MODULE 3 – SUPPLEMENTARY MATERIAL

Biomass: Fuels, Combustion and Energy Conversion

SHaKE – Sharing Heat and Knowledge on Energy Communities
Erasmus+ KA220-HED Cooperation Partnerships in Higher Education
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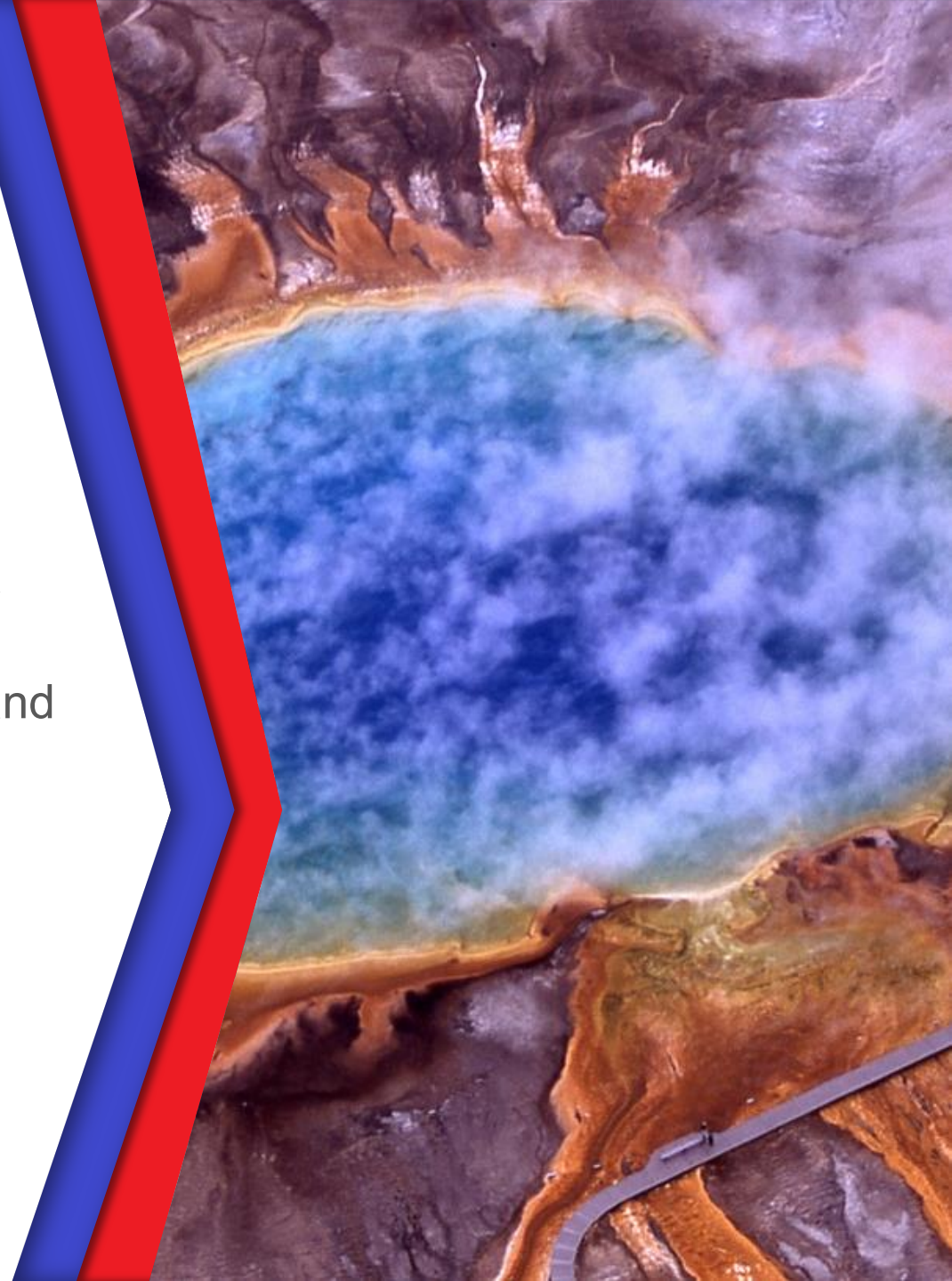
SHaKE
Sharing Knowledge on Energy Communities



Grouping of biomass

- *Solid*
  - *Woody (woodchips etc)*
  - *Herbaceous (straw etc.)*
- *Liquid*
  - *Bioethanol*
  - *Biomethanol etc.*
- Gaseous
  - Biogas
  - Biomethane
  - Deponia gas etc.

