MEDEAS

MODELING THE RENEWABLE ENERGY TRANSITION IN EUROPE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

EMP-E 2019: Parallel Session 1B

Methodology for Stability, Uncertainty and Sensitivity analysis applicable to energy models

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The MEDEAS models

- Energy-economy-environment IAM at 4 geographical scales (World, EU, Austria and Bulgaria)
- Built in Vensim® and translated to Python
- Main novelties:
    - Economic production (35 sectors) constrained by energy availability
    - Hybrid top-down-bottom-up approach
    - Dynamic estimation of the EROI (low EROIs reduce net energy and increase demand)
    - Climate change impacts -> increases energy demand for adaptation

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HOW TO GET IT

https://medeas.eu/model/medeas-model

https://gitlab.com/MEDEAS/pymedeas_models

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Objectives

1. Finding model **stability ranges** (convergence issues, detect unexpected/unrealistic behaviours)
2. **Assessing uncertainty** of model projections (caused by inputs uncertainty) -> **essential for using models for policy making**
3. Identifying and categorising most/least influential model input parameters (**factor prioritisation**)
    - Comparing and fitting the outputs from different models (MEDEAS, TIMES, LEAP)

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Required steps

1. **Selecting the inputs** to analyse -> the most uncertain or those expected to play an important role
2. **Selecting the outputs** on which uncertainty will be estimated -> 23 common parameters in MEDEAS, TIMES and LEAP models
3. Expert elicitation to **narrow the ranges of the uncertain parameters**
4. **Stability and Uncertainty and Sensitivity** exploration

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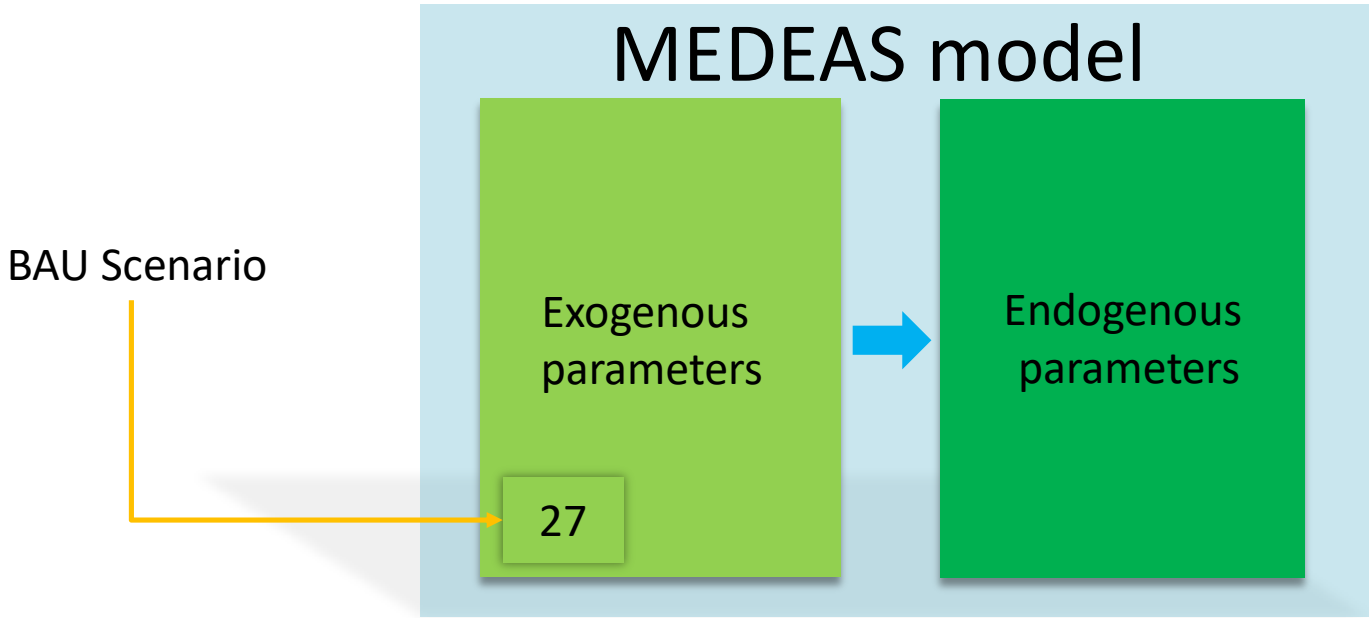
Uncertainty and Stability analysis

