



UNIVERSITY OF TARTU



W. Ostwald ja vesiniku tehnoloogiad 2023. aastal

Enn Lust

füüsikalise keemia professor

ETA liige

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Tartu, 06.10.2023, VII vesinikupäev



170 aastat Nobelisti W.
Ostwaldi sünnist!
Füüsikalise keemia ja roheline
vesinikuenergeetika rajaja!
**Omistati 1909 a. Nobeli
preemia heterogeense
katalüüsi alal!**

Wilhelm Ostwald
memorial tablet on the main
building wall of the University of
Tartu



- Töötas välja kütuseelementide termodünaamilise teooria
- ...ja vesinikuenergeetika alused
- tegeles teaduse süstematiseerimisega
- harrastas „kauneid kunste“.
- Avastas nn Ostwaldi ripeng nähtuse: osaksete ümberkristalliserumine potentsiaali all.

Ostwald ripening is a phenomenon observed in solid solutions and liquid sols that involves small crystals or sol particle the change of an inhomogeneous structure over time, in that it first dissolve and then redeposit onto larger crystals or sol particles.

Thus, loss of catalytic surface area and total formation rate of reaction products



Kasutades Pt/Pt H₂SO₄ kütuseelemendi eksperimentaalseid andmeid , töötas välja teooria:

Pt-based fuel cells, theoretical bases given by W. Ostwald in 1896

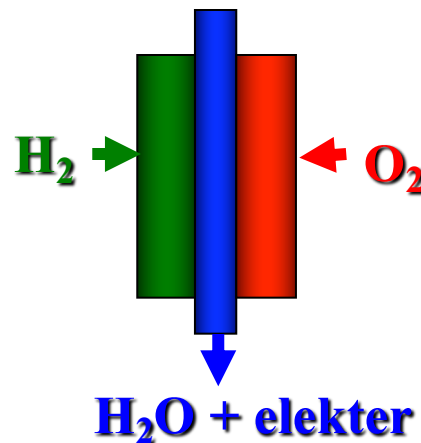
associated prof. at Univ. Tartu (1875-1881), prof. of Leipzig Univ. (1888-1906)

Now: testing the influence of the characteristics of carbon materials on PEMFC energy and power density; development of Pt-metals free d-metal-N₂ materials (Fe-N₂; Co-N₂; Fe-Co-N₂) for PEMFCs

Mida kõrgem on kütuseelemendi töötemperatuur, seda kiiremine protsessid toimuvad ja seda suurem on kasutegur. Sellepärast püütakse väljatöötada kõrgtemperatuurseid kütuseelemente ja elektrolüüsereid, sünteesireaktoreid. Tekib probleem materjalide termilise vastupidavusega.

$$\Delta E^0 = -\Delta G/nF = (RT/nF)\ln K_a$$

$$\Delta G = \Delta H - T\Delta S$$

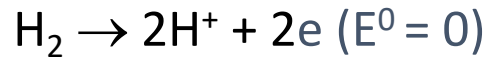




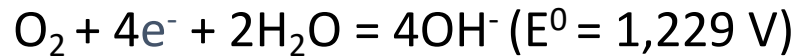
H₂-O₂ kütuseelement, teoreetilised alused W. Ostwald

- H₂-O₂ kütuseelement - 1839 Sir W. Grove, 1893-1898 W. Ostwald (teooria, Pt/Pt + happeline lahus)
- PEMFC - 1955 T. Grubb, 1958 L. Niedrach (General Electric, NASA), pH < 7, prootonjuhtivusega kütuseelement

Anoodil vesinik (kütus) oksüdeerub



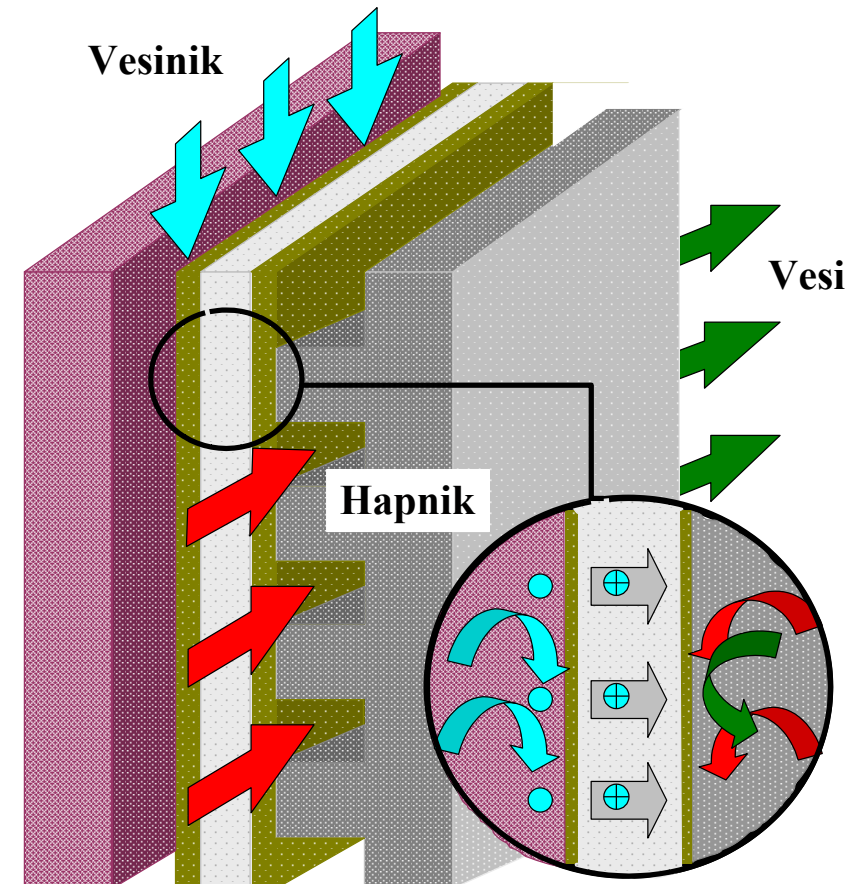
Katoodil hapnik redutseerub



Summaarne ioonreaktsioon: $\text{H}^+ + \text{OH}^- = \text{H}_2\text{O}$

- Pole kõrvalprodukte!
- T = 60-80 °C
- Tekib elektrivool ja soojus ning ainult ülipuhas vesi!
- Vett saab koguda ja kasutada vesiniku taastootmiseks, kui PEMFC võimsus 50 kW ja rohkem!

$$\Delta E^0 = -\Delta G / nF = RT \ln K / nF$$





Carl Ernst Claus: Andis väga olulise panuse Pt-metallide uurimisse.

(Karl Karlovich Klaus) 23.01.1796-24.03.1864 (Dorpat)

World-wide reputation scientist in the Pt-metals studies

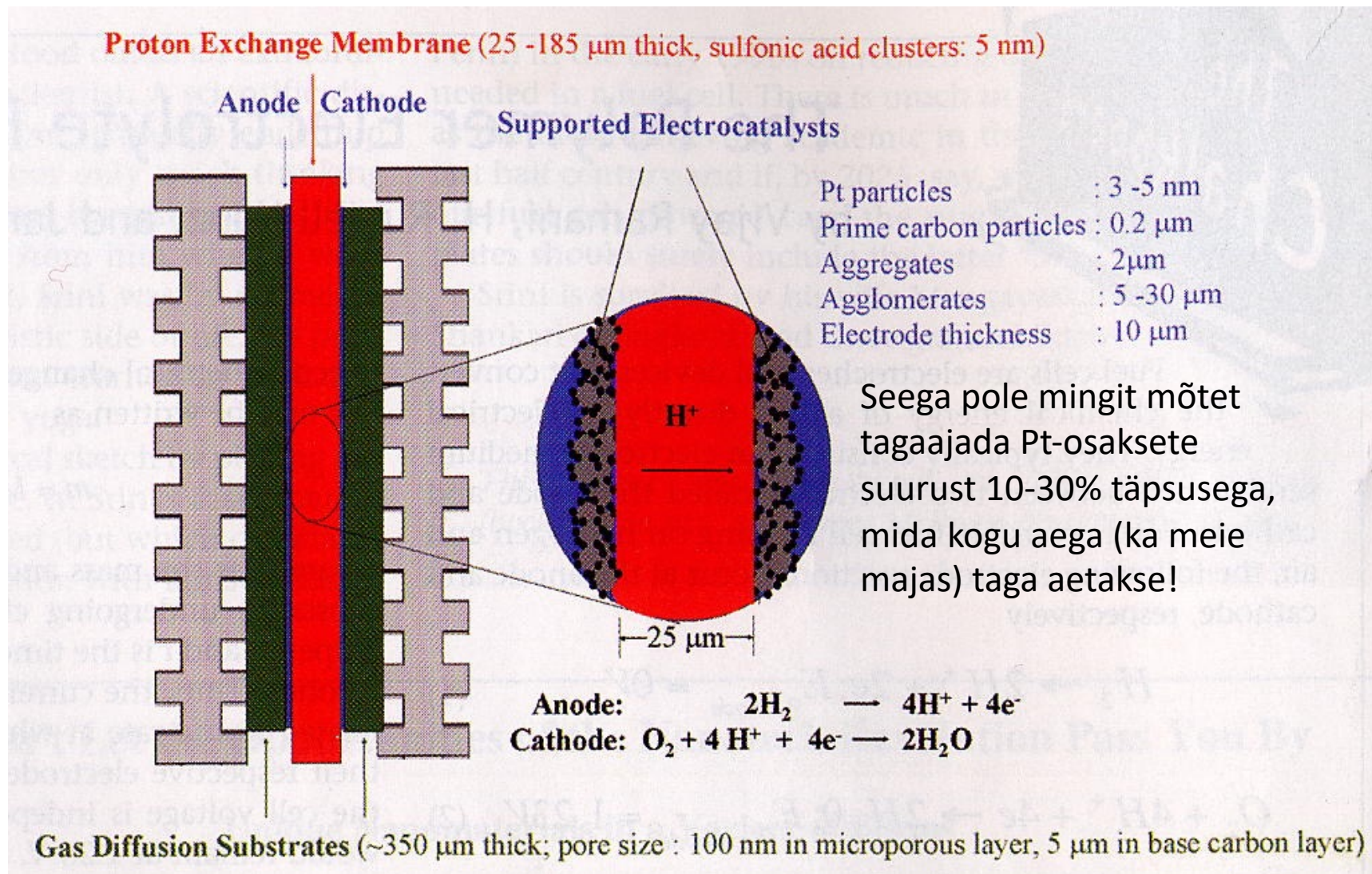
- Carl Claus was born in Russia, Dorpat,
- 1810 a pharmacist at St. Petersburg, 1815 back to Dorpat, passed the pharmacy examination at the Univ. Dorpat, 1815 back to St. Petersburg, 1817 to Saratov
- **1831 became an assistant in the chemistry at the Univ. Dorpat**, defended masters degree,
- 1838 established the chemistry laboratory at Kazan University.
- 1839 received doctoral degree, professor extraordinarius of chemistry,
- **1844 separated finally the element Ruthenium from Pt metal refineries**, Ru (not accepted by S. Arrhenius) (Rh, Pd, Os and Ir were separated in 1828 by Berzelius but Osann (Univ. Dorpat) already claimed the presence of the new metal – now known as ruthenium).
- **1852 back to Tartu to occupy a newly established chair of pharmacy at the Univ. Dorpat**,
- 1861 a corresponding member of the Russian Academy of Sciences,
- 1863 he visited Western Europe University laboratories and platinum refineries

