Teollisuuden dekarbonisaatio ja vedyn rooli

Contact: ville.nikkanen@vtt.fi

Summary

- Yleiskatsaus teollisuuteen
- Vety Suomessa
- P2X: Energia raaka-aineena
- Energia Suomessa
- Työkalupakki 2035

Yleiskatsaus

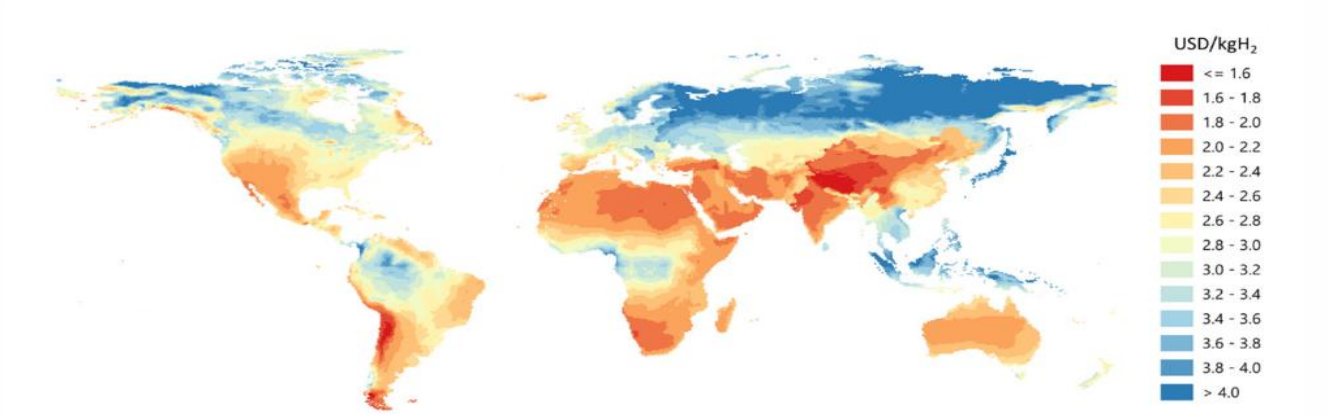
Teollisuus nykyisin

- Isoja energian kuluttajia
- Kulutus nykyisin 8700 tuntia vuodessa
- Isoja CO2 päästölähteitä
- Prosessit vaativat korkeita lämpötiloja
- Prosessit vaativat pelkistimiä / raaka-aineita

Vety Suomessa

Hydrogen: Solar and wind

Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



Notes: Electrolyser CAPEX = USD 450/kWe, efficiency (LHV) = 74%; solar PV CAPEX and onshore wind CAPEX = between USD 400–1 000/kW and USD 900–2 500/kW depending on the region; discount rate = 8%. Source: IEA analysis based on wind data from Rife et al. (2014), NCAR Global Climate Four-Dimensional Data Assimilation (CFDDA) Hourly 40 km Reanalysis and solar data from renewables.ninja (2019).

