

Uncertainty, accuracy and more



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University of Geneva

Summer school on uncertainty in
energy and integrated assessment
models

19 June 2026



RES



**UNIVERSITÉ
DE GENÈVE**

FACULTÉ DES SCIENCES

sweet swiss energy research
for the energy transition



**Swiss National
Science Foundation**



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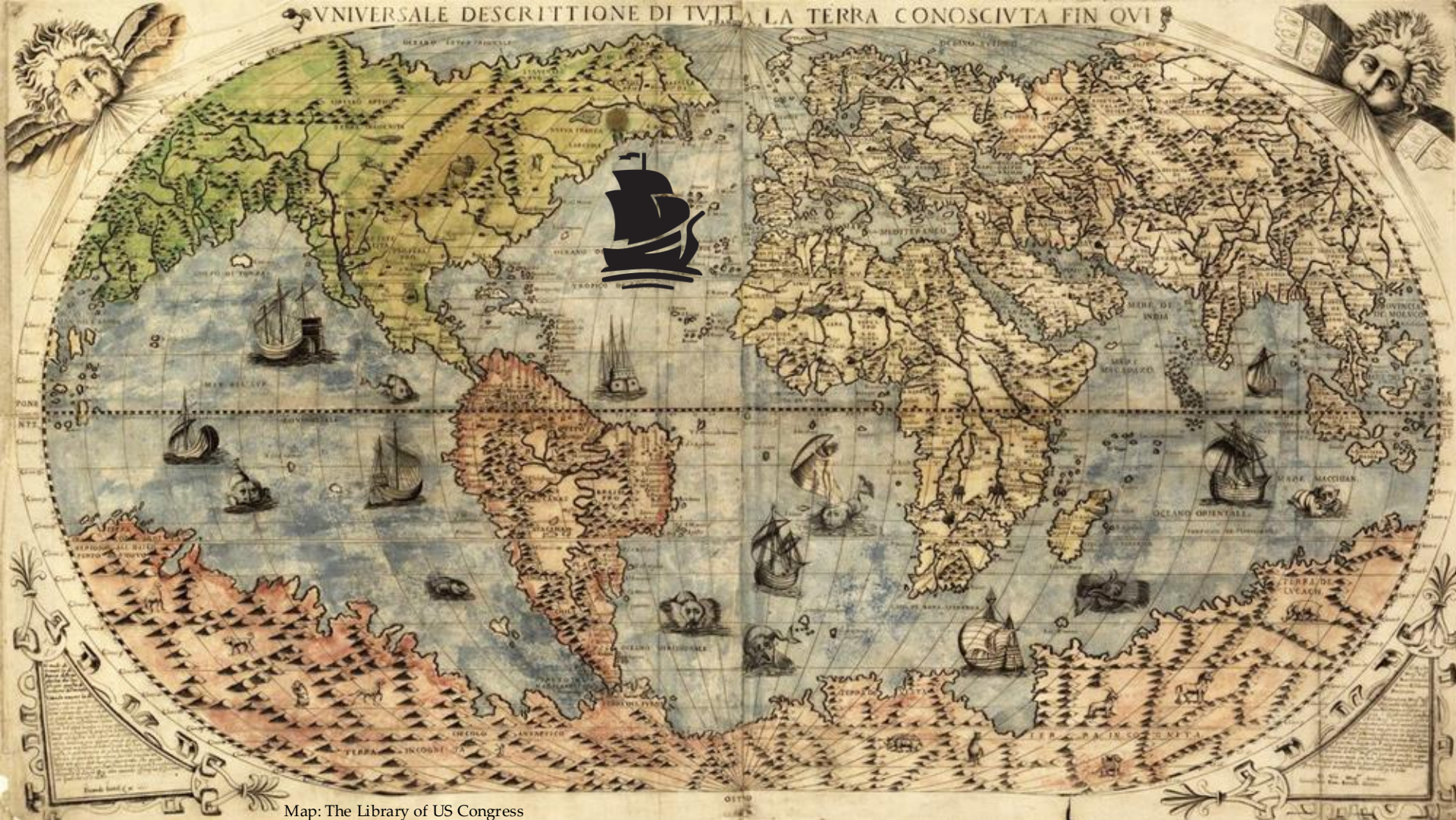
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Research and Innovation SERI



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European Union

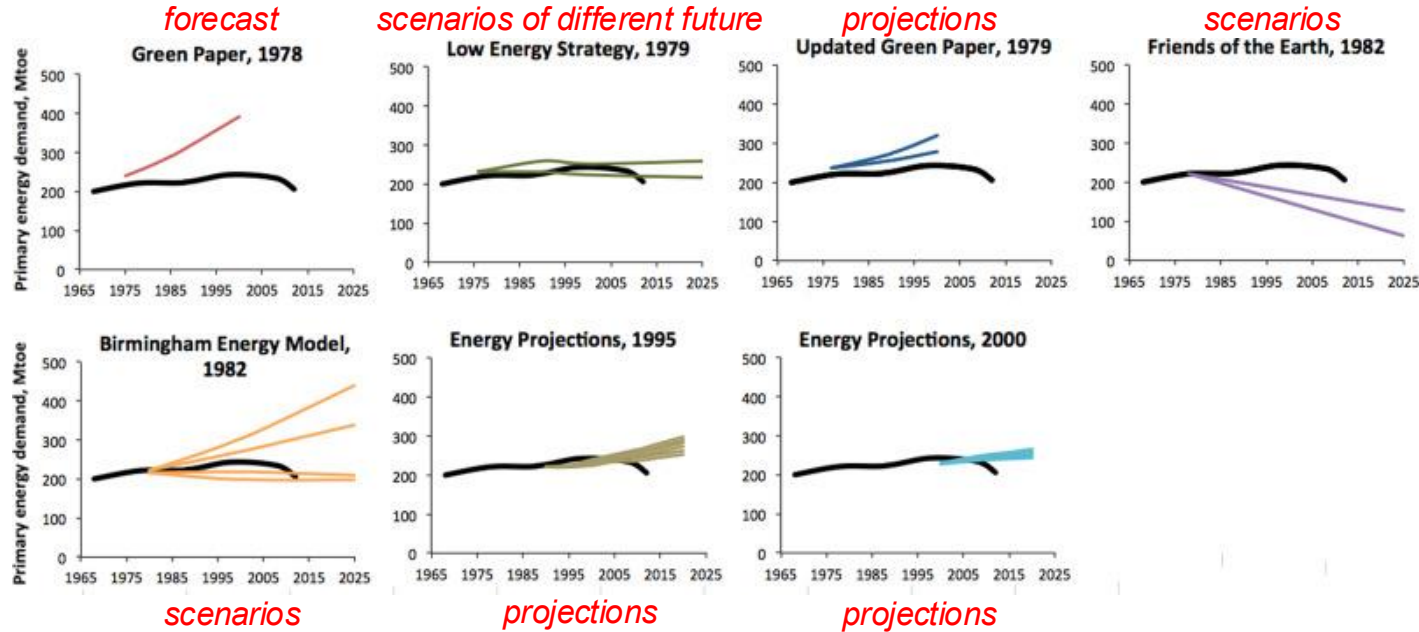






OPTIONS

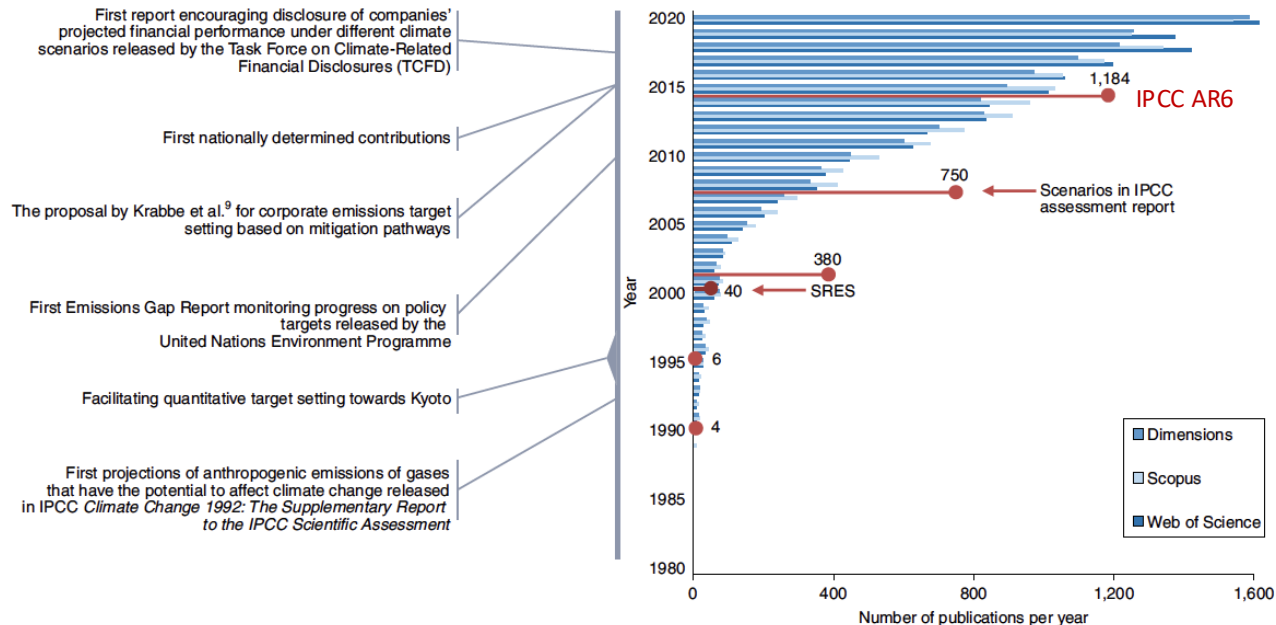
Learning from the past: UK energy forecasts, projections, and scenarios



Source: Trutnevyte et al. (2016) Sustainable and Renewable Energy Reviews

Ever increasing ensembles of models and scenarios

Global emissions scenarios



- More funding, more models, publishing culture
- Better computing power, more model runs
- Community databases

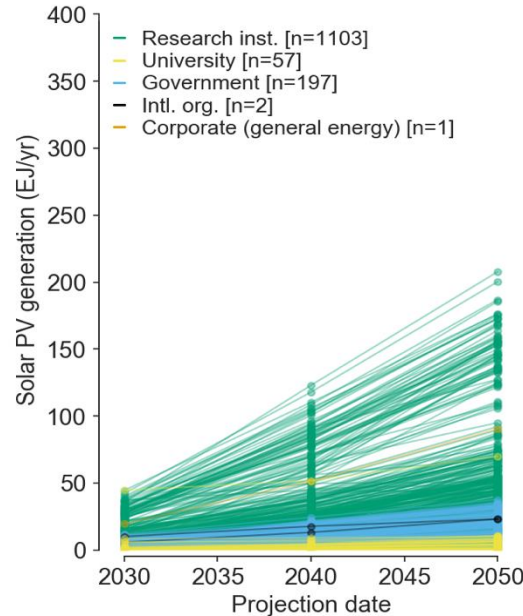
Source: Guivarch et al. 2022 *Nature Climate Change*

Is the uncertainty consideration sufficient?

