Biomass and Bioenergy 116 (2018) 198–204

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

Research paper

Development of a new micro CHP pellet stove technology

Ingwald Obernberger[a], Gerhard Weiß[a,*], Manuel Kössl[b]

[a] BIOS BIOENERGIESYSTEME GmbH, Hedwig-Katschinka-Straße 4, A-8020 Graz, Austria
[b] RIKA Innovative Ofentechnik GmbH, Müllerviertel 20, A-4563 Micheldorf, Austria

ARTICLE INFO

Keywords:
Stove
Combined heat and power generation (CHP)
Wood
Pellet
Thermoelectric generator

ABSTRACT

BIOS and RIKA developed within the ERA-NET-project “Small-scale BM based CHP” a new micro CHP technology based on a wood pellet stove (thermal capacity 10.5 kW) with a thermoelectric generator (TEG), that enables the operation of the stove without electric grid connection. Thereby, the wear- and maintenance-free and also noiseless TEG system is cooled by a water circuit which makes it possible to supply an additional room with heat. To achieve a self-sustaining operation of the pellet stove a TEG with an electric power of up to 50 W was installed into the casing of the pellet stove and the electricity consumption has been reduced significantly by an optimization of the control system and the selection of appropriate low voltage components. Based on transient system calculations and CFD simulations as well as test runs with two testing plants the system has been optimized. To demonstrate the practical suitability of the new technology in real life, 8 h load cycle tests were carried out. At these tests overall efficiencies up to 92.6% were achieved and in addition to the coverage of the own electricity consumption of the stove, 50 W h surplus electricity were produced which can be used to charge mobile phones or other small consumers.

1. Introduction and objectives

Biomass based room heating systems are very common for space heating throughout Europe. In Austria, biomass stoves represent about 50% of the total number of installed single room heaters [1]. In the recent 15 years pellet stoves became more and more popular due to their advantages regarding automatic control, user friendliness (automated ignition, easy and clean fuel handling) and their low emissions in comparison to logwood stoves. The current market for pellet stoves in Europe is in the range of 200,000 units per year whereby the markets with the highest volumes are Italy and France [2–4]. However, the need of an external electric power supply to provide electricity for the start-up and operation is a disadvantage of pellet stoves especially with regard to fail-proof and independent heating systems. Thus, new and innovative solutions to overcome this deficiency of pellet stoves are required to further support room heating technologies with high efficiencies and low emissions.

The implementation of TEG systems in logwood stoves has already been successfully realised [5,6]. In order to enable the operation of an automatically controlled pellet stove without electric grid connection, a new micro CHP technology based on a wood pellet stove with a thermoelectric generator (TEG) and appropriate power electronics was developed. A TEG consists of several thermoelectric modules (TEM) connected in series. In this paper TEM refers to the single TEM unit, while TEG refers to the electricity generating system. The work was done in close cooperation of BIOS and RIKA within the ERA-NET-project “Small-scale BM based CHP”, funded by the Austrian Climate and Energy Fund.

RIKA has worked in former projects on the development of a TEG to cover the own-electricity consumption of a pellet stove [7]. Thereby, the general applicability of the TEG technology for stoves was proven and a pre-selection of suitable TEMs took place. However, several key-issues remained unsolved:

- Number of TEMs needed to guarantee a sufficient power production
- Positioning of the TEMs to get high and homogenous hot side temperatures as constant temperature differences between the hot and the cold side at all TEMs implemented increase the achievable electricity output of the system
- Selection of an appropriate cooling system for the TEG as the cold side temperature of the TEM has a considerable impact on the electric efficiency
- Design of the pellet stove to guarantee a complete burnout of the flue gas before it is cooled by the TEG in order to minimise deposit formation on the surface of the TEMs (deposits hamper the heat transfer and thus reduce the temperature difference between hot and cold side)
- Development of appropriate power electronics for the TEG system

* Corresponding author.
E-mail addresses: obernberger@bios-bioenergy.at (I. Obernberger), weiss@bios-bioenergy.at (G. Weiß), koessl@rika.at (M. Kössl).

https://doi.org/10.1016/j.biombioe.2018.06.020
Received 29 September 2017; Received in revised form 15 June 2018; Accepted 24 June 2018

- Optimization of the power consumption of the pellet stove
- Minimum additional costs for the TEG integration in order to make the grid independent system economically interesting

The goal of the project was to address the issues listed above and to develop the new technology towards commercialisation. Within this paper the new pellet stove technology with TEG is described and an overview regarding the development and optimization of the new technology and the results achieved is given.

2. Methodology

In order to ensure an efficient and target oriented development during the project, the following methodological approach was chosen.

2.1. Technical approach

The new CHP technology is based on an automatically controlled pellet stove with a thermal capacity of 10.5 kW which is coupled with a TEG and equipped with appropriate power electronics. The cooling of the TEG is done by a cooling device for the TEG which supplies thermal power to room heaters. Additionally, an accumulator and appropriate power electronics are considered for the new technology (see Fig. 1).

