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Breaking Barriers: Unleashing Research's Potential for Shaping Decarbonized Futures

Sonja Wogrin
Institute of Electricity Economics and Energy Innovation
Graz University of Technology

02.05.2024

www.iee.tugraz.at



Institutsleiterin

Prof. DI Dr Sonja Wogrin MSc

Institut für Elektrizitätswirtschaft und
Energieinnovation (IEE)

Technische Universität Graz

E-Mail: wogrin@tugraz.at

Web: IEE.TUGraz.at



Sprecherin

E-Mail: energetic@tugraz.at

Web: energetic.TUGraz.at

What's new?



Austrian Energy Transition



Research Center ENERGETIC



ERC Grant

Optimization and data aggregation for net-zero power systems

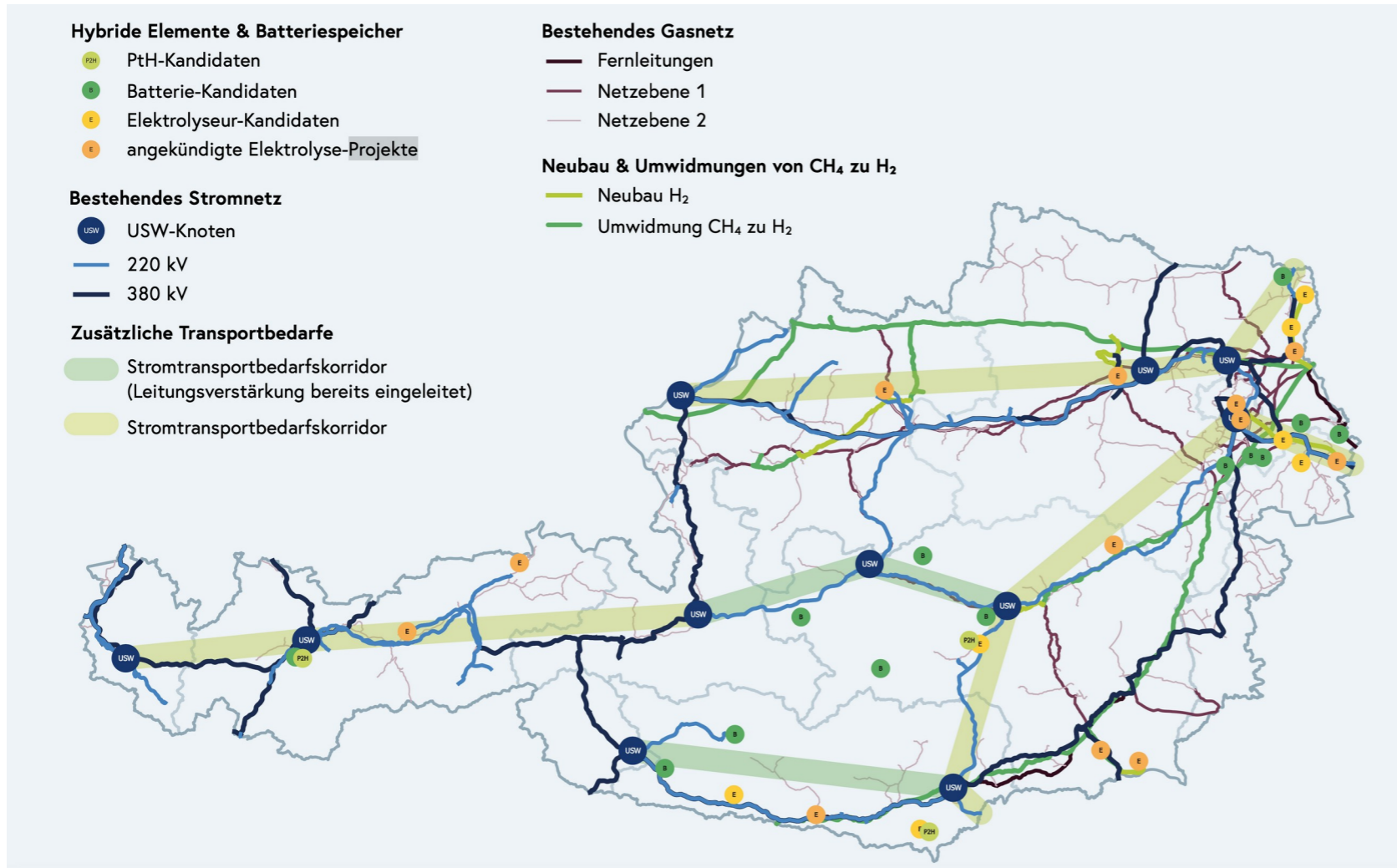


