A Case Study of Elva district heating network

Environmental aspects
&
cost-benefit analyses

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TOPICS

1.Environmental aspects (carried out by Hendrikson & Ko):

The aim of the analyses was not to assess all environmental impacts of woodchip fuel, but to focus on air emissions from the boiler houses as the most significant environmental aspect of fuel combustion.

TOPICS:

-Burning wood fuel - air pollutants from boiler plants; comparison of scenarios

-Assessment of Life Cycle emissions for woodchips for Elva case study

-Utilization of ashes

2. The results of the Cost-Benefit analyses (carried out by Aado Altmets):

Greenhouse Gas inventories - methodology

The Basis for GHG Inventories:

- "2006 IPCC *(Intergovernmental Panel on Climate Change)* Guidelines for National Greenhouse Gas Inventories"
- In Estonia: 16.07.2004 regulation No 94 of Minister of the Environment "Välisõhku eralduva süsinikdioksiidi heitkoguse määramismeetod"

...According to these guidelines and regulations CO2 emissions from burning wood fuel are equalized to 0.

Explanation:

Wood fuel (eg. wood chips) is considered to be carbon neutral. As a tree grows it absorbs carbon dioxide (CO2) from the atmosphere. The same level of CO2 is subsequently returned to the atmosphere when the processed wood is burnt. This means that burning wood fuel does not result in Greenhouse Gas (GHG) emissions.

<u>Burning process</u> of wood fuel - Air pollution and emissions

Two different kind of impacts were considered:

1.Maximum values of different pollutants from boiler plants in the surrounding air were analyzed for the existing situation.

2.Total emissions were calculated for Scenarios I and II, also for the hypothetical situation where shale oil is used for fuel.

Carbon footprint was calculated - total Greenhouse Gas (GHG) emissions were given as the **CO2 equivalent** emitted.

1. EXISTING SITUATION - Concentration of pollutants

Maximum values of pollutants from boiler plants in the surrounding air (µg/m³):

CAS code	Pollutant	Limit Value (SPV_1)	*µg/m³ Nooruse boilerhouse*	*µg/m³ Kirde boilerhouse*
10102-44-0	NO_2	200	13	10
PM SUM	Particles	500	49	39
630-08-0	CO	10000*	50	41
7446-09-5	SO_2	350	25	18
VOC COM	VOC (Aliphatic Hydrocarbons)	5000	2	2

SPV_1 – hourly average

* - average for 8 hours

The table shows that **concentrations of all pollutants from both boiler plants are far below the limit levels and there are no adverse impacts to the surrounding air quality due to emissions from the Elva boiler plants**.

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2. COMPARISON OF SCENARIOS:

Hypothetical scenario - burning fossil fuels (SHALE OIL)

vs

Existing situation – wood chips (scenario I)

Existing situation (scenario I)

vs

CHP plant (scenario II)

Emissions from burning process – base year

	Scenario I		Scenario II
Pollutant	**Total emissions (t/y) SHALE OIL**	**Total emissions (t/y) WOODCHIPS**	**Total emissions (t/y) CHP**
NO_x	9,499	6,391	**11,69**
Particles (PM SUM)	6,333	**15,038**	5,028
CO	6,333	**62,3**	39,986
SO_2	**25,968**	1,091	0,9
VOC COM	0,069	2,956	**3,142**
CO_2	**4851**	83,639	22,135
Heavy metals	**25**	7,5 kg/a	9,2 kg/a

Emissions from burning process - 2025

	Scenario I		Scenario II
Pollutant	Total emissions (t/y) SHALE OIL	Total emissions (t/y) WOODCHIPS	Total emissions (t/y) CHP
NO_x	5,392	3,644	**8,472**
Particles (PM SUM)	3,595	**8,52**	3,398
CO	3,595	**35,247**	28,156
SO_2	**14,752**	0,671	0,651
VOC COM	0,04	1,69	**2,251**
CO_2	**2753**	59,59	16,544
Heavy metals	**14,2**	4,3 kg/a	6,4 kg/a

Emissions from burning process, COMPARISON:

The results show that:

- Burning **shale oil** results in bigger emissions for:
  - SO2,
  - CO2
  - heavy metals.
- **Scenario I (existing situation)** results in bigger emissions for:
  - Small Particles (PM SUM)
  - CO.
- **Scenario II** results in bigger emissions for:
  - NOx
  - VOC,
  - however, **CO_2 emissions are reduced remarkably**.
- Results are similar to the base year and to the year 2025, with the year 2025 just having smaller values because of the reduction in heat consumption.