During operation of the pellet stove the TEG supplies the stove with electricity. Surplus electricity is stored in an accumulator. The accumulator supplies electricity during the next start-up for the ignition and other power consumers (fan, fuel feeding, and control system) until the TEG starts the electricity production.

Thermoelectric generators enable a maintenance-free and silent electric power generation from heat. Thus, this technology is particularly suitable to realise a grid-independent operation of stoves, which are usually installed in residential areas (e.g. for heating of the living room). The principle of the TEG is based on the Seebeck effect, in which heat is directly converted into electricity by two connected and differently doped semiconductors placed at different temperatures (Fig. 2).

The electric output of the TEMs and thus the TEG is influenced by the type of the TEM, the number of TEMs used, the temperature difference between the cold and hot side of the TEMs/TEG (with rising temperature difference the electric output is increasing) and the TEM/TEG cold side temperature (with rising cold side temperature the efficiency is decreasing). Thus, a high temperature difference between the cold and hot side combined with a low cold side temperature of the TEMs/TEG is the aim in order to achieve a high electric output of the TEG. In Fig. 3 a cross section of the new pellet stove micro CHP technology shows the position of the TEG in the flue gas path. It is located downstream the post combustion chamber where the flue gas temperatures are high and flue gas burn-out is already completed.

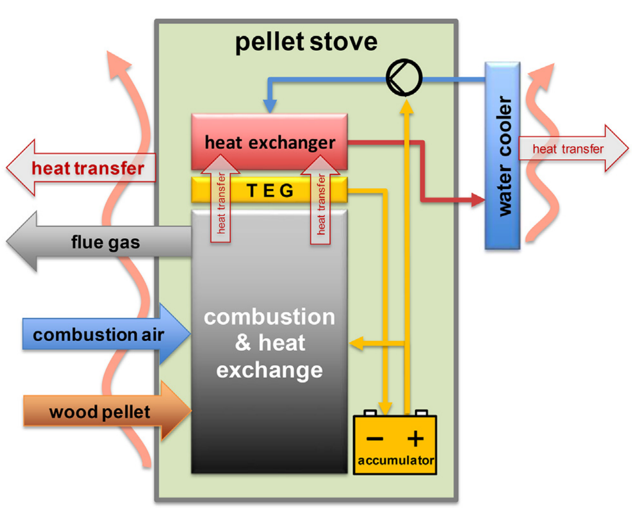

Fig. 1. General approach of the new pellet stove micro CHP technology.

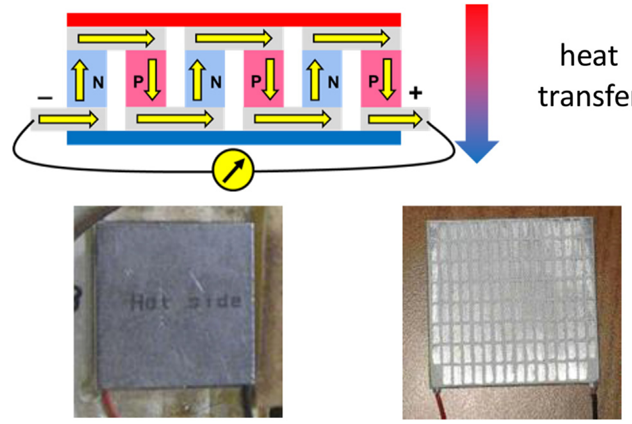

Fig. 2. General structure of a TEM (top) and photographs of the TEM with and without ceramic substrate (N … n-doped semiconductor; P … p-doped semiconductor).

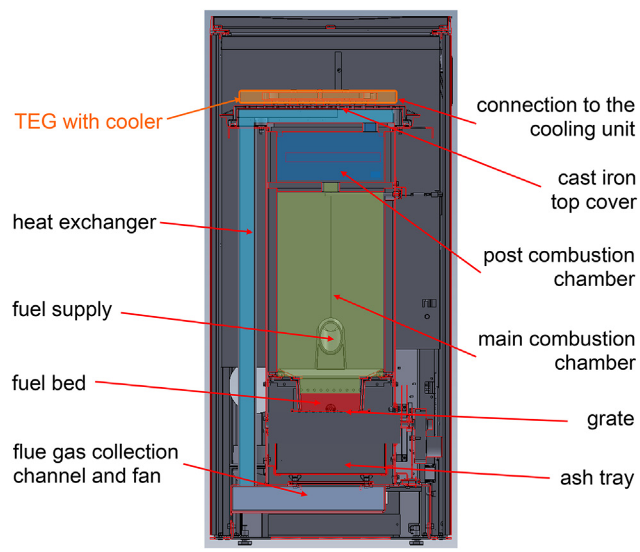

Fig. 3. Cross section of the new pellet stove CHP technology.

The electricity produced is stored in the accumulator for the next start-up of the pellet stove. The surplus electricity produced, when the accumulator is fully charged, can be used to charge external devices via USB port implemented in the new power electronics.

