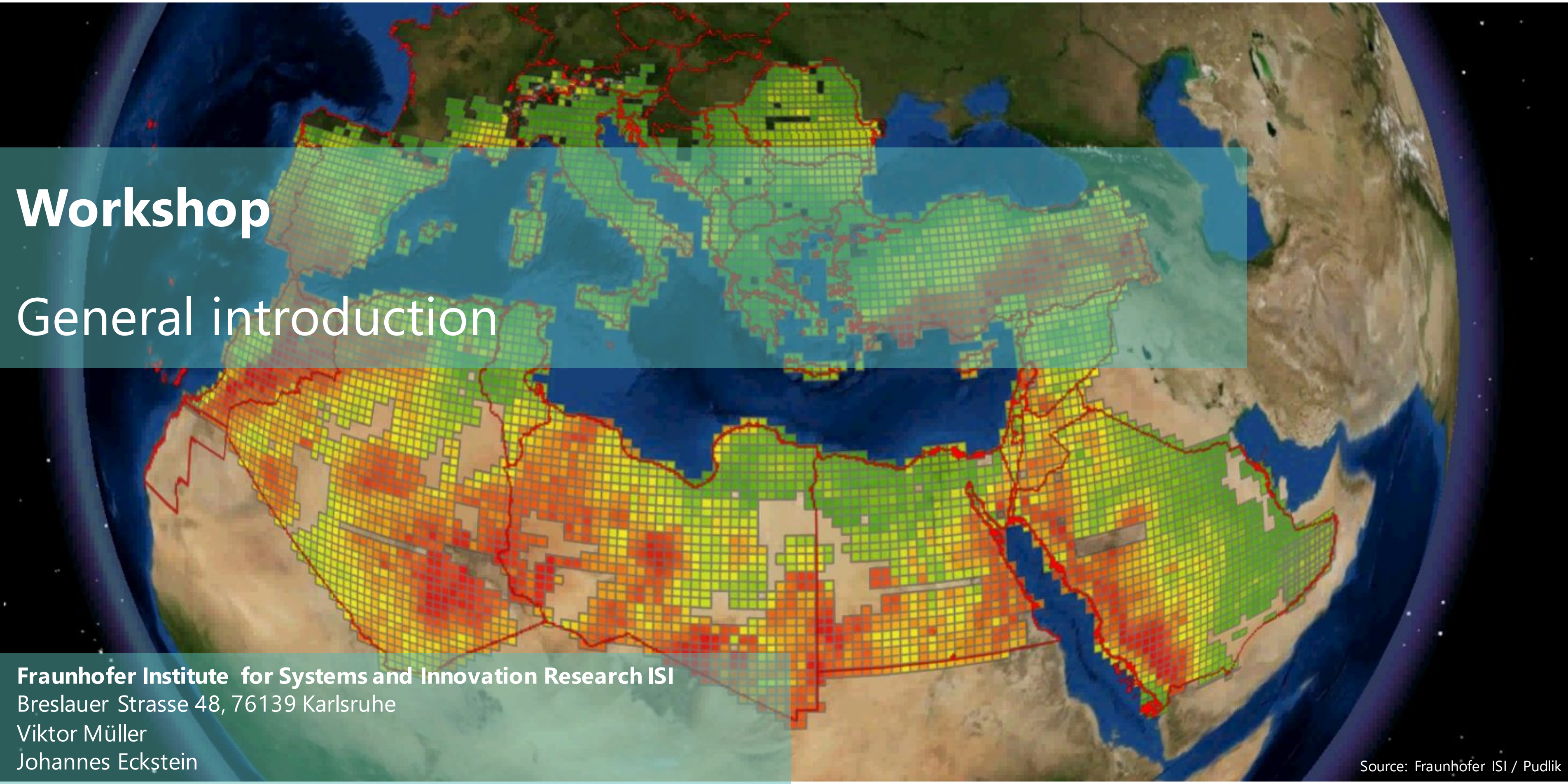
LEAP USER GROUP WORKSHOP AS PART OF THE REGIONAL EXCHANGE OF MODELLING EXPERTS IN THE WB6



Workshop

General introduction

Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48, 76139 Karlsruhe
Viktor Müller
Johannes Eckstein

Source: Fraunhofer ISI / Pudlik

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WORKSHOP PROGRAM

- 24.02: Selecting and programming indicators
- 03.03: Integrating non-energy sectors and emissions in LEAP
- 10.03: Structuring your LEAP model to reflect policies
- 17.03: Supply-side optimization with LEAP