1854 main summary: Beiträge zur Chemie der Platinmetalle. 1856 established formation principles of Pt metals amines

Schematic of a PEFC listing key dimensions

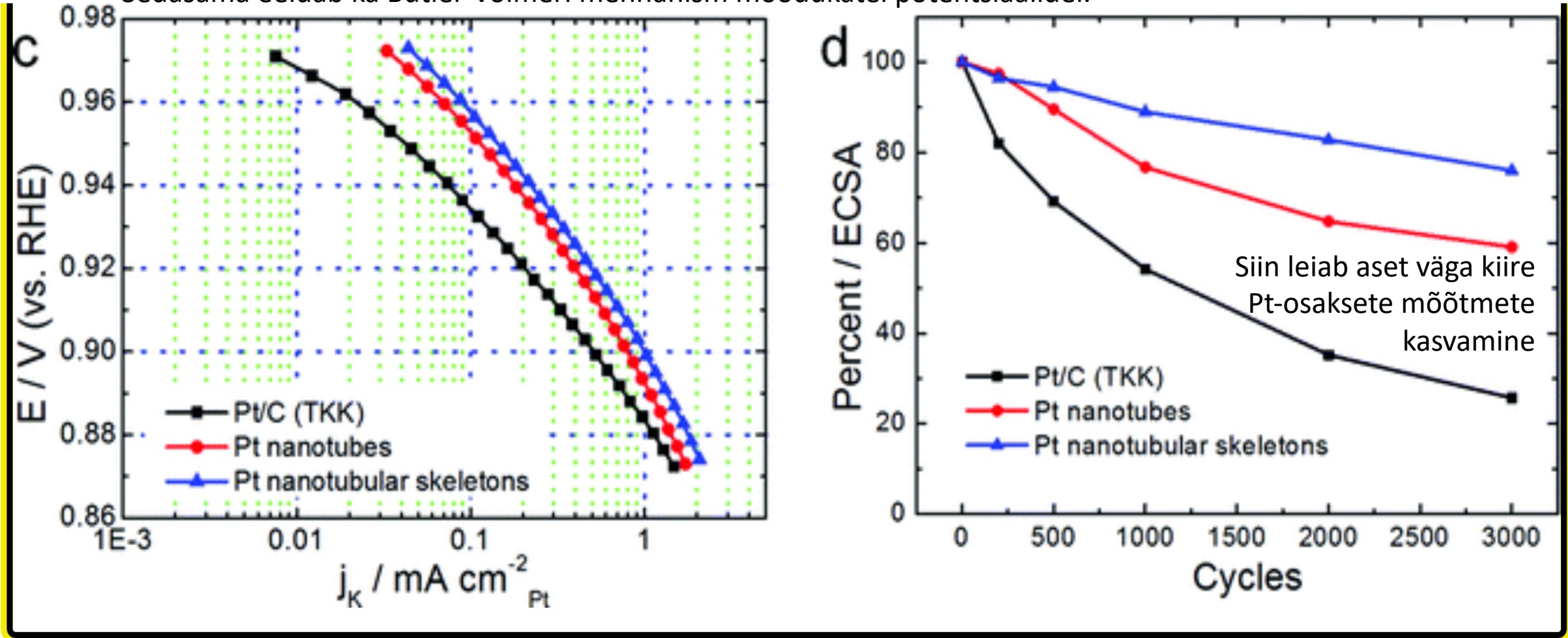
Suurim probleem: **katalüsaatori osakeste ebastabiilsus (Ostwald ripening!+ more)**

- Kui keegi usub/arvab, et Pt nanoklastrite suurus (eriti + laengute osas) ei sõltu pinnalaengust, siis ta eksib väga rängalt.
- Mida väiksem on Pt nanoklaster, seda ebastabiilsemad on selle mõõtmed ja kuju.
- Tuntakse nii **katoodil** (--pinnalaeg) aset leidvat **dispegeerumist** (eemaldumist nanoklastritena) kui **ka oksüdeerumist (Pt-oksiidid(oksohüdrosiidi) moodustumist)** ja seega **võimalikku lahustumist ja hiljem sadenemist lahusefaasist uude kohta**. Selle tulemusel võib osasese suurus kasvada ja katalüsaatori aktiivsus väheneda!



Tafeli sõltuvused

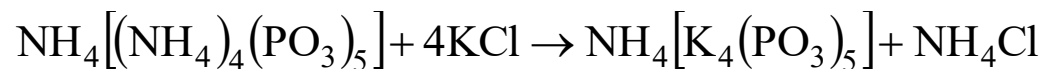
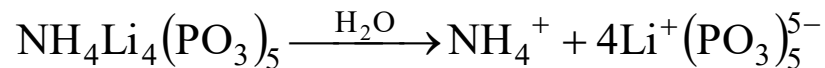
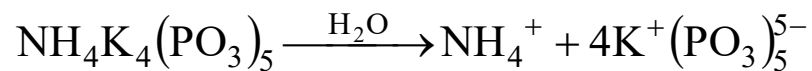
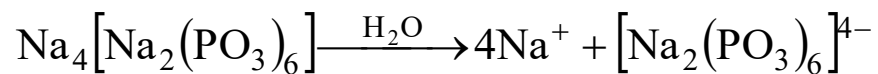
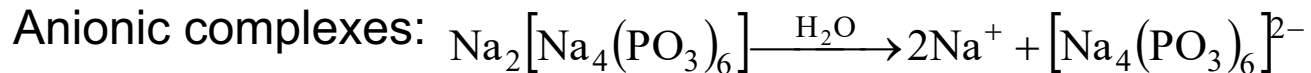
Tulenevalt Marcus-Hush'i ja L.I. Krišthaliku mudelitest (aktivatsioonienergia on sõltuv ülepingest) ei tohigi nn Tafeli sõltuvused (j_k vs E) olla lineaarsed, vaid see on võimalik ainult teatud eksootilistel erijuhtudel (st. väga kõrgetel potentsiaalidel, kus on aktivatsioonienergiata reaktsiooni piirkond). Sedasama eeldab ka Butler-Volmeri mehhanism mõõdukatel potentsiaalidel.





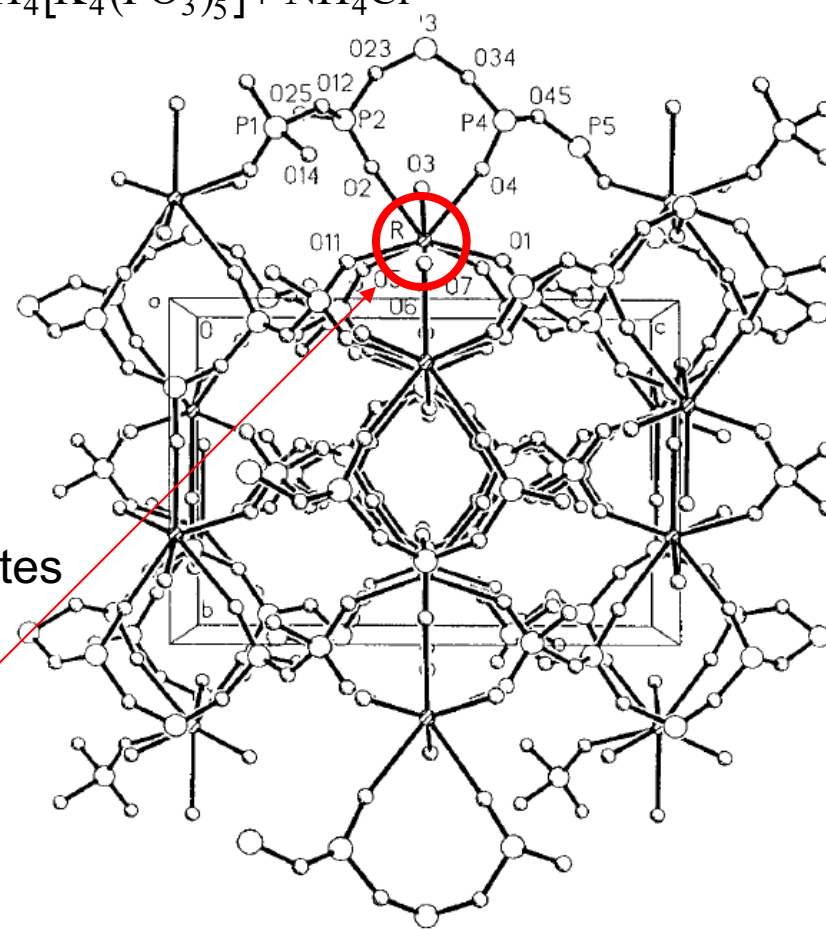
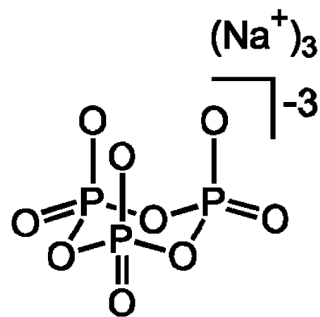
1887 – Ph.D. thesis on metamerism of metaphosphates

