Environmental impact assessment of a high efficiency small scale pellet boiler

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1. Introduction

This research has been carried on in the framework of the EU FP7 Research Project "BioMaxEff" (Cost efficient biomass boiler systems with maximum annual efficiency and lowest emissions, Period: 2011-2014) that aims at the demonstration of ultra-low emissions and high efficiency small scale biomass boilers. This work focuses on the environmental impact assessment (through LCA analysis) of a high efficiency small scale pellet boiler (Variowin 12kW, VW12, Windhager model). A parallel analysis has been carried on for a traditional 15 kW oil boiler (Jetwin model, JW) to finally compare the two LCA analysis results.

2. Objectives

- Real pellet boiler emission factors calculation (model VarioWin 12, Windhager);
- Pellet boiler environmental impact assessment evaluation;
- Comparison between the pellet boiler system and an oil boiler;
- TSP emission factor sensitivity analysis.

3. Methods

3.1 Calculation of boiler emission factors

Real emission factors are calculated according to the following formula:

$$EF_{C_i} = \frac{\sum_{t_0}^{t_5} dm_{C_i}}{E_{Fuel}} \times 10^{12} \quad [kg/TJ]$$

where

t_i ($0 \leq i \leq 5$) are time intervals from start to stop phase

$E_{Fuel} = m'_{Fuel} \times NCV \times \Delta t \quad [J]$

$m'_{fuel} = instantaneous\ fuel\ consumption$, NCV=net calorific value

The SimaPro software (v. 7.3, Eco-Indicator 99 Impact Assessment method, Egalitarian version [1]) has been used to perform the LCA analysis for both VW12 and JW boilers. Impact Assessment has been evaluated with respect to Human Health, Ecosystems Quality and Resources Depletion. Functional unit: VW12 energy production over its life cycle (1080 GJ).

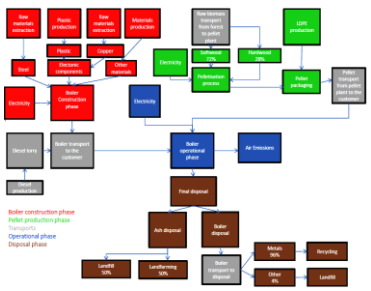

Fig. 1: System boundaries: Austrian case study

Boiler's type	VarioWin 12	Jetwin
Fuel type	Pellet	Light fuel oil
Nominal Output	12 kW	13,6 kW
Thermal efficiency	85%	89,50%
Useful lifetime	20 years	20 years
Fuel consumption	3 ton per year	2 000 l per year

Table 1: Boilers technical features

PHASES CONSIDERED:
- Boilers construction;
- Operational phase;
- Boilers transport;
- Boilers and ash disposal;
- Fuel production;
- Fuel transport.

4. Results

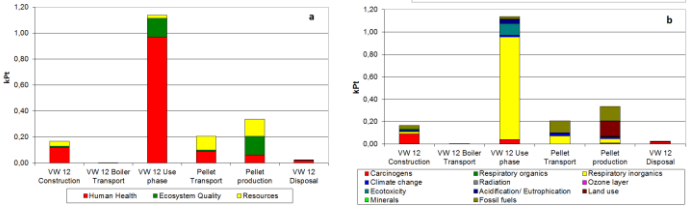

*Fig.4a-4b: **VW12 impact assessment:** weighted processes contributions over the 3 damage macrocategories and specific subcategories.*

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VW12 LCA results:
- Combustion phase (60,7%);
- Pelletisation phase (18%);
- Boiler construction phase (9%);
- Pellet transport (11%);
- Final boiler and ashes disposal (1,3%).

JW LCA results:
- Fuel production phase (67%);
- Operational phase (30%) ;
- Boiler construction (3%).

Parameter	Emission Factor	Unit
CO	282	kg/TJ
NO_x	65	kg/TJ
TSP	26	kg/TJ

Table 2: VW12 experimental emission factors

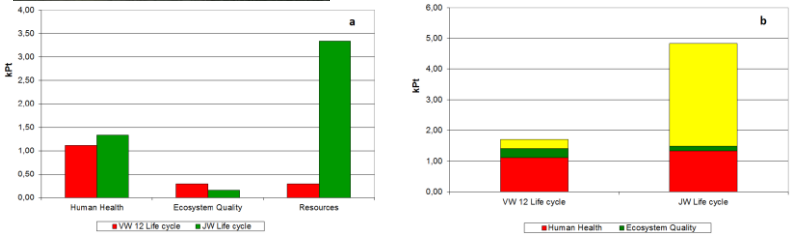

*Fig.5a-5b: **Comparison between VW12 and JW boilers**: life cycle impact over the 3 damage macrocategories.*

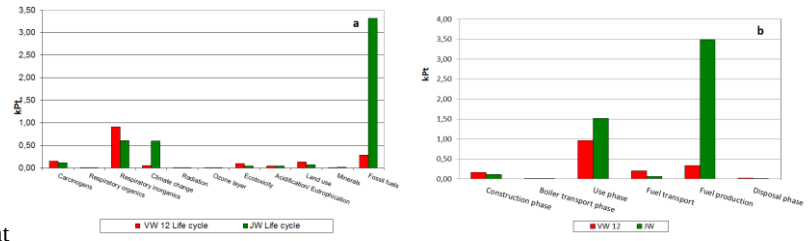

*Fig.6a-6b: **Comparison between VW12 and JW boilers**: life cycle impact over specific subcategories and phases contributions.*

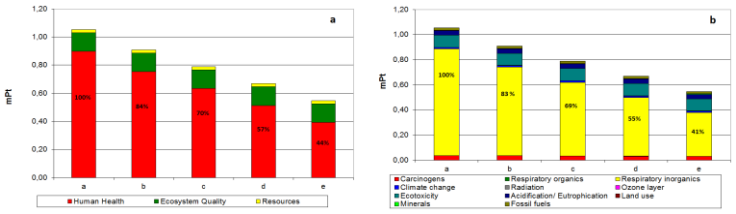

*Fig.7a-7b: **Sensitivity analysis** changing the TSP emission factor according to different scenarios (a-e). TSP(a) = 26mg=MJ; TSP(b) = 20mg=MJ; TSP(c) = 15mg=MJ; TSP(d) = 10mg=MJ; TSP(e) = 5mg=MJ.*

5. Conclusions

- VW12 operational phase has the highest environmental impact (60% contribution over the whole life cycle);
- JW oil boiler has an environmental impact 2,8 times higher than VW12;
- VW12 impacts on Human Health are mainly restricted to respiratory inorganics subcategory (TSP emissions);
- VW12 environmental impact on Human Health (restricted to the specific Respiratory Inorganics subcategory) is reduced by percentages up to almost 57% just considering the boiler operational phase impact reducing TSP emission factor down to 5 mg/MJ;
- 2048 processes have been analyzed; 35 processes with significant (>1%)

References:

[1] Mark Goedkoop and Renilde Spriensma, The Eco-indicator 99 a damage oriented method for life cycle impact assessment: methodology annex. Report annex. Pre consultants, 2011.

[2] Christian Bauer, Holzenergie. Final report Ecoinvent 6-IX. Dubendorf, Paul Scherrer Institut, Villigen and Swiss Centre for Life Cycle Inventories, 2007.

[3] M. Diaz et al., Comparison of the environmental impact of biomass and fossil fuels medium scale boilers for domestic applications employing life cycle assessment methodology, Proceedings of the 16th European Biomass Conference and Exhibition, Valencia, 2008