House of Energy Markets & Finance

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Learnings and Prospects of Stochastic Modeling in Adequacy Assessments … and beyond

October 26, 2023 | Prof. Dr. Christoph Weber
Project Workshop (VeSiMa)

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Our ambition

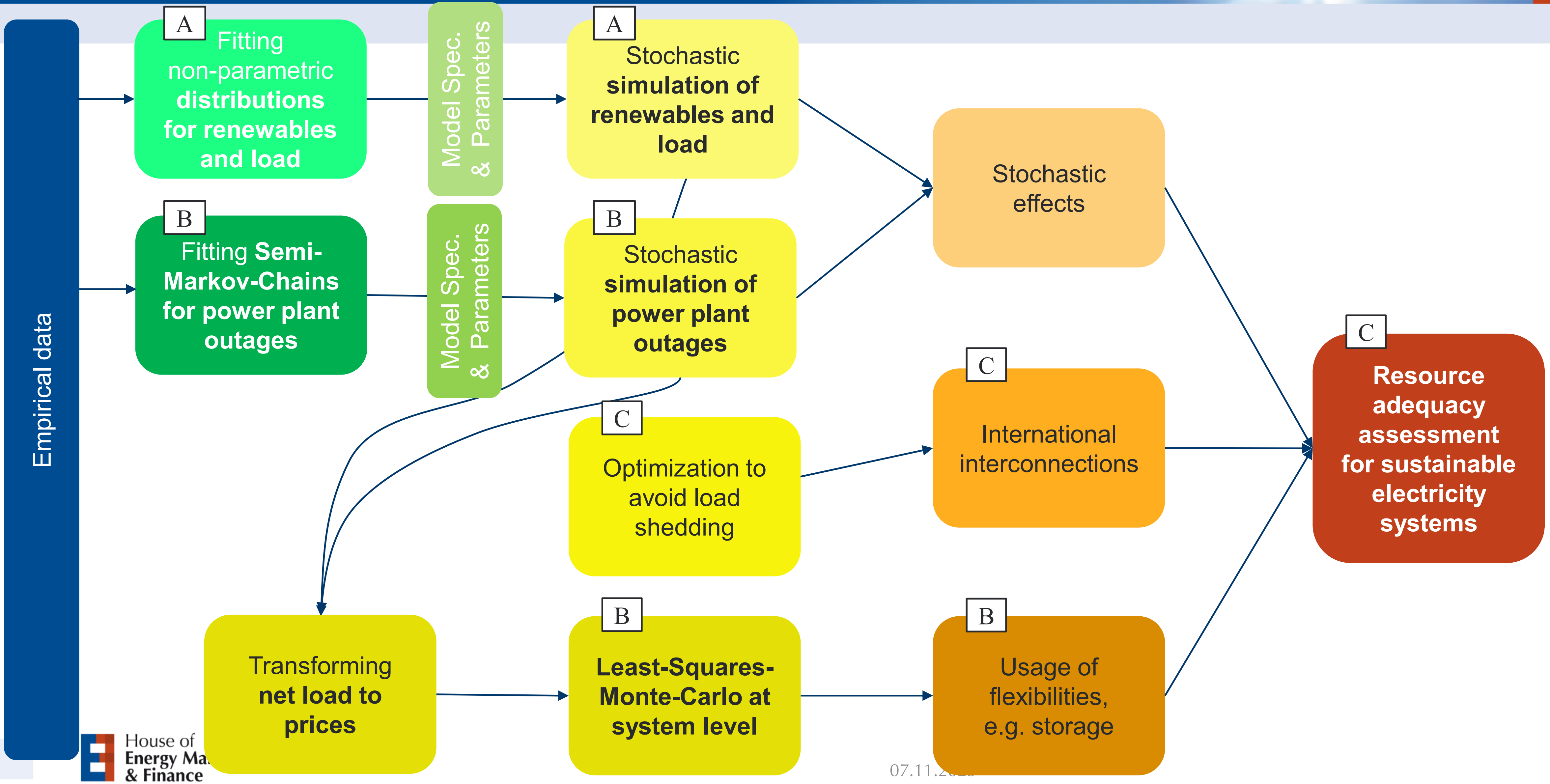
Decision support for sustainable energy systems

