2026 INFORMS Annual Meeting
Beyond Single Scenarios: Advanced Large-Ensemble Methods for Climate and Energy Policy Analysis

The MGA4all toolbox.

Interoperable and uncertainty-aware MGA

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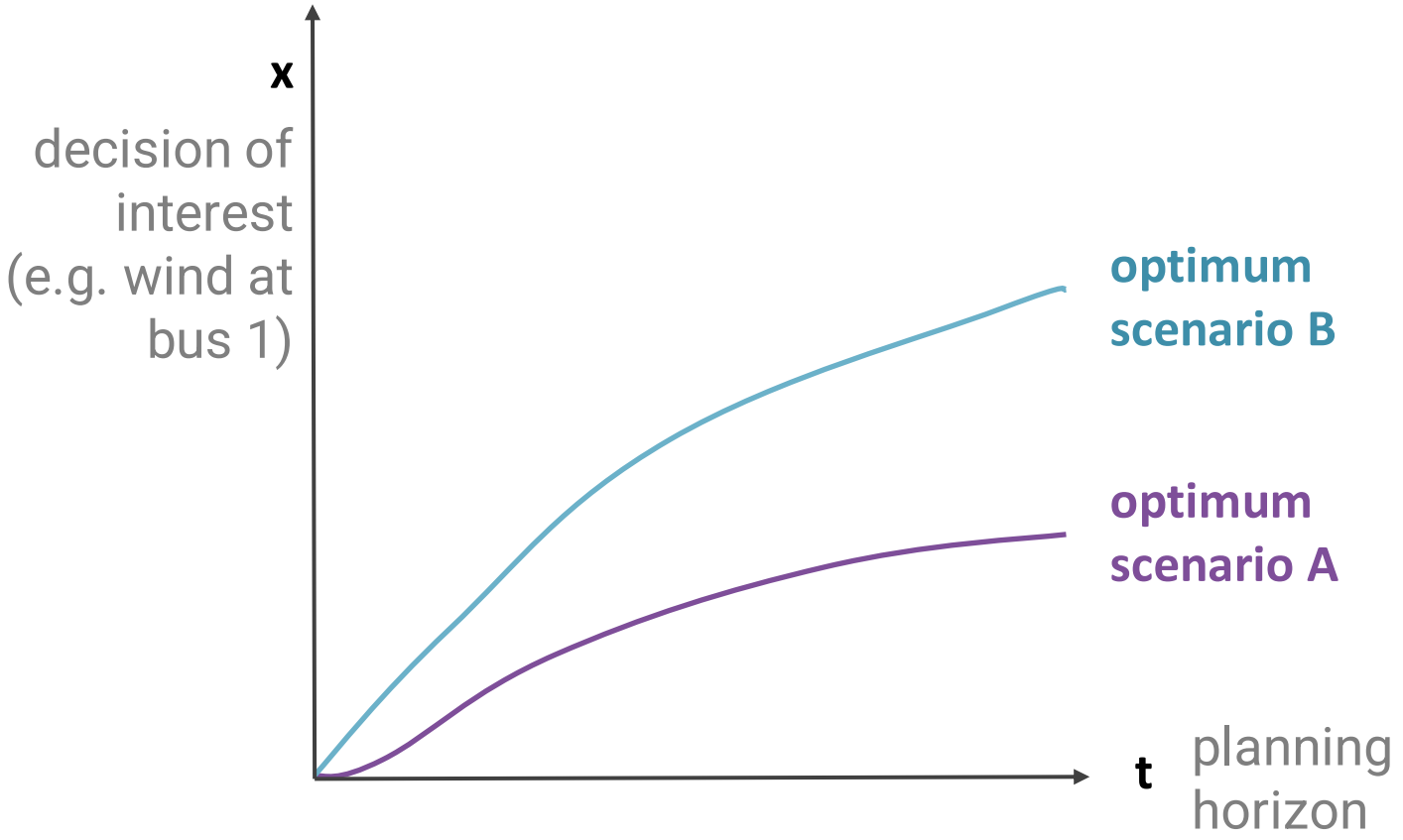
Faculty of Technology, Policy and Management

