

Luonnonvara- ja Biotalouspäivät Lappeenranta 20.9.2023

## Puhdas energia-Suuri kasvumahdollisuus Suomelle

Petteri Laaksonen, D.Sc., Research Director

petteri.laaksonen@lut.fi

LUT UNIVERSITY STRATEGY 2030 • TRAILBLAZERS – Science with a Purpose

# SYSTEM

AIR Turning emissions into opportunities

BUSINESS AND SOCIETY Sustainable renewal of business and industry

WATER Refining sidestreams into value ENERGY Transition to a carbon-neutral world



## LUT is among the world's TOP11 best small universities





#### **GREEN ELECTRIFICATION & P2X ECONOMY**



#### **Competitive advantages for Finland in P2X**

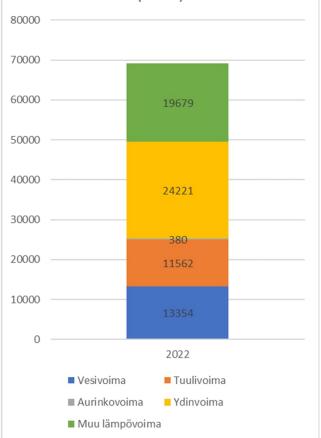
Large and sparsely populated country

#### >> Raw material availability

- Bio based CO<sub>2</sub> raw material (20+ MtCO2 annually), equals to 150 Mt MeOH & 15 BEUR/a revenue
- Cheap electricity compared to rest of the Europe
  - Very big potential for new production (wind and solar) and fast to ramp-up
- Educated people, good education system
- Process industry heritage and skills
  - Steel
  - Chemical
    - Pulp and paper
- Robust infrastructure
  - Good reputation within investors.
    - Fast permitting processes (some exceptions)

## Electricity production in Finland

Sähkön tuotanto tuotantomuodoittain 2022 (GWh)



Electricity production in 2022 69 TWh. Nuclear is the biggest source of electricity.

#### Uusiutuvan energian kasvuvauhti kiihtyy



Fingrid Best estimate skenaario H1/2023

Wind power will pass nuclear 2024 In 2023 wind power exceeds exsiting production

8000 Aurinkovoimakapasiteetti vuoden alussa (MW) 7000 (MM) Tuotettu sähkö (TWh) 6000 5000 4000 3000 2000 1000 2022 2023 2024 2025 2026 2027 2028 2029 2030 FINGRID

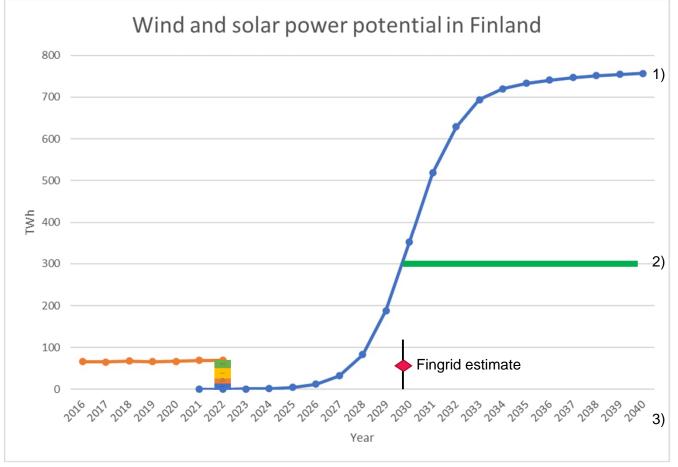
Aurinkovoimakapasiteetin kasvuennuste

Solar power will support the renewable production will be approximately +10% in 2030