Bulk H_2 Storage Methods

NG Spherical Pressure Vessel, Germany

NG Pipe Storage, Erdgas, Switzerland

LH_2 Cryogenic Storage, NASA

FY 2019 Work

- Pipe storage, salt cavern, lined rock cavern

Future Work

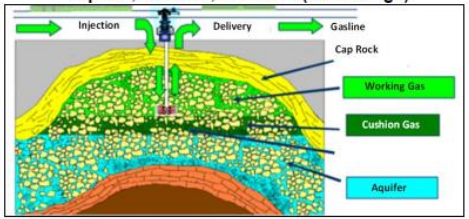
- Forecourt, cryogenic

	Pressure Vessels				Cryogenic	Geologic Storage		
	Spherical Vessels	Pipe Storage	Pre-stressed Concrete	WireTough		Aquifer	Salt Cavern	Lined Rock Cavern
Pressure, bara	1-10.4	7-100	7-875	7-875	20	150-170	55-152	10-230
Diameter, m	39.5	1.4	2.2	0.43	20			35
Wall Thickness, mm	34		110					6-12
Length, m		200 (13x15)		9.2				
Depth, m						1,500	1,200	115
Height, m			5.3					52
Water Volume, m^3	32,000	6,100	22	0.77	3400	4,141,000	566,000	40,000
Net Volume (STP), m^3	273,664	500,556	10,979	428	2,558,399	211,346,012	41,379,324	7,119,024
H_2 Stored, t	27	50	1	0.0389		54,000	6,000	672
Working Capacity, t	24.6	45	0.987	0.0385	230	19,000	3,720	640
Application		City Gate	Forecourt	Forecourt	City Gate Forecourt		City Gate	City Gate

Salt Cavern, H_2 Storage, Praxair, Texas

Rock excavation (dome), Skallen,

Aquifer, Stenlille, Denmark (NG storage)



See slide 30 for references

https://www.hydrogen.energy.gov/pdfs/review19/st001_ahluwalia_2019_o.pdf

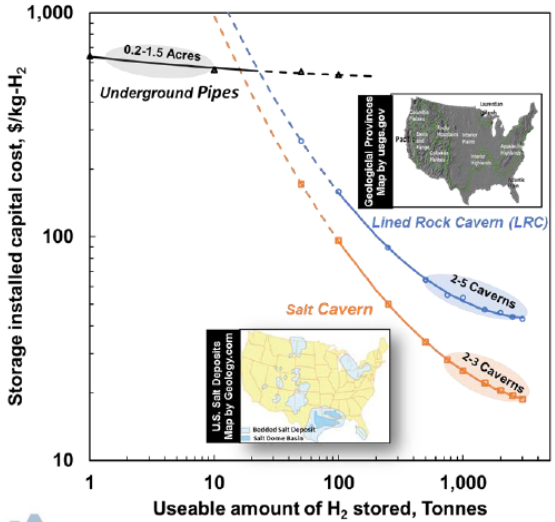
Accomplishment

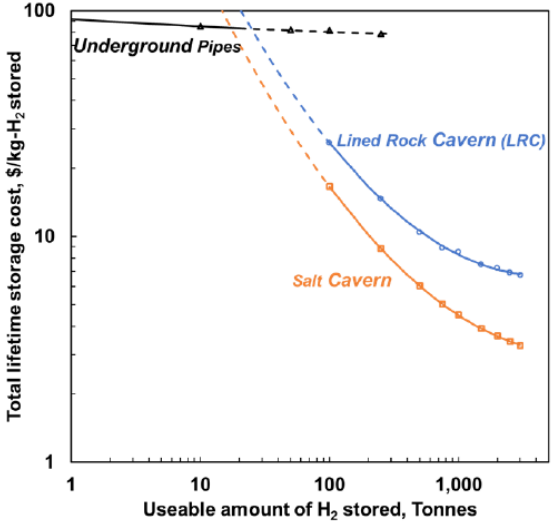
Bulk H_2 Storage: Outlook

- Underground pipes more economical than geological storage for <20-t usable stored H_2
- At large scale, salt caverns generally more economical than lined rock caverns
- Storing >750-t usable H_2 may require multiple caverns

Installed Capital Cost
- Underground pipes: 100 bar
- LRC and salt caverns: 150 bar

