

Indicator Selection and Rationale

Indicator Selection

SUSTAINABLE ENERGY WATCH (SEW) has created a baseline set of indicators from which to infer progression towards or regression from energy-related sustainability. By concentrating on feasible, policy-relevant, energy-related indicators at the intersection of economic, social, technological and environmental sustainability this tool can deliver a usable set of goals and measurements to citizens and decision-makers alike. However, important as the indicators are, they are only carefully chosen statistics and merely give one part of the story. The most interesting contribution of the reports prepared by SEW comes from the qualitative personal assessment given by the observer-reporters in each country. Indeed this is the component that generates the greatest added-value in the SEW reports.

Several criteria have guided the selection of SEW's indicators:

1. Each indicator must:
 - be clearly definable, simple to understand, and easily communicated to citizens and decision-makers alike;
 - be relevant to actual or anticipated policies;
 - reflect an important aspect of the social, economic, environmental, or technological elements of the energy system;
 - measure something of obvious value to observers and decision-makers; and
 - have durability and long-term relevance.
2. The underlying metric —the actual measurement or statistic used— must be generally available for most, if not all, countries. This combines measurability, data availability, and achievability; in other words, data collection and vector calculation must be do-able;
3. If calculation is required to derive an indicator, it must be simple to do;
4. The indicator set as a whole is indicative of a country's and the world's progress towards energy-related sustainability; and
5. Improvement in an indicator's measurement is indicative of genuine progress toward an energy system that sustains and improves human health and happiness.

The aim of this indicator set is to be applicable to the current energy situation in a given country and to highlight what is pertinent and achievable. SEW has selected eight indicators. Each indicator has been chosen because it reflects an underlying and measurable value ; ultimately an indicator value should be as small as possible, reflecting a smaller footprint, i.e. impact.

SEW has determined this set of "sustainability objectives," not so much as absolute goals —for nobody knows what a sustainable goal really entails— but to act as a series of benchmarks. It is better to be approximately right than precisely wrong.

The indicators cover the following aspects:

- environmental
 - CO2 emissions per capita (global pollution)
 - ambient energy-related emissions (local pollution)
- social
 - guaranteed access to electricity
 - investments in clean energy
- economic
 - energy resilience
 - burden of public energy investments
- technological
 - energy intensity
 - renewable energy deployment

Indicator Description

Indicators for Environmental Sustainability

Indicator 1: Per Capita Energy Sector Carbon Dioxide Emissions

Global environmental impact is measured by carbon dioxide (CO₂) emissions per capita. Each nation's per capita emissions will be compared to the 1990 global average. The long term objective is a convergence towards a reduction of seventy percent of global emissions (Intergovernmental Panel on Climate Change - IPCC).

Indicator 2: Most Significant Energy-Related Local Pollutant(s)

Selecting the indicator for the most significant local environmental pressure is done by SEW local observer-reporters. It is necessary to choose a pollutant that strongly impacts local human or environmental health, i.e. impacting human respiratory, reproductive, and immune systems, negatively effecting forestry, lakes and rivers, agriculture, domestic animals, fisheries, or infrastructure etc. Such pollution sources are frequently related to industry, mining, fuel refineries, manufacturing, or electric power plants. Non-point pollution sources such as vehicles often pose the greatest hazard to health and are often difficult to mitigate. If information is available their emission

rates could be used. The objective is a nine-tenth reduction of the selected pollutant(s).

Indicators for Social Sustainability

Indicator 3: Households with Access to Electricity / Percentage of Household Income Spent on Energy

Access to electricity is considered a social good; it helps spread literacy and education, it contributes to improved health through the refrigeration of medicines, and to increased communication and awareness. While western standards of electric consumption need not be adopted, access to some level of affordable power is appropriate.

