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Swiss State Secretariat for Economic Affairs SECO

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Final Report:

Pulpa Pyro Peru ï

Clean generation of biochar and energy from coffee pulp

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1. Summary

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.
During winter 14/15, a full-size prototype applying the novel pyrolysis process was successfully tested in the laboratories of CATSE. It produced Biochar that meets the EBC-standards from dry and wet harvest residues, such as coffee pulp, cashew shells, wine pomace, wood chips and cherry seeds and hemp straw.
In July 2015, a technology transfer workshop has been held ï 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 visit a farm in central Switzerland, which already applies pyrolysis and uses the biochar in different ways in the feeding, 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 ï 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 ï 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 support of REPIC, press articles could be placed which rose additional international interest ï from Nicaragua, Tanzania, Kenia 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.

2. Starting Point

The pre-study, ordered by the National Cleaner Production Center in Peru ñCER+ò in coordination with the SECO (Switzerland) and the UNIDO Program RECP goals for waste minimization and valorization in coffee and rice production was evaluating the solutions to valorize coffee pulp and propose a solution appropriate for the size and distribution of typical Peruvian coffee plantations.
*See **chapter 3 ñthe farmers needs the driving force for this projectò** in the attached final report from CATSE, as well as the pre-study, published December 2012. A summary is given as follows:*

1) 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 ï 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 ï only as an addition in very low percentage remains digestable [8, 29]
- Could be partially used as a source of Pectin ï 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].

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

3) Thirdly ï there is **a need for fertilizer:** The farmer has to decide between spending roughly 1ê000 US$ per hectare and year for fertilizer [5] or live with significant less harvest.

The pre-study validated the proposal of a low-cost but low-emission pyrolysis plant ï most likely in the size of 300 to 600 t wet input per year, generating hot air and biochar out of the coffee pulp. The unit should be able to process 54% water content ï the minimum achieved with a mechanical press during pre-study testing. The units should have an appropriate heat capacity for the typical beneficios (raw-coffee treatment plants) of 50 kW thermal.

3. Results

a) Description of the projectôs original objectives ï the original text in the project proposal from June 2013 (in German).

Es wird eine Lösung erarbeitet, um Biomasse-Ernterückstände, die wie Kaffee-Pulpe kei-ne direkte Verwendbarkeit oder sogar Problemstoffcharakter haben, in einen Wertstoff, in Energie und in Düngerersatz zu verwandeln und gleichzeitig ein Entsorgungsproblem zu lösen. Der gewählte Pyrolyseprozess hat den Vorteil, dass die Anlage ähnlich einem Heizkessel in kurzer Zeit betriebsbereit ist und die im Betrieb anfallenden Ernterückstände (z.B. Kaffeepulpa) in wenigen Stunden oder Tagen verarbeitet werden können. Die erzeugte Trocknungswärme kann mittels Gebläse direkt an den Kaffeetrockner abgege-ben werden.

Der erste Schritt bis zum Meilenstein I (siehe Projektplanung im Kapitel 15 ff) soll die Machbarkeit des vereinfachten Prozess klar aufzeigen, inklusive Qualtität der Abgase und der Kohle gemäss den unten erwähnten Kriterien. Die Nichterfüllung des Meilenstein I führt zum Projektabbruch.

Der in der Phase II erzeugte Fullscale-Prototyp soll

- *mindestens 50 bis 90 kg/h Nassinput verarbeiten können.*
- *mindestens 40 kW Trocknungswärme abgeben können (genaue Leistungen wer-den noch angepasst in Absprache mit dem Hersteller der zur Kaffeetrocknung am häufigsten verwendeten Trockner).*
- *höchstens 1 Tonne schwer und 3 x 2 x 2 (l x b x h) gross sein, um später auf ei-nem Kleinlaster installiert optimale Mobilität gewährleisten zu können.*
- *höchstens 1.5 kW elektrische Leistung benötigen, um höchstens den Stromver-brauch der bisherigen Wärmeerzeuger aufzuweisen und evtl. auch ohne Netzan-schluss betrieben werden zu können, d.h. die Bordstromversorgung eines Klein-LKW, welcher die mobile Anlage trägt, nicht zu*

überlasten. Das Gerät soll darauf vorbereitet sein, später einen Abwärmemotor „Aactor !3S" integrieren zu können.