BUSINESS UNIT: CLIMATE POLICY

- Questions regarding climate policy developments (part. gas markets, hydrogen) and innovation support policies (EU Innovation Fund, CCfDs)
- Questions related to emission trading systems (EU and other ETS)
- Climate change mitigation strategies and their assessment

- **Johannes Eckstein** is senior researcher in the business unit Climate Policy in the Competence Center Energy Policy and Energy Markets
- Work focus:
  - energy and climate policy development and evaluation
  - focus on industrial applications and policies
  - scenario-based energy system modelling

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BUSINESS UNIT: GLOBAL SUSTAINABLE ENERGY TRANSITIONS

- **Support of planning and implementation of sustainable energy and development strategies in emerging and developing countries.**
  - assessment of potentials and possible diffusion pathways for renewable energy technologies
  - model-based analyses of energy systems
  - evaluation of local value creation potentials for energy technologies
  - development of policy instruments and strategies supporting sustainable energy transitions.

- **Viktor Müller** is junior researcher in the business unit Global Sustainable Energy Transitions in the Competence Center Energy Policy and Energy Markets
- Work focus:
  - promotion strategies for renewables energies
  - hydrogen technologies and synthetic fuels
  - modelling of energy systems

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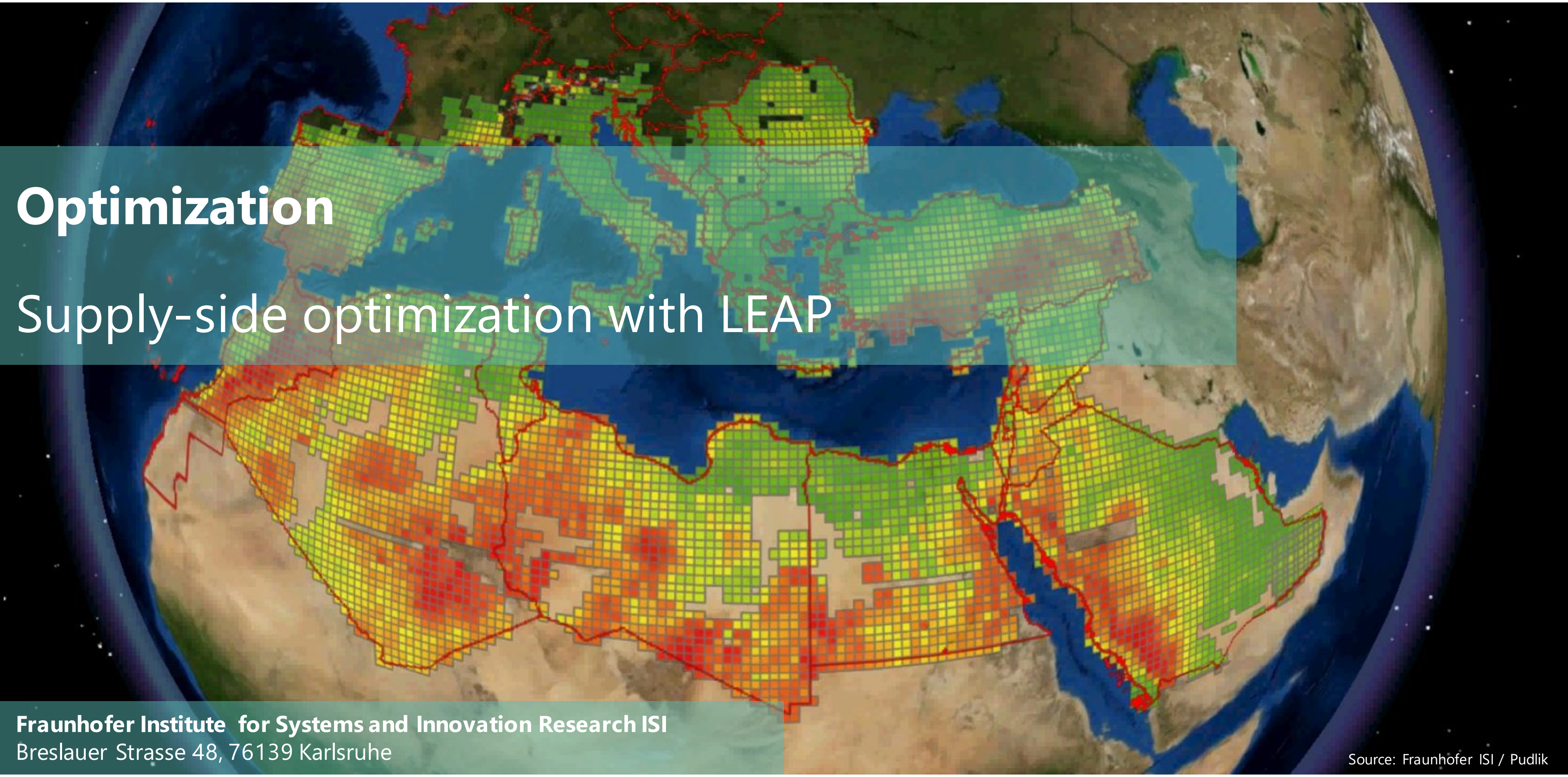

