Renewable Energy Workshop
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Renewable Energy – the bigger picture

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Renewable energy – the bigger picture

Outline

1. *Introduction – what is Renewable Energy?*
2. *The Global perspective*
3. *A brief survey of renewable energy and technologies*
4. *Viability study*
5. *Developing an Energy Systems Life Cycle*

1. What is renewable energy?

- Fossil fuels are non-renewable, i.e. will run out eventually
  - derived from mineral oil
  - petrol, diesel, kerosene, (jet fuel), heavy fuel
  - They also include natural gas
- Nuclear energy is also non-renewable
- Renewable energy is energy that is “recently derived” from solar energy (compare with fossil fuel)

Renewable energy intro.(cont.)

- The main types of renewable energy are wind, hydro-electric, solar photo-voltaic, solar-thermal, biomass (and biofuel), geothermal and ocean energy
- These forms are accessible to different extents – hydropower most mature technology, ocean energy technologies still development stage

Renewable energy intro (cont.)

- Further categorization
  - hydro = large hydro (>10MW) or small hydro
  - biomass = traditional (cooking and heating) or modern biomass
  - **Renewable energy** divided into **traditional biomass**, **large hydro** and the **new renewables**
  - The new renewables are small hydro, modern biomass, wind, solar, geothermal and biofuels

