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Low Energy CO_2 free C_xH_y Splitting

A Distributed Hydrogen Generation Model
with value adding by-products

Innovation

A proprietary concept to provide maximum flexibility and retention of CARBON from waste/biomass in the anthropogenic cycle of matter and a Clean Fuel (Hydrogen) deliverable and/or flexible hydrocarbon liquids (synthetic gasoline) via the use of Hydrogen as a reactant.

A concept that can generate enough added value to be economic by itself enabling **"Waste to Economy"**, in stead of costly Waste Remediation or need for ongoing Subsidies, Feed-in Tariffs or market regulations.

- CH_4 emitted in landfills or anaerobic decomposition of Organics (Sewage, MSW or agricultural waste)

CH_4 —our reaction→ (nano)C + $2H_2$

state of art → Electricity **(if you don't USE it you LOOSE it**'s economics**)**

- **Unlocking the potency of Hydrogen Economy**:
  - from renewable feedstock
  - at low GHG emissions
  - with added value byproducts

Our Methane Splitting Technology

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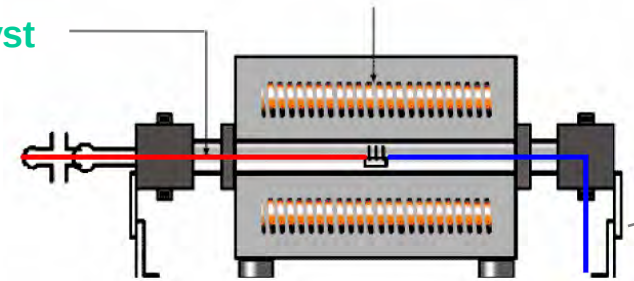
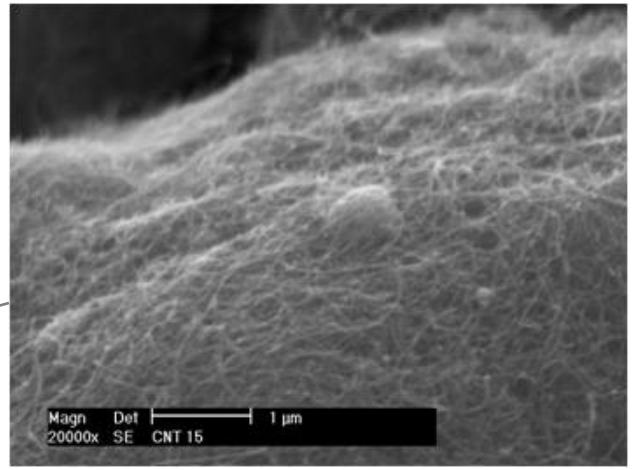
Continuous Chemical Vapor Deposition



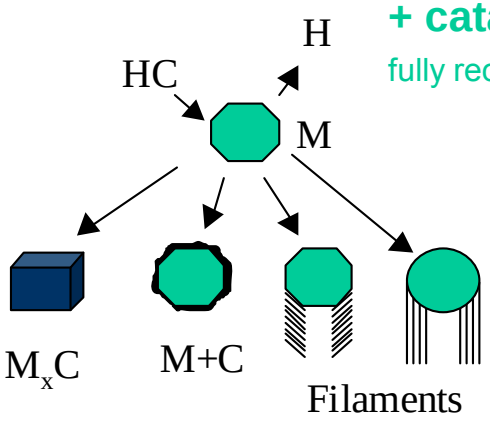


product gas 90% H_2
10% CH_4

CH_4 → $2H_2$ + C (nano Carbon as a by-product)

