Climate protection through recycling (circular economy) e. V. – Turn words into deeds

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Abstract

The industry initiative 'Climate Protection through Recycling (Circular Economy) e. V.' is an association of members from all relevant organizations of the waste and recycling industry as well as large and small, private and municipal waste management companies but also other actors from NRW. With the founding of the association the waste management industry in NRW has set itself the objective to jointly continue to develop their climate-related innovations and technology, services, projects and objectives under this one roof, and thus also supporting 'KlimaExpo.NRW' – a project of the Government of North Rhine-Westphalia – on a long-term basis. This way, the successful transformation process of the disposal industry will continue, and recent significant contributions of the recycling economy towards climate protection can be secured and expanded even further.

Content

The present paper deals with the industry characteristics in NRW first. Thereby it shows how the waste and recycling industry has changed and moved forward in recent years. The association 'Climate protection through recycling (circular economy) e.V.' was established with the aim to make technological developments and achievements in climate protection visible to a broad national and international audience. The association also intends to promote an exchange between companies, associations and other players in the waste and recycling industry, which are actively involved in the area of climate protection. Changes of the recycling industry as well as the establishment of the association make clear why climate protection has become important for the recycling industry. In conjunction with the 'KlimaExpo.NRW', circular economy becomes an expo-capable format with successful projects, making circular economy understandable and touchable for a wide audience up to an international level. Additional commitment of climate protection is to be created.

The second section presents the 'route of circular economy'. This route was developed by the association, on the one hand to convey knowledge about the connections between circular economy and climate protection, and on the other hand to present new technologies or projects from the recycling industry to the broad public. Individual topics of the route are organized along the value chain of the circular economy.

Keywords

Climate protection, circular economy, climate protection through circular economy, recycling industry, CO_2-reduction, climate-friendly technologies, protection of climate and resources, KlimaExpo.NRW

1 Climate protection through recycling (circular economy)

1.1 Transformation of the recycling industry

In the last 25 years, through the process of transforming itself from a landfill-based industry to a recycling industry, Germany's waste management and recycling sector has cut greenhouse gas emissions to almost 60 million tons of carbon dioxide equivalent (CO_2eq). In 1990, the waste management industry was still emitting 40 million tons of CO_2eq, however, by 2006 the circular economy already prevented approx. 18 Mio. tons of CO_2eq (Cf. BDE, ITAD, VDMA, 2016). The sector achieved this transformation in three ways:

Prevention of greenhouse gas emissions: Closing landfill sites
Reduction of greenhouse gas emissions: Energy- and resource-efficient production and comprehensive and high-quality recycling
Recovery of energy from waste: energy recovery, alternative fuels, biomass power plants and anaerobic digestion

1.2 Foundation of the association

Our association 'Climate protection through recycling (circular economy) e.V.' wants to prove that the recycling industry in North Rhine-Westphalia is helping to reduce the amount of greenhouse gas emissions. Members of the association are different players from the circular economy industry, who want to promote climate protection by introducing innovative technologies along the value chain. And that's not all. Over the last 25 years, the sector has shown how climate protection can become an engine for progress. As a result of a successful process of transformation, the waste management and recycling industry has contributed to the reduction of Germany's CO_2-emissions by 20 per cent since 1990 (Cf. BDE, ITAD, VDMA, 2016). The associated development of highly efficient systems to recover energy and materials from waste was not only significant in terms of saving energy and resources. It has also led to the sector becoming specialized, achieving above-average growth rates and, with 62,000 employees, it is now one of the most important industries in NRW's green economy (Cf. MKULNV, 2015).

1.3 Climate protection through a circular economy

The waste management and recycling industry in North Rhine-Westphalia is characterized by its economic strength, capacity for innovation and the presence of waste-management companies across the federal state. A good starting point from which to present the "holistic system of the circular economy" on a project-by-project basis. In this project, the waste management and recycling industry is working as a partner to

KlimaExpo.NRW. This state-based climate initiative gives a wide audience – from local to international level – the opportunity to access and gain an understanding of successful climate-protection projects and stakeholders. Accordingly, it inspires more people to get involved in the climate-protection movement.

