IFE

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From organic waste and residues to valuable bio-based fuels and products

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Outline

Growing urban areas

- Today, 55% of the world's population lives in urban areas (4.2 billion in 2018)
- This proportion is expected to increase to 68% by 2050
- This increase is due to a shift from rural to urban areas combined with the overall growth of the world's population
- 90% of this increase is taking place in Asia an Africa
- Together, India, China and Nigeria will account for 35% of the projected growth of the world's urban population between 2018 and 2050

Source: United Nations

Tokyo, Japan

New Dehli, India

Challenges of growing urban areas

- Sustainable urbanization is key to successful development
- Many countries will face challenges in meeting the needs of their growing urban populations, including for
  - housing
  - transportation
  - energy systems
  - other infrastructures like waste handling
  - employment
  - basic services such as education and health care
- Policies are needed to manage urban growth taking into account the necessity of a **safe environment**
- Waste handling in urban area has to be part of the solution

Source: United Nations

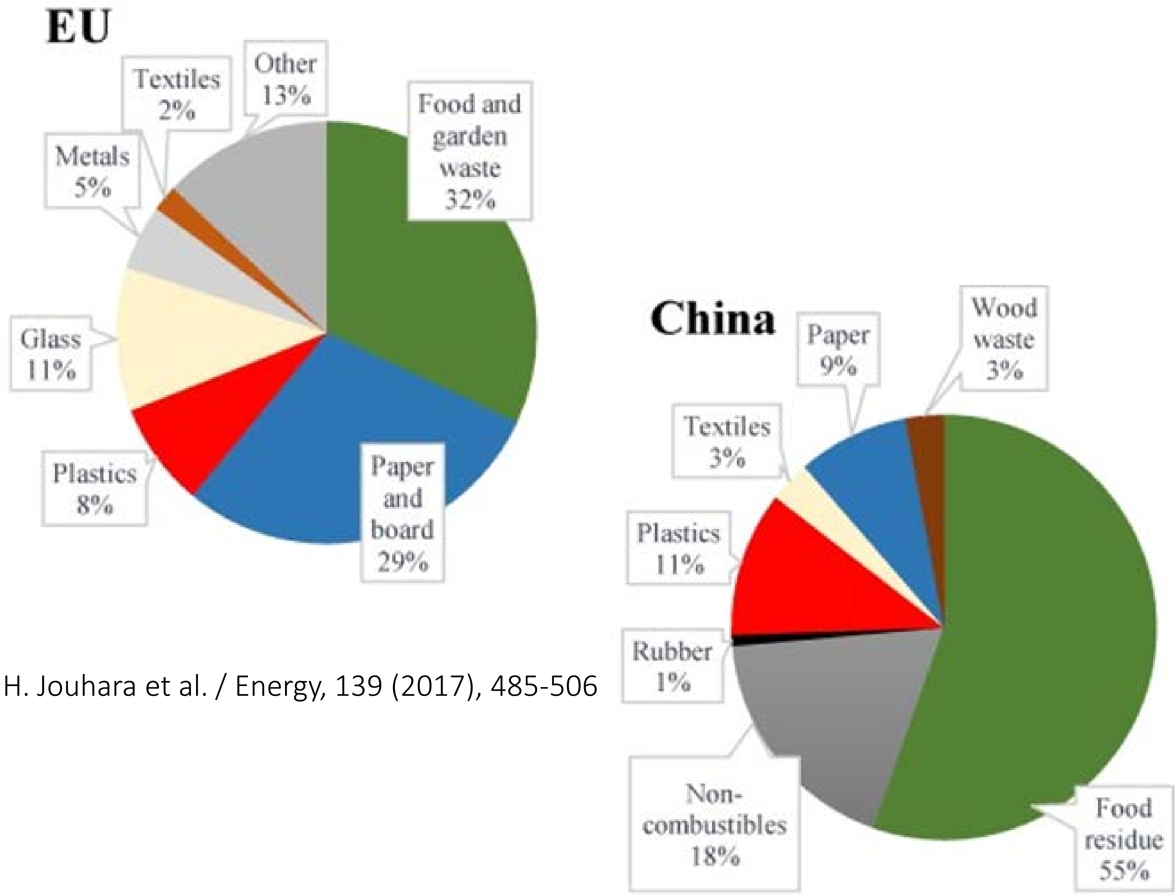
Lagos, Nigeria

Sao Paulo, Brasil

Sao Paulo, Brasil

Waste and residues from urban areas

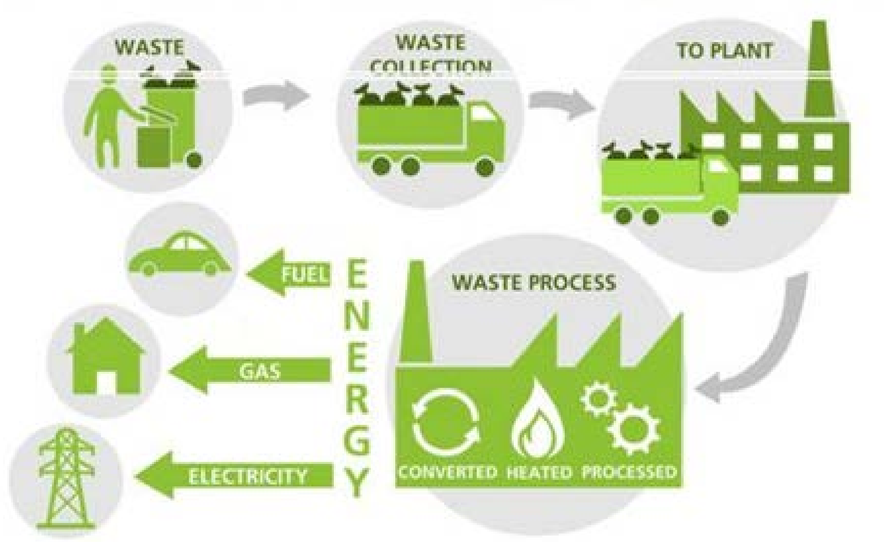
- Sewage (waste water)
- Municipal Solids Waste (MSW)
  - Food
  - Paper and cardboard
  - Glass
  - Plastics
  - Metals
  - Garden waste
  - Wood
  - Textiles
  - Rubber
- Waste from nearby industries
  - Food, beverage, agricultural industries ++



H. Jouhara et al. / Energy, 139 (2017), 485-506

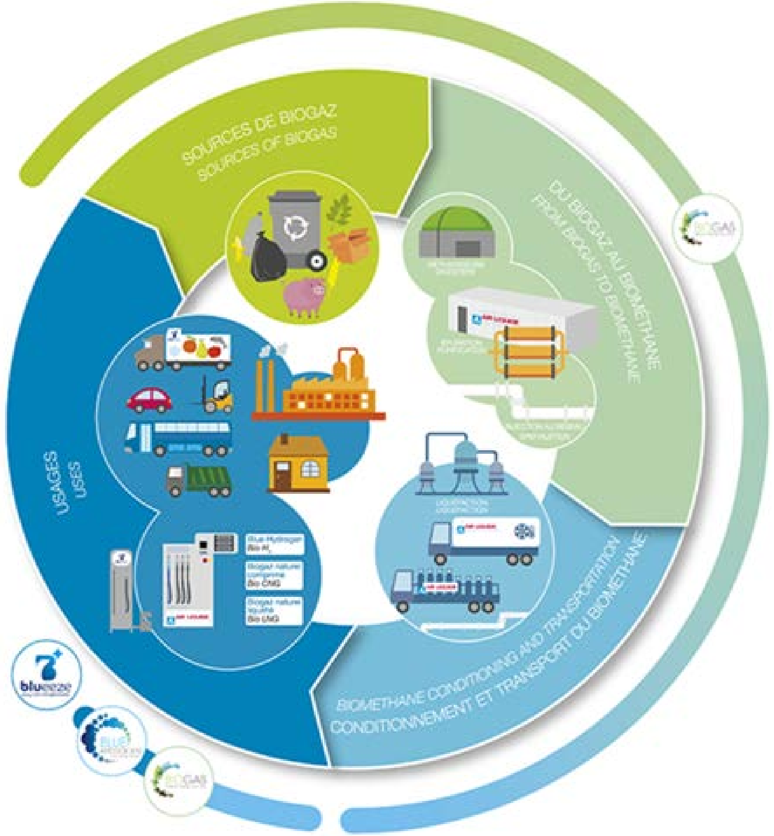
Solving the waste problem and creating value