Yearly Storage Cost
- Inclusive of CAPEX and operating & maintenance cost



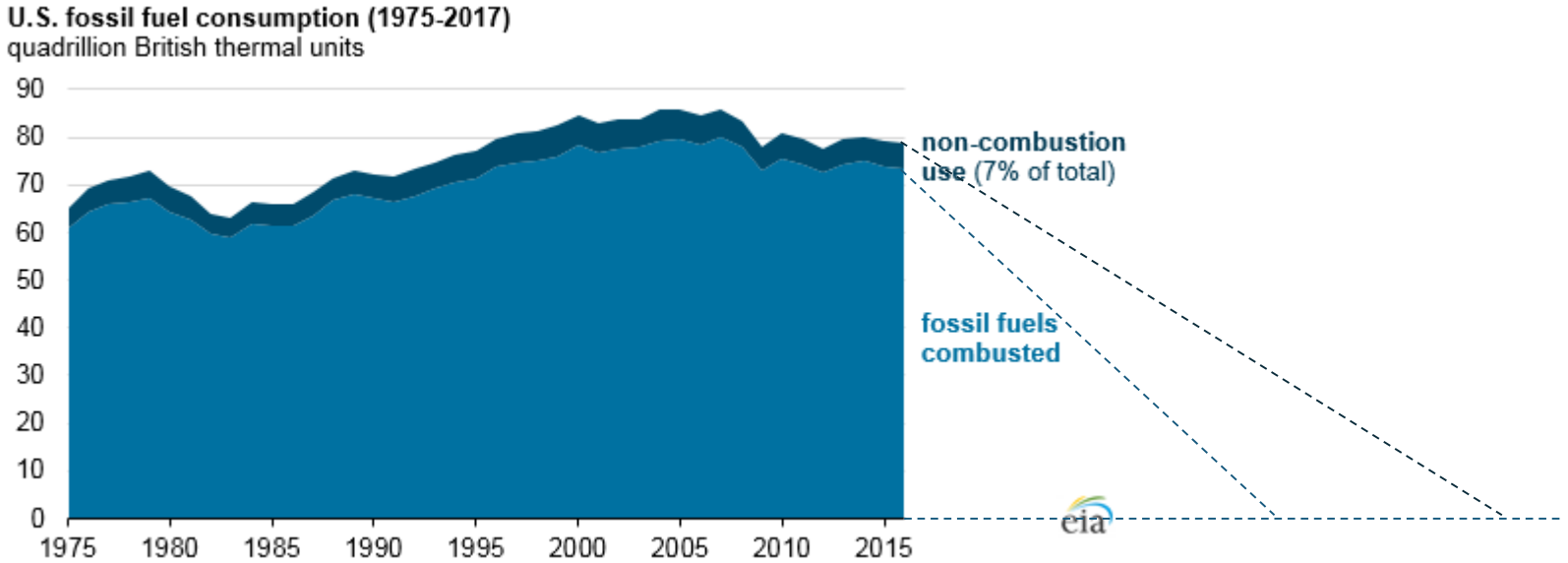


https://www.hydrogen.energy.gov/pdfs/review19/st001_ahluwalia_2019_o.pdf

P2X

Energia raaka-aineena

Material use of fossil resources



Electrification of chemical industry: Germany

Synteettinen nafta / öljy

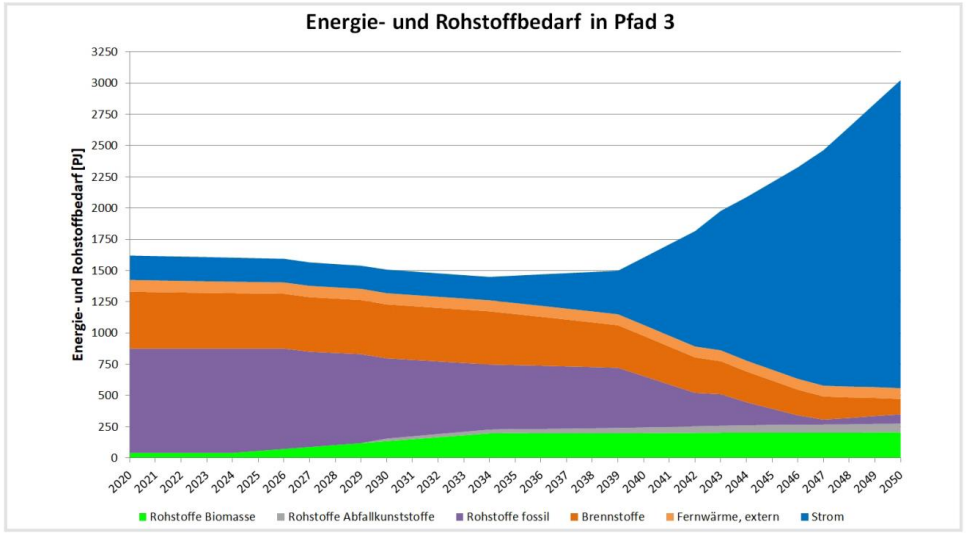


Abbildung 24: Entwicklung des Energie- und Rohstoffbedarfs der deutschen chemischen Industrie im Technologiepfad für verschiedene Energieformen und Rohstoffe.