2.2. Transient system calculations

For the definition of the number of TEMs needed to provide electricity sufficient for the operation of the pellet stove and to evaluate different cooling options for the TEG system, transient system calculations were performed based on an in-house developed Microsoft Excel™ spread sheet considering the heat-up, stable operation, load changes and cooldown phases of the system. These calculations enabled a realistic overall dynamic system modelling based on the given boundary conditions regarding pellet stove operation, TEG and ambient. Thereby, different cooling options such as air cooling (II), heat storage (I) and cooling with a water circuit (III) were modelled and evaluated (see Fig. 4).

2.3. Selection of appropriate system components

As a first step towards a self-sustaining operation, the own

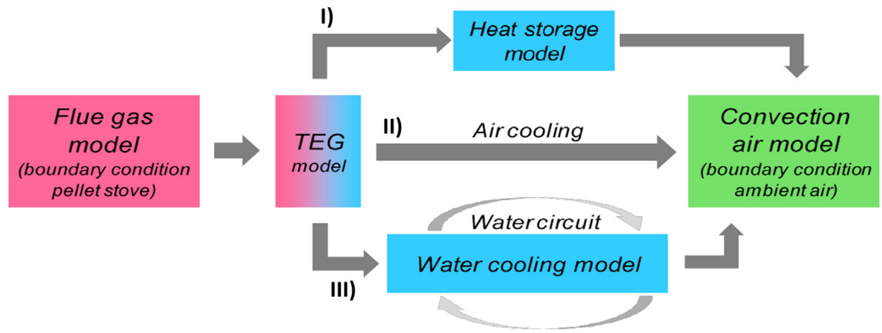

Fig. 4. Structure of the transient system calculations for the three (I - III) cooling options investigated.

consumption of the pellet stove had to be reduced. This was achieved by RIKA by selecting low voltage system components (ignitor, flue gas fan, fuel feeding system, water pump and accumulator). In a second step the power output had to be maximized. This goal could be accomplished by adapting and optimizing the TEG, the accumulator and the power electronics. As criteria for the selection of a suitable TEM, the acceptable maximum hot side temperatures (to increase the temperature difference between hot and cold side of the TEM), high electric efficiencies as wall as low costs were considered. The selected type of TEM has subsequently been implemented into the testing plant 1 and 2. For all components selected the investment costs were, apart from suitable technical specifications, an important basis of decision, since the additional costs for the new CHP technology compared to standard pellet stoves should be kept to a minimum.

2.4. Construction of testing plants (2-stage approach)

Based on the results of the development work described above, a pre-optimized prototype of the pellet stove technology equipped with a TEG and a cooling system (water circuit) was constructed (testing plant 1). The test runs with testing plant 1 focused on the performance of the pellet stove regarding efficiency and emissions, the general function and the achievable hot and cold side temperatures of the TEG for different operation loads of the pellet stove as well as the performance of the cooling water circuit.

Based on the data and experiences gained from the test runs with testing plant 1, the system was optimized and a second – close-to-the-product - testing plant was constructed and tested. For testing plant 2, especially the TEM position in the stove as well as the heat exchangers on the hot and cold side of the TEMs were modified in order to increase the electric output of the system. Furthermore, the air staging and insulation of the main and the post combustion chamber were modified in order to improve the burnout quality.

In addition, for testing plant 2 a suitable power electronics were already available and an accumulator was integrated. Consequently, with testing plant 2 a grid-independent start-up and operation was possible and thus the overall system could be evaluated at different operation modes under close-to-real-life conditions.

2.5. CFD based design of the pellet stove with integrated TEMs

Based on the preliminary design of the pellet stove with integrated TEG a stepwise optimization took place by CFD (Computational Fluid Dynamics) simulations as a basis for testing plant 1. Based on the results of the test runs performed, and the adapted design of the pellet stove provided by RIKA, CFD simulations for the testing plant 2 were performed and the system was improved gradually. Table 1 gives an overview over the CFD models considered. The main purposes of the CFD simulations performed for the new pellet stove CHP technology were to achieve:

Table 1
Overview over CFD models applied.

	Model
Combustion of pellets:	Empirical combustion- and release model (in-house code) for fixed beds [8]
Turbulence:	Realizable k-ε model
Gas phase combustion:	Eddy dissipation mode global methane 3-step mechanism (CH_4, CO, CO_2, H_2, H_2O and O_2) [9]
Radiation:	discrete ordinates model/weighted-sum-of-gray-gases model for gas radiation (gray radiators CO2, H2O)/soot formation and radiation model of soot particles
Shell-conduction model:	3D - heat conduction in the metal sheets surrounding the combustion zone

- Optimal positioning of TEMs regarding high and homogeneous hot side temperatures
- Efficient CO burnout and air staging
- Good flushing of the window by secondary air to ensure a clean window
- High total efficiency
- Low temperatures for the water pump and accumulator in the pellet stove casing

2.6. Measurement and analysis methods applied

A significant number of different measurement technologies were applied in order to gain detailed information about the performance of the new micro CHP technology. The following continuous measurements were performed during the test runs with testing plant 1 and 2:

- Operation parameters: flue gas temperature according to EN 13240, combustion chamber temperature and chimney draught, volume flow of flue gas, combustion air and cooling water circuit as well as temperatures of the hot and cold side of the TEG and in the cooling water circuit
- Flue gas composition downstream the stove using standard flue gas analysers for O_2 (paramagnetic sensor), CO, NO (NDIR) and OGC (FID)
- Determination of the particle size distribution and concentration of aerosols in the flue gas downstream the stove with an electrical low-pressure impactor (ELPI)
- Electricity consumption (separate measurement of the ignitor, flue gas fan, water pump for the water circuit and electronics), electricity production of the TEG (voltage and current) and voltage of the accumulator

Besides these continuous measurements, fuel and ash samples were taken periodically and the total fly ash (TSP) and aerosol concentrations in the flue gas downstream the stove were determined with a filter method and a 9-stage Berner-type low-pressure impactors (BLPI) respectively.

