# UNIVERSITY OF PATRAS
# DEPARTMENT OF ECONOMICS

# Energy Economics

## FALL SEMESTER 2022-2023

**Lecturers 1-2$^{nd}$– Introduction and Energy Demand**

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# Energy Economics

## 1nd-2nd Lecture: Introduction and Energy Demand

- Energy and its different sources are a critical factor for economic growth. This course examines key energy sources such as oil, coal and natural gas and tries to understand their role in the economy.
- Also, the relationship between the different energy sources and the economy is presented analytically, analyzing issues such as energy production and consumption, the structure of energy markets, the pricing and taxation of different sources as well as the environmental impact from their use.
- Finally, issues such as energy efficiency and energy security are considered, while policies related to these issues are being studied and a first introduction into the economics of climate change.

# Aims-Targets of EE

- To get a comprehensive picture of the different energy sources in different sectors of the economy and to be able to describe trends at European level.
- They can explain the basic economic concepts for the main markets for electricity, liquid fuels, coal and RES, focusing on both the producer's and the consumer's side.
- Understand the functioning of the energy market and price formation mechanisms.
- Understand concepts such as energy conservation as well as energy security and gain an insight into the economics of climate change.

# Outline of Energy Economics

- Introduction, definition and relevant issues-Well known databases
- Energy demand and forecasting
- Energy supply
- Energy Markets-Gas-oil-RES e.t.c
- Pricing and taxation on Energy markets
- Economics of RES
- Regulation and deregulation on energy markets
- Energy saving and efficiency
- R&D on energy sector
- Economics of climate change
- Energy security.

# Relevant Subjects

- Econometris
- Industrial Organization
- Microeconomics
- Macroeconomics
- Enviromental Economics

# Thematic Issues

- Climate change and global warming
- Threats and energy security
- Energy markets, regulations and deregulation
- Energy demand
- Energy and economic growth
- Economics of energy infrastructure
- Enviromental Policy
- Energy Polcy
- Energy substitutes
- Enery demand forecasting
- Energy elasticities in demand and supply

# Energy Economics in other universities

- http://www.abdn.ac.uk/study/courses/postgraduate/taught/int_business_energy
- http://www.dundee.ac.uk/postgraduate/courses/energy_studies_postgraduate_courses.htm?cepmlp_esee
- http://www.oxfordenergy.org/
- http://web.stanford.edu/~jsweeney/paper/Energy%20Economics.PDF
- http://www.surrey.ac.uk/postgraduate/energy-economics-and-policy
- http://ocw.mit.edu/courses/energy-courses/
- http://www.feweb.vu.nl/nl/afdelingen-en-instituten/spatial-economics/

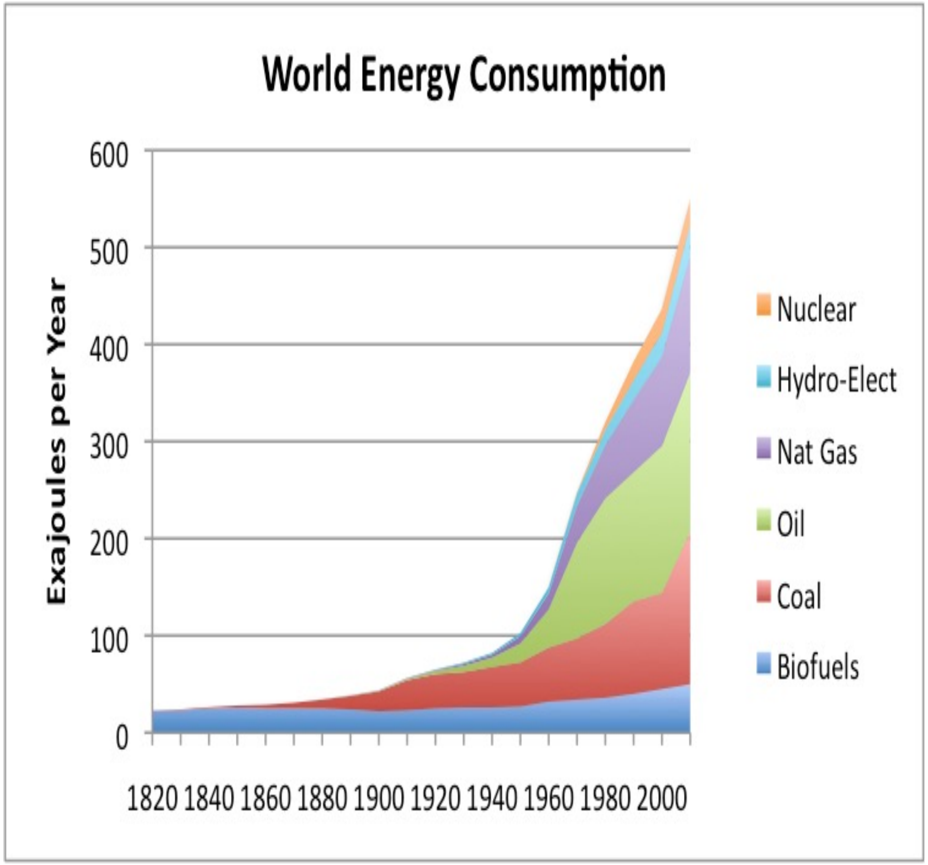
# Energy Economics Definition

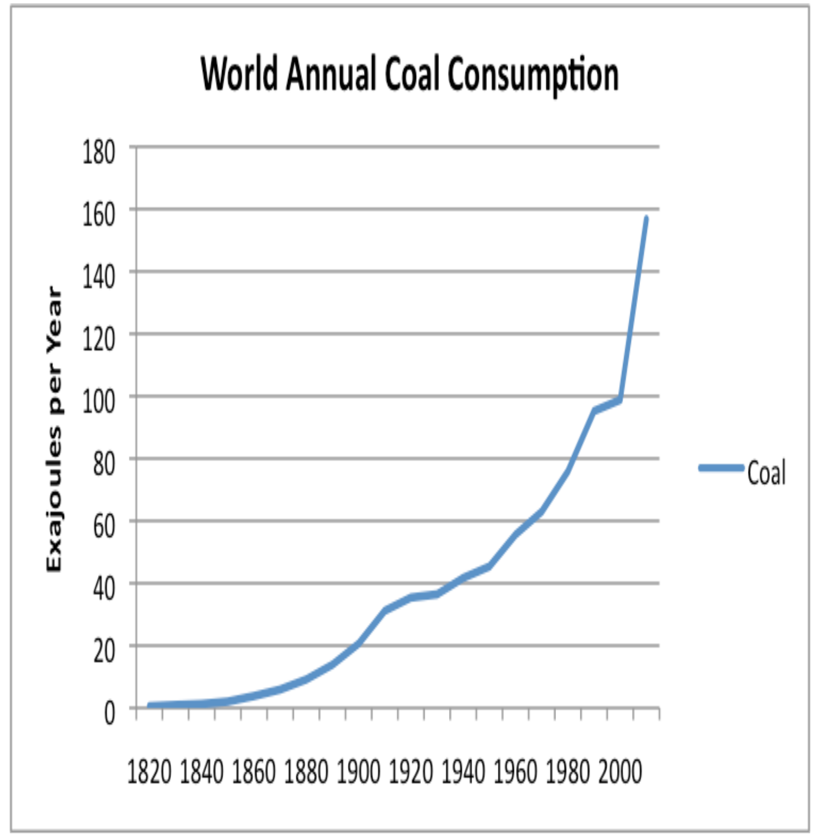
- "Energy economics is a branch of applied economics where economic principles and tools are applied to ask the right questions (Stevens, 2000) and to analyze them logically and systematically to develop a well-informed understanding of the issues"
- First discussion on energy economics relevant subjects after the first oil crisis.

# Complexity

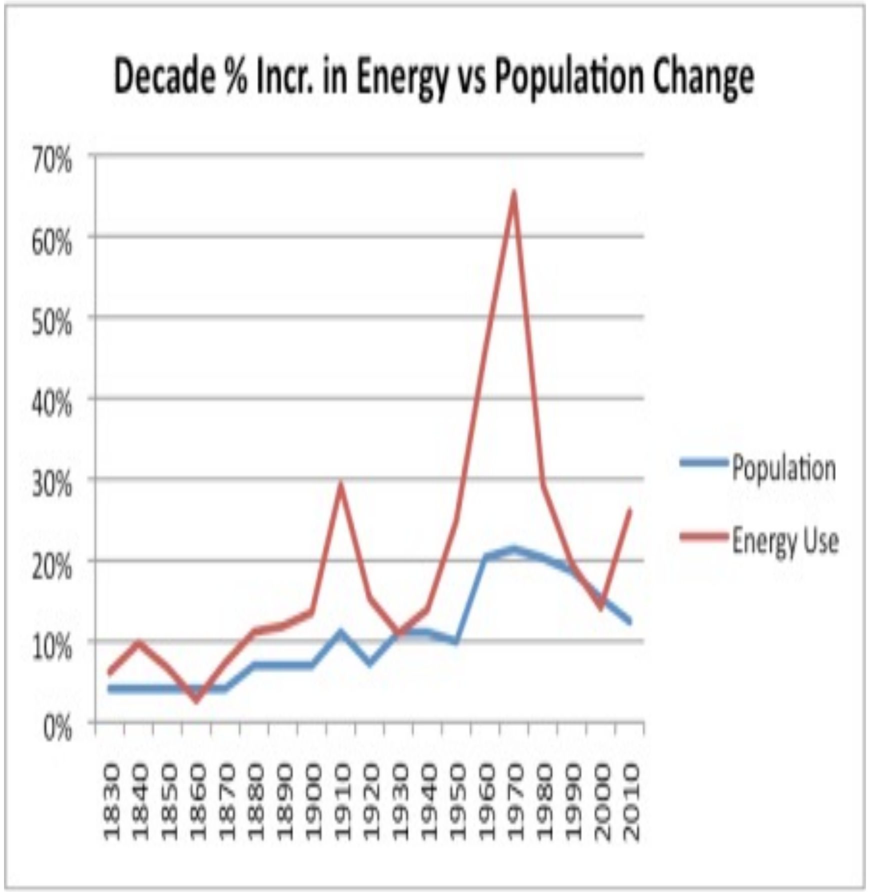
- The constituent industries tend to be highly technical in nature, requiring some understanding of the underlying processes and techniques for a good grasp of the economic issues.
- Each industry of the sector has its own specific features which require special attention.
- Energy being an ingredient for any economic activity, its availability or lack of it affects the society and consequently, there are greater societal concerns and influences affecting the sector.
- The sector is influenced by interactions at different levels (international, regional, national and even local), most of which go beyond the subject of one discipline.

