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New wind farm operating strategies accounting for variable production costs and electricity prices for higher returns. Review and outlook based on the KORVA and OTELLO projects.

Procedure

Presentation content

1. **Overview**
2. **Methods**
3. **Case studies / results**
4. **Summary and outlook**

Overview

Context, objectives and methods of the project KORVA

Context of future wind farm operation

- Variable electricity market prices
- Variable plant lifetime
- Post EEG operation (Germany)

Objectives for developing a new operating strategies

- Ensure economical operation
- Maximize profit over the plant lifetime
- Demand-orientated feed-in of wind power at minimum cost

Methods

- Modelling of technical and economic aspects
- Annuity method for the overall economic assessment of the investment
- Development of an optimization tool to provide a generalized schedule for a wind park

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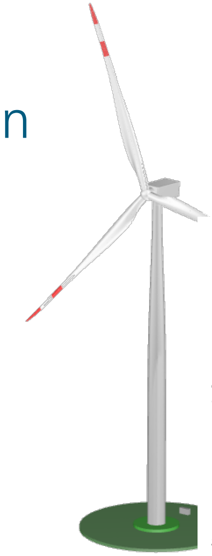
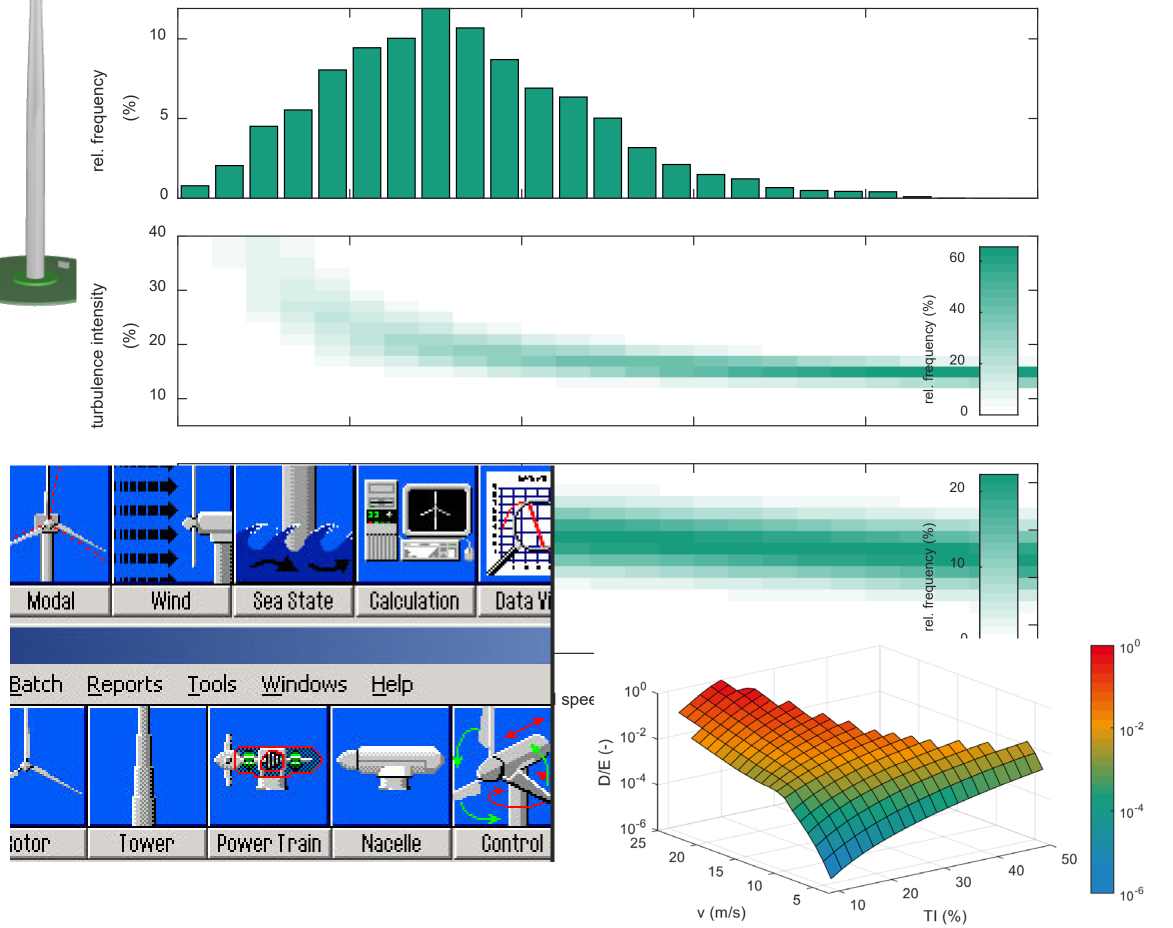
Methods

