Supplementary Materials for

Greater leverage for energy security with demand-side policies

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The PDF file includes:

Materials and Methods
Supplementary Text
Boxes S1 to S4
Figs. S1 to S7

Supplementary Materials (SM).

INDEX

Materials and Methods *(Methodological issues, such as lists of indicators, surveyed countries and datasets, procedures, and policy illustrations, are presented in boxes.)*

Boxes

Supplementary Text *(Extended presentation of the results from the analysis are presented in figures.)*

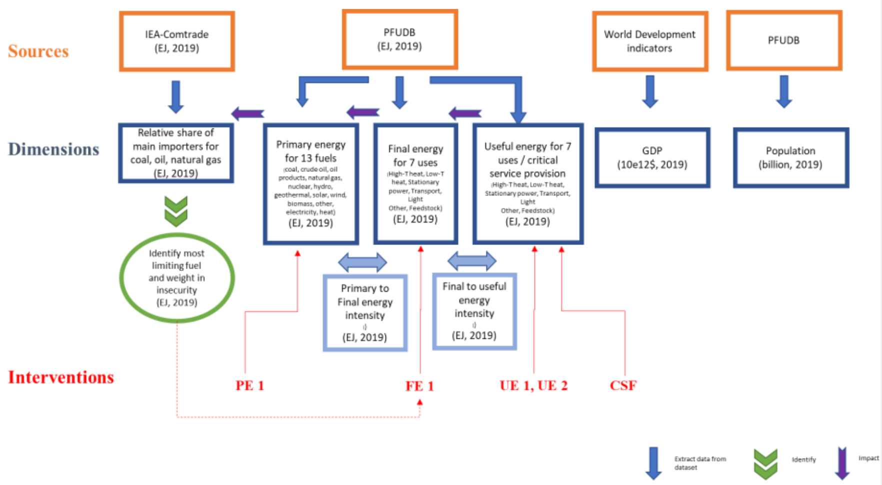
Figures

box S1. Key energy security indicators used in the literature. Includes indexes (composite indicators). Circle (○) indicates indicators that have been proposed but not quantified, full dot (●) denotes indicators that have been proposed and estimated, while circles with a hole (◉) signal those that have been considered through scenario analyses.

Indicator	Kruyt et al. 2009	Sovacool & Mukherjee 2011	Winzer 2012	GEA 2012	Jewell et al. 2014	Ang et al. 2015	Kisel et al. 2016	Gasser, 2020
Energy intensity of the economy	○	○		●	●	○		○
Energy affordability	●	○				○		○
Energy efficiency	◉	○			◉	○		○
Capacity of energy storage	○			●		○	○	
Access to modern energy services		○		●		○		○
Vulnerability to energy shocks	○	○	●	●	○	○	○	○
Diversity of supplies in end-use sectors	○	○			○	○	○	○

Sources : Kruyt et al. 2009 (*4*) ; Sovacool & Mukherjee 2011 (*5*) ; Winzer 2012 (*6*) ; GEA 2012 (*10*); Jewell et al. 2014 (*9*) ; Ang et al. 2015 (*7*) ; Kisel et al. 2016 (*11*) ; Gasser, 2020 (*3*).

box S2. Data and methods



scheme S1. Flow-chart describing the procedure followed in this study.

Our methodology follows several stages to compare the effects of different types of policy interventions. Scheme S1 summarizes the main stages. We explain the procedure around the three main stages: data extraction from original sources and preparation: estimation of the indicators for 2019 (base case) by considering the relevant dimensions of the data; simulation of the policy interventions' impact and comparisons.

<u>Data extraction and preparation</u>

The data for the analysis comes from multiple sources covering different dimensions. We list here the main sources:

- PFUDB - Primary, Final and Useful Energy Database (*12*);
- IEA's World Energy Balances (*14*);
- COMTRADE: UN COMTRADE (*15*), BACI (*16-17*);
- World Development Indicators: World Bank (*18*).

The PFUDB database provides country-specific data on primary energy (PE), final energy (FE) and useful energy (UE). The IEA's World Energy Balances gives the origin (domestic production or imports) of the energy sources across countries. UN COMTRADE dataset and the modified BACI-Comtrade database contains trade data on energy imports and exports by source (oil, natural gas, etc.) and by country of origin and destination, both in physical and monetary terms. World development indicators provide countries' socioeconomic numbers such as the GDP.

We assemble the datasets by country and fulfill the relevant dimensions needed to calculate the indicators of energy security. From the PFUDB database, we obtain the PE for 13 fuels (coal, crude oil, oil products, natural gas, nuclear, hydro, geothermal solar, wind, biomass, other electricity, heat). We further take the FE and the UE for 7 uses (high-temperature heat, low-temperature heat, stationary power, transport, light (illumination), other). The PFUDB also provides the data for the countries' population. From the IEA and the COMTRADE data, we identify the relative shares of the main energy importers for coal, oil and natural gas. It is important to note that data is reported on direct equivalent in PE for all non-fossil energy carriers, which is markedly different from the so-called substitution equivalent accounting method that artificially inflates the primary energy equivalent of non-fossil electricity generation.

Estimation of base case indicators

We calculate a set of 12 energy security indicators per country for the year of 2019 (see more details in Box 1). We also estimate the indicators for the year 2014 as a further sensitivity analysis. We perform the calculations in an Excel spreadsheet with a standardized format used for all countries in the sample. The spreadsheet computes the result of the indicators automatically based on the provided data. The estimations for the year 2019 serve as the base case for comparing the results of the different policy interventions.

Simulation of policy interventions and comparisons

The objective is to assess the policy impact of measures corresponding to 10% primary energy demand (e.g., equivalent to 9 EJ in the US or 2 EJ in Japan). When such measures are implemented at final or useful energy levels, the figures are adjusted downwards by the respective efficiencies of FE/PE or UE/PE conversion (see Box 3. for more details). At the end, we calculate the energy security indicators and compare the policy intervention based on the results for the indicators.

To reach the 10% PE target, we compare four (4) policy interventions and one scenario (CSF):

- PE 1: supply-side, import diversification (all the rest remains the same as in the base case);

- FE 1: supply, oil to biofuels (domestically produced) substitution in transport at the final energy level;

- UE 1: demand, reduction of the useful energy demand for low-temperature heat in buildings (e.g., via insulation);

- UE 2: demand, reduction of useful energy demand in transport through substitution of conventional combustion vehicles by electric vehicles (transport electrification);

- CSF: critical social functions (energy services needed to maintain vital energy services that support critical social functions at a sufficiency level or enough to guarantee decent living standards for all in developing countries).

We simulate the effects of each policy intervention following the procedures described in the next paragraphs.

PE 1 – import diversification away from the two largest importers

To implement the import diversification scenario while keeping other variables unchanged, we implement the following steps using trade values (of fossil fuels) from the BACI-COMTRADE database.

We identify the largest fossil fuel import (usually oil). Then we reduce import flows from the two largest sources to 0. We calculate the concentration ratio (CR2) using the shares of the 3rd and 4th original largest import sources. This ratio is then used to calculate the compound Shannon indexes. The imports from the original two largest sources are allocated to the category "other import sources".

FE 1 – reduction of ~10% PE equivalent in final energy (FE) demand for transport through fuel substitution (oil to biofuels)

We start by reducing the part of oil in transport FE demand by an amount equivalent to 10% PE considering the relative transport oil efficiency (i.e., FE/PE). That is, the reduction will be slightly lower than 10% PE due to the conversion losses (from PE to FE) avoided given the reduction of the transport FE demand.

