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MSW-residue & Coal Co-Gasification in lieu of Incineration

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Today post recyclables & valuables picking MSW residue still gets discarded to the cheapest space available

2 different worlds but all share the same climate

financially self sufficient and affordable for the poor, but unhealthy and a climate threat

very hygienic but operated on society's cost, unaffordable for emerging & developing countries

Best Available Technology yet needs to be designed in

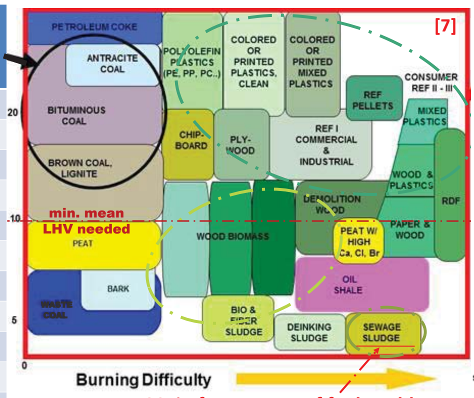
Initiatives across Europe and North America to substitute incineration based on different gasification Technologies:[1]

Type	Fixed Bed [FB]	Entrained Flow [EF]	Plasma	Solid Fuel SMR	SD-FICDFB
Advantage	simple construction	High Volume Capability	Anoxic volatilization of fuel	good waste destruction emission values; Low Volume Economics	highly fuel flexible, auto-thermal volatilization in anoxic atmosphere at ½ the water/fuel ratio of EF- or FB- Gasification.
Disadvantage	difficult tar handling, except MILENA not an anoxic destruction zone	requires air separation unit (energy), little fuel flexibility, maintenance cost (high temperature)	High parasitic allothermal (secondary = costly) energy input required	Limited in scalability => not easily economic for high value adding down stream usage paths	Limited in scalability to ≤ 15t Solid Fuel/h and not economic below 3t/hr; complex slag handling

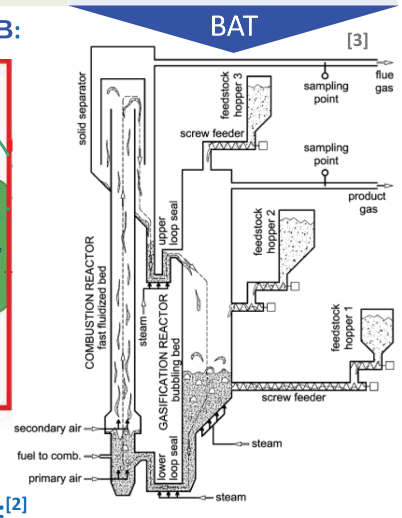
Feedstock's tested by FICDFB experimental campaigns

Tested Fuels' fractional [$\%_{wt}$]	wood tested	Small Light Fraction plastics[2]	MSW foil & laminates[2]	Lignite[5] EFG Fuel Range
Water Content	6.11	0.87	2.81	3.6
Ash Content	0.27	10.67	12.47	29.97
Carbon	47.16	64.36	52.42	53.15
Hydrogen	5.67	7.87	7.08	3.27
Nitrogen	0.05	13.34	23.31	1.34
Oxygen	40.73	0.92	0.91	7.88
Sulfur	0.005	0.31	0.20	0.75
Chlorine	0.003	1.65	0.80	0.04
Volatile Matter	81.17	78.9	76.42	26.18
Fixed Carbon [wt]	12.72	20.23	20.77	70.22
LHV [MJ/kg]	17.46	31.95	24.09	19.33

Full Range Fuel Flexibility of FICDFB:



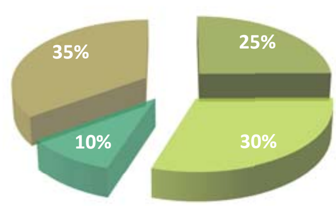
≤ 30% of mean LHV of fuel could come even from sewage sludge[8]



