Feasibility of renewable energy implementation in Tallinn, Estonia

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1. Feasibility of renewable energy implementation in Tallinn

1.1. Basic data of Tallinn

- Tallinn: 8 districts; total area 158.3 km^2
- Population in 2008 : 403 000 persons

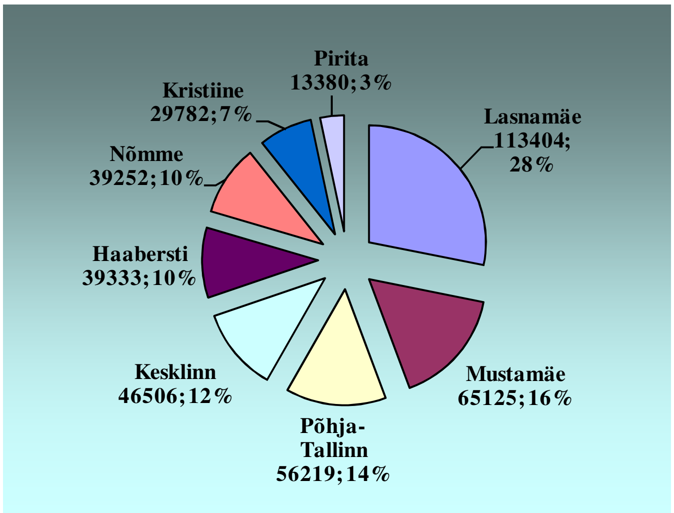


Figure 1-1 Tallinn population by districts

From above districts in Pirita and Nõmme there are private houses areas with different heating systems, including RES in use. In other bigger districts boiler houses with local networks and district heating with widespread networks are the main heat suppliers. The main heat producers for district heating are Iru CHP Plant and mighty boiler houses in Mustamäe and Kadaka. The main fuel for these big suppliers is imported natural gas with heavy fuel oil as a reserve fuel.

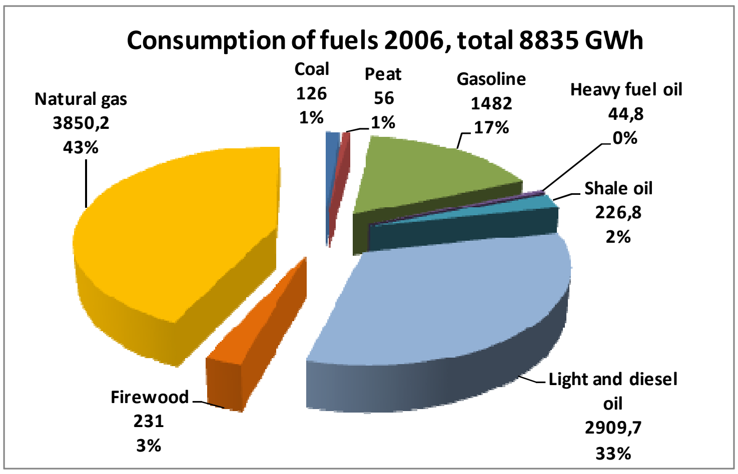


Figure 1-2 Primary energy of fuels consumed in Tallinn 2006 (Statistics Estonia)

On Figure 1-2 and Table 1-1 all fuels used in Tallinn is presented.

Table 1.1 Primary energy of fuels in Tallinn 2006

Fuels consumed	Natural Units	Energy GWh	Energy %
Coal (th. ton)	18	126	1,4
Peat (th. ton)	16	56	0,6
Gasoline (th. ton)	114	1390,8	15,7
Heavy fuel oil (th. ton)	4	44,8	0,5
Shale oil (th. ton)	21	226,8	2,6
Light and diesel oil (th. ton)	247	2909,7	32,9
Firewood (th. sm^3)	132	231	2,6
Natural gas (mln. m^3)	414	3850,2	43,6
Total energy		8835,26	100,0

Heat market in Tallinn

Fuel energy used for heating is presented on the Figure 1-3. The total amount of annual fuel energy is calculated to be close to 4000 GWh.

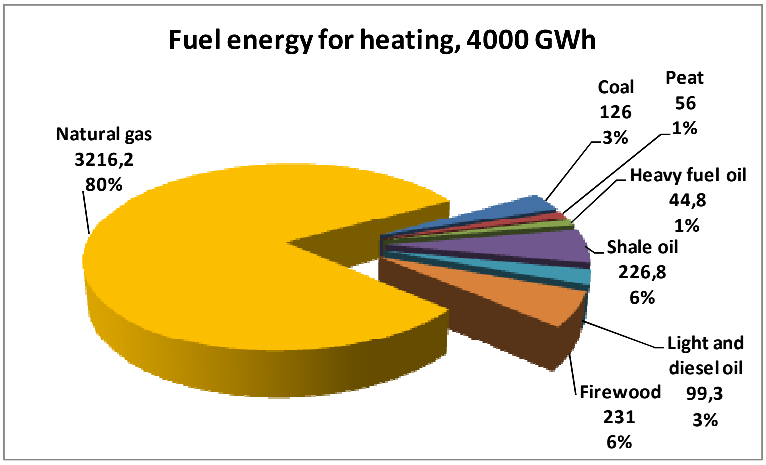


Figure 1-3 Primary energy of fuels consumed in Tallinn for heat production

As seen, the share of RES (firewood) in Tallinn heat production is 6%. Up to 2009 the firewood was used only for private houses heating.

The 6% Tallinn's RES share for energy production is much lower than this of Estonian average (18% in 2005), including electricity (1,76% in 2005). The share of RES in Estonian heating sector is over 20%.

As seen from figure, the natural gas share is 80% of total heat production. Also electricity, co-produced by Iru CHP in Tallinn, is entirely based on imported natural gas. So the Tallinn energy supply is prevailingly based on imported fossil fuel – natural gas.