Indicator 4: Investment in Clean Energy (a proxy for employment)

Several studies show that investment in clean energy —renewable energy and energy efficiency— create more jobs and generates faster growth than comparable investment in conventional energy. For this social indicator new employment in clean energy projects could be measured, e.g. employment in cleaning up conventional energy projects through the installation of pollution control equipment or the reclamation of mined areas or wetlands restoration etc. However, comprehensive data on employment gains are not available in most countries. SEW has therefore selected a substitute indicator for which data are generally available: investment in renewable energy and energy efficiency.

Indicators for Economic Sustainability

Indicator 5: Energy Resilience: Energy Trade Benefits

Many countries are highly dependent on imported fuels for transportation, heating, cooling and lighting of buildings and electric power generation. The threat of supply interruption is real, primarily for unforeseeable political reasons but also due to pipeline accidents, system vulnerabilities, embargoes, terrorism, and civil strife. The more universal threat is price fluctuations that can destabilize both importing and exporting nations. The development of improved extraction technologies and new discoveries of reserves have led to increased fossil fuel supplies that have out-paced consumption. Indeed, contrary to price forecasts, energy prices have declined strongly in real terms since the mid-1970s. The latest international problems brought about by disruption of supplies, e.g. war in the Middle East, hurricanes, however have recently raised the price of fuels significantly.

Separate metrics have to be selected for import-dependent and export-dependent countries. In order to provide an incentive for net energy importers without discouraging imports of renewable energy, imports of non-renewable energy are measured as a fraction of non-renewable energy

consumption. Importing countries can improve sustainability by reducing either imports or consumption of non-renewables or increasing imports or consumption of renewable energy.

Indicator 6: Burden of Public Energy Investments

This indicator compares government investment in non-renewable energy supply to total Gross Domestic Product (GDP) as a measure of the burden of energy development on the economy. The primary purpose of this indicator is to measure the level of public funds in the energy supply sector and to provide incentives for investment in cost-effective renewable energy supplies and end-use efficiency. Government enterprises and deals with private entities tend to shift scarce resources into capital-intensive buys. Such investment should either be decreased or shifted to the private sector, or both should occur.

Indicators for Technological Sustainability

Indicator 7: Energy Intensity (energy consumption/GDP)

This indicator measures each nation's progress towards increasing the level of economic activity per unit of energy consumed. Many nations already track such progress and the World Bank, United Nations, International Energy Agency and the OECD publish periodic comparative reports. However, this simple calculation is complicated by a number of factors. The available data compare economies with widely different geography, economic development, climate and levels of industrialisation. Some sources compare indices of energy efficiency, e.g. fuel economy of personal vehicles, others compare specific sectors, e.g. industrial energy use per dollar of industrial output, while others aggregate the nation's economy. Only consumption of commercial energy is typically counted, thus ignoring large quantities of "traditional" fuels such as wood, charcoal, bagasse, and other biomass fuels used in many countries. A consistent definition of what is meant by economic output is not clear-cut either; the convention of counting GDP output at current exchange rates works better for comparing industrialised countries than developing nations. In the latter cases, purchase power parity (PPP) accounts of GDP are more appropriate.

Indicator 8: Renewable Energy Deployment

Global use of renewable energy is growing faster than the use of fossil fuels and electricity. Globally, wind power capacity is increasing annually. The use of photovoltaic cells —semiconductor devices that turn solar radiation directly into electricity— is expanding nearly as fast as wind power. Fossil fuels and nuclear power—heavily subsidised and politically favored for decades—still generate a large fraction of the world's electricity. Yet the market is changing, as is political and popular support. Renewable costs are falling and are becoming more competitive even without counting the multiple benefits of clean, environmentally superior power. India, Germany, and Denmark are now leading the world in installed wind power capacity.

Indicator Calculation

Two indicators are used for each aspect of sustainability.¹ The selected indicators are presented followed by examples. In order to observe the progression of indicator 1990 is to be used as the reference year.²

It is recommended to review the examples carefully, not only to understand the equations but also to understand how the parameters are used in each of the equations.

