Performance Test Protocol for Small Scale Gasifier

White Paper elaborated 2015 under IEA Bioenergy, Task 33 Thermal Gasification of Biomass

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Abstract

This White Paper "Performance Test Protocol for Small Scale Gasifier" [PTP] was elaborated by the IEA Bioenergy under Task 33 (Thermal Gasification). For the last years appeared more commercial available gasifier units on the market. As a guideline during a project for a Gasifier CHP unit this white paper can help to improve the project quality and the successful proof of performance after commissioning. The handover of a gasifier CHP unit from supplier to the client will be easy and successful, if there is accurate PTP existing.

CONTENT:

1 Project management and Performance Test Protocol

A Performance Test Protocol [PTP] for commercial Small Scale Gasifier CHP units helps involved parties to reduce differences and unrealistic expectations. PTP can be useful in a project during evaluation, ordering of equipment, commissioning and tests. For the final tests PTP is “the Tool” for the handover to the client.

PTP implication in a commercial project is a must. In Bioenergy Project it is even more necessary because of a high variety of the input fuel types and quality. It is also advised to think about PTP already in the first steps of projects evaluation. It is a must to have a PTP at least before the procurement begins and shall be part of the orders of equipment. A PTP is always a specific individual document and different for each Project. To have its full value, the PTP should be included in the Contract suite of documents. This ensures that the purchaser and the supplier have the same view on what specific items should be validated during the performance tests, and by which methods the validation shall be implemented.

The aim of using PTP will be the achievement of:

- Content and pleased involved parties of small scale gasifier projects
- Small differences between expectations and reality
- Verification of the guaranteed values and performance and warranties
- Verification of achieving regulated emissions, noise and other permits criteria’s from authorities
- The gasifier CHP installation targets such as environmental ecological benefits, economic benefits, stable long-term operation and stable financial long-term situation
- Long term effect: Increasing the trust and credibility of the thermal gasification technology

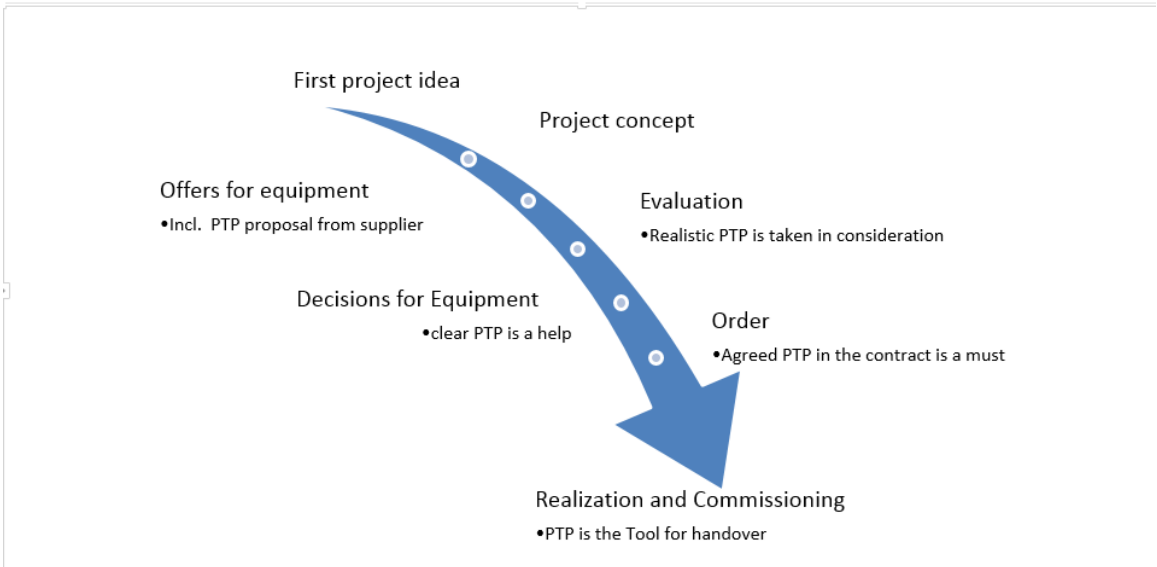

Fig 1 Steps where PTP appears in a Project

2 Information Base for PTP

2.1 Involved Parties and Boundaries

For project management it is crucial to line out involved parties, suppliers, officials, clients, operator's etc. A very helpful tool is a graphical setup of boundaries and connections as shown below in example.