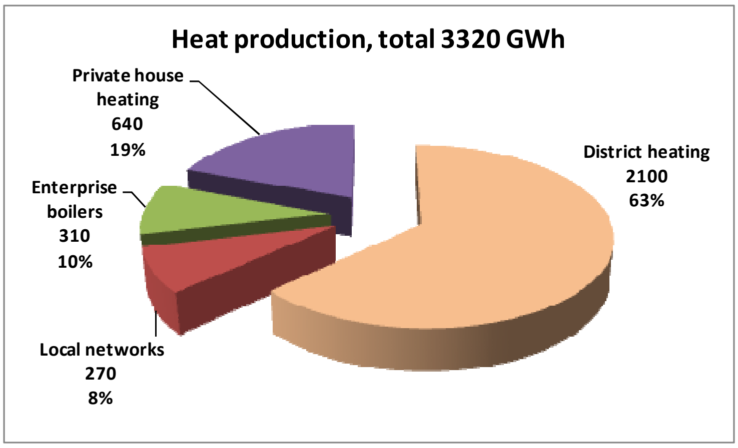


Figure 1-4 Shares of heat production (yearly average) in Tallinn

According to statistics heat consumption in Tallinn is decreasing, due to ongoing energy conservation measures in housing sector. From other side, new houses and enterprise buildings are under construction, depending on economical development. These two tendencies are stabilizing each other, therefore heat consumption for coming 5-10 years are assessed being more or less stable, depending mainly on yearly average outdoor temperatures.

The district heating sector covers 71% of total heat need, including also local networks of smaller boiler houses. In district heating the main heat supplier is Tallinna Küte (Tallinn Heat), which produces heat itself and transfers heat produced by Iru CHP Plant. In total, Tallinna Küte stably contributes 850-900 GWh per annum while the production provided by Iru CHP has been 1200-1300 GWh per annum.

Electricity market

Electricity in Estonia is almost entirely produced on fossil fuel basis. Oil-shale share in power production is app. 90% (90,18% in 2006). The share of RES in electricity production was under 1,0% in 2005 and 2006, but the goal for 2010 to achieve is 5,1%. On the diagram below the RES share is assessed for the coming years. In 2009 two bio-fuelled CHP and new wind-parks will start operation; due to this the 5,1% share of RES will be achievable.

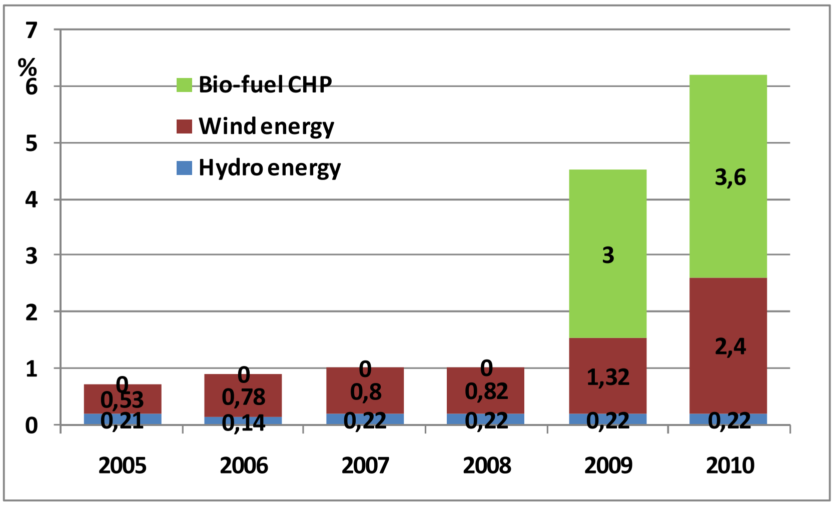


Figure 1-5 Assessed RES share (%) in Estonian power production

Electricity market in Tallinn is stabilized at 1600 GWh per annum. From this the share of enterprises is app. 77%, and the rest is consumed by households.

Minimal electricity load of Tallinn is 50 MW, and maximal app. 350 MW. The load yearly distribution is presented on Figure 1-6.

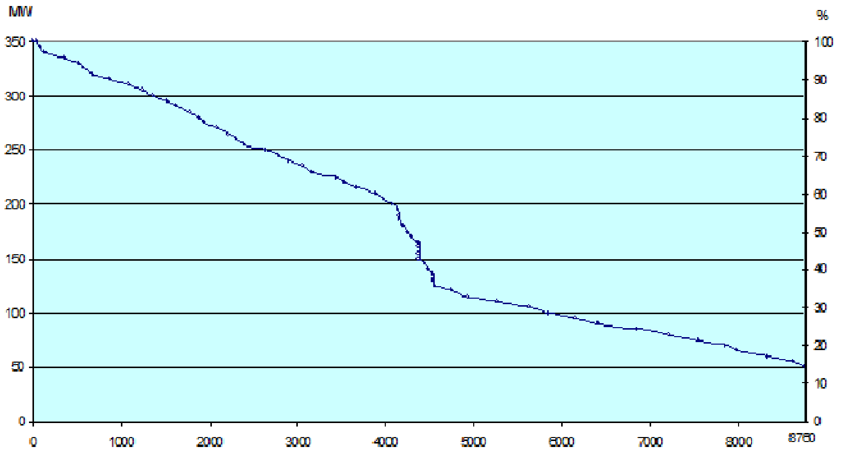


Figure 1-6 Yearly distribution of power load in Tallinn

Power is supplied to Tallinn via the national electricity grid; some share (up to 80 MW) in winter is also produced by Iru CHP Plant.

1.2. Overview of existing and potential RES projects in Tallinn

Up to 2009 the following RES were in usage: landfill gas from former Pääsküla landfill and biogas produced by Tallinn Waterworks from wastewater sludge.

Landfill gas from closed landfill

- Produced at Pääsküla landfill, which was closed for deposits in 2003.
- During 40 years 8.5 million tons of waste was deposited.
- The territory lies on 25 ha and the average waste layer thickness is 40 meters.
- In 1994 3000 m of gas collecting pipes and 1000 m of transfer pipes were installed by Terts Ltd. Today the corresponding numbers are 10000 and 5000 m.
    - Assessed biogas production 1000 nm^3/h with average CH_4 content 50%.
    - Gas was used for heating app. 1000 apartments, today the number is 2000.
- There are two Jenbacher Gas Engine based CHP installed. The capacity of each 836/1050 kWe/kWh.

Production figures in 2006: Gas 763 MW/h; heat 9 265 MW/h and electricity 13 241 MW/h.

RES in Tallinn: Biogas from wastewater sludge

All Tallinn City wastewater is collected and cleaned at Paljassaare Wastewater Centre by applying mechanical, chemical and biological treatment.

- The average wastewater volume is 5 000 m^3/h, but the maximum rises to 28 000 m^3/h.
- All collected sediment goes through methane cisterns, where the biogas is fermented. The biogas production is variable: 200 m^3/h – 360 m^3/h, due to variable nature of sludge.
- Biogas (fuel capacity 1.4-2.5 MW) is used for own production needs.