Austrian Energy Transition

Source: <https://unsplash.com/photos/RVyc3Zzhpt8>

Integrierter Österreichischer Netzentwicklungsplan

ÖNIP



IEE war Teil des
**InfraTrans2040 Projektes &
ÖNIP**

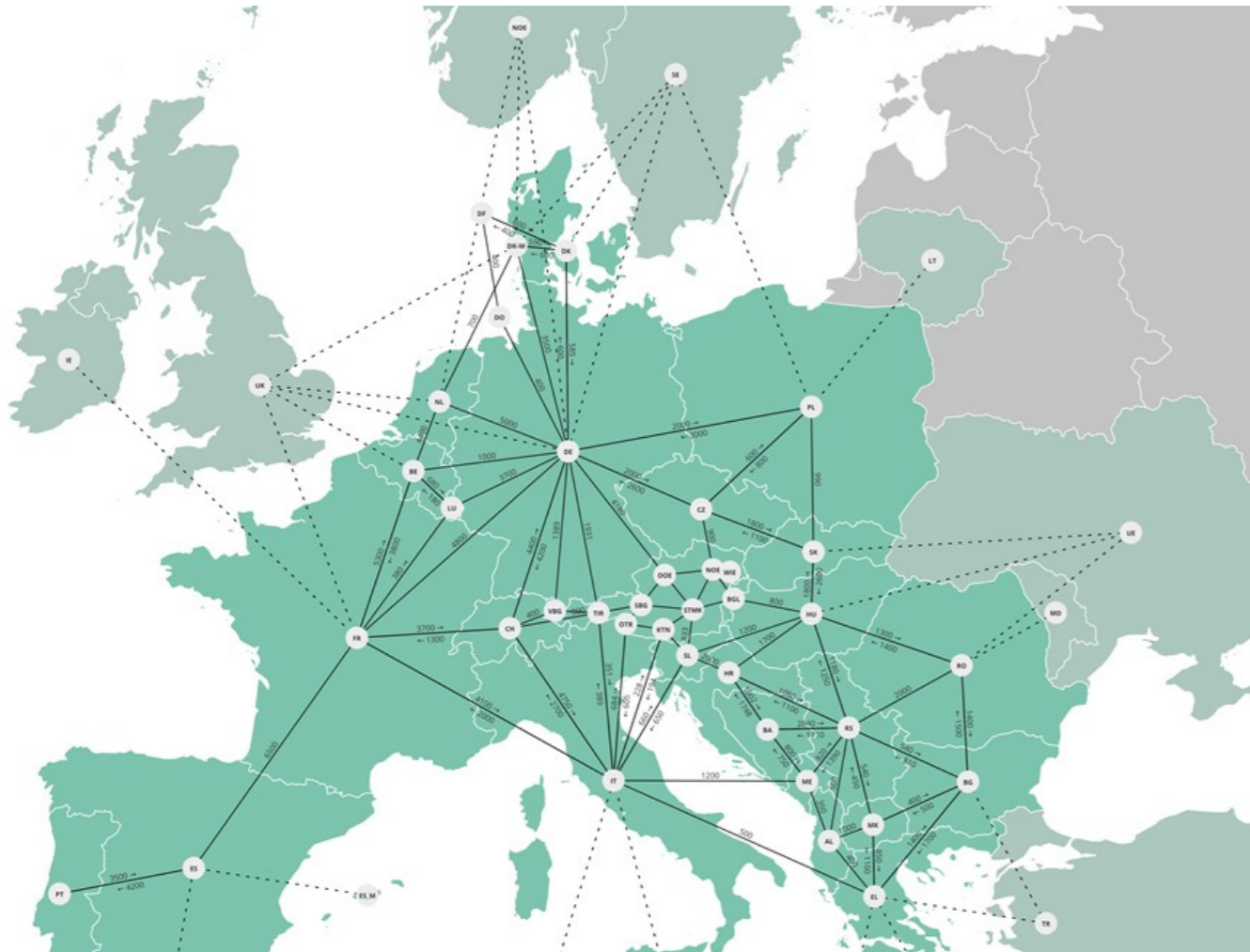


Spoiler: wir brauchen **mehr
Ausbau!**



Challenge:
**zugrundeliegenden
Energiesystemmodelle** (z.B.
Einbettung ins Europäische
Übertragungsnetz) **sehr
rechenintensiv**

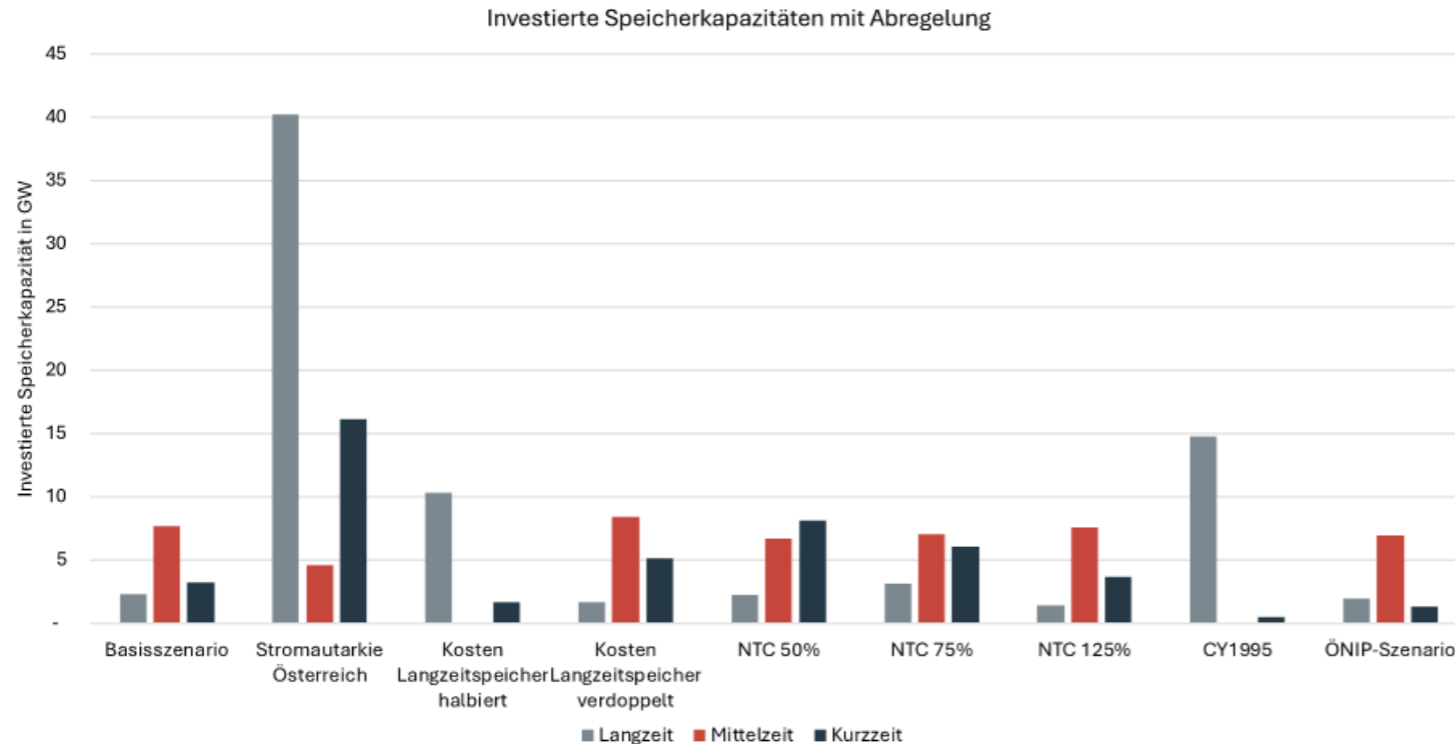
Ermittlung des Speicherbedarfs im österreichischen Elektrizitätssystem 2040



- **Optimale Speicherinvestitionen in Österreich für 2040:**
 - **Kurz-/Mittel-/Langzeit** Speichertechnologien
 - **Ausbau in Erneuerbare** vorgegeben
 - **Stündliche** Auflösung

