

Article

Comparing world economic and net energy metrics: SUPPLEMENTAL INFORMATION

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Abstract:

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1. Figures and Tables showing Supplemental Information and Data

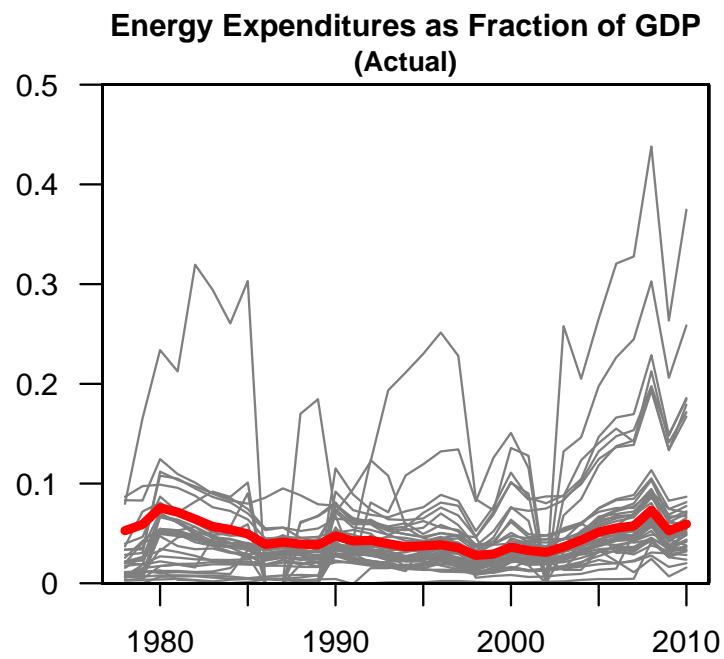


Figure S1. The fraction of GDP spent on energy ($f_{e,GDP}$) for each of the 44 countries set as calculated from the *actual* data in the IEA data set. Thin gray lines represent individual countries, and the single thick red line is the GDP-weighted average for all countries.

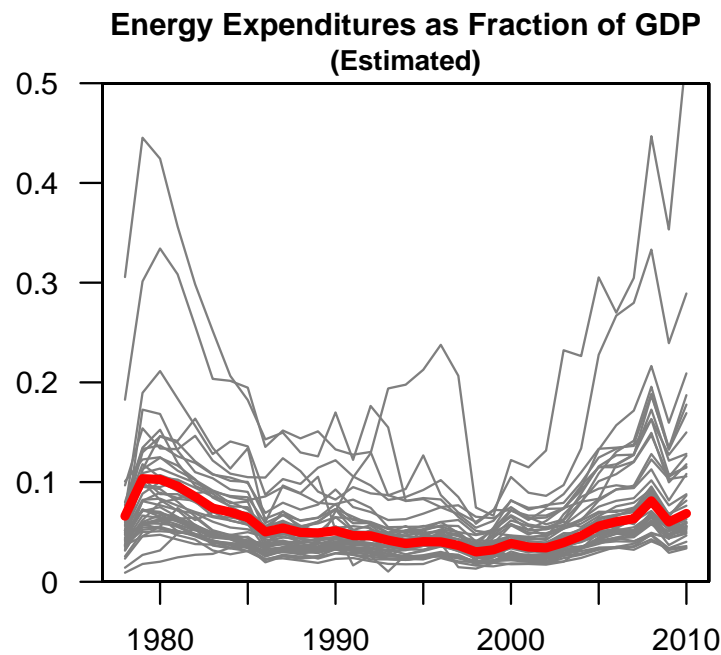


Figure S2. The fraction of GDP spent on energy ($f_{e,GDP}$) for each of the 44 countries set as calculated when *estimating* prices for data missing from the data in the IEA data set. Thin gray lines represent individual countries, and the single thick red line is the GDP-weighted average for all countries.

We compare U.S. data from multiple sources to describe the context of our calculated $f_{e,GDP}$ (see Figure S3) as an additional comparison to the world trend of our 44 country data set. The U.S. energy expenditures calculated in this paper reside below the energy expenditures reported by the U.S. Department of Energy’s Energy Information Administration (EIA)¹ and approximately equal to slightly above personal consumption expenditures for energy goods and services as reported by the U.S. Bureau of Economic Analysis (BEA)². The EIA energy expenditures should be larger than our calculation because they include expenditures for commodities that we do not: refined petroleum products and taxes; all retail electricity instead of only non-fossil electricity; biomass; and biofuels. Thus, the boundary of our expenditures fits logically within the bounds of other existing energy expenditures estimates from the U.S. government.

Figure S3 also shows two energy expenditures estimates for the U.S. using data from the World Input-Output Database (WIOD). We count three of the 35 WIOD industrial sectors as “energy” sectors: Mining and Quarrying; Coke, Refined Petroleum and Nuclear Fuel; and Electricity, Gas and Water Supply. These sectors both exclude some aspect of energy sector transactions and include non-energy transactions (e.g., water supply is not energy). The intermediate spending by these three sectors very closely matches that of our energy expenditures using IEA data in this study, as we would hope. Also,

¹ Energy expenditures as a percentage of GDP from Table 1.5 and 3.5 of the Monthly or Annual Energy Review. From Table 3.5 of Annual Energy Review: “Expenditures for primary energy and retail electricity by the four end-use sectors (residential, commercial, industrial, and transportation); excludes expenditures for energy by the electric power sector.”

² BEA personal consumption expenditures for “energy goods and services” are from Table 2.3.5 and “Consists of gasoline and other energy goods and of electricity and gas.”

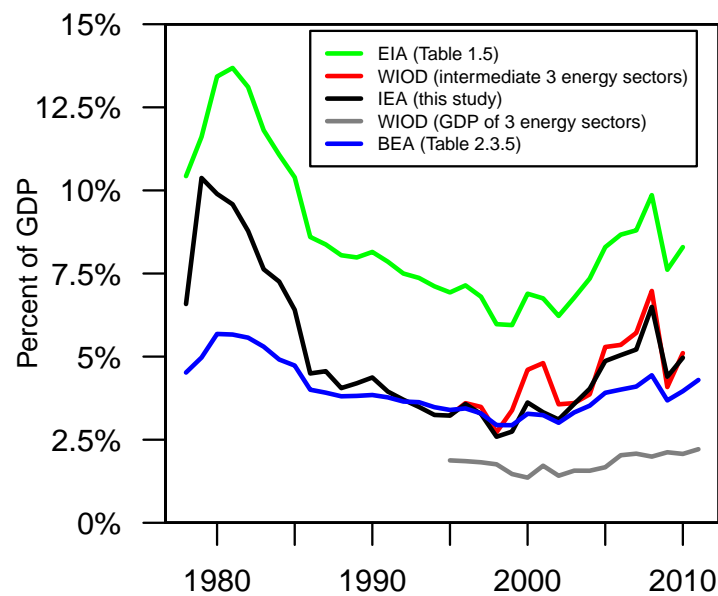


Figure S3. A comparison of energy expenditures relative to GDP for the U.S. shows that the calculation in this paper most closely matches intermediate expenditures in the three energy sectors of the WIOD. EIA (Table 1.5): data from Table 1.5 of the Energy Information Administration Annual Energy Review. WIOD (intermediate 3 energy sectors): Intermediate expenditures by three “energy” sectors of the World Input Output Database. IEA (this study): estimated energy expenditures for the United States as calculated in this manuscript. WIOD (GDP of 3 energy sectors): the net output, or contribution to GDP, of the three “energy” sectors of the World Input Output Database. BEA (Table 2.3.5): personal consumption expenditures for energy goods and services as reported by the Bureau of Economic Analysis in Table 2.3.5.

the proportion of GDP associated with these three energy sectors is much less than our IEA-based energy expenditures estimate. We do not expect the GDP associated with the three energy sectors to match our calculation because of different boundary conditions: our IEA-based energy expenditures includes mostly intermediate spending on primary energy whereas the net output, or portion of GDP, associated with the energy expenditures includes energy carriers and not intermediate spending.

Figure S4 shows a comparison of our expenditures as calculated from the 44-country data set of the IEA to world expenditures on fossil energy using data from the BP Statistical Review of World Energy. The BP data do not have any prices for electricity, so we do not show an estimate of expenditures for non-fossil electricity. However, the BP data do provide for calculation of electricity generation from non-fossil electricity (nuclear, hydropower, solar, wind, and “geothermal, biomass, and other”). Multiplying BP’s non-fossil electricity by the average world industrial and residential prices from the IEA data produce expenditures of 0.1% (1978) to 0.3% (2010) of GDP using the industrial electricity price and expenditures of 0.2% (1978) to 0.5% (2010) of GDP using the residential electricity price. Thus, we could expect the annual calculation from the BP data in Figure S4 to be a few tenths of a percent higher if including non-fossil electricity.