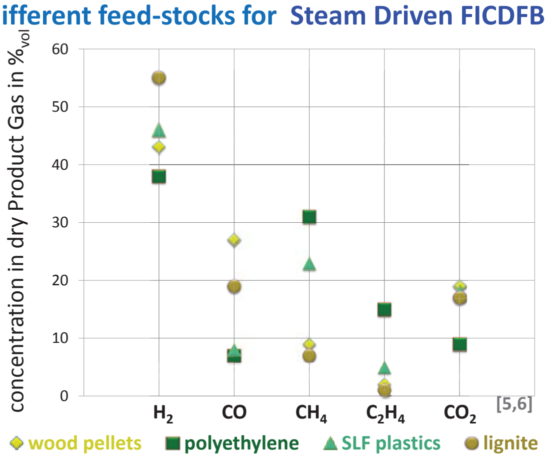
Product gas composition of different feed-stocks for Steam Driven FICDFB Gasification:[2]

Mixed Fuel Capability

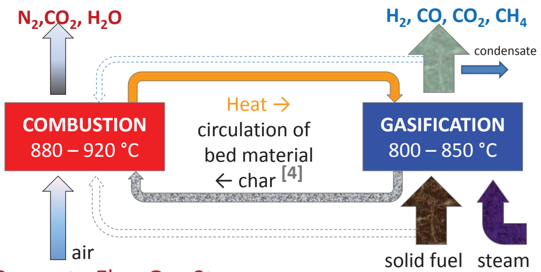
(for max. local resource use)



halving fossil CO_2 emissions[9]



- ✓ **no direct combustion** of fuel
- ✓ **anoxic atmosphere** in the **"decomposition chamber"**
- ✓ solid fuel transformation into usable energy by heat induced from a transferring medium (fast circulating Bed Material)



Separate Flue Gas Stream (12% CO_2, 6% O_2, 83% N_2)

- ✓ combustion chamber runs on unconverted Carbon & NO_x lean
- ✓ ashes extracted by cyclones and flue gas filtering
- ✓ contaminants primarily Hydrides separated out by Gas-cleaning

General Conclusions:

Co-Gasification of mixed carbonaceous solid fuels by FICDFB has not only been demonstrated feasible, but showed advantageous nexus' effects on product gas composition. Together with Carbon Capture for Use refining of C_xH_y fractions by our Thermo Catalytic Dissociation into Hydrogen and $_{nano}$Carbon added value of U$ 16.20 – 19.50 per GJ compounded mean LHV feedstock can be unlocked.

[1] S. Petters, K. Mauthner, K. Tse, "Global Initiatives in Waste Gasification"; "7th Intl. Conference on Waste Management & Environment" Ancona, May 2014; [2] V. Wilk, S. Kern, H. Kitzler, S. Koppatz, J.C. Schmid, H. Hofbauer "Gasification of plastic residues in DFB-gasifier - Characteristics and performance compared to biomass"; TU-VIE & BioEnergy 2020+; [3] V. Wilk, H. Hofbauer; TU-VIE, "Dual fluidized bed gasification: operational experiences and future developments"; Newcastle, 10 23 2013 [4] H. Hofbauer, Ch. Pfeifer, T. Proell, R. Rauch, H. Kohl; Brochure Future Energy Technology R&D Platform of University of Technology Vienna; [5] S. Kern,* C. Pfeifer, H. Hofbauer; „Gasification of Low-Grade Coal in a Dual Fluidized-Bed Steam Gasifier" Energy Technol. 2013, 1; [6] S. Kern, C. Pfeifer, H. Hofbauer; Co-Gasification of Wood and Lignite in a Dual Fluidized Bed Gasifier; Energy Fuels 2013, 27 [7] S. Petters, M. Fuchs, K. Mauthner; ISWA 2013, Vienna; Potential Economics from Waste's Carbon recycling; [8] H. Hofbauer, J. Kotik, G. Tondl (University Technology for Energy of the Future) "Bio-refinery products from low value feed-stocks"; feasibility for guo Business Development, Vienna June 2012 [9] Pat. CN 201420137432.2 Bestrong International Ltd.