+ catalyst + 37,8kJ/mol H_2

fully recyclable ≈ 55% of SMR

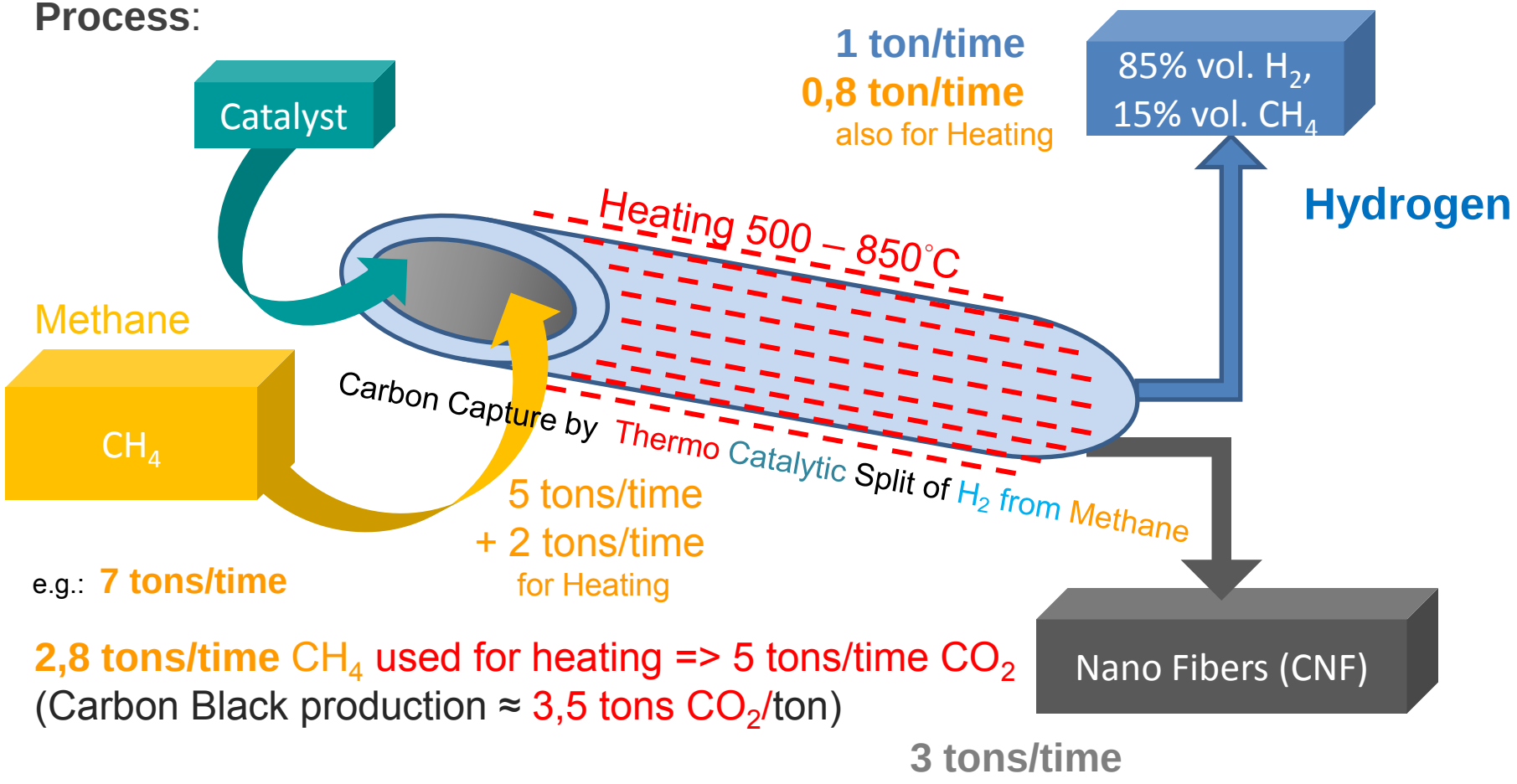


Carbon Capture by Thermo Catalytic Split of Methane

Low Green House Gas Emission Hydrogen

Upgrading Methane into Clean Fuel – Hydrogen

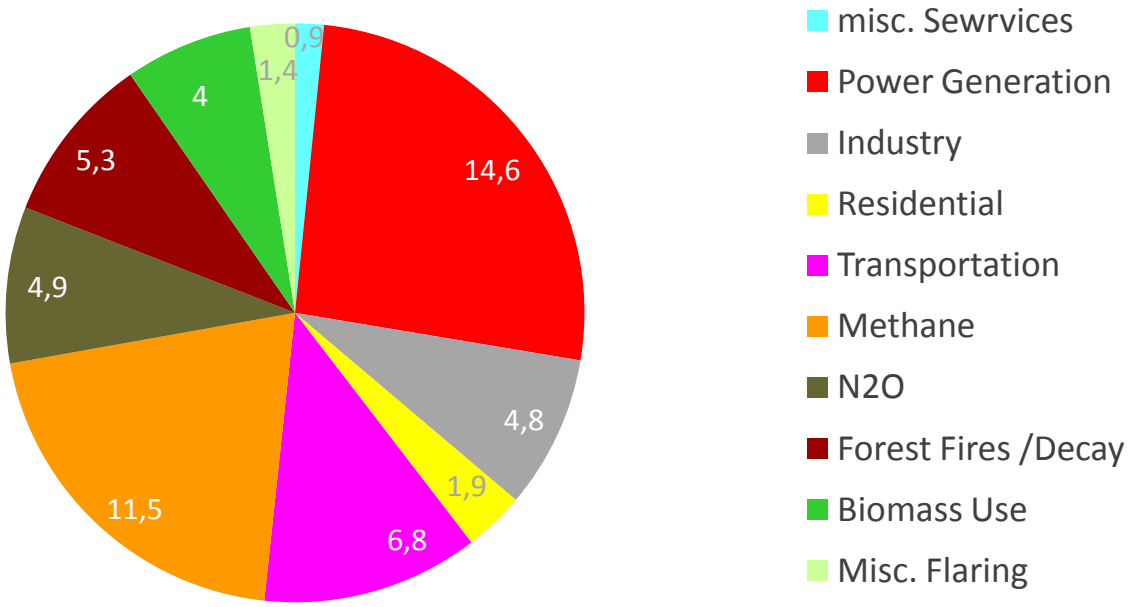
in **C**losed **L**oop – **C**ontinuous **C**hemical **V**apor **D**eposition [**CL-CCVD**] **Process**:



2,8 tons/time CH_4 used for heating => 5 tons/time CO_2
(Carbon Black production ≈ 3,5 tons CO_2/ton)

Proposed Development into Application

nano**C**arbon **C**apture for **U**se from Anthropogenic CH_4



Target-areas for nCCU application:

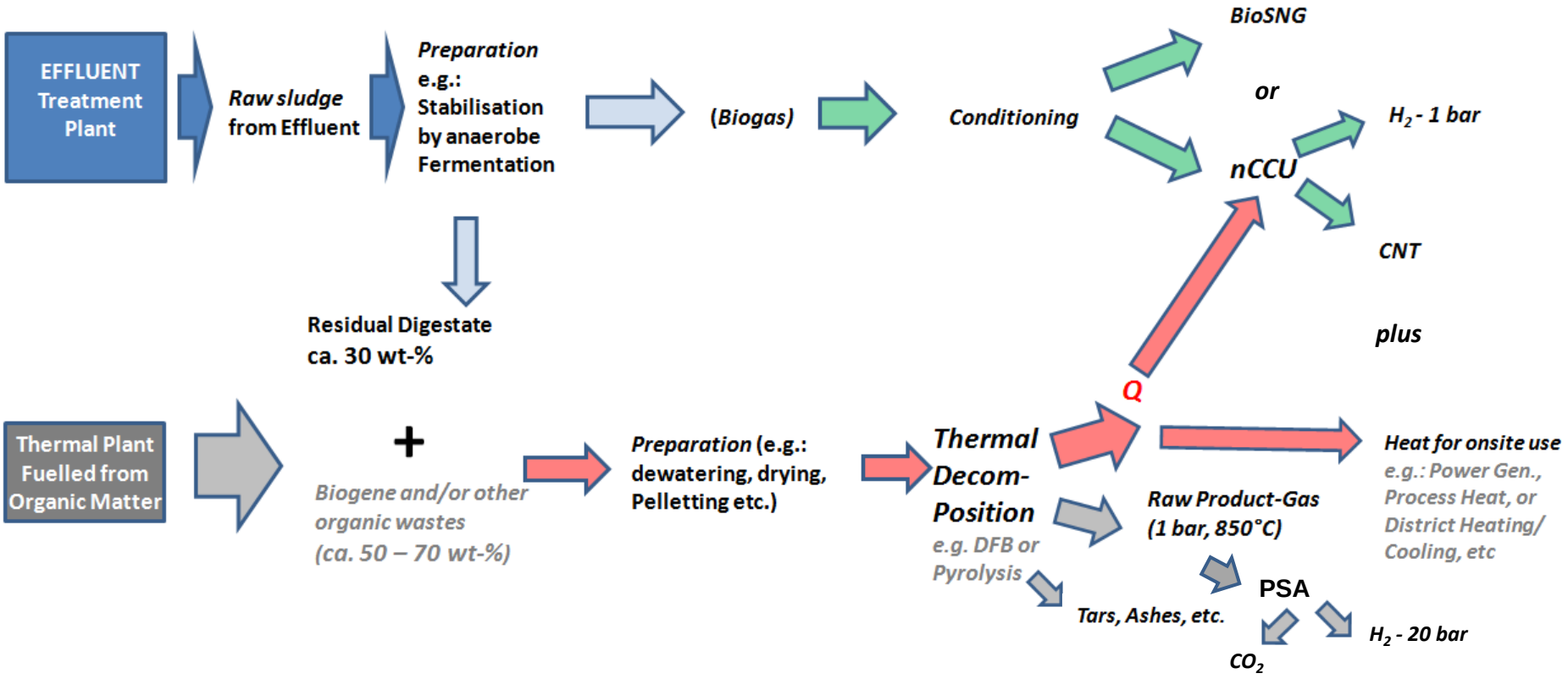
Ideally in combination within municipalities allowing CHP use within a plant and its waste heat for district HVAC utilization