- **Input parameters:** 27 (from BAU scenario)
- **Input Distribution:** Uniform (min & max)
- **Type of analysis:** Multivariate
- **Software:** Vensim



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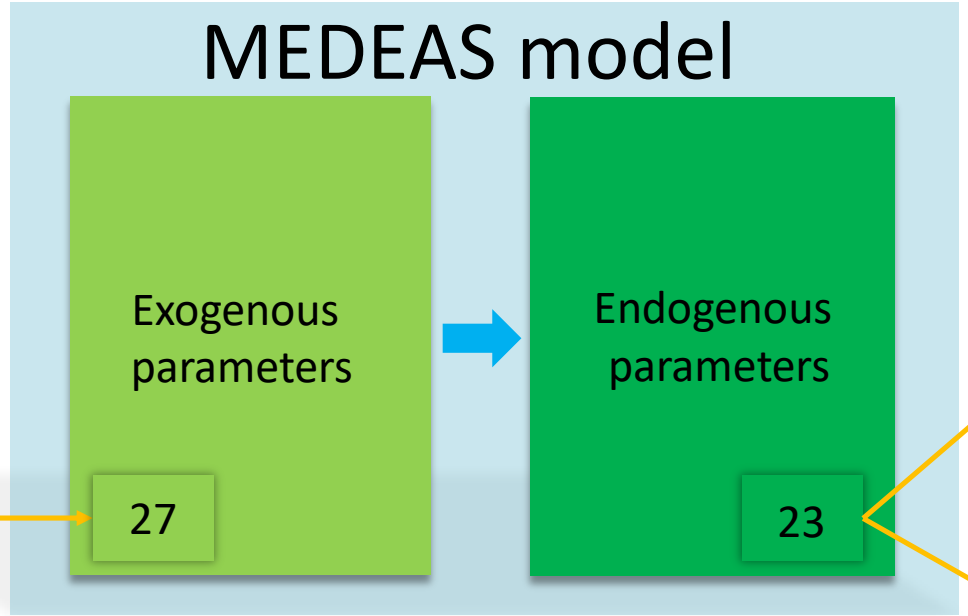
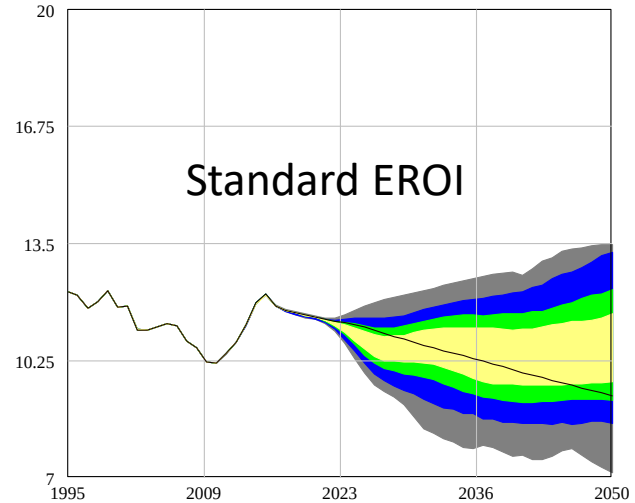
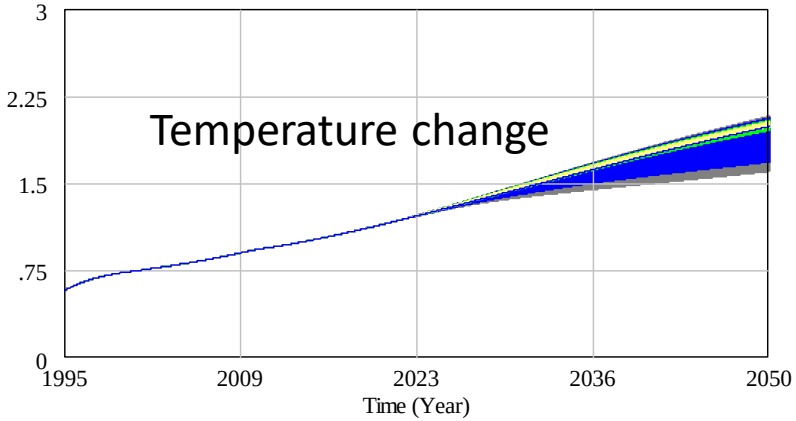
1000 **Monte Carlo** simulations

