Renewable Energy:
Technology, Economics and Environment

Lecturers:
Syafaruddin & Takashi Hiyama

Time and Venue:
Wednesdays: 10:20 – 11:50, Room No.: 208

Contents:

Assessment and References

Assessment:

•Attendance (10%)

•Assignment-1 (45%)

(Essay, 2000words about past, present and future renewable energy sources* related to technology, economics and environment)

•Assignment-2 (45%)

(Presentation, select and present one of the most recent papers that discusses about the prospective implementation of renewable energy sources in your country)

References:

•Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: 'Renewable Energy: Technology, Economics and Environments', Springer 2007

•Leon Freris, David Infield: 'Renewable Energy in Power Systems', Wiley 2008

**other than our discussed topic in this lecture (you may consider tidal power, biomass, geothermal, small scale hydro power)*

Today's Lecture

Renewable Energy: An Overview

A. Preface

B. Energy System

- Energy terms
- Energy Consumption

C. Applications of Renewable Energy

- Renewable energy classification
- Investigated possibilities

D. Structure & Procedure

- Principles
- Technical description
- Economic & environmental analysis

Preface

- Utilization of renewable energies is not at all new!!!

(in the history of mankind renewable energies have for a long time been the primary possibility of generating energy)

- Industrial Revolution changed the energy trend

  (lignite and hard coal became increasingly more important)

Later on, also crude oil gained importance → easy transportation & processing, raw material: **Crude oi**l (primary energy applied today)

Natural gas for space heating, power provision and transportation → Important due to abundantly available and only requires low investments in terms of energy conversion

* As fossil energy carriers increase for energy generation in Industrial countries → Renewable energy becomes secondary importance of total energy generation

Preface...cont.

- However, Undesirable Side effects of fossil fuel utilization:

(Increasingly sensitized to possible environmental and climate effects) ---realized in the beginning of 21st Cent.)

- Price increase for fossil fuel energy on the global energy markets in the last few years
- **Results**: The search for environmental, climate-friendly and social acceptable, alternatives suitable to cover the energy demand has become increasingly important.

Utilization of renewable sources of energy

Energy system

- Our current living standard could not be maintained without energy!!!
- As the energy utilization increases → "energy problem" in conjunction with the underlying "environmental problem" continues to be a major topic in energy engineering, as well as in the energy and environmental policies in the world.
- Energy system: **Energy terms** & **Energy Consumption**

Energy system …cont.
(Energy terms)

- What is Energy?

Max Planck: energy is defined as the ability of a system to cause external action

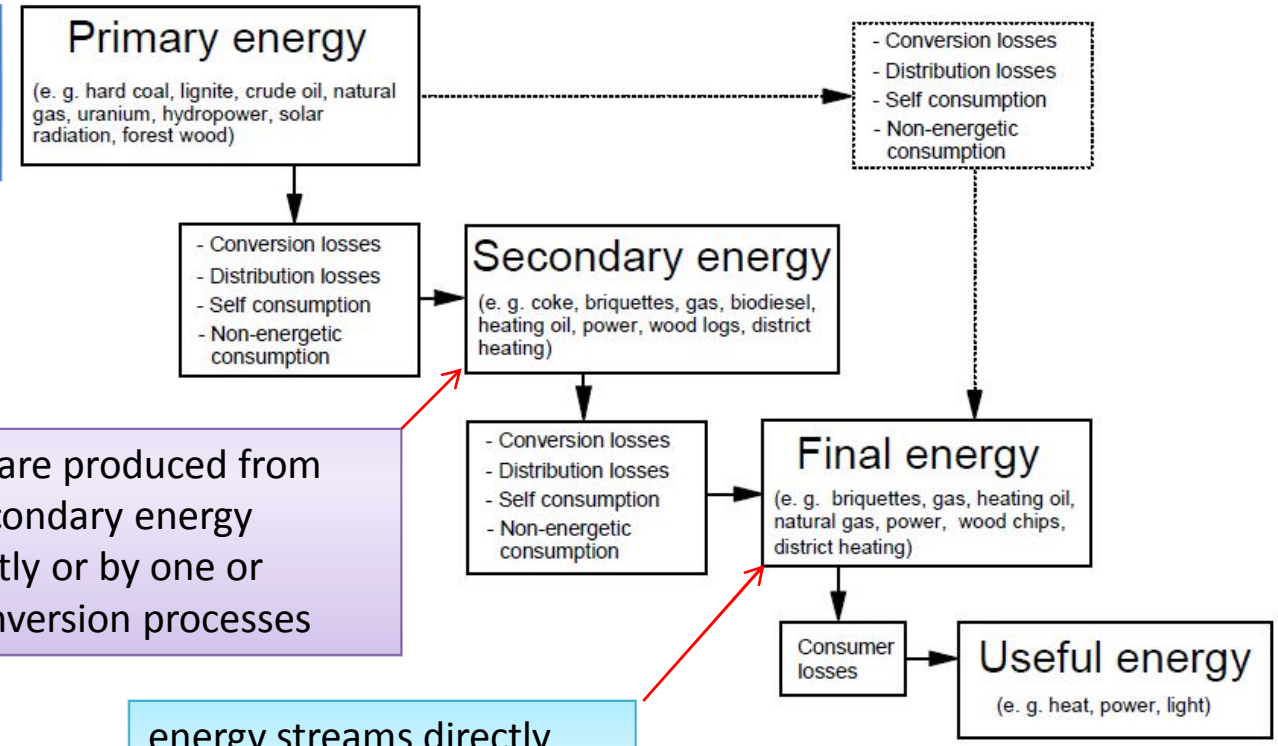
Forms of energy: mechanical energy (i.e. potential or kinetic energy), thermal, electric and chemical energy, nuclear energy and solar energy

