Estonian Development Fund

Final Report

Energy resources of Estonia

ENMAK 2030+

Ahto Oja, Mõnus Minek Ltd.

+327 5082990

ahto.oja@monusminek.ee

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Content

Estonia's renewable energy potential

Principles of sustainable development

The Act on Sustainable Development of Estonia[1] (ASD) states on short: if renewable energy source (more or less at the same cost) can replace fossil non-renewable sources, then it should be replaced. The principles of Sustainable Development are fixed in ASD - The need to minimize pollution of the natural environment, and to use natural resources to an extent, which maintains the natural balance, is a fundamental requirement of economic activity. (Article 3, (3)). And also the article 6 of ASD "Non-Renewable Natural Resources" states, that in planning the use of non-renewable natural resources (peat and oil shale in Estonia) the following main conditions shall be taken into account:

1) the adequacy of explored reserves in the longest possible term;

2) the possibility of switching to products made of renewable natural resources or to renewable energy sources;

3) the possibility of substituting non-renewable natural resources with waste or other secondary raw materials.

(2) In planning economic activity the reserves of non-renewable natural resources located within protected areas shall be excluded from the usable reserve stock.

(3) Annual allowable rates of use of non-renewable natural resources shall be determined by the Government of the Republic. Law shall establish the procedure for their use. (Article 6.)

Objectives

The aim of the Energy Resources Working Group (ER-WG) was to gather the best data and information on the identified and proved energy resources of the Estonia. Also the prognosis of the identified energy resource up to 2030, with vision up to 2050 was made.

Methodology

Firstly, Energy resources working group was established on the basis of participants of Open Seminar of ENMAK in October 2012. Secondly, additional experts were invited to the Working Group after first meeting of the ER-WG in 14.11.2013. Working group experts were called to upload their published results and to write the chapter in wiki on the respective resource. The content of each source of the energy includes the volume, availability, use restrictions and price estimates of respective resource. The experts were asked to write the chapter into wiki, and other experts were asked to comment it under section " Arutelu=discussion".

[1] http://www.envir.ee/orb.aw/class=file/action=preview/id=1101227/Act+on+SD_2009.pdf

The given period of time didn't allow to create a new basic info. Experts were also asked to define the questions that need further investigation and those will be included into R&D working group report.

Calculations and tables are available at ENMAK 2030 Google Doc's at request, which allows to share the content of it over the web. In practice the content of current chapter on energy resources was created in three ways.

Firstly, sector expert wrote the chapter into wiki (practically only wind energy sector) and uploaded the material to wiki (both graphs and background material).

Secondly, the sector experts wrote the chapter in word format with pictures and coordinator of the ER-WG uploaded those texts into wiki, uploaded the graphs to wiki and included those into chapter text. This was the case for the most resources. Also the discussion didn't happen in wiki, but still over the emails. The coordinator of the ER-WG uploaded the most relevant arguments from email discussion to wiki-discussion part.

Thirdly, the sector didn't reply in time and the national development plans were used and coordinator wrote the chapter with assistance of experts from Estonian Development Fund (in case of oil shale).

Geothermal energy source was included after the first ER-WG meeting to potential sources of energy. It was skipped in later stage, as sector experts recognised by themselves, that it is too early for geothermal energy source to be included into ENMAK. The research has to be made firstly, and after more accurate information on the geothermal energy source it can be included into ENMAK in future.

The separate chapter will be completed later on future technologies (bio-refinery, tidal energy, methane from rocks from earth crust, etc.).

Summary

The total theoretical annual amount of primary energy is 245 TWH (883 PJ), the share of renewable sources is 188 TWh (607 PJ) and non-renewable sources 57 TWh (206 PJ).

The total applicable maximum primary energy potential is 123 TWh (444 PJ), out of which the share of renewable energy sources is 73.5 TWh (264 PJ).

Estonian theoretical primary energy potential

Estonian theoretical potential of local renewable and non-renewable primary energy resources are given in GWh/y and in PJ/y in table 1.

Assumptions for calculating the theoretical potential of the energy carriers of Estonia:

Accounted for 100% of the forest stumps (778,000 cubic meters), firewood, wood waste, cuttings of non-forest land and firewood energy potential,

The amount of the municipal waste stored in 5 landfills in 2011 was 272'472 t/y and the reused waste amount under code R1 in reporting of the environmental information centre to produce energy or fuel was 276'319 t/y, both amount were counted for energy use 100%.

Straw and reed beds were included 100% according to the MES Biomass report 2007.

The green biomass from land of semi-natural habitats is calculated from 25 000 ha.

Biogas is considered from land of semi-natural habitats from area of 75,000 hectares, 100% of the unused agricultural land and 5% of the biomass potential of agricultural land, other inputs for biogas are taken into account for the use of 100%, the landfill gas is not taken into account (this is given under waste amount).

Solar panels are rated to be installed 45 km^2 (4'500 ha), which is 0.1% of Estonia's land area with average potential of 1000 $kWh/m^2/y$.

Wind is considered onshore 41-year 50TWh.

Wind power at sea is considered according to the Basrec numbers, without environmental restrictions - 15,466 MW (64TWh)

Hydropower is considered theoretical installed capacity of 300 MW

Peat is calculated as an annual rate of 2.6 million is allowed useable amount by law. The total peat resource, which decreases over time period are following: active useable reserves are 154 million tons and active margin reserve is 81 million tons, total passive peat reserves are 523 million tons.

Oil shale is calculated as an annual allowable amount of 20 million tons/year (The total resource, which decreases over time is following: active useable reserve of 1,008 million tonnes, active margin reserve of 302 million tons, a total Passive stock is 3581 million tons.

The total theoretical annual amount of primary energy is 245 TWH, the share of renewable sources is 188 TWh and non-renewable sources 57 TWh.

Table 1. Estonian theoretical primary energy potential, in case of peat and oil shale, the annual allowable amount of resource is considered.

Eesti ressursside primaarenergia teoreetilised kogused/Theoretical potential of primary energy sources		2013	
Allikas/ source		GWH	PJ
Forest/wood	Mets	14,794	53
Waste	Jäätmed	1,207	4
Reed	Roog	250	1
Straw	Põhk	3,201	12
Semi-natural areas	Poolloodusliku d	469	2
Biogas	Biogaas	6,412	23
Solar	Päike (45 km^2)	45,000	162
Wind on shore	Tuul maismaa	50,000	180
Wind off-shore	Tuul merel	64,000	230
Hydro energy	Hüdro	2,628	9
Peat	Turvas	10,612	38
Oil shale	Põlevkivi	46,670	168
Taastumatud/fossil total/kokku		*57,282*	*206*
Taastuvad/renewables	*Kokku/total*	*187,961*	*677*
Kõik kokku/Total		**245,244**	**883**

Applicable primary energy potential

The applicable primary energy potential of Estonia with approximate year of using it is presented in table 2A (GWh) and Table 2B (PJ).

Table 2A. Estonian applicable primary energy potential in GWh with approximate year of use, the timing of the application year is very indicative and in certain market circumstances the uptake of one or another resource may happen sooner or later or not at all.