Calculation Methodology

Below is the generic formula used to calculate the eight indicators. Only four variables are used to calculate each indicator with the definitions of these variables remaining the same for each indicator.

The generic formula is written as:

$$I = (X - Y) / (W - Y)$$

Where:

- I = the value of the vector (in relative terms)
- X = the value (in absolute terms) of the environmental, economic social or technological parameter
- Y = the objective of sustainability in absolute terms and corresponds to the value 0 of the vector
- W = the value (in absolute terms) which corresponds to value 1 of the vector
- Z = the value of the segment (in absolute terms) which goes from 0 to 1 on the vector.

The X value varies over the long-term while values W and Y are constant. Thus, once the difference (W-Y) has been calculated it can be kept as the denominator when calculating both the base and current years. Therefore:

¹ Sometimes it is necessary to use more than one parameter to calculate an indicator, as in the case with Indicator 2. In this instance, the final indicator value will be the average of two intermediary indicators.

² Signatories countries to the Kyoto Protocol agreed to limit their greenhouse gas emissions, relative to the levels emitted in 1990

$$Z = W - Y$$

Where:

- Z = the value of the segment (in absolute terms) which ranges from 0 to 1 on the vector (in relative terms)

The formula for the indicator calculation therefore becomes: $I = (X - Y) / Z$

One can see in these two equations the importance of clearly defining the Y value, which corresponds to the sustainability objective, and W, which corresponds to a state of unsustainability. As the value between Y and W increase, the impact of variation of the variable (X) becomes less.

Indicators for Environmental Sustainability

Indicator 1: Per Capita Energy Sector Carbon Dioxide Emissions

Parameters

- X = emissions for current year and those for 1990
- W = 1130kgC/capita (world average for 1990)
- Y = 339 kgC/capita (3/10 the world's average for 1990)
- Z = 791 kgC/capita

$$\text{Equation: } I = (X - 339) / 791$$

Example

- United States, 1995
X = 5602 kg of carbon emitted per capita

$$\text{Indicator value "I" = } (5602 - 339) / 791 = 6.654$$

Given that per capita emissions are way above the world average in the majority of industrialised countries and are the most elevated in the US, it is not surprising that the calculated value is so high. It also indicates that energy balance that is unsustainable

- Albania, 1995
X = 141 kg carbon per capita emission

$$\text{Indicator value "I" = } (141 - 339) / 791 = -0.250$$

Since this value is negative, it is already within the target of SEW. Albania therefore will be able to increase its emissions by continuing its economic growth or, better still, extend its economy without increasing its emissions. With the latter, the country has an asset or

which could be “sold” on the international market via through negotiable permits or Joint Implementation projects.

Indicator 2: Most Significant Energy-Related Local Pollutant(s)

Parameters

X = selected pollutant for current year and for 1990

W = 1990 value

Y = 1/10 of 1990 value

Z = W - W/10 = 9W/10

$$\text{Equation: } I = (X - 0.1W) / 0.9W$$

Example

- United States, 1996 – single pollutant
 - X(1996) = 42.8 kg of SO₂ per capita
 - W = 57.2 kg of SO₂ per capita
 - Y = 5.7 kg of SO₂ per capita (equal to 1/10 of 1990 value)
 - Z = 57.2 - 5.7 = 51.5 kg of SO₂ per capita

$$\text{Indicator value "I" = (42.8 - 5.7) / 51.5 = 0.720}$$

The US reduced its sulphur emissions through trading of credits which reduced emissions at a faster rate and with lower anticipated costs.