(i.e. HPO₃ acid salts (NaPO₃)₂, Mg₆Na₂(PO₃)₁₄)



Synthesis of M₃Na₂(PO₃)₈ (M = Mg, Co, Zn, Ni)

M₄Na₄P₂O₇ (M = Ba, Pb, Cu)



General chemical formular for polymeric phosphates

linear M^I_{n+2}P_nO_{3n+1}

cyclophosphates M^I_nP_nO_{3n}

ultraphosphates MP₅O₁₄

(M = La, Nd, Sm, Eu, Gd)

**Gustav Heinrich
Johann Apollon
Tammann** uuris
fosforis happe
soolade omadusi,
ka nn **polümeer-
seid fosfaate.**

Samuti metallide
sulameid ja töötas
välja roostevabad
terased (Krupp'i
kahuritorude
materjali ,jne)



Juba 19. sajandi keskpaigas oldi teadlikud, et mõned elemendid on kriitilise tähtsusega moodsa tehnoloogia arendamiseks.... näiteks Pt-metallid! REEd, HHM ,

Kriitiseks loetakse:

(tähestiku järjekorras):

As, B, Cd, Cr, Co, Cu, Dy, Ga, Ge, C (grafiit), Hf, In, Nb, Pb, Li, Mg, Mo, Ni, Hg, Te, Ta, Sn, Ti, W, V, Ir, Pt-grupi metallid, Pr, Y, Se, Si.

Gruppide kaupa:

Mittemetallid: B, Se,

Poolmetallid: Si, As, Sb, Te

Pt-metallid, (Ir, Pd, Pt, Ru, Os)

Haruldased muldmetallid, (REE)

(17 tükki, eriti Nd, Dy, Y, Yd, Pr,

Ce, Ho, Sm, Lu)

Hajutatud haruldased metallid (HHM)(Hf, Ta, Nb, W, Mo, Ti, V):

D-metallid: Cu, Ni, Co, Cr,

Sp-metallid: Li, Al, Cs, Mg, Sn,

Pb, Hg, Ga

[U.S. Geological Survey Releases 2022 List of Critical Minerals \(2022\) www.usgs.gov > news > national-news-release](https://www.usgs.gov/news/national-news-release/2022/07/11/critical-minerals-data-explorer)

Critical Minerals Data Explorer

Global demand projections for 37 critical minerals needed for clean energy transitions across the three main IEA scenarios and 12 technology-specific cases

Last updated 11 Jul 2023

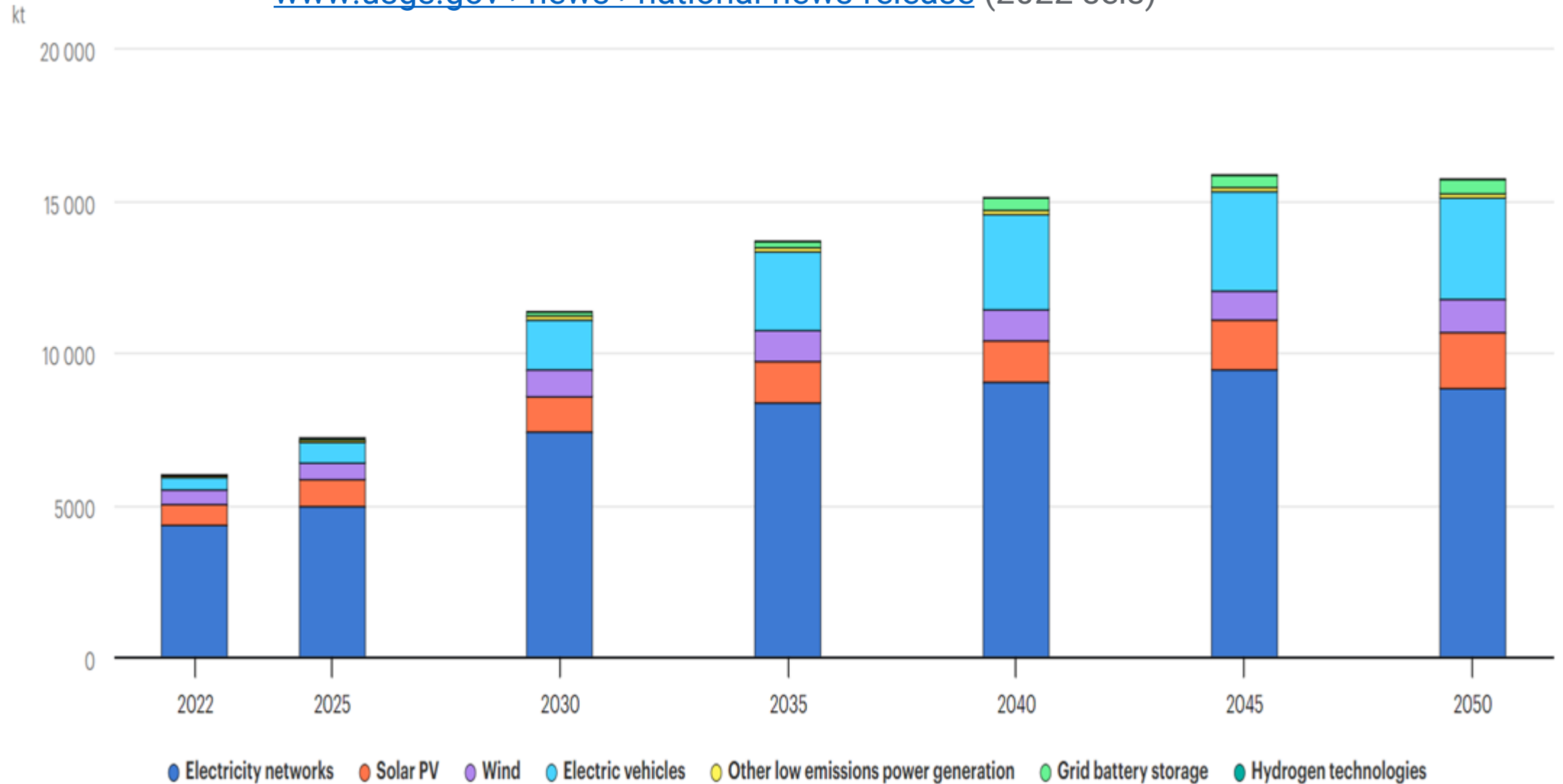
As demand for metals and minerals such as lithium, nickel, cobalt, graphite, copper, aluminium, and rare earth elements soar, this interactive tool makes quantitative data and projections on these critical materials available to the public and policymakers.

In its first release, the tool provides demand projection results under various energy scenarios and technology evolution trends. Users can look up total demand for key minerals (copper, lithium, nickel, cobalt and neodymium) and projected mineral demand in the clean energy sector by technology and commodity under different scenarios and technology cases, including 12 alternative cases modeling the impact of different technologies or consumer behaviours



Vase kasutusala (kogus kilotonnides)

www.usgs.gov › news › national-news-release (2022 seis)