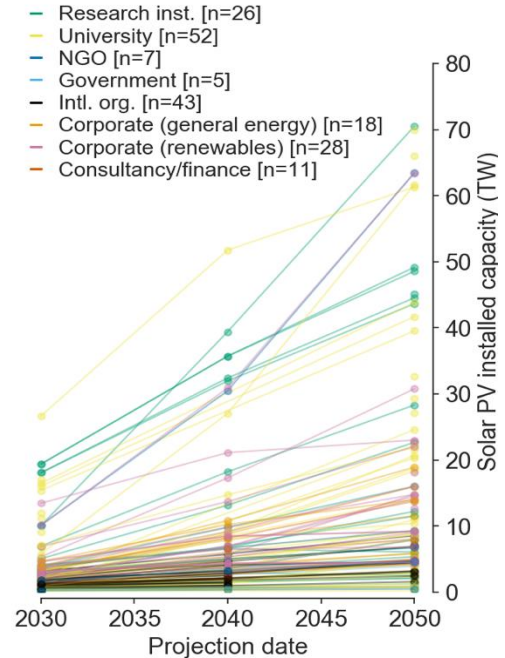
1'550 scenarios from 190 peer-reviewed
and grey publications as well as IPCC AR5
and SR1.5 databases



IPCC scenarios

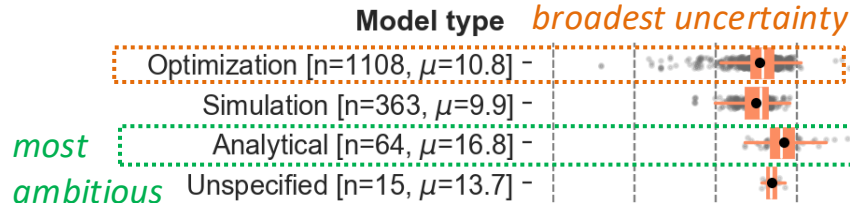
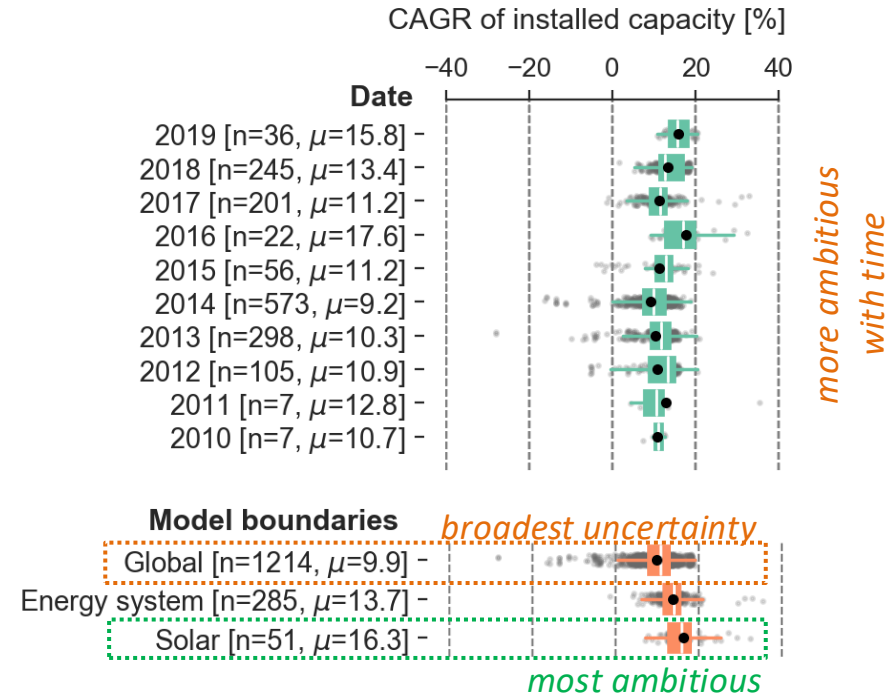
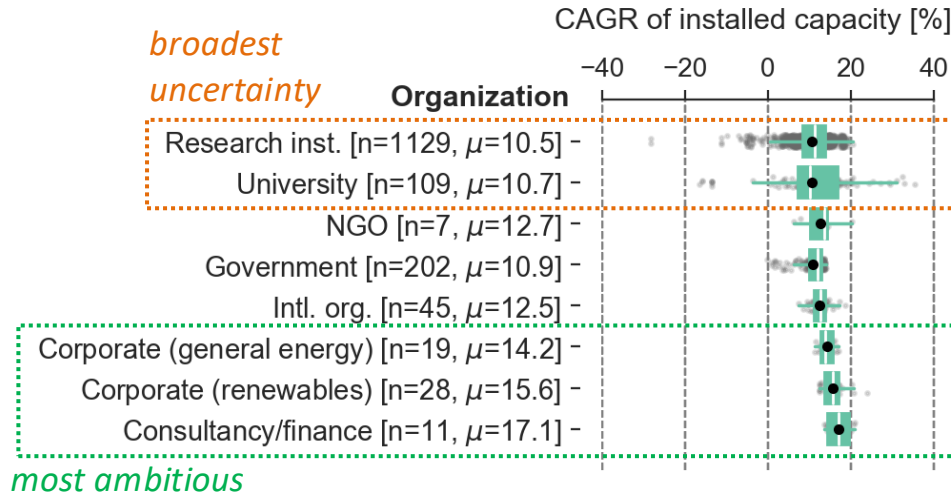


Non-IPCC scenarios



Source: Jaxa-Rozen & Trutnevyte (2021) Nature Climate Change

Meta indicators of global PV projections (1)



Source: Jaxa-Rozen & Trutnevyte (2021) Nature Climate Change



Predicting scenario outcomes using meta indicators

73% average accuracy for classifying scenarios into quintiles of projected PV growth, using XGBoost

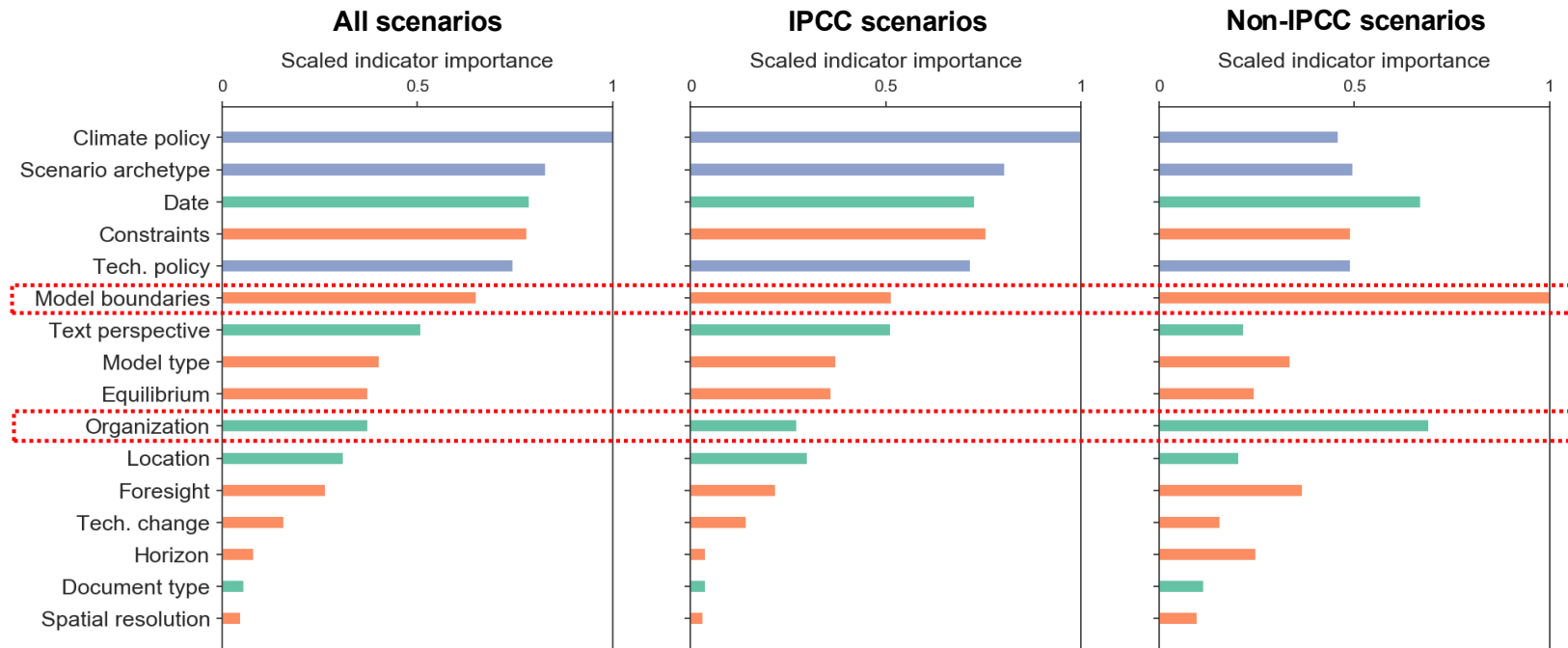
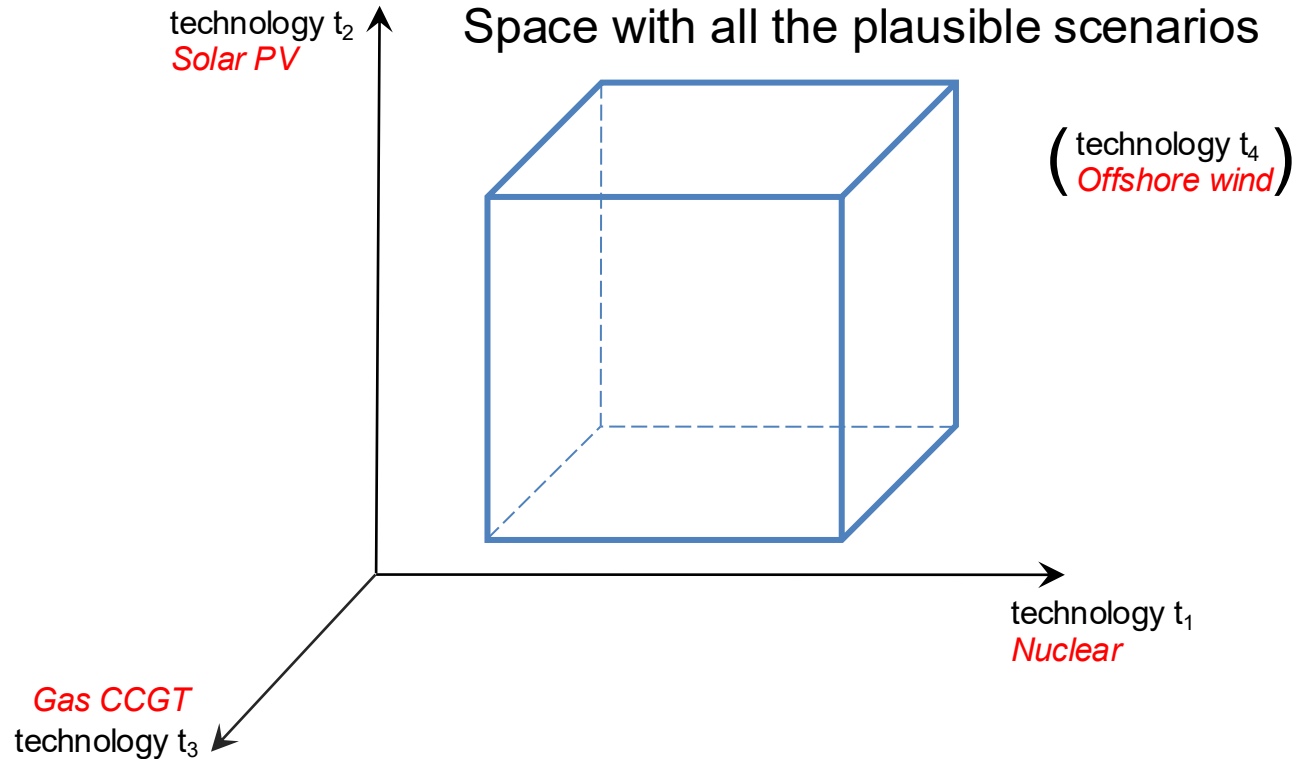
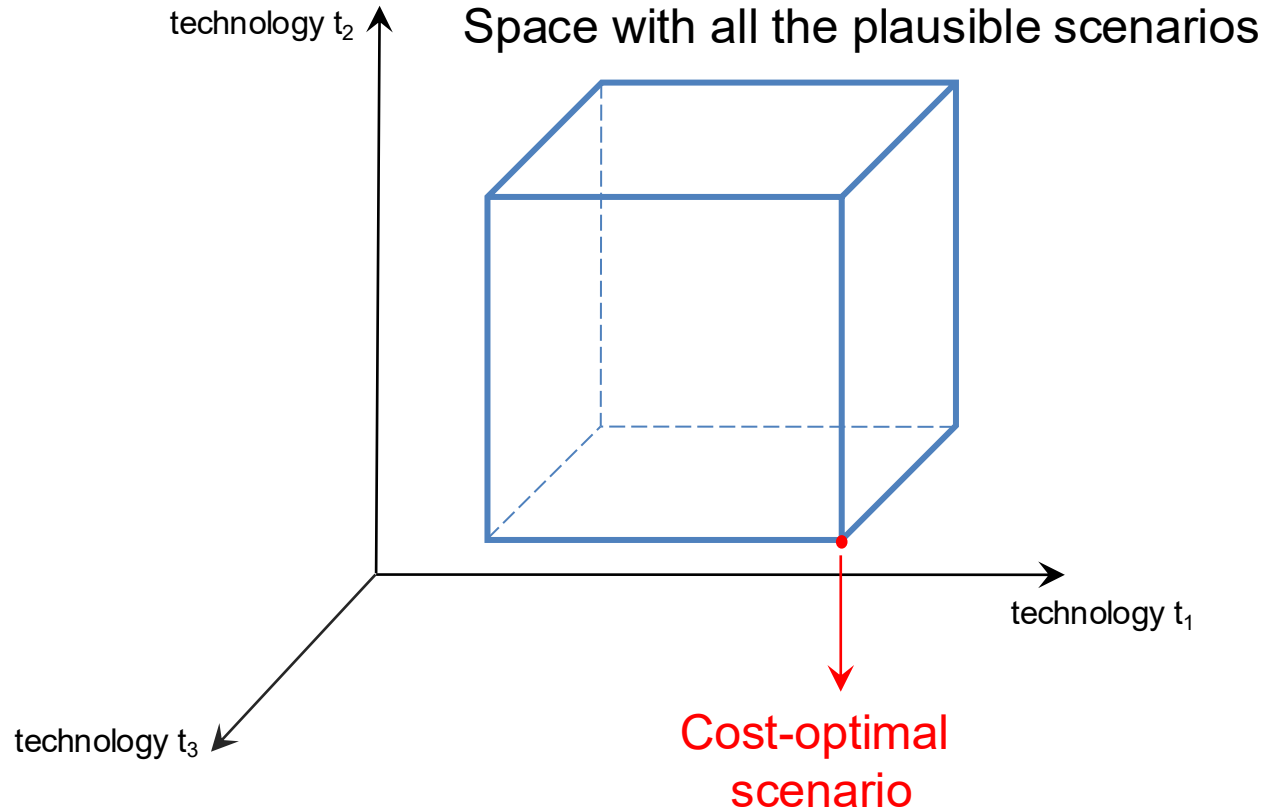