The KlimaExpo.NRW climate initiative and the association ‘climate protection through circular economy e.V.’ are official partners and are jointly developing ways of promoting the work being done to protect the climate. To support the goals of KlimaExpo.NRW, the industry initiative plans events and environmental education projects, encourages companies to get involved with KlimaExpo.NRW and develops themed routes to highlight links along the value chain and processes related to the circular economy in North Rhine-Westphalia.

2 Themed route of circular economy - Experience the circular economy

The conception and realization of themed routes is one of the central areas of activity of the KlimaExpo.NRW. The KlimaExpo.NRW is a new climate change initiative from the North Rhine-Westphalian (NRW) state government. Industrial change is based on innovation, education and climate protection. The major challenges to achieving this change include realizing the energy transition and reaching climate protection goals. The KlimaExpo.NRW aims at presenting successful projects to a large audience ranging from the local to the international level. The goal is to do so in a way that is easily accessible and understandable and thus encourages continued and enhanced advancement in climate protection. Based on good experiences of the federal state North-Rhine-Westphalia (NRW) with the international construction exhibition ‘Emscher Park’ (which was also designed as a ‘decade project’); thematically connected projects and locations in NRW should be combined into themed routes, which can be selected and visited by interested visitors. Similar themed routes will be introduced to the KlimaExpo.NRW by ‘Klimametropole Ruhr 2022’ through the so called ‘routes of innovations’ and the ‘route of energy’.

Thus, the basic idea was adopted by our association wide initiative ‘Climate protection through recycling (circular economy) e.V.’.By using examples of different innovative projects, factories or even locations, which represent individual steps of the circular economy the ‘route of circular economy’ explains how a modern circular economy works and which climate protection potentials can be realized in a successfully managed circular economy. Individual topics of the route along the value chain are explained below (in six topics). In the figures below you can see on the hand our map with a first range of localized projects of our ‘themed route of circular economy’ (1) and on the other hand the value chain of circular economy with our six topics, which are marked (2).

Figure 1 *Themed route of circular economy (Source: Klimaschutz durch Kreislaufwirtschaft e.V.)*

