Pulpa Pyro Peru - Clean generation of biochar and energy from coffee pulp

This project is about the development and technology transfer of an appropriate waste-to-power and energy plant for harvest residues on small to midsize farms. With the support of the consulting company SOFIES-EMAC, the success of this project has been additionally increased: After successful testing during winter 14/15, a technology transfer workshop has been organised in July – but not only with a delegation from Peru, but as well from Vietnam. Furthermore, a professional documentary film team accompanied the workshop and produced a very helpful and informative short video which was distributed to all project partners.

At the end of the workshop, a tour was organized to see a farm in central Switzerland, which already applies pyrolysis and uses the biochar in different ways in the barn, in the manure and to produce new soil (humus). After a handshake with Federal Councilor Burkhalter at the national day ceremony in Zurich, the two delegations turned back to their countries with a full documentation of the full size prototype and the knowledge to adapt the technology according the local needs. Only six weeks later – the first photographs reached us from Vietnam, showing their plant in production.

In 2014, a scientific full size plantation test was started in Peru by the team CER: An array of young coffee bushes have been given a variety of mixtures of compost and biochar. After the second harvest until now – the first results of the soil benefits can be presented. The very good results in terms of emission levels and the flexibility of the new developed process increased as well the interest within Switzerland, so that a collaboration with companies in the clean tech industry could be initiated by end of September 2015. With the help of REPIC, press articles could be placed which rose additional international interest – from Nicaragua and El Salvador.

The now important following projects in Vietnam and Peru have to ensure, that the success of this project is being spread and the pioneers receive support in the target countries.

Final report

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29th December 2015
1. **The carbon balance from a global and a local perspective**

![Diagram of global carbon cycle and deposits. Source: Wikipedia](image)

The soils store more than the double amount of carbon compared to the atmosphere. Talking about Greenhouse Gases and Climate Change, without taking the soils and agriculture into the discussion, would be ridiculous. However politics does not fully reflect these facts so far.

The circle-turnover of CO2 from agriculture is 3 to 4 fold bigger than the complete output of mankind burning fossil fuels. If agriculture makes "mistakes" in this balance of more than 20 Giga-tonnes CO2 in and out of the soils of the year, the problem will be big. And agriculture as it is performed today creates severe problems in many regions of this planet:

1) Carbon loss through oxidation caused by ploughing and while drying wetlands
2) Carbon loss through oxidation caused by ground water level decrease (overuse of water) caused by inadequate watering and losses through evaporation
3) N2O emissions through inadequate application of fertilizer
4) CH4 emissions through inadequate composting and fermentation methods.
5) Emissions and energy demand created by fertilizer lack in one region and overproduction in a different region through the distances between cattle feed production and the cattle (for example soya from Brazil for cattle in Europe).
6) Losses of micro-organisms and soil flora and fauna through soil treatment methods and agrochemical substances – and therefore erosion due to decreased soil stability.
7) Erosion and soil losses though mono-cultures and too much "open time" (bare land) between planting cycles.

a.s.o.

*Carbon and fertilizer loss is both a local and a global problem: It reduces the soils fertility and increases Greenhouse gas content of the atmosphere.*
2. **Terra-Preta – it started more than 3’000 years ago**

![Figure 2 comparison of the “normal” poor oxisol soil and the Terra Preta soil, both found in the Amazonian basin (Peru and Brazil). Picture: elfenwald.org](image)

Throughout the last 500 years, Terra Preta (Portuguese: black soil) spots have been used for agriculture in Brazil without neither loss of fertility nor suffering erosion, enjoying a big crop yield. These soils are quite untypical for wet tropical regions where usually Oxisols with very limited humus content are found. Nobody questioned the natural background of these black soils until scientists discovered, that these soils where created by mankind of a culture at least 3'000 years ago: The soil has been built up by mixing feces with char coal created from branches, leaves and other harvesting residues, as well as with bones and other waste of mostly mineral content. However the charcoal pieces where found still “complete” – the char remains stable in the soil, without turning into hydrocarbons. The role of the biochar seems to be different compared to biomass and other living elements – more likely a structural element like the core of a coral reef – creating habitat for micro-organisms, providing a big surface and cavities to accumulate water and storing other substances, create an environment of high pH-value, acting as a catalytic surface.

Also in Europa, elderly gardeners remember that char coal dust is very good to create fertile garden soils comparable or even better than adding peat (Turf). The soil beneath charcoal kiln was used as a soil for gardening.

The most fertile soils in Europe have been found covering 56% of the surface of Ukraine. The very thick black humus layer (Tschoronozem [45]) is explained by natural bush- and grassland-fires (ignited by thunderstorms) that generated a natural mixture of biochar and compost.

After the turn of the millennium, research and application started around the globe to learn about biochar from biomass residues, how to produce and apply it as well as measure its influence on both soil and climate effects.
3. The coffee farmers needs – the driver for this project

Figure 3  piles of coffee pulp waste – need for energy (drying in the drum-dryer) – high costs for Potassium (K) and Nitrogen (N) fertilizer. Photos: J. Schmidlin; CER Peru

Since more than 60 years intensive research has been performed to develop solutions to get rid of the piles of coffee pulp waste. The pulp is tough and moist - pulp is:
- Composting very slowly, creating acid liquid that mix with ground water – the resulting sour compost is of low value for the already acidic soils [1,8,29] [with exception of application in a special Lombri-culture 34, 35].
- Not useful as a cattle feed – only as an addition in very low percentage remains digestable [8, 29]
- Could be partially used as a source of Pectin – but turned out not to be economic. [1,8, 29]
- Not burnable [2] in a fire place or biomass boiler.
- It is not suitable for biogas plants (too sour and containing biozids) and biogas in general is not suitable as the coffee harvest is only 6 to 8 weeks per year [4,28].

On the other hand, the farmer needs on-site and in-time energy to process the coffee – because he sells the coffee pre-pealed and dried as so called “café pergamino”. That means that the coffee still contains the silver skin or hard shell but is dried to 12% total water content [5]. Therefore, additional fuel has to be used for heating the drying process.

Thirdly – there is a need for fertilizer: The farmer has to decide between spending roughly 1’000 US$ per hectare and year for fertilizer [5] or live with significant less harvest.
4. What’s in coffee pulp?

<table>
<thead>
<tr>
<th>Prüfparameter</th>
<th>Prüfmethode</th>
<th>Prüfergebnis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wassergehalt</td>
<td>DIN 51 718</td>
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<tr>
<td>Kohlenstoffgehalt</td>
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<td>44,2</td>
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<td>Wasserstoffgehalt</td>
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<td>Stickstoffgehalt</td>
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<td>Sauerstoffgehalt</td>
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<td>Schwefelgehalt</td>
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<td>0,173</td>
</tr>
<tr>
<td>Heizwert, unterer</td>
<td>DIN 51 900-2</td>
<td>16983</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td>1580</td>
</tr>
<tr>
<td>Aluminium</td>
<td></td>
<td>448</td>
</tr>
<tr>
<td>Silizium</td>
<td></td>
<td>636</td>
</tr>
<tr>
<td>Phosphor</td>
<td></td>
<td>1480</td>
</tr>
<tr>
<td>Chlor</td>
<td></td>
<td>767</td>
</tr>
<tr>
<td>Kalium</td>
<td></td>
<td>53800</td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
<td>14300</td>
</tr>
<tr>
<td>Schwefel</td>
<td></td>
<td>1730</td>
</tr>
<tr>
<td>Mangan</td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>Eisen</td>
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<td>2</td>
</tr>
</tbody>
</table>

Figure 4 chemical and physical analysis of Coffee pulp, wood pellets, cereal milling residues, elephant grass.