Figure: Jaxa-Rozen & Trutnevte (2021) Nature Climate Change

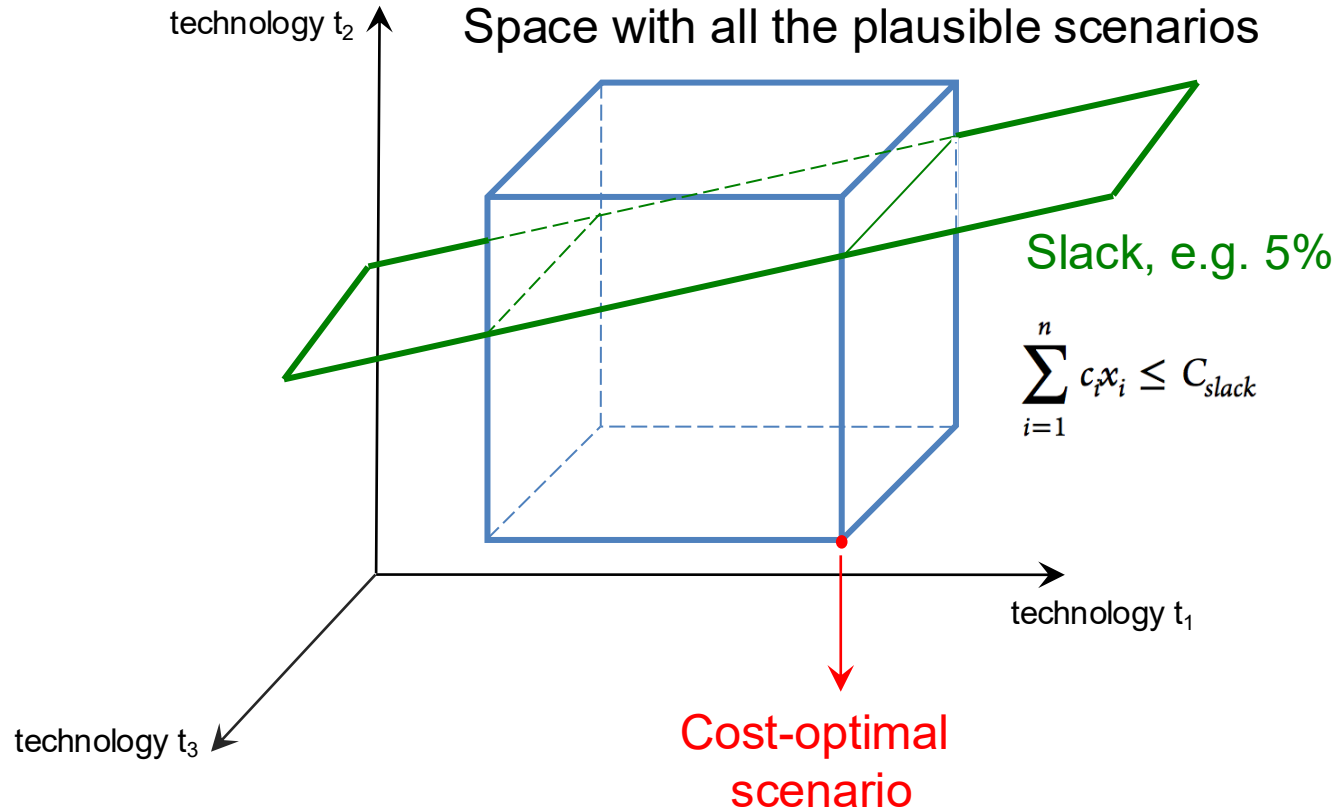
Modeling to Generate Alternatives (MAG) with optimization models



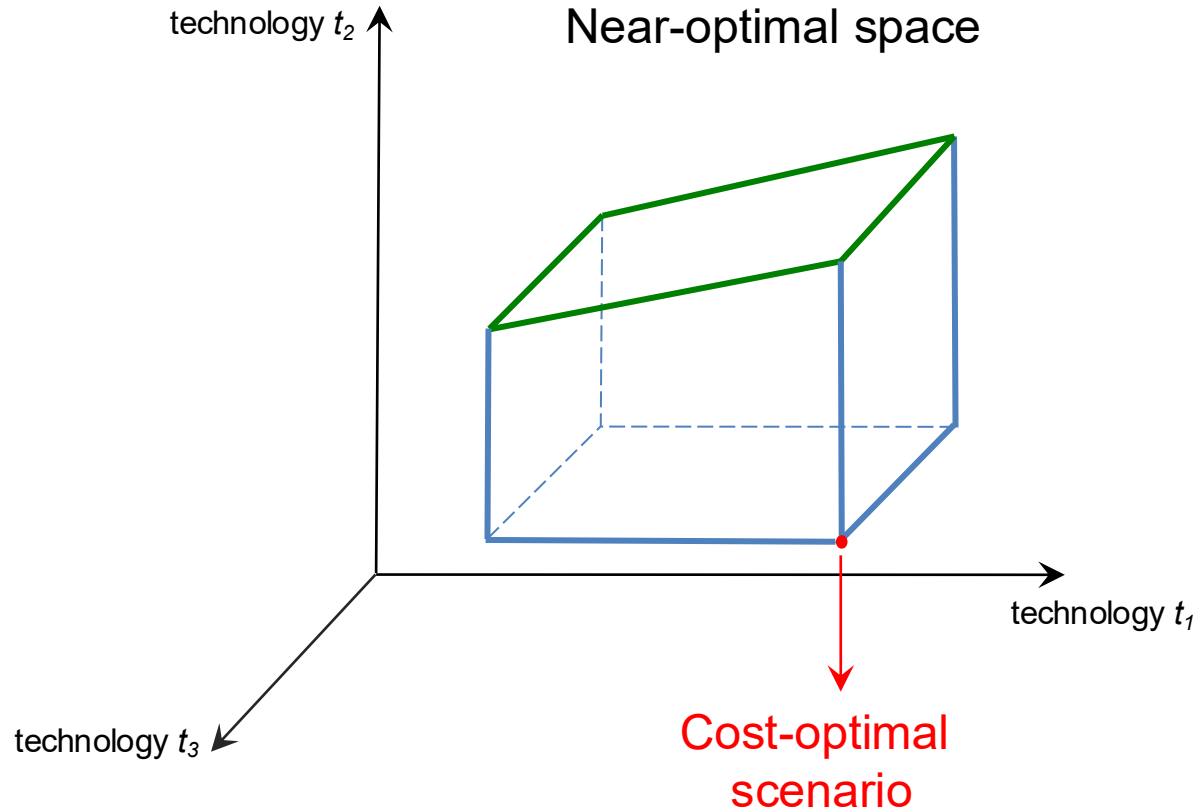
Modeling to Generate Alternatives (MAG) with optimization models



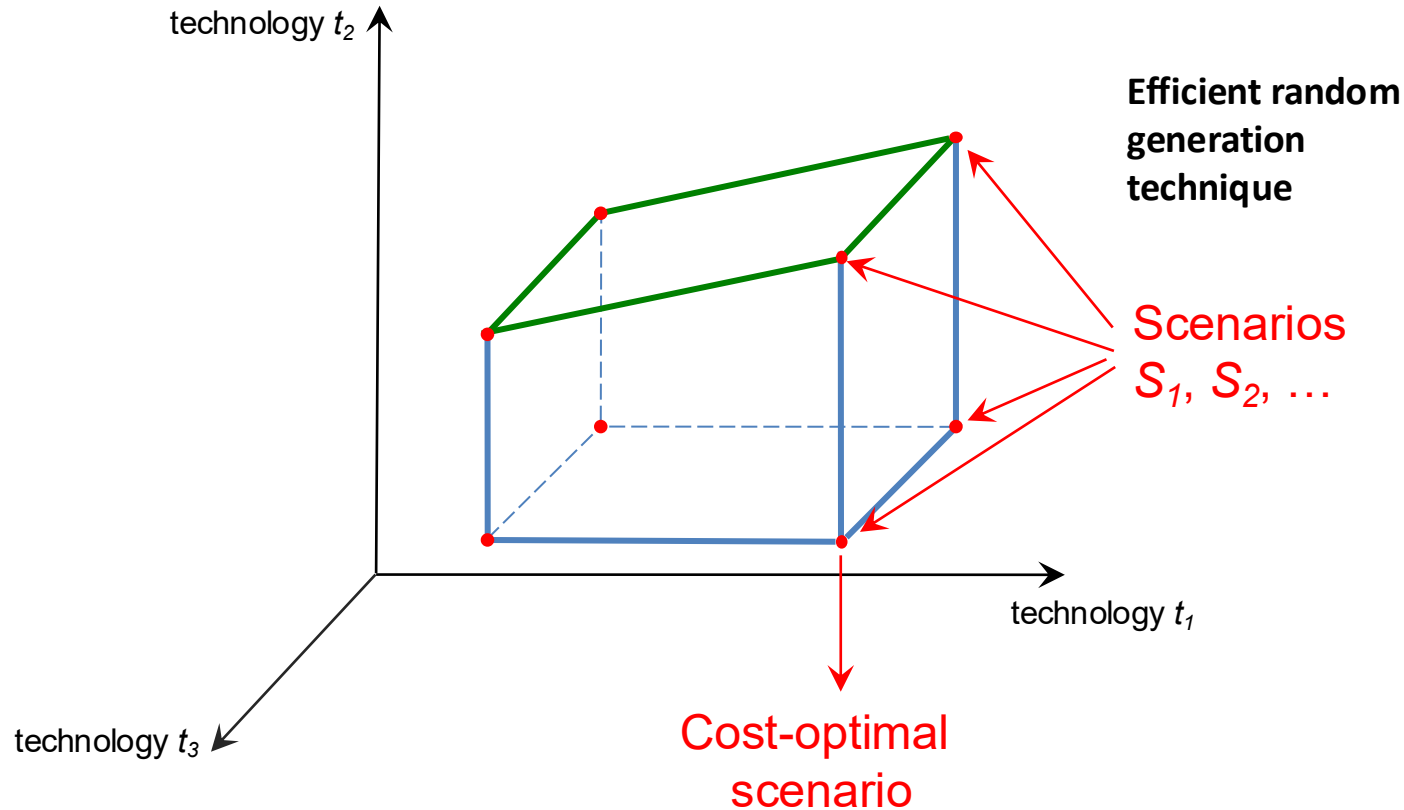
Modeling to Generate Alternatives (MAG) with optimization models



