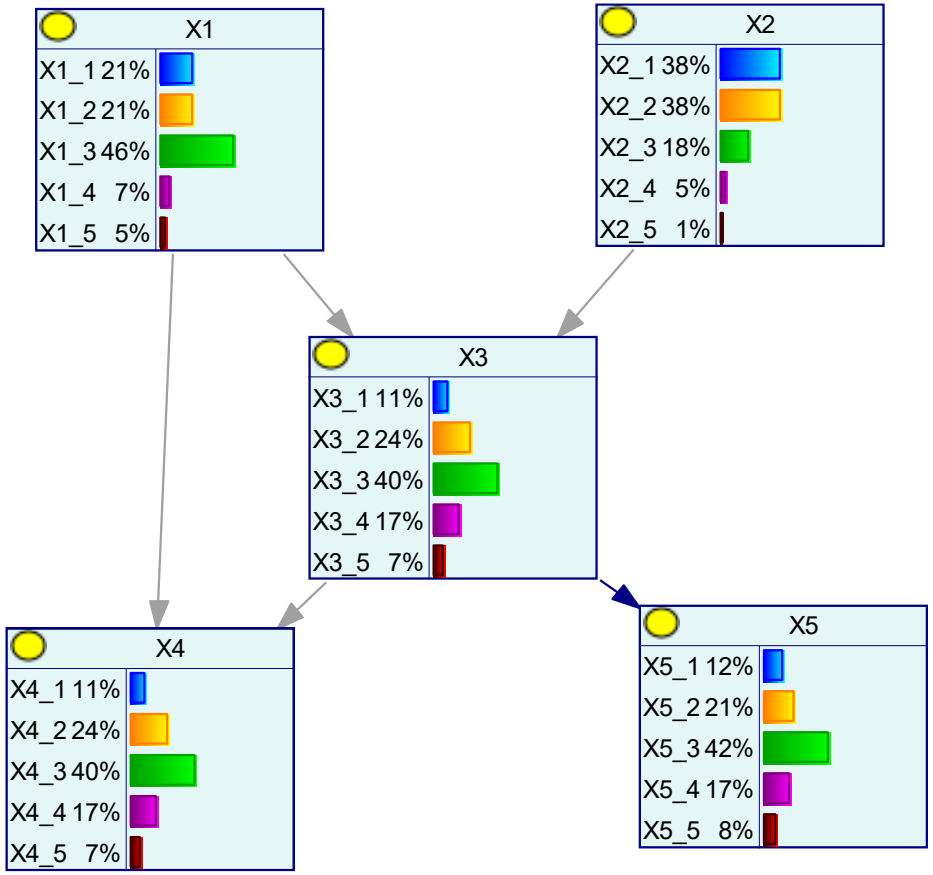
PSI
Center for Nuclear Engineering and Sciences
Center for Energy and Environmental Sciences

Visualise, understand and analyse complex models

Bayesian Network Application for Energy Systems Analysis & Scenarios



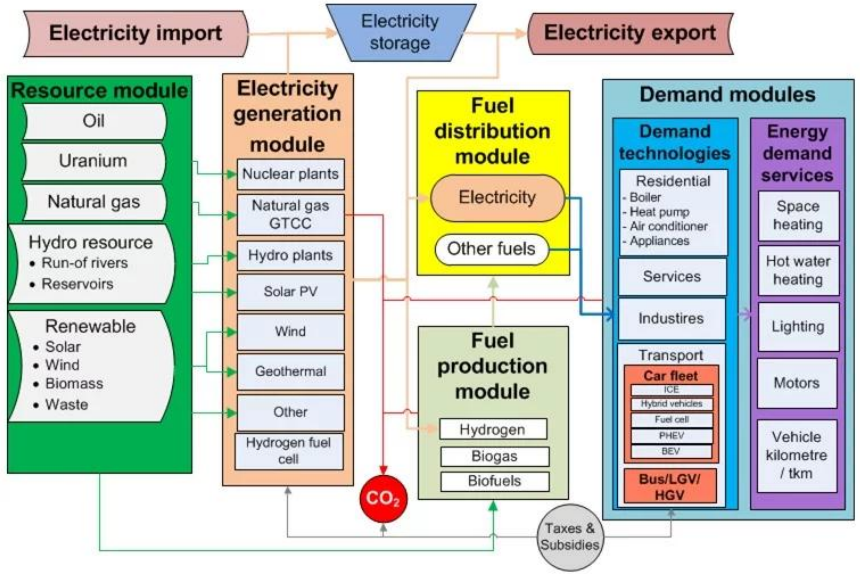
Evangelos Panos, Head of Energy Economics Group, Laboratory for Energy Systems Analysis
6th International Forum on Long-Term Scenarios (LTES) for Clean Energy Transition, IRENA, Bonn, 30 October 2025