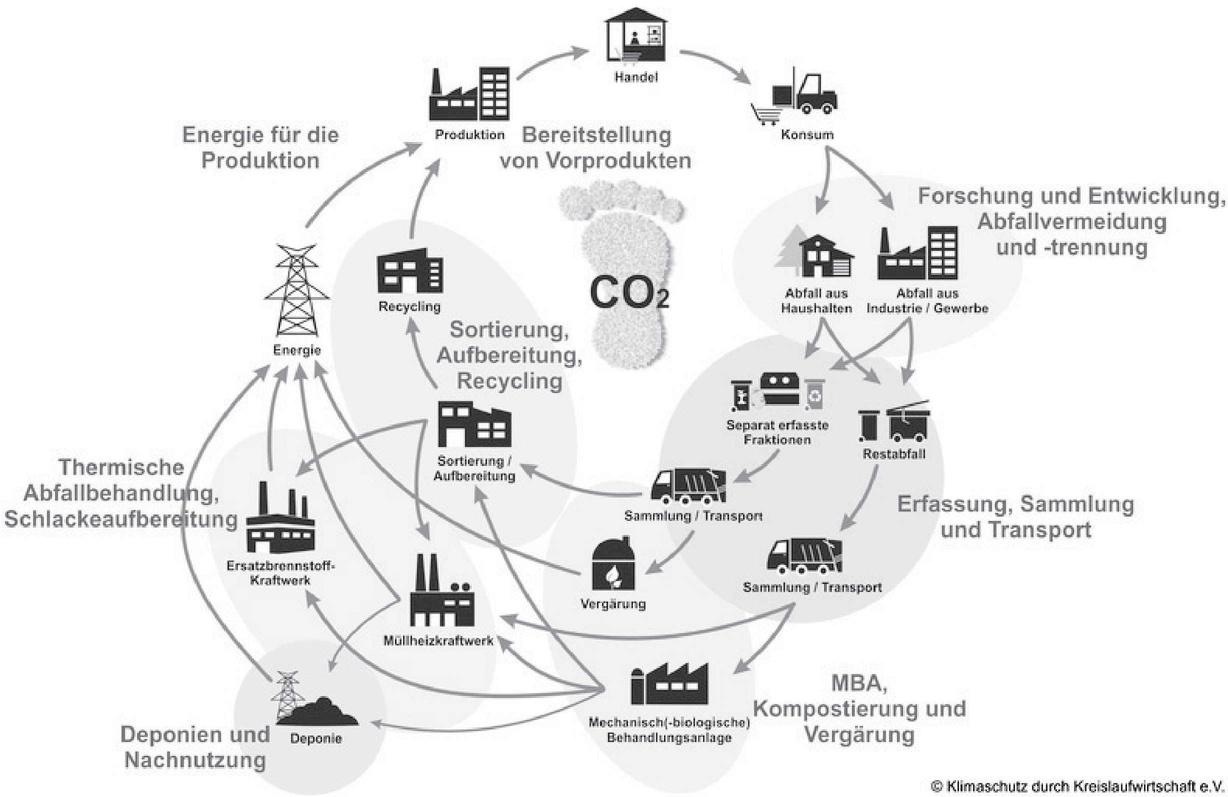

Figure 2 *Value chain of circular economy (Source: Klimaschutz durch Kreislaufwirtschaft e.V.)*

2.1 Topic 1: Research and development, waste prevention and separation

Our ‘themed route of circular economy’ starts with the history of environmentally friendly waste disposal. Thereby interactions between the ever-changing settlement structures of urban developments and consequent organizational and technological changes in waste disposal and treatment are presented in an illustrative manner and over time. How nowadays waste can be avoided and properly separated should be experienced in practice in so called ‘out-of-school learning places’. The aim is to promote a sustainable behavior in the field of waste prevention and waste separation to pupils and other visiting groups.

Furthermore in recent years a learning environment has been established in which nursery children, pupils, young people and adults have the opportunity, to learn all about the topics of waste prevention, climate protection and recycling. Important for the circular economy beside the knowledge transfer is to support the generation of knowledge, or better enable research with a focus on the ‘right’ ways of waste.

2.2 Topic 2: Listing, collection and transport of waste

The way from waste to a secondary product starts with throwing rubbish into a waste bin. For example, underfloor containers, which are presented in the themed route, save CO_2 emissions through improved waste separation and optimized logistics in contrast to classic and mobile types if a waste bin or an underfloor container is filled, the transport of waste is necessary. The world's first hybrid waste disposal vehicle, which is used on the route, contributes to the reduction of emissions, as it is operated with braking energy during the collection process. This vehicle generation completely switches off the engine during collection and is electrically driven and braked. Another energy-saving option presented is a waste collection vehicle with a battery, which is charged by using the normal electricity network during the night. The engine is only used whilst driving, the collection is thus a completely silent and emission-free operation. Furthermore, if introducing intelligent logistics concepts, long distances driven by trucks can be avoided. One concept, for example shifts residual household waste transports from road to rail, this way is not only reducing the number of collection vehicles on the road, but also the overall fuel consumption per year. After transport, there are basically two key options available for further treatment of residual waste:

- mechanical-biological treatment with the aim of regaining recyclable fractions, calorific fractions for energy from waste processes and using biological processes to obtain an output fraction, which can be landfilled

- thermal waste treatment with the aim of recovering electricity and heat as well as reprocessing metals contained in slags

2.3 Topic 3: Mechanical-biological treatment, composting and fermentation

Since mid-2005, it is not allowed to store un-pre-treated waste on landfill sites in Germany. As alternative mainly two different processes are used for the (per-) treatment of mixed residual and commercial waste. On the one hand, thermal waste treatment in incineration plants and on the other hand mechanical-biological treatment of waste. The advanced technology of mechanical-biological treatment processes residual waste into calorific fractions like RDF and SRF. Residual waste, which are no further recyclable, will be thermally utilized in a waste to energy plant. Through plant operation, which is shown in the themed route, almost 36,000 Mg CO_2 equivalent / year are avoided by energy recovery and by recovered metals.