*On behalf of all contributors,
as listed at: github.com/mga4all

CC BY

The context.
The rise of MGA

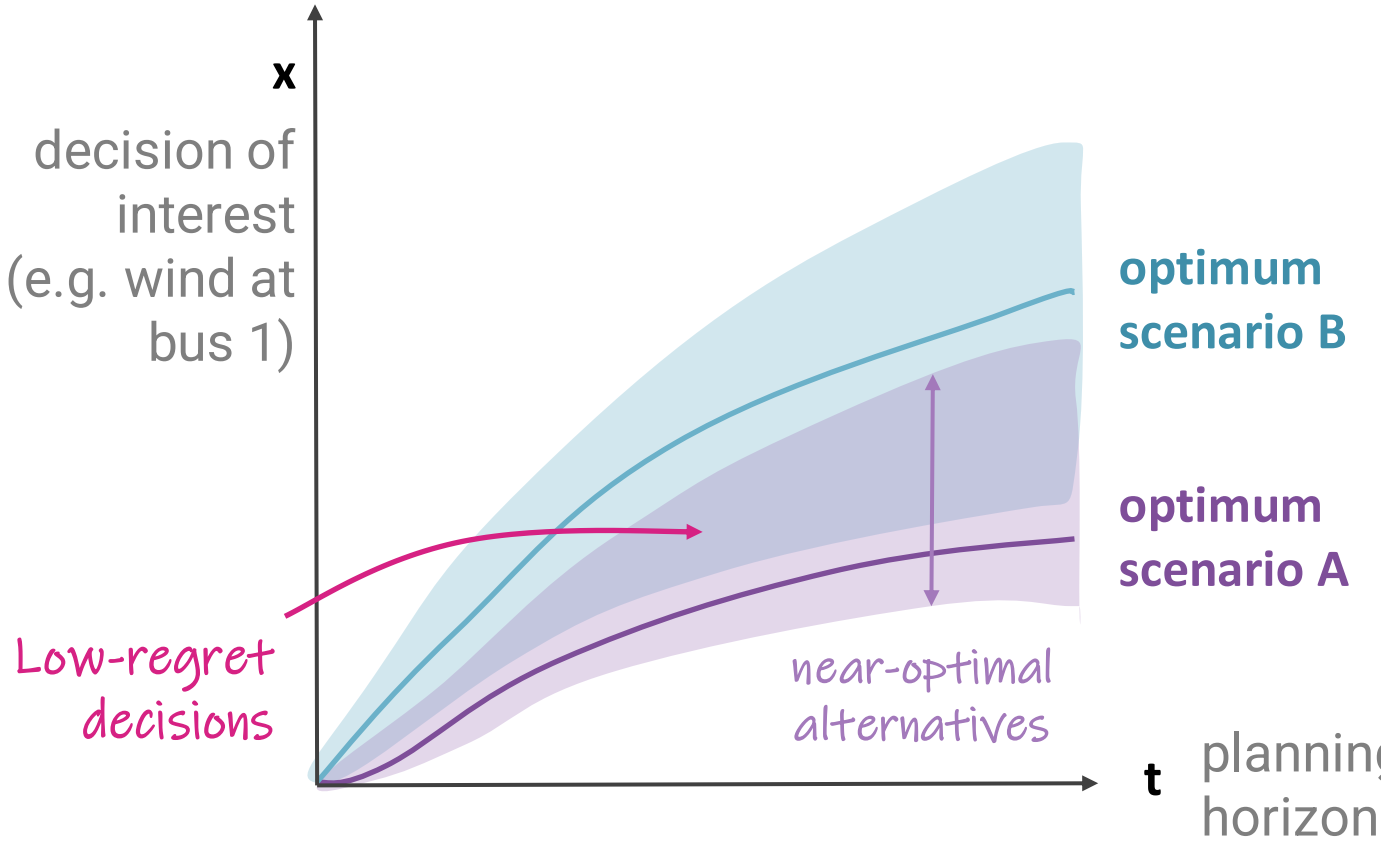
Energy planning and integrated assessment models both rely on **cost optimisation** (or welfare maximisation)



Visualisation inspired by: van Greevenbroek et al., *Joule*, 2025, doi.org/rvp2

The context.
The rise of MGA

Energy planning and integrated assessment models both rely on **cost optimisation** (or welfare maximisation)



Modelling to Generate Alternatives (MGA) offers a more insightful and reliable way to use the same models

