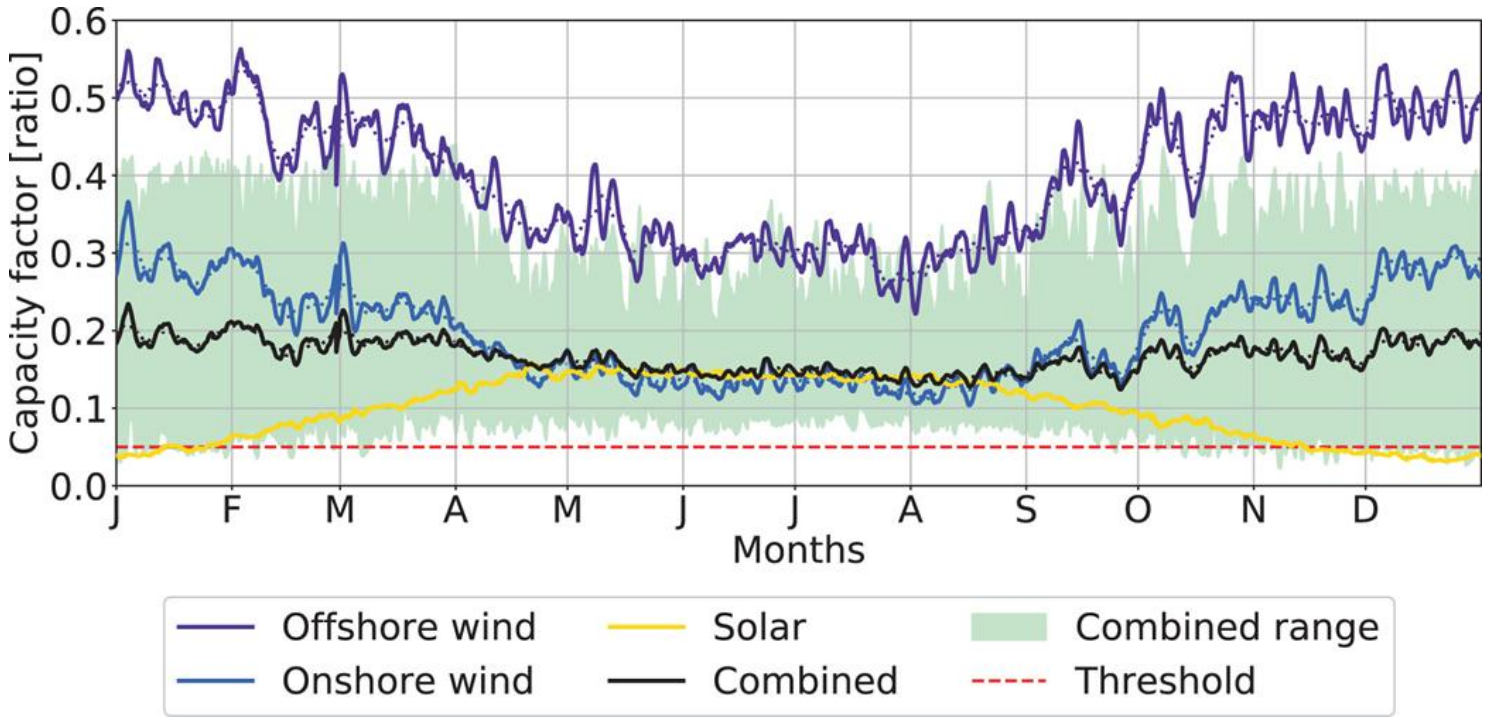
Dunkelflaute Forecasting

When do these events usually occur?

- Solar production is on average consistently below the threshold in winter.
- Wind fluctuation cause Dunkelfalute.
- Dunkelflaute occur almost exclusively in winter.
- Roughly 4 Dunkelflaute per year.



