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Energy & Chemical Engineering

KATYUSHA Technology Services

Anthropogenic Methane Utilization via co-production of Green Hydrogen and crystalline Carbon as intermediates for Bio -Refineries

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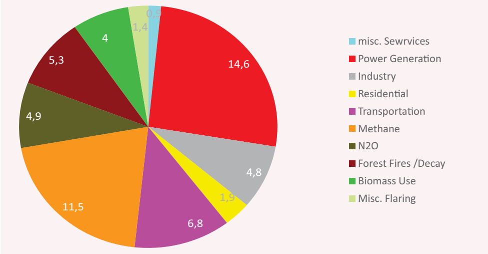
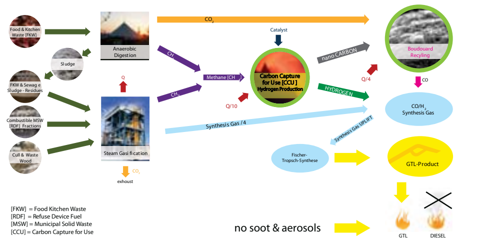
Subject Matter: post recyclables & valuables picking MSW residue still gets discarded to the cheapest space available



Global Anthropogenic Methane from agriculture-, foresting-, mining- as well as wastewater- and municipal solid household waste disposal (landfills) is number two Green House Gas [GHG] contributor after the energy sector.[i] The commonly used 21-multiple CO_2 equivalent for such emissions relates to a 100-year average. CH_4 however decomposes in the troposphere faster than CO_2, which means, that the short term GHG-effect through appropriate mitigation measures would result in an even higher multiple CO_2 equivalent reduction.
State of the art usage paths usually lack financial self-sufficiency and are therefore not afforded. Even world leading Technology demonstrated in Guessing falls short of economic self-sufficiency by just generating Electricity or producing Substitute- Natural Gas [SNG]. However as already demonstrated in a Polygeneration's part-use of the available Hydrogen-/Carbon monoxide fractions from the producer gas off Steam Driven Indirect Fluidized Bed [SDIFB] Gasification, the usage paths for such Synthesis gas output unlock higher level planes in the value adding pyramid[ii]. Unlike CHP energy recovery, you don't loose it if you don't use it immediately.

Solution Challenge: Economy from Ecology Waste Approach



Integrating dissociation of gaseous hydrocarbon into the two basic elements, Hydrogen & highly surface active crystalline Carbon[iii], via a materials Technology, developed over the last 10 years (we call it the Carbon Capture for Use [CCU] approach) into a combination of the "energy Cell" application developed in Guessing with bio-chemical decomposition of fermentable residues, the entire decomposition gas stream can be transformed into chemical synthesis adequate H_2:CO ratio of 1:1[iv]. A decomposition gas use in a Fischer Tropsch fuel synthesis, the simulated bio-refinery unsubsidized output products could compete at arms' length U$ 110/bbl oil market price covering cost.

UNIQUE SOLUTION PROPOSITION [USP]:

$$CH_4 \xrightarrow[\text{(at 37,8 kJ/mol } H_2)]{@\,560\text{-}960°C \;+\; \text{Catalyst}} C + 2H_2$$

Due to availability of suitable high temperature waste heat off gasification dry thermo-catalytic CH_4 splitting can be performed without auxiliary energy supply. As the process's endothermic requirement is only ~55% of Steam Methane Reforming [SMR][v], remaining high temperature waste heat for a consumption of the carbon output in a Boudouard reactor can transform thermal waste energy and CO_2 into chemical energy in the aggregate of CO[vi].

$$CO_2 + C \xrightarrow[\text{(at 103,3 kJ/mol CO)}]{@\,960\text{-}1.100°C \;+\; \text{Catalyst}} 2\,CO$$

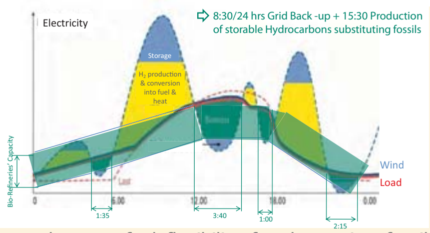
Delinquent net process- heat requirement can be covered by H_2 in excess of 1:1 ratio. (synthesis' requiring a 2:1 ratio can either use excess CO in a Water-Shift [WS] reaction, or sell crystalline carbon to procurers of natural graphite).