Learning from the data

Making best use of domain-specific knowledge

➢ VeSiMa is a showcase example

Key modules assembled for purpose



Key achievements regarding the purpose:

Resource adequacy assessment for sustainable electricity systems

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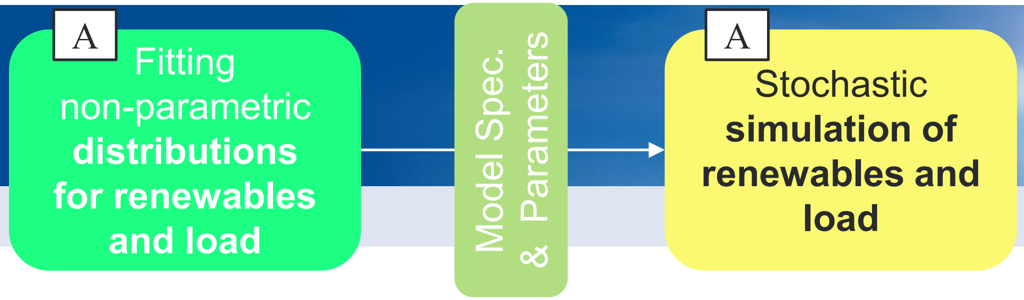
- **Full tool chain operational**
- Enables resource **adequacy assessment** based on **ten thousands** of stochastic **simulations**
- Inclusion of **multiple** interdependent **stochastic factors** along with deterministic drivers
- Rapid **fitting to varying scenario settings** possible

Potential extensions:

- Endogenous treatment of capacity expansions using an EVA-type approach (economic viability assessment)
- Improved treatment of hydro reservoirs and CHP
- Test of further stochastic specifications

Key achievements regarding renewables modelling:



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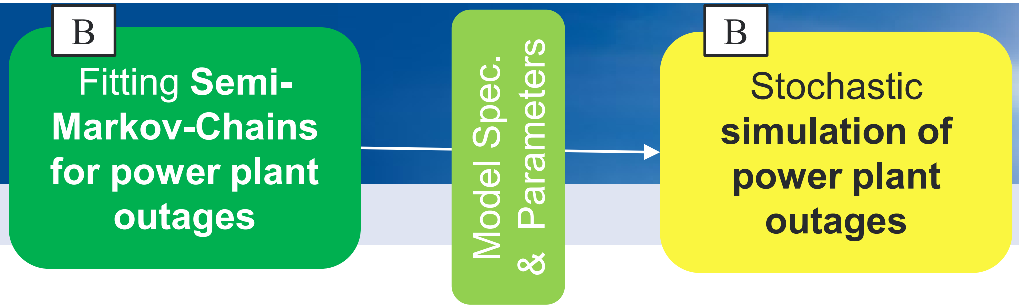
- **Full coverage of major countries and technologies**
- **Stochastic** modelling approach enabling detailed **simulations**
- **Non-parametric approach** adapting flexibly to multivariate data
- Inclusion of **multiple interdependencies** in **space and time** along with deterministic drivers
- Based on **large set of empirical data** (PECD by ENTSO-E)

Potential extensions:

- Testing of alternative specifications – especially regarding temporal interdependencies
- Test of machine learning approaches
- Extension of the geographical scope

Key achievements regarding availability modelling:



- Coverage both of **planned maintenance** and **forced outages**
- Adapted **stochastic** approach to **match failure characteristics**
- Fitted to **large set of empirical data** (power plant database by ENTSO-E)

Potential extensions:

- Improved data cleansing methods
- Pooled regressions across technologies and vintage classes

Key achievements regarding storage modelling:

C

Least-Squares-Monte-Carlo at system level

→

C

Usage of flexibilities, e.g. storage

- Development of a **LSMC** approach at **system level**
- Generalization to the **multi-storage** and **multi-country** case
- **Efficient computation** for large samples

Potential extensions:

- Extension to demand-side flexibilities
- Improved handling of international interconnections

Key achievements regarding interconnection modelling:

C
Optimization to avoid load shedding

C
International interconnections

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- Implementation of a **simplified optimization** to check **international back-up** possibilities when needed
- **Efficient computation** for large samples
- Intertemporal **optimization plus regression** to assess **impacts** on **national net load**

Potential extensions:

- Prediction of grid congestions based on neural networks
- Principal component analysis of drivers for congestions

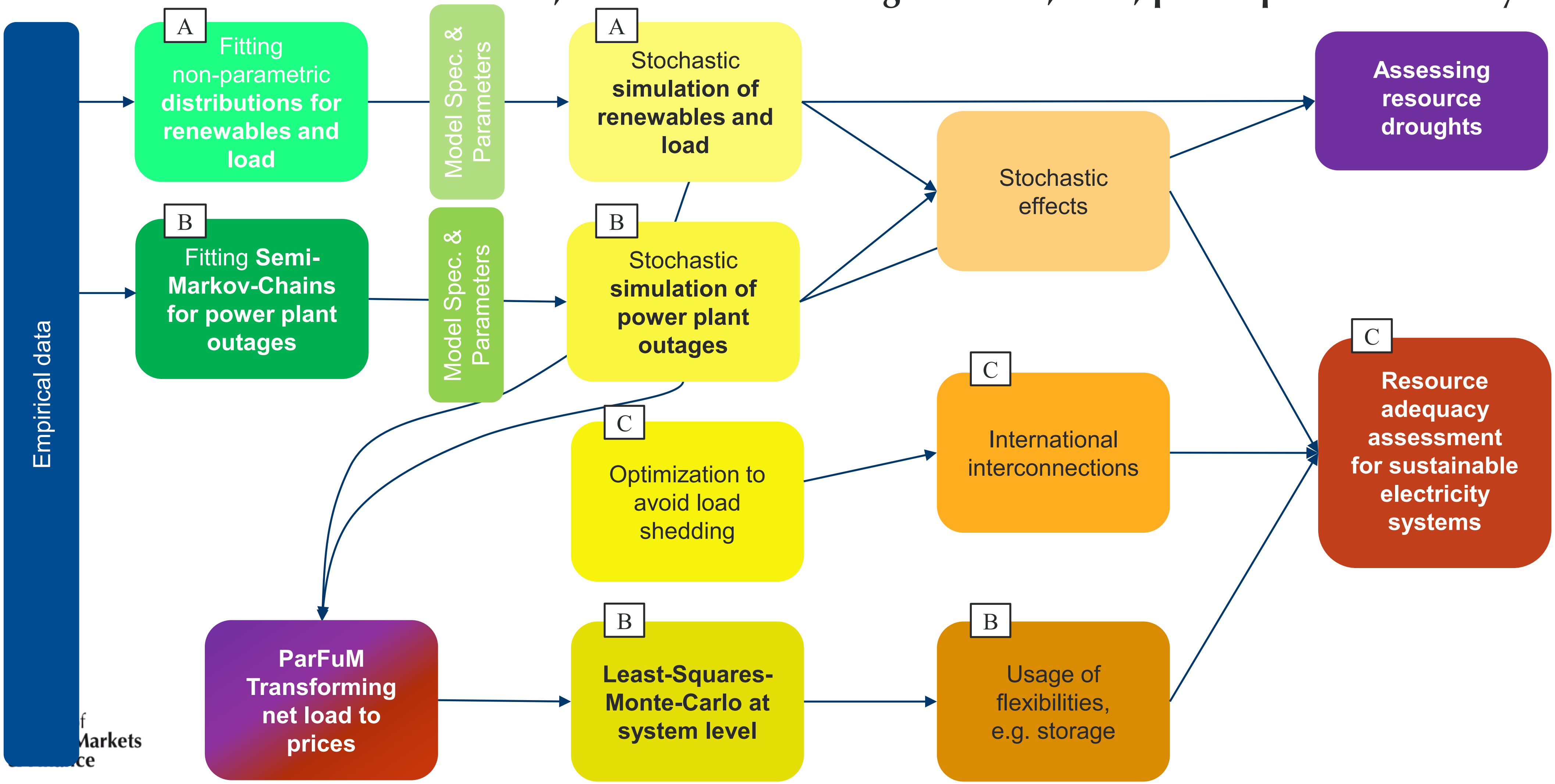
Key lessons learnt

- Building-up **basic model not overly complex**
- **Testing** and comparison of **multiple specifications** time-consuming
- **Multiple storages** and flexibilities **challenging** – both methodologically and computationally
- **Data quality** challenging for outage data

- **Application** study requires **careful calibration** – even if number of parameters limited
- Results aligned with expectations
- In extreme situations, additional **operational constraints** have a **large impact** on load shedding

Incorporating stochastics in the VeSiMa simulation tool

- Stochastic factors: **Wind onshore & offshore, PV and run-of-river generation, load, power plant availability**



Stochastic modeling in adequacy assessments: VeSiMa vs. ERAA

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Incorporating stochastics in the ENTSO-E European Resource Adequacy Assessment (ERAA):

- **Climate years** to reflect stochastic fluctuations
  - No explicit stochastic modelling
- **Monte-Carlo simulations** for power plant **availability**
- **System operation** optimized under **perfect foresight** for sample years **- including also storage**

