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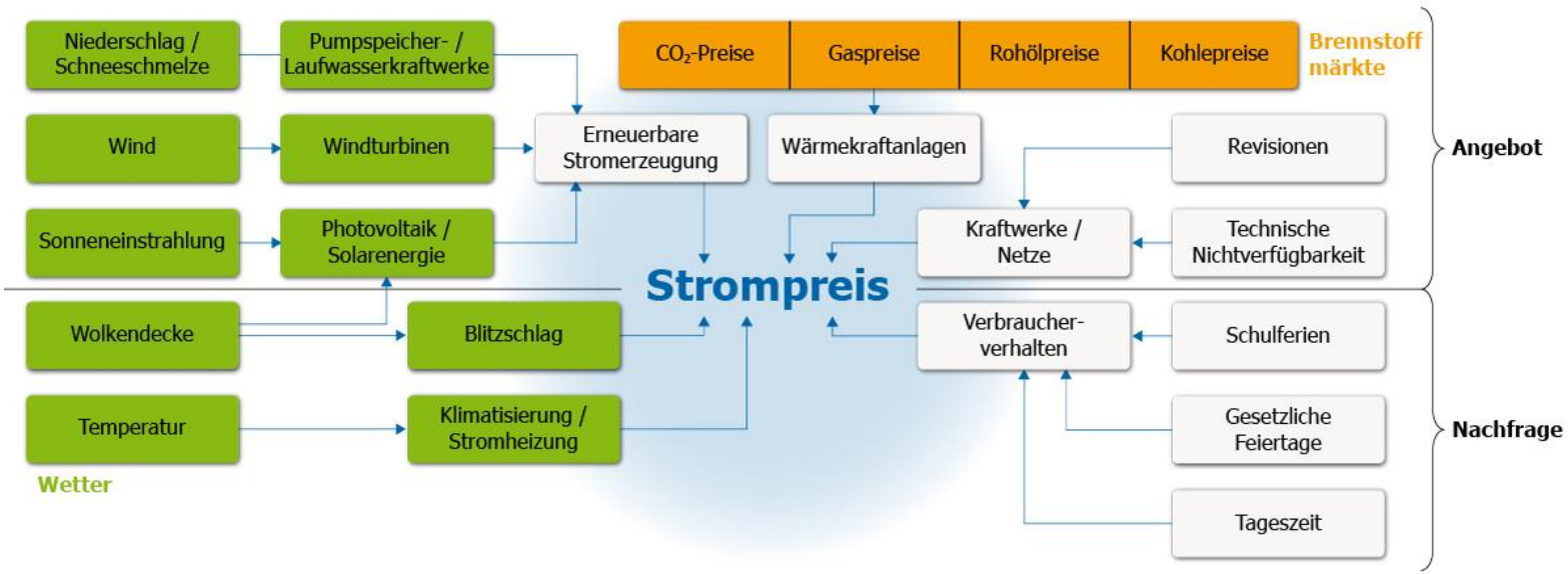
ENGERY PRICES AND WEATHER INFLUENCES

The important price is not the spot market price

- „Der Terminmarkt macht mehr als 90 Prozent des Stromhandels aus", erläutert Martin Schelker. Der Ingenieur ist bei der EnBW Trading zuständig für den Handel mit Strom, Kohle und CO2-Emissionsrechten. Ähnlich wie an den Warenterminbörsen wird bei einem Termingeschäft die Lieferung einer bestimmten Menge Strom zu einem bestimmten Preis für einen späteren Zeitraum vereinbart. (Stuttgarter Zeitung 16.02.2014)

- We assume that the Spot market shows more influcences to the weather situation

Weather dependent components of elecricity prices



Non-elastic consumption

- The electricity marekt is very inelastic.
- Most customers purchase based on a contract that fixes a price for a given amount in MWh. Thus these prices do not depend on short term variation. Because of this the demand does not change much when the price changes.
- Main influencing factors on the demand are: weather, time of day and day of year.

- This talk does not focus on the demand, but on the price, which can be seen as part of the demand.

Meteorologic influcence

- A direct influcence of the weather on price seems to be a logical implication, because the solar panels and wind turbines are changing the supply of energy.

- E.g. at the daily moring briefing of the EnBW energy sales department two meteorologists are at the table.

  The meteorologsts are setting up forecasts for solar radiation and wind.

Hypothesis & Goals

1) **Spot-Market-Prices** are influenced by the amount of **renewable energy production**.

2) Thus **spot-market-prices** depend indirectly on the **weather** (sun intensity and wind speed/direction)

3) Use the knowledge about these relationships to set up a **reasonable prediction-model** for the spot-prices.

Methodology

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1) Generate models to describe the **renewable energy-production**.

2) Model the dependencies of spot-market-prices and renewable energy-production.

Quantifiying Renewable Energy Production

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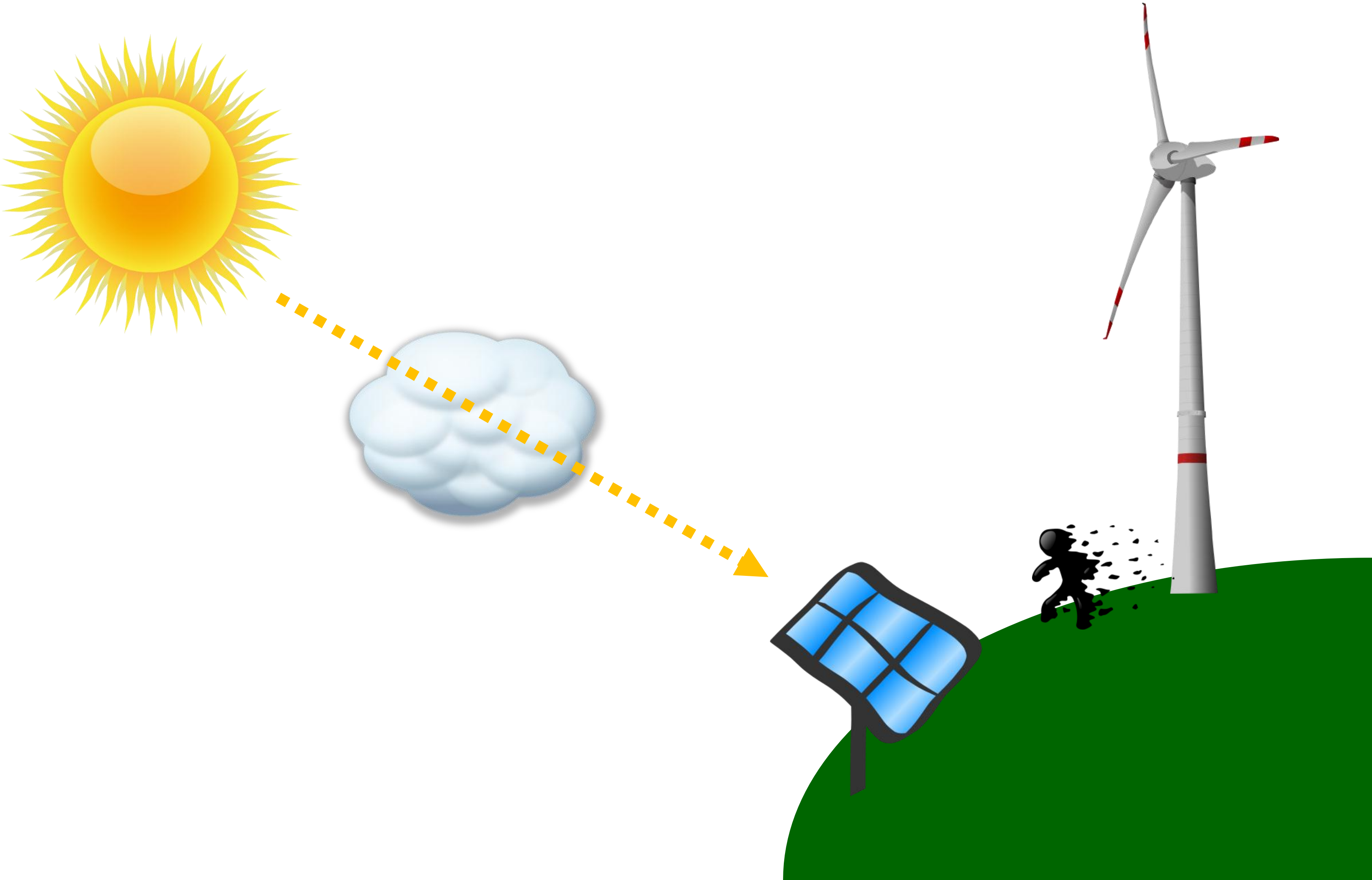
- It`s nearly impossible to get reasonable data on how much energy is produced by renewables at a certain time in Germany (or any country in the world).
- Problem is the distributed network and the lack of measurements.
- Thus the amount of energy has to be estimated based on **physical theory**.

