

Food-, Water- and Energy- Security Require a World in Carbon Balance

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Abstract. A doubled population 11-folded its Carbon consumption over the last 50 years to the #1 resource used, comprising 57% of global resource management. But in contrary to other resources like iron ore Carbon is used in a way as if it was a one-way package of energy and not consequently recycled for multiple re-use [1]. Whether in Agriculture or the Energy sector Carbon's role in Nature and Environment is grossly misjudged. Concerning Climate Change mitigation efforts, the world is misleadingly focused on Energy only, although the real battle will have to be won in Agriculture!

Introduction

The Intergovernmental Panel for Climate Change [IPCC] contemplates 400Gt Carbon too much in the atmosphere, representing about 13% of today's top-soil Carbon [2]. Top soil holds approximately 10 times the planet's remaining 2°C Carbon Budget allowance – wherever you see dry seasons' soil cracked up in canyons, you witness the consequences of unsustainable farming practice, driving a soil degradation that can lead to Carbon respiration of 1-2% per year hitting the 10% within 7 years only.

Such soil erosion has about 3 times the effect of all anthropogenic fossil and renewable Carbon (mis)management. Top Soil Carbon plays a major role in water and nutrient storage capability of land [3]. While the general perception of abundant availability of Carbon still prevails, water scarcity has won more awareness by the general public [4]. But unfortunately not yet enough to stop mindless Energy Recovery efforts from Renewable Carbon to the burden of decent composting.

Although proper Composting can drastically reduce the necessity of chemical soil treatment, often poisoning ground water through fast wash-out from top soil unable to retain water for extended times, significant agricultural sectors do not replenish their top-soil through proper composting. Throwing some stuff on heaps or taking sludge out into plantations is definitely not a proper composting!

We see some good composting practice for organic household waste, but due to undeterminable residual contents of hormones, antibiotics and other substances soil-output of such waste treatments are not advisable to be reintroduced into the food-chain and don't really help Agriculture therefore.

Climate Change mitigation is a big business today and some countries afford to take extra charges to cover cost overruns under a do-gooder code of behavior. But looking at the correlation between so called Carbon Abatement Cost development and effectiveness of measures one can often find opposite rebound effects from such "*Green Business-Developments*" [5]! So the public ends up having to pay add on cost for *Feed in Tariffs* [FiT], *Extended Producer Responsibility* [EPR] fees or *Clean Development Mechanism* [CDM] certificates for enticing "*Green Investors*" to finance uneconomic implementations.

Between Energy and Agriculture in 2014 the world turned totally 13Gt of Carbon, $\frac{2}{3}$ fossil and $\frac{1}{3}$ biogenic. Most of it is lavishly squandered as CO₂ into atmosphere after Energy recovery today. And as long as we use more than the planet's metabolism can handle burning biogenic Carbon cannot be neutral! This year's "*Earth Overshoot Day*" on 08.08.2016 represented an over usage of factor 1.6!

Carbon Recycling

Biogenic Carbon (Carbo-Hydrates)

In reality Carbon content of biomass should never be valued below fossil Carbon cost, today requiring inclusive Finding, Development & Exploration [FD&E] U\$ 500/tonne. So 1 tonne of woody biomass having at 40%_{wt} moisture about 30%_{wt} Carbon content would have to cost U\$ 150 or pelletized and torrefacted U\$ 250/t just for the Carbon!

If burned in a latest state of the art fluidized boiler for electricity generation with waste heat use in Organic Rankine Cycle [ORC] and pre-drying of feedstock cost of electricity would be U\$ 120/MWh, about 3 times conventional producer prices in Europe. The MWh from woody biomass causes CO₂ emissions of ≥ 0.9 tonnes – Natural Gas on the other hand could produce 1MWh from $\sim 250\text{m}^3$ and therefore only 0.45 tonnes CO₂ emissions at \sim U\$ 40/MWh.

On the other hand bio- or thermo- chemically decomposed biomass into energy rich gas comes at a 1.3:1 Hydrogen : Carbon ratio being > 1.5 times better than crude oil and needs $\frac{1}{3}$ hydro-cracking only of crude oil towards achieving a 2:1 chemical synthesis Hydrogen : Carbon ratio – so refining biomass should be seen more Carbon Efficient than using crude oil or coal!

However, refineries operate at multiple scale sizes than biomass logistics reasonably suggest. Therefore we advocate to maximize physical Carbon Recovery from biogenic feedstock in a logistically easy to handle aggregate that can be centrally processed into fossil substitute products from cumulated Captured Carbon of a number of decentral feedstock processing locations.

Fossil Carbon (Hydrocarbons)

Fossil Hydrocarbons are naturally transformed biogenic Carbo-Hydrates of earlier eons. Nature functions by *//: building up and breaking down://* combinations of Hydrogen – Carbon – Oxygen. By-products may be CO₂ transformation losses and water, also needed as intermediate or reactant.

In the case of coal almost only Carbon is left, while crude oil still contains some Hydrogen. But Natural Gas, predominantly being Methane is Nature's preferred equilibrium aggregate for Hydrogen storage and the most stable hydrocarbon compound. Therefore under availability of water any solid or liquid Hydrocarbon can be steam-reformed and synthesized to Substitute Natural Gas [SNG], rather than directly burning it [6].