Why AI in Energy Planning: clarity in a complex system

- Energy models create millions of interactions, but decision-makers need *simple* insights
- AI can accelerate analysis and uncover relationships otherwise hidden *in the noise*

How to adopt AI that speeds up planning while preserving trust, transparency and sovereignty?

Complex energy system



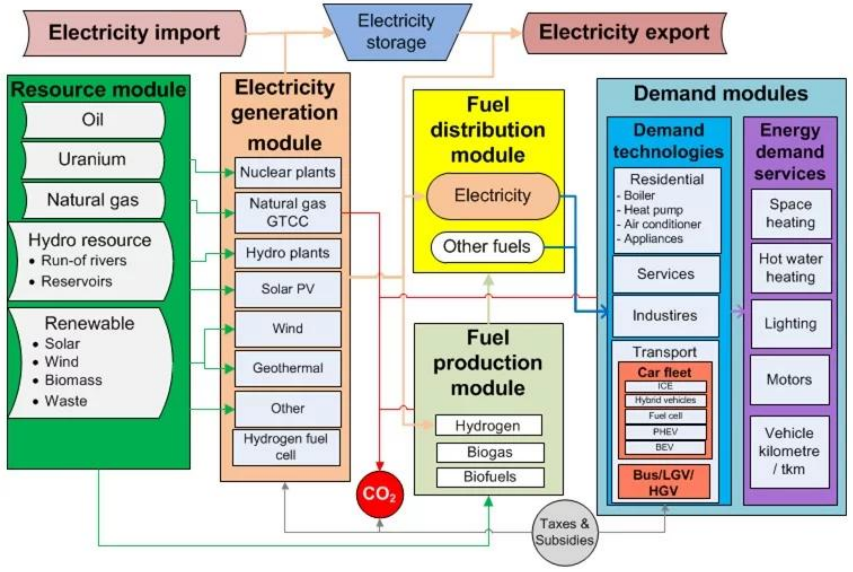
AI for Insight (Explainability & Speed)

Clear Insights

Explainable AI Surrogates: Bayesian Belief Networks at PSI

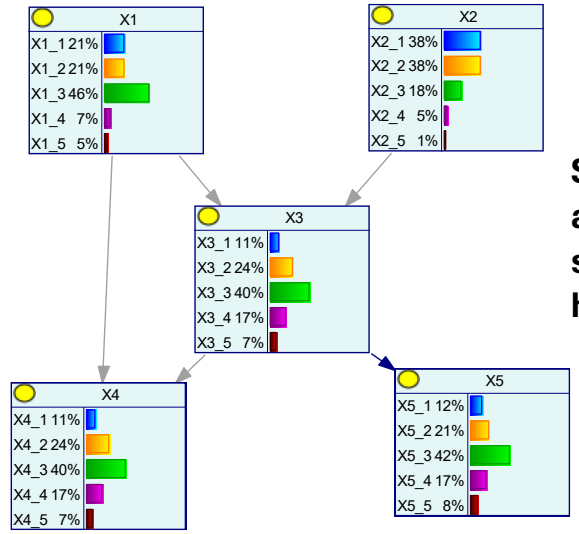
- Causal graphs that show *why* outputs change
- Fast uncertainty propagation
- Quick scenario exploration
- What-if and goal-seeking without black-box mysteries
- Keep policy ownership with humans: the model becomes a map, not a maze

