



## Module 3b

### Bioenergy end-use and applications

#### Outline

- > Solids, gas, liquids
- > Electricity, heat, power, CHP
- > Prime movers
- > Small scale rural and urban usage
- > Modern industrial usage



## Biofuels

- > Solid
  - Charcoal
  - Briquettes
- > Liquids
  - Alcohols: ethanol, methanol
  - PPO
  - Biodiesel
  - Pyrolysis oil
- > Gaseous
  - Producing gas, syngas
  - Biogas

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## Heat and power production

- Stirling engines
  - Steam engine
  - ORC
  - Fuel cells
  - Micro-gasturbines
  - Gas engines
  - Diesel engines
- Solid biofuels
- Liquid or gaseous biofuels

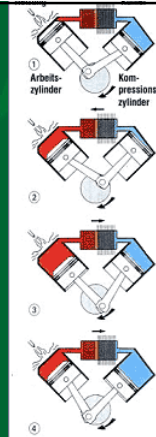
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## Stirling engine

- > External combustion
- > Heat source needed
  - all sorts of biomass possible
- > Reliable
- > No "additional" emissions
  
- > High investment
- > Pollution
- > High temperature needed



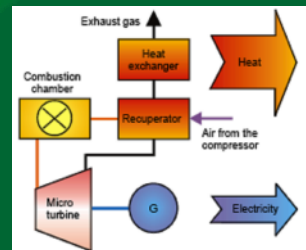
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## Micro gasturbine

- > Biogas and landfill gas
  - > fuel flexible
- > Low maintenance
- > Reliable
  
- > High investment
- > Only experience with natural gas
- > Efficiency rather low
- > Sensitive compressor: impurities and moisture



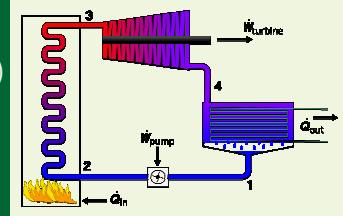
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## Organic Rankine Cycles

- > “External combustion”
  - comparable to steam cycle (Rankine)
  - water replaced by organic fluidum
- > All sorts of biomass possible
- > For low T waste heat
- > Low maintenance
- > High investment
- > Optimalisation organic fluidum



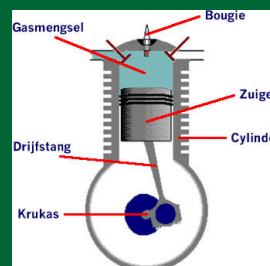
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## Gas engine

- > Internal combustion
- > Most “proven” option
- > Flexible
  - variable power
  - mobile and stationary
  - wide capacity range
  - suitable for all sorts of “bio”-gas
- > Relatively high maintenance
- > Relatively high emissions and noise



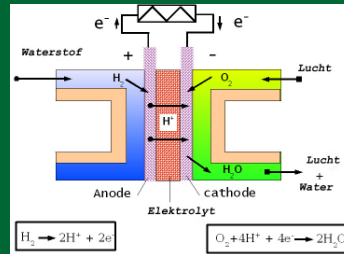
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## Fuel cells

- > Elektrochemical conversion
- > Hydrogen as fuel
- > No noise or emissions
- > High E-efficiency (Carnot)
- > Demanding gas cleaning
- > Several gas compounds are poisons
- > High investment



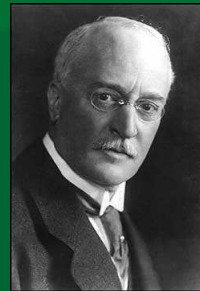
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## Diesel engine

- > Self ignition
- > Biodiesel, oils, fats, “dual-fuel”
- > Proven technology
- > Flexible
  - variable power
  - mobile and stationary
  - wide power range
- > Relatively high maintenance, noise
- > Relatively high emissions (soot)



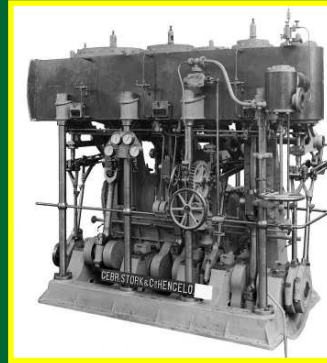
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## Steam engine

- > “External combustion”
- > All sorts of biomass possible
- > Low maintenance
- > Very proven technology
- > Wide power range
  