Positive effect of CHP – Additional CO_2 reduction from produced electricity

As electricity is also produced in case of scenario II, **global CO_2 savings** were calculated.

In Estonia vast majority of electricity is produced from oil shale and the carbon footprint of electricity production is great. Therefore, when electricity is produced in a CHP locally, it results in remarkable CO_2 reduction globally.

The results of the calculations were as follows:

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OVERALL CO_2 emissions and reduction for the scenarios

		CO2 for FOSSIL FUEL	CO2 for SC I (Wood- chips)	SCENARIO II (CHP)			
				CO2 EMISSIONS FROM BOILER PLANT	PRODUCED ELECTRICITY	CO2 SAVINGS FROM ELECTRICITY	SUM CO2 SAVINGS
Base	t CO2 / y	**4851**	**84**	22	3700 (MWh/a)	-3626	**-3604**
	kg CO2 / MWh	352	6	2	3700 (MWh/a)	-259	-257
2025	t CO2 / y	**2753**	**60**	17	2700 (MWh/a)	-2646	**-2629**
	kg CO2 / MWh	293	6	2	2700 (MWh/a)	-270	-268

The results for the Elva case study show that replacing fossil fuels with woodchips results in remarkable CO_2 reduction. But almost as big additional global CO_2 reduction can be achieved if switching from existing woodchip boiler houses to combined heat and power plant technology.

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LCA – Life Cycle Analyses

As said earlier:

BURNING wood fuel (eg. wood chips) is considered to be carbon neutral...

CO2 emissions from burning wood fuel are equalized to 0.

But the overall GHG emissions from the whole life cycle of wood chips may be impacted by **production and transportation** of biofuels, in the worst case to a great extent.

Life Cycle of wood fuel / Renewable Energy Directive

The Renewable Energy Directive (RED), adopted in 2008:

... setting the framework for reduction of GHG emissions for biofuels and bioliquids.

- DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

- REPORT FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT on sustainability requirements for the **use of solid and gaseous biomass sources in electricity, heating and cooling**.

The methodology set out in RED considers also the <u>Life Cycle</u> of biofuels.

The Directive establishes the need for each Member State to develop a set of emission factors for all biofuels that consider the whole life cycle of the biofuels applicable to the specific condition in the member state.

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Life Cycle of wood fuel in Estonia - ?

A report by Ministry of Economic Affairs and Communications, 2011:

"Eesti Vabariigi aruanne Euroopa Komisjonile taastuvatest energiaallikatest toodetud energia kasutamise ja edendamise edusammude kohta" MKM 2011:

-Detail calculation of the the reduction of CO2 according to RED methodology has not yet been carried out in Estonia.

-So far there are no necessary studies in Estonia to develop the methodology for Estonian conditions (to consider life cycle impacts).

= work yet to be done in Estonia.

Life Cycle of wood fuel in Elva

Description of the life cycle on woodchips for the Elva case:

-The main sources of woodchips used in Elva are: forest residues, brushwood, waste from sawmills, timber processing etc.

-Before use in Elva boiler houses woodchips do not need energy consuming processing.

-Woodchips are transported to Elva from distances of 50-70 km.

Calculation of CO_2 emissions from some of the more significant stages of the life cycle was carried out, such as:

-production of woodchips;

-Transport of woodchips.