- Mockert et. al. 2023

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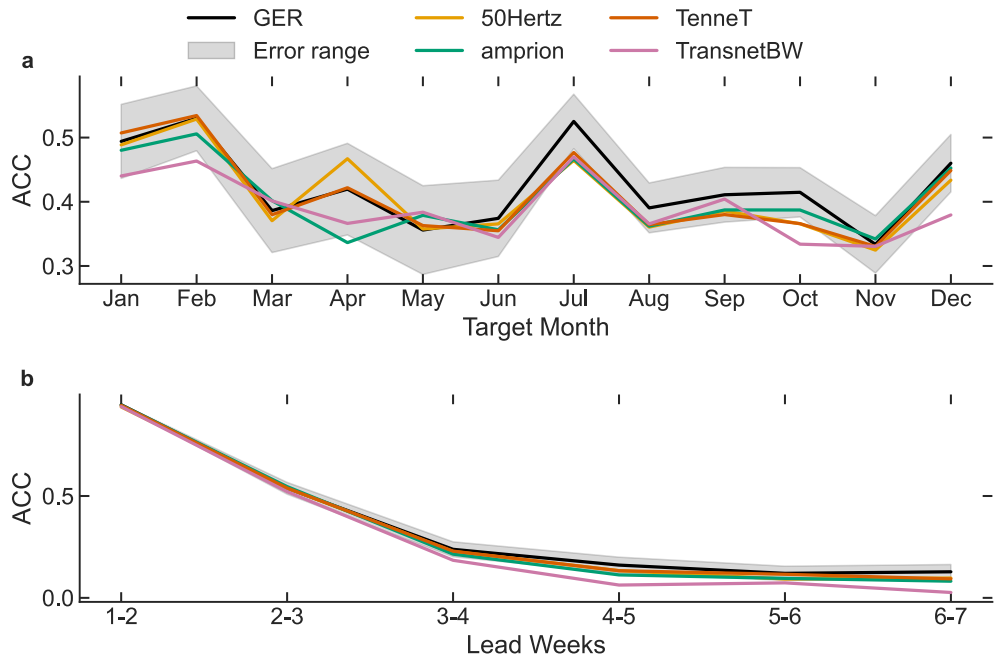
Energy Forecasts

Probabilistic Forecasting

Sub-seasonal Power Forecasting

- Forecasting Mean Energy for next five weeks: ECMWF EEFH (20 years). Ground Truth: Simulated Power (ERA5)
- Skills calculated for calibrated weekly means of energy anomalies.
- Skillful forecasts especially during peak winter and summer.

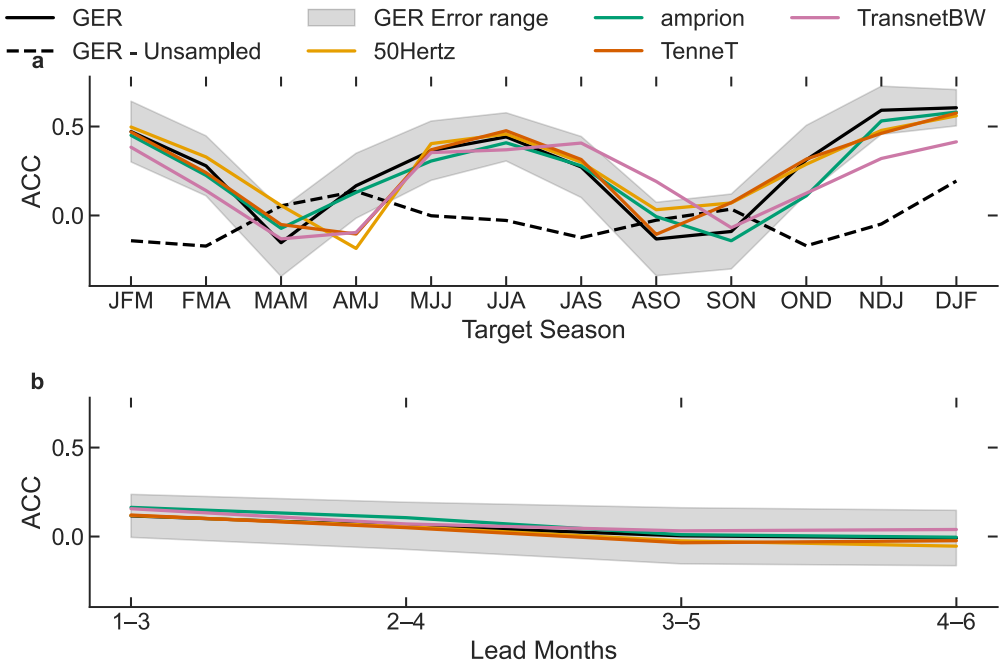


Energy Forecasts

Probabilistic Forecasting

Seasonal Power Forecasting

- Ensemble Forecasting Model: GCFSVersion2.1 (30 years). Ground Truth: ERA5
- Subsampling enables selection of skillful ensemble members.
- Skills calculated for calibrated 3-months means of energy anomalies.
- Aggregated seasonal energy forecasts show significant skills in peak winter and summer seasons.



