



HELSINGIN YLIOPISTO



EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE



Energy Positive Farm - ENPOS

System analysis, system borders

ENPOS Seminar - Energy use in plant production - Otepää 20 - 22 January 2010

What is a system?

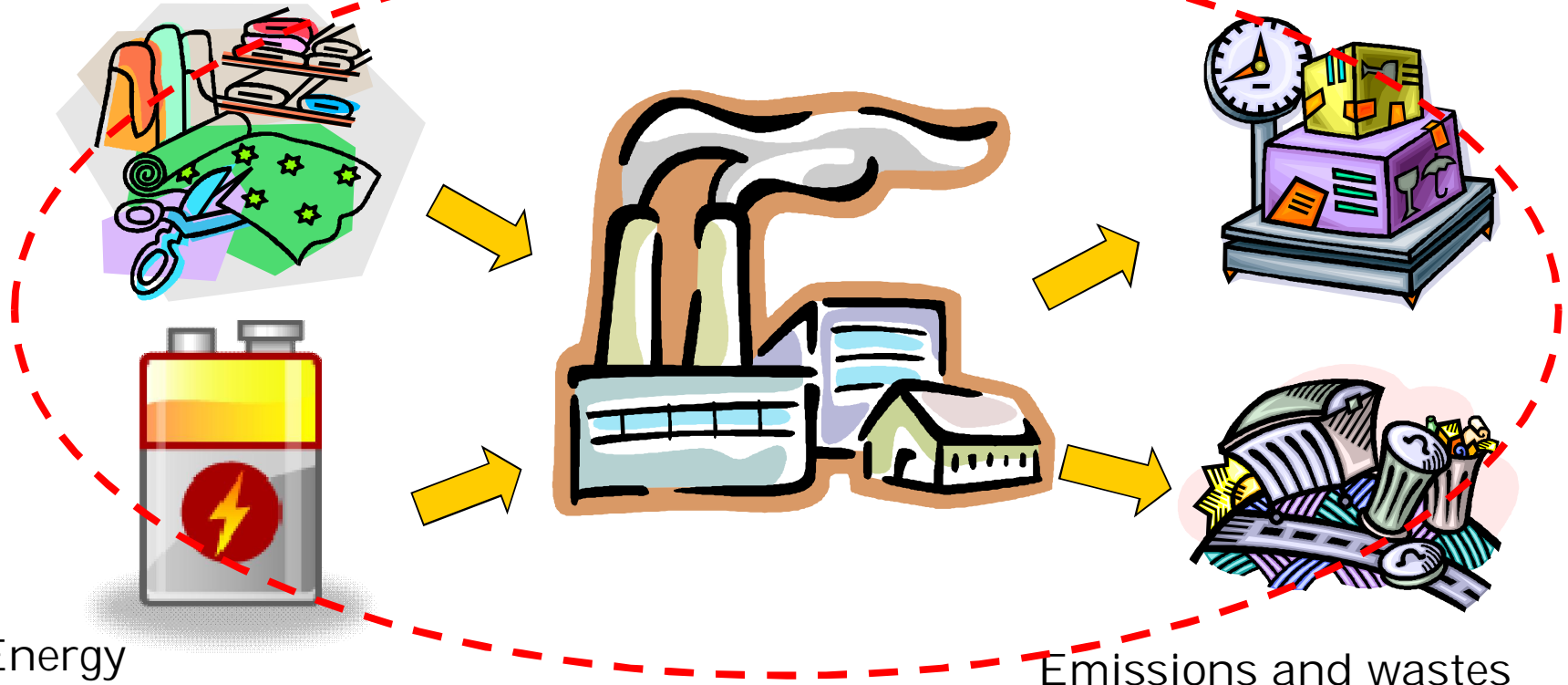
- ▶ A system consists of
 - 1) some kind of elements
 - 2) relationships between elements
- ▶ System is separated with a boundary from the rest of the world
- ▶ The rest of the world is called surroundings or environment

Source: Liljenström, H. 2008. System, modell and simulation

Definition of a system

Rawmaterial

Products and by-products



Energy

Emissions and wastes

Bioenergy systems are typically complex biological systems

- ▶ A large number of components
- ▶ System includes living organisms, which behaviour is known only partially
- ▶ System is influenced by unpredictable factors e.g. weather