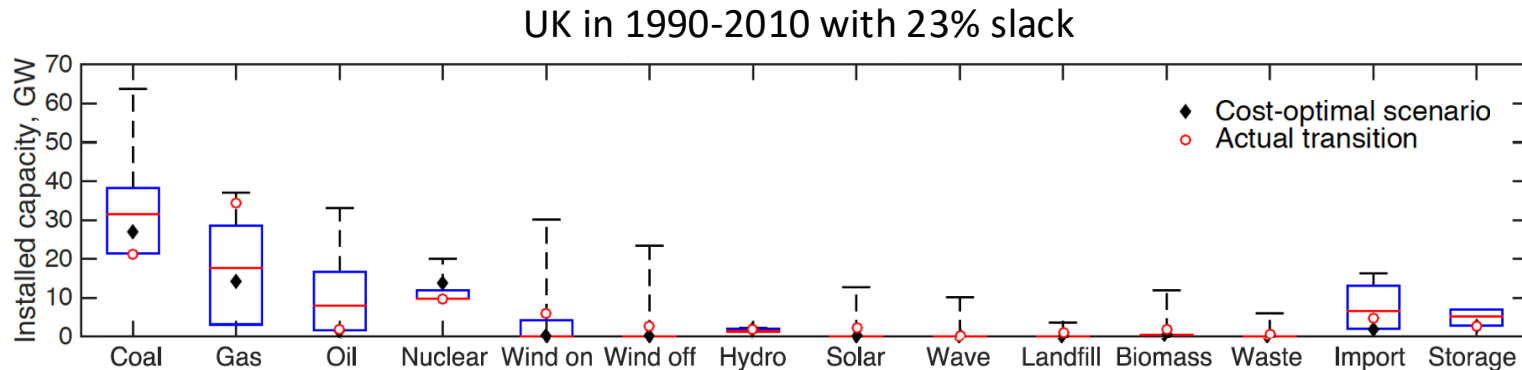
Modeling to Generate Alternatives (MAG) with optimization models



Modeling to Generate Alternatives (MAG) with optimization models

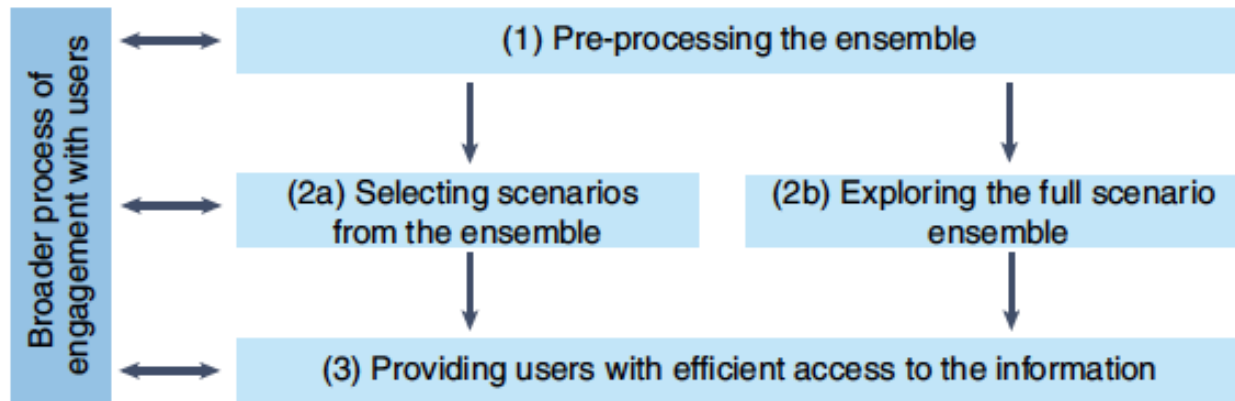


Technology deployment under Modeling to Generate Alternatives (MGA)



Source: Trutnevyte 2016 *Energy*

Methods for working with large scenario ensembles



- Diversity metrics
- Clustering
- Cross-impact balance
- Scenario discovery
- ...

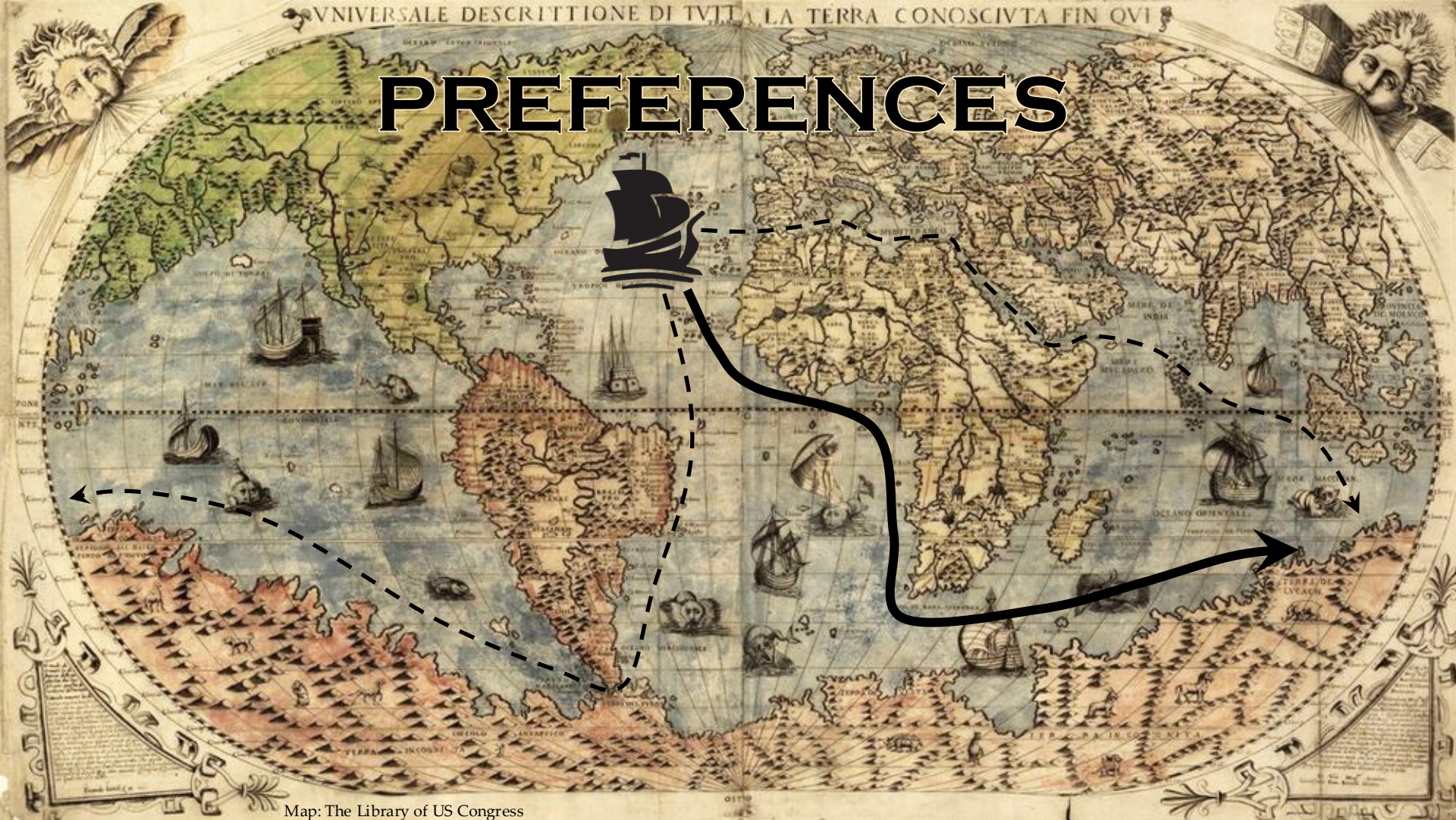
- Descriptive statistics
- Global sensitivity analysis-like approaches
- Multiple regression analysis
- Decision making under uncertainty
- ...

Source: Guivarch et al. (2022) *Nature Climate Change*



OPTIONS

PREFERENCES



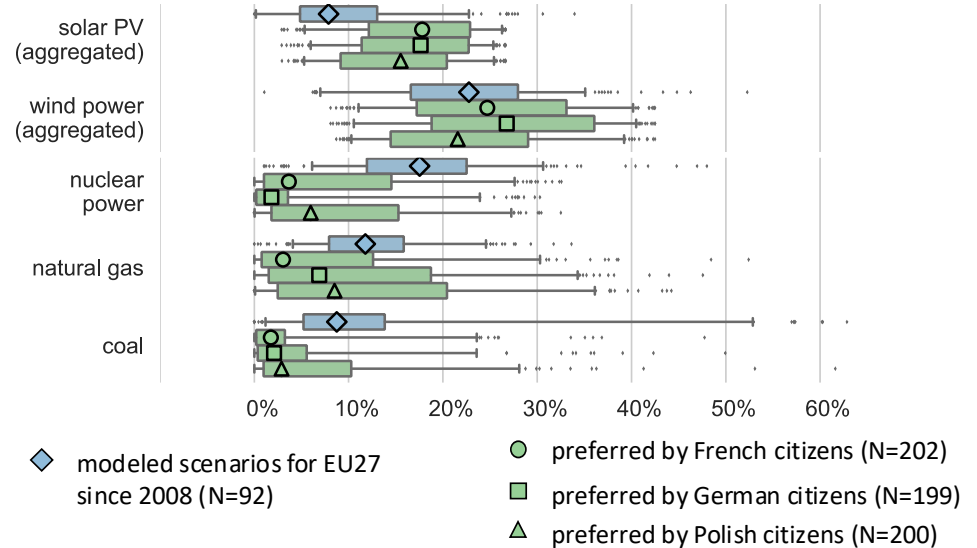
Integration of preferences using an interactive tool



www.riskmeter.ch

for Switzerland, France, Germany, Poland, and EU27

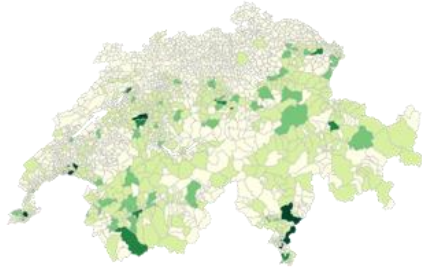
Technology shares in EU27 electricity scenarios for 2035 (selected examples)



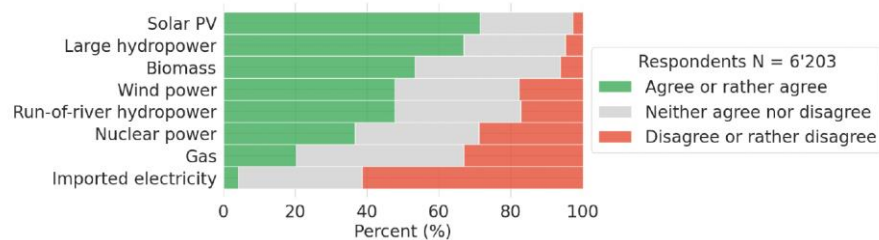
Source: Xexakis & Trutnevyte (2022) RSET

Testing various integration methods

High-resolution electricity sector model for Switzerland

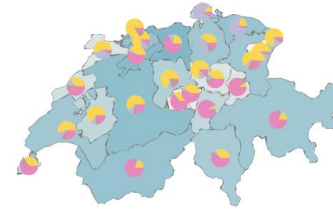


Population survey on technology acceptance

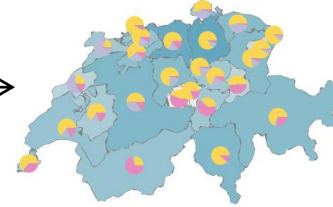


119
integration
methods →

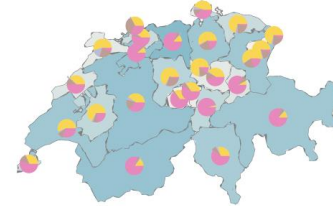
Cost optimization
(New renewable technologies: 11.7 GW)



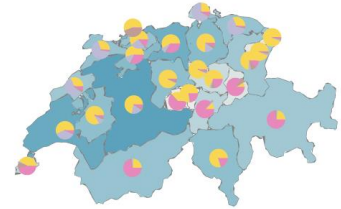
High resistance to nuclear power
(New renewable technologies: 32.7 GW)



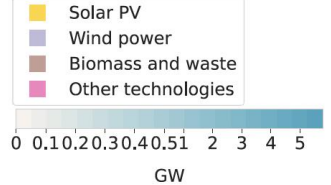
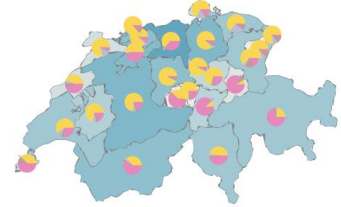
High resistance to renewable sources
(New renewable technologies: 5.1 GW)



High acceptance of renewable sources
(New renewable technologies: 33 GW)