Modeling the technical sub-aspects for optimization





Reference wind turbine and wind farm
- Reference wind turbine design from the TU Munich
- 3.35 MW rated power, 110 m hub height
- Onshore park comprising a total of 20 turbines

Wind conditions and spot market prices
- Probabilistic model of the dependencies of wind speed, turbulence intensity and electricity price -> reference year
- Depending on the location

AI models for feed-in power and component wear
- Fast models are required for optimization algorithm
- Training data from extensive detailed simulations
- Derivation of fast replacement models with the help of machine learning methods

Reliability model (Input / Project Offshore Times / IWES)
- Calculation of operating costs and component failure rates
- Depending on ageing and individual operating mode

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Methods

Annuity method / Determination of the maximum annuity for a specific schedule

Static Inputs:

- Initial investment (I_0)
- Residual value (R_N)
- Interest rate parameter (i)
- Feed-in tariff
- Replacement prices
- Various rates of change
- …

Dynamic Inputs:

- Generated electricity (AEP)
- Stock exchange revenues (Rev)
- Operating costs (OPEX)
- Failure rate of major components
- Damage to non-replaceable components
- …

The annuity is greater than 0: the investment can be expected to generate annual profits. The size of the annuity describes the annual surplus of income over expenditure.

Annuity module

Output:

Maximum annuity (EAN) in €/a

$$EAN = \frac{i(1+i)^t}{(1+i)^t - 1}\left(-I_0 + \frac{R_N}{(1+i)^N} + \sum_{t=1}^{N} \frac{C_t}{(1+i)^t}\right)$$