Swiss TIMES Energy System Model - STEM



The energy system model generates data to develop and train a BBN

A BBN is a probabilistic model graphically presenting causality



Surrogate model of a complex energy system model with high fidelity

Using a BBN model as surrogate models for energy systems

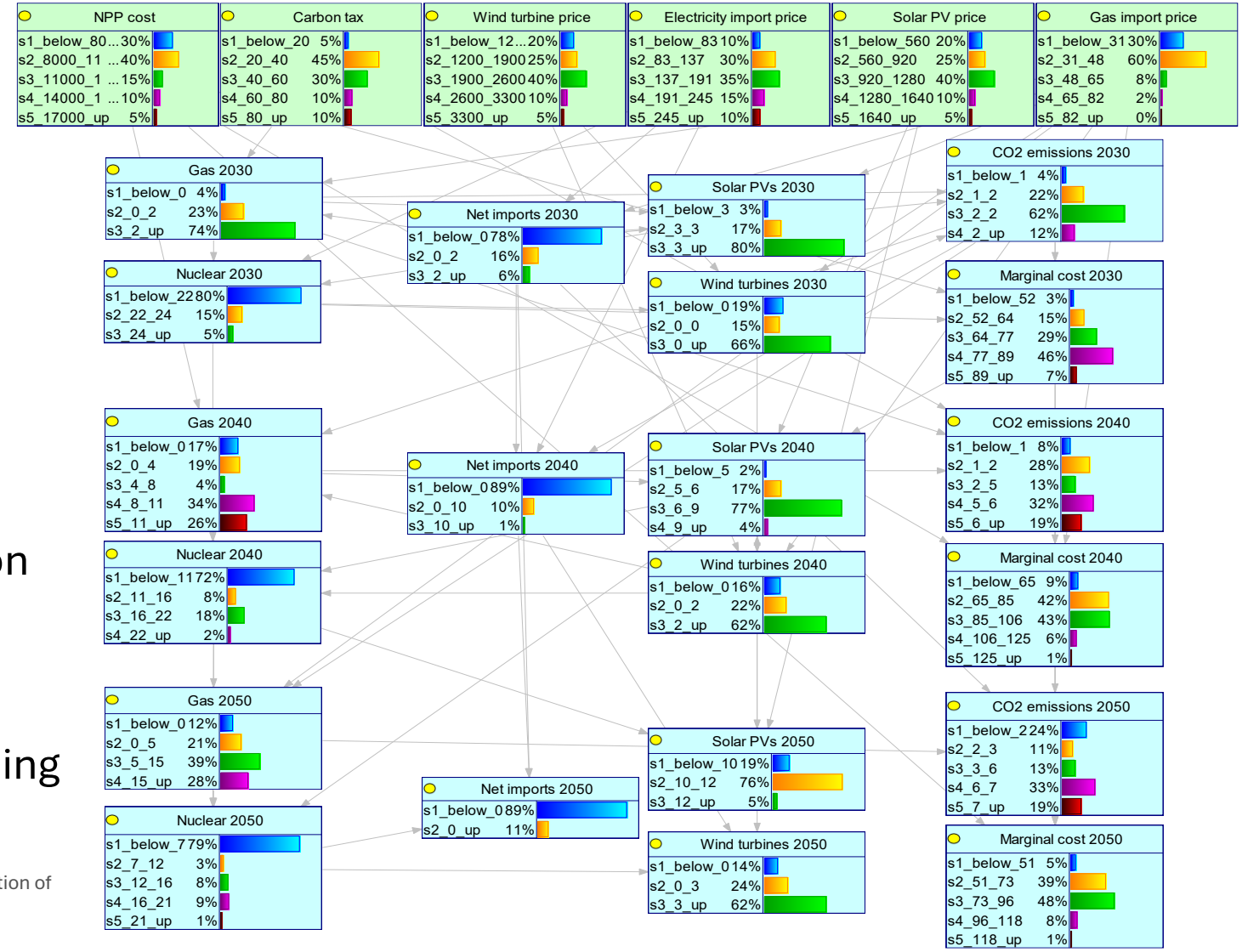
PSI

BBN main uses:

- Uncertainty in inputs
- Goal-driven analyses
- What-fi analyses

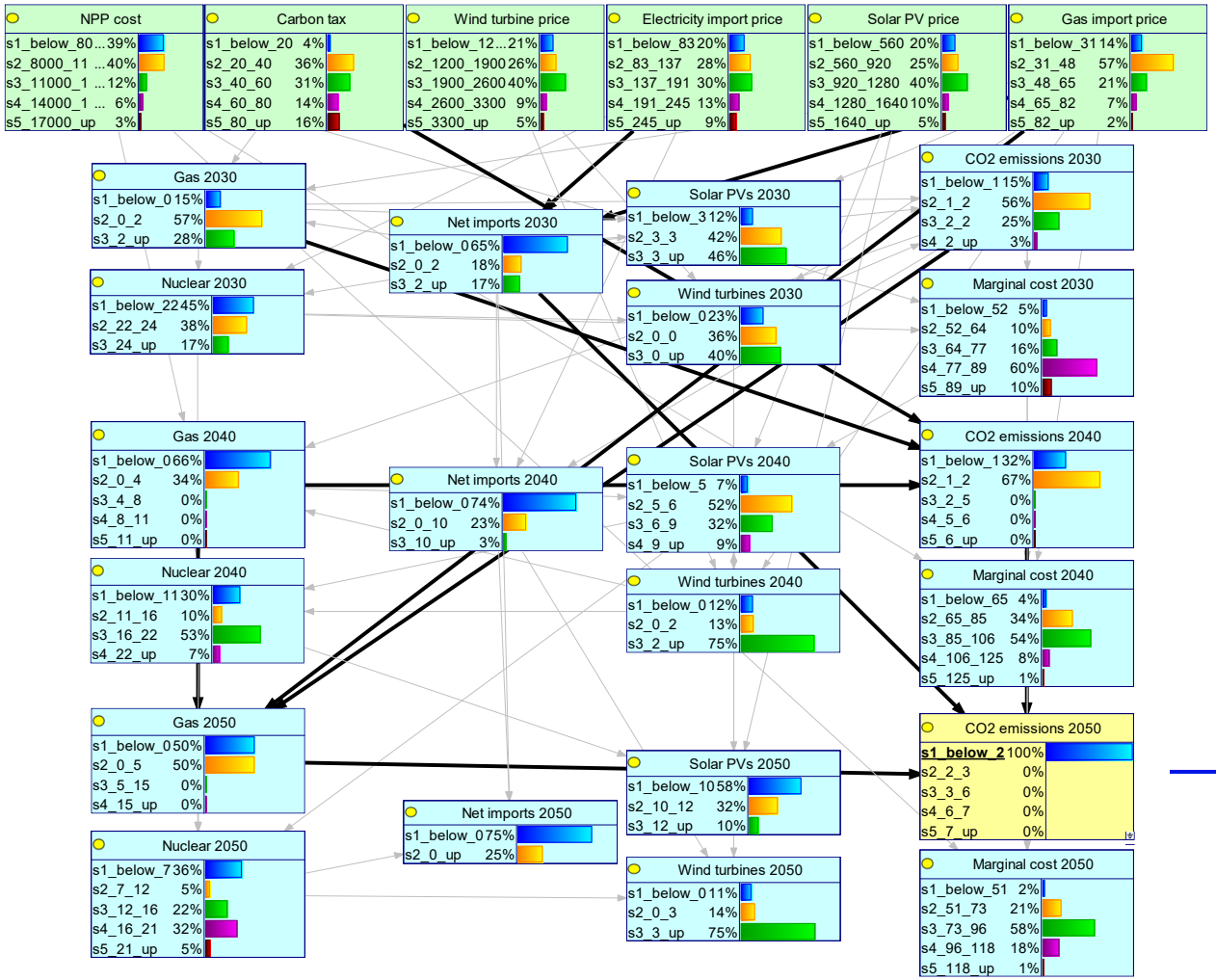
BBN attractiveness

- Visualisation of energy systems model relationships
- Fast and intuitive uncertainty propagation
- Backward reasoning
- Best estimates and prediction errors
- Small risks of using BBN outside its training range