Then, we increase the FE demand for biofuels in transport proportionally to the reduction in oil. We propagate the changes to the PE level using the current efficiencies for oil and biomass in transport. In the cases where there are no transport biofuels available, we assume a PE to FE conversion efficiency of 75%, based on the best-case scenario for Brazilian ethanol and US corn ethanol. Lastly, we update the PE production numbers for biofuels and adjust the import numbers to reflect the reduction in oil consumption.

UE 1 – reduction of ~10% PE equivalent in useful energy (UE) demand for low-temperature heating (e.g., through better insulation of building envelopes)

We decrease the UE demand for low-temperature heating from fossil fuels—including oil, gas, and biomass, and coal where appropriate. The amount of reduction corresponds to 10% of PE equivalent, that is multiplied by the ratio UE/PE of low-temperature heat efficiency. The reduction is allocated among the different fuel sources (usually oil and natural gas) to minimize fossil fuel imports.

We propagate the changes to FE and PE levels using corresponding fuels-specific low-temperature heat efficiencies (from base case). Finally, we adjust imports (and production if needed) to ensure consistency with the modified energy balance.

We note that the impact of this policy can be relatively modest, particularly for conventional supply-side energy security indicators such as independence ratios, as both imports and PE are scaled down proportionally. For that reason, we consider one alternative policy case involving the reduction of UE demand for low-temperature heating of 10% PE equivalent through improved insulation and subsequently supplying all the remaining energy needed through electric heat pumps with a high efficiency of 300% in converting FE to UE. We additionally assume that all additional electricity required could be generated from domestic renewable sources, similarly to policy UE 2 (transport electrification, see next). This alternative intervention is considered for sensitivity analyses (see the results for Japan in fig. S7).

UE 2 – reduction of UE in transport to the equivalent of 10% PE via electric vehicles

We start by reducing the UE demand for oil in transport by 10% of PE multiplied by the UE/PE efficiency. Then we increase the UE demand for electricity in transport by the same amount.

We propagate the changes to FE by using existing transport UE/FE efficiencies for oil, and assuming an efficiency of 100%, i.e., UE=FE, for electricity. (Different assumptions for losses were tested with non-substantial impacts.) Next, we propagate changes from FE to PE. For that, we again assume transport FE/PE efficiencies for oil and no losses for electricity. We allocate additional electricity uniformly across all non-fossil domestic electricity options (even if current production is 0). Finally, we adjust the PE balance by the additional inputs to electricity generation (using the direct equivalent PE accounting method) and correct oil import flows and PE production to be consistent with the modified energy balance.

CSF – critical social functions

We calculate the energy requirements of critical social functions by scaling down current demand (applying adequate multipliers). That is, primary, final and useful energy needs for critical social functions are estimated as a proportion of the current total consumption. CSF excludes industrial energy uses (high-temperature heat, stationary power [industrial drives] and petrochemical feedstocks). CSF fractions were determined iteratively, by comparing the results of different scaling factors (or multipliers) in terms of their resulting aggregate energy consumption per capita (GJ per year) and considering sufficiency levels for the OECD countries. Given the energy demand of many developing countries remains low with large segments of the population underserved with modern energy services, the multipliers are different for these countries to guarantee that these countries remain above the threshold levels given in the literature on decent living standards (e.g., *19*). The table shows the multipliers that are used to scale down the energy balances for determining CSF:

Multipliers (PE-FE-UE)	Non-OECD	OECD
High-Temperature heat	0	0
Low-Temperature heat	0.75	0.5
Stationary power	0	0
Transport	0.5	0.25
Light	1	1
Other	1	1
Feedstocks	0	0

With these assumptions, the CSF values are aligned with representative sufficiency and decent standards of living values across OECD and non-OECD countries (i.e., ranging from >9 GJ/capita FE in India to ~60 GJ/capita FE in the USA).

We propagate the changes to production and import flows by assuming that the lowered demand of CSF first leads to reduce imports and then to lower domestic production. That is, if the countries' domestic production is larger than CSF PE demand (by source), imports are set to 0 and domestic production is adjusted accordingly.

Final remarks on the propagation of demand changes to the supply-side (production, imports and exports):

We correct the PE (supply) balances by the difference between the demand per source in the base case (year 2019) and under the policy intervention considered, through the following procedure:

1. first reduce imports;

2. if demand reduction is larger than imports, decrease domestic production;

3. only if demand reduction is larger than imports and production (steps 2 and 3 are not enough), reduce exports.

The 3rd step is the last resort as exports are an important source of revenues for developing countries. Non-OECD countries need foreign currency revenues as they have little industrial exports.

Finally, in the cases where PE demand *increases* per source (such as a growth in renewable energy sources in UE 2 – transport electrification), we proceed as following:

4. start by reducing exports;

5. if demand increase is higher than exports, then allocate the remaining to (increasing) domestic production;

6. do not change imports.

Auxiliary calculations for estimating the energy security indicators (energy expenditures, etc.):

Energy expenditures in 2019 are estimated by taking the prices from COMTRADE (e.g., coal, oil, natural gas, electricity). Prices are converted from $/MWh to $/1000 MJ units to make them more comparable. In the case of electricity, and for isolated countries (e.g., Australia), we search for wholesale prices (without taxes) from different available sources (official national sources, IEA, etc.).

Decadal variance on annual energy prices is identified to calculate the share of energy expenditures on GDP under minimum and maximum decadal prices (between the years 2012 to 2021). For coal, oil and natural gas, energy prices come from BP (*20*). Electricity prices are from IEA (*21*). We consider the electricity prices at the end-use level (for households) net of taxes. We use the same net prices for all the electricity generation as a proxy of the opportunity costs of production independently of the primary source. Finally, biomass is valued at the price of the cheapest PE (coal) for all countries, OECD or developing countries.

box S3. Illustrative policy interventions with real-world examples. Includes four policy interventions with equivalent effect to 10% change in primary energy use and a scenario aiming to provide for critical social functions only.

Code	Policy	Detail	Examples of real-case policies
PE 1	import diversification	reducing the import flow of the two largest energy importers up to 10% of primary energy and obtaining this flow from the 3rd and 4th largest providers	EU countries imposed sanctions on Russian crude oil and refined petroleum products following the Russian-Ukraine conflict. For example, Germany sharply reduced the imports of oil and gas from Russia, representing around 10% and 24% of total primary energy in 2021 respectively, to nearly 0% in early 2023 (22). This amounts to a total displacement of around 4 EJ or a third of the country's primary energy consumption (see also Box S4).
FE 1	fuel substitution	substituting imported oil with domestic biofuel (biomass) by increasing production proportionally to the policy target (10% of primary energy)	The Brazilian ethanol production reached its peak in year 2019 with 35 billion liters (*23*). This equates to 1.2 EJ or 10% of total primary energy of Brazil in 2019.
UE 1	reduce low-temperature heat	reducing the low temperature heat demand of residential and commercial buildings through, e.g., better insulation of walls or installation of efficient windows	EU countries approved emergency laws in the outset of the Russian invasion of Ukraine to reduce gas consumption by 15% in 2022. In Germany, for example, immediate demand reductions in response to the Ukrainian War (through a mix of behavioral change, policy and warm temperature) led to a reduction of -14% in gas demand in 2022 compared to the 2018-2021 average, or about 5% of primary energy (*22*)—(24) reports higher reductions (-22%) in gas consumption in the 2nd half of 2022.
UE 2	transport electrification	reducing the energy demand in transport via the electrification of transport modes	Norway approved a mandate to have 100% of zero-emission vehicles sales in 2025, thereby banning Internal Combustion Engines by that time. In 2023, Norway keeps VAT exemption and subsidy schemes for new EV sales. As a result of purchase incentives and infrastructure deployment, EVs already represented 17% of the car park and 88% of new sales in Norway, at the end of 2022 (*25*). This contributed to a reduction in gasoline consumption of around 0.02 EJ or 10% of primary energy in the last decade (*26*). In the US, CAFE fuel consumption standards reduced oil demand by 200 EJ between 1975 and 2018 or on average by 5 EJ per year (*18*). In 2018 this effect was estimated to amount to 10.3 EJ or 10.7% of primary energy (*13*, *26*).
CSF	critical social functions	energy services necessary to ensure critical social functions (minimum thermal comfort in buildings, transport, etc.)	The net COVID effect on PE consumption in the US in 2020 was -7.9 EJ or -7.5% (*26*). The French Energy Sobriety Plan aims to reduce final energy consumption in 10% by 2024 and 40% between 2022 and 2050.