- The ability to perform work becomes *visible* by force, heat and light
- The ability to perform work from chemical energy, nuclear and solar energy is only given if these forms of energy are transformed into mechanical and/or thermal energy

Energy system …cont. (Energy terms)

- **Energy carriers** definition: a substance that could be used to produce useful energy, either directly or by one or several conversion processes
- Energy carriers: primary, secondary & final energy carriers

Substances which have not yet undergone any technical conversion



Energy carriers that are produced from primary or other secondary energy carriers, either directly or by one or several technical conversion processes

energy streams directly consumed by the final user

energy available to the consumer after the last conversion step to satisfy the respective requirements or energy demands

Energy system …cont.
(Energy terms)

Energy resources are generally distinguished:

- **Fossil energy resources** are stocks of energy that have formed during ancient geologic ages by biologic and/or geologic processes.

  -fossil biogenous energy resources (i.e. stocks of energy carrier of biological origin) E.g: hard coal, natural gas, crude oil deposits

  -fossil mineral energy resources (i.e. stocks of energy carrier of mineral origin or non-biological origin) E.g: energy contents of uranium deposits and resources to be used for nuclear fusion processes.

- **Recent resources** are energy resources that are currently generated, for instance, by biological processes; E.g: the energy contents of biomass and the potential energy of a natural reservoir.

Energy system …cont.
(Energy terms)

Available energies or energy carriers can be further subdivided:

- *Fossil biogenous energy carriers* primarily include the energy carriers coal (lignite and hard coal) as well as liquid or gaseous hydrocarbons (such as crude oil and natural gas). A further differentiation can be made between fossil biogenous primary energy carriers (e.g. lignite) and fossil biogenous secondary energy carriers (e.g. gasoline, Diesel fuel).
- *Fossil mineral energy carriers* comprise all substances that provide energy derived from nuclear fission or fusion (such as uranium, thorium, hydrogen).
- *The term renewable energy……*

Energy system …cont.
(Energy terms)

The term of **Renewable energy** refers to primary energies that are regarded as inexhaustible in terms of human (time) dimensions.

Characteristics:

- They are continuously generated by the energy sources solar energy, geothermal energy and tidal energy.
- The energy produced within the sun is responsible for a multitude of other renewable energies (such as wind and hydropower) as well as renewable energy carriers (such as solid or liquid biofuels).
- The energy content of the waste can only be referred to as renewable if it is of non-fossil origin (e.g. organic domestic waste, waste from the food processing industry).

  Properly speaking, only naturally available primary energies or primary energy carriers are renewable but not the resulting secondary or final energies or the related energy carriers.