ENMAK 2030/2050 Energiakandjad/Energia muundamiseks						
Kokkuvõte	GWh					
		2011	**2020**	**2030**	**2040**	**2050**
Wood	Puit	8,770	12,311	12,311	12,311	12,311
Waste	Jäätmed	146	795	786	777	770
straw, hay, reed	Energia	75	248	387	624	914
biogas	Biogaas	32	1,550	2,630	3,240	3,708
Solar (both with PV	Päike	1	15,036	25,179	35,269	45,359
Wind on shore	Tuul	460	1,016	1,270	3,303	4,573
Wind off shore	Tuul	0	942	5,839	5,839	5,839
Hydro	Hüdro	33	34	36	37	38
Peat	Turvas	1,264	1,264	1,184	2,184	3,184
Oil Shale	Põlevkivi	46,667	46,667	46,667	46,667	46,667
Fossil	*kokku*	*47,931*	*47,931*	*47,850*	*48,850*	*49,850*
Taastuvad/	*Kokku*	*9,518*	*31,932*	*48,437*	*61,400*	*73,513*
Total	**Kõik kokku**	**57,448**	**79,862**	**96,287**	**110,250**	**123,363**

Table 2B. Estonian applicable primary energy potential in PJ with approximate year of use, the timing of the application year is very indicative and in certain market circumstances the uptake of one or another resource may happen sooner or later or not at all.

Wood	Puit	32	44	44	44	44
Waste	Jäätmed	0.53	3	3	3	3
straw, hay,	Energia	0.27	1	1	2	3
biogas	Biogaas	0.12	5	9	12	13
Solar (both	Päike	0.04	54	91	127	163
Wind on	Tuul	1.66	4	5	12	16
Wind off	Tuul	0.00	3	21	21	21
Hydro	Hüdro	0.12	0	0	0	0
Peat	Turvas	5	5	4	8	11
Oil Shale	Põlevkivi	168	168	168	168	168
Taastuvad/	***Kokku***	34	115	174	221	264
Total	**Kokku**	207	287	347	397	444

1. Renewable energy

1.1 Wooden biomass for energy

Märt Riistop, Ott Otsman, Peeter Muiste, Enn Pärt, Mati Valgepea

Wood from forests for energy and resource requirements for the use of its assumptions:

Annual capacity of fellings is 12 million cubic meters of timber according to the Forestry Development Plan 2020, based on moderate use of timber for wood supply optimum scenario, because it would be a sustainable rate for the next 40 years.

Stumps are included in amount of 150,000 cubic meters of the total of annual amount of 778 thousand cubic meters.

Wood wastes (sawdust, bark etc.) from wood and paper industry are included in amount of 2.232 million m^3.

Fuel wood from non-forest land is available in the amount of 200 thousand cubic meters.

Cutting leftovers (branches, stem tops, small-sized trees) are available at the amount of 0.718 million m^3 *(50% of the amount of total cutting leftovers from regeneration fellings).*

All abovementioned wooden sources and their quantities do not change significantly over the time period. Forest Development Plan will be renewed before 2020, if needed the amount of wood available for energy conversion, will be changed then and after that the new calculations will be included into the ENMAK 2030.

Potential effects from imports and exports of timber are not included.

Pulpwood energy resource is not included.

Possible competition to the same resources from the chipboards industry is not included, while the amount is insignificant.

The prices of the energy wood are very hard to estimate.

Firewood from forests and related management (cuttings, stumps) and processing residues and non-forest land available firewood for **energy resource is in total of 44 PJ per year (12.311 TWh). (Energy content is 2 MWh/tm in average). (Table 3)**

Table 3A. Forest and wood energy potential.

		Puitse biomassi maht (1000 m3) Volume of woody biomass (1000 scm)										
		Puidu maht raietest Volume of wood from fellings (1000 m3)										
		Raiutud puude tüvepuidu sortiment* Stemwood timber sortment from fellings*										
Puuliik	Tree species	Jämepalk Logs	Peenpalk Small logs	Paberipuu Pulpwood	Küttepuu Fuelwood	Jäätmed*** Residues***	Kokku Total	Raidmed** Felling residues**	Kännud Stumps	Puit mittemetsamaalt Timber felled from non-forest land	Puidu töötlemise jäätmed metsatööstusest**** Woody biomass from wood industry residues**** (1000 m3)	Kokku puit energia tootmiseks Total woody biomass for energy production
Mänd	Pine	1447	568	431	186	519	3151					
Kuusk	Spruce	772	500	761	483	538	3054					
Kask	Birch	371	213	1061	329	519	2493					
Haab	Aspen	167	45	439	321	228	1200					
Sanglepp	Black alder	46	39		380	93	558					
Hall-lepp	Grey alder	14	41		920	173	1148					
Teised	Other	53	23		237	58	371					
Kokku	Total	**2870**	**1429**	**2692**	**2856**	**2128**	**11975**	**1435**	**150**	**200**	**3402**	
Kasutatav energia tootmiseks Usable for energy purposes		**0**	**0**	**0**	**2856**	**0**	**2856**	**718**	**150**	**200**	**2,232**	**6,156**
Energia potentsiaal/ energy potential GWh					**5712**			**1436**	**300**	**400**	**4,464**	**12312**

In case of stumps and timber felled from non-forest land only the possible harvested quantity is indicated

* According to the theorethical assortmentation of volume of felled tree stems, based on the modelling of data of measured stumps of felled trees; Source National Forest Inventory - Estonian Environment Information Centre

** Felling residues from regeneration fellings - wood which can be collected after the fellings: mostly branches, tree tops and/or small sized trees; after some drying residues are chipped and used for energy generation. Up to 50% of volume is predicted to be used for energy purposes

*** Residues - parts of the stem which are not divided into sortments: bark of logs, oversize of logs, stem tops, sawing paths, undercut. Used for energetic purposes as part of felling residues (stem tops) or fuelwood (stem tops) or by wood processing industries (bark, oversize of logs). Usability for energy is reported under column "Woody biomass from wood industry residues"

**** For composition of woody biomass residues see table "Metsatööstuse kõrvaltoodangu energiatootmiseks kasutamise võimalused"

Table 3B. Energy potential from wood processing industry.

Tabel Metsatööstuse kõrvaltoodangu energiatootmiseks kasutamise võimalused

Puidulise biomassi (sh energiatootmiseks sobiva) tekkimine kõrvaltoodanguna ja kasutus tööstuses toodete tootmiseks sisendina

I. Kõrgema kvaliteediga tooret tarbiv tööstus ja puidulise biomassi **teke** selle tööstuse kõrvaltoodanguna							
Puidutööstuse liik	**Toodangumaht (m3)**	**Toormevajadus, (m3)**	**Kõrval-toodang, (m3)**	**Jäätmetena arvestamise osakaal (%)**	**Jäätmetena arvestatud (m3)**	**Kõrvaltoodangu liik**	Märkused
1. Saetööstus + muu (sh postid), toormevajadus on ülemõõduta ja kooreta tüvepuidu maht	1,900,000	3,800,000	1,170,000	0	0	hake (60% saagimisel kõrvaltoodanguks mineva puidu kogumahust, sisaldab ülemõõtu)	See blokk kasutab primaarseks toormeks metsast tulevat peamiselt kõrgekvaliteedilist ressurssi ja jätkutööstuses saematerjali
			780,000	100	780,000	saepuru (40% saagimisel kõrvaltoodanguks mineva puidu kogumahust, sisaldab ülemõõtu)	
			110,000	100	110,000	ülemõõt (3% palkide kogumahust)	
			390,000	100	390,000	koor (10% lisaks kooreta ülemõõduga palkide mahule)	
2. Jätkutööstus = saematerjali kasutav tööstus höövelдamine, jätkamine, liimimine, komponendid jmt Saematerjali näivtarbimine, sisaldab importi 1 000 000 m3.		2,000,000	600,000	100	600,000	saepuru ja laast, klotsid jmt	
3. Vineeri ja spooni tootmine	160,000	420,000	260,000	100	260,000	koor ja hake	
Kokku kõrvaltoodang:			**3,310,000**		**2,140,000**		
II. Paberi- ja termomehaanilise puitmassi tootmine, (osaliselt saab kasutada ka ülemise bloki kõrvaltoodangut)							
Paberitööstuse liik	**Toodangumaht (t)**	**Toormevajadus, (m3)**	**Kõrval-toodang, (m3)**	**Jäätmetena arvestamise osakaal (%)**	**Jäätmetena arvestatud (m3)**	**Kõrvaltoodangu liik**	Märkused
1. Termomehaaniline puitmass	160000	400,000	40000	100	40000	koor	See blokk kasutab primaarseks toormeks metsast tulevat paberipuu iseloomuga ressurssi ja osaliselt I blokis olevat kõrvaltoodangut
2. Paberi tootmine	65,000	320,000	32000	100	32000	koor	
Kokku paberitööstuse kõrvaltoodang:			**72000**		**72000**		
III. Madalama kvaliteediga puittooret tarbiv tööstus ja puidulise biomassi kasutus tööstuslike toodete tegemiseks							
Puidutööstuse liik	**Toodangumaht**	**Toormevajadus, m3**	**Kõrval-toodang (m3)**	**Jäätmetena arvestamise osakaal (%)**	**Jäätmetena arvestatud (m3)**	**Kõrvaltoodangu liik**	Märkused
1. Pelletite tootmine	500 000 tonni	1,250,000					See blokk kasutab primaarseks toormeks metsast tulevat madalakvaliteedilist ressurssi ja I blokis olevat kõrvaltoodangut
2. Puitlaastplaadi tootmine	170 000 m3	280,000	19,600	100	19600	segajäätmed	
3. Puitkiudplaatide tootmine	70 000 m3	44,000					
Kokku madalakvaliteedilist puitu toormeks kasutava tööstuse kõrvaltoodang			**19,600**		**19600**		

