

HELLENIC MEDITERRANEAN UNIVERSITY | DEPT. OF MECHANICAL ENGINEERING

Geothermal, Bioenergy, Cogeneration & Smart Grids

Advanced Energy Technologies, Renewable Systems, and
High-Efficiency Grid Integration

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Fossil Power Generation & Transmission Cascade

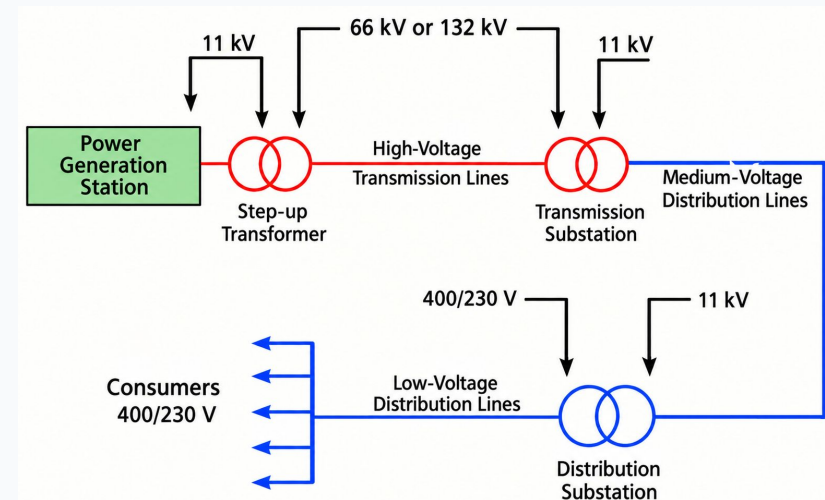
🏭 Thermal Conversion Process

- **Chemical to Thermal:** High-temperature fossil fuel combustion in steam boilers.
- **Thermal to Mechanical:** High-pressure steam drives turbine expansion.
- **Electromechanical Conversion:** Synchronous alternators generate electrical power.



⚡ Grid Voltage Hierarchy

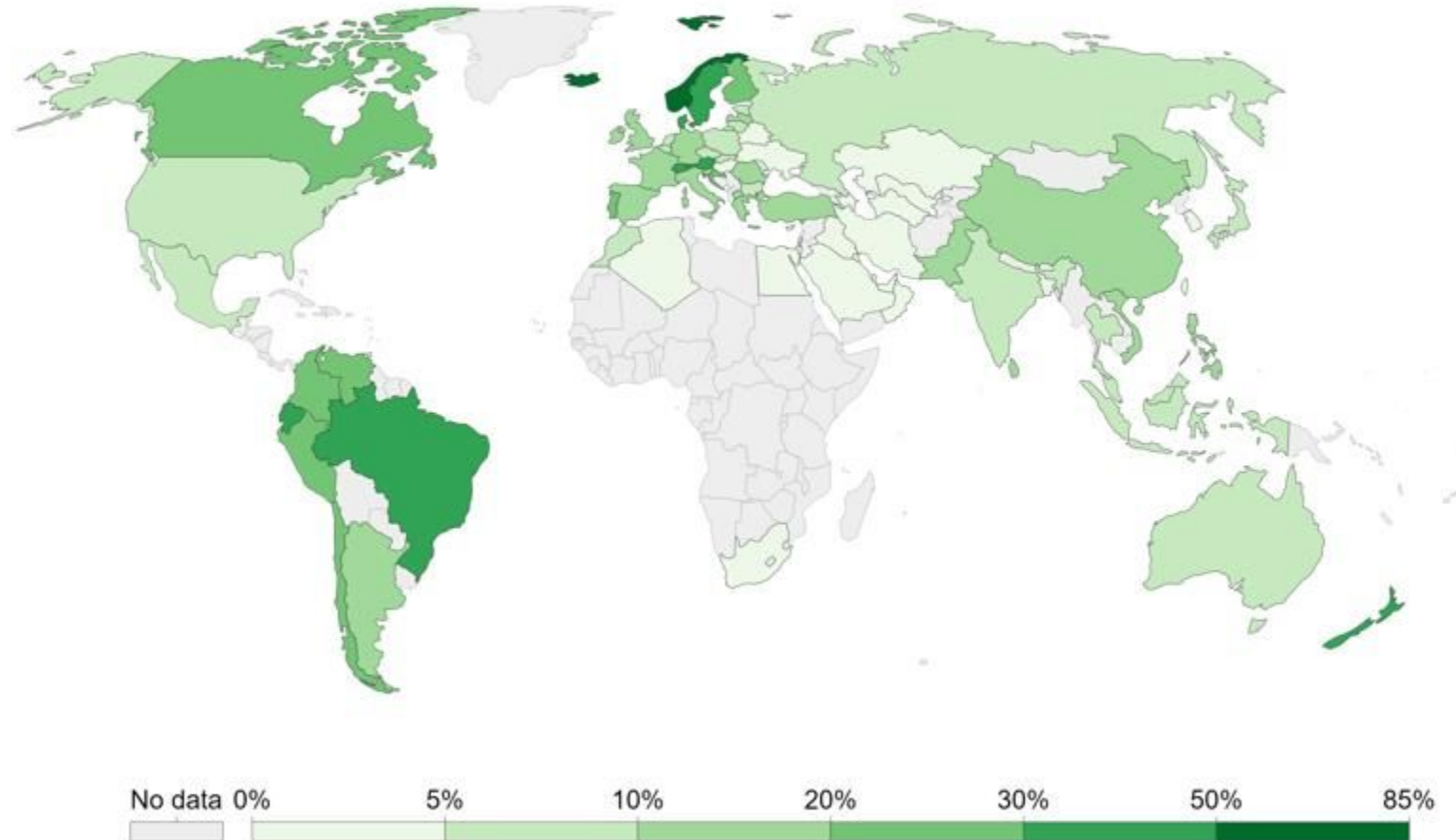
- **Generation Step-Up:** 11 kV power transformed to 66 kV / 132 kV transmission lines.
- **Medium Voltage Distribution:** Transmission substations step down power to 11 kV lines.
- **Low Voltage End-Users:** Distribution transformers deliver 400 V / 230 V consumer power.