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Abstract:

Direct biomass gasification and chemical municipal waste treatment appear to share scale of economy orders of magnitude. Actually this may relate to similar logistic implications. Also the mean calorific value and range of mix in quality of fuel fractions deem to provide synergies in use of similar technical solutions.

Indeed there can be seen several initiatives across Europe and North America, where alternatives to incineration have been based on different gasification Technologies[1]. Also at TU Vienna various fuel mixes had been investigated in Fast Internal Circulating Fluidized Bed Gasification, confirming potential synergies between biomass and MSW residues[2].

Of course waste is a very local issue and can vary in its composition widely, depending on the local population's income, nutrition habits and degree of formalization in the waste remediation sector. Since this conference is collaboration between China's and Austria's scientific academic capacities in the field of Gasification, we would like to bring up some aspects of possible application of Austrian Technology potentially able to meet specific needs of China in the field of MSW treatment.

1. Introduction:

Recent achievements in untreated biomass gasification have proven reliable operations at scales up to an order of 10t/h feedstock of as low as 10GJ/t average mean calorific value, aiming towards another scale-up towards 50t/h. [3] Alternative approaches had been feedstock fuel preparations to make biomass more coal like, so the usually much larger scale plant designs of coal gasification could be used. However, inland locations, limited to road and rail logistics have shown a logistic ceiling of ~ 1,500t/d as still reasonably manageable.

In Waste Management we can see most incineration installations at an order of 250,000 – 300,000t/year. So, quantitatively today's state of art untreated biomass gasification order of scale seems pretty synergistic with typical MSW treatment. However, the average mean calorific value may vary significantly, depending location and income situation of the local population. In China for example one has to expect practically all combustibles picked from the waste prior to arriving at a final cremation installation.

Therefore incineration in China has to heavily apply auxiliary fuel which due to its local availability should preferably be coal. Bituminous coal, actually, which is not an easily clean combustible fuel by itself and very awkward if applied in an undefined mix with MSW residues.

Waste incineration on the other hand requires a high degree of process capability to be able to prevent potentially poisonous and health threatening exhaust fumes, such as Dioxins, Sulfur- or Nitrogen- Oxides, etc. Therefore even in China serious citizens' initiatives have raised rejections against the direct combustion of MSW residues today.

Indirect gasification could become a great solution for overcoming the problems from using locally available coal in China. Actually Fast Internal Circulating Dual Fluidized Bed Gasification has demonstrated a bandwidth of fuel tolerance, allowing combining biomass, coal, MSW residues and even sewage sludge into a fuel compound of a mean lower heating value ≥ 10GJ/t. Doing so, allows thermo-chemical cremation of MSW residues to minimize final sink landfill space need and landfill gas mitigation and neutralizes CO_2 emissions for the non coal fuel fractions.

Actually there are 700.000 coal fired district heating boilers in China today, burning 15% of China's coal consumption and causing 55% of all the smog relevant emissions. Switching those installations to a MSW and sewage sludge cremation capable mixed-fuel gasification, could solve several sustainability issues at the same time. Due to partial atmospheric carbon fuel contents accountable CO_2 emissions of such coal-MSW fuel compound could be reduced to below Natural Gas burning CO_2 emissions.

At the same time Synthesis Gas output from such thermo-chemical waste utilization could open new level planes in the value pyramid from waste, making such alternative to land filling affordable.[4]

2. Concept and methodology:

Fuel preparation providing a mean calorific value of $\geq$ 10GJ/t via various means of moisture reduction and admixture of coal at a rate required for achieving such compounded heating value can bring MSW residues into the process window desirable for Indirect Gasification by a Fast Internally Circulating Fluidized Bed dual reactor.

This reactor concept has been chosen by University of Technology Vienna after 15 years of research in gasification already 15 years ago as the most promising pathway for optimum use from poor carbonaceous fuels. Through the use of steam as gasification agent fuel moisture variations can be evened out to some extent on the expense of overall efficiencies.