- To meet sustainability, the benefit of the solutions should address the following:
  - Treating the waste to avoid pollution of the environment (avoid landfilling)
  - Reduce the carbon footprint of cities and their emissions to air
  - Create value
- The Waste to Energy approach meets these requirements
  - Heat and electricity for households
  - Biofuels for transportation
  - Bio-products for recycling
- The challenge is to put in place a proper waste collection and sorting system



The biogas value chain

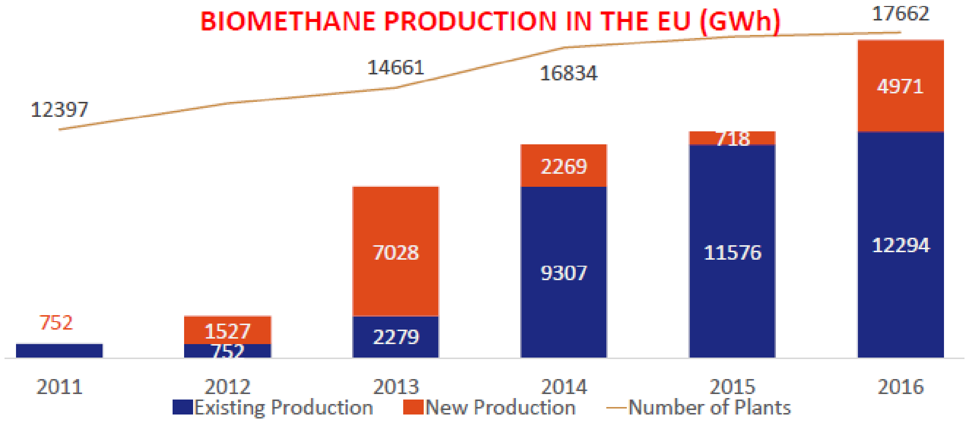
- Biogas production is a natural biodegradation process (digestion) of organic matter by organisms in the absence of oxygen
- Biogas is produced in a close system in anaerobic digestors or bioreactors
- Biogas contains mainly methane and CO_2, plus small concentrations of impurities
  - Typical biogas composition is 60% CH_4 and 40% CO_2
- Biogas is typically produced from
  - Sewage sludge
  - Food, animal and agriculture waste