- **Szenarioanalysen:**
 - Stromautarkie
 - Kostensensitivität
 - NTC-Sensitivität
 - Wetterjahr-Sensitivität

Ermittlung des Speicherbedarfs im österreichischen Elektrizitätssystem 2040



Key Takeaways:

- **Ausbau an Speichern reduziert Importabhängigkeit**
- **Stromautarkie Österreich ist auf keinen Fall anzustreben** (Auswirkungen auf Gesamtsystemkosten)
- Berücksichtigung **verschiedener Klimajahre** kann den **Bedarf** an Speicherkapazität **erheblich verändern**
- Zusammenhang zwischen dem Ausbau von Speicherkapazitäten und dem **Ausmaß der erlaubten Abregelung**

Future Work:

- Erneuerbare und Netzinfrastruktur **co-optimieren**
- **Integration** der Sektoren **Gas/Wärme etc.**
- **Analyse Wirtschaftlichkeit** von Speichern



Research Center **energetic**

Research Center for ENERGy Economics & Energy AnalyTICs

Research Center ENERGETIC

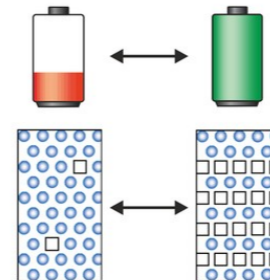
puts into reality

Interdisciplinary cutting-edge research that supports transitioning energy systems on the path toward full **decarbonization.**

Scientific competence to tackle this **energy crisis** with efficient and **sustainable solutions.**



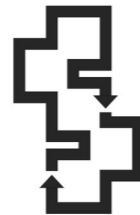
Techn. Chemie & Verfahrenstechnik



Mathe, Physik & Geodäsie



Maschinenbau & Wirtschaftswiss.



Architektur



Bauingenieurwesen



Elektrotechnik



Informatik & Biomed.



Core Research Areas (CRA)



CRA1: Energy System
Modeling & Analysis



CRA2: Digital Energy
Systems



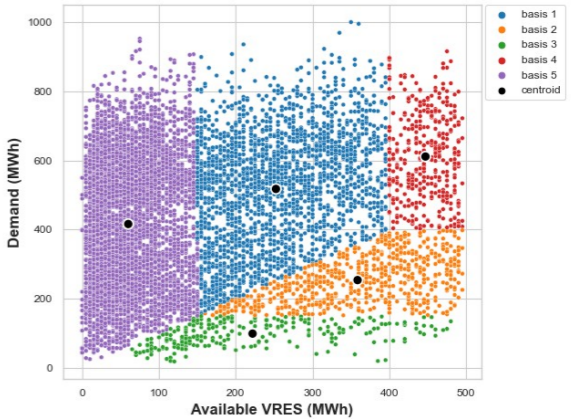
CRA3: Innovative
Technology Solutions

ENERGETIC Inter-disciplinary Activities



RINGs

iKlimEt



Source: <https://www.tugraz.at/forschung/forschen-an-der-tu-graz/research-centers/research-center-for-energy-economics-and-energy-analytics-energetic>
 Foto von [Kaleidico](#) auf [Unsplash](#) sowie von [Marvin Meyer](#) auf [Unsplash](#)