- There are two aeration ventilators with biogas engines 0.8 MW each; the engines heat (0.5 MW each) is also recovered to preheat the methane cisterns.
- There are also three boilers (1.4; 1.4 and 0.8 MW) operating on biogas, the heat is used for heating methane cisterns sediment as well as for own room heating needs.
- The wastewater mud (up to 1000m^3/d) is preheated to mesophile temperature +37˚C, required for proper fermentation.

In emergency situations some natural gas is also used.

Heat Pumps

- By 2006, 2790 ground heat pumps had been installed in Estonia, additionally 2393 air heat pumps and 198 ventilation heat pumps.
- The total capacity of Estonian heat pumps is about 60 MW; the annual heat energy generation is approx. 133 GWh (44.8 GWh electricity is consumed for that).
- From these figures the heat pumps share of Tallinn and suburbs is estimated to be approx. 50%.

Incentives for RES implementation

There are special incentives enacted to support RES implementation in Estonia.

Table 1.2 Tariffs and subsidies *applicable to producers from renewable and for CHP*

Kind of energy production	Purchase obligation tariff EEKc/kWh	Subsidy EEKc/kWh	Current market price EEKc/kWh	Assumable Sale price EEKc/kWh
Renewable energy sources*	115	84	40,95***	124,95
Efficient cogeneration **	81	50	40,95	90,95

*- Subsidy is paid if the net capacity is not higher than 100 MW. Wind energy is subsidized until the total wind energy production does not exceed 400 GWh per annum.
**- Subsidy is paid if waste, peat or oil shale processing retorting gas is used as the source of energy production. As well it is paid if CHP plant is erected to replace existing district heat supply boiler plant with the capacity not exceeding 1ˇ0MW;
***- The price for Narva Elektrijaamad Ltd, as for the market dominant producer.
The abbreviation EEKc/kWh means cents of Estonian kroon.

1.3. Potential objects and RES to be used

For ongoing Rebecee project a house at Kauge str. 4 has been elected. The old house was demolished and the new building under construction. The house is designed as a social home for handicapped people. Up to 107 permanent inhabitants have been designed, plus app. 15 service employees.

1.3.1 District heating versus local heating with RES usage at Kauge 4 object

Kauge 4 object is still under construction and RES devices being installed. Therefore energy consumption of the house is assessed by experience and by the standards of the house thermal insulation.

The house:

Flats 2

Closed area, net	1041,3 m^2;
Total area	1254,8 m^2;
Volume	4253 m^3;
Incl. above ground floor	2903 m^3;
Incl. under ground floor	1350 m^3;
Height	9 m;
Maximum area under basement	450 m^2;
Site area	1446 m^2

District heating is the basic heat source for heating and hot water supply. In addition to this two renewable sources will be implemented: a heat pump for first floor heating and 18 solar collectors for hot water supply. If implemented, this will be the biggest solar heating unit in Estonia.

1.3.2. Yearly, seasonal and daily heat consumption

General energy efficiency requirements for buildings have been established by the Estonian Governmental Act no: 258, 20.12.2007 "Energiatõhususe miinimumnõuded" (Minimal Requirements for Energy Efficiency). According to the Act the general requirements for building envelope become obligation for new buildings from 2009:

The insulation should follow high energy efficiency requirements. The common upper limit for heat losses of building envelope must be 1,0 W/m^2K.
For small buildings the following basic data should be used:

- exterior walls U=0,2-0,25 W/m^2K;
- roofs and floors U=0,15-0,2;
- windows and doors U=0,7-1,4W/m^2K;

The final values depend on compactness of the house and applied heating and ventilation solutions. For business and office buildings the "free" heat sources (heat induction from lighting, appliances and people) should also be considered.

The valid Estonian Building Code set up the maximal U-values for building components, which have also been considered in Kauge 4 design:

exterior walls	0,28 W/m^2K (incl. 150 mm insulation);
floors on ground	0,36 W/m^2K (incl. 100 mm insulation);
ceiling	0,22 W/m^2K (incl. 180 mm insulation);
Windows	1,4 W/m^2K (two selective glasses, argon insulated)

These values are app. 5 times lower than the appropriate values of widespread in Tallinn prefabricated apartment buildings, and in line with the values of Minimal Requirements for Energy Efficiency.
The building envelope U-values are low compared to conventional construction, but do not match to those under the Passive-house standards. Therefore the house should not be considered a passive house.

Heat supply

Heat will be supplied to the house by the heat substation, located on the first floor. According to design, three heat exchangers of the substation have the following capacities:

Heating	56 kW
Hot water supply	172 kW
Ventilation	85 kW
Total	**313 kW**

Heating season	214 days (5136 hours);
Average outdoor temperature	0,4˚C;
Average room temperature	18-21˚C (23˚C in dressing rooms);
Minimal outdoor temperature	-27,5˚C;

RES to be implemented: solar panels for hot water supply and an air/water heat pump 16 kW.

Assessed heat consumption by sources:

Heated area (net closed area)	1041,3 m^2;
Heating period average heat load	23,35 kW;
Average load of the heat pump	6,67 kW;
Average load of the electrical floor heating	1,88 kW;
Total average load of heat supply sources	31,9 kW;
Total assessed heat consumption for heating	163 838 kWh;
incl. via radiators	119 926 kWh;
incl. by heat pump for water floor-heating	34 257 kWh;
incl. for electrical floor heating	9 655 kWh;
Total specific heat consumption	189 kWh/m^2;
Specific heat consumption without ventilation heat-exchangers	157,34 kWh/m^2;
incl. via radiators	115,2 kWh/m^2;
Heat consumption for hot water preparation	113 515 kWh

1.3.3. Maximal heat load and annual heat production by designed renewable energy sources

Solar collectors

Assessed maximal specific heat supply by solar collector in summer months 290 kWh/m^2

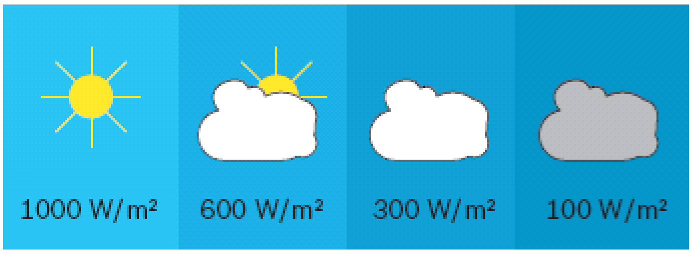


Figure 1-7 Specific capacity of a vacuum tube collector depending on sunshine

There was 18 Logasol SKN 3,0 collectors for the house hot water supply proposed by Buderus Baltic SIA Estonian department. According to their assumption the diurnal hot water consumption by an inhabitant is 25 liters. This gives 25*107= 2675 l, or maximum 3m^3 hot water/day with temperature 55˚C. This is considerable less than foreseen by initial design (50 l/person, day or 5,35 m^3/day).