BAU Scenario







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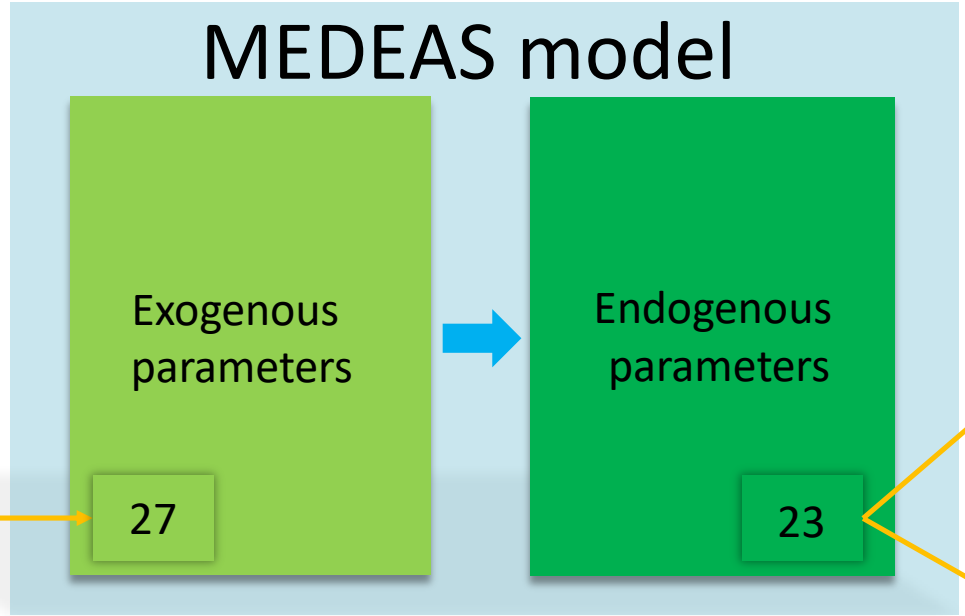