- Landfill gas
- Sewage gas
- Organic MSW (final deposit reduction) by Anaerobic Digestion or RDF usage
- Sewage Sludge Remediation
- Agricultural Decay nutrient recycling

Total Resource Efficiency Bio-Refinery

an opportunity for distributed H_2 Generation from MSW & sewage sludge

Schematic Mass-Flow

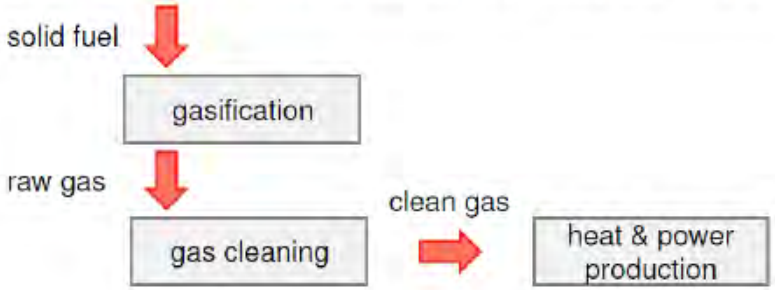


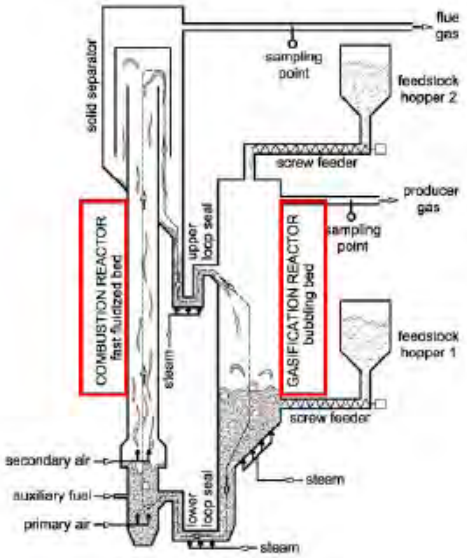
Thermal Decomposition of Organic Matter

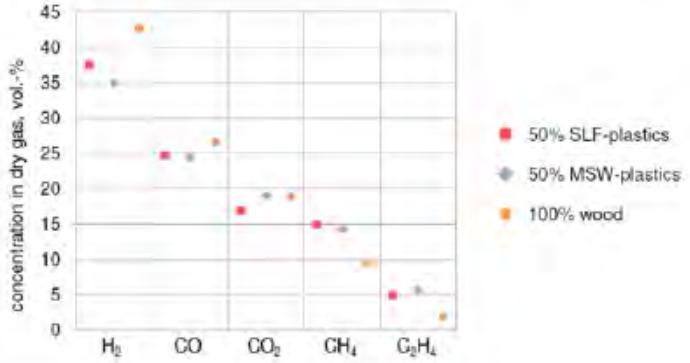
by Dual Fluidized Bed Gasification

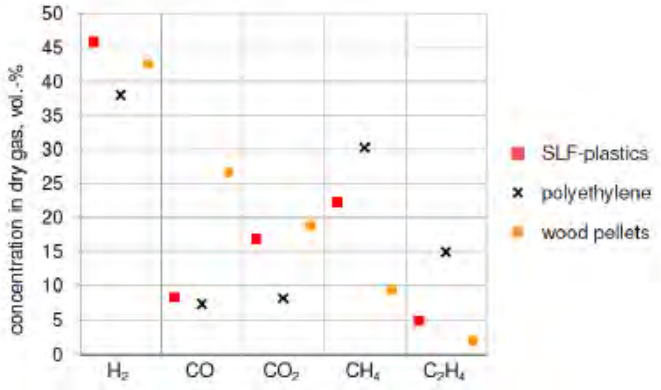
State of Art:

In order to achieve low emission thermal decomposition Dual Fluidized Bed Gasification has been developed and proven low sensitivity to different feedstock materials.[i]





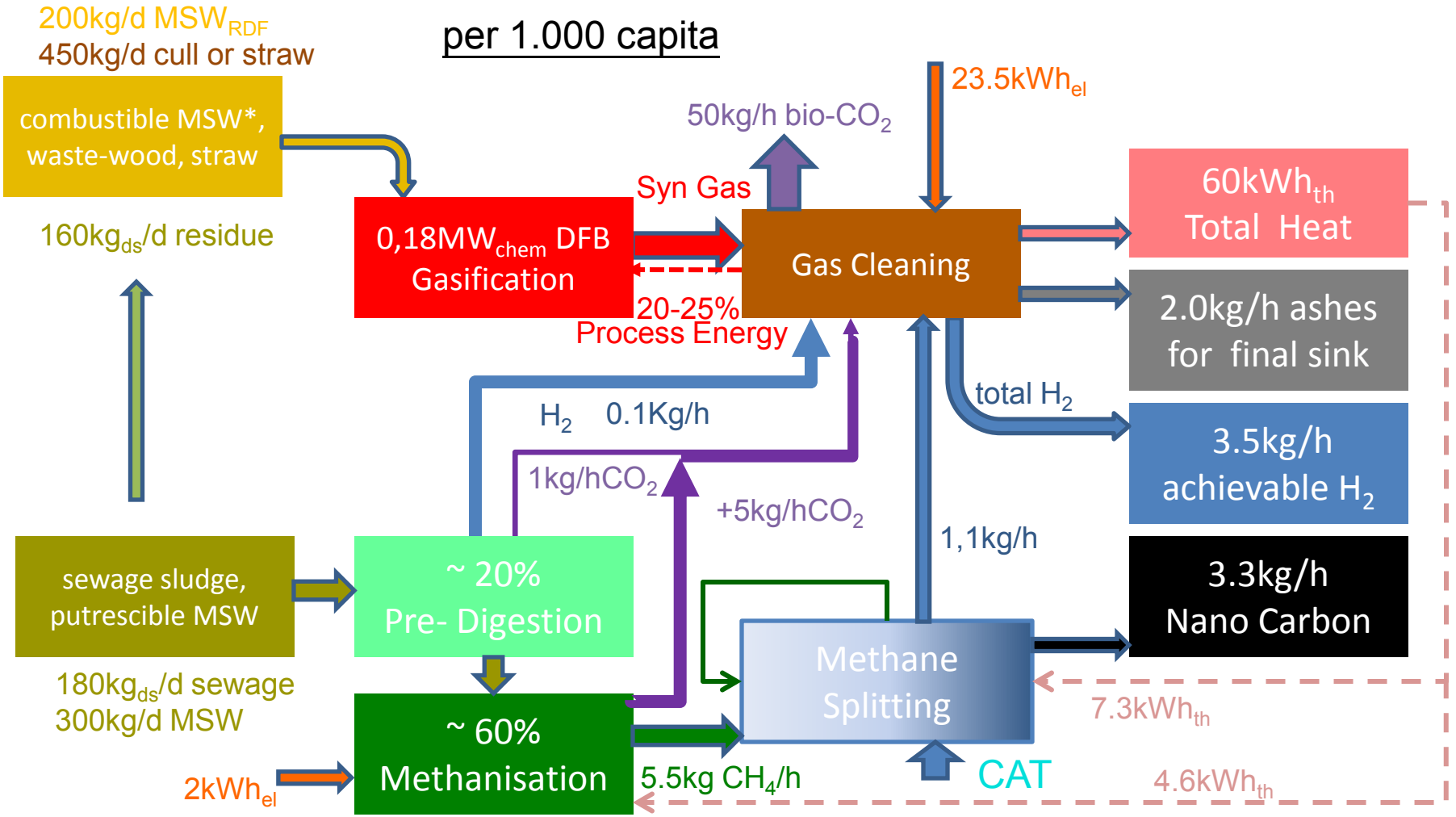




[i] BioEnergy2020+ (H.Hofbauer, R. Rauch, V. Wilk)