Each solar collector to be installed on the roof have area 2,4 m^2 and absorber area 2,2 m^2. Total absorber area of 18 collectors is 39,6 m^2. For heat transfer a heat exchanger and two accumulator tanks (1500 l/each) will also be installed. The solar heating battery will be connected with the ordinary hot water system, which enables hot water supplies when there is no sunshine. There is a special heat-meter foreseen to register heat produced only by battery of solar collectors.

The diurnal energy supply by solar collectors, considering the average number of sunny days during summer, is 2 kWh/m^2, day. The total diurnal heat by solar battery will be up to 80 kWh, which is enough to heat app. 2 m^3 of tap water.

It is assessed, that from May till September the total solar heat will be 11 484 kWh. This would make 10,1% of annual heat need for hot water supply.

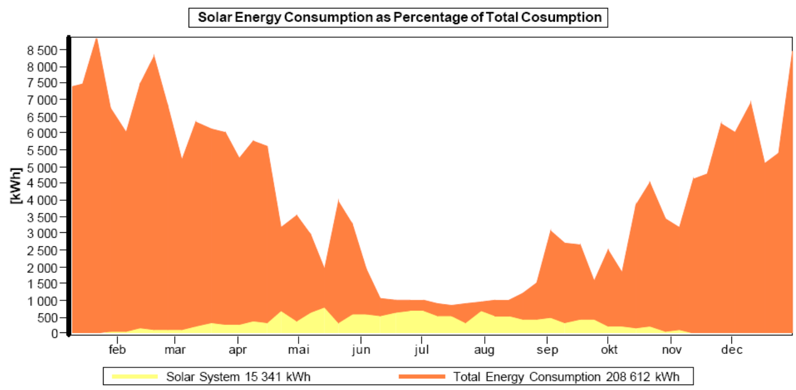


Figure 1-8 Assessment of annual heat supply by the solar system

On figure 1-8 yearly heat supply by the solar system is assessed to be **15 341 kWh**. This figure will be used in feasibility calculation. After a yearly test period the real production data will be fixed and registered.

Heat pump
The house basement floor and some rooms on first floor have water-tube based floor heating, max 20 kW heat supply for this is foreseen by an air/water heat pump. The temperature regime of the floor heating system is 40ºC /33ºC, which is proper for a heat pump installation.

The air/water heat pump **LW150A Alpha-InnoTec** is supplied by REGenergia Ltd, with electrical capacity 9 kW and heat production capacity 15 kW. In case of higher heat need, the rest will be covered by district heating.

Annual heat supply by the heat pump is assessed to be **23 125 kWh**.

1.3.4. Assessment of RES investments and operation and maintenance costs

Solar collectors
Investment cost of the battery with 18 solar collectors and auxiliary devices is 33 066,4 €uro (without VAT).
Annual heat production is estimated to be 15,3 MWh. The system must run automatically and does not need special service. The assessed operation and maintenance cost is 2,3 €uro/MWh.

Heat pump
Investment cost of the 15kW heat pump and auxiliary devices is 20 360 €uro (without VAT).
Annual heat production is estimated to be 23,1 MWh. The system must run automatically and does not need special service.
The estimated operation and maintenance cost (power consumption) is 19,5 €uro/MWh or 450,5 €uro/year.

1.3.5. Feasibility of RES implementation compared with district heating

Feasibility calculations have been performed by the special program for energy supply devices. The program calculates average heat production cost for the project financial period, 15 years. Capital real discount rate was taken to be 5%, average inflation rate and increase of labor cost 2%, nominal bank loan interest rate 7,1%. Results of the feasibility calculations are presented in Table 1.3.

Table 1.3. Results of the feasibility calculation

Project	Investment €ur	Average prod. cost €ur/MWhth	Heat cost of DH, €ur/MWhth	IRR %
Solar collectors	33 066,4	220,78	59,4	-6,47
Heat pump 15kW	20 360	108,56	59,4	-0,45

As seen from the table, both options are not commercially feasible. Production cost of MWh by solar collectors is 3,72 times higher than this of natural gas based district heating. Production cost of MWh by the heat pump is 1,83 times higher than this of natural gas based district heating.

The main reason of non-feasibility is too high investment cost and modest heat production. Concerning solar collectors, increase of heat production is hardly possible, because this is limited by sunshine conditions in Tallinn.
Concerning the heat pump, increase in annual heat production under certain conditions is possible. If the heat production will be doubled, from assessed 23,1 MWh to 46,2 MWh, the production cost will become comparable with this of district heating.

1.3.6. Assessment of emission reduction due to RES implementation compared with district heating

CO_2 reduction by heat production
Annual heat generation by the solar battery is planned to be 15,3 MWh and by the heat pump 23,1 MWh. But to run the heat pump app. 7,7 MWh of electricity will be consumed.

The average CO_2 emission rate of gaseous fuel based district heat is 222 kg CO_2/MWh_h. The average CO_2 emission rate (the baseline) of power consumption is 1,14 ton CO_2/MWh_e.

The calculated CO_2 emission reductions with the implementation of the project will be:

Amount of reduced CO_2 by heat production via solar collectors:

Annual reduction	-3,4 ton CO_2

Amount of reduced CO_2 by heat production via heat pump:

Annual reduction	-5,1 ton CO_2
Annual emission of CO_2 by use of 7,7 MWh electricity	8,8 ton CO_2
Total emissions by using heat pump	3,7 ton CO_2 or 160,2 kg/MWh_h

Conclusions

- Heat produced by the solar battery will reduce annual amount of CO_2 by 3,4 ton compared with district heating.
- Heat produced by the heat pump will cause 3,7 ton of annual CO_2 emissions, due to use of electricity. But to produced heat unit (MWh) the emission rate is lower than this of district heating.

2. Renewable energy implementation in Tallinn district heating via Väo Bio CHP Plant

2.1. Overview of potential RES projects in Tallinn

Figure 2-1 Plan of the Tallinn district heating networks

On the plan of district heating networks is seen that there are three big networks in Tallinn. Two of them, Kesklinn (Ülemiste or KSVR) and Lasnamäe have been connected, but Mustamäe and Kadaka (MSVR) network is so far separated, in spite of planned connection.