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Life Cycle of wood fuel in Elva - RESULTS

Calculations of CO_2 emissions carried out showed that:
- Production of 1 m^3 of woodchips from forest residues and brushwood results in emissions of about 3 kg CO_2.
- Transportation of 1 m^3 of woodchips to Elva boiler houses results in emissions of about 3 kg CO_2.

Based on this, the production of **1MWh of heat** in Elva boiler plants results in emissions of about **8 kg CO_2** from <u>production and transportation</u> stages of woodchips.

When comparing this result with the CO_2 emissions from the burning process in boiler plants (see the table above – on slide 11) it can be concluded for the Elva case study that the production and transportation stages of woodchips give a small CO_2 emission compared to the CO_2 reductions from combustion stage.

Utilization of ashes

The utilization of ashes in Estonia is so far poorly covered by strategic development documents, laws, regulations etc...

According to the law, ash is waste,
therefore to be handled according to the Waste Act.

At the same time the topic is not adressed in the National Waste Management Plan (neither in the local management plans).

Possibilities for utilization of ashes from boiler plants (in Estonia):
- **Giving over to the waste handler**
- **Using as a fertilizer in agriculture**
- **Using as a fertilizer in forestry**
- **Reusing as infill (in construction, landscaping etc)**

1. Giving over to the waste handler

+ The most accessible and convenient option for the boiler plants.

- Probably not the cheapest option.

The waste handler:
- deposits waste ash in landfills (non-hazardous waste);
- Reuses the waste ash.

Most of the ash from wood fuel in Estonia is reused:
- Reuse in landfills (eg as separating layers);
- Reuse as (lime) fertilizer;
- Reuse as additive to compost.

Reuse of the waste ash **requires a waste permit**.

2. Using as a fertilizer in agriculture

+ Correct reusage reduces the environmental impact;

+ Much of the agricultural land in Southern and South-Eastern Estonia is acidic, but neutral soil provides better conditions for most agricultural species (ashes would help)

+ In long run could be cheaper for the boiler plant.

- Not a commom option for boiler plants so far.

Needed:

- **Waste permit is needed** to use ash as fertilizer (as officially it is “reusage of waste”).

- Boiler plant needs to **register the ash as lime fertilizer in the fertilizer registry**.

- The composition of ash must be in accord with the requirements set in the Regulation No 23 of 10.03.2005. a. „Nõuded väetise koostisele liikide kaupa“. **Most notably heavy metals may become a problem**.

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3. Using as a fertilizer in forestry

This has been long studied in the Nordic Countries. And as of recent increasingly used in practice. Requirements for such fertilization have been set in legislation.

The potential for Estonia:

- usage in forestry (neutralizing soils, nutrients);
- Usage in recultivating depleted peat fields.

Shortcomings:

- **No regulations** in Estonia.
- **No practice** in Estonia.
- Not enough research yet (so far research has shown mostly positive but also some negative results).

= Option for a little longer perspective.

4. Reusing as infill (in building, landscaping)

Usage of ash for filling (inert waste) used to be common, as there **were no requirements** for inert waste.

Requirements were set with the regulation in 2004.

It may be assessed that **most probably the ash from wood fuels does not comply with the requirements**. The most probable shortcomings:

- soluble matter content exceeds limits;
- unburned carbon exceeds limits;
- ash water is too alkaline.

These shortcomings may be eliminated with treatment (eg pelleting) but there has been no such practice in Estonia.

Cost-benefit analyses

Financial analysis of the investments was carried out on four separate scenarios for the period 2011 to 2032. In all scenarios, the investment is placed on years 2015 - 2017, the useful life-time of the new equipment is 15 years (2018-2032).

Economic analysis is guided by methodology of the cost-benefit analyses of investment projects implemented by European Union.

Cost-benefit analyses

Evaluation of the results is based on:

- the Net Present Value (**NPV**) – has to be more than 0.
- Internal Rate of Return (**IRR**) of the investment – has to be more than discount rate (6%).

- The net present value (NPV) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values of the individual cash flows of the same entity.