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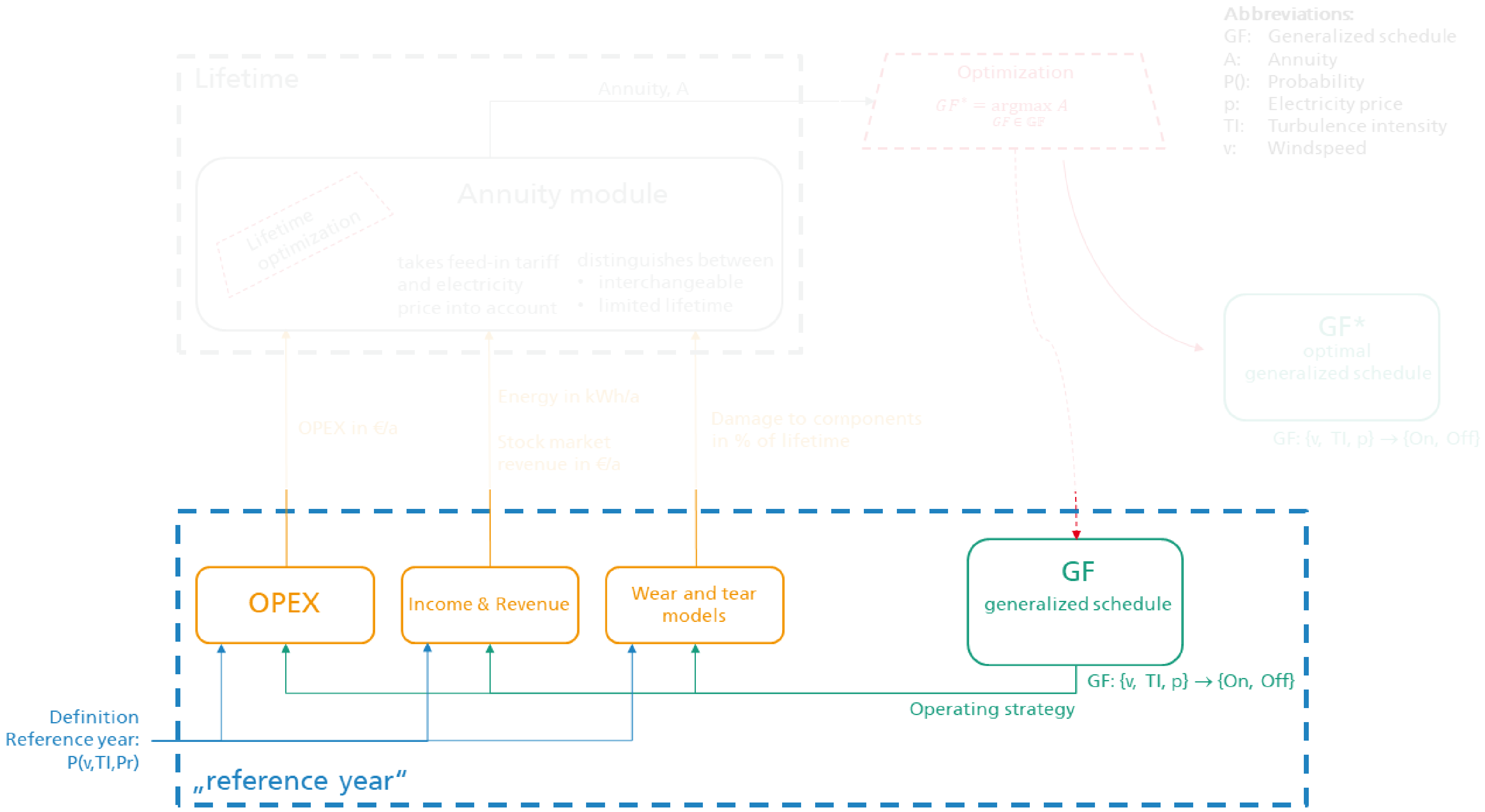
Methods

Optimization tool / Generation of a generalized schedule

How the schedule works

- Determination based on
  - Realizable revenue
  - Operating costs (OPEX)
  - Plant wear and tear
- Valuation based on the achievable lifetime extension and profitability using the annuity method
- Decision: Switching the systems on or off depending on the current electricity price and weather conditions