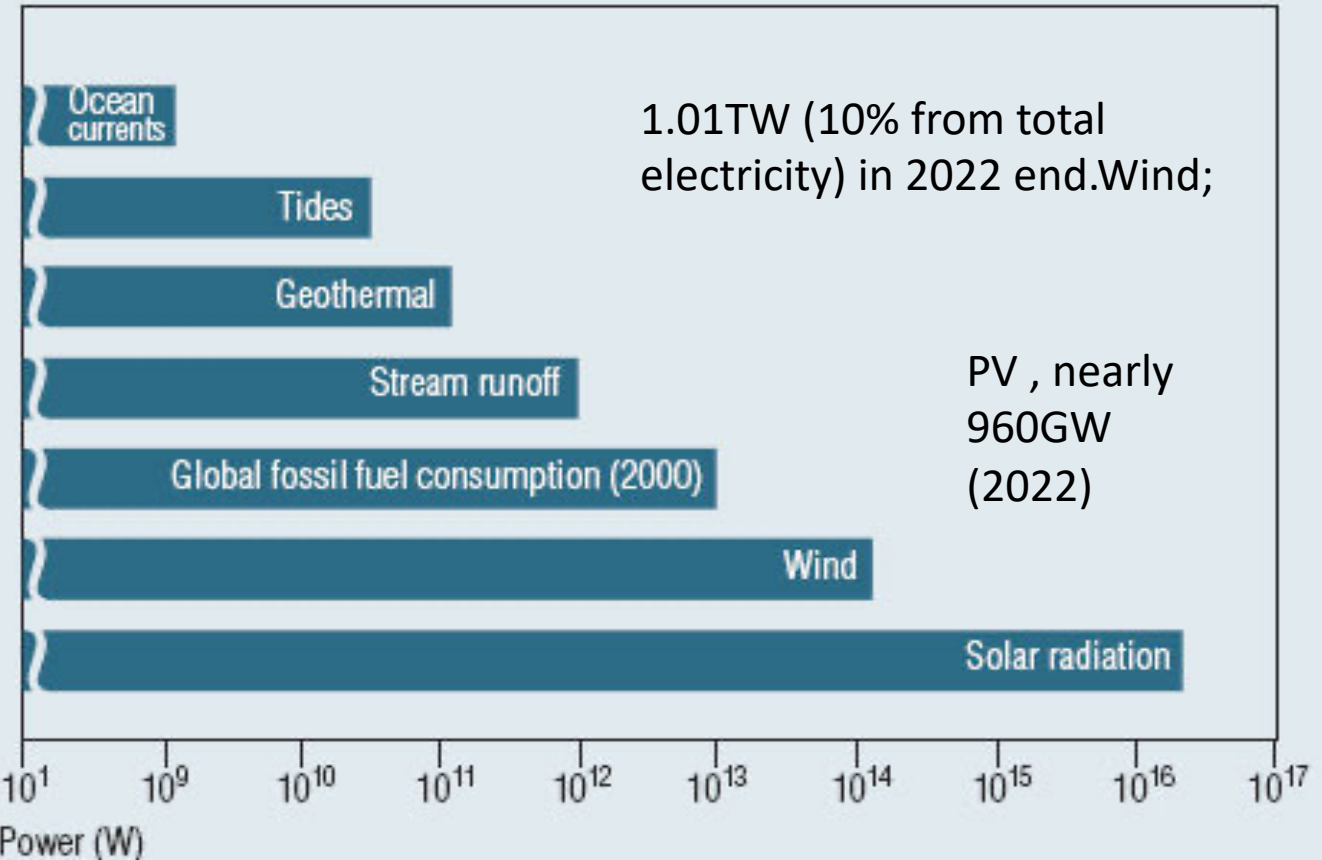


Mis saab energiatehnoloogias edasi?

Kui maailm loodi, siis otsustati, et paneme arenguobjektid igavesele proovile, kas nad on võimelised võtma kasutusele nendele mõeldud keskkonda mittesaastavaid ressursse? Hinnanguliselt teame, et tuuleenergiat on vähemalt 15-25 korda rohkem ja päikese-energiat langeb maale 1500-2000 korda rohkem kui momendil kogu käideldava energeetika maht. Seega ülikiiresti tuult ja päikest „püüdma“ ning genereeriud soojust ja elektrit SALVESTAMA !!!!!!! Aegade jooksul on inimkond väga palju arenenud ja momendil juba päris hästi arendusülessandega hakkama saamas! 18.-20. sajandil teinud aga ka „vähikäiku“ ja arendanud keskkonda ülimalt saastavaid sisepõlemismootoritel/süsteemidel põhinevaid tehnoloogiaid! (CO_x, NO_x, SO_x, VOC, nanoosakesi ja ka H₂S, CO jne.tootvaid tehnoloogiaid)

1. Energy potential

Global flux of renewable energies vs. fossil fuel consumption



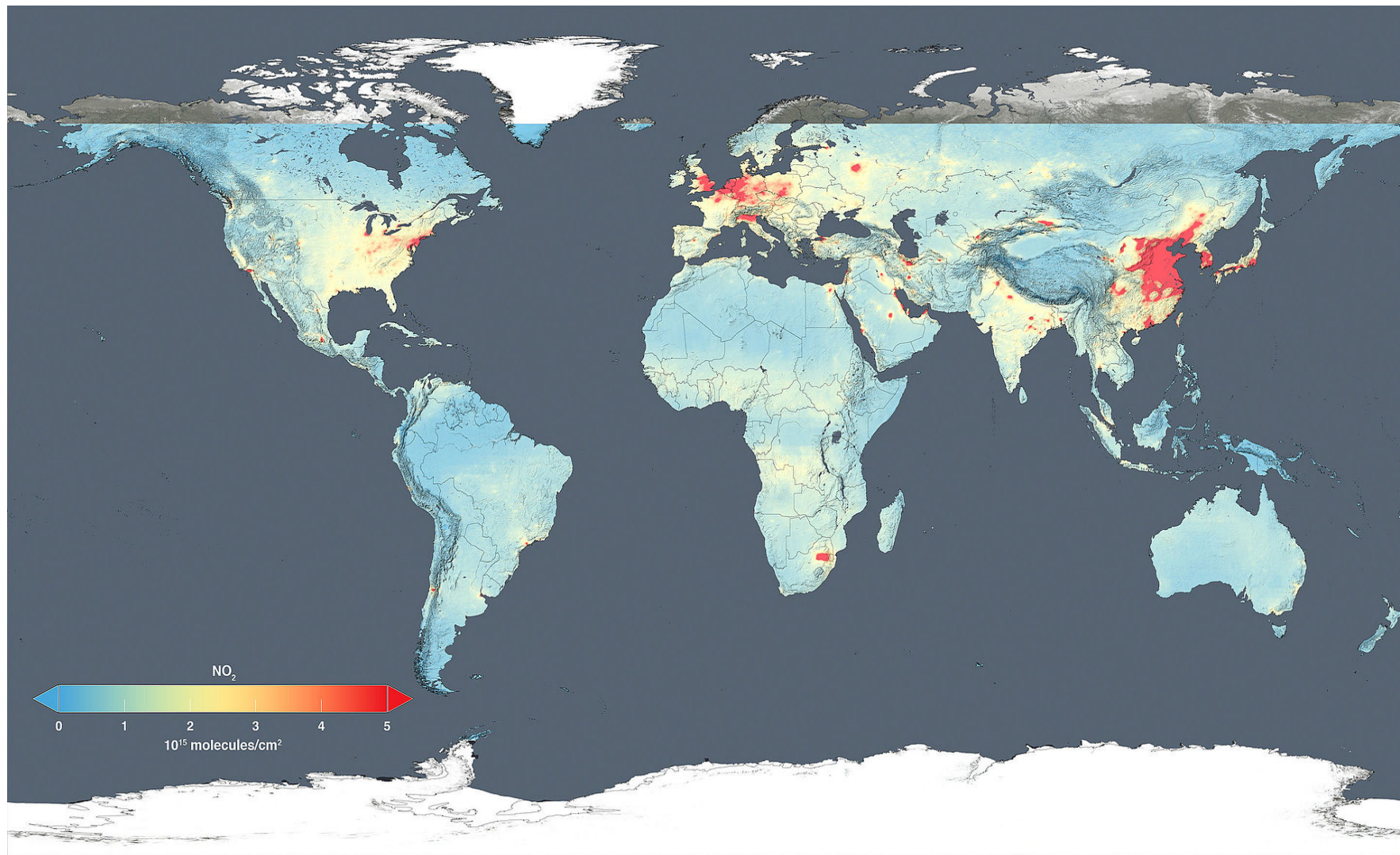
Source: V. Smil



Saastatus: globaalne probleem, kuid osades kohtades väga kriitiline

Maailmas on kuus kuni seitse üliasaastatud piirkonda, kus elamine on ülisuure tervise riskiga seotud: Hiina, Lõuna-Korea, Madalmaad, Suur-London, Lombardia piirkond, Jaapan, USA ida-rannik, Moskva, Lõuna-Aafrika

Selleks, et me endid päris ära ei mürgitaks, tuleb otsustavalt vähendada „tossava“ majanduse ja tehnoloogia rakendamist kõigil elualadel!

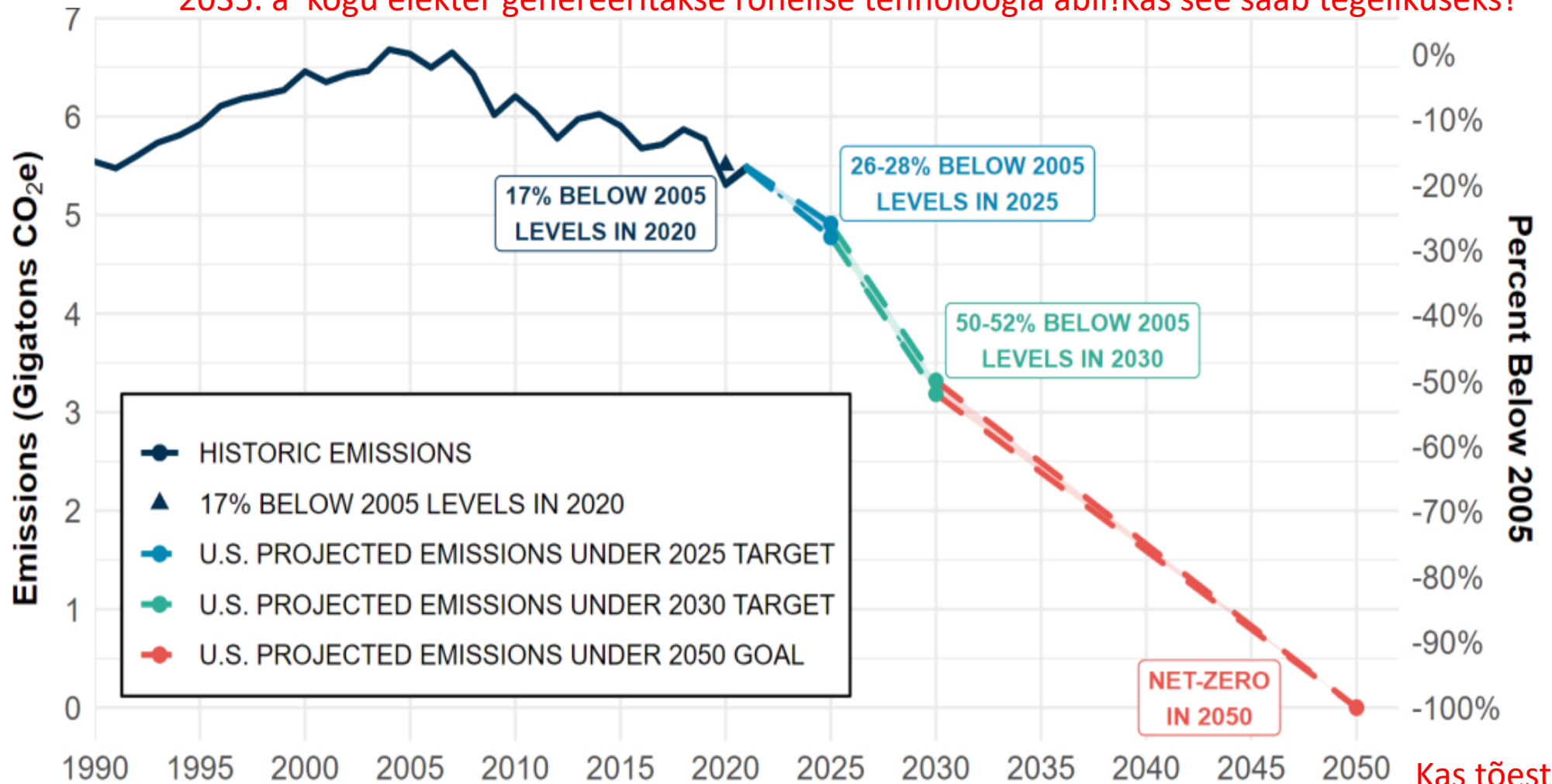




USA on end väga tõsiselt muutma hakanud!