Fossil Fuel Limitations & Environmental Urgency

Share of primary energy from renewable sources

Renewable energy sources includes hydropower, solar, wind, geothermal, bioenergy, wave and tidal. It does not include traditional biofuels, which can be a key energy source especially in lower-income settings.



Source: Our World in Data based on BP Statistical Review of World Energy (2020)

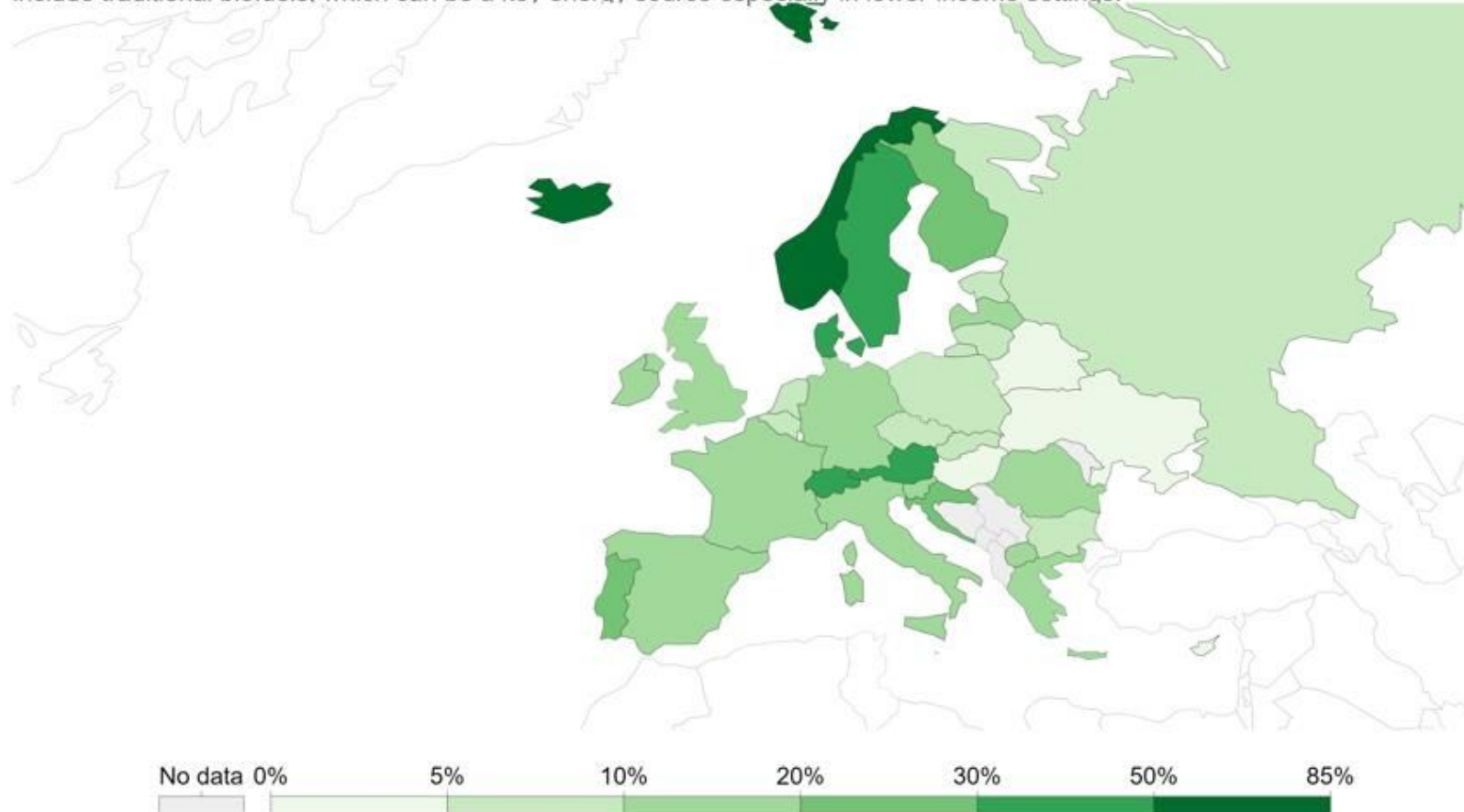
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Note: Primary energy is calculated using the 'substitution method' which takes account of the inefficiencies energy production from fossil fuels.

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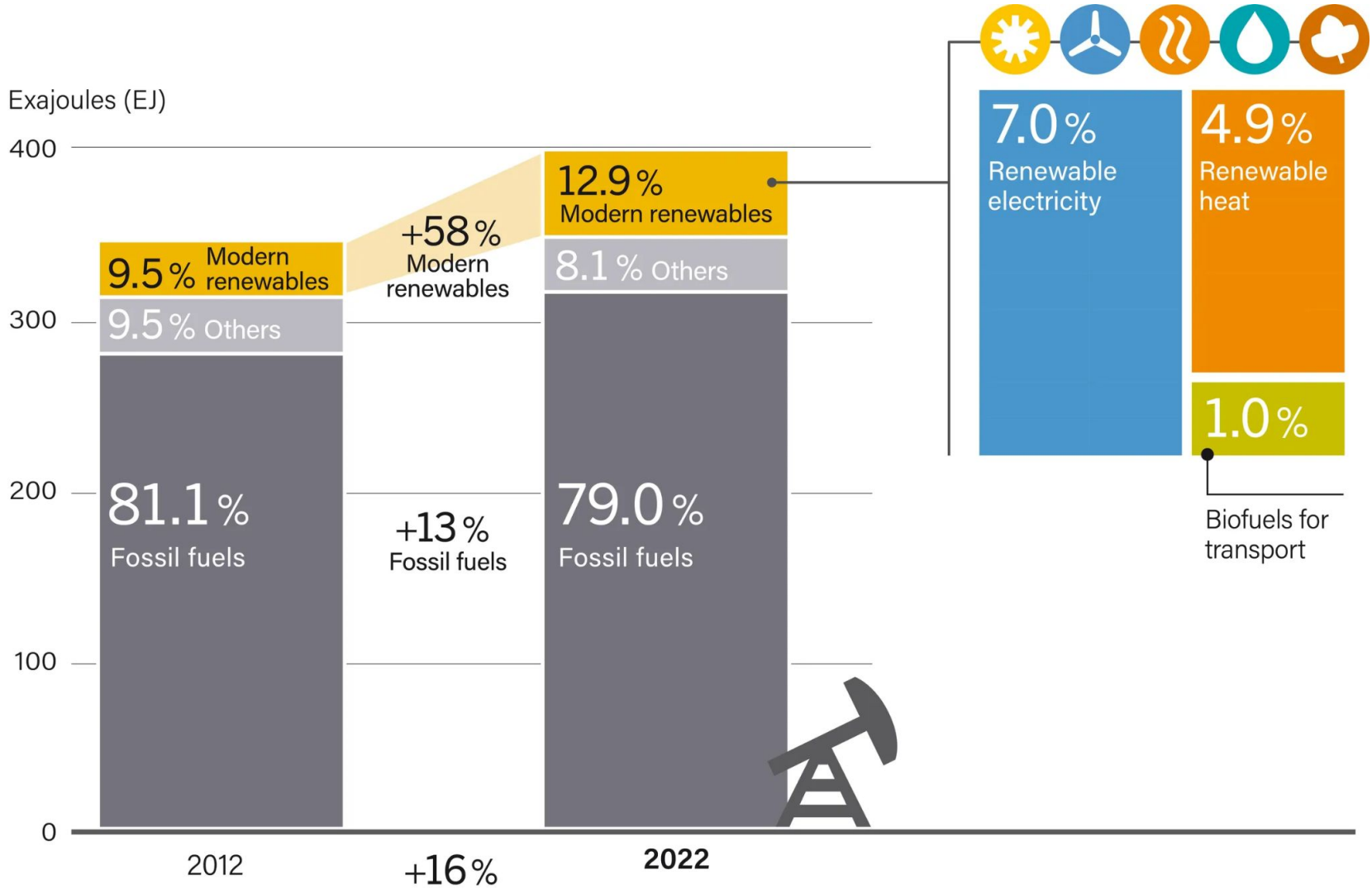