The biggest heat supplier Iru CHP Plant is located in Lasnamäe region. The new Väo Bio CHP is also located at the same district.

2.1.1. Capacity and basic production data of the Väo Bio CHP Plant

Heat load and capacities installed

There is remarkable overcapacity installed to supply heat for Tallinn district heating.

Table 2.1 Installed production capacities and maximum consumption load (MW)

Capacity and load	Mustamäe + Kadaka (MSVR)	Ülemiste (KSVR)	Lasnamäe (LSVR) (IRU CHP)
Installed capacity	522+348 = 870	232	808 (incl.460 CHP)
Output max load	286	173	268
To be connected	25		

Network total max	311	441

As seen from table 2.1 the maximal real heat load of all large DH networks is 727 MW, but total installed capacity is 1910 MW.

With Väo Bio CHP entering the market the installed heat capacity will increase by 50-70MW.

Current heat output

The heat output volume necessary for the heating network of the city is **2100 GWh/year** in average. Currently this is covered by:

Iru CHP Plant	1200 GWh,	(57%)
Mustamäe and Kadaka Boiler Houses	900 GWh,	(43%)
Ülemiste Boiler House (occasionally)	10 GWh	

Heat output from 2009 (biofuelled Väo Bio CHP entering the market)

Estimated heat output of Väo CHP Plant	400 GWh;
Estimated heat output of Iru CHP Plant	800 GWh;
Mustamäe-Kadaka Boiler Houses	900 GWh;

Heat outputs after Mustamäe-City Centre heating networks to be connected

Estimated heat output of Väo Power Plant	470 GWh;
Estimated heat output of Iru Power Plant	1460 GWh;
Mustamäe-Kadaka Boiler Houses	170 GWh;

As we can see, in the latter case the ones losing most of their heating market would be the Mustamäe-Kadaka boiler houses - their market share would decrease by more than 5 times. This would allow closing down one of these boiler houses. In fact, this option has been discussed over a number of years, because in Mustamäe-Kadaka region (MSVR) there is 2,63 times more capacities installed in Mustamäe and Kadaka boiler plants then consumers' maximal load.

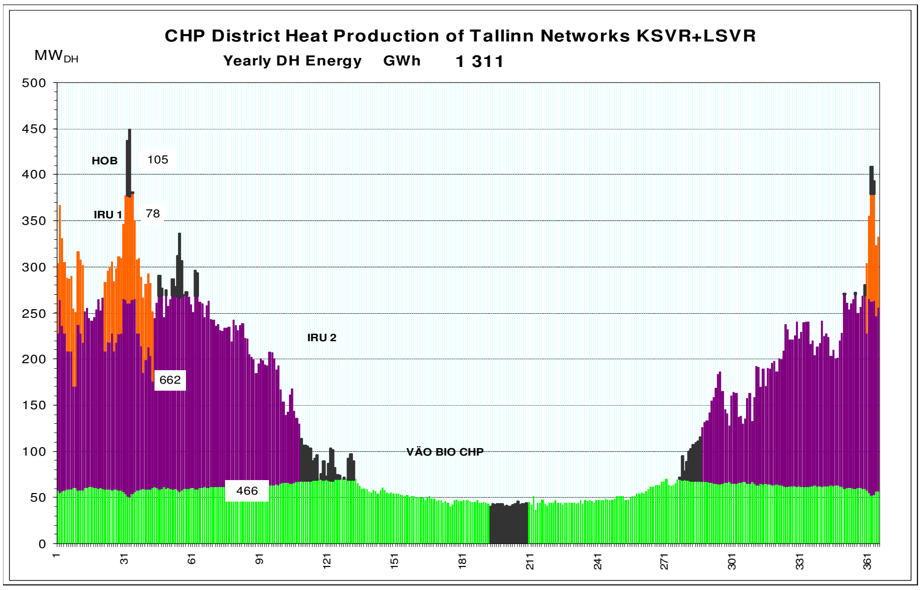


Figure 2-2 Assessed Väo Bio CHP share in Tallinn district heating production

Väo Bio CHP

Väo Bio CHP is a bio fuelled small scale CHP Plant to supply heat to the Tallinn Central City and Lasnamäe districts. The Plant have a bio-fuel boiler generating high-pressure steam, a steam turbine and a set of heat exchangers recovering heat from the turbine exhaust steam. The plant have heat capacity 50 MW_{th}; electrical capacity: gross 25,4 MW_e; net 23,4 MW_e.

The plant has the following main components:

Steam Boiler

The plant has a BFB boiler with steam capacity of 30,1 kg/s, capable of burning wood as side and basic fuel and 100% peat as reserve fuel.

- 75,5 MW_{th} steam power; fuel power – up to 82 MW;
- Primary steam pressure 90 bar, temperature 510°C
- Furnace – bubbling fluidised bed (BFB) type.

The boiler has flue gas heat recovery unit (flue gas condenser), enabling to increase the heating capacity up to 70 MWth.

Steam Turbine

Steam turbine plant consists of a backpressure steam turbine with 5 steam extractions, 25 MVA generator, two heat exchangers (50 MW_{dh} together), condensate-, and feedwater heating plant and auxiliaries. The steam turbine generator has been designed for the following conditions: inlet steam 30,1 kg/s, 90 bar(a), 510 °C.

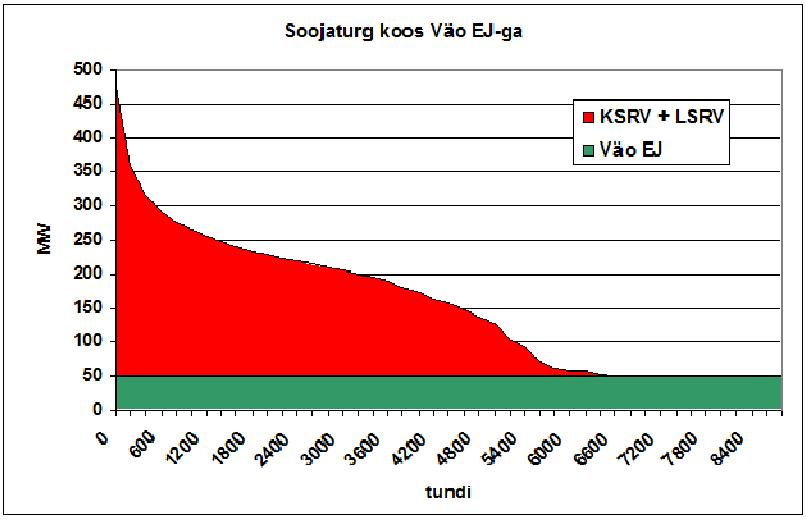
Production capacity

Electrical capacity:	23,4 MWe
Heat production capacity	50,0 MWth

Efficiency

- Electrical efficiency, net 28,7%
- Total net efficiency 90,4% (summer load) and 89,7% (ambient winter load).