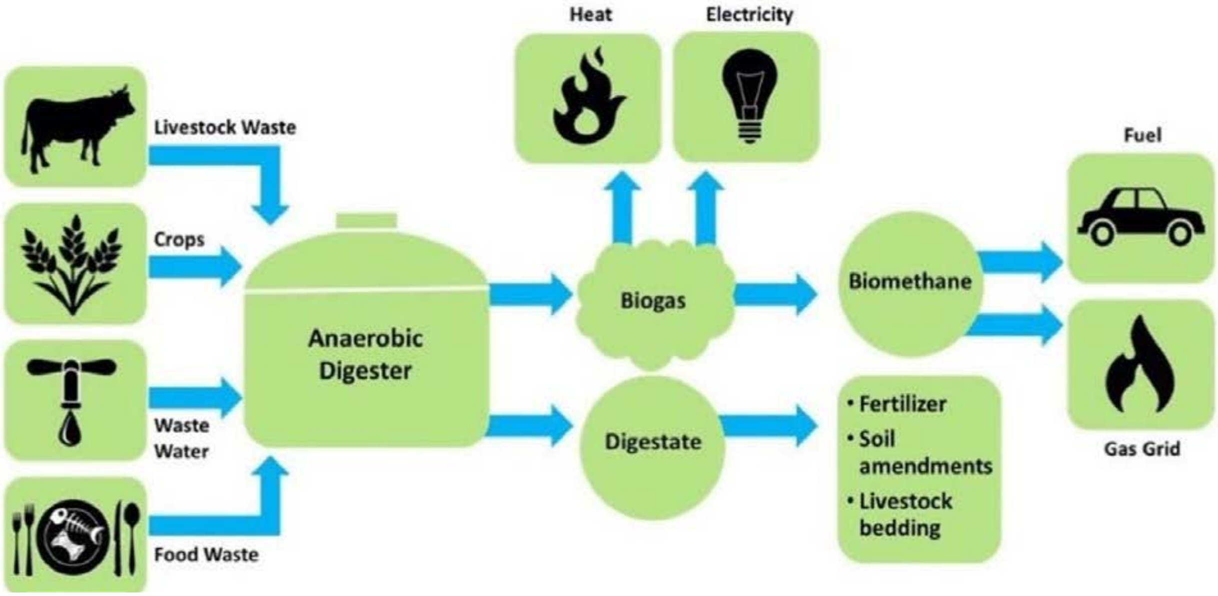


Source: Air Liquide

The biogas value chain

- Typical applications are
  - Combined Heat and Power (CHP)
    - Gas engines
    - Fuel Cell systems for high efficiency (50%)
  - Transportation fuel as biomethane (97% CH_4)
    - Upgrading necessary
    - Compressed or liquified



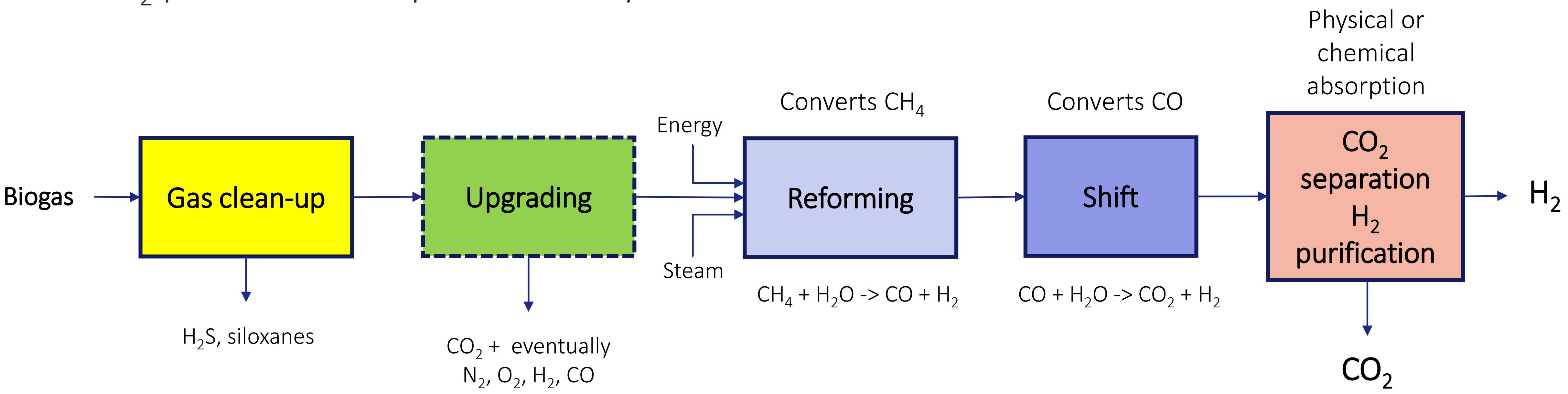


Other uses for biogas/biomethane

- Biomethane can be used as a substitute for fossil natural gas and therefore contribute to reduce the carbon footprint of products produced from natural gas
- One of these products is **hydrogen (H_2)**
- Conversion of biogas/biomethane to H_2 can contribute to the production of green hydrogen and to the early decentralized implementation of this market
- The use of green H_2 in the transportation sector in Fuel Cell Electric Vehicles (FCEV) will allow to increase the efficiency (+10-15%) and to reduce NOx emissions in urban areas