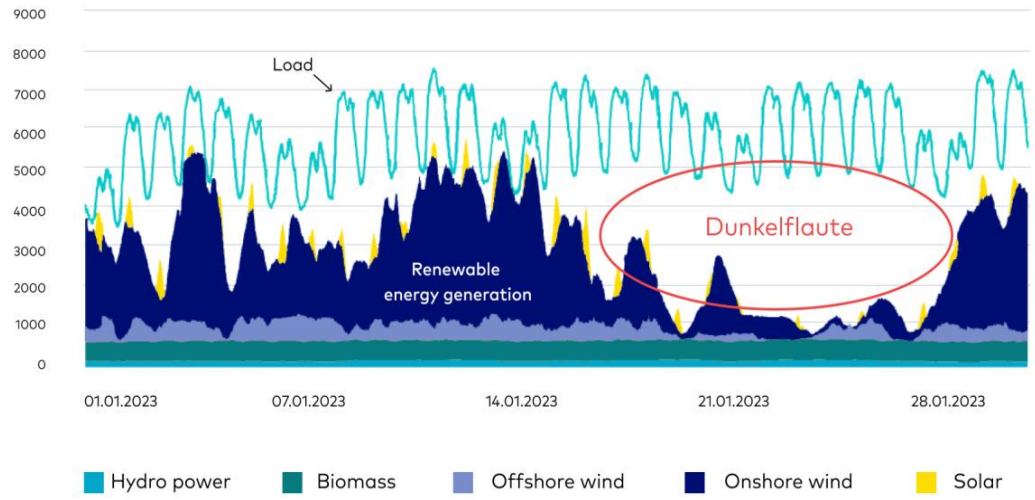
Dunkelflaute forecasting

Microapplication of seamless forecasting

Can the high resolution events be forecasted at sub-seasonal and seasonal level?