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Fossil Fuel Limitations & Environmental Urgency



Fossil Fuel Limitations & Environmental Urgency

79%

Global primary energy still supplied by fossil fuels
(2022)

⚠ Critical Drivers for Reform

- ✓ **Rapid Resource Depletion:** Consumption rates vastly exceed natural fuel formation speed.
- ✓ **Greenhouse Emissions:** Combustion releases carbon dioxide responsible for global warming.
- ✓ **Climatic Impacts:** Glacier loss, rising sea levels, and severe weather disruptions.
- ✓ **Economic Vulnerability:** National economic growth remains heavily dependent on power stability.

Theoretical Modules & Course Scope



Geothermal

Geothermal fluid dynamics, thermal gradient mapping, field evaluation, and heat exchanger sizing.



Bioenergy

Biomass feedstocks, conversion processes, gasification, anaerobic digestion, and liquid biofuels.



Cogeneration

Combined Heat and Power (CHP) cycles, district heating/cooling, and thermal efficiency optimization.



Smart Grids

Bi-directional information flow, demand side management, microgrids, and hydrogen technologies.

Course outline

- 1) Technical Reports: Writing & Communication
- 2) Project: Literature Review (Stage 1)
- 3) Project: Methodology (Stage 2)
- 4) Techno-economic Analysis of Projects
- 5) Project: (Stage 3)

Geothermal Engineering Fundamentals

-  **Subsurface Thermal Flow:** Analysis of subterranean heat flux and rock temperature profiles.
-  **Geothermal Fluid Dynamics:** Underground hot fluid circulation and physical-chemical properties.
-  **Field Assessment:** Identification and production drilling of high/medium enthalpy fields.
-  **Utilization Design:** Sizing heat exchangers and binary cycle turbines for power/heat.



Bioenergy Feedstocks & Categorization

Energy Crops

Dedicated agricultural and forestry plants including sweet sorghum, energy reeds, and eucalyptus.

Crop Residues

Agricultural and forest leftovers like straw, corn stalks, cotton stalks, tree prunings, and manure.

Byproducts & Waste

Processing byproducts like olive pomace, sawdust, cotton gin trash, and municipal organic waste.

Biofuel Conversion Pathways



Thermochemical

Gasification & pyrolysis generating solid biochar, syngas, and bio-oil.

Biochemical

Anaerobic digestion and fermentation yielding biogas and bioethanol.