It is clearly visible, that coffee pulp contains high amounts of Potassium (Kalium K-Fertilizer), Calcium, Nitrogen (N-Fertilizer) and Phosphor (P-Fertilizer) – which is very positive for its use as fertilizer and significant contents of sulphur (corrosion), chlorine (corrosion + potential for dioxins), silicium (slagging) and magnesium (slagging), which is a bad message for everybody that wants to burn it in a conventional energy system (steam boiler e.c.).

The energy content (heat value) is reasonable with respect to the high ash content of 11% of weight. However tests have shown that it is not burnable without a co-combustion fuel [2].

Coffee pulp contains high amounts of phenols which are biocides

Summary:

1) Coffee pulp or its ash should be used as a fertilizer – however without being so
2) Acid – the pH-value has to be risen significantly
3) The duration of the composting should be shortened significantly and
4) The energy should neither be used by combustion nor fermentation
5) Potential Toxics should be cracked.

The solution that could potentially fulfil all mentioned needs it the pyrolysis.
5. Pyrolysis - a short explanation

Pyrolysis is a thermal process with more or less complete absence of oxygen. With biomass, the process is partly auto-thermal (as the biomass itself contains oxygen) and emits a mixture of gases that are of medium to high heat value. Together with the combustion of this gas, the process is highly exothermal. Besides of the pyrolysis gas, the biomass is cracked into pyrolysis oil and char coal, the so called biochar (Pflanzenkohle). Roughly half of the heat value remains in the char – the other half is set free to be used in and after the process.

Pyrolysis is widely used for plastics recycling - to return them into monomers and gaseous fractions. This method is called "Hamburger Verfahren" and needs a complex installation that looks similar to a petrol-refinery.

The "real pyrolysis" is a very intensive consumer of high grade steel. In the following, the process is explained using a Pyreg P500 [pyreg.de] plant as an example:

![Pyreg P500 plant with optional Exhaust Harvester® Turbine (innovation by Ökozentrum).](image)

The double wall pyrolysis reactor (in the upper center of the picture) with rotating locks on both ends is heated from outside with 1'000°C exhaust from the pyrolysis gas burner (upper right). The biochar and the pyrolysis gas leave the reactor both on the “hot side”. The indirect heating heats the inner steel drum of the reactor to almost 800°C. Together with the erosive and corrosive ambient inside the reactor – **highest grade steel is needed.** Through the way of the pyrolysis gas (and oil vapor) along the biochar outlet side – it carries biochar dust with it. A contamination of the biochar with tar-fractions condensed from the gas flow was not observed in the existing systems. However three disadvantages can be observed:

1) Need for high grade steels
2) Loss of biochar and mineral dust entrained by the pyrolysis gas
3) Loss of biochar by entrained oil vapors that would otherwise split into gas and biochar if furtherly treated (thesis).
6. PPP-method

The new process developed in the beginning of this project has not yet a name – we call it PPP-process (after the project name Pulpa Pyro Peru – or Pyro-Power-Plant) – it is a mixture of pyrolysis, steam-reforming, gasification – with a variety of degrees of freedom:

![Diagram of PPP120 plant](image)

**Figure 6** PPP120 plant, as it has been developed for this project.

The biomass-waste is feed via the lock (in this project designed as a rotary valve) into the reactor. The reactor remains always full during nominal service. The lean gas low NOx burner (FLOX®) is started with a liquid or gaseous fuel (propane in this project). The clean exhaust gas of this burner is being split into a portion that directly reaches the dust cyclone and the heat use – the other portion returns via reactor back to the burner. This hot exhaust recirculation EGR is cooled to the appropriate temperature at the entrance into the reactor.

Through this hot EGR, the reactor is directly heated internally. The wall temperatures of the reactor are <500°C and can be produced from normal steel or even as masonry or fire brick or concrete, as there is no need for heat transfer. The reactor can be designed more compact and in the case of coffee pulp, rice husks, cashew shells, cherry seeds and other free-flowing input, there is no need for any mechanical transport devices within the reactor. The pyro-gas the leaves the reactor is of course diluted with the EGR which has no negative effect on the combustion. The pyro-gas / exhaust mixture passes on its way through the reactor the yet cold and fresh input – which has a filtering and a condensing effect: tar and dust remains in the reactor and will later processed again into biochar and gas.

The combustion is performed at low excess air ratio – close to 1 – resulting in an exhaust gas with 1 to 5% oxygen content. To still be able to control the combustion temperature – cold EGR can be taken from the “chimney” (stack) at the very end of the process. However an elevated oxygen content up to 15% for short periods (time) does not have a negative influence on the process in the reactor. Only at oxygen levels >15%, the process reverses – the reactor would start to burn and the temperature would
rise in the upper part of the reactor. However even this situation would remain completely controllable and reversible – it has been tested with the bench scale PDU (2 kg/h input) in the first 9 months of the project.

Additionally the PPP-process offers the flexibility to chose between more energy and more concentrated minerals or more biochar, less concentrated mineral output. The Boudouard-Equilibrium describes the reaction of CO2 and C to 2 x CO at high temperatures (>85% reaction at >900°C) or remaining C and CO2 (<15% reaction <650°C). Additionally, water vapor reacts as well at high temperatures with C to hydrogen and CO. As our hot EGR contains CO2 and water vapor, we can choose by controlling the temperature, if “only” pyrolysis shall happens or additionally steam reforming and gasification. Read more in chapter 8.4.

7. The full-size prototype

7.1 Evaluation results from the pre-study

Before this project could be started, a pre-study of the Literature and in the field in Peru was performed. It was financed by the National Cleaner Production Center of Peru CER – indirectly support by the SECO of Switzerland. Besides the findings that have been mentioned in chapter 4 according needs and methods – the pre-study was also made to learn about size and integration.

In the Peruvian mountains, the world’s highest quality of coffee is being produced on altitudes varying from 1’000 to 2’000 m above sea level. The average size of a coffee plantation is only 2.5 ha per finca. The harvest time is only 6 weeks to times per year – however over the different altitudes – the harvest spreads over 10 months. Several small farms together run a beneficio, where the coffee is pre-dried to be sold. It is sold as “Café pergamino” (coffee bean including the hard shell “cascarria” or “silver skin”. The pulp and the sludge “mucielago” is being peeled and washed away in the wet process before drying. A typical dryer is a drum dryer with a 50 kW hot air generator as mentioned in Figure 3. Bigger plantations in Peru reach a size of 100 ha but not more. Per beneficio, the typical power demand is between 5 and 10 kW electric.

At the end of the pre-study and until now, three Letters of Interest LoI for such a waste pyrolysis plant have been signed by a cooperation of fincas in the region of Cajamarca as well as two farms in the region of Villa Rica. Additionally a LoI was signed with the most important producer for coffee harvest treatment equipment, the company IMSA in Lima, origin as well from Villa Rica.

The unit should be transportable – at best on a pick-up-truck “camioneta” – should produce 50 kW of useful heat and therefore needs an input of 100 to 120 kW coffee pulp by heat value.

Figure 7 (B) Planta movil con un modulo tamaña medio con secadora mas simple, usando directamente el aire caliente.

The finally chosen version had a connection with a flexible air channel directly to the dryer.
The most important findings were on the economic side: the unit pays itself back by far more via the fertilizer savings than by the fuel savings. Because – the most often used fuel is cascaria or wood which is relatively cheap. The most often used fertilizers are imported Potassium-Clorides.