This study: Proof of Concept dealing with Flaute forecasting

Dunkelflaute in Germany in January 2023

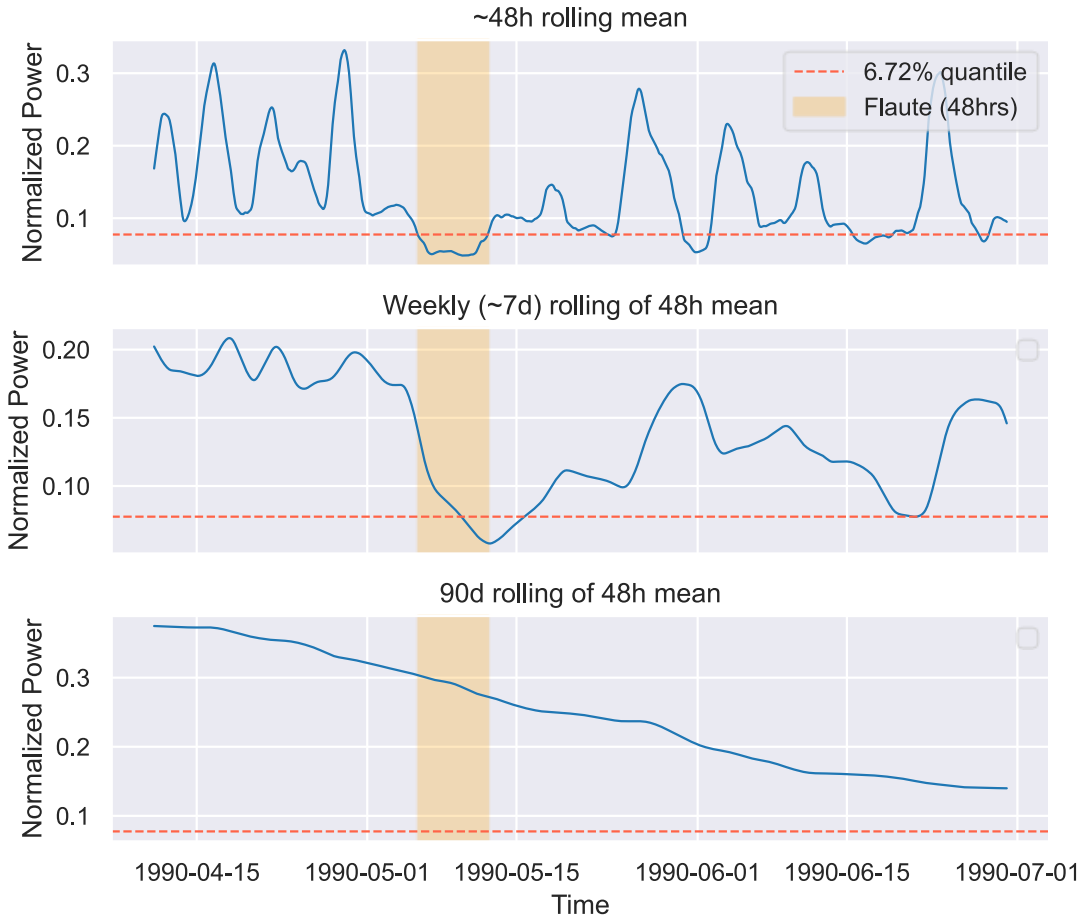


Dunkelflaute forecasting

Methodology

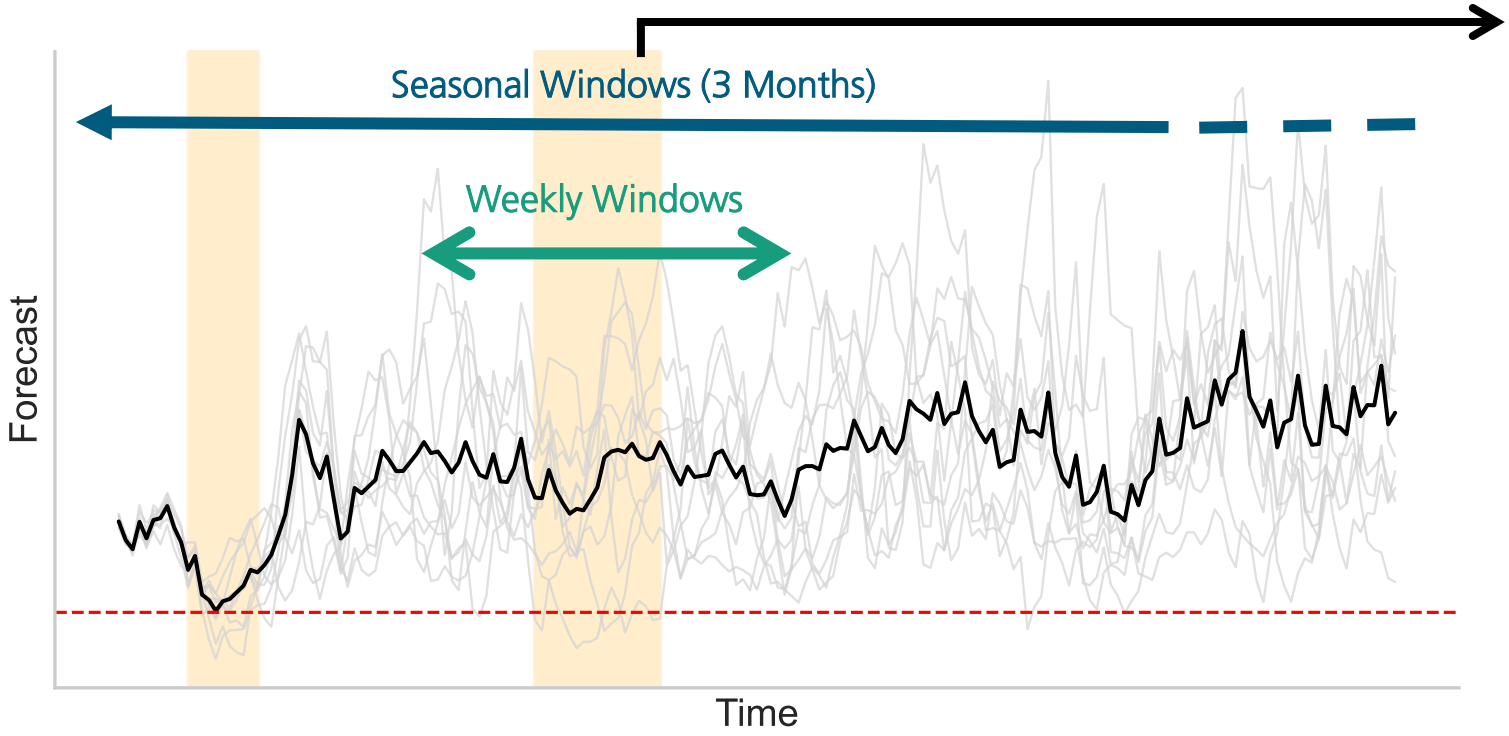
- Dunkelflaute's time scale (48 hours) is much shorter than the time scale of sub-seasonal (7 days) and seasonal forecasts (3 months) at which they show skills.