Modeling Renewable Energy-Production



Variables

Sunpower

Variable	Description
Global Radiation	Variable of interest. Problem: No forecast.
Humidity	Proxy for cloudiness
Time	Proxy for position of the sun relative to location

Windpower

Variable	Description
Wind Speed	Problem: No forecast.
Wind Direction	Problem: No forecast.

Feldberg (Taunus)

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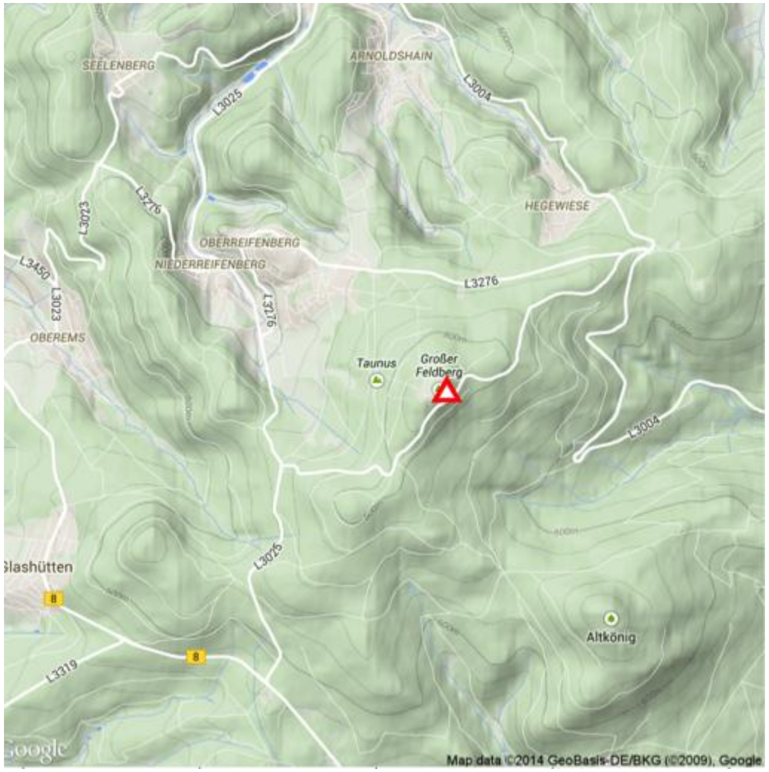
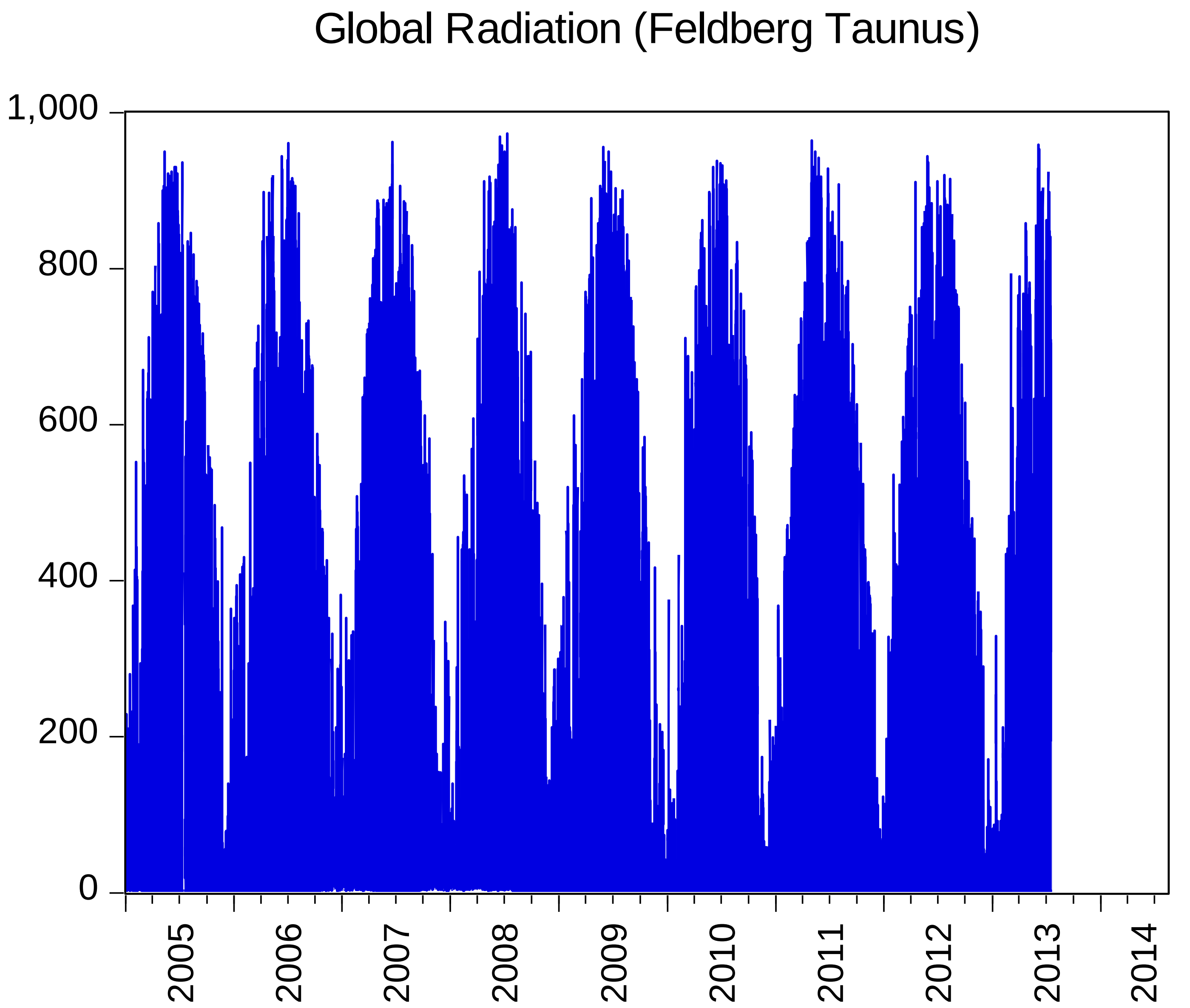
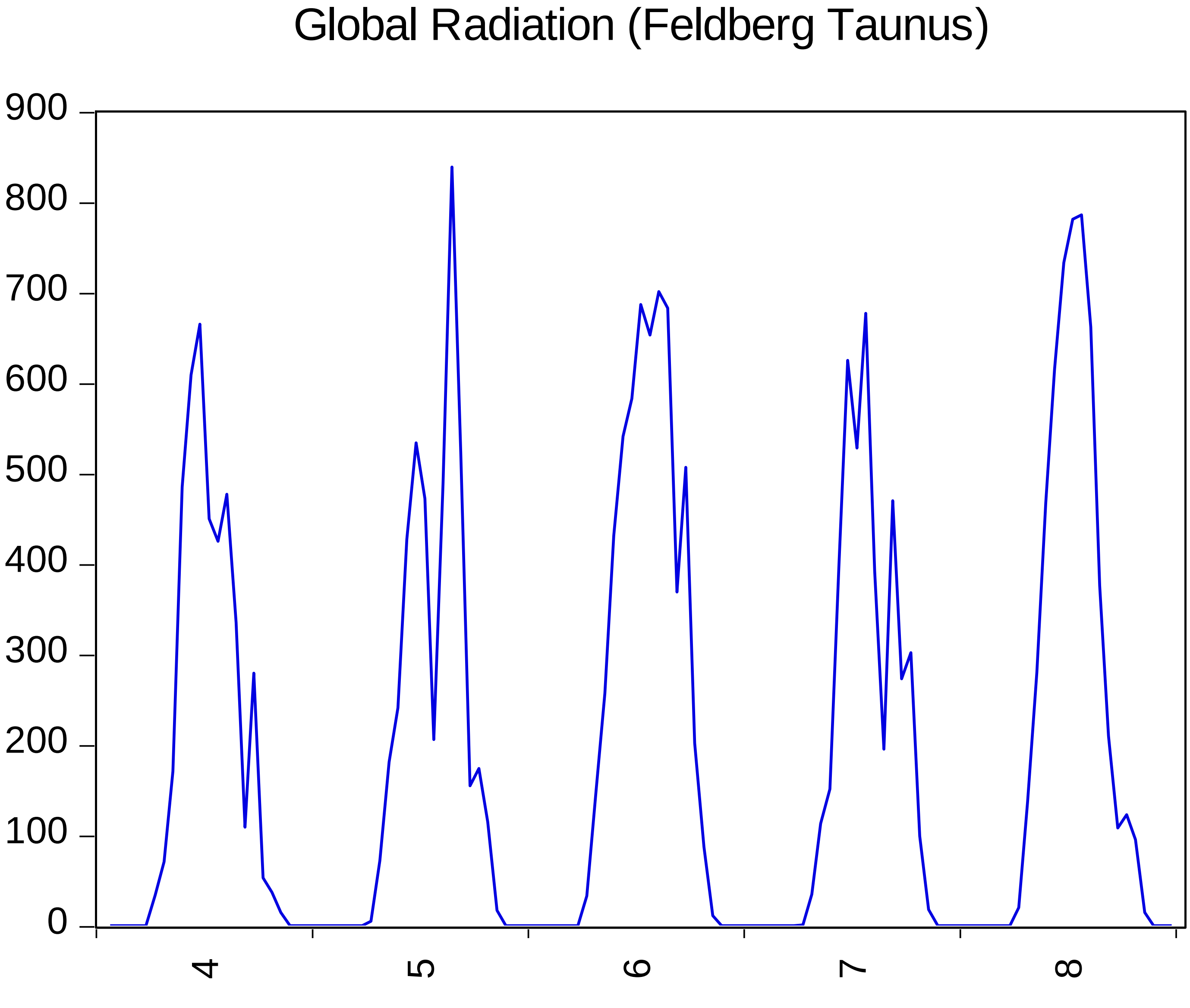