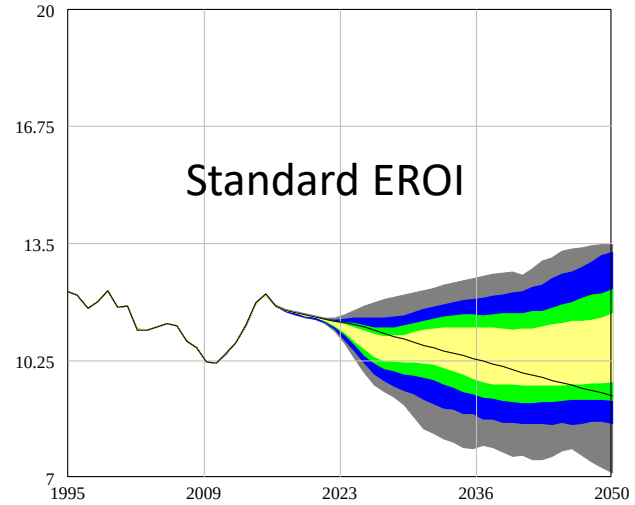

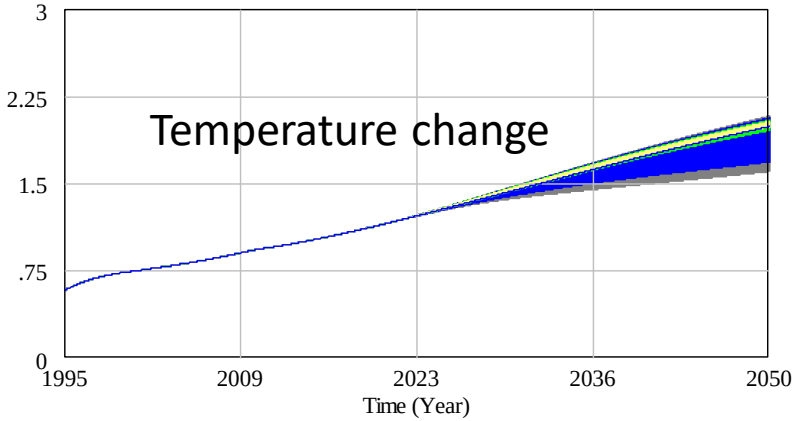

The ranges given to the input parameters become the **tested stability ranges** of the model

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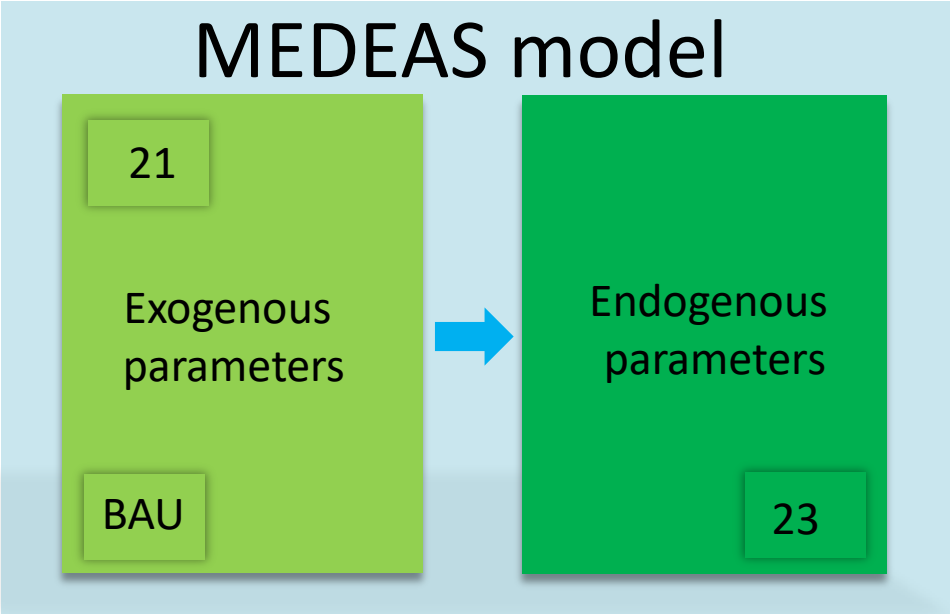
Sensitivity exploration

- **Input parameters:** 21 fixed parameters
- **Input Distribution:** min & max values
- **Number of simulations:** 43 (21*2+1)
- **Software:** Python