- Using high resolution seasonal and sub-seasonal forecasts directly does not lead to skilful forecasts.



Dunkelflaute forecasting

Methodology



Calculate statistical features
(Mean, std, skew, kurtosis, Events (P>0.1|0.2|0.3), # Disjoint Events **..)**

ML Classifier

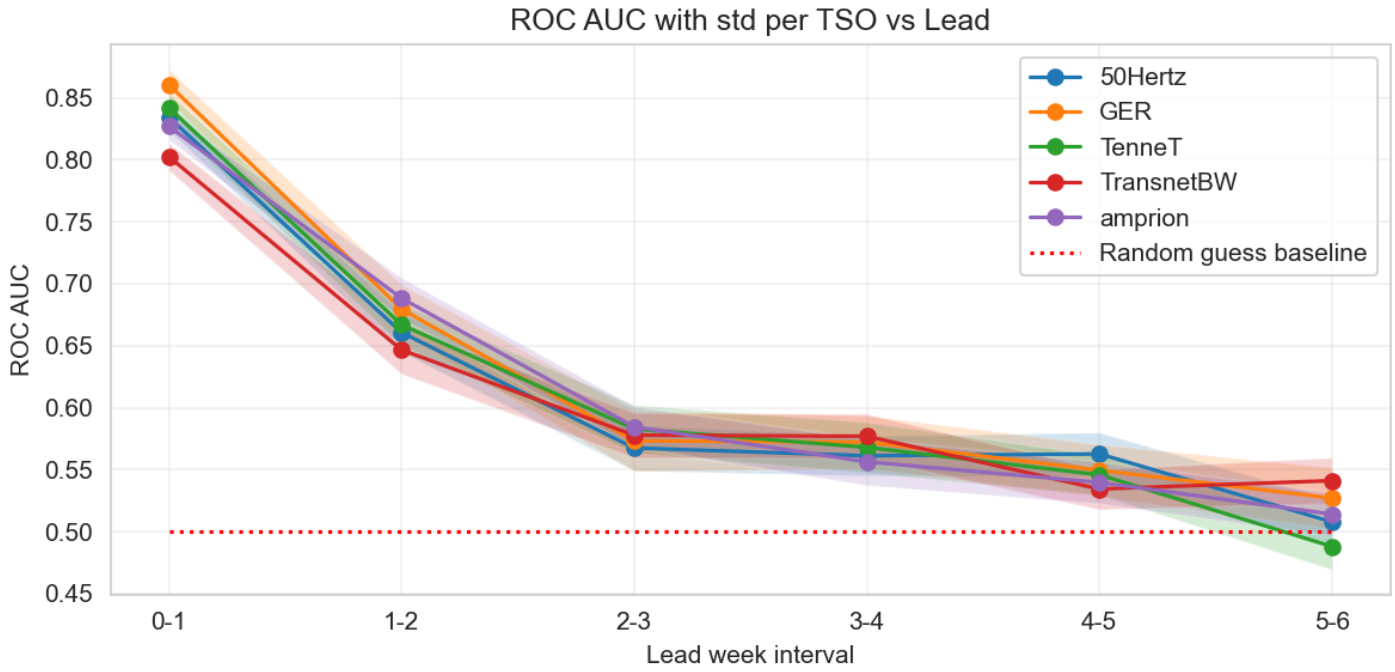
Yes/No Flaute	Flaute Intensity

Flaute Forecasting

Sub Seasonal Results

- **ML Classifier** can skilfully predict only events persisting for at least 12 hours