2. The Global perspective

Source: (REN21) Renewables 2007: Global Status Report

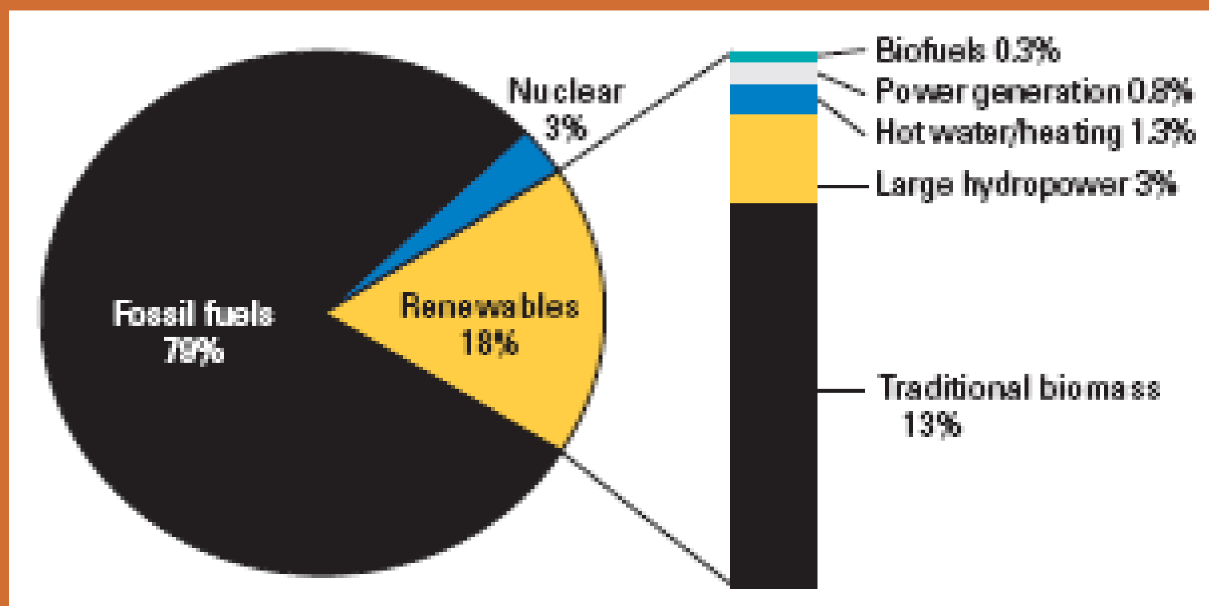
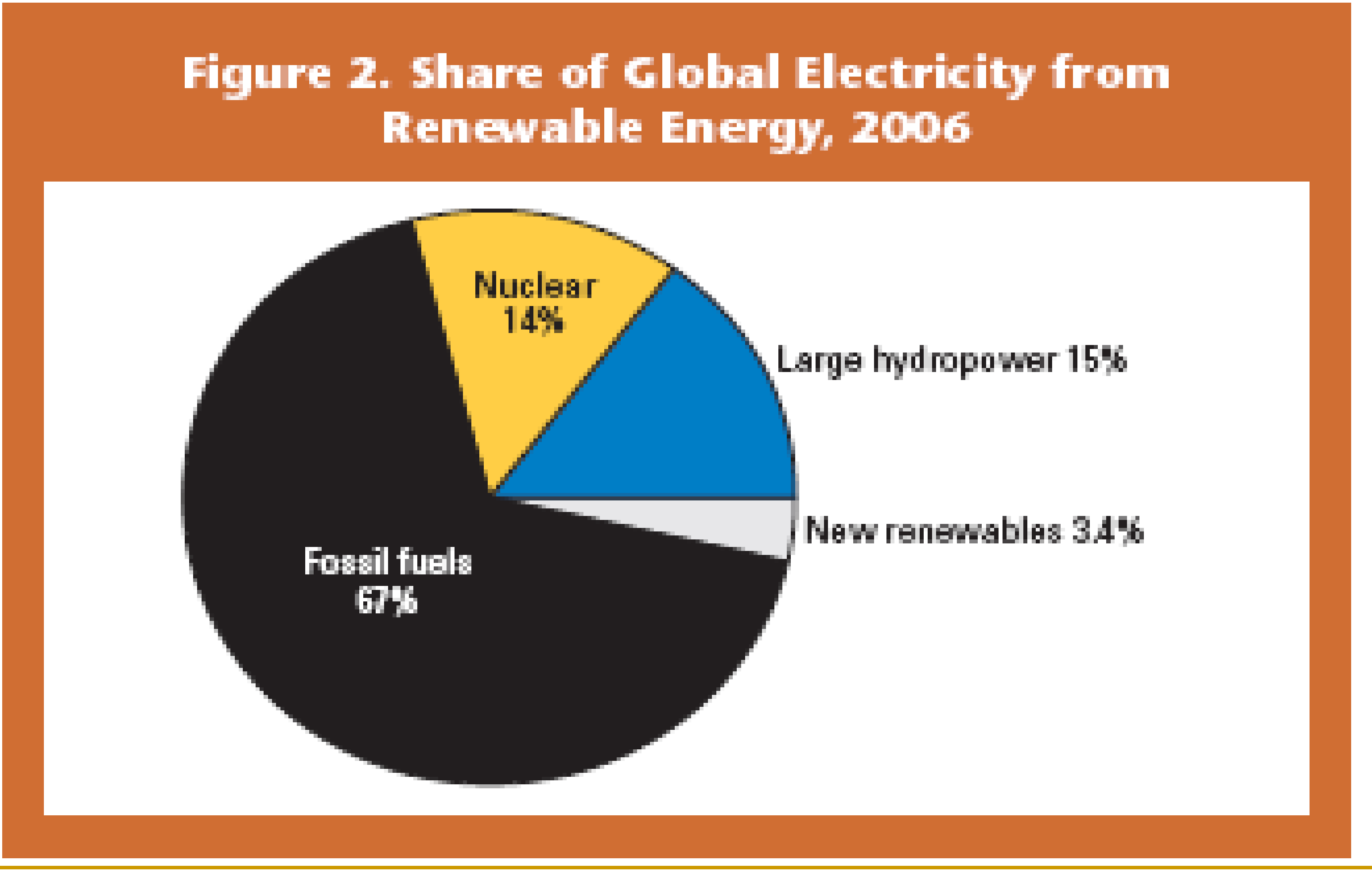


Figure 1. Renewable Energy Share of Global Final Energy Consumption, 2006

Global perspective (cont.)

Source: Renewables 2007: Global Status Report



Global renewable electric power capacity (GW), 2006

Technology	Developing country	World total
Wind power	10.1	74
Small hydro	51	73
Biomass power	22	45
Geothermal	4.7	9.5
Solar PV-grid	-0	5.1
Solar thermal	0	0.4
Ocean tidal	0	0.3
Total R.E. power	88	207
Large hydro	355	770
Total	1650	7300

Uses of renewable energy

- Traditional use: cooking and heating
  - Firewood used for cooking
    - – 13% of global energy consumption
    - - fuel wood, crop wastes, forest wastes, dung, etc
    - - largest use in developing countries

- Transportation
  - Biofuels – ethanol, biodiesel, biogas

- Power generation (grid and off-grid)
  - Biomass (fuelwood, forest waste), hydro, wind, solar PV, geothermal, wave, tidal, OTEC
- Industry
  - Process heat from crop waste (bagasse), fuel wood, forest and timber-milling residues
  - Grid electricity from large hydro