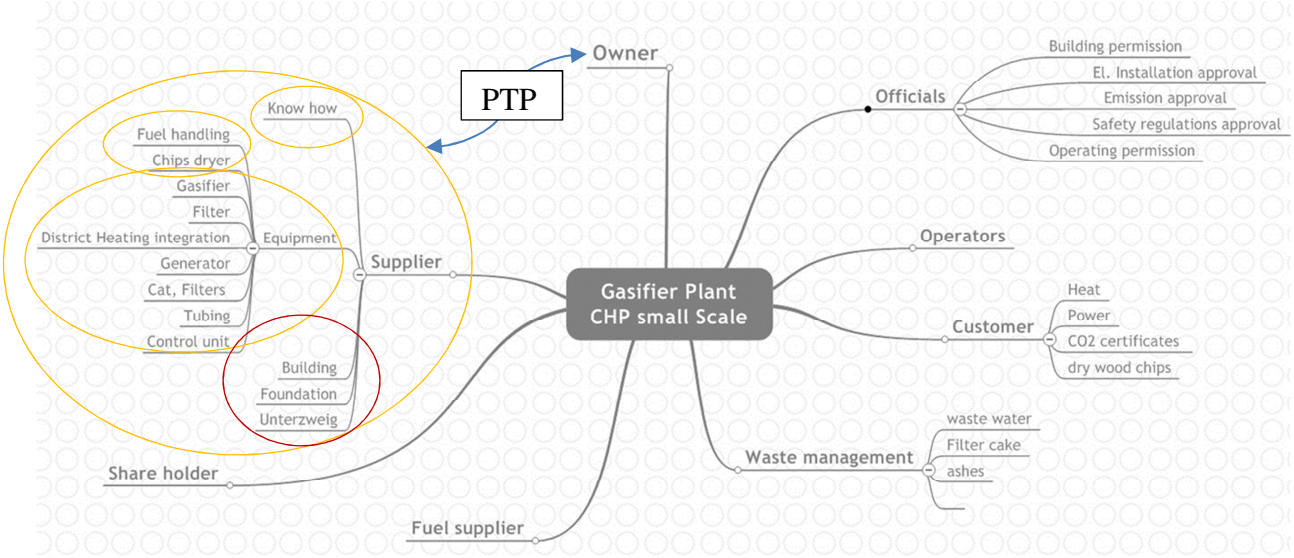

Fig 2 Example of Project-Boundaries and Involved Parties

If in Project there is one supplier only, then usually there is only one PTP needed if the supplier makes than PTP to his sub-supplier or sub-contractor is up to him. But if there is say two or more different supplier in a gasification line and both are responsible to the client, it is wise to have cleared up interconnections and a separate PTP.

The supply of a biomass gasification plant can contractually be managed by several means such as for example:

- Turn-key lump sum contract for the works
- Engineer, procure, construct lump sum contract (EPC)
- Engineer, procure, construct and manage the works (EPCM,)
- The Client designs the works and contracts a party to build the plant under its instructions.(Design-Build)
- Supervisory Service Contract
- Etc.

To support the management of the project and its structure it is advisable to have a suitable contract that, apart from the scope of supply, contract price and payment instalments, time schedule and milestones, guaranteed performance and general technical stipulations, defines the roles, rights and obligations of all parties. Another important issue is the split of responsibilities between the client and the supplier when working on the site regarding both the material conditions on the site (e.g. power supply, the storage, office and staff facilities, site, cleaning and security) but also immaterial conditions (health and safety, accident prevention, minimization of environmental impacts, relation with authorities and third parties, etc. and last but not least the responsibility of coordination of such activities between the supplier(s) and the client and their respective sub-suppliers and -contractors)

The PTP should be seen as a support in the context of the performance tests at plant take-over and the fulfilment guaranteed performance in the warranty period.

There are several model contracts that can be used as a starting point, see Appendix 1. These have been developed for certain forms of performing the supply, different value of the supply and also being adapted to certain judicial settings, such that a contract should be suited to the jurisdiction of the client. Nevertheless, such contracts can be used as a checklist and often includes appendices that can be use, e.g. a tick box chart for site responsibilities

2.2 Technical Specifications of the Gasifier CHP Unit

2.2.1 General

Technical Specification must be included in **the contract** to the promised performance of heat and power out of a specific fuel. Specifications show inputs and outputs of the process during normal operation condition. Lay out, flow chart, Mass flow and energy flow diagrams underline the process information and are necessary document of a contract.