			Kõrval-toodang (m3)		**Jäätmetena arvestatud (m3)**		
KOKKU puitne kõrvaltoodang metsatöötusest			**3,401,600**		**2,231,600**		

* Jäätmet all on mõeldud metsatööstuse kõrvaltoodangut, mida saab kasutada energiatootmiseks; ei sisalda haket saetööstusest, mida kasutatakse paberitööstuse toorainena

Kõik mahud m3 on tihedad mahud

Tabel ei arvesta puidulise biomassi kasutamist tööstuses toimuvaks energiatootmiseks vaid ainult toodete sisse minevat osa, kuna tööstuses toimuv energiatootmine võetakse arvesse energiatootmise mahu planeerimisel

Peenpuitu tarbivat tööstust võib lisanduda tulevikus

1.2 Energy from waste

Peeter Eek, Harri Moora

Assuming that AS Eesti Energia owned IRU CHP will work by 2020 on full power and use the 220,000 t/a of municipal solid waste for energy production, it will be 136 GWh/y of electricity and 330 GWh/y of heat energy (Source: Äripäev: 03.01.13 "Waste incineration is an effective way of energy production"). Landfill gas has the energy value in amount of 91 GWh/y according to the estimation of the EBA and the quantity of landfill gas will decrease by 10% by the end of a each decade, because biogas generation ending in a closed landfills.

Additional assumption 08/01/2013: waste forecasts were made SEI Tallinn expert Harri Moora, who estimated that above to 220,000 tonnes of municipal waste burnt in IRU CHP, the additionally 100,000 tonnes of different waste fractions can be included into waste energy (e.g. RDF, MBT residual fractions, etc.)). For the sake of simplicity, the calorific value of waste is equal to the calculated concentration of primary 2.2 MWh/t.

The European Directive on Waste of Landfill 1999/31/EC [6] obligates to collect biogas from all landfills. The small polluting landfills are closed. Five new European standard landfills currently collect biogas and it was estimated, that **80% of landfill biogas** is applicable for energy production.

Estonian **landfills** fulfil the requirements of EU Waste of Landfill Directive and all new Estonian EU-standard landfills collect biogas. Biogas collection systems have been installed also some closed Soviet landfills (e.g. Pääsküla, Aardlapalu). The **theoretical** amount of landfill biogas is estimated **21 million Nm³** (National Report 2010). Practically available is 80% and thus the **applicable** biogas potential from landfills is **16,8 million Nm³, equals to 91 GWh/y, (0.33 PJ)**.

Energy from waste assumptions:

Iru burned 220,000 t/y of municipal waste

Other wastes are added in the order of 100,000 t / a (RDF, MBT, etc.)

In case there is not enough municipal waste generated in Estonia, it is assumed that the missing amount of municipal waste will be imported.

Landfill gas is a potential annual 91 GWh / a

Other waste fuel-making opportunities are not taken into account.

Quantity of landfill biogas will decrease by 10% per year from the closed landfill due to the decreasing volumes of biogas generation in closed landfills.

The energy heating value is taken in average of 2.2 MWh/t.

In total, therefore, the **energy potential of waste is 795 GWh / a, or 2.86 PJ (Table 4).**

Table 4. Energy potential from waste.

	Amount kogus	Ühik/unit
IRU SEK+ 100'000 t/a muid jäätmeid (RDF, MBT, ehitus)/Municipal waste for energy IRU CHP+100'000 t/a	320000	Tonn/ton
Kütteväärtus/heating value	2.2	MWh/t
Biogas from landfill/Prügilagaas	90.72	GWh/y
IRU Primaarenergia/IRU+ 100 000 t/a primary energy	704	GWh/y
Kokku/Total	**794.72**	GWh/y

1.3 Green biomass

1.3.1 Hay form areas semi-natural habitat, reed, straw

Katrin Heinsoo, Aleksei Lotman, Argo Normak, Jüri-Ott Salm

Conversion of the renewable energy from non-wood biomass has 3 options: biomass from semi-natural habitats (PLK), and the use of the agricultural land for energy plants, which includes grasslands, both currently managed and un-managed agricultural lands.

The area of the semi-natural habitats in the whole is now about 100 000 ha. In Rural Development Plan (RDP) is expected that by the end of the 2007-2013 period the semi-natural habitats management support through the Natura 2000 network will be provided for 35 000 hectares in total. (Source: Area payments 2011, ARIB).

1.3.1.1 Energy potential of semi-natural habitats

Assumptions:

The whole area of the semi-natural habitats is now about 100 000 ha.

It does not change significantly over time.

The total area of the wooded, mesic and floodplain meadowland is 49 000 ha.

RDP is expected that approximately to the 35 000 hectares the semi-natural habitats management support through the Natura 2000 network will be provided by the end of the 2007-2013 period.

The total number of submitted requests were 886 for a total management on PLK areas of 23 503 ha in 2010.

By 2050, the mowed area of PLK will increase up 50 000 ha and hay and silage for energy purposes can be collected. The land is deficit globally and will be used as much as possible, the remaining 50,000 hectares of PLK are used for grazing, feed, or for the management is restricted there.

Out of "energy purposes biomass" from 50 000 hectares, the half of it (25,000 hectares) will be used for the cultivation of biomass to be used in anaerobic digestion for biogas production and is included into biogas chapter. (Table 6).

The second half (25 000 ha) the collected hay and dry biomass will be used (if appropriate making pellets) in boiler houses or in CHPs. (Table 5).

The data for the calculation of the potential energy potential of this dry biomass from 25 000 ha Heinsoo et al (2013) reference is used, because the hay from different types of PLK has different energy potential (the calculated energy potential of the semi-natural grassland was only 29, 47 and 104 GJ/ha for wooded, mesic and floodplain meadows, respectively)[2].

Thus, the energy potential of semi-natural habitats in abovementioned assumptions is 469 GWh (1.69 PJ) per year. (Table 5).

Table 5. Applicable energy potential from straw, reed and hay from semi-natural habitats.