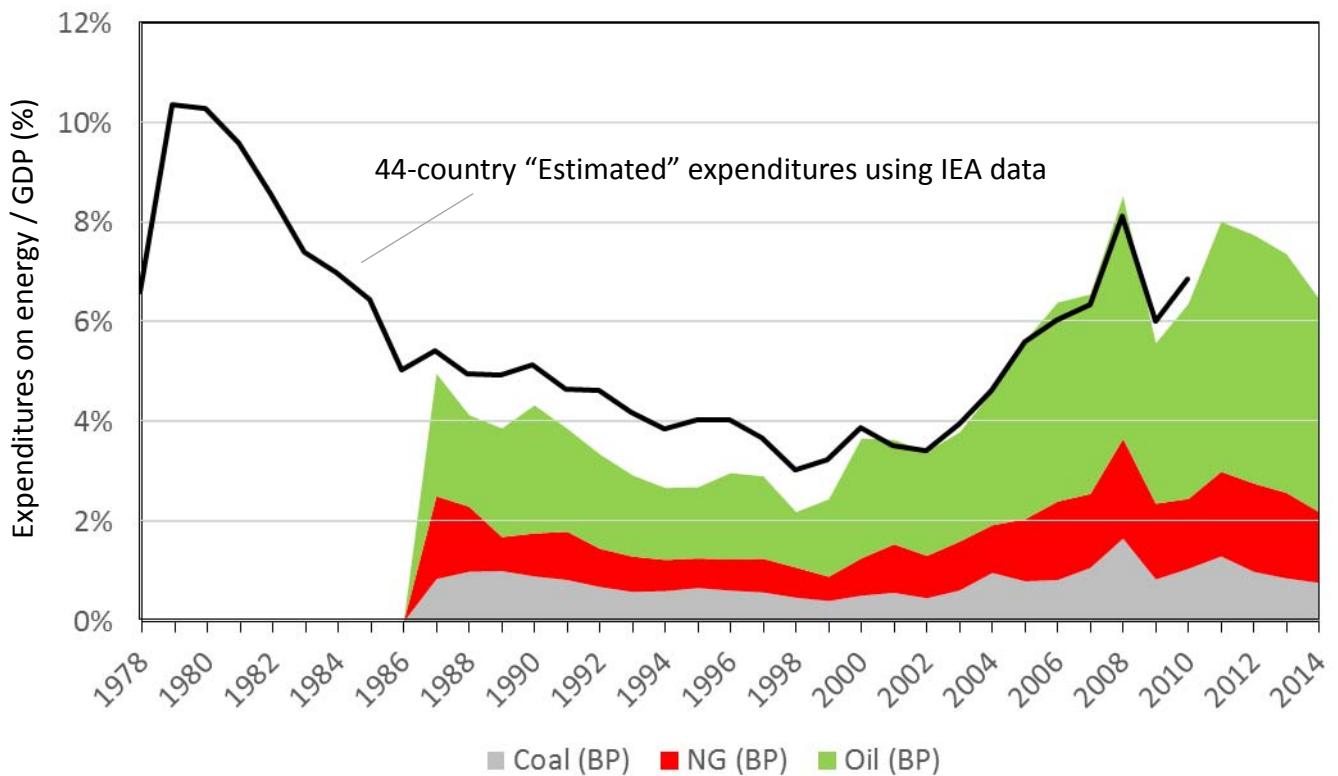


Figure S4. This figure compares two calculations for ‘world’ expenditures on energy divided by GDP, $f_{e,GDP}$. The black line is our Estimated $f_{e,GDP}$ calculated using the IEA data for the 44-country aggregate. The stacked chart for oil, natural gas, and coal use data from the BP Statistical Review of World Energy and divide by the world GDP (in nominal USD) as provided by the World Bank. Assumed prices for the BP calculations are: nominal crude oil price (\$/BBL) from worksheet ‘Oil - Crude prices since 1861’; German import natural gas price (\$/MMBtu) from worksheet ‘Gas - Prices ’; and for coal we used the Northwest Europe marker price (\$/tonne). Assumed energy consumption for BP calculations are: Total World oil consumption (BBL/yr) from worksheet ‘Oil Consumption - Barrels’; Total World natural gas consumption (Bcf/day) from worksheet ‘Gas Consumption - Bcf’ converted to trillion Btu per using BP’s conversion of 1.01133308326587 TBtu per 1 Bcf; and Total World coal consumption is from worksheet ‘Coal Consumption - Mtoe’ where we use an energy density conversion (Mtoe/million tonnes) as calculated from BP production data from sheets ‘Coal Production - Tonnes’ and ‘Coal Production - Mtoe’.

2. Introduction to data description and use

Due to restrictions in distribution of the IEA data (that are available for a fee), we cannot list the price values that have been allocated using our method. However, we do list the description of the prices that we substituted for missing values and other data sets used to estimate energy expenditures for each country. We also describe our estimate of the IEA's Total Primary Energy Supply.

3. Estimating Total Primary Energy Supply (TPES)

There are several limitations in the way the International Energy Agency (IEA) data are collected and available for our calculations. Due to data limitations, we are unable to completely reproduce the IEA's TPES calculations for the purpose of estimating energy expenditures. We estimated total energy consumption in each country using "bottom-up approach" from the IEA data to which we could associate a commodity price. We aggregate the total energy consumed by summing the energy consumed for each of the fuel types considered in this paper. Our "bottom-up" approach multiplies the consumption of fuel types by sector for coal, electricity, and natural gas (usually in mass units, e.g., kt) multiplied by energy content of fuel (energy per mass, e.g., kJ/kg) on an annual basis. For oil and refined oil products, we do not aggregate or use sectoral-specific data.

In Equation 2 of the manuscript, the sum of energy consumption does not equate to TPES from IEA. The IEA calculates total primary energy supply (TPES) as = production + imports – exports – international marine bunkers – international aviation bunkers ± stock changes. Note, exports, bunkers and stock changes incorporate the algebraic sign directly in the number. IEA TPES does include energy supplies used as industrial feedstocks. In general consumption = production + imports – exports for primary energy supplies and electricity. For refined oil products, to avoid double-counting of consumption of refined oil feedstocks, consumption = imports – exports. In order to maintain mathematical consistency, we only count individually-listed energy sources such that we can match each energy supply with a price, and generally we underestimate TPES, with some exceptions (see Figure S5). As mentioned in the main manuscript, the 44 countries within the IEA data set compose approximately 93–95% of world GDP and 73-79% of the IEA's listed world Total Primary Energy Supply (TPES) (78% after 1994) from 1978-2010. Here, our calculated energy consumption for the 44 country aggregate, to which we apply prices to estimate expenditures, is only 65-73% of that calculated by IEA for the selected 44 countries. Clearly our estimate of overall energy expenditures for the 44 country 'world' aggregate is an *underestimate* of total energy expenditures for these countries.

The countries for which our calculated energy consumption in any year from 1980-2010 is significantly different ($> \pm 20\%$) than the IEA's TPES are (see Supplemental Information data sheet for detailed ratios):

- Netherlands (we overestimate energy consumption by 16-56%),
- Russia (we underestimate by 12-22%),
- Finland (we underestimate by 13-24%),
- Sweden (we underestimate by 10-24%),

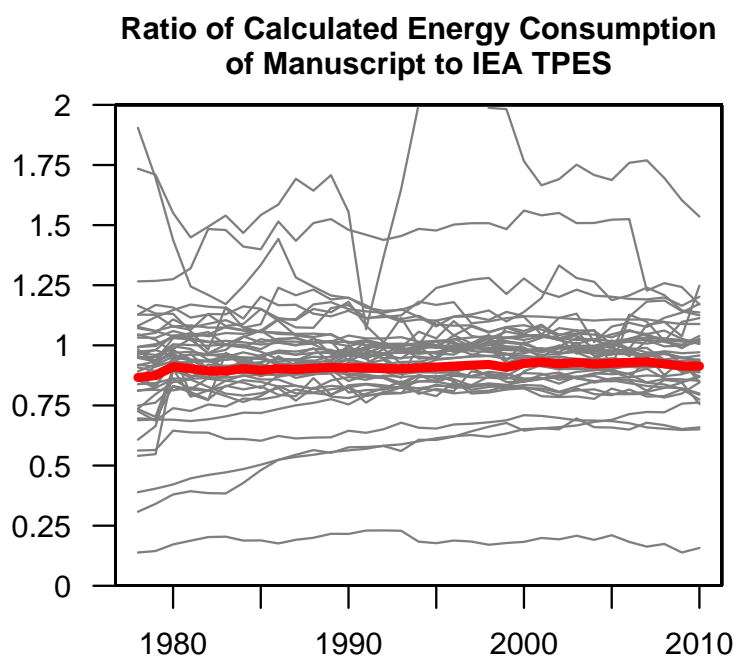


Figure S5. This figure displays calculations for the ratio of the total energy consumption calculated in the manuscript divided by the total primary energy supply (TPES) as reported in the IEA data. While we were able to accurately estimate TPES for most industrialized countries, the overall 44 country aggregate energy consumption (bold red line) ranges from a minimum of 89% (in 1980) to a maximum of 93% (in 2007) of that of the TPES reported by the IEA. The estimates for 1978 and 1979 are slightly lower at 87% due to assuming the ratio of nonfossil energy is the same as in 1980.

- Belgium (we overestimate by 5-33%),
- Brazil (we underestimate by 31-40%),
- China (we underestimate by 5-41%),
- Colombia (we underestimate by 6-23%),
- Greece (we overestimate by 7-28%),
- India (we underestimate by 24-58%),
- Indonesia (we underestimate by 30-62%),
- Iran (we underestimate by 23% in the year of highest underestimate and overestimate by 5% in the year of highest overestimate),
- Kuwait (we overestimate by 6-113%),
- Libya (we overestimate by 25% in 2010 and by < 20% for all other years),
- Nigeria (we underestimate by 77-84%),
- Saudi Arabia (we overestimate by 17-44% from 1980–1989 and < 20% after 1989), and
- Turkey (we underestimate 17-27% from 1980–1991 and < 20% after 1991).

Possible reasons for over or underestimating of TPES from our method are:

1. the difference between the fraction of electricity generation by type (or fuel) and fraction of electricity consumption by type (or fuel). For instance, we are assuming that if 10% of electricity generation in a country is from natural gas, then also 10% of electricity consumption is from natural gas.
2. statistical differences between EIA and IEA data on electricity generation types,
3. consumption of energy for which there is no associated commodity price or for which the energy resource is not commercially traded (e.g., some forms of biomass),
4. poor and incomplete reporting to the underlying data sets we used from IEA, and
5. incomplete or incorrect replication of IEA methods.

3.1. Oil and refined oil products

The IEA provides data on consumption in ‘transformation processes’ and ‘Final consumption’ of oil, natural gas liquids (NGLs), refinery feedstocks, additives/blending components, and ‘other hydrocarbons.’ We use these data for tracking crude oil and feedstocks.

The IEA also provide data for production, imports, and exports of gasoline, diesel, and fuel oil (here assumed as ‘light fuel oil’). We use these former data to estimate consumption of refined oil products that are imported as refined products as well as to subtract consumption for oil supply that is refined and exported, thus not consumed by the refining country. Thus, consumption of refined products is adjusted by net imports = imports + exports (exports listed as negative values). We do not consider production of refined products as energy consumption for a country as we do not want to double count the refinery inputs (e.g., crude oil) that we already count as consumed within the country.

IEA data units for oil and refined oil products are in kilotonnes.