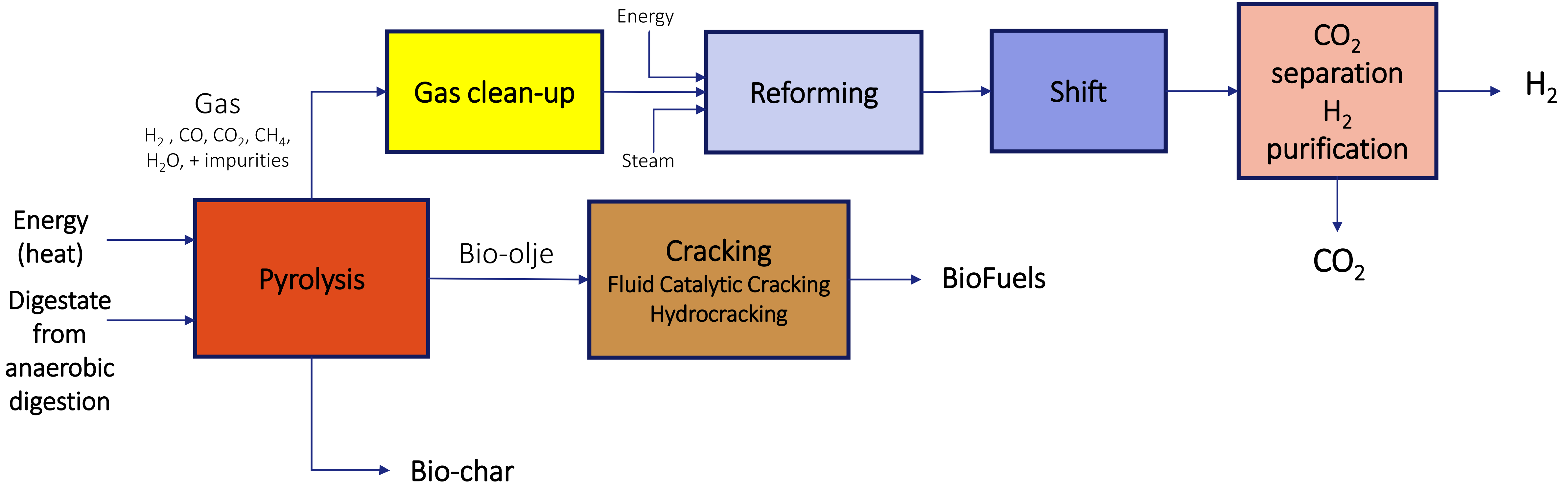
Conversion of biogas/biomethane to hydrogen

- Uses the reforming route
- Requires gas cleaning and usually an additional upgrading step
- Converts methane to green H_2 and bio-CO_2
- H_2 purification step is necessary



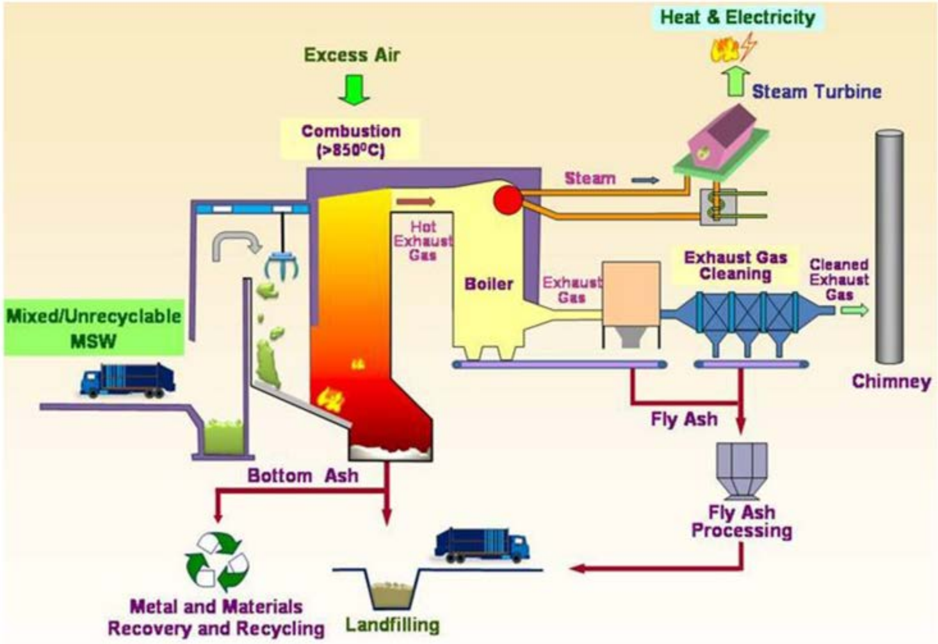
Conversion of digestate from anaerobic digestion