RINGs

Struktur- und Prozessoptimierung resilienter Quartiers-Energienetze

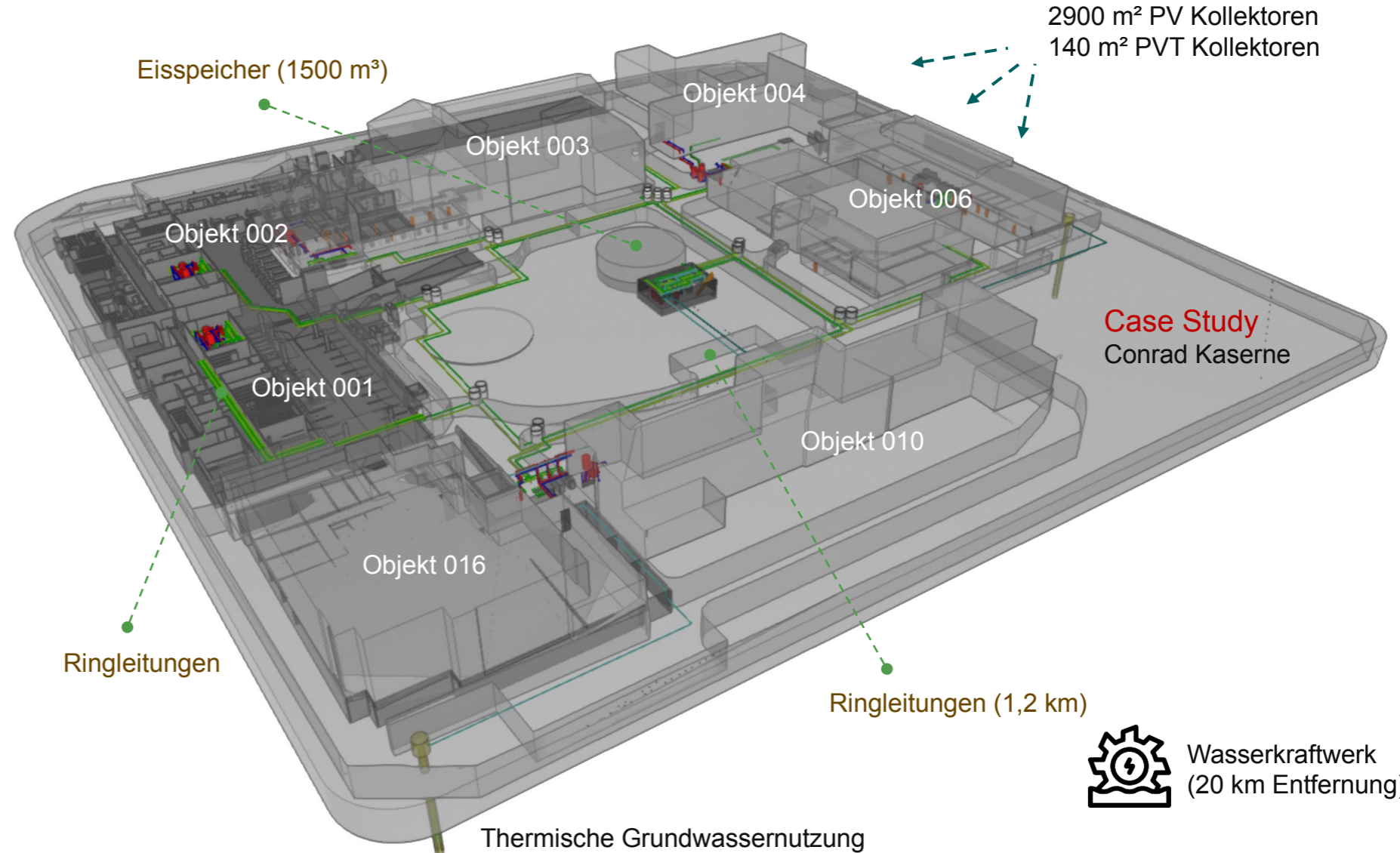
Ziele

Thermoelektrische
Simulationsmodelle von
Anergienetzen

Performance Evaluierung und
Modellvalidierung mit Messdaten

Fehlerdedektion
Physik-informiertes Machine
Learning

Optimierungsmodelle
Zielfunktionen: Kosten, Emissionen,
Autarkie



RINGs

Struktur- und Prozessoptimierung resilienter Quartiers-Energienetze

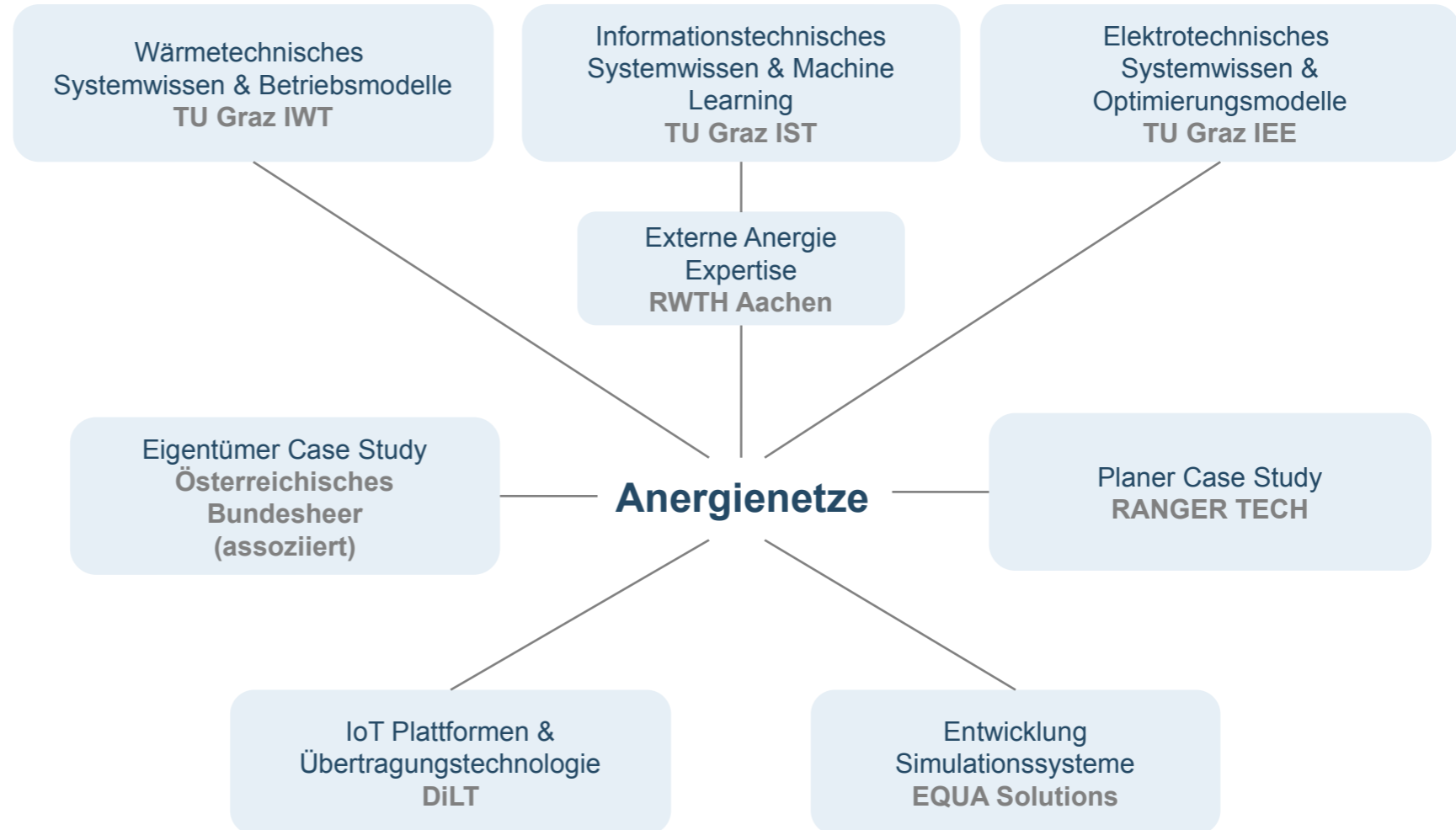