- The internal rate of return (IRR) is a rate of return in capital budgeting Used to Measure and compare the profilitability of Investments. The value of the IRR must be higher than the nominal discount rate. Nominal discount rate unites both the costs of the capital and the rise of consumer prices.

If the IRR is higher than discount rate (or the NPV has positive value), it's clear, that the cash flow can cover all the financing and management costs concerned to investment. Otherwise it's necessary to find additional resources – contributions, funding or price increases.

Scenarios

- the First, the so-called 0-scenario, means the continuation of current practices. There will remain three boiler plants in Elva, with their own heating districts. The bulk of the heat is produced from wood chips, but also there are smaller oil boilers to cover peak load for heat in winter period;
- the Second scenario connects heating districts of Nooruse (Central) and Kirde boiler plants. The old boilers will be replaced by ORC-type combined heat and power unit;
- the Third Scenario connects heating districts of Nooruse, Kirde and Elva hospital boiler plants. The old three boilers will be replaced by ORC-type combined heat and power unit;
- in the Fourth scenario an existing boiler equipment in Nooruse is replaced by a smaller ORC-type combined heat and power unit, district heating networks are not consolidated.

(EUR)	Total	Discounted
I scenario (0)		
Initial Investment	2 164 690	1 244 388
Revenues	17 356 168	7 385 213
Operating Expenses	16 564 026	6 727 091
Residual Value	0	0
Net Present Value	-586 266	
Internal Rate of Return	-	
II scenario		
Initial Investment	5 452 180	3 146 413
Revenues	20 243 584	8 322 286
Operating Expenses	15 767 856	6 373 738
Residual Value	0	0
Net Present Value	-1 197 865	
Internal Rate of Return	-3,66%	
Simple Payback Period	15	
III scenario		
Initial Investment	5 857 352	3 392 964
Revenues	21 374 071	8 804 897
Operating Expenses	16 848 393	6 808 726
Residual Value	0	0
Net Present Value	-1 396 793	
Internal Rate of Return	-4,63%	
Simple Payback Period	18	
IV scenario		
Initial Investment	3,659,690	2,103,009
Revenues	17,555,050	6,748,176
Operating Expenses	10,895,798	4,392,922
Residual Value	0	0
Net Present Value	252,245	
Internal Rate of Return	12.43%	
Simple Payback Period	6	

Cost-benefit analyses – RESULTS

Economically the most cost-effective opportunity is establishing a high efficiency Heat and Power Unit for existing heating district in central town of Elva, i.e. scenario IV. This scenario does not require additional investments in heating networks, while investment in equipment is significantly less than in scenarios II and III. Such a project is profitable even without European Union funding. The other scenarios would require grants or supports to ensure the sustainability of the investments.

The advantage of the 0-scenario consists in flexibility. It's the way to manage costs, while making maximum use of existing facilities and equipment. It is possible that the actual investment costs turn out to be smaller than predicted here. Also the 0-scenario brings for consumers relatively small increase of the heat costs.

Cost-benefit analyses – PRELIMINARY RESULTS

Scenario III is calculated as being slightly feasible

- With preliminary calculations the IRR was 9.07%.

Scenario II (as detailed so far) is not economically feasible

Te be feasible, it requires to maintain a positive cash flow.

For example:

- to increase the price of the heat (approximately 10%) or
- the European Union's support (25% of investments).

MAIN CONCLUSIONS

-There are no adverse environmental impacts due to emissions from the existing Elva boiler plants.

-The main environmental advantages of usage of woodchips for fuel (compared to shale oil) are:

- smaller emissions of pollutants (SO_2) and CO_2 reductions.

-Combined heat and power plant further results in higher efficiency + global CO_2 savings from producing electricity.

- Continuation of the existing situation calculates as economically feasible.

- Other scenarios (especially scenario IV) may prove feasible as well. But of course more precise cost-benefit analyses are needed to take into account all factors.

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Thank you!

Cost-Benefit Analyses:

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Environmental topics:

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