Title 2DV.2.28: **Synthesis gas opportunities from "dry thermo-catalytic Bio-CH4 splitting":**

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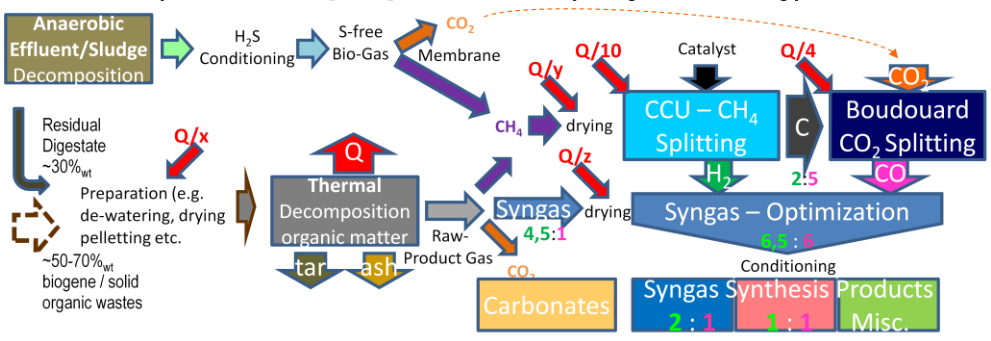
To optimize output value in waste gasification and reforming processes, the use of dry thermo-catalytic Methane splitting, co-producing Hydrogen and highly surface active Carbon as downstream refining intermediaries was simulated in an integrated system in combination with bio-gas. To increase the ratio of carbon monoxide in the decomposition gas, CO_2 can be split with the carbon derived from Methane Splitting in a coal gasification reactor. The endothermic energy requirements for the two gas splitting steps can largely be covered by the waste heat from the gasification module and some Hydrogen in excess of the 1:1 H_2/CO.

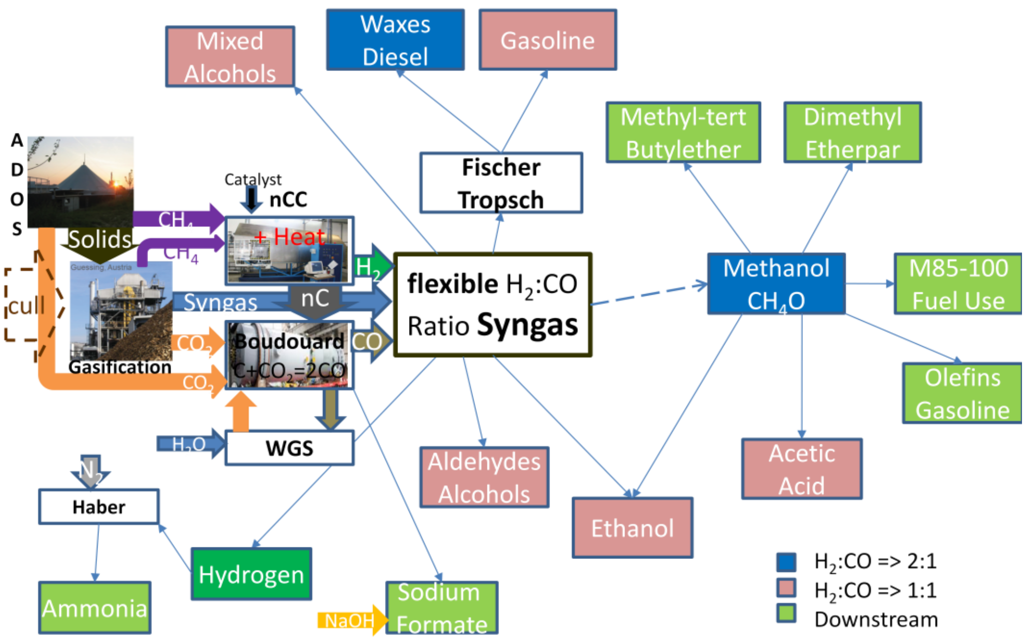
Carbon Capture for Use [CCU] in CO_2 for Recycling Mass/Energy Flow:



For 2:1 H_2/CO hydro-carbon synthesis a water-shift reaction can be added, thus allowing flexibility on the final downstream usage paths for the synthesis gas.

Scientific Innovation & Relevance:

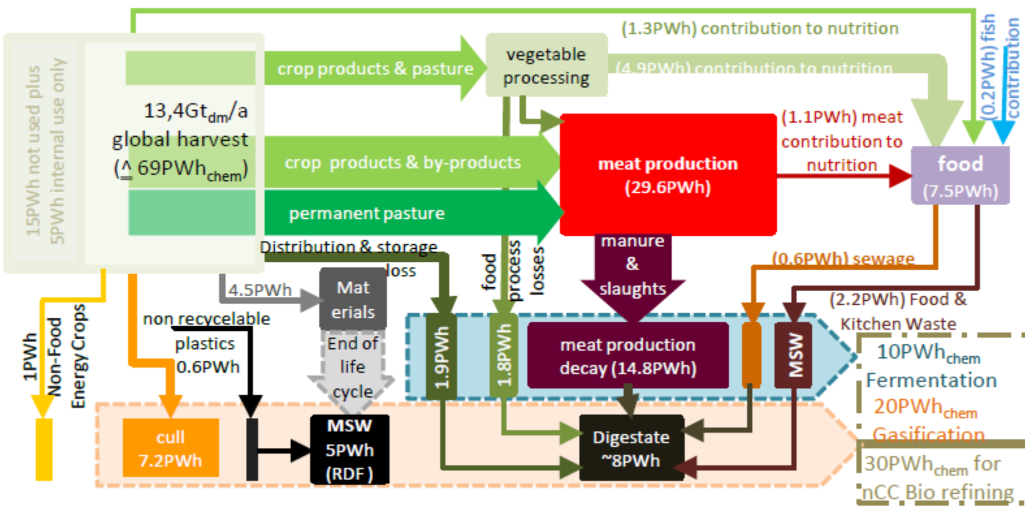
Accelerated decomposition of organic matter into energy rich gas can be economically leveraged by transforming the output gas into a Synthesis Gas of a controllable CO/H_2 ratio, allowing an additional plane level within the value adding pyramid from organic waste.