Rahmenbedingungen

Laufzeit:
Juni 2024 – Mai 2027

Förderung:
FFG

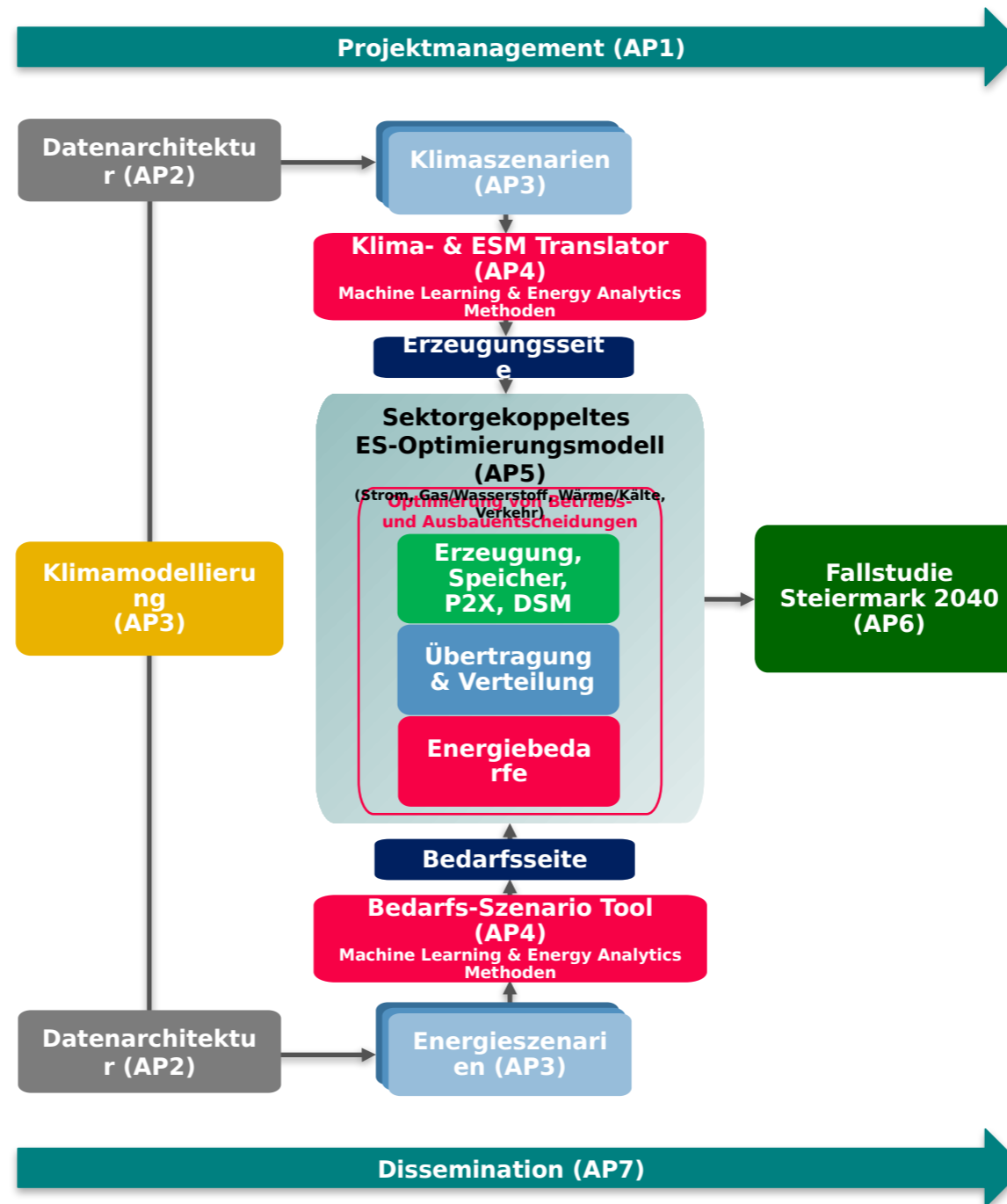
Programm:
ENERGIEFORSCHUNG 2022

Forschungskategorie:
Industrielle Forschung





Klimawandel



Energiesystemplanung

Rahmenbedingungen

Laufzeit:
Jänner 2024 – Dezember 2026

Förderung:
FFG

Programm:
ENERGIEFORSCHUNG 2022

Forschungskategorie:
Industrielle Forschung



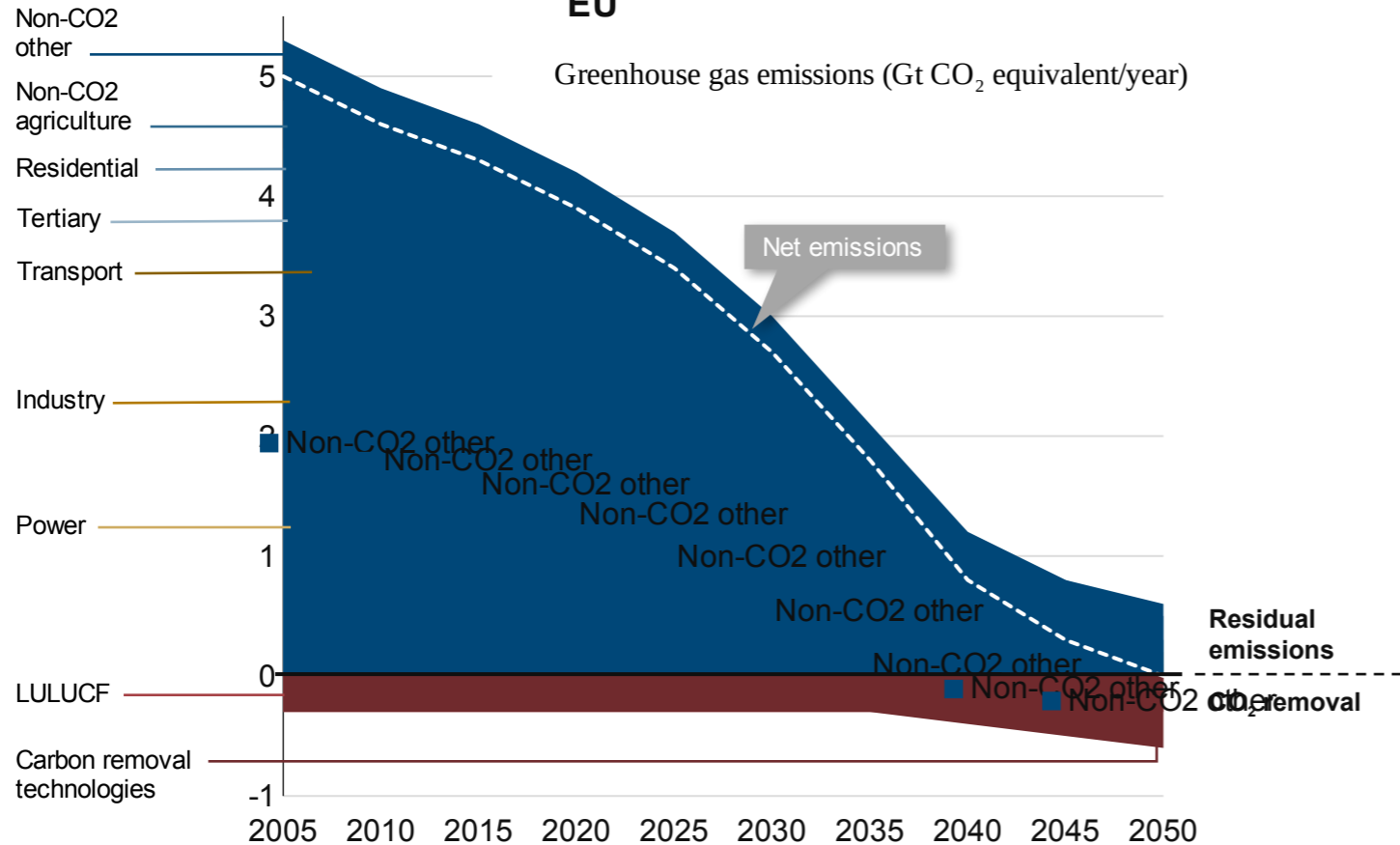


ERC Grant

ata aggregation for net-zero power systems (NetZero-Opt)