Source: *https://millerwaste.ca/wp-content/uploads/2024/09/13454164705_6980009784_b.jpg*

Source: *https://www.youtube.com/watch?v=ekyrOkpIZQs*

Solid biomass

- *Woody (woodchips etc)*
  - *Source: wood industry, residual, waste wood*
  - *LHV 9 000 – 18 000 kJ /kg (moisture)*
  - *Low alkaline content (high ash melting point)*
  - *Low ash content*
  - *High energy demand during fuel preparation*
- *Herbaceous (straw etc.)*
  - *Source: agricultural residual*
  - *High alkaline content (low ash melint point)*
  - *High chlorine content (corrosion, emission)*

Source: https://www.maresch.co.at/wp-content/uploads/produktion/hackschnitzel_saegespaene0003-1024x682.jpg

Source: *https://alternativenergia.hu/csokkent-a-pecsi-eromu-porkibocsatasa/*

Solid biomass

Solid biomass

- *Relatively low heat price.*
- *Good storability*
- *Solid biomass is a typical fuel for district heating systems.*
- *Used for both direct (heat only) and cogeneration.*
- *Its use requires responsible forest management.*
- *Flue gas cleaning required.*
- *One of the best ways to green district heating..*

25 MW biomass hot water boiler for distric heating in Kecskemét

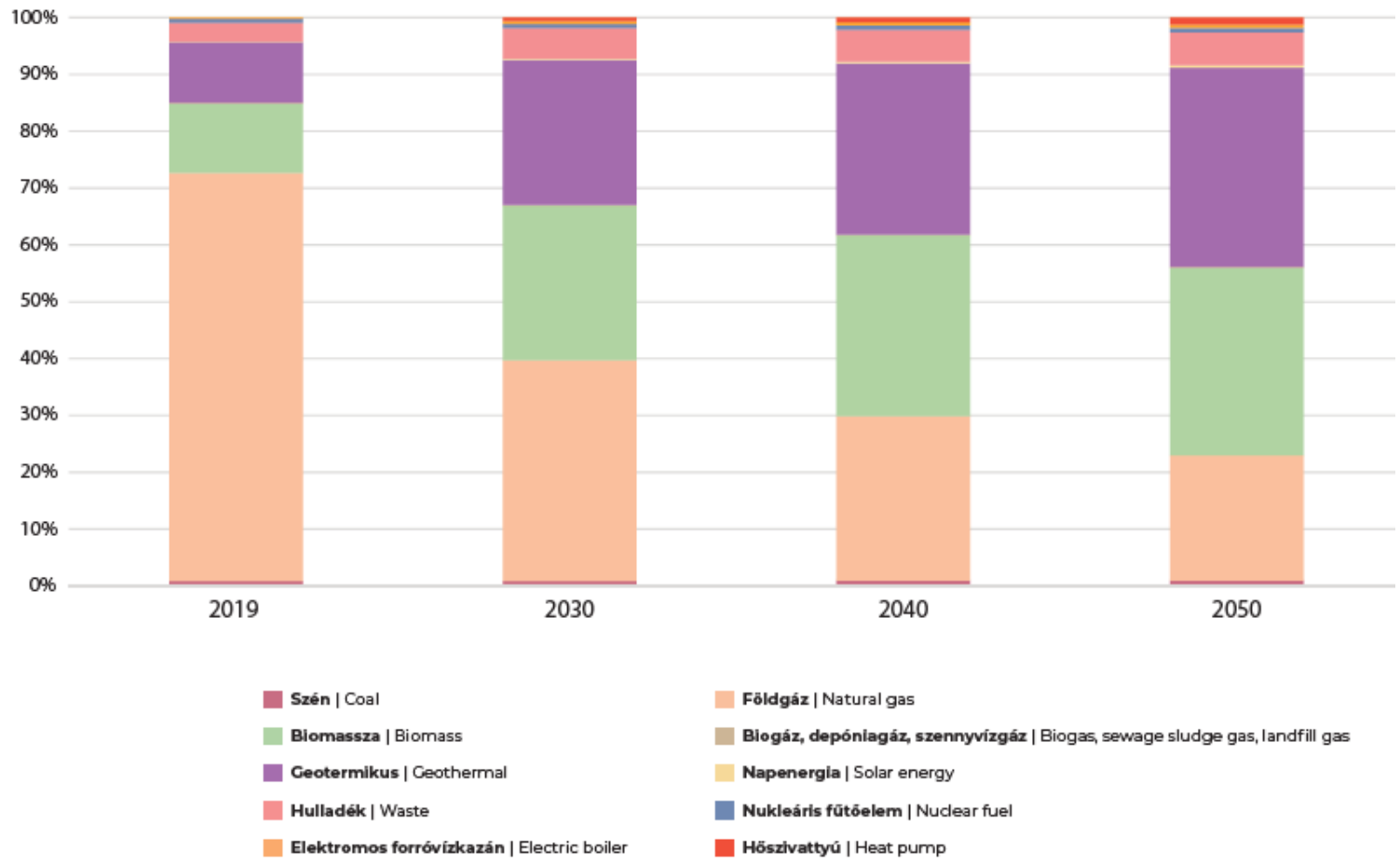
Source: *https://termostar.hu/rolunk/zold-tavho-atfogo-fejlesztesi-projekt/zold-tavho-fejlesztesi-projekt*

15 MW biomass hot water boiler for distric heating in Kaposvár

Solid biomass

Solid biomass

- *The Hungarian district heating strategy also relies heavily on solid biomass.*
- *The current 10% biomass share is planned to increase to 25% by 2030.*