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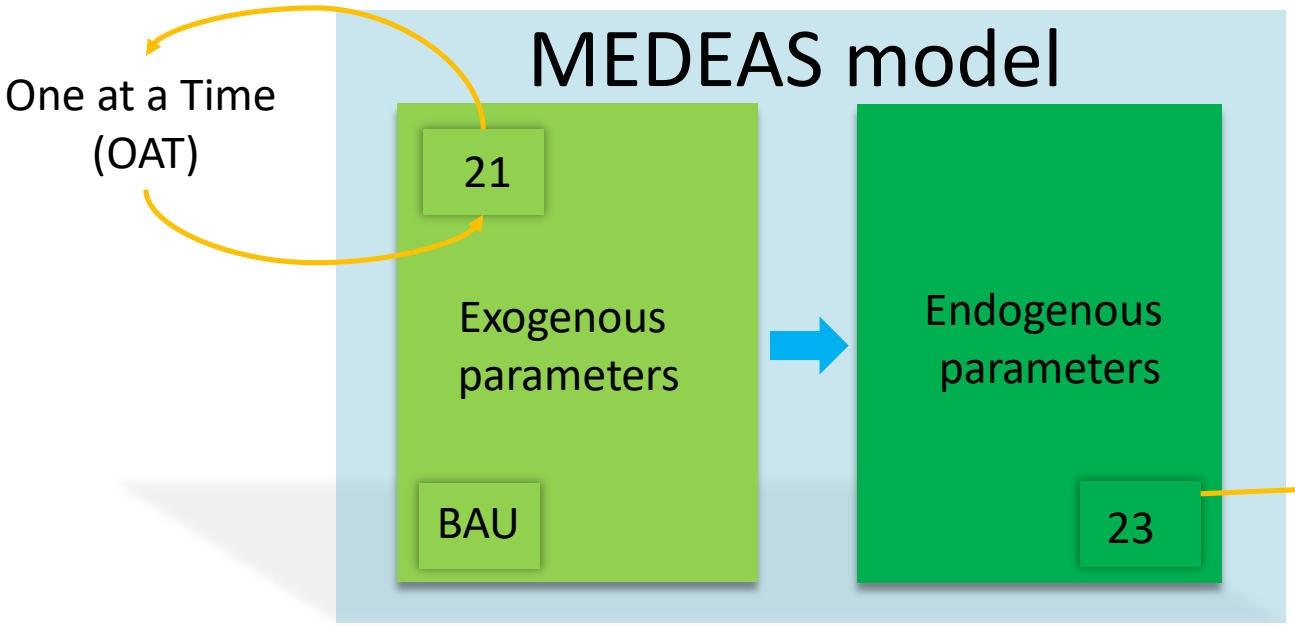

Results interpretation

- Sensitivity of each output to each input
  - Spider plots
  - RMSD (quantitative)
- Overall importance of each input
  - Euclidean distances (quantitative)

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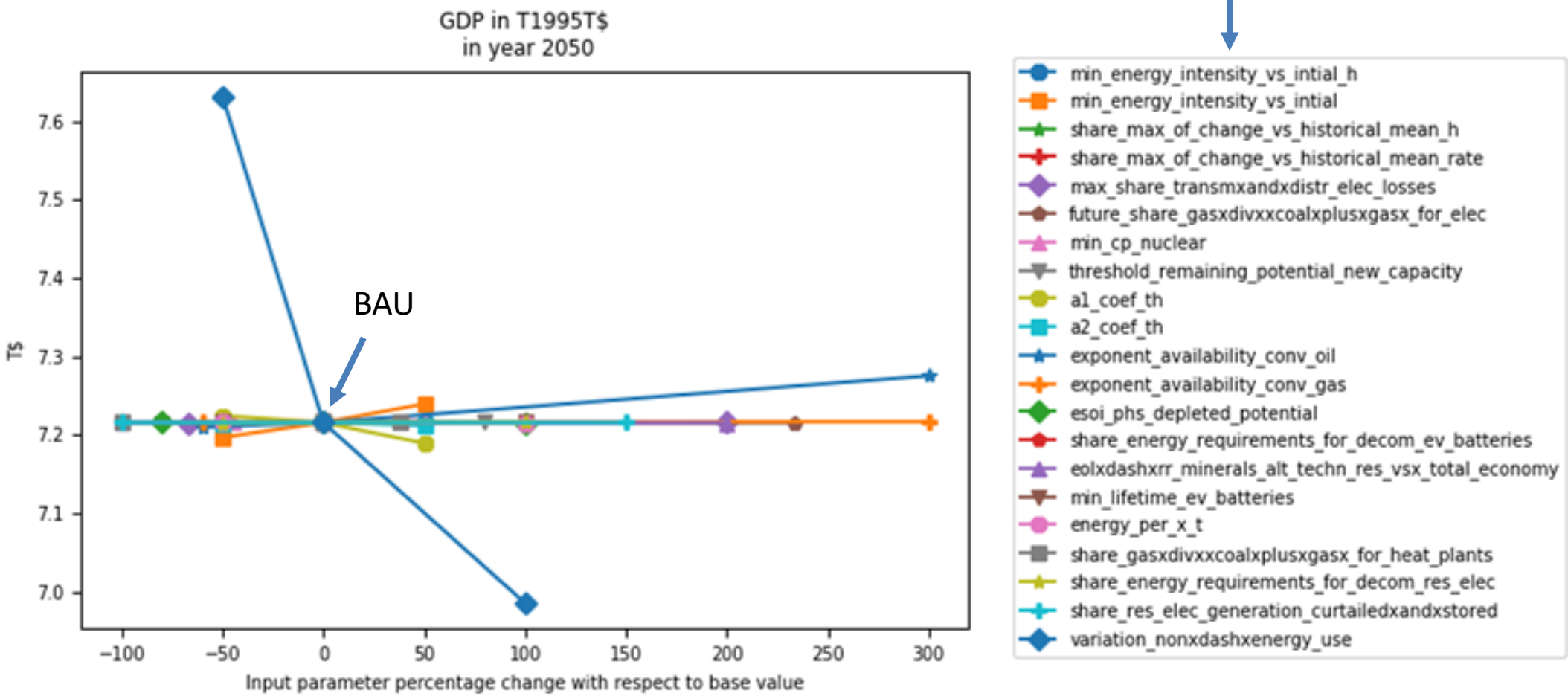
Sensitivity exploration