The Path Towards Net-zero Power Systems

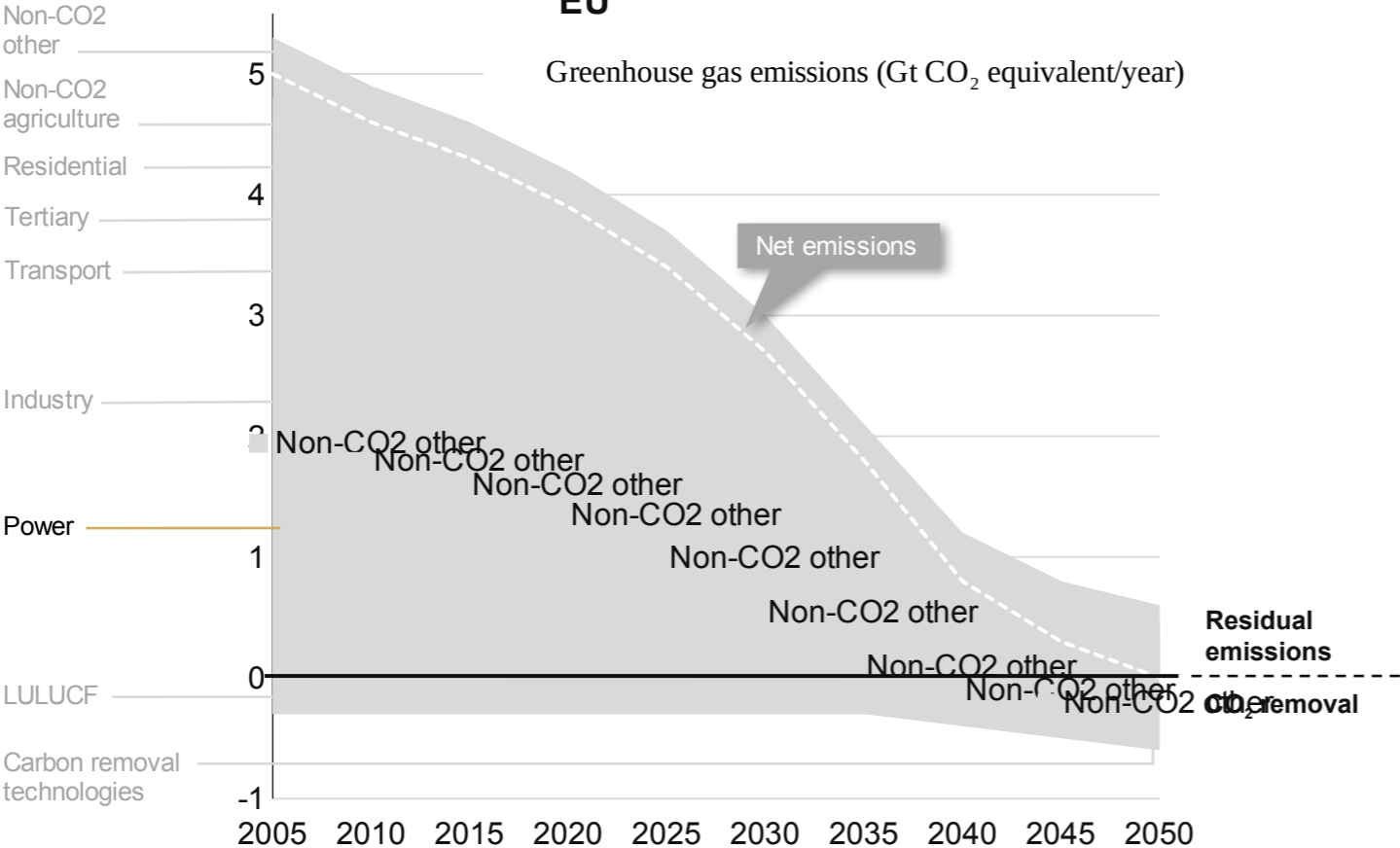
Illustrative emissions pathways to achieve a net-zero target in the EU



Source: European Commission, In-depth analysis in support of the commission Communication com(2018) 773

The Path Towards Net-zero Power Systems

Illustrative emissions pathways to achieve a net-zero target in the EU



Power System Optimization Models

Objective:



Minimize total system cost

Constraints:



Intermittent renewables



Power flow

Source: European Commission, In-depth analysis in support of the commission Communication com(2018) 773

Power System Optimization Models are Complex



Technical
Power flow, unit commitment, etc.



Uncertainty
Renewable energy sources etc.



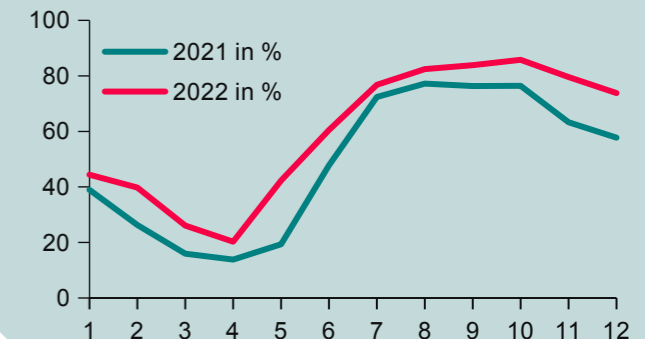
Spatial
Power grids etc.



Temporal
Long planning horizons with hourly resolution.
Challenge: interdependent time periods.

NetZero-OPT

Austrian hydro reservoir – monthly (%)



Computational Challenge

EU Power System Model



Variables: 630 M

NetZero-Opt
Variables: 0.5 M

3 orders of magnitude



World's Fastest Supercomputer*
600 M\$



Typical Workstation**
5000 €

Hourly Resolution

18 Days

Intractable

NetZero-Opt

<1 ms

12 Days

Source*: Frontier (supercomputer) - Hewlett Packard Enterprise Frontier, or OLCF-5, 1102 exaFLOPS. Estimated cost: 600 M\$.
Source**: Normal PC assumed to carry out 120 gigaFLOPS. Estimated cost: 5000€.

