Socially preferable and technically feasible: European citizens choose solar power and import independence over lower costs

Supplemental material

Tim Tröndle
Franziska Mey
Johan Lilliestam

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Figure S1: Trace plot of the alpha parameters

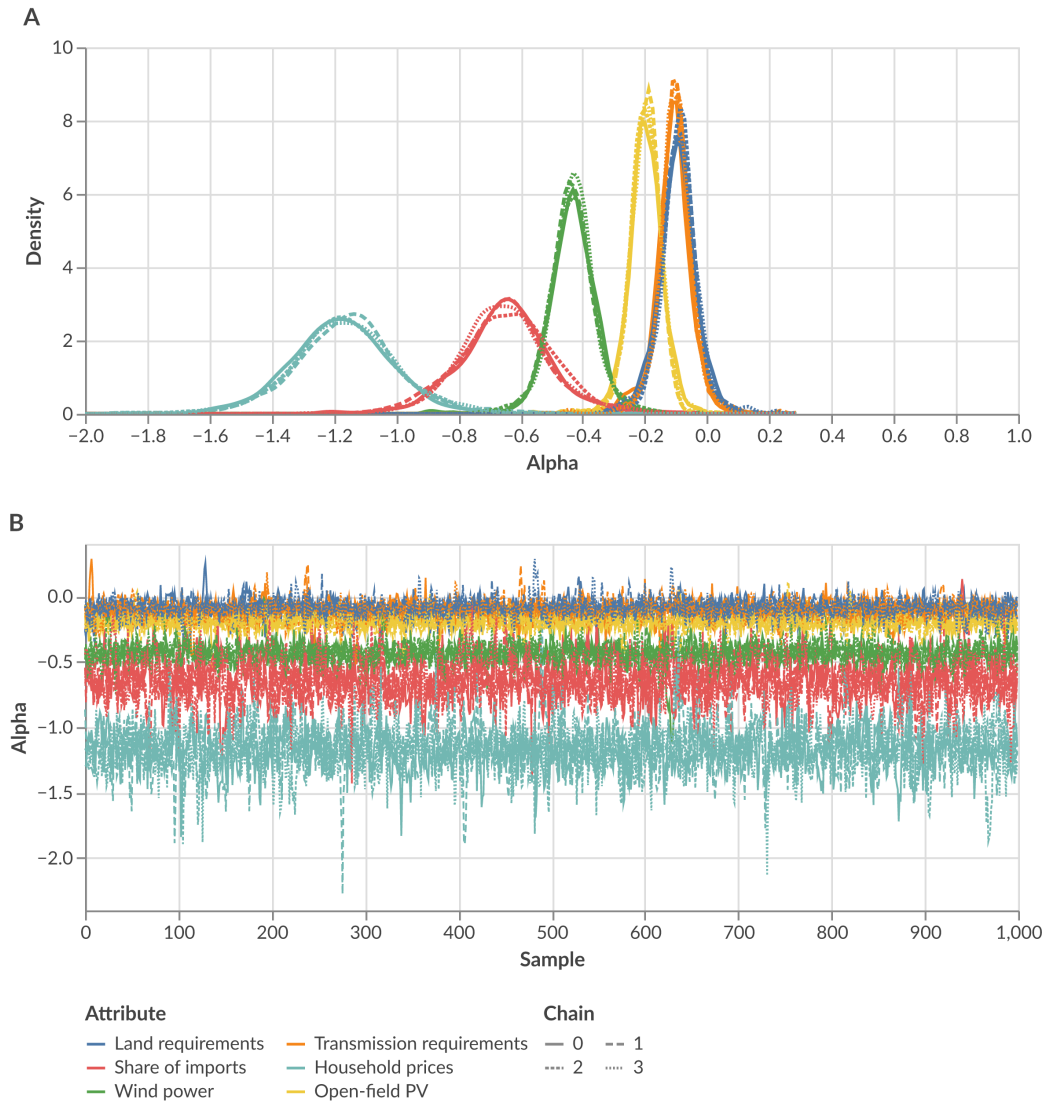

Figure S1: Trace plot of the alpha parameters of the choice model "selection". Both (A) density and (B) trace of the parameters are shown for each individual Markov chain and attribute.