2.2.2 Example of Technical Specifications and PTP

Following see an example for “Technical Specification of small compact CHP gasifier unit”. This list is to understand as a guideline and not complete. It shall help for crosschecks and negotiations in between client and supplier.

Helpful therefore are also to include schemata, layouts and Sanky diagrams in the specifications to underline Information and avoid misunderstanding. (See 2.2.3 - 2.2.7, Fig 3-7) Already here in the specification it is useful to show and point out the measuring points for operation, test runs and PTP relevant information.

Input output Specification **also Listed in**

- Fuel type, Fuel quality, Consumption per hour (see 2.2.7) PTP
- Electric power production PTP
- Thermal power production PTP
- Ash and dust production PTP
- Waste water and sludge production PTP
- Exhaust gas production, emissions PTP

Consumables Specifications for normal operation:

- Intern electric power consumption PTP
- Water or steam consumption, Additives …. PTP

Operating specifications are also advised to point out such as:

- Manpower needed during normal operation PTP
- expected running hours per year
- Minimal start up time from cold unit to full load production PTP
- Minimal time for normal shut down PTP
- List of consumables per running hour
- Noise level

Maintenance Information

- Minimum shut down time for yearly maintenance
- Manpower needed for maintenance
- Maintenance plan
    - Inside cleaning intervals of gasifier, filters, coolers…
    - Oil change and lubrication interval of motors valves….
    - shut down time for that regularly recurring maintenance
- Dismantling and mounting time for important components in case of unexpected shut down such as for feeding systems, gates, gasifier, filters
- Others information

2.2.3 CHP Gasifier Block diagram and Boundaries

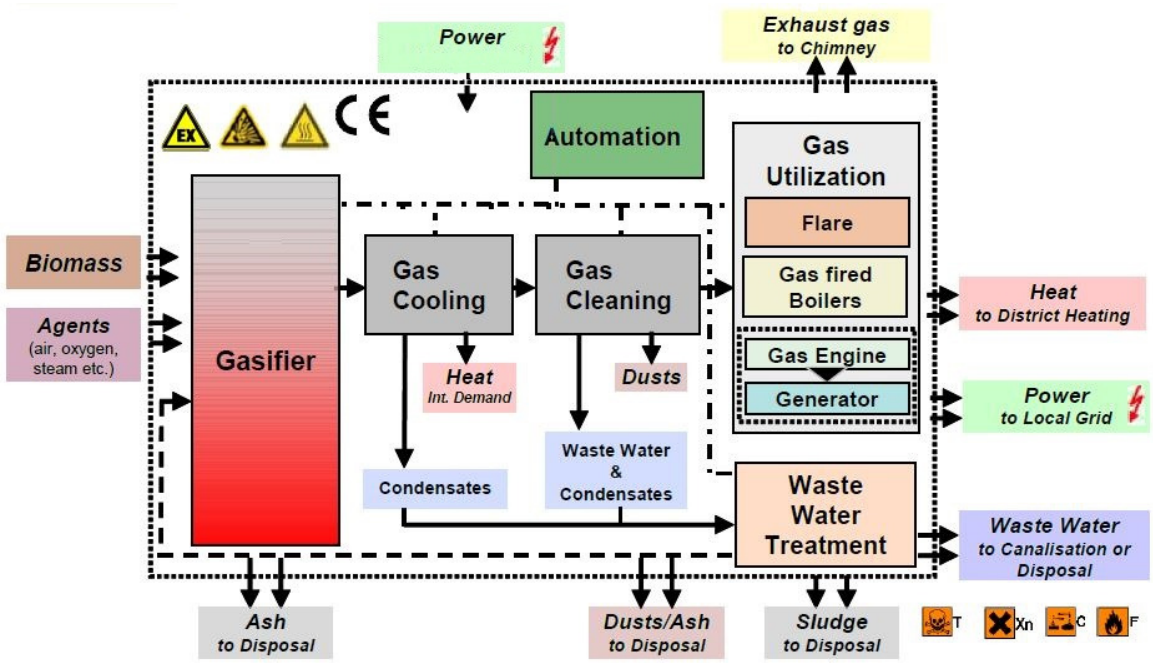

Fig 3 Shows example of block diagram and boundaries of a compact CHP gasifier unit delivered by one supplier, PTP relevant input and output points, simple boundaries and connection points as base for responsibility's