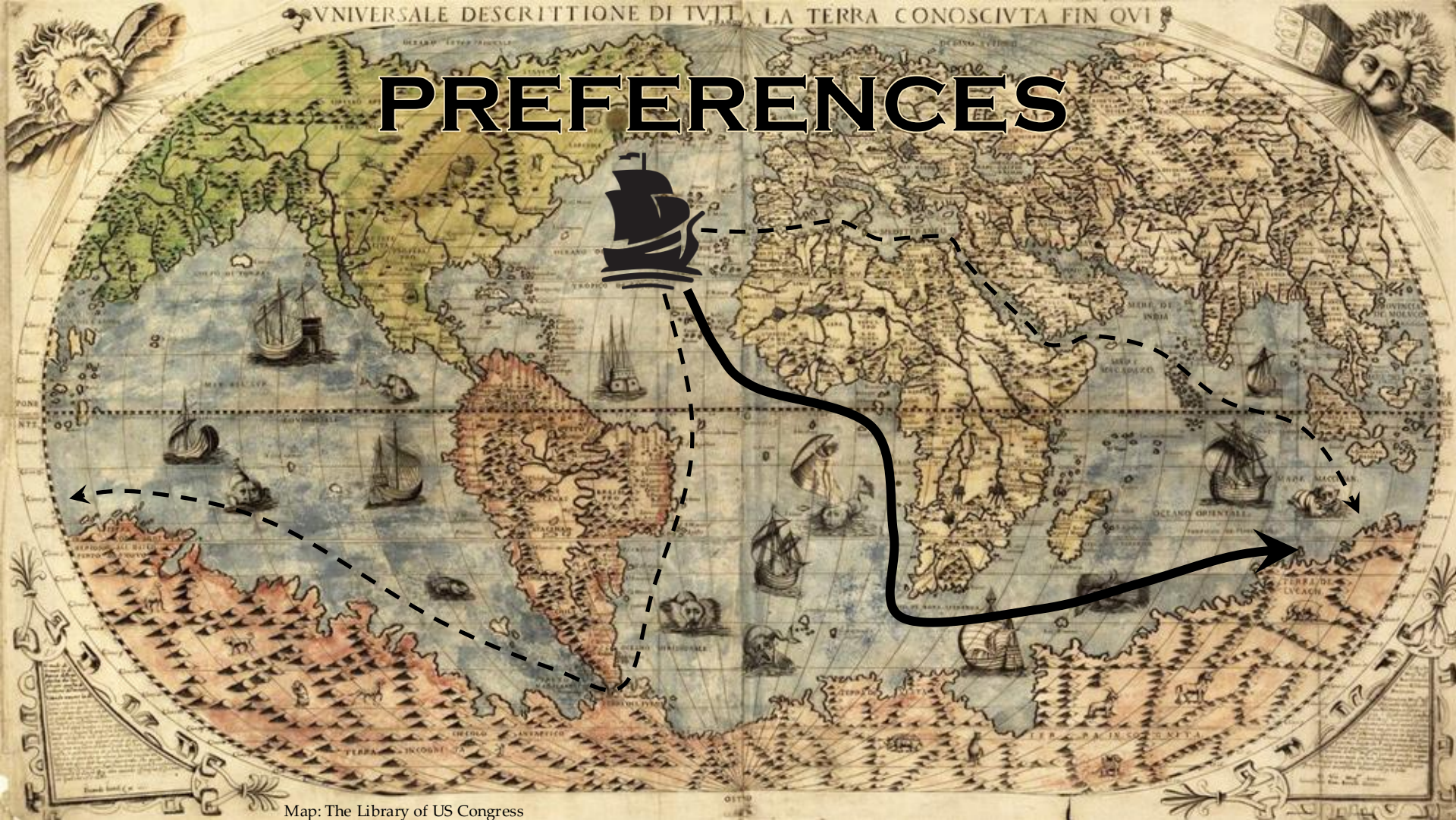


High resistance to wind power
(New renewable technologies: 19.4 GW)

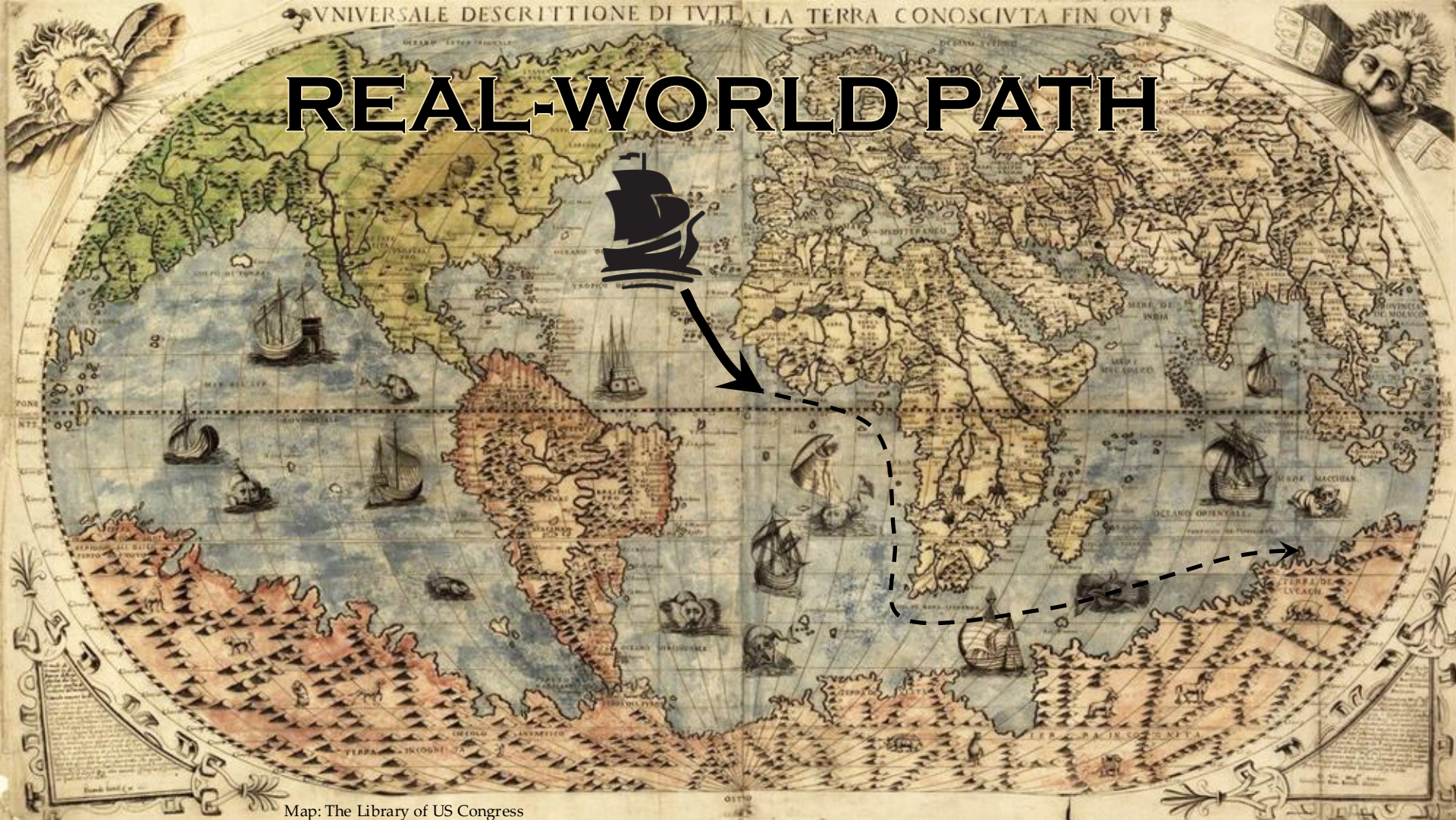


Source: Wen et al. (2025) *Applied Energy*

PREFERENCES

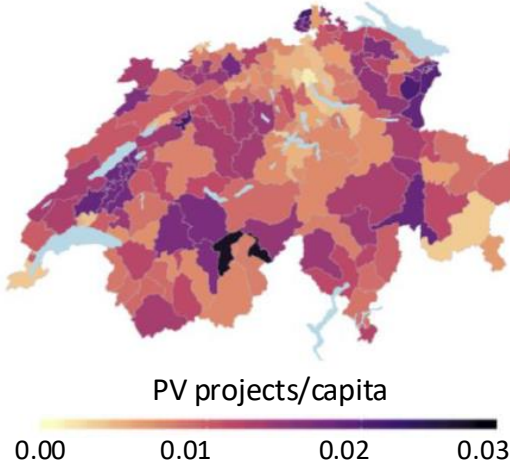


REAL-WORLD PATH



Statistical analysis of solar PV in Switzerland

> 68'000 solar PV projects
in 2017



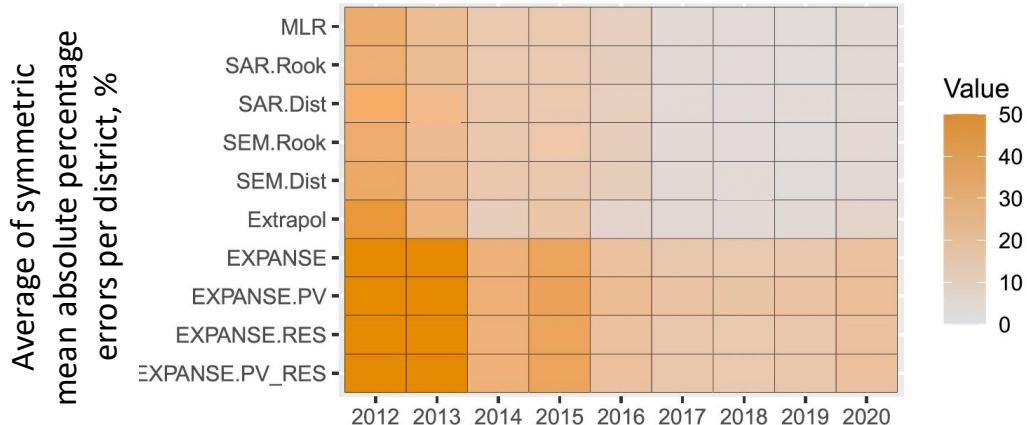
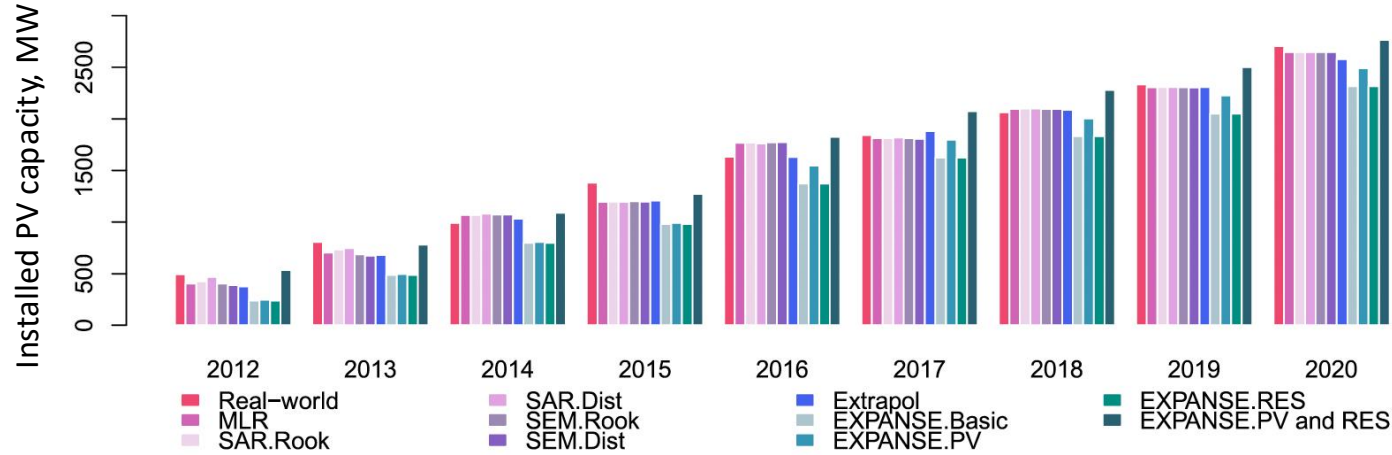
N=143 districts	Multiple linear regression (MLR)	Simultaneous autoregressive model (SAR), radial distance weights
Exploitable PV potential	0.29***	0.27***
Household size	0.24***	0.25***
Age coefficient	0.14***	0.15***
Electricity price	0.09**	0.05
Return on investment	0.05	0.03
Energiestadt label	0.05	0.03
Green voters	0.01	0.01
Electricity demand	-0.02	-0.02*
Net personal income	-0.07*	-0.03
Unproductive area	-0.14***	-0.13***
Intercept	-4.68***	-2.62***
Adj. R²	0.71	0.81