box S4. Effects of the German response to the energy crisis

The share of Russian gas in the German gas mix has decreased from 52% in 2021, via 22% in 2022 to 0% in early 2023 (*22*). This translates to a reduction from around 24% in 2021 to 0% of PE in 2023, with a total substitution of around 3 EJ of Russian gas (*22*, *27*).

In addition, the share of Russian oil in the German oil mix decreased from around 35% before the war (2021/2022) to close to 0% in early 2023 (*28-29*). This translates to a reduction from close to 10% of PE (~1 .1 EJ) in Russian oil to 0%.

In Germany, for example, immediate demand reductions in response to the Ukrainian War (through a mix of behavioral change, policy and temperature) led to a reduction of -14% in gas demand in 2022 compared to 2018-2021 average, about 5% of PE (*22*).

box S5. List of energy security indicators surveyed

Indicator	Unit	Energy security dimensions	Energy security issues	Definition and formula	Energy system level
Energy-Supply indicators					
Share of non-fossil fuels	%	Sustainability	Climate and geopolitical risks	Share of coal, oil and nat.gas in total primary	PE
Import independency	%	Continuity	Risk of trade disruption	Energy import divided by total primary energy	PE
Shannon diversity index PE	Non-dimensional	Continuity	General vulnerability to disruptions in energy import	Shannon–Weaver Diversity Index (SWDI)	PE
Compound Shannon diversity index PE	Non-dimensional	Continuity	Weighted dependence in diversity issues	SWDI adjusted for net imports	PE
Compound Shannon diversity index PE with import diversification	Non-dimensional	Continuity	Weighted dependence to major energy importers in diversity issues	SWDI adjusted for concentration ratio (CR2)	PE
Energy-Demand indicators					
Final energy efficiency	EJ/trillion USD2015	Affordability, Sustainability	General vulnerability to price and supply disruptions	Total final energy divided by GDP	FE
Compound Shannon FE	Non-dimensional	Continuity	General vulnerability to disruption in energy carriers	SWDI using FE shares	FE
Compound Shannon FE incl. electricity by source	Non-dimensional	Continuity	General vulnerability to energy carriers disruptions and limited switching	SWDI using FE shares and electricity sources	FE
Share of energy expenditures on GDP - [min/max]	%	Affordability	Price change risk	Relative size of energy expenditures estimated with decadal maximum and minimum prices	FE
Savings in energy expenditures on fossil TPE on GDP	index (base=100)	Affordability, Sustainability	Vulnerability to climate and trade disruptions on fossil fuels	Policy impact on reducing the share of GDP non-devoted to expenditures on fossil fuels	PE
Savings in energy expenditures on GDP	index (base=100)	Affordability	Vulnerability to energy burden increase due to energy crisis	Policy impact on reducing the share of GDP non-devoted to energy	PE
Savings in primary energy demand	index (base=100)	Continuity, Sustainability	General vulnerability due to increasing exposure to energy supply and prices disruptions	Policy impact on reducing primary energy consumption	PE

box S6. List of countries and policy impacts

Energy impact matrix – in EJ

EJ	PE (2019)	10% PE target	PE 1 import diversification	FE 1 fuel substitution	UE 1 low-temp. heat	UE 2 transport elec.
Australia	6.0	0.60	0.60	0.55	0.24	0.18
Brazil	12.4	1.24	0.75	1.19	0.53	0.22
Canada	12.4	1.24	1.24	1.06	0.59	0.35
China	140.6	14.06	7.35	12.89	6.94	3.67
France	7.6	0.76	0.76	0.74	0.50	0.24
Germany	12.2	1.22	1.22	1.14	0.78	0.37
India	38.4	3.84	3.84	3.55	1.12	0.61
Italy	6.4	0.64	0.64	0.66	0.39	0.19
Japan	17.1	1.71	1.71	1.62	1.01	0.53
Nigeria	6.6	0.66	0.35	0.66	0.08	0.07
Poland	4.4	0.44	0.44	0.43	0.22	0.19
South Africa	5.9	0.59	0.59	0.57	0.12	0.11
United Kingdom	7.2	0.72	0.72	0.67	0.45	0.22
United States	88.9	8.89	8.89	8.40	5.04	2.97
Average	26.2	2.62	2.08	2.44	1.29	0.71
Min	4.4	0.44	0.35	0.43	0.08	0.07
Max	140.6	14.06	8.89	12.89	6.94	3.67

Sources PE: PFUDB 2023 (*12*), IEA 2023 (*14*).

Energy impact matrix – index (10% PE target=100%)

Index	10% PE target	PE 1 import diversification	FE 1 fuel substitution	UE 1 low-temp. heat	UE 2 transport elec.
Australia	100%	100%	91%	41%	31%
Brazil	100%	61%	96%	43%	17%
Canada	100%	100%	85%	47%	28%
China	100%	52%	92%	49%	26%
France	100%	100%	97%	65%	32%
Germany	100%	100%	94%	64%	30%
India	100%	100%	92%	29%	16%
Italy	100%	100%	103%	61%	29%
Japan	100%	100%	95%	59%	31%
Nigeria	100%	53%	100%	13%	11%
Poland	100%	100%	98%	50%	43%
South Africa	100%	101%	98%	21%	19%
United Kingdom	100%	100%	93%	63%	31%
United States	100%	100%	94%	57%	33%
Average	100%	91%	95%	47%	27%
Min	100%	52%	85%	13%	11%
Max	100%	101%	103%	65%	43%

In our energy security analysis, we considered 14 individual countries—the sample of 15 countries from above, minus Former Soviet Union which was not analyzed because of the breakup of the Soviet Union into individual countries that do not pursue the same energy policies. Altogether, these 14 countries represent about two thirds (63% of primary energy, 62% of final energy, and 66% of useful energy) of the world energy use in 2019, and thus they are very representative of the world situation.

This sample size was chosen to be consistent with the PFUDB sample used for the long-term historical analysis. The policy analysis reported here, in principle, are replicable for any other country for which energy balances are available from the IEA.

We include the five largest energy systems (China, US, India, Japan, Germany) as well as, in addition larger representatives of each continent (Brazil, Canada, France, South Africa, Nigeria, Australia), and the remaining countries that are covered in the PFUDB (United Kingdom, Italy, Poland) to ensure consistency between our historical analysis (fig. S3) and the policy analysis at the national level.