Source: MATÁSZSZ's vision on the future of Hungarian district heating's energy source structure (https://tavho.org/uploads/statisztika/MEKH_statisztikai_kiadvany_TAVHO_2024.pdf)

Liquid biomass

- *High energy density*
- *Ease of use*

  → applicable in transport as fuel
- *From primary biomass (maize)*
- *More difficult to evaporate than petrol*
- *Shorter shelf life due to its hygroscopic property*
- *High fuel prices (not coming from waste)*

  →not typically used for power or heat generation

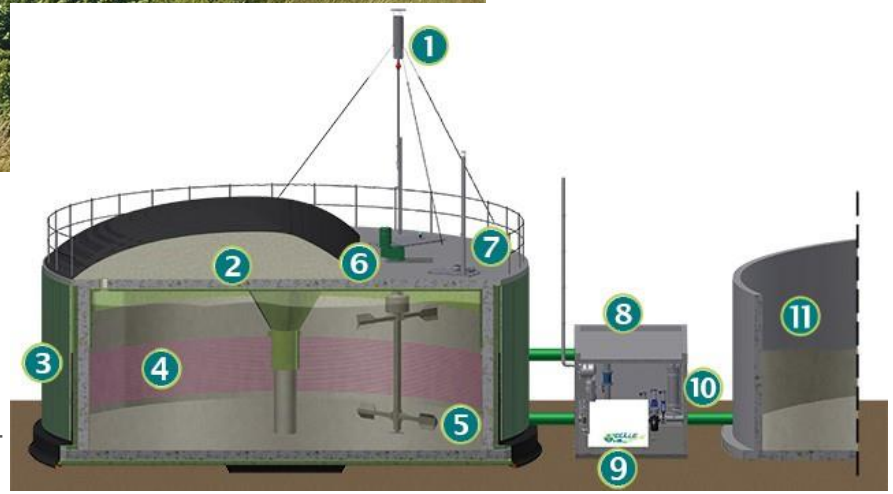
Pannonia Ethanol Plant, Dunaföldvár, Hungary

Source: www.pannoniabio.hu

Gaseous biomass

- Biogas
  - Source: fermentation of organic waste
  - Typical composition
    - 50-70 % CH4
    - 30-50 % CO2
    - N2
    - H2S (corrosive)
    - CO
- Biomethane
  - biogas purified to natural gas quality
- Landfill gas
  - siloxane content (clogging risk)

Source:https://bioenergyconsultant.com/biogas-benefits-drawbacks/



Source: https://www.nq-anlagentechnik.de/1-behaeltersystem-nq-guelleenergie/

Gaseous biomass

- Biogas production is often part of waste treatment and disposal (wastewater treatment).
- Part of the heat is used to heat the fermenters.
- The use of biogas and landfill gas for district heating is not common, as production is located far from cities and thus from the district heating system.
- Where feasible, high energy efficiency can be achieved through cogeneration.

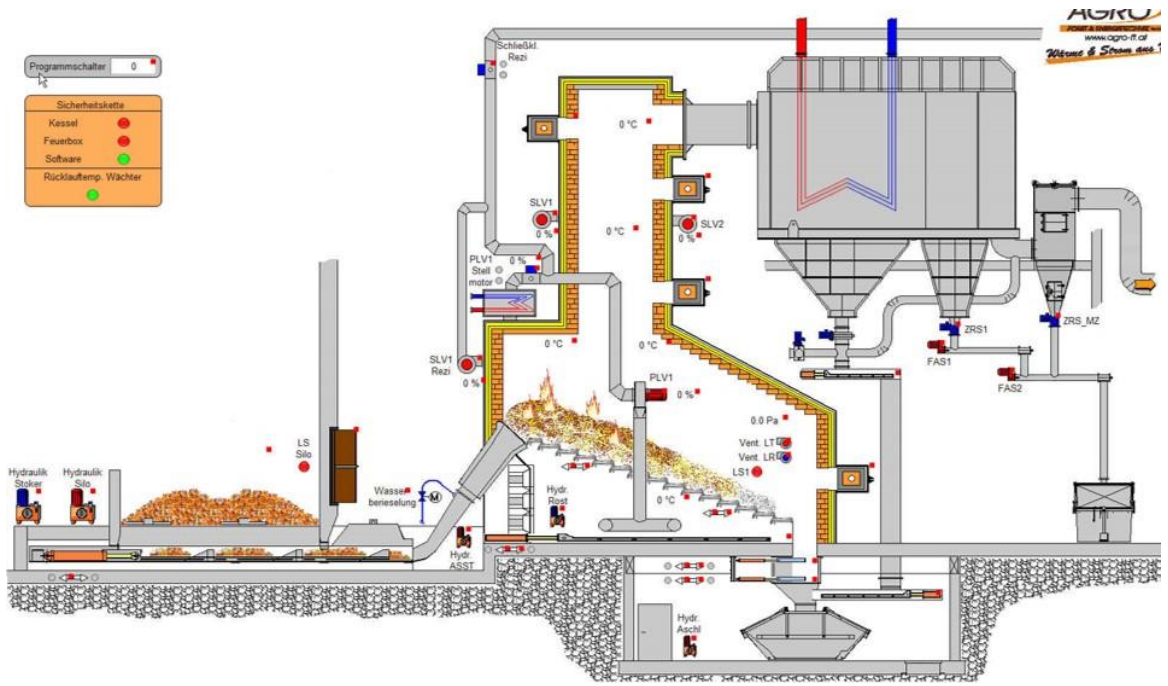
Wastewater sludge fermentors

Source:https://eromuvekejszakaja.hu/wp-content/uploads/photo-gallery/Szeged_SZVT_1.jpg?bwg=1753689110