2.4 Topic 4: Waste sorting, processing and recycling

Waste sorting, processing and recycling of recyclable materials such as plastic, glass, paper or metal is an important step for the circular economy and the associated climate protection, to either return materials into respective material circuits or to use the energy they contain. The most modern recycling plant (called *Wertstoffaufbereitungsanlage WAA*) in Europe, which is shown in our route, currently sorts about 95,000 tons of light weight packaging (LVP) from private households. Approximately half of this (43,000 tons) can be recycled, while the rest (52,000 tons) is used as fuel for the heat production - in waste incineration plants or in RDF power plants. From the processing of light weight packaging an annual saving of 73,000 t CO_2 eq. / a can be achieved.

Three key areas of expertise ensure that resources are protected and CO_2 emissions are avoided, for example at the industrial location Lippewerk. In many plants on the factory premise, different types of waste are processed and prepared for further use. For example, plastics are converted into granules, metal is sorted out from slags and remaining waste is turned into fuels. Industrial and household waste fractions are used directly as secondary source in the industry and last, but not least biomass is processed by biomass power plants to generated energy. Thus, *Lippewerk* saves about 416,000 tons of greenhouse gases each year in these technological areas of expertise.

2.5 Topic 5: Thermal waste treatment and slag processing

Thermal treatment of waste includes both, thermal treatment of mixed residual waste (originating from households and commercial entities) and sorting residues as well as recovery of RDF in wte and RDF power plants. Furthermore, thermal treatment also includes co-incineration of high calorific fractions (secondary fuels) in cement and coal fired power plants. This way, waste to energy plants fulfill three important tasks: treatment of residual household waste, treatment of the calorific output from sorting plants (RDF) and the function as a pollutants sink for sorting residues from recycling processes. Metals, which enter the thermal treatment process within mixed residual wastes can be recovered during a subsequent process of slag treatment. Nowadays thermal treatment in waste to energy plants generating heat, steam and electricity is a highly-developed waste recovery process: It destroys organic pollutants and emits inorganic pollutants for safe deposition. In the course of energy recovery, valuable secondary raw materials such as metals can be secured, ash form the thermal process can be e.g. used as construction material. Energy recovery of waste saves more CO_2 emissions than it generates.

2.6 Topic 6: Landfill and reuse approaches

Nowadays landfills stand for a permanent and environmentally safe deposit of inert (non-reactive) mineral wastes. In Germany until the ban of disposal of un-pre-treated waste in 2005 a large part of waste, including organic components, was disposed of. Particular methane, which emerged from those landfills caused a considerable strain on the climate. Today, methane from landfills is collected and by using combined heat and power plants converted into electricity as well as heat. Furthermore closed landfill sites increasingly serve as sites for photovoltaic and wind power plants.

3 Summary and perspective

To sum up, the 'themed route of circular economy' developed by our association combines thematically related projects and locations from different members of our association in the region of NRW in order to promote CO_2 -saving projects. All projects can be visited by interested experts as well as the public.

With our design of the first 'themed route of circular economy' the association would like to contribute actively to the decade-project 'KlimaExpo.NRW'. In the future the themed route will also be presented to the public on the interactive home page of 'KlimaExpo.NRW'. This way visitors will be able to find out more about individual climate protection projects belonging to the 'route of circular economy'. In addition the themed route will be constantly expanded and further improved.

4 Literature

BDE - Bundesverband der Deutschen Entsorgungs-, Wasser-, und Rohstoffwirtschaft e.V. (Hrsg.)/ ITAD - Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V. (Hrsg.)/ VDMA - Verband Deutscher Maschinen- und Anlagenbau e.V. (Hrsg.);	2016	Branchenbild der deutschen Kreislaufwirtschaft. Kompetent • Leistungsstark • Zukunftsorientiert
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5 Attachments: Pictures

Kick-off event 2015 Source: Ralf Breer

GREENTEC
AWARDS
2017 TOP 10

TOP 10 placement at the GreenTec Awards 2017

NRW community stand at the IFAT 2016 Source: Ralf Breer

Decarbonization and energy generation can go hand in hand: The future is climate-positive!