Figure S2: Trace plot of the beta parameters

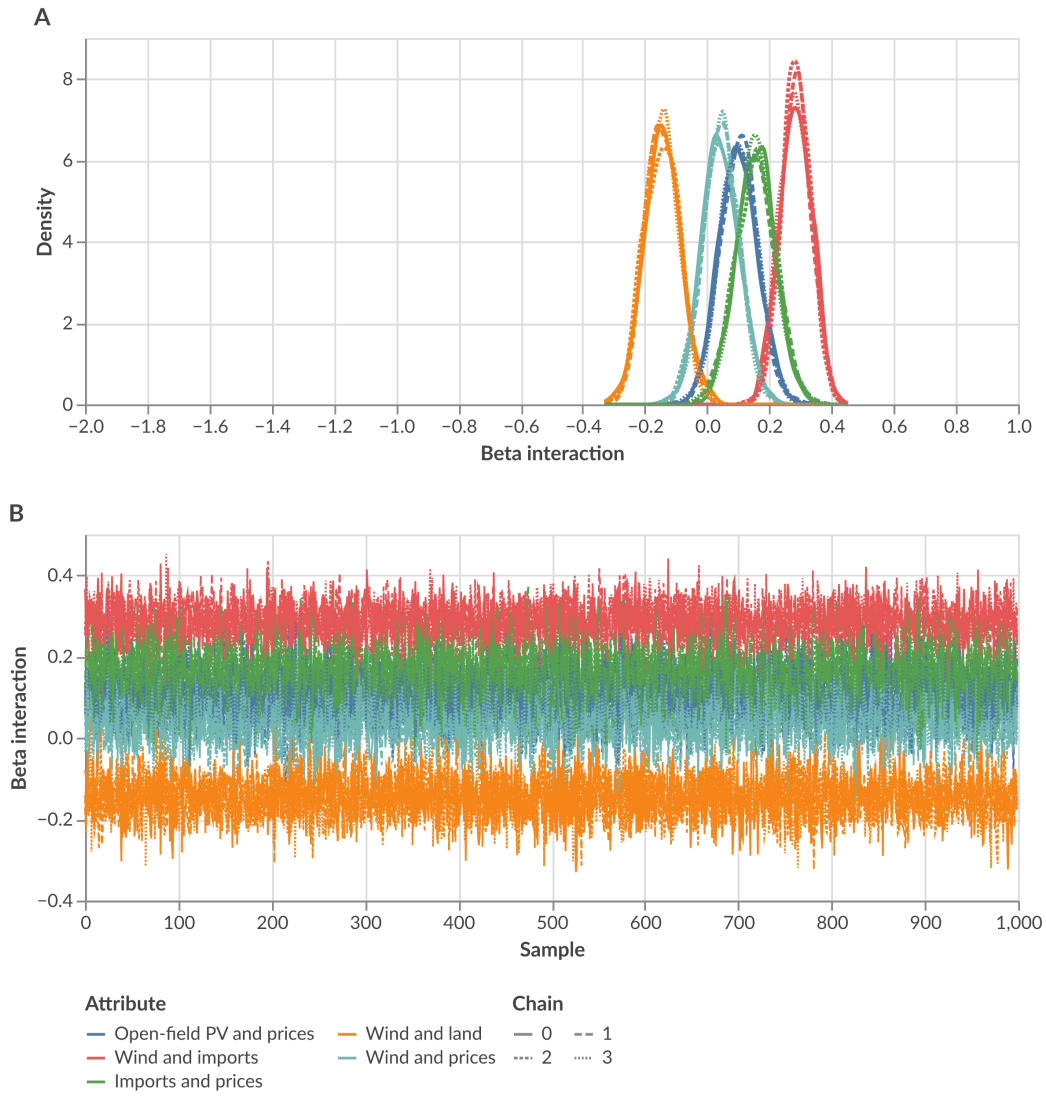

Figure S2: Trace plot of the beta parameters of interactions of the choice model "selection". Both (A) density and (B) trace of the parameters are shown for each individual Markov chain and interaction.

Figure S3: Mapping functions

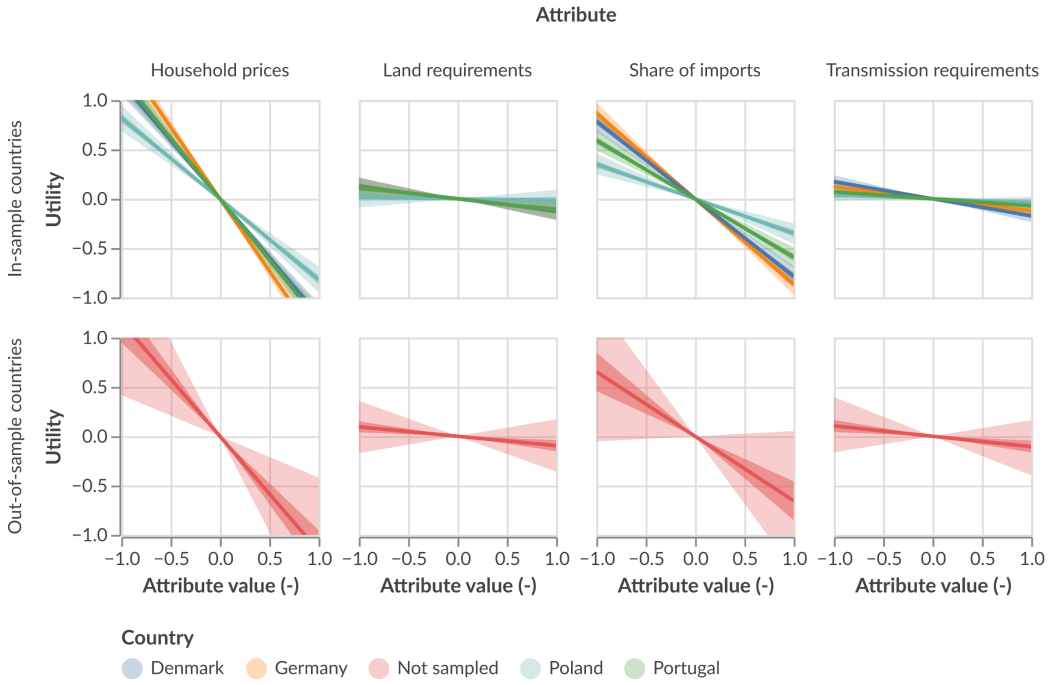

Figure S3: Mapping functions derived from the choice model "selection". Functions that map from normalised attribute values to utility values, by attribute and country. Thick lines show expected values, dark-shaded areas show interquartile range, and light-shaded areas show the 95% range. Utility from interaction effects and technology attributes are not shown here.