Renewable energy and the environment

- Renewable energy is clean energy
  - Less pollutants than fossil fuels
  - Global warming:
  - Three main GHGs are carbon dioxide, methane and nitrous oxide
    - wind, hydro, solar, ocean energy have zero emissions
    - But beware carbon debt situations
    - Biomass is "carbon neutral"
    - But recent studies show large carbon debts can be incurred during planting of biofuel crops

3. A brief survey of renewable energy technologies: a) Hydropower

Hydro-power is the most established form of renewable energy

- Technology started ~ 100 years ago (water-wheels for mechanical power), turbines last 50 yrs
- rapid response for power generation – used for both load and peak demand
- high efficiencies (~ 90%)
- Large hydro provides 770 GW, or 15% of global electrical power requirements
- Small hydro provides 73 GW, or 1.4%

Principles

- Essential features: water source, (water storage- e.g. dam), pipe (penstock), turbine, generator, control and distribution
- Input power to the turbine is given by the fundamental formula

$$P = \rho QgHa$$

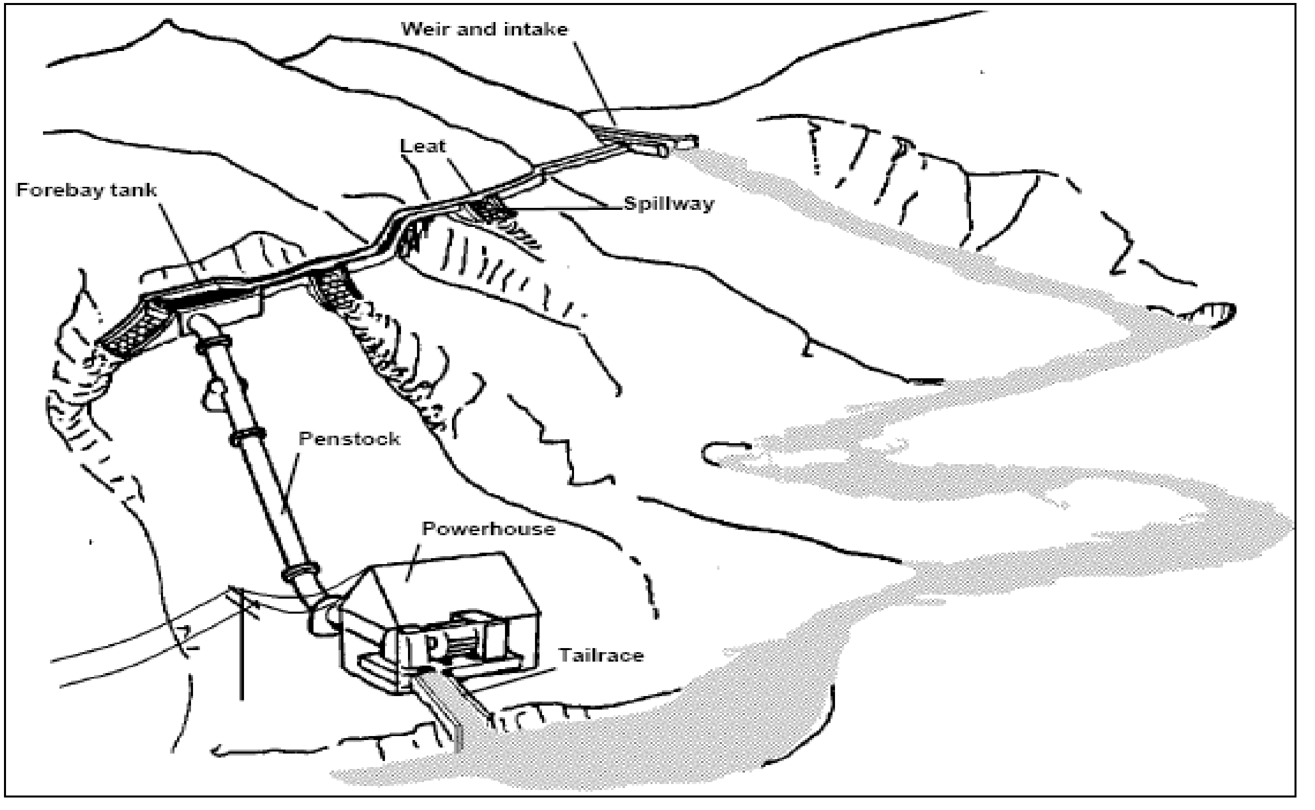
where ρ = density of water, Q = flow rate, g = acceleration due to gravity and Ha = the available, or effective Head.

$$P(kW) \sim 10\ QH_a$$

- Important quantities are the available head H_a and the flow rate Q.