Data


Global Radiation (Feldberg Taunus)
1,000
800
600
400
200
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Data


Global Radiation (Feldberg Taunus)
900
800
700
600
500
400
300
200
100
0
4
5
6
7
8
8/2014

Model

Idea

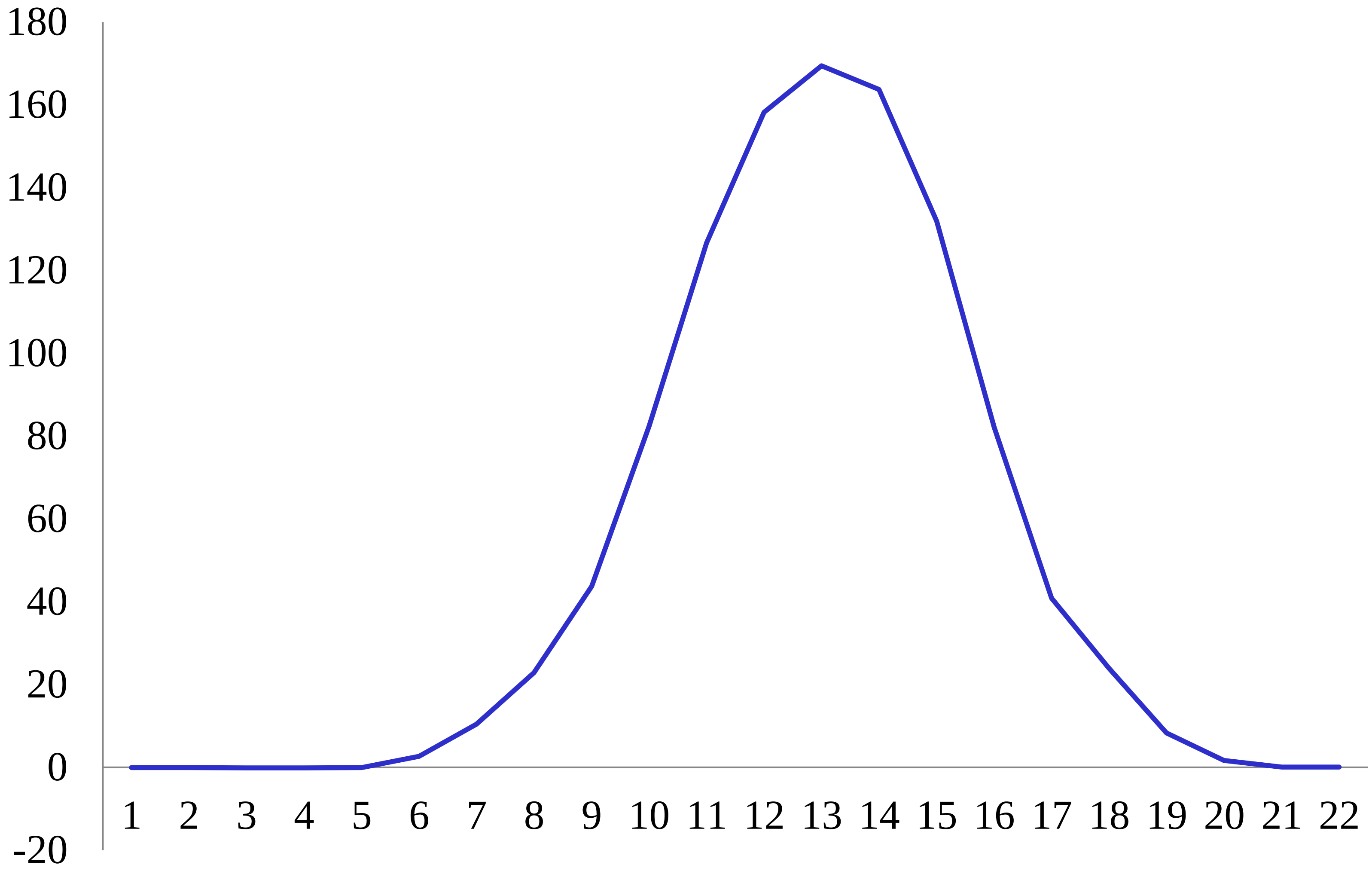
Explain the **Global Ration** by **hour** of day, **month** of year including the corresponding interaction. Additionally: **Humidity** as a proxy for cloudiness.