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Figure S4: Cumulative distribution functions of partworth utilities

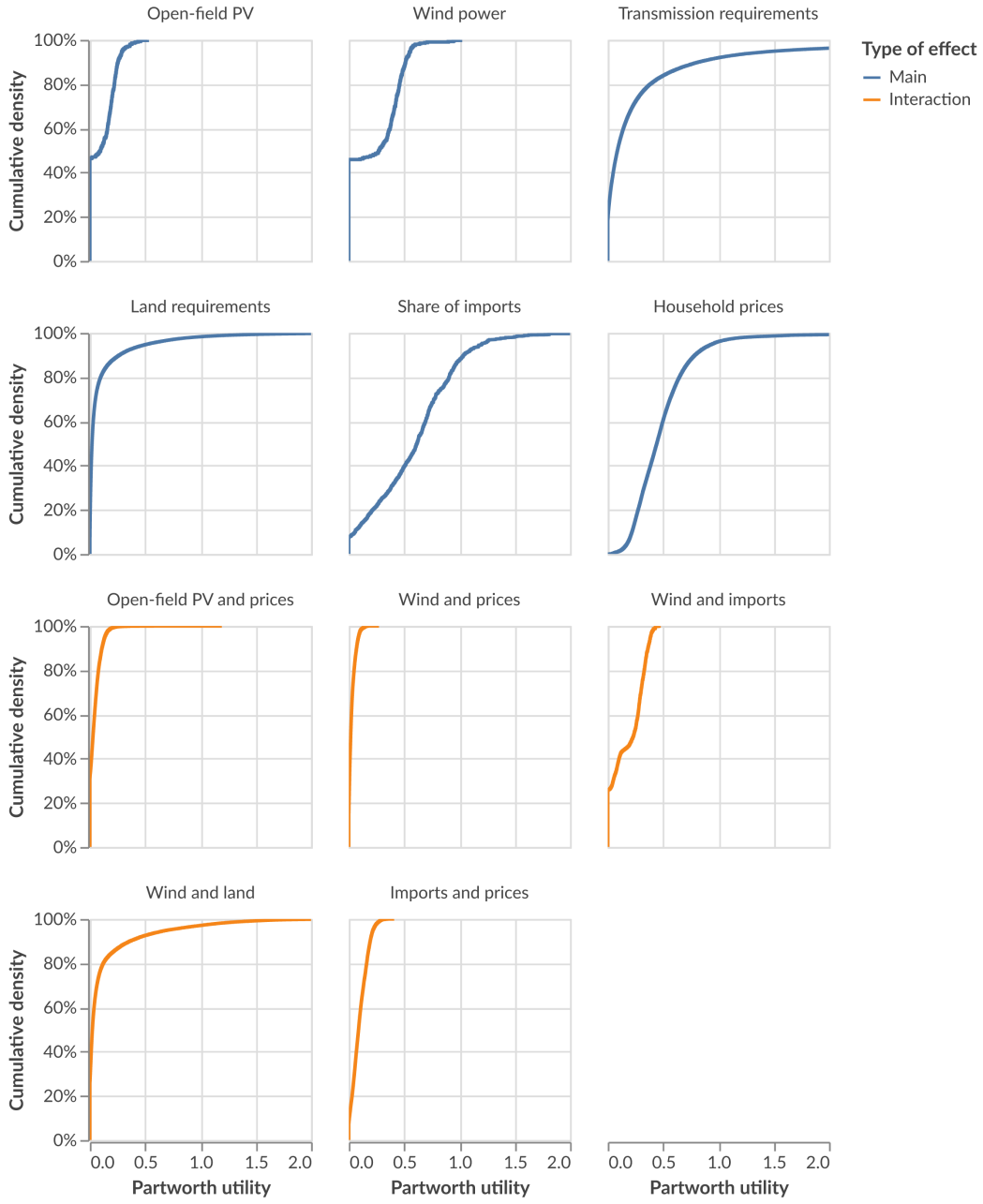

Figure S4: Cumulative distribution functions of partworth utilities of main and interaction effects in the self-sufficiency study [1]. Partworth utilities in this study are defined across scenarios, locations (subnational regions), effects (main and interaction), and estimation uncertainty (samples). Here, we show the estimated cumulative density functions of the largest differences across scenarios, combined for all subnational regions.