Energy analysis is
one application
of systems analysis

Energy Analysis

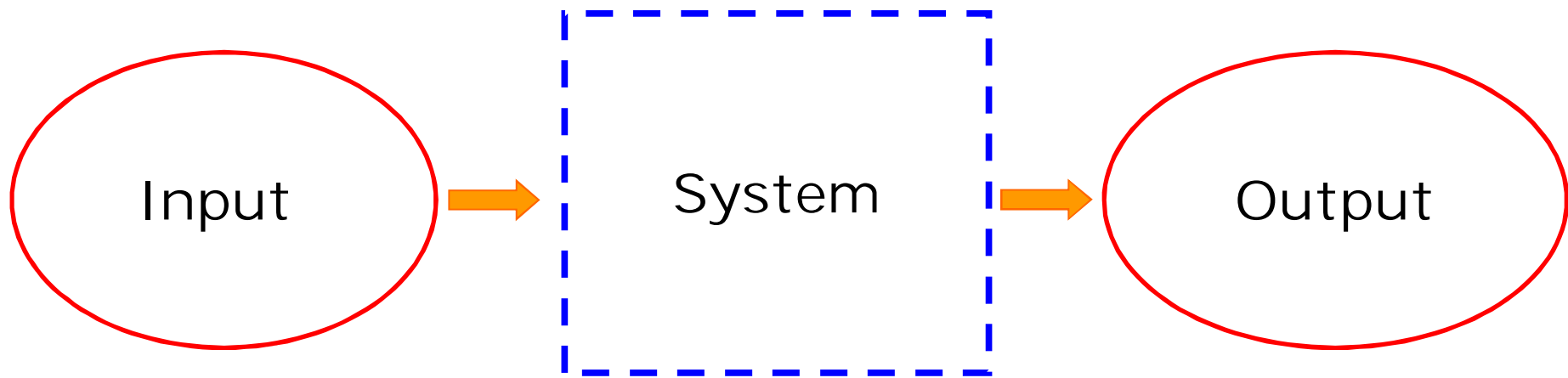
- ▶ 2/2009 623 milj. hits with words "energy analysis" in Google
- ▶ 1/2010 923 hits with the same words
- ▶ Applications are often related to bioenergy and sustainable use of energy
- ▶ Complex systems are considered
→ A system analytical approach is advisable

An energy analysis? Why and for what?

- ▶ Decisions relating to future energy management should be based on authentic information
- ▶ Energy analysis helps to answer the question: Which energy sources are worth investing?

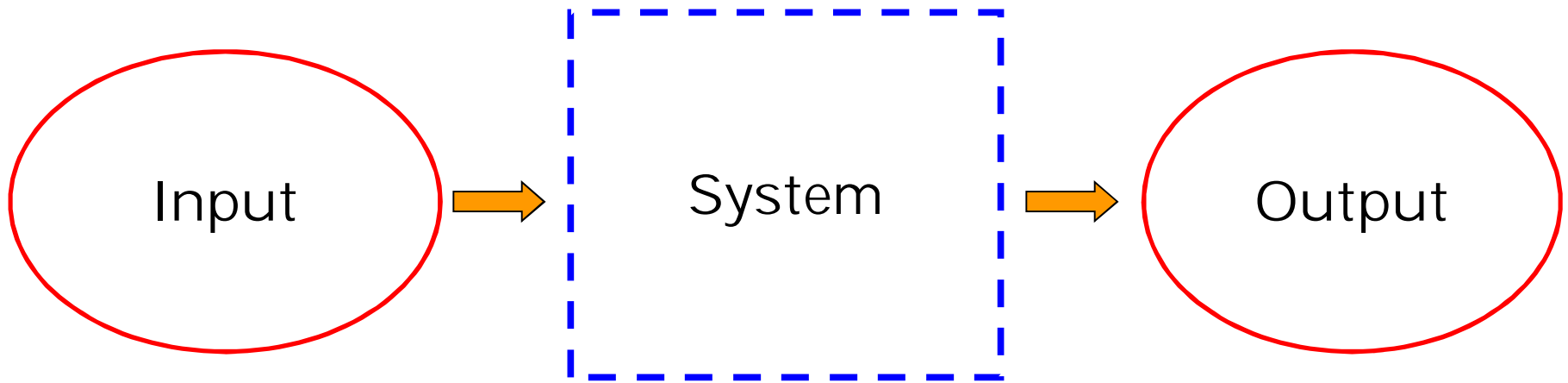
E.g. in Lithuania, which energy source would be the most suitable to cover the gap left by closing the Ignalina nuclear power plant?