1. Oil energy consumption is calculated by multiplying the mass (e.g. kilotonnes) of consumption in each end-use sector by the net calorific value (e.g. kJ/kt) for each of the materials listed in the IEA database.
 - a. Materials aggregated into “oil”
 - i. crude oil,
 - ii. natural gas liquids (NGLs),
 - iii. refinery feedstocks,
 - iv. additives/blending components, and
 - v. other hydrocarbons.
 - b. Refined oil products
 - i. motor gasoline
 - ii. diesel
 - iii. fuel oil
 - c. Sectors
 - i. no oil sectors

3.2. Natural gas

IEA provides natural gas consumption data in gross calorific value (GCV) and we convert it to net calorific value (NCV) using the IEA suggested correction factor of 0.9 units of NCV per 1 unit of GCV (all natural gas consumption except for Blast Furnace Gases).

1. Natural gas energy consumption is calculated by using the data of energy consumption already in units of energy (e.g. TJ) in each of the sectors listed in the IEA database.
 - a. Materials aggregated into “natural gas”

- i. natural gas (only)
- b. Sectors
 - i. Electricity,
 - ii. Industrial, and
 - iii. Residential.

3.3. Coal

We use the IEA data for five types of coal (anthracite, coking coal, other bituminous, sub-bituminous, and lignite) that are listed as being consumed in the time period from 1978-2010. IEA data units are in kilotonnes.

1. Coal energy consumption is calculated by multiplying the mass (e.g. kilotonnes) of consumption in each end-use sector by the net calorific value (e.g. kJ/kt) for each of the materials listed in the IEA database.
 - a. Materials aggregated into “coal”
 - i. Anthracite,
 - ii. coking coal,
 - iii. other bituminous coal,
 - iv. sub-bituminous coal, and
 - v. lignite
 - b. Sectors
 - i. Electricity,
 - ii. Industrial, and
 - iii. Residential.

3.4. Electricity

IEA electricity consumption data are listed in units of GWh/yr for total consumption and for residential consumption. We estimate industrial consumption as the total electricity consumption minus residential electricity consumption.

1. The IEA data indicate electricity generation fuel *input* in TJ/yr for the following types of fossil fuel inputs:
 - a. Coal (five sub-types above)
 - b. Natural Gas
 - c. Crude oil (five sub-types above)

d. Other various fossil-based fuel inputs

For non-fossil fuel electricity generation, the IEA data list *output* in GWh/yr for the following generation categories:

e. Nuclear (non-fossil)

f. Hydropower (including pumped hydro storage) (non-fossil)

g. Solar (two sub-types) (non-fossil)

h. Tide, wave and ocean (non-fossil)

i. Wind (non-fossil)

In order to estimate an expenditure for electricity consumption that *does not double-count* the fossil fuel inputs for electricity generation, we multiply the listed electricity prices (industrial and residential) by the fraction of electricity generation that does come from the non-fossil fuel sources. Due to data availability, we calculate this “non-fossil electricity” fraction using electricity *generation* data from the U.S. Electricity Information Administration website for international energy data (<http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=12>). Thus, we approximate the fraction of non-fossil electricity *consumption* as being equivalent to the fraction of non-fossil electricity *generation* for each country. This assumption is not purely true as some electricity is generated in one country and consumed in others.

4. Energy Conversion Factors

4.1. Oil

For OECD countries from 1980-2010 the oil price data are the first import oil price for each country (Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, & United States). For all countries for 1978-1979 and all non-OECD countries from 1978-2010 the applied oil price is the Brent Crude Oil spot price. Oil prices are converted from nominal US dollars per barrel (BBL) to real 2005 US dollars per MJ assuming 6.119 GJ/BBL.

Per the IEA Energy Statistics of OECD Countries: Beyond 2020 Documentation, we assume the following energy densities (kJ/kg) for refined products of gasoline, diesel, and fuel oil, respectively: for European countries 44,000, 42,600, and 40,000; for countries in the Americas 44,800, 42,600, and 40,200; for Asia and Oceania countries 44,600, 42,600, and 42,600.

4.2. Coal

The raw IEA price data for coal are in units of nominal \$US/tonne, and to calculate prices in units of \$US/MJ we used the IEA reported energy densities for each coal type (e.g., anthracite, coking coal, other bituminous, subbituminous, and lignite) and sector (e.g., electricity, industrial, or residential) as reported in units of kJ/kg. In some cases, the IEA data include a coal price in \$US/tonne but do not

include the energy content, in kJ/kg, of the specific type of coal per sector. We attempt to use a reported energy content for a country in a given year as much as possible. The process is as follows:

1. We calculate an average sector-specific (electricity, industrial, and residential) energy content for each year and each country based upon both the energy content (kJ/kg) and quantity (kt) of each type of coal consumed in that sector. The average energy content is total coal energy consumed divided by total mass consumed.
 - a. **Electricity sector:** If there is no reported energy content of coal for electricity in a given year, we substitute industrial coal content first, and residential coal content second.
 - b. **Industrial sector:** If there is no reported energy content of coal for industry in a given year, we substitute electricity coal content first, and residential coal content second.
 - c. **Residential sector:** If there is no reported energy content of coal for residential in a given year, we substitute industrial coal content first, and electricity coal content second.
2. For any instance in which there is a reported quantity of coal consumption, in units of kilotonnes (kt), but there is no reported coal energy content for that that type of coal in that year, we assume an energy content of 26,000 kJ/kg, regardless of country, coal type, or sector.

4.3. Natural Gas

The raw IEA price data for natural gas are in units of nominal \$US/10⁷ kcal, and to calculate prices in units of \$US/MJ we assumed a conversion of 2.3885 MJ/10⁷ kcal, or 1 kcal = 4186.8 J (= 1 × 10⁷ kcal = 41,868 MJ). The IEA reported data of natural gas supply are in "gross calorific value" (GCV). Thus, to calculate EIR and energy expenditures for natural gas we convert natural gas to "net calorific value" (NCV) by multiplying all GCV values by the IEA suggested factor of 0.9 for all natural gas types except for "Blast furnace gases" which is not altered.

4.4. Electricity

The raw IEA price data for electricity are in units of nominal \$US/kWh, and to calculate prices in units of \$US/MJ we use the IEA conversion of 1 kWh = 3.6 MJ.

The data for estimating the fraction of electricity derived from "non-fossil" sources (e.g., hydropower, nuclear, wind, solar) were obtained from the U.S. Energy Information Administration (EIA) International Energy Statistics [1]. The IEA data do not list consumption by electricity generation technology, but only electricity generation by technology and fuel. We assume that fraction of electricity *generation* from non-fossil sources is equal to the fraction of electricity *consumed*, but this is not strictly correct due to electricity imports and exports between countries (see Equation ??). The EIA statistics exist for 1980-2010, and for years 1978 and 1979, we assume the same fraction of non-fossil electricity as in 1980.

We also use the EIA data for estimating the fraction of electricity generation from nuclear power. This is important for comparing our "bottom-up" estimate of TPES to that from the IEA. In estimating TPES from non-fossil electricity, we use the conversion 1 kWh = 3.6 MJ for all electricity generation except

for nuclear power. The IEA assumes that nuclear power is 33% efficient such that for nuclear power 1 kWh = 10.9 MJ of TPES. The IEA also assumes that geothermal electricity is 10% efficient, but we do not specifically separate geothermal electricity since it is a very small fraction of electricity generation in the forty-four countries of our analysis.

$$\text{fraction non-fossil electricity} = 1 - \frac{\text{Generation from Fossil Fuels}}{\text{Total Net Generation}} \quad (\text{S1})$$

5. Calculations of $\text{EIR}_{p,n}$ and $f_{e,\text{GDP}}$

An Excel file has separate worksheets with the final data as calculated and presented in this paper:

1. **FractionGDPonEnergyWorld:** $f_{e,\text{GDP}}$ for each of the nine aggregated categories of energy commodity per end use for the aggregated 44 country data set.
2. **FractionGDPonEnergyActual:** $f_{e,\text{GDP}}$ for each country and year using the prices in the IEA data set.
3. **FractionGDPonEnergyEstimated:** our best estimate for $f_{e,\text{GDP}}$ for each country and year by substituting energy commodity prices for missing values per the method described in this supplemental information.
4. **$\text{EIR}_{\text{coal},\text{elec}}$:** $\text{EIR}_{p,n}$ for coal consumption for electricity for each year and country.
5. **$\text{EIR}_{\text{coal},\text{ind}}$:** $\text{EIR}_{p,n}$ for coal consumption for industry for each year and country.
6. **$\text{EIR}_{\text{coal},\text{res}}$:** $\text{EIR}_{p,n}$ for coal consumption for residential use for each year and country.
7. **$\text{EIR}_{\text{NG},\text{elec}}$:** $\text{EIR}_{p,n}$ for natural gas consumption for electricity for each year and country.
8. **$\text{EIR}_{\text{NG},\text{ind}}$:** $\text{EIR}_{p,n}$ for natural gas consumption for industry for each year and country.
9. **$\text{EIR}_{\text{NG},\text{res}}$:** $\text{EIR}_{p,n}$ for natural gas consumption for residential use for each year and country.
10. **$\text{EIR}_{\text{elec},\text{ind}}$:** $\text{EIR}_{p,n}$ for electricity consumption for industry for each year and country.
11. **$\text{EIR}_{\text{elec},\text{res}}$:** $\text{EIR}_{p,n}$ for electricity consumption for residential use for each year and country.
12. **EIR_{oil} :** $\text{EIR}_{p,n}$ for oil consumption for each year and country.
13. **PctGDPonOil_Estimated:** The fraction of GDP spent on oil for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
14. **PctGDP_CoalRes_Estimated:** The fraction of GDP spent on coal in residential sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.

15. **PctGDP_CoalInd_Estimated:** The fraction of GDP spent on coal in industrial sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
16. **PctGDP_CoalElec_Estimated:** The fraction of GDP spent on coal for the electricity generation sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
17. **PctGDP_NGRes_Estimated:** The fraction of GDP spent on natural gas in residential sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
18. **PctGDP_NGInd_Estimated:** The fraction of GDP spent on natural gas in industrial sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
19. **PctGDP_NGElec_Estimated:** The fraction of GDP spent on natural gas for the electricity generation sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
20. **PctGDP_ElecInd_Estimated:** The fraction of GDP spent on electricity in the industrial sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
21. **PctGDP_ElecRes_Estimated:** The fraction of GDP spent on electricity in the residential sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
22. **PctGDP_NFElecInd_Estimated:** The estimated fraction of GDP spent on non-fossil electricity in the industrial sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
23. **PctGDP_NFElecRes_Estimated:** The estimated fraction of GDP spent on non-fossil electricity in the residential sector for each of the 44 countries using 'estimated' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
24. **PctGDPonOil_Actual:** The fraction of GDP spent on oil for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
25. **PctGDP_CoalRes_Actual:** The fraction of GDP spent on coal in residential sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
26. **PctGDP_CoalInd_Actual:** The fraction of GDP spent on coal in industrial sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.