$$gbr = \beta_0 + \beta_1 hour_d + \beta_2 month_d + \beta_3 hour_d * month_d + \beta_4 humidity + \beta_5 humidity * time$$

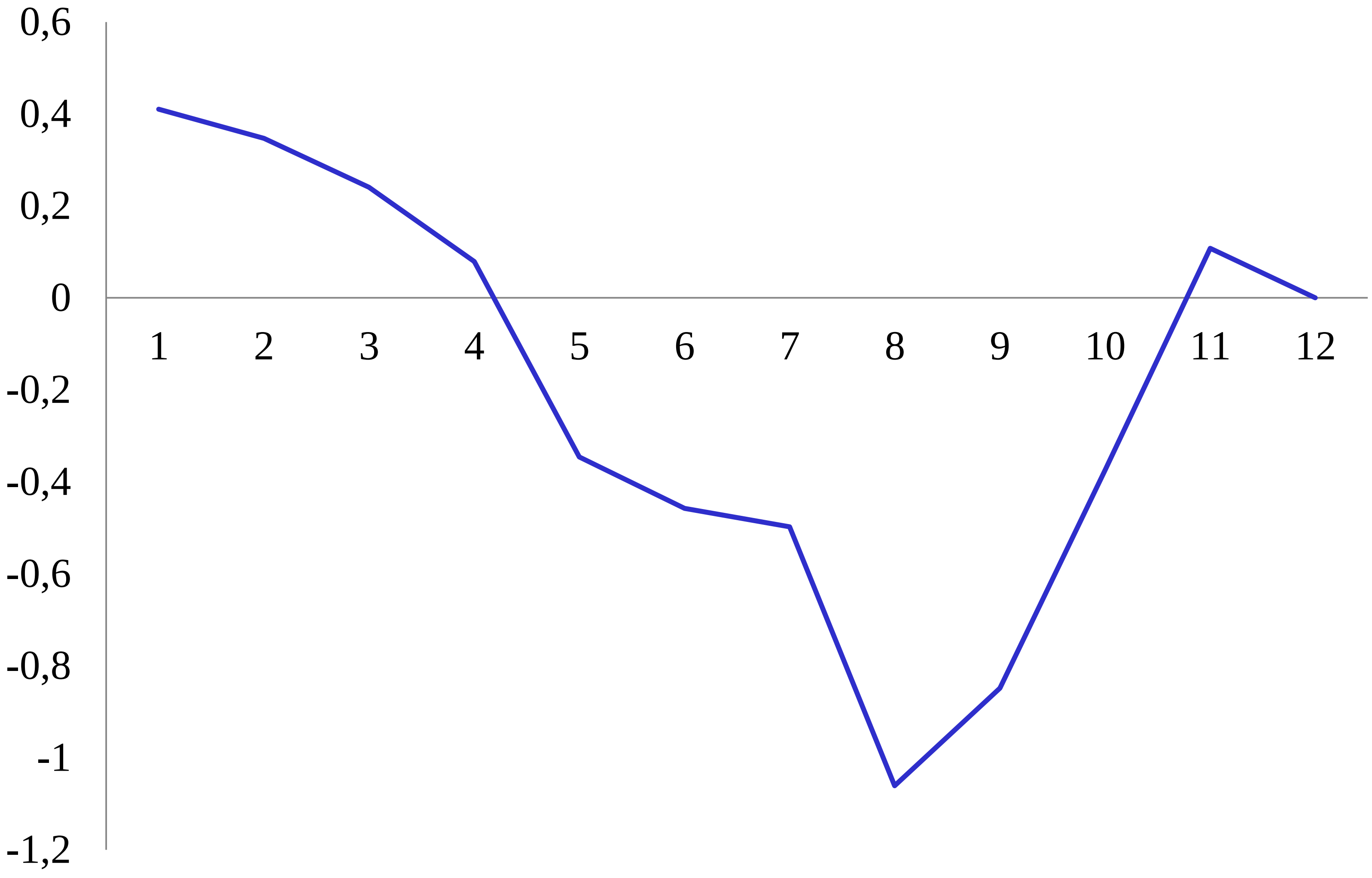
Expectation

- β_1: Nonlinear effect. Zero radiation at night.
- β_2: Nonlinear effect. Less radiation in winter-season.
- β_3: Interaction to respect the different day-light-length in different seasons.
- β_4: Positive effect.