Visualisation inspired by: van Greevenbroek et al., *Joule*, 2025, doi.org/rvp2

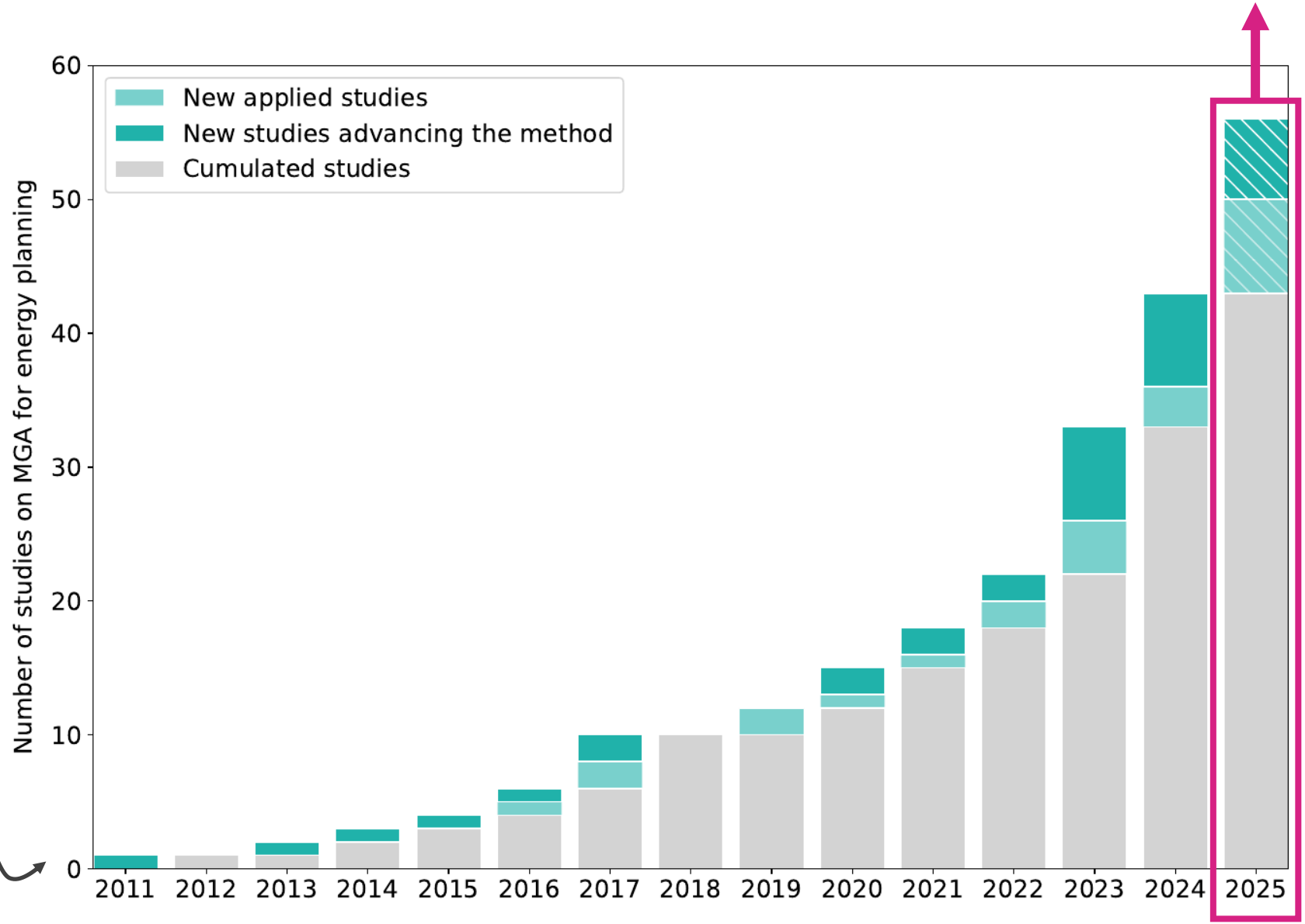
The context.
The rise of MGA

informs PubsOnLine

The Use of Optimization Models in Public-Sector Planning

E. Downey Brill, Jr.

1979



Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö. *Joule,* 2025. doi.org/p8b5

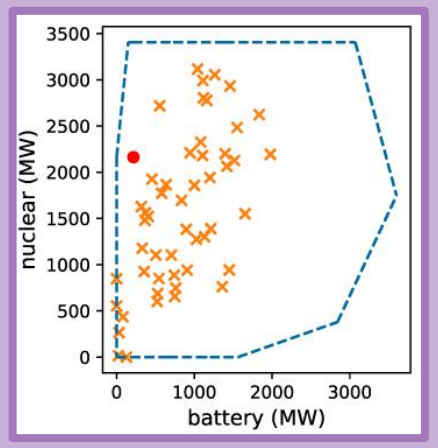
The context.

The rise of (next-gen*) MGA

*Selected illustrative examples from: Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö. *Joule,* 2025. doi.org/p8b5

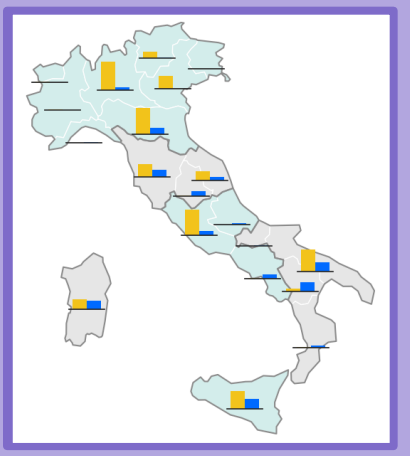
Lau, Patankar, Jenkins. *Env. Res.: Energy,* 2025. doi.org/p8nk

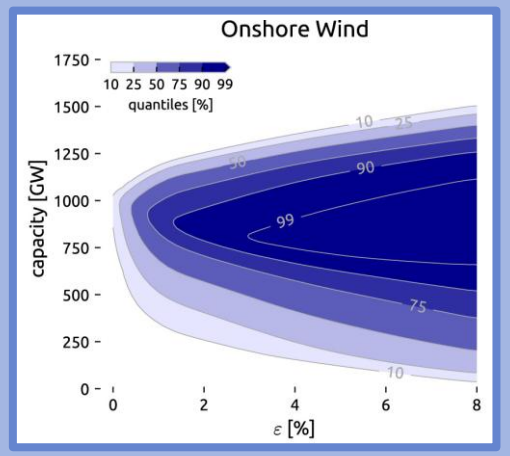
More efficient and robust computation



Lombardi, Pickering, Pfenninger. *App. En.,* 2023. doi.org/j457

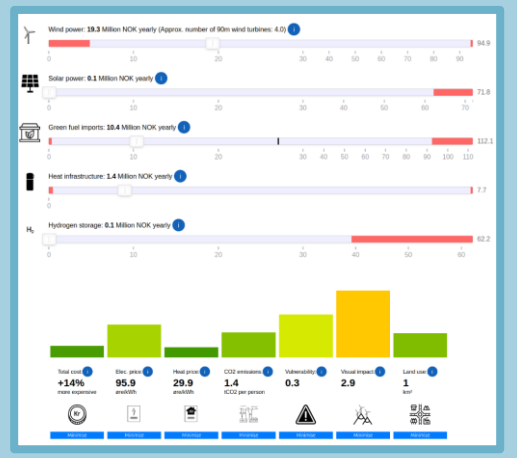
Tailored search for spatial aspects





Integration with parametric uncertainty

Neumann, Brown. *iScience*, 2023. doi.org/g27qjq



Intuitive and practically applicable outputs

Vågerö, van Greevenbroek, Grochowicz, Roithner. *iScience*, 2026. doi.org/rvhf

Next steps.
Interoperability & technology readiness



Different MGA methods have specific advantages but **exist only in specific tools**.