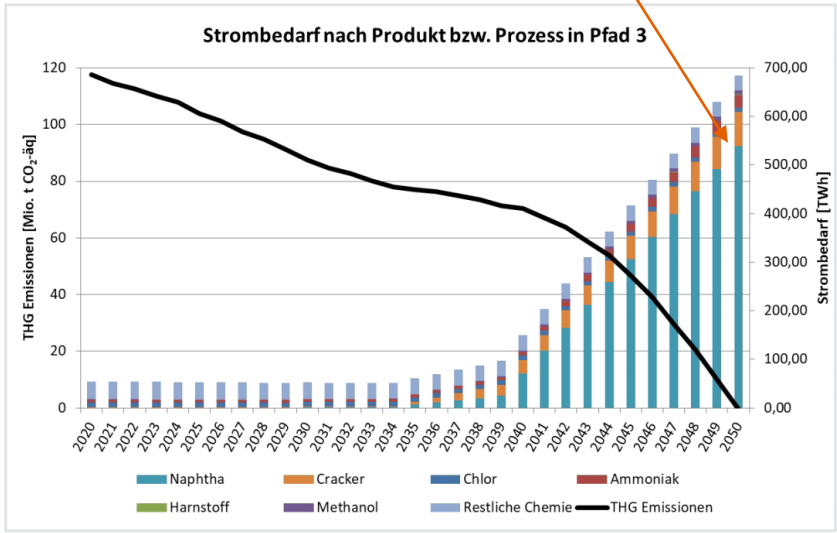


Abbildung 27: Strombedarf in Pfad 3 nach Produkten bzw. Prozessen (Balken) und Verlauf der THG Emissionen zwischen 2020 und 2050 (schwarze Linie). Nicht-betrachtete Basischemie- und Spezialchemieprodukte sind als „restliche Chemie" zusammengefasst.