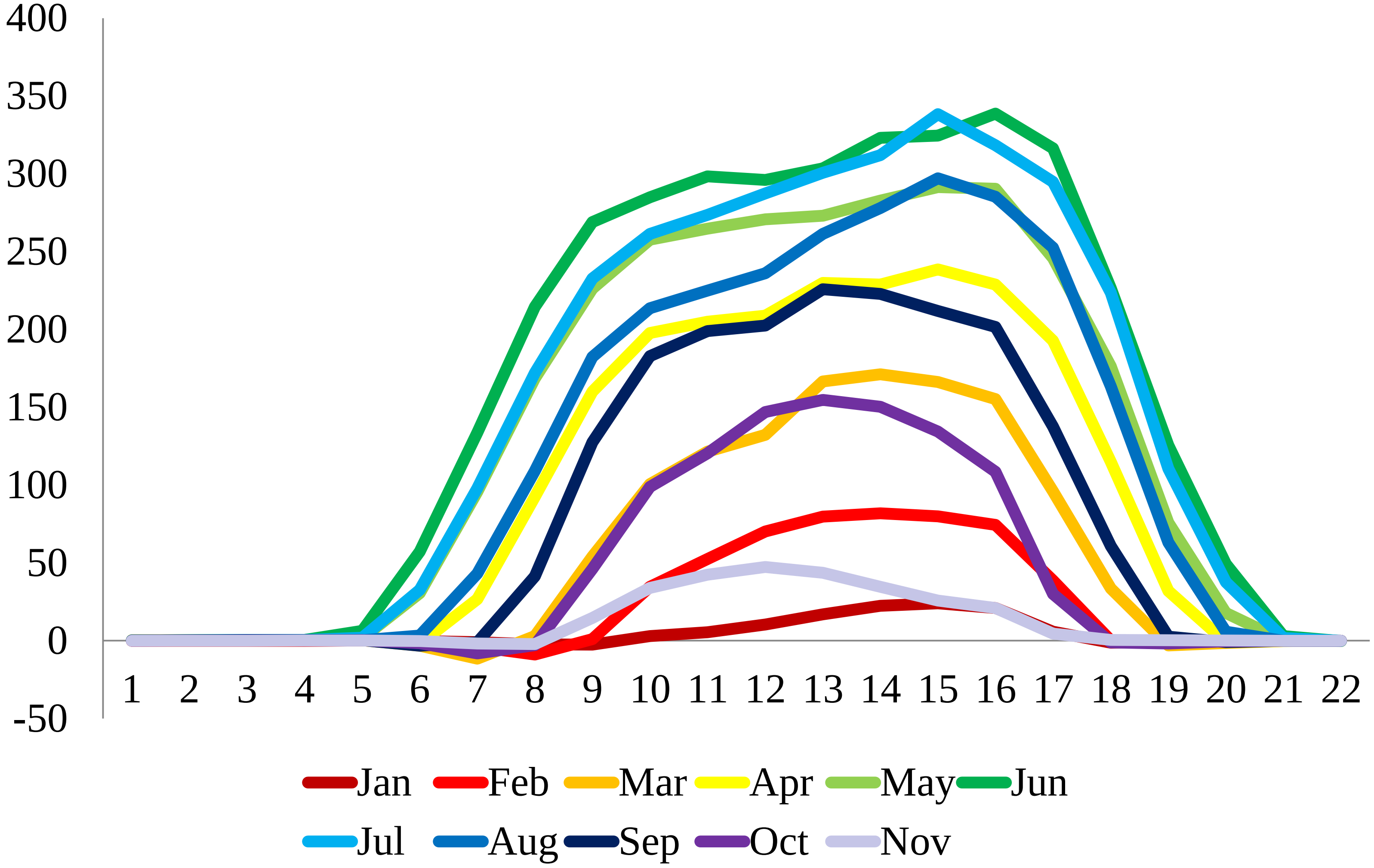
Hour-Dummy-Coefficients



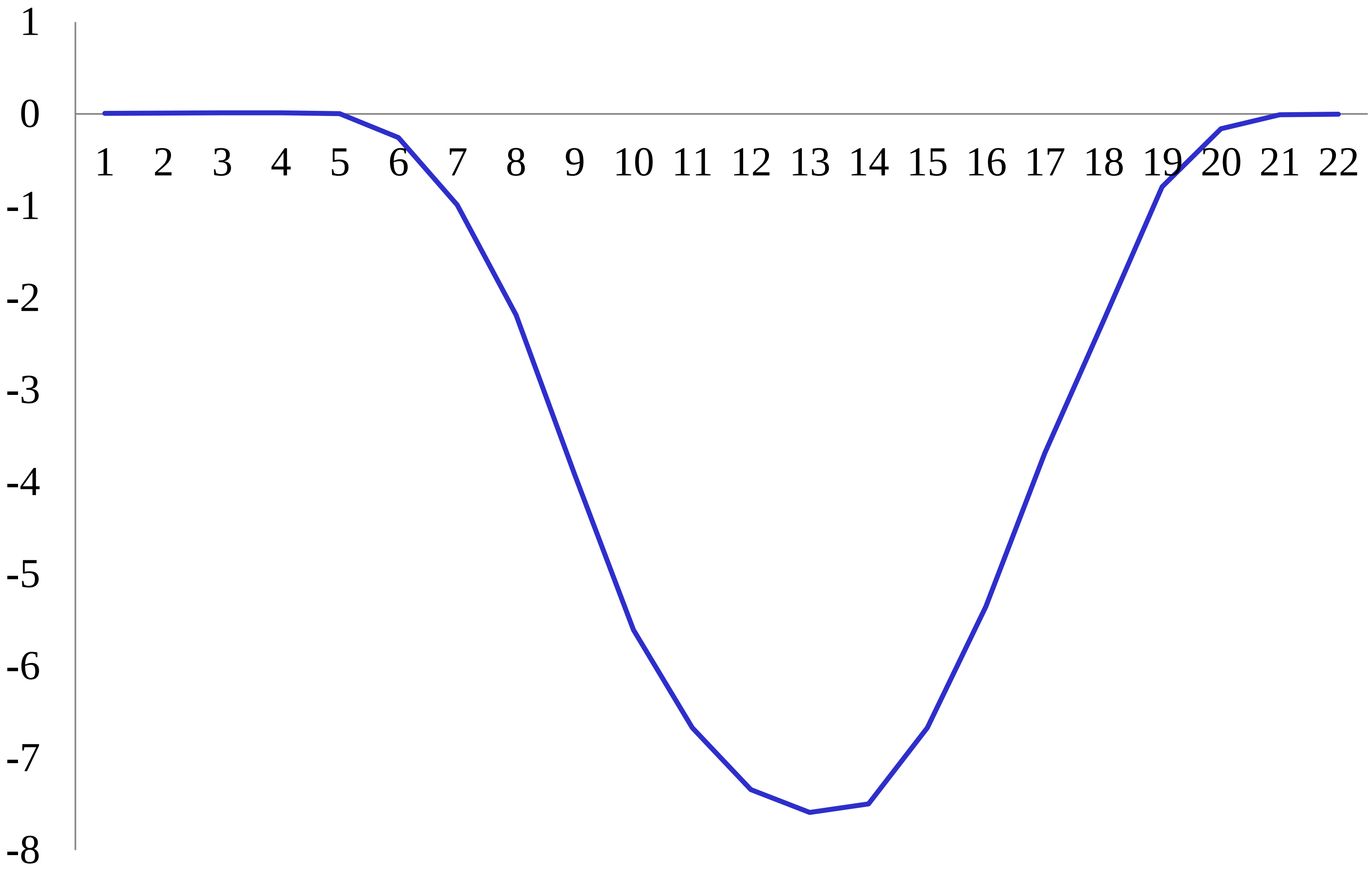
Month-Dummy-Coefficients (non-significant)