27. **PctGDP_CoalElec_Actual:** The fraction of GDP spent on coal for the electricity generation sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
28. **PctGDP_NGRes_Actual:** The fraction of GDP spent on natural gas in residential sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
29. **PctGDP_NGInd_Actual:** The fraction of GDP spent on natural gas in industrial sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
30. **PctGDP_NGElec_Actual:** The fraction of GDP spent on natural gas for the electricity generation sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
31. **PctGDP_ElecInd_Actual:** The fraction of GDP spent on electricity in the industrial sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
32. **PctGDP_ElecRes_Actual:** The fraction of GDP spent on electricity in the residential sector for each of the 44 countries using 'actual' data (primarily prices) to fill in data that are missing in the IEA data set for country-specific consumption quantities and prices.
33. **PctGDP_NFElecInd_Actual:** The estimated fraction of GDP spent on non-fossil electricity in the industrial sector for each of the 44 countries using 'actual' data as available in the IEA data set for country-specific consumption quantities and prices.
34. **PctGDP_NFElecRes_Actual:** The estimated fraction of GDP spent on non-fossil electricity in the residential sector for each of the 44 countries using 'actual' data as available in the IEA data set for country-specific consumption quantities and prices.
35. **PrimaryEnergyRatio:** The fraction of Total Primary Energy Supply (TPES) calculated in this paper as compared to the TPES reported by the IEA. A value less than 1 indicates a lower energy supply calculation than TPES.
36. **GEPR_Direct: Gross External Power Ratio (GEPR)** considering only direct power (energy/yr) inputs. The ratio of "total production (TJ)" to "total energy industry own use (EIOU)" for each of the 44 countries in the IEA data set. "World, all countries available" is the average of all countries, weighted by total energy production by each country, for all countries that do have data for a given year. "World, 44 countries" is the world average of all 44 countries weighted by total energy production by each country (for years without data for a given country, this column represents the average for all countries that do have data). "World, 28 countries in WIOD" is the average of only the 28 countries that are in both the IEA and WIOD data sets, weighted by total energy production by each country, and composed of the following countries: Australia, Austria,

Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Korea, Mexico, Netherlands, Poland, Portugal, Spain, Sweden, Turkey, U.K., U.S., Brazil, China, India, Indonesia, and Russia. “World, 26 OECD countries” is an average of the following countries, weighted by total energy production by each country: Australia, Austria, Belgium, Canada, Czechoslovakia/Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, U.K., U.S.

37. **NEPR_Direct: Net External Power Ratio (NEPR)** considering only direct power (energy/yr) inputs. The ratio of “total primary energy production (TJ) minus total energy industry own use (EIOU)” to “EIOU” for each of the 44 countries in the IEA data set. “World, all countries available” is the average of all countries, weighted by total energy production by each country, for all countries that do have data for a given year. “World, 44 countries” is the world average of all 44 countries weighted by total energy production by each country (for years without data for a given country, this column represents the average for all countries that do have data). “World, 28 countries in WIOD” is the average of only the 28 countries that are in both the IEA and WIOD data sets, weighted by total energy production by each country, and composed of the following countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Korea, Mexico, Netherlands, Poland, Portugal, Spain, Sweden, Turkey, U.K., U.S., Brazil, China, India, Indonesia, and Russia. “World, 26 OECD countries” is an average of the following countries, weighted by total energy production by each country: Australia, Austria, Belgium, Canada, Czechoslovakia/Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, U.K., U.S.
38. **NetImportRatio:** The ratio of net energy imports to energy supply for selected years = (imported energy - exported energy)/(TPES).
39. **WIOD_IC_GDP:** The sum of Intermediate Consumption (domestic and imports) plus Gross Capital Formation (domestic and imports) for 3 “energy sectors” of the World Input-Output Database (WIOD) divided by GDP. The 3 “energy sectors” are: “mining and quarrying”; “coke, refined petroleum, and nuclear fuel”; and “electricity, gas, and water supply”). This is calculated for each of the 28 countries in the WIOD database, using the WIOD national sheets.

6. Energy commodity types and end-use sectors

1. Oil energy consumption is calculated by multiplying the mass (e.g. kilotonnes) of consumption in each end-use sector by the net calorific value (e.g. kJ/kt) for each of the materials listed in the IEA database.
 - a. Materials aggregated into “oil”
 - i. crude oil,

- ii. natural gas liquids (NGLs),
 - iii. refinery feedstocks,
 - iv. additives/blending components, and
 - v. other hydrocarbons.
 - b. Sectors
 - i. no oil sectors
2. Natural gas energy consumption is calculated by using the data of energy consumption already in units of energy (e.g. TJ) in each of the sectors listed in the IEA database.
 - a. Materials aggregated into "natural gas"
 - i. natural gas (only)
 - b. Sectors
 - i. Electricity,
 - ii. Industrial, and
 - iii. Residential.
3. Coal energy consumption is calculated by multiplying the mass (e.g. kilotonnes) of consumption in each end-use sector by the net calorific value (e.g. kJ/kt) for each of the materials listed in the IEA database.
 - a. Materials aggregated into "coal"
 - i. Anthracite,
 - ii. coking coal,
 - iii. other bituminous coal,
 - iv. sub-bituminous coal, and
 - v. lignite
 - b. Sectors
 - i. Electricity,
 - ii. Industrial, and
 - iii. Residential.
4. The IEA data indicate electricity generation fuel *input* in TJ/yr for the following types of fossil fuel inputs:
 - a. Coal (five sub-types above)
 - b. Natural Gas
 - c. Crude oil (five sub-types above)

d. Other various fossil-based fuel inputs

For non-fossil fuel electricity generation, the IEA data list *output* in GWh/yr for the following generation categories:

e. Nuclear (non-fossil)

f. Hydropower (including pumped hydro storage) (non-fossil)

g. Solar (two sub-types) (non-fossil)

h. Tide, wave and ocean (non-fossil)

i. Wind (non-fossil)

In order to estimate an expenditure for electricity consumption that *does not double-count* the fossil fuel inputs for electricity generation, we multiply the listed electricity prices (industrial and residential) by the fraction of electricity generation that does come from the non-fossil fuel sources. Due to data availability, we calculate this “non-fossil electricity” fraction using electricity *generation* data from the U.S. Electricity Information Administration website for international energy data (<http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=12>). Thus, we approximate the fraction of non-fossil electricity *consumption* as being equivalent to the fraction of non-fossil electricity *generation* for each country. This assumption is not purely true as some electricity is generated in one country and consumed in others.

7. Estimating energy commodity prices where data are missing

The “estimated” expenditures on energy uses a method to estimate the total expenditures for fuel and sector types on that particular energy commodity within the sector when there is no price listed by the IEA. The IEA price data provided a great starting point for researching the prices for these fuel types. There are many countries within the IEA database that have the annual energy consumption for coal, natural gas, crude oil and electricity for each year. But for the work in this paper, the information that can be used by the IEA data is usually limited by the availability of price data. For various reasons, prices are not continually available on an annual basis. For the purposes of this research there were only 6 countries that had full data fidelity for consumption and prices for the years 1978-2010. This limitation created difficulty for tracking trends in the fraction of GDP spent on energy as countries would drop in and out of the calculations as the prices were available. Our “estimated” calculations are a good-faith efforts to use a methodology to assign prices to countries when those data are absent.

This allocation method is adapted from papers by Dittrich & Bringezu 2010 and Dittrich & Bringezu 2012, which used a similar approach to calculate indirect trade flows across countries when data were inconsistent [2,3]. Our hierarchy used to allocate prices is as follows:

1. Use other in-country prices for different sector product for given year
2. Use nearest geographic neighbor price for same product
3. Use nearest geographic neighbor for similar product
4. Use global average price based on available prices for that year within that sector

7.1. Price Allocation: Coal Prices - Electricity

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (2003-2010 Applied Japan industrial coal prices)
4. Germany – (No allocation applied)
5. Canada – (1985-1989 applied Canada industrial coal prices & 1993-1999 & 2010 applied USA elec coal prices)
6. Turkey – (1978 applied Austria elec coal price)
7. Spain – (1986-2010 applied Portugal elec coal price)
8. Russia – (1978-1996, & 2004-2010 applied Finland coal elec price, 1997-2003 applied Russia coal elec price)
9. Holland – (1994-2010 applied German coal elec price)
10. Italy – (1999-2002 applied Italy industrial coal price)
11. France – (1978-1979 applied France industrial coal price)
12. Austria – (1995-1999 applied Austria industrial coal price)
13. Denmark – (1983, 1987-1995 applied Denmark industrial coal price, 1996-2010 applied Germany elec coal price)
14. Finland – (No allocation applied)
15. Norway – (1978-1989 applied Sweden elec coal price, 1990-2010 Finland elec coal price)
16. Sweden – (1990-2010 applied Finland coal elec price)
17. Argentina – (1978-1979 applied dataset minimum, 1980-1987 & 1999-2010 applied Mexico elec coal price, 1988-1998 applied Brazil elec coal price)
18. Australia – (1992-2010 applied USA elec coal price)
19. Belgium – (2010 applied Germany elec coal price)
20. Brazil – (1978-1979 applied dataset minimum, 1980-1987 & 1999-2010 applied Mexico elec coal price)
21. China – (1978-1979 applied dataset minimum, 1980-1991 applied India elec coal price, 1992-2004 applied China industrial coal price, 2005-2009 applied Chinese Taipei elec coal price, 2010 applied dataset average elec price)