DECHEMA

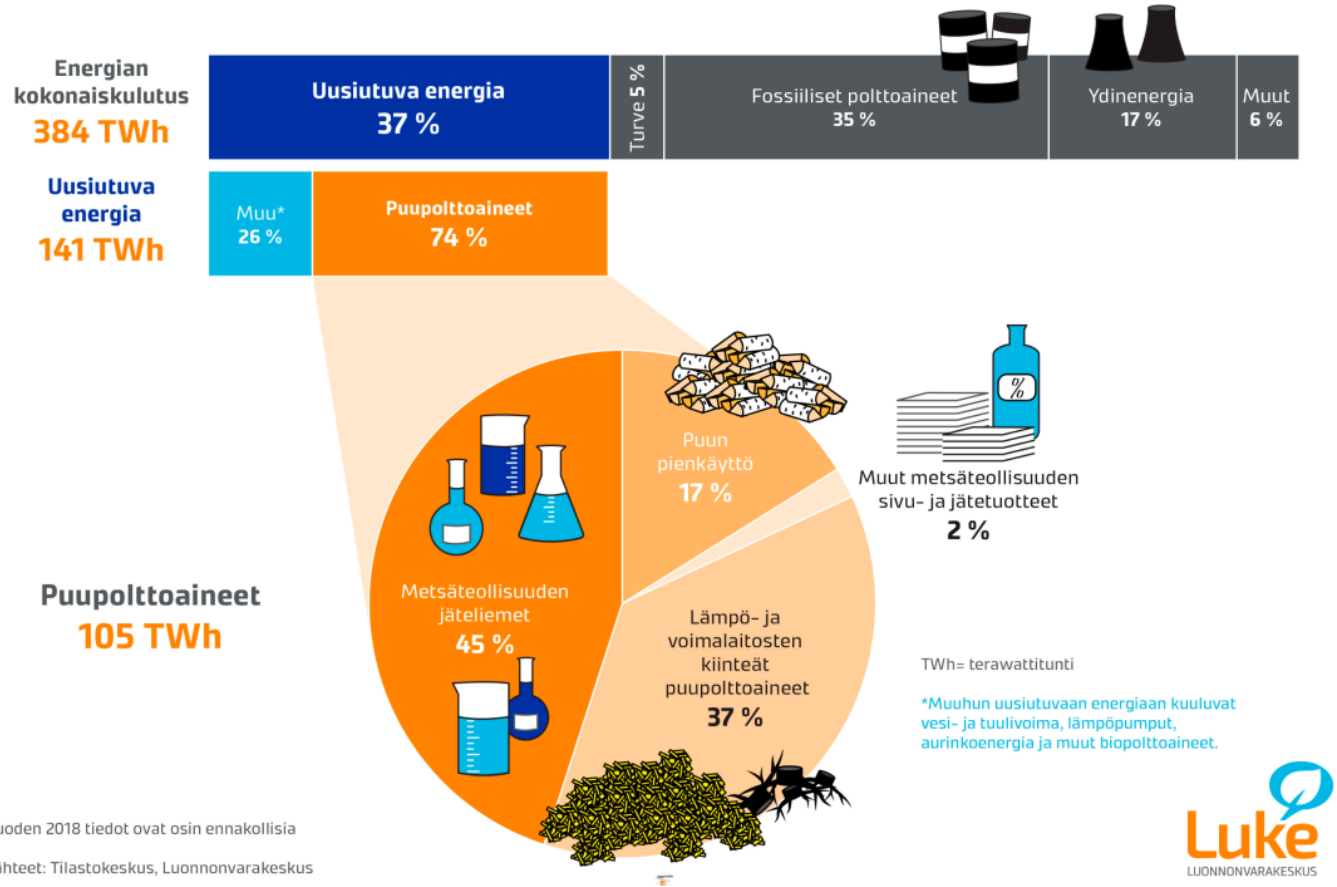
https://www.vci.de/vci/downloads-vci/publikation/2019-10-09-studie-roadmap-chemie-2050-treibhausgasneutralitaet.pdf

Routes to hydrogen

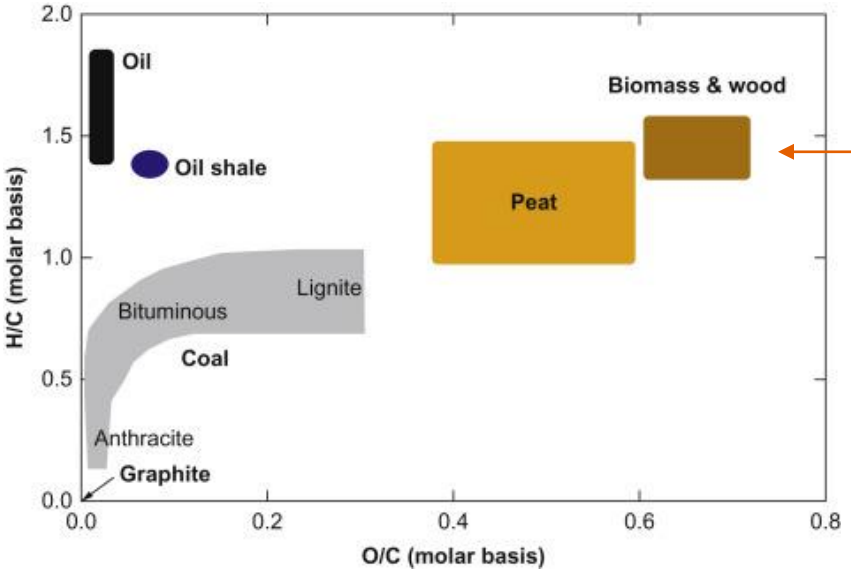
Electrolysis:	$2\ H_2O \rightleftharpoons 2\ H_2 + O_2$	286 kJ/mol_{H2}
Steam reforming:	$CH_4 + 2\ H_2O \rightleftharpoons 4\ H_2 + CO_2$	43 kJ/mol_{H2}
Gasification:	$C + 2\ H_2O \rightleftharpoons 2\ H_2 + CO_2$	45 kJ/mol_{H2}
Thermolysis:	$CH_4 \rightleftharpoons 2\ H_2 + C$	37 kJ/mol_{H2}