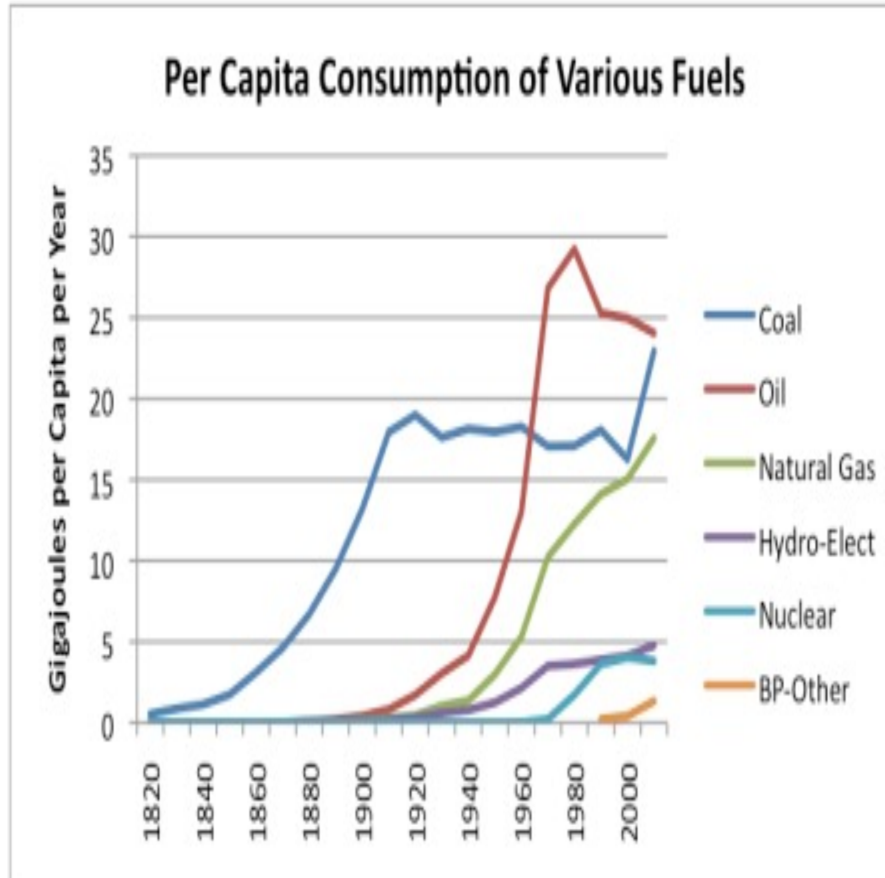
# Some graphs I



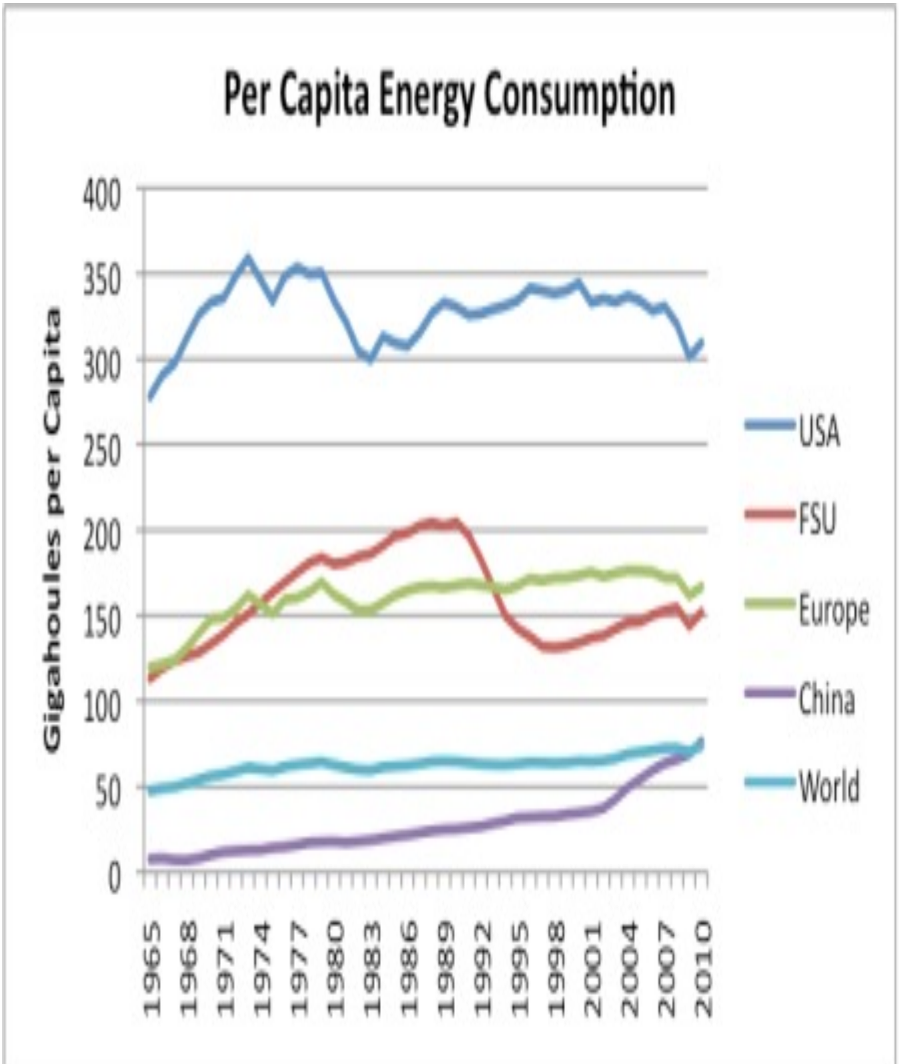



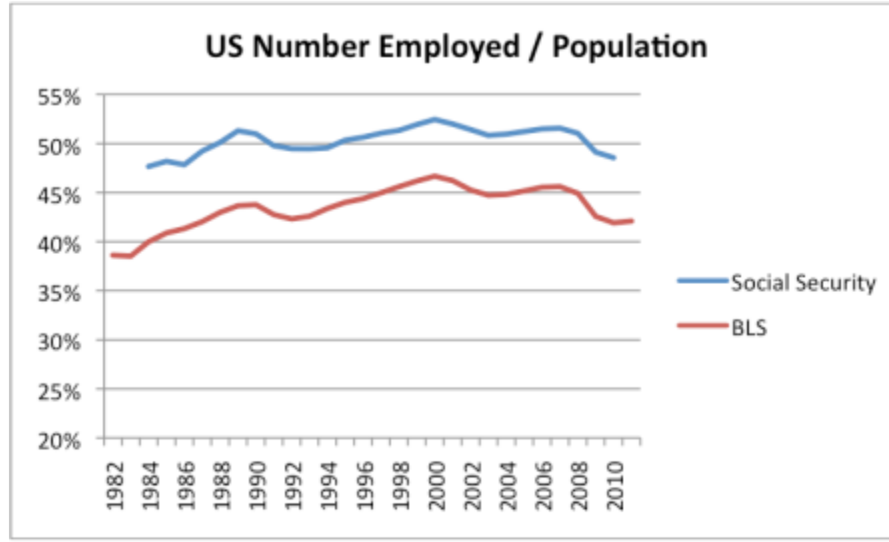
# Some graphs II

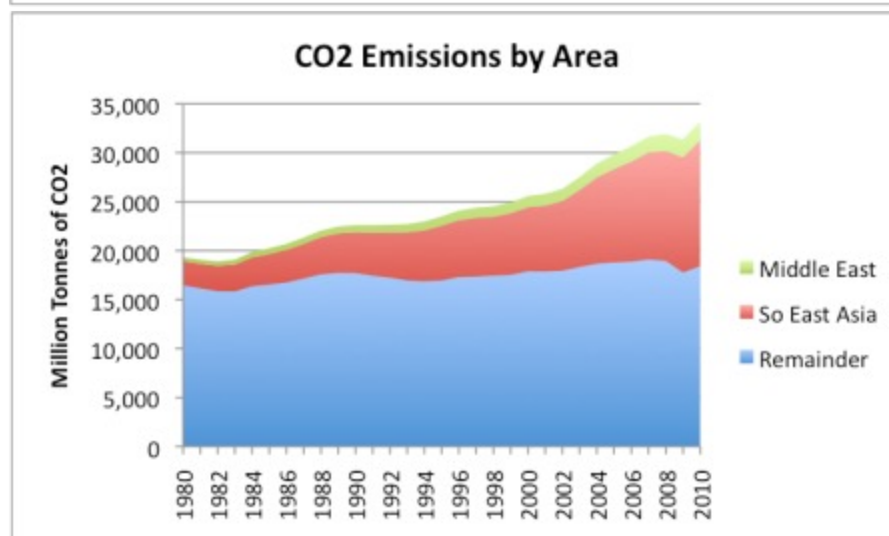


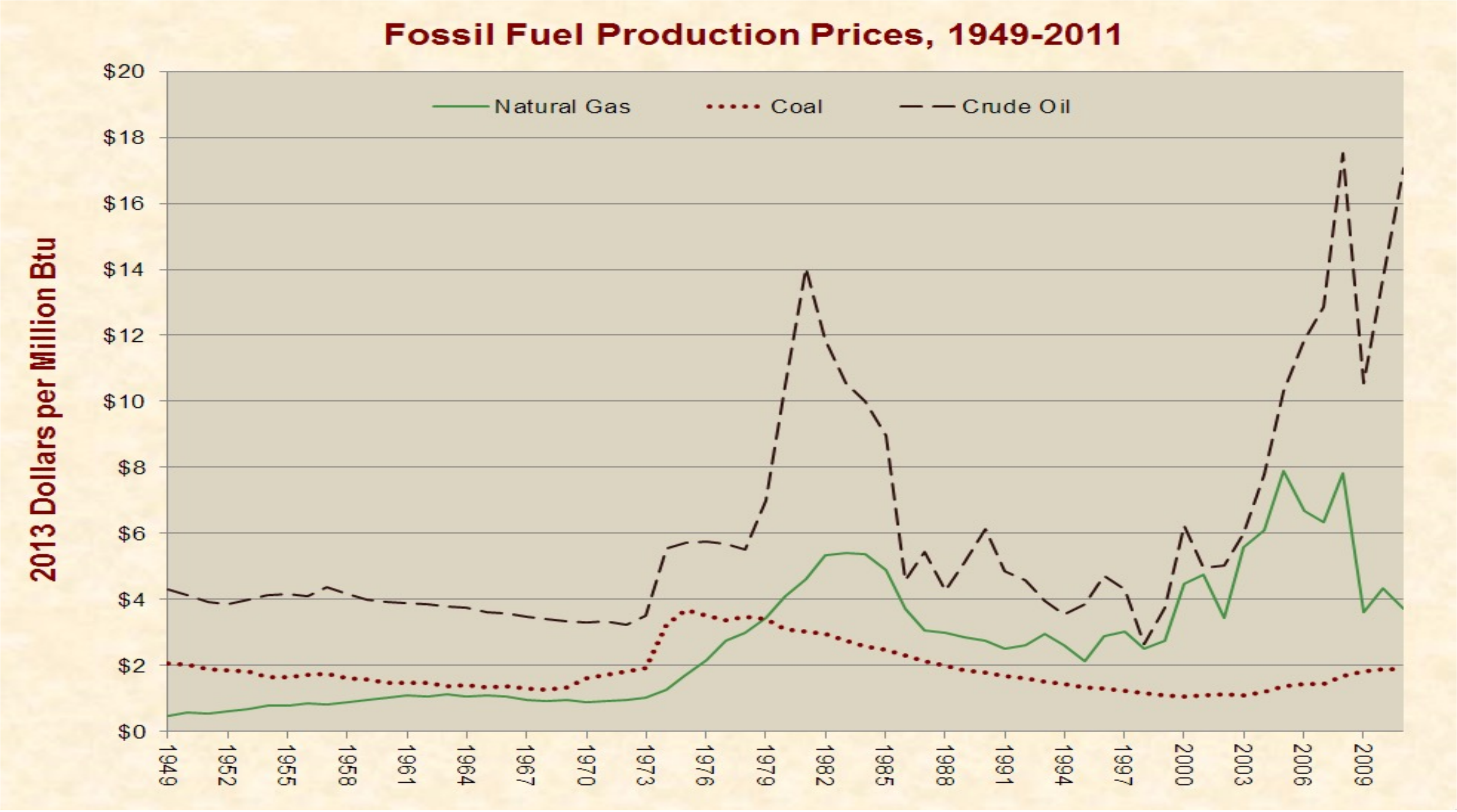
# Some graphs III



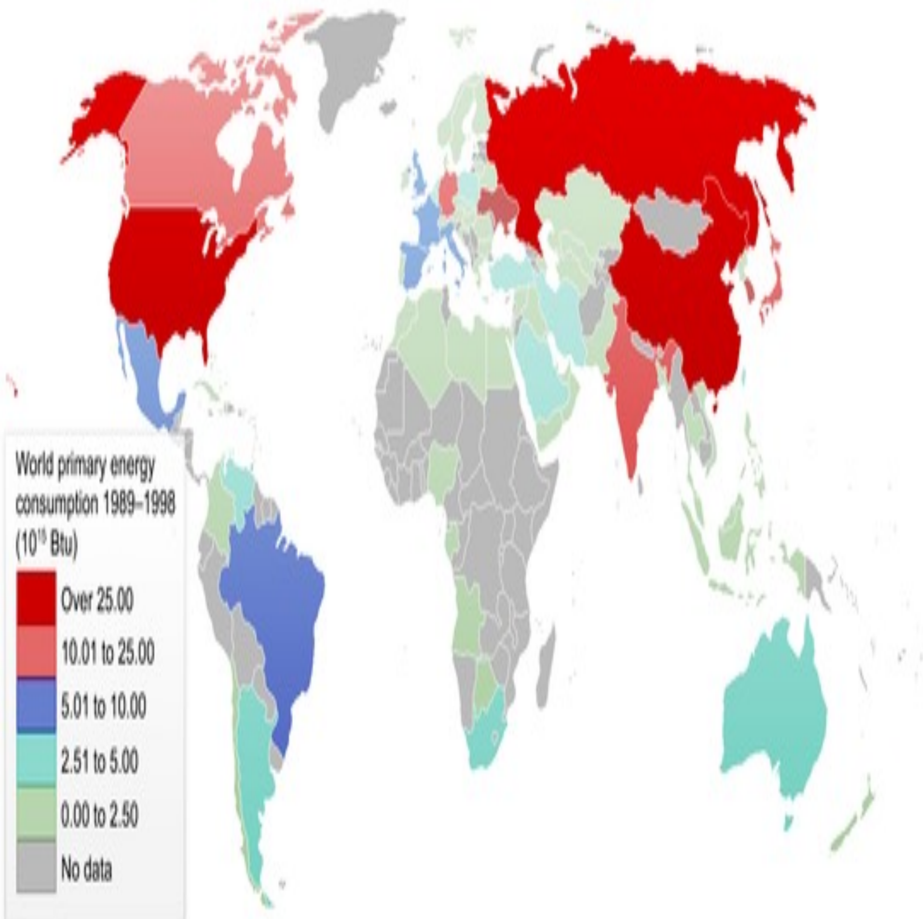



# Some graphs IV



# Today



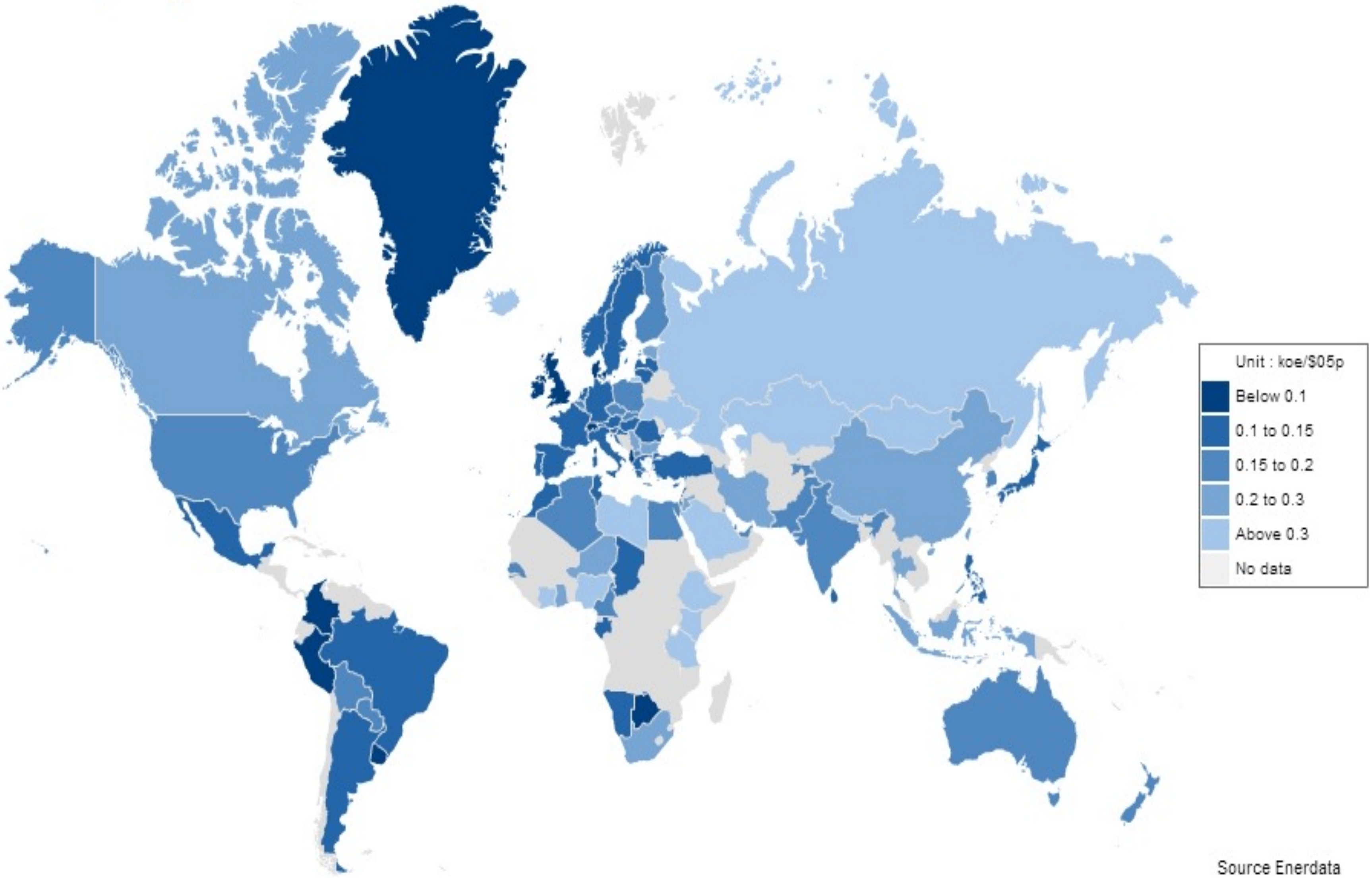

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2011 | 2012 | Share in EU-28, 2012 (%) |
|---|---|---|---|---|---|---|---|---|
| EU-28 | 1 667.6 | 1 671.3 | 1 727.1 | 1 825.1 | 1 759.1 | 1 699.5 | 1 682.9 | 100.0 |
| Belgium | 48.7 | 53.9 | 59.2 | 58.7 | 60.6 | 59.2 | 56.3 | 3.3 |
| Bulgaria | 27.6 | 22.7 | 18.5 | 19.8 | 17.8 | 19.1 | 18.2 | 1.1 |
| Czech Republic | 49.8 | 41.7 | 41.2 | 45.1 | 44.7 | 43.2 | 42.8 | 2.5 |
| Denmark | 17.9 | 20.2 | 19.8 | 19.6 | 20.1 | 18.7 | 18.1 | 1.1 |
| Germany | 356.3 | 341.6 | 342.3 | 341.9 | 333.7 | 317.1 | 319.5 | 19.0 |
| Estonia | 10.1 | 5.6 | 5.0 | 5.6 | 6.2 | 6.2 | 6.1 | 0.4 |
| Ireland | 10.3 | 11.0 | 14.3 | 15.0 | 15.1 | 14.0 | 13.8 | 0.8 |
| Greece | 22.3 | 23.9 | 28.3 | 31.4 | 28.8 | 27.8 | 27.0 | 1.6 |
| Spain | 90.1 | 102.1 | 123.6 | 144.2 | 129.9 | 128.2 | 127.3 | 7.6 |
| France | 227.8 | 241.8 | 257.6 | 276.4 | 267.1 | 257.9 | 258.4 | 15.4 |
| Croatia | 9.0 | 7.1 | 7.8 | 8.9 | 8.6 | 8.5 | 8.1 | 0.5 |
| Italy | 153.4 | 161.7 | 174.1 | 187.5 | 174.5 | 171.8 | 163.1 | 9.7 |
| Cyprus | 1.6 | 2.0 | 2.4 | 2.5 | 2.7 | 2.7 | 2.5 | 0.1 |
| Latvia | 7.9 | 4.6 | 3.9 | 4.6 | 4.8 | 4.4 | 4.5 | 0.3 |
| Lithuania | 15.9 | 8.6 | 7.1 | 8.7 | 6.8 | 7.0 | 7.1 | 0.4 |
| Luxembourg | 3.5 | 3.3 | 3.6 | 4.8 | 4.6 | 4.6 | 4.5 | 0.3 |
| Hungary | 28.8 | 26.2 | 25.3 | 27.6 | 25.8 | 25.1 | 23.6 | 1.4 |
| Malta | 0.6 | 0.8 | 0.8 | 1.0 | 1.0 | 0.9 | 0.9 | 0.1 |
| Netherlands | 66.8 | 72.8 | 75.8 | 82.3 | 86.6 | 80.2 | 82.0 | 4.9 |
| Austria | 25.0 | 27.1 | 29.0 | 34.4 | 34.6 | 33.6 | 33.7 | 2.0 |
| Poland | 103.3 | 98.8 | 89.0 | 92.5 | 100.9 | 101.2 | 98.0 | 5.8 |
| Portugal | 18.2 | 20.6 | 25.3 | 27.5 | 24.3 | 23.6 | 22.2 | 1.3 |