The tables above show the impact of the policy interventions to reach the same target of 10% of the focal country's primary energy (PE). Interventions at final energy (FE) and useful energy (UE) levels are smaller since conversion losses increase the effect at the PE level. For example, in average, to change 10% of primary energy of the countries in the sample or 2.62 EJ, only 2.44 EJ change is needed at the FE level and only 0.71 EJ if the policy is implemented at the UE level in case of transport electrification. These are respectively 95% and 27% of the target value (2.63 EJ). (The policy intervention "PE 1 – import diversification" is not comparable as it deals with diversifying the two largest energy import sources of the country that may not total 10% of PE as the case in Brazil, China, or Nigeria.)

The intervention at PE level of 10% results in 90% of PE staying unchanged and 10% being adjusted, e.g., relocation of imports (PE 1), replacement of 10% of PE oil imports by domestic biomass based transport fuels (FE 1). Propagation of the interventions at the different levels can vary depending on the sectors and primary energy sources involved—as explained in Box 2. In short, interventions at the UE and FE levels propagate upstream to PE, impacting the energy mixes and imports. This propagation considers the efficiency differences in PE-to-FE or FE-to-UE, by taking into account the specific contributions of each subsector to total final/useful energy of the country under analysis.

Additional assumptions had to be made for the cases in which there was not enough demand at UE or FE levels to reach the 10% target at PE. In these cases, the reduction in demand could not be larger than the respective total UE or associated FE demand. For example, some developing countries (e.g., Nigeria) have so low useful energy in transport that the reduction cannot be so large as to yield 10 EJ at PE. In these cases, the policy impact was constrained to not exceed the actual demand in the demand category considered. This was the case for FE 1 thermal demand from Residential and Commercial buildings (Australia and Brazil) and for UE 2 transport (China, India, and Nigeria).

fig. S1. Number of indicators and indexes (i.e. composite indicators) of energy security by type in the literature. Sources: Authors' elaboration using indicators and indexes proposed in Sovacool & Mukherjee (*5*), Jewell et al (*9*), Gasser (*3*) and Ang et al. (*7*).

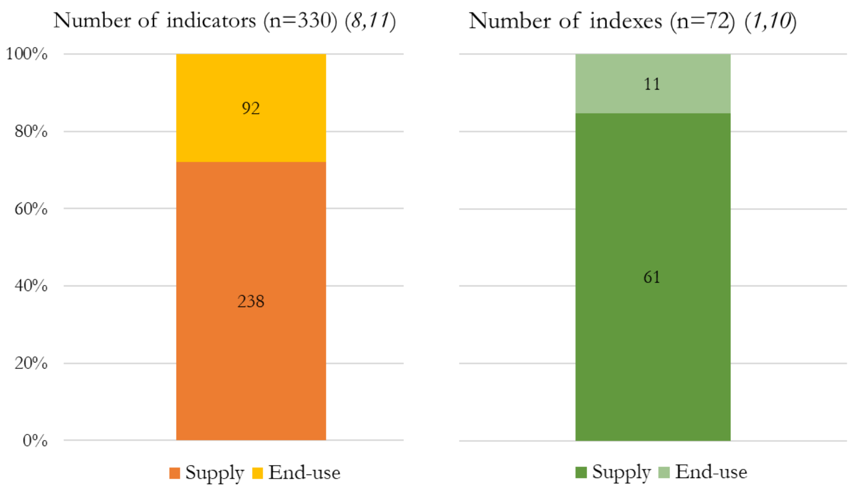


fig. S2. Energy intensity and shares of energy expenditures on GDP, OECD countries in 2019.
Source: IEA (*14*); OECD (*30*). TFC: total final consumption (primary energy).

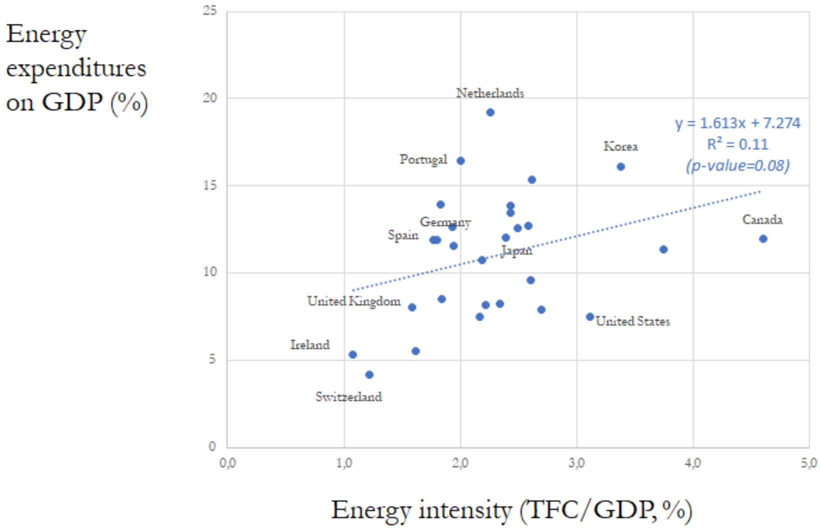
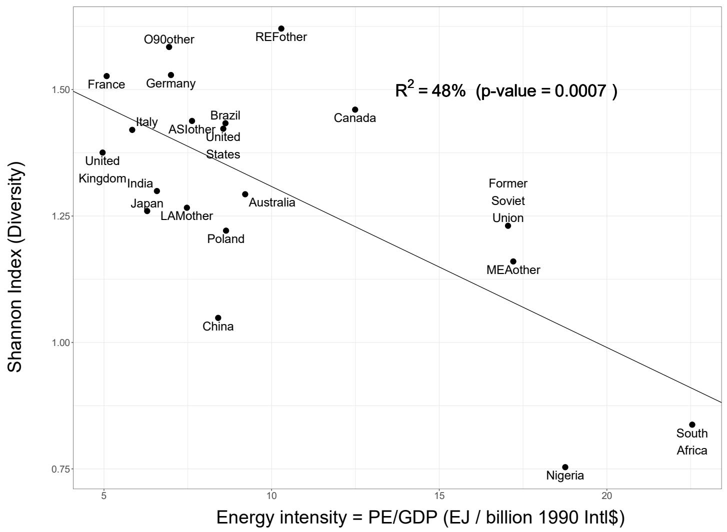
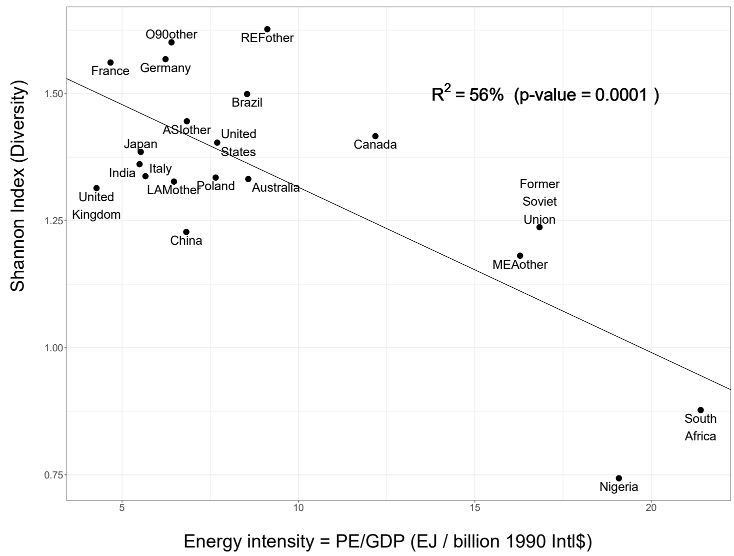


fig. S3. Energy intensity and diversity of primary energy sources (Shannon Index). Developed, developing countries and macro regions (n=40) from the PFUDB database (19) in 2014 (**A**), in 2019 (**B**), and six countries between 1900 and 2020 (**C**). Source: (*12*).