Principles (cont.)

Hydro-scheme components



The effective head H_a is the vertical height of the Penstock less head losses, and the flow rate is the volume of water passing a point in the penstock per second.

Principles (cont)

Weir and intake for a mini hydro scheme – the Sadap minihydro

Photo 2. Intake structure of the Sadap MHP rural electrification scheme financed through district government development funds.

Net Head (Hn)	14.5 meters
Flow (Q)	100 liters / sec
Power (P)	8 kW
Turbine Type	Cross Flow T-14
Generator Type	Synchronous
Controller Type	Electronic Load Controller (ELC)

Capacity

Hydro power stations come in a range of sizes:

- large (>100MW),
- medium (1-15MW),
- mini (100kW-1MW),
- micro (5kW-100kW),
- pico (1-5 kW),
- nano (<1KW)

The Itaipu dam – the world's largest, located at the Paraguay-Brazil border, has an installed capacity of 12.6 GW

Capacity (cont.) - Tiko's nano-hydro at Savu Village, Naitasiri

Dam height: 6 m, total head: 20 m, power output: 150 W

3. Survey of renewables (cont)

b) Wind energy

- Wind energy is the most important within the new renewables
- Supplied 95GW to global power generation in 2007 – an increase of 40% over its 2006 value
- Mature technology
- Both grid and off-grid
- Important component of remote hybrid systems