2.2.4 CHP Gasifier Schemata

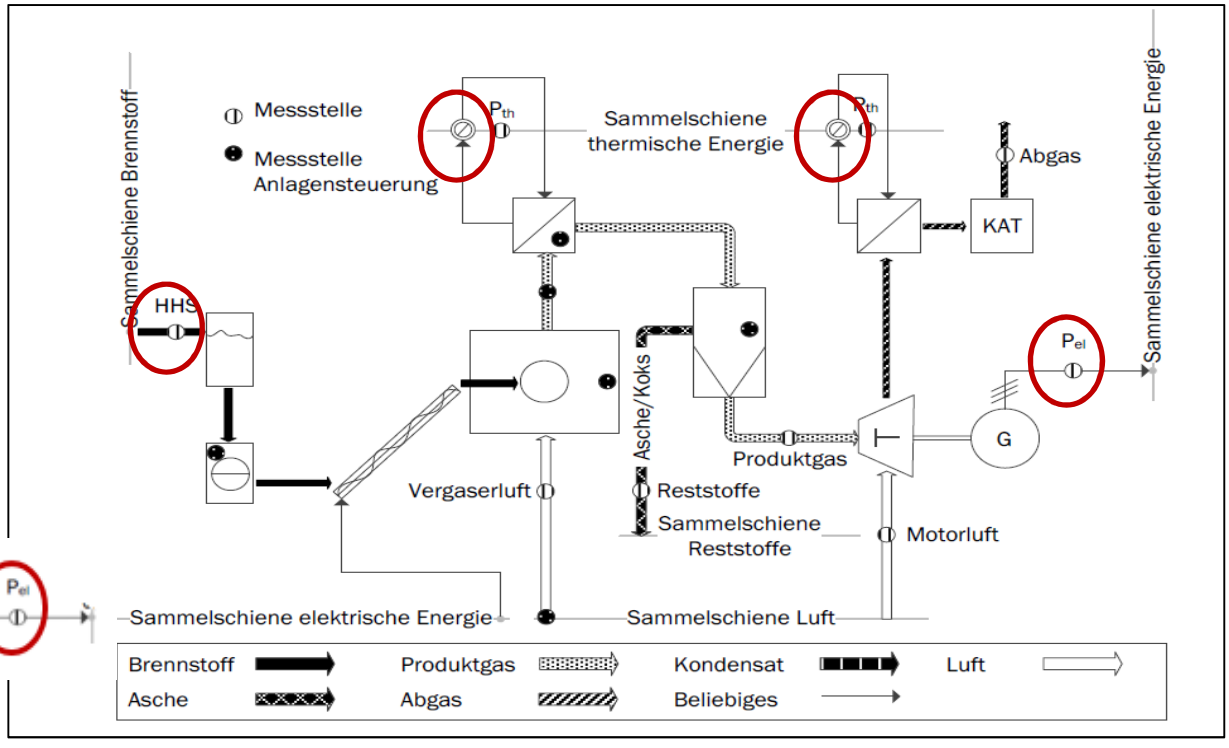

Fig 4 Schemata CHP Gasifier with shows also PTP measuring points (red)