A. Static correlation 2014



B. Static correlation 2019



C. Dynamic correlation 1900-2020

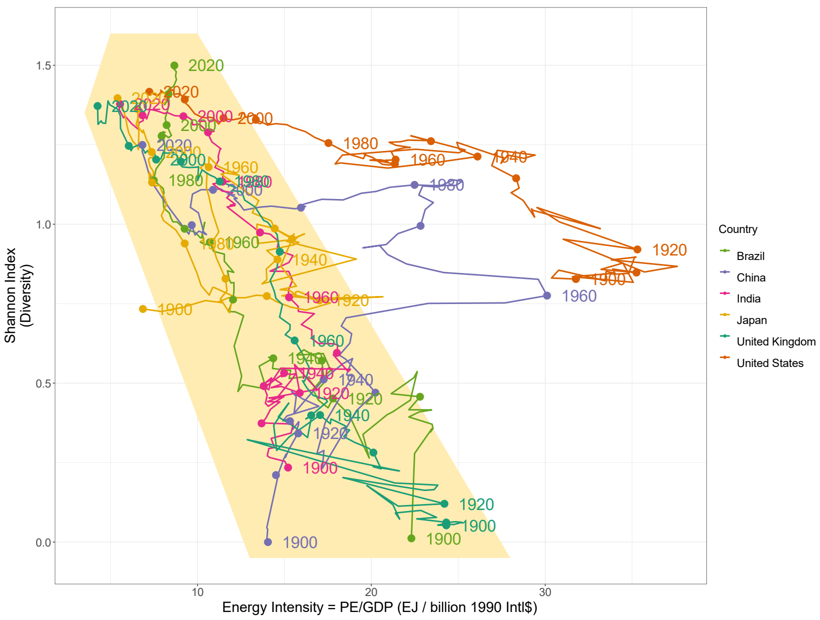


fig. S4. Policy effort equivalent to a 10% in primary energy reduction target. EJ in brackets, countries are ordered by size of energy system and split into net importers and net exporters. China, Nigeria, and Australia are not shown as their import diversification policy could not reach the 10% Primary Energy reduction target. See box S6 for more details.

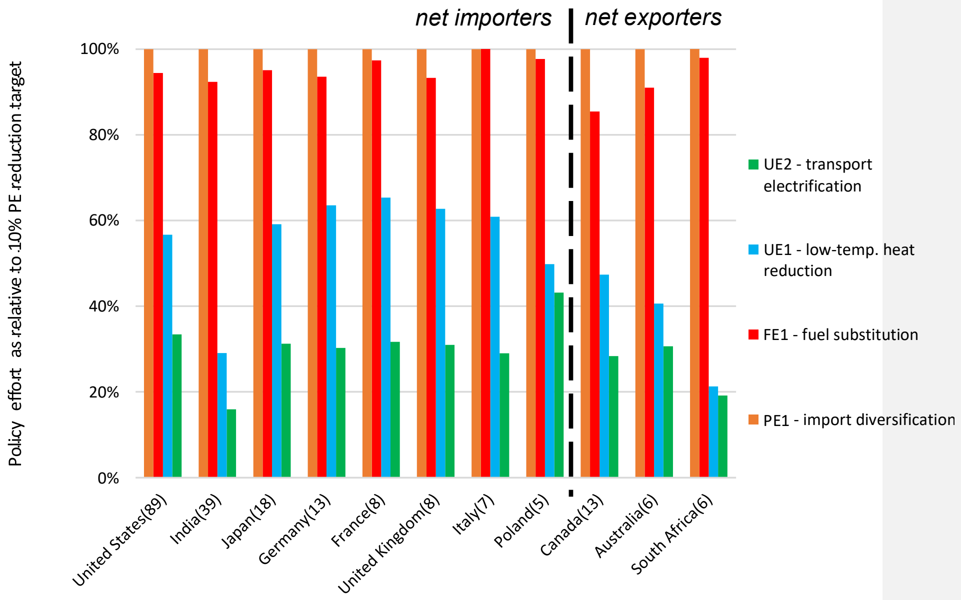
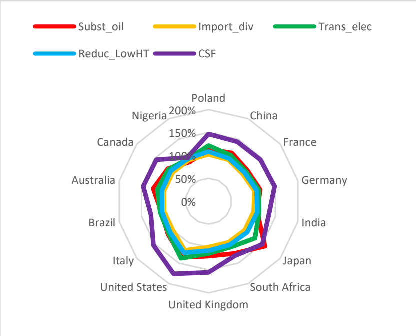


fig. S5. Effects of policy interventions in improving the energy security indicators: average of all indicators and by country. CSF means critical social functions. See more details in the spreadsheet “Summary”.

