HYDROGEN AND P2G IN FINLAND

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NEO CARBON ENERGY

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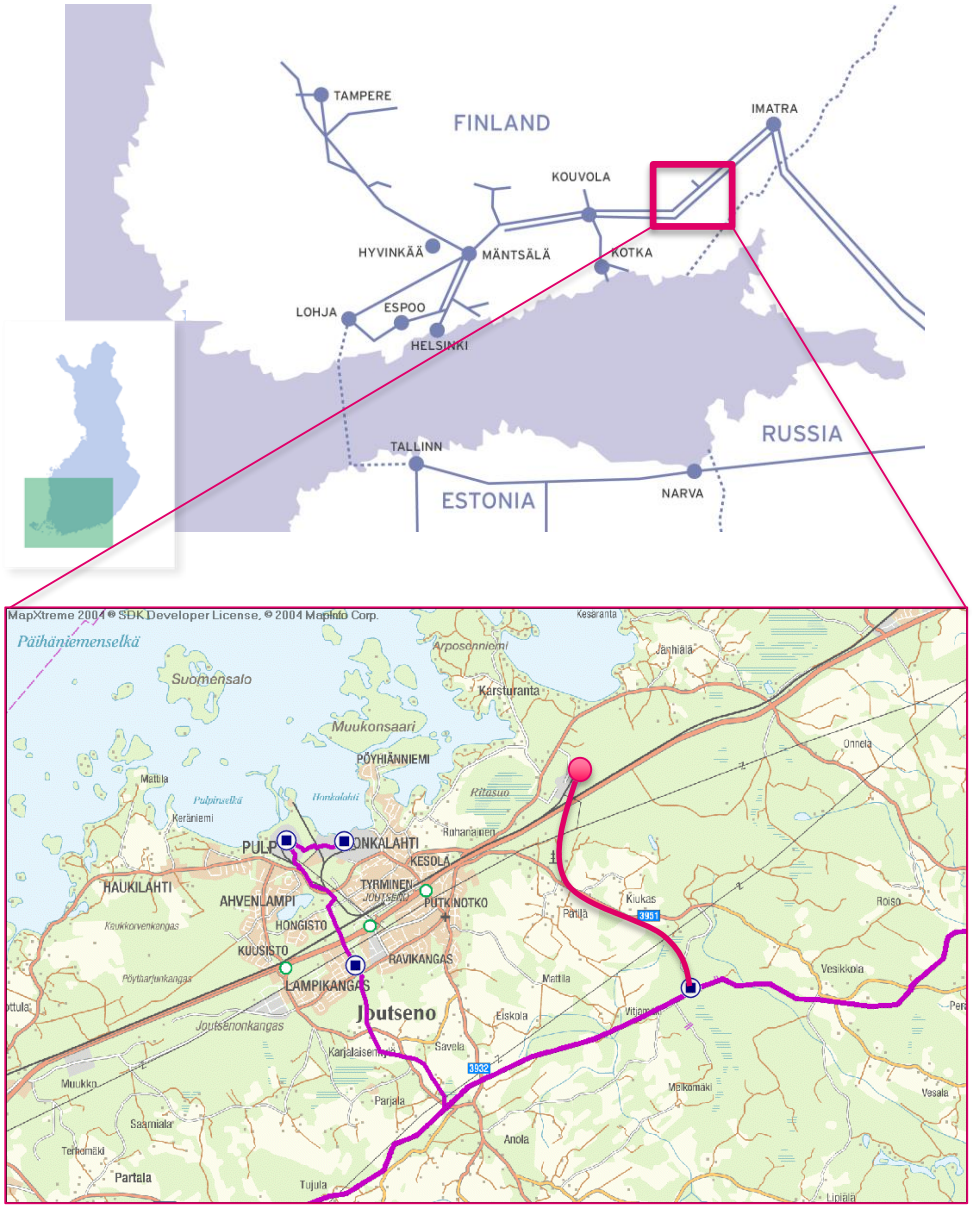
/ HYDROGEN

Hydrogen & gas transmission grid in Finland

Case Joutseno:

- Max 3500 m3/h pure H_2
- At atmospheric pressure
- Near Gas transmission grid:
  - flow between 200-900.000 m^3/h
  - Pressure 35-54 bar
- Technical feasibility study completed
  - Compressor(s), pipeline 5 km, analyzers
- Commercial negotiations on-going