2.2.5 CHP Gasifier Lay out

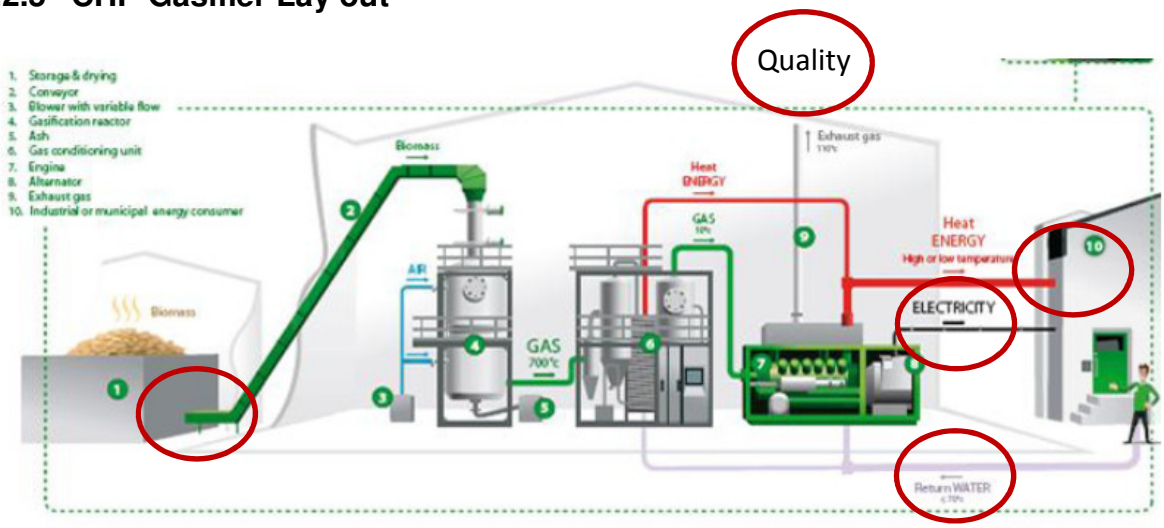

Fig 5 Lay out of CHP Gasifier with shows also PTP measuring points (red)

2.2.6 Mass Flow Sankey Diagram

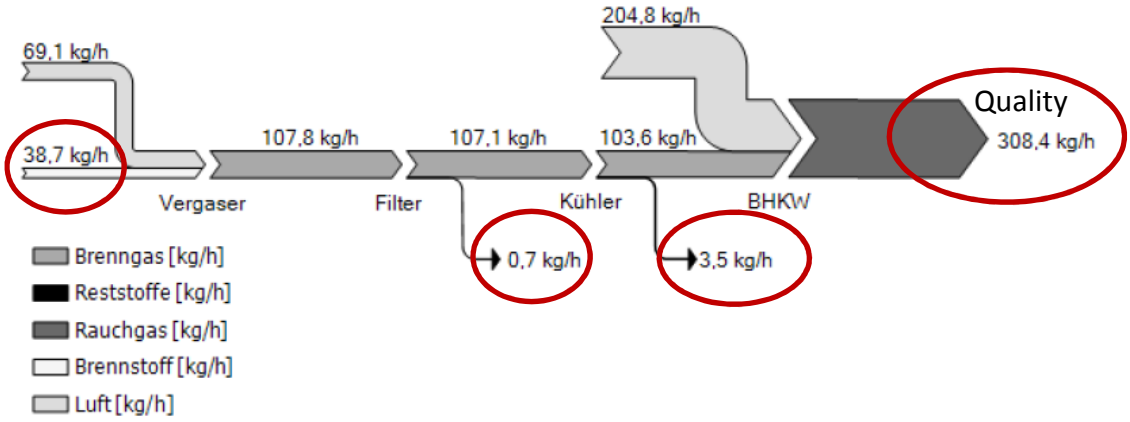

Fig 6 Mass flow of CHP Gasifier with shows also PTP measuring points (red)

2.2.7 Energy Sanky Diagram

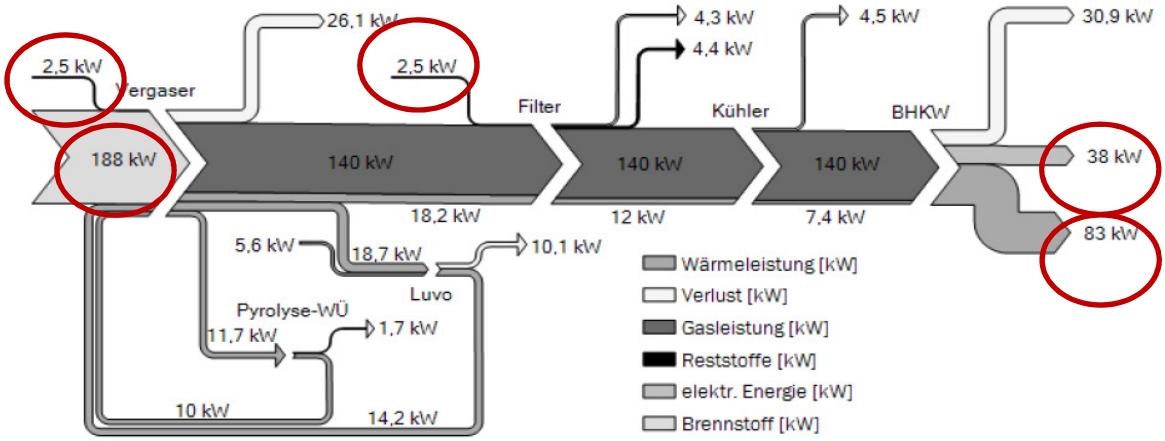

Fig 7 Energy flow of CHP Gasifier with shows also PTP measuring points (red)