22. Chinese Taipei –(1978-1979 applied dataset minimum, 1980-1991 applied India elec coal price, 1992-1998 applied China industrial coal price, 2010 applied dataset average coal elec price)
23. Colombia – (1978-1979 applied dataset minimum, 1980-2010 applied Mexico elec coal price)
24. Czech Republic –(2003-2010 applied Austria elec coal price)
25. Greece – (1978-1980 applied Greece industrial coal price, 1981-1998 & 2003-2010 applied Italy elec coal price, 1999-2002 applied Italy industrial coal price)
26. Hungary – (1978-1979 applied dataset minimum, 1994, 2000-2010 applied Austria elec coal price, 1995-1999 applied Austria industrial coal price)
27. India – (1978 applied dataset minimum, 2010 applied dataset average elec coal price)
28. Indonesia – (1978-1979 applied dataset minimum, 1980-1989 applied India elec coal price, 2010 dataset average elec price)
29. Iran – (No calculable elec coal consumption, 1978-2010 applied dataset average elec coal price)
30. Iraq – (No calculable elec coal consumption, 1978-2010 applied dataset average elec coal price)
31. South Korea – (1978-1979 applied Japan elec coal price, 1980-2004 applied South Korea industrial coal price, 2010 applied Japan industrial coal price)
32. Kuwait – (No calculable elec coal consumption, 1978-2010 applied world average elec coal price)
33. Libya – (No calculable elec coal consumption, 1978-2010 applied world average elec coal price)
34. Malaysia – (1978-1989 applied India elec coal price, 1990-2009 applied Indonesia elec coal price, 2010 applied Japan industrial coal price)
35. Mexico – (No allocation applied)
36. New Zealand – (1978-1984 applied New Zealand industrial coal price, 1985-1991 Australia elec coal price, 1992-2010 applied USA elec coal price)
37. Nigeria – (1978-2006 applied South Africa elec coal price, 2006-2010 applied UK elec coal price)
38. Poland – (1978-1979 dataset minimum coal elec price)
39. Portugal – (No allocation applied)
40. Qatar – (No calculable elec coal consumption, 1978-2010 applied dataset average elec coal price)
41. Saudi Arabia –(No calculable elec coal consumption)
42. South Africa – (2006-2010 applied dataset minimum elec coal price)
43. Switzerland – (No calculable elec coal consumption, 1978-2010 applied Germany elec coal price)
44. Venezuela – (1978-1979 USA elec coal price, 1980-1993 & 2000-2010 Mexico elec coal price)

7.2. Price Allocation: Coal Prices – Industrial

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (No allocation applied)
4. Germany – (1995-2010 applied Germany elec coal prices)
5. Canada – (1990-1993 & 2000-2009 applied Canada elec coal price, 1993-1999 & 2010 applied USA industrial coal price)
6. Turkey – (1978 applied dataset minimum)
7. Spain – (1978-1985 applied Spain elec coal price, 1986-1996 & 2004-2009 applied Portugal elec coal price, 1997-2003 & 2010 applied Portugal industrial coal price)
8. Russia – (1978-1995 & 2004-2010 applied Finland elec price)
9. Holland – (1992-1994 applied Germany industrial coal price, 1995-2010 applied Germany elec coal price)
10. Italy – No allocation applied
11. France – (2004-2010 applied France elec coal price)
12. Austria – (No allocation applied)
13. Denmark – (1996-2010 applied Germany elec coal price)
14. Finland – (1978-2010 applied Finland elec coal price)
15. Norway – (1995-2010 applied Finland elec coal price)
16. Sweden – (1992-2010 applied Finland elec coal price)
17. Argentina – (1978-1979 applied dataset minimum industrial coal price, 1980-1987 & 1999-2010 applied Mexico elec coal price, 1988-1998 applied Brazil industrial coal price)
18. Australia – (1978-1981 & 1990-1991 applied Australia elec coal price, 1992-2010 applied UK industrial coal price)
19. Belgium – (1978-2009 applied Belgium elec coal price, 2010 applied Austria industrial coal price)
20. Brazil – (1978-1979 applied dataset minimum industrial coal price, 1980-1987 & 1999-2010 applied Mexico elec coal price)

21. China – (1978-1979 applied dataset minimum industrial coal price, 1980-1991 applied India elec coal price, 2005-2009 applied Chinese Taipei elec coal price, 2010 average dataset industrial coal price)
22. Chinese Taipei – (1978-1979 applied dataset minimum industrial coal price, 1980-1990 applied India industrial coal price, 1991 applied India coal elec price, 1999-2009 applied Chinese Taipei elec coal price, 1992-1998 applied China industrial coal price, 2010 applied dataset average coal industrial price)
23. Colombia – (1978-1979 applied dataset minimum industrial coal price, 1980-2010 applied Mexico elec coal price)
24. Czech Republic – (1978-1984 applied Czech Republic elec coal price, 2003-2010 applied Austria industrial coal price)
25. Greece – (1981-2010 applied Italy industrial coal price)
26. Hungary – (1978-1979 applied dataset minimum industrial coal price, 1980-1993 applied Hungary elec coal prices, 1994-2002 applied Czech industrial coal price, 2003-2010 applied Austria industrial coal price)
27. India – (1991 dataset average industrial coal price, 1992 China industrial coal price, 2010 dataset average industrial coal price)
28. Indonesia – (1978-1979 applied dataset minimum industrial coal price, 1980-1989 applied India elec coal prices, 2010 dataset average industrial coal price)
29. Iran – (1978-1979 applied dataset minimum industrial coal price, 1980-2009 applied India elec coal price, 2010 applied dataset average coal price)
30. Iraq – (No calculable industrial coal consumption, 1978-2010 applied dataset average industrial coal price)
31. South Korea – (1978-1979 applied dataset minimum industrial coal price, 2010 applied Japan industrial coal prices)
32. Kuwait – (No calculable industrial coal consumption, 1978-2010 applied world average industrial coal price)
33. Libya – (No calculable industrial coal consumption, 1978-2010 applied world average industrial coal price)
34. Malaysia – (1978-1979 applied dataset minimum industrial coal price, 1980-1989 India industrial coal price, 1990-2009 Indonesia industrial coal price, 2010 applied Japan industrial coal price)
35. Mexico – (1978-1979 applied dataset minimum industrial coal price, 1980-2010 applied Mexico elec coal price)

36. New Zealand – (1985-1991 applied Australia industrial coal price, 1992-2010 applied UK industrial coal price)
37. Nigeria – (1978-1990 applied South Africa elec coal price, 1991-2001 & 2003-2005 applied South Africa industrial coal price, 2002 applied South Africa elec coal price, 2006-2009 applied Canada elec coal price, 2010 applied world minimum industrial coal price)
38. Poland – (1978-1979 applied dataset minimum industrial coal price, 1980-2010 applied Poland elec coal price)
39. Portugal – (1978-1996 & 2004-2009 applied Portugal elec coal price)
40. Qatar – (No calculable industrial coal consumption, 1978-2010 applied world average industrial coal price)
41. Saudi Arabia – (No calculable industrial coal consumption, 1978-2010 applied world average industrial coal price)
42. South Africa – (1978-1989 applied South Africa elec coal price, 2002 applied South Africa elec coal price, 2006-2010 applied dataset minimum industrial coal price)
43. Switzerland – (No allocation applied)
44. Venezuela – (1978-1979 applied dataset minimum industrial coal price, 1980-1993 & 2000-2010 applied Mexico elec coal prices, 1994-1999 applied Venezuela elec coal price)

7.3. Price Allocation: Coal Prices - Residential

1. United States – (1978-2010 Applied dataset average residential coal price)
2. United Kingdom – (No allocation applied)
3. Japan – (1978-2010 Applied dataset average residential coal price)
4. Germany – (1995-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
5. Canada – (1978-2010 Applied dataset average residential coal price)
6. Turkey – (1978-1979 Applied dataset minimum residential coal price)
7. Spain – (1978-2002 Applied France residential coal price, 2003-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
8. Russia – (1978-2010 Applied Czech Republic residential coal price)
9. Holland – (1988-1994 Applied Germany coal residential price, Applied 1995-2005 Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)

10. Italy – (1984-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
11. France – (2003-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
12. Austria – (2006-2010 Applied Czech Republic residential coal price)
13. Denmark – (1978 & 2003-2005 Applied Austria residential coal price, 2006-2010 applied Czech Republic residential coal price)
14. Finland – (1978-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
15. Norway – (1986-2005 applied Austria residential coal price, 2006-2010 applied Czech Republic residential coal price)
16. Sweden – (1990-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
17. Argentina – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
18. Australia – (No calculable residential coal consumption, 1978-2010 applied data set minimum residential coal price)
19. Belgium – (1978-1994 Applied Germany residential coal price, 1995-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
20. Brazil – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
21. China – (1978-1991 & 2003-2010 Applied dataset average residential coal price)
22. Chinese Taipei – (1978-1901 data set average residential coal price, 1992-2002 Applied China residential coal price, 2003-2010 Applied dataset average residential coal price)
23. Colombia – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
24. Czech Republic – (No allocation applied)
25. Greece – (1978-1983 Applied Italy residential coal price, 1984-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
26. Hungary – (1978-2010 Applied Czech Republic residential coal price)
27. India – (1978, 1991, 2004 & 2006-2010 Applied dataset average residential coal price, 1992-1996 Applied China residential coal price)

28. Indonesia – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
29. Iran – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
30. Iraq – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
31. South Korea – (No calculable residential coal consumption, applied world dataset average residential coal price)
32. Kuwait – (No calculable residential coal consumption, 1978-2010 applied world average residential coal price)
33. Libya – (No calculable residential coal consumption, 1978-2010 applied world average residential coal price)
34. Malaysia – (No calculable residential coal consumption, 1978-2010 applied world average residential coal price)
35. Mexico – (No calculable residential coal consumption, 1978-2010 applied world average residential coal price)
36. New Zealand – (1978-1980 Applied UK residential coal price, 1985-2010 Applied dataset average residential coal price)
37. Nigeria – (No calculable residential coal consumption)
38. Poland – (1978-1994 Applied Germany residential coal price, 1995-2005 Applied Austria residential coal price, 2006-2010 Applied Czech Republic residential coal price)
39. Portugal – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
40. Qatar – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
41. Saudi Arabia – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)
42. South Africa – (1978-1989 South Africa electricity coal price, & 2006-2010 Applied dataset minimum residential coal price)
43. Switzerland – (1993-2010 Switzerland industrial coal price)
44. Venezuela – (No calculable residential coal consumption, 1978-2010 applied dataset average residential coal price)