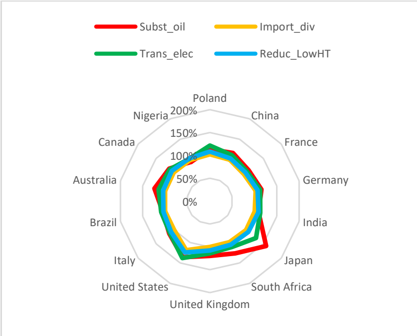
Average of all indicators

ALL ANALYZED COUNTRIES

With CSF



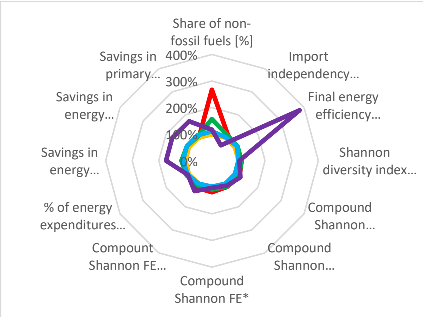
Without CSF



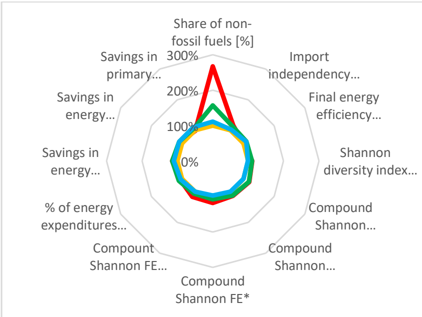
Values of all indicators

AUSTRALIA

With CSF

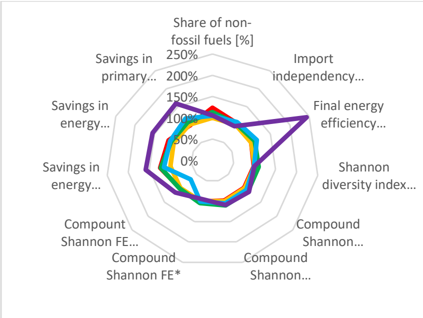


Without CSF

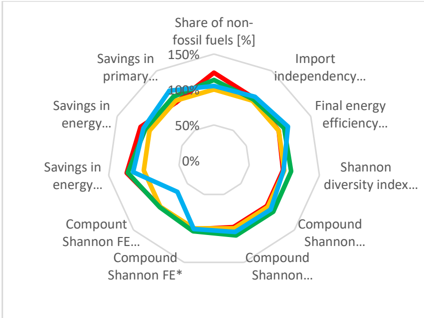


BRAZIL

With CSF

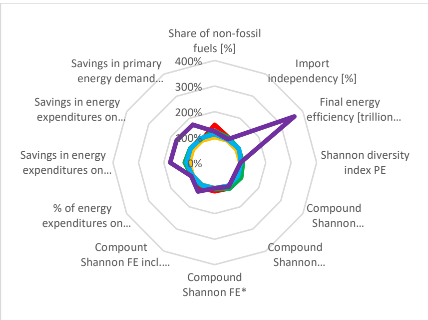


Without CSF

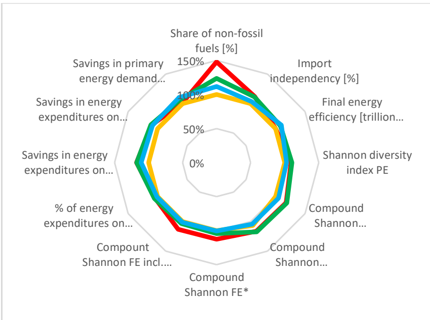


CANADA

With CSF

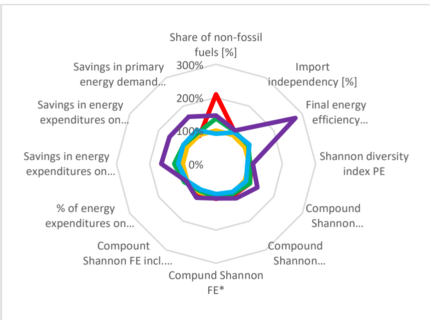


Without CSF

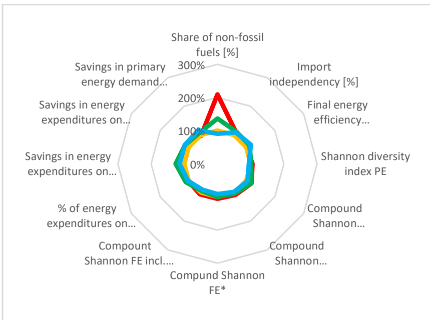


CHINA

With CSF

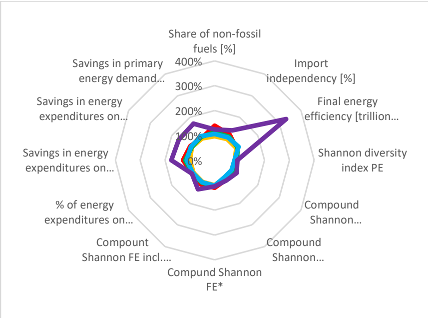


Without CSF

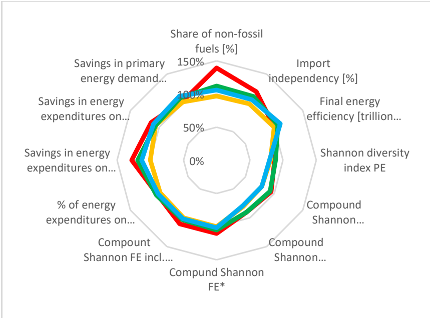


FRANCE

With CSF

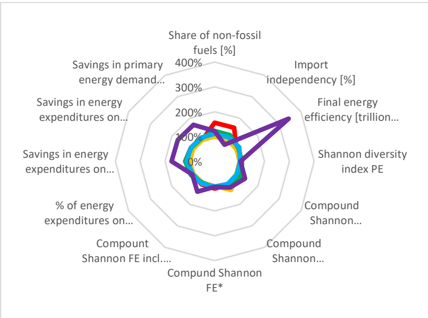


Without CSF

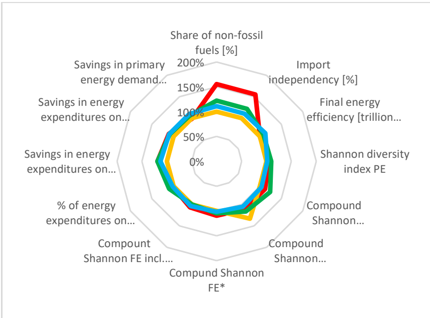


GERMANY

With CSF

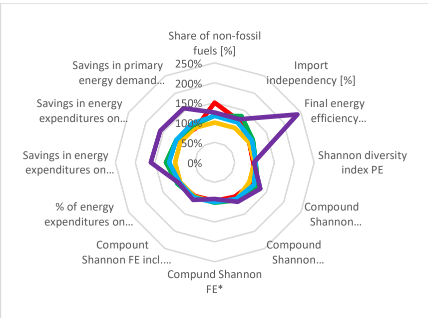


Without CSF

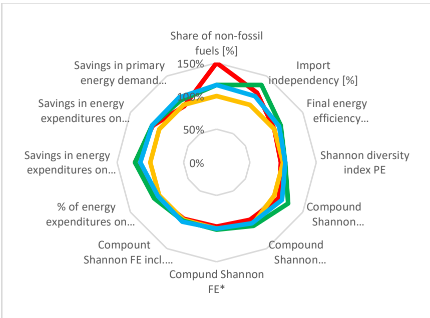


INDIA

With CSF



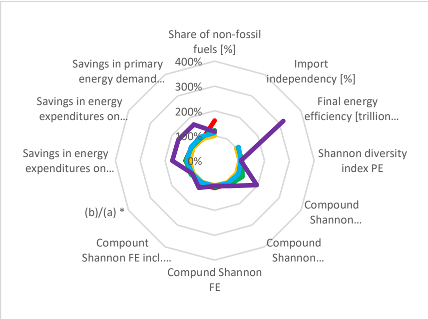
Without CSF

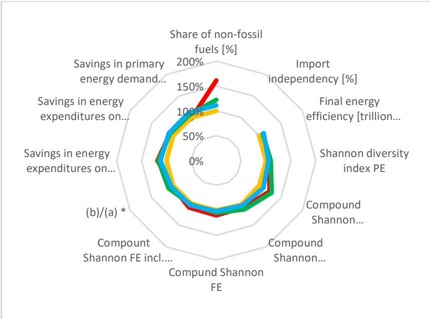


ITALY*

(import independency being 0, no improvement rates are possible to calculate.)*