Optimization

Supply-side optimization with LEAP

Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Strasse 48, 76139 Karlsruhe

Source: Fraunhofer ISI / Pudlik

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SUPPLY-SIDE OPTIMIZATION WITH LEAP

- How do you use optimization functionalities of LEAP in your work?
- How to set up supply side optimization and what LEAP can (not) do
- Should you be using an optimized model for the NECP?

OPTIMIZATION

LEAP includes the capability to automatically calculate **least-cost capacity expansion** and dispatch of supply-side Transformation modules based on the use **linear programming-based optimization** frameworks.

- *optimal* is defined as ...

  ... the energy system configuration with the **lowest total net present value of the social costs** of the system **over the entire period of calculation** (from the base year through to the end year), subject to various **constraints such as meeting energy demands, or limiting emissions.**

source: SEI LEAP Help https://leap.sei.org/help/

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OPTIMIZATION

Mathematical formulation

$$minimize: \sum \begin{matrix} discounted\ energy \\ system\ costs \end{matrix}$$ ← objective function

$$subject\ to: g_i(\boldsymbol{x}) \leq 0 \quad i = 1, \dots, m$$

← constraints

$$and: h_j(\boldsymbol{x}) = 0 \quad j = 1, \dots, n$$

$$and: \boldsymbol{x}^L \leq \boldsymbol{x} \leq \boldsymbol{x}^U$$ ← variables with lower & upper bounds

OPTIMIZATION

Feature	OSeMOSYS	NEMO
Developer:	KTH	SEI
Installation:	Integrated into LEAP	Via Separate Download
Platform:	GLPK (last updated 2018)	Julia (actively developed at MIT)
Open source:	Yes	Yes
Licensing:	Free & Included with LEAP	Free. No separate license required. Can be downloaded from LEAP web site.
Small data sets:	Faster	Fast
Larger data sets:	Slow	Fast
Time slicing:	Limited Flexibility	Very flexible (e.g. seasons, day types & day as 24 slices)
Energy storage:	No	Yes
Solvers:	GLPK, CPLEX	GLPK, Cbc, CPLEX, Gurobi, MOSEK, XPRESS.
Parallel processing:	Only when using CPLEX	Yes
Actively developed:	Unknown	Yes, by SEI, new capabilities planned.
Network & power flow simulations:	No	Yes in NEMO & coming to LEAP/NEMO
Support:	Community-supported forum.	Professional & community support.

source: SEI LEAP Help https://leap.sei.org/help/

OPTIMIZATION

nemo

Main Features of NEMO

- Least-cost optimization of energy supply (and demand[1])
- Modeling of emissions and emission constraints
- Modeling of renewable energy targets
- Modeling of energy storage
- Support for multiple regions and regional trade
- Nodal network simulations and modeling of power and pipeline flow
- Support for multiple solvers, both open-source (CBC and GLPK) and commercial (CPLEX, MOSEK, GUROBI and XPRESS)
- Data stored in an open-source relational database (SQLite), allowing easy access to inputs and results

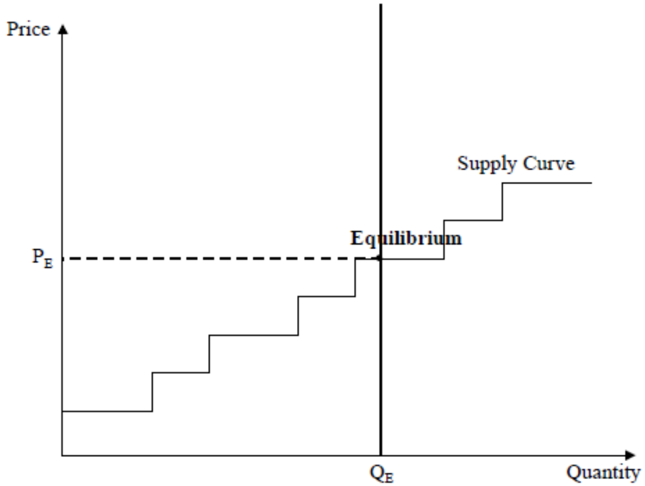
source: SEI https://leap.sei.org/default.asp?action=NEMO