- Cannot choose the **best suited for a given question**

MGA4all aims to addresses both needs



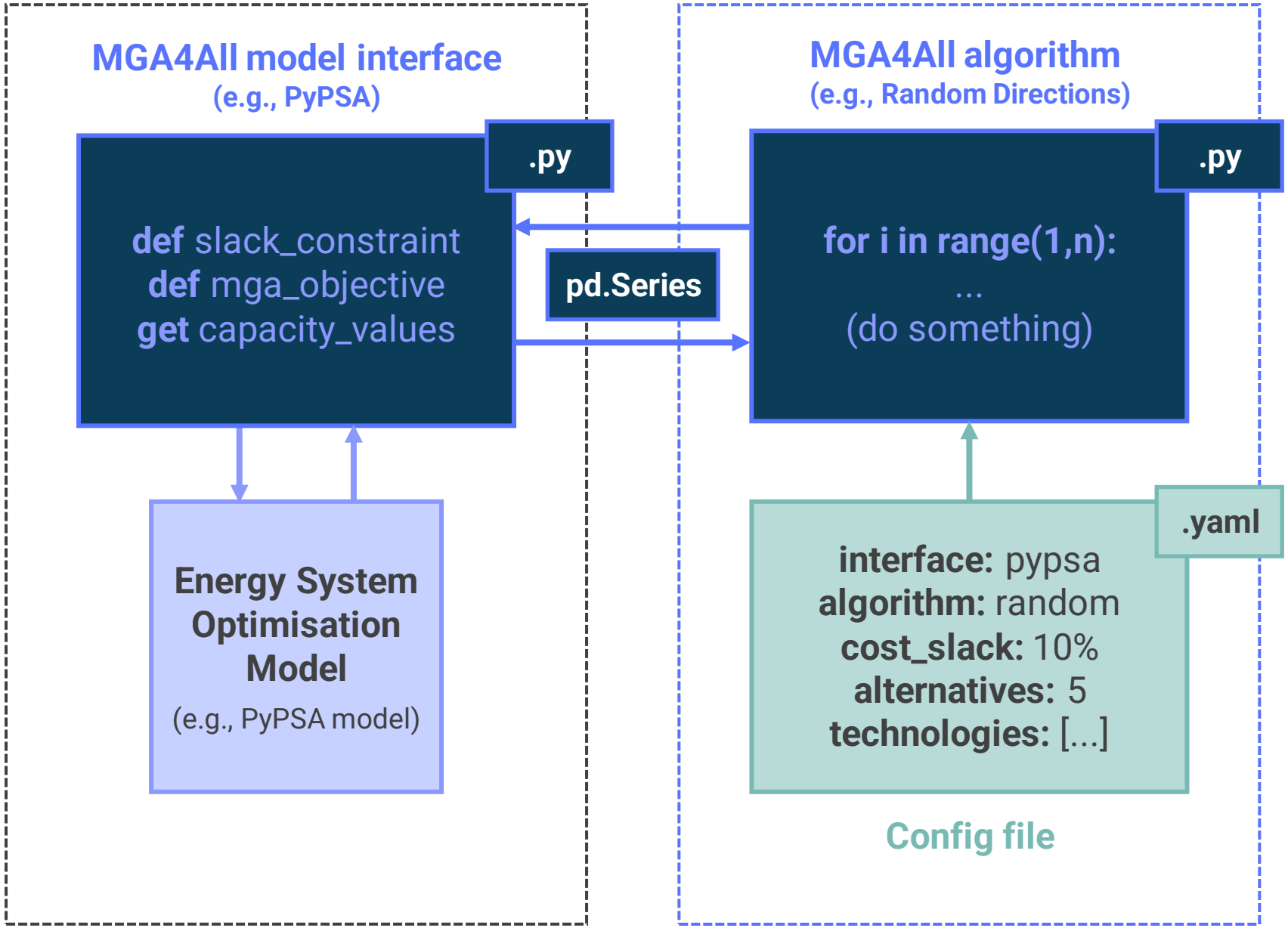
Benefits of MGA are scientifically established but MGA is **not yet a standard in practice**.

- MGA use must be g**streamlined further**

and its integration with existing approaches (e.g. sensitivity analysis)

MG4All algos

Separation of **model interface** and **algorithms**





github.com/MGA4all/mga4all_algorithms

Developers (listed alphabetically): S. Ali, C. Dinga, F. Lombardi, S. van Rijn





MGA4all - algorithms

Various Modelling to Generate Alternative (MGA) algorithms for different energy system optimisation modelling frameworks

Implemented Algorithms and supported model backends

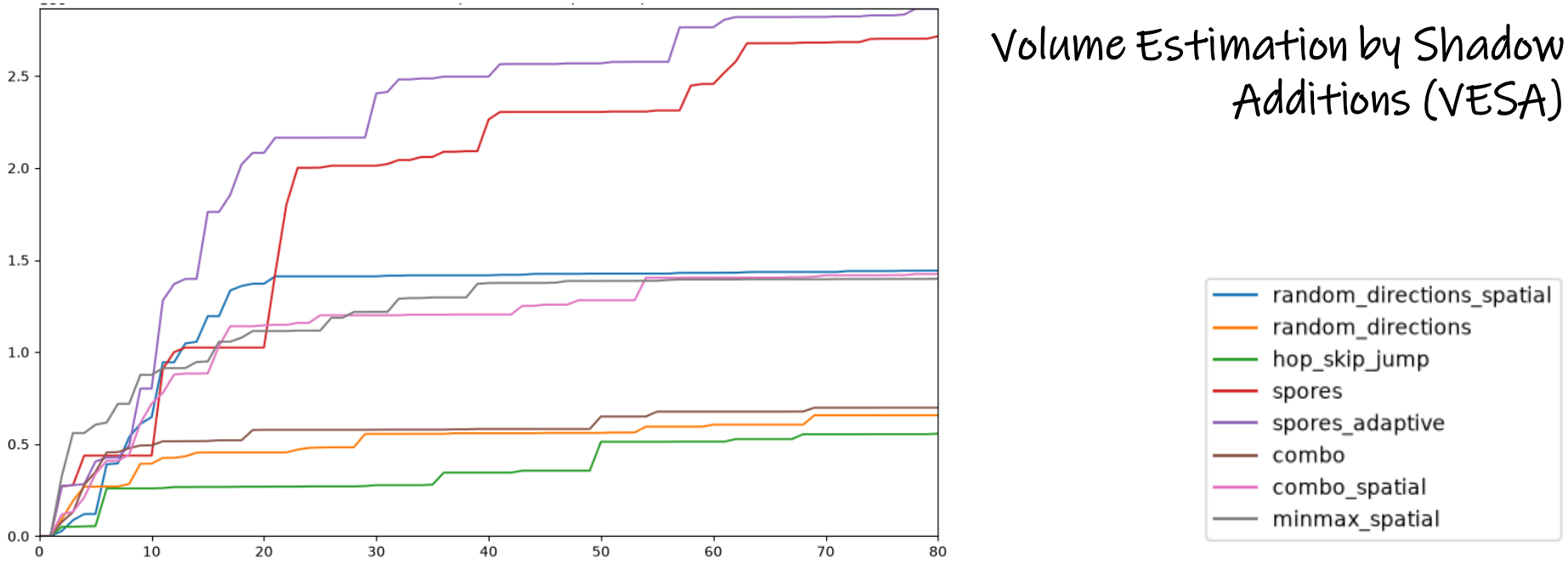
Algorithm	PyPSA + linopy	GenX	EnergyScope
Combo	✅		
SPORES (new, improved version)	✅		
Random Directions	✅		
Min-Max (acessible within Combo)	✅		
Hop-Skip-JUmp	✅		