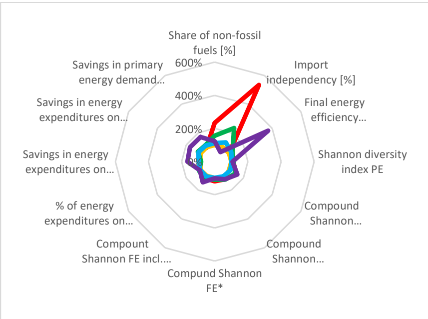
With CSF | Without CSF

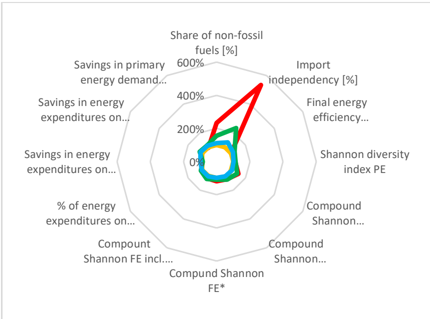




JAPAN

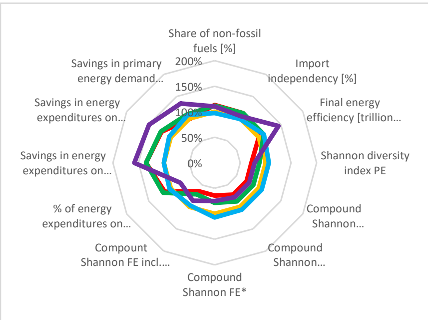
With CSF | Without CSF

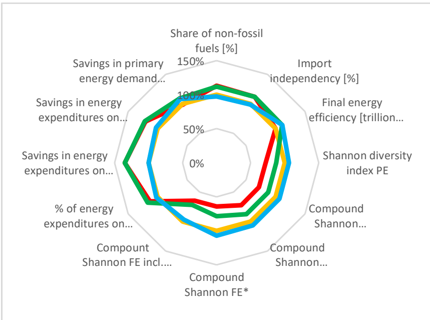




NIGERIA

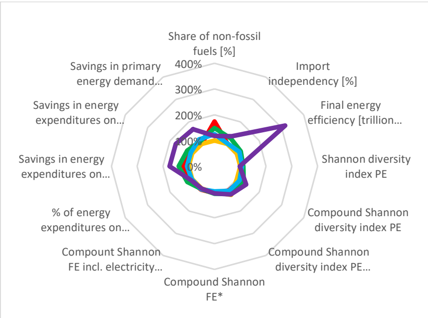
With CSF | Without CSF

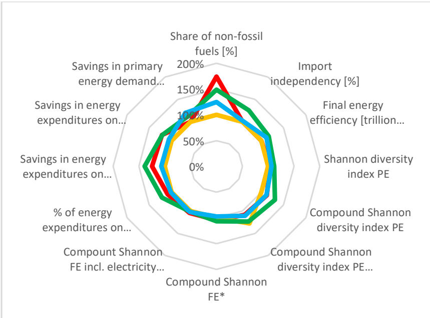




POLAND

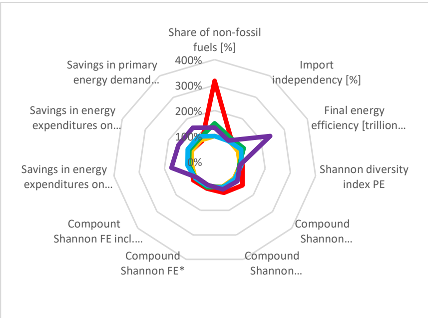
With CSF | Without CSF

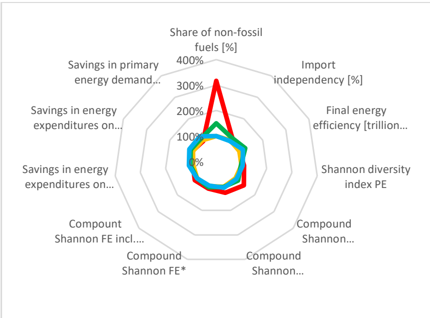




SOUTH AFRICA

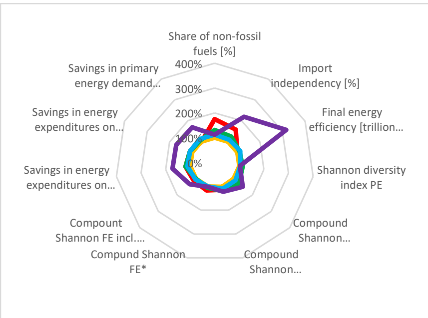
With CSF | Without CSF

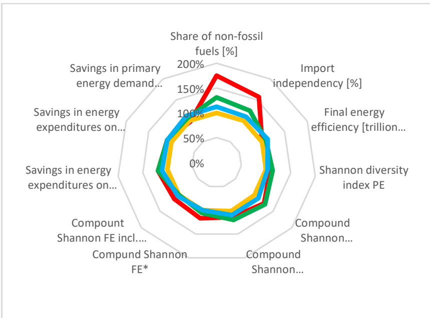




UNITED KINGDOM

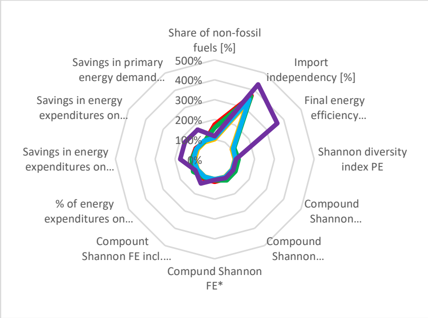
With CSF | Without CSF





<u>UNITED STATES</u>

With CSF



Without CSF

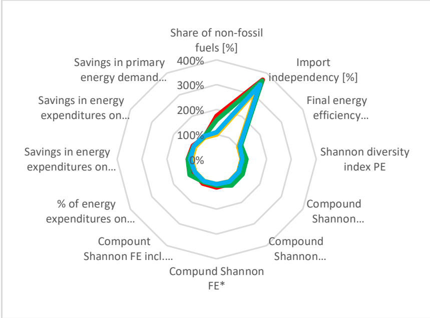
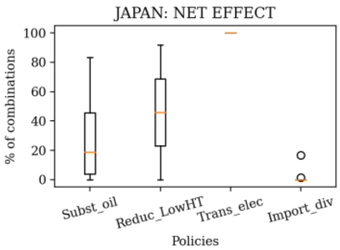
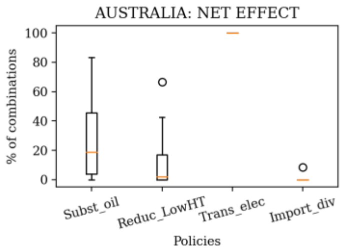


fig. S6. Sensitivity analysis: Box plot comparison of policy interventions for representative developed (OECD) vs developing (Non-OECD) countries and energy importers vs exporters. Average and range of times that each policy interventions ranks first in the combinations of the 12 indicators by n = 1,…, 12 group of indicators.