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Procedure

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Case studies / results

Example for direct marketing of newly constructed wind farms

Operating strategies

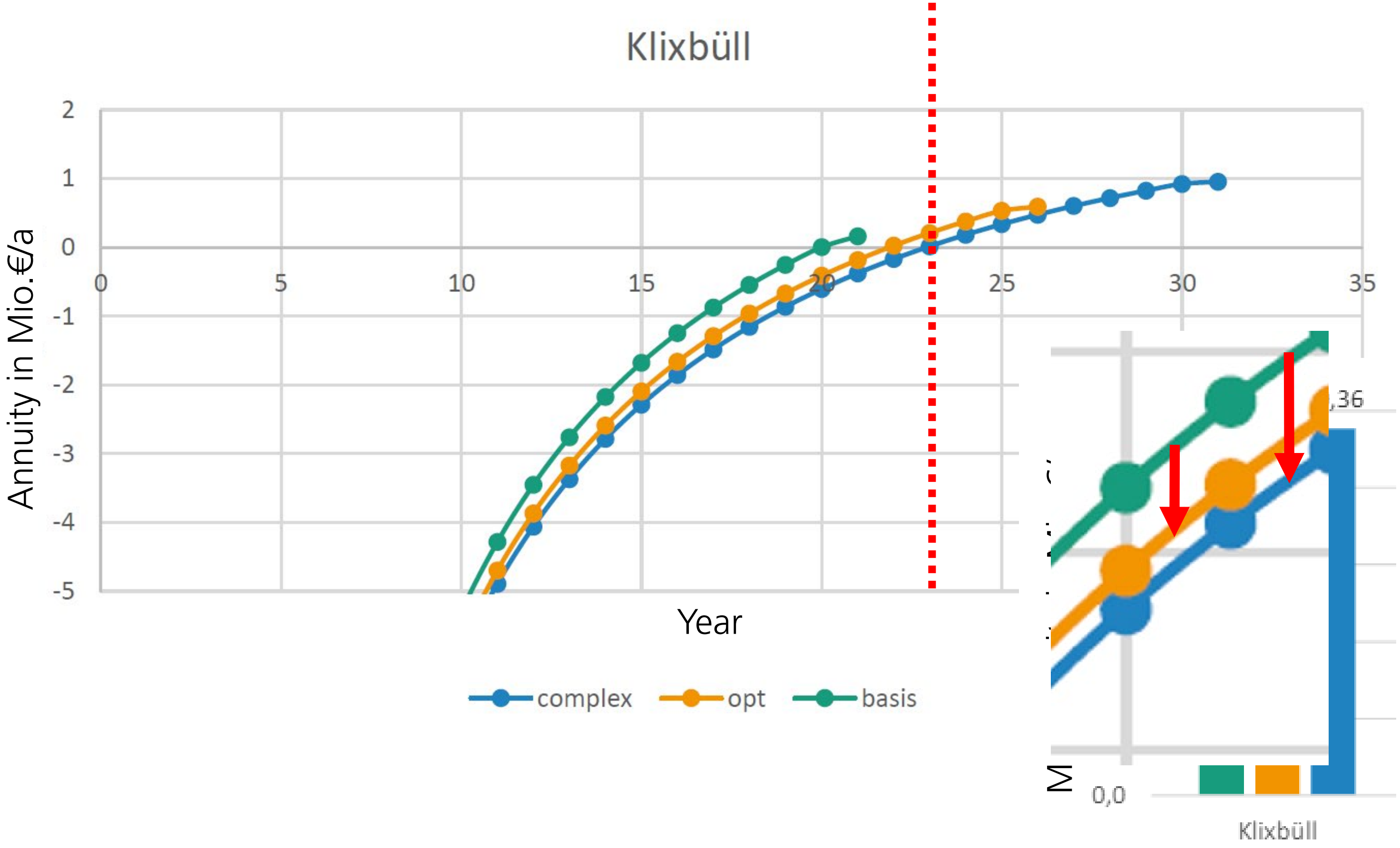
- Basis: all wind conditions / positive market prices
- Opt: Event shutdown = f(€)
- Complex: Event shutdown = f(€,v_{wind} ,TI)

Results

- compared to "basis" the operating strategy "complex" as well as "opt" increases the investment quality

Disadvantages / Problems

- Initial and long-time annuity losses
- Very long investment period (-> great uncertainty)



Case studies / results

Example for direct marketing in continued operation

Situation: „Das Schäfchen ist im Trockenen“ (german saying)