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Abstract

Biochar will change the world! Our planet's soil contains more than twice as much carbon as the atmosphere. The biggest species is carbon of pyrolytic origin (biochar) from forest or grassland fires, not because fires happen so often, but because this is the most stable and long-lasting way of storing carbon. These forms of carbon have an impact that we today sum up as fertility, a combination of increased water storage capacity while preventing water logging, increasing cation exchange capacity and increasing the catalytic surface, raising pH value and being reductive (anti-oxidising). Biochar can be made out of any organic residues. With state-of-the-art technology using an exothermal process, it can generate heat and power while also being much cleaner than any other solid fuel combustion process without exhaust treatment. If this biochar is incorporated into the soil after being used as feed additive, bedding material or simply being mixed with urine, each kilowatt-hour of energy generated would have a carbon footprint of minus 500g CO2 – and be climate positive. The world's soils are degrading – now we have a powerful tool to reverse this – and the global potential of harvest residues that are not otherwise used is large enough for pyrolysis and biochar to potentially stop or reverse climate change!

Keywords

Biochar, climate-positive, carbon-negative, material AND energy use of residues.

1 Initial situation

Agriculture makes a massive contribution to greenhouse gas emissions through the oxidation of ploughed fields, other types of humus loss (erosion) and methane, nitrous oxide and ammonia emissions from fertiliser production and the handling of farmyard manure (slurry rather than manure etc.) [1]. However, agriculture also has the potential to contribute towards reducing greenhouse gas emissions. The estimated potential in this area extends to fully offsetting anthropogenic emissions and even reducing the atmosphere's carbon content to pre-industrial levels [2]. The interesting aspect of the potential climate actions taken by agriculture are their additional local benefits (an increase in soil fertility, an increase in tolerance of extreme weather situations, a reduction in fertiliser loss and odour problems, an improvement in stable hygiene, a corresponding decrease in external costs for fertiliser, irrigation and veterinary treatment). These benefits some-times or even mostly exceed the costs of the measures, meaning that the global benefits of climate protection have no cost. [3].

One of these measures extends well beyond the confines of agriculture and into urban energy generation and material recycling: the pyrolysis of biomass-based residues to produce biochar. Pyrolysis is the thermal decomposition of substances containing hydrocarbons in the absence of air. It produces a hydrogen-rich gas mixture and a mixture of liquid substances (summed up as tar or pyrolysis oil) and coke or activated carbon, also known as wood char or just biochar, depending on the feedstock. When pure-grade plastics are used, pyrolysis can produce monomers and an amount of energy using the Hamburg process [4]. Since biomass pyrolysis is highly exothermal, energy is released simultaneously while still producing a material stream that can easily be used.

The most fertile soil in the world is called chernozem (black earth) and contains biochar that has either been created by natural processes, for instance by steppe fires in Ukraine and western Russia [5], or that has been added to soil by human hand together with manure and compost, something that was practiced 3,000 to 7,000 years ago in the Amazon basin (Terra Preta, literally black soil in Portuguese) [6] and in western Africa for at least 700 years (latest discoveries by ethnologists in Sierra Leone, Ghana, Guinea and Liberia [7]). However, further research brought out by these findings has now proven that carbon introduced as biochar remains stable for thousands of years across all tested types of soil [8]. At the same time, biochar can store other substances in the ground thanks to its large surface and initially high pH value; it can support beneficial transformation processes as ion exchangers.

Billions of tonnes of substances that are hard to exploit are awaiting meaningful use around the globe: harvest residues (straw, husks, shells, pulp, bark and kernels), landscaping cuttings (green cuttings, root wood with sand), materials extracted during composting, biogas and hydropower (screen residues, solid digestate and driftwood) and sludge that has already been digested or is hard to digest (sewage sludge and paper sludge).

Access to technical power and fertiliser is often especially challenging in rural areas in the tropics. Soil there is also often lacking in humus.