<table>
<thead>
<tr>
<th>Rentabilidad de una unidad (375 t Pulpa/a = 150 ha Cafe, 156 d à 16 h = 3'000 h/a servicio)</th>
<th>Var1</th>
<th>Var2</th>
<th>Var3</th>
<th>Var4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahorro Secado (cascarilla) $/a</td>
<td>(240 soles/t)</td>
<td>8'102</td>
<td>8'102</td>
<td>8'102</td>
</tr>
<tr>
<td>Ahorro Fertilizante KCl (-100%) $/a</td>
<td>(-72 kg/ha*)</td>
<td>9'750</td>
<td>9'750</td>
<td>9'750</td>
</tr>
<tr>
<td>Ahorro Fertilizante Urea (-25%) $/a</td>
<td>(-75 kg/ha)</td>
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<td>6'188</td>
<td>-</td>
</tr>
<tr>
<td>Certificates (GS-Microscale) $/a</td>
<td>(3.9$/t CO2eq)</td>
<td>1'682</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vento carbon vegetal $/a</td>
<td>(0.6 sol/kg)</td>
<td>7'064</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Soil improvement $/a</td>
<td></td>
<td>n/a</td>
<td>n/a</td>
<td>-</td>
</tr>
<tr>
<td>Ingreso maximal $/a</td>
<td></td>
<td>25'722</td>
<td>24'040</td>
<td>15'166</td>
</tr>
<tr>
<td>costo planta PPP $</td>
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<td>20'000</td>
<td></td>
<td></td>
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<tr>
<td>interes de credito</td>
<td></td>
<td>17.80%</td>
<td></td>
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<tr>
<td>costos de capital annual (5a) $/a</td>
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<td>31.83%</td>
<td>6'366</td>
<td>6'366</td>
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<tr>
<td>mantenimiento $/a</td>
<td></td>
<td>800</td>
<td>800</td>
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</tr>
<tr>
<td>gastos de personal $/a</td>
<td></td>
<td>6'500</td>
<td>6'500</td>
<td>6'500</td>
</tr>
<tr>
<td>gastos camioneta $/a</td>
<td></td>
<td>1'500</td>
<td>1'500</td>
<td>1'500</td>
</tr>
<tr>
<td>beneficio $/a</td>
<td></td>
<td>10'556</td>
<td>8'874</td>
<td>0</td>
</tr>
<tr>
<td>beneficio</td>
<td></td>
<td>41.0%</td>
<td>36.9%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

(* = 37 kg K (Potasio) = 72 kg KCl (cloruro di potasio))

Erklärungen zur Wirtschaftlichkeitsrechnung:
Beim Ersatz des Brennstoffes wurde der preisgünstigsteste Ersatzbrennstoff angenommen, mehrfach günstiger als Heizöl oder Propan
Der Vorteil, dass das Kalium als reines Kalium oder Kalium-Hydroxid anstatt KCl vorliegt, wurde nicht berücksichtigt.
Beim eingesparten N-Dünger wurde eine Einsparung von 25% (Literatur spricht von 30 bis 40%, siehe Vorstudie) ausgegangen
Beim CO2-Handel wurden die aktuellen Zahlen für den Goldstandard-Microscale von Myclimate angenommen, mit -1.15 t CO2 / t Pulpa
Die erzeugte Pflanzenkohle kann nur alternativ als Holzkohle verkauft werden. Es wurde der günstigste Marktpreis in Peru (0.6 sol/kg entspricht 240$/t) angenommen - der höchste im Internet gefundene für Peru gültige Preis beträgt aktuell 490 $/t
Die restlichen Wirkungen auf die Umwelt (weniger N-Verluste, mehr Wasserspeicherung) wurden vernachlässigt, weil sie noch nicht bezifferbar sind.
In Variante 4 wird die Anlage zinslos vorfinanziert oder selbst finanziert, es werden nur die entgangenen Bankzinsen von 2.3% gerechnet, was bei 5 Jahren eine Annuität von 21.40% anstatt 31.83% ergibt.

Figure 8 economical analysis from the pre-study.

Finally, the figures turned out to be correct mostly – only the revenue if the biochar is sold as charcoal for cooking is much too low: the value of charcoal is about similar in Peru as in Europe (900 to 1’000 US$/t, 2.5 sol/kg), so that the income in ”Var3”would be similar to”Var2”.

7.2 The bench-scale PDU

For the validation of the new PPP-process idea, a bench scale unit was built 2013 and tested until April 2014.

Figure 9 PDU I with horizontal/slightly upwards oriented reactor (left) and the original sketch from the study 2012 (right). For the sake of science, additional measurement devices are attached.
Figure 10  PDU II with the vertical reactor and natural circulation. Additionally, the cyclone for the collection of the finer particulates is added (central left). The burner is hidden behind the reactor.

7.3 The fullsize prototype

Figure 11  The final size of the unit was taken into service and testing in October 2014. Tests have been performed until February 2015 and during the Workshop in July 2015.
Continuous operating semi-automated biomass pyrolysis system:
Automated input and output rotating valves and vibration feed unit, lambda sensor controlled FLOX® burner, automated pressure controlled exhaust fan,

**Input:**
25 to 50 kg/h biomass waste with 0 to 55% water content (0 to 120% hum. bone dry)
Electricity connection tri-phase, 1.5 kW
To start (10 to 20 minutes) liquid gas (approx. 1 kg per each cold start)
Fuels tested:
Coffee pulp, wheat husks, cherry seeds, cashew-shells, hemp straw, wood chips, grape pomace

**Output:**
Hot air 35 to 70 kW, Temperature according customer needs >50 <100°C
Biochar (bio carbon) up to 22% of dry mater of input
Approx. 45% of biomass energy in heat – 55% remains in biochar

**Emissions:**
Pariculate matter <5 mg/m³ @13% O₂ (Swiss clean air act for waste incineration: 10, for agricultural waste combustion: 20 mg/ m³)
Carbon monoxide: <10 mg/m³ @13% O₂ ; NOx very low but depending on substrate.

**Yearly savings on a coffee plantation:** up to 16’000 $ fertilizer and 8’000 $ fuel = 24’000 $/a

Customer price target: <24’000 $/unit
Producer for Peru and all Americas: IMSA café, Lima: contact: sidunosara@gmail.com

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**7.4 The integration into the coffee production**

![Diagram of coffee production chain](image)

**Figure 12** Integration of the PPP-unit into the coffee production chain: in blue the existing paths – in red the additional benefits and product paths – in brown the not anymore necessary.

Even if a PPP-unit is too big for a plantation – it could produce additional products to be sold.
8. Results from testing the PPP-system

8.1 The emissions in the exhaust

It is very important, that the emissions of such an installation do neither emit environmental pollutants or particles that could be in conflict with clean air acts – nor emit Greenhouse-relevant substances. The original target was to reach emission levels similar to Swiss Clean Air act (LRV) for wood combustion. However the test have shown, that the unit is so clean, that PPP120 fits even into - the regulations for agricultural waste incineration (LRV: “Anlagen zum Verbrennen von biologischen Abfällen und Erzeugnissen der Landwirtschaft”, Ziffer 74) or even - big waste incinerators (LRV: “Anlagen zum Verbrennen von Siedlungs- und Sonderabfällen ”. Ziffer 71)

without a need for a filter.