Interaction: Hour*Month



Interaction: Humidity*Time



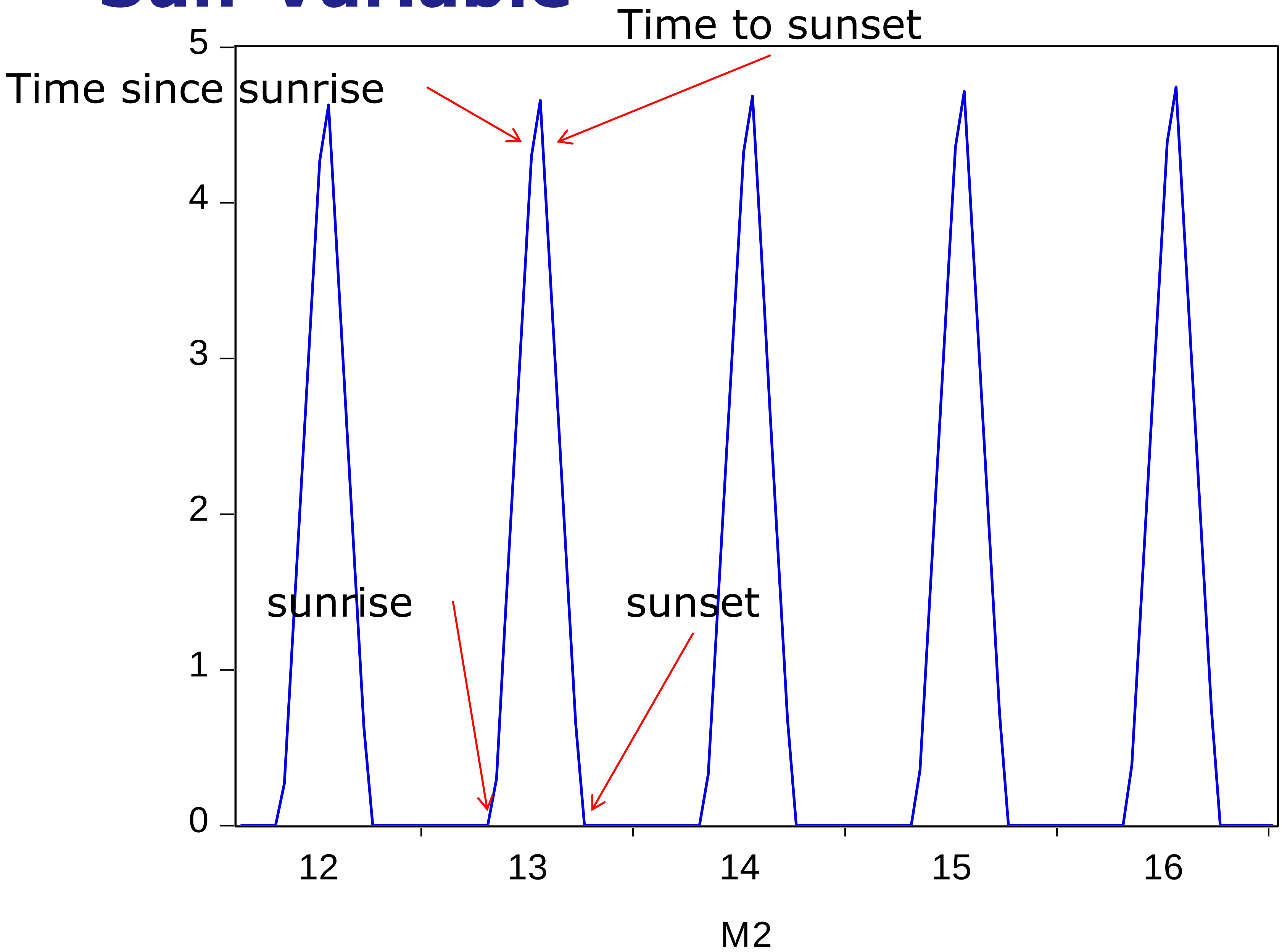
Alternative Model

Explain the **global radiation** just based on the **sunrise** and **sunset-times** together with **humidity** and **month** (i.e. season).

$$gbr = \beta_0 + \beta_1 sun + \beta_2 humidity + \beta_3 month + \beta_4 sun * humidity + \beta_5 sun * month$$

- Advantage: Less parameter, less dummies

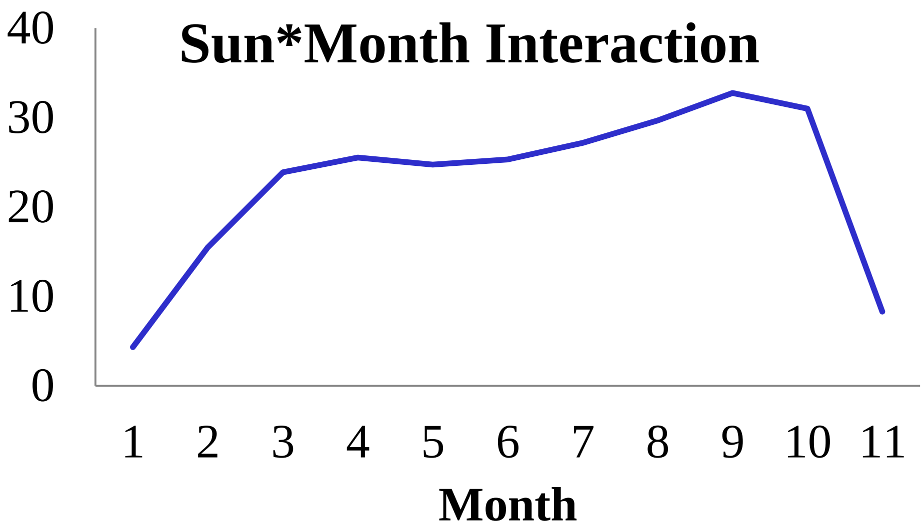
Sun-Variable



Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	25.22470	2.835361	8.896469	0.0000
SONNE	38.11178	1.004565	37.93859	0.0000
REL_HUM	-0.229551	0.025971	-8.838873	0.0000
REL_HUM_CENTERED*SONNE	-1.346033	0.008327	-161.6522	0.0000

*Month itself is not significant



Comparison of Both Models

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	Model 1: Time Based	Model 2: Sun
R2	0.8125	0.8120
Statistical Valdidity	no	
Usabilty for Forecasts	Limited (needs good forecasts for humidity)	
Ease of Interpretation	A bit harder (due to number of coefficients)	Easier