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#### POTENTIAL OF GREEN ELECTRICITY PRODUCTION

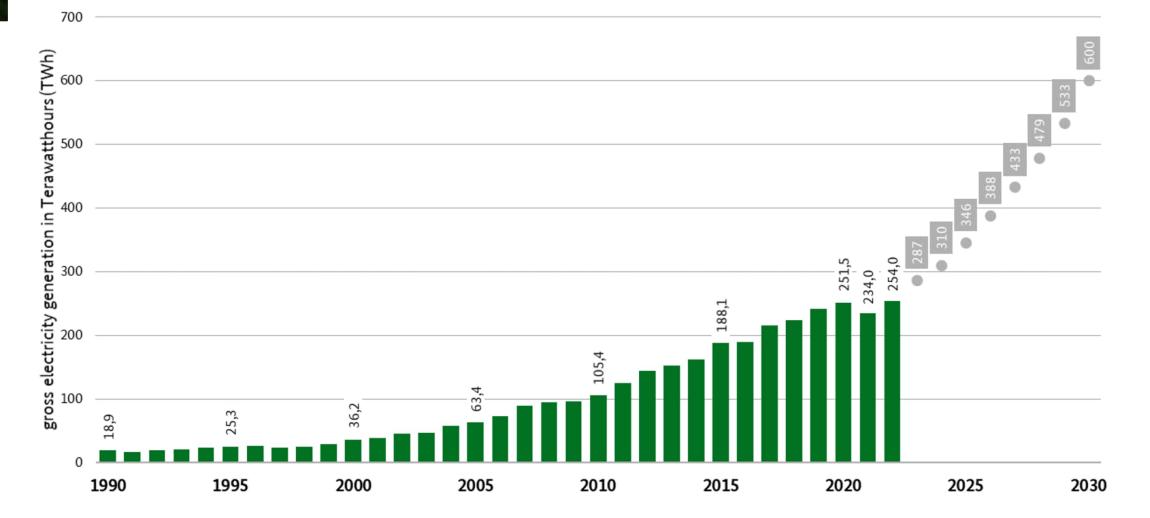


Investments in energy production approximately 400 BEUR

- Based on Actual Grid Connection Request in Finland. Source: Energy transmission infrastructure as enabler of hydrogen economy and clean energy system. Fingrid and Gasgrid Finland's joint project, 15 March 2022. Updated 10.1.2023, Mikko Heikkilä, Fingrid 200 GW+.
- 2) Fingrid estimates 300 TWh wind production to Finnish system (Mikko Heikkilä, Bryssels, 9/2022)
- 3) Timeline not real estimate, just referential.

#### Gross electricity production from renewable energy sources in Germany

and target values accoring to new renewable energy law (EEG 2023)