For selected test runs representative samples of the fuel used (wood pellets ENPlusA1) were analysed regarding the moisture content (determination of weight loss at 105 °C - ÖNORM EN 14774–1.2009 12 01), ash content (method according to ÖNORM EN 14775:2009 12 15) and main elements C, H and N (ÖNORM EN 15104:2001 04 01).

2.7. Performance of test runs, evaluation and stepwise optimization of the technology

Test runs at different loads (30%, 50%, 65% and 100% of nominal load) were performed with both testing plants to evaluate the new system in regard to the thermal power of the pellet stove, the thermal efficiency as well as the gaseous and particulate emissions. Furthermore, the test runs focused on the electricity production of the TEG, the electricity consumption of the pellet stove and the performance of the water cooling system.

Additional test runs were performed with testing plant 2 in order to optimize the start-up and shutdown procedure concerning electricity consumption and production. Moreover, "worst case" tests regarding breakdown of the water pump were performed. Finally, load cycle tests were carried out to demonstrate the practical suitability of the new technology in real life. The applied load cycle test has been developed within [10] based on field monitoring data of pellet stoves with and without water jacket. The duration of the load cycle test is 8 h and includes four different load phases and three start-ups of the pellet stove (see Fig. 5).

The test runs were evaluated in detail and mass and energy balances as well as carbon balances were made for plausibility checks.

3. Results and discussion

The transient system calculations pointed out, that due to the low and stable TEG cold side temperatures achievable, the water circuit was identified as the most suitable cooling option for the TEG. Furthermore, this cooling option offers the possibility to heat an additional living room. In addition, the calculations pointed out that about 10–12 TEMs are required to ensure a sufficient power production of the TEG at any load (i.e. from minimum partial load at 30% to nominal load of the pellet stove).

The test runs with testing plant 1 showed very promising results regarding thermal efficiency and gaseous emissions. The electric power potential of the TEG depends on the temperature difference between cold and hot side of the TEMs/TEG and is thus directly correlated to the power of the pellet stove. Results showed that at a temperature difference of 60 °C (achieved at 30% part load of the pellet stove) the electric power potential is 10 W, while for a temperature difference of 200 °C, which can be reached at nominal load of the pellet stove, the electric power potential increases up to 50 W (Fig. 6). The average electricity consumption of the pellet stove (including the power consumption of the pump for the water circuit but excluding the power electronics which were not installed in testing plant 1) amounted to 10.1 W at nominal load. The cooling system worked properly and the feed temperatures were in the range from 35 to 60 °C (depending on the stove load).

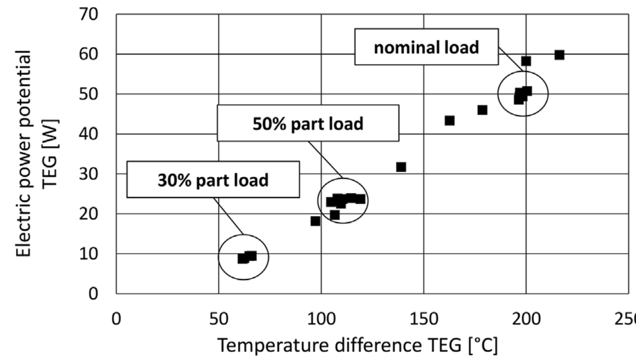

Fig. 6. Electric power potential of the TEG for testing plant 1 in dependence of the stove operation load and temperature difference between cold and hot side of the TEMs/TEG respectively.

In addition, the impact of the TEM/TEG cold side temperature (influenced by the cooling system applied) on the electric output was investigated. Therefore, test runs with varying cold side temperatures (by adjusting the operation parameters of the cooling system) and almost constant hot side temperatures (stable load of the pellet stove) have been performed. The test run results confirmed the expectations and underlined the huge influence of the cold side temperature on the electricity output of the TEG system of about 0.5 W/K (see Fig. 7). Thus, an efficient cooling of the TEMs is essential to reach a high electric output.