Example

- China, 1995 - using the concentration of ambient pollutants and combining two pollutants to calculate an indicator.
 - combine the concentration of particulates in an urban area with the sulphur dioxide concentrations in Beijing
 - change the metric of the indicator so that
 - 1 = 100% of the World Health Organisation (WHO) maximum level for each pollutant
 - 0 = 20% of WHO maximum levels

WHO maximum levels for total particulate suspension:

$$W(\text{PTS}) = 50 \mu\text{gr}/\text{m}^3$$

$$W(\text{SO}_2) = 60 \mu\text{gr}/\text{m}^3$$

Objective:

$$Y(\text{PTS}) = 20\% \times 50 = 10 \mu\text{gr}/\text{m}^3$$

$$Y(\text{SO}_2) = 20\% \times 60 = 12 \mu\text{gr}/\text{m}^3$$

Ambient pollution levels in Beijing:

$$X(\text{PTS}) = 377 \mu\text{gr}/\text{m}^3$$

$$X(\text{SO}_2) = 90 \mu\text{gr}/\text{m}^3$$

$$Z(\text{PTS}) = W(\text{PTS}) - Y(\text{PTS}) = 50 - 10 = 40 \mu\text{gr}/\text{m}^3$$

$$Z(\text{SO}_2) = W(\text{SO}_2) - Y(\text{SO}_2) = 60 - 12 = 48 \mu\text{gr}/\text{m}^3$$

$$\text{Vector value "I(PTS)"} = (377 - 10) / 40 = 9.175$$

$$\text{Vector value "I(SO}_2\text{)"} = (90 - 12) / 48 = 1.625$$

Giving equal weight to each pollution:

$$\text{Indicator value "I"} = (9.175 + 1.625) / 2 = 5.4$$

Social Sustainability

Indicator 3: Households with Access to Electricity / Percentage of Household Income Spent on Energy

Parameters

X = percentages of households who have access to electricity in current year and in 1990

W = 0% of households that have access to electricity

Y = 100% of households have access to electricity

Z = -1

$$\text{Equation: } I = (X - 100\%) / -1$$

Example

- Brazil
37% of rural households have access to electricity.

$$\text{Indicator value "I"} = (37.017\% - 100\%) / -1 = 0.630$$

Indicator 4: Investment in Clean Energy (a proxy for employment)

Parameters

X = the ratio between investment between clean energy investment and the total investment in the energy sector

W = the value of X in 1990

Y = 95% of energy sector investment

Z = W - 95%

$$\text{Equation: } I = (X - 95\%) / (W - 95\%)$$

Example

- Elbonia, 1998
An imaginary country ELBONIA invested 10 billion euros in the energy sector in 1990 and 13 billion euros in 1998. Its investment in clean

energy (renewable energy and energy efficiency) was 560 million euros in 1990 and 820 million euros in 1998.

$W = 560 \text{ million euros} / 10 \text{ billion euros} = 5.6 \%$

$X (1998) = 820 \text{ million euros} / 13 \text{ billion euros} = 6.3\%$

$Y = 95 \%$

$Z = 5.6\% - 95\% = -89.4\%$

Indicator value "I" = $(6.3\% - 95\%) / -89.4\% = 0.992$

Indicators for Economic Sustainability

Indicator 5: Energy Resilience: Energy Trade Benefits

Parameters - country that is a net importer of energy

X = ratio between imports of non-renewable energy and the consumption of non-renewable energy (in Joules)

W = 100%

Y = 0%

Z = 1

Equation: $I = (X - 0\%) / 1 = X$

Parameters - country that is a net exporter of energy

X = ratio between the export of non-renewable energy and the value of all exports (in monetary value)

W = 100%

Y = 0%

Z = 1

Equation: $I = (X - 0\%) / 1 = X$

Example - country dependent on energy importations

- United States, 1997

The imports of non-renewable energy were raised to 23.51EJ in 1997 (23.66 EJ minus 0.15 J of hydroelectricity imported from Canada).

Energy consumption of non-renewable energy rose to 82.53 EJ.