The results can be summarized as follows – testing performed with cherry seeds (54% water content) and wood chips (35% water content):

<table>
<thead>
<tr>
<th>Topic</th>
<th>Measured</th>
<th>LRV 74 (agri)</th>
<th>LRV 71 (waste)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate matter (pm)</td>
<td>&lt;5mg/m³ (13%O₂)</td>
<td>20mg/m³ (13% O₂)</td>
<td>10mg/m³ (11% O₂)</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>&lt;15</td>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>Nitrogen oxides (NOₓ as NO₂)</td>
<td>2*</td>
<td>250**</td>
<td>80</td>
</tr>
<tr>
<td>Combustion power (allowed)</td>
<td>80 kW</td>
<td>(&gt;70 kW)</td>
<td>(&gt;350 kW)</td>
</tr>
</tbody>
</table>

(*) depending on fuel – 2 with propane, not systematically measured with other fuels. The FLOX burner does hardly produce any thermal NOₓ – the NOₓ generated are depending on the input material nitrogen content – however nitrogen mostly remains in the biochar with pyrolysis

(**) at a NOₓ mass flow >2'500 g/h – below no limitation.

Why are the emissions so low?

The answer is already written in the low particle concept of Ökozentrum 2003 [13] from which the PPP-process is a further step forward: when the reaction zone is lacking oxygen and the temperatures are below 800°C, no low melting oxides from minerals and fuel-nitrogen are being created – and therefore not evaporated. Using only EGR instead of diluting the primary air with EGR and performing pyrolysis at 500°C instead of gasification at 750°C, the emissions are even lower than found in 2003.

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![Figure 13](image.png)

**Figure 13** Oxygen and CO measurements during 7 hours of testing with wood-chips and cherry-seeds. Oxygen on the left scale – CO on the right. At 5:40 there is a CO peak and oxygen was at zero – that was because the lambda-sensor was not yet used to control automatically.
The emissions via the biochar

It is equally important, that the biochar does not carry any toxics into the soil. H.P. Schmidt from Ithaka-Institute and Isabel Hilber from Agroscope developed therefore a catalog of requirements that should be fulfilled by biochar – the so called European Biochar Certificate EBC. With the EBC, it became possible by March 2013 to authorize and register biochar from woody residues to be a “fertilizer-like substance according the Swiss fertilizer regulation” (Eidg. Düngemittelverordnung). The EBC sets limits for the 16-PAK (typical polyaromatic Hydrocarbons), PCB (chlorinated diphenyls) and heavy-metals.

As we tested only natural biomass with low chlorine content, only the 16-PAK-test was done from seven samples from hemp straw, coffee pulp, wood chips. The results showed levels (1.2 to 5.3 mg/kg d.m.) far below the limit of 12 mg/kg dry matter according the EBC. The tests where only performed with samples from the bench scale PDU, which didn’t deliver such a constant quality than the full-scale prototype. We are convinced, that the levels are even lower with the PPP120.

News from research at Agroscope RT (ZH): biochar and active char are both used as well to decontaminate soils. This means, that the chars are taking toxics up and don’t release them anymore. This changes the view on the toxics that are already in the char: will they be bio-accessable? Will they be washed out into ground water? The future goal is to define an environmental-accessibility rather than a total content of heavy metal or PAK in the biochar.

News from research at Kaskad-E: There is no clear correlation between smell and PAK-content of biochar. We have to admit that this attempt to create a simple test has failed. However it seems more and more obvious, that PAK is not a topic for the biochar from the PPP-process – and the other (Heavy-metal and PCB) tests are not necessary as long as the origin and content of the waste is known and is natural biomass.

The “dirt” within the system – how about the handling of PPP120?

Figure 14 View from an opening in the top of the reactor down to the EGR-tube. The reactor remained clean „like new“ during 10 tests with approximately 60 operating hours between October and December 2014.

In general, the system does not accumulate any substances – the reactor and the burner remains clean. There is only one critical point that has to be observed carefully:
Figure 15 right there where the pyrogas enters the burner...

If the reactor is emptied at the end of the service – the filter effect of the wet and fresh input disappears: This can result in forming a sticky foam out of biochar dust and soot in the burner head. However this can be melted away with the next start – or not even created by stopping the system with a full reactor.

8.4 Effect of the Boudouard-Equilibrium onto biochar yield – visions:
Continued from chapter 6: The inlet temperature of the EGR into the reactor influences the biochar yield very much:

![Boudouard effect on biochar yield](image)

Figure 16 influence of exhaust inlet temperature on biochar yield.

A biochar yield of 22% of the d.m. of the input is quite good for a substrate with low ash content (wood). 29% would be the theoretical maximum at zero percent side reaction neither with water vapor of the substrate nor oxygen from leakages. However we had earlier experiments with yields as low as 7 to 10% at inlet temperatures around or above 900°C.
With 22% d.m. biochar yield, 55% of the energy remains in the char, 45% are in the gas. With 7% d.m. biochar yield, 18% of the energy remain in the char, 82% are in the gas. With other words – controlling the inlet temperature can change the power output by a factor of 2, without changing the input – and reduce the biochar output by a factor of 3.

Now thinking about the recycling of phosphor from sewage sludge or potassium from coffee pulp – this opens a new perspective. Let’s take the example of coffee pulp:

The total mineral content of coffee pulp = 11% d.m.; Potassium K = 5.3%.
Creating “normal biochar” out of it – it will have: 35.5% mineral content; Potassium K = 17%
Creating “concentrated fertilizer” out of it: 63.8% mineral content; Potassium K = 31%

However the bio-accessibility is part of ongoing research at several institutes in Europe – especially on phosphor [49, 50].

9. Results from testing coffee plants with biochar

Under the lead of CER, field testing has been performed in Peru on the plantation of COOPARM, Finca Santa Josepha.

Figure 17 Instruction how to applicate dry fertilizer and similar treatments close to the flat roots of a coffee plant. The same instruction was used to apply the Terra Preta produced from the biochar.
Unfortunately – and through the lack of bigger amount of biochar made from coffee pulp, the team decided to add a constant amount of mixture of biochar and compost – instead of a constant amount of compost with an increasing amount of biochar. A total of 20 plants was studied – four plants for every parameter studied.

Figure 18  Soil sampling (left) and marking (right) of the respective coffee plants on the test plot at COOPARM, Peru.

Figure 19  Coffee harvest of 20 plants treated with 0 to 3 kg compost and 0 to 2 kg biochar. Each column represents the first and second harvest of 4 plants with the same parameters of treatment – and therefore also the “radius” (half) of the standard deviation that shows the range of the results.
The results cannot be said to be significant. It is obvious and “normal”, that biochar without any additional nutrients does reduce the soil fertility in the first year as the sponge effect attracts existing nutrients to move into the biochar “being stored for later”. However this would not explain the low values of T3 (1 kg biochar and 2 kg compost). So if somebody wants to see positive effect – it could be done so with T2 and T4 – however scientifically spoken, there is no effect to be reported. We don’t know about the respective size of the plants at the begin of the tests, the shadow, the ground water access for each position. However it is clearly visible, that there is no negative effect of the biochar onto the plants – except the mentioned T5, where “empty” biochar is applied “potentially slowing the flow of nutrients” to the plant roots.

It will be interesting to learn about the behavior of the plants in the future, when the biochar can “play the role of managing” water and nutrients over several years. We are trying hard to maintain contact to the people that know about this project – however it is not easy since CER activities have been reduced significantly and so has been reduced the support of SECO/UNIDO-RECP it.