The basic idea of an energy analysis!

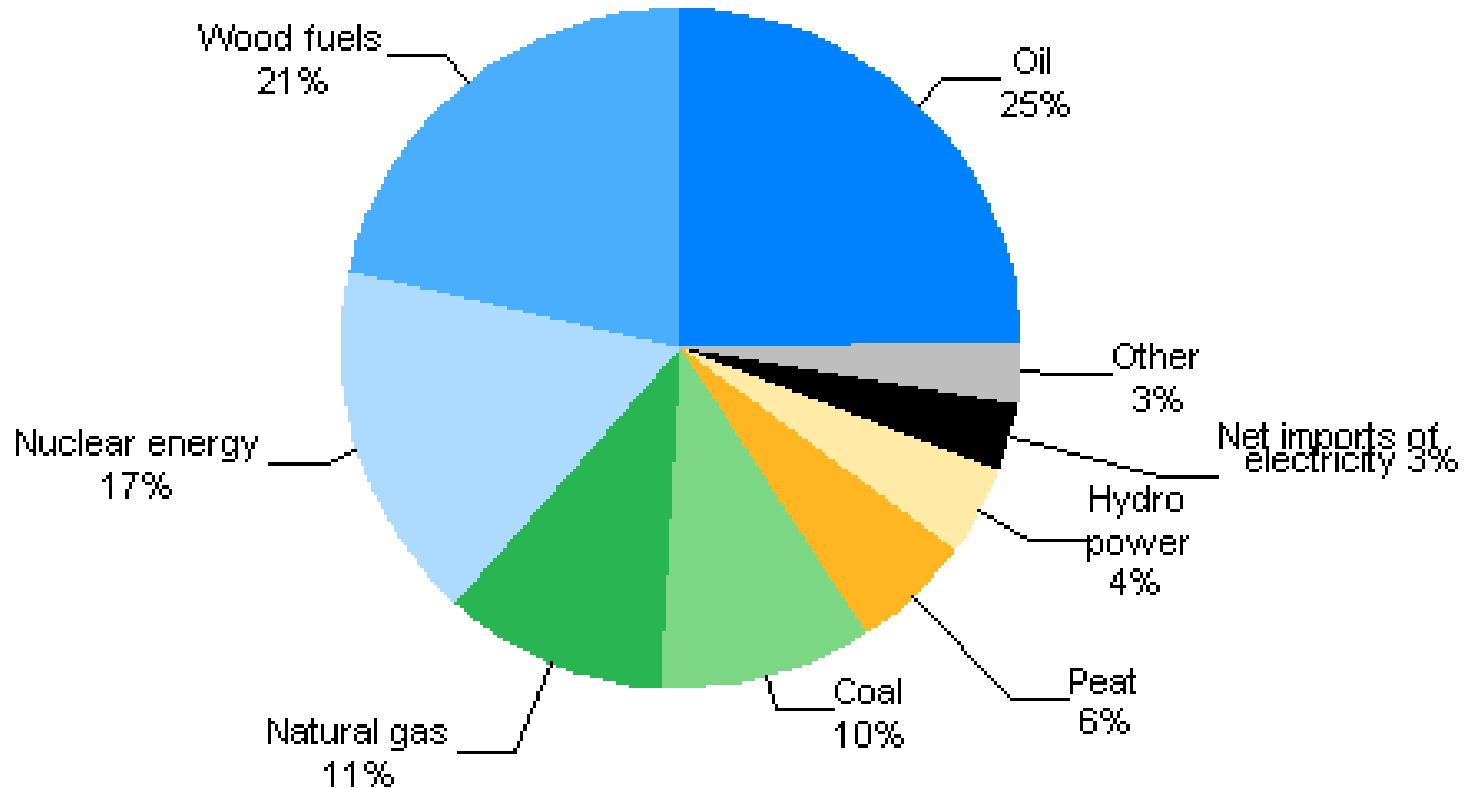


Applications of an energy analysis!

Distribution of input energy by different energy categories or energy sources?