2035. a kogu elekter genereeritakse rohelise tehnoloogia abil! Kas see saab tegelikuseks?

Kui ka Hiina
India, Brasiilia
jt suured
tossutajad
sama
intensiivselt
tegutseksid, siis
oleks meil veel
lootust ellu
jääda!



Kas tõesti 0????

Figure 1: U.S. economy-wide net greenhouse gas emissions. A net-zero system will require transformative technologies to be deployed across sectors.³⁵

16.65 TWh



Figure 5: The opportunity for clean hydrogen in the United States.

Momendil (2022) 98MMT/aastas (kogu maailm): rohelist elektrolüütilist H₂ 6-9 MMT aastal 2022.

USA on tegemas väga kiiret „roheline vesiniku“ elektrolüütilise tootmise kiirendust. Kavatakse pool vesinikust toota hajutatud süsteemides, et tagada suurem nn energiajulgeolek kas sõja, terrorirünnaku või looduskatastroofi korral. Algatatud Biden-Harris kiirteede elektrifitseerimise ja vesinikuga varustamise ülisuur projekt. Iga 50-80km järel patareide laadimisjaam; iga 150-200km järel vesiniku tankla. (on korduvalt parameetreid muudetud)

EU states have agreed to build hydrogen fuelling stations in all major cities and at **least every 200km along the core Trans-European Transport Network (TEN-T)** after the Council of ministers and the European Parliament reached political agreement on the new Regulation for the deployment of alternative fuels infrastructure (AFIR) late last night. The deal also includes new rules for battery electric vehicles (BEV), including **recharging stations for heavy-duty vehicles (with a minimum output of 350kW) along every 60km of the TEN-T core network and every 100km of the larger TEN-T comprehensive network from 2025 onwards (with complete network coverage by 2030).**



USA CO₂ vaba majanduse oletatav paiknemine mandriosal.

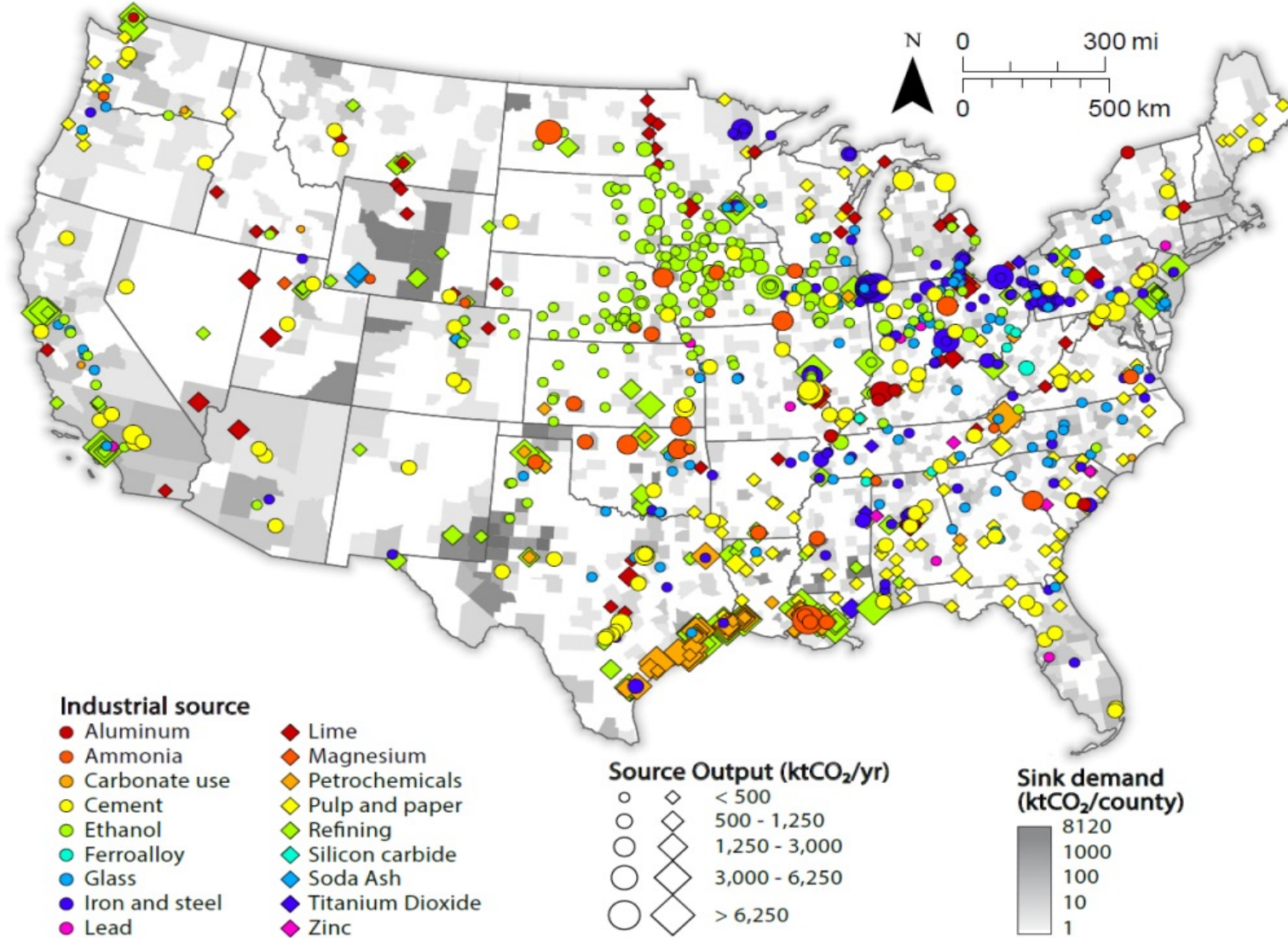
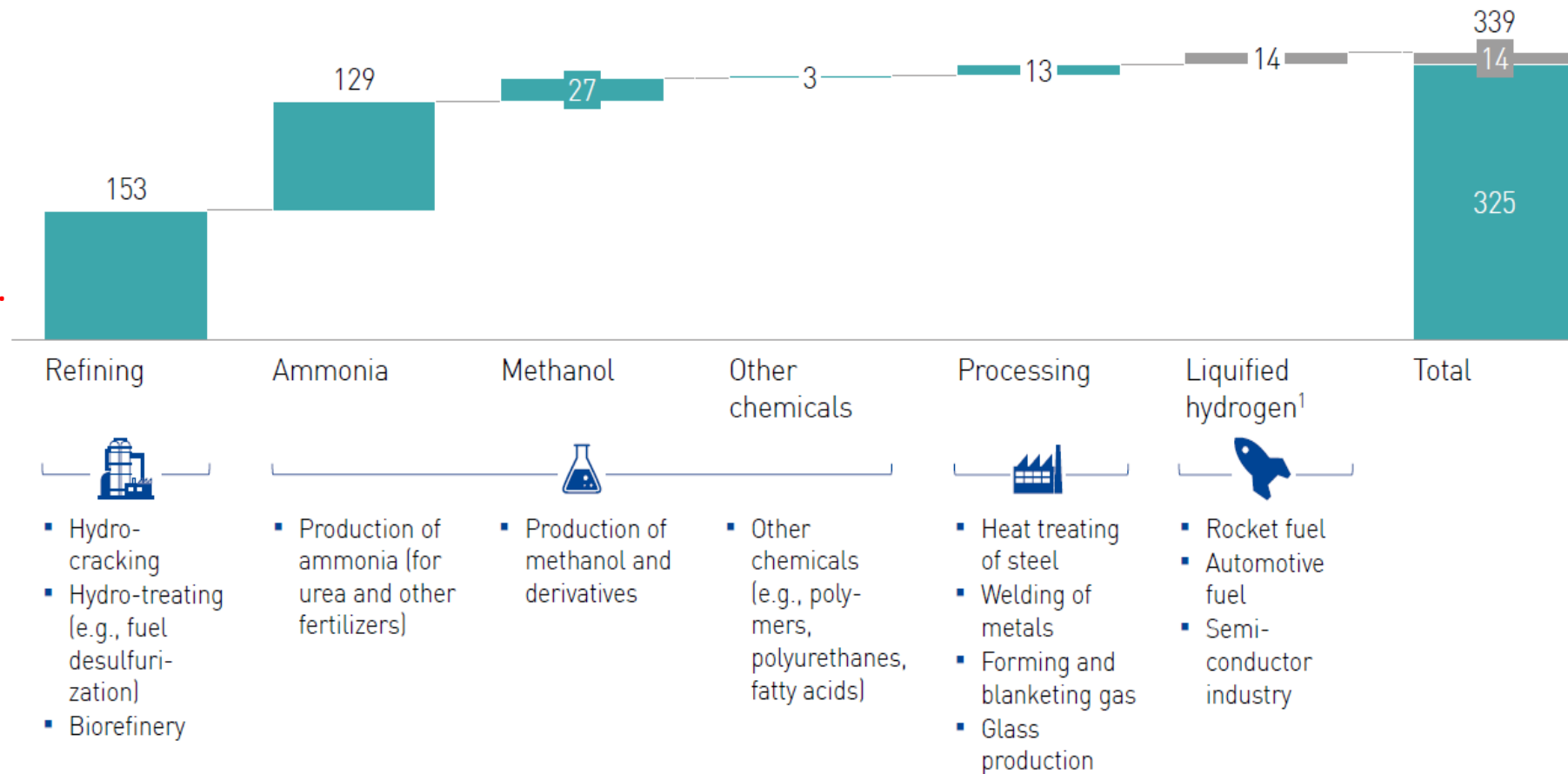


Figure 33: Industrial clusters in the United States create potential regions for decarbonization hubs. (Source Psarras et al.¹⁸³)

u.S. National Clean Hydrogen Strategy and Roadmap (energy.gov.)