The test runs with testing plant 1 showed that the general concept of the new CHP technology is working properly. However, the results of the test runs and the results of subsequent CFD simulations also revealed the potential for further optimization. The main areas for optimizations were:

- Repositioning of the TEMs in order to achieve higher and homogeneous temperatures on the hot side of the TEMs
- Improved TEG cooler design
- Improved burn-out quality and minimization of depositions on the front window of the main combustion chamber by improving the insulation of the main combustion chamber and modifying the ratio

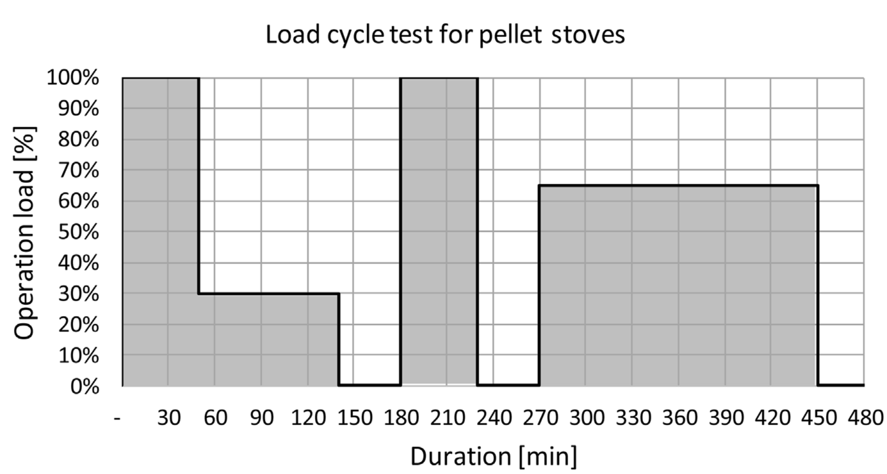

Fig. 5. Load cycle test for pellet stoves [9].

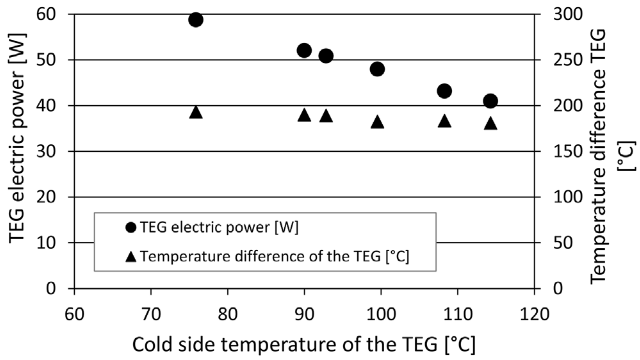

Fig. 7. Electric power potential of the TEG in dependence of the cold side temperature of the TEMs/TEG.

between primary and secondary air.

The adaptations recommended were considered for testing plant 2. In addition, the power electronics specially developed for the new CHP technology were implemented together with the accumulator. Thus, testing plant 2 already represented a close-to-the-product system.

A re-design of the insulation and geometry of the main and post combustion chamber, based on the CFD simulations performed, led to increased flue gas temperatures (see Fig. 8), which is a requirement to reach high temperatures on the hot side of the TEMs/TEG and also to achieve a complete burnout before the flue gas passes the TEG area (important to prevent deposit formation on the surfaces of the TEG heat exchanger).

Based on the CFD simulations for testing plant 2 an optimized positioning of the 12 TEMs with high and rather uniform surface temperatures was achieved (Fig. 9). In addition the maximum application temperature for the TEMs of 330 °C was kept for all operation modes simulated (maximum temperature 314 °C), which has also been confirmed by the experimental tests.

The expected maximum temperatures of the new components water pump, electronics and accumulator were also evaluated by CFD simulations and reduced by increasing convection air openings and considering metal sheets for radiation protection for the construction of testing plant 2. In addition, for testing plant 2 the air staging and window flushing was optimized to ensure a clean window and a low O_2 content in the flue gas (high thermal efficiencies).

Due to the effort taken regarding selection and implementation of components with low electricity demand and due to the optimized control system a further reduction of the electricity demand for testing plant 2 could be achieved. The electricity demand was 9 W for nominal load and 5 W for 30% part load operation, including the power consumption of the water pump for the water circuit and the power electronics (see Fig. 10).

The electric power production at the different loads of the pellet stove is displayed in Fig. 10. The gap between the electricity production and electricity consumption represents the capacity to charge the accumulator during operation of the pellet stove. Even at 30% part load the electricity production is 5 W higher than the consumption. The amount of surplus electricity available to charge the accumulator increases up to 40 W at nominal load. If the accumulator is fully charged the electricity produced can be used to charge external devices (e.g. mobile phone) via an USB-port.

The electric efficiency of the TEG related to the thermal power input from the flue gas to the TEG is in the range of 1.4% at 30% part load to 2.2% at nominal load. At nominal load 8.4 kW of the useful heat is released by the pellet stove itself (radiation and convection air) and about 2.3 kW, which represents 21% of the total heat output, is released by the radiators of the TEG water cooling system to heat a second living room. The share of the heat transferred to the water circuit remains with about 20% the same for all operation loads of the pellet stove. Based on the test run results, the thermal efficiency at nominal load is 91% and rises up to 97% for 30% part load (see Table 2), which is well comparable with the typical range of efficiencies of state-of-the-art pellet stoves. Due to the optimized design and insulation of the main and post combustion chamber, with testing plant 2 an almost complete burnout of the flue gas has been achieved. Thus, the CO emissions at nominal load were with 30 mg/MJ three times lower than the state-of-the-art for pellet stoves (90 mg/MJ based on type testing results).