P2X

Energia Suomessa


Energian kokonaiskulutus
384 TWh
Uusiutuva energia
37 %
Turve 5 %
Fossiiliset polttoaineet
35 %
Ydinenergia
17 %
Muut
6 %
Uusiutuva energia
141 TWh
Muu*
26 %
Puupolttoaineet
74 %
Puupolttoaineet
105 TWh
Puun pienkäyttö
17 %
Muut metsäteollisuuden sivu- ja jätetuotteet
2 %
Metsäteollisuuden jäteliemet
45 %
Lämpö- ja voimalaitosten kiinteät puupolttoaineet
37 %
TWh= terawattitunti
*Muuhun uusiutuvaan energiaan kuuluvat vesi- ja tuulivoima, lämpöpumput, aurinkoenergia ja muut biopolttoaineet.
Vuoden 2018 tiedot ovat osin ennakollisia
Lähteet: Tilastokeskus, Luonnonvarakeskus
Luke
LUONNONVARAKESKUS

Vety + Happi + Hiili



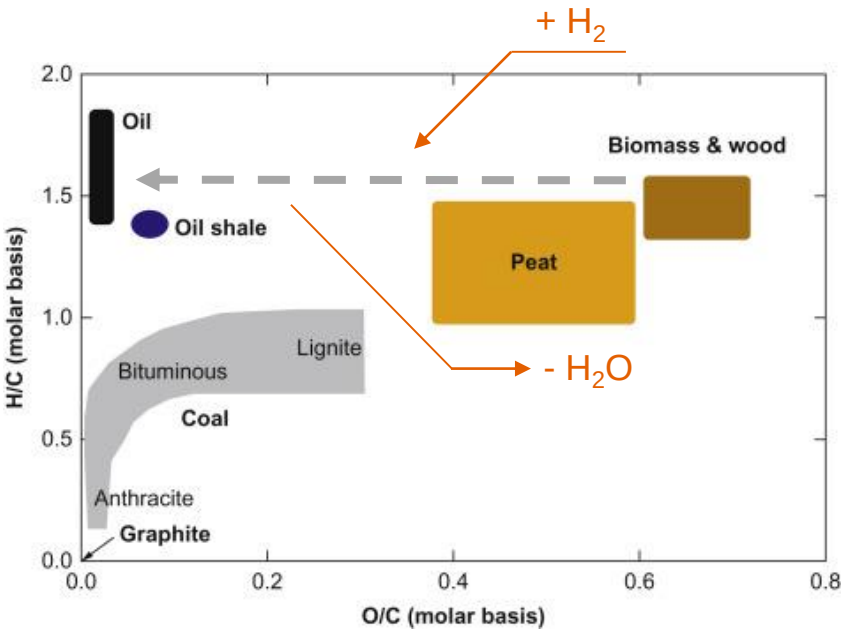
105 TWh

> 30 Miljoonaa tonnia CO2

Fletcher, 2017

Vety + Happi + Hiili

Synthetic bio-naphta



Fletcher, 2017

Työkalupakki 2035

Työkalupakki 2035

- Elektrolyysi
- Vedyn varastointi
- Prosessien suora sähköistys
- Prosessien joustavuus (Demand Side Management)
- Prosessien hiilitehokkuus (Vältetään CO2 muodostuminen)
- CO2 infrastruktuuri (Negatiiviset päästöt)

beyond

the obvious

Ville Nikkanen
ville.nikkanen@vtt.fi
+358 40 1435175

@VTTFinland

www.vtt.fi

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