- Uses the pyrolysis route (heating without the presence of oxygen)
- Produces valuable gas, bio-oil and bio-char
- Combined with reforming and cracking, pyrolysis converts residual organic matter to green H_2, bio-CO_2, bio-fuels and bio-char



Solid waste incineration

- Today, about 1.3 billion tons Municipal Solid Waste (MSW) are produced yearly worldwide
- **MSW incineration** is likely to be the first choice for treating MSW due to:
  - expected large increase of MSW generation
  - strict regulations for landfilling
- The heat produced during the combustion can be easily recovered for district heating
- In the EU, the **energy produced from incineration plants covers 8% of the overall renewable energies**



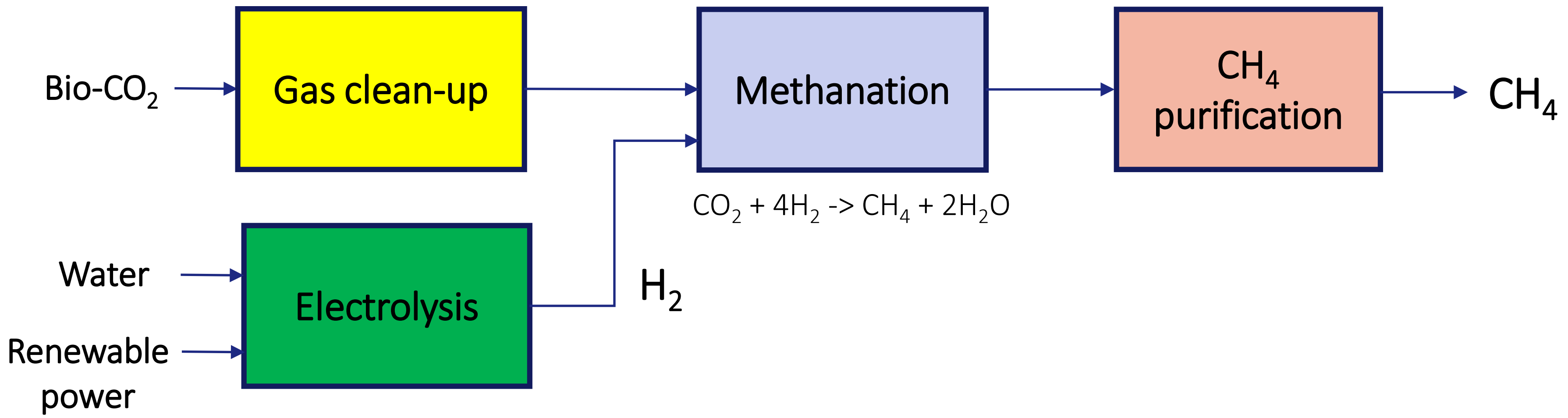
Solid waste incineration

- In Europe, there are about 450 incineration plants in operation and this number is likely to increase rapidly
  - They generates about 90 million tons CO_2 in the atmosphere yearly
- About 60% of the carbon contained in MSW is biogenic
- Capturing CO_2 from incineration plants can therefore open the way for:
  - Reducing the CO_2 foot-print of urban areas if combined with CO_2 transport and storage (BECCS → carbon negativity)
  - Re-using the carbon (or part of the carbon) contained in the CO_2 to produce valuable products like synthetic methane/methanol in a power to chemical concept
    - Methanation process or methanol synthesis
    - Requires hydrogen