Since in real life pellet stoves are operating at different loads and most of the time not at stable conditions the new micro CHP technology was evaluated based on a load cycle test especially developed for pellet stoves (see Chapter 2.7). The load cycle tests were performed with the testing plant 2 before and after optimization of the control strategy regarding start-up and shutdown to evaluate the improvements

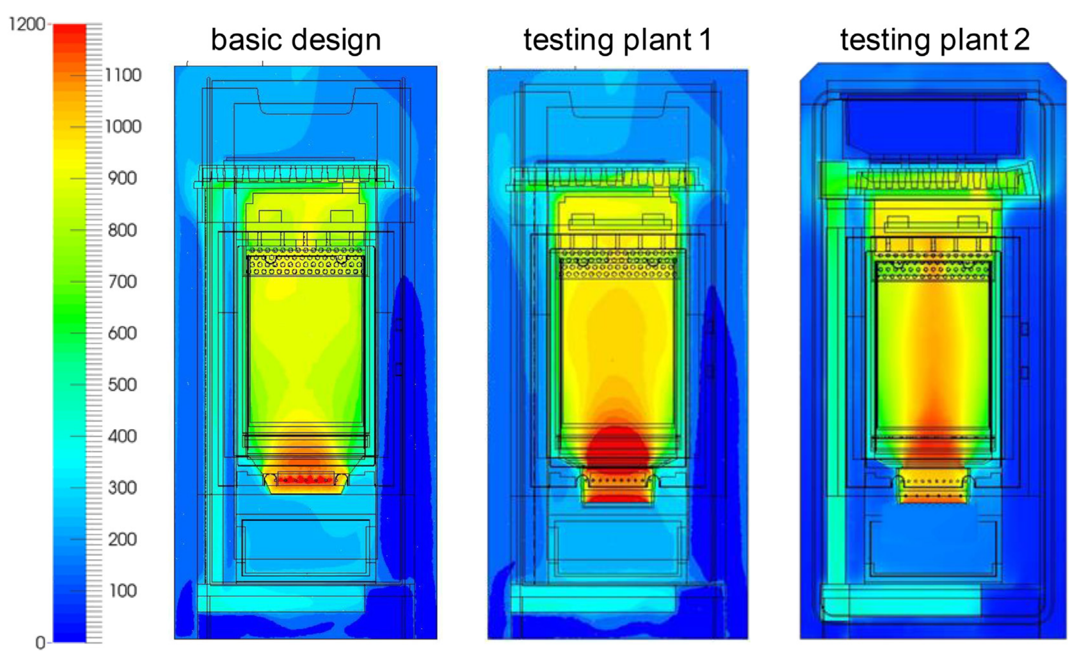

Fig. 8. Results from CFD simulations – iso-surfaces of flue gas, convection air and stove temperatures [°C] at nominal load operation.

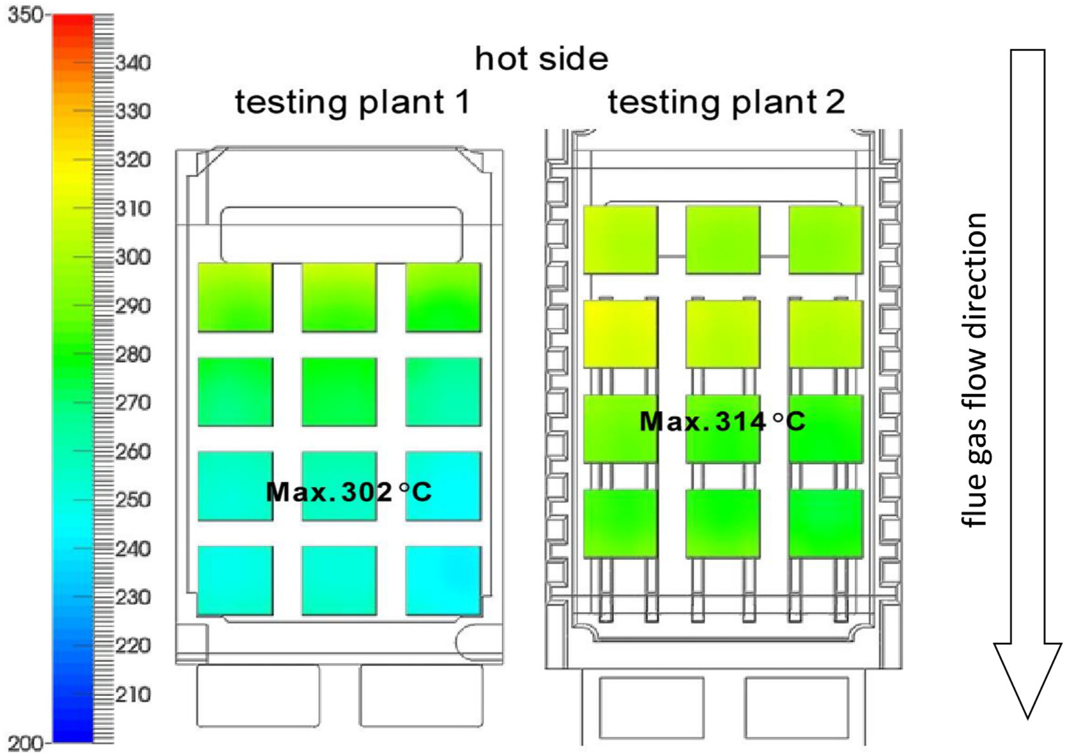

Fig. 9. Results from CFD simulations - iso-surfaces of temperatures [°C] on the hot side of the TEMs in the TEG at nominal load operation (top view).