Figure S5: Cumulative distribution functions of partworth utilities

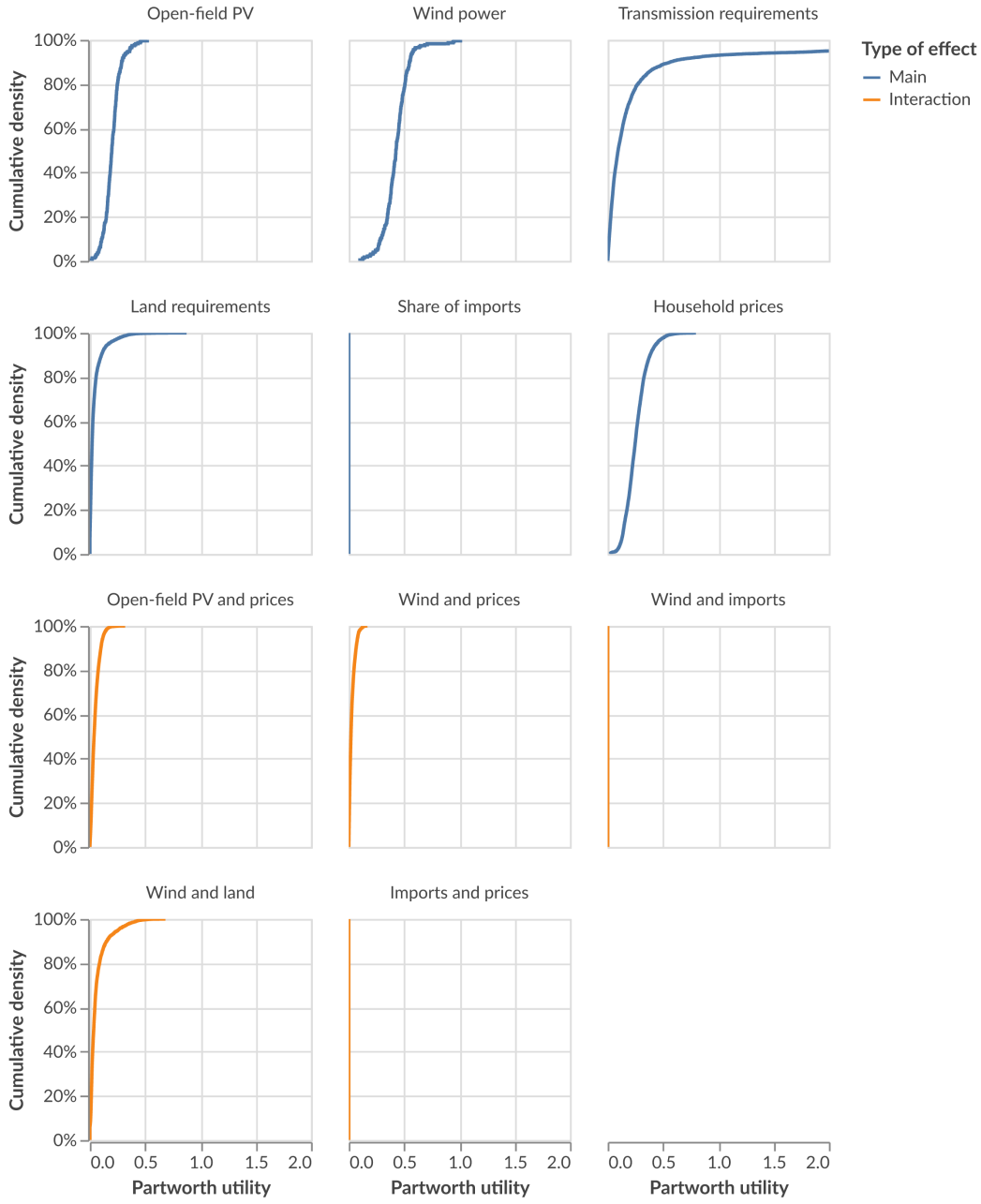

Figure S5: Cumulative distribution functions of partworth utilities of main and interaction effects in the technology mix study [2]. Partworth utilities in this study are defined across scenarios, locations (countries), effects (main and interaction), and estimation uncertainty (samples). Here, we show the estimated cumulative density functions of the largest differences across scenarios, combined for all countries. All effects based on imports are 0 as there are no net imports into countries within this study.

Figure S6: Local sensitivity analysis

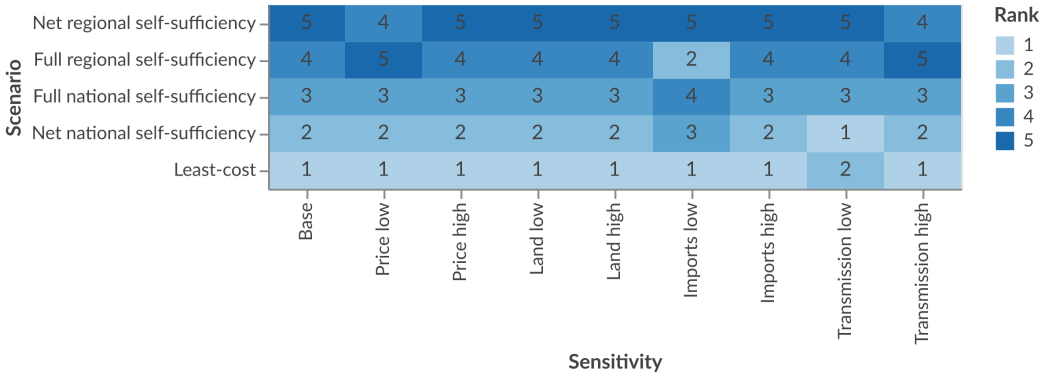

Figure S6: Sensitivity of attribute preferences on scenario preferences. Sensitivity of ranking of scenarios of the self-sufficiency study [1] to changes in attribute preferences. Ranking are derived from scenario utility, i.e. the scenario with highest utility and preference has the highest rank. Attribute preference is either increased by 75% ("high") or decreased by 75% ("low") compared to the "Base" case.