7.4. Price Allocation: Natural Gas Prices & Electricity

1. United States – (No allocation applied)
2. United Kingdom – (1990-1992 Applied UK industrial natural gas price)
3. Japan – (1998-2010 Applied Japan industrial natural gas price)
4. Germany – (2001-2010 Applied Germany industrial natural gas price)
5. Canada – (1993-1999 & 2008-2010 Applied Canada industrial natural gas price)
6. Turkey – (1982-1987 Applied dataset average electric natural gas price)
7. Spain – (2001-2010 Applied Spain industrial natural gas price)
8. Russia – (1978-1992 & 1995-2000 Applied dataset minimum electric natural gas price, 1994 & 2004-2010 Applied Russia industrial natural gas price)
9. Holland – (1999-2003 & 2007-2010 Applied Holland industrial natural gas prices, 2004-2006 Applied UK electric natural gas price)
10. Italy – (1996-1999 Applied Austria industrial natural gas price, 2000-2010 applied Germany industrial natural gas price)
11. France – (1978-2010 Applied France industrial natural gas price)
12. Austria – (1995-1999 Applied Austria industrial natural gas price, 2000-2010 Applied Germany industrial natural gas price)
13. Denmark – (No calculable electric natural gas consumption, 1978-2000 applied German electric natural gas price, 2001-2010 applied German industrial natural gas price)
14. Finland – No allocation applied
15. Norway – (1978-1989 & 1993-2010 Applied UK electric natural gas price, 1990-1992 applied UK industrial natural gas price)
16. Sweden – (No calculable electric natural gas consumption; 1978-1989 & 1993-2010 Applied UK electric natural gas price, 1990-1992 applied UK industrial natural gas price)
17. Argentina – (1978-2010 Applied dataset average electric natural gas price)
18. Australia – (1978-1997 Applied Australia industrial natural gas price, 1998-1999 & 2008-2010 applied Canada industrial natural gas price, 2000-2007 Applied Canada electric natural gas price)
19. Belgium – (1998-2010 Applied Germany industrial natural gas price)
20. Brazil – (1978-2010 Applied dataset average electric natural gas price)

21. China – (1980-1989 Applied dataset average electric natural gas price, 1990-2010 Applied Chinese Taipei electric natural gas price)
22. Chinese Taipei – (1978-1989 applied dataset average electricity natural gas price)
23. Colombia – (1978-2010 Applied Mexico electricity natural gas price)
24. Czech Republic – (1978-1984 Applied Germany electric natural gas price, 2004-2010 Applied Czech Republic industrial natural gas price)
25. Greece – (1997-2005 & 2007-2010 Applied Greece industrial natural gas price, 2006 Applied Hungary electric natural gas price)
26. Hungary – (1978-1979 Applied Austria electric natural gas price)
27. India – (1978-2010 Applied dataset average electric natural gas price)
28. Indonesia – (1978-1989 Applied dataset minimum electric natural gas price, 1990-1998 Applied Indonesia industrial natural gas price, 2010 dataset average industrial natural gas price)
29. Iran – (1978-2010 Applied dataset minimum electric natural gas price)
30. Iraq – (1978-2010 Applied dataset minimum electric natural gas price)
31. South Korea – (1978-1997 Applied Japan electric natural gas price, 1998-2003 & 2010 Applied Japan industrial natural gas price)
32. Kuwait – (1978-2010 Applied dataset minimum electric natural gas price)
33. Libya – (1978-2010 Applied dataset minimum electric natural gas price)
34. Malaysia – (1978-2010 Applied dataset minimum electric natural gas price)
35. Mexico – (No allocation applied)
36. New Zealand – (1978-1984 Applied dataset average electric natural gas price, 1985-2010 Applied New Zealand industrial natural gas price)
37. Nigeria – (1978-2010 Applied dataset minimum electric natural gas price)
38. Poland – (1978-2000 applied Germany electric natural gas price, 2001-2003 applied Czech Republic electric natural gas price)
39. Portugal – (1978-2000 Applied Spain electric natural gas price, 2001-2002 applied Spain industrial natural gas price)
40. Qatar – (1978-2010 Applied dataset minimum electric natural gas price)
41. Saudi Arabia – (1978-2010 Applied dataset minimum electric natural gas price)

42. South Africa – (1978-2001 & 2003-2005 applied South Africa industrial natural gas price, 2002 & 2006-2010 dataset average industrial natural gas price; No calculable electric natural gas consumption in IEA data)
43. Switzerland – (1978-2010 Applied Switzerland industrial natural gas price)
44. Venezuela – (1978-1996 & 2001-2010 Applied dataset minimum electric natural gas price)

7.5. Price Allocation: Natural Gas Prices - Industrial

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (No allocation applied)
4. Germany – (No allocation applied)
5. Canada – (No allocation applied)
6. Turkey – (1982-1987 Applied dataset average industrial natural gas price)
7. Spain – No allocation applied)
8. Russia – (1978-1992 & 1995-1999 Applied dataset minimum industrial natural gas price)
9. Holland – (2004-2006 Applied United Kingdom electric natural gas price)
10. Italy – (1999-2003 Applied Spain industrial natural gas price)
11. France – (No allocation applied)
12. Austria – (2000-2003 Applied Spain industrial natural gas price, 2004-2010 Applied Italy industrial natural gas price)
13. Denmark – (1981-2010 Applied Germany industrial natural gas price)
14. Finland – (1978-2010 Applied Finland electric natural gas price)
15. Norway – (1978-2010 Applied UK industrial natural gas price)
16. Sweden – (1985-2006 Applied Finland electric natural gas price)
17. Argentina – (1978-2010 Applied Mexico electric natural gas price)
18. Australia – (2000-2007 Applied Canada electric natural gas price, 1998-1999 & 2008-2010 applied Canada industrial natural gas price)
19. Belgium – (1978-1997 Applied Belgium electric natural gas price, 1998-2010 Applied France industrial natural gas price)

20. Brazil – (1978-1987 Applied dataset minimum industrial natural gas price, 1999-2010 Applied Mexico electric natural gas price)
21. China – (1978-1989 Applied dataset average industrial natural gas price, 1990-1996 & 1998-2010 Applied Chinese Taipei electric natural gas price)
22. Chinese Taipei – (1978-1989 Applied dataset average industrial natural gas price, 1990-2010 Applied Chinese Taipei electric natural gas price)
23. Colombia – (1978-2008 Applied Mexico industrial natural gas price, 2009-2010 applied dataset average industrial natural gas price)
24. Czech Republic – (1978-1984 Applied Austria industrial natural gas price)
25. Greece – (1978-1996 & 2006 Applied Italy industrial natural gas price)
26. Hungary – (1978-1984 Applied Austria industrial natural gas price, 1985-2010 Applied Czech industrial natural gas price)
27. India – (1978-2010 Applied dataset average industrial natural gas price)
28. Indonesia – (1978-1989 Applied dataset minimum industrial natural gas price, 2001-2009 Applied Indonesia electric natural gas price, 2010 applied dataset minimum industrial natural gas price)
29. Iran – (1978-2010 Applied dataset minimum industrial natural gas price)
30. Iraq – (1978-2010 Applied dataset minimum industrial natural gas price)
31. South Korea – (1978-2003 Applied Japan industrial natural gas)
32. Kuwait – (1978-2010 Applied dataset minimum industrial natural gas price)
33. Libya – (1978-2010 Applied dataset minimum industrial natural gas price)
34. Malaysia – (1978-2010 Applied dataset minimum industrial natural gas price)
35. Mexico – (2008-2010 Applied Mexico electric natural gas price)
36. New Zealand – (1978-1984 Applied dataset average industrial natural gas price)
37. Nigeria – (1978-2010 Applied dataset minimum industrial natural gas price)
38. Poland – (1978-2010 Applied Germany industrial natural gas price)
39. Portugal – (1978-2001 Applied Spain industrial natural gas price)
40. Qatar – (1978-2010 Applied dataset minimum industrial natural gas price)
41. Saudi Arabia – (1978-2010 Applied dataset minimum industrial natural gas price)
42. South Africa – (2002 & 2006-2010 Applied dataset average industrial natural gas price)

43. Switzerland – (No allocation applied)
44. Venezuela – (1978-1996 & 2001-2010 Applied dataset minimum industrial natural gas price, 1997-2000 Applied Venezuela electric natural gas price)

7.6. Price Allocation: Natural Gas Prices - Residential

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (No allocation applied)
4. Germany – (No allocation applied)
5. Canada – (No allocation applied)
6. Turkey – (1982-1987 Applied dataset average residential natural gas price)
7. Spain – (No allocation applied)
8. Russia – (1978-1992, 1995-1999 & 2005-2010 Applied absolute minimum residential natural gas price due to price control in gas-producing county)
9. Holland – (No allocation applied)
10. Italy – (2000-2003 Applied Austria residential natural gas price)
11. France – (No allocation applied)
12. Austria – (No allocation applied)
13. Denmark – (1980-1983 & 2006-2008 Applied Germany residential natural gas price)
14. Finland – (1978-1979 & 1984-2005 Applied Denmark residential natural gas price, 1980-1983 & 2006-2010 Applied Germany residential natural gas price)
15. Norway – (1978-2010 Applied UK residential natural gas price)
16. Sweden – (1978-1984 & 2006 applied UK residential natural gas price, 1985-2005 Applied Denmark residential natural gas price)
17. Argentina – (1978-2010 Applied dataset average residential natural gas price)
18. Australia – (1998-2010 Applied Canada residential natural gas price)
19. Belgium – (1978-2010 Applied Germany residential natural gas price)
20. Brazil – (1978-2010 Applied dataset average residential natural gas price)

21. China – (1978-2010 Applied dataset average residential natural gas price)
22. Chinese Taipei – (1978-2010 Applied dataset average residential natural gas price)
23. Colombia – (1978-2010 Applied dataset average residential natural gas price)
24. Czech Republic – (No allocation applied)
25. Greece – (1978-1997 & 2006 Applied Italy residential natural gas price)
26. Hungary – (1978-2010 Applied Czech Republic residential natural gas price)
27. India – (1978-2010 Applied dataset average residential natural gas price)
28. Indonesia – (1978-1990 & 2001-2010 Applied minimum residential natural gas price due to assumed price control in gas-producing county)
29. Iran – (1978-2010 Applied minimum residential natural gas price due to price control in gas-producing county)
30. Iraq – (No calculable residential natural gas consumption, 1978-2010 Applied minimum dataset residential natural gas price)
31. South Korea – (1987-2003 Applied Japan residential natural gas price)
32. Kuwait – (No calculable residential natural gas consumption)
33. Libya – (No calculable residential natural gas consumption, 1978-2010 Applied dataset minimum residential natural gas price)
34. Malaysia – (1978-2010 Applied minimum residential natural gas price due to price control in gas-producing county)
35. Mexico – (1978-2003 Applied USA residential natural gas price)
36. New Zealand – (1978-1984 Applied dataset average residential natural gas price)
37. Nigeria – (No calculable residential natural gas consumption)
38. Poland – (1978-2010 Applied Germany residential natural gas price)
39. Portugal – (1978-2001 Applied Spain residential natural gas price)
40. Qatar – (No calculable residential natural gas consumption)
41. Saudi Arabia – (No calculable residential natural gas consumption)
42. South Africa – (No calculable residential natural gas consumption, applied dataset average residential natural gas price)
43. Switzerland – (No allocation applied)

44. Venezuela – (1978-2010 Applied minimum residential natural gas price due to price control in gas-producing county)

7.7. Price Allocation: Oil

Due to differences in mass densities (kg/m^3) and energy densities (kJ/kg) of different crude oils, we assume a constant energy density of 6,119 MJ/BBL for all oil to convert from units of \$/BBL to \$/MJ.