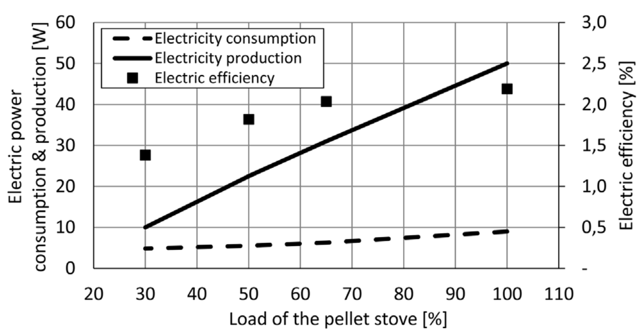

Fig. 10. Electric power production and consumption as well as the electric efficiency of the TEG at different loads for testing plant 2 of the pellet stove.

Table 2
Energy balance at different operation loads of the pellet stove with TEG.

Operation load	[%]	100	50	30
Biomass fuel input	[kg/h]	2.40	1.20	0.72
Biomass fuel power input (NCV)	[kW]	11.78	5.59	3.54
Thermal power combustion air	[kW]	- 0.05	- 0.03	- 0.01
Heat losses flue gas	[kW]	1.11	0.29	0.10
Thermal power cooling system (water circuit)	[kW]	2.26	1.21	0.72
Thermal power pellet stove (radiation & convection air)	[kW]	8.41	4.40	2.72
Total thermal power pellet stove	[kW]	10.67	5.61	3.44
Share of the heat released by the water system	[%]	21.2	21.5	21.3
Thermal efficiency (related to NCV)	[%]	90.6	95.1	97.2
Electric capacity TEG	[W]	50.0	22.5	10.0
Electric efficiency (based on thermal input)	[%]	2.2	1.9	1.4

achieved.

The optimization of the control strategy led to a reduction of the electricity demand by 7% from 74 to 69 W h per load cycle test. Furthermore, an overall efficiency (including the cooldown phases between the operation phases and at the end of the load cycle test) for the load cycle test of 91.1% before optimization of the control strategy and 92.6% with the optimized control strategy were achieved.

The load cycle tests with the new micro CHP pellet stove technology showed that after each start-up of the stove the accumulator can be recharged within the given time of operation. Thus, at the end of the load cycle test the accumulator is fully charged. In addition, an electric potential of about 50 W h to charge external devices is given by the TEG (represented by the light red areas in Fig. 11).

The final test run results with testing plant 2 showed that the electricity demand of the pellet stove can be covered over the whole load range by the electricity production of the TEG and that sufficient electricity can be stored in the accumulator during operation to enable the next start-up of the pellet stove. Thus, the key targets of product development have been achieved.

4. Conclusions

Based on a common pellet stove (thermal capacity 10.5 kW) and a thermoelectric generator a new micro CHP technology was developed. The new technology represents an automatically controlled room heating technology which can operate off-grid. The TEG system is a wear- and maintenance-free as well as noiseless technology and thus ideally suitable for applications in living rooms.

The transient system calculations performed pointed out that 12 TEMs have to be integrated in the TEG to cover the electricity demand during operation of the pellet stove and to charge the accumulator for the next start-up. Furthermore, with the transient system calculations different cooling options for the TEG were evaluated with the result that a water circuit with radiators to heat an additional living room is the most suitable technology for the new micro CHP system. The appropriate position of the TEMs to achieve high and homogeneous

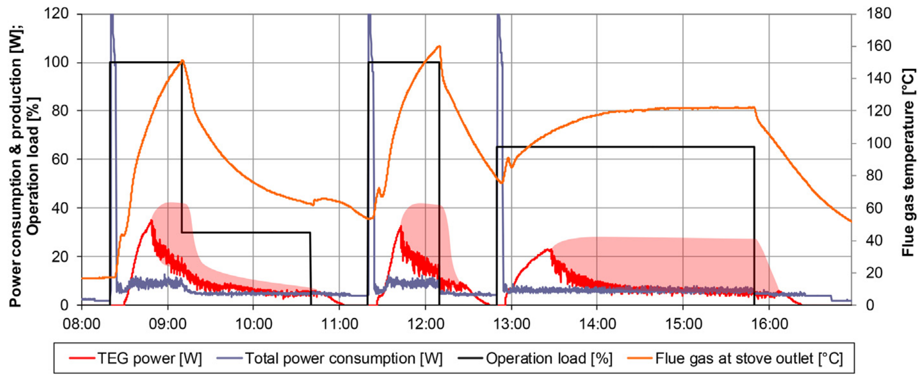

Fig. 11. Load cycle tests performed with testing plant 2 and optimized control system (Explanations: light red areas show the potential to charge external devices). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

hot side temperatures were identified by CFD simulations. Furthermore, CFD simulations were also used to optimize the flue gas burnout and to evaluate and reduce the maximum surface temperatures of the additional components needed for the new technology (water pump, accumulator).