Lessons Learned

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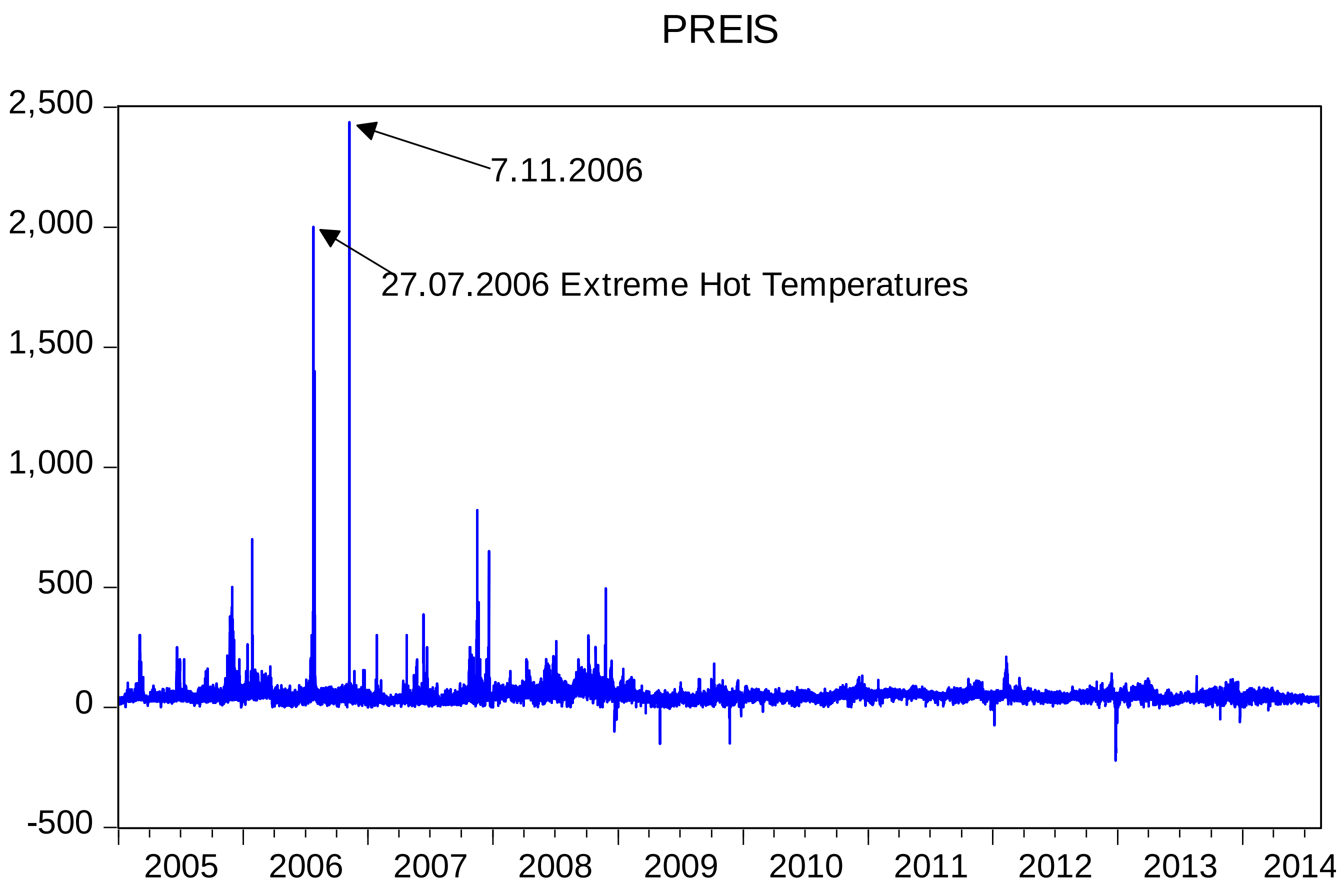
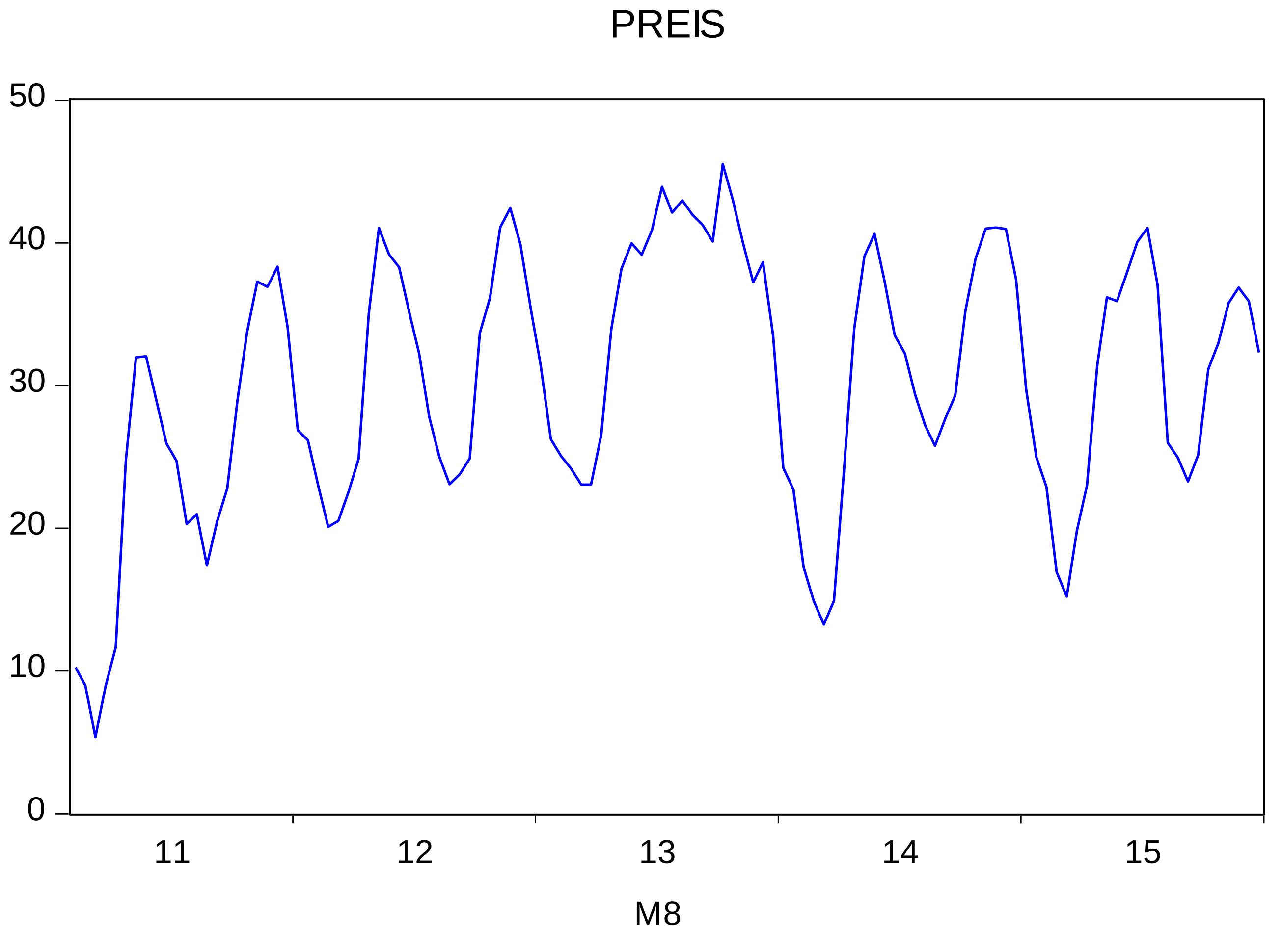
- Global Radiation might be a good proxy for the production of sunpower-based energy.
- Global Radiation can be explained reasonably well based on time/sun and humidity. This might be useful for forecasts in a model using Global Radiation as predictor for the prices.
- Only data from one location in germany was used. This limits of course the representativity of the results.