EXHIBIT 17: USE OF HYDROGEN TODAY

Total hydrogen use in the EU, in TWh



¹ Counted in transportation segment

Et saavutada kiire CO₂ ekvivalendi vähenemine, on lähema 10-ne aasta jooksul vaja teostada nn **neljas tehnoloogiline revolutsioon**.

Põhilised arengumootorid on:

roheline elekter ja vesiniktehnoloogiad.

Lisaks erinevad tsüklilise ja taastava materjalidetehnoloogia lahendused.

Rohelise vesiniku kasutusala

Rohelise vesiniku

mõningad kasutusala:

- **Tööstus** (kõik koos nii keemia, kütuste puhastamise tööstus, metallurgia, biokeemia jne) **50%**,
- **transport** **25%**
- **küttemajandus** **15%**
- **kõik ülejäänud** **10%** kogu toodetud rohelisest vesinikust.



Fe jt metallid 15-19%
Biokeemia 10-12 %
Kütuste tootmine 30%

Figure 1. Wide application of hydrogen in the industry [14].



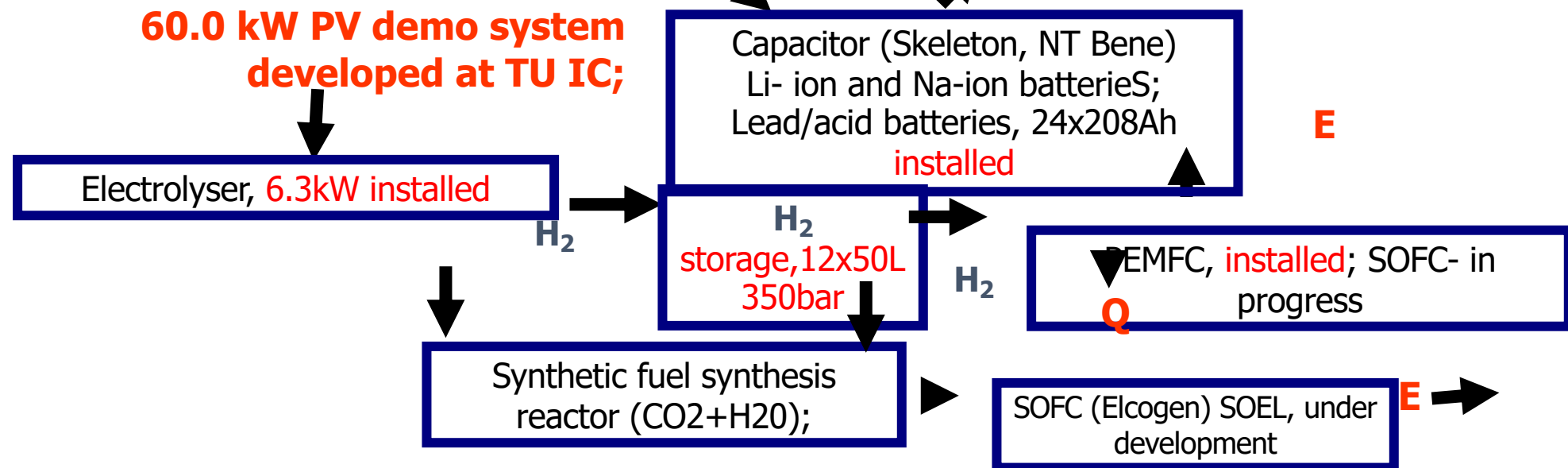
Demokeskus Chemicumis

Ega siin muud võimalust
polegi kui **tuule- ja**
päikeseenergia muudamine
elektriks ja selle salvestamine
ja taaskasutamine paljudel
majandus- ja elualadel!
Chemicumi näitel see töötab!



Development of wind and solar
energy storage and generation
complex systems

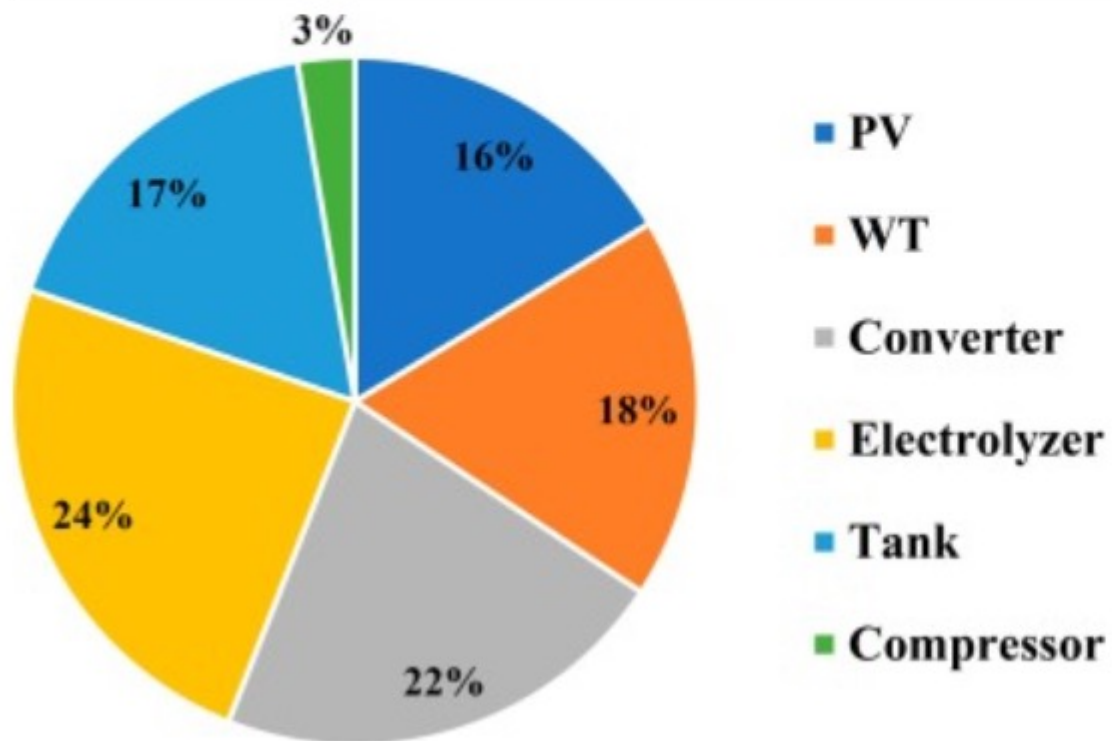
**Estonian electricity
installations 1.76 GW**





Ülevaade DOE poolt arvatatud kulutuste proportsioonidest

Fig. 14 illustrates the capital cost of the system's components. The power generation unit (PV+WT) accounted for 34%, the top portion of the project's initial cost. The electrolyzer cost comes in second place with 22%, followed by a converter unit at 22%. Finally, the compression unit (compressor and tank) comes in the final spot with 20% of the project's initial cost.



Kõige kallimad koostisosad:

- elektrolüüser
- Konverter/inverter
- tuulegeneraator



Table 2. Overview of Simulation Results for Three Scenarios that Represent the Range of Ambition in This Work in Terms of Renewable Energy Penetration

	2015 System	EU Reference 2030	ENTSO-E Vision 3 2030
Wholesale electricity price (€/MWh)	44 (±2.2%)	82 (±2.1%)	60 (±3.6%)
Price received by wind generation (€/MWh)	48 (2.2%)	81 (1.3%)	56 (4.4%)
Price received by solar generation (€/MWh)	45 (2.8%)	86 (1.7%)	40 (4.5%)
Price received by gas generation (€/MWh)	69 (2.5%)	92 (2.0%)	95 (1.8%)
Price received by coal generation (€/MWh)	50 (2.5%)	91 (1.2%)	128 (5.3%)
Price received by nuclear generation (€/MWh)	40 (2.2%)	75 (1.3%)	61 (3.2%)
Total generation cost (€B)	47.11 (±0.8%)	86.83 (±2.1%)	50.28 (±4.2%)
Total CO ₂ emissions (Mt)	1001 ^a (±1.0%)	917 (±1.3%)	233 (±5.0%)
Emissions intensity (gCO ₂ /kWh)	322.6 (±1.0%)	247.8 (±1.3%)	68.5 (±5.0%)

S. Collins et al., Joule 2 (2018) 2076.

Miks just
tuulelekter ja
PV: sest

pikemaagsed
prognoosid annavad
2030. aastaks kõige
odavamad hinnad
PV- ja tuulelektrile.



Kui õige arvutaks, kas diiselkütusel töötava bussi odavam hind on **kasulik kriteerium võrreldes kütuse hinna ja saastemaksudega arvestamisel:**

Lähtutud on EL ametlikust dokumendist,

<https://cdn2.hubspot.net/hubfs/2007428/Premium%20Content/Economic%20Case%20Hydrogen%20Buses%20Europe/PT-Ballard-Fuel-Cell-Buses-in-Europe-Summary.pdf>

kus FC busside hinnad ja vesiniku hind on ülehinnatud ja saastemaksud on alahinnatud.