Figure S7: Local sensitivity analysis

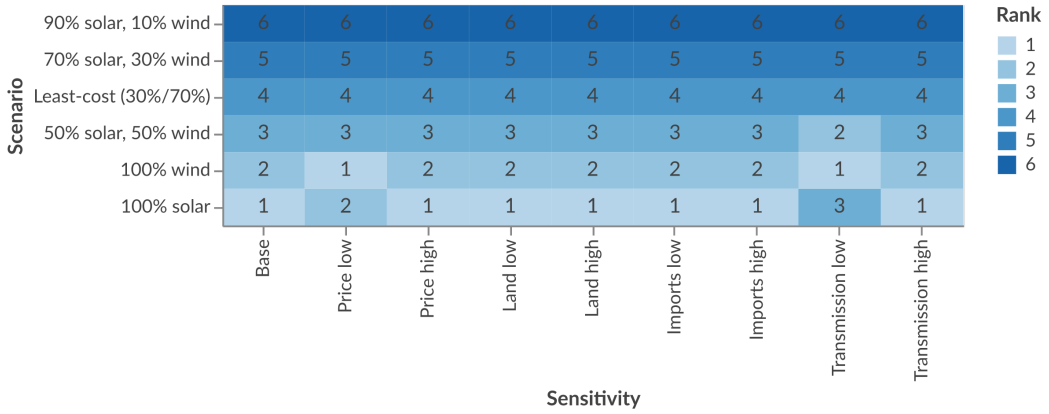

Figure S7: Sensitivity of attribute preferences on scenario preferences. Sensitivity of ranking of scenarios of the technology-mix study [2] to changes in attribute preferences. Ranking are derived from scenario utility, i.e. the scenario with highest utility and preference has the highest rank. Attribute preference is either increased by 75% ("high") or decreased by 75% ("low") compared to the "Base" case.

Figure S8: European choice probabilities across self-sufficiency scenarios

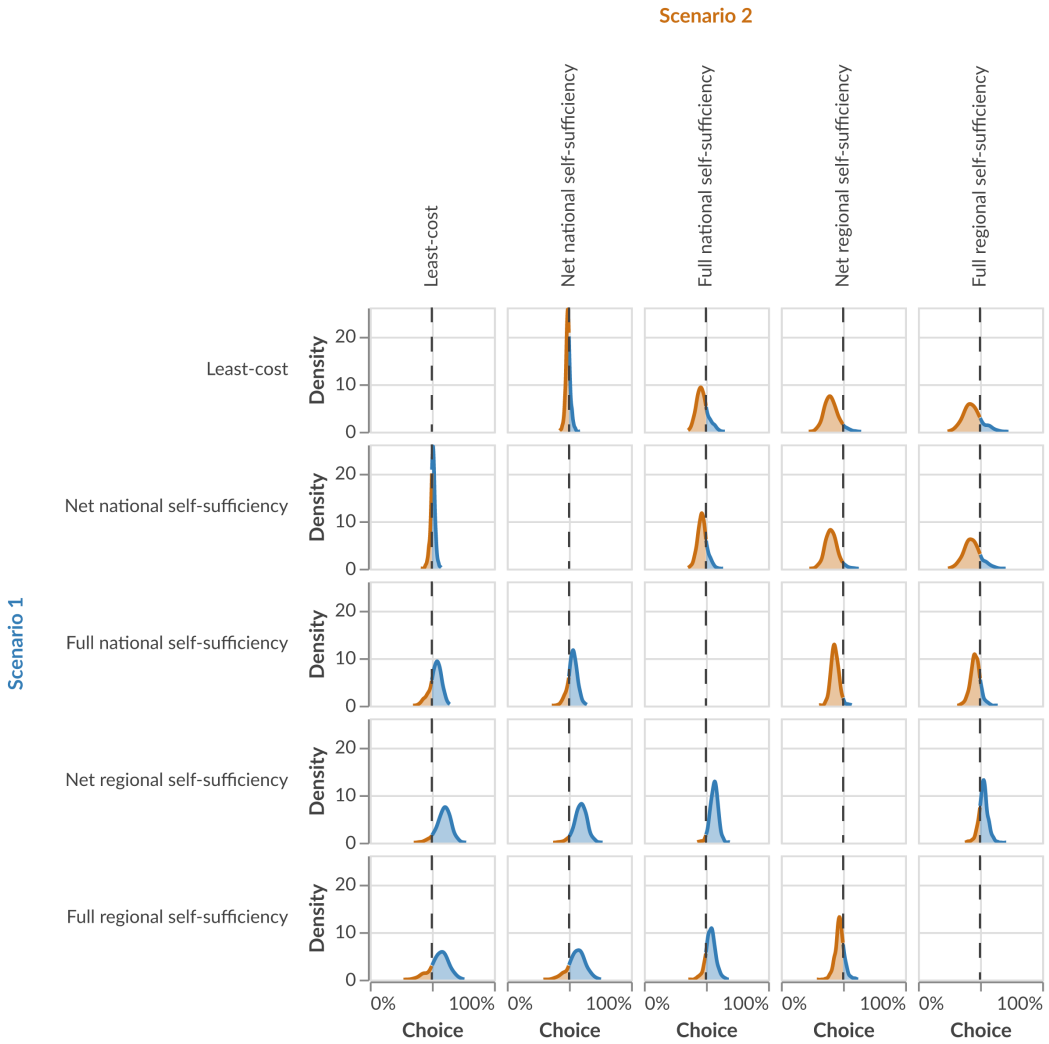

Figure S8: European choice probabilities across self-sufficiency scenarios. We colour density blue when it is in favour of, and orange when it is in opposition to scenario 1 (shown in rows). Choice probabilities are mirror inverted on the diagonal.