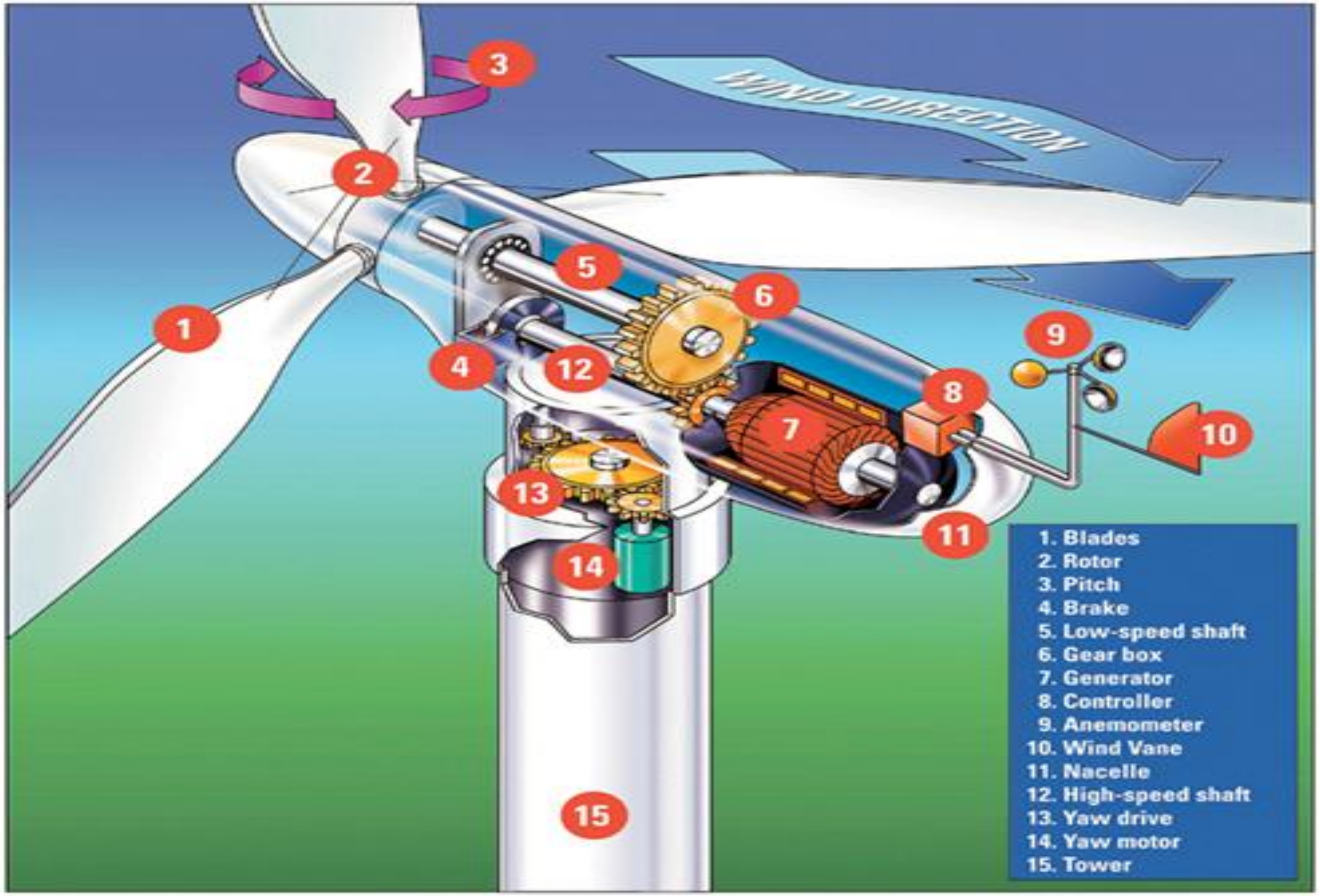
Wind energy - technology

Turbine types:

- Horizontal or vertical axis
- Single, two, three or multi-bladed
- Upwind with active or passive steering
- Downwind self oriented or power steered

An example of a wind farm

Wind energy (cont)



Components of a wind turbine

Wind energy (cont)

- Rated maximum power given by

$$P_r = ½\, C_p\, A\, \rho\, u^3$$

  - where A = area swept by rotor

    ρ = density of air

    u = wind speed

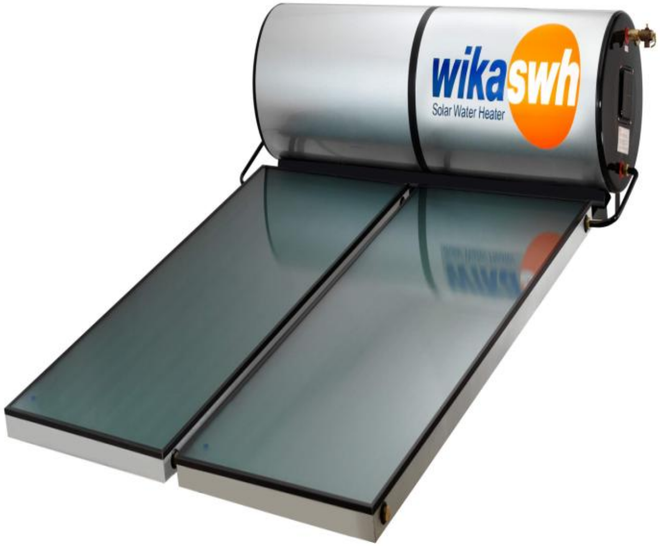
    C_p = the power coefficient

- The power coefficient gives the fraction of power extracted from the wind
- It has a theoretical maximum value of 16/29 = 0.59, and actual values usually much smaller

3. Survey of renewables (cont)
c) Solar energy

- Solar energy used as solar thermal (e.g. hot water collectors) or solar photo-voltaic (PV)
- In 2006 solar PV supplied 2.7GW to the grid world-wide
- Grid-connected PV is the fastest growing energy technology today

Solar energy (cont.)