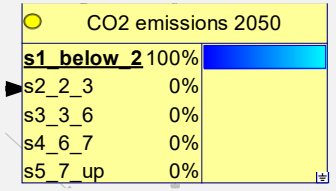


Kelk, Rainer and Podofillini, Luca and Dang, Vinh N. and Panos, Evangelos, 2025. Explorative Application of Discrete Bayesian Networks as Surrogate Models for Energy Systems Analysis. Applied Energy, 394 https://doi.org/10.1016/j.apenergy.2025.126146

Example of use: goal-driven analysis

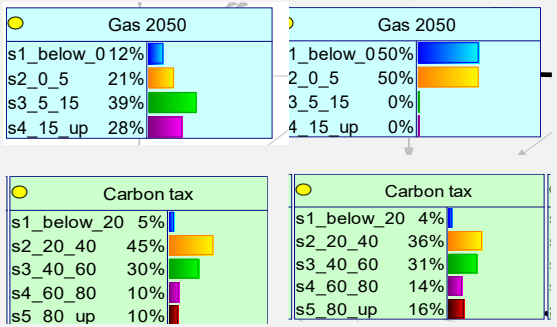


Goal-driven analysis - example: low CO2 emissions in 2050 (<2Mt/yr)



Instantaneous update of all probabilities

Baseline **Low emissions**



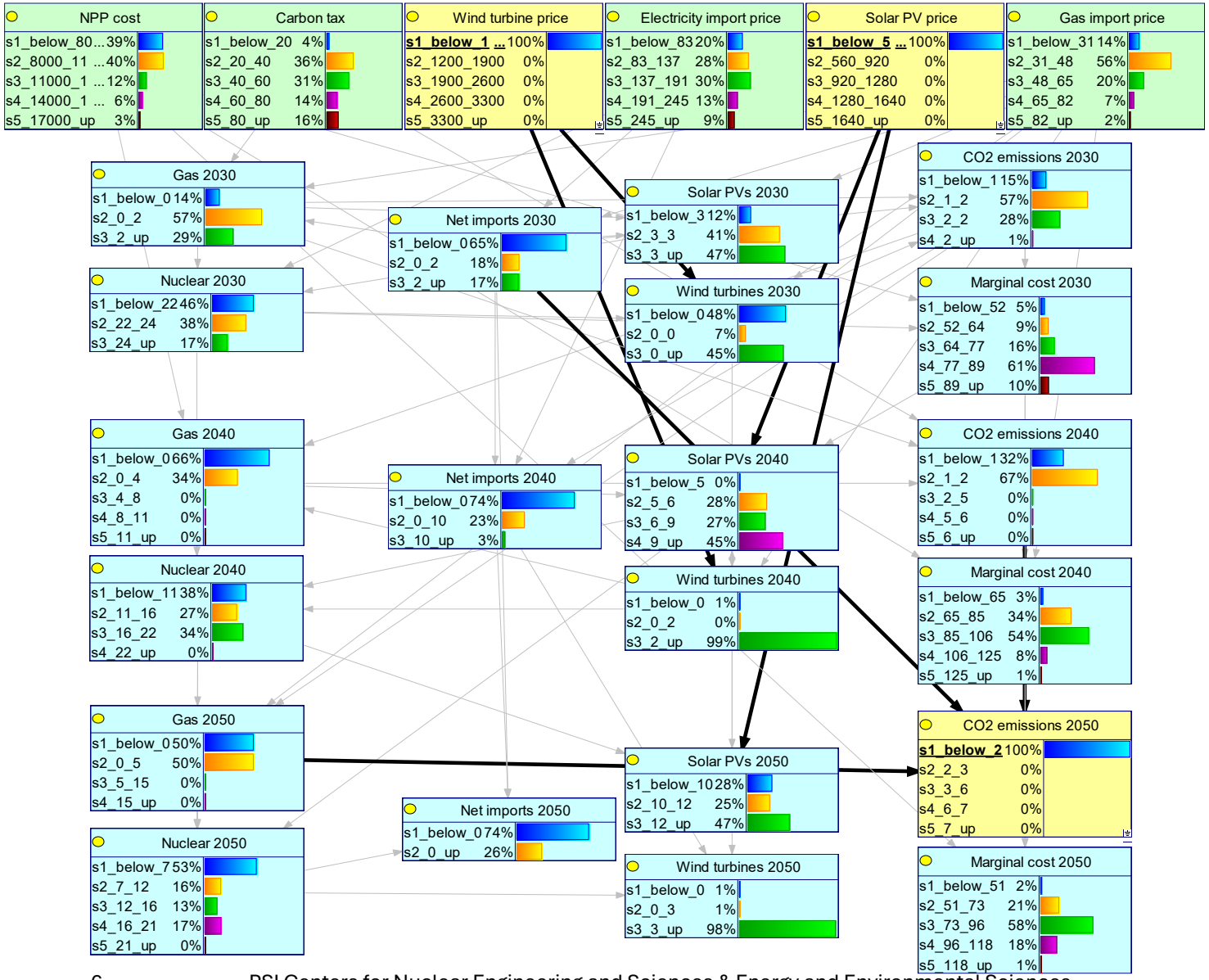
Electricity from gas ↓

Carbon tax ↑

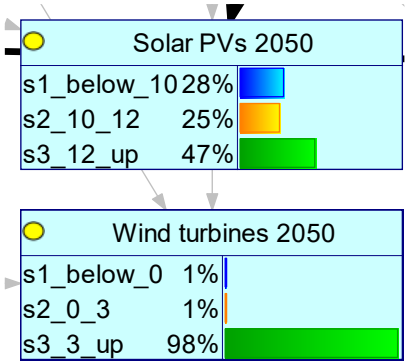
XAI: what are the drivers for **low CO2 emissions 2050**:

- Gas turbine production (2050, 2040, 2030)
- CO2 emissions (2040, 2030)
- Gas import price
- Electricity import price
- Carbon tax