The IEA data list first import oil prices for most OECD countries for 1980-2010. For each country, OECD and non-OECD, for 1978 and 1979, we assumed the annual average Brent oil price for "Estimated" oil expenditures, using reported values in the 2013 BP Statistical Review in nominal US dollars per barrel (\$/BBL).

Note: Because of the assumed price allocation for calculating 'estimated' world oil expenditures, the BP Brent oil price is greater than the 'maximum' oil price in the IEA data set for 1980, and thus the 'estimated' world oil expenditures are close to, but greater than, the calculated 'maximum' world oil expenditures for 1980.

All other oil price allocations are listed as below:

1. Czech Republic – (1980-1991 & 1996-1999 Applied German first import oil price)
2. Finland – (1980-1991 Applied Norway first oil import price)
3. France – (1980-1991 Applied German first import oil price)
4. South Korea – (1980-1994 Applied Japan first import oil price)
5. Poland – (1980-2007 Applied German first import oil price)
6. Turkey – (1980-1982 Applied Greece first import oil price)

7.8. Price Allocation: Electricity - Industrial

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (No allocation applied)
4. Germany – (No allocation applied)
5. Canada – (No allocation applied)
6. Turkey – (No allocation applied)
7. Spain – (2010 Portugal industrial electric price)
8. Russia – (1980-2001 Applied Canada electric industrial price)
9. Holland – (2002-2006 Applied Germany electric industrial price)

10. Italy – (No allocation applied)
11. France – (No allocation applied)
12. Austria – (2001-2003 & 2009-2010 Applied Germany electric industrial price)
13. Denmark – (No allocation applied)
14. Finland – (1980-1991 & 2000-2010 Applied Norway electric industrial price, 1992-1999 Applied Denmark industrial electric price)
15. Norway – (1992-1999 Applied Denmark industrial electric price)
16. Sweden – (1998-2006 Applied Denmark industrial electric price)
17. Argentina – (1980-2010 Applied dataset average industrial electric price)
18. Australia – (2005-2010 Applied New Zealand industrial electric price)
19. Belgium – (1980-2010 Applied France industrial electric price)
20. Brazil – (1980-1987 & 1999-2010 Applied dataset average industrial electric price)
21. China – (1980-1989 & 1997-2000 Applied Canada electric industrial price, 2001-2010 Applied Russia industrial electric price)
22. Chinese Taipei – (1980-1989 & 1997-2000 Applied Canada electric industrial price, 1990-1996 Applied China industrial electric price, 2001-2010 Applied Russia industrial electric price)
23. Colombia – (1980-2010 Applied dataset average industrial electric price)
24. Czech Republic – (1980-1984 Applied Austria industrial electric price)
25. Greece – (2006-2007 Applied Italy industrial electric price)
26. Hungary – (1978-1984 Applied Austria industrial electric price, 1985-2010 Applied Czech Republic industrial electric price)
27. India – (1978-1987 Applied Canada electric industrial price, 1988-1991 & 2001-2010 Applied Indonesia industrial electric price)
28. Indonesia – (1978-1987 Applied Canada electric industrial price)
29. Iran – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
30. Iraq – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
31. South Korea – (2010 Applied South Korea residential natural gas price)

32. Kuwait – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
33. Libya – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
34. Malaysia India – (1978-1987 Applied Canada electric industrial price, 1988-2010 Applied Indonesia industrial electric price)
35. Mexico – (No allocation applied)
36. New Zealand – (No allocation applied)
37. Nigeria – (1978-2006 Applied South Africa industrial electric price, 2007-2010 Applied Indonesia industrial electric price)
38. Poland – (1978-2010 Applied Germany industrial electric price)
39. Portugal – (No allocation applied)
40. Qatar – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
41. Saudi Arabia – (1978-2001 Applied Canada electric industrial price, 2002-2010 Applied Russia industrial electric price)
42. South Africa – (2007-2010 Applied dataset minimum industrial electric price)
43. Switzerland – (No allocation applied)
44. Venezuela – (1978-2010 Applied dataset average industrial electric price)

7.9. Price Allocation: Electricity \hat{A} Residential

1. United States – (No allocation applied)
2. United Kingdom – (No allocation applied)
3. Japan – (No allocation applied)
4. Germany – (No allocation applied)
5. Canada – (No allocation applied)
6. Turkey – (No allocation applied)
7. Spain – (2010 Portugal residential electric price)
8. Russia – (1978-1992 & 1995-2010 Applied Canada residential electric prices)

9. Holland – (No allocation applied)
10. Italy – (No allocation applied)
11. France – (No allocation applied)
12. Austria – (No allocation applied)
13. Denmark – (No allocation applied)
14. Finland – (1978-2010 Applied Norway residential electric prices)
15. Norway – (No allocation applied)
16. Sweden – (1997-2006 Applied Norway residential electric prices)
17. Argentina – (1978-2010 Applied dataset average residential electric price)
18. Australia – (2005-2010 Applied Canada residential electric price)
19. Belgium – (1978-2010 Applied France residential electric price)
20. Brazil – (1978-1987 & 1999-2010 Applied dataset average residential electric price)
21. China – (1978-1994 & 1998-2010 Applied Canada residential electric price)
22. Chinese Taipei – (1980-1994 & 1998-2010 Applied Canada residential electric price, 1995-1997 Applied China residential electric price)
23. Colombia – (1978-2010 Applied dataset average residential electric price)
24. Czech Republic – (1978-1984 Applied Austria residential electric price)
25. Greece – (2006-2007 Applied Italy residential electric price)
26. Hungary – (1978-2010 Applied Czech Republic residential electric price)
27. India – (1978-1987, 2004, & 2006-2010 Applied dataset average residential electric price, 1988-1991 Applied Indonesia residential electric price)
28. Indonesia – (1978-1987 Applied dataset average residential electric price)
29. Iran – (1978-2010 Applied Canada residential electric price)
30. Iraq – (1978-2010 Applied Canada residential electric price)
31. South Korea – (No allocation applied)
32. Kuwait – (1978-2010 Applied Canada residential electric price)
33. Libya – (1978-2010 Applied Canada residential electric price)

34. Malaysia – (1978-1987 Applied dataset average residential electric price, 1988-2010 Applied Indonesia residential electric price)
35. Mexico – (No allocation applied)
36. New Zealand – (No allocation applied)
37. Nigeria – (1978-2006 Applied South Africa residential electric price, 2007-2010 Applied dataset average residential electric price)
38. Poland – (1978-2010 Applied Germany residential electric price)
39. Portugal – (No allocation applied)
40. Qatar – (1978-2010 Applied Canada residential electric price)
41. Saudi Arabia – (1978-2010 Applied Canada residential electric price)
42. South Africa – (2007-2010 Applied dataset average residential electric price)
43. Switzerland – (No allocation applied)
44. Venezuela – (1978-2010 Applied dataset average residential electric price)

7.10. Electricity allocation between Industrial and Residential sectors

Several countries could not have prices allocated because they did not have an electricity sector ratio broken down between industrial and residential, though there were data in total for the amount of electricity consumed. Many of these countries are non-OECD countries. Given this fact, we applied Mexico's ratio of industrial to residential electricity consumption to all of those countries which did not have an allocation between the industrial and residential sectors for electricity consumption.

N/A = IEA data set specifies the electricity end-use sector each year.

1. United States – N/A
2. United Kingdom – N/A
3. Japan – N/A
4. Germany – N/A
5. Canada – N/A
6. Turkey – N/A
7. Spain – N/A
8. Russia – 1980-2010 Constant 80% industrial/20% residential ratio held
9. Holland – N/A

10. Italy – N/A
11. France – N/A
12. Austria – N/A
13. Denmark – N/A
14. Finland – N/A
15. Norway – N/A
16. Sweden – N/A
17. Argentina – 1980-2010 Mexico electricity sector
18. Australia – N/A
19. Belgium – N/A
20. Brazil – 1980-2010 Mexico electricity sector
21. China – 1980-2010 Mexico electricity sector
22. Chinese Taipei – 1980-2010 Mexico electricity sector
23. Colombia – 1980-2010 Mexico electricity sector
24. Czech Republic – N/A
25. Greece – N/A
26. Hungary – N/A
27. India – 1980-2010 Mexico electricity sector
28. Indonesia – 1980-2010 Mexico electricity sector
29. Iran – 1980-2010 Mexico electricity sector
30. Iraq – 1980-2010 Mexico electricity sector
31. South Korea – N/A
32. Kuwait – 1980-2010 Mexico electricity sector
33. Libya – 1980-2010 Mexico electricity sector
34. Malaysia – 1980-2010 Mexico electricity sector
35. Mexico – N/A

36. New Zealand – N/A
37. Nigeria – 1980-2010 Mexico electricity sector
38. Poland – N/A
39. Portugal – N/A
40. Qatar – 1980-2010 Mexico electricity sector
41. Saudi Arabia – 1980-2010 Mexico electricity sector
42. South Africa – 1980-2010 Mexico electricity sector
43. Switzerland – N/A
44. Venezuela – 1980-2010 Mexico electricity sector

8. Oil prices for oil exporting countries

Our analysis uses energy prices and not energy costs for calculating expenditures and energy intensity ratios ($EIR_{p,n}$). This presents a limitation in that the calculations represent estimates of the net energy and energy return ratios of the world above the actual cost of producing energy. This limitation is evident in the way energy prices are collected, and most specifically net oil exporting countries. Those countries are often much more protective of their data and especially the price at which the country quotes for domestic consumption of oil products. Those countries which are net importers of oil often times have much more transparency in the price that is paid for imports of crude oil. The IEA supports this data collection activity for OECD countries and attempts to sort out taxes, inflation, and exchange rate effects that might distort our EIR measures in any given year. Some countries that are net exporters of crude oil such as Norway, Mexico and Canada have fairly reliable price data that are of good quality relative to importing OECD countries. This type of openness perhaps helps these countries avoid distortion impacts to the EIR measures in contrast with other net export countries for which net energy measures are only an estimate in this paper.