Only for burning	2010	2020	2030	2040	2050
Semi-natural habitats (GWh) (25%)	35	74	150	300	469
Straw/Põhk (GWh) (10%)	30	109.7943	156.849	224.07	320
Reed/Roog (GWh) (50%)	10	64	80	100	125
Kokku/Total (GWh)	**75**	**247.7943**	**386.849**	**624.07**	**914**
Total (PJ)	***0.27***	***0.89***	***1.39***	***2.25***	***3.29***

[2] http://www.energiatalgud.ee/images/1/13/Heinsoo-melts-sammul-holm.pdf

1.3.1.2 Reed

Based on the estimation of the Heat Engineering Institute of the Tallinn Technical University (TTU) reed bed spread suitable for harvesting has dry matter yield of 4.5 t/ha of with heating value of 4.93 MWh/t, one can consider that the energy potential from reed is theoretically 250 GWh/year, where Western Region (Läänemaa) accounted for 42% from total [MES biomass report, Muiste Peter et al, 2007, p 65]

The assumption: The reed bed for energy production is available in share of 50% of the total reed bed by the 2020. The rest of the reed resource is unreachable or is used in building sector (for roof making).

Thus, the reed beds energy potential is 125 GWh or 0.45 PJ. (Table 5).

1.3.1.3 Straw

Total production of straw in period 2004-2006 was in average of 673’945 tons, which represents the theoretical value of energetic potential of 3201 GWh/y. However, the large majority of the straw is probably not useable for energy production, because it is a major source of organic (carbon) matter, which has to be given back into the soil. This is especially important in the South-Estonian poor soils. [MES Biomass report, EMÜ, Muiste Peter et al, 2007, p 43]

The minor share of straw for energy production can come from a winter crop straw, particularly barley straw, but only as fuel to a local farm or business boiler houses. In the future, increases in crop yields can also increase the usage of straw for biofuel. [MES Biomass report, EMÜ, Muiste Peter et al, 2007, page 44]

Assumption: We assume that 10% of the theoretical amount of straw is used for energy purposes, and 90% goes back to the soil.

Consequently, the useable energy potential from straw will be 320 GWh/y, (1.15 PJ). (Table 5)

1.3.2 Energy plants, cultivated on unused land

Energy potential of energy plants, cultivated on unused land, is included into the for the production of biogas. We assume that none or minimal I generation energy crops are used to fulfil sustainability criteria, mainly the unused land is grassland, and on cropland energy plants are cultivated only via crop rotation.

Assumptions:

The area of the arable land without pasture is 1'078'330 ha.

The hectare based support “Single Area Payment Scheme (SAPS)” was provided to land owners of the arable land of 915'561 ha in 2011.

Thus, unused land (not received support via SAPS) area was 162'769 ha in 2011.

20% of unused land was cultivated with energy plants for biogas production in 2020 (equal to 32'554 ha).

50% of unused land was cultivated with energy plants for biogas production in 2050 (equal to 81'385 ha).

The total area of grasslands was 246'330 ha in 2011 without 100 000 ha of semi-natural habitats, described earlier.

The owners of grassland of 192,000 ha have received the SAPS in 2011, but they don't have cattle, thus the assumption is, that majority of them only mow the grassland for receiving the SAPS, but leaving the green biomass on field.

We assume that 20% of biomass mowed on this area is used for the production of biogas in 2020, i.e. 38'400 ha.

We assume that 50% of biomass mowed on this area is used for the production of biogas in the year 2050, i.e. 96'000 ha.

Thus, the total energy potential from unused land in 2050 is 2'227 GWh (8 PJ). (Table 6).

1.3.3 Biomass from agricultural land in use

Assumptions

Arable land area without pastures is 1'078'330 ha.

According to the RDP, 5% arable land is recommended to use for the cultivation of the energy crops, i.e. on 53'917 ha.

It does not change over time.

The biomass is used for the production of biogas.

Thus the potential energy from energy plants cultivated on arable land is 677 GWh (2.44 PJ). (Table 6).

1.4 Biogas

The biogas from semi-natural habitat land, unused and used agricultural land was described in previous chapter. The rest of biogas production inputs, such as biowaste, manure and sludge, are described in this chapter. Landfill biogas was included into waste chapter. Summarizing here:

Energy potential from 25% semi-natural habitats (meadows) in 2050 is 91 GWh/y (0.33 PJ).

Energy potential from 50% unused land in 2050 is 2'227 GWh/y (8.02 PJ)

Energy from 5% cropland in 2050 is 677 GWh/y (2.44 PJ).

Council Directive 91/271/EEC of 21 May 1991 concerning urban wastewater treatment [7] demands the purification of wastewater to protect environment. It was estimated that **50% of sewage sludge** is used for biogas production.

The biogas production form wastewater sewage **sludge** is implemented in 3 Estonian cities (Tallinn, Narva and Kuressaare) and in 2 are under construction (Tartu and Rakvere). The theoretical biogas production from sewage sludge is **9 million Nm³** and practically is available half of it, **4,5 million Nm³**.

Thus, the energy potential from sludge is 30 GWh/y (0.11PJ).

The cattle breeding are concentrated to big and modern automatized farms. Sixty per cent of all registered cattle are in farms over 500 livestock units. Only pig and cattle farms were analysed. It was estimated, that most of them will produce biogas from slurry and manure, thus from total number of pigs and cows **60% of total manure and slurry** can be used for biogas production.

The number of pigs was 364 900 and the amount of cattle was 237 900 in Estonia in 2009. The amount of pig slurry is 5,35 kg per animal per day and for cattle this amount is 37,5 kg per animal per day [13], thus the total amount of **slurry and manure** is 3 968 421 tons per year. The **theoretical** biogas production from this amount of manure is **111 million Nm³** per year. The **applicable** amount of the biogas production from manure is 60% from theoretical, **66,6 million Nm³** per year.

Thus the energy potential of cattle and pig manure is 441 GWh (1.59 PJ).

The waste management is obligation of local self-government. Only 10% have organized the separate collection of biowaste, **thus 10% of biowaste (food industry, kitchen waste) is applicable for biogas production.** In practice, several leftovers (cooking oil, fats from treatment plant of the first category of the slaughter house by-products) have already the secondary market and considered not waste at all.

The **biowaste** has good biogas potential, but this is most difficult to collect, because the amounts of biowaste are small and very scattered. The **theoretical** biogas production from biowaste was estimated in amount of **25 million Nm³**. The **applicable** biogas production is 10% from theoretical, **18 million Nm³**.

Thus the potential energy from biowaste is 109 GWh/y (0.39 PJ).

The energy potential from industrial waste (black liquor, etc.) is 79 GWh/y (0.28 PJ).

The total annual theoretical biomethane production is 641 million Nm³ equal to 6'410 GWh/y (23 PJ).

Thus, the applicable energy potential of biogas is in total 3'655 GWh/y (13.16 PJ). (Table 6)

Table 6. Biogas applicable potential, including green biomass for AD.

Only for Anaerobic digestion (AD)	**2010**	**2020**	**2030**	**2040**	**2050**	PJ
Poollooduslikud kooslused (hay from Semi-natural habitats (25%) for AD)	0	87	70	80	145	0.52
Kasutamata maadelt/silage from unused land (50%)	0	891	1,500	2,000	2,227	8.02
Põllumaadelt/silage from cropland (5%)	0	338	400	500	677	2.44
Läga ja sõnnik/slurry and manure	15	150	441	441	441	1.59
Biojäätmed/Biowaste	0	40	109	109	109	0.39
Tööstusjäätmed/industrial waste for AD	0	33	79	79	79	0.28
Reoveesete/waste water sludge	17	11	30	30	30	0.11
Kokku/Total (GWh)	**32**	**1,550**	**2,630**	**3,240**	**3,708**	13.35
Total (PJ)	0.12	5.58	9.47	11.66	13.35	

1.4 Solar energy

Rein Pinn

On average, the total solar radiation levels is 1000kWh/m² per year in the whole of Estonia 45 thousand km ², at local level the installation angle needs to be the best for radiation, in average it is 48 degrees. If to cover only 1 % of Estonia roofs, facades and unused areas in total 450 km2, also 450 TWh of solar energy can be converted. The installation costs (CAPEX) of solar PV utilities are estimated to decrease. If today for small systems up to 10kW the CAPEX is 1800 €/kW, it will fall down to 1200 €/kW by 2030; for medium size utility up to 100 kW the CAPEX is estimated 1600 €/kW this year and 1000 €/kW by 2030. For larger PV installation over 100 kW, the estimated CAPEX is 1300 €/kW this year and 800 €/kW by 2030. Currently just some small PV installations and few medium utilities are installed.