For the example of a downstream FiT-fuel synthesis output the mass-energy flow simulation in IPSE-Pro came out > 40% overall chemical Input/Output energy efficiency, which would outperform the one of fossil fuels.

Economic Significance:

Most Bio-Fuel developments fall under the "**Food <–> Fuel**" conflict and raise questions about land-use. From looking at current decade's annual harvest's usage pattern, **Organic Wastes** become an interesting potential feed-stock

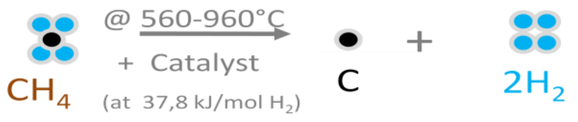


CCU – CO_2 recycling Bio-Refineries would actually deliver answers to several discrepancies of our civilization:

- ✓ reduction of **Final Sink** (Sanitary) Landfill space requirement
- ✓ economic returns for treating organically polluted **water** and residues
- ✓ improved **Resource Efficiency** from Anthropogenic **Carbon Metabolism**
- ✓ distributed local **Closed Loop Economy Carbon Hydride Energy Supply**
- ✓ flexibility towards new energy carrier infrastructures (**e.g. H_2 Economy**)

Literature:

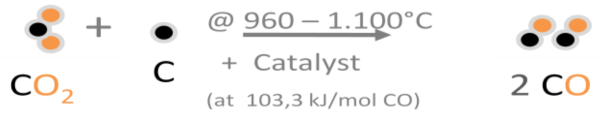
Dry thermo-catalytic Splitting of Methane:



In differentiation to earlier efforts of e.g. Choren, our approach promises quite accurate aggregates & process capabilities at each operation step at 55% endothermic requirement of Steam Methane Reforming [SMR].

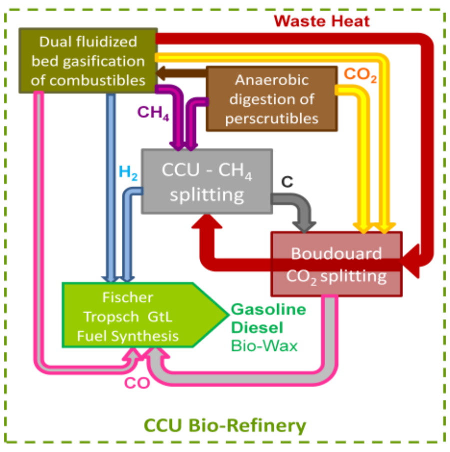
Highly Surface Active Carbon for CO_2+ Waste Heat Recycling:

Apart from the good energy efficiency of the Hydrogen from a.m. Carbon Capture mechanism, the high specific surface of the generated Carbon powder coinciding with still considerable high temperature waste heat redundancy induces a splitting of onsite available



transforming recycled Carbon into additional Synthesis Gas CO to upgrade the raw gas from the Steam driven Gasification into a pure Hydrogen – Carbon Monoxide mixture for further downstream Chemical Synthesis steps.

Since this process sequence for different organic residues can be normalized at this Synthesis Gas intermediate, all final output products can be synthesized from a standardized quality of feed stock of Gas to Liquid [GtL] Synthesis.



Waste Heat from Gasification occurs from 2 Sources:

a) 25% from Flue Gas at temperatures from 580 – 920°C
b) 66% from Product Gas cooling

For CH_4 and CO_2 Splitting only the flue gas energy content is used.

The rest is available for other purposes (on or off site)

Competitive Analysis for Organic MSW practice:

per 1 ton organic MSW		Biorefinery	ADOS	Incinerations	Landfills
Waste collected	fermentable	✓	✓	with auxiliary fuel	✓
	combustibles	✓	with extra treatment	✓	✓
Cost/ ton of waste handled		€ 40	€ 12	€ 32	€ 14
Main deliverables		CCU for CO_2 recycle & H_2–> GtL-Synthesis	biogas	waste heat	landfill gas
Application of deliverables		bio-polymers, clean fuel for ICE vehicles & aviation	$400kW_{el}$	$230kW_{el}$	$250kW_{el}$*)
CO_2 reductions / million tons of waste handled		1,170,000 tons	300,000tons	400,000 tons	150,000 tons*)
Revenue/ton of waste handled		€ 180 @ € 0,60/ltr. Gasoil & € 4,50/kg Bio Wax	€ 28 @ € 0,07/kWh	€ 16 @ € 0,07/kWh	€ 18 *) if sanitary
Gross profit %		13%	8%	<5%	10%
Payback time		<6 years	>7 years	12 years	?infrastructure?

Incineration needs ca. 80% of fermentable waste energy yield equivalent auxiliary fuel to compensate drop of heating value by the wet content. Further Refuse Derived Fuel fractions in incineration or cement firing do add further value, nor recycle CO_2.
On the other hand, district heating heat requirements also Gasification can deliver.

CCU – CO_2 recycling Bio-Refineries can refinance themselves at arms length market prices for its deliverables without permanent subsidies