10. Power generation

10.1. Overview

Generation of power via the cleaning of pyrolysis gas or oil to be fired internally in an engine or gas turbine has never been an option. After 35 decades of own experience in decentralised energy systems and 31 years with cogeneration systems (combined heat and power CHP) CATSE is still convinced that a small, robust, simple CHP system will rather be with complete combustion first – and thermodynamics after. The loss of so many companies in the field of biomass gasification CHP and the extrem demand on the fuel quality of still existing systems on the market confirm our choice.

With complete combustion: 4 possibilities are remaining:

1) Steam (organic or water rankine cycle) – very complex and economically feasable >500 kWe (4'000 kW thermal input)
3) Externally fired gas turbine / hot air turbine/motor: simple and feasable for systems above 50 kWe. CATSE develops and tests systems since 2006.
4) Inverted brayton cycle turbine/motor: not very efficient but very simple and feasable for clean exhaust (low particle) – economic feasability starts at 3 to 5 kWe. CATSE develops and tests systems since 2007.

The advantages of air/exhaust systems compared to steam are given by physics:
- With a given amount of heat – much more volume expansion can be created with air than with production and overheating of steam
- An air heat exchanger will not explode – only leak - if cracked opern. A steam boiler...
- The open air cycles do not make necessary to cool the working fluid down to the lowest cycle temperature.
- The end temperature of the cycles are high enough to fulfill all wishes about heat use (typically above 300°C).
- With inverted brayton cycle – it is possible to directly use the exhaust gas without any heat transfer costs and temperature losses.

From the above mentioned 4 possibilities, (3) and (4) are planned to be applied in CATSE-projects. Unfrotunately, the solutions are not yet so much ready and cost effective, that they could have already
been integrated into this project, into the full-size prototype PPP120. However we will report about the state of art:

10.2 Inverted Brayton Cycle Turbine – direct use of the exhaust

![Inverted Brayton Cycle Turbine Diagram]

**Figure 20** the inverted Brayton cycle exhaust turbine is very simple: it consists of a turbocharger and a cooler. It can create a suction (pressure lower than ambient) at p1 and overpressure at p4 – which both can be used to either save energy from existing blowers, fans, increase efficiency of an existing power plant or – or give the mechanical power to an expander with a generator.

![Inverted Brayton Cycle Turbine Diagram]

**Figure 21** For lean landfill gas flaring, CATSE already applied this technology in three units. The first is in service since May 7th 2015. The hot exhaust from the flare enters (yellow arrow – the burner is behind the turbine) to the first turbine (Turbocharger) – the power is generated in the separate expander (top of the picture plus generator in the left – with transmission gear in between) – leaving via the red arrow to the cooling – returning cold via the blue arrow (from below) to the compressor and leaving to the exhaust (blue arrow to the right).
Figure 22  Screen shot from the remote control system: The system creates from the exhaust of a flaring system a suction of 42 hPa, an overpressure of 4 hPa plus a feed-in power of 1.35 kWe. Together with the saved power at blowers and landfill gas pumps, the gain is about 5 kWe. Some explanations: (1) the turbine aspires the hot exhaust and expands to -600 hPa (2). (3) at the generator expander, a further expansion to -672 hPa takes place. (4) the Recuperator preheats the combustion air to 579°C and cools the exhaust to below 277°C. The Intercooler heats air und cools the exhaust down to 35°C. (6) The compressor, driven by the turbine compresses the cold exhaust back to ambient pressure. The exhaust fan (7) is needed to start only.

**Why not applied at PPP120?**
The heat exchanger at PPP120 is prepared to hold an expander between the cyclone and the further pipes. However it would double the costs of the unit and reduce the usefull heat slightly. As all generated heat at PPP120 is used and the massflow of exhaust is so low, that only about 1 kWe power could be generated. A typical small coffee treatment assembly has a total energy consumption of around 5 to 10 kWe – an external generator or grid connection would be needed anyway. Of course – it would be possible to create an energy autarkic PPP120 – but not including the drum dryer and despulpadora. The turbine expander, especially its transmission gear is noisy and inefficient. Takiung this into account, it was decided to not implement it at PPP120.

We are expecting much more from Aactor !3S, “the three stroke engine” – the more efficient version for small units. First insight into the testing of a privately financed PDU can be found on:

youtube.com/watch?v=UbE7s0CK0p4

Investors are heartily welcome!
This engine can be applied with exhaust (inverted) or pressurized (externally fired).
10.3 EFGT – externally fired hot air turbine/engine

For bigger systems – for instance for a typical size of rice mill – or in Europe for compost plant, sewage sludge incineration plant, the externally fired cycle is much more appropriate: existing microturbines can be applied – the danger to damage the turbine with exhaust gas components is ruled out.

A system to convert 4'000 t/a screen waste from compost and biogas-plant is about to be designed:

**The output of the system will be approximately:**

- **Electricity:** 150 kW (@ 8'000 h @ 0.2 $/kWh = 240'000 $/a)
- **Hot air, hot water:** 550 kW (@ 8'000 h @ 0.07 $/kWh = 300'000 $/a)
- **Biochar up to** 22% of dry mater of input up to 600 t/a (@ 800 $/t = 480'000 $/a)

**Figure 23** schematic sketch of the new system PPP1500 (PyroPowerPlant1500 kW) – the figure is the approximate heat value of the input material.

**Figure 24** Screen shot from the presentation of the new system PPP1500
11. Economy

As the capital costs are extremely high in Peru, the investment and the payback time have to be kept low and short. From all the sensitivity analysis that have been done, 12 results will be shown and discussed in the following basing on the data collected at the Finca Santa Josepha, Villa Rica, Peru – but with calculated effects on 60, 120 and 180 hectares of coffee plantation size – 180 hectares corresponds to 8'330 operating hours – the maximum possible – basing on a wet input of 35 kg/h coffee pulp with 53% water content – so we are talking about 16.5 kg/h dry matter (dm) or 75 kg/h input of raw coffee pulp from the wet process (625 t/a).

Baseline scenario:
- cafe pergamino is being dried with cascaria (not fuel oil)
- No pyrolysis is applied
- typical amounts of N- and K-fertilizer are applied
- a typical yield of coffee is assumed

Szenario 1:
- cafe pergamino is being dried with pyrolysis heat from coffee pulp
  - *Only the amount of coffee pulp is pyrolysed to meet the drying heat demand*
  - Biochar is sold as charcoal at a mean price of 750 US$/ton
  - typical N- and K-fertilizer + Calcium demand,
  - typical yield
  - Investment 20'000 US$, interest rate 18%

Szenario 2:
- cafe pergamino is being dried with pyrolysis heat from coffee pulp
  - *Only the amount of coffee pulp is pyrolysed to meet the drying heat demand*
  - Biochar is used as soil enhancer –
  - The effect of the first 8 years of biochar application on the soil is leveled (mean values)
  - Reduced N- and K-fertilizer demand,
  - Very small increase of yield (0.05% / a)
  - Investment 20'000 US$, interest rate 18%

Szenario 3:
- cafe pergamino is being dried with pyrolysis heat from coffee pulp
  - *The complete amount of coffee pulp is processed – much more than the drying heat demand*
  - The effect of the first 8 years of biochar application on the soil is leveled (mean values)
  - Reduced N- and K-fertilizer demand,
  - Very small increase of yield (0.06% / a)
  - coffee is being dried with Pyrolysis heat
  - Investment 20'000 US$, interest rate 18%

Szenario 4:
- Biochar is used as soil enhancer – the effect is starting to spread.
  - *The complete amount of coffee pulp is processed – much more than the drying heat demand*
  - The effect of the first 8 years of biochar application on the soil is leveled (mean values)
  - Reduced N- and K-fertilizer demand,
  - Slightly increased yield (0.06% / a)
  - coffee is being dried with Pyrolysis heat
  - *additional 5 kW electric power is being produced from exhaust heat*
  - Investment 38'000 US$, interest rate 18%, electricity saved at 150 US$/MWh (15cts/kWh)
Figure 25 12 results (examples) of the simulation of the data base
Main findings from the economical sensitivity analysis:

- The revenue from the fertilizer savings is at least as high if not higher than the savings from coffee drying fuel demand. In the pre-study, it was even more: the reason is that the effects do not immediately occur on the complete plantation. If more than 8 years would be studied, the fertilizer effect would be much greater – as the biochar is given “once but forever” to every spot of the plantation.