Assumption:

If to use 0.1% of Estonian area (45 km2, 4500 ha) for PV panel installations, 45 TWh can be produced.

Thus, depending from the area covered by the solar panel, 0.1%-1% (45-450 km2), the solar energy potential is 45-450 TWh/y. (Table 7).

Table 7. Solar energy potential in case of 0.1% surface (45 km2, 4500 ha) is covered with PV panels.

	2010	**2020**	**2030**	**2040**	**2050**
Solar PV - elektri tootmiseks (GWh)	10	15000	25000	35000	45000
Solar thermal (GWh)	1	36	179	269	359
Kokku/ total (GWh)	**11**	**15036**	**25179**	**35269**	**45359**
PJ	***0.04***	***54.13***	***90.64***	***126.97***	***163.29***

1.5 Wind energy

Tuuliki Kasonen

The Swedish University of Uppsala, Institute for Meteorology made the Model calculations of wind energy potential at 103 m above sea level on the base of 2008, ordered by the Eesti Energia Ltd. The results indicated, that coastal sites of Estonian part of Gulf of Finland, Gulf of Riga and Saaremaa and Hiiumaa in the west had the best wind potential, where the wind speed was between 9.01 to 9.25 m/s in average. The wind speed can be more than 9.25 m/s further from the coast. In remote forested areas the wind speed can be 7.26 to 7.50 m/s. Areas with annual average wind speed at 80 meters height of 6.5 m/s is considered to be compliant for wind energy development projects.

Referring to Ain Kull, the senior researcher of the Institute of Geography, University of Tartu, the "Estonian coast deforested areas suitable for the erection of wind turbines is in a total of nearly 114 000 ha or 7.9% of the coastal areas, which allows to set more than 7,000 wind turbines." If we consider that today the average wind turbines have 2.5 - 3MW nominal power, the total nominal capacity of those wind turbines is 17.5 GW - 21GW, with an approximate yield in efficiency of 29%, the potential of on-shore wind energy is 45-53 TWh/year. The recent regional studies and development plans in Western part of Estonia indicated the applicable area for wind parks on-shore in total amount of 8868 ha, taking the very rough energy potential 0.15 MW/ha, the nominal energy potential is 1300 MW. Including potential areas from other regions of Estonia (e.g. North-East Estonia with closed mines and oil shale ash hills) and considering, that 50% of all applicable areas will be actually used for wind energy production, the total applicable energy potential on-shore is 1500 MW.

Referring Basrec (Baltic Sea Region Energy Co-operation), a consortium of the Baltic Sea wind energy researchers assessed the Baltic Sea wind power deployment potential according to the three major cost factors (wind speed, water depth and distance from shore) through Estonian waters of good and very good location and concluded the marine wind power implementation potential in amount of 15,466 MW nominal capacity (the 64TWh). Although the study did not address in detail the environmental constraints, in general environmental limits were assessed, which decreased the marine wind energy potential 80%, thus the off-shore wind energy potential in amount of 1,429 MW was agreed in Estonia. Consider, that in both cases of wind energy potential estimation from on-shore and off-shore sites, the most strict environmental and other restrictions were included. One can imagine, that in less restrictive conditions the wind energy potential will increase significantly.

A similar result was achieved in the TE100 process, where it was estimated that by the year 2030, it is possible to install 1,550 MW of offshore wind farms (5649GWh), but only 500 MW on-shore wind farms (1274GWh) were identified then, as mentioned earlier, new indication shows the on-shore applicable potential also in range of 1500 MW.

Table 8. Predicted CAPEX for different renewable energy nominal electricity installations (million EUR/MW).

Eeldatud elektrienergia võimsuste investeerimiskulu MW kohta

EUR m / MW*	2010[1)]	2020[5)]	2030[2)]	2040[5)]	2050[2)]
Hüdro	3,80	3,80	3,80	3,80	3,80
Biomass koostootmisjaamad (*CHP*)	3,49	3,49	3,49	3,49	3,49
Biogaas	3,65	3,65	3,65	3,65	3,65
Tuul maismaa	1,33	1,19	1,05	1,05	1,05
Väike tuul	2,00[3)]	2,00[3)]	2,00[3)]	2,00[3)]	2,00[3)]
Tuul avamere	2,95	2,58	2,20	2,15	2,10
Päikese fotoelemendid *PV*	2,40	1,80	1,20	1,10	1,00
PHAJ	0,65[4)]	0,65[4)]	0,27[4)]	0,27[4)]	0,27[4)]
Varujaam (gaasijaam)	0,56[6)]	0,56[6)]	0,56[6)]	0,56[6)]	0,56[6)]

*** Investeerimiskulud on 2010.a väärtustes ning ei arvesta inflatsiooni**

Allikad: 1) Financing Renewable Energy in the European Energy Market. Ecofys. 2011 European Commission, DG Energy
2) Roadmap 2050. A practical guide to a prosperous low-carbon Europe. European Climate Foundation. www.roadmap2050.eu
3) my!Wind hinnang http://www.mywind.ee/htdocs/my_info.php
4) OÜ Energiasalv hinnang
5) 2020.a investeerimiskulud on arvutatud kui 2010 ja 2030 keskmine. 2040. a investeerimiskulud on arvutatud kui 2030. ja 2050. keskmine
6) The Projected Costs of Generating Electricity: 2010 Edition. International Energy Agency

1. Hüdro= hydro; 2. Biomass=biomass CHP; 3. Biogas=biogas; 4. Tuul maismaa=wind on-shore; 5. Väike tuul=small wind; 6. Tuul avamere= wind off-shore; 7. Päikese OV=Solar PV; 8. PHAJ=pump hydro power plant. All CAPEX are given in 2010. Currency without inflation.

At the end of 2012, Estonia has 275 MW of installed wind power capacity, all of which are land-based. Referring to signed agreements between the power system operator Elering and wind energy developers the total capacity of applications to join the grid is in capacity of 1,944.20 MW. In addition, projects that do not have the signed “grid-joining-agreement” include developments of offshore wind farms. Estonian Wind Power Association has estimated, that total nominal capacity to be installed in near decades, both on- and off-shore, is about 3,000 MW of nominal capacity.

Price

According to the European Commission in 2010, the investment cost of wind energy onshore was 1.33 MEUR/MW and at off-shore 2.95 MEUR/MW. Referring to the roadmap *“Roadmap 2050th a practical guide to a prosperous low-carbon Europe. The European Climate Foundation.”* the onshore investment cost from 2020 onwards (2050) will be 1.05 MEUR/MW. Sea offshore investment cost falls as 2.20 MEUR/MW by the year 2030 and will be 2.10 MEUR/MW by 2050. SUMMARY TABLE: full cost of wind generation will be 61.0 euros/MWh on-shore by 2030, small windmills it is 141.1 EUR/MWh and the sea off-shore wind parks it is € 90.5/MWh. (Table 8).