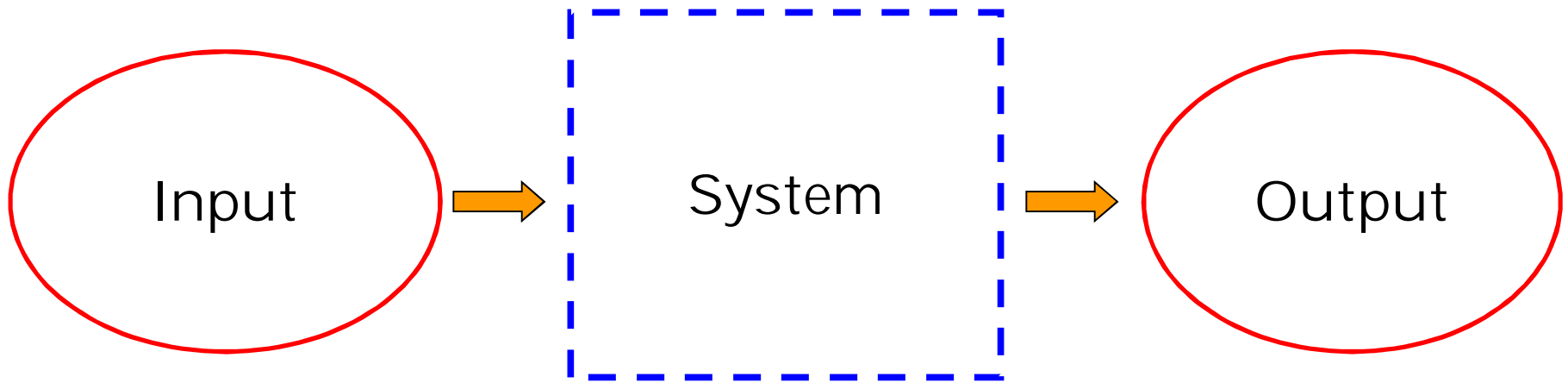
Energy sources in Finland 2008



Source: Statistics Finland, http://www.stat.fi/til/ekul/2008/ekul_2008_2009-12-14_kuv_001_en.html

Applications of an energy analysis!

Distribution of input energy for different processes of the system?

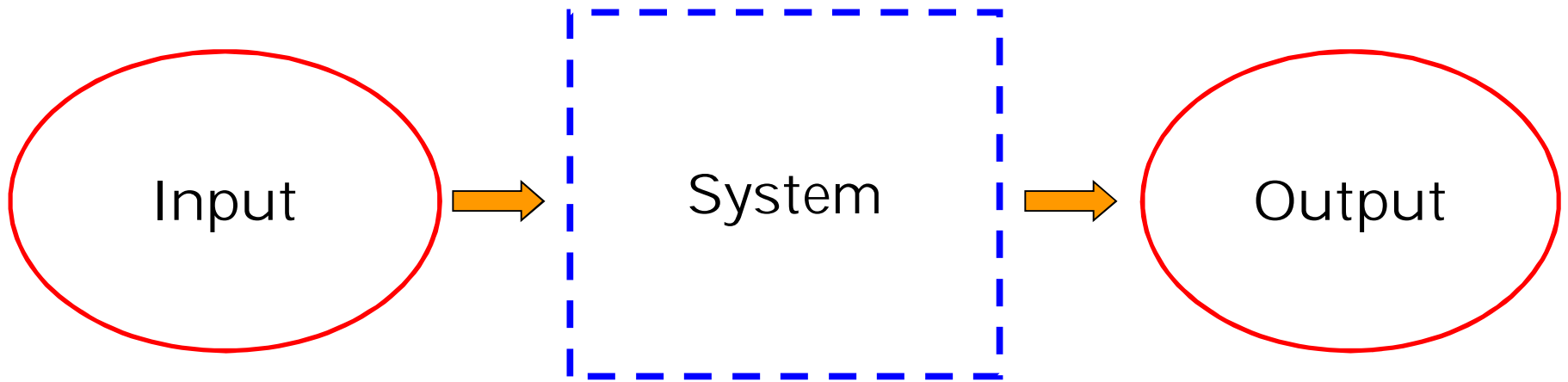


Distribution of energy consumption on a farm

- ▶ Plant production
- ▶ Animal production
- ▶ Forestry
- ▶ Household

Applications of an energy analysis!