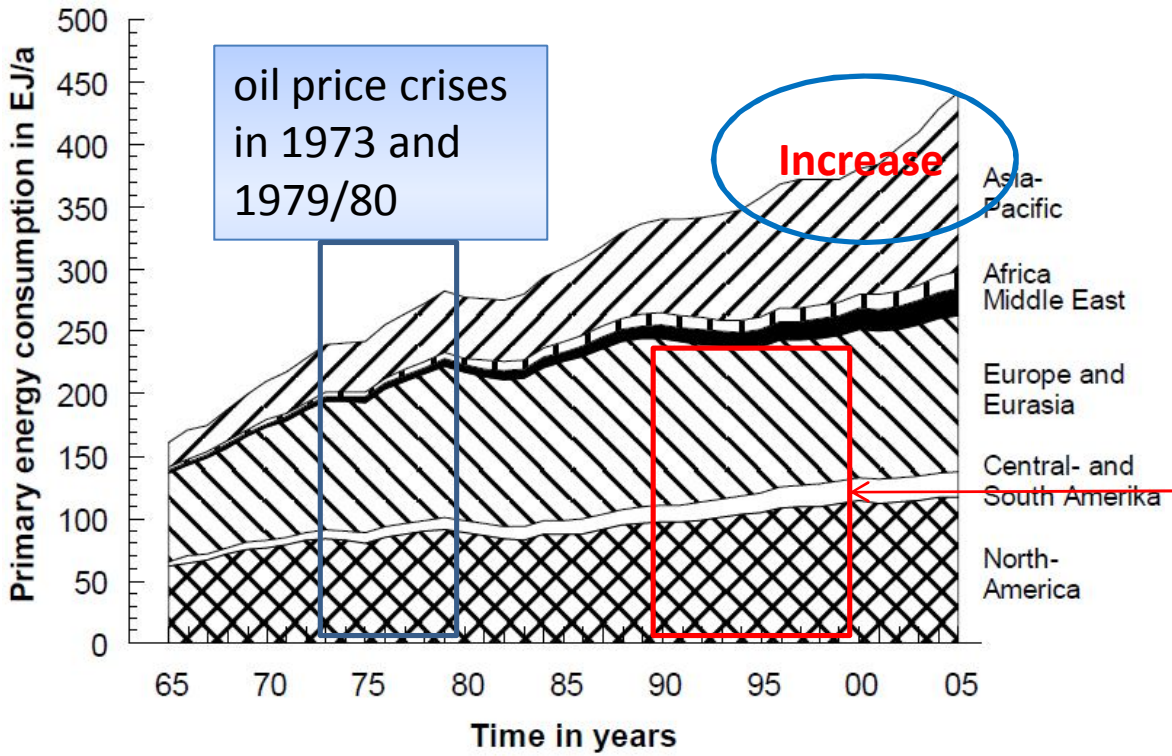
  However, in everyday speech secondary and final energy carriers derived from renewable energy are often also referred to as renewable.

Energy system …cont.

(Energy Consumption)

Evolution of primary energy consumption of fossil energy carriers and hydropower according to regions over the past 40 years

the worldwide primary energy consumption has increased by more than the factor of 2.5 over this period of time