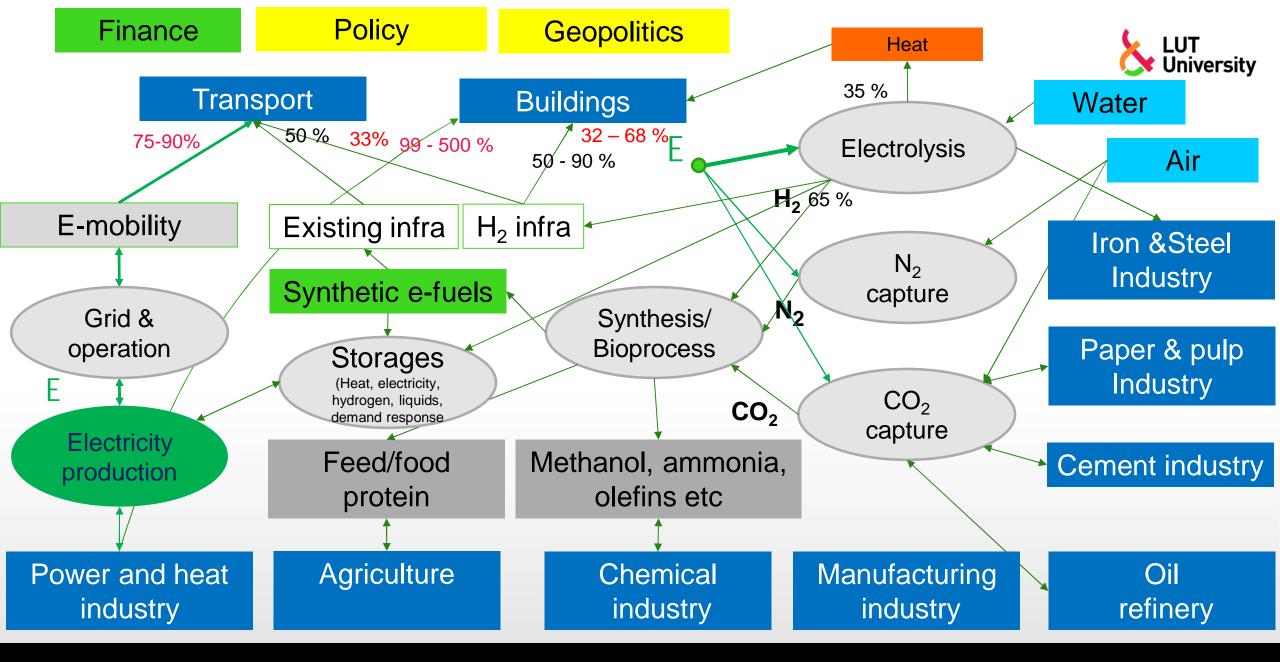


target values for the years 2021 and 2022 according to EEG 2021, target values for the years 2023 to 2030 according to EEG 2023 Source: Working Group on Renewable Energy-Statistics (AGEE-Stat); as of February 2023



#### **NORDIC ELECTRICITY SUPERPOWERS**

- Total renewable electricity potential in Finland exceeds 1000 TWh, representing 10% of the electricity demand in EU.
- Combined with Sweden and Norway, the potential could be 3500 4500 TWh, covering 35-45%% of the European electricity demand of 10 000 TWh
- New P2X investments will be located neat the electricity production. Investments in synthesis of methanol, ammonia and other P2X products exceed investments in electricity generation.
- Total investments exceed 1000 BUER in Nordic countries.

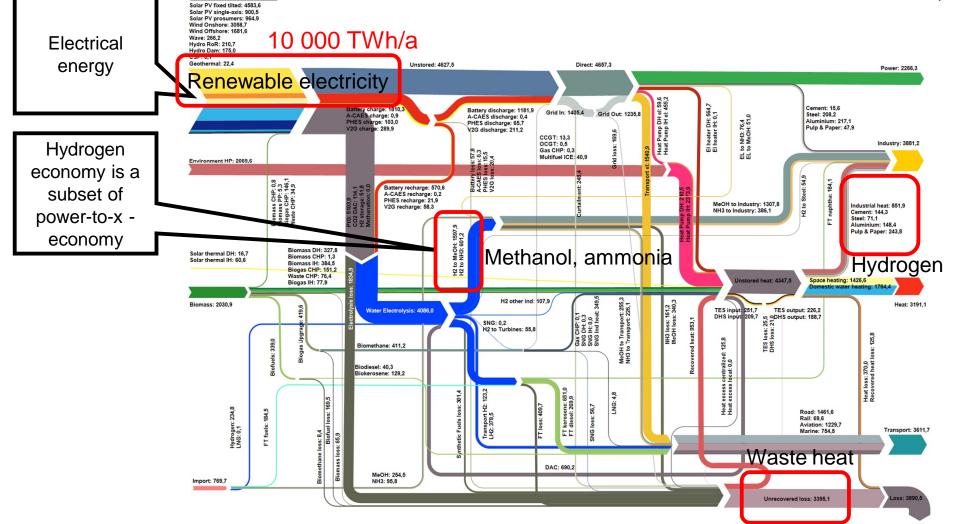


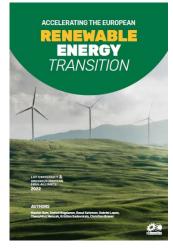
#### **Energy system transition in Europe**

Europe - RES-2040 2050



- Core characteristic of energy in future: Power-to-X Economy
  - Primary energy supply from renewable electricity: mainly solar PV and wind power
  - Direct electrification wherever possible: electric vehicles, heat pumps, desalination, etc.
  - Indirect electrification for e-fuels (marine, aviation), e-chemicals, e-steel; power-to-hydrogen-to-X





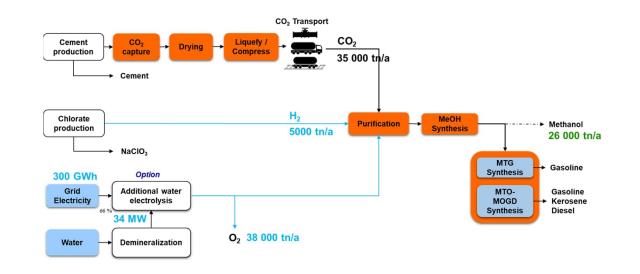
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Greens/EFA, 2022