- *einfach in der Herstellung sein und die Kosten der importierten Fremdkomponen-ten und die Materialkosten insgesamt 10'000 CHF nicht überschreiten. Dadurch sollte bei der Produktion in Peru ein Produktionspreis von 20'000 US$ erreichbar sein.*
- *Pflanzenkohle erzeugen, die den EBC-Test besteht und der dafür eingesetzte PAK16-Test soll den Möglichkeiten eines Kleinstlabors in Peru angepasst werden. Diese Vereinfachung wird durch Kaskad-E während dem Projekt geprüft.*
- *Abgaswerte aufweisen, die die neusten Schweizer LRV-Grenzwerte für naturbe-lassene Biomasse für Anlagen über 70 kW Leistung einhalten (<50mg Feinstaub pro Normkubikmeter bei 13% Sauerstoff, <500 mg Kohlenmonoxid CO /m3n @ 13% O2). Eine Anpassung an landesübliche Grenzwerte wird während dem Pro-jekt geprüft.*

b) All results are at least achieved or better – summary of the quantifiable objectives according the above list:

- *Achieved maximum input wet (at 78% water content) = **80 kg/h** pre-processed to 50% water content equals 35 kg/h input to the pyrolysis plant*
- *54% water content could be achieved to be processed in the pyrolysing unit – however it is recommended to process substrates not much above 40% water content (67% humidity b.d.).*
- *Achieved 40 to 70 kW depending on substrate.*
- *Total weight including additional measurement devices for research <600kg. The unit is higher (through the final design with vertical reactor) – but smaller in horizontal dimensions: 2.10 x 0.85 x 2.6 m (l x w x h)*
- *Achieved <1.5 kW total electric consumption. The installation is prepared to be equipped with a Aactor !GT inverted micro turbine or the mentioned exhaust engine Aactor !3S – the exhaust line from the cyclone to the further heat exchanger includes two flanges to attach it.*
- *Achieved- the Peruvian company IMSA-Cafe confirmed a customer price for the unit of estimated 22'000 to 24'000 US$ - the production costs are therefore below 20'000 US$.*
- *All test samples from the tested substrates past the EBC-Test with very low values for PAH16. However the proposed „nose-test" did not work: Even smelly samples from the frist try-outs at the bench-scale test PDU passed the PAH6 test. It is assumed, that the nose test is „too good" – meaning the following: The threshold to smell the Poly Aromatic Hyrocarbons is much lower than the threshold of the 12 mg/kg dry matter allowed by the European Biochar Certificate.*
- *The achieved exhaust gas values are even significantly lower than the projects goals: The tested full size prototype without filter would meet the Swiss clean air act regulations for waste incinerators (LRV Ziffer 71).See the data below.*

Topic	***Measured***	***LRV 74 (agri)***	***LRV 71 (waste)***
Particulate matter (pm)	<5mg/m^3_n (13%O_2)	20mg/m^3_n (13% O_2)	10mg/m^3_n (11% O_2)
Carbon monoxide (CO)	<15	500	50
Nitrogen oxides (NOx as NO_2)	2*	250**	80
Combustion power (allowed)	80 kW	(>70 kW)	(>350 kW)

(*) 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 >2500 g/h – below no limitation.

Additionally see chapters 4 to 9 in the main report from CATSE.

4. Project Review

4.1 Project Implementation

The project was carried out according the original plan. Besides minor changes in staff, the project organization remained as proposed 2013. Additionally SOFIES organized the participation of the Vietnam delegation in the technology transfer workshop. The roles of the partners summarized:

- CATSE (Ökozentrum, Langenbruck CH): Design and production of the PDU I, PDU II and full-size-prototype. Testing and exhaust analysis, fundraising including relationship to public and sponsors, project management and responsible for the reporting to REPIC. Coordination and financing of all subcontractors and suppliers. Coordinator and host for the technology transfer workshop. Financial controlling. Staff of the project: Constanze Hacker and Bettina Marti, Jan Herzog, Martin Schmid, additional support according need.