- It makes therefore a lot sense to convert all pulp and not only the amount necessary to dry the coffee. Even if not due to economics – we are talking about climate positive energy – we should “waste energy”.

- Depending on the market price of charcoal (which is between 500 and 1’000 $/ton) – there is a potential “risk” that the biochar is sold as charcoal instead of as soil enhancer. However to reach this market, a bricking machine has to be added which is additional investment.

- The electricity production is not so attractive as it increases the investment to almost the double. Therefore, only the simulation for 8’330 h/a (180 ha of plantation) creates an additional benefit. However one has to be aware that these figures only reflect an assumed grid power price of 15 cts/kWh. If it is an off-grid situation, the power produced by a small generator is by far more expensive as the mentioned 15 cts. Therefore, it would be more interesting to have the power being generated from the heat. If the pyrolysis unit is on the back of a truck, the question arises, whether it makes more sense to keep the truck engine running or prefer a separate source of power.

For the more curious: the figures used for this simulation are in the attachments in German.
12. Technology-Transfer Workshop
Between Sunday 26th of July and Saturday 1st of August: a Delegation from Vietnam and a delegation from Peru where hosted in Switzerland. It was

the director of the National Cleaner Production Center of Vietnam, 
Mr. Dinh Manh Thang, company VNCP Co.,Ltd, at Hanoi University of Science and Technology

the managers and co-owners of a coffee harvest procession machinery industry in Vietnam, 
Mr. Le Viet Vinh and Mr. Le Viet Hien; company Viet Hien Mechanical Co.,Ltd, at Buon Ma Thuot City

and the manager and owner of a coffee harvest processing machinery industry in Peru, 
Mr. Sid Sara Garcia; IMSA Peru in Villa Rica and Lima

Short Summary of the Program:
The workshop was held at CATSE offices, meeting halls and the research hall. From Monday until Wednesday, the PPP full-size prototype was in service and processed cashew shells. The visitors could directly see, learn, ask, measure directly at the unit in service, and as well going through the design within the CAD-system displayed by beamer; and passing through the calculations of the design parameters.

On Wednesday, a film team organized by SOFIES created a movie [46] while the ongoing workshop, accompanied by short interviews.

On Thursday the prototype was opened for inspection by the delegations and finally each visitor was given a complete documentation of the construction and calculations, as well as reports and fotos of the week. In the afternoon, Angela Mastronardi from REPIC; Philipp Ischer from SECO; Hannes Zellweger and Martin Fritsch from SOFIES-EMAC joined the meeting. A short review and assessment was performed to check if all important information has flown.

On Friday, the delegations where led by Constanze Hacker and Martin Schmid to visit a farm in central Switzerland that already applies biomass-waste-pyrolysis and the biochar within the processes. Mr. Fredy Abächerli and Mr. Franz Keiser gave a complete insight into the processes including the production of new humus by co-composting dung, green waste and biochar.

Some impressions:
Figure 26 1,2: in the laboratory of CATSE, operating the full-size-prototype; 3,4: Visiting a Pyreg P500 plant and the production of compost at the Farm of Franz Keiser and Fredy Abächerli; 5,6: Franz Keiser measuring the CO2-content in the compost pile. The two delegation and a big-bag (1.3 m³, 450 kg) of biochar (www.pflanzenkohle.ch). 7,8: turning a movie and: technology transfer by working together through the 3D-CAD-model.
A short wrap-up lead by Martin Fritsch and Philipp Ischer helped to shape out some main conclusions of this week of technology transfer:

• All participants confirmed with enthusiasm, that Pyrolysis has not only a great potential in the coffee sector but also in the entire agricultural sector, when it comes to provide heat from biomass for different drying purposes.
• The technical feasibility in the two target countries appears to be not a specific problem nor a limiting factor.
• However a successful market introduction will call for some additional efforts, since the technology will require probably a higher investment than the present inefficient and pollutive burning of coffee hard shells. This will apparently lead to a new setting between the famers, dryers and coffee processors. It is possible that the latter will have to take over a more leading role in the entire drying process and thus along the supply chain from the farmer to the processor.
• For capitalizing best from the advantages of the Pyrolysis technology, also the use of bio-char is an essential component. This calls for a new element, which is the generation of more knowhow on farm level about the high value of this by-product with it's positive effects on soil properties such as water and fertilizer retention. Finally this will become an important positive cost and quality factor for the farmers. This will require the collaboration with the farmers and the corresponding experts.
• Furthermore there is also a social and environmental driving factor to be considered: In particular Mr. Thang from VNCPC has pointed out several times, that the successful introduction of Pyrolysis is not only a technical and financial issue. The present resistance from the population against the heavy smoke pollution of the traditional coffee hard shell burners has already put the responsible actors under pressure to act and improve the situation.
• We used the workshop to organize a round table, gathering besides the participants, the Ecocenter and SOFIES-EMAC also the representatives from SECO (Philipp Ischer) and the REPIC Platform (Angela Mastronardi). See two more photos attached.

Next steps in brief:
• Forthcoming contract conclusions by UNIDO for the involved national CPCs.
• Form now onwards start for building a pyrolysis test plant by IMSA (Peru) and Viet Hien Mechanical Ltd (Vietnam): Final adapted design, suitable material, cost estimation, specifications for operation and maintenance etc.
• In parallel: Evaluation and setting up of a complementary REPIC follow-up project focusing mainly on market introduction in collaboration between SOFIES-EMAC and the Ecocenter as well as with all national partners and actors in the two target countries (VNCPC, technical providers, launching customers, farmers, dryers and agricultural soil and coffee farm specialist).
• Next field activities for the coffee sector: November 2015 according the advance of the listed activities.

We are happy to keep you updated and look very much forward to continue collaborating with you all!
12.1 Integration of Pyrolysis and biochar in a typical Swiss farm

Figure 27 Pyrolysis and use of biochar integrated into a typical Swiss farm.

Blue are the existing paths leading to the existing products Dairy-, Meat-, Cereal- and woodchip-products.

New are the red paths and the additional “products”:

1) Fertilizer savings,
2) Potentially more crop yield
3) Stable and steady production through resilience of the soils
4) Greenhouse Gas reduction
5) New Soil for sale (terra preta products)
6) Biochar for sale to gardeners and composting companies
7) Increased income for dried wood chips with the label “Qualischnitzel” (woodchips of quality)

Some of these products of course do not yet have a price tag – however others will compensate for that lack.

The visit was very impressive for all visitors, including the organisators.
Many thanks to Fredy and Franz!
12.2 Feedback from Vietnam and Peru

By end of this project, we can proudly present the news, that in both target countries, the production of a first unit has started. We are thankful that REPIC has approved the sketch of the follow-up of the project – supporting the implementation in Vietnam. We are sorry that the international support for the same project in Peru is not yet on the way, as the activities of the National Cleaner Production Center of Peru are stopped.