Restrictions on use

Technical limitations - referring to the study prepared by Ea Energy Analyses "Wind Power in Estonia - An analysis of the possibilities and limitations for wind power capacity in Estonia within the next 10 years"" the wind power can be integrated with Estonian electricity in the coming years without serious balancing costs, because :

Prior to the completion of Estlink 2, Estlink 1 provides connection with Finland 600 MW

after completion Estlink 2 is the connection capacity with Finland 900-1100 MW.

Environmental Impacts

The noise is most important environmental impact from wind turbines, in practice the basis for most stringent requirement for noise is 40 dB in residential areas. (Minister of Social Affairs on 4 March 2002. Regulation No. 42 of " normal noise levels of living and recreation areas, residential and public buildings and noise measurement methods ").

Thus, on shore the theoretical wind energy potential is 50’000 GWh (180 PJ).

The off shore the theoretical wind energy potential is 64’000 GWh (230 PJ).

Altogether, the theoretical wind energy potential is 114’000 GWh (410 PJ).

Useable wind energy potential:

Thus, on shore the applicable wind energy potential is 4’573 GWh (16 PJ).

The off shore the applicable wind energy potential is 5’839 GWh (21 PJ).

Altogether, the applicable wind energy potential is 10’412 GWh (37 PJ). (Table 9).

Table 9. Wind energy potential, installed capacity and produced electricity (GWh and PJ).

MW	2012	2020	2030	2040	2050
Tuul maismaa/on shore	275	400	500	1300	1800
Tuul avamere/off-shore	0	250	1550	1550	1550
Kokku/Total	**275**	**650**	**1600**	**2850**	**3350**
GWh	**2012**	**2020**	**2030**	**2040**	**2050**
Tuul maismaa/on shore	460	1016	1270	3303	4573
Tuul avamere/off-shore	0	942	5839	5839	5839
Kokku/Total (GWh)	**460**	**1958**	**7109**	**9142**	**10412**
Kokku/Total (PJ)	***1.66***	***7.05***	***25.59***	***32.91***	***37.48***

1.6 Hydroenergy

Hydropower energy resource, quantity, usage restrictions, and price forecasts

Peter Raesaar

The hydropower potential of Estonia is very modest because of flat landscape.

Before the Second World War, the share of hydropower in the overall energy balance of the Estonia was quite large: a combined capacity of 9,343 MW and electricity output of 28,770 MWh was accounted for 28.6% from total electricity output of Estonia that time.

The capacity of Narva HPP is 125 MW, built in 1955 and it still works, but the Russian Federation runs it. As of March 2011, 47 different electricity-generating watermills and hydroelectric installations were connected to the Estonian electricity networks in power range from 4 kW to 2 MW, with total nominal capacity of 8.09 MW. Some of them (the Eagle, Kunda) are now at a standstill. For 2011-2020 9 additional mini and micro hydroelectric stations are expected to join electricity distribution networks with total nominal capacity of 1.224 MW. Exceptionally high capacity is in Omut Narva river waterfalls, where hypothetically (because the other river bank belongs to Russian Federation) the HPP can be built with 30 MW nominal electrical capacity.

Estonia's gross theoretical hydropower potential of the river is about 300 MW. Several recent studies and experts estimate that Estonian technical hydropower potential is about 30 MW, without the Narva River, with Omut part of Narva River it is about 45-60 MW.

Thus **hydropower potential is** taken from TE100, as sector didn't provide any other estimation, **38 GWh/y (0.14 PJ). (Table 10)**

Table 10. Hydropower applicable potential according to TE100 (GWh and PJ 2010-2050).

	2010	2020	2030	2040	2050
Hüdroenergia/Hydroenergy (GWh)	33	34	36	37	38
PJ	***0.12***	***0.12***	***0.13***	***0.13***	***0.14***

2. Fossil energy sources of Estonia

2.1 Peat

Tarmo All, Erki Niitlaan

The Estonian peat balance at 31 December 2011 was following: well-decomposed peat of active useable reserves 153,846,300 tons, passive useable reserves 46,327,300 tons, an active reserve stock 81,290,700 tons and passive reserve stock 476,470,000 tons, less-decomposed peat of active useable reserves 45 397 500 tons, passive useable reserves of 11,998,700 tons, active reserve stock and 82,801,100 tons of passive reserve stock 109,133,000 tons. A total amount of 1,357,934,300 tons of well-decomposed and 249,330,300 tons less-decomposed peat is in peat register.

According to the adopted regulation, it is possible to draw a maximum of 2.6 million tons per year of peat.

The whole Estonian critical and usable peat reserve stocks and annual rates are as follows:

• 1) the critical size of the stock – 1’590’000’000;

• 2) the size of the useable stock – 573’100’000;

• 3) annual rate to use- 2’653’000 t/a.

Peat extraction fee rate will not change till 2014. Less-decomposed and well-decomposed peat mining fee rates are respectively 1.4 and 1.15 €/t[3]. After that new fee the Act of Government will endorse rates.

Today is annual allowed amount of peat mining (2.65 million tons) not achieved, the actual extracted mining amount has been between 0.8 to 1 million per year.

There's no research done so far, but it is unlikely that the energy sector would use less-decomposed peat, because gardening sector can probably always offer a better price for it. Less-decomposed peat is probably also not so useable for burning for energy, because its lower heating value. The use of less-decomposed peat for biogas production is not considered. This is the research question for next couple of years.

There is no other legislative restriction to the use of peat, except annual allowable amount (2.6 mln tons/a, which is divided between 15 counties.

The current mining area is around 17 thousand ha and the annual amount of excavated peat is in average of 800 thousand tons. To use 2.65 million tons, consequently, it is necessary to extract approximately 54 000 hectares of the mining area. If the market demand exists, then it would be technically possible. However, if to lose the current administrative restrictions, it will take of 15 years at minimum to achieve the size of this mining area, maybe even more. However, as said before, not all peat is useable for energy due to its low heating value, and therefore it is not economically feasible.

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[3] http://www.envir.ee/1179745

On the other hand, the installed capacity of boiler houses currently limits the use of peat in such a large quantity. At the same time, Eesti Energia AS is making combustion experiments in Narva plants right now to co-fire peat and other fuels in oil shale boilers. This can give a whole new perspective domestic peat. The peat, which has too low quality for gardening, using in cattle breeding or for using in CHP, can be used for biogas production, which needs further investigation and therefore this potential is not considered in this report.

Thus, the maximum allowable primary energy potential on peat (at 2.6 mln t/a annual permitted use) is 10'612 GWh (38 PJ).

Assumptions

Annual useable peat reserve will not change over time (2.6 mln t/a)

Approximately 30% of peat mined in total last years (0.8-1 mln t/a) is 316'000 t/a, which is used for energy production, (4 MWh/t), by 2020.

By 2050, 30% from annual allowable amount (2.653 mln t/a) will be used for energy production (796'000 t/a)

In practice, by 2020 one third of mined peat (316'000 t/a), is considered for being applicable for primary energy potential 1'264 GWh (12.7 PJ)

By 2050, the primary energy potential from peat is 3'183 GWh (11 PJ). (Table 11).

Table 11. Primary energy potential of peat, considering the limit of 30% is available resource for energy production from actually mined amount in 2020 (reference year is 2011) and 30% of allowed amount of peat is used for energy production in 2050.

	2010	2,020	2030	2040	2050
Turvas/Peat (GWh)	1264	1264	1,183.60	2,183.6 0	3,183.60
PJ	***5***	***5***	***4***	***8***	***11***

2.2 Oil shale

2.2.1 Reserves of oil shale

According to the Earth's Crust Act of Estonia oil shale is a state-owned mineral, which does not belong to the tenement (landowner). Oil shale reserves are divided into three categories: useable stocks, reserve stocks and prognosis stocks.