- Profit is essentially assured

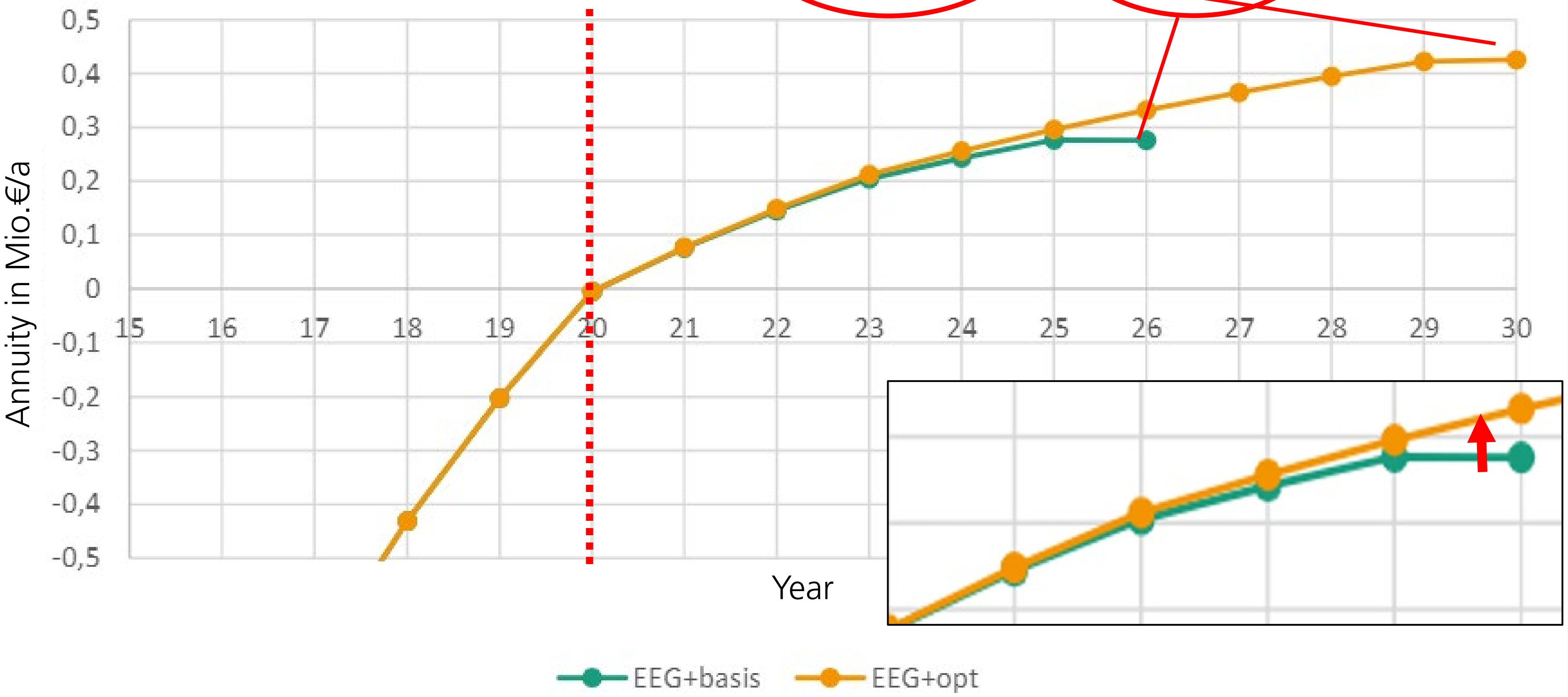
Operating strategies

- Basis: all wind conditions / positive market prices
- Opt: shutdown via KORVA for optimal lower electricity price limit

Results

- Limited influence
- A better investment at any time
- With the "opt" continued operation strategy and a four-year longer term, a total of € 5.6 million more can be generated (initial invest ≈100 Mio. €)

$$0.42 \cdot 30 - 0.28 \cdot 26 = 5.32$$



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Summary and outlook

Know-how from research for practical application

The most important things in a nutshell

- Profitability of wind farms can be increased by the shown operational optimization
- Simple switch-on/switch-off strategies condition based on electricity market prices after or without EEG remuneration
- Better balancing of system wear and tear and feed-in revenues
- BUT: Future value developments are not worth it without uncertainties