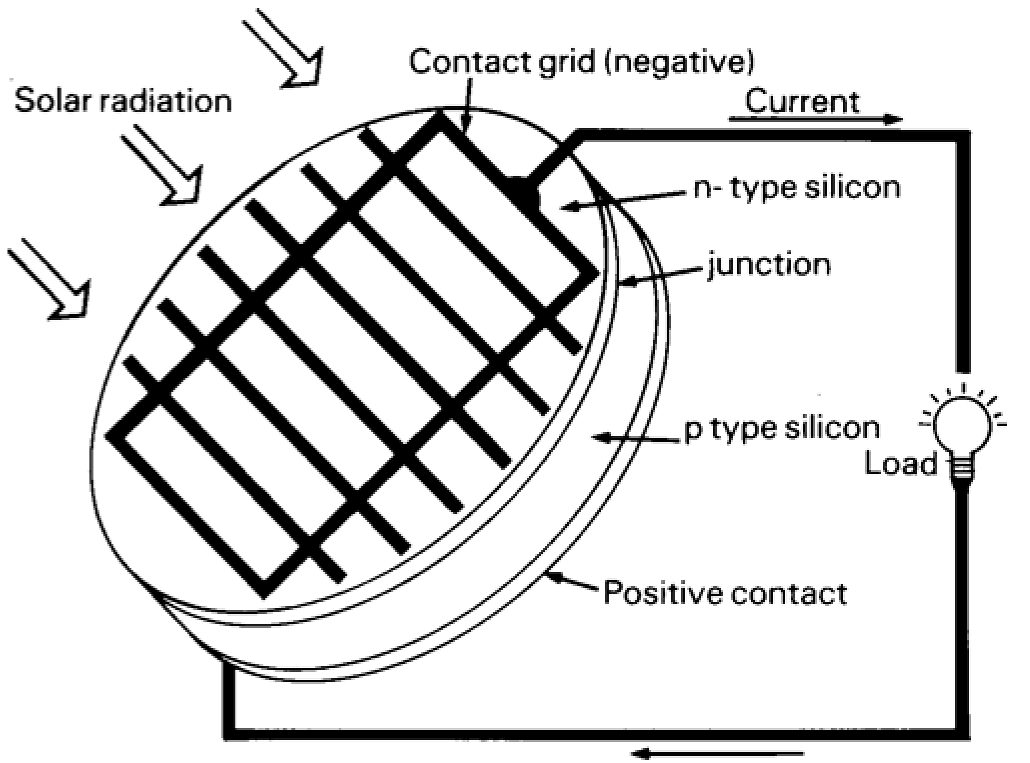
Examples of roof-top solar PV panels and hotwater collector

Solar energy (cont.)

A single PV solar cell – metal strips provide electrical conduction. PV panels are made up of many such cells connected in series to provide a useful voltage output

Solar energy (cont.)

Solar cells are devices that generate electricity (electron-hole pairs) when sunlight strikes them. They have inbuilt potential differences that separate the electron from the hole at a "pn junction" region and produce a current in the external circuit



3. Survey of renewables (cont)

d) Biomass energy and biofuels

- All biomass energy originates from organic matter which was formed recently (i.e. historical, not geological time scales) through the process of photo-synthesis.
- Primary sources of biomass (e.g. trees, agri crops, algae etc) can be either
  - Burnt directly (**combustion**) to produce energy for heating, cooking and power-generation
  - Treated thermo-chemically to produce **secondary fuels** such as **syngas** through the process of **gasification**
  - Treated biochemically to produce secondary fuels such as biogas, ethanol and biodiesel
- Vegetable oils can be used directly as diesel or gas turbine fuels

Biomass energy (cont)

Jatropha fruits (left) and seeds (right). Jatropha oil is widely claimed to be an ideal biofuel as it is poisonous and thus will not displace food crops for biofuel use.

Babassu nuts – oil from these nuts were used to patially power a Virgin Atlantic flight from Heathrow to Amsterdam

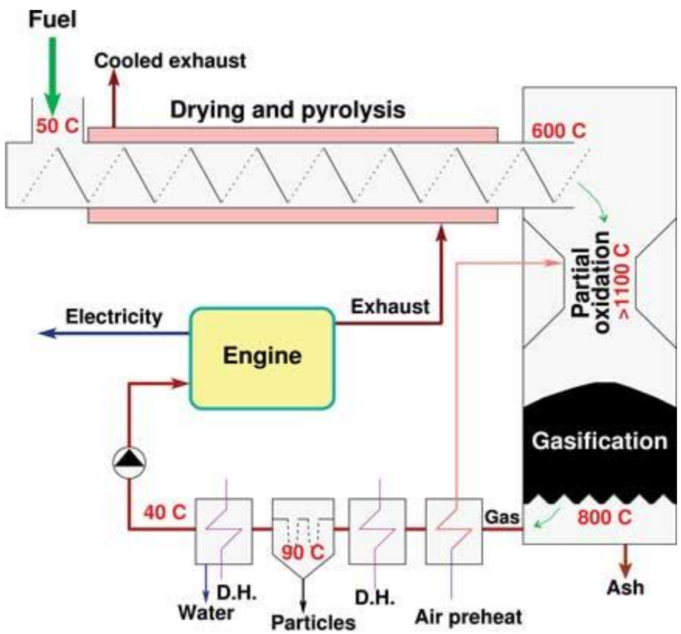
Biomass energy (cont)

Oil palm tree (left) and kernels (right). Oil palm is being extensively cultivated in Indonesia and Malaysia to provide feedstock for the production of biodiesel.