![First picture from the PPP-unit in production in Vietnam](image)

*Figure 28* First picture from the PPP-unit in production in Vietnam (oct. 2015 bei Le Viet Hien Mechanical Company Co Ltd).

13. National and international action and cooperation

- **7th January 2014**  
  Meeting with a representative from the National Cleaner Production Center (NCPC) of Peru “Grupo GEA”, Juerg Schmidlin, and a project coordinator from SOFIES Geneva, Hannes Zellweger, at CATSE in Langenbruck. Goal: coordination of action in Peru and towards accompanying UNIDO-RECP-action.

- **9th January 2014**  
  *Separate project*: Testing of the Xhost Harvester Turbine at a
Pyreg500 plant in Doerth (D) – Goal: Service of a Pyrolysis System with much less electric energy demand for fans and blowers. Technical discussion with producer of commercial pyrolysis systems.

- 10th January 2014 Separate project: Intermediate meeting of the participants of the international project “Phosphor-Recycling with biochar from sewage sludge” at University of Bingen. Goal: presentation of the first results from plant-biology research on the use of pyrolysed sewage sludge as a fertilizer – with special focus on toxicity, phosphor-availability as fertilizer, heavy-metal retention and treatment. 25 participants from Germany; Uni Giessen (Dr. Kammann and her Team), Uni Bingen (Prof. Appel and his Team), Austria (Boku-University and Switzerland (Hanspeter Schmidt, Ithaka Institute, via Videoconf.) took part.

- 29th January 2014 Meeting with representatives from UNIDO (Mr. Nussbaumer), REPIC Platform (Mrs. Mastronardi and Mr. Gnos), SOFIES Geneva (mentioned above), Kaskad E GmbH (Stephan Gutzwiller) at CATSE in Langenbruck.

- 12th February 2014 Visit of the distillery Wirz Obstbau in Reigoldswil. Goals: a) source of wet substrates similar to coffee pulp, b) visit of pre- and after treatment processes, c) gain of interested party for medium scale pyrolysis technology in Switzerland.

- 19th February 2014 Visit of existing “gasification&pyrolysis” pilot plant (BASA-process) in Läufelfingen (BL) developed in 1990. Goal: meet the representatives of Carboilino AG (Mr. Suter) and learn about the advantages and disadvantages of the similar process.

- 31st March 2014 Meeting with Mr. Groux and Team [39], the founder and inventor of BASA-process for “biowaste gasification and pyrolysis” plants and the team of Carboilino in Bern. Three plants have been built in the 1990’s in Spain (2 t/h) and Uganda (750 kg/h), Pilotplant in Switzerland (80 kg/h). Goal of the meeting: shaping of a unique selling point that would explain the choice of this technology to be re-activated.

- 4th April 2014 Separate project: Meeting with Professor Worlitschek and Team and Mr. Bucher at Univ. of Lucerne. Goals: presentation of CATSE’s new patented expander technology and design for a CHP-project and meeting with an interested group for a further Pyreg500 plant in eastern Switzerland with novel heat use and storage concepts (would be plant Nr. 3 in CH).

- 9th April 2014 Meeting with Mr Schwegler (Tropical mountains Single Farm Café, La Merced, Peru) and Mr. Kurth (student of Univ. Wädenswil). Goal: cooperation, common efforts for fundraising among coffee roasters, as well as interest in the purchase of one of the first PPP-Systems.

- Dec 13 and Mar 14 Visits of the peruvian Team of Grupo GEA on rice-mills and decentral coffee harvest treatment plant (benificio) in northern and central Peru. Goal: further study of processes, needs and size of the equipment. Study of actual use of coffee pulp, quality of compost. See attached photographs and below.
• 6th/7th June 2014  Presentation of the PPP project at the Green Summit 2014 at the university of Liechtenstein to an interested audience in the field of green business development. Meeting with Hanspeter Schmidt, Ithaka-Institute.

• June to September ‘14  Separate project: Bachelor work in environmental engineering from Yan Kurth from ZHAW (Prof. Dr. Urs Baier, Wädenswil), elaborated on the Finca Tropical Mountains from Thomas Schwegler in Peru. Title: “CO2-neutrale Produktion und Aufarbeitung von Kaffee in der Finca Tropical Mountains in Peru.

• 6th June 2014  Separate project: Support to prepare the visit of a delegation from Indonesia to see the BASA-pyrolysis plant in Läufelfingen (Carboilino) in service. Jan Herzog from Ökozentrum manages to start the gas engine.

• End of July 2014  Separate project: Exhaust turbine for German pyrolysis plant “Pyreg500” financed by the German BMBF (ministry of professional education and research) runs better then expected.

• August 2014  Production of Biochar from dried coffee pulp on the COOPARM (Cooperative de Café de Rodriguez de Mendoza), coordinated by CER Peru.

• September 2014  Separate (private) project: Blending pieces of plastic bags into the garden in a micro pyrolysis installation has no remarkable effect on emissions nor quality of biochar. Learning about the Hamburger Verfahren, a pyrolysis process for plastic recycling.

• Early October 2014  Application of the biochar at a test plot of young coffee plant field of COOPARM – scientific arrangement with different amount of biochar per plant and control samples.

• Mid October 2014  delivery of cherry seeds from Wirz Ostbau in Reigoldswil BL – and interested party for a Swiss version of the PPP-plant (substitution of 25’000 liter fueloil for the distillery and a positive influence on the ph-value of the compost by the biochar) and delivery of wet wood chips from a second interested party, the farm “Silberdistel” in Holderbank SO. Both parties receive the biochar in return.

• 23rd October 2014  analysis of the soil samples at university of Lima, organized by CER Peru.

• 4th November 2014  Presentation of the PPP-project and its follow-up at the annual conference of REPIC in Fribourg. With interest from DEZA and supporter for Colombian CPC, Mr. Velasquez among others.

• 11th November 2014  Separate project: Building up and presenting a proposal for a possible solution to Haitits Vetiver-Oil-production (perfume-component, gained by steam-distilling). Prepared by Pierre Günthert (Groupe Gruner), Stephan Gutzwiller (Kaskad-E) and CATSE (Ökozentrum). 4'500 t/a of
roots could replace 340'000 litres/a fueloil and produce biochar in the same time. The roots cannot be combusted directly as the content to much sand (glazification, slagging).

- 13th November 2014  
  Separate project: presentation of the FLOX-lean-gas burner system used at PPP at the Swiss Green Economy Summit in Winterthur.

- 14th November 2014  
  Separate project: request from waste management project in the Dominican Republic.

- 12th March 2015  
  separate project: First service of the field test unit of a inverted brayton cycle exhaust turbine for landfill gas – potentially applied at PPP-units as well.

- 7th May 2015  
  separate project: Presentation of the PPP-project at the biomass to power and heat conference at the Hochschule Zittau (D).

- 29th June 2015  
  separate project: SOFIES travels to VietNam to spread to word about the PPP-project.

- 27th to 30th June ’15  
  Technology-Transfer-Workshop with a delegation from Peru und Vietnam.

- 31st July 2015  
  Visit of a farm in central Switzerland with already integrated biochar production and application with the two delegations.

- September 2015  
  Several interviews with journalists.

- 15. September 2015  
  Publishing the new 3.5min documentary movie [46]

- 2nd October 2015  
  separate project: Signature of LoI with Swiss industry to develop PyroPowerPlant1500, a 10 fold bigger unit with an integrated EFGT (externally fired gasturbine).