Grouping of biomass boilers

- *Heat transfer medium types*
  - *warm water*
    - *pressure 2-4 bar(g), temperature <95°C*
  - *hot water*
    - *pressure 6-8 bar(g), temperature >95°C*
  - *steam*
    - for industrial heat supply, stable condensation heat metering and high condensation heat transfer
    - *pressure 6-18 bar(g)*
  - *thermo oil*
    - high temperature (180-300 °C) at low pressure (2-3 bar(g))
    - high pumping work demand
    - high cost
    - flammable

Biomass fiered thermo oil boiler

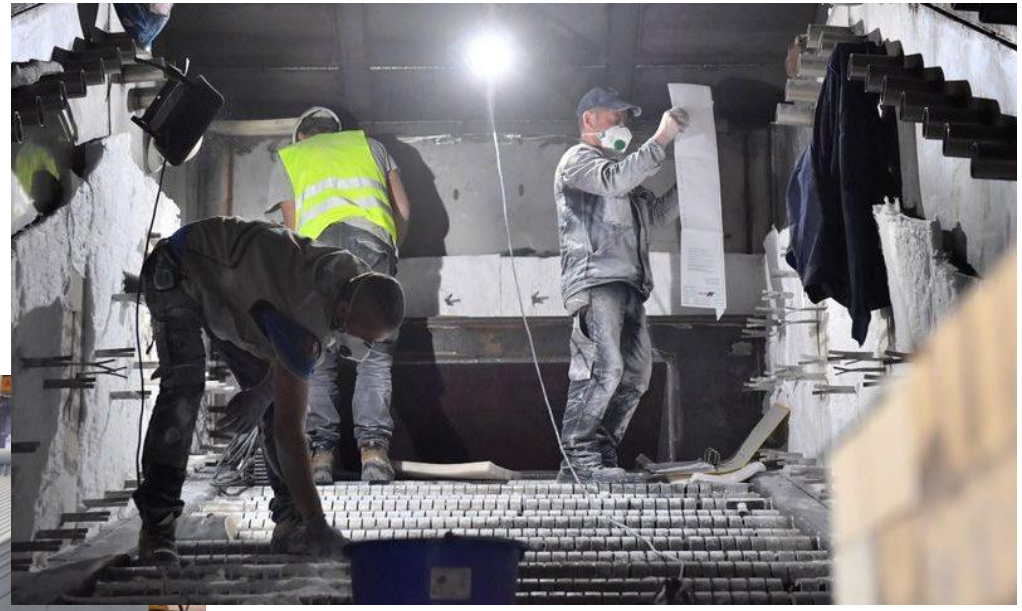


Source: https://www.agro-ft.at/en/company/

Grouping of biomass boilers

Grouping of biomass boilers

- *Combustion chamber types*
  - *Reciprocating (step) grate*
  - *Rotating grate*
  - *Vibrating grate*
  - *Fluidized bed*
    - *Bubbling (BFB)*
    - *Circulating (CFB)*



Step grate in Kaposvár (7,5 MW)

Source: https://www.sonline.hu/rovat/kozelet?page=2980

Vibrating grate

Source: https://en.mesin-pks.com/product/vibrating-grate-boiler-sparepart-boiler-p1339897.aspx