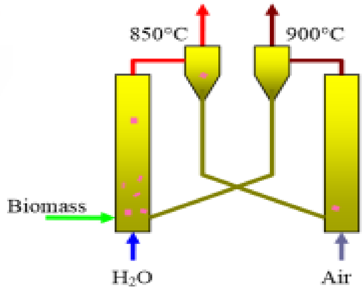

Fig.1: Indirect Dual Reactor Gasification

Even the best available incineration solutions today do not provide competitive energy efficiencies compared to fossil fuel heat or electricity generation, which usually are 50 – 100 times in scale. Such Energy Recovery from Waste is therefore not easily affordable for countries with significant poverty among their population. Therefore there is a need for alternatives to be designed for achieving highest possible added values from anoxic waste residues' decomposition into secondary resources without secondary auxiliary energy input requirement.

Therefore prior to thermo-chemical treatment the waste should be undertaken a bio-chemical degradation, delivering a collectable eluate for anaerobic transformation into Methane and CO_2. Such Methane can then be added to the product gas from the co-gasification of the final residues with coal as a building block for further down-stream synthesis.

Substitute Natural Gas Synthesis already widely produced in China by much larger coal gasification installations is suffering from coal and about two times as much water required, rarely coincide within reasonable logistic reach. Also cost barely can compete against today's LNG world market prices, so that pure synthesis gas to liquid downstream usage paths might be more rewarding. By substituting up to ⅔ of coal by atmospheric carbon stock residues' admixture, locally available, distributed typical waste treatment plant size installations could be located further away from the coal mines and reduce their water consumption through moisture contents of the admixed organic fuel fractions. For the Methane conversion into Synthesis Gas, dry thermo-catalytic splitting can be added, using gasification's high temperature flue gas waste heat as endothermic supply, to co-produce Hydrogen and solid phase crystalline Carbon as further refining intermediates.[7]

3. Results

Various fuel tests at a 100kW test plant of Vienna's University of Technology, Institute of Chemical Engineering have demonstrated the feasibility of the above outlined concept. While fuel fractions with higher Oxygen content tend to increase CO and CO_2 yields in the product gas, plastic residues increase the C_xH_y fractions, being decomposition products of polymers on the expense of Hydrogen in the product gas, as more Hydrogen remains attached to Carbon in the Hydrocarbon gases and tars.[5] They result in a slightly higher volumetric Lower Calorific Value of the product gas. Coal fractions in the mixed fuel increased Hydrogen to almost $150\%_{vol}$ compared to biomass and lowered the permanent gas components CO and CO_2 by ~12%, while CH_4 decreased by almost $60\%_{vol}$ and C_2H_4 by $74\%_{vol}$. [6] This is due to the higher water conversion ratio by the lignite carbon's reactivity.

High ash content fuel fractions such as sewage sludge or lignite have also demonstrated to crack more tar in the free board's equilibrium zone, potentially acting catalytically there. However, high ash content fractions of the fuel may drag-out too much heat from the SMR reaction zone, which requires looping part of the product gas back into the combustor, lowering overall efficiency.[8]

MSW in China has substantial organic content with an average LHV of 6.5GJ/t. Further recent achievements in waste water treatment have resulted in high sewage sludge, averaging 2.6GJ/t at $60\%_{H_2O}$ and $50\%_{wt}$ organic content remediation demands. To process by FICDFB gasification, a mix-fuel compounded from $25\%_{wt}$ sewage sludge, $40\%_{wt}$ MSR and $35\%_{wt}$ Lignite could be envisaged.[9] With an average Carbon content of $37\%_{wt}$ of such fuel a steam to Carbon ratio of 1.8 for such a mixed fuel would require $0.7m^3$ H_2O/t, whereof ~50% could already be covered from the compounded $37\%_{wt}$ contained moisture in mixed fuel.

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