- CER (Centro de Ecoeficiencia y Responsabilidad, Lima Peru) : LoIôs with interested coffee production cooperatives and plantations, acquisition for own RECP-action, coordination of plantation testing (including biochar production) with COOPARM, documentation (data, fotographs) of situation on plantations, coordination of laboratories analysis with University of Lima. Reporting of Peru-action to CATSE. Staff of the project: Nicolas Detiffe, Jürg Schmidlin.

- IMSA-café: Producer of coffee post-harvest treatment machinery ï signed LoI in 2012 for the interest in production of such a pyrolysis unit. Production and distribution of the units for latin America. Project staff: Erik Schuler, Sid Sara Garcia

- SOFIES (Zürich CH): supporting and guiding the international relation of the project towards UNIDO, SECO, DEZA and the new interested groups in Vietnam, Cambodia, Colombia. Coordinator for the participation of the Vietnamese delegation at the technology transfer workshop. Acquistion of the follow-up activities in the target countries. Supporting the relation between CER, IMSA and CATSE. Involved staff: Hannes Zellweger, Martin Fritsch

- Kaskad-E (Basel CH): Biochar specialist ï designing the field testing in Peru, supporting the biochar production for the field testing in Peru; development of the simplified testing method; economical analysis (programming and application). Project staff: Stephan Gutzwiller

- Agroscope Reckenholz Tänikon (Zürich CH) on behalf of Ithaka Institute: Testing the biochar (PAH16-analysis): Project staff: Isabel Hilber

- COOPARM (Finca Santa Josepha, Villa Rica Peru): LoI signed 2012 (1 of the first 3 interested users); conducting the field testing (20 coffee plants). Project staff: Carmen and her colleagues

4.2 Achievement of Objectives and Results

All objectives of the project have been more than only achieved. See Chapter 3 of this report or the chapters 4 to 9 in the CATSE final report, attached.

4.3 Multiplication / Replication Preparation

This project has been initiated mainly by the international demand for the technological solution in the coffee and rice sector: The order for the pre-study came from one of the target countries and at the time of the start of the present project, already 3 signed LoIôs from Peru existed. Parallely, the earlier mentioned RECP-action of the UNIDO, basing on the former CPC-initiative from SECO, pulled as well. With SOFIES as coordinator ï the spread of the technology into the other target countries ï has already started ï but once more is more ñpulled than pushedò With the help of the great little documentary movie and several printed articles, the project spreads the word ñautomaticallyò With its local and global impacts the project and its follow-ups gain momentum. Additionally, the economy of the designed product will help to spread: compared to a biogas plant, where the substrates remain usually 30 days within the system, it is only one hour in the PPP-reactor. With this factor of ñ700ò one can imagine that the specific investments are significantly lower ï beside of the additional benefits, that the output material is dry, odor-free, lightweight and easy grindable. Nevertheless ï the word has to be spread about biochar itself ï here and in the target countries. Therefore, a follow-up project should support the initiatives in Vietnam and Peru. Additionally, CharNet.ch has been founded en of November 2015 to connect the ñprofisò on this topic in Switzerland.

4.4 Impact / Sustainability

In both target countries, the initiation of the production of a first unit each has been reported.

The potential ecological sustainability of the projects subjective and its wide impact to most important ecological topics can be summarized in an example as follows:

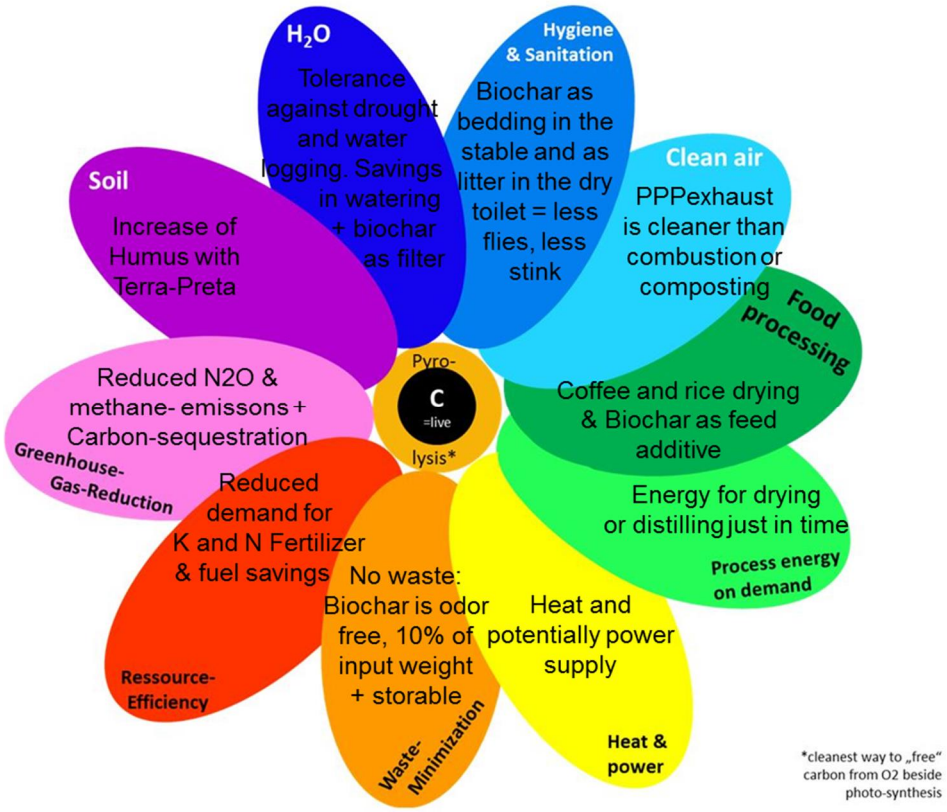

Figure 1 A rainbow full of ecological benefits of biochar if applied on site on a coffee plantation or similar agricultural entity.

With this graph a summary is being given about the opportunities that arise from pyrolysis of biomass residues in agriculture. Further informations see the CATSE final report attached.

5 Outlook / Further Actions

5.1 Multiplication / Replication

What are the next planned steps?

a) *Vietnam:*
In coordination with the NCPC Vietnam and the local company Le Viet Hien Mech. Co. that attended the technology workshop, the first production unit will be commissioned and optimised together with a CATSE technician. This is planned to take place in the frame of a RE-PIC project. Within this project, a Vietnamese cooperation of small coffee farmers, will buy one or more units, with the support of the Hans R. Neumann foundation. The same foundation will also finance and coordinate the application of biochar on a test plantation with the special focus on drought tolerance and need for watering. Too dry weather conditions are a typical problem in Vietnam. The agricultural aspects and the plant biology of the testing will be accompanied by Dr. Michael Scheifele of FiBL.

b) *In Peru, the ñsimilar programòhas to take place. On one hand, the project is more advanced ï but on the other hand has lost the support of RECP (UNIDO) as the NCPC did not invest*

enough efforts. In Peru, the test plantation already exists but the knowledge about it has to be secured with or without NCPC ñICERò

What is being done to promote multiplication / replication?

- *One very important aspect is the test plantation in each target country ï it is not only about ñresearchò but about having a place to meet and see and feel the soil ï for workshops and formation courses*
- *The internet-videos (of this workshop and of the Kaffakocher by Kaskad-E) turned out to be a big help for the local producer to convince their environment.*
- *CharNet.ch will increase the efficiency of the efforts in this field, as it shares information about all Swiss ongoing efforts.*
- *It will be especially in Peru a help to point out, that it is an old South American tradition to make Terra Preta, whereas it must be shown to be something ñvery modernò in South East Asia. Workshops have to be organized to spread this knowledge.*

Which hurdles need to be overcome in order to have successful multiplication / replication?