*** $p \leq 0.001$

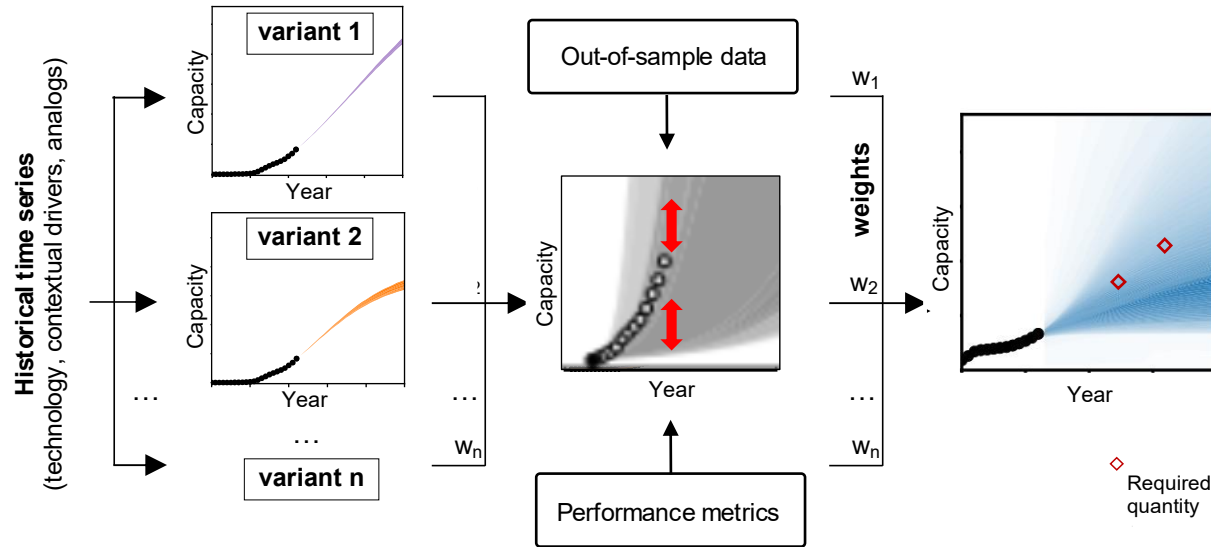
* $p \leq 0.05$

Source: Müller & Trutnevyte (2020) *Applied Energy*

Statistical vs. optimization models



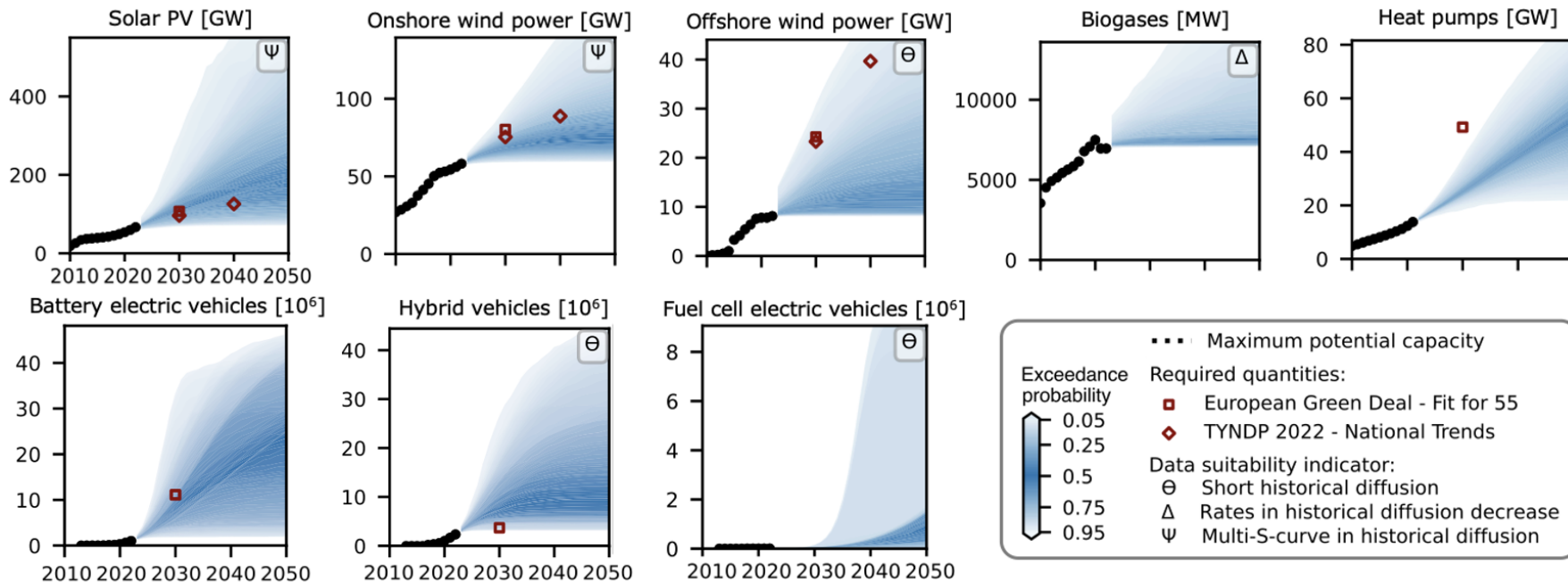
PROWIDE model for probabilistic projections with technology growth models



Source: Zielonka and Trutnevte (2025a, 2025b), Zielonka et al. (2023, 2026)

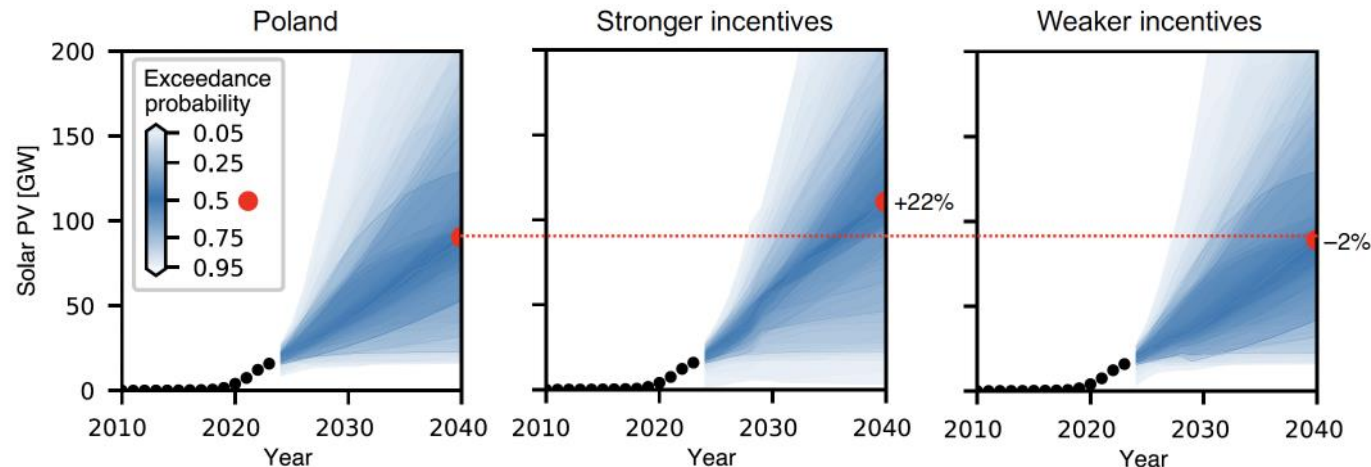
Expected growth of various granular technologies

Germany



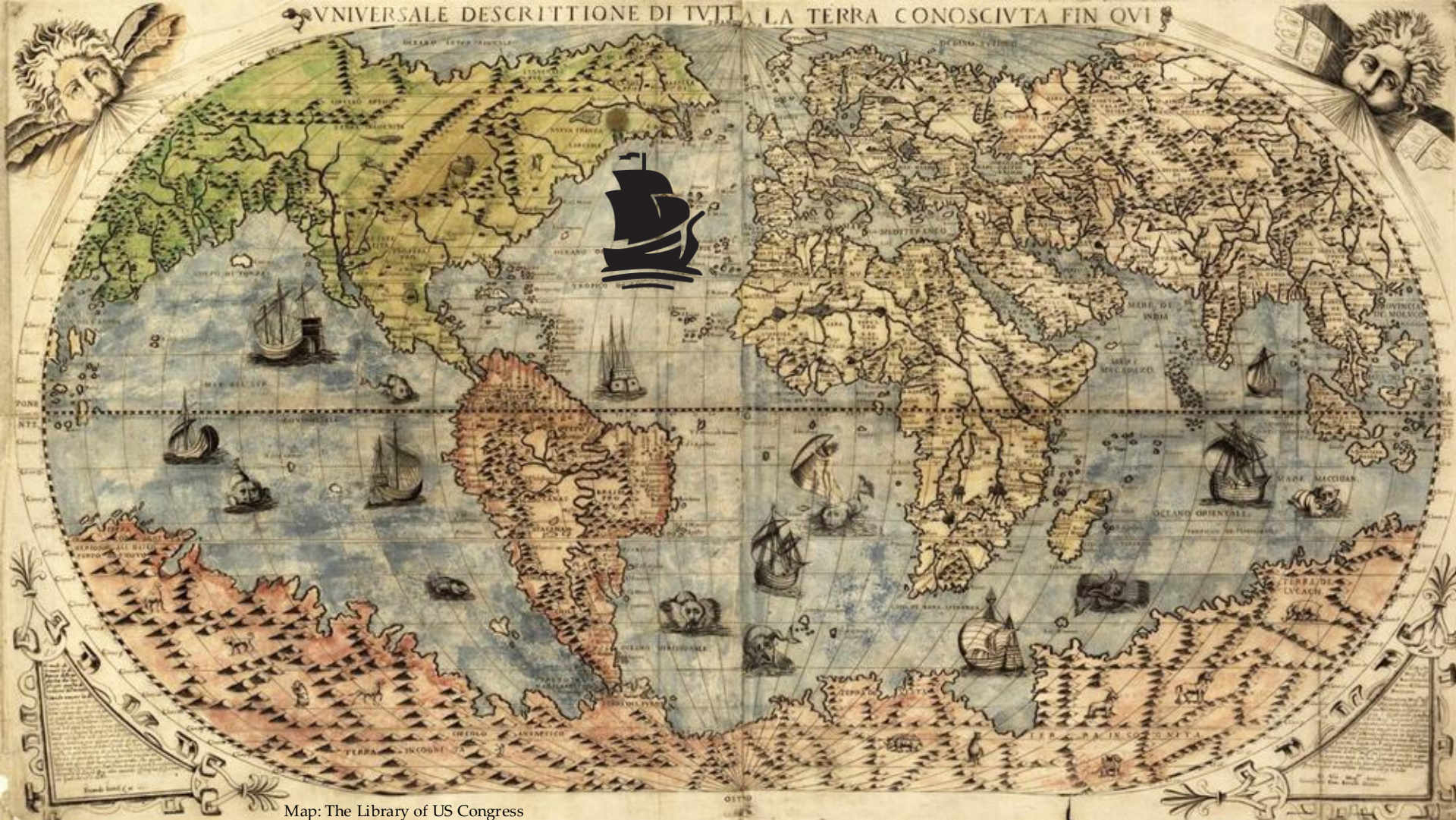
Source: Zielonka and Trutnevte (2025) *iScience*