2.3 Fuel

Generally it can be sad that homogenous fuel is one of the most important factor to run a gasifier plant successfully and smoothly. But in reality homogenous bioenergy fuel is in most cases not the fact. Tolerances of humidity, quality, size, wood structure and type are wider than wished. Even on pellets today the most normative product with small tolerances on the energy market have after storing remarkable changes of humidity and heating value and physical stability. For operating a gasifier with bioenergy means with chips, saw dust, pellets etc. it is highly advised to consider that fact very strongly.

Fluctuating fuel quality affect in a negative way so the energy production, the number of shut downs, efficiency, wear and tear and the operating costs.

Exact Fuel specification for every fuel that can be used according to the contractual specification, even proven with examples is a must in a gasifier contract and an important reference for PTP. It is advisable to cover all relevant aspects such as humidity, particle size distribution, composition, energy content etc. by following a relevant standard, e.g. ISO 17225 in the technical specification.

Also note that it is advisable to use relevant sampling procedures, see e.g. ISO/DIS 18135, when taking out samples to ensure that samples are representative. This is in particular important when the sample can be assumed to have a wide particle size variation or otherwise show high variability.

2.4 Experiences of traditional Failures on Gasifier CHP units

IEA Bioenergy Task 33 have made long term experience with gasifier units from R+D to commercial units. As conclusion, we can declare somehow “typical failures” on components. In the table below is an overview shown and is typical for prototypes and single delivered units. For Suppliers who delivered more units from one type of gasifier, the number of modification after commissioning and failures are normally reduced.

	Fuel preparation	Fuel Feeding system	Gasifier	Filters	Gas Cooler	Heat Coupling	Motor Generator	Control System
Failures appeared	●●	●●●	●	●	-	-	-	●
Modification after commissioning	●●	●●●	-	●	-	●	●	●
Expected running hours not achieved		-	●●	●●	●	-	-	
More maintenance than expected		●●●	●	●	●●	●	-	●

●●● very often ●● often ● sometimes - barely

Fig 8 Probability of failures in prototype and early commercial CHP gasifier

The predominance of failures related to fuel preparation and fuel feeding, which partially is also related to fuel preparation issues, clearly shows that the fuel quality specification should be given particular attention.
The consequences of such failures and how they reduce utility performance, yearly full load hours and power output has to be considered.

2.5 Financial aspects

Financial goals with a gasifier project are expected. Therefore it is important to elaborate during evaluation budgets not only for investments, but also for yearly operation, including electricity in and out, heat, water, consumables, lubricants, additives, waste (such as water, ash, filter cakes..) maintenance, needed spare parts, costs for staff etc. All this calculation is based one expected full load hours during one year. Nice to have are sensitive analyses for fuel prices and operating hours.

Is there according to PTP a difference to claim with the initially declared specification of the contract the financial aspect can be calculated. On that base after PTP the involved parties can deal out financial aspects.

During a technical project it is very helpful to include a clear structure of payment in the contract. The payment is split normally at least in three parts. Each payment refers to a milestones and deliverable. Four CHP unit with supplier warranties of yearly running hours it makes sense, that the last fourth payment will be done after performance tests and the contractually agreed warranty period. Alternatively, the supplier provides a performance bond or bank guarantee associated with the first payment that runs throughout the project duration, the take-over of the installation, when its value is adjusted to the value of any outstanding warranty.