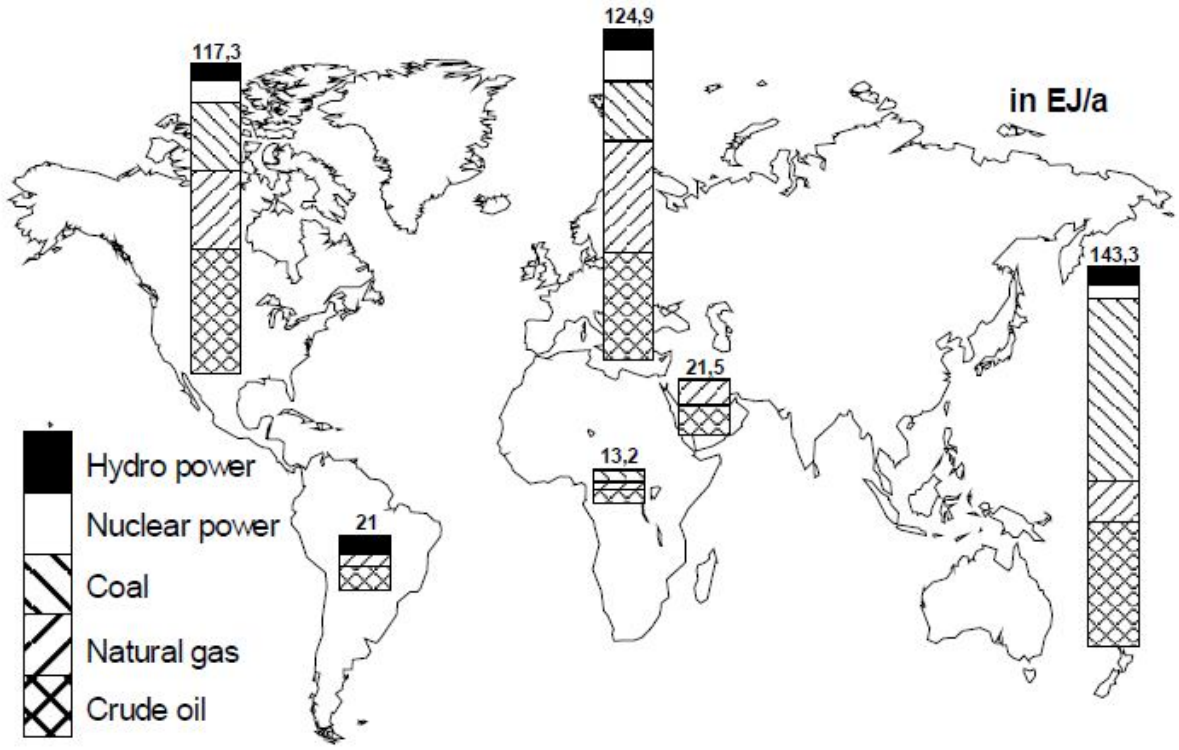


the primary energy consumption slowed down again to increase noticeably at the beginning of the first decade of the 21st century.

downturn of the global economy

Energy system …cont.

(Energy Consumption)



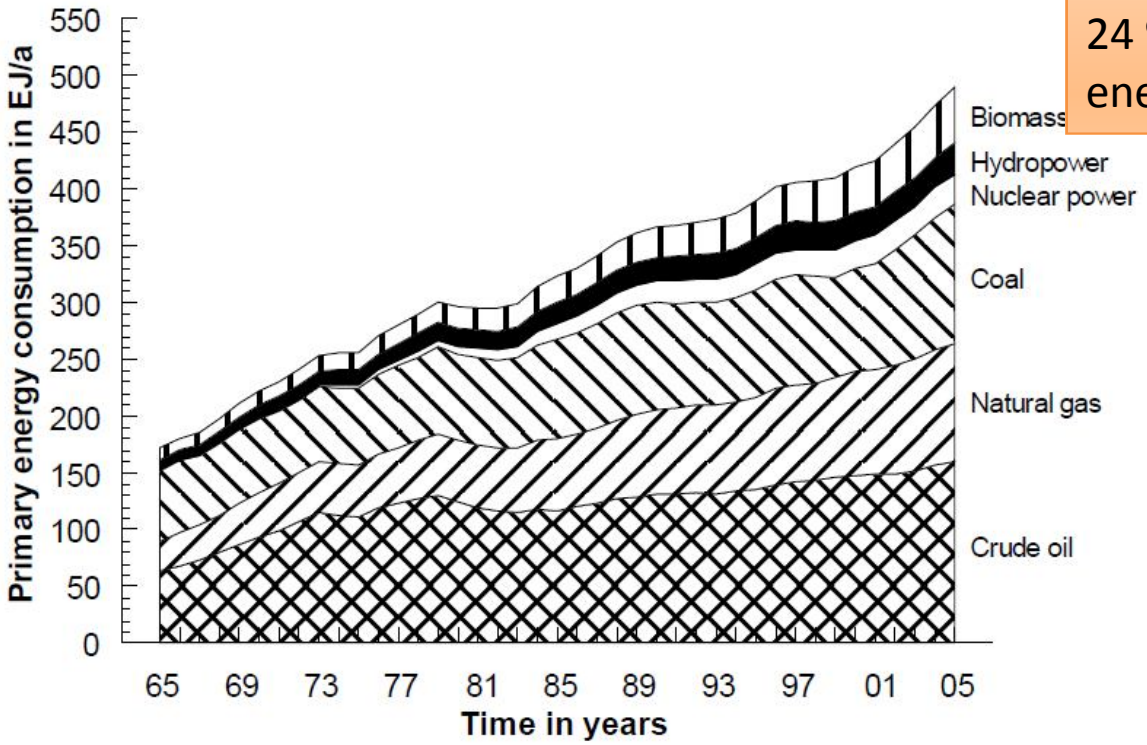
Worldwide consumption of fossil primary energy carriers and hydropower according to regions and energy carriers in the year 2005