## **P2X**

#### **Case Pulp Mill**





#### **CASE IMATRA MILLS – METHANOL PRODUCTION**

- Annual biobased CO2 emissions 2,1 Mt (2017)
- Chemical scrubbing (amine, 40 - 140 °C)
  - >> CO2 capture efficiency 98%
  - >> CO2 capture purity >99
- >> Electrolyser 2 GW
- >> Annual electricity 17 TWh
- Green Methanol production 1,5 Mt/a
- >> Value á 1000 EUR/tn
- $\rightarrow$  1,5 Mrd EUR/a

Utilization time	e 750	0 h/a										
Electricity	<b>Electricity</b> 2260,15 MW <sub>e</sub>		Electrical efficien	cy 66 %	Carbondioxide 276 996 h		kg/h					
Elektrolysis 2000,00 MW <sub>e</sub>		Annual energy	16951 GW	564 26		Nm <sup>3</sup>						
Auxiliaries	260,00 MW <sub>e</sub>					6 648	tCO <sub>2</sub> /d					
Own use	0,15 MW <sub>e</sub>					2 077 000	tCO <sub>2</sub> /a					
	Water 340,	8 m <sup>3</sup> /h	1			_						
	340,									Methanol	201 673	kg/h
											141 067	Nm <sup>3</sup>
•	+					♥					4 840 152	kg/d
Elektrolysis		Annual tn	285 483	<b>Methanolsynthesis</b>	Methanolsynthesis					1 513 000	tCH <sub>3</sub> OH/a	
Electricity	Electricity 2000,00 MW <sub>e</sub>		Hydroge		Efficiency, Heat	Efficiency, Heat 65,0 %		%				
Efficiency	75,0 %			423 201 Nm <sup>3</sup>				_		Higher HV**	1288,47	MW <sub>CH3OH</sub>
				285 483 tH <sub>2</sub> /a	CO <sub>2</sub> (g	$() + 3 H_2(g) -$	→ CH <sub>3</sub> OH(g)			Lower HV**	1114,80	MW <sub>CH3OH</sub>
			Higher HV	1500,0 MW			100,0 9	%		Efficiency		
$\Delta_{\rm r} {\rm H}$	286 kJ/mol		Lower HV	1268,8 MW	Δ <sub>r</sub> H	Δ <sub>r</sub> H		-50 kJ/mol		Electrolysis	55,7	%
										Plant	49,3	%
Oxygen	302 098 kg/h 211 601 Nm <sup>3</sup>		Annual tn	#######			Water	113,39 m <sup>3</sup> /h ###### kg/h				
	211 001						₽		(g/li			
Cooling re	<b>g.</b> 500,	0 MW <sub>th</sub>			Cooling reg.	119,52	MWth					
-	-				Methanation	42,61	MWth					
					Steam condensation	76,90	MWth					
Sold Heat		0 MW <sub>th</sub>			Sold Heat	107,56	MWth					
Temperature		0°C			Temperature	325						
Efficiency	90 9	%			Efficiency	90 %	4					