23 Spider plots (1 for each output)



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Sensitivity exploration

Root Mean Square Difference (RMSD) -> normalised by the percentage change of the input parameter

Outputs

Input parameter	gdp	real_tfec	tpes_intensity_ej_tdollar	…
min_energy_intensity_vs_intial	2,74E-02	1,57E+00	2,13E-01	
a1_coef_th	1,89E-02	7,64E-01	8,39E-02	
share_energy_requirements_for_decom_res_elec	-	-	-	
variation_nonxdashxenergy_use	**1,48E-01**	4,55E-01	1,23E-01	
a2_coef_th	-	-	-	
min_energy_intensity_vs_intial_h	-	-	-	
threshold_remaining_potential_new_capacity	-	-	-	
max_share_transmxandxdistr_elec_losses	-	-	-	
min_cp_nuclear	-	-	-	
future_share_gasxdivxxcoalxplusxgasx_for_elec	-	-	-	

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max_share_transmxandxdistr_elec_losses	-			
min_cp_nuclear	-			
future_share_gasxdivxxcoalxplusxgasx_for_elec	-			

Parameter name	Times among the top 3
min_energy_intensity_vs_intial	15
variation_nonxdashxenergy_use	8
a1_coef_th	7
min_energy_intensity_vs_intial_h	4
max_share_transmxandxdistr_elec_losses	4
threshold_remaining_potential_new_capacity	3
share_energy_requirements_for_decom_res_elec	1
a2_coef_th	1
min_cp_nuclear	1
future_share_gasxdivxxcoalxplusxgasx_for_elec	1