| Romania | 58.1 | 46.3 | 36.6 | 39.2 | 35.8 | 36.6 | 35.4 | 2.1 |
| Slovenia | 5.7 | 6.1 | 6.5 | 7.3 | 7.2 | 7.3 | 7.0 | 0.4 |
| Slovakia | 21.8 | 17.7 | 18.3 | 19.0 | 17.9 | 17.4 | 16.7 | 1.0 |
| Finland | 28.8 | 29.4 | 32.5 | 34.5 | 37.1 | 35.5 | 34.1 | 2.0 |
| Sweden | 47.4 | 51.5 | 48.9 | 51.0 | 50.8 | 49.7 | 49.8 | 3.0 |
| United Kingdom | 210.6 | 222.3 | 230.6 | 234.0 | 211.2 | 197.9 | 202.3 | 12.0 |

*Source:* Eurostat (online data code: nrg_100a)

# Energy consumption demand

| | 1820 | 1870 | 1913 | 1939 | 1973 | 2000 | 2006 |
|---|---|---|---|---|---|---|---|
| Consumption (mtoe) | 225 | 397 | 1214 | 1713 | 6417 | 10392 | 12029 |
| Growth rate | | 1,1 | 2,6 | 1,17 | 4 | 1,8 | 2,5 |

Primary energy intensity



# A first definition

- Energy is commonly defined as the ability to do work or to produce heat. Normally heat could be derived by burning a fuel—i.e. a substance that contains internal energy which upon burning generates heat, or through other means—such as by capturing the sun's rays, or from the rocks below the earth's surface (IEA 2004).
- Similarly, the ability to do work may represent the capability (or potential) of doing work (known as potential energy as in stored water in a dam) or its manifestation in terms of conversion to motive power (known as kinetic energy as in the case of wind or tidal waves).
- Thus energy manifests itself in many forms: heat, light, motive force, chemical transformation, etc. Energy can be captured and harnessed from very diverse sources that can be found in various physical states, and with varying degrees of ease or difficulty of capturing their potential energies.
- Initially the mankind relied on solar energy and the energy of flowing water or air. Then with the discovery of the fire-making process, the use of biomass began. The use of coal and subsequently oil and natural gas began quite recently—a few hundred years ago.

# Categorization I

- The term primary energy is used to designate an energy source that is extracted from a stock of natural resources or captured from a flow of resources and that has not undergone any transformation or conversion other than separation and cleaning (IEA 2004). Examples include coal, crude oil, natural gas, solar power, nuclear power, etc.