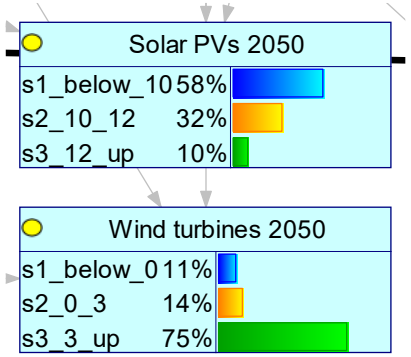
Example of use: Subsidy in renewables



Low costs for renewables



Low emissions



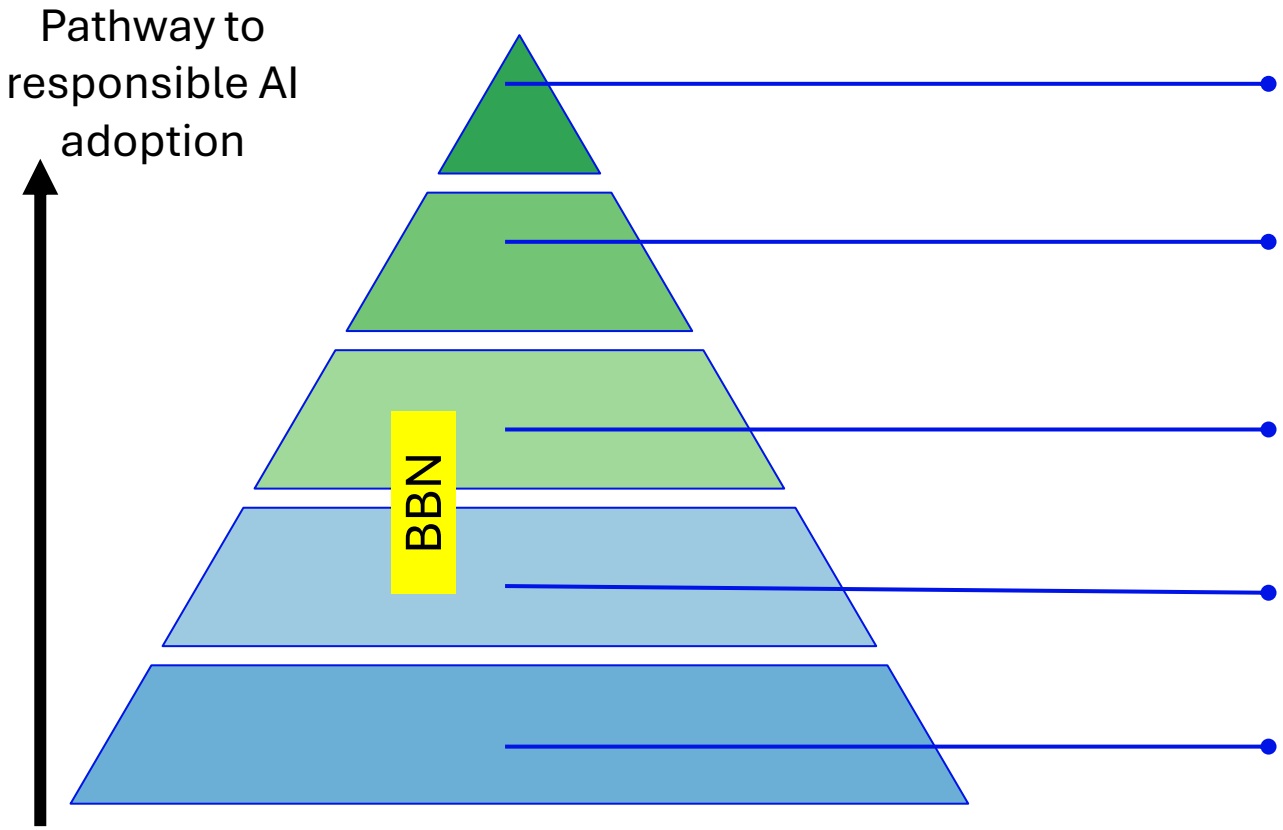
Bridging Explainable AI and Government Planning

from technical to institutional trust

Government function	How Explainabel AI such as BBN Helps	Institutional Outcome
Policy review & communication	Convert complex model outputs into visual causal maps showing what drives emissions, costs, etc.	Decision makers can see why results change, improving transparency
Validate assumptions	BBNs test sensitivities & dependencies before approving scenarios	Analysis identify key uncertainties early → better scenario robustness
Build internal capacity	Turn model results into interactive BBN dashboards for learning reasons	Shared understanding and capability-building across ministries
Governance embedding	Include BBN explainability layers in national planning protocols	Establishes permanent culture of model validation & accountability

Institutional Conditions for Responsible AI adoption

what must be in place before governments adopt AI in energy planning



Institutionalisation & Adoption

Expanable AI becomes a standard, not an experiment, with processes, skills and tools are integrated into planning frameworks

Governance & Maintenance

Define polcies how AI is used, validated and governed, who approves resutls, who is responsible for decisions informed by AI

Capacity & Skills

Analysts & planners need the ability to understand, interpret & question AI models

Validation & Benchmarks

AI outputs must be checked against know models or historical evidence

Data Quality and Interoparabilty

Governments must first have reliable, standardised, and shareable energy data

AI should not replace expertise. It should reveal hidden relationships in our own models and scenarios. Explainable AI, like Bayesian networks, allows governments to start small, validate what they see, and build trust step by step.

My thanks go to:

Dr. Luca Podofillini, PSI, luca.podofillini@psi.ch

Dr. Vinh Dang, PSI, vinh.dang@psi.ch

Contact:

Evangelos Panos

evangelos.panos@psi.ch