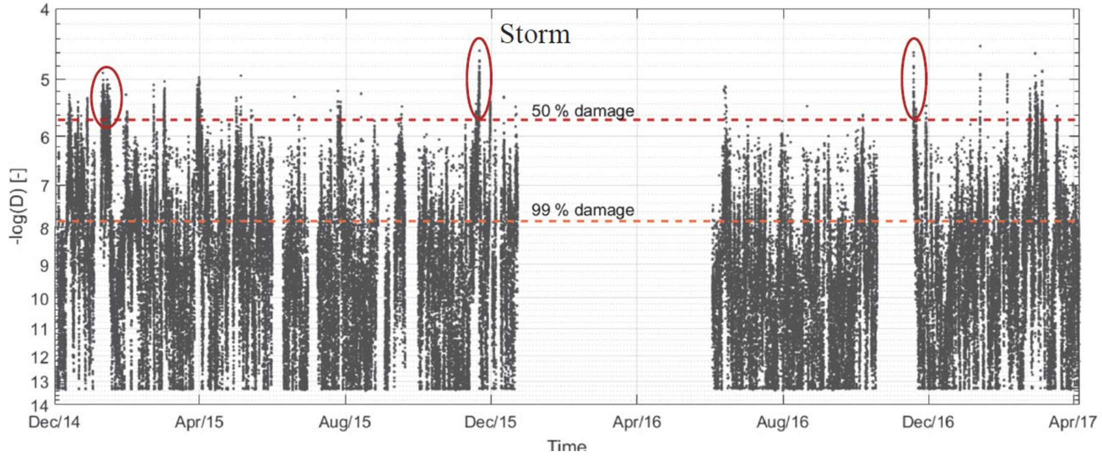
Outlook

Outlook project OTELLO

"Toxic operating situations" / Initial thoughts

Measurement campaign on the tower of a Vestas V90 (2MW)

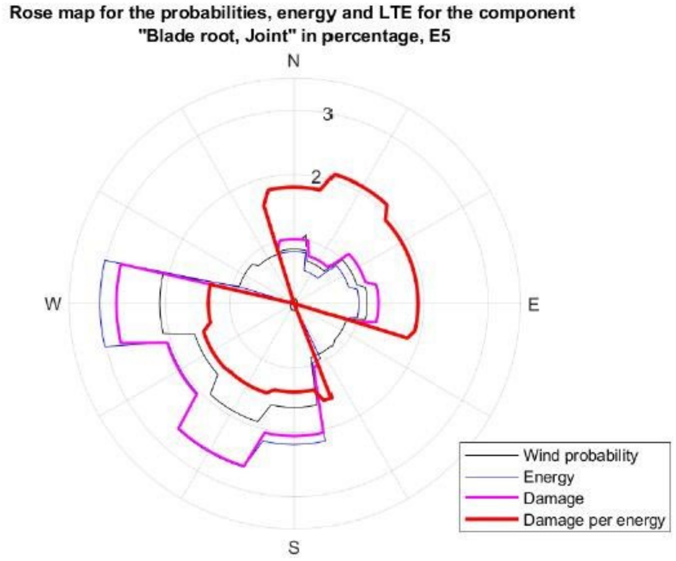
- 50% of the damage during 1.3% of the observation period (7.8 of 604 days)
- A few storm events have the greatest impact



Loraux, C. (2018): Long-term monitoring of existing wind turbine towers and fatigue performance of UHPFRC under compressive stresses. PhD thesis.