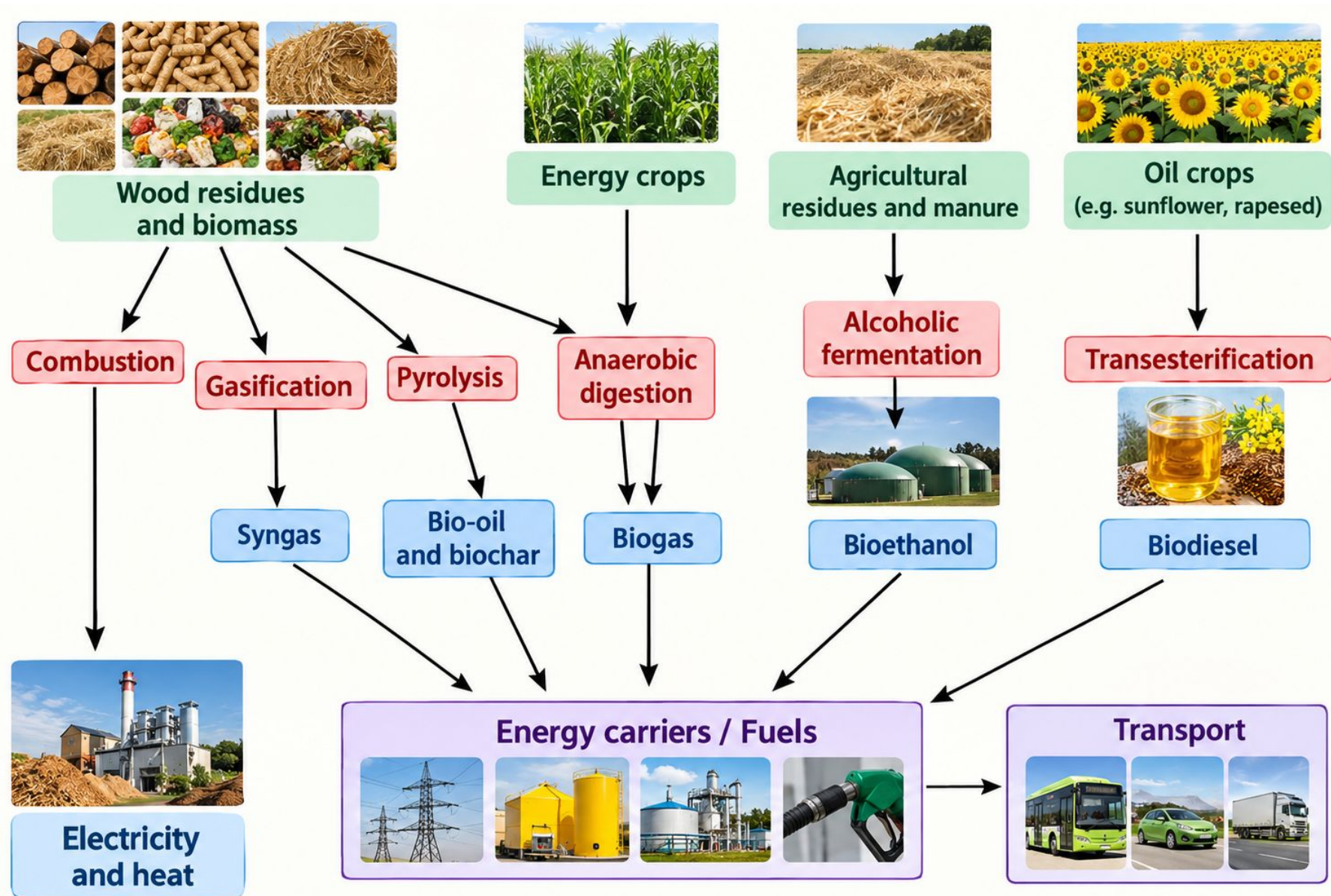
Chemical Transesterification

Conversion of plant oils and animal fats into high-purity biodiesel.

Energy Characterization

Moisture content, bulk density, and Lower Heating Value (LHV) metrics.

MODULE 2: BIOENERGY OVERVIEW



Cogeneration (CHP) Principles & Efficiency Gain

CONVENTIONAL GENERATION

35% Efficiency

65% of fuel energy rejected as waste heat through cooling towers and exhaust stack gas.