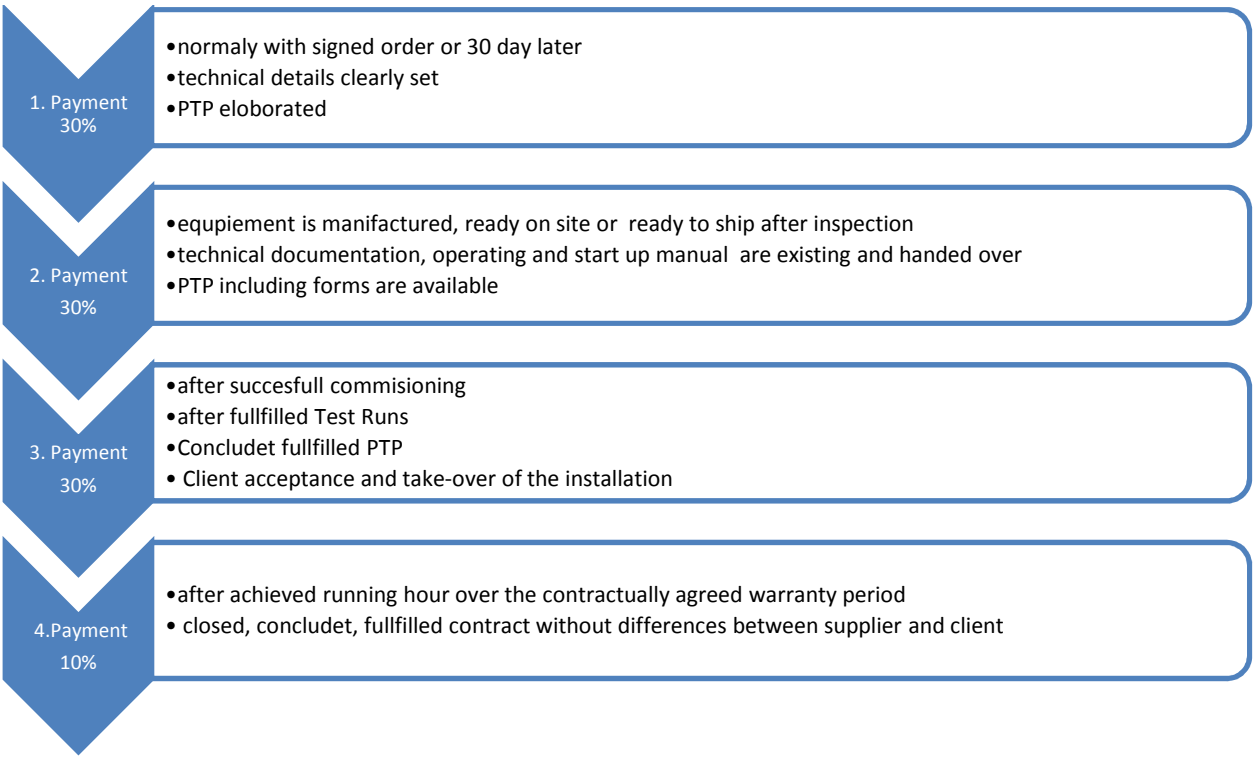

Fig 9 Advised payment structure of a small CHP gasifier unit

2.6 Warranties, Guaranties, Penalty and Bonus Malus Agreements

The expected Power production as well the expected operating hours and costs serve as the base lane for bonus malus agreements and penalty's.

Warranties, Guaranties for components are based mostly on operating hours or time frame. The fulfilled PTP show differences to expectations according to contract specifications. Values measured and listed in PTP is the important tool for the claim of financial compensation. A bonus malus agreement motivate supplier highly to full fill their obligation. It is also advised that last payment of equipment is linked to fulfilled PTP, fulfilled contracts and after final the Take-over of equipment.

Following the take-over of the installation by the client, the supplier or similar will have little presence on the site and therefore the follow-up of performance and warranties is mainly in the hands of only one party, the client, it is important that methods, procedures, reporting etc. is defined in the original contract.

3 Performance Test Protocol for Small Gasifier CHP

Bioenergy conversion is a complex matter and under that aspect to elaborate a PTP is crucial. The Performance Test Protocol is part of the contract between supplier and costumer. The PTP refers on boundaries, the connection points, there specifications, load factors, measurement points of input and output, the mass flow, as well energy flow of the gasifier. A PTP refers also under which environmental condition tests has to be done; further the test run modality and procedure are part of the PTP. Duration and numbers of test, type of test and how they must be protocolled are listed. After commissioning and reported Test runs the PTP can be completed and shows the performance of the CHP gasifier in the conclusions.
If any differences are to claim, with a valuable fulfilled PTP discussions between client and suppliers will refer on a measured facts.
PTP must be practical, correct, and simple as possible, as well refer on the reality. It shall not be a cost driving factor in the project.