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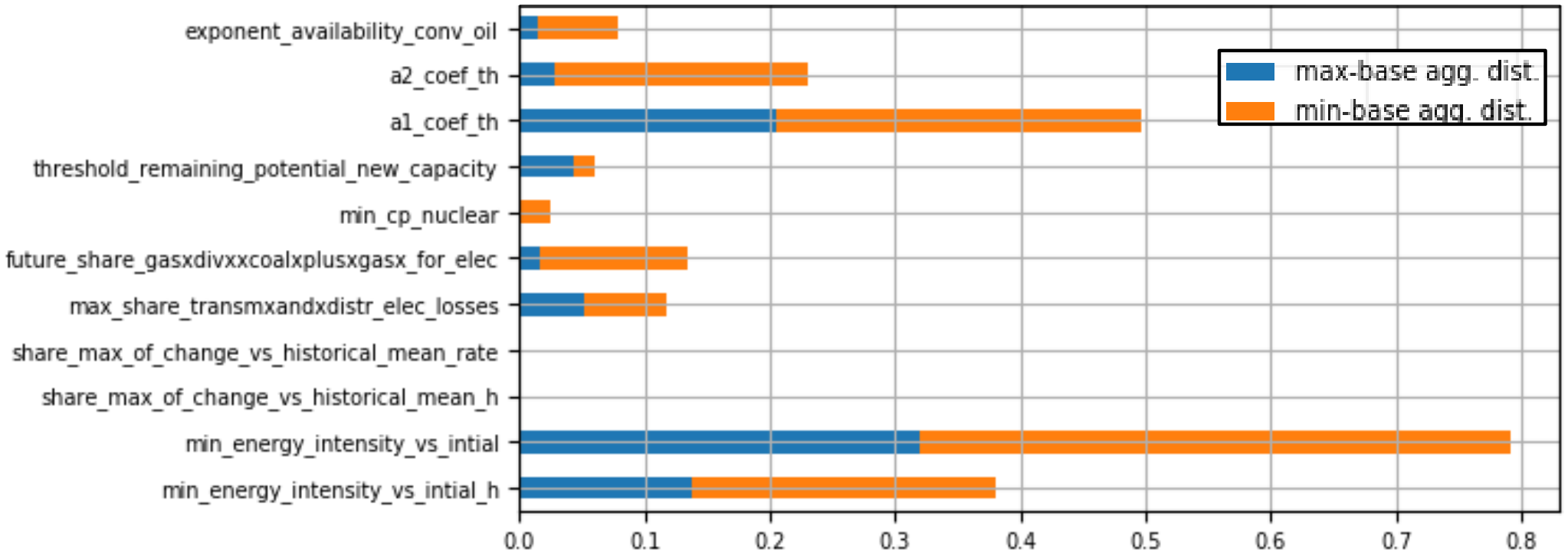
Sensitivity exploration

Euclidean distances -> standardised outputs, aggregated, divided by the percentage change of the input parameter

Input parameters



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Conclusions

1. Reducing uncertainty is essential if energy models are to be used for decision support and policy making
2. We presented a methodology, applicable to all energy models, to evaluate stability, uncertainty and sensitivity
3. The model was stable for the tested input parameter ranges
4. Output uncertainty was evaluated based on input uncertainty and the behavioural boundaries identified
5. A preliminary OAT sensitivity exploration was performed to identify irrelevant parameters for further analysis
6. Global sensitivity methods are more suitable for non-linear models, and should be used to examine a wider spectrum of the input parameter space and parameter interactions (EE method, variance-based methods, etc.)

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Thank you

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Euclidean distance

Vector of standardised outputs with max value of one input parameter

$$E_t^{p_i,max-nom} = \sqrt{\sum_{j=1}^{23} \left(\check{Z}_{j,t}^{p_i,max} - \check{Z}_{j,t}^{p_i,nom} \right)^2}$$

Time series

Vector of normalised outputs with nominal value of input parameter

"normalised" by the percentage change of each input

$$E^{p_i,max-nom} = \sum_{t=1995}^{2050} E_t^{p_i,max-nom}$$

$$\delta p_i^{max-\mathrm{nom}} = \frac{p_i^{max} - p_i^{nom}}{p_i^{nom}}$$

Scalar

Final Euclidean distance between the outputs of two simulations

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Parameter description

Min_energy_intensity_vs_initial -> Minimum value that the energy intensity for each economic sector could reach, obviously always above zero. This minimum value is very difficult to estimate, but based on historical values it has been considered that it can reach 30% of the value of 2009. (Capellán-Pérez et al., 2014)

A1_coef_th -> Coefficients for the calculation of variations of transport intensities

Variation_nondashx_energy_use -> variation of the use of fuels for non-energetic purposes (e.g. feedstock in the chemical industry or for the production of bitumenand lubricants in refineries)

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