Biomass energy (cont.)

- Biomass combustion
  - Produces heat for cooking, heating
  - Power generation via steam turbine or gas-turbine, or combined cycle power plants
- Biomass gasification produces syngas which can be used in integrated gasification power plants
- Biomass-fired power plants provided 45 GW (0.9%) of total global electricity generation in 2006

Biomass energy (cont)

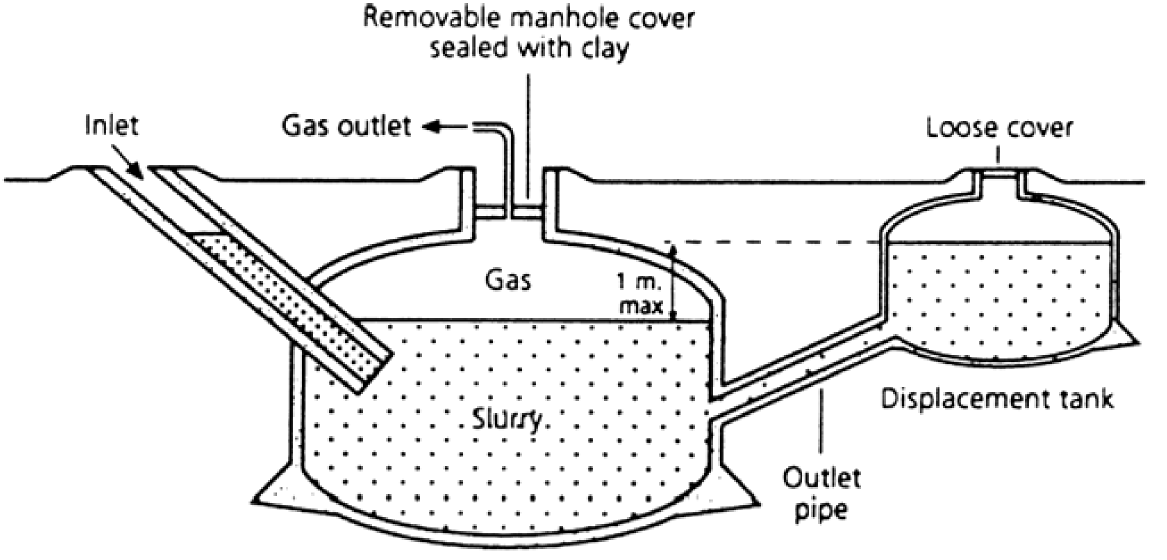


Right: a thermal gasification power plant – the Viking two-stage gasifier, built by the Biomass Gasification Group at MEK, Denmark. Left: the schematic design.

Biomass energy (cont)

Biofuels

Biogas (a mixture of methane and carbon dioxide) is produced by the action of groups of anaerobic bacteria on biomass such as animal manure in a biodigester.



Fixed-Dome Biogas Digester

Ethanol production

- Ethanol is produced by the fermentation of carbohydrates such as sugars, starches and ligno-cellulosic material (e.g. wood) by yeasts, followed by distillation

Feedstock for the fermentation process are

- Sugarcane, sugar beet - two dominant feedstocks
- USA – corn, grains, sorghum
- Starches, e.g. cassava
- But cellulose and hemi-cellulose can also be broken down (hydrolysed) (use of sulphuric acid) to give sugars – not commercially viable at the moment

Biomass energy (cont)

Biodiesel

- Biodiesel is an ester produced by the reaction of vegetable oils and fats (which are triglycerides, i.e. esters of glycerol) with either methanol or ethanol to produce the biodiesel and glycerol.
- e.g. coconut oil + methanol = coconut methyl ester (CME) + glycerol

Biomass energy (cont)

Use of biofuels as transportation fuel

- Ethanol can be used as a 10% blend (E10) in normal petrol engines without any modification
- CME can be used as a diesel engine fuel either as a blend or unblended
- Various combinations of blended and unblended biofuels and normal, modified or flexi-vehicles now in use in Brazil, the USA, UK etc

4. Viability study

Not all forms of renewable energy are available at all locations. Even if they are, there may be other factors limiting, or preventing their full utilization.