Näitaja	Diisel buss (18m)	FC buss (18m)
Hind soetamisel (€) (sõltub bussi tootjast)	360 000	550 000- 760 000
Läbisõit km aastas	80 000	80 000
Eluiga aastates	12	12
Kütusekulu 100km	44 liitrit	6 kg
Kütuse ühiku maksumus (€)	1.8	4.5
Kütuse maksumus 100km läbimiseks (€)	79.2	27
Kütuse kulu aastas (€)	63360	21670
Kütusekulu 12 aasta jooksul (€)	760320	260040
Kogu kulu (ilma remontideta) 12a (€)	1 120320	810040
Seega FC bussiga isegi momendi bussi ja H2 hinnaga on vahe	310280 €	
Kui võtta arvesse ka CO ₂ , NO _x ja NP saastemaksud siis		
CO _x , NO _x ja NP üks aasta	7271,6€	1752€ (NB! Arvestatud tootmisel eralduvaid gaase)
, 12 aastat CO _x , NO _x ja VNP trahve	87252€	21024€
Siis on vahe veelgi suurem		376508 €

NB! Hoolduskulud on diiselbussil 2 kuni 3 korda kallimad kui FC bussil.



Equivalent carbon price recovered by bus type

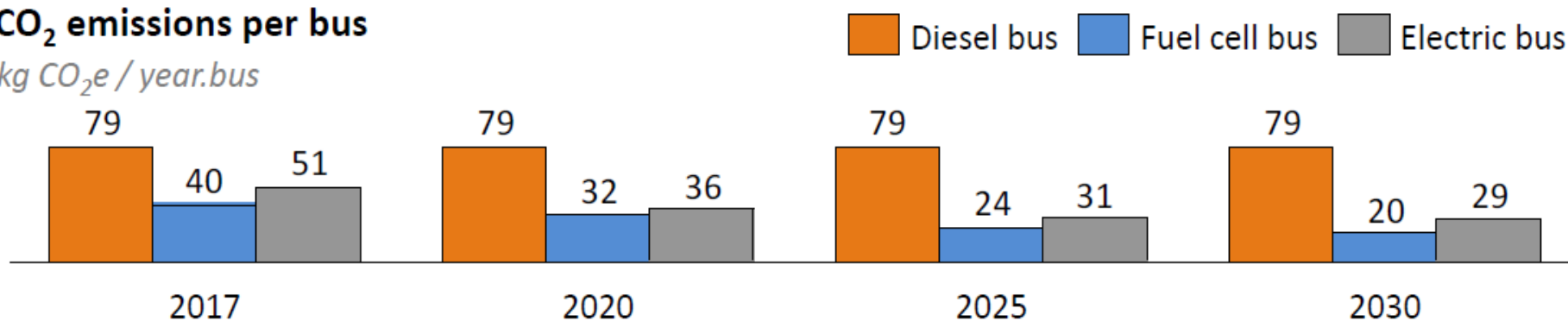
- The plots below show the results of an analysis of the lifetime CO₂ emissions and relative costs (the full analysis is shown in the annex).
- The result of this analysis implies that operation of both electric and fuel cell buses can result in significantly lower CO₂ emissions than an equivalent diesel bus.
- This translates into ETS savings of thousands of Euros per year per bus.

Kui arvestame CO₂ ekvivalendist tulenevat maksu, siis olukord muutub oluliselt - FC ja patarei busside seis muutub otsustavalt paremaks.

Alles jääb patareibusside ülilipikk laadimisaeg võrreldes FC bussiga. Kui kunagi tuleb ka NO_x, SO_x, VOC ja nanoosakeste ohtlikkust arvestav maks, siis on küll targem diiselbussid garaaži jätta!

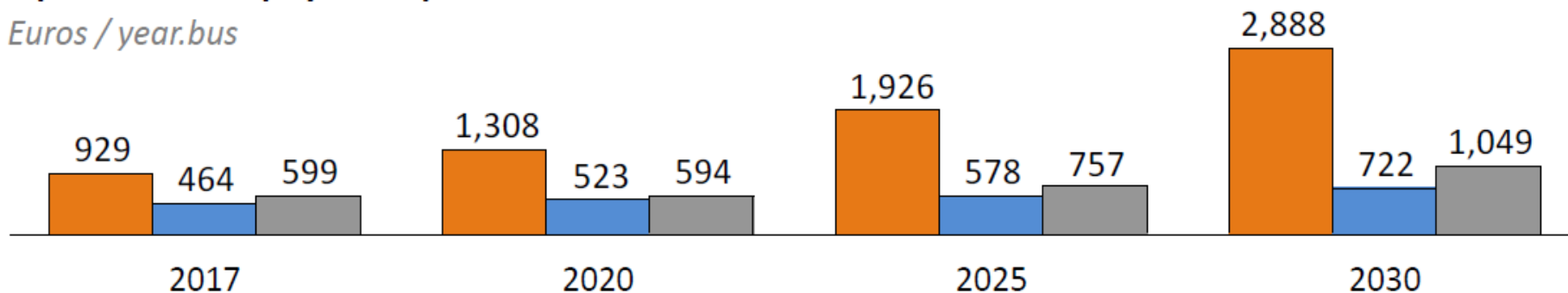
CO₂ emissions per bus

kg CO₂e / year.bus



Equivalent ETS payment per bus

Euros / year.bus





Kütuseelementide ja vesiniktehnoloogia maksumuse alandamiseks on tegelikult veel palju võimalusi:

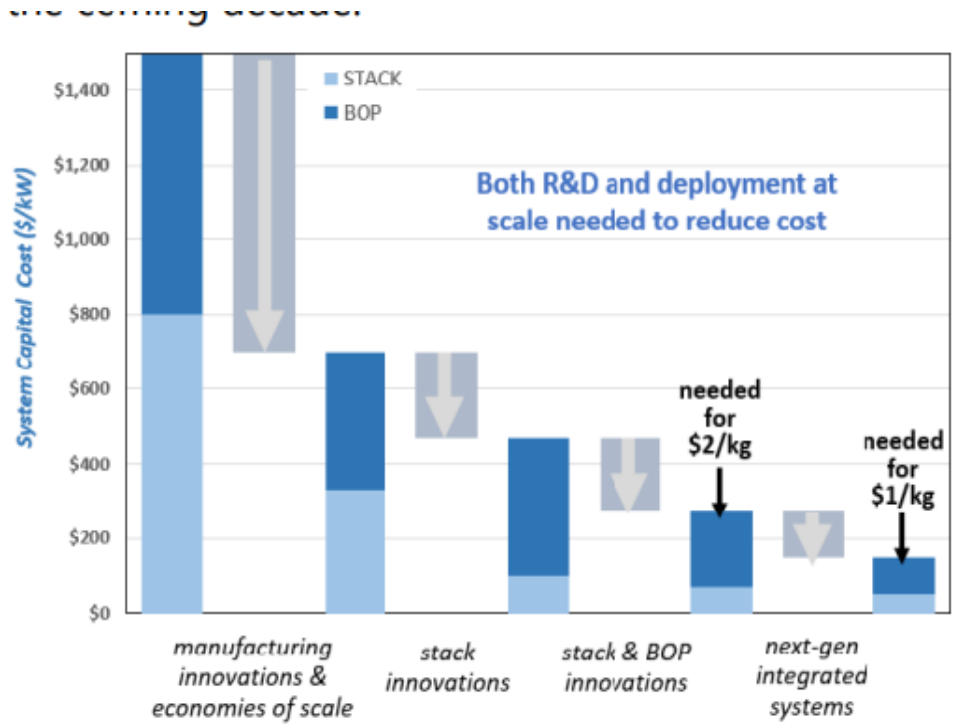


Figure 21: Reducing electrolyzer capital costs will require reaching economies of scale and innovating the electrolyzer stack and balance-of-plant components.

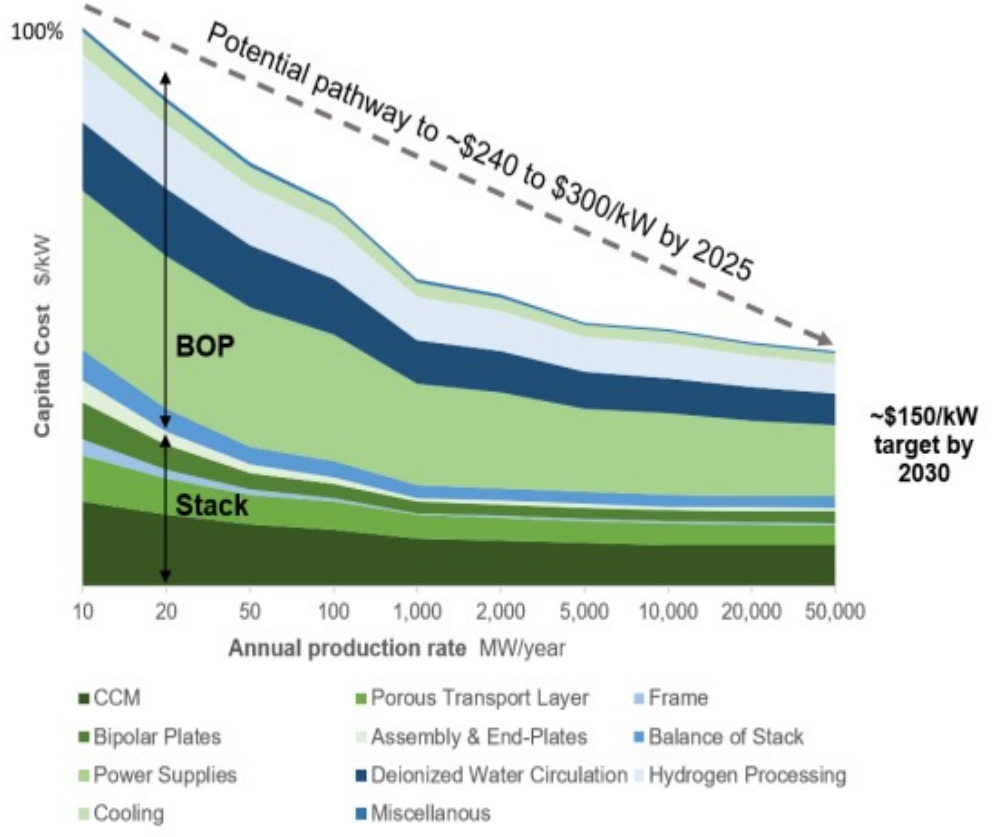


Figure 22: There are many drivers for electrolyzer stack and balance-of-plant capital cost reductions.