Organic Waste – Bio-Refinery

Hydrogen Production & nCCU from Organic Residues



Added Value from Wastes

From 50,000 capita or 200.000 capita communities

Input / Output	50,000 cpt	200,000 cpt
Putrescible MSW	15t/d (30% water cont)	60t/d (30% water cont.)
Sewage Sludge	150t/d (90% water cont.)	600t/d (90% water cont.)
combustible MSW (RDF)	10t/d (at 19MJ/kg)	40t/d (at 19MJ/kg)
forest cull or waste straw	23t/d (20% water cont.)	90t/d (20% water cont.)
TOTAL chem. Energy IN	**9MW$_{chem}$/h**	**37MW$_{chem}$/h**
Hydrogen OUTPUT	4 t/d (1,500 t/yr)	17 t/d (6,000 t/yr)
Nano Carbon OUTPUT	4 t/d (1,400 t/yr)	16 t/d (5,750 t/yr)
estimated capex required	€ 14mio.	€ 35mio.
achievable revenues*)	€ 8.7mio./a	€ 35mio./a

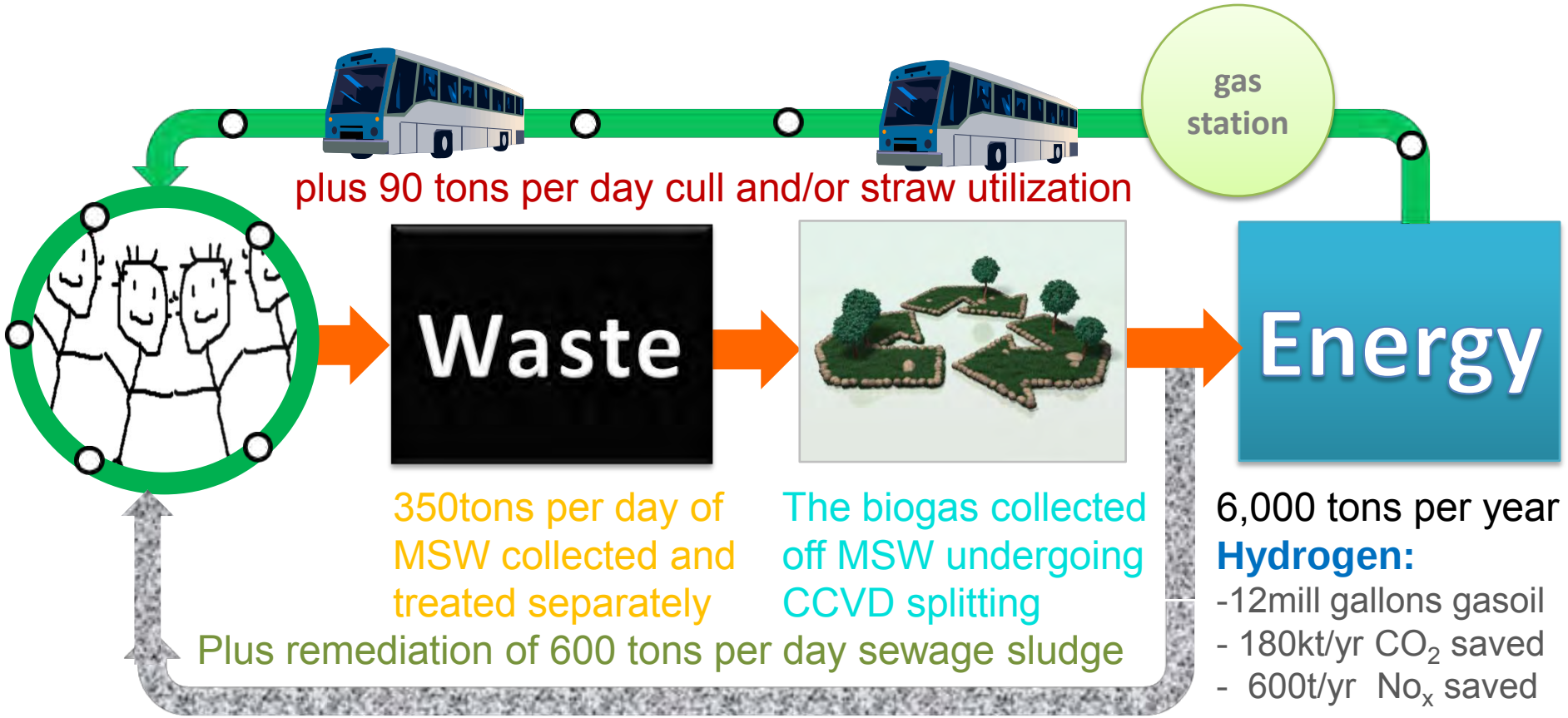
HYDROGEN **Nano Carbon**

*) at € 3,-/kg H_2 Fuel

*) at € 3,-/kg Carbon Black Substitute

Deploy H_2-Economy in 200,000 cpt towns

Support 20,000 LDV or 1,200 public FC buses from MSW usage



6,000 tons per year

Hydrogen:

-12mill gallons gasoil

- 180kt/yr CO_2 saved
- 600t/yr No_x saved

5,750 tons of **CNF** as carbon black substitute; or enhanced thermo-plastics at 5-times usage value

- 28kt/yr CB substitute
- 100kt/yr CO_2 saved

Sustainability Opportunities

Partners needed to make Predicted Markets happen

MSW authority

Increase Economic Value of MSW

Eliminate Green House Gas Emissions from land filling

Remediate Sewage Sludge to 25% Ashes

Add Value to cull and/or waste straw in logistically manageable volumes

Save oil/gas at auxiliary fueling for mixed MSW incineration

Rubber Industry

Build lighter Tires

Eliminate Green House Gas Emissions from Carbon Black Content of Tires

Develop rubber s with self diagnostic functions

OEM Industries

Decrease weight from Thermoplastic Parts

Replace Metal Parts through Injection Molded or extruded EMI shielding nano Carbon Composites

Optimize Plastic Part Surfaces

Enable direct galvanic painting on Plastics -

to allow Recyclability of Plastic Product contents

e.g. for Automotive, Handheld Devices and Household Appliances

Electricity Providers

Get 90% of the Energy Potential from Biomass in storable form

Save Green House Gas Emissions from thermal power generation