The important factors that determine the viability of a renewable energy technology are the availability of the energy resource, the supply reliability, the generating costs of the installation, financing, technology complexity and maintainability, knowledge base and human resources.

A proper appraisal of all these factors is crucial for the effective and successful utilization of renewable energy resources.

Viability study (cont)

- Resource availability
  - Are there sufficient energy resources of the type you are interested in available? E.g. is there enough water and appropriate terrain available at the proposed site to provide the head and flow rate for the size of your proposed installation?
- Supply reliability
  - RE resources may be continuous, variable or intermittent. Water resources for hydros are fairly constant in time (allowing for seasonal variations), however wind resources are intermittent, and may not be big enough. Also solar radiation is both intermittent (changes with cloud cover in the day) and is unavailable during the night

Viability study (cont)

- Generating costs

  These include

  - Capital costs of installation of the equipment
  - Lifetime – how long the hardware will last before replacement is necessary (i.e. replacement costs)
  - Financing costs – costs of financing the loan borrowed to purchase the equipment for the installation
  - Operation and Maintenance (O&M) costs

Viability study (cont)

- Technology complexity and maintainability
  - The required technology may be too complex or sophisticated for the community to manage – e.g. a wind turbine-diesel hybrid system in a remote rural setting. Also, because the technology is, e.g. too hi-tech, it may not be serviceable in the local community
- Knowledge base
  - The users need to be trained in the operation and maintenance of the system. Such training is usually retained personally. This personally-retained knowledge and any written records form the knowledge base essential for the successful operation of the system. When trained persons leave, others have to be trained to take their part.

Viability study (cont)

- Human resources
  - The installation, operation and maintenance and management of the renewable energy technology requires personnel with various types and levels of training, knowledge and know-how. Without such people, the successful use of RE technologies is not possible. There is a need for developing countries to build their capacities in this area.
- In summary
  - Putting renewable energy to work involves the appraisal and analysis of a complex web of inter-related factors. It is crucial that all these factors are taken into account before any real commitments are made.

5. Developing an Energy Systems Life Cycle

Introduction

- We need an energy supply system that will produce the required energy needs for a community or country
- We must know what these needs are
- As population grows, new industries and commercial centres spring up over the years, the demand changes. The supply must cater for this.
- To produce the required level of electricity, we must know what types of RE resources are available, and make up the rest with fossil fuel.
- If there is a draught, our hydros will dry up
- If there is a coup or national unrest, there may be possible acts of sabotage and terrorism
- If…..If…….If…..If………
- What if …….

Energy systems life cycle (cont)

- Do we have enough money for the project?
- How long will each component of the system last? Do we have replacement plans? Will we be able to keep up with repayments for our loan?
- It is clear that we must have a plan that will
  - Develop an appropriate energy supply system that meets the needs of the community
  - Sustain and maintain this system over the fore-seeable future
  - Answer all the questions raised above and more

Energy systems life cycle (cont.)

- We need to develop a system that
  - Supplies the energy needs of the consumers
  - Monitors changes in demand and the ability to supply, and continuously adjusts to these changes

We need to develop the concept of an Energy Systems Life Cycle, and use it to meet the energy needs of Fiji and other PICs

Energy systems life cycle (cont.)

The basic elements of this cycle must include

Demand side analysis:

- ***Demand assessment***
  - how much energy, who wants it, where?
  - A full picture of what is required, why it is required and what is expected of you as an energy supplier

Supply side analysis:

- ***Resource assessment***
  - What RE resources exist, how much, where?

Energy systems life cycle (cont.)

- ***Technology identification***
  - Will it be hydro or wind or PV or a hybrid of these?
  - How much supplementation by fossil fuel, what is the correct mix of technologies?
- ***System sizing, design and financing***
  - How big and what types, where is the money coming from and what are our revenue forecasts? How much do we pay towards repayments, maintenance, dividends…
- ***Contingencies***
  - What if there is a draught, a coup, mass migration..
- ***Physical implementation***
  - Putting the physical system on the ground

Energy systems life cycle (cont.)

- ***Performance review***
  - Periodically evaluating the system to see how it is keeping up with plans
  - Includes activating contingency plans when required
  - Also, are we still carrying out our CORE FUNCTIONS?

- ***Loop back to Technology Identification after the review process or major contingencies (and begin the cycle again)***
  - How do we change the system to better meet the current needs (NOT foreseen when the system was initially designed)

Energy system life cycle (cont.)

We can do better if we plan better

Thank You