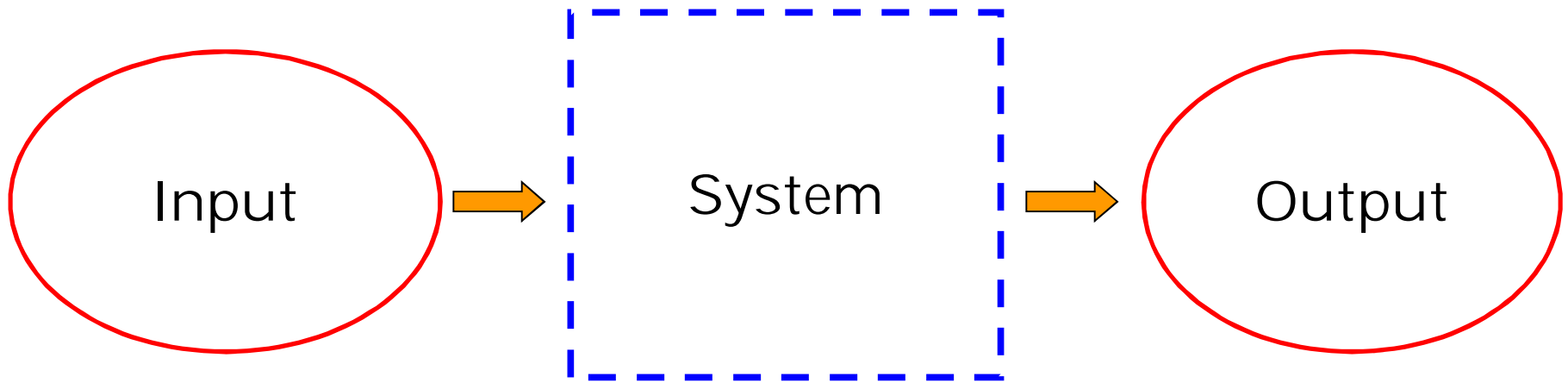
Comparison of different production methods or parallel products?



A good reference is needed!!!

Applications of an energy analysis!

Definition of parameters, key figures, key ratios.



Energy ratio = Energy Return of Investment (=EROI), Net Energy, Shares of fossil and renewable, ...

Applications of an energy analysis!

- ▶ For product developing, decision makers, politicians, citizens
- ▶ To improve energy efficiency
- ▶ To cut costs
- ▶ To guide choices of customers
- ▶ To plan taxation
- ▶ To protect environment
- ▶ To help to make a better and more sustainable world!

Important concepts in an energy analysis

- ▶ Defining a system and its boundaries
- ▶ Primary energy and Secondary energy
- ▶ Direct and Indirect energy
- ▶ Functional unit
- ▶ Cut-off criteria
- ▶ Allocation of energy for the main product and by-product(s)

Instructions for defining a system

Include

- ▶ All relevant energy and material inputs
- ▶ Energy inputs crossing the cut-off criteria

Possible to exclude

- ▶ Indefinite energy inputs
- ▶ Energy inputs, which are equal in the system under study and in the reference system
- ▶ Energy inputs going under the cut-off criteria

Direct and Indirect energy

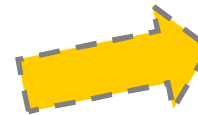
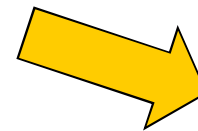
Direct energy:

electricity, liquid fuels,
gas, coal, firewood etc.

Indirect energy:

embodied in material, human
labour, infrastructure, machines,
buildings, education, services...

Input energy



A problematic, gray region in an energy analysis!

Primary energy and Secondary energy

- ▶ Primary energy

Primary energy is energy found in nature that has not been subjected to any conversion or transformation process.

- ▶ Secondary energy

Secondary energy is primary energy which has been transformed in energy conversion processes to more convenient forms of energy, such as electrical energy or refined fuels.

Functional unit

- ▶ Definition in EN ISO 14040 -standard: *Quantified performance of a product system for use as a reference unit.*
- ▶ A functional unit is needed because energy analysis is often a relative approach which compares
 - 1) Same product manufactured with different ways
 - 2) Different products, which can be used for the same purpose

Examples from the functional unit: 1(3)

- ▶ Same product, different manufacturing technology

Diesel oil as a fuel for a passenger car:

Biomass → Gasification → F-T-synthesis → Diesel oil

Crude oil → Refining → Diesel oil

Which parameter would express quantified performance of these product systems and could be used as a reference unit?