- Secondary energy on the other hand refers to any energy that is obtained from a primary energy source employing a transformation or conversion process. Thus oil products or electricity are secondary energies as these require refining or electric generators to produce them.
- Both electricity and heat can be obtained as primary and secondary energies.

# Categorization II

- A non-renewable source of energy is one where the primary energy comes from a finite stock of resources. Drawing down one unit of the stock leaves lesser units for future consumption in this case. For example, coal or crude oil comes from a finite physical stock that was formed under the earth's crust in the geological past and hence these are non-renewable energies.
- On the other hand, if any primary energy is obtained from a constantly available flow of energy, the energy is known as renewable energy. Solar energy, wind, and the like are renewable energies.

# Categorization III

- This classification is based on the technologies used to capture or harness energy sources. Conventional energies are those which are obtained through commonly used technologies.
- Non-conventional energies are those obtained using new and novel technologies or sources.
- Once again the definition is quite ambiguous as conventions are subject to change over time, allowing non-conventional forms of energies to become quite conventional at a different point in time.

# Categorization IV

- Commercial energies are those that are traded wholly or almost entirely in the market place and therefore would command a market price. Examples include coal, oil, gas and electricity.
- On the other hand, non-commercial energies are those which do not pass through the market place and accordingly, do not have a market price. Common examples include energies collected by people for their own use (see Stevens (2000) for more details).