Every new approach becomes an Innovation only upon physical implementation for its actual added value realization

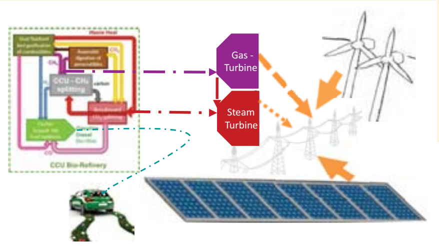
Gasification exists since 180 years. At first for the production of „town gas" from coal and since 90 years for the production of synthetic chemicals. SDIFB Gasification was originally developed as an environmentally clean and energy efficient method for flexible energy recovery from poor carbonaceous fuels (e.g. FB sewage sludge incineration)[vii]. While coal gasification typically ranges in the order of 500 – 1,800GJ feed-stock, SDIFB gasification has so far addressed a range from 50 – 300GJ feed stock. Due to lower operating temperatures its product gas' equilibrium contains about 30% energy content in the form of Methane. The more plastic fractions a feed-stock contains, the higher.[viii] Therefore most applications looked towards SNG production from logistically awkward feed-stock (such as ligneous biomass or MSW), for which SDIFB gasification deems best suited. But still we see increasing MSW incinerations and caloric biomass use only.

Growing needs for new solutions:

Chemical synthesis products today are a domain of the fossil industry, enjoying scale of economy advantages from their higher density primary energy carriers like coal or oil. But an environment with increasing distributed volatile power generation needs economic back-up capacities for their off-times. At the same time a progressing highly urbanized and still growing world population, projected to generate 2-times of today's MSW by 2030 is in urgent need of economically self supporting, affordable sustainable waste treatment methods.



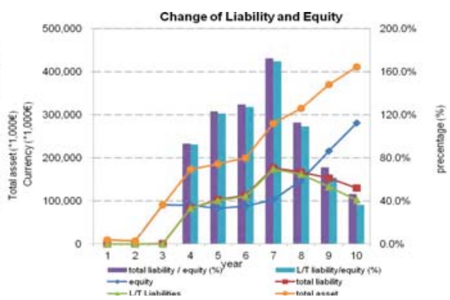
Typically required back-up is in an order of 25% NRE peak capacity. At single wind turbine peak power of 8 MW a 150GJ CCU Bio-refinery can pair 6 turbines in distributed grids. When wind or sun are on, it wont idle but produce chemical synthesis added value products, substituting fossil equivalents.[ix]



Actually there is a demand towards more fuel flexibility for decreasing fossil dependence in transportation and mobility. Aviation contemplated that in 30 years we will either fly on 2nd generation bio-fuel or not at all anymore.[x] CCU enhanced SDIFB gasification 50 – 150GJ bio-refineries fueled by MSW represent a viable business model for organic residues treatment from just combining existing proven Technologies from the different areas . And none of the then synthesis products would conflict with land use or food, nor import carbon from earlier ages into our aera.

Affordable Roll-Out:

A roll-out for 10 installations at today's knowledge over 10 years term shows a net present value based on DCF method of about factor 3 for the initial investment required. Apart from this economic attractiveness foregoing application model for future MSW treatment would have substantial macroeconomic relevance at National levels. Apart from full cost coverage for the waste management derived synthetic fuel volumes would not just be CO2 neutral, but also substitute otherwise imported energy carriers, burdening the National trade deficit.
Over the next 20 years this anthropogenic methane use concept could create a multi billion capital equipment market segment employing a few 10,000 people and reduce 3 times the CO2 emission per ton of organic MSW, current state of the art Waste to Energy concepts can, fossil fuel substitution being the leverage.



In Austria today's Waste to Energy constellation has reached a standard, not leaving waste left for a new way of treatment. However, future resource efficiency requirements may interest the local strongly export oriented medium sized environmental plant companies.

In particular for the European scenario employment creation point of view would prevail in the economy from sustainability aspects through qualitative growth.

References: [i]IEA Report 2009; [ii]Energiezentrale Guessing, H. Hofbauer, R. Rauch, S. Fürnsinn, Ch. Aichernig; TU-Vienna; 79/2006 BMVIT Report on Energy & Environment; [iii]Muradov, N., Thermocatalytic decomposition of methane using fi xed bed reactor, Proc. 1996 U.S. DOE Hydrogen Prog. Rev., Miami, 96; [iv]Bio-refinery products from low value feed-stocks; Hofbauer, Kotik, Tondl i.A. guo Business Development; [v]EP 1623957 to Mauthneret. Al; [vi]H.J. Glinz, Carbon Capture for Products, Wietersdorfer Gruppe, CO2 Symposium Linz 11/2012; [vii]S. Koppatz, C. Pfeifer, H. Hofbauer, Chem. Eng. J. 2011, 175, 468 – 483; [viii]V. Wilk, R.Rauch, H. Hofbauer; "Methane Production from woody biomass", Biofuel Conference Berlin 2012; [ix]J.C. Meerman, Utrecht University „ exible gasification cogeneration facilities" ICPS2011 Austria; [x]Dr. Alexander Zschocke, Senior Manager Aviation Bio-Fuels of Lufthansa, Fuels of the Future Conference, Berlin 2012; [xi]Dr. Christian Helmenstein, Bio-Raffinerien für Abfallstoffe (Regional- und volkswirtschaftlicher Impakt, fiskalische Leistung und außenwirtschaftlicher Beitrag), Economica Institut für Wirtschaftsforschung, Austria 2013