Source: IPCC

Methanation of bio-CO_2

- Converts bio-CO_2 to synthetic methane by reacting it with hydrogen
- Hydrogen produced from excess renewable power
- Methanation can also be applied to convert bio-CO_2 contained in biogas
- Use of synthetic methane as green chemical for substitution of fossil natural gas



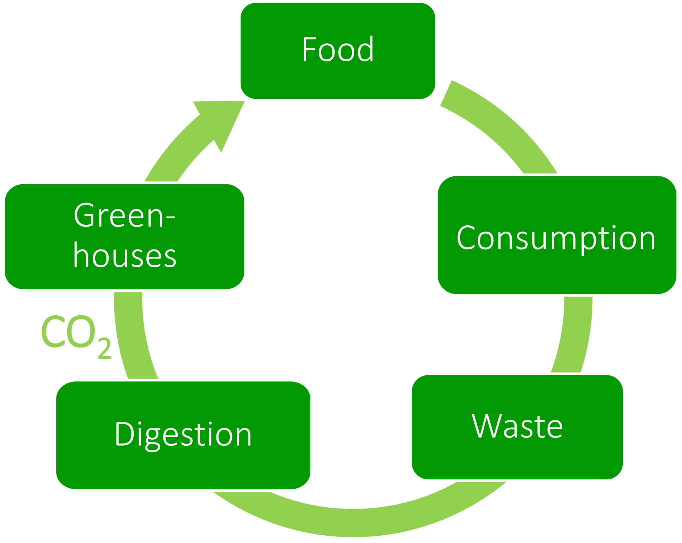
Closing the loop using the bio-CO_2

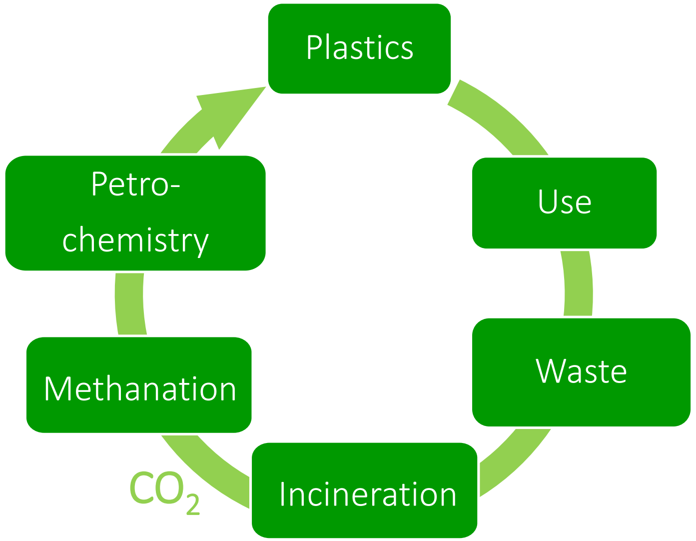
- Using bio-CO_2 generated from waste will allow closing the loop contributing to sustainable development in urban areas and value creation

- Use of bio-CO_2 in greenhouses
  - food to waste to food: vegetables

- Use of bio-CO_2 to produce synthetic methane or methanol for petro-chemical and refining industries
  - plastics to waste to plastics: PE, PP, PVC

- Challenges
  - Building the value chains
  - Value chain economy: reduce the cost of technologies, policies





IFE's research in the field

- Hydrogen production from biogas/biomethane with CO_2 capture
  - Development of a new reforming process using high temperature CO_2 capture with solid sorbents: Sorption-Enhanced Reforming (SER)
  - Allow avoiding the upgrading and shift steps leading to potentially 20% cost reduction
  - Extract more than twice the amount of bio-CO_2 than conventional technology

MEMBER

https://member-co2.com/content/home

- Production of bio-methanol from biomass
  - Integration of gasification and SER technology

CONVERGE

CarbON Valorisation in Energy-efficient Green fuels

http://www.converge-h2020.eu

- Enhanced methanation
  - Technological developments to improve the efficiency of the methanation process and reduce its cost (catalyst, membranes, reactor design)

Thanks for your attention

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