- 12th October 2015  
  Project sketch for the follow-up of this projected for Vietnam is accepted by REPIC steering comitee.

- 18th October 2015  
  After the full page article about the project in the NZZ am Sonntag, interested farmers from Nicaragua and El Salvador contacted us. The contact to the Cleaner Production Center El Salvador was refreshed.

- 6th November 2015  
  presentation of the project to invited press and crew on the Marine Research Ship SY Aldebaran.

- 25th November 2015  
  separate project: establishment of CharNet.ch – a thematic network of professionals arround biochar, soil-enhancement, climate farming and pyrolysis – research, application and lobbying – in Switzerland.
Figure 29 Creating CharNet.ch – 41 visitors and founding-members visiting the PPP-Full-Size-prototype in service with wood chips and cashew shells.

14. Publications

- 2013: A poster for the yearly conference of REPIC in September
- 2013: article published in the Ökonews, printed newsletter of CATSE 2/13 (November)
- 2014: contribution to a four page article in the magazine “Zeitpunkt” (Nr. 131, Mai/Juni 2014) about biochar in general and the present project [40].
- 2014: article published in the Ökonews, printed newsletter of CATSE 2/14 (November)
- 2014: Our Sponsor Blaser Trading published our project description plus the newsletter 1/15 on its homepage [47]
- 2014: Jürg Schmidlin from CER presented the project in Arequipa Peru (Oktober) [56]
- 2015: article published in the Ökonews, printed newsletter of CATSE 1/15 (June)
- Other publications have been made by partners for the Kaffa-gasifier cooker (Project in Ethiopia) [41].
- 2015: A flyer about the pyrolysis in general has been published on our website
- 2015: The UNIDO published a press article after the workshop – August 1st 2015 [48]
- 2015: A 3.5 minute professional documentary is published on SOFIES-News [51], on our website [52] and Youtube [53]
- 2015: Full page article on “Wissen” NZZ am Sonntag, Zürich, 18.10.2015 [54]
- 2015: two page article in “Swiss Engineering” [55]
- 2015: three pages article in Umwelttechnik Schweiz, issue december [57]
15. **Thanks**  
This project is supported by great, visionary, frank and strait and very active people at REPIC, SECO, SOFIES, Kaskad-E, at our Sponsors Blaser Trading, private and communal supporters and donators – and a very strong team at CATSE! Thank you very much for the great cooperation and making this happen!

Martin Schmid

16. **Literature and References (continued collection)**


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http://www.umweltbundesamt.de/daten/klimawandel/treibhausgas-emissionen-in-deutschland
### Sensitivitätsanalyse PPP für Finca Santa Josepha, Villa Rica, Peru

**Größen der Höhe**
Dornacherstrasse 192, 4053 Basel

**Zusammenfassung des Berichts**
Sensitivitätsanalyse PPP für Finca Santa Josepha, Villa Rica, Peru, spring 2015

**Wirtschaftlichkeitsanalyse**

<table>
<thead>
<tr>
<th>Variablen</th>
<th>Wert</th>
<th>Varianz 1</th>
<th>Varianz 2</th>
<th>Variante 3</th>
<th>Variante 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aktivitäten</td>
<td>126</td>
<td>83</td>
<td>108</td>
<td>123</td>
<td>129</td>
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<tr>
<td>Erlöse aus CO2-Zertifikaten</td>
<td>12.6%</td>
<td>6.4%</td>
<td>2.4%</td>
<td>2.4%</td>
<td>2.4%</td>
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<tr>
<td>Erlöse aus CO2-Zertifikaten: Verhinderung Zusatzemissionen (andere als CO2) aus unkontrollierter Pulpe-Zersetzung</td>
<td>9.6%</td>
<td>4.4%</td>
<td>2.6%</td>
<td>2.6%</td>
<td>2.6%</td>
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<tr>
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<td>...</td>
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</tbody>
</table>

**Technische Parameter**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Wert</th>
<th>Varianz 1</th>
<th>Varianz 2</th>
<th>Variante 3</th>
<th>Variante 4</th>
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<tbody>
<tr>
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</tbody>
</table>

**Erklärung der Werte**

- **Größen der Höhe**: Dornacherstrasse 192, 4053 Basel
- **Zusammenfassung des Berichts**: Sensitivitätsanalyse PPP für Finca Santa Josepha, Villa Rica, Peru, spring 2015
- **Wirtschaftlichkeitsanalyse**: Tabelle mit Werten und Prozentzahlen
- **Technische Parameter**: Tabelle mit weiteren technischen Parametern

**Input-Data sensitivity analysis economics – basing on figures Finca Santa Josepha, Peru, spring 2015**

**Page 1 of 2**
## Wirtschaftliche Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Daten Einheit</th>
<th>Beschreibung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kohelegabe</td>
<td>kg pro Jahr</td>
<td>Pflanzenkohle biochar aus der Verstromung</td>
</tr>
<tr>
<td>Essenerntegabe</td>
<td>100 kg pro Jahr</td>
<td>Energieverwertung der Pflanzenkohle</td>
</tr>
<tr>
<td>Warenausgabegewinn</td>
<td>62.00</td>
<td>Einnahmen aus der Verkauf von Carbon-Crediten (Pulpa)</td>
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<tr>
<td>Gewinnquote</td>
<td>28.00 %</td>
<td>Gewinnrelation des PPP-Anlage</td>
</tr>
<tr>
<td>Steuer</td>
<td>15%</td>
<td>Steuerquote des PPP-Anlage</td>
</tr>
<tr>
<td>Zins</td>
<td>15%</td>
<td>Zinssatz des PPP-Anlage</td>
</tr>
<tr>
<td>Aufschlag</td>
<td>15%</td>
<td>Aufschlagquote des PPP-Anlage</td>
</tr>
<tr>
<td>Brutto PP-Netto</td>
<td>100.00 %</td>
<td>Brutto-Netto-Quote des PPP-Anlage</td>
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## Sensitivitätsanalyse

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<thead>
<tr>
<th>Variable</th>
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<tbody>
<tr>
<td>Kohelegabe</td>
<td>kg pro Jahr</td>
<td>Sensitivitätsanalyse der Bedarfe von Pulpa-Biochar</td>
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<tr>
<td>Essenerntegabe</td>
<td>100 kg pro Jahr</td>
<td>Sensitivitätsanalyse der Energieverwertung der Pflanzenkohle</td>
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<tr>
<td>Warenausgabegewinn</td>
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<td>Sensitivitätsanalyse der Einnahmen aus der Verkauf von Carbon-Crediten (Pulpa)</td>
</tr>
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<td>Gewinnquote</td>
<td>28.00 %</td>
<td>Sensitivitätsanalyse der Gewinnrelation des PPP-Anlage</td>
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<td>Steuer</td>
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<td>Sensitivitätsanalyse der Steuerquote des PPP-Anlage</td>
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<tr>
<td>Zins</td>
<td>15%</td>
<td>Sensitivitätsanalyse der Zinssatz des PPP-Anlage</td>
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<td>Aufschlag</td>
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<td>Sensitivitätsanalyse der Aufschlagquote des PPP-Anlage</td>
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<tr>
<td>Brutto PP-Netto</td>
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## Investitions- und Finanzierungsparameter

<table>
<thead>
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<tr>
<td>Investitionskosten PPP-Anlage</td>
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<td>Investitionskosten für die PPP-Anlage</td>
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<td>Einnahmen aus Pflanzenkohle</td>
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## Gesamterlös

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<tr>
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<td>Gesamterlös</td>
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## Brutto- und Nettoergebnisse

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## Abschluß

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