With modified technologies, pyrolysis-based solutions that generate energy and biochar locally or at least regionally can now be developed for all feedstock, wet or dry, and for any business size or even family-run micro-scale farms. This might be the Pyro-Cook [9], which allows a smallholder family in Haiti to turn dry garden cuttings rather than forest wood into charcoal while also cooking without smoke. Another example is the PPP120 plant [10], which generates biochar and process heat out of moist coffee pulp in a coffee processing centre for 30 smallholders or in a medium-sized business. This process simultaneously dries green coffee to marketable quality – or converts 4,000 tonnes per year of screening residues from composting generated by a major Swiss nursery with greenhouses into 600 tonnes of biochar, 500 kW of constant heat and 150 kW of constant power, corresponding to annual greenhouse gas reductions of close to 5,000 tonnes of CO2.

2 Approach

Ökozentrum has been developing and testing biomass energy systems since 1983. Since 1994, the centre has been refining the FLOX® (flameless oxidation) technology and has been developing the resulting lean gas burning technology and its industrial-scale use since 2004. Ökozentrum has favoured hot-air turbine technology for combined heat and power generation from solid biomass since 2006 [11] – and has thus also reviewed and refined this technology. The modified technologies are supported to series production both here in Central Europe and in development cooperation around the globe with local SMEs.

Coffee pulp is a pollutant residue whose use had been tested unsuccessfully since the 1960s [12]. Working on behalf of the Cleaner Production Center Initiative, Ökozentrum explored new solutions starting in 2009 [13] and suggested pyrolysis to make biochar in 2011. It developed a simplified process, which was successfully implemented and underwent laboratory testing in 2013. In 2014, a full-scale prototype was then built and tested for a Peruvian machinery producer for processing the coffee harvest. This technology turns up to 40 kg/h of moist coffee pulp with a water content of up to 54% into 70 kW of heat and up to 6 kg/h biochar. The first technology transfer workshop took place in 2015 [14], and the first plants are under construction or already up and running in Peru and Vietnam at the start of 2016. Dissemination in Vietnam and an agricultural research project with a smallholder cooperative with assistance from the German Research Institute for Organic Farming (FiBL) is presently being supported.

A network of professionals called CharNet was founded in Langenbruck, Switzerland in autumn 2015 given many activities and requests for information about biochar in the country [15]. This network pools research needs in the field of biochar and forges internal and external connections. It already has more than 70 members from the worlds of research (Eawag, ZHAW, FiBL, Agroscope, Ithaka and Ökozentrum), urban farming, agriculture, composting, horticulture, water and soil conservation and plant builders for small and large pyrolysis systems. CharNet has been an association member of Biomass Switzerland since June.

At the same time, Ökozentrum has been working together with an experienced Swiss builder of composting plants and biogas technology since October 2015 to develop a plant that combines the aforementioned lean gas technology, hot-air turbine technology and pyrolysis to create a robust unit that converts any kind of solid biomass residues, including impurities like sand, stones and plastic film, into biochar, power, heat, climate protection and very clean exhaust gases.

The new modified pyrolysis process, which we are calling PPP (for Pulpa Pyro Peru or Pyro Power Plant) for now offers some benefits: it requires less to no heat-resistant steel since heat is not introduced via the reactor surface, but directly enters the reactor by injecting exhaust gas low in oxygen. Consequently, the system is also impervious to overheating in the event of a blackout. The reactor is more compact as a result and does not need any internal conveying systems. The reverse flow means that gas is filtered and condensed by fresh biomass in the cold portion of the reactor. The gas is then almost free of tar and cold, and can easily be pumped. Tar is then returned to the pyrolysis unit with biomass and cracked to produce more carbon and gas. The resulting carbon immediately has the properties of activated carbon since gas activation is integrated into the process.

3 Results

3.1 Emission control

The most important element when introducing environmental measures is, of course, that they do not pose any new potential risks to land, water or air. As we know from traditional burning in furnaces, pyrolysis can also emit greenhouse gases, waste energy and create carbon that might produce substances toxic to the environment through heavy metals and chlorine components in the feedstock and through improper process management. The Ithaka Institute (Arbaz), Agroscope (Tänikon) and Eurofins Ost (Freiberg) thus developed the European Biochar Certificate (EBC) [16] governing all of these factors – both through limit values for polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and heavy metals and through a positive list of approved feedstock as well as a recommendation on the use of heat. Exhaust gases must also comply with exhaust gas rules.