# Further Categorization

| **Conventionality** | **Renewability** | |
|---|---|---|
| | Renewable | Non-renewable |
| Commercial | Large scale hydro<br>Geothermal<br>Nuclear | Fossil fuels<br>Other nuclear |
| Traditional/non-commercial | Animal residues<br>Crop residues<br>Windmills and watermills<br>Fuelwood (sustainable) | Unsustainable fuelwood |
| New and novel | Solar<br>Mini and micro hydro<br>Tidal and wave<br>Ocean thermal | Oil from oil sands<br>Oil from coal or gas |

Source Codoni et al. (1985) and Siddayao (1986)

# Appropriate Information set

In general we need:

1. Energy used, consumption data frm different economic aciivities
2. Energy use, conversion and diffucion in different users
3. Financial data
4. Macroeconomic information regarding country's economy
5. Technical and operational statistic of manyufacturing e.t.c

But also

- Energy Prices
- Investments in the energy sector
- R&D effort in energy
- Energy management
- Projects in short and long run

# Energy Databases

- http://www.enerdata.net/enerdatauk/knowledge/subscriptions/database/
- http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/data/database
- http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/
- http://unstats.un.org/unsd/energy/edbase.htm
- http://www.re-database.com/
- http://www.iaea.org/OurWork/ST/NE/Main/databases.html
- http://www.etde.org/edb/energy.html
- https://data.worldbank.org/topic/energy-and-mining

**Some conversion factors**

- **Unit Values-Volume conversion**
- **1 US gallon 3.785 lt**
- **1 UK gallon 4.546 lt**
- **1 Barrel 158.9 lt (or 42 US gallons)**
- **1 cubic foot 0.0283 cubic metres**
- **Cubic metre 1000 lt**
- **Mass conversion**
- **1 kilogram (kg) 2.2036 lb**
- **1 Metric tonne 1,000 kg**
- **1 long ton 1016 kg**
- **1 short ton 907.2 kg**
- **1 lb 453.6 grams**
- **1 tonne of crude oil 7.33 barrels**

- **Description-Conversion factor**
- **1 cubic metre of Natural gas 35.3 cubic feet of natural gas**
- **1 cubic feet of natural gas 0.028 cubic metre of natural gas**
- **1 billion cubic metre of natural gas 0.9 Mtoe or 35.7 trillion Btu**
- **1 billion cubic feet of natural gas 0.025 Mtoe or 1.01 trillion Btu**
- **1 cubic feet of natural gas 1000 Btu**
- **1 million tonne of LNG 1.36 billion cubic metres of gas or**
- **48.0 billion cubic feet of gas**
- **1 million tonnes of LNG 1.22 Mtoe or 48.6 trillion Btu**
- **Source BP Statistical Review of World Energy 2009**

- **1 calorie 4.1868 J**
- **1 Btu 252 cal**
- **1 kWh 3.6 MJ = 859.845 kcal**

- **Fuel Gross calorific value Carbon content**
- **Anthracite coal 7000–7250 kcal/kg 778–782 kg/t**
- **Coking coals 6600–7350 kcal/kg 674–771 kg/t**
- **Other bituminous coals 5700–6400 kcal/kg 590–657 kg/t**
- **Metallurgical coke 6600 kcal/kg 820 kg/t**
- **Coke-oven gas 19 MJ/m3 464 kg/t**
- **Crude oil 107 kcal/t**
- **Petroleum products (1.05–1.24) 9 107 kcal/t**
- **Natural gas 37.5–40.5 MJ/m3**
- **Source UN (1987), IEA (2004) and IEA (2010)**

**Conversion from precise to imprecise units**
**Energy units**
**1 Mtoe 107 Gcal**
**1 Mtoe 3.968 9 107 MBtu**
**1 GWh 860 Gcal**
**1 GWh 3412 MBtu**
**1 TJ 238.8 Gcal**
**1 TJ 947.8 MBtu**
**1 MBtu 0.252 Gcal**
**1 MBtu 2.52 9 10-8 Mtoe**
**1 Gcal 107 Mtoe**
**1 Gcal 3.968 MBtu**

# ENERGY DEMAND I

- Energy demand" can mean different things to different users.
- Normally it refers to any kind of energy used to satisfy individual energy needs for cooking, heating, travelling, etc., in which case, energy products are used as fuel and therefore generate demand for energy purposes.
- Energy products are also used as raw materials (i.e. for non-energy purposes) in petrochemical industries or elsewhere and the demand for energy here is to exploit certain chemical properties rather than its heat content.

# ENERGY DEMAND II

- Different kind of users
- Please be careful using primary energy demand and final energy demand.
- What is the meaning of energy use? Is energy demand-energy consumption  the same concepts?

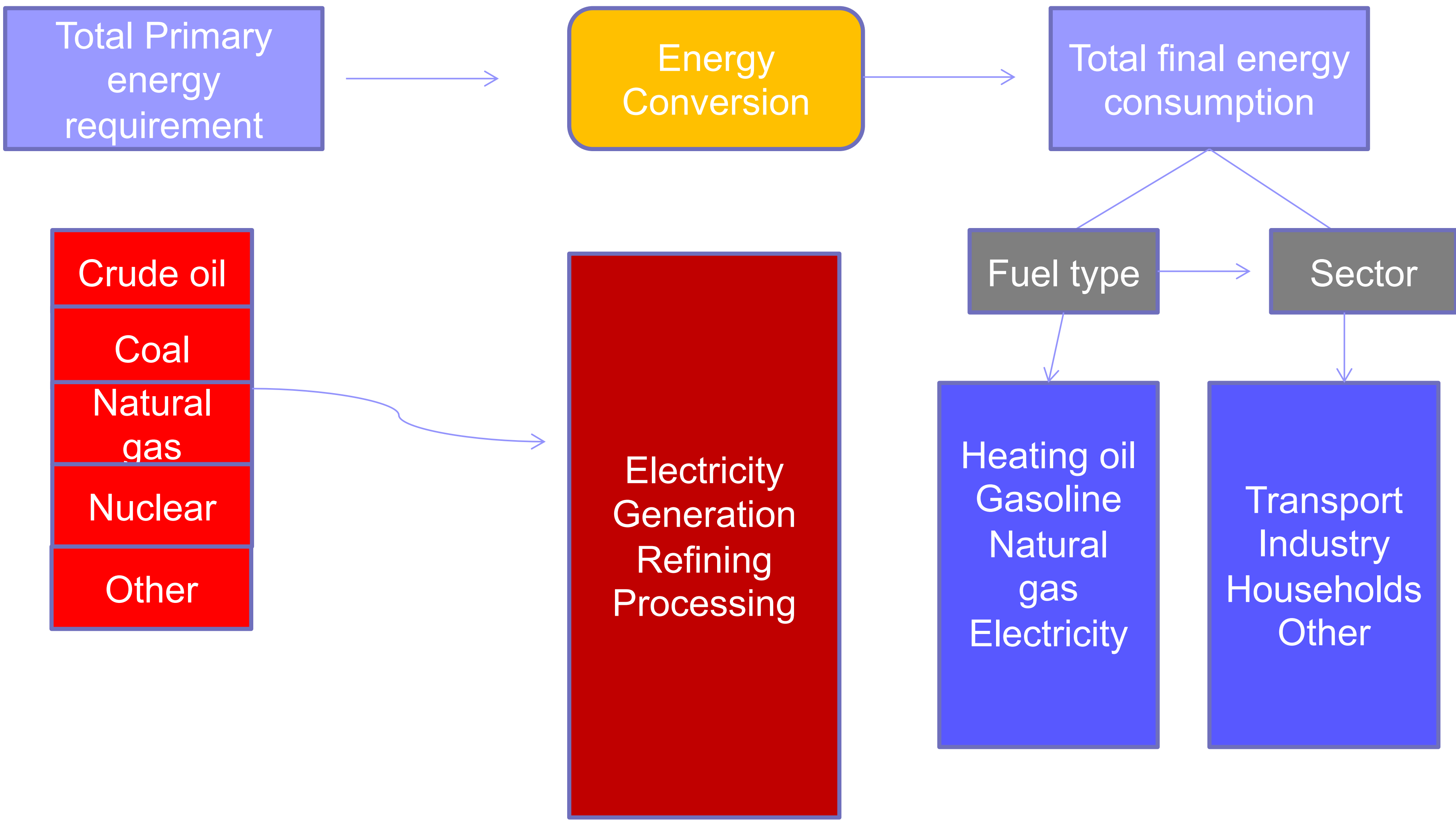
# Energy demand vs Energy consumption?

- A distinction is sometimes made between energy consumption and energy demand. Energy demand describes a relationship between price (or income or some such economic variable) and quantity of energy either for an energy carrier (e.g. electricity) or for final use (such as cooking). It exists before the purchasing decision is made (i.e. it is an ex ante concept—once a good is purchased, consumption starts).
- Demand indicates what quantities will be purchased at a given price and how price changes will affect the quantities sought.. Consumption on the other hand takes place once the decision is made to purchase and consume (i.e. it is an ex post concept). It refers to the manifestation of satisfied demand and can be measured.

# Main problem during energy demand estimation (Bhatia, 1997)

- Data on traditional energies used widely in rural areas may be lacking and may have to be estimated.
- Many poor consumers lacking purchasing power may not enter the commercial energy ladder but over time a shift to commercial energies takes place.
- Supply shortage in many developing countries implies that consumption may not represent the actual demand due to the existence of unfulfilled demand.
- The availability and consumption of commercial energy may be greatly influenced by a few large consumers.
- Response to price changes is more difficult to assess due to "difficulties of obtaining complimentary non-energy inputs, the absolute shortages of certain
- fuels, imperfect product and capital markets."