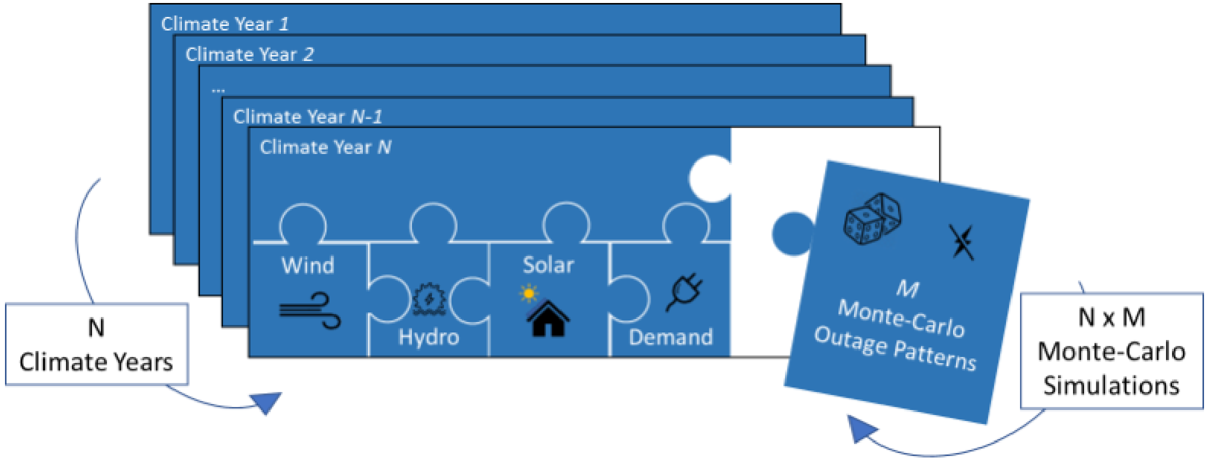


Figure 18: Monte Carlo simulation principles for a given target year