3.1 Content of PTP

The performance test protocol must be elaborated individually for each project. Early consideration about the PTP helps to make a project and the performance test successfully. At least in the contract of equipment order a PTP must be available. Specification according 3.1.1 to 3.1.5 are documented, clear and agreed. The PTP must be ready during commissioning and can be completed after the test runs. A closed fulfilled PTP is part of the handover procedure for Project from supplier to the client. In generally a PTP contains the following part:

3.1.1 Object, Terms and Scope
Refer to chapter 2

3.1.2 Reference to Fuel, Equipment and Operating Specifications
Refer to chapter 2.2 and 2.3

3.1.3 Measurement Points and Instrumentation
Refer to chapter 2.2.2 to 2.2.7

3.1.4 Persons who assists Test run
List all persons who have to be present during test runs. An neutral entity with a contract to carry out the tests and with capacity for sampling and the required analytics, or an expert as the observer is advisable.

3.1.5 Type, numbers and duration of performance test runs
List the type, numbers and duration of performance test runs, including also the required steady state periods and the number of samples and analyses of solids, gases, emissions and by-products that are required. (see example Annexe)

3.1.6 Test run reports and forms
Refer to example in Annexe

3.1.7 Documentation and report of results

Refer to example in Annexe

3.1.8 Conclusion of Performance

The conclusion of fulfilment of the performance shall be made in written form. This conclusion shall refer to test forms, the printouts, lists and data logs of the equipment and shall point out if the performance is in line with expectations according to the contract specification. If there are any differences of performance to claim, it must appear in the conclusion in written form and underlined with calculation and extrapolation.

3.1.9 Signature of involved Parties

The signature of all involved Parties of the PTP is a substantial part. The persons in charges from supplier, client and neutral experts who assisted the test runs shall sign the fulfilled PTP for legal compliance.

4 Standards for Bioenergy CHP Gasifier

As Bioenergy conversion is new technology there are not many specific standards concerning bioenergy CHP gasifier. ASME published "*Integrated Gasification Combined Cycle Power Generation Plants* "(see [4]). Standards for some parts and equipment of thermal gasifier are existing, but those are not or only limited applicable for small scale gasifier. For small scale gasifier CHP standards are no publications at all found.

4.1 Standards for PTP

There are no standards for small scale gasifier CHP PTP published.

4.2 Bioenergy Fuel Standards

For solid biofuel are standards available from CEN and ISO (see [5] and [6]). Pellets and wood chips where covered in EN14961-1 this standards are replaced with CEN/TC335. Standards for biofuel as gas and also for natural gas are under ISO/TC238.

5 Literature

[1] Huisman G.H., *Acceptance Test for Large Biomass Gasifier,* 2010
http://www.ieatask33.org/app/webroot/files/file/publications/AcceptanceTest.pdf

[2] Mr. John Vos or Mr. Harrie Knoef, *Guideline for Safe and Eco-friendly Biomass Gasification*, EUC project 'Gasification Guide' November 2009
http://www.gasification-guide.eu/gsg_uploads/documenten/D10_Final-Guideline.pdf

[3] Zeymer, Herrmann, Oehmichen, Schmersahl, Schneider, Heidecke, Ling, Volz: *Kleintechnische Biomassevergasung*, DBFZ Deutsches Biomasseforschungs-zentrum Gemeinnützige GmbH November 2013

[4] ASME: PTC-47-2006 *Integrated Gasification Combined Cycle Power Generation Plants*
https://www.asme.org/products/codes-standards/ptc-47-2006-integrated-gasification-combined#pdf

[5] ISO 18123:2015 *Solid Biofuels - Determination of the content of volatile matter*
https://www.iso.org/obp/ui/#iso:std:iso:18123:ed-1:v1:en

[6] CEN/TC 335 – *Solid Biofuels:*
http://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:19930&cs=17158638AB0C35D5E52A369017E54A1D6
List of published standards under CEN/TC 335 Solid Biofuel:
http://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:19930,25&cs=19F087DBDE0BACDFD4078ABA84D4941DC

[7] CEN/TC 238 - *Test gases, test pressures, appliance categories and gas appliance types*
http://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:6219,25&cs=1E571D8B1B04B25EB7A7917E5274EF779

[8] DIN EN 14 961-1 Solid Biofuels is replaced by EN ISO 17 225-1 to EN ISO 17225-7:2014 see List of [6]

6 Annexes

1. List of Model Contracts for Equipment
   (see separate document)
2. Example for Performance Test Report and Form for Small Scale CHP Gasifier
   (see separate document)