ORACLE	
MH-MGA	

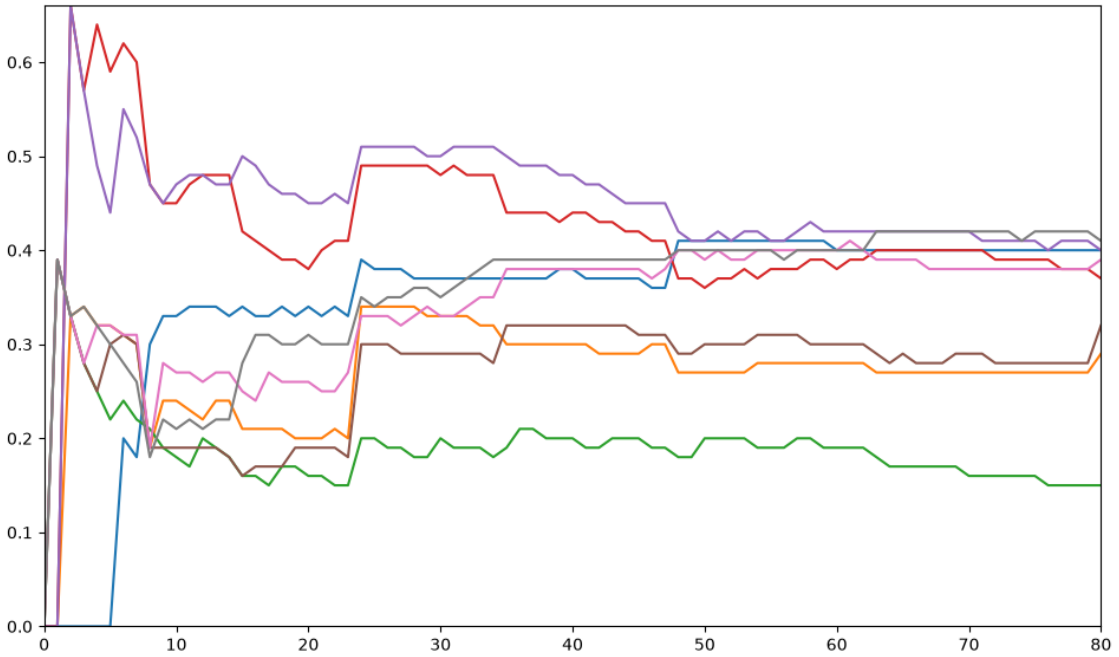
Upcoming talk by H. Thawley!



Volume Estimation by Shadow Additions (VESA)



Entropic diversity (Shannon Index)