Heat market shares



Drawing 2-3 Shares of the district heat market, including Väo PP (without Mustamäe-City Centre linking)

If the Väo Power Plant would take 50 MW of the main load, the remaining market share of Iru PP would account for maximal 0-400 MW for nearly 5500 hours in total.

With the linking of the Mustamäe-City Centre heating network, Iru PP could produce heat during the heating period, i.e. up to 5500 hours per year with the estimated production volume of 1460 GWh. For Väo Bio CHP the heat market share would increase also, but is limited with its maximal capacity of 70 MW, if flue gas condenser is able to work correctly (it depends on district heating temperature regimes).

2.1.2. Biofuels to be used, annual fuel consumption, overall investment cost and other initial data of the Bio CHP

The initial data below are mainly based on Väo CHP project design. Real data are not yet available, because official commercial start-up of the plant is planned on March 2009. At moment the test run of the CHP is going on.

Fuels

The basic fuel to be used is wood (wood-chips), and peat as reserve fuel.

	Wood	Peat
LHV, dry fuel (net)	19000 kJ/kg	20800 kJ/kg
Design moisture content	40%	50%

Wood and wood chips

In the calculations with wood the following composition is considered: C^c=51%, H^c=6.1%, O^c=42.3% and N^c=0.6%. The sulphur content of the wood is very low: 0.05%. The real content of moisture depends on season, growing place and age of tree; for raw wood it is 40-60% and for dried wood 15-20%.

LHV of different types of wood and wood-chips is different depending on moisture. The average values used in calculations are shown in table 2.2.

Table 2.2 Average data of wood chips produced from different woods

Bulk density kg/m^3	LHV		Energy released by burning one bulk cubic meter wood chips
	MJ/kg	KWh/kg	KWh/m^3
244	11,32	3,13	767

<u>Peat</u>

The calorific value (dry matter) of peat (AS Tootsi Turvas) is 17,2-18,2MJ/kg. The moisture content of peat is in wide range. Peat consists about 90% water and 10% dry matter. The moisture content for dried peat can be in range of 35-55%. The content of volatiles is 70-80%. Average moisture content is 45-48%. High moisture content causes low average heating value: 8-12 MJ/kg (2,2-3,3 kWh/kg).

<u>Fuel consumption</u>

Maximal capacity of primary (fuel) energy:	82,0 MW
Efficiency of fuel consumption	89,5%
Annual fuel energy consumption	649 528 MWh
Fuel energy price	14 €uro/MWh
Yearly price escalation	2,0%

<u>Operation and production data</u>

Maximal operating hours	8 760 hours
Real operating hours	7 920 hours (90,4%)
Annual electricity production	185 GWh
Annual heat production	400 GWh

<u>Electricity and heat sales</u>

Sales price of electricity (renewable)	73,5 €uro/MWh
Sales price of heat (to network)	28 €uro/MWh
Electricity price escalation	2,0%
Heat price escalation	3,0%

<u>Operation and Maintenance cost</u>

Project's annual costs of the company are fuel costs, variable and fixed O&M costs, administration costs and pollution taxes.

Variable O&M costs incl emission taxes	4,45 €uro/MWh electr.
Fixed O&M costs incl admin. cost	67 €uro/kW electr.
Consumer price index	2,0%

<u>Total investment cost</u>	77 mill. EUR
Share capital	30%
Loan (5,1%, 20 years)	70%

Depreciation base	70%
Depreciation time	20 years

Project incomes of the Bio CHP Plant consist of electricity and heat sales incomes.

2.1.3. Feasibility of energy production by the Väo CHP Plant

Based on above data the feasibility of Väo CHP was calculated. No VAT was considered in prices.

Description	Väo Bio CHP 25/50MWe/MWth

Basic data					
Discount rate	**5,10%**	Projekt life	**20**	Date.	21.01.2009
Annual Capital Cost	8,09%	Constr.period	**1,5**	Price index	-
				Curreency	Euro

Euro/MWh	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Average	
Fuel cost	**14,00**	15,46	17,07	18,84	20,80	22,97	16,48	2,0%
Fuel taxes	**0,00**	0,00	0,00	0,00	0,00	0,00	0,00	2,0%
Elektric.price	**73,50**	81,15	89,60	98,92	109,22	120,58	86,51	2,0%
Heat price	**28,00**	32,46	37,63	43,62	50,57	58,63	35,90	3,0%

Specific investment	**3 276,6**	Euro/kW.el	equals to.	77 000	kEuro totally.
			-->	657,0	GWh(fuel)
Electric output	**23,5**	MWel	-->	188,0	GWh(el)
Heat output	**50,0**	MWth	-->	400,0	GWh(th)
Total effic.	**89,5%**		α : 47,0%		EL to HEAT
			η : 28,6%		EL to FUEL
Annual O&M	**67,0**	Euro/kW.el	~	2,04%	Year
Variable O&M	**4,45**	Euro/MWh.el	~	1,09%	Year
Full Load Hours	**8 000**	hours/year			

Estimated Long-Term production cost (5%)		
Electric production Co:	**28,86**	Euro/MWhel
NPV [adjusted to year 0]:	**133,9**	MEuro
Net present value (NPV) sum factor :	*12,36*	*[-]*

Internal rate of return (IRR) : 16,84%
Bank loan 70% with nominal 11,3% (nominal) interest, 30% share capital
Annuity Euro 7.746 million
Project is feasible