H_2	Min 99,9 %
Inert (N_2)	Max 200 ppm-vol
Cl_2	Max 2 ppm-vol
O_2	Max 20 ppm-vol
CO_2	Max 30 ppm-vol
H_2O	Dew point at less than -30 C°



Woikoski P2H_2 plant in Kokkola

- The largest facility in Europe to produce hydrogen from water by electrolysis, and will simultaneously produce ultra-pure oxygen
- 3 x 3 MWe pressurised alkaline electrolysis
- H_2 to cobalt reduction process

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/ KEY FIGURES

- **5 years 2014-2019**
- **14 M€**
- **3 Finnish research partners**
- **16 industrial partners**
- **3 NGOs**
- **5 international partners**

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1. **Futures research**
2. **Energy system modelling, simulation and economics**
3. **Business case identification. Feasibility**
4. **Process modelling and simulation**
5. **Experimental**
6. **International activities**
7. **Management and dissemination**

FINNISH ASPECTS TO P2G

Snapshot for EU legislation post 2020

AMENDMENTS BY THE EUROPEAN PARLIAMENT*

to the Council position at first reading

DIRECTIVE (EU) 2015/…

OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

amending Directive 98/70/EC

relating to the quality of petrol and diesel fuels

and amending Directive 2009/28/EC

on the promotion of the use of energy from renewable sources

Article 1

Amendments to Directive 98/70/EC

Directive 98/70/EC is amended as follows:

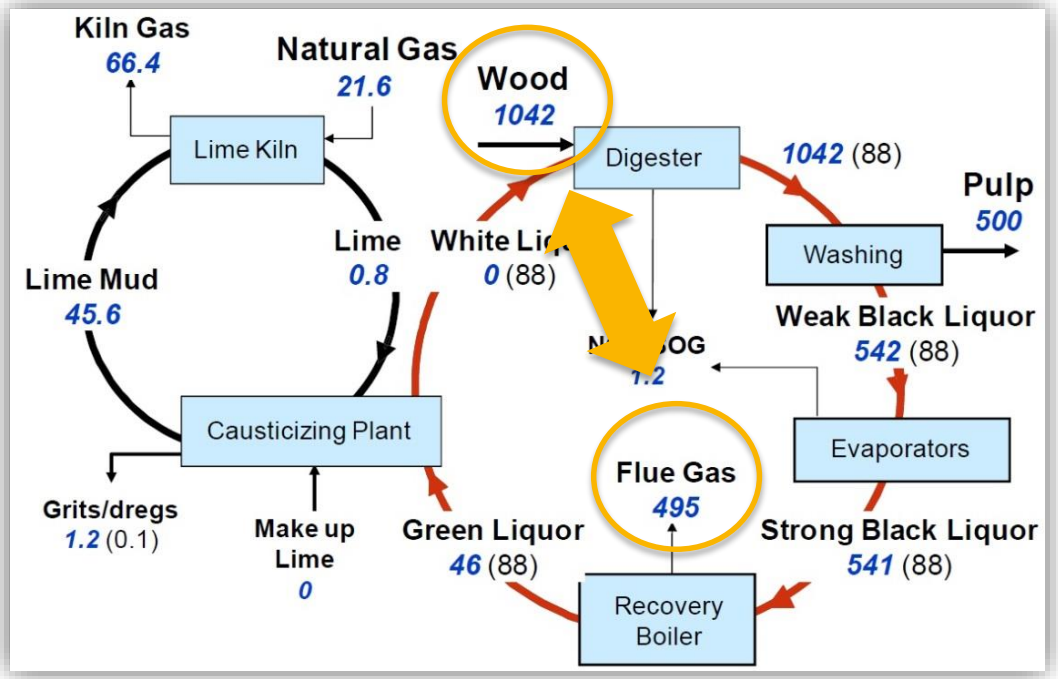
(1) In Article 2, the following points are added:

"*9a. "renewable liquid and gaseous transport fuels of non-biological origin" means gaseous or liquid fuels other than biofuels whose energy content comes from renewable energy sources other than biomass, which are used in transport;*

- http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+REPORT+A8-2015-0025+0+DOC+PDF+V0//EN
- http://www.europarl.europa.eu/sides/getDoc.do?type=TA&reference=P8-TA-2015-0100&language=EN&ring=A8-2015-0025