CHP COMBINED GENERATION

>85% Efficiency

Recovers reject heat for industrial steam, hot water, process heating, and district absorption cooling.

CHP Prime Movers

Gas & Steam Turbines

Open/closed cycle gas turbines
back-pressure or extraction steam
turbine systems.

Internal Combustion

Reciprocating gas and diesel engine
units spanning small-scale (15 kW) to
large plant (>6 MW).

Organic Gas Turbines

Rankine steam cycles with organic
fluids

District Heating Networks



District Networks

Ptolemaida case study: Utilizing power plant heat to double energy extraction per kg lignite and reduced CO2 emissions.



Other systems

Thermo-electric systems
Decentralised systems
Tri-generation systems
District heating & cooling
(TELE -heating -cooling)

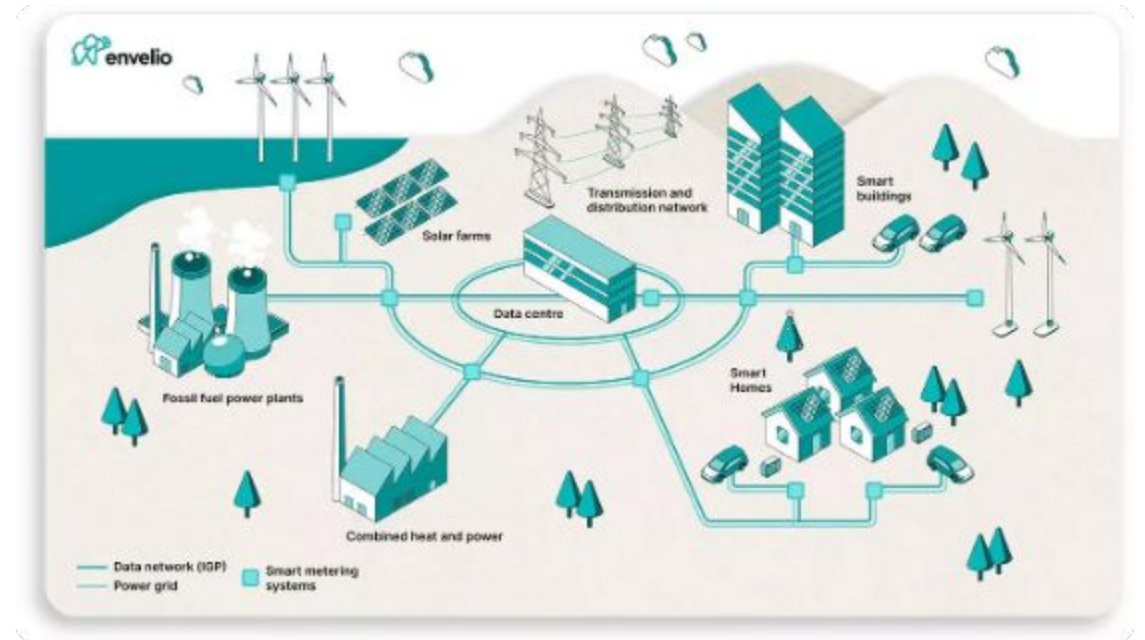
Ptolemaida CHP COMBINED GENERATION

>70% Efficiency

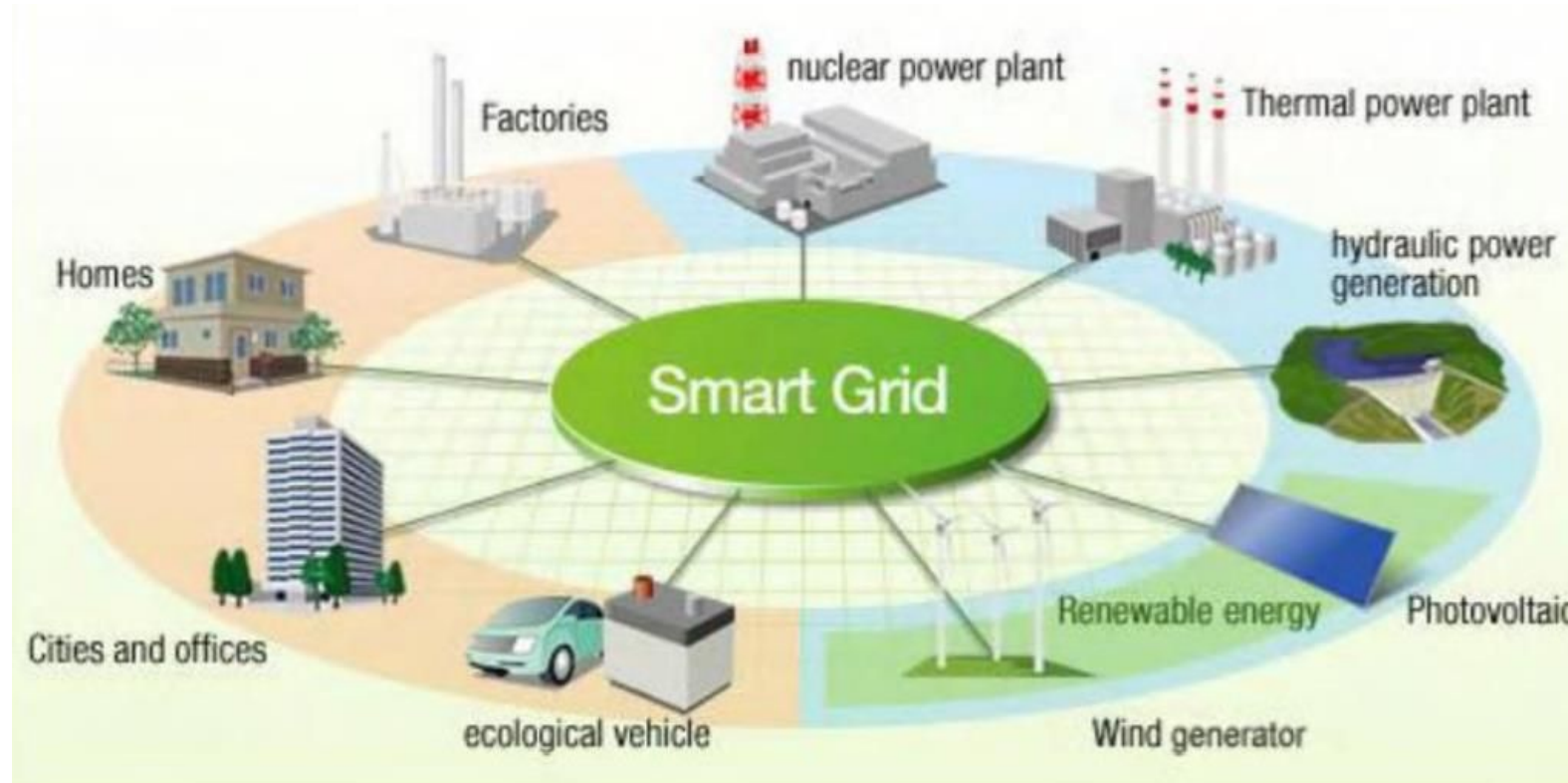
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Smart Grid Capabilities & Self-Healing Networks

- ↔ **Bi-Directional Flow:** Simultaneous two-way movement of electric power and data telemetry.
- ⊕ **Automated Self-Healing:** Real-time disturbance detection and sub-millisecond fault isolation.
- ⚙️ **Demand Response:** Automated load shifting to off-peak hours to minimize consumer cost.
- 📈 **Grid Optimization:** Continuous algorithmic monitoring and performance balancing.



Core Subsystems of Modern Smart Grids



Power Subsystem

Central plants, distributed microgrids, rooftop solar, wind farms, and battery energy storage.

Information Subsystem

Smart meters, edge processors, special protection schemes, and grid analytics software.

Communication Layer

High-speed telecommunication networks for real-time sensing, signaling, and remote control.

MODULE 5 & COURSE SUMMARY

Hydrogen Technologies & Clean Energy Synthesis

Integrating Geothermal, Bioenergy, Cogeneration, Smart Grids, and Green Hydrogen
for a Decarbonized Energy Future.

Hellenic Mediterranean University | Department of Mechanical Engineering

Image Sources



<https://www.thinkgeoenergy.com/wp-content/uploads/2025/05/Hatchobaru-geothermal.png>

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Source: www.valmet.com



https://envelio.com/hubfs/Envelio_November2024/Images/smart-grid-illustration-en-1300x0-c-center-1.webp

Source: envelio.com