Still private work-in-progress at: github.com/MGA4all/MGA4all_dashboard

Developers (listed alphabetically): A. Amen, F. Lombardi, A. Nedelcu, E. Pallano

MG4ll dash

1 **Load and validate** your MGA data

2 **Explore** clusters and specific alternatives

3

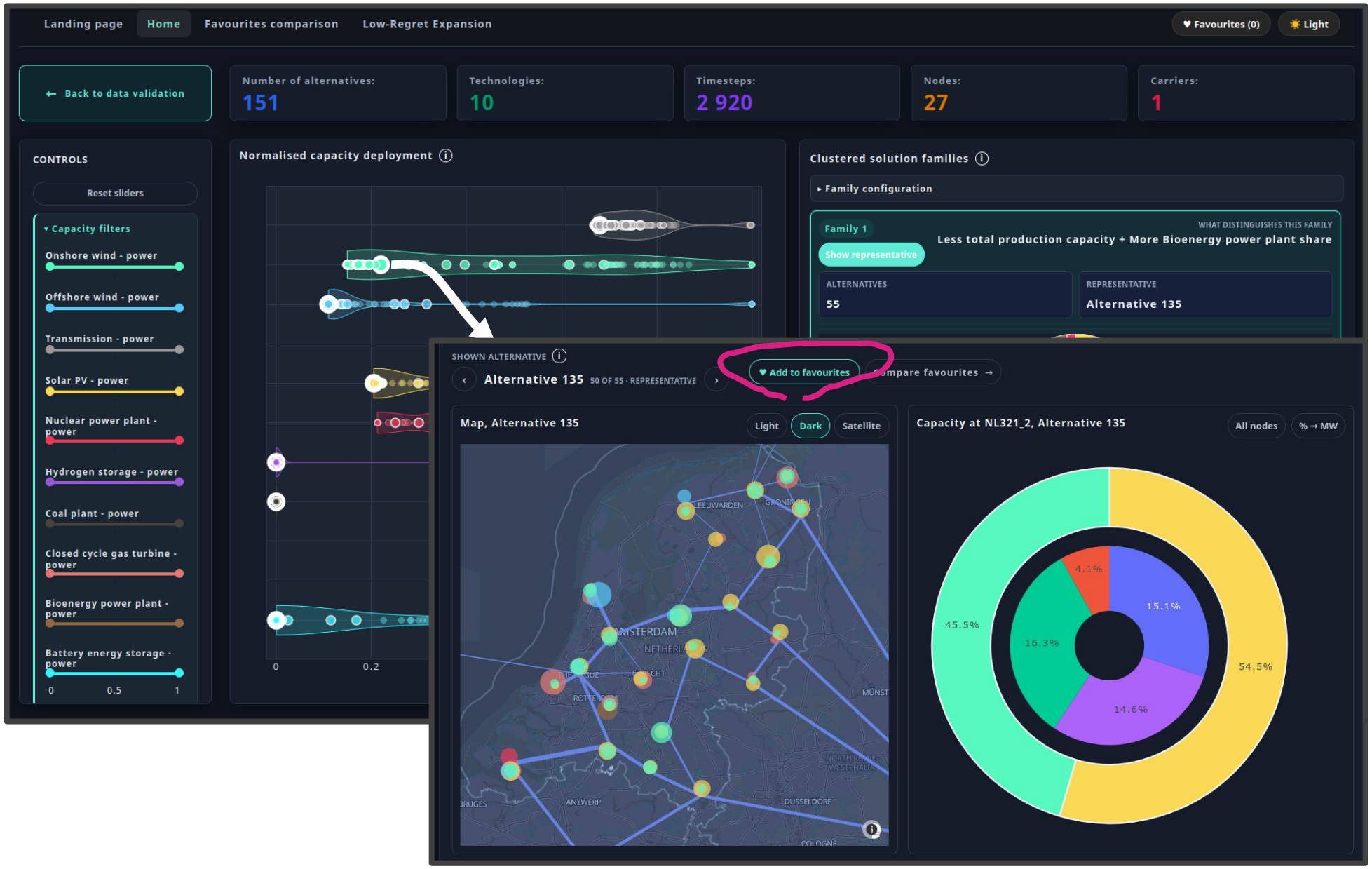
4

Automated, customisable information reduction

MG4II dash


Landing page
Home
Favourites comparison
Low-Regret Expansion
♥ Favourites (0)
☀ Light
← Back to data validation
Number of alternatives:
151
Technologies:
10
Timesteps:
2 920
Nodes:
27
Carriers:
1
CONTROLS
Reset sliders
▾ Capacity filters
Onshore wind - power
Offshore wind - power
Transmission - power
Solar PV - power
Nuclear power plant - power
Hydrogen storage - power
Coal plant - power
Closed cycle gas turbine - power
Bioenergy power plant - power
Battery energy storage - power
0
0.5
1
Normalised capacity deployment
0
0.2
0.4
0.6
0.8
1
Clustered solution families
▸ Family configuration
Family 1
Show representative
WHAT DISTINGUISHES THIS FAMILY
Less total production capacity + More Bioenergy power plant share
ALTERNATIVES
55
REPRESENTATIVE
Alternative 135
Average capacity mix
Family 2
Show representative
WHAT DISTINGUISHES THIS FAMILY
More Offshore wind share + Less Onshore wind share
ALTERNATIVES
22
REPRESENTATIVE
Alternative 115

MG4II dash


Landing page
Home
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0
0.5
1
Normalised capacity deployment ⓘ
0
0.2
Clustered solution families ⓘ
▸ Family configuration
Family 1
Show representative
WHAT DISTINGUISHES THIS FAMILY
Less total production capacity + More Bioenergy power plant share
ALTERNATIVES
55
REPRESENTATIVE
Alternative 135
SHOWN ALTERNATIVE ⓘ
‹
Alternative 135
50 OF 55 · REPRESENTATIVE
›
♥ Add to favourites
Compare favourites →
Map, Alternative 135
Light
Dark
Satellite
LEEUWARDEN
GRONINGEN
AMSTERDAM
NETHERLANDS
UTRECHT
ROTTERDAM
MÜNST
NORTH RHINE-WESTPHALIA
ANTWERP
BRUGES
DUSSELDORF
COLOGNE
Capacity at NL321_2, Alternative 135
All nodes
% → MW
4.1%
15.1%
45.5%
16.3%
54.5%
14.6%