1) LEAP is currently limited to do optimization on a single transformation module within an energy system; SEI is currently working on allowing a full energy system optimization modelling with NEMO (similar to TIMES and MESSAGE)

nemo

Fixed demand vs Partial equilibrium

NEMO



- Demand does not depend on supply

- Demand subject to price elasticity, price depends on supply

source: SEI https://leap.sei.org/sida2021/lecture_6.pdf
TIMES Documentation, Part 1

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OPTIMIZATION

nemo

Perfect foresight vs limited foresight

NEMO

Perfect foresight

- Costs for all years in planning horizon minimized simultaneously (global optimum found)

Limited foresight

- Costs for subsets of years minimized
- Results from first interval provide starting conditions for second, and so on

source: SEI https://leap.sei.org/sida2021/lecture_6.pdf

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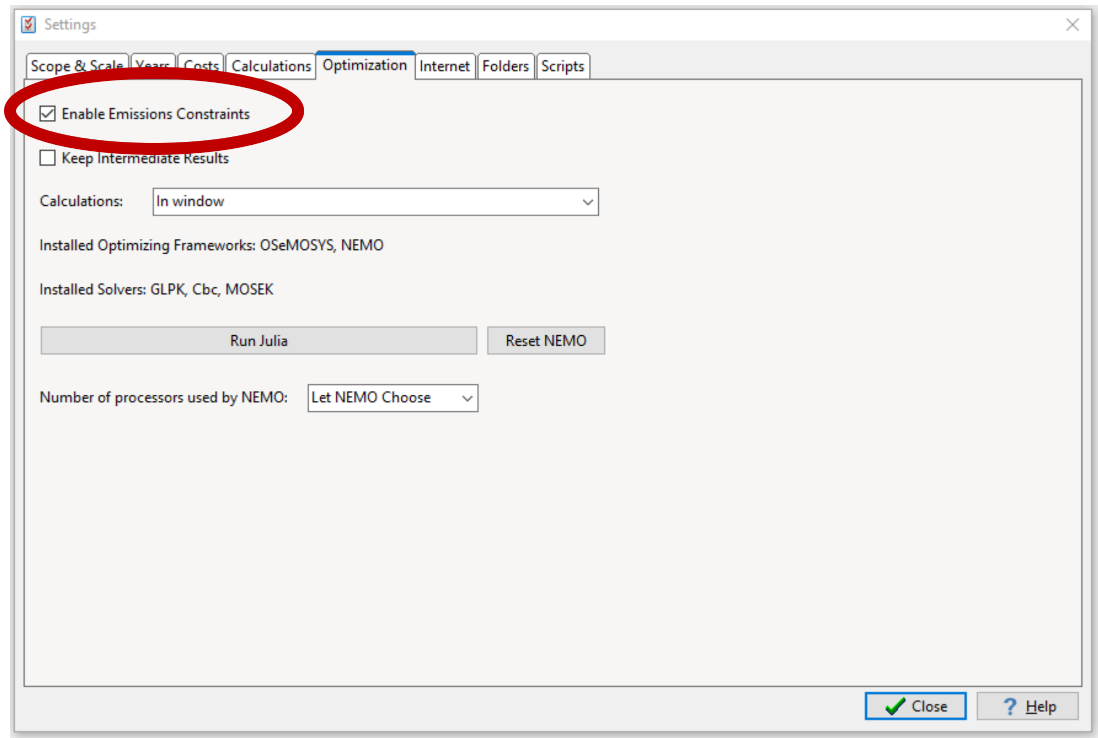
OPTIMIZATION

Sensitivity and plausibility

- Many optimization models are quite sensitive to their parameters (exogenous inputs)
- Their initial tendency is to produce a corner solution – e.g., building only one technology
- This compels modeler to add constraints to attain a plausible result
- The content of these iteratively determined constraints is critically important – in many ways, it decides the outcome!

source: SEI https://leap.sei.org/sida2021/lecture_6.pdf

OPTIMIZATION



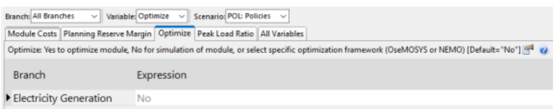
Ticking “Enable Emissions Constraints” provides the option to:

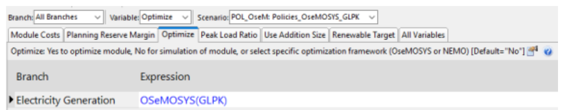
- add an emission limit as a constraint
- add externality costs associated with the emissions