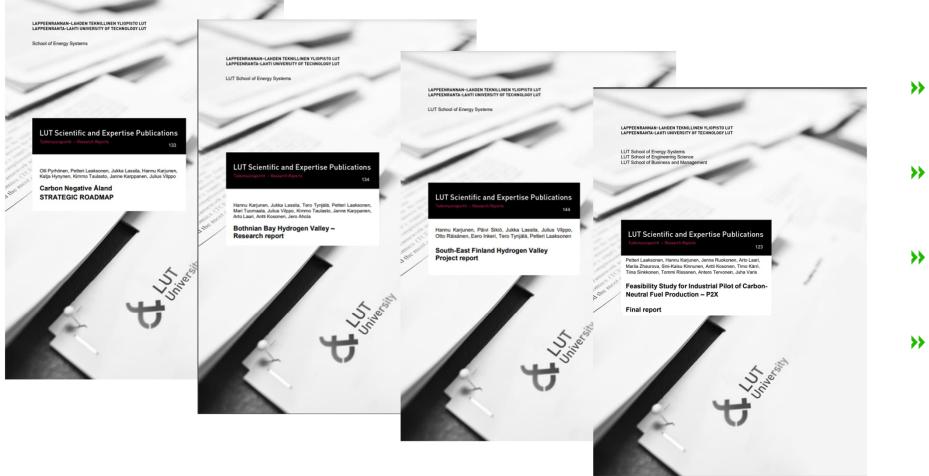


## Thank you!

Petteri Laaksonen, D.Sc., Research Director

petteri.laaksonen@lut.fi

#### P2X in Finland – some LUT research



- Carbon Negative Åland: Strategic Roadmap <u>https://lutpub.lut.fi/handle/10024</u> /163456
- Bothnian Bay Hydrogen Valley Research report <u>https://lutpub.lut.fi/handle/10024</u> /163667
- South-East Finland Hydrogen Valley – Research report <u>https://lutpub.lut.fi/handle/10024</u> /164642
- Feasibility Study for Industrial Pilot of Carbon-Neutral Fuel Production – P2X <u>https://lutpub.lut.fi/handle/10024</u> /162597



## **P2X TECHNOLOGIES**

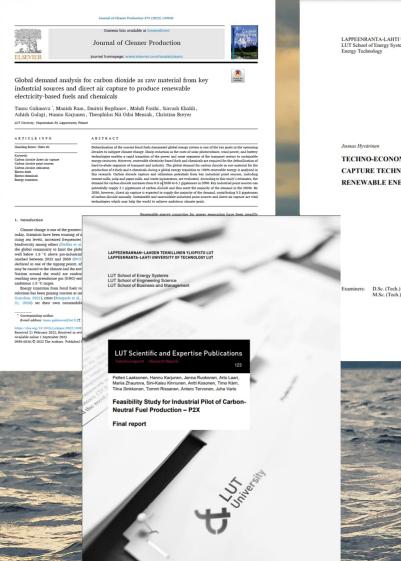
- >> Commercially available
- >> Technology Readiness Level 9



Technology	Supplier	Technology type	Reference
Electrolysis	Cummins	Alkaline, PEM	[21]
	Green Hydrogen Systems	Alkaline	[22]
	Hydrogen Pro	Alkaline	[23]
	ITM Power	PEM	[24]
	McPhy	Alkaline	[25]
	NEL Hydrogen	Alkaline, PEM	[26]
	Siemens	PEM	[27]
	Sunfire	Alkaline, SOEC	[28]
CO <sub>2</sub> capture	Air Liquide Engineering & Construction	Cryogenic	[29]
	Aker Carbon Capture	Amine	[30]
	Carbon ReUse	Water	[31]
	GE Power	Amine, oxy-combustion	[32]
	Mitsubishi Heavy Industries	Amine	[33]
	Shell	Amine	[34]
	Toshiba Energy Systems & Solutions Corporation	Amine	[35]
MeOH synthesis	Air Liquide Engineering & Construction	Syngas/CO <sub>2</sub> to MeOH	[29]
	BSE Engineering	n.a. <sup>15</sup>	[36]
	Carbon Recycle International	CO <sub>2</sub> to MeOH	[37]
	Johnson Matthey	Syngas to MeOH	[38]
	Mitsubishi Gas Chemical	Syngas to MeOH	[39]
Fuel synthesis	Chemieanlagenbau Chemnitz	MTG	[40]
	ExxonMobil	MTG	[41]
	Haldor Topsøe	MTG, syngas to gasoline	[42]
	Sunfire	Fischer-Tropsch	[28]



#### P2X & Carbon Dioxide



LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY LUT LUT School of Energy Systems

TECHNO-ECONOMIC EVALUATION OF CARBON CAPTURE TECHNOLOGIES INTEGRATED TO FLEXIBLE RENEWABLE ENERGY SYSTEM

Check for updates

Insuport Fuels via Olofe

teachernic Killinge Mahal

Rearised In May 212 Annymed 9 June 2021 Published: 15 June 2021

Processes

Modelling and Cost Estimation for Conversion of Green Methanol to Renewable Liquid Transport Fuels via Olefin Oligomerisation

Jenna Ruokonen <sup>1,8</sup>), Harri Nieminen <sup>1</sup>, Ahmed Rufai Dahiru <sup>2</sup>, Arto Laari <sup>1</sup>, Tuomas Koiranen <sup>1</sup>, ri Laaksonen 3, Ari Vuokila 2 and Mika Huuhta