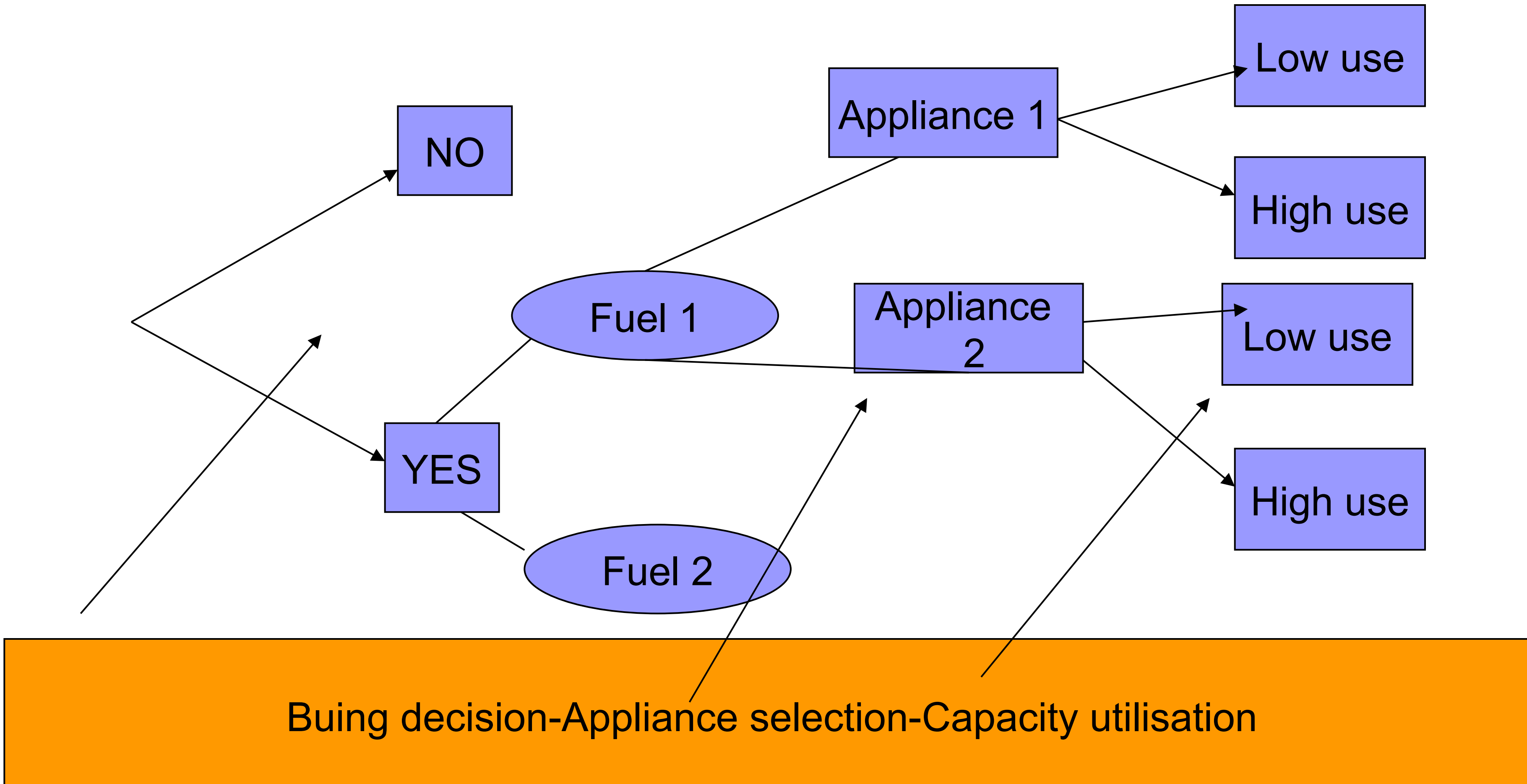
# Total Primary energy requirement



# A closer inspection on households

- First, the household has to decide whether to switch or not (i.e. switching decision).
- Second, it decides about the types of appliances to be used (i.e. appliance selection decision).
- In the third stage, consumption decision is made by deciding the usage pattern of each appliance (i.e. consumption decision). All these stages influence energy demand.

# Graphical representation



# Basics Assumptions

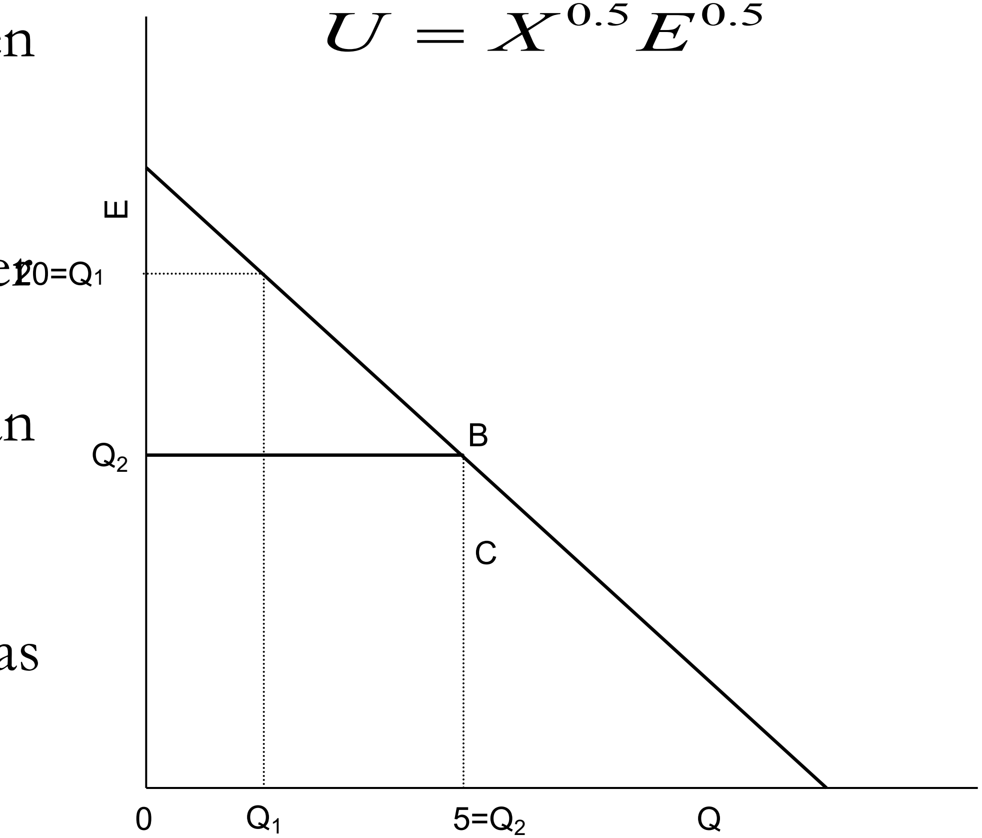
- Consumers know their preference sets and ordering of the preferences.
- Preference ordering can be represented by some utility function.
- The consumer is rational in that she will always choose a most preferred bundle from the set of feasible alternatives.

# Energy Consumer Demand I

$$100 = 5E + 20X$$

$$U = X^{0.5}E^{0.5}$$

Assume that an individual has 100 dollars to allocate between energy E and other goods X. One unit of energy costs 5 dollars while one unit of other goods costs 20 dollars. Accordingly, the individual can buy 20 units of energy or 5 units of other goods or a combination of these goods as shown by the shaded area of

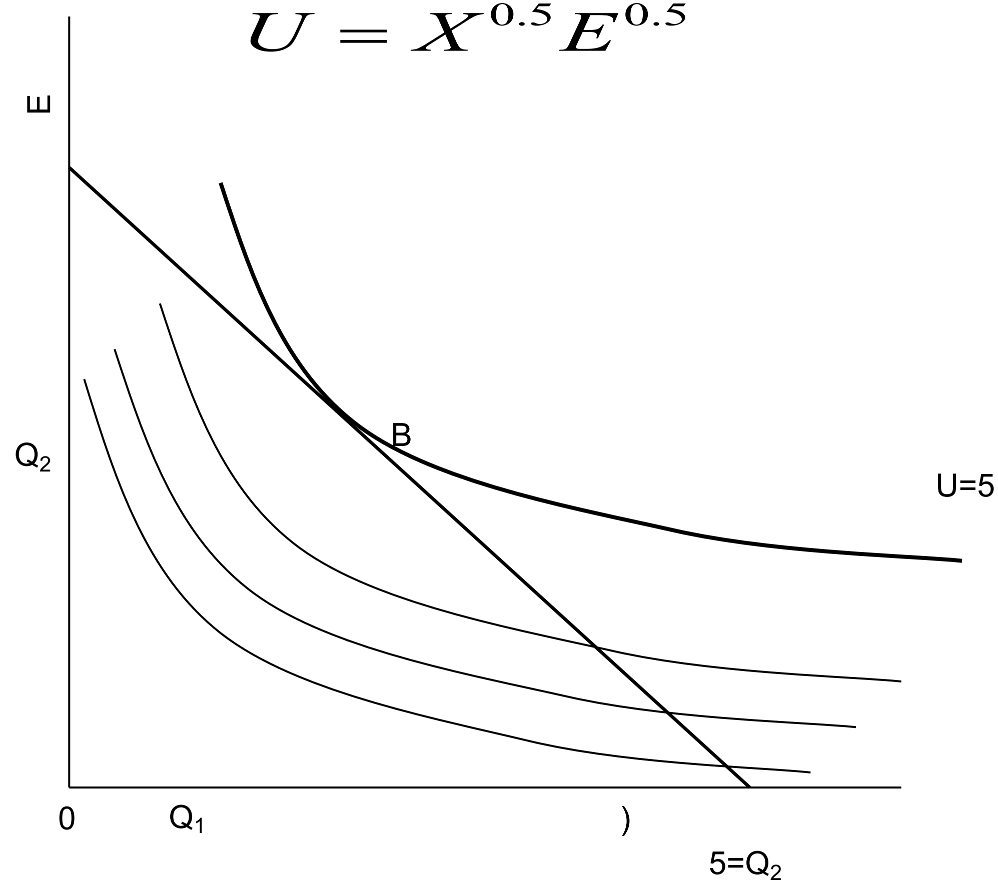


# Energy Consumer Demand II

The combinations of X and E for various levels of utility (e.g. U = 2, 3, 4 and 5) can be easily determined for this function. These curves are called indifference curves. The optimal demand for energy and other commodities could be determined for the given individual from the budget line and the indifference curves