CO_2 RESOURCE

- Half of the carbon in pulp production ends up to CO_2 (black liquor combustion)
- Production of pulp in Finland is 7 Mt_{AD}, from the CO_2 emitted some 70 – 80 TWh CH_4 can be produced, half of the mills are connected to the gas grid
- Natural gas consumption in Finland 30 TWh
- Total biomass use in power plants 70 TWh, about 140 TWh P2G CH_4 can be produced from wood-based CO_2



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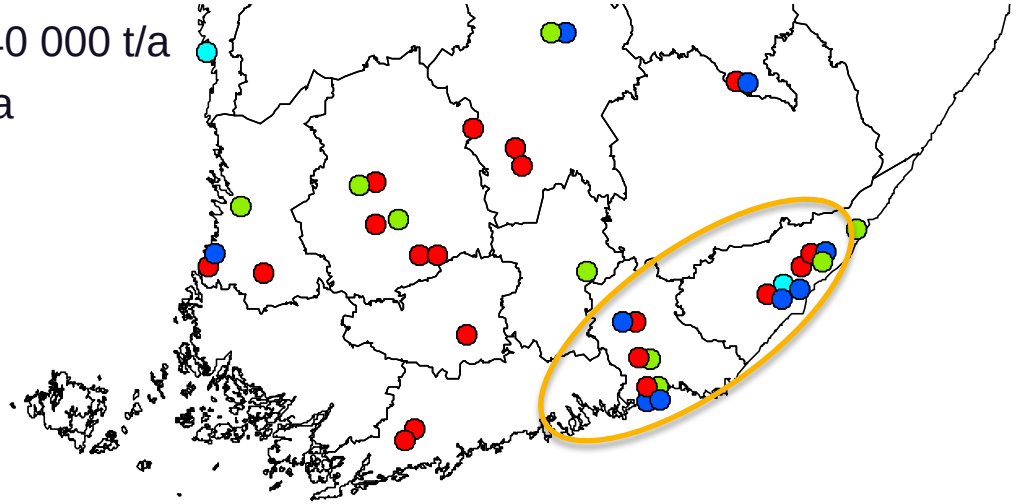
Pulp mills along the gas network

Blue points:

- Joutseno, 630 000 t/a
- Kaukopää, 850 000 t/a
- Kotka, 170 000 t/a
- Tainionkoski, 170 000 t/a
- Sunila, Kotka, 370 000 t/a
- Kaukas, Lappeenranta, 740 000 t/a
- Kymi, Kouvola, 600 000 t/a



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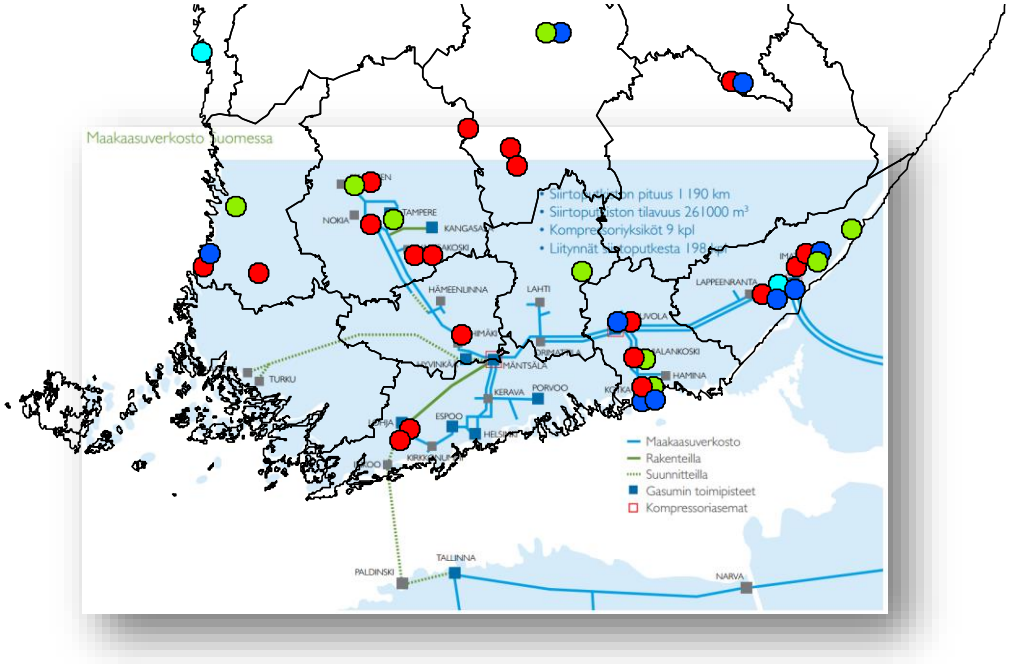
Pulp mills along the gas network