Indicator value "I" = $23.51 / 82.53 = 0.285$

Example - energy exporting country

- Norway, 1998

In 1998, Norway exported 17 billion euros of crude oil, petroleum products, natural gas and 2.6 billion euros of hydro-electricity. The total value of all these exports was equal to 47 billion euros. The ratio between the export of non-renewable energy and the value of all exports:

Indicator value "I" = $17 \text{ billion euros} / 47 \text{ billion euros} = 0.362$

The indicator value of .362 illustrates that Norway's dependency on fossil fuel is low. By improving its national electric efficiency, via its hydroelectric capacity, Norway would be also be able to increase its renewable electricity exports.

Example - energy exporting country

- Saudi Arabia, 1997

This country exported 43.8 billion euros of oil and petroleum products while total level of exports topped 50.1 billion euros.

Indicator value "I" = 43.8 billion euros / 50.1 billion euros = 0.874

This vector value indicates a high vulnerability to price and demand fluctuations.

Indicator 6: Burden of Public Energy Investments

Parameters

X = ratio between public investment in non-renewable energy and GDP

W = 10%

Y = 0%

Z = 0.1

$$\text{Equation: } I = (X - 0\%) / 0.1 = 10X$$

Example

- India, 1995

The Indian government invested 13.7 billion euros (this included multi-lateral aid) in building nuclear power and coal fired power stations, developing coal mines, performing research and development, developing oil and gas fields, refining, and energy transportation. India also invested an addition 3.4 billion euros in major hydroelectric and wind projects (these numbers are not part of the 13.7 billion). GDP of India in 1995 was 319.7 billion euros.

Dividing 13.7 billion euros by the GDP = 13.7 billion euros/319.7 billion euros = 0.0429 or 4.29%

Indicator value "I" = 10X = 10 x 0.0429 = 0.429

Indicators for Technological Sustainability

Indicator 7: Energy Intensity (energy consumption/GDP)

Parameters

- X = ratio between energy consumption and GDP
- W = 10.64 MJ/euros which corresponds to the average world consumption of primary energy per unit of GDP in 1990
- Y = 1.06 MJ/euros which corresponds to 1/10 W
- Z = 10.64 - 1.06 = 9.58

$$\text{Equation: } I = (X - 1.06) / 9.58$$

Example

- Canada, 1995
Canada's energy productivity was X=16.39 MJ per euro of GDP

$$\text{Indicator value "I"} = (16.39 - 1.06) / 9.58 = 1.600$$

This is considerably higher than the 1990 world average of 10.64 MJ.

Example

- Israel, 1995
In Israel, energy intensity was X = 6.12 MJ per euro of GDP, far lower than the world average of 10.64 MJ, but still higher than the sustainable level for energy productivity.

$$\text{Indicator value "I"} = (6.12 - 1.06) / 9.58 = 0.528$$

Indicator 8: Renewable Energy Deployment

Parameters

- X = ratio between renewable energy consumption and total primary energy consumption
- W = 8.64% which corresponds to the ratio between global consumption of renewable energy and total global consumption of primary energy for 1995
- Y = 95%
- Z = 8.64% - 95% = -0.8636

$$\text{Equation: } I = (X - 95\%) / -0.8636$$

Example

- Cameroon, 1995
Cameroon consumed 278 PJ of primary energy, of which 222 PJ is supplied by "renewables", primarily biomass.

The proportion of renewable energy is $X = 222 \text{ PJ} / 278 \text{ PJ} = 0.7986$ or 79.86%

$$\text{Indicator value "I"} = (79.86\% - 95\%) / (-0.8636) = -0.1514 / -0.8636 = 0.175$$

This is a value close to the desired objective (of zero)

Example

- Japan, 1997

Primary energy production in Japan was around 23.387 EJ with renewable energy production around 1.001 EJ.

The proportion of renewable energy: $X = 1.001 \text{ EJ} / 23.387 \text{ EJ} = 0.0428$ or 4.28%

$$\text{Indicator value "I"} = (4.28\% - 95\%) / (-0.8636) = -0.9072 / -0.8636 = 1.050$$

This value is well above the sustainability level of zero so therefore unsustainable