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1. Preface

Global Anthropogenic Methane from agriculture-, foresting-, mining- as well as wastewater- and municipal solid household waste disposal (landfills) is number two Green House Gas [GHG] contributor after the energy sector[i]. But state of art usage paths usually lack financial self-sufficiency and are often not afforded. Only as already demonstrated in a Polygeneration's part-use of the available Hydrogen-/Carbon monoxide fractions from a producer gas off Steam Driven Indirect Fluidized Bed [SDIFB] Gasification, chemical synthesis output could unlock higher level planes in the value adding pyramid[ii]. Unlike CHP only, you wouldn't loose it if you don't use it.

2. Bio-Refineries for downstream Chemical Synthesis production

Integrating dissociation of gaseous hydrocarbons via our materials Technology developed in the last 10 years, co-producing Hydrogen and highly surface active, crystalline Carbon[iii] (we call it the Carbon Capture for Use [CCU] approach) as refining intermediaries into the "energy cell" application developed in Guessing, the entire decomposition-gas stream could be transformed into a chemical synthesis adequate H_2:CO mixture. A simulation model in IPSE-Pro was developed and validated within the team of authors, promising economical mass- and energy- balances.[iv]

Dry thermo-catalytic splitting [CCU] was applied to the Methane fractions of thermo- and bio-chemically decomposed organic residues in the ratio typically co-existing in MSW, typically requiring 50 – 150GJ installations. Its renewable synthesis product outputs do not conflict with land use or food.

The available high temperature waste heat of the gasification allows CCU to be performed without auxiliary energy supply. The process's endothermic requirement is only ~55% of Steam Methane Reforming [SMR].[v] Left over high temperature waste heat can further support a Boudouard reactor to transform thermal waste energy and CO_2 into chemical energy in the aggregate of carbon monoxide [CO] [vi] by consuming the produced carbon. Delinquent net process- heat requirement can be covered by the Hydrogen in excess of an achievable 1:1 synthesis gas ratio.

The simulated decomposition gas usage for Fischer Tropsch fuel synthesis at today's raw oil prices of ~U$ 110/Barrel shows output products producible at arms length's unsubsidized market price covering cost.

3. Implementation of Bio-Refinery Innovation

Large scale gasification exists since 180 years. At first for the production of „town gas" from coal and since 90 years for the production of synthetic chemicals. SDIFB Gasification originally was developed as an environmentally clean and efficient method for flexible energy recovery from poor carbonaceous fuels (above and beyond FB sewage sludge incineration).[vii] While coal gasification typically ranges in the order of 500 – 1,800GJ feed-stock, SDIFB gasification has so far addressed a range from 50 – 300GJ feed stock. Due to lower operating temperatures its product gas' equilibrium contains about 30% energy content in the form of Methane. The more plastic residues a feed-stock contains, the higher.[viii] But most applications looking towards SNG production from logistically awkward feed-stock (such as ligneous biomass or MSW), for which SDIFB gasification deems to be best suited, yet fail to meet NG market prices.

On the other hand, a Roll-Out of $\geq$10 installations for chemical synthesis products over a 10 years term shows a net present value based on DCF method, at a multiple of the initial investment required and could create a multi billion capital equipment market segment employing a few 10,000 people and reduce 3 times the CO_2 emission per ton of organic MSW, current state of the art Waste to Energy concepts can, with fossil fuel substitution as a leverage.

4. References

[i] IEA Report 2009

[ii] Energiezentrale Guessing, H. Hofbauer, R. Rauch, S. Fürnsinn, Ch. Aichernig; TU-Vienna; 79/2006 BMVIT Report on Energy & Environment

[iii] Muradov, N., Thermocatalytic decomposition of methane using fi xed bed reactor, Proc. 1996 U.S. DOE Hydrogen Prog. Rev., Miami, 96

[iv] Bio-refinery products from low value feed-stocks; Hofbauer, Kotik, Tondl i.A. guo Business Development

[v] EP 1623957 to Mauthneret. al

[vi] H.J. Glinz, Carbon Capture for Products, Wietersdorfer Gruppe, CO2 Symposium Linz 11/2012

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