Biochar adhering to the EBC rules has been “suitable to place on the market” in Switzerland since March 2013 under the Swiss Fertiliser Ordinance [17]. Its use as a feed additive is also approved in most European countries (including Switzerland).

Tests performed on the PPP system for coffee pulp have already shown that exhaust gas from this new process can comply with the most stringent of limit values, even without a filter. Exhaust gas is particle-free (below the measuring device’s measuring threshold) and carbon monoxide emissions are below 10 mg/m^3_n (at 13% oxygen) [18].

The carbon produced met the PAH limit values with a very large margin of error in all tested cases [18].

3.2 Climate protection

When this biochar is stored in humus soil, each kilogramme of carbon represents a reduction of 3.66 kg CO_2 in circulation and thus in the atmosphere. Considering the energy generated at the same time from pyrolysis, each kilowatt-hour (kWh) of useful energy generated removes 900 g CO_2 from the atmosphere because of prior plant growth into 500 g of dry biomass. However, the combustion process for pyrolysis gas does release 400 g CO_2. On a net basis, 500 g CO2 is thus removed from the atmosphere for each kWh of useful energy and is stored in the ground as 136 g of carbon. Therefore, it can be described as climate-positive energy.

The additional climate change effects caused by biochar in animal bowels, in stables, in slurry pits and on the fields by preventing other emissions (e.g nitrous oxide and methane) are not yet considered here. Some researchers estimate that this effect is at least just as large again [19].

3.3 Economics and technical implementation

Since a pyrolysis unit works very quickly compared with a biogas plant, for instance, with feedstock only staying in the reactor for about an hour (for drying, heating, pyrolysis and cooling), its design is compact, too. Like in a combustion system, energy is also released within a few minutes and technology can thus start up and shut down just as quickly. These systems thus deliver process energy as needed.

Including the benefits of biochar, a market value close to charcoal is created – but it can even be higher as a feed additive (similar to activated carbon). Data collected worldwide reveals a spectrum of USD500 to €1,300 per tonne for large purchases (big bags (1.3 m^3) or larger).

The market value of the energy is primarily based on the decrease in internal consumption by agricultural or industrial businesses. It was estimated to stand at CHF0.16 per kWh of power and CHF0.06 per kWh of heat for the purposes of the following statements.

Based on these figures, it can be said that the income from producing biochar and energy each contribute about half to revenues. A pyrolysis system might be multiple times more affordable than a dedicated biomass energy plant, assuming that even “worse” fuels than a biomass heating power plant and thus fuels that are cheaper or even free or subject to waste management costs may be used and no post-treatment of exhaust gas is needed.

From a climate protection standpoint, it can be said that income of USD/CHF/EUR300-500 per tonne of CO_2 captured (again without additional emission mitigation by carbon in agriculture) is generated.

Therefore, this is presumably the only **carbon capture and storage (CCS)* technology** that not only costs nothing, but actually generates income!

(*)CCS generally relates to industrial-scale concepts that capture CO2 from exhaust gases emitted by fossil fuel power plants (hard coal, brown coal and heavy oil) so that it can be deposited in the earth's interior in former underground mines or empty gas or oil fields. These approaches are rightly criticised because they alter pressure in the earth's interior and appear to mainly serve as an excuse for coal-fired power plants to receive a reprieve. All of these technologies very clearly have two drawbacks: they cost energy and money so nobody adopts them voluntarily.

4 Discussion and outlook

Consequently, pyrolysis can close another material cycle in agriculture around the globe that creates many additional benefits. It can also make biomass power plants significantly more affordable and, not least, make a sizeable contribution towards protecting the climate without requiring financing with certificates or other subsidies. The following section shows existing (blue) and new (red) material and product streams in the context of a Swiss agricultural business that already uses pyrolysis.

Worldwide research in this field is yielding very encouraging signs; the improvements in yields are massive in the tropics. If every square metre of arable land around the globe produced 200 grams of carbon from harvest residues that is returned to the ground, this would offset all anthropogenic greenhouse gas emissions. However, this process must be clean and also use the released energy. So, let's clean up!