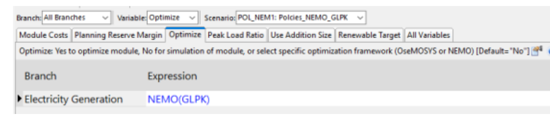
OPTIMIZATION

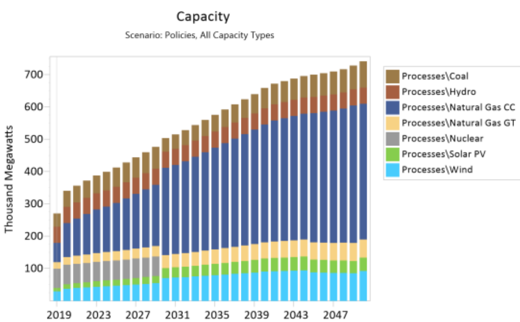
nemo

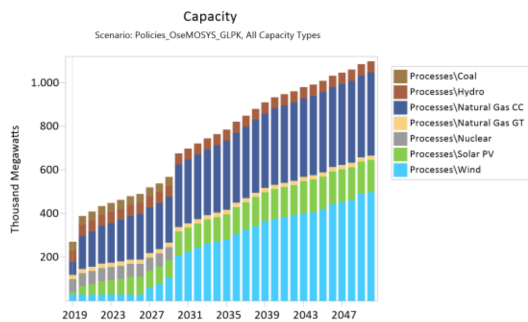
No Optimization	OseMOSYS	NEMO

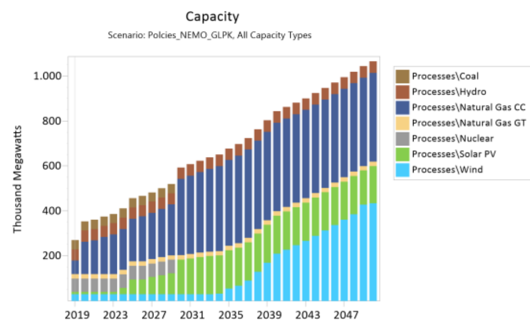












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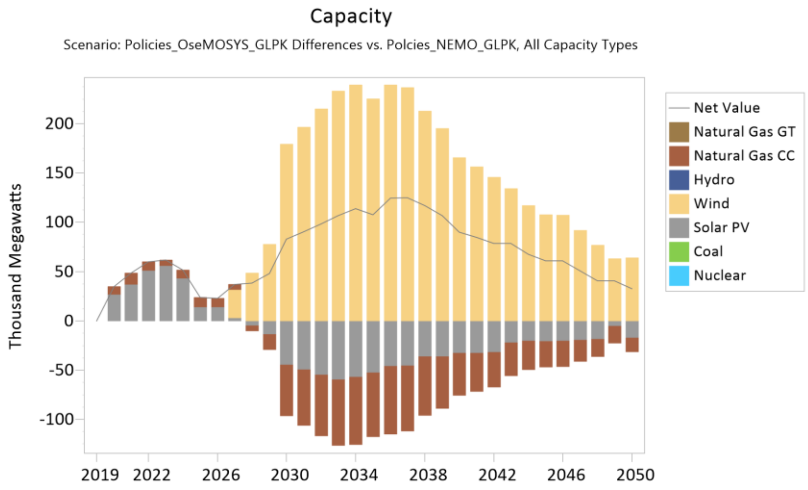
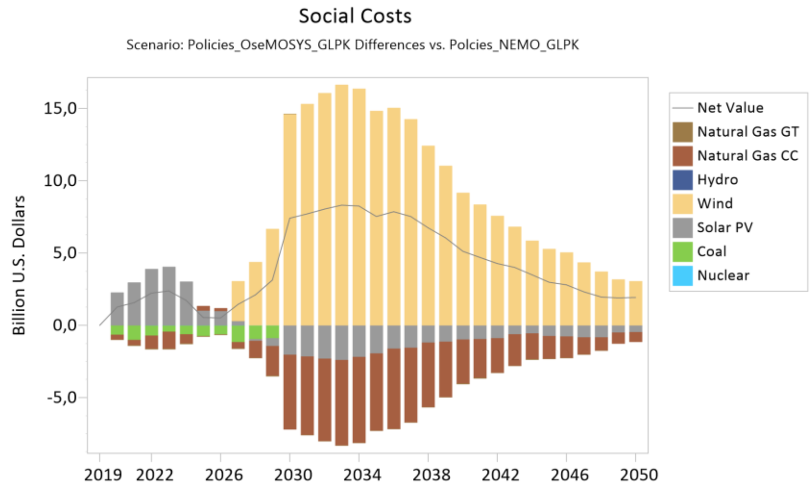
OPTIMIZATION