- > Low E-efficiency
- > High noise level
- > High maintenance

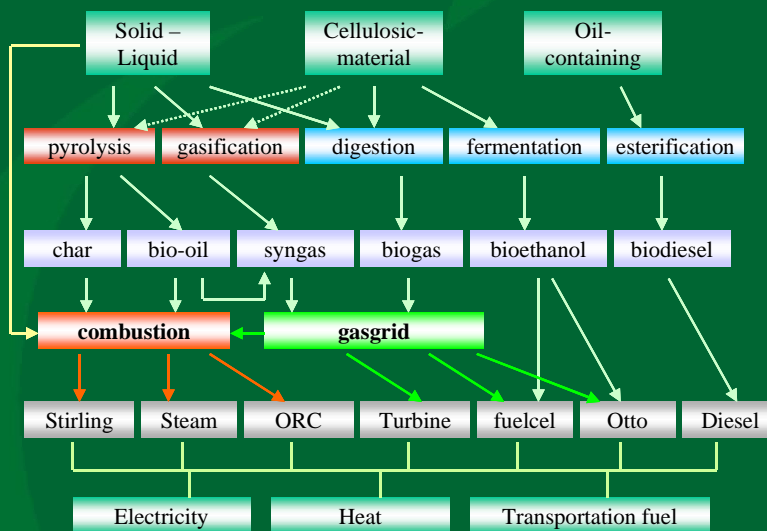


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## Possible routes



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## Characteristics CHP options

	Micro-turbine	Stirling	ORC	Otto-Diesel	Fuel-cell
Capacity (kWe)	25 - 250	1 - 50	5 - 1500	15 - 10000	10 - >5000
E-efficiency	15 - 35	15 - 35	10 - 20	30 - 40	40 - 60
Heat %	50 - 80	60 - 80	70 - 85	45 - 50	
Overall %	75 - 85	80 - 90	85 - 95	75 - 85	
Lifetime (hour)	50.000	50.000	n.a.	25.000 - 60.000	

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## Electricity production costs

	Micro-turbine	Stirling	ORC	Otto-Diesel (stoom)	Fuel-cell
Capacity (kWe)	25 - 250	1 - 50	5 - 1500	15 - 10000	10 - >5000
Investment (€ / kWe)	1700 - 1900	4000 - 6000	1700 - 4000	500 - 1400 (1500-3000)	2800 - 4400
O & M (ct/kWh)	0,6 - 1,7	1,7 - 2,8	0,27 - 0,30	0.4 - 2 (0.4 - 0.8)	1.1 - 2.8
Biofuel (ct/kWh)	2	2	1,5	2 (2)	2
Production costs (ct/kWh)	3 - 4	3 - 4	2 - 3	2.5 - 3.5 (3 - 4)	5 - 8

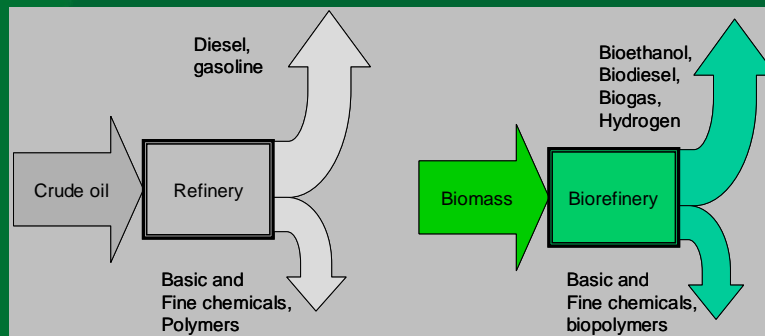
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## Biorefinery

> (Upgraded) biomass is used as feedstock



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## Exercise

- Following sheets present six modern bioenergy applications that may be relevant for developing the bioenergy market in developing countries
- What is your opinion of, or experience with, each of these applications

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## 1. Electricity from combustion of solid biomass

- Modern biomass fired power (or CHP) plants can supply electricity to industry or the national grid
- Main benefits are substitution of energy imports and improving the grid
- Depending on the circumstances, such power plants are generally economic from 1 MWe upward
- At large scales, production becomes more efficient and cost effective but the logistics (and sustainability) of the biomass supply gets more complicated
- Larger installations may greatly benefit from carbon credits

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## 2. Industrial biogas (including landfill gas)

- Biogas plants are generally small or medium scale (up to several MWe)
- The economics are often connected to the benefits from waste treatment and other environmental benefits
- CDM prospects are often good for this type of project

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### 3. Transport fuels (import substitution / export)

- Resources for the production of ethanol or biodiesel can be obtained from residues (e.g. from agro-industries) but most often require production on dedicated plantations
- Given quality requirements of liquid biofuels, processing is only feasible on large scales
- An alternative is the local use or export of straight vegetable oils
- Sustainability of liquid biofuel production is an important aspect



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### 4. Vegetable oil for small scale power production

- Vegetable oils can be used in modified diesel engines for (off grid) electricity or shaft power generation
- This type of project has a high potential for MFP (multi function platform) applications and as such for improving energy access to the poor
- Energy access and local oil production can provide an economic impulse in rural areas.



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## 5. Modern cooking fuels

- Ethanol based cooking fuels or charcoal from crop residues are convenient and clean household fuels that contribute to the fight against deforestation
- Their production may induce economic impulse in rural areas.



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## 6. Family scale biogas

- Digestion of animal manure in small digestion units, providing biogas for cooking and lighting, are highly successful in Asia
- The application could provide energy to millions of households in the region but depends on several requirements at household level
- A key issue is the development of companies for construction and maintenance of biogas units.



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