*On a regional level these fractions are strongly dependent on local and national characteristics due to varying national energy politics or available primary energy resources

*For instance, in Asia the major share of the given demand for fossil primary energy carriers is covered by coal (this applies in particular to the People's Republic of China), whereas this energy carrier is of almost no importance in regions such as the Middle East.

Energy system …cont.

(Energy Consumption)



Worldwide consumption of fossil primary energy carriers, hydropower and biomass according to energy carriers

While this energy carrier only had a share of roughly 17 % in the overall consumption of fossil energy carriers and hydropower in 1965, it contributed with about 24 % to cover the overall primary energy demand in 2005.

In 1965, nuclear energy had still no importance on a global scale; in the year 2005; however, it covered roughly 6 % of the global primary energy demand and still has a strong tendency to increase.

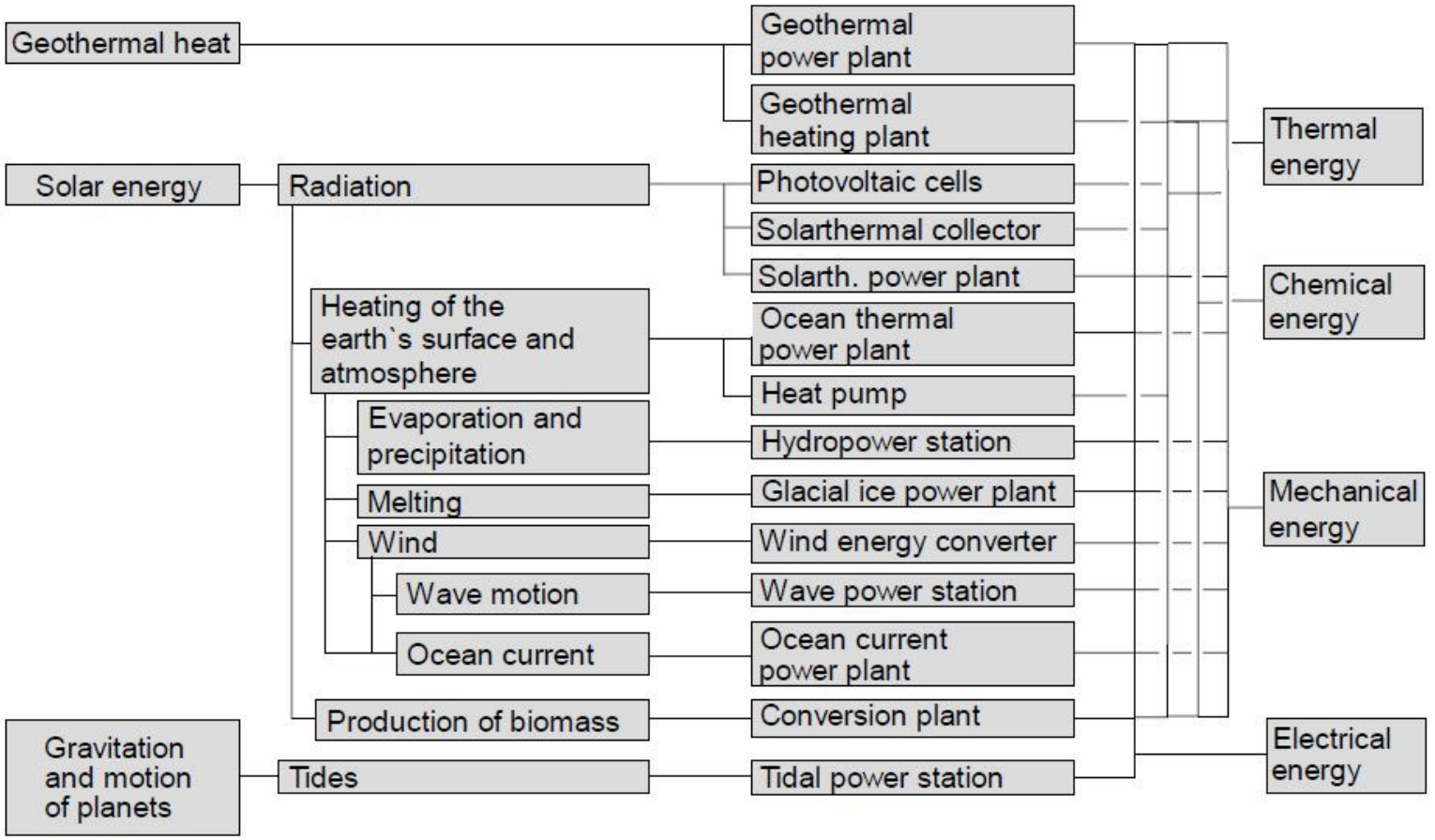
Coal consumption diminished from 40 % in the year 1965 to scarcely 28 % in 2005