- **Prediction skill:** Skill declines with lead time across all TSOs and Germany

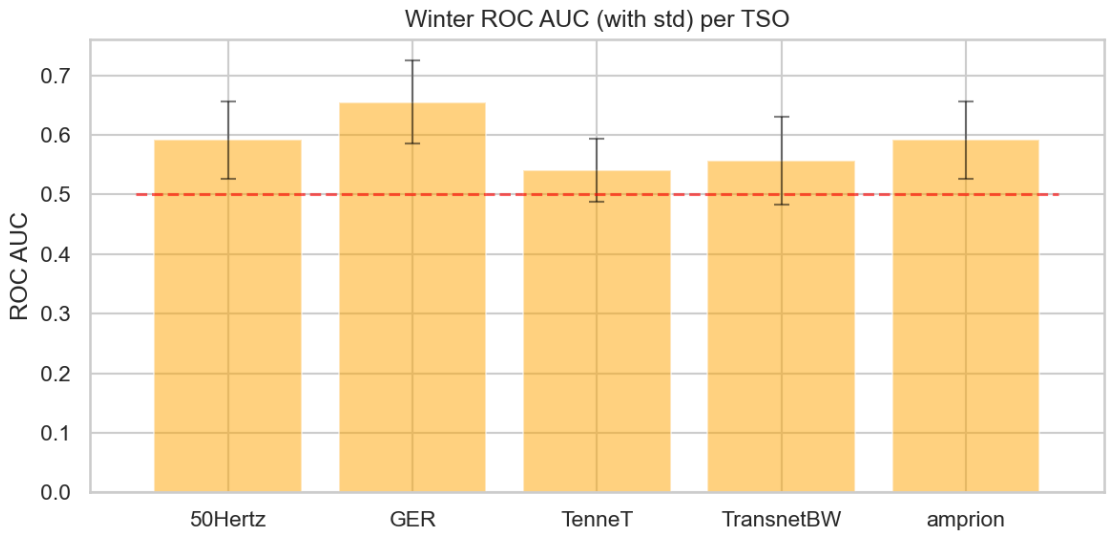


Flaute Forecasting

Seasonal Results

- **ML Classifier** can skilfully predict only events persisting for at least 4 days.

- **Prediction skill:** Slightly better than a random classifier. Skill isn't strongly dependent on the lead time.