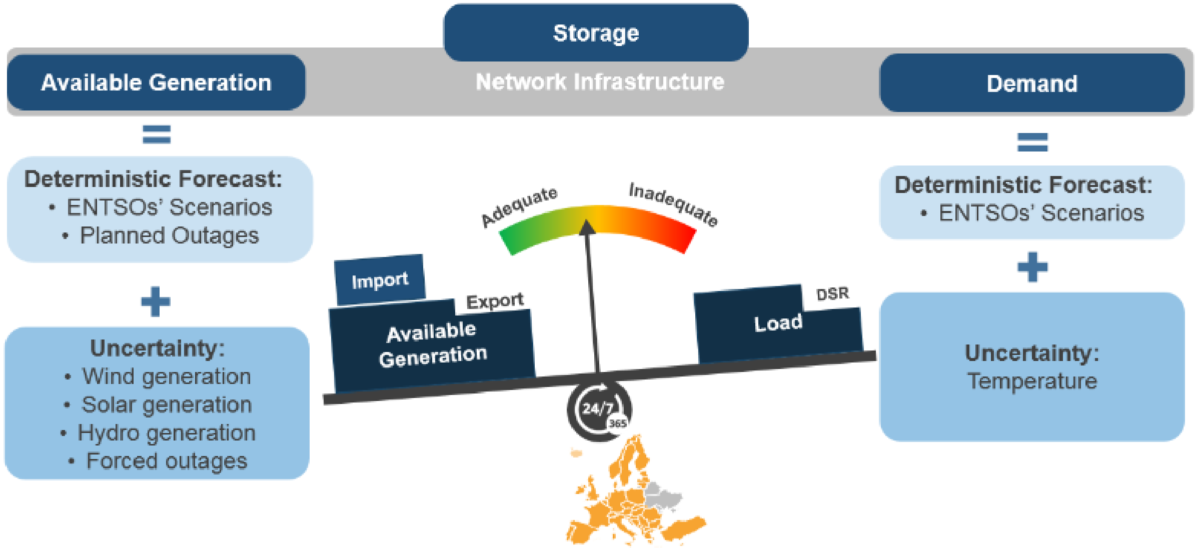


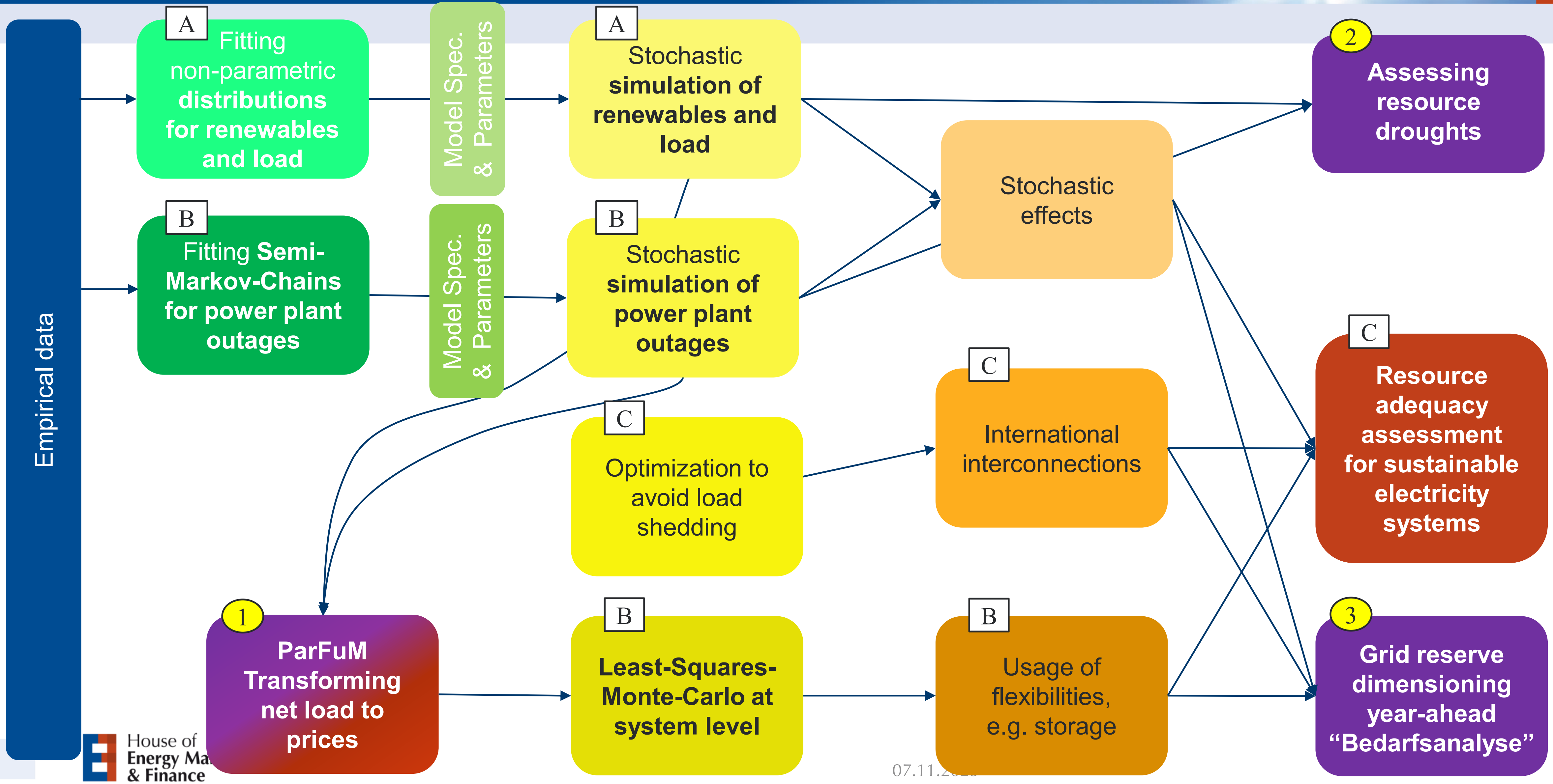
Figure 2: Overview of the ERAA 2022 methodological approach