By selecting appropriate low voltage components and optimization of the control strategy finally a reduction of the electricity consumption of the pellet stove down to 9 W (including the power consumption of the pump for the water circuit) has been achieved.

Based on the simulations performed, testing plant 1 equipped with a TEG and its respective cooling system was constructed and manufactured. The test runs with testing plant 1 focused on the performance of the pellet stove regarding efficiency and emissions, the achievable hot and cold side temperatures of the TEMs/TEG for different operation loads as well as the performance of the cooling water circuit. The evaluation of the test runs show satisfying results regarding the cooling system and the thermal efficiency of the pellet stove as well as promising electric power potential of the TEMs. However, to increase the electricity production of the TEG and to further reduce the emissions of the pellet stove an optimization of the testing plant by applying additional CFD simulations took place and a second – close-to-the-product – testing plant was constructed and tested.

The focus of the test runs with testing plant 2 were on the evaluation of the overall system at the different operation modes and on load cycle tests to demonstrate the practical suitability of the new technology in real life.

The evaluation of the test runs has shown a surplus electricity production of about 40 W at nominal load and that even at 30% part load the electricity demand of the pellet stove can be covered by the electricity generated by the TEG. The load cycle tests with testing plant 2 demonstrated, that a grid-independent start-up and operation at different loads is possible. Thereby, an overall efficiencies up to 92.6% were achieved and in addition to the coverage of the own electricity consumption of the stove, 50 W h surplus electricity were produced which can be used to charge mobile phones or other small consumers. Moreover, due to the water cooling system with feed temperatures in the range from 35 to 60 °C (depending on the stove load) and a thermal capacity of up to 2.2 kW, a second living room can be heated by the new technology. The final design of the new micro-CHP system and long-term testing of the new components is currently ongoing.

Acknowledgements

The work was carried out within the scope of the ERA-NET Bioenergy programme “7th Joint Call for Research and Development Proposals of ERA-NET Bioenergy”.

We gratefully acknowledge the Austrian climate and energy fund, for funding the project “Small-scale BM based CHP” (grant number 843799) under its program “e!MISSION.at – 4th call”.

References

[1] Statistik Austria: Energiestatistik: MZ Energieeinsatz der Haushalte 2015/2016, Statistik Austria Bundesanstalt Statistik Österreich, Vienna, Austria, (2016).
[2] P. Biermayr, et al., Innovative Energie-technologien in Österreich Marktentwicklung 2015 Bundesministerium für Verkehr, Innovation und Technologie, Wien, Austria, 2016.
[3] European Commission DG TREN, Preparatory Studies for Eco-design Requirements of EUPs (II): Lot 15 Solid Fuel Small Combustion Installations, Task 2: Economic and Market Analysis –Final Version December 2009, (2009).
[4] H. Haneder, Biomasse-heizungserhebung 2017, Landwirtschaftskammer Niederösterreich, Abteilung Betriebswirtschaft und Technik, St, Pölten, Austria, 2017.
[5] A.M. Guodarzi P, et al., Integration of thermoelectric generators and wood stove to produce heat, hot water, and electrical power; Department of Mechanical Engineering, Babol Noshiravani University of Technology, Babol, Iran, Journal of Electric Materials 42 (7) (2013).
[6] A. Montecucco, J. Sivitera, A.R. Knox, A combined heat and power system for solid-fuel stoves using thermoelectric generators, The 7th International Conference on Applied Energy – ICAE, School of Engineering, University of Glasgow, Glasgow, UK, 2015.
[7] M. Moser, S. Aigenbauer, S. Feldmeier, H. Stressler, E. Höftberger, Bewertung von thermos-elektrischen Modulen mittels eines mit Pellets befeuerten Teststands; BIOENERGY 2020 + GmbH, Wieselburg, Austria, (2015).
[8] R. Scharler, C. Benesch, A. Neudeck, I. Obernberger, CFD based design and optimisation of wood log fired stoves, Proc. of the 17th European Biomass Conference, June 2009, Hamburg, Germany, 2009 ISBN 978-88-89407-57-3, pp. 1361–1367, ETA-Renewable Energies (Ed.), Florence, Italy.
[9] R. Scharler, Entwicklung und Optimierung von Biomasse-Rostfeuerungen durch CFD-Analyse, PhD Thesis Institute for Process Engineering, Graz University of Technology, Austria, 2001.
[10] G. Reichert, et al., Definition of suitable measurement methods and advanced type testing procedure for real life conditions; final report of the “beReal” project, funded by the FP7-SME-2013-2, Research for SME Associations within the 7th Framework Programme of the EU, 2016 http://www.bereal-project.eu.