MJ/MJ or MJ/km

Examples from the functional unit: 2(3)

- ▶ Different products used for same purpose

Biomass → Gasification → F-T-synthesis → Diesel oil

Crude oil → Refining → Gasoline

MJ/km

Examples from the functional unit: 3(3)

- ▶ You want to make an energy analysis for two different paints. How do you define the functional unit?
- ▶ Researcher X wants to make an energy analysis for a mobile phone and for 1 kg potatoes. Is this pair valid? How do you define the functional unit?

Exercise nr 1:

- ▶ Form teams of two persons
- ▶ Define an object for an energy analysis
- ▶ Define the functional unit
- ▶ After 10 minutes, every team presents their objects and justifies their functional unit
- ▶ The whole course assesses the validity of the objects and functional units

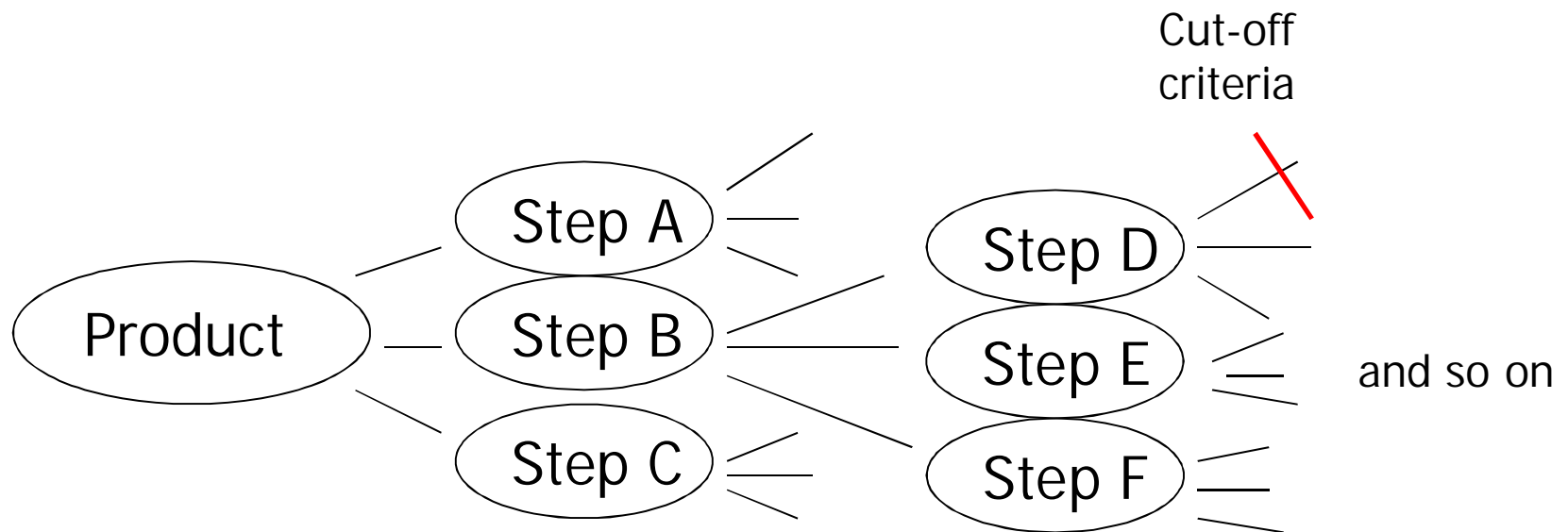
Exercise nr 2:

- ▶ Define system boundaries for one of the objects of the Exercise 1
- ▶ Suggest, which energy inputs are included and which are excluded
- ▶ Think, which definitions should be commented in the discussion of the study

Cut-off criteria

- ▶ Definition in EN ISO 14040 -standard: The amount of energy flow to be excluded from a study.
- ▶ Define cut-off criteria clearly
- ▶ Cut-off criteria is a percentage of a single energy input from the total energy input e.g. 0.1%, 1%, 5%
 - ▶ an overrunning energy input is included
 - ▶ an undergoing energy input is excluded

A sketch of the cut-off criteria in a process analysis



Factors affecting on the definition of the cut-off criteria

- ▶ Accuracy of the analysis
- ▶ The purpose the analysis (for what?)
- ▶ The amount and quality of data available
- ▶ What is the reference chain and how energy inputs have been handled in the reference chain