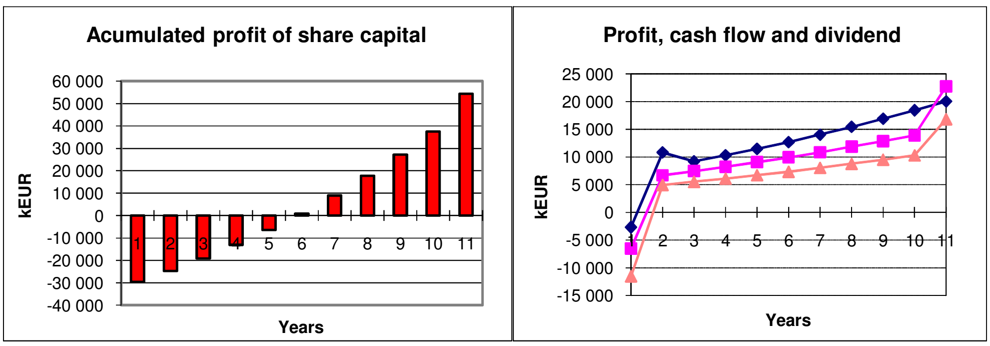


Figure 2-4 Main results of the feasibility calculation

Results with IRR=16,84% and NPV= 133,9 Mill. €uro during 20 year period are quite promising. But this would be achieved only if the following circumstances were considered during project period:

- annual average 89,5% efficiency;
- electricity purchase obligation and price incentive for renewable electricity 73,5 Euro/MWh (7,35 Eurocent/kWh);
- low fuel (wood-chips) cost compared to high cost of imported natural gas – the main fuel in Tallinn District Heating;
- only renewable fuel (wood-chips) to be used;
- natural gas price increase continuing by 3%/year.

Overview of the performed feasibility and electricity production cost calculations is presented in the following table.

Table 2.3. Results of the feasibility calculation

Bio CHP Plant	Investm. Mill.€ur	Average prod. cost €ur/MWhe	NPV Mill.€ur	IRR %
Väo CHP	77	28,86	133,9	16,84

From calculations follows that the payback time is app. 11,5 years.

2.1.4. Assessment of emissions and GHG reduction by Väo Bio CHP

Table 2.4 Annual emissions, calculated according to EU-directive limits

Flue gas component	mg/NM3	kg/h	t/y
SO2	200	28,8	2304
Nox	400	57,6	4608
CO	250	36	2880
Dust	50	7,2	576

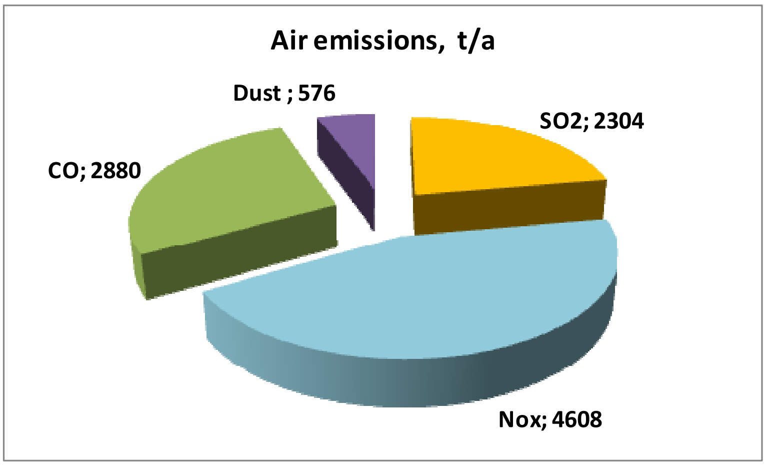


Figure 2-5 Annual air emissions, considered only renewable fuel

According to Estonian Pollution Charge Act § 8 Section 2, pollution charge rates are increased twice (excluding CO_2) in case of stationary contamination sources located in Tallinn.

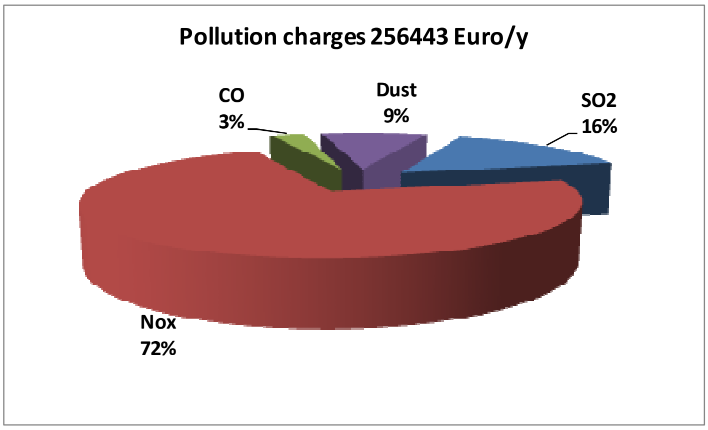


Figure 2-6 Assessed air pollution charges from Väo Bio CHP

CO_2 emission reduction

For new CHP the CO_2 emission reduction calculation is somewhat complicated, because the reduction of CO_2 emission has to be calculated for different products (electricity and heat) separately. For correct CO_2 emission calculation the special "Baseline Study" is required. In hereby calculation the existing CO_2 baseline study calculation for Estonian power sector was used.

The study is based on assumption, that the bio fuel CHP operation will reduce total amount of Greenhouse Gas (KHG) Emissions, comparing with the existing situation in Estonian Power sector (electricity) and in Tallinn District Heating sector (heat). We have to calculate avoided or reduced CO_2 emissions from power and heat production by using biomass (with 0-emissions of CO_2) and by improving overall efficiency of conversion.

<u>CO_2 reduction by power production</u>

Annual power generation by new BIO CHP is planned to be 185 GWhe (including own consumption). The average CO_2 emission rate for this period in Estonian Energy sector is 1140 tCO_2/GWhe. The calculated CO_2 emission reductions with the implementation of the project with annual power generation of 185 GWh are estimated to be 210900 ton/year. For the CHP operation periods the CO_2 emission reduction will be as follows:

Amount of reduced CO_2 by power production will be as follows:

Annual CO_2 reduction	210 900 ton
For Kioto commitment period (2008-2012):	843 600 ton
Total reduction during 20 years:	4 218 000 ton

<u>CO_2 reduction by heat production</u>

Annual heat generation by new BIO CHP Plant is planned to be 400 GWh. The average CO_2 emission rate on gaseous fuel is 202 tCO_2/GWhfuel. Fuel (natural gas) energy needed for this production is 440 GWh. The calculated CO_2 emission reductions with the implementation of the project with annual fuel energy consumption of 440 GWh are estimated to be 88 880 ton CO_2/year.