Disaggregating context changes that cannot be assigned probabilities

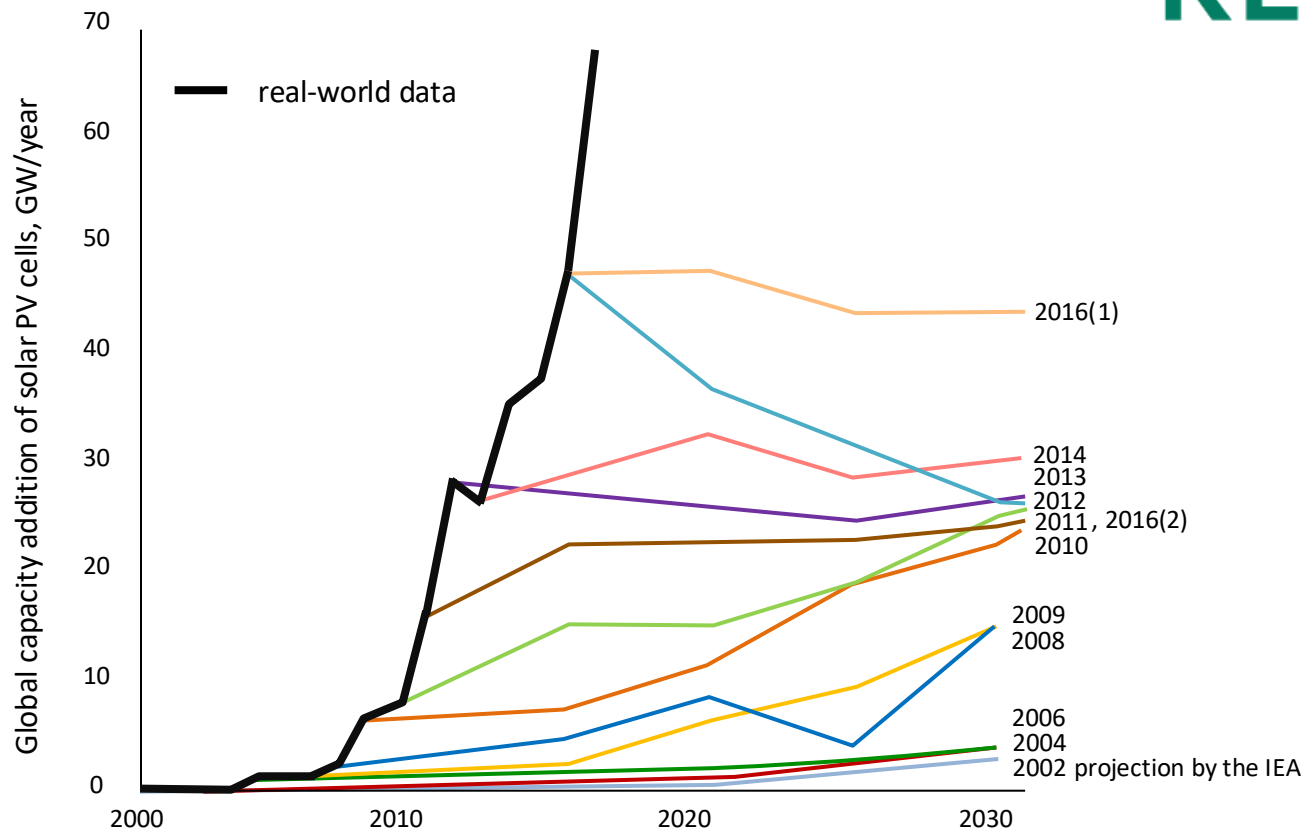


+ the use and testing of historical analogs for technologies with little track record

Source: Zielonka and Trutnevyte (2025b), Zielonka et al. (2026)



Well-known challenge of long-range projections



Hindcasting to inform long-range modeling

Historic data

Data in Brief 43 (2022) 108459

Contents lists available at ScienceDirect

Data in Brief

journal homepage: www.elsevier.com/locate/dib

ELSEVIER

Data Article

Historic data of the national electricity system transitions in Europe in 1990–2019 for retrospective evaluation of models

Marc Jaxa-Rozen^{1,*}, Xin Wen, Evelina Trutnevyte

Renewable Energy Systems, Institute for Environmental Sciences (RES), Section of Earth and Environmental Sciences, University of Geneva, Switzerland

zenodo

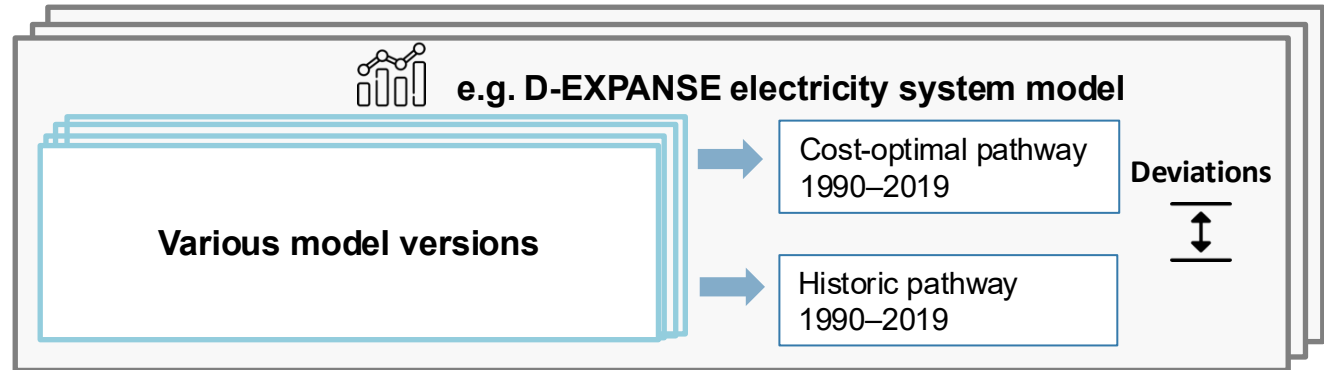
March 8, 2022

Historic data of the national electricity system transitions in Europe in 1990–2019 for retrospective evaluation of models [dataset]

Marc Jaxa-Rozen, Xin Wen, Evelina Trutnevyte

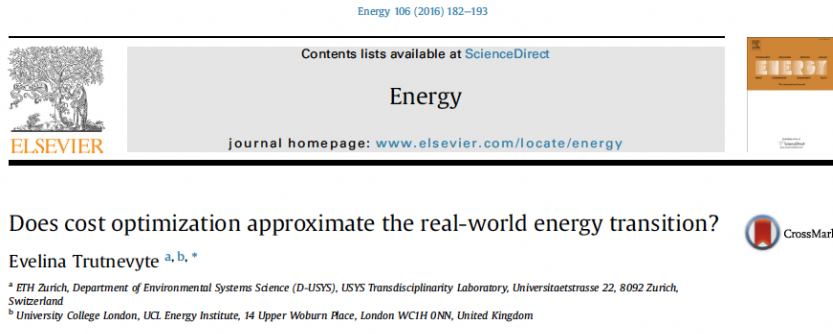


31 national models for 1990–2019 and 2020–2050
(EU27, UK, Switzerland, Norway, Iceland)

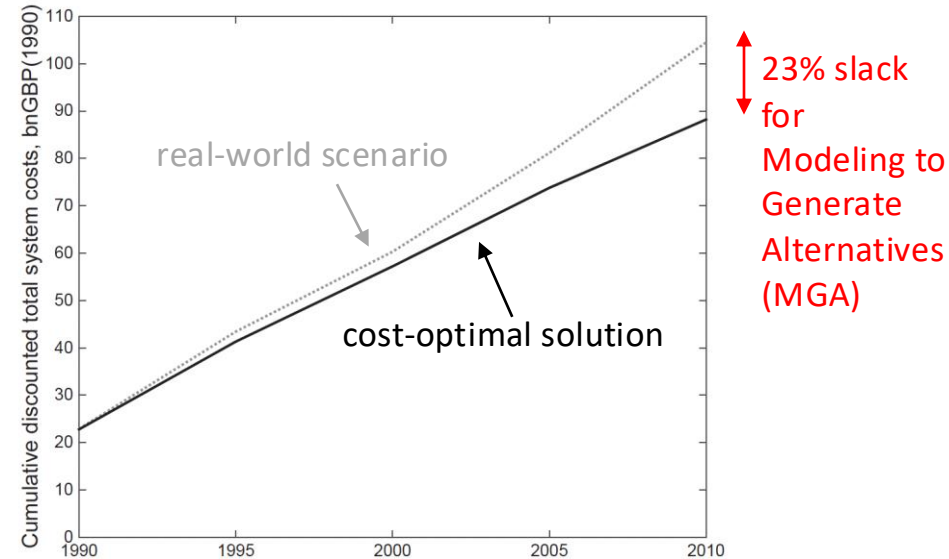


Source: Jaxa-Rozen et al. (2022) *Data in Brief*, Trutnevyte (2016) *Energy*, Wen et al. (2022, 2023) *Applied Energy*, Fossas-Tenas et al. (2026) *Energy*

Real-world deviation (slack) from cost-optimal solution

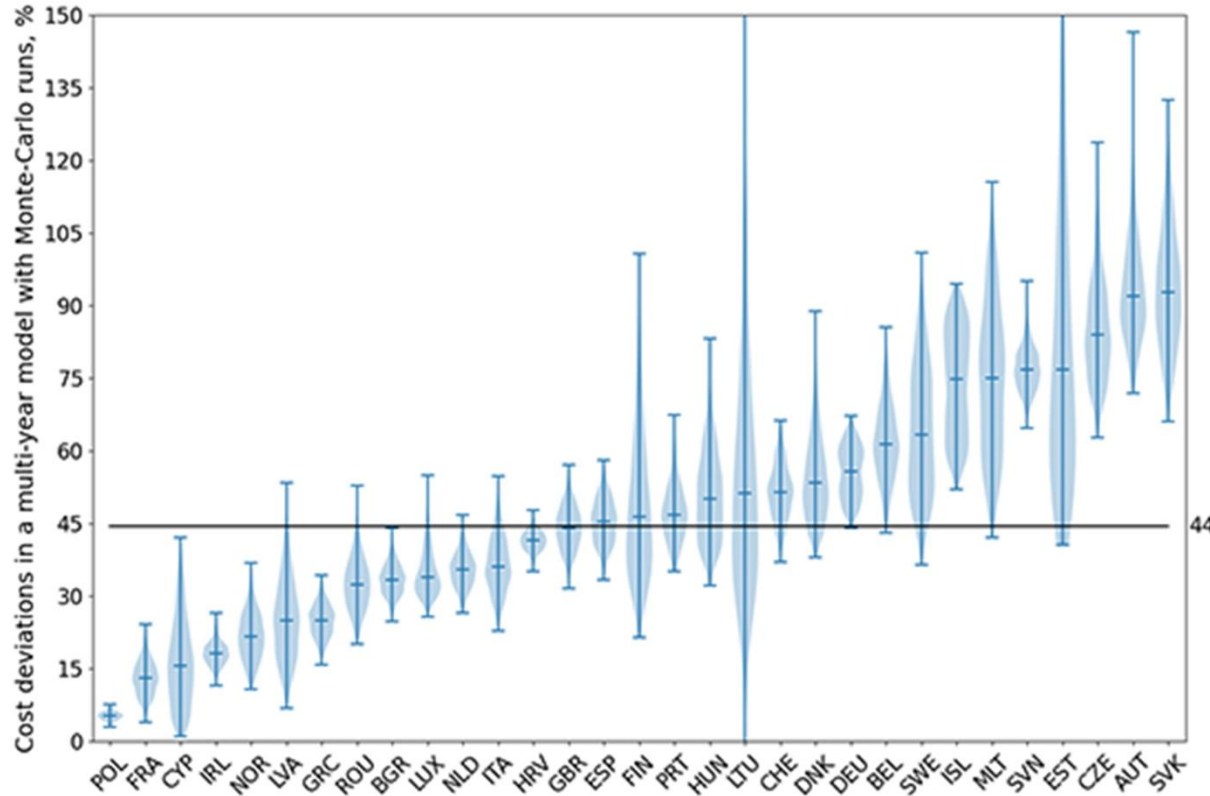


UK example in 1990 - 2014



Source: Trutnevyte (2016) *Energy*

Deviations (slack) across 31 countries



Assumptions:

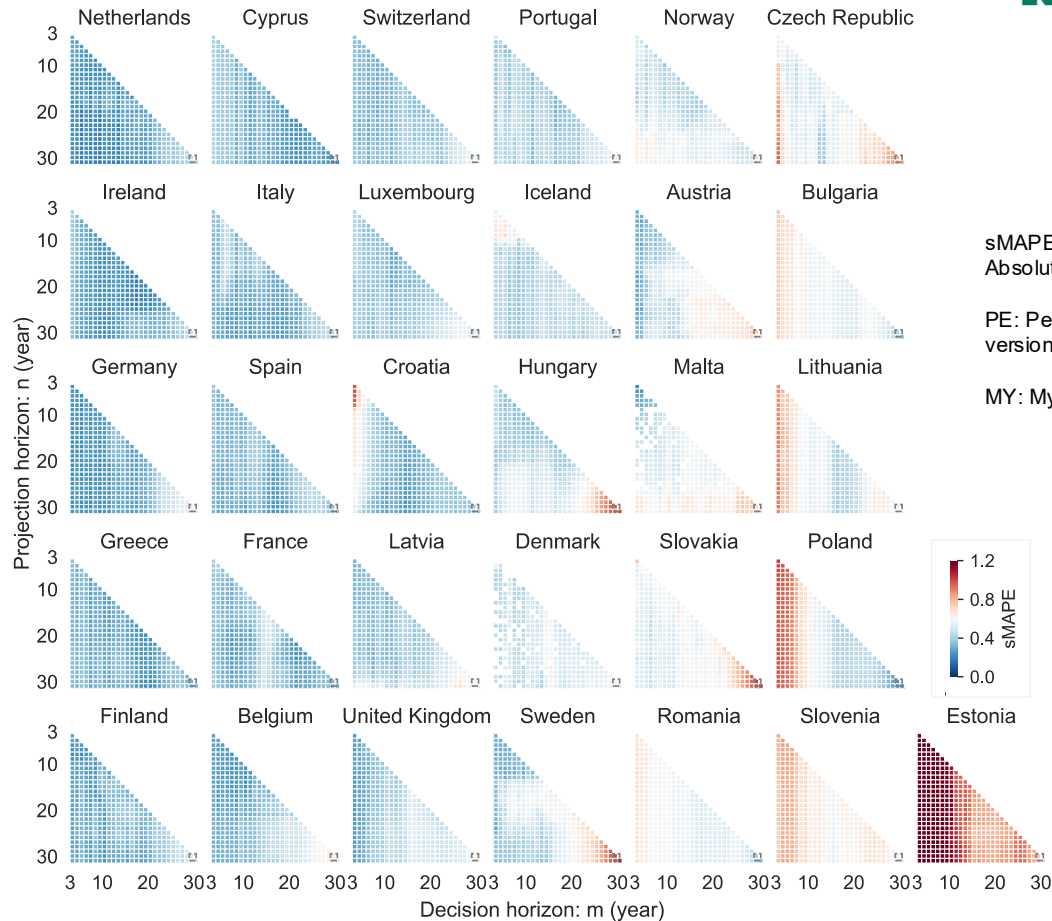
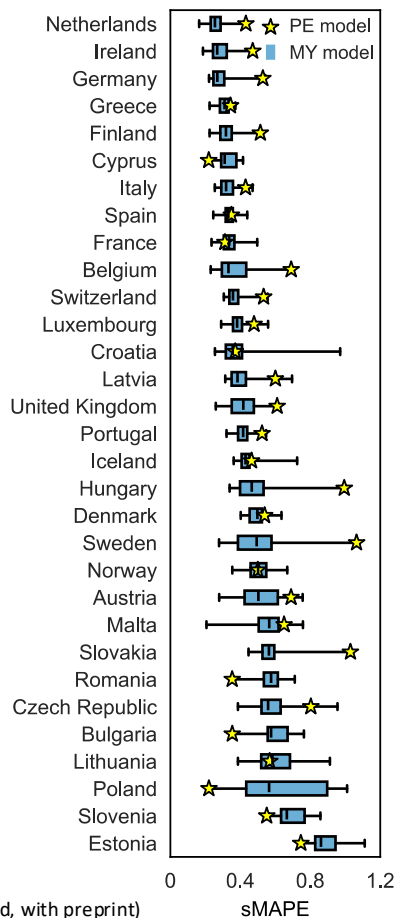
- 30 years ahead
- 1000 Monte Carlo runs
- Accounting for costs only during the modelled period

Source: Fossas-Tennas et al. (2026) *Energy*

Perfect foresight vs. myopic model

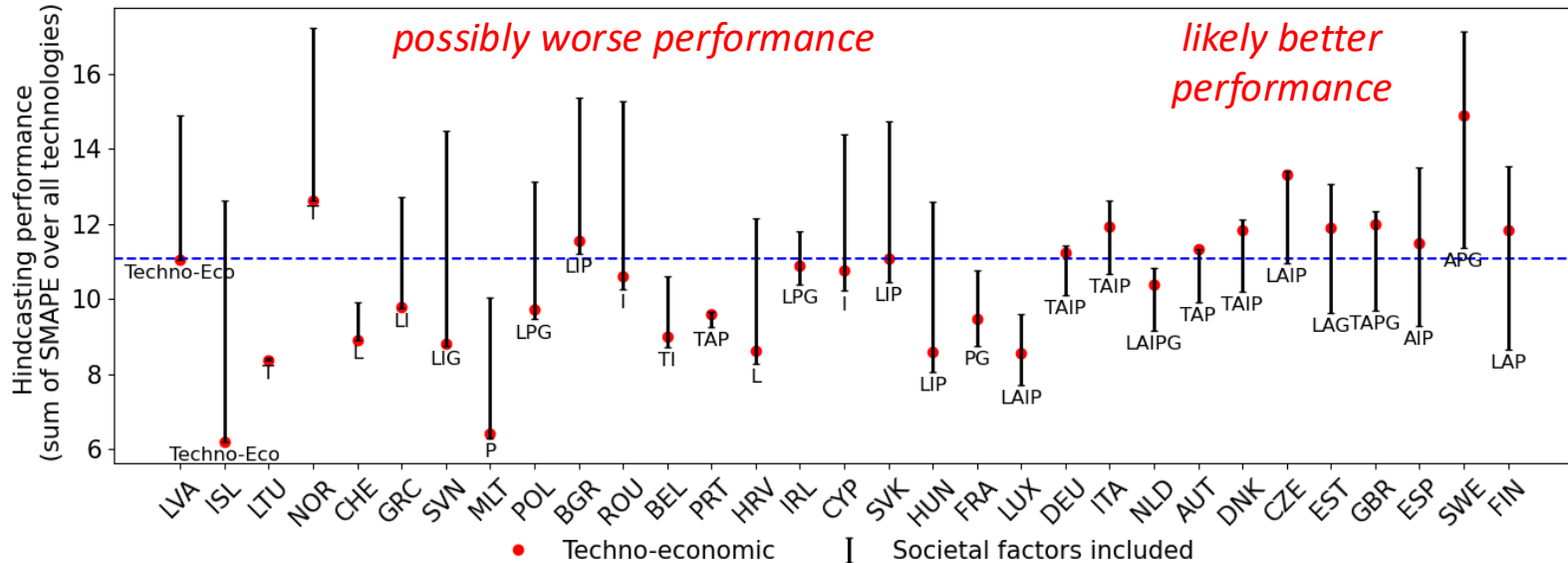


**Total
system
costs**



Societal factors in electricity sector models

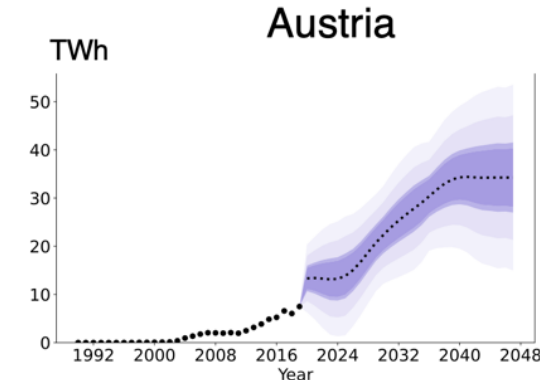
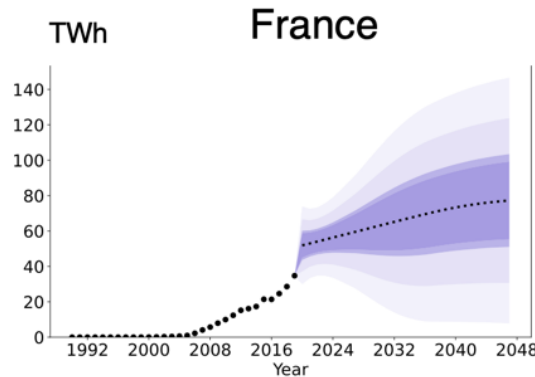
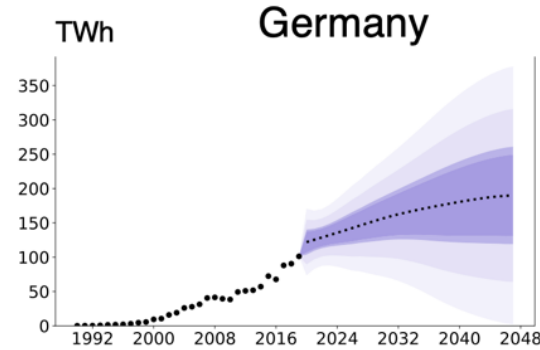
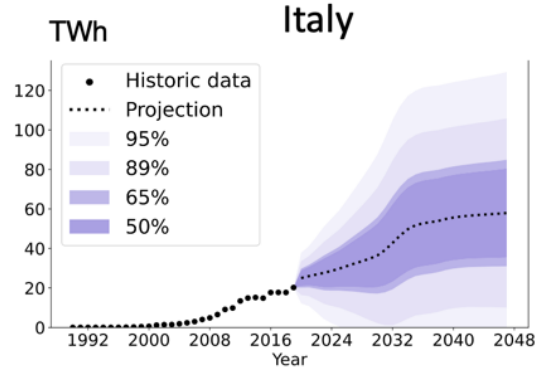
Hindcasting performance of a simulation model with and without societal factors
(actor heterogeneity, infrastructure lock-in, rapid transition, investment risk, public acceptance, and governance)



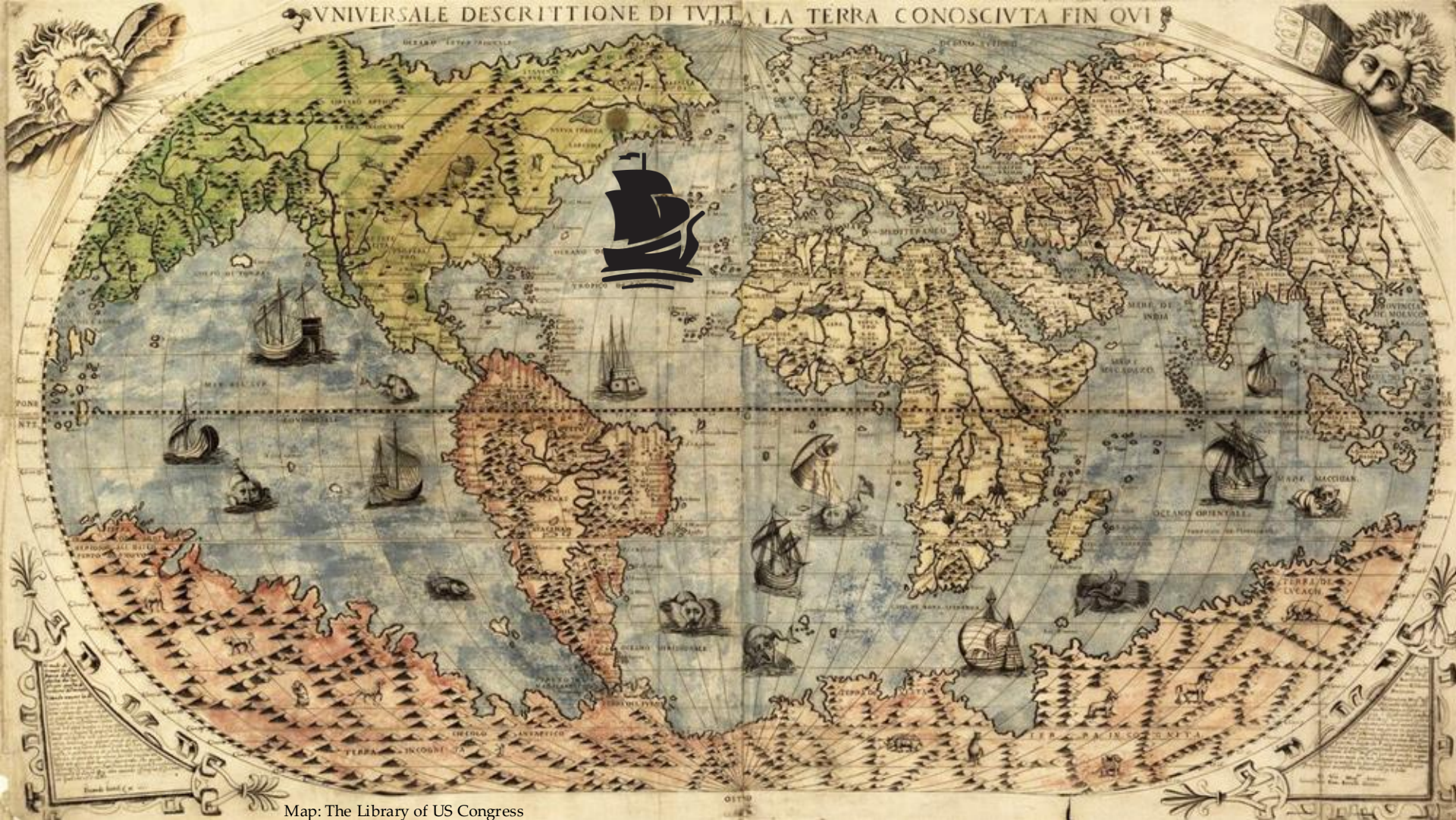
Source: Fisch-Romito et al. (2025) *Nature Energy*

Hindcasting-based probabilistic projections

Onshore
wind
power



Source: Wen et al. (in preparation)



Map: The Library of US Congress



Get in touch with
questions and
comments!

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sweet swiss energy research
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