Ability to generate Distributed Power on Demand wherever CHP Heat Energy can be used

Petro Chemical Industry

Save Natural Gas for Exports

Save CO_2 Emissions from Steam Reforming

Benefit from distributed Hydrogen generation for the build up of a potential Hydrogen Infra-structure

Extend Clean Fuel Product Portfolio for National and Export Markets

Development into Application Road Map

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cost: € 1M

Feasibility ongoing

Laboratory
Optimizations
R&D activities

cost: € 8M

Demonstration for a 8-9,000cpt town

30m³/h CH_4 splitting plant
+ Simulation Model

Full Descriptions
Safety Certification
Detailed Plant Costing
Detailed Process Costing

CAPEX: € 35M; with 60% Gross Margin (w.o. Feedstock Cost)

Pilot plant for200,000cpt

Operations &
Endurance Testing
500m³/h CH_4 splitting
Pilot Plant based on
Simulation validated
by 30m³ demonstrator
Sales – Marketing and
General & Admin Cost
(incl. IP cost)
15MW_{chem} Gasifier

Open up a multi-billion market and create a distributed H_2 economy

Worldwide at 30% ratio:
15,000 bio-refinery plants
for MSW **utilization**

Total reduction:
COD: 150,000,000tpa
CO_2: 750,000,000tpa
SO_2/NO_x: 2,700,000 tpa

Making Economy from Waste without needing ongoing subsidies or trade regulations

>10 years experience in nC application at GUO's team

FCV, H_2 infrastructure develop

*) with increasing nC plastic composite applications↑€/kg_{CNF}

2010 2012 2014 2016 year

Sustainability

Economic

- Renewable/Repeatable Energy from waste
- **Distributed Clean/Green Fuel** for HFCV roll-out
- **Unlocking multi-billion markets (nC and H_2)**
- **Closed Loop Circular Local Energy Economy**
- **Job opportunities (>1,000)**

Social

- **Waste utilization for fuel not competing against Food**
- Boosting **collaborations between key economic sectors**
- **Strengthen local competitiveness by closed loop circular energy-economy**

Environment

- **Total reduction (COD, CO_2, NO_x, SO_2)**
- Higher added value from waste allows more sustainable Agricultural Practice

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" The future is something that most of the time already happens before we anticipate it"

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