OseMOSYS vs NEMO

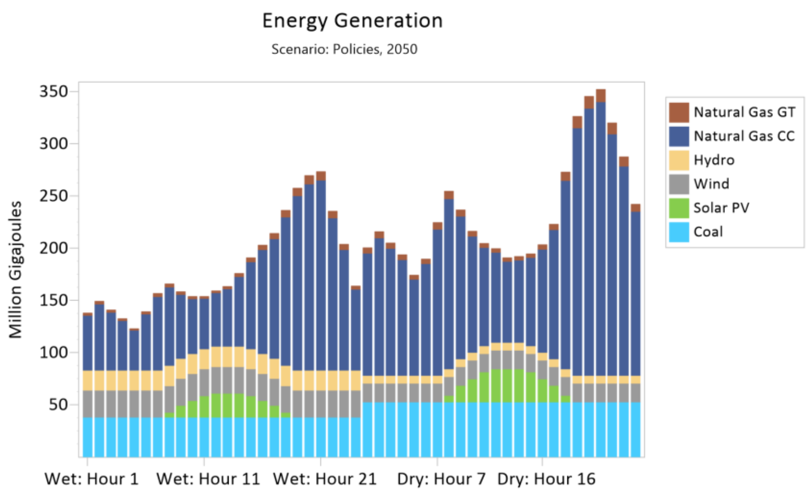


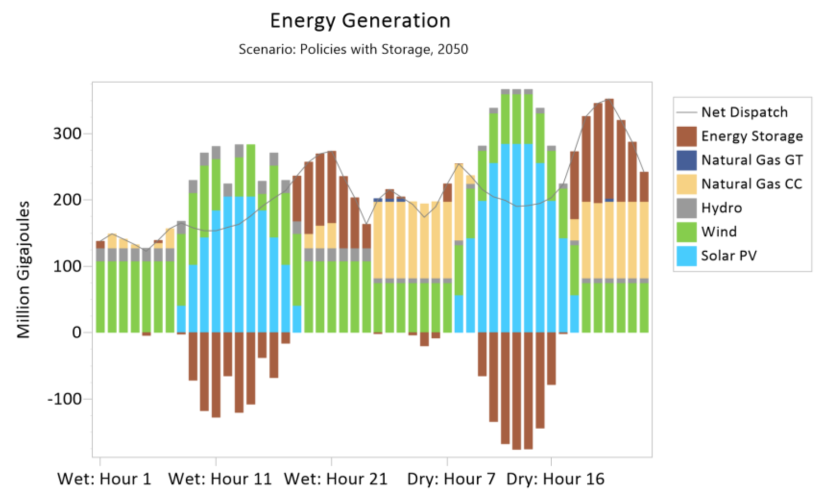


OPTIMIZATION

nemo

NEMO without Storage vs with Storage

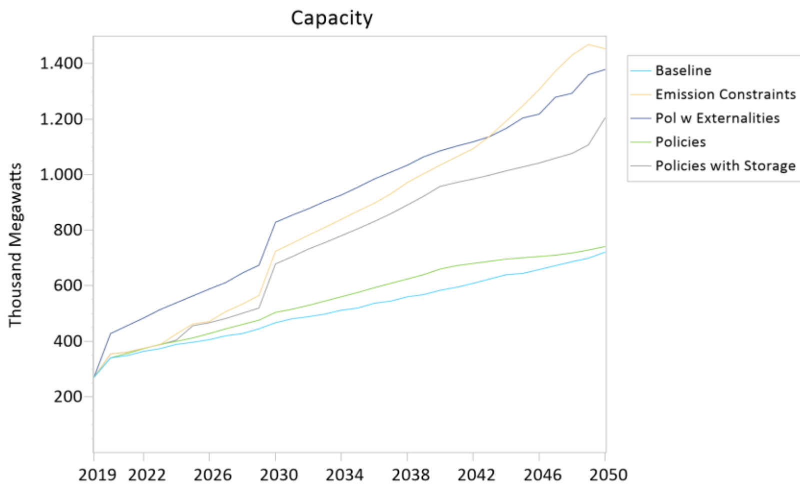


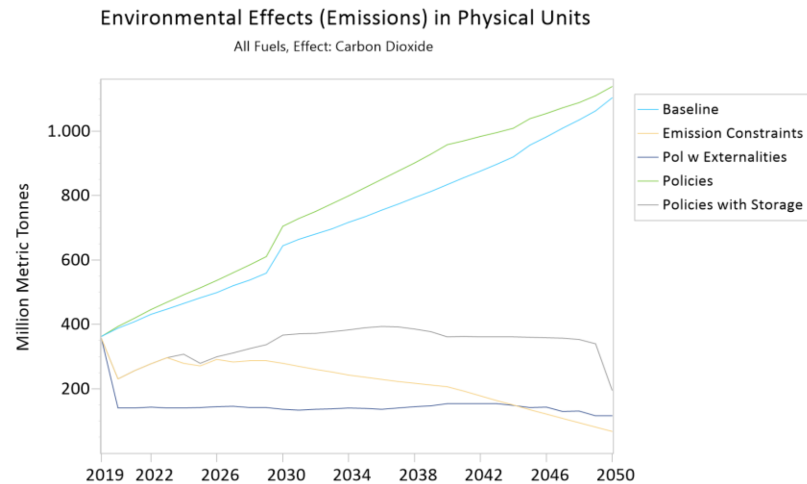


OPTIMIZATION

nemo

Emission Constraints





Scenario	Tab	Effect	Expression	Scale	Units
Emission Constraints	Annual Emission Constraint	Carbon Dioxide	InterpFSY(2020; 1000; 2040; 300; 2050; 120)	Million	Metric Tonne
Pol w Externalities	Externality Cost	Carbon Dioxide	100		USD/Metric Tonne

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OPTIMIZATION

Coal vs. renewables

Least-cost optimization of the Indonesian power sector

Marek Fritz[a], Jose Antonio Ordonez[a,b,*], Johannes Eckstein[a]