- *Usually it is the risk of investment that slows the spread of new technology in countries of low income. However local and international support has to be addressed to overcome this hurdle.*

5.2 Impact / Sustainability

What are the expected sustainable effects (environmental, socio-economic aspects, CO2 relevance, resource efficiency, etc.)?

- *Social economic aspects: For Peru, it was originally planned that the pyrolysis-plant will be operated on the back of a pickup truck throughout 10 months of the year ï each with an operator/driver ï who would find his full income from this work. Together with the maintenance, the pilot region San Martin in the North of Peru would have created a number of new technical jobs in rural regions. However it seems economically interesting enough to operate the units on one site only ï but different substrates according the harvest seasons. For the operation on each plantation, the workload would not differ too much from the already existing operation of wood burners and hot air generators for the dryers ï which reduces the potential of creating new jobs on the rural regions again. However the savings of imported fertilizer and external fuel and creation of own fertilizer and fuel will create increase wealth in rural areas. In Vietnam: The equipment producers and the coffee processors have been confronted by law-suits due to smoke pollution to neighborhoods. Therefore it is of high economic importance for those companies to present solutions as soon as possible.*
- *CO2-relevance: The environmental aspects have been mentioned in figure 1 (chapter 4.4). However in figures, it can be said that each unit reduces directly CO2-emissions by roughly as much tons CO2eq per year as the substrate input into the pyrolysis plant in tons ï up to 350 t CO2eq per year and unit. These estimations include only the C-sequestration and a conservative estimation of the methane emissions of the pulp piles. Additionally N2O and ammonia emissions are potentially lower in the soil and in the barns and toilets where biochar is applied ï however this has not been turned into figures so far ï the most recent R&D [58] about those effects could not yet be taken into account. However the effects will be significant: only in Germany, the estimated and ñstinkyò losses of Nitrous-gases from manure into the atmosphere count to a 500ô000 tons multiplied with the GHG-factor for N2O of 310 results in 150 million tons CO2eq per year ï which is a large emission compared to the total GHG-emissions of Germany of 914 Mio tons CO2eq in 2014 [59]. The ecological effects of fuel and fertilizer savings are of minor scale compared to the above mentioned but are of course significant too. For communication ï we use the C-sequestration effect (which is the same for all biomass) which is* ***-500 gr CO2 per kWh useful energy generated ï climate positive or CO2-negative energy.***
- *Ressource efficiency: The technology and the biochar creates fuel savings (wood, cascaria or fossile fuels) and fertilizer savings (K, N, Calcium) and potentially creates watering savings. The fertilizer savings are economically spoken more important than the fuel savings. See the sensitivity study in the CATSE final report, attached.*

6 Lessons Learned / Conclusions

What are this projectõs main findings and conclusions?

Pyrolysis and the new appropriate process confirmed the projectõs aims to provide clean and ecologically and economically sound solutions for the biowaste of the coffee and rice sector. The developed unit fulfilled the project goals completely or more than that: The exhaust emissions are much lower than the project goals. The producers in the two target countries confirmed the feasibility at the price target.

Which recommendations can be made for similar projects, or within this context?

The project can only be successful with a very close relationship to at least one person ï at best in the local CPC office in the target country. Due to changes in personal during the project, the activities in the CPC in Peru weakened significantly and finally the connection was too loose to get the important informations: The technology transfer had to be postponed several times due to unknown reasons until the former employee of CPC Peru, Hannes Zellweger, made a phone-call. The project end had to be postponed by 9 month due to that. So there must be a personal contact, a friendship, to one person in the target country at least. However this longer project duration was rewarded by allowing the Vietnamese delegation to join the workshop.

7 References

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 ñZeitpunktò(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 ï 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 ñWissenòNZZ am Sonntag, Zürich, 18.10.2015 [54]
- 2015: two page article in ñSwiss Engineeringò[55]
- 2015: 1 page press release published by SY Aldebaran plus press conference on board, Deutsche Meeresforschungsstiftung on the way to Paris Climate Conference, Hamburg, Basel, 6.11.2015
- 2015: three pages article in Umwelttechnik Schweiz, issue december [57]

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8 Annex

See final CATSE-report attached.