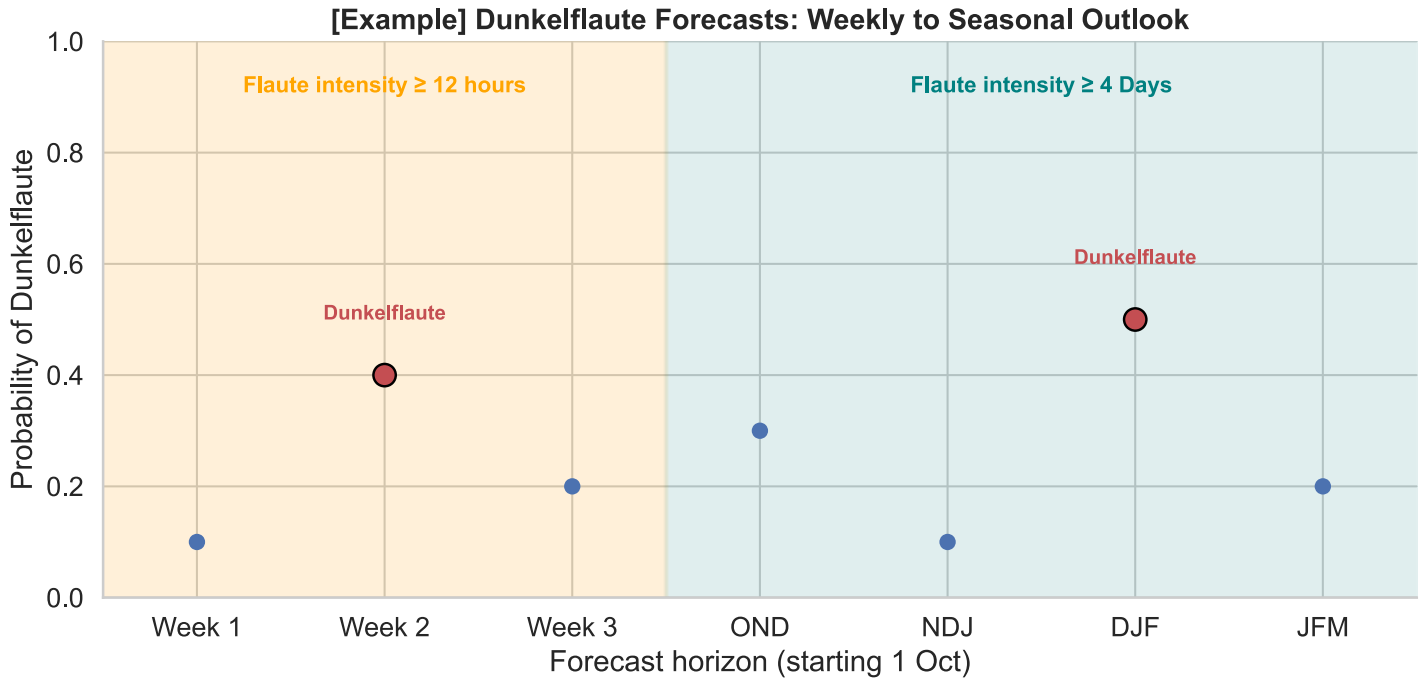


Flaute Forecasting

Seamless Warnings

- Seamless warnings for different classes of flaute at different time horizon

- This might overlap with different preventive measures at those scales.



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What benifi does the model have in operational context?

A simple cost model approach

Definitions:

- Cost of damage: *c*, Preventive cost: *kc*
- Given threshold (*t*)*: FP*(*t*)*, TP*(*t*)

Costs:

- Model predictions: $C_m(t) = kc(TP + FP) + cFN$
- Do nothing: $C_n(t) = cp = c(TP + FN)$
- Climatology: $C_c(t) = \max(pc; kc)$

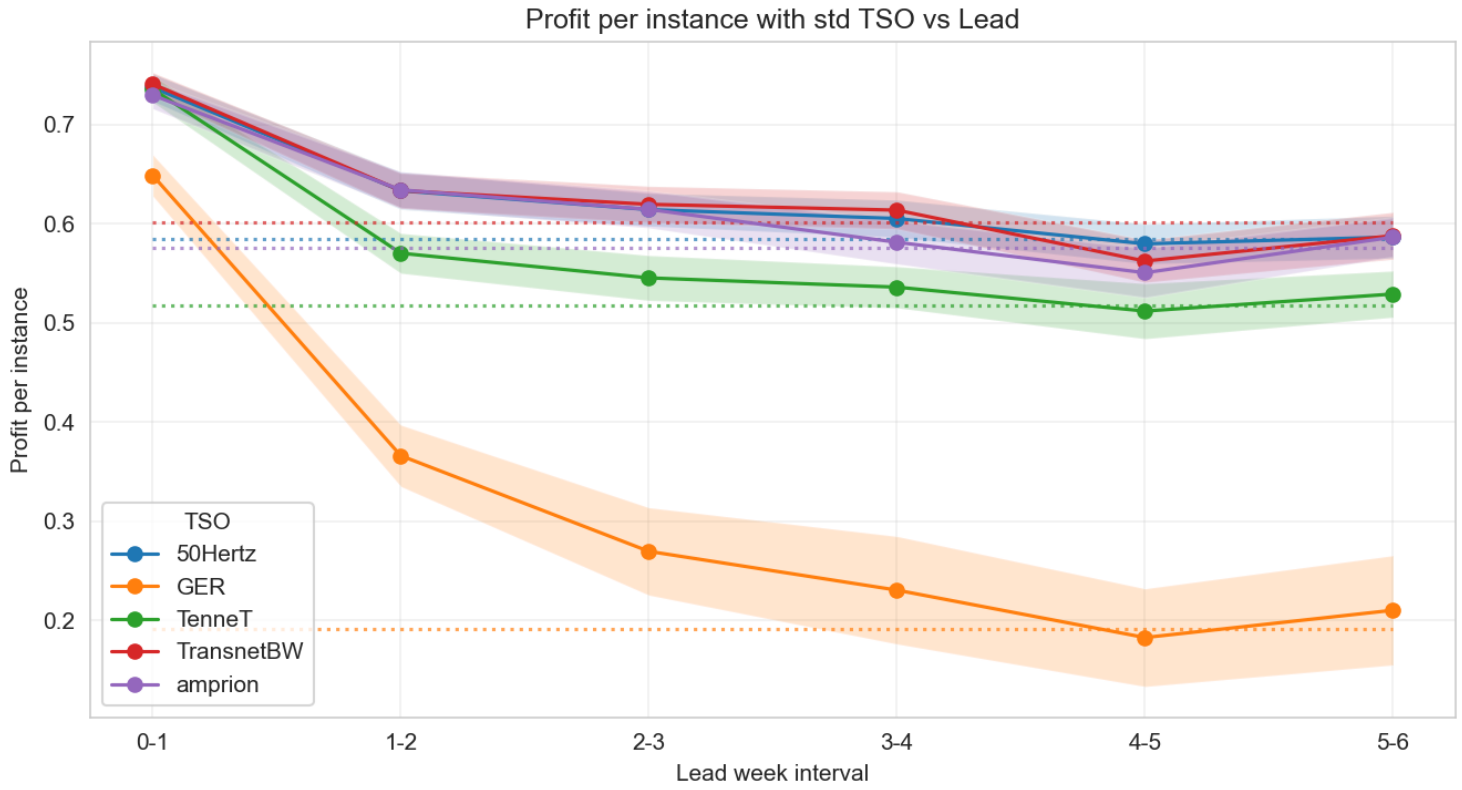
Profit:

- Model: $\Pi_{m(t)} = C_m(t) - C_n(t) = c[(1-k)TP(t) - kFP(t)]$
- Climatology: $\Pi_c(t) = C_m(t) - C_c(t) = \max\big((p-k)\cdot c, 0\big)$

Flaute Forecasting – Operational Cost Model

Sub Seasonal Results

- **ML Classifier** remains profitable in comparison to climatology for upto 3 weeks (k=0.1,c=1).
- Results change sharply with the choice of preventive cost.
- Horizontal line represent the climatological baseline

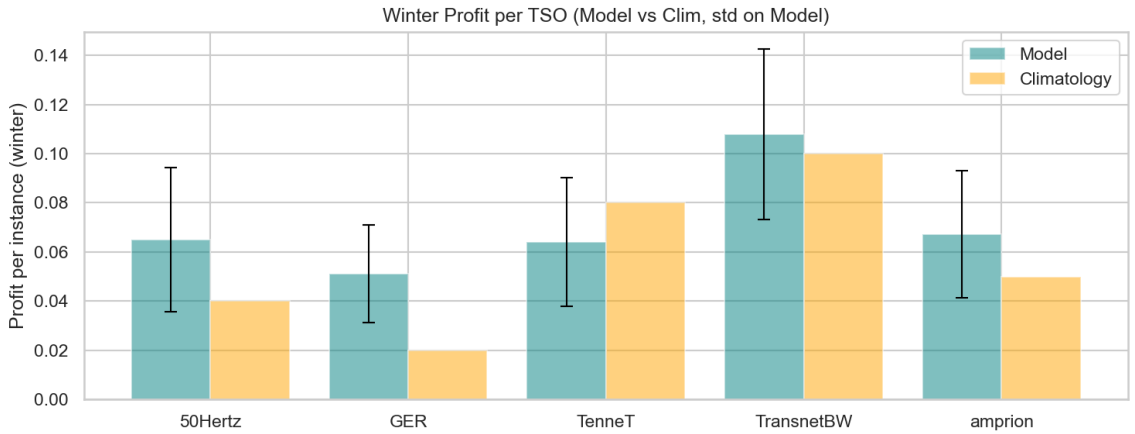


Flaute Forecasting – Operational Cost Model

Seasonal Results

- **ML Classifier** is only slightly more profitable in comparison to climatology (k=0.1,c=1)

- Results change sharply with the choice of preventive cost (more sensitive compared to seasonal forecasts)



Future steps

- Improving skills in seasonal Flaute forecasting by integrating teleconnection indices as features
- Integrating PV production for Dunkelflaute forecasts
- Estimating the skills at shorter horizons (14 days)
- A more nuanced cost model

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