Figure S9: European choice probabilities across technology mix scenarios

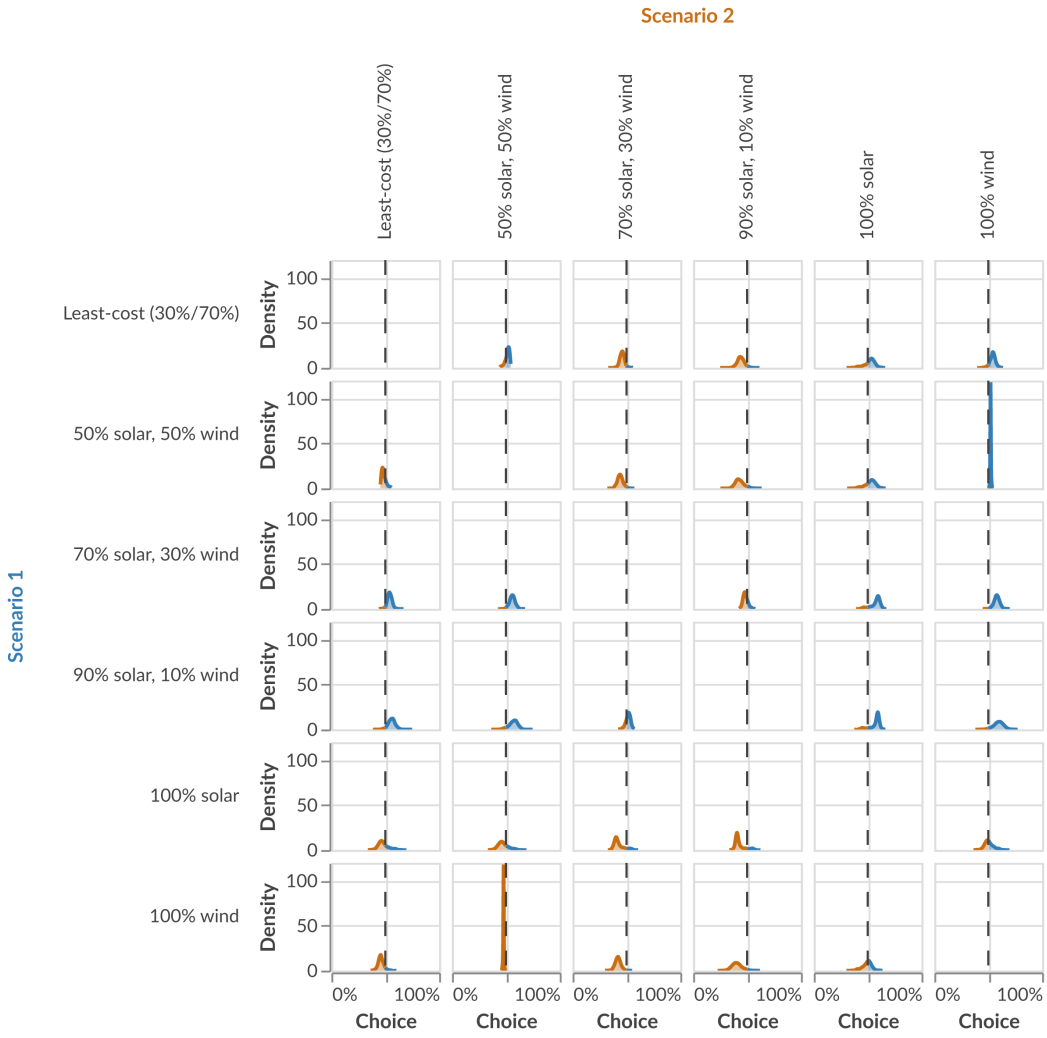

Figure S9: European choice probabilities across technology mix scenarios. We colour density blue when it is in favour of, and orange when it is in opposition to scenario 1 (shown in rows). Choice probabilities are mirror inverted on the diagonal.