Rose map for the probabilities, energy and damage of a selected wind turbine (Source: UL)

- Directional contributions to energy and damage
- Ratio of damage to energy significantly more favorable for southwest winds

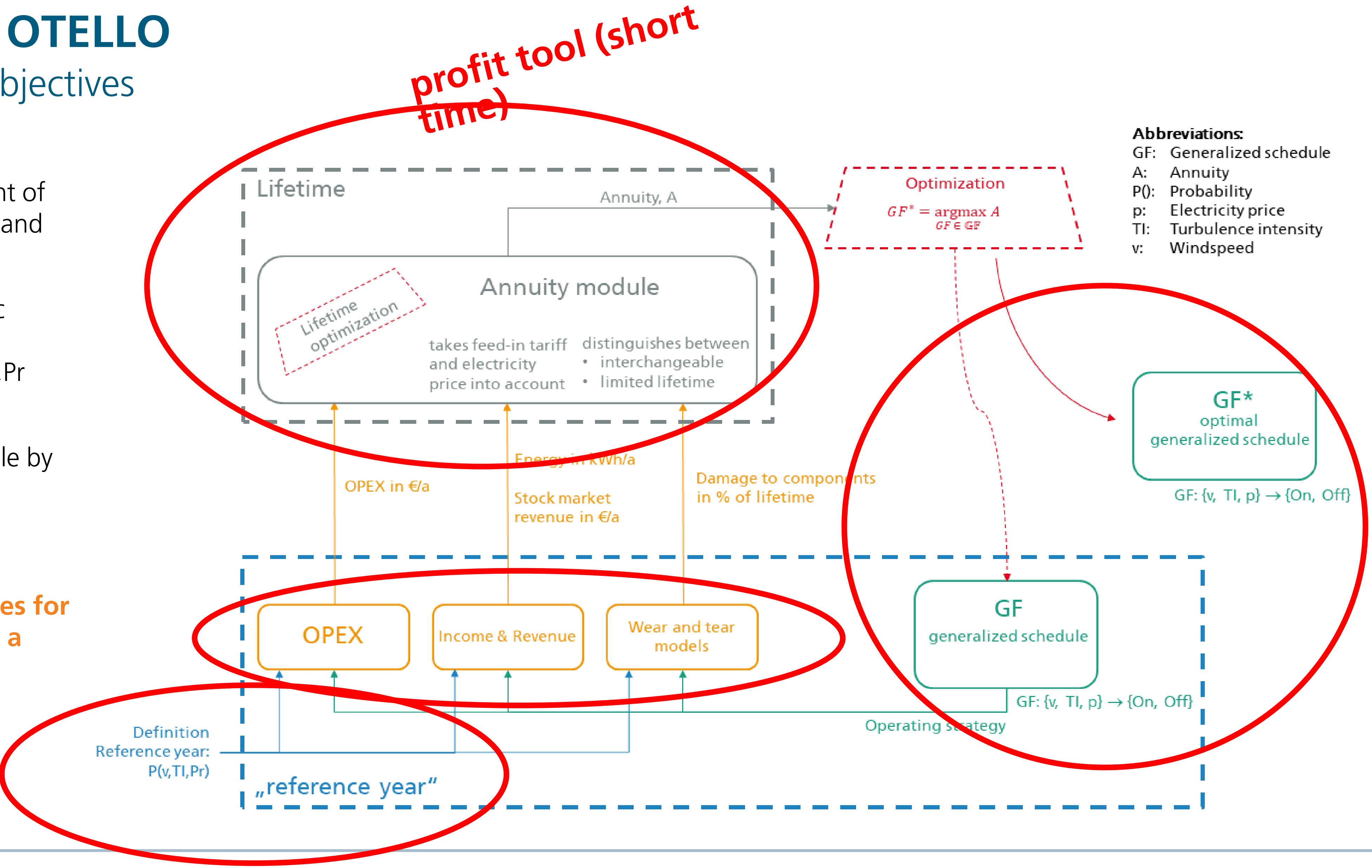


Outlook project OTELLO

Follow-up project / Objectives

- Improvement and refinement of the individual models (Data and model usage - RAVE)
- Replacement of probabilistic model
  Use of forecast inputs – v,TI,Pr
  (Data usage - RAVE)
- Replacement Annuity module by a profit tool

Concrete operating schedules for the next few days and thus a marketable product



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Thanks

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Further Information:
https://www.iee.fraunhofer.de/de/projekte/suche/2024/otello.html

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