Oil shale useable stock is active resource stock, when the mining technology and equipment guarantee a rational use of it with environmental compliance. Mineral reserves are passive, if its use is not environmentally feasible or there is no such technology, but which may in future prove to be feasible.

Oil shale active useable and reserved stock are in total of 1'312 million tons, accounting the oil shale mining loss of approximately 30%, so the actual useable geological reserves are of about 1'000 million tonnes.

In addition, when talking about useable geological reserve of oil shale, it is important to keep in mind the definition of the term of " oil shale," defined in Estonian standard EVS 670:1998, which provides oil shale quality standards and quality characteristics of extracted oil shale as a commodity groups. To simplify, one raw useable geological ton of oil shale (geoloogilise varu tonn) is equal to 1.2 tons of "tradable oil shale" (kaubapõlevkivi). It can be claimed for the sake of simplicity, that useable oil shale tradable stock is approximately 1'200 million tons.

From ENMAK point of view we talk about useable stock of raw oil shale only and the annual limit for oil shale use is 20 mln t/a. (equal to 24 mln tradable oil shale tons).

Using the mining loss coefficient and tradable oil shale factor, capacity of **useable tradable oil shale amount is approximately 16.8 million tons per year (24 mln t/y minus 30% losses during mining)**. Given a maximum allowable annual mining amount and tradable oil shale stock levels, the active stocks of oil shale will continue to be available for the next 70 years.

Currently, the Estonian Development Plan of Oil Shale Use in 2016-2030 (further Oil Shale Plan) is under revision and new plan will be drafted in coming months. As part of this re-drafting process, different analyses have been made, the first results of those were introduced in December 2012 and the power point presentations with these results are uploaded in wiki.

Draft Study on Oil Shale Use described the consumption forecast of oil shale companies. Maximum tradable oil shale consumption in 2016-2023, in million tons is following[4]:

• 7.8 million tonnes of Eesti Energia Oil Industry

• 5.5 million tonnes of VKG oil industry

• Chemical Kiviõli Factory 0.6 million t

• Thermal Power Plants (Eesti Energia) 14.6 mln t

• Kunda Nordic Cement 0.3 million t

• **A total of 28.8 million tons,**

which is above the annual limit of 20 mln t of raw oil shale (16.8 mln tradable oil shale), therefore there is the competition between different oil shale users.

Considering these oil shale consumption forecasts (although those forecasts did not took into account the potentiality of new efficient technologies coming to the market or new consumers) the **first priority should be given to the rational and most profitable use of oil shale production.** E.g. comparing the value added amount of burning oil shale in power plants with making shale oil out of it, while ensuring security-of-supply (S-o-S) of energy supply to the Estonian population. Keeping in mind the principles of sustainable development, quoted in the beginning: to explore non-renewable reserves in the longest possible term and if possible, to switch to products made from renewable

[4] Source: added to wiki - Oil Shale preliminary development plan - Leo. Rummel (discussion) 9 January 2013 at 16:07 (EDT)

natural resources or in case of **energy production to replace fossil resources with renewable energy sources**.

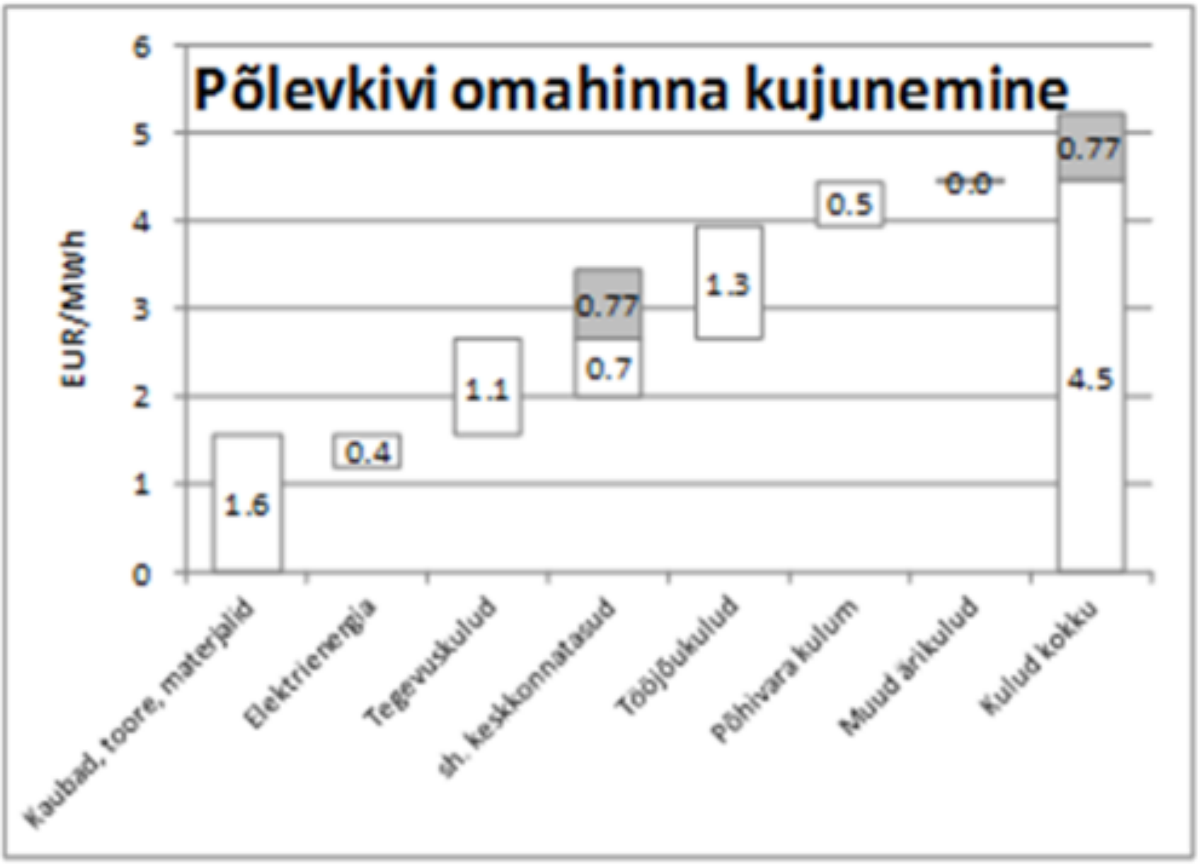
2.2.2 Price of Oil Shale

The price of oil shale is no longer, from beginning of 2013, the subject of the administrated price. This is the additional reason to the abovementioned sustainability criteria, why since 2013 the planning of the oil shale use should be based on the principle to achieve maximum added value.

Mining cost

"Electricity produced from oil shale and shale oil export / import opportunities in 2016-2030," study p. 4 describes energy cost per unit of AS Eesti Energia Mines in the extraction of oil shale formation.

Figure 1. Price of oil shale while mining.



The translation of the Y-axis from left: raw material, electricity, operational costs, environmental fees, labour cost, depreciation and amortization, other costs, total cost (most right); grey colour indicates environmental fees.

2.2.3 Price Formation of oil shale

The increase of oil shale mining fee is from € 1.1/t in 2011 to € 2.4/t in 2015. Assuming that 1 tonne of oil shale heating value is 2.33 MWh. The average mining cost of oil shale was 10.5 €/t in Estonian Energy Mines and assuming an increase of environmental charges 0.77 €/MWh, the increase of the cost will be up to 12.4 €/t. It is important to note that in future the mining costs of Eesti Energia AS Mines will increase due to fact, that cheapest mines will be exploited.