Methane. Carries 55% of its energy content in Hydrogen molecules attached to a Carbon backbone holding 45% energy. For power generation accounting for 40% of Natural Gas [NG] consumption today, the Hydrogen content only could deliver in a one-step electrochemical transformation the same amount of electricity today's 3-step transformation practice of \rightarrow heating steam for \rightarrow motion power to propel \rightarrow generators does (whereas any heat losses can be used for combined heat and power in either case). So actually, depending on the Carbon Efficiency of the methane-splitting into Hydrogen- and storable Carbon molecules, Methane undertaken Carbon Recovery could deliver Zero Emission Electricity! In other words, as Methane can be synthetically produced from any form of fossil or biogenic Carbon, electricity could be de-carbonized to the extent of Carbon transformation losses.

Theoretically such Carbon Capture and Hydrogen Electricity can be put into a multiple circle at least doubling the Carbon Efficiency of Natural Gas Power generation. In combination with Power to Gas [P2G] from excess New Renewable Electricity [NRE] storage this architecture can 5-fold Carbon Efficiency of SNG-Power generation from the Captured Carbon. But it won't happen as long as regulatory regimes reallocate consumers' purchasing power to entice less Carbon Efficient solutions.

Economics of Carbon Recycling

At crude oil (incl. FD&E) at \sim U\$ 55/bbl cost for Capturing Carbon from e.g. Municipal Solid Waste [MSW] holding $\sim 30\%$ _{wt} of Carbon could be U\$ 0.50/kg Carbon recovered. Capturing it from NG traded at U\$ 2.8/MMBtu for a use as crude oil substitute it could be U\$ 0.30/kg and would be par with worth of Carbon contained in NG if from a recycling loop for Hydrogen electricity. Calculating an Organic Waste refining simulation model we came out at $\sim 80\%$ Carbon Recycling rate. Cost for a

160GJ per hour intake installation shows ~ US\$ 120/tonne total treatment expenditures whereof the Carbon Recovery represents $\frac{1}{3}$ of the US\$ 0.50/kg Carbon recovered. So waste could be refined into crude oil substitute products without uncovered cost overruns needing to be allocated to the public.

For lignite coal our simulation model showed a Carbon Recovery rate of 67% from idling mode and 8% during Hydrogen Fuel Cell Power generation from the coal's gasification. In a 60:40 percent Idling : Generation mode of such coal fueled Hydrogen Utility on demand installation the Carbon Emissions per MWh_{el} could be reduced to 50% of a conventional boiler coal power plant.

In the case of using coal as primary fuel just for SNG synthesis Carbon Recovery would be 38% only at ~67% E_{chem} efficiency. However introducing the SNG into above described multiple cycle SNG Carbon Capture Hydrogen Electricity, Carbon Efficiency could be improved by factor 2.2.

Therefore physical Carbon Recycling in combination with either fossil substitute product refining or Hydrogen Fuel Cell Utility power generation allowing multiple re-use of the Carbon can compete economically against direct or near term combustion of the Carbon. If rolled out as part of a Hydrogen Economy approach the fossil Carbon reduction potential lies between 20 and 50%, depending on the availability of P2G or other Carbon Emission free Hydrogen sources for Hydrocarbon Synthesis with Captured Carbon and water.

Summary

Given the current overshoot Carbon consumption overshoot of factor 1.6 the world would need a 40% improvement in Carbon Efficiency to get back into balance. Carbotopia™ originated from Materials Technology backgrounds of its founders. In Agriculture other Technologies able to keep the Carbon in the soil replenishment cycle should always be prioritized. But ashes of upstream thermo-chemical decomposition might be reasonably combined with proper composting techniques, able to mineralize Carbon and build nutrients into microbial tissue. Only then Agriculture, Energy and Environment will come into a sustainable alliance under secure food, energy and water supply.

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References

- [1] G. Passerini; University Politecnica delle Marche; "Environmental Impact"; Wessex Waste Management Conference 2014, May 2014, Ancona [IT].
- [2] A. Raggam; <http://www.verein-biofair.at/wp-content/uploads/2014/02/August-Raggam-Bauern-als-Klimaretter.pdf>, Feb. 2014, 7521 Bildein [AT].
- [3] D. Pimentel; Springer: Environment, Development and Sustainability (2006) 8: 119-137.
- [4] P. Brabeck-Letmathe; Chair of Nestlé, Dialogue on Food and Water Security; AFF, Jan. 2016, Hong Kong. [S.A.R. CN]
- [5] J. Plummer; The Climate Economic Foundation: IAEE Founder's News Letter, Rethinking the Economics of Global Warming and Renewable Energy; Feb. 2015, Las Vegas, Climate Economics Institute. [US]
- [6] S. Kern; Energy & Fuels 2013, 27, 919–931; Co-Gasification of Wood and Lignite in a Dual Fluidized Bed Gasifier; Jan. 2015, Vienna University of Technology. [AT]