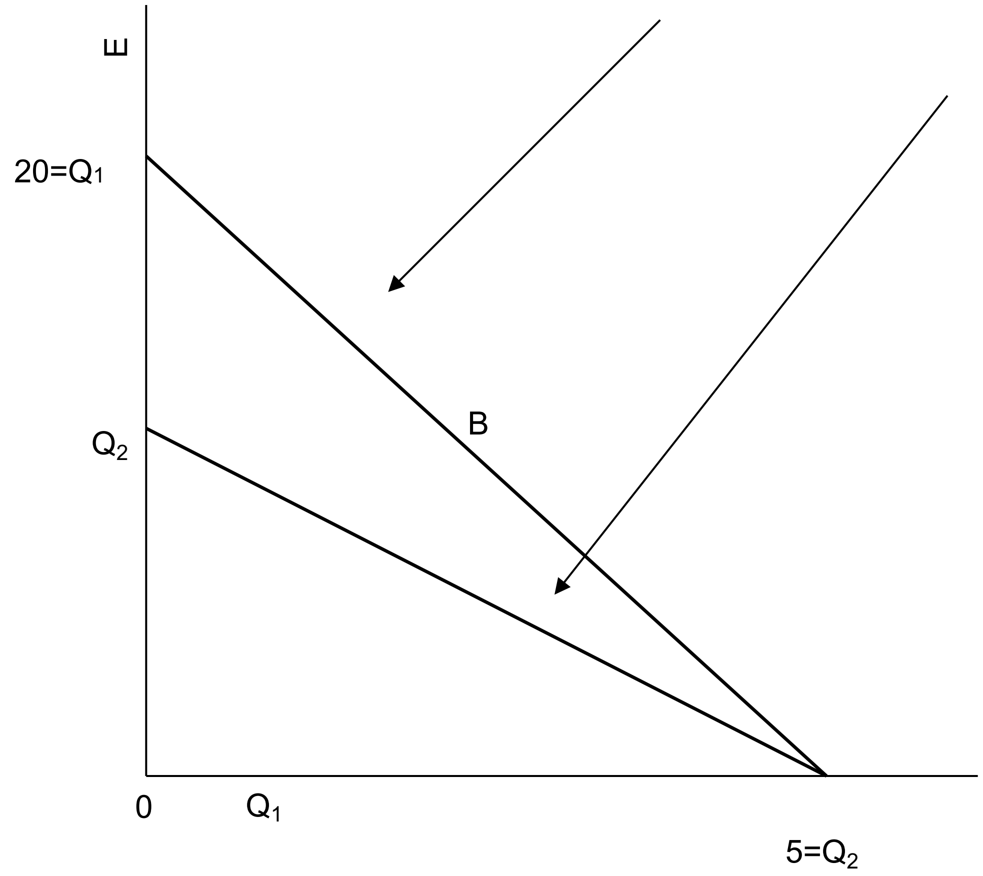
$$100 = 5E + 20X$$

$$U = X^{0.5}E^{0.5}$$



# Energy Consumer Demand III

$$100 = 10E + 20X$$
$$U = X^{0.5}E^{0.5}$$



# Some mathematics

Consumer Utility function is defined as

$$utility = U(X_1, X_2, .., X_N, E)$$

While the budget constraint is

$$I = p_1 X_1 + p_2 X_2 + \ldots + p_n X_n + p_{\mathrm{E}} E$$

Thus we can form the Langrange

$$L = U(X_1, X_2, .., X_N, E) - \lambda p_1 X_1 + p_2 X_2 + \ldots + p_n X_n + p_{\mathrm{E}} E$$

# A Dynamic approach I

$$\max \sum_{t=0}^{T} \beta^t U\left(X_t, E_t\right)$$

Enery

Income

$$s.t \ \ p_{X_t} X_t + p_{E_t} E_t + p_{K_t} I_t + S_t \leq Y_t + \left(1+r\right) S_{t-1}$$

Price of goods

$$E_t \equiv \frac{u_t}{e_t} \mathrm{K}_t$$

Savings

$$I_t = K_t - \left(1-\delta\right) K_{t-1}$$

$$X_t, u_t, K_t \geq 0$$

Capital stock

# A Dynamic approach II

The solution of the previous model is the following

$$U_{K}\frac{u^{*}_{t}}{e_{t}}=U_{Z}\left[p_{E_t}\frac{u_{t}}{e_{t}}+p_{K_t}-p_{K_t-1}\left(\frac{1-\delta}{1+r}\right)\right]$$

User cost of the capital stock

# Energy-Capital relationship

$$E_t \equiv \frac{u_t}{e_t} \mathrm{K}_t$$

Capital capacity utilization

Energy USe

Capital stock

Energy Efficiency

$$km \equiv \left(\frac{km}{lt}\right)\left(\frac{lt}{vehicle}\right) vehicle$$

# A representative firm!

The solution of cost minimization is given below.

$$\min_{K,L,E,M} TC$$

$$s.t \quad \overline{\mathrm{Q}} = f(K,L,M,E)$$

$$\mathrm{TC{=}rK{+}WL{+}}\, p_E E + p_M M$$

$$E_t \equiv \frac{u_t}{e_t}\mathrm{K}_t$$

$$E^* = E\left(\overline{\mathrm{Q}}, r, w, p_E, p_M\right)$$

$$\min_{K,L,M,u,e}\left(\mathrm{r}{+}p_E\frac{u}{e}\right)\mathrm{K{+}wL{+}}p_M M + \phi e + \lambda\left(\overline{\mathrm{Q}} - f(K,L,M,\frac{u}{e}\mathrm{K})\right)$$

# A representative household

$$\max_{C,E,S} \sum_{t=0}^{T} \beta^t U\left(C_t, E_t\right)$$

$$s.t\ \ p_{C,t}C_t + p_{E,t}E_t + p_{K,t}K_t + S_t \le Y_t + \left(1+r\right)S_{t-1}$$

$$\mathrm{I}_t = \mathrm{K}_t - (1-\delta)\mathrm{K}_{t-1} + \mathrm{WL} +$$

$$E_t \equiv \frac{u_t}{e_t}\mathrm{K}_t$$

$$C_t, u_t, \mathrm{K}_t \ge 0, t = 1, 2, \ldots, T$$

$$U_K \frac{u_t^*}{\varepsilon_t} = U_Z \left[ p_{E,t} \frac{u_t^*}{\varepsilon_t} + p_{K,t} - p_{K,t+1} \left( \frac{1-\delta}{1+r} \right) \right]$$

# Alternative approaches for energy demand estimation

Mathematical tools for energy demand measures

| | | |
|---|---|---|
| Year-on-year growth rate | $$A = \frac{(E_{t+1} - E_t)}{E_t}$$ | A: = annual growth in demand, |
| Annual average growth rate over a period | $$e_t = E_{T_0}\left(1 + \left(\frac{E_{T_1}}{E_{T_0}}\right)^{1/(T_1 - T_0)} - 1\right)^{(T_1 - T_0)}$$ | Eτi:energy demand on i-period |
| Demand elasticities | $$e_t = \frac{\left(\Delta EC_t / EC_t\right)}{\left(\Delta I_t / I_t\right)}$$ | EC:energy consumption, I variable of interest |
| Energy intensity | $$EI_t = \frac{E_t}{I_t}$$ | EC:energy consumption, I variable of interest |
| Energy intensity in case of aggregated fuels | $$EI_t = \frac{\sum_{i=1}^{n} E_{it}}{I_t}$$ | $E_{it}$ energy consumption of the i-fuel on period t |