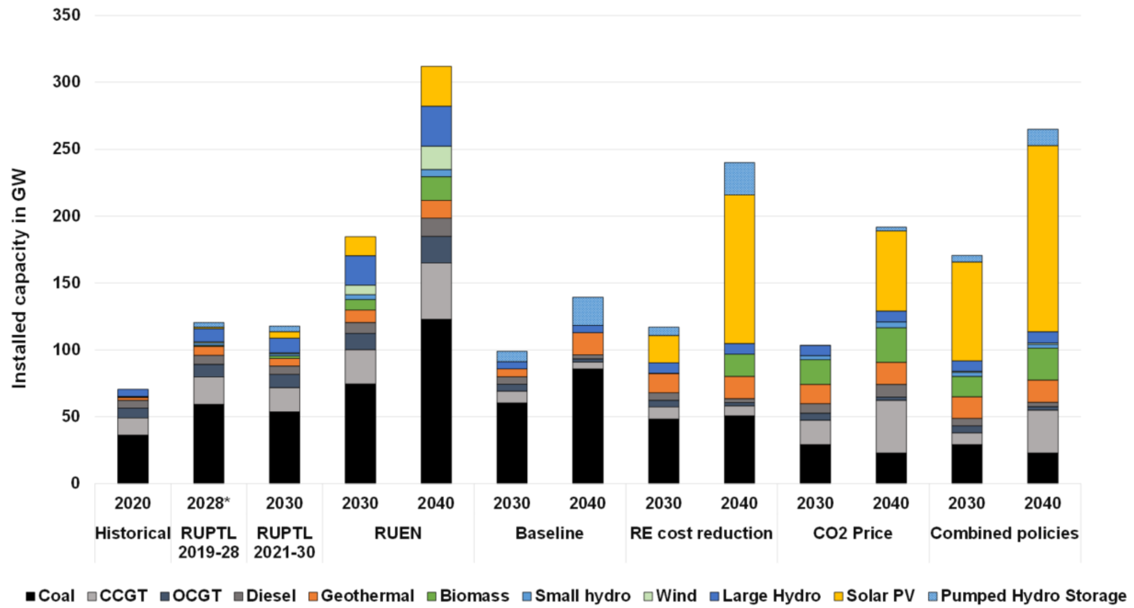

Figure 3: Installed capacities in 2020, 2030 and 2040 for official power sector plans and cost optimized scenarios. (*) RUPTL 2019-2028 is shown until 2028, as this is the last year of the plan. ¶

OPTIMIZATION

Helpful Links for Optimization with NEMO

YouTube:

Introduction: Introducing NEMO: The Next Energy Modeling system for Optimization
Tutorial 2020: Using LEAP2020 to Model Seasonal and Daily Variations in Demand and Supply including Energy Storage
Tutorial 2021: Sida LEAP Training Lecture #6: Optimization Modeling with LEAP and NEMO

GitHub

Main Page with source code: https://github.com/sei-international/NemoMod.jl
Documentation: https://sei-international.github.io/NemoMod.jl/stable/