Consequences for the adequacy assessment

- Solely using climate years and outage scenarios limits possibilities to quantify rare extreme events
- Use of a deterministic optimization model assumes (unrealistically) **perfect forecasts** and **perfect coordination**

ENTSO-E. European Resource Adequacy Assessment 2022 Edition: Annex 2: Methodology

Developed key modules
– and potential further applications



Possible future applications

1. **Stochastic price simulations**
   - **Already implemented** in the current model → basis for optimal storage operation
   - **Extensions** possible along the lines of **ParFuM**, the parsimonious fundamental model, to cope with further fundamental effects, e.g., CHP (cf. Kallabis et al. 2016, Beran et al. 2019)
   - **Improved fitting** to **empirical prices** possible along the lines of Pape et al. (2016) and Vogler et al. (2023)
2. **Estimations of renewable resource droughts ("Dunkelflauten")**
   - Relevant for the **dimensioning of back-up** capacities and/or long-term storage capacities
   - **Stochastic simulations** of renewable infeed, load and availabilities **as basis**
   - **New evaluation tools** needed, focusing on the **cumulative energy deficit**
3. **Grid reserve dimensioning year-ahead ("Bedarfsanalyse")**
   - Yearly process by German TSOs to ensure feasibility of load serving in (winter) stress situations
   - Could be based on stochastic simulations of load and infeed at regional (e.g. state) level
   - Stochastic simulations have to be adapted to subnational data

Further data-driven approaches for decision support

Current project applications:

1. **Efemod:** use publicly available data to empirically estimate the parameters for energy system and energy market models using modern methods of statistics and machine learning
   - Notably use of ENTSO-E transparency platform data in conjunction with other data
   - Empirical substantiation of key model parameters of bottom-up energy system models
   - Strengthening of medium-term forecasting capabilities for more aggregated energy market models
   - Application include valuations of demand flexibility and storage
2. **FEVEA:** use available market data and statistical models to determine fair values for PPAs (power purchase agreements), notably for wind energy
   - Transpose concept of fair valuation from finance to energy markets
   - Detailed empirical analysis of prices and quantities with a focus on the intraday market
   - Modelling of all relevant markets and effects like forecast updates
3. Ongoing application: Extension of the VeSiMa modelling approach to multiple sectors and under consideration of impacts of climate change

Conclusion

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Decision support for sustainable energy systems
can be improved by

- **learning from the data** in combination with
- **making best use of domain-specific knowledge.**

Particularly relevant in case of **abundant data** and **infrequent events,**
e.g., **threats to resource adequacy**

➢ **VeSiMa has developed a novel approach – which can certainly provide added value** in this application and beyond.

Thank you for your attention.

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