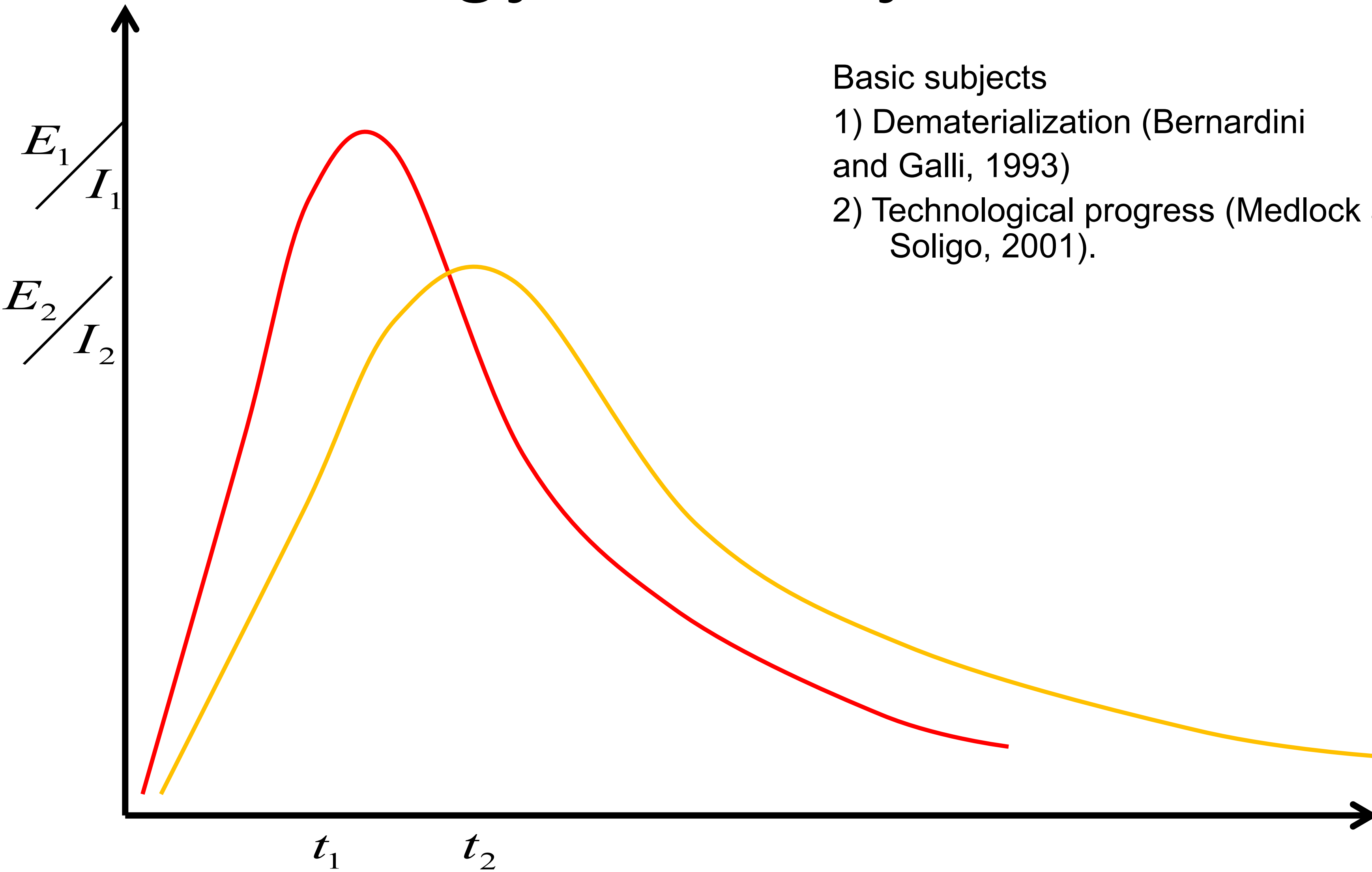
# An application I

According to BP Statistical Review of World Energy, the world primary energy consumption was 9,262.6 Mtoe in 2000. The demand increased to 11,104.4 Mtoe in 2007 and 11,294.9 Mtoe in 2008. Calculate the growth rate of demand between 2007 and 2008. Also calculate the annual average growth rate between 2000 and 2008.

# An application II

- The primary energy consumption in China increased from 1,970 Mtoe in 2004 to 2,225 Mtoe in 2005. The GDP increased from 14,197 Billion Yuan in 2004 to 15,603 Billion Yuan in 2005 at constant 2,000 prices. What was the GDP elasticity of energy demand in China?

# Energy Intensity-Factors




Basic subjects

1) Dematerialization (Bernardini and Galli, 1993)

2) Technological progress (Medlock and Soligo, 2001).

# A question

$$\frac{E}{Y} = \frac{E_A + E_I + E_s}{Y} = \frac{E_A}{Y_A}\frac{Y_A}{Y} + \frac{E_I}{Y_I}\frac{Y_I}{Y} + \frac{E_S}{Y_S}\frac{Y_S}{Y} =$$

$$\frac{E_A}{Y_A}\theta_{\mathrm{A}} + \frac{E_I}{Y_I}\theta_I + \frac{E_S}{Y_S}\theta_S$$

$$\frac{d\left(E/Y\right)}{d\theta_I} = ???$$

Consider three different sectors, A agriculture, industry I and services S.

$$\theta_{\mathrm{A}} + \theta_I + \theta_S =$$

# A second question

$$\frac{E}{Y}=\frac{E_A+E_I+E_s}{Y}=\frac{E_A}{Y_A}\frac{Y_A}{Y}+\frac{E_I}{Y_I}\frac{Y_I}{Y}+\frac{E_S}{Y_S}\frac{Y_S}{Y}=$$

$$\frac{\left({u_A}/{\varepsilon_A}\right)K_A}{Y_A}\theta_{\mathrm{A}}+\frac{\left({u_I}/{\varepsilon_I}\right)K_I}{Y_I}\theta_I+\frac{\left({u_S}/{\varepsilon_S}\right)K_S}{Y_S}\theta_S$$

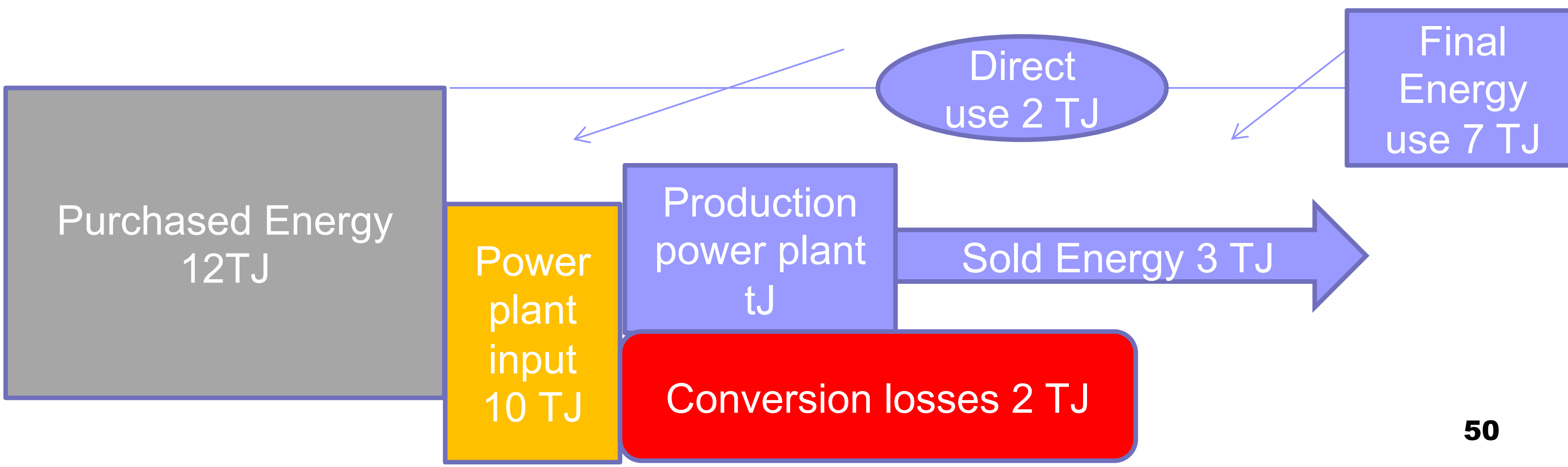
$$\frac{d\left({E}/{Y}\right)}{d\varepsilon_I}=???$$

$$\theta_{\mathrm{A}}+\theta_I+\theta_S=1$$

Can you estimate the effect of an increase in energy efficiency because of the adoption a=of energy savings technologies?

# Energy Use

- Define energy users?
- We calculate purchased energy.
- Final Energy used= Purchased Energy-Sold Energy+Own extraction+Extraction from stock



# Conversion of energy use

- Crucial role of losses.

Primary Energy use

Electricity use

Fuel use

$$E_p = F + \frac{E}{n_e}$$

Conversion efficiency from electricity production system

# IEA STATISTICS

| | Coal | Oil | Gas | Electricity | Other | Total |
|---|---|---|---|---|---|---|
| Production | | | | | | |
| Imports | | | | | | |
| Exports | | | | | | |
| Reserves | | | | | | |
| TPES | | | | | | |
| Electricity | | | | | | |
| Energy conversion | | | | | | |
| TFC=TPES-inputs conv+output conv. | | | | | | |
| Industry | | | | | | |
| Transportation | | | | | | |
| Households | | | | | | |
| Other | | | | | | |
| Electricity produced | | | | | | |

# References


- Bhattacharyya, Subhes C. (2011) Energy Economics: Concepts, Issues, Markets and Governance. Springer. Chapters(1-2-3)
- Evans, Joanne and Lester Hunt,(2009), International Handbook on the Economics of Energy. Edward Elgar
- https://www.iea.org/statistics/resources/balancedefinitions/