Further information

SEI "NEMO: the Next Energy Modeling system for Optimization"
https://www.sei.org/projects-and-tools/tools/nemo-the-next-energy-modeling-system-for-optimization/
LEAP Help "Introduction To Optimization"
https://leap.sei.org/help/leap.htm#t=Optimization%2FOptimizationIntroduction.htm&rhsearch=optimization&rhhlterm=optimization&rhsyns=%20

Download

https://leap.sei.org/ –> Download –> NEMO

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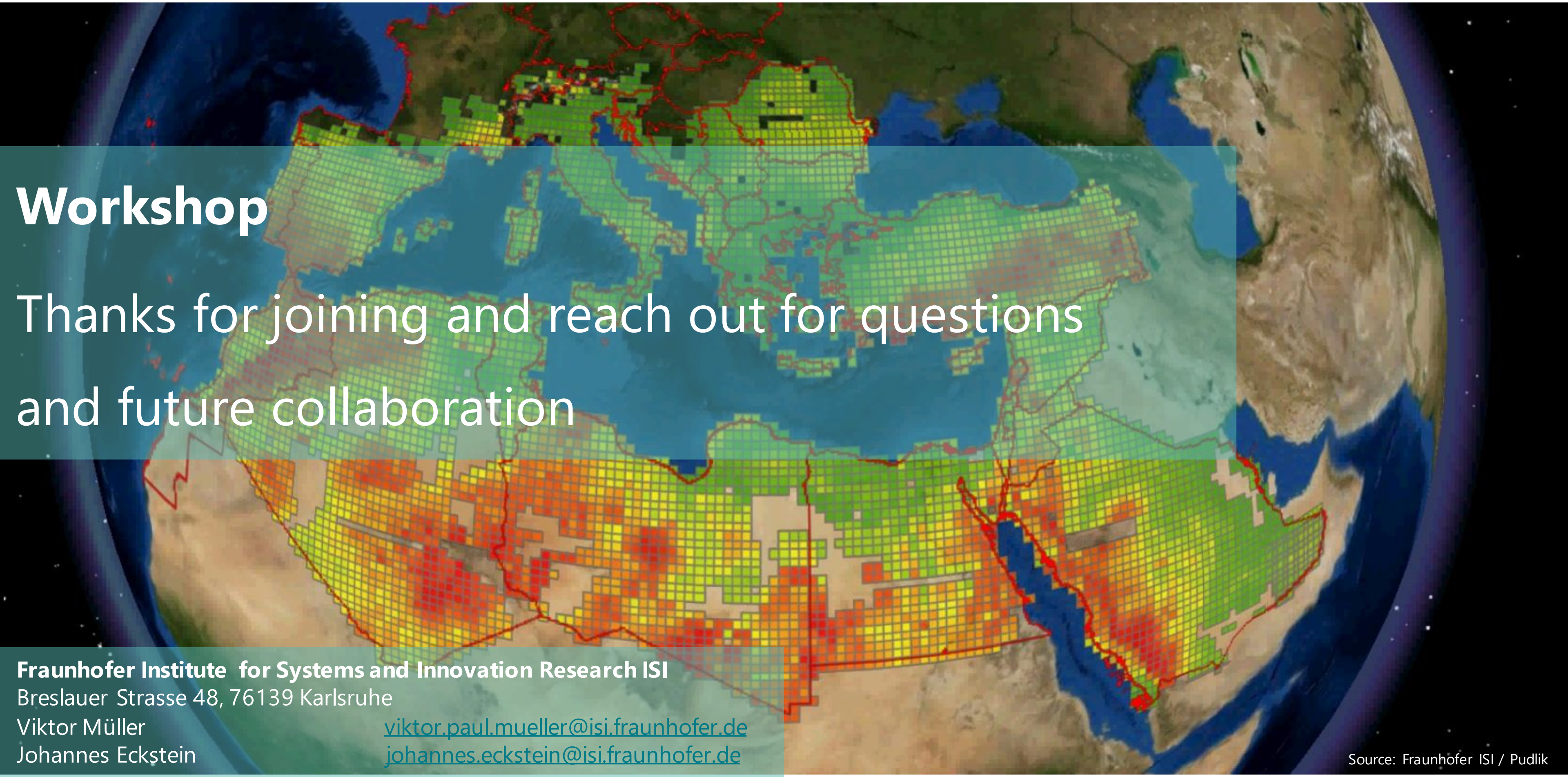

Source: Fraunhofer ISI / Pudlik

Workshop

Thanks for joining and reach out for questions and future collaboration

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