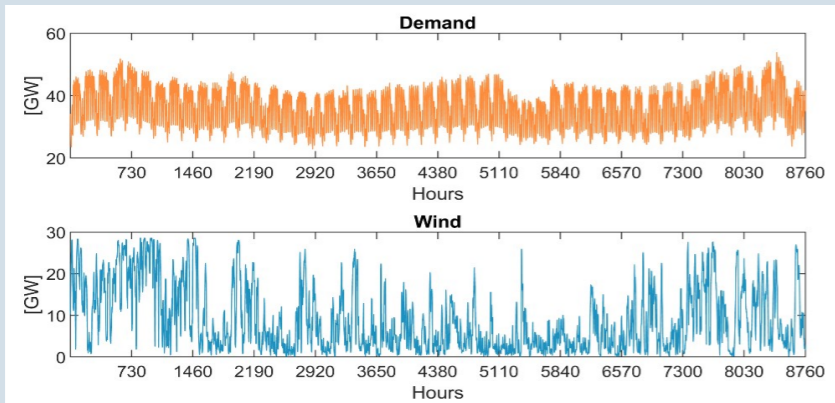
Time Series Aggregation* (TSA)

Traditional Framework

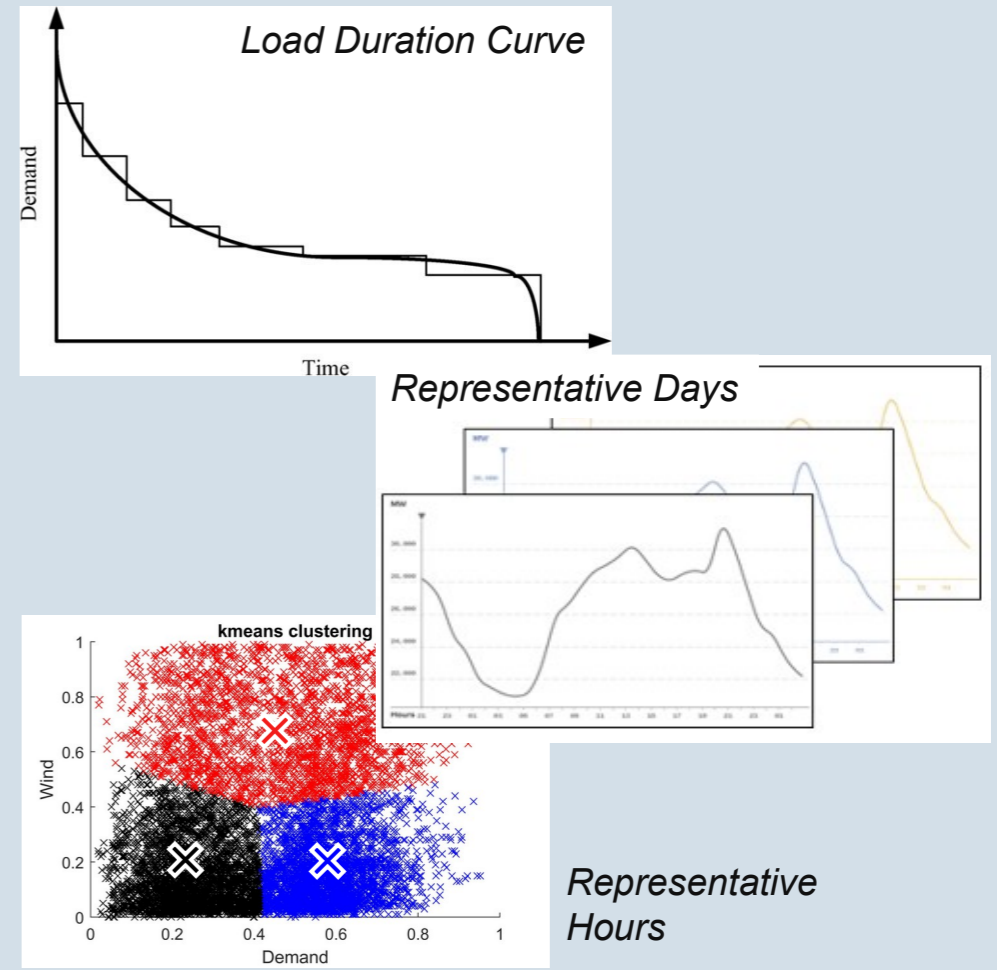
Focus on best approximation of input data.

TSA

Original Data Time Series



Times Series Aggregation



Source*:

Teichgraber, H. and A.R. Brandt. "Time-series aggregation for the optimization of energy systems: Goals, challenges, approaches, and opportunities." *Renewable and Sustainable Energy Reviews* (2022)

Li, C. et al. "On representative day selection for capacity expansion planning of power systems under extreme operating conditions." *International Journal of Electrical Power & Energy Systems* (2022)

Hoffmann, M. et al. "A review on time series aggregation methods for energy system models." *Energies* (2020)

Hilbers, A.P. et al. "Importance subsampling: improving power system planning under climate-based uncertainty." *Applied Energy* (2019).

Net-Zero Power Systems

Traditional aggregation framework **no longer valid for net-zero power systems!**



Time series aggregation should **focus** on approximating full **model outputs**.

NetZero-Opt



Theoretical and universally applicable time series aggregation framework.



Build **reliable net-zero** power systems.



Save costs in a global **1.8 trillion*** € industry.

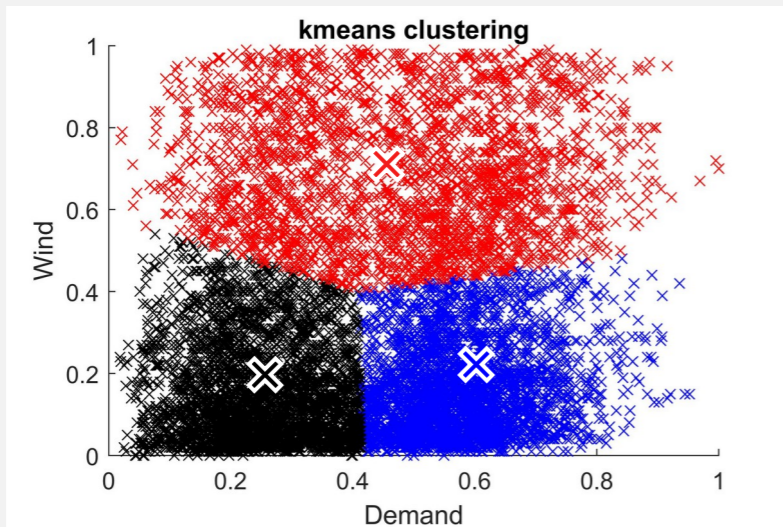
Source* (estimated for 2022): <https://www.precedenceresearch.com/power-generation-market>