Important key words or concepts of this lesson:

- ▶ System
- ▶ Definition of the system
- ▶ Direct energy and indirect energy
- ▶ Primary energy and Secondary energy
- ▶ Functional unit
- ▶ Cut-off criteria

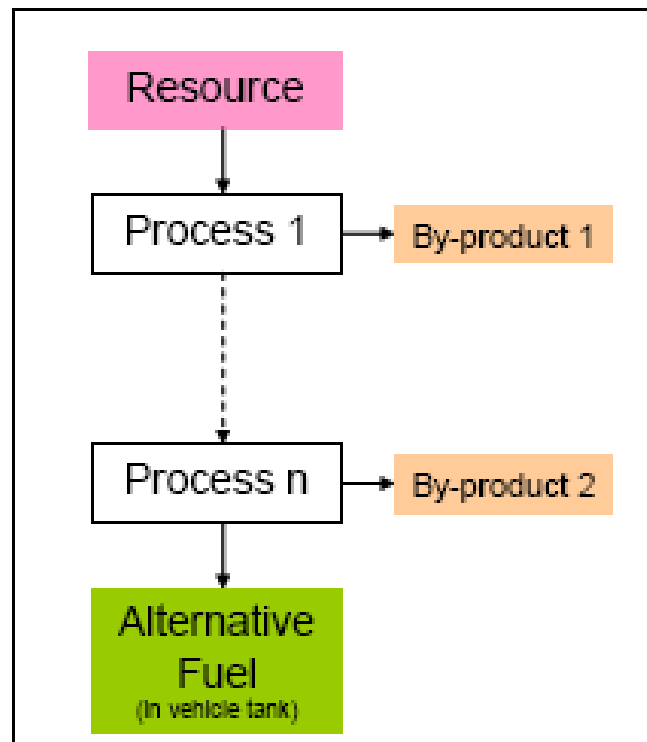
Handling by-products

Besides the main product, production generates often by-products

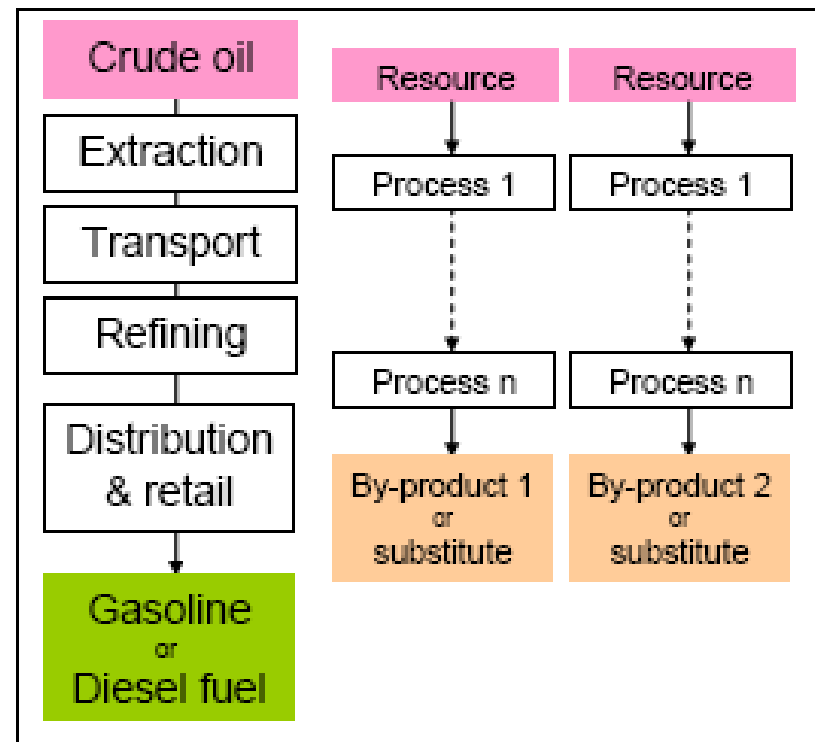
- ▶ System boundaries are expanded so that allocation of energy is unnecessary
- ▶ System is credited with energy, which is needed to produce by-products
- ▶ Energy can to be allocated to main- and by products according to the
 - ▶ mass
 - ▶ market value

An advisable crediting methodology for a by-product

Alternative scenario



Reference scenario



Source: WTW Report, version 2b, May 2006