- Today some 40 TWh/a of renewable CH_4 can be produced at the (large point CO_2 emission source) pulp mills that are connected to the gas network
- Finnish road transportation energy use 50 TWh/a
- Total potential at the pulp mills can cover the gas need for Finland and the Baltics, total 80 TWh/a (to the Baltics through the Balticconector)



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Case UPM Kaukas pulp mill: CH_4 production is profitable today for transportation use, if electrolyser provides frequency containment for the E-TSO

Case A:

- **hydropower supply, baseload operation, no RE fuel quota value**
- **not (yet) profitable**

					-4438								4149	annual profit	-289	k€/a
Annual expenditures			price		k€/a		**Annual incomes/benefits**			price		k€/a			
power requirement	76800	MWh/a	40	€/MWh	-3072		O2	12170	t/a	8	c/kg	974			
water	13703	t/a	25	c/m3	-3		Steam @ 6.5 bar from methanation	8045	MWh/a	0	€/MWh	0			
CO2 purchase	8367	t/a	10	€/t	-84		Sold bio-CH4	42341	MWh/a	75	€/MWh	3176			
CAPEX (electr.+methanation)	17,9	M€	0 %	WACC	-895		Heat from electrolysers	20736	MWh/a	0	€/MWh	0			
other OPEX (electr.+methanation)	9600	kW	40	€/kW,a	-384		Decreased CH4 consumption (BtL+limekiln)	0	MWh/a	35	€/MWh	0			
CAPEX (H2 storage)	0,00	M€	0 %	WACC	0		Decreased CO2 allowances (BtL+limekiln)	0	t/a	20	€/t	0			
other OPEX (H2 storage)	0,0	k€/a			0		Decreased H2 converison costs in BtL plant	0	MWh/a	7	€/MWh	0			
extra personnel for grid service	0	k€/a			0		Grid service	9,6	MW	0	€/MW,h	0			
							renewable energy fuel quota value	42341	MWh/a	0	€/MWh	0			

Case B:

- **hydropower supply, 4.8 ±4.8 MW operation (>8000 operation hours per year), grid services**
- **profitable for integrated value chain (O_2, grid services, H_2 substitute, bio-SNG for mobility)**

					-2783								3352	annual profit	568	k€/a
Annual expenditures			price		k€/a		**Annual incomes/benefits**			price		k€/a			0	
power requirement	38400	MWh/a	40	€/MWh	-1536		O2	6546	t/a	8	c/kg	524	WACC	5,4 %		
water	7371	t/a	25	c/m3	-2		Steam @ 6.5 bar from methanation	1082	MWh/a	0	€/MWh	0	RoE	11,0 %		
CO2 purchase	1125	t/a	10	€/t	-11		Sold bio-CH4	5694	MWh/a	75	€/MWh	427				
CAPEX (electr.+methanation)	15,5	M€	0 %	WACC	-775		Heat from electrolysers	10368	MWh/a	0	€/MWh	0				
other OPEX (electr.+methanation)	9600	kW	30	€/kW,a	-288		Decreased CH4 consumption (BtL+limekiln)	23004	MWh/a	35	€/MWh	805				
CAPEX (H2 storage)	1,73	M€	0 %	WACC	-87		Decreased CO2 allowances (BtL+limekiln)	4546	t/a	20	€/t	91				
other OPEX (H2 storage)	34,7	k€/a			-35		Decreased H2 converison costs in BtL plant	23004	MWh/a	7	€/MWh	161				
extra personnel for grid service	50	k€/a			-50		Grid service	4,8	MW	35	€/MW,h	1344				
							renewable energy fuel quota value	5694	MWh/a	0	€/MWh	0				

NEO-CARBON Energy project is one of the Tekes strategic research openings and the project is carried out in cooperation with Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology LUT and University of Turku, Finland Futures Research Centre FFRC.