- LUT School of Engineering Science, Lappeersanta Labit University of Vechnology, PO. Box 20, FI-53851 Lappeerstanta, Fieland; harri niemineerilliat fi (FLN); arto laariilliat fi (A.L.): tuomas koistave rilliat fi (CK) nennan konstructuren (Hack II (EK.) Ferritrenen tal and Chemiska Enginaering, University of Ouka, PO. Box 4000, F8001 Ouka, Felnaher rafat, dehirafilosular (i (A.R.D.); ari vuokilefloulur (i (A.V.); mika hundratarenflioulu (i (M.H.) 117 School of Festore Veneza 1
- LUT School of Energy Systems, Lappeentanta Lahti University of Technology, PO. Box 20, H-53851 Lappeentanta, Feland: petteri laakooren#Bat.fi Consepondenes: jonna ruokooren#Bat.fi; Te1: +358-80-648-2478

Abstract The ambitious CO<sub>2</sub> emission reduction targets for the transport sector set in the Paris Climate Agreement require low-carbon energy solutions that can be commissioned rapidly. The production of gasoline, kerosene, and diesel from prowable methanol using methanol-to-olefing Citation Ruckman, L/Namiran, (MTO) and Mobil's Olefins to Gasoline and Distillate (MCGD) syntheses was investigated in this H; Dahiru, A.R.; Lauri, A.; Koimmer study via process simulation and economic analysis. The current work presents a process simulation Lasksower, P. Vuokila, A. model comprising liquid fuel production and beat integration. According to the economic analysis, the total cost of production was found to be  $3499 \text{ eV}_{tube}$ ,  $C23 \text{ eVMV}_{LIP}$ , corresponding to a merevable methanol price of 80 CH (124 CeWW<sub>LIP</sub>). The calculated fael price is considerably Harram, M. Modelling an Methanul to Renewable Liquid higher than the current cost of fouil faels and biotuel blending components. The prize of mnewable methanol, which is largely dictated by the cost of electrolytic hydrogen and mnewable electricity, riation. Process 2021. 8 was found to be the most significant factor affecting the profitability of the MTO-MOGD plant. To htps://doi.org/10.33 reduce the price of renewable fuels and make them economically viable, it is recommended that the EU's sustainable transport policies are enacted to allow flexible and practical solutions to reduce 'ransport-related erei as within the member state

Keywords: methanol; MTO-MOGD; hydrocarbon fuels; mnewable energy; sustainable transp

#### Publisher's Note: MDPI stars results with report to jurializitional claims it

The legal framework set by the Paris Climate Agreement [1] calls for practical techno-logical solutions to realise emission reduction targets at both the European Union (EU) and od maps and institutional affil togent sendbase incase transactions statistically give according to adaptions of the transaction of the send of the EU is to gradually achieve carbon neutrality by 2050 [2]. The realisation of considerable emission reductions requires marked recom-figuration of the energy sector. The role of hydrogen in the energy transation has gained 0 0 "O spin interest, and the question of whether to use nearwable electricity directly as a source of power or to convert electricity to hydrogen via the electricitys of water remains unresolved. The direct use of electricity in battery electric vehicles is the most energy Convright () 2021 by the authors aw MDPL Bank, Switzerland. This article is an open assess article distributed under the terms and efficient option, and this can be readily observed by comparing the overall well-to-wheel efficiencies of fully electric vehicles and internal combustion engine vehicles. After taking fuel production, distribution, retail, and vehicle losses into account, the well-to-wheels unditions of the Ontative Commons Attribution (CC SV) Ionnae (https:// efficiency of fossil fuel-powered internal combustion engine vehicles is only 25-29%, while the corresponding figure for battery electric vehicles charged with renewable electricity is

mers 2021, 9, 1046. https://doi.org/10.3390/pr9061046

MDPI

Hannu Karjunen

ANALYSIS AND DESIGN OF CARBON DIOXIDE UTILIZATION SYSTEMS AND INFRASTRUCTURES

IVERSITATIS LAPPEENRANTAENSIS 1048



Katja Kuparinen

TRANSFORMING THE CHEMICAL PULP INDUSTRY -FROM AN EMITTER TO A SOURCE OF NEGATIVE CO, EMISSIONS

ACTA UNIVERSITATIS LAPPEENRANTAENSIS 870

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