2.2.4 Oil shale value-added products

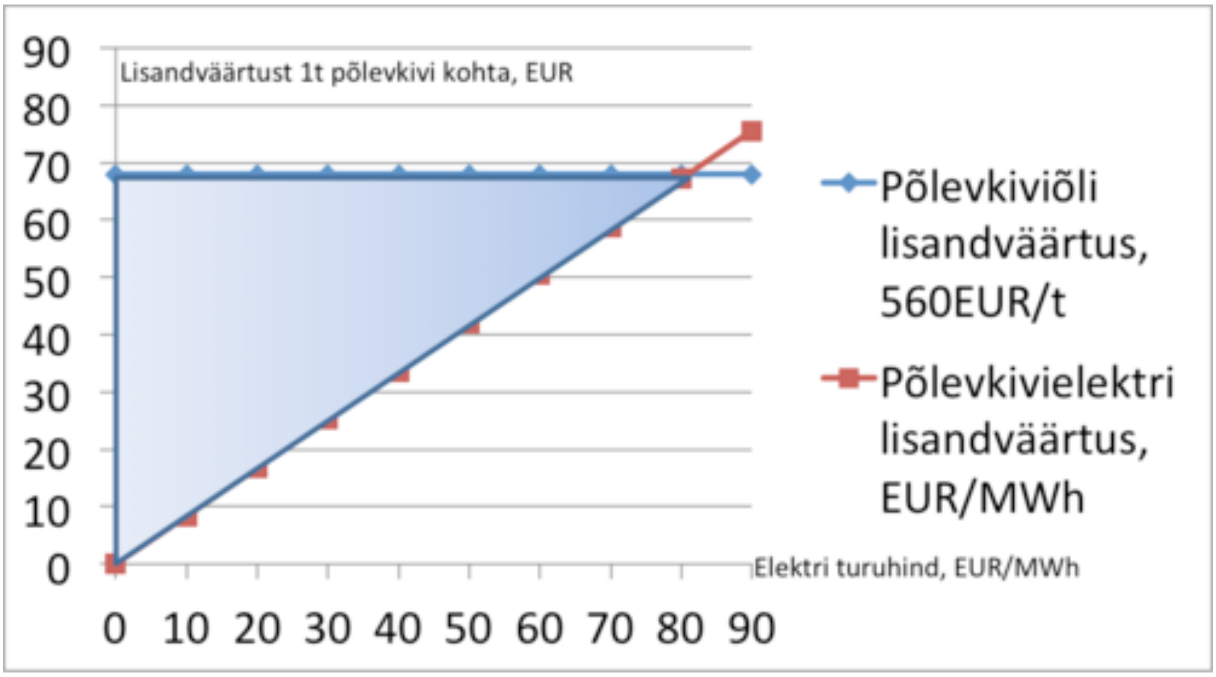
The oil shale market didn't exist till nowadays, because all the oil shale companies were vertically integrated companies, which have been both extracted and processed oil shale, just government gave them permits for certain amount of oil shale, for certain time to mine in certain place (fixed in mining permits). Therefore, the fair pricing of oil shale is now, in new circumstances in particular interest. Oil shale is the main raw material for the production of electricity and production of shale oil. Companies using oil shale for shale oil production are currently developing new shale oil refinery capacities to make diesel according to vehicle engine fuel requirements.

The oil price trend

Therefore, AS Eesti Energia announced plans to expand production of shale oil, with a further capacity of 22,000 barrels of motor fuel refining capacity per day, of which at least half would be eligible for EURO 5 quality (ULSD diesel fuel). Another large oil shale company Viru Chemistry Group is also planning the expansion of the shale oil production, with capacity of 250,000 tons of shale oil per year.

The value added of two oil shale consumption technologies is compared: power generation, and shale oil production. Assuming the price of a heavy heating oil market price to be 590 EUR/t (heavy heating oil is comparable with shale oil, the price of shale oil is usually 30EUR/t lower than heavy heating oil). Thus the market value of 1 ton of shale oil produced from oil shale is 68 EUR. For comparison, assuming that the average price of electricity is 45 EUR/MWh with power generation efficiency of 36%, then the value of the electricity produced from 1 ton of oil shale is 38 EUR. This means that producing electricity from one tonne of oil shale one will lose the opportunity to produce approx. 30EUR more, while producing from the same ton of oil shale the shale oil with market price of 68 €/t, keep in mind that only the value added was compared and in this case the production cost or other variables doesn't affect to it.

Figure 2. Comparison of value added of two oil shale technologies: electricity and shale oil.



X-axis: value added per 1 ton of oil shale (€), Y-axis: the market price of electricity (€/MWh); blue line: value added of shale oil from 1 ton of oil shale (with reference price of heavy heating oil 560 €/t); red line: value added of electricity produced from 1 ton of oil shale.

The figure shows clearly, that the electricity generation from oil shale production will make sense, when it will be equal with value added of shale oil only, which will happen at the market price of electricity being 80EUR/MWh. Assuming that the oil shale as a national asset has to be used prudently, the blue triangle diagram on the figure can be defined as opportunity cost of electricity production from oil shale

Background

Estonia's largest oil shale based Narva Power Plant net installed capacity is 2000 MW. Since 2008. Estonia is obliged to comply with the EU Large Combustion Plant Directive. VKG Energia Narva Power Plants and Power Plant North LLC (formerly Jõhvi Power) plants should be in line with the requirements of the Directive by 31 December 2015. This means parts of the old burning units will be closed and to others necessary installations removing the sulphur and nitrogen compounds, has to be installed. As result, net installed capacity of the Estonian oil shale power plants will decrease ("Security of Supply Review, by Elering 2011, p. 33").

Theoretical primary energy potential of oil shale (at 20 mln t/a) is 46’667 GWh (168 PJ) (8.4 MJ/kg) (Table 12).

Table 12. Primary energy potential of oil shale at 20 mln t/a annual allowable use.

	2010	2020	2030	2040	2050
Põlevkivi/Oil shale (GWh)	46667	46667	46667	46667	46667
PJ	***168***	***168***	***168***	***168***	***168***

Energy Resources Working group members:

Participated in WG meetings:

1. Ahto Oja, Arengufond/EBA/OÜ Mõnus Minek
2. Alvar Soesoo – TTÜ/ Eesti Geotermaalenergia Assotsiatsioon
3. Andre Lindvest – 4E Tehnoinvest OÜ
4. Enn Pärt, Keskkonnateabe keskus
5. Irje Mölder, Arengufond
6. Janek Parkman, AS Elering
7. Kristiina Rebane - TÜ magistrant energiaõiguse alal
8. Märt Riistop, EMPL
9. Mihkel Härm, WEC-Eesti
10. Ott Otsman, EMPL
11. Peep Pitk, TTÜ (Skype)
12. Peep Siitam, Arengufond
13. Peeter Muiste, EMÜ
14. Priit Enok, OSPA
15. Raul Kotov, Eesti Gaas

16. Rein Pinn, EPEA
17. Siim Meeliste - MKM
18. Siim Meeliste, MKM
19. Taivo Denks, KKM
20. Toomas Saks, Eesti Õliühing
21. Tuuliki Kasonen, ETEA
22. Uku Sukles – Eesti Geotermaalenergia Assotsiatsioon
23. Ülo Kask, TTÜ, STI

Contributed in written in wiki or over emails

1. Aleksei Lotman
2. Argo Normak
3. Enn Pärt
4. Erki Niitlaan
5. Harri Moora
6. Jüri-Ott Salm
7. Katrin Heinsoo
8. Kristiina Rebane
9. Liis Kuresoo
10. Märt Riistop
11. Ott Otsman
12. Peeter Eek,
13. Peeter Muiste
14. Peter Raesaar
15. Raul Kotov
16. Rein Pinn
17. Tarmo All
18. Tuuliki Kasonen
19. Ülo Kask
20. Valdur Lahtvee

Annex 1. Excel table with calculations of ENMAK 2030+