Amount of reduced CO_2 by heat production will be as follows:

Annual reduction	88 880 ton
Kioto commitment period (2008-2012):	355 520 ton
Total reduction during 20 years:	1 777 600 ton

Total amount of reduced CO_2 emissions (power + heat):

Annual CO_2 reduction	299 780 ton/a
Kioto commitment period (2008-2012):	1 199 120 ton
Total (20 years):	5 995 600 ton

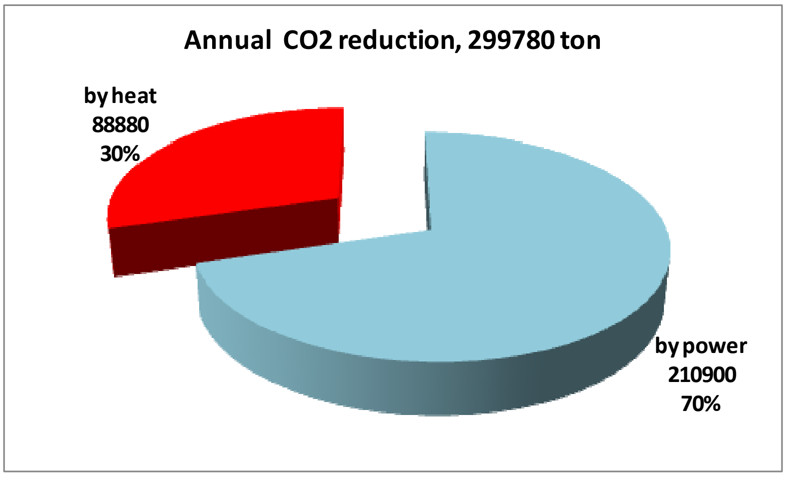


Figure 2-7 Annual CO_2 reduction by Väo Bio CHP plant

Considering the Emission Trading System potential cost of a ton CO_2=20 EURO; the estimated annual CO_2 subsidy by sales of ERU may be up to 5,996 million Euro.

In case the fuel consumed is not entirely renewable, but consists of 10-15% peat, the potential CO_2 reduction share would be accordingly lower.

3. Overview and conclusions

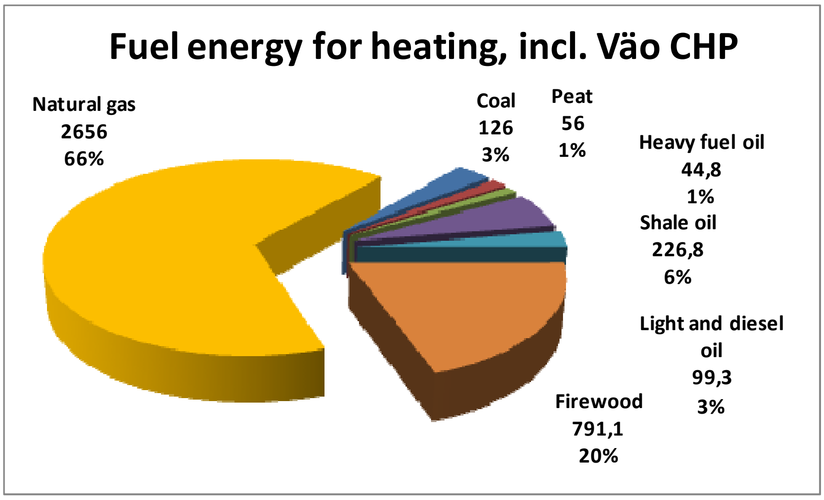


Figure 3-1 Primary energy of fuels in Tallinn heat production incl. Väo Bio CHP

After Väo Bio CHP entering the market RES share in Tallinn district heating will rise from 6 to 20%, while the share of natural gas will drop from 80 to 66%.

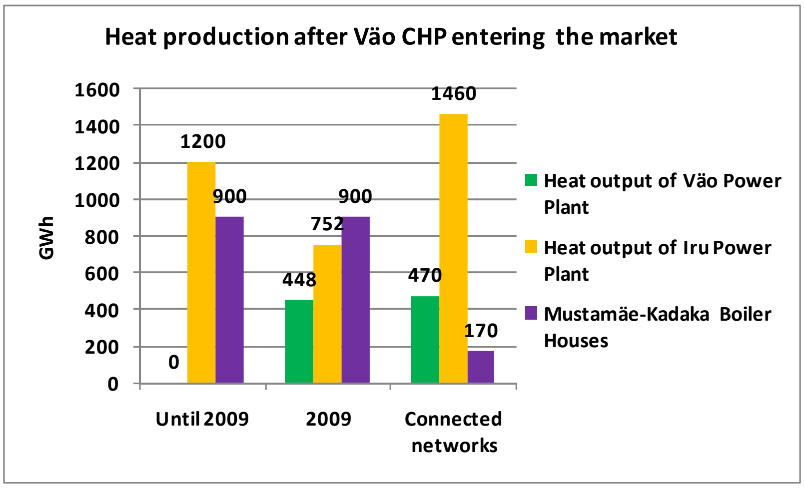


Figure 3-2 Heat suppliers in Tallinn incl. Väo Bio CHP

Heat supplier's shares depend a lot on the potential connection of Mustamäe and Central City DH networks. Until the networks are separated, the biggest heat supplier will be Mustamäe and Kadaka Boiler houses. With connected networks, the biggest heat producers will be Iru Power Plant and Väo Bio CHP.

Conclusions

Kauge str. 4 social house

- RES implementation in Kauge str. 4 object without substantial investment subsidies is not commercially feasible.
- At the same, RES should be installed as a pilot project for research and study purposes. First of all the real RES potential of solar collectors in Tallinn and Estonia will be cleared out. This gives reliable experimental data for further implementations.
- Once substantial investment has been implemented, RES should be kept in operation as much as possible.

<u>Väo Bio CHP Plant</u>

- RES implementation in Väo Bio CHP Plant is commercially feasible.
- Feasibility is achieved due to:
  - ✓ incentives enacted to support RES implementation in Estonia: electricity purchase obligation and price incentive for renewable electricity 73,5 Euro/MWh (7,35 Eurocent/kWh);
  - ✓ low fuel (wood-chips) cost compared to high cost of imported natural gas – the main fuel in Tallinn District Heating;
- Total annual reduced CO_2 emissions (power + heat) will be 299 780 tonCO_2/a, if only renewable fuel (wood-chips) to be used;
- RES share in Tallinn district heating will rise from 6 to 20%;
- Väo Bio CHP enables to achieve 5,1% share of RES in electricity production, the Estonian Republics goal for 2010.

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