Still private work-in-progress at: github.com/MGA4all/MGA4all_dashboard

Developers (listed alphabetically): A. Amen, F. Lombardi, A. Nedelcu, E. Pallano

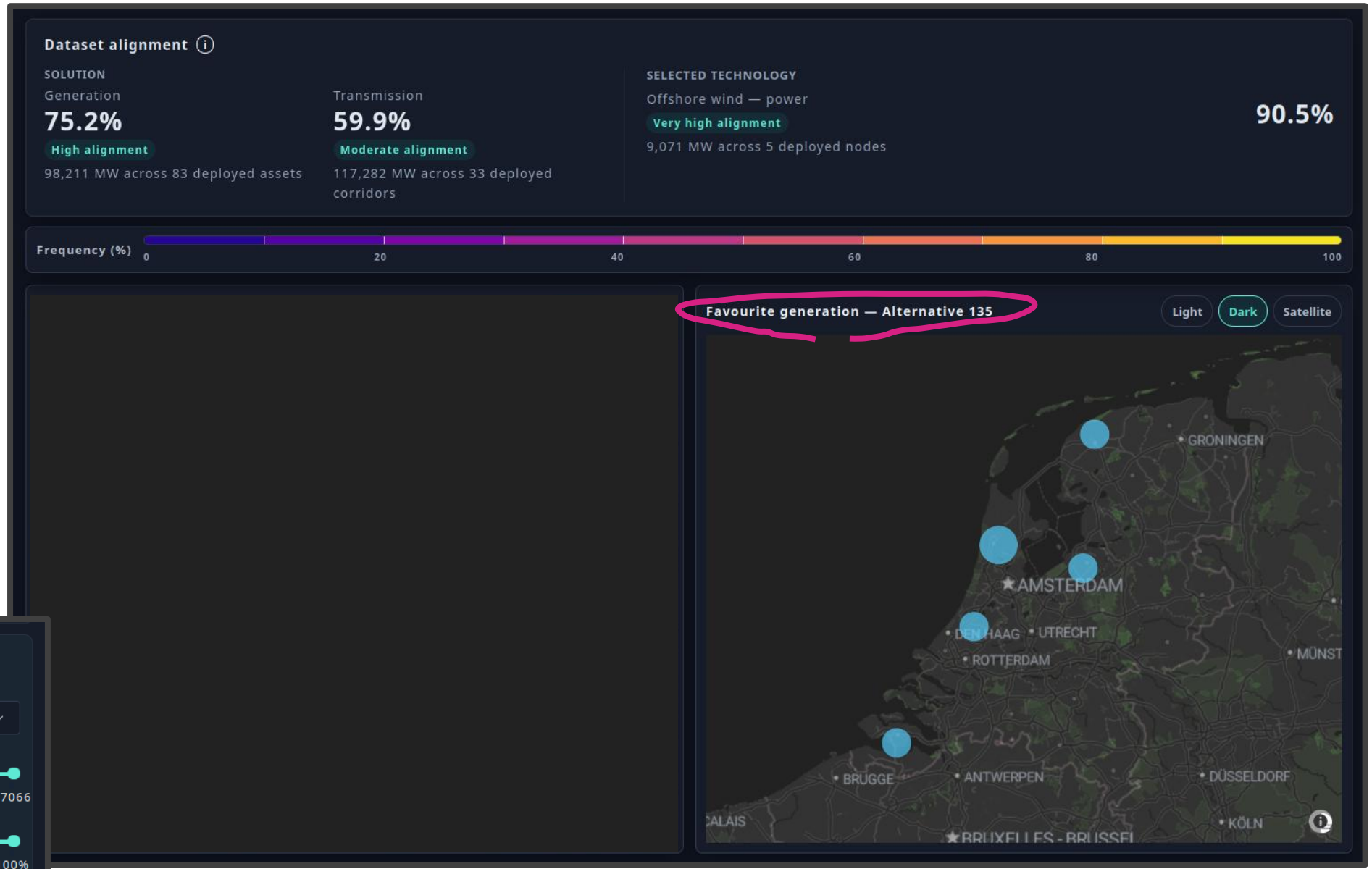
MG4ll dash

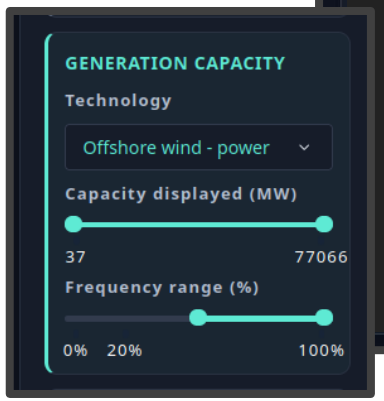
1. **Load and validate** your MGA data
2. **Explore** clusters and refine the design details
3. **Compare** designs you saved as **favourites**
4. **Identify low-regret components** of your design