Proof of Concept

Economic Dispatch Problem

Traditional Framework

- Approximate 8760 hours of original time series using only **3 representative hours** with kmeans clustering:

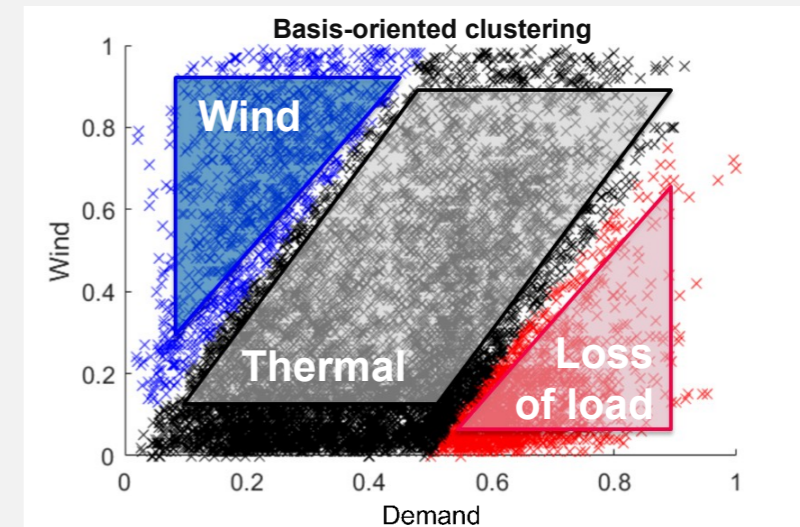


Results of economic dispatch problem:

- Relative **total system cost error 91%**.
- Relative **error in estimated loss of load 100%**.

NetZero-Opt

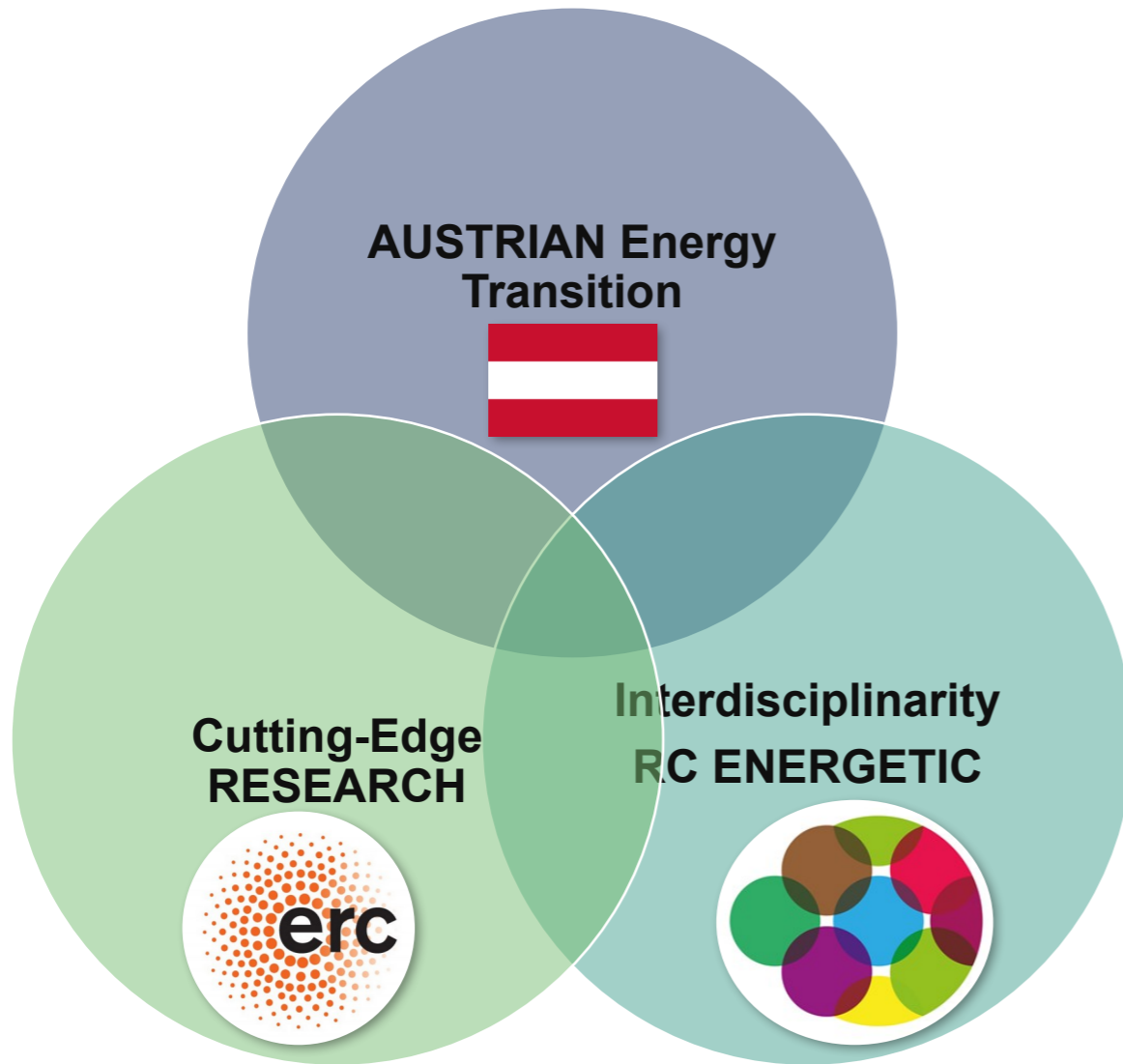
- Also uses 3 representative hours, but chosen with **theoretical underpinnings***:



- Results yields **proven relative error of 0%!**
- Aggregation potential of **3 orders of magnitude** (measured in number of model variables).

Source*: **Wogrin, S.** "Time series aggregation for optimization: One-size-fits-all?" IEEE Transactions on Smart Grid (2023).

Summing up!



Source: Foto von [Jeremy Yap](#) auf [Unsplash](#)