Figure S10: Uncertainty of choice probabilities

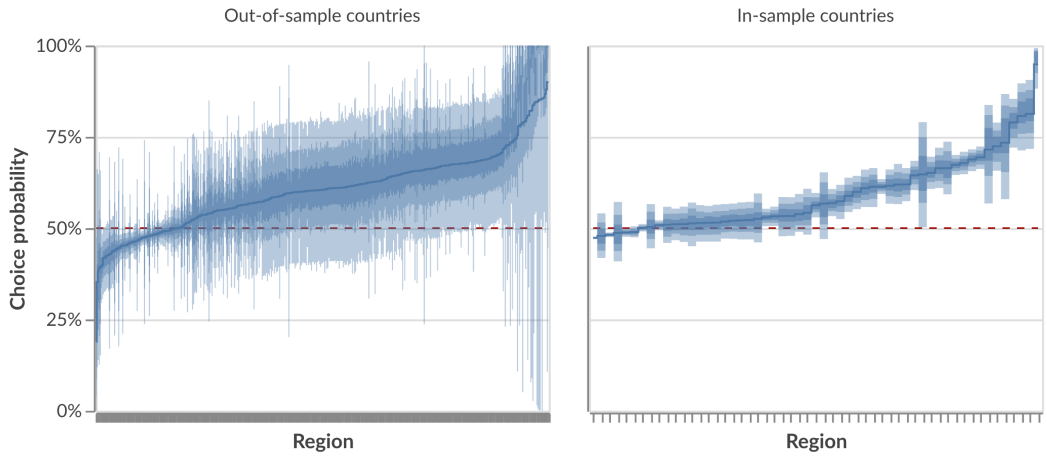

Figure S10: Uncertainty of choice probabilities of all 497 subnational regions. Choice probabilities are based on the choice between a least-cost and a regional net self-sufficiency scenario. We show different ranges of uncertainty by colour: 50% highest density interval (darkest), 80% highest density interval (medium), and 96% highest density interval (lightest). In addition, we show the expected value as a dark line. Regions are grouped by country: countries included in the choice experiment data ("In-sample countries") and countries not included ("Out-of-sample countries").

Table S1: Attributes and attribute levels of the choice experiment

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Attribute	Level
Dominant supply technology	Rooftop PV
	Open-field PV
	Onshore wind
Land requirements used for generation in the region	Very low (0.5% of all land)
	Medium (2% of all land)
	High (4% of all land)
	Very high (8% of all land)
Overhead transmission capacity expansion in the region compared with today	Slight decrease (-25%)
	Today's level (0%)
	Slight increase (+25%)
	Moderate increase (+50%)
	Strong increase (+75%)
Share of electricity demand served through imports from outside the region	None (0%)
	Low (10%)
	Medium (50%)
	High (90%)

Attribute	Level
Change in household electricity price compared with today	No increase (+0%)
	Slight increase (+15%)
	Moderate increase (+30%)
	Strong increase (+45%)
	Very strong increase (+60%)
Ownership of generation assets or non	Local and regional communities: cooperatives - profit associations
	Public sponsors: municipal utilities or municipal associations
	Private utilities

Table S2: Sample statistics for parameters in the choice model

Table S2: Sample statistics for parameters in the choice model "selection".

Parameter	Mean	Sd	Ess_bulk	Ess_tail	R_hat
alpha[TECHNOLOGY:Open-field PV]	-0.20	0.05	1803	1718	1.00
alpha[TECHNOLOGY:Wind]	-0.43	0.08	1829	1852	1.00
alpha[TRANSMISSION]	-0.10	0.06	1262	1259	1.00
alpha[LAND]	-0.09	0.06	1679	1797	1.00
alpha[SHARE_IMPORTS]	-0.65	0.15	1278	1739	1.01
alpha[PRICES]	-1.17	0.17	1673	1870	1.00
mu_left_intercept	0.12	0.01	5651	3502	1.00
beta_interaction[TECHNOLOGY:Open-field PV/PRICES]	0.10	0.06	3167	3034	1.00
beta_interaction[TECHNOLOGY:Wind/PRICES]	0.04	0.06	3564	3186	1.00
beta_interaction[TECHNOLOGY:Wind/SHARE_IMPORTS]	0.28	0.05	6585	3556	1.00
beta_interaction[TECHNOLOGY:Wind/LAND]	-0.14	0.06	5563	3277	1.00
beta_interaction[SHARE_IMPORTS/PRICES]	0.16	0.06	6513	2637	1.00
sigma_country[TECHNOLOGY:Open-field PV]	0.05	0.05	1369	1755	1.00
sigma_country[TECHNOLOGY:Wind]	0.10	0.07	1274	1474	1.00
sigma_country[TRANSMISSION]	0.10	0.07	1411	2069	1.00
sigma_country[LAND]	0.09	0.07	1209	1350	1.00

Parameter	Mean	Sd	Ess_bulk	Ess_tail	R_hat
sigma_country[SHARE_IMPORTS]	0.28	0.12	2153	2391	1.00
sigma_country[PRICES]	0.31	0.14	2042	2301	1.00
sigma_left_intercept	0.29	0.03	806	1330	1.00
beta_partworths[DNK, TECHNOLOGY:Open-field PV]	-0.18	0.04	3472	3221	1.00
beta_partworths[DNK, TECHNOLOGY:Wind]	-0.35	0.06	3415	3266	1.00
beta_partworths[DNK, TRANSMISSION]	-0.17	0.03	3115	2319	1.00
beta_partworths[DNK, LAND]	-0.12	0.05	4787	3502	1.00
beta_partworths[DNK, SHARE_IMPORTS]	-0.79	0.05	4864	3506	1.00
beta_partworths[DNK, PRICES]	-1.19	0.07	3665	3379	1.00
beta_partworths[DEU, TECHNOLOGY:Open-field PV]	-0.18	0.04	3426	3342	1.00
beta_partworths[DEU, TECHNOLOGY:Wind]	-0.47	0.05	4158	3337	1.00
beta_partworths[DEU, TRANSMISSION]	-0.12	0.03	5185	3161	1.00
beta_partworths[DEU, LAND]	-0.12	0.05	4846	3473	1.00
beta_partworths[DEU, SHARE_IMPORTS]	-0.87	0.06	5276	3974	1.00
beta_partworths[DEU, PRICES]	-1.46	0.07	3489	3566	1.00
beta_partworths[PRT, TECHNOLOGY:Open-field PV]	-0.23	0.05	2466	2701	1.00
beta_partworths[PRT, TECHNOLOGY:Wind]	-0.47	0.05	3918	3519	1.00