Automated, customisable information reduction

Intuitive decision prioritisation

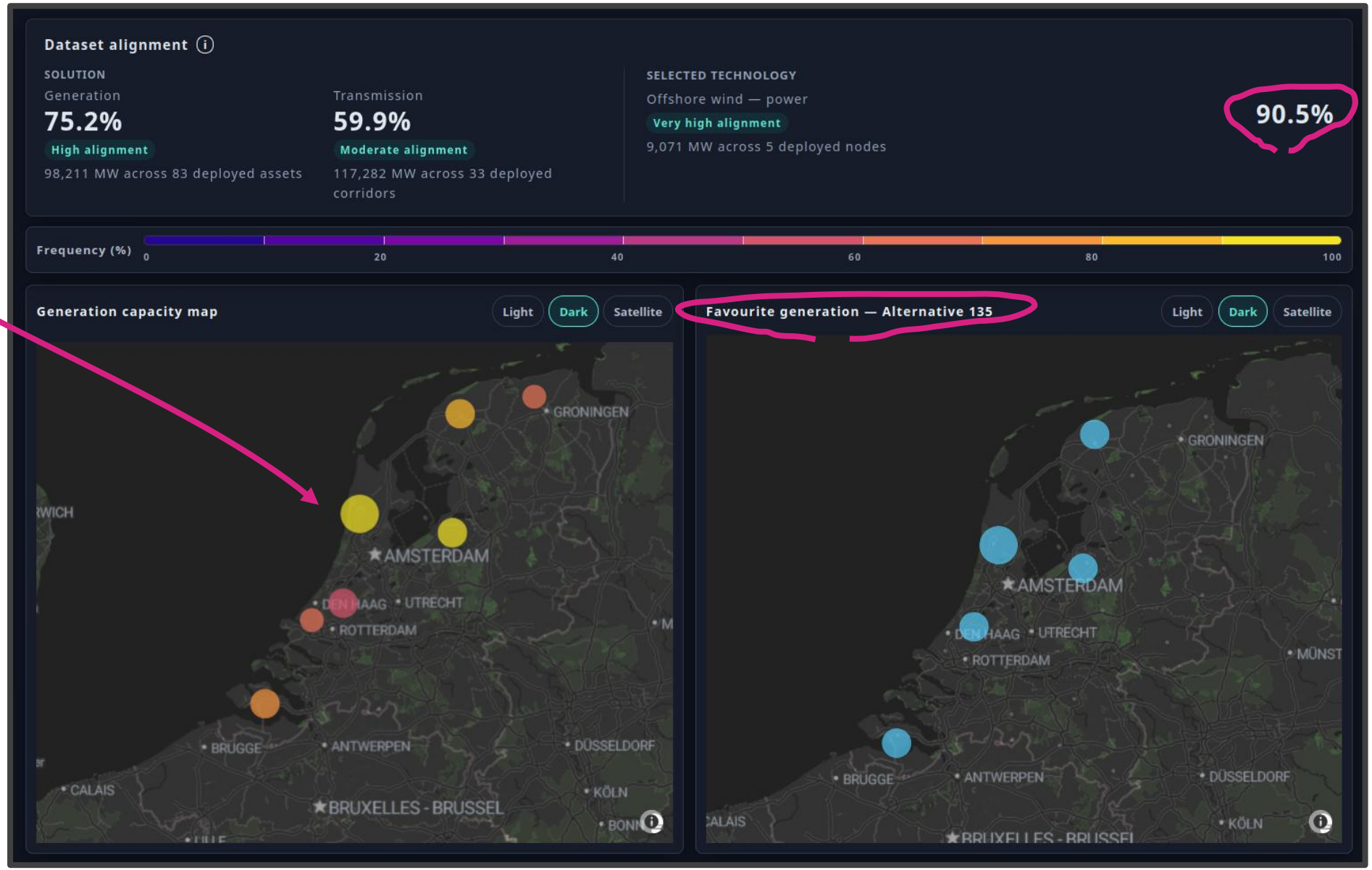
MG4II dash


Dataset alignment
SOLUTION
Generation
75.2%
High alignment
98,211 MW across 83 deployed assets
Transmission
59.9%
Moderate alignment
117,282 MW across 33 deployed corridors
SELECTED TECHNOLOGY
Offshore wind — power
Very high alignment
9,071 MW across 5 deployed nodes
90.5%
Frequency (%)
0
20
40
60
80
100
Favourite generation — Alternative 135
Light
Dark
Satellite
GRONINGEN
AMSTERDAM
DEN HAAG
UTRECHT
ROTTERDAM
MÜNST
BRUGGE
ANTWERPEN
DÜSSELDORF
CALAIS
KÖLN
BRUXELLES - BRUSSEL


GENERATION CAPACITY
Technology
Offshore wind - power
Capacity displayed (MW)
37
77066
Frequency range (%)
0%
20%
100%

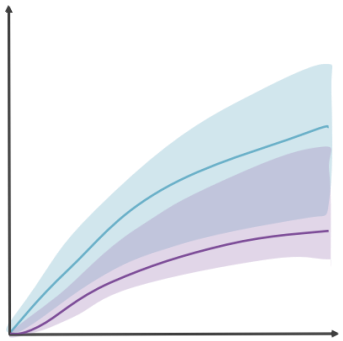
Low-regret decisions

MG4II dash



Low-regret decisions

MG4II dash



Dataset alignment

SOLUTION

Generation
75.2%
High alignment
98,211 MW across 83 deployed assets

Transmission
59.9%
Moderate alignment
117,282 MW across 33 deployed corridors

SELECTED TECHNOLOGY
Offshore wind — power
Very high alignment
9,071 MW across 5 deployed nodes

90.5%

Frequency (%) 0 20 40 60 80 100

Generation capacity map — Light Dark Satellite

GRONINGEN
AMSTERDAM
DEN HAAG
UTRECHT
ROTTERDAM
BRUGGE
ANTWERPEN
DÜSSELDORF
CALAIS
BRUXELLES - BRUSSEL
KÖLN

Favourite generation — Alternative 135 — Light Dark Satellite

GRONINGEN
AMSTERDAM
BRUGGE

CONTROLS

Datasets to explore

Select / deselect all

Data Big Normalized

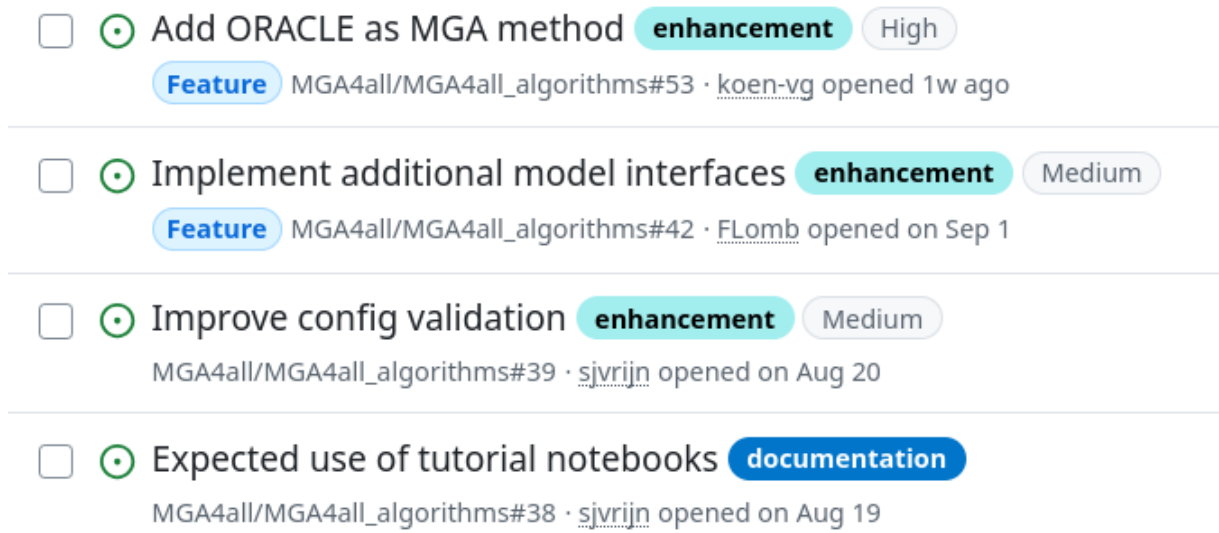
Data Harsh Normalized

1 dataset · 151 alternatives

Intersecting scenarios: stronger insights

MGA4all is designed as a **platform for collaboration**!

Contribute your MGA algorithm, favourite model interface...



Make MGA a standard best practice

...or simply try it out and find bugs to fix or suggest improvements!

We follow the **All Contributors** convention, meaning all forms of contribution (e.g., 💻 🔬 🤔 📖 🚧 🎨 📓 📆) are welcome and automatically acknowledged!