Applications of renewable energies

- Provision of final or useful energy using renewable energies is based on energy flows originated by the movement and gravitation of planets (i.e. tidal energy), heat stored and released by the earth (i.e. geothermal energy) and in particular energy radiated by the sun (i.e. solar radiation)
- There is thus a great variety of renewable energies in terms of *energy density*, *variations of the available forms of energy* and the *related secondary or final energy carriers and final energy* to be provided

Applications of renewable energies… (RE Classification)

The energy flows available on earth that directly or indirectly result from these renewable energy sources vary tremendously, for instance, in terms of energy density or with regard to spatial and time variations.



Applications of renewable energies…
(Investigated possibilities)

there are tremendous variations in terms of utilization methods, status of technology and given perspectives

•solar heat provision by passive systems (i.e. architectural measures to use solar energy),
•solar thermal heat provision by active systems (i.e. solar thermal collector systems),
•solar thermal electrical power provision (i.e. solar tower plants, solar farm
•plants, Dish/Stirling and Dish/Brayton systems, solar chimney plants),
•photovoltaic conversion of solar radiation into electrical energy (i.e. photovoltaic
•systems),
•power generation by wind energy (i.e. wind turbines),
•power generation by hydropower to provide electrical energy (i.e. hydropower plants),
•utilization of ambient air and shallow geothermal energy for heat provision (i.e. utilization of low thermal heat by means of heat pumps),
•utilization of deep geothermal energy resources for heat and/or power provision (i.e. utilization of the energy stored in deep porous-fractured reservoirs by means of open and closed systems) and
•utilization of photosynthetically fixed energy to provide heat, power and transportation fuels (i.e. energy provision on the basis of biomass).

Structure and procedure

- Due to the great variety of possibilities to use renewable energy sources with the aim to fulfill the demand for end or useful energy, *it is very difficult to present the different possibilities in a similar manner.*
- It is thus highly important to explain the different utilization methods in a **flexible manner.**

Structure & Procedures… (Principles)

The possibilities and boundaries to convert renewable energies into end or useful energy largely depend on the respective physical and technical conditions.

Efficiency: the ratio of useful power output (e.g. electricity, heat) to the power input (e.g. solar radiation, geothermal energy). It depends on the respective operating conditions of the conversion plant, as well as a series of other factors, which vary over time .

Utilization ratio: the ratio of the total output of useful energy to the total energy input within a certain period of time (e.g. one year). The observed time periods may include part load periods and breaks as well as start-up and shutdown times.

Technical availability: describe the portion of the time period under observation, within which a plant has actually been available for its intended purpose and thus considers time periods during which the plant has been unavailable due to malfunctions.

Structure & Procedure…
(Technical Description)

based on state-of-the-art technology and current conditions

*physical principles and supply characteristics:

Appropriate conversion plants into secondary or end energy carriers, or directly into useful energy

Discussion includes:

✓characteristic curve

✓energy flow

✓respective losses given within the entire provision or conversion chain

✓further aspects related to the respective conversion technology

Structure & Procedure
(Economic & Environmental analysis**)**

Definition of reference plants: Based on the current market spectrum, *appropriate reference plants* are defined according to the present state of technology.