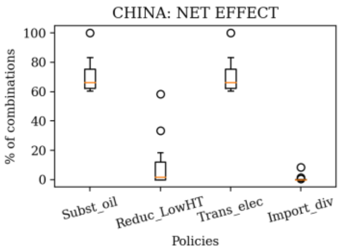
Energy importer Energy exporter

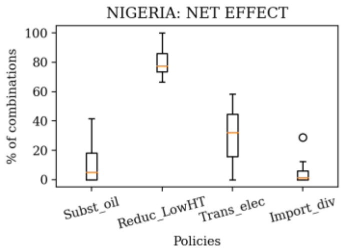
OECD





NON-OECD





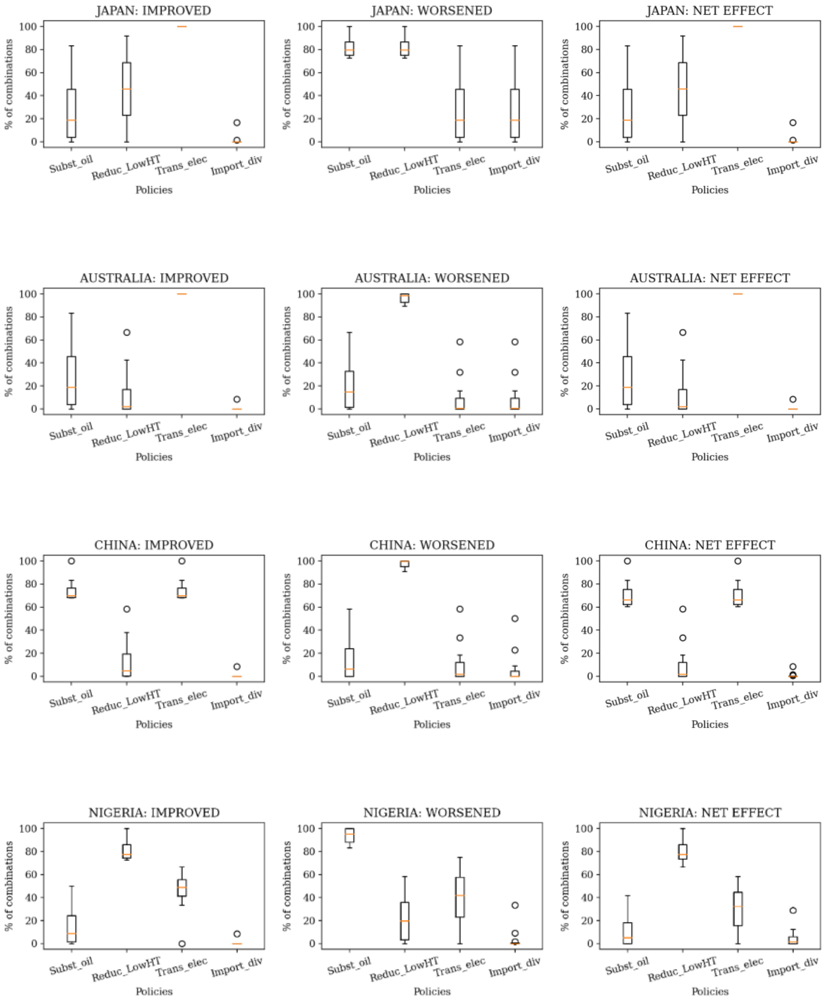
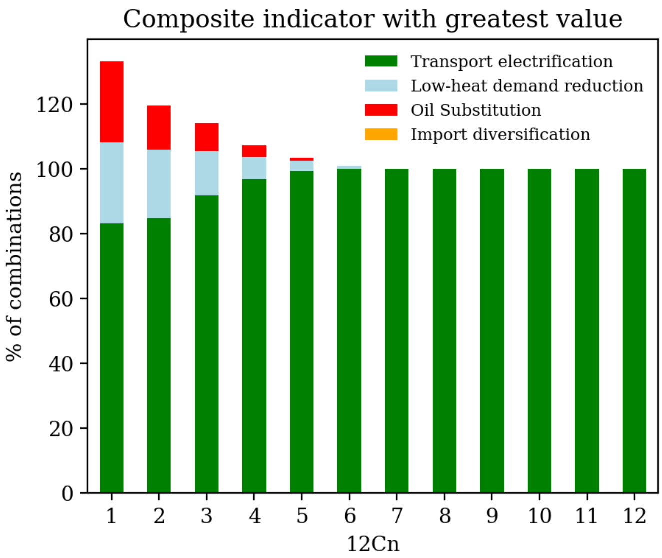

JAPAN: IMPROVED
JAPAN: WORSENED
JAPAN: NET EFFECT
AUSTRALIA: IMPROVED
AUSTRALIA: WORSENED
AUSTRALIA: NET EFFECT
CHINA: IMPROVED
CHINA: WORSENED
CHINA: NET EFFECT
NIGERIA: IMPROVED
NIGERIA: WORSENED
NIGERIA: NET EFFECT
% of combinations
0
20
40
60
80
100
Subst_oil
Reduc_LowHT
Trans_elec
Import_div
Policies

fig. S7. Best policies interventions according to the different combinations possible of the 12 indicators available in sub-sets of n=1,…, 12 elements, for all 14 countries surveyed. See more details in the Script in attachments.



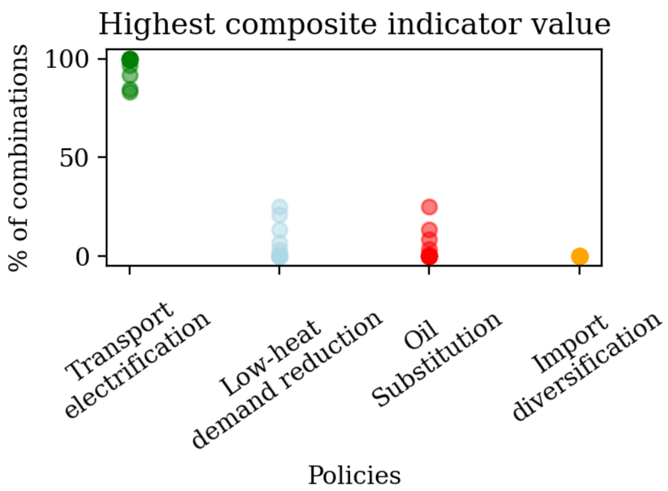
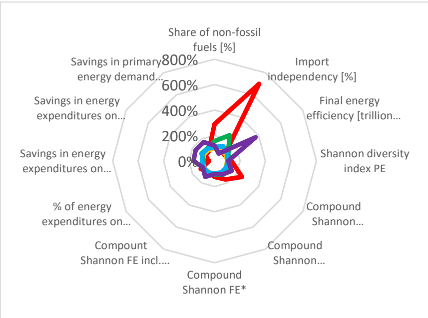


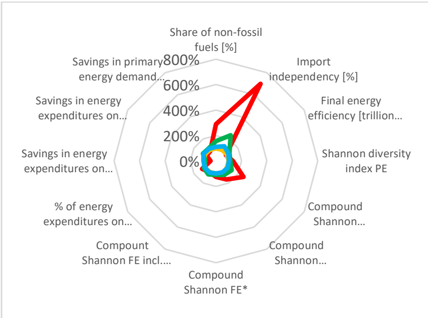
fig. S8. Comparison of alternative policies for Japan. Hydrogen production for fuel substitution and heat pumps deployment to increase efficiency in low-temperature heat. Labels are the same as in fig. S4. See more details in the spreadsheet "Summary".

Fuel substitution with hydrogen production

With CSF

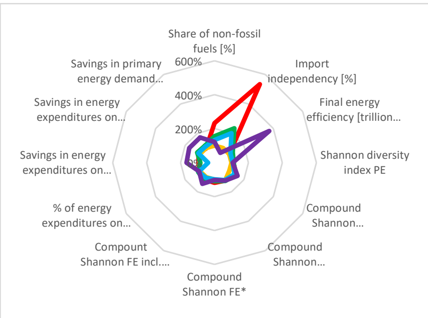


Without CSF



Low-temperature heat reduction with heat pumps

With CSF



Without CSF

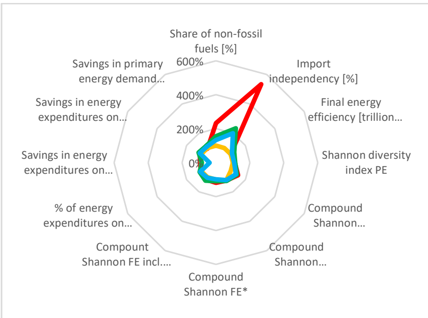
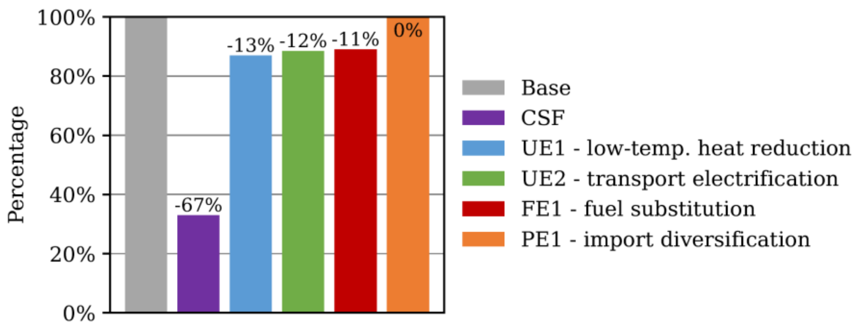


fig. S9. Impact of the policy interventions on reducing CO2 emissions relative to Base (100%). See more details in the spreadsheet “Summary”, in the sheet “emissions.”



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Field Code Changed