Tuuleelekter koos päikeseelektriga annab kõige madalama täistsükli hinna vesiniku tootmise ja säilitamise jaoks.

Table 6. Costs in USD per concept for the case study.

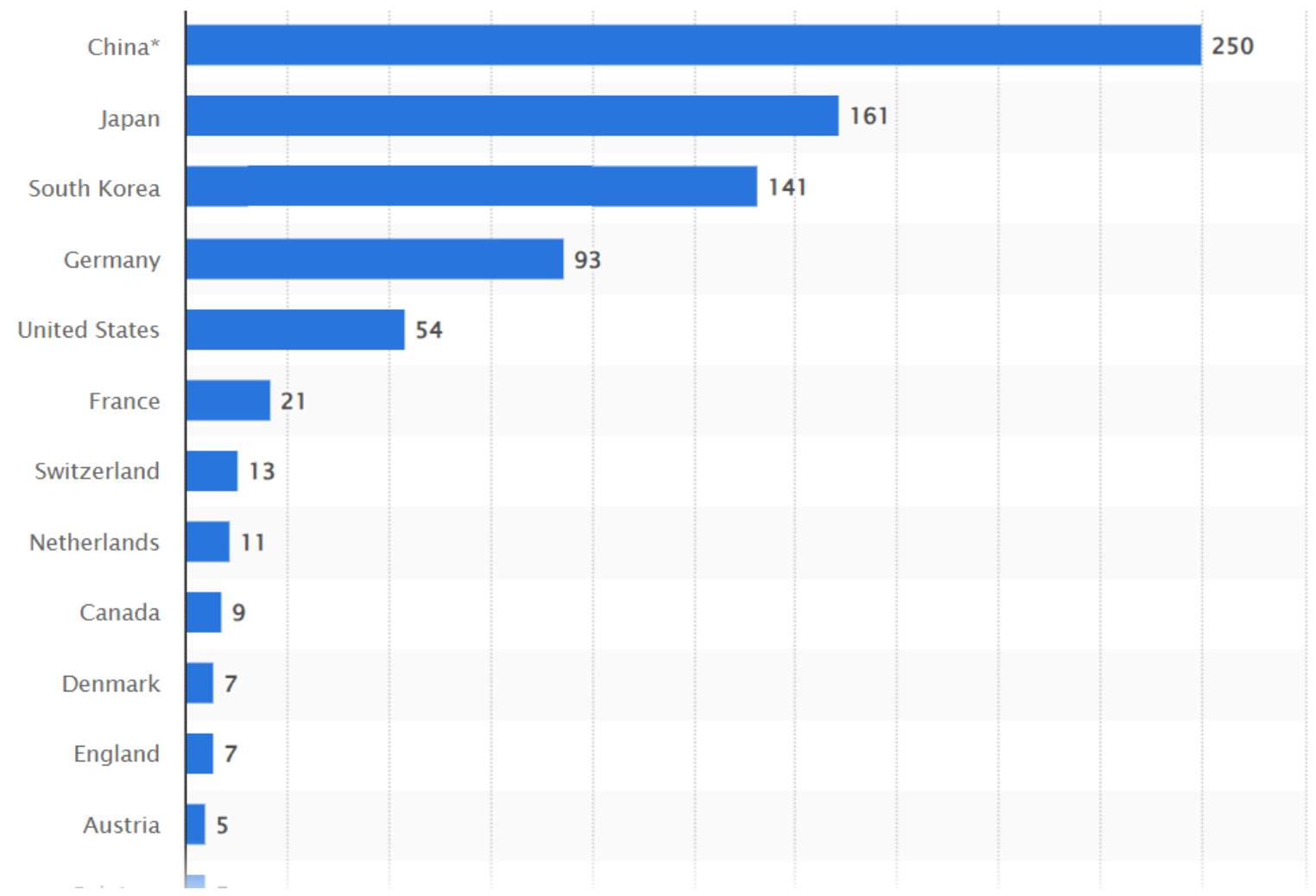
Concept	Formulation	Value
System PV	$C^{pv} \cdot P^{PV}$	133,522,425
OPEX PV	$1.7 \% \cdot C^{pv} \cdot P^{PV}$	2,269,881
Electrical grid	$\sum (E_k^{grid} \cdot PPA)$	229,324,902
Electrolyser system	$C^{elect} \cdot P^{elect}$	102,788,107
OPEX electrolyser	$2\% \cdot C^{elect} \cdot P^{elect}$	2,055,762
Water	$\sum (C^{H2O} \cdot C^{sp.H2O} \cdot \dot{m}_k^{H2})$	435,803
Storage system	$C^{CGH2} \cdot T^{CGH2}$	5,663,381
OPEX storage	$2\% \cdot C^{CGH2} \cdot T^{CGH2}$	113,268
Total cost of the system	-	476,173,527

Case Study	Solar Plant	Electrolyser	Storage	LCOH
Base case	180 MW	171 MW	11 ton	3.5 USD/kg
Case 1	246 MW	234 MW	24 tons	3.25 USD/kg
Case 2	108 MW	103 MW	0 ton	3.18 USD/kg
Case 3	247 MW	235 MW	24.7 tons	2.98 USD/kg
Case 4	242 MW	230 MW	22 tons	3.48 USD/kg
Case 5	247 MW	235 MW	24.7 tons	2.62 USD/kg



Hydrogen refueling stations in World (2022, december)

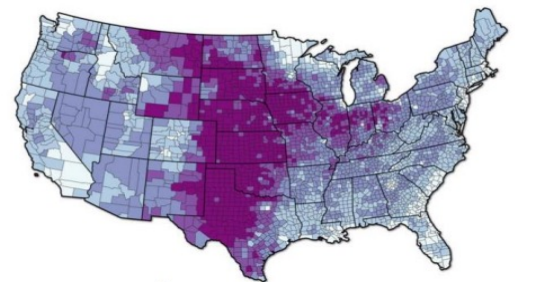
In 2022, there was nearly 1000 RHS in World.
More than 60 countries have at least 1 RHS with 4 positions.
Estonia????



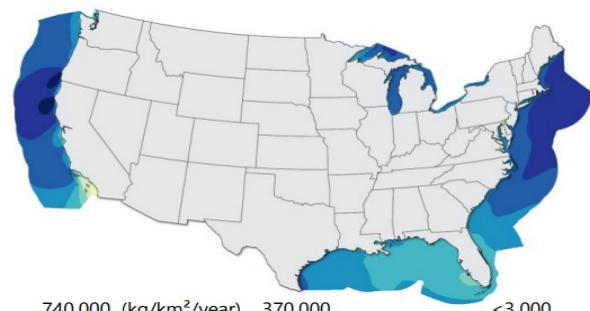


USA (DOE) rehendus näitavad, et kasulik on integreerida PV, maismaa ja meretuulikud ühtseks dc võrgustikuks!

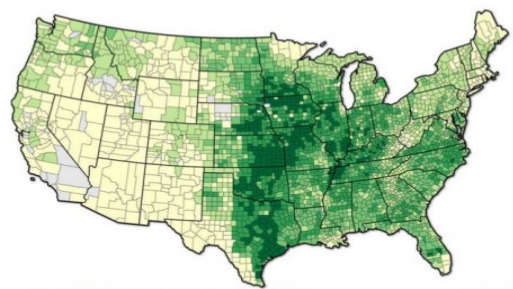
USA keskosa on sobilik nii tuule-, biomassist, kontsentreeritud päikeseenergia kui ka otse PV-elektri ja vesiniku tootmiseks ilma, et oleks vaja pikemaegseid salvestusvõimsuseid rakendada. Ainult ida- ja läänerannik aga sobivad meretuuleparkide ja hüdroenergia abil elektri ja vesiniku tootmiseks. Rannikualadel arendatakse laineenergia ja tõusude – mõõnade kasutamist.



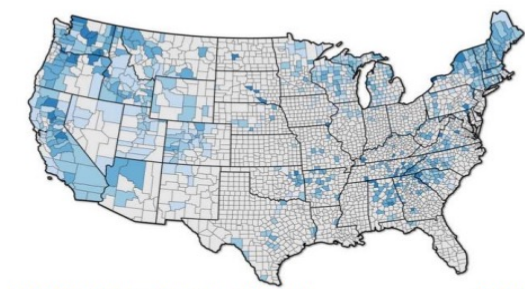
a) *Hydrogen production potential from onshore wind resources, by county land area*



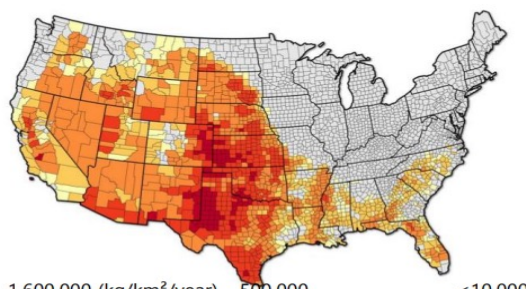
b) *Hydrogen production potential from offshore wind resources, by area*