9. Calculating $NEPR_{direct}$

9.1. Data availability

All data for ‘energy production’ and EIOU are in provided by IEA in units of kilotonnes, and we multiply them by conversion factors (kJ/kt) from the IEA Energy Statistics Database and the IEA Energy Statistics Manual (2005) to obtain units of energy.

The countries and dates with sufficient data to perform the $NEPR_{direct}$ calculation are as follows. We indicate this to highlight that there are no data (from the International Energy Agency or supplementary sources such as the U.S. Energy Information Administration) to calculate the 44-country aggregate

NEPR_{direct} for 1960-1979. The following bullets indicate the time spans and countries with Energy Industry Own Use (EIOU) data that allow the calculation of NEPR_{direct}.

1. From 1978-2010 these 26 countries have data from the IEA. They also have data from 1960-1977 except as indicated with specific country and year missing data indicated with a specific added description: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, U.K., and U.S.
 - a. Denmark: no data 1971
 - b. Finland: no data 1960-1973
 - c. Sweden: no data 1968-1973
 - d. Czechoslovakia/Czech Republic: no data 1960-1970
 - e. Hungary: no data 1960-1964
 - f. South Korea: no data 1960-1970
 - g. Mexico: no data 1960-1970
 - h. Switzerland: no data 1960-1973
2. From 1980-2010 these 18 additional countries have EIOU and energy production data: Argentina, Brazil, China, Chinese Taipei, Colombia, India, Indonesia, Iran, Iraq, Kuwait, Libya, Malaysia, Nigeria, Qatar, Russia, Saudi Arabia, South Africa, and Venezuela.

9.2. Primary energy production data

Data availability for primary energy production are as follows:

1. Primary Coal Products

- a. 1960-1977: Hard Coal, Brown Coal (aggregate groups)
- b. 1978-2010: Anthracite, Coking Coal, Other Bituminous Coal, Sub-bituminous, Lignite

2. Primary Oil Products

- a. 1960-1971: Crude Oil/NGL/Feedstocks (aggregate group)
- b. 1971-2010: Crude Oil, Natural Gas Liquids (NGL)

3. Natural Gas

4. Renewables (electricity): Wave/Tide, Hydro+Pumped Hydro, Solar, Wind, and Geothermal

- a. For the 26 OECD countries, all data on renewable energy production come from the IEA.

- b. For the 18 additional non-OECD countries, data for renewable energy production come from the IEA for 1990-2010 and from the International Energy Statistics website (<http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm>) of the U.S. Energy Information Administration for 1980-1989.

5. Nuclear electricity

9.3. Energy Industry Own Use (EIOU) data

The IEA lists the following energy types for EIOU:

1. Coal

- a. Primary Coal Products
- b. Derived Fuels
 - i. Peat
 - ii. Patent Fuels
 - iii. Coke-oven coke
 - iv. gas coke
 - v. coal tar
 - vi. briquettes (BKB)
 - vii. gas works gas
 - viii. coke oven gas
 - ix. blast furnace gas
 - x. other recovered gases

2. Oil

- a. Primary Oil Products
- b. Secondary Oil Products
 - i. Additives/blending components
 - ii. refinery feedstocks
 - iii. refinery gas
 - iv. ethane
 - v. liquefied petroleum gases
 - vi. motor gasoline
 - vii. aviation gasoline
 - viii. gasoline type jet fuel
 - ix. kerosene type jet fuel
 - x. other kerosene

- xi. gas/diesel oil
- xii. fuel oil
- xiii. naphtha
- xiv. white spirits & SBP
- xv. lubricants
- xvi. bitumen
- xvii. paraffin waxes
- xviii. petroleum coke
- xix. non-specified oil products
- xx. heat output from non-specified combustible fuels

NOTE: Conversion Factors for crude oil only do not appear in the IEA statistics database until 1971; from 1960-1970 energy densities are grouped under an aggregate “crude oil/NGL/feedstocks” energy density. In order to estimate production and EIOU for the following countries for 1960-1970, the relevant aggregate conversion factor was used as a substitute for the following years and countries:

- 1960-1970: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Turkey, U.K., and U.S.
- Hungary: 1965-1970
- New Zealand: 1964-1970
- Switzerland: 1963-1970

3. Natural Gas Natural gas, gas works gas, and coke oven gas were converted from gross to net TJ by multiplying by a factor of 0.9 per the IEA (2005) Energy Statistics Manual.

4. Electricity

- a. Electricity
- b. Heat
- c. Municipal waste (non-renewable)
- d. Renewables
- e. Elec/heat output from non-specified manufactured gases
 - i. Industrial waste
 - ii. Municipal waste (renewable)
 - iii. Primary solid biofuels
 - iv. Biogases
 - v. Biogasoline
 - vi. Biodiesels

- vii. Other liquid biofuels
- viii. Non-specified primary biofuels
- ix. Charcoal

5. Renewables

Renewables are defined here as to include solar, hydro and pumped hydro, wind, geothermal, and tide (IEA Energy Statistics Manual). Net GWh were converted to TJ by multiplying by a factor of 3.6 TJ/GWh per IEA methods. Additionally, EIOU for geothermal is divided by 0.1 to account for the IEA assumption of 10% efficiency for geothermal power.

6. Nuclear

Net GWh from nuclear power plants were converted to TJ by multiplying by a factor of 3.6 TJ/GWh per IEA methods (same as for Renewable electricity). To convert to primary energy equivalent in TJ, nuclear power (GWh) was further divided by 0.33 to account for the IEA assumption of 33% power plant efficiency for nuclear.

9.4. Additional information on coal data availability

Some countries lacked conversion factors for individual years or groups of years for calculating energy production or EIOU. Replacement energy conversion factors (e.g., kJ/kg) were estimated using the following protocol similar to that for estimating missing data for energy expenditures:

1. Using the chronologically nearest conversion factor from the same country and coal sub-type (e.g., a missing anthracite value in 1965 replaced using the 1966 value),
2. Using the chronologically nearest conversion factor from the same aggregate group, hard coal or brown coal, and
3. Using the "average" energy density value for the specific sub-type as defined by the IEA Energy Statistics Manual.

For estimating both energy production and EIOU (in energy units of joules), substitutions were similarly used for coal for those countries missing specific years. The following list the countries needing estimates, years and sub-types missing conversion factors, and the conversion factor used (in the format [Country with missing data: Missing data (substitute data)]).

1. Australia: Coking Coal 1978-2010 (Hard Coal 1977), Anthracite 1978-2010 (Hard Coal 1977)
2. Belgium: Coking Coal 1987, 1988 (Coking Coal 1986)
3. Canada: Coking Coal 1978-2010 (Hard Coal 1977), Sub-bituminous 1981-1983, 1986-2010 (Sub-bituminous 1985), Lignite 2007-2010 (Lignite 2006)
4. Czech Republic: Coking Coal 1978-1984, 2002-2010 (Coking Coal 1985, 2001)
5. Denmark: Brown Coal 1968-1970 (Brown Coal 1967)

6. France: Coking Coal 1978-1995 (Hard Coal 1977)
7. Germany: Coking Coal 1978-2010 (Hard Coal 1977)
8. Italy: Coking Coal 1978-2010 (Hard Coal 1977)
9. Japan: Anthracite 1990 (Hard Coal 1977)
10. Mexico: Hard Coal 1971-1977 (26300 kJ/kt), Coking Coal 1978-2010 (28200 kJ/kt), Sub-bituminous 1981-2000 (Sub-bituminous 2001)
11. Netherlands: Brown Coal 1960-1968 (Brown Coal 1967)
12. New Zealand: Coking Coal 1978-1986, 1998-2008 (Coking Coal 1987, 1989)
13. Norway: Coking Coal 1978-1987 (Hard Coal 1977)
14. Poland: Coking Coal 1978-1995, 2004-2006 (Coking Coal 1996, 2003), Lignite 2007 (Lignite 2006)
15. Portugal: Brown Coal 1960-1969 (12600 kJ/kt)
16. Spain: Anthracite 2004-2005, 2009 (Anthracite 2006, 2008), Coking Coal 1978-1989 (Coking Coal 1990), Sub-bituminous 1994-2010 (Sub-bituminous 1993), Lignite 1978-2007 (Brown Coal 1977)
17. Turkey: Sub-bituminous (1994, 1996-1999, 2001) (Sub-bituminous 1993, 2000)
18. U.K.: Coking Coal 1992, 1997-1998 (Coking Coal 1991, 1996)
19. U.S.: Coking Coal 1978-2010 (Hard Coal 1977)

10. Description of use of World Input-Output Database (WIOD)

There are 44 countries for which there are energy prices in the IEA data set or in which we estimated energy prices. Of these 44, only 28 of them have input-output tables in the WIOD. These countries are: Australia, Austria, Belgium, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Italy, Japan, South Korea, Mexico, Netherlands, Poland, Portugal, Russia, Spain, Sweden, Turkey, United Kingdom, United States.

11. Calculating expenditures on CO₂

For the consideration of annual CO₂ emissions from fossil fuels (oil, natural gas, and coal) for the 44 countries we use CO₂ emissions data from the IEA website: http://www.iea.org/media/freepublications/stats/CO2_Emissions_From_Fuel_Combustion_Highlights_2014.XLS.)

The hypothetical costs of internalizing CO₂ emissions (in metric tons, t) are calculated by multiplying the annual emissions by a constant price of CO₂ (in \$/tCO₂).

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