MODELLING SPOT-PRICES

Explorative Data Analysis



Explorative Data Analysis



Step 1: Saisonality

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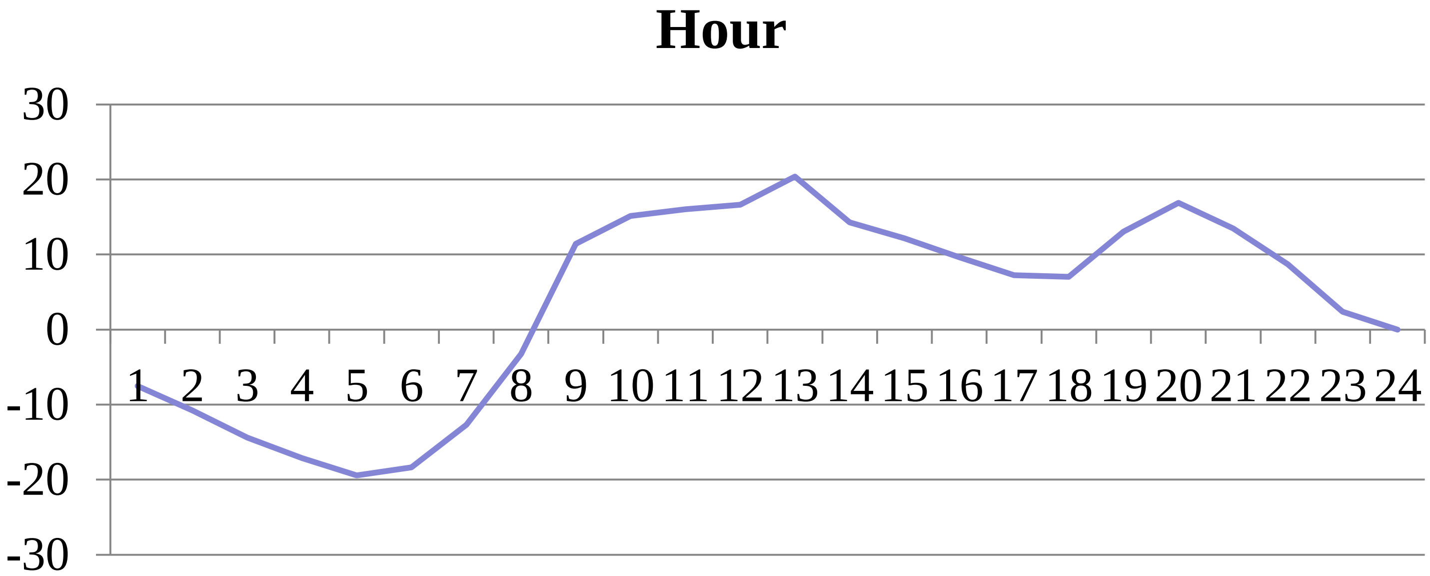
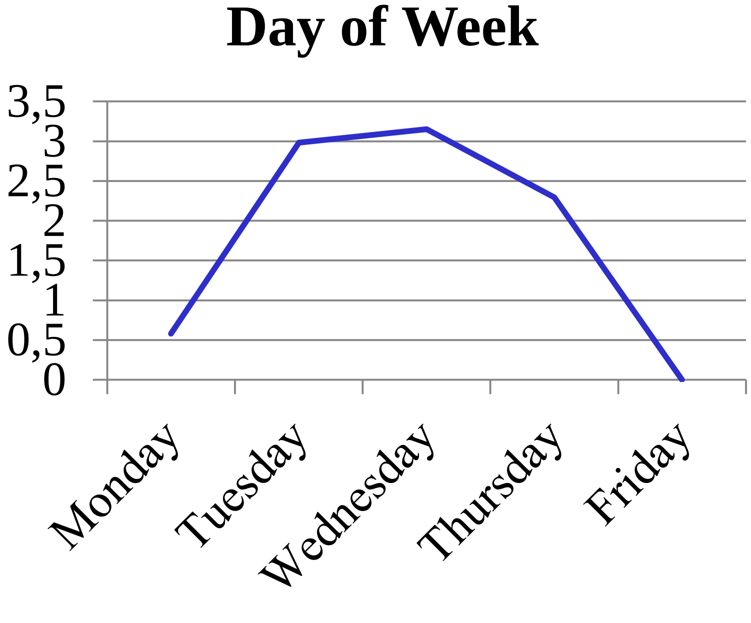
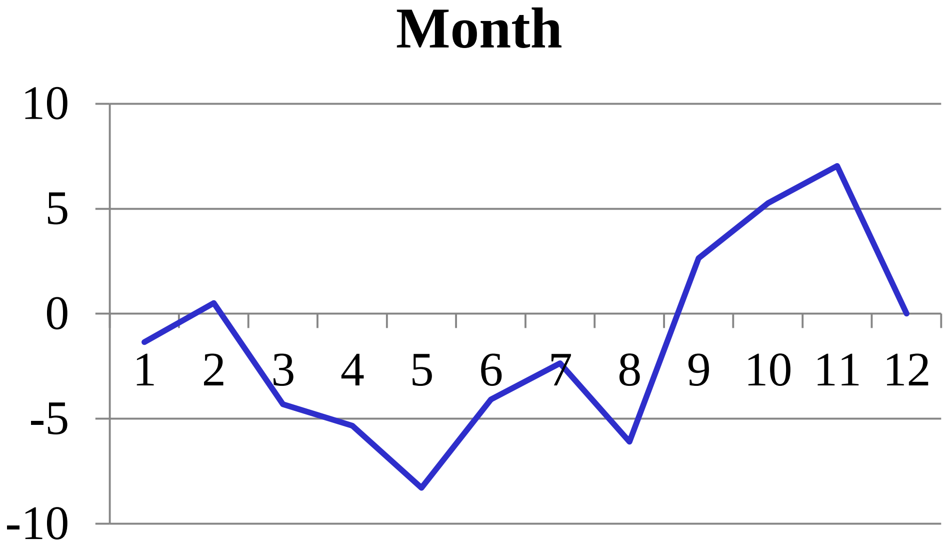
- Model Saisonality in Prices via Dummy-Variables.
  - Hour of day
  - Day of week
  - Month of year
- Remove selected extreme prices via Dummies

Model Effects







Step 2: Explaining Prices

- Use the seasonal adjusted prices as response.
- Explain these prices by our global radiation and wind speed as proxies for solar and wind-energy-production.

$$price = \beta_0 + \beta_1 * \text{radiation} + \beta_2 * windspeed$$

- Interpreation:
  - β_1: Importance of Solar-Power for spot-prices. Is expected to have negative sign.
  - β_2: Importance of wind-power for spot-prices. Is expected to have negative sign.

Model

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Dependent Variable: SA_PREIS
Method: Least Squares
Date: 10/17/14 Time: 13:52
Sample (adjusted): 1/06/2005 10:00 8/15/2014 23:00
Included observations: 56595 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.850305	0.213612	13.34339	0.0000
GBS	-0.000800	0.000432	-1.851111	0.0642
WIND	-0.869346	0.054216	-16.03497	0.0000

R-squared	0.004525	Mean dependent var	-0.159381
Adjusted R-squared	0.004490	S.D. dependent var	21.23119
S.E. of regression	21.18347	Akaike info criterion	8.944373
Sum squared resid	25395070	Schwarz criterion	8.944847
Log likelihood	-253100.4	Hannan-Quinn criter.	8.944520
F-statistic	128.6333	Durbin-Watson stat	0.327760
Prob(F-statistic)	0.000000		

Lessons Learned

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- While GBS and Wind seem to be significant, the model has major statistical problems:
  - Residuals are correlated.
  - Residuals are not normal.
  - Residuals are heteroscedastic.
  - The model does not explain a whole lot (R2).
- Transformations of the response did not help to solve these problems.
- Other modelling techniques might be needed.
- Maybe Gamma-regression might be usefull, but GLMs are rarely studied in time-series-context and the (rare) negative prices are a problem.

Lessons Learned

- Reason for the lack of fit in the model might be the Feldberg not being representative for the whole renewable energy-production in Germany.
- Prices on the weekend would allow a better insight, because those would show large average shift.
- To explain the extreme price events 15min data might be helpful

References

1) **Open Clipart Library**: https://openclipart.org
2) …