Parameter	Mean	Sd	Ess_bulk	Ess_tail	R_hat
beta_partworths[PRT, TRANSMISSION]	-0.07	0.03	4865	3760	1.00
beta_partworths[PRT, LAND]	-0.12	0.05	4762	3920	1.00
beta_partworths[PRT, SHARE_IMPORTS]	-0.59	0.05	4630	3250	1.00
beta_partworths[PRT, PRICES]	-1.23	0.07	3668	3713	1.00
beta_partworths[POL, TECHNOLOGY:Open-field PV]	-0.19	0.04	3618	3153	1.00
beta_partworths[POL, TECHNOLOGY:Wind]	-0.45	0.05	4229	3467	1.00
beta_partworths[POL, TRANSMISSION]	-0.04	0.03	3573	2784	1.00
beta_partworths[POL, LAND]	-0.02	0.05	2356	2603	1.00
beta_partworths[POL, SHARE_IMPORTS]	-0.35	0.05	4332	3251	1.00
beta_partworths[POL, PRICES]	-0.82	0.07	3489	3312	1.00
beta_partworths[NOT_SAMPLED, TECHNOLOGY:Open-field PV]	-0.20	0.09	3515	2772	1.00
beta_partworths[NOT_SAMPLED, TECHNOLOGY:Wind]	-0.43	0.14	3342	2885	1.00
beta_partworths[NOT_SAMPLED, TRANSMISSION]	-0.11	0.14	3437	2852	1.00
beta_partworths[NOT_SAMPLED, LAND]	-0.10	0.13	4456	2729	1.00
beta_partworths[NOT_SAMPLED, SHARE_IMPORTS]	-0.65	0.35	3295	2390	1.00
beta_partworths[NOT_SAMPLED, PRICES]	-1.16	0.38	3162	2589	1.00

Table S3: Model variants with different sets of interaction effects

Table S3: Model variants with different sets of interaction effects.

Model Variant	Interactions	Logic
Base	None	No interactions
Full	All fifteen possible	All interactions are feasible.
Selection	• Open-field PV & prices prices • Wind & prices • Wind & imports • Wind & land • Imports & prices	A priori expected interactions
Minimal	• Wind & imports	Only the single largest posterior interaction.

Table S4: Comparison of models with different sets of interaction effects

Table S4: Comparison of models with different sets of interaction effects. We compute expected log pointwise predictive density (ELPD, higher is better) by Pareto smoothed importance sampling leave-one-out cross-validation (LOO). The models are sorted by their predictive fit, from best to worst. The table shows the predictive fit (ELPD (LOO)), the standard error of the predictive fit (SE), the predictive fit distance to the best model (ELPD difference), the standard error of the predictive fit distance to the best model (SE difference), and the overfitting penalty (penalty). For details on the models, see Table S3.

Model Variant	ELPD (LOO)	SE	ELPD Difference	SE Difference	Penalty
selection	-20805.1	59.9	0.0	0.0	554.1
full	-20807.4	60.1	2.3	3.4	572.2
minimal	-20809.7	59.8	4.5	4.1	548.8
base	-20824.4	59.7	19.3	6.9	541.8

Note S1 – Sensitivity analysis of priors

We choose weakly informative priors over more diffuse priors to aid convergence. We also run a sensitivity analysis with more diffuse priors to test the impact of the weakly informative priors. For that, we set the standard deviation of $\alpha_{\text{attribute}}$ from 4 to 10 and we set the gamma of the exponential distribution of $\sigma_{\text{attribute, country}}$ from 4 to 0.1. This delivers β priors that are essentially flat between -10 and 10 and range beyond -100 and 100.

The more diffuse priors have little to no impact on the inference of parameters of the sampled countries. They do, however, impact the uncertainty range for countries not sampled. This can be explained by the different sample sizes of the corresponding parameters. For sampled countries, the dataset comprises about 8,000 samples per country, based on ~1,000 respondents with 8 choice tasks each. This large sample size makes the inference insensitive to the priors. For countries not sampled, estimations are based on the observed variation across sampled countries for which the sample size is 4. This low sample size is not enough to alter priors significantly, leading to inference results that are sensitive to the choice of priors.

The expected value of the posterior variation across countries ($\sigma_{\text{attribute, country}}$) for all attributes is <<1 both for weakly informative and more diffuse priors, which is why we deem our weakly informative prior choice of $Exp(4)$ superior over the more diffuse prior $Exp(0.1)$.

References

[1] Tröndle T, Lilliestam J, Marelli S, Pfenninger S. Trade-offs between geographic scale, cost, and infrastructure requirements for fully renewable electricity in Europe. Joule 2020;4:1929–48. https://doi.org/10.1016/j.joule.2020.07.018.

[2] Tröndle T. Supply-side options to reduce land requirements of fully renewable electricity in Europe. PLOS ONE 2020. https://doi.org/10.1371/journal.pone.0236958.

[3] Mey F, Lilliestam J, Wolf I, Tröndle T. Visions for our future regional electricity system: Citizen preferences in four EU countries. iScience 2024;0. https://doi.org/10.1016/j.isci.2024.109269.