*Heat provision & Power provision (*must be distinguished*):
Heat provision: supply tasks are also defined, because no nation-wide heat distribution grids exist and heat provision must always be considered in the context of secured consumer supply.
Power provision: the respective renewable energy supply to be tapped by the reference plants is defined. These typical plants for the current situation will later on serve as a basis for the actual economic and environmental analyses.

More about heat provision….

Supply tasks for the heat provision:

- three different single family houses (SFH) with a different heat demand
- one multiple family house (MFH)
- three district heating networks (DH)

Table 1.1 Supply tasks for heat provision

		Small scale systems				Large scale systems		
Demand case		SFH-I[a]	SFH-II[b]	SFH-III[c]	MFH	DH-I	DH-II	DH-III
Domestic hot water demand	in GJ/a	10.7	10.7	10.7	64.1	8,000	26,000	52,000
Space heating demand[d]	in GJ/a	22	45	108	432			
Building / Total heat load[e]	in kW	5	8	18	60	1,000	3,600	7,200

[a] corresponds to low-energy housing construction; [b] corresponds to state-of-the-art heat insulation; [c] corresponds to average heat insulation in Central Europe; [d] excluding transmission losses of boiler and domestic hot water storages or distribution losses (district heating network and house substations); [e] in case of district heating networks of all connected consumers.

these supply tasks are characterized by heat demand for domestic hot water and space heating (SFH and MFH) or the corresponding total heat demand (DH).

The analyzed single-family-houses represent the heat demand of:

- ✓a low-energy house (SFH-I)
- ✓a building realized with state-of-the-art heat insulation (SFH-II)
- ✓a building with heat insulation typical for Central Europe (SFH-III)

More about heat provision….

◆The system boundary for the economic as well as environmental investigations is defined by the respective *feed-in points* into the house distribution network for domestic hot water (e.g. storage tank exit) or space heating (e.g. boiler exit).

◆However, heat distribution losses within the respective buildings as well as the power consumption of the circulating pumps for the heating system and the domestic hot water system have not been considered.

◆These system elements have been assumed to be the same for all observed technologies based on fossil and on renewable energies.

More about power provision….

Power provision:

- *For power generation systems no supply tasks have been* defined.

- The system boundary is the feed-in point into the power grid.

- For this reason, potential requirements for net reinforcements and modifications within the conventional power plant park have not been considered.

- Capacity effects have not been investigated either.

Economic & Environmental analysis (*Economic analysis*)

Key figures of any energy generation opportunity are **the costs**.
For this purpose, Concerning:
*The initial investments for the most important system components of the applied conversion technology
*the overall investment volume

The specific energy provision costs is calculated based on:
the basis of the monetary value of the year including inflation-adjusted costs

In general, the indicated costs refer to the overall economy;
i.e. plants are depreciated over the technical lifetime *L of the respective* plant or respective plant component that may vary according to the applied technology or system.

Some parameters need to be considered for economic calculations :
•taxes (e.g. value added tax),
•subsidies (e.g. granted within the scope of market launches, credit from public bodies which reduce interest rates)
•extraordinary depreciation possibilities.

More about
Economic analysis….

On the basis of the yearly annuity (i.e. the share of the total investment cost mature each year throughout the overall technical lifetime) → **the overall annual costs** can be calculated by considering the additional respective variable costs (e.g. maintenance costs, operation costs, fuel costs (if applicable)).

From these overall annual costs **the specific energy provision costs** (i.e. electricity production costs in €/kWh, heat provision costs in €/GJ) can be calculated considering *the mean annual energy provision at plant exit* (e.g. electrical energy of a wind turbine fed into the grid, the caloric energy of a heat pump fed into a heat supply system within a dwelling house required to utilise shallow geothermal heat).

Economic & Environmental analysis
(*Environmental analysis*)

- Within energy politics and energy industry, discussions on environmental effects caused by the use of a certain energy source or energy carrier are of major importance.
- This is why for every option of using renewable energy sources for the provision of useful energy; also selected environmental effects will be addressed.
- This assessment will be performed for environmental effects related to manufacturing, ordinary operation, malfunctions and the end of operation.