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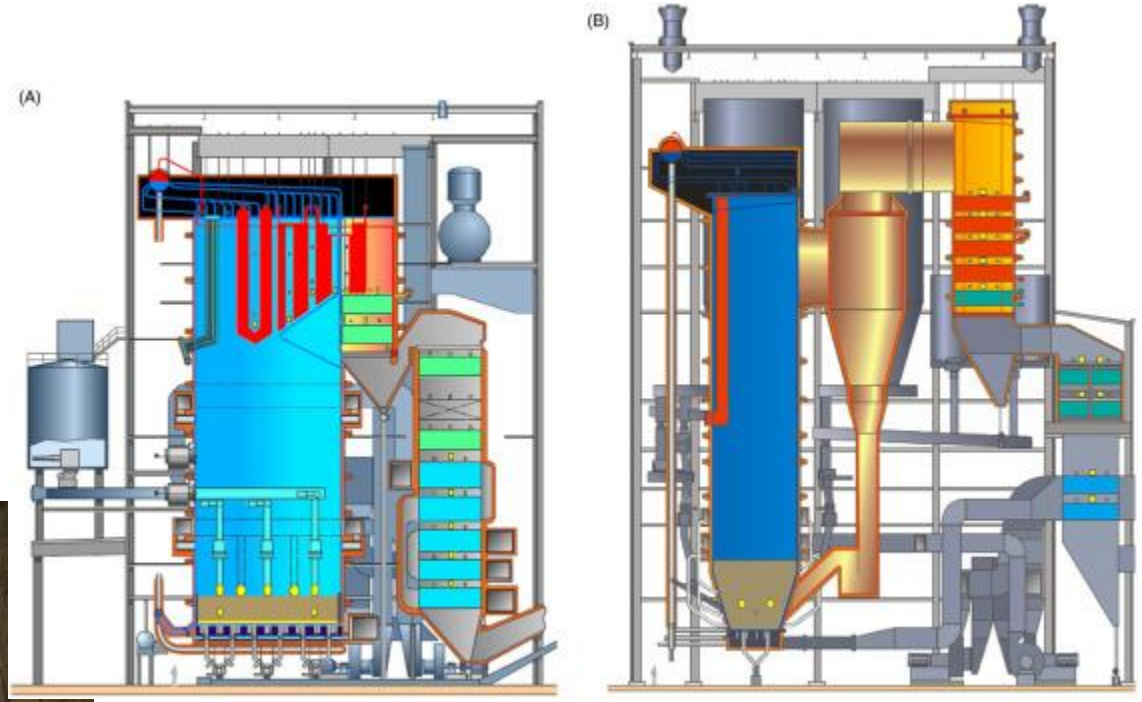
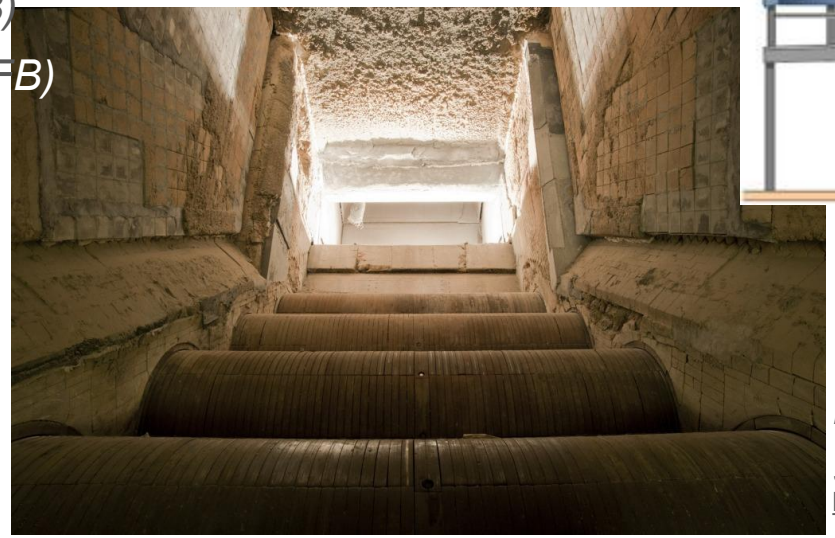


Bubbling Fluidized Bed *Circulating Fluidized Bed*

Source: https://www.sciencedirect.com/topics/engineering/bubbling-fluidized-bed-boiler



Rotating grate boiler

Source: https://enbudapestem.hu/2023/10/16/mi-a-szemet-utja-a-kukanktol-a-radiatorig-a-hulladekhasznosito-belulrol

Energy conversion system for biomass combustion

- *Steam turbine*
- *condensing*
- *partial condensing*
- *back pressure*
- *Organic Rankine Cycle*
- *Energy conversion system for biomass combustion*
- *Gas turbine*
- *Gas engine*

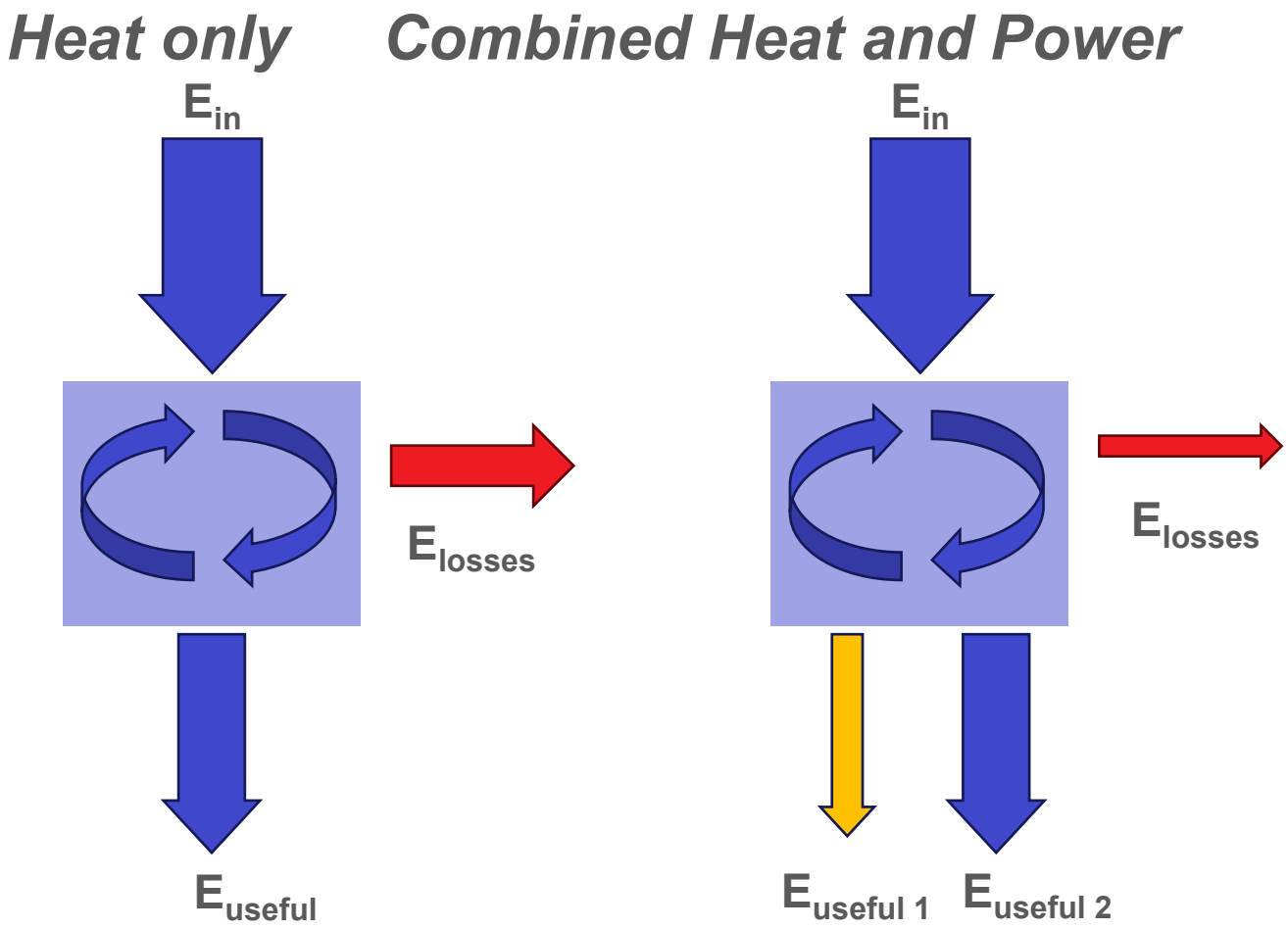
Back-pressure steam turbine generator

Source: https://eromuvekejszakaja.hu/wp-content/uploads/photo-gallery/thumb/oglasjhi.png?bwg=1750842570

Energy conversion system for biomass combustion

Energy conversion system for biomass combustion

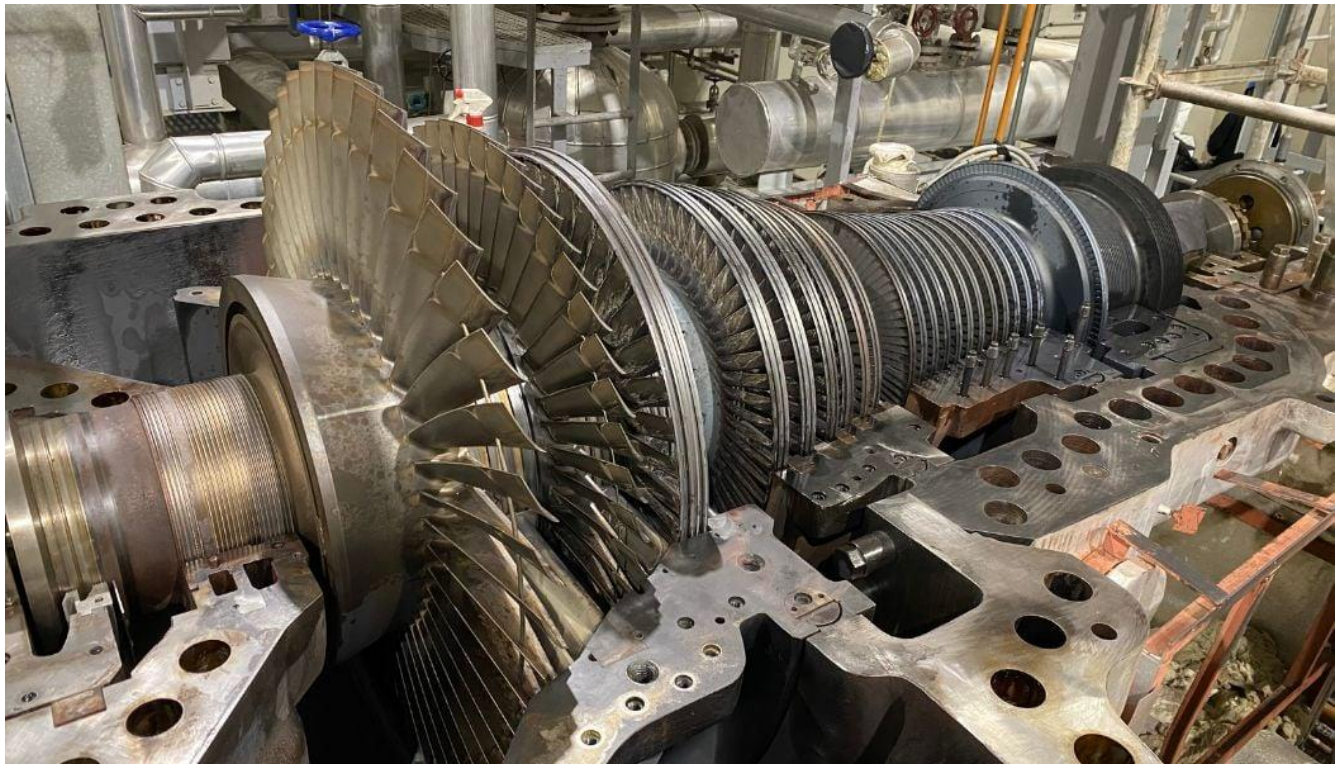
- Specific heat consumption
  - $q = \frac{E_{in}}{E_{useful}}$
- Specific electric power production
  - $k = \frac{E_{electric}}{E_{heat}}$ $\eta_{CHP} = \frac{E_{useful1} + E_{useful2}}{E_{in}}$
- Efficiency
  - Electrical
    - $\eta_{electrical} = \frac{E_{useful1}}{E_{in}}$
  - Heat
    - $\eta_{heat} = \frac{E_{useful2}}{E_{in}}$



Steam turbine

Steam turbine

- ***condensing***
  - *No useful heat output*
  - *Low outlet temperature, and pressure*
- ***partial condensing, extracted steam***
  - *Part of steam goes to DHheat exchanger*
- ***back pressure***
  - *The expansion ended at higher pressure, the whole steam flow goes to DH heat exchanger*



Source: https://www.araner.com/hs-fs/hubfs/steam_turbine_work.jpg?width=1050&height=600&name=steam_turbine_work.jpg

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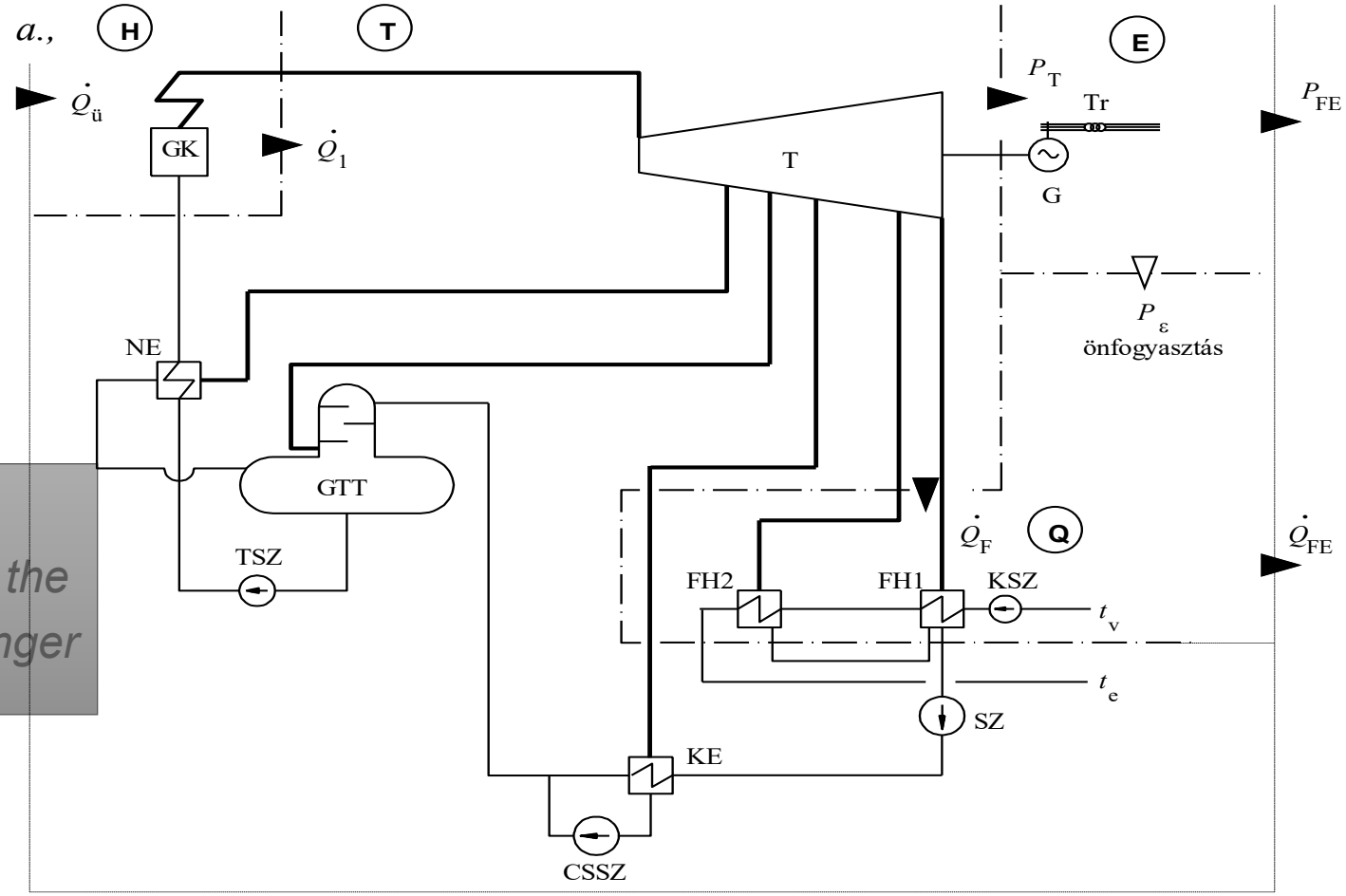

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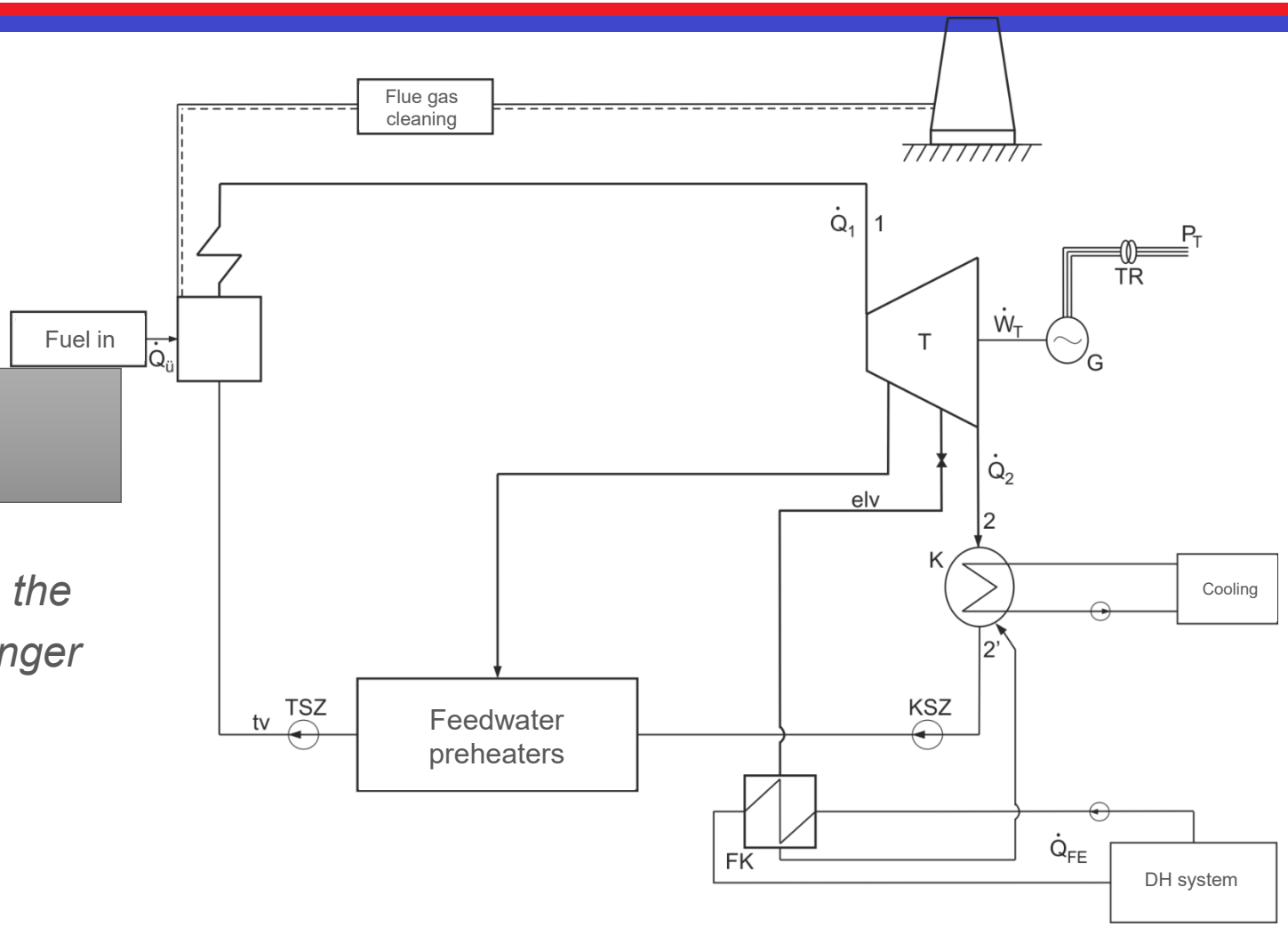

Thank you!

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https://www.shakeproject-dhc.eu/

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