Department of Mechanical Engineering,
Pulchowk campus, Institute of Engineering,
Tribhuvan University

Sustainable Energy Technologies
(Session 2)

Energy Resources and Classifications

Dr. Shree Raj Shakya
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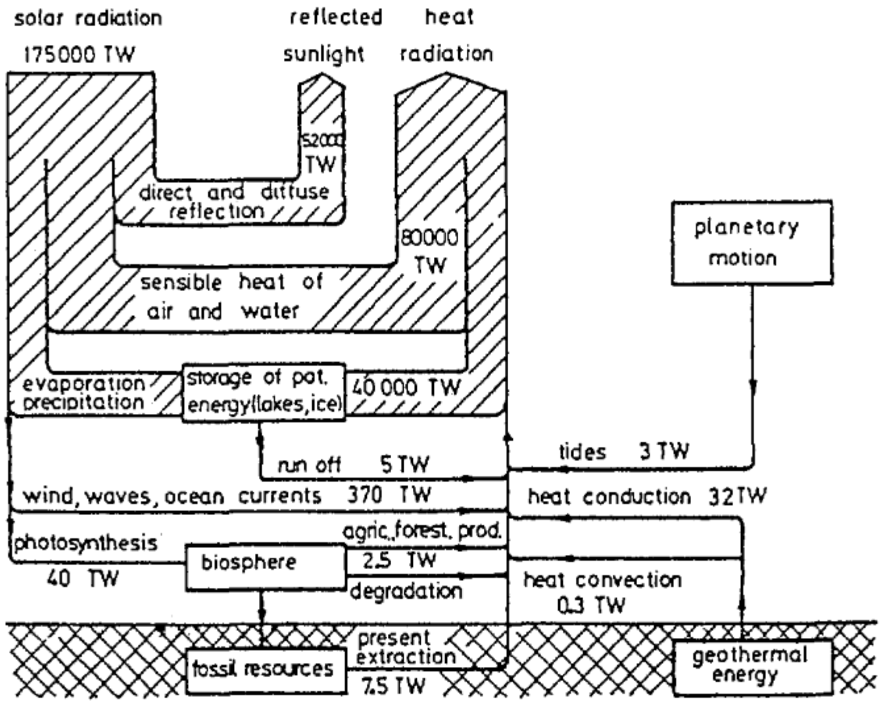
Energy: Technical aspect

- In 1826 French physicist **J.V. Poncelet** coined the name from the Greek "**energeia**" which means "**the driving**" in the sense of **driving power**
- It was only gradually recognized that **heat, motion, light and chemical energy** are external forms of the same basic energy
- The best short definition of energy originates from **Max Planck**, as the “**capacity of a system to determine external effects**”
- The popular dictionary formulation: **“energy is the ability to do work”**

Energy: Technical aspect

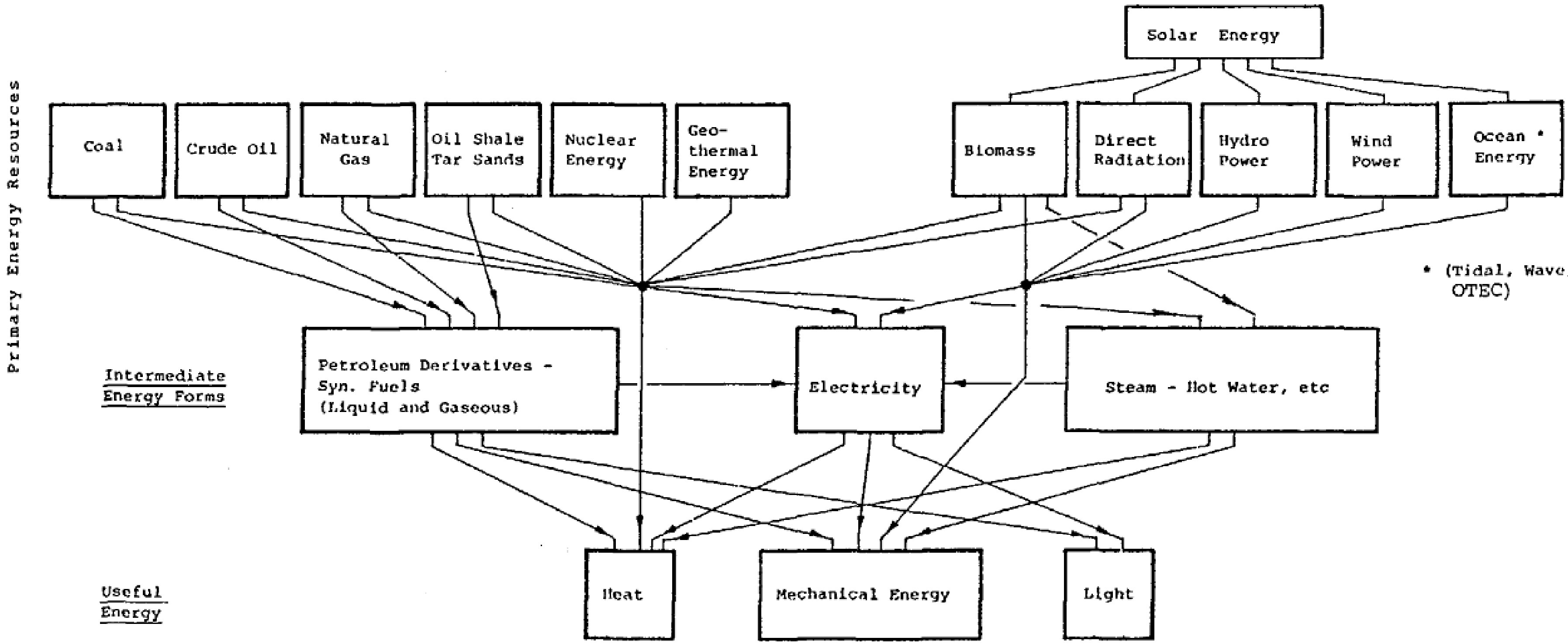


the **biosphere of the Earth** contains **two categories of primary energy resources**:

1. A **continuously renewed presence of an energy potential** originating from the permanent action of three main natural energy sources: **solar, geothermal and gravitational energy**, and
2. A **finite, non-renewable deposit** of primary energy resources, which enter its circuit under anthropogenic action.

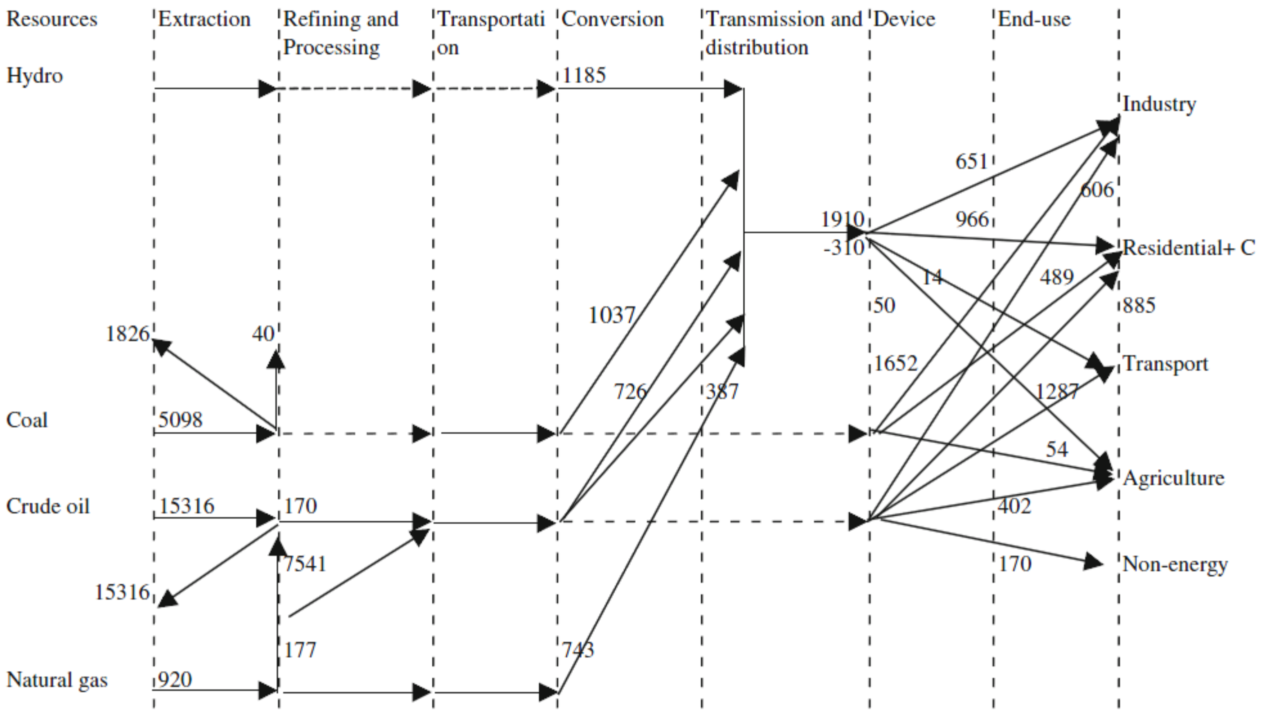
- The **main** world **energy consumption** is currently **based on the non-renewable reserves of the second group**, which in fact represent accumulated solar energy
- **increasing interest in** the so-called **new and renewable primary energy resources in future** due to issues related to **sustainability of supply, global GHG emission, local environment pollutants etc**.

Structure of Energy System



- An energy system consists of integrated network system with the final forms of useful energy required to satisfy consumer needs on the output side, and, a mixture of primary energy resources available or made available for supply on the input side.
- Physically, it includes all facilities, plants and constructions serving for exploration, extraction, harnessing, conversion, transport, distribution and utilization of primary energy resources and converted energy carriers.

Reference Energy System



- In energy system modeling field energy system is referred as Reference Energy System (RES).
- The RES is a map, which, in a schematic way, illustrates the structure of an energy system. The RES describes the flow of energy from the sources to the final use, by means of lines, which connect different components for energy conversion or distribution.

Needs for useful energy and supply of final (end-use) energy

To satisfy its needs, humankind requires the services of energy in the following useful forms

1) **Heat and cold** — serving for space heating and conditioning, food preparation and hot/cold water supply as well as for various industrial processes
2) **Mechanical energy** — needed for transportation and as prime mover for industrial equipment and domestic appliances
3) **Radiant energy** — for lighting and telecommunications.

Relevant terminology for the conversion potential in the final stage of an energy system

- **Useful energy** - the **amount of** one or more **useful energy** forms absolutely **necessary to perform an activity** and/or to assure adequate ambient conditions for living and working
- **Energy losses** - These represent the **auxiliary consumption of end-use energy in the final conversion process**. They can be reduced but hardly completely avoided. Taking the above examples, **such losses depend on the efficiency** of the electric motor, on the efficiency of a heating stove or on the quality of conversion of electricity into radiant energy for lighting.
- **Final energy or energy consumption of the final stage** — **the energy actually consumed for meeting the required demand for useful energy including losses** in the final stage. It is also called "**end-use energy**", i.e. the energy supplied to the final-stage consuming sectors.

Primary energy resources

The primary energy resources are basically characterized by following

- **Renewable and Non-renewable** (replenishable energy **resources** ?)
- **Commercial and Non-commercial** (traded in well established **market** ?)
- **Conventional and Non-conventional** (resources usable by well-established **technologies** or are still susceptible to substantial progress)

Primary energy resources

The primary energy resources are basically divided into following sub-groups

- (1) The **commercial primary energy resources** containing:
  - (1a) the **commercial conventional energy resources**: solid fuels (hard coal, brown coal, lignites, peat), petroleum, natural gas, hydro- and nuclear fission energy — the latter often improperly designated as 'primary electricity' — and
  - (1b) the **commercial non-conventional energy resources**: geothermal energy, heavy oils, geopressure natural gas, oil shale, tar sands and nuclear fusion.
- (2) The **non-commercial primary energy resources** containing:
  - (2a) the **non-commercial conventional energy resources**: firewood, dung and agricultural wastes as well as human and animal draught power, this subgroup sometimes being considered as containing the 'traditional’ non-commercial primary energy resources, and
  - (2b) the **non-commercial non-conventional energy resources**: solar (direct radiation), wind, tidal, wave, OTEC, biomass (except firewood and agricultural wastes).

Energy conversion and transport chains — intermediate energy forms

- **Conversion into an intermediate energy form** to be supplied to the final consumer **might be necessary for many reasons**, such as technical adequacy, transport possibility, economy, substitution, etc.
- The **lines of supply in RES represent energy transport flows between the different stages and energy forms of an energy system**. Together with the conversion processes they constitute the various energy chains which **link the input side and output side of the energy system**.

Types of Energy Commodities

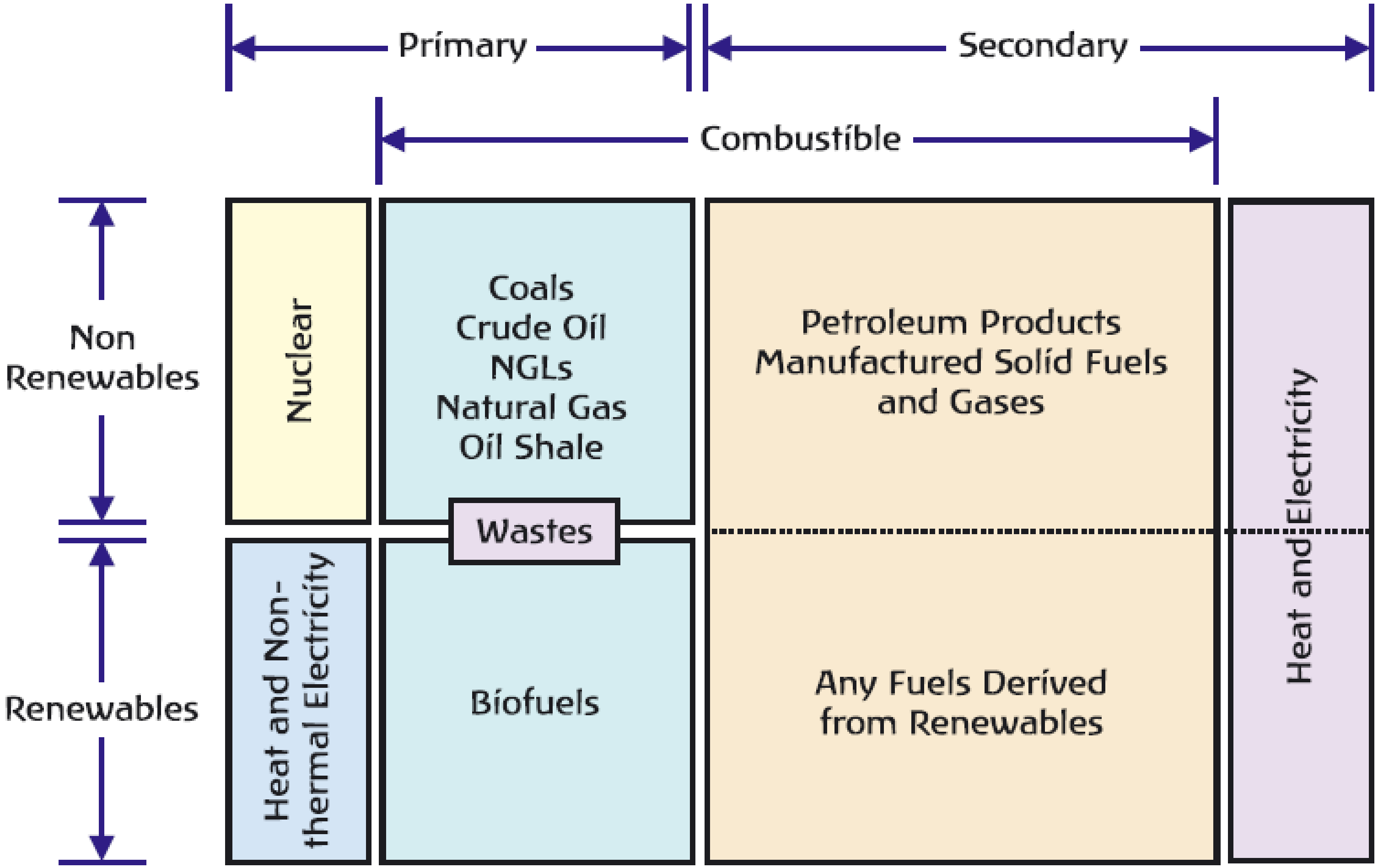
Primary and Secondary Energy commodity (IEA, 2005)

- **Energy commodities are either extracted or captured directly from natural resources**(and are termed primary) such as crude oil, hard coal, natural gas, **or are produced from primary commodities**.
- **All energy commodities which are not primary** but **produced from primary commodities** are termed **secondary commodities**.
- **Secondary energy comes from** the **transformation** of primary or secondary energy.
  - The generation of electricity (secondary) by burning fuel oil (secondary)
  - petroleum products (secondary) from crude oil (primary),
  - coke-oven coke (secondary) from coking coal (primary),
  - charcoal (secondary) from fuelwood (primary), etc.

Primary and Secondary Energy commodity

- **Primary energy commodities** may also be **divided into fuels** of **fossil origin** and **renewable energy** commodities.
- **Fossil fuels are taken from natural resources** which were **formed from biomass in the geological past**. By extension, the **term fossil is also applied to any secondary fuel manufactured from a fossil fuel**.
- **Renewable energy commodities**, apart from geothermal energy, **are drawn directly or indirectly from current or recent flows of the constantly available solar and gravitational energy**.
  - For example, the energy value of biomass is derived from the sunlight used by plants during their growth.

IEA Terminology for Energy Commodities



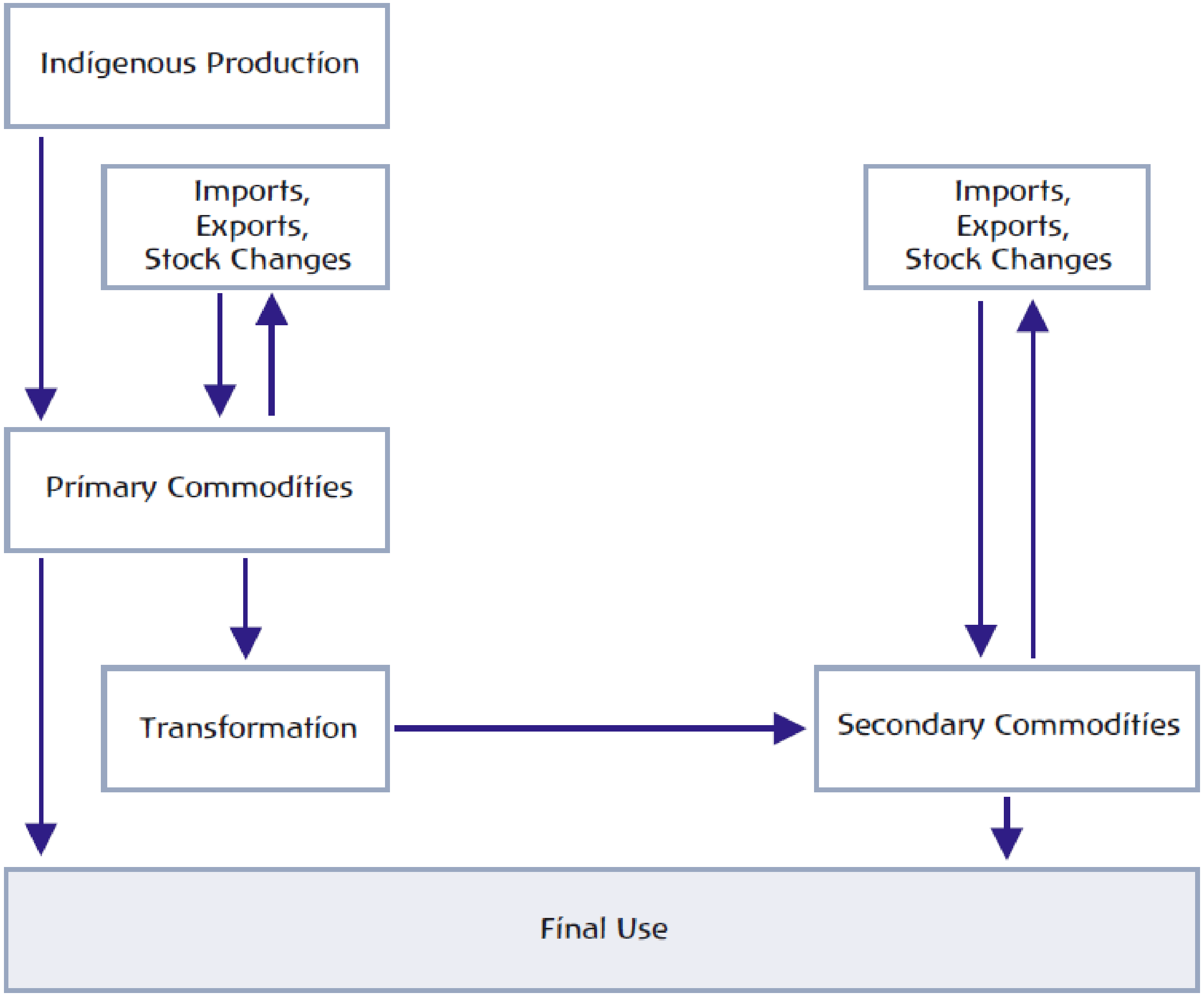
- A schematic illustration of renewable versus non-renewable energy, and primary versus secondary energy

Energy Commodity Flow

Commodity Flow (IEA, 2005)

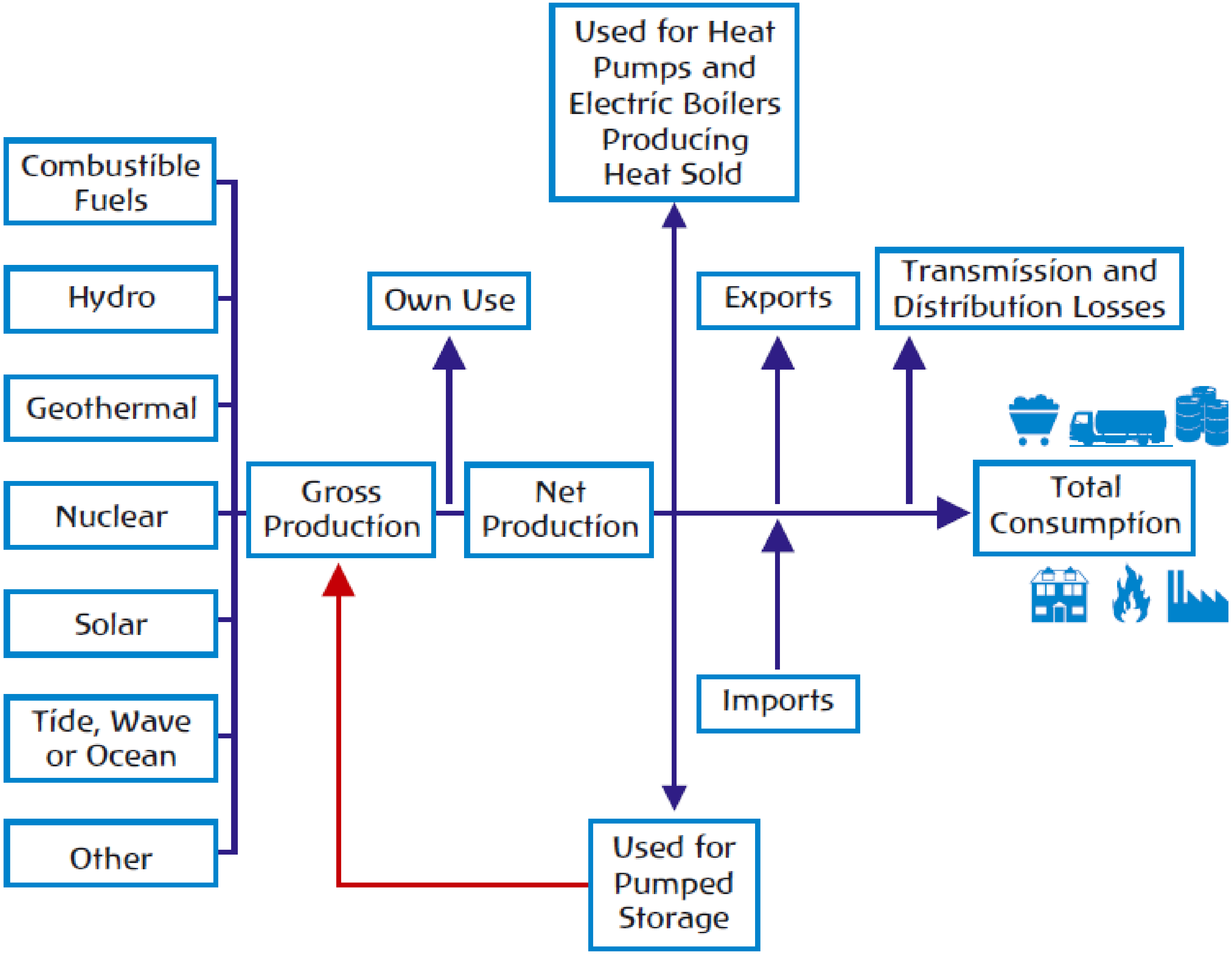
- **Fossil fuels are extracted from natural reserves** and biofuels are taken from the biosphere and **either used directly or converted to another fuel product**. A country **may import a commodity** it needs **or export** a commodity in excess of its requirements.
- Main commodity flow **illustrates the general pattern of the flow of a commodity from its first appearance to its final disappearance** (final use) from **the statistics**.
- A commodity flow can be **recorded at the main points between its arrival and disappearance**, and the important criterion for a successful statistical account of the flow is that the **commodity must not change its characteristics during its lifetime** and that the **quantities must be expressed in identical units** for each source of supply and type of use.
- The characteristics which matter are those which affect its energy producing capacity.

Commodity flow of the energy system

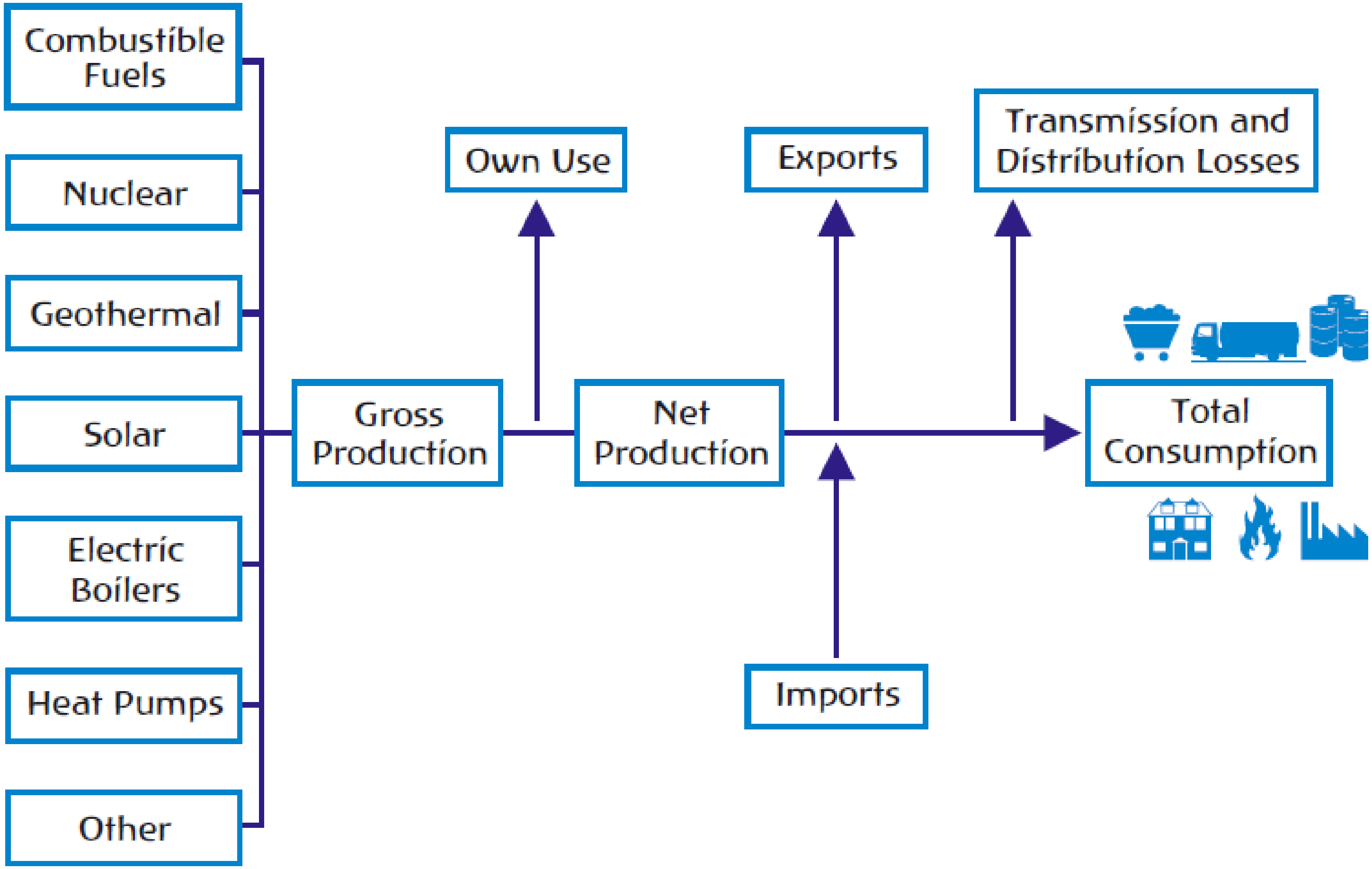


- A similar flow diagram exists for heat and electrical or mechanical power
- (see IEA Energy Statistics Manual, 2005)

Simplified Flow Chart for Electricity (IEA, 2005)



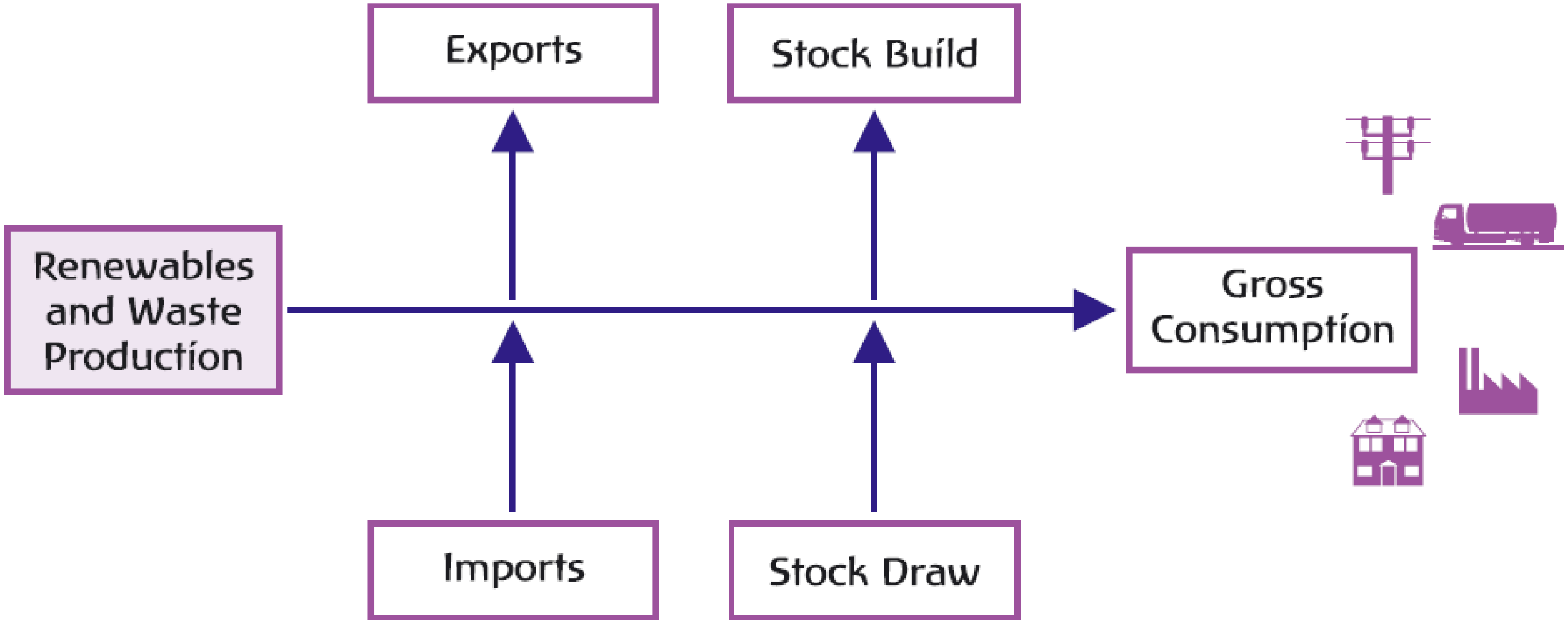
Simplified Flow Chart for Heat (IEA, 2005)



Primary versus Secondary Oil (IEA, 2005)

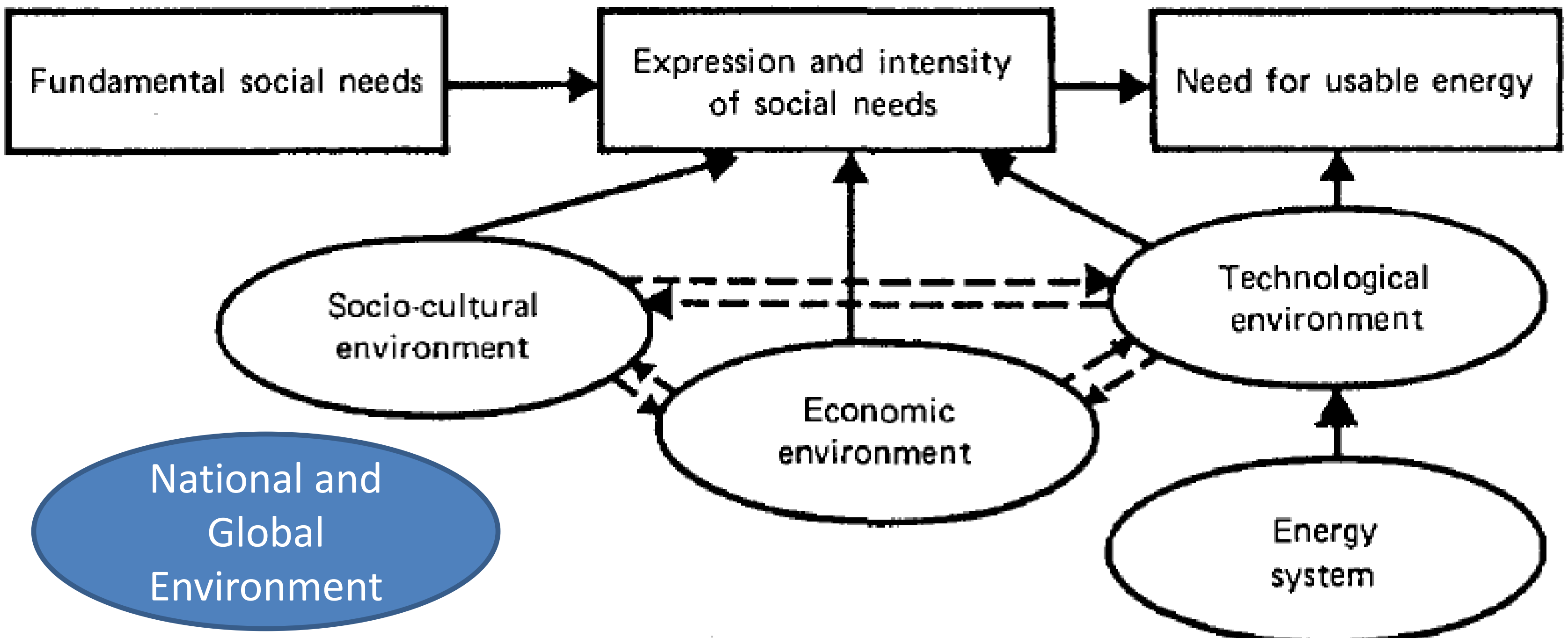
PRIMARY OIL PRODUCTS	Crude oil	
	Natural gas liquids	
	Other hydrocarbons	
SECONDARY PRODUCTS	Additives/blending components	
INPUTS TO REFINERY	Refinery feedstocks	
SECONDARY OIL PRODUCTS	Refinery gas	Transport diesel
	Ethane	Heating and other gasoil
	Liquefied petroleum gases	Res. fuel: low-sulphur content
	Naphtha	Res. fuel: high-sulphur content
	Aviation gasoline	White spirit + SBP
	Gasoline type jet fuel	Lubricants
	Unleaded gasoline	Bitumen
	Leaded gasoline	Paraffin waxes
	Kerosene type jet fuel	Petroleum coke
	Other kerosene	Other products

Simplified Flow Chart for Renewables and Waste (IEA, 2005)



Economic Issues of Energy System

Economic Issues:
The socio-economic integration of the energy system



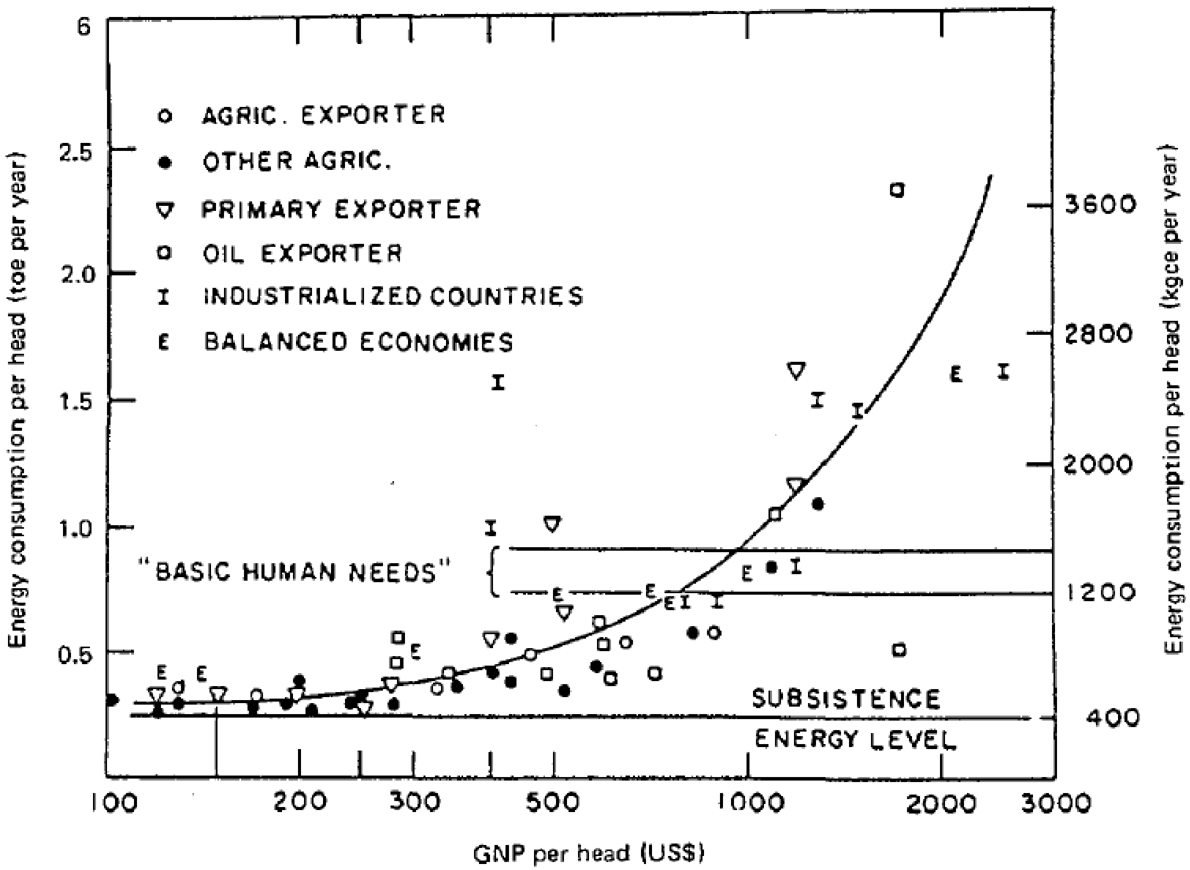
- A **national energy system is deeply embedded in the country's socio-economic environment** and has also **external relations of international or even worldwide character**.
- Its **integration occurs** both at **macro- and microeconomic level**, since, energy permeates the whole economy and **acts as the physical counterpart of money**.
- Figure illustrates the socio-cultural, economic and technological environment in which the energy system is embedded and how it finally serves the fundamental social needs of mankind and society.
- **Now Environmental aspect** is also considered as **the most important integral part** of energy system

Economic Issues:
The socio-economic integration of the energy system

- The **multilateral and complex relationship** of the energy system with the biosphere, economy and society **makes an optimization of its development very difficult**
- In fact **it could only be tackled with the help of modern tools**, in a global systems analysis approach and using computer models of comprehensive structure and high computing power
  - **Multi-optimization energy system planning tools**

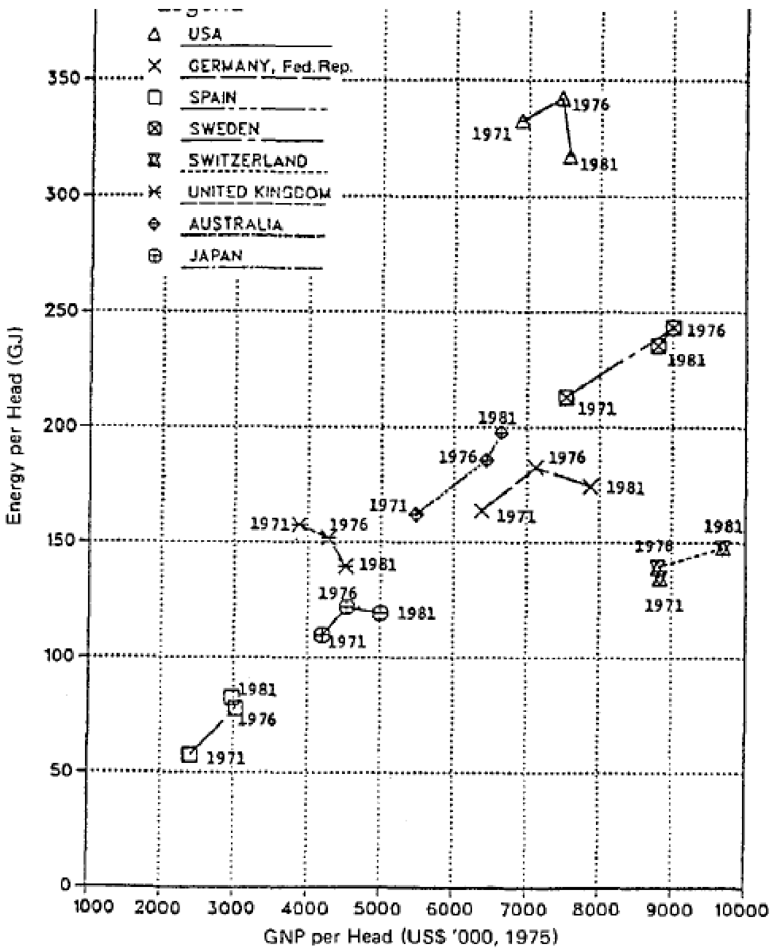
Economic Issues:
Energy and economic development
Energy/economic growth relationship assumed in the past

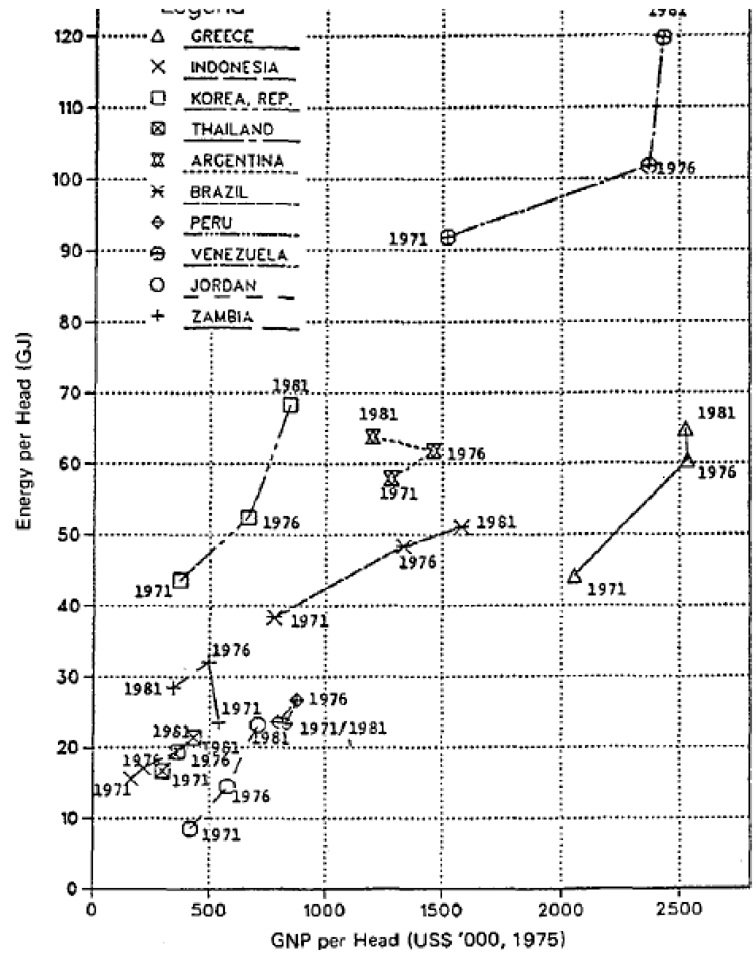
Relationship of per head energy consumption to per head GNP



Economic Issues:
Energy and economic development
Energy/economic growth relationship assumed in the past

GNP per head versus energy consumption per head in: (a) developed countries, (b) developing countries





Economic Issues:
Energy and economic development
Energy/economic growth relationship assumed in the past

The relationships between energy and GNP are expressed either on the global level or on a per head basis by using elasticity concept:

Plotted on logarithmic scales, all these different clouds of points are analytically estimated by a linear equation in log-log:

$$\log E = a + b \cdot \log Y$$

Where, E is energy consumption and Y is GNP

or a power function: $E = AY^b$

The second step consists of evaluating the coefficient of elasticity between energy and GNP, that is to say, the ratio between the increase rate of both, thus:

$$e = \frac{\Delta E/E}{\Delta Y/Y} = \delta \log E/\delta \log Y = b$$

The **coefficient of elasticity b is used later on to make energy forecasts** when the future GNP is assumed to be known

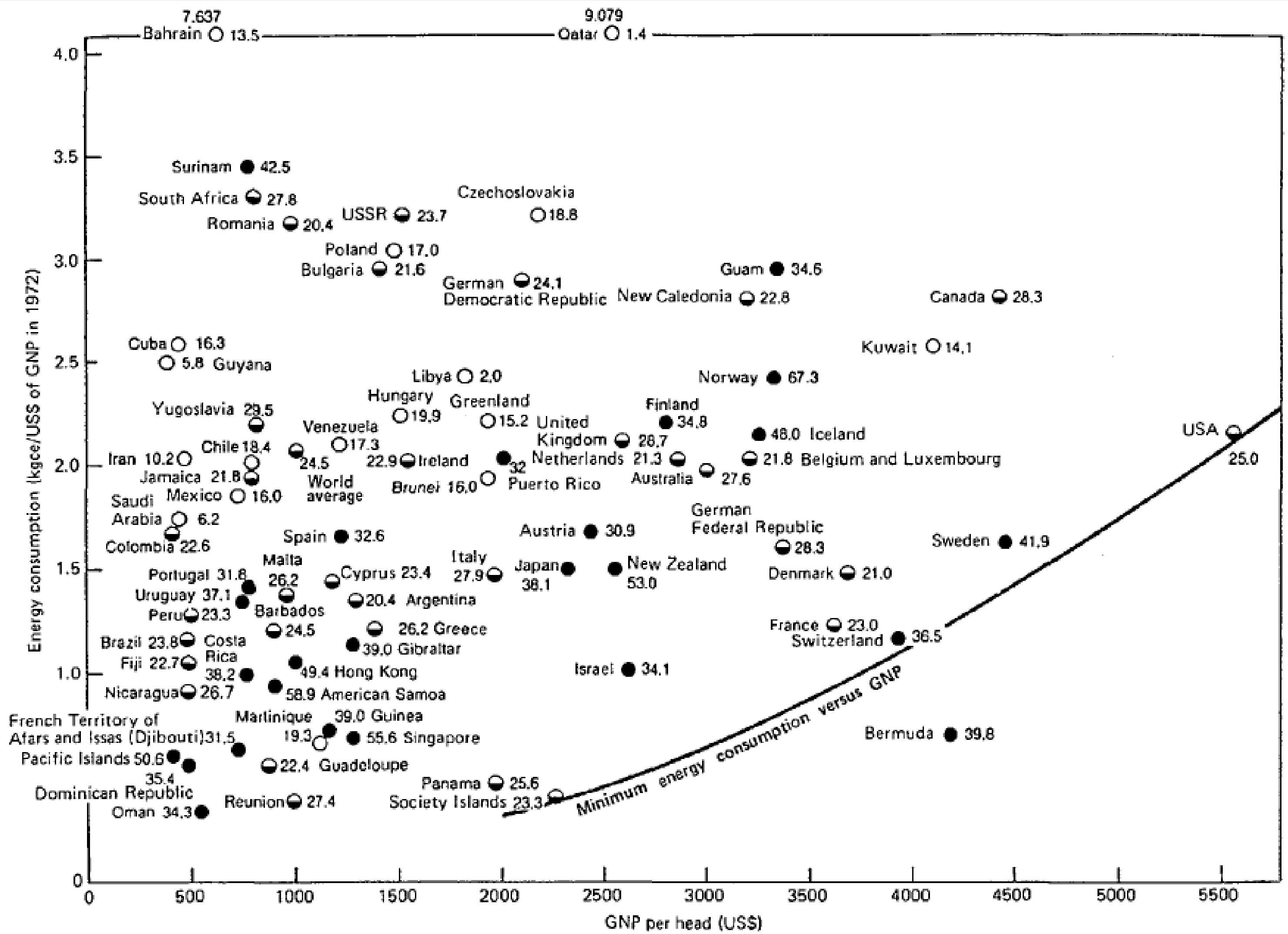
Economic Issues:
Energy and economic development
Energy/economic growth relationship assumed in the past

- Several remarks could be made on these types of simple and very aggregate relationships:
  - Most of the graphs are drawn on logarithmic paper which has a **large scale effect, smoothing results** which otherwise could appear incoherent.
  - The elasticity coefficient thereby obtained is an approximation of the income elasticity. GNP is a useful substitute for the national income generally less ascertainable by statistics. But **the tax system of a given country can completely bias the relationship** because:

  GNP = National Income + Taxes + Depreciation (amortization)

  - If such a correlation between energy and GNP were structurally correct, it should be possible to verify it at any level of the economy's structure; which is not the case. Therefore, one could suspect that such **a good correlation is rather due to the effect of large numbers** than to a real structural link.
- **Although such a relationship is too general** to be the basis of energy consumption forecasts, it has unfortunately **continued to prompt a number of long-term energy demand projections**.

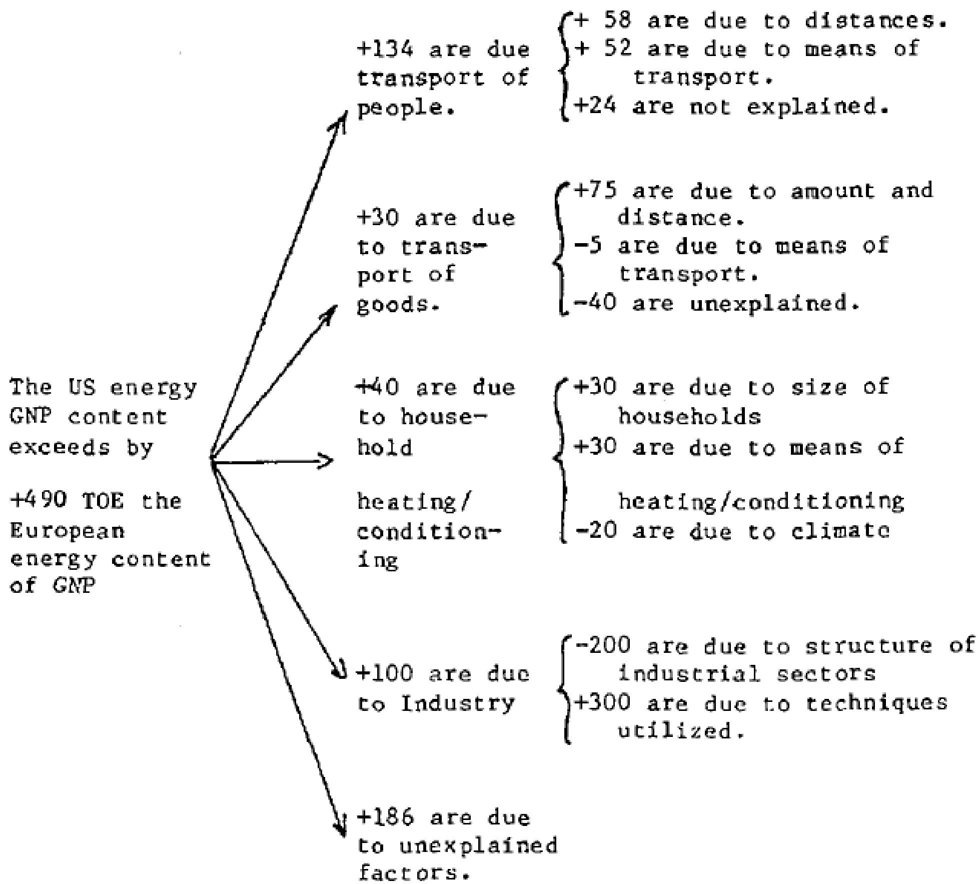
Economic Issues:
Energy and economic development
The energy content of the GNP



Economic Issues:
Energy and economic development
The energy content of the GNP

Comparison of the Energy Content of GNP in the USA and in Western Europe

Energy content of the GNP in the USA is 1490 toe per million US dollars and in Western Europe is 1000 toe per million US dollars in 1972

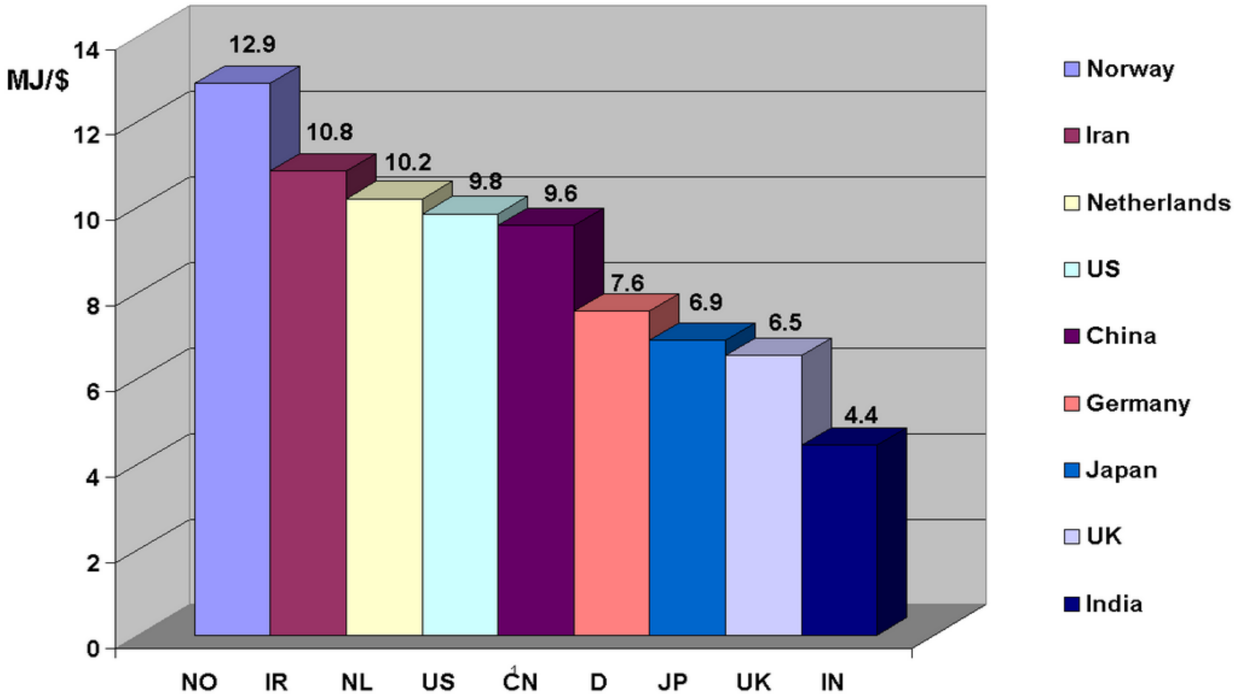


Economic Issues:
Energy and economic development
The energy content of the GNP

Evolution of Energy content of GNP in industrialized countries

	1973	1975	1979	1982
USA	100	95	90	81
Japan	100	93	85	70
Fed. Rep. of Germany	100	92	93	81
France	100	88	86	78
United Kingdom	100	92	90	80
Italy	100	96	93	84

Economic Issues:
Energy and economic development
The energy content of the GNP

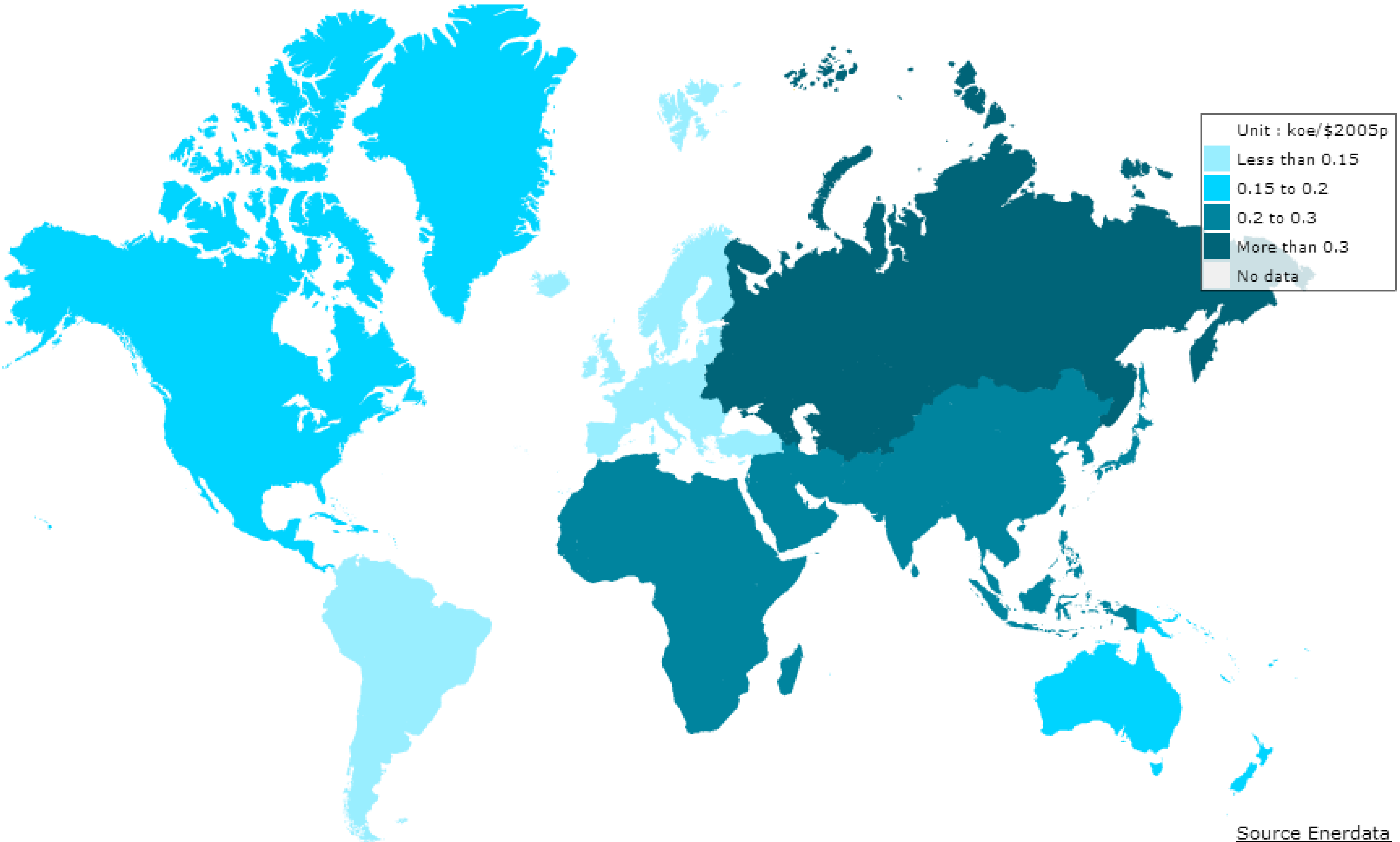


[Source: http://en.wikipedia.org/wiki/Energy_intensity](http://en.wikipedia.org/wiki/Energy_intensity)

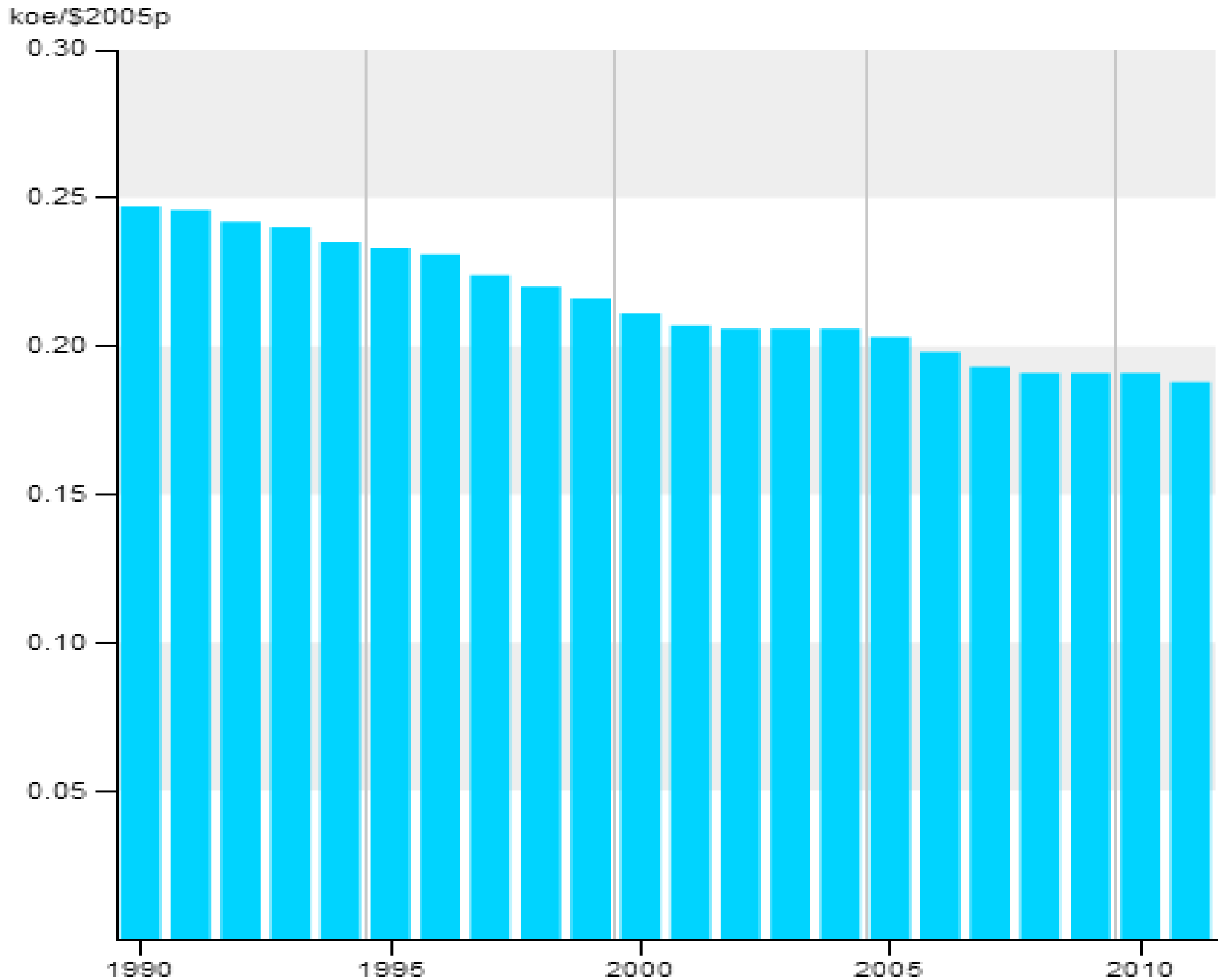
- **Energy intensity** is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP.
- High energy intensities indicate a high price or cost of converting energy into GDP.
- Low energy intensity indicates a lower price or cost of converting energy into GDP.

Economic Issues:
Energy and economic development

The energy intensity of GDP in 2011



Economic Issues:
Energy and economic development
Trend of Global energy intensity of GDP in 2011



[Source: http://yearbook.enerdata.net/energy-intensity-GDP-by-region.html](http://yearbook.enerdata.net/energy-intensity-GDP-by-region.html)

Economic Issues:
Energy and economic development
Change in energy intensity of GDP in 2010-2011

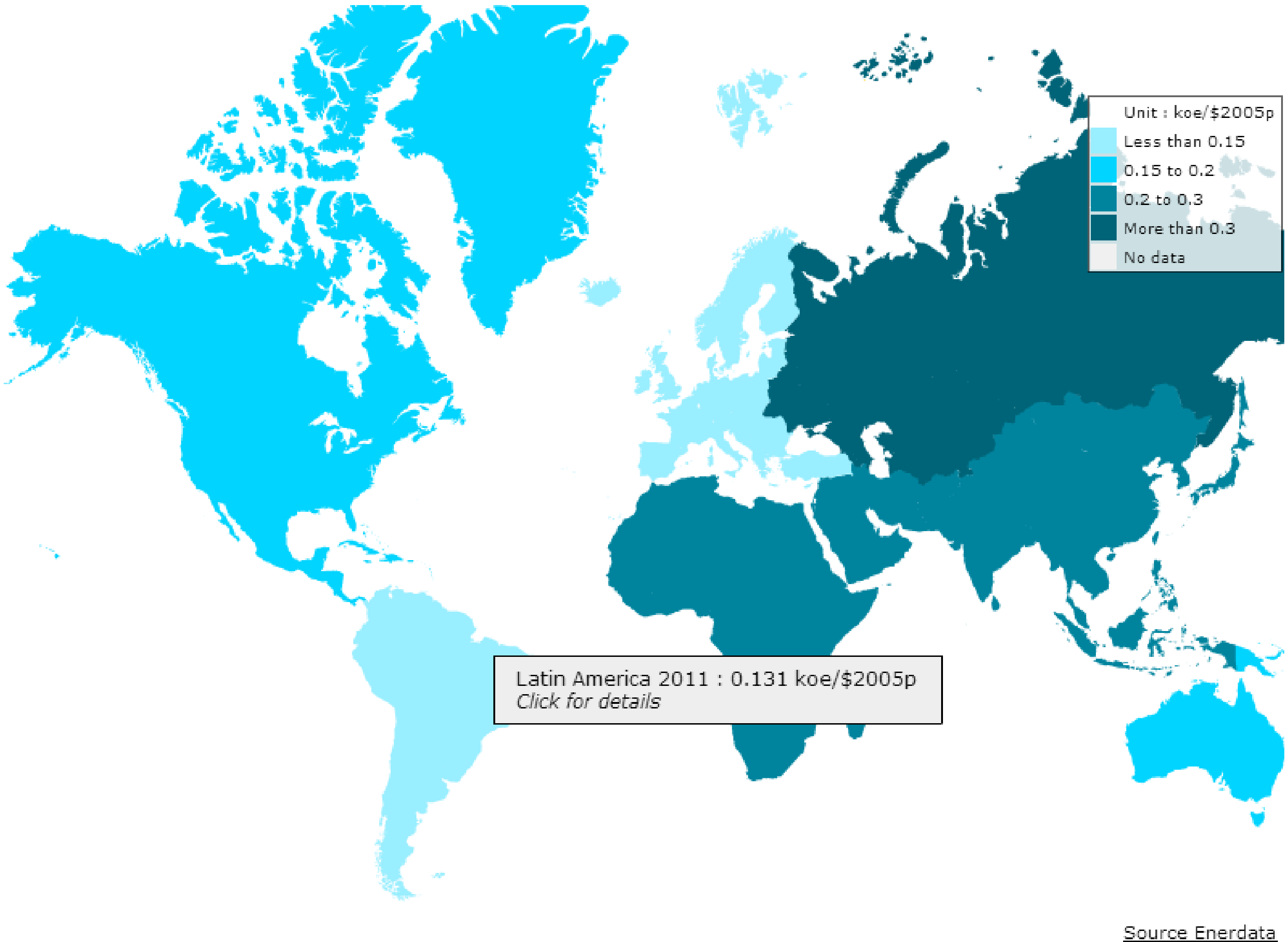


Figure 1. Primary energy intensity of GDP evaluated with market exchange rates (2004)

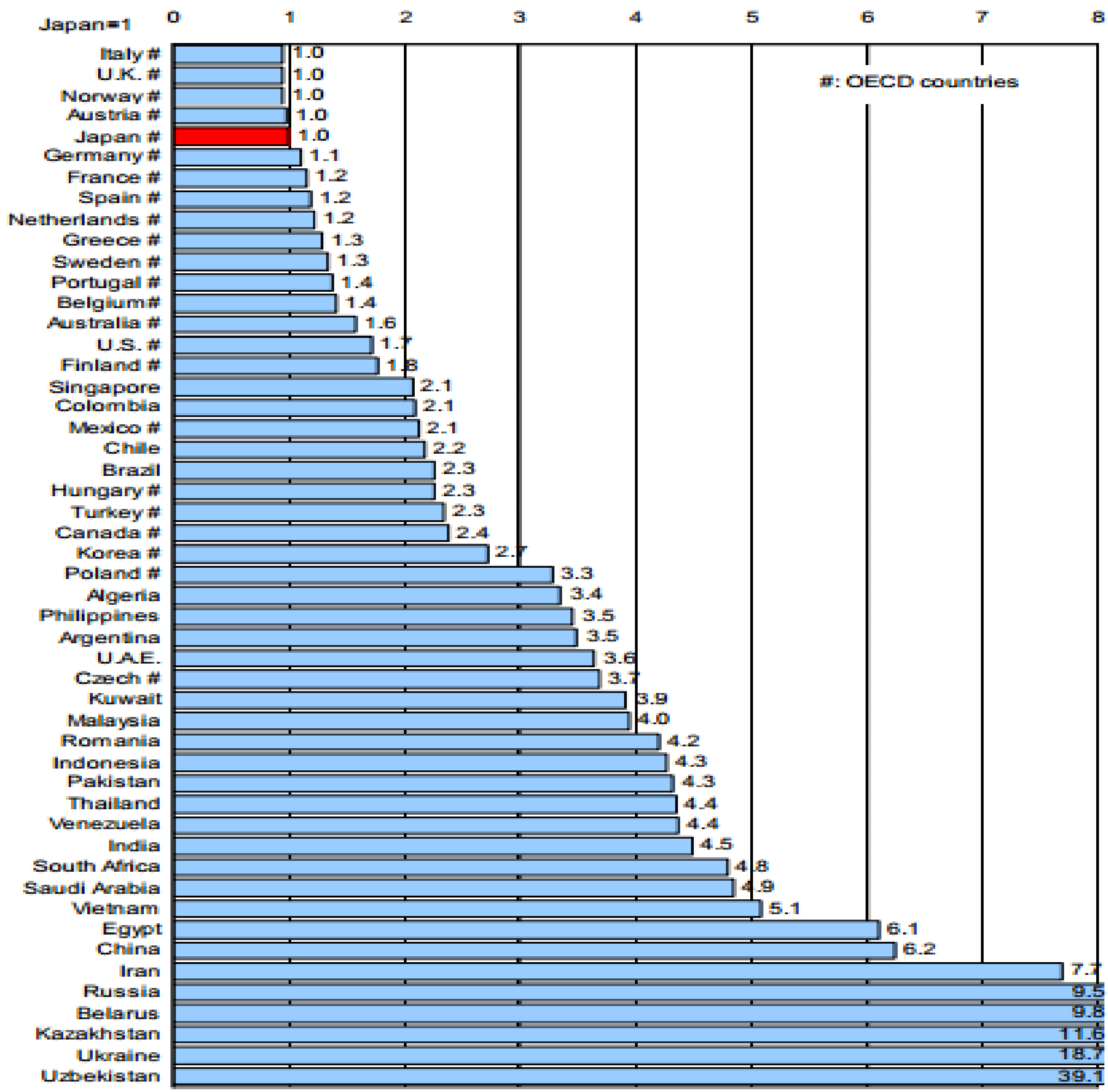
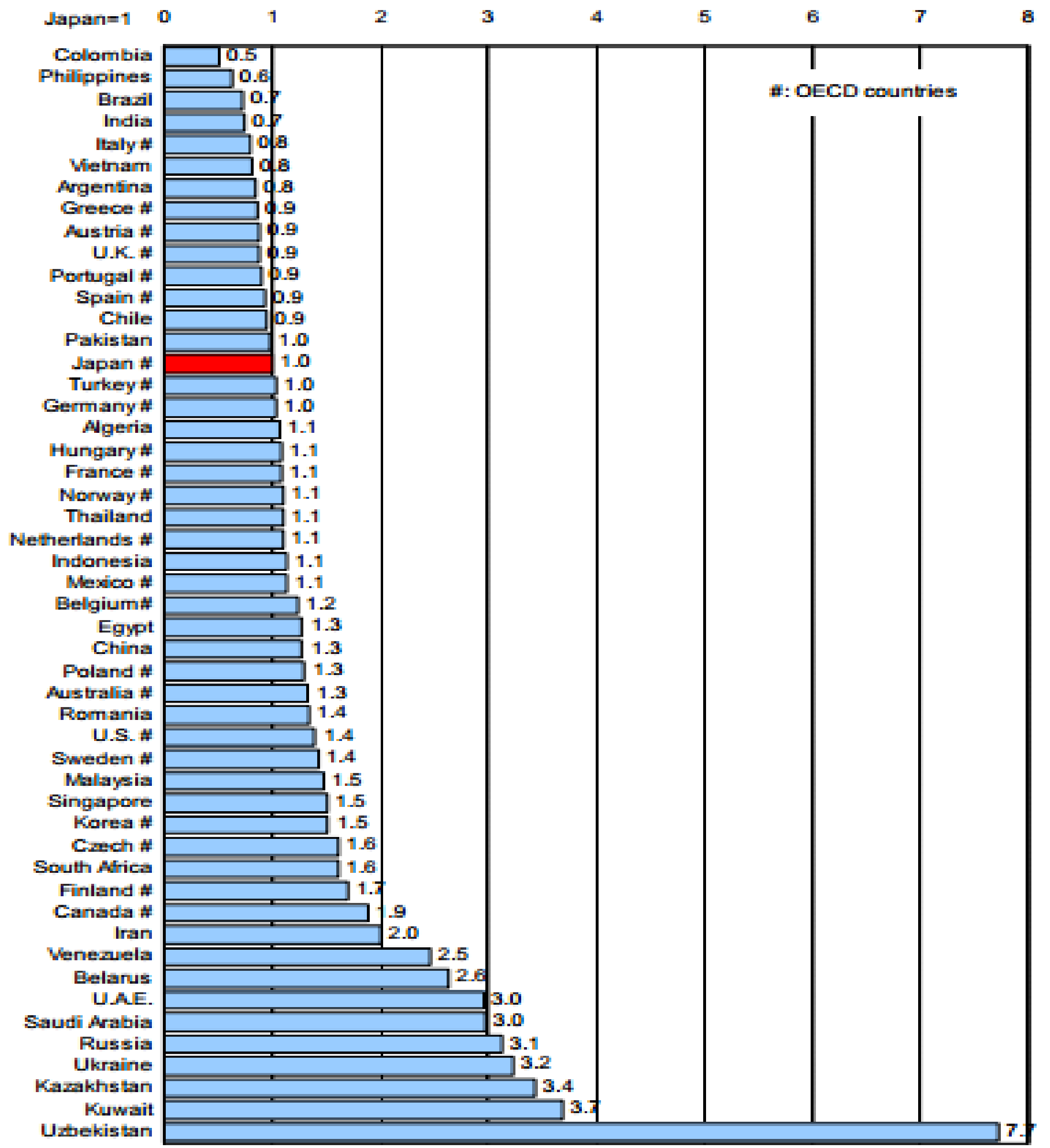
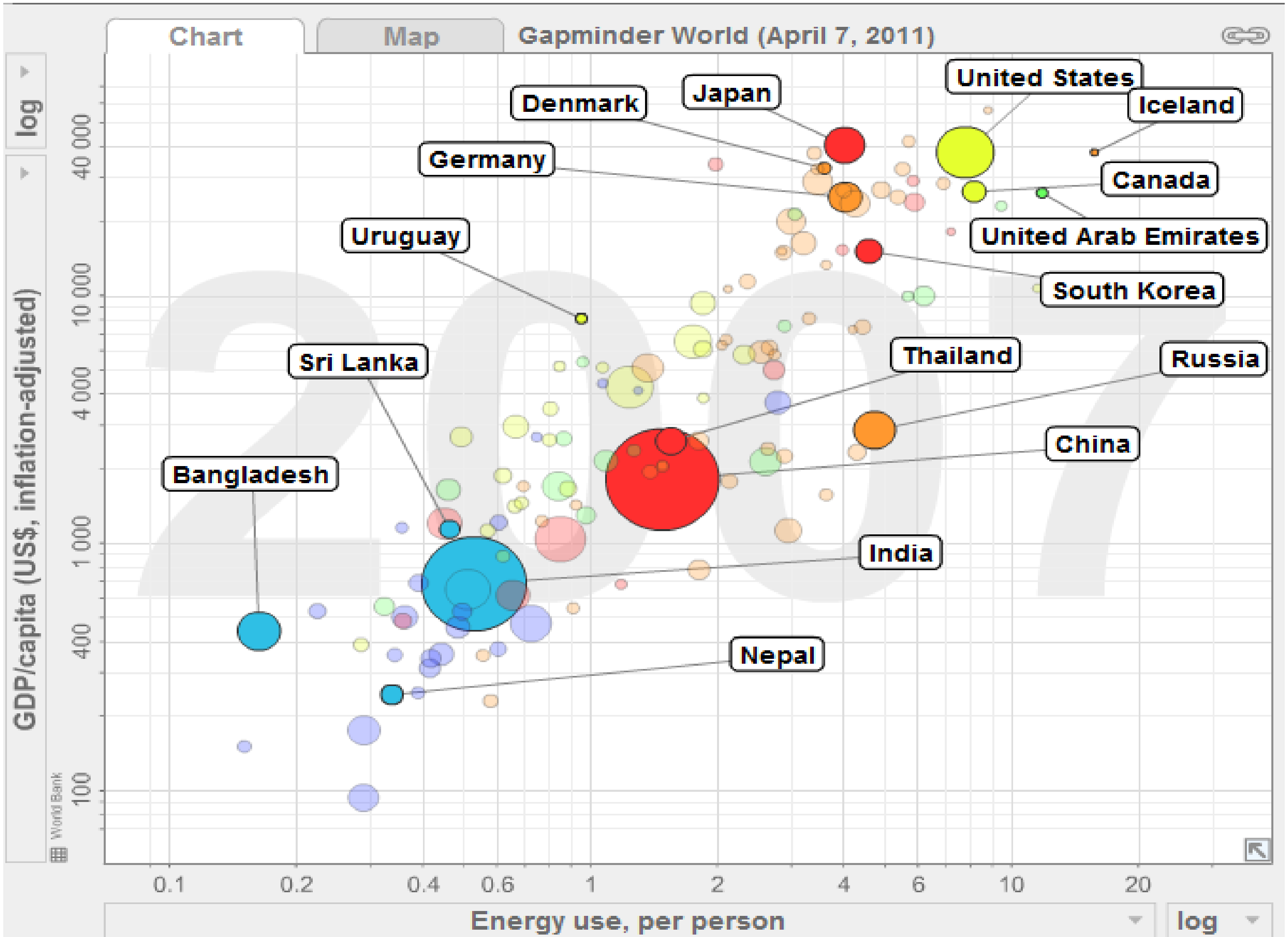


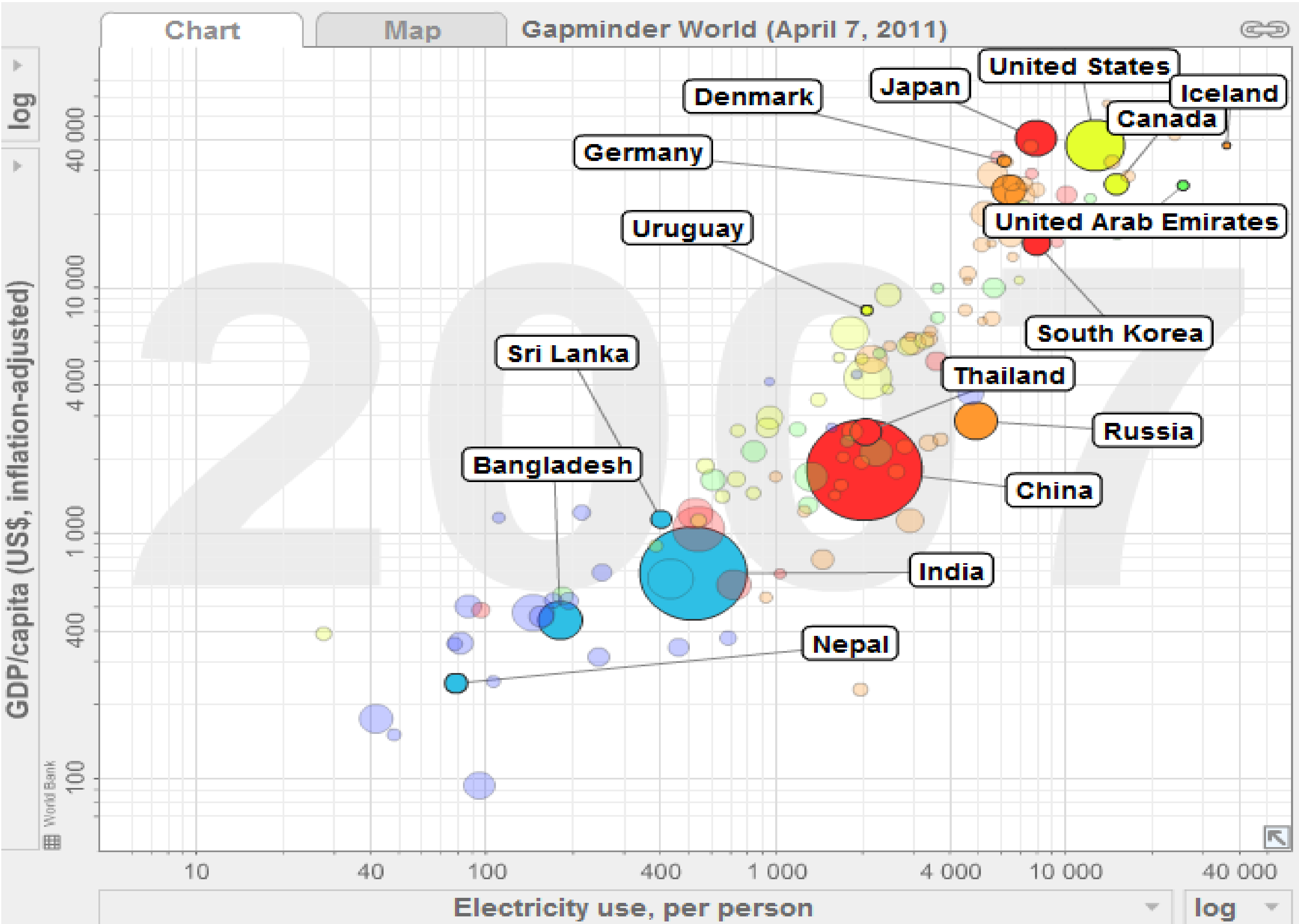
Figure 2. Primary energy intensity of GDP evaluated with purchasing power parity (2004)



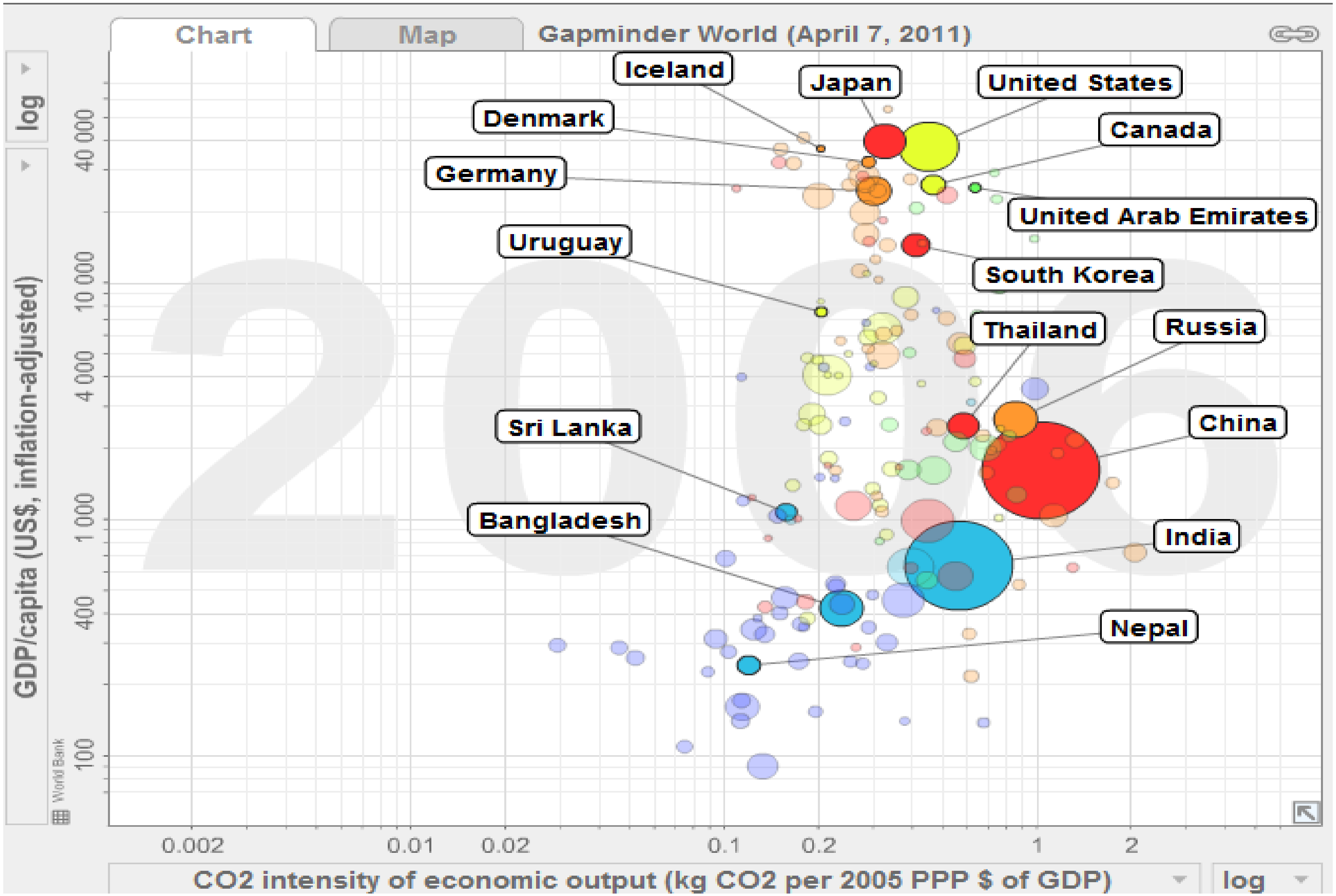
GDP/capita Vs Energy use/person



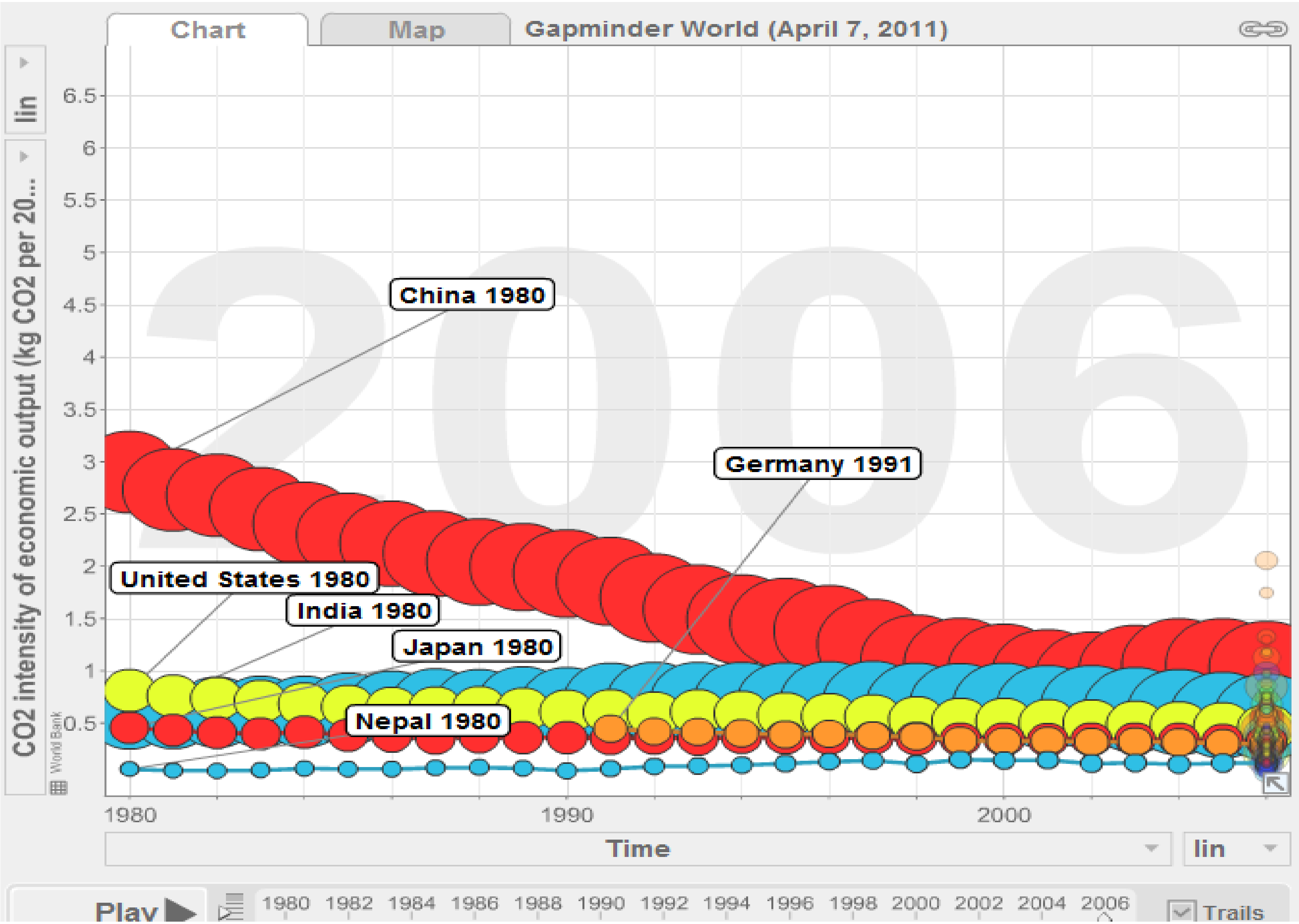
GDP/capita Vs Electricity use/person



GDP/capita Vs CO2 intensity of GDP



Trend of CO2 intensity of GDP



Energy Balance

Energy Balance

- **Energy balance** summarizes the **quantitative behavior** of an energy system for a **given time period**.
- It is an **efficient analytic tool reflecting the system dynamics when examining past series**, or **comparing future alternative energy developments**.

Energy Balance Construction

Commodities Balances — X → Conversion Factors → Reformat Operation — = → Energy Balance

- The first step is to **convert the natural units** in the commodity balances to the **chosen energy unit** by multiplying by the **appropriate conversion equivalent** for each of the natural units.
- Major international energy organizations, such as the IEA and Eurostat, use energy units of **tonnes of oil equivalent** for their balances, where one tonne of oil equivalent (toe) is *defined to be 41.868 gigajoules*. Many countries use the **terajoule** as the unit for their national energy balance.
- The **reformat operation** consists of **arranging the converted commodity balances** alongside one another, **rearranging certain of the rows** and **introducing a sign convention in the transformation** sector.
- There are **different ways** an organization can present its energy balances depending on conventions and emphasis **(see Energy Statistics Manual, IEA (2005))**

Commodity Balance (IEA, 2005)

- The **most commonly used format** for the **presentation of energy commodity data is** the **balance in which both the sources of supply for each commodity and its uses** are shown in **a single column**.
- The balance format is conceptually **identical to** a **simple cash account** where the sources of income should, when summed, balance the total of expenditures after changes in cash deposits are taken into account
- The balance format is appropriate for energy commodities provided that **they are homogeneous at each point in the balance**. This requirement is represented in commodity flows. In addition, energy commodities should be **expressed, as far as possible, in mass or energy u**nits as volume units (cubic metres) are dependent on pressure or temperature.
- **Many Commodity Balances are used** during **development of Energy balance**

Commodity Balance (IEA, 2005)

Sources of supply

+Transfers between commodities

= DOMESTIC SUPPLY

statistical difference

TOTAL DEMAND =

Transformation input

\+ Energy sector own use

\+ Distribution and other losses

\+ FINAL CONSUMPTION =

Non-energy use

\+ Final energy consumption

Production

Other sources

Imports

Exports

International marine bunkers

Stock change

Commodity Balance (IEA, 2005)

FRANCE 1999 — GAS/DIESEL OIL — kilotonnes

EUROSTAT format

Primary production	-
Recovered products	-
Imports	11 668
Stock change	1 213
Exports	-2 230
Bunkers	-419
Gross inland consumption	**10 232**
Transformation input	**48**
Public thermal power stations	18
Autoprod. thermal power stations	23
Nuclear power stations	-
Patent fuel and briquetting plants	-
Coke-oven plants	-
Blast-furnace plants	-
Gas works	-
Refineries	-
District heating plants	
Transformation output	**32 621**
Public thermal power stations	-
Autoprod. thermal power stations	
Nuclear power stations	-
Patent fuel and briquetting plants	-
Coke-oven plants	-
Blast-furnace plants	-
Gas works	-
Refineries	32 621
District heating plants	-
Exchanges and transfers, returns	**-865**
Interproduct transfers	0
Products transferred	-529
Returns from petrochem. industry	-336
Consumption of the energy branch	**4**
Distribution losses	**-**
Available for final consumption	**41 936**
Final non-energy consumption	**1 383**
Chemical industry	1 383
Other sectors	-
Final energy consumption	**42 818**
Industry	1 092
Iron & steel industry	35
Non-ferrous metal industry	15
Chemical industry	0
Glass, pottery & building mat. industry	122
Ore-extraction industry	1
Food, drink & tobacco industry	110
Textile, leather & clothing industry	38
Paper and printing	14
Engineering & other metal industry	200
Other industries	557
Transport	26 801
Railways	368
Road transport	25 948
Air transport	-
Inland navigation	485
Households, commerce, pub. auth, etc.	14 925
Households	8 442
Agriculture	2 026
Statistical difference	**-2 265**

IEA format

Production	32 621
From other sources	-
Imports	11 668
Exports	-2 230
Intl marine bunkers	-419
Stock change	1 213
DOMESTIC SUPPLY	**42 853**
Transfers	-529
Statistical difference	2 265
TRANSFORMATION	**384**
Electricity plants	41
CHP plants	-
Heat plants	-
Blast furnaces/gas works	-
Coke/pat. fuel/BKB plants	-
Petroleum refineries	-
Petrochemical industry	336
Liquefaction plants	-
Other transformation sector	7
ENERGY SECTOR	**4**
Coal mines	-
Oil and gas extraction	-
Petroleum refineries	4
Electricity and heat plants	-
Pumped storage	-
Other energy sector	-
Distribution losses	-
FINAL CONSUMPTION	**44 201**
INDUSTRY SECTOR	**2 475**
Iron and steel	35
Chemical and petrochemical	1 383
of which: Feedstock	*1 383*
Non-ferrous metals	15
Non-metallic minerals	122
Transport equipment	48
Machinery	152
Mining and quarrying	1
Food and tobacco	110
Paper, pulp and print	14
Wood and wood products	-
Construction	409
Textile and leather	38
Non-specified	148
TRANSPORT	**26 801**
International civil aviation	-
Domestic air	-
Road	25 948
Rail	368
Pipeline transport	-
Internal navigation	485
Non-specified	-
OTHER SECTORS	**14 925**
Agriculture	2 026
Commerce and pub. services	4 450
Residential	8 442
Non-specified	7
NON-ENERGY USE	**-**
Industry/transformation/energy	
Transport	-
Other sectors	-

- Useful for Specific Energy Commodity Supply Planning (NEA, NOC etc)
- Becomes basis for Energy System Planning

Energy Balances

Production (+)	**Supply**
Imports (+)	
Exports (-)	
Bunkers (-)	
Stock Change (+ or -)	
Primary Energy Requirement (PER)	
Statistical Difference	**Conversion**
Transformation input (-)	
Energy sector's own use (-)	
Transmission and Distribution losses (-)	
Net Supply Available	
Net Domestic Consumption	**Demand**
Final energy consumption	
Agriculture	
Industry	
Transport	
Residential	
Commercial	
Non-energy uses	

Energy Balances

- **Energy balance** summarizes the **quantitative behavior** of an energy system for a **given time period**.
- It could **apply for a past period** and as such **be based on statistical data** or **elaborated for the future**. It took some time, however, to recognize in the initial energy balance sheets of accounting character an **efficient analytic tool reflecting the system dynamics when examining past series**, or **comparing future alternative energy developments**.
- At the present stage, with a few exceptions, the energy balances do not extend into the final stage of the energy system, i.e. **do not include the consumption of useful energy**. They stop short at this point, quantifying only the end-use energy. Therefore, **neither the losses nor possible waste in the final consumption stage are accounted** for. Nor do they include on the input side **figures on energy resources left** in situ owing to low recovery factors, nor **expand on the potential of the reserves or resources themselves**.

Use of Energy Balances

Energy balances can usefully serve for following:

- **evaluating the dynamics of the historical evolution of the energy system** in relation to the general **socio-economic development** and the **individual economic sectors**
- in-depth study of the **structure of the involved energy system**
- determining for each energy resource **the competitive uses and conservation potential**, both for savings as well as for substitution
- better organization and **management of energy data and information**
- offering a **reliable basis for short-term energy planning** and **supportive reference for medium- and long-term energy projections and scenarios**.

Energy Balance of Nepal (1,000 toe)

2010

SUPPLY AND CONSUMPTION	Coal & peat	Crude oil	Oil products	Natural Gas	Nuclear	Hydro	Geotherm. solar etc.	Biofuels & waste	Electricity	Heat	Total
Production	10	-	-	-	-	276	-	8699	-	-	8984
Imports	193	-	1072	-	-	-	-	-	60	-	1324
Exports	-	-	-	-	-	-	-	-	-3	-	-3
Intl. marine bunkers	-	-	-	-	-	-	-	-	-	-	-
Intl. aviation bunkers	-	-	-88	-	-	-	-	-	-	-	-88
Stock changes	-	-	-	-	-	-	-	-	-	-	-
TPES	**202**	-	**984**	-	-	**276**	-	**8699**	**57**	-	**10218**
Electricity and CHP plants	-	-	-1	-	-	-276	-	-	276	-	-1
Oil refineries	-	-	-	-	-	-	-	-	-	-	-
Other transformation*	-	-	-	-	-	-	-	7	-97	-	-90
TFC	**202**	-	**983**	-	-	-	-	**8706**	**236**	-	**10128**
INDUSTRY	**202**	-	**22**	-	-	-	-	**53**	**90**	-	**367**
Iron and steel	-	-	-	-	-	-	-	-	-	-	-
Chemical and petrochemical	-	-	-	-	-	-	-	-	-	-	-
Non-metallic minerals	-	-	-	-	-	-	-	-	-	-	-
Other/non-specified	202	-	22	-	-	-	-	53	90	-	367
TRANSPORT	-	-	**624**	-	-	-	-	-	**0**	-	**625**
Domestic aviation	-	-	-	-	-	-	-	-	-	-	-
Road	-	-	624	-	-	-	-	-	-	-	624
Other/non-specified	-	-	-	-	-	-	-	-	0	-	0
OTHER	**1**	-	**337**	-	-	-	-	**8653**	**146**	-	**9136**
Residential	1	-	140	-	-	-	-	8602	104	-	8847
Comm. and public services	-	-	81	-	-	-	-	51	33	-	164
Agriculture/forestry	-	-	116	-	-	-	-	-	5	-	121
Other/non-specified	-	-	-	-	-	-	-	-	4	-	4
NON-ENERGY USE	-	-	-	-	-	-	-	-	-	-	-
Electricity and Heat Output											
Electricity generated - GWh	-	-	3	-	-	3204	-	-	-	-	3207
Heat generated - TJ	-	-	-	-	-	-	-	-	-	-	-

* Includes transfers, statistical differences, energy industry own use, and losses.

Source: IEA (2012)

IEA Energy Balance Table for Spain, 1999 (a)

Million tonnes of oil equivalent

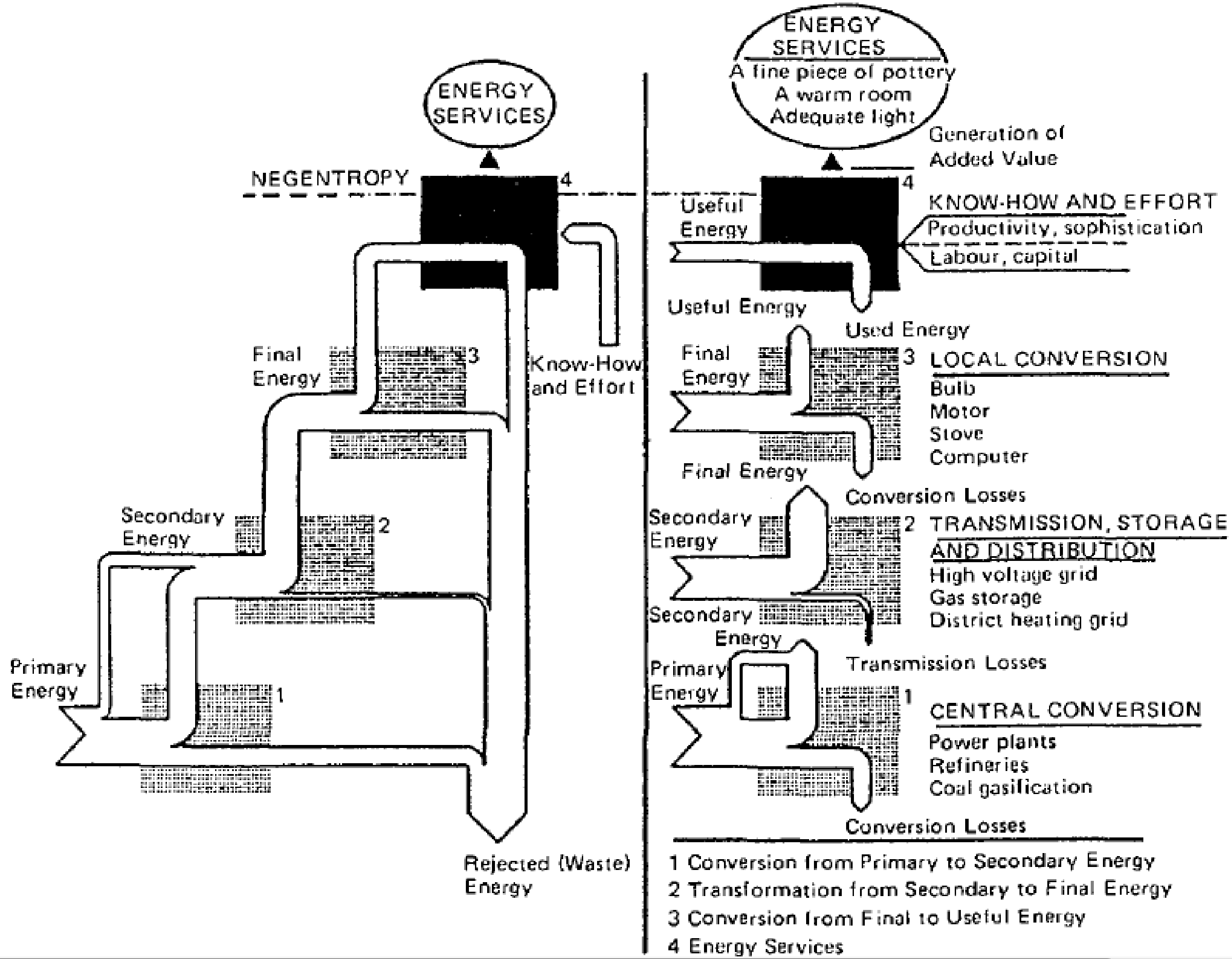
SUPPLY AND CONSUMPTION	Coal	Crude Oil	Petroleum Products	Gas	Nuclear	Hydro	Geotherm. Solar etc.	Combust. Renew. & Waste	Electricty	Heat	Total
Production	8.60	0.30	-	0.13	15.34	1.97	0.27	4.08e	-	-	30.70
Imports	11.30	60.01	16.85	13.90	-	-	-		1.03	-	103.09
Exports	-0.28	-	-7.09	-	-	-	-	-	-0.54	-	-7.90
Intl. Marine Bunkers	-	-	-5.88	-	-	-	-	-	-	-	-5.88
Stock Changes	-0.36	0.54	-0.97	-0.74	-	-	-	-	-	-	-1.54
TPES	**19.26**	**60.85**	**2.91**	**13.29**	**15.34**	**1.97**	**0.27**	**4.08**	**0.49**	**-**	**118.46**
Transfers	-	-1.56	-1.52	-	-	-	-	-	-	-	0.05
Statistical Differences	-0.35	-	-0.74	-	-	-	-	-	-	-	-1.08
Electricity Plants	-16.27	-	-3.44	-0.59	-15.34	-1.97	-0.24	-0.28	15.30	-	-22.82
CHP Plants	-0.04	-	-1.58	-2.37	-	-		-0.75e	2.44e	0.07	-2.22
Heat Plants	-	-	-	-	-	-	-	-	-	-	-
Gas Works	-	-	-0.14e	0.03	-	-	-	-	-	-	-0.11
Petroleum Refineries	-	-62.44	62.16	-	-	-	-	-	-	-	-0.27
Coal Transformation	-1.05 e	-	-	-	-	-	-	-	-	-	-1.05
Liqufaction Plants	-	-	-	-	-	-	-	-	-	-	-
Other Transformation	-	0.03	-0.03	-	-	-	-	-	-	-	-0.00
Own Use	-0.23	-	-4.27	-0.02	-	-	-	-	-	-	-5.81
Distribution Losses	-	-	-	-0.25	-	-	-	-0.00e	-1.71	-	-1.96
TFC	**1.32**	**0.01**	**53.37**	**10.09**	**-**	**-**	**0.03**	**3.04**	**15.24**	**0.07**	**83.18**
INDUSTRY SECTOR	**1.17**	**0.01**	**9.78**	**7.69**			**0.00**	**1.02**	**6.57**	**0.07**	**26.33**

Source: IEA (2005), Energy Statistics Manual

IEA Energy Balance Table for Spain, 1999 (b)

TFC	**1.32**	**0.01**	**53.37**	**10.09**	**-**	**-**	**0.03**	**3.04**	**15.24**	**0.07**	**83.18**
INDUSTRY SECTOR	**1.17**	**0.01**	**9.78**	**7.69**	**-**	**-**	**-0.00**	**1.02**	**6.57**	**0.07**	**26.33**
Iron and Steel	0.89e	-	0.37	0.68	-	-	-	-	1.14	-	3.08
Chemical & Petrochemicals	0.06	0.01	5.35	1.78	-	-	-	-	0.92	0.02	8.15
of which: Feedstocks	-	-	4.60	0.43	-	-	-	-	-	-	5.03
Non-ferrous Metals	0.05	-	0.14	0.13	-	-	-	-	0.77	-	1.09
Non-metallic Minerals	0.15	-	1.94	2.28	-	-	-	0.08e	0.76	-	5.21
Transport Equipment	-	-	0.13	0.35	-	-	-	-	0.28	-	0.76
Machinery	0.02	-	0.23	0.21	-	-	-	-	0.46	-	0.93
Mining and Quarrying	0.00	-	0.13	0.08	-	-	-	-	0.13	-	0.34
Food and Tobacco	0.01	-	0.59	0.75	-	-	0.00	-	0.66	0.01	2.01
Paper, Pulp and Printing	0.00	-	0.31	0.83	-	-	-	-	0.47	-	1.61
Wood and Wood Products	-	-	0.04	0.07	-	-	-	-	0.12	-	0.23
Construction	-	-	0.11	0.00	-	-	-	-	0.11	-	0.22
Textile and Leather	-	-	0.18	0.53	-	-	-	-	0.34	0.01	1.06
Non-specified	-	-	0.25	0.01	-	-	0.00	0.94 e	0.40	0.04	1.65
TRANSPORT SECTOR	**-**	**-**	**32.33**	**0.01**	**-**	**-**	**-**	**-**	**0.31**	**-**	**32.65**
International Civil Aviation	-	-	2.62	-	-	-	-	-	-	-	2.62
Domestic Air Transport	-	-	1.75	-	-	-	-	-	-	-	1.75
Road	-	-	25.86	0.01	-	-	-	-	-	-	25.87
Rail	-	-	0.50	-	-	-	-	-	0.21	-	0.70
Pipeline Transport	-	-	-	-	-	-	-	-	-	-	-
Internal Navigation	-	-	1.62	-	-	-	-	-	-	-	1.62
Non-specified	-	-	-	-	-	-	-	-	0.10	-	0.10
OTHER SECTORS	**0.14**	**-**	**7.28**	**2.39**	**-**	**-**	**0.03**	**2.02**	**8.36**	**-**	**20.23**
Agriculture	-	-	1.75	0.08	-	-	0.00	0.00e	0.39	-	2.23
Comm. and Publ. Services	0.01	-	1.47	0.54	-	-	0.02	-	3.87	-	5.91
Residential	0.13	-	4.06	1.77	-	-	0.01	2.00e	3.91	-	11.88
Non-specified	-	-	-	-	-	-	-	0.02e	0.19	-	0.21
NON-ENERGY USE	0.01	-	3.97	-	-	-	-	-	-	-	3.97
in Industry/Transf./Energy	0.01	-	3.64	-	-	-	-	-	-	-	3.65
in Transport	-	-	0.31	-	-	-	-	-	-	-	0.31
in Other Sectors	-	-	0.02	-	-	-	-	-	-	-	0.02
Electricity Generated - GWh	***75436***	**-**	***24445***	***19058***	***58852***	***22863***	***2761***	***2902e***	**-**	**-**	***206317***
Electricity plants	75071	-	14541	2643	58852	22863	2761	1161	-	-	177892
CHP Plants	365	-	9904	16415	-	-	-	1741e	-	-	28425
Heat Generated - TJ	-	-	320	2205	-	-	-	576	-	-	3101
CHP plants	-	-	320	2205	-	-	-	576	-	-	3101
Heat plants	-	-	-	-	-	-	-	-	-	-	-

Energy flow (Sankey) charts/diagrams



Energy flow charts/diagrams and energy balances

- The **energy flow chart of an energy system** consists of the **characteristic lines suggesting possible energy chains representing the actual energy flows**, expressed in a **common energy unit** and represented on a **convenient scale** by the width of the respective ramifying bands.
- In this manner, **a representation is gained which visualizes the physical energy flows so as to give a rapid overview**, where not only the **structure of the system** can be recognized, but also the **occurring energy losses** identified and evaluated.
- Such **energy flows** can **refer to a geographical framework** which could be a **country, a region, the entire world** or to a determined entity — **an industry, a workshop or even a small energy consumer**, a house or an industrial machine.
- In parallel to energy flow charts, themselves a graphic energy balance, numerical energy balances — **energy balance sheets** — are very much used both for accounting purposes and energy efficiency analysis for auditing.

Energy Flow Chart of UK 2007 (million toe)

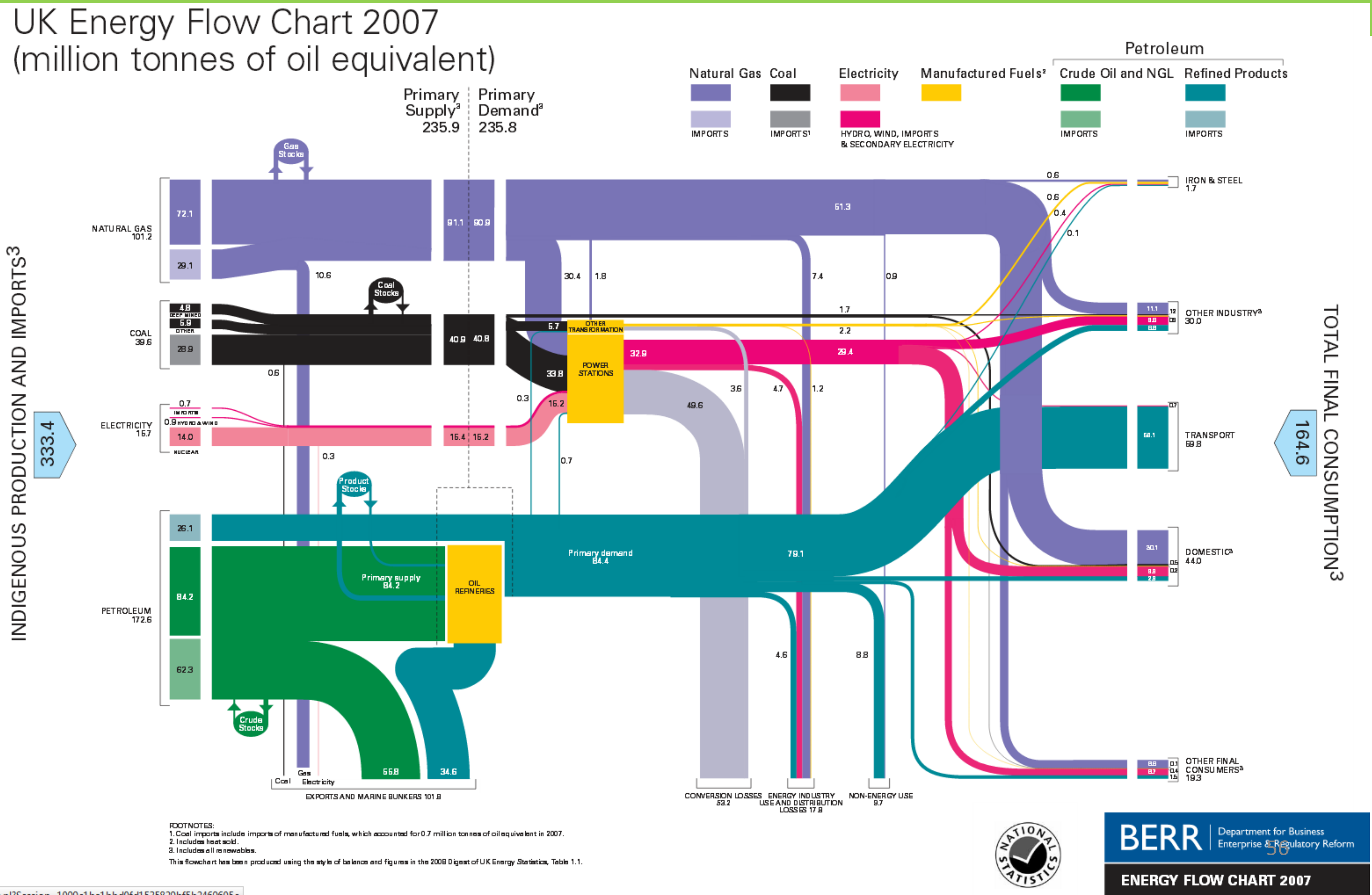


Diagram of energy flow in Spain in 1981 (in PJ)

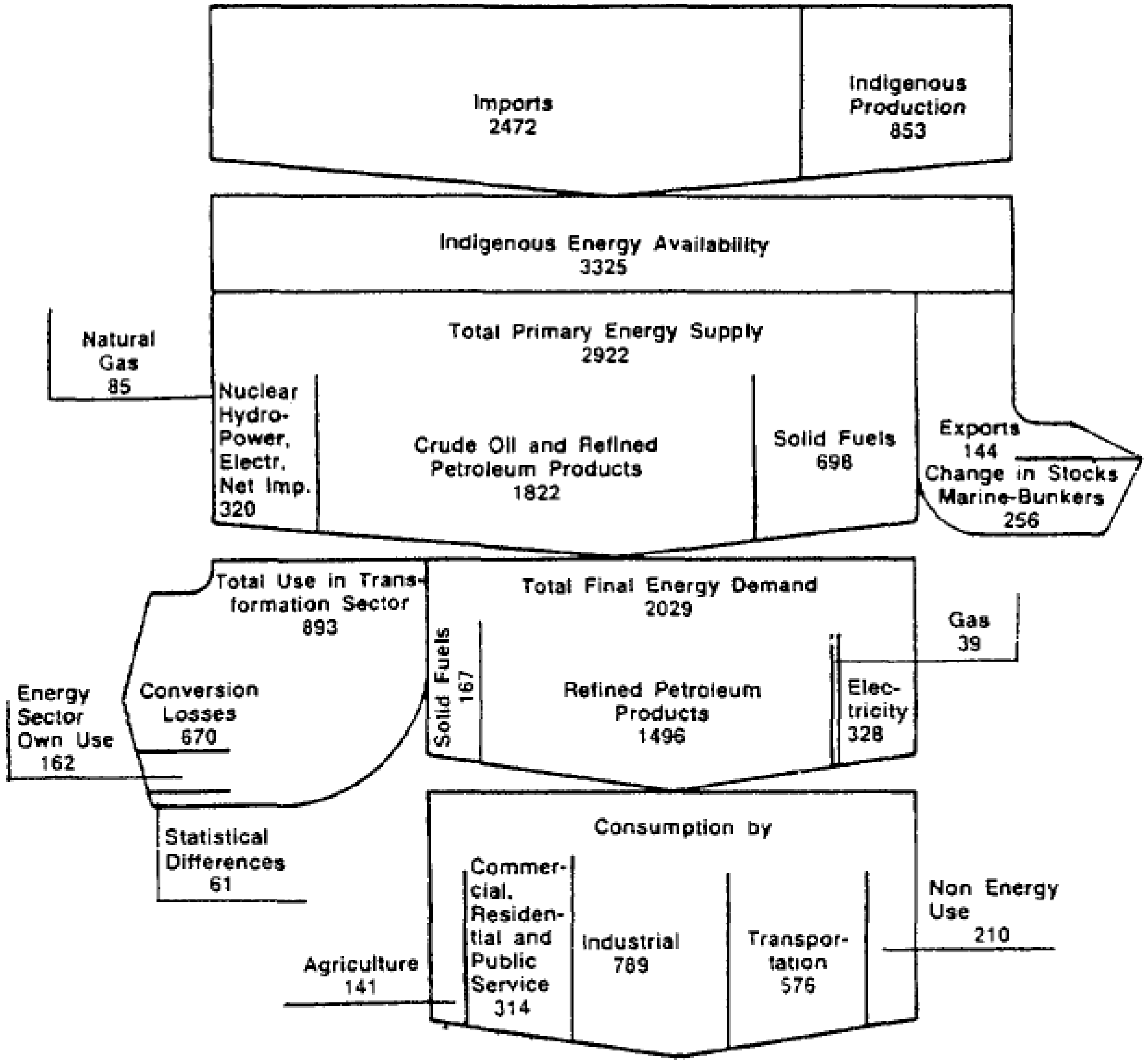
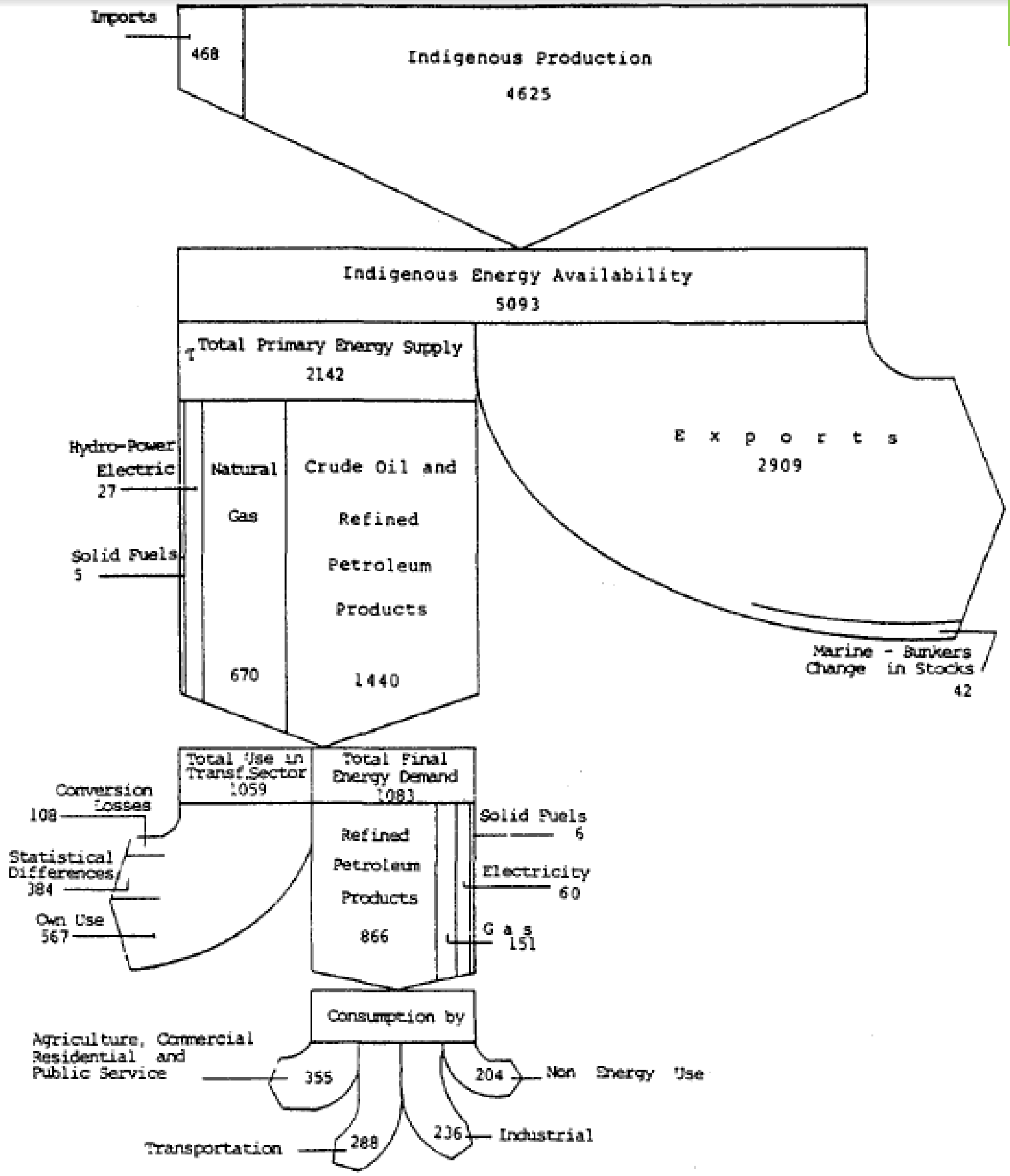
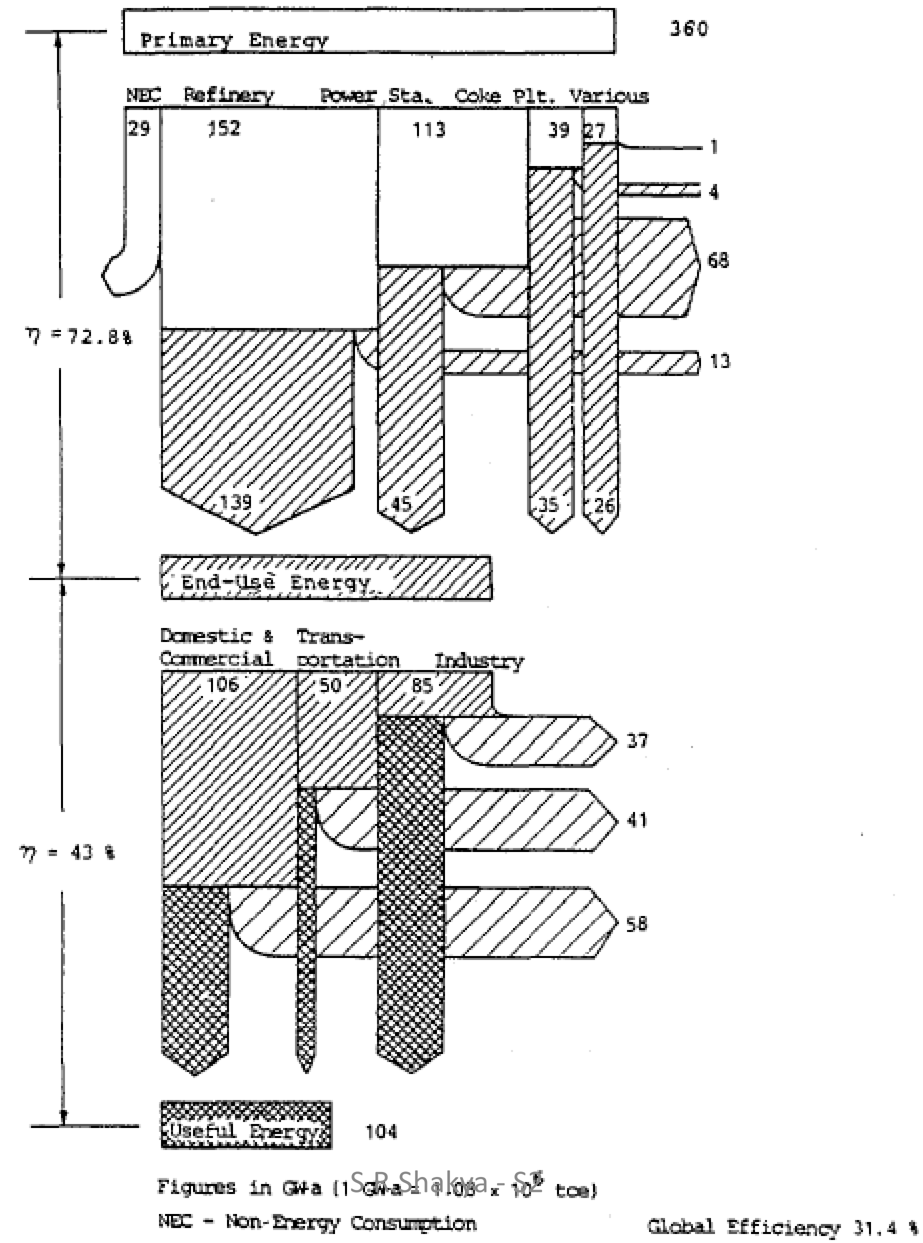


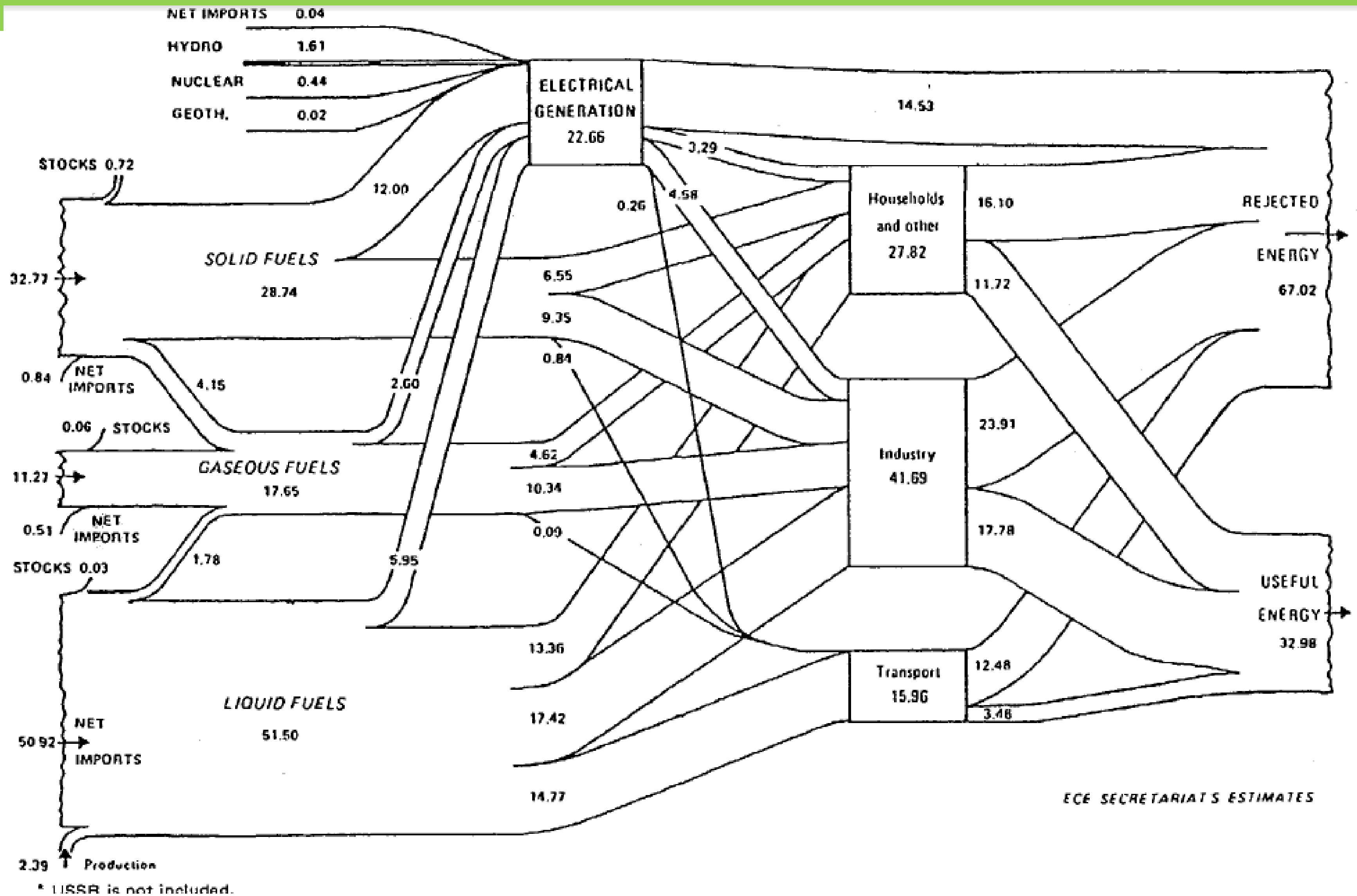
Diagram of conventional energy flow in Indonesia, 1981 (in PJ)



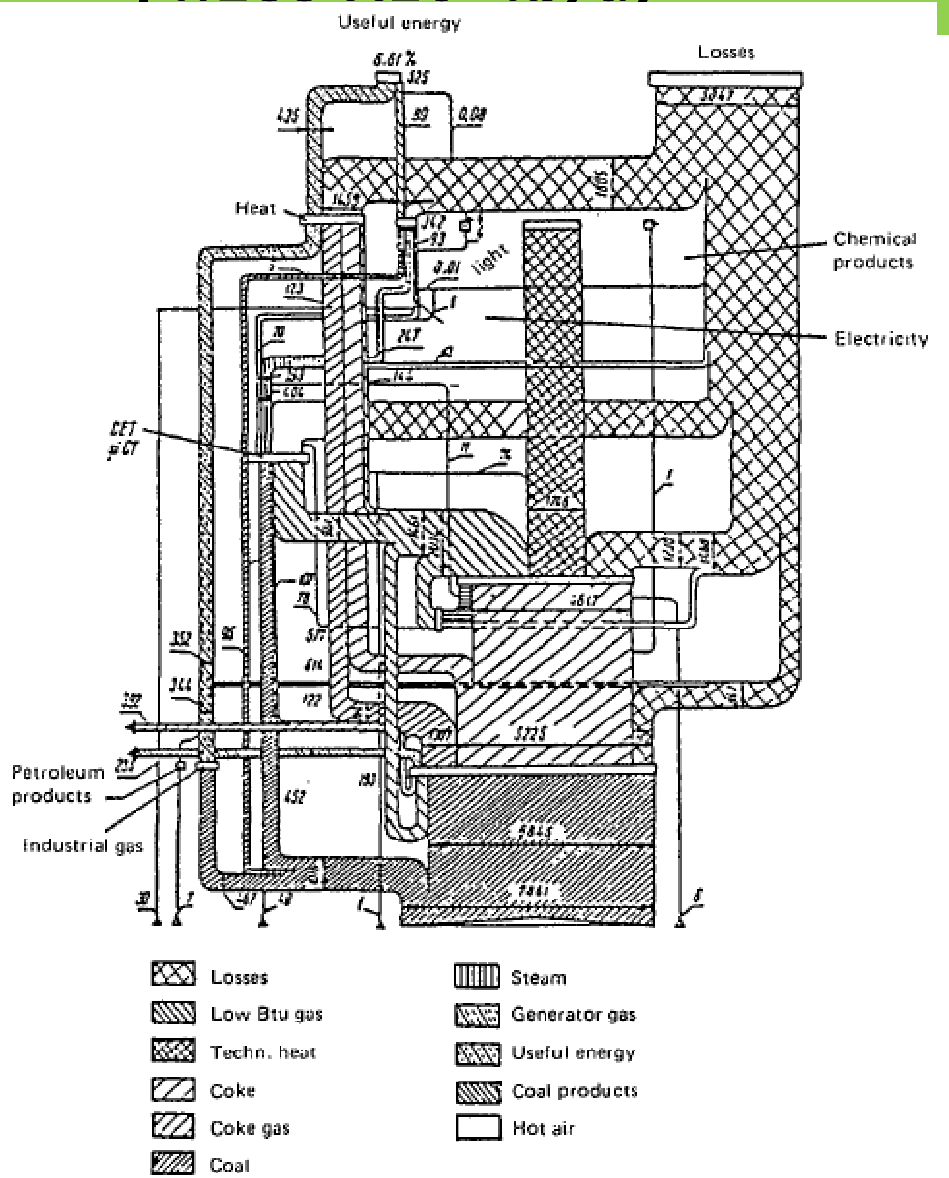
Energy flowchart in the Federal Republic of Germany in 1978



Energy flow in Europe in 1972 in %



Energy flowchart in an iron and steel plant in 10^9 kcal/a (4.185×10^9 kJ/a)



Assignment 1

- Do literature review on the relationship between **GDP/Capita** and **Electricity Consumption per capita** for at least 100 countries containing 50% developed and 50% developing worlds.
- If Nepal is to attain average GDP/Capita of Developing Countries by 2022 and Developed Country by 2050, what should be the **Electricity Consumption per capita** of Nepal for the year 2022 and 2050?
- Project population of Nepal for 2022 and 2050
- Estimate Total Electricity Consumption for 2022 and 2050
  - Considering same **Electricity Consumption per capita** of Nepal as that of 2010
  - Considering different **Electricity Consumption per capita** as that of the average value of **Electricity Consumption per capita** given for Developing country in 2022 and the value for Developed country in 2050
- Do critical analysis from Sustainable Energy Perspective and Discuss the result?

Due Date: 5 February 2015

Submit the individual report with proper format and referencing

Basic contents of the Report: Introduction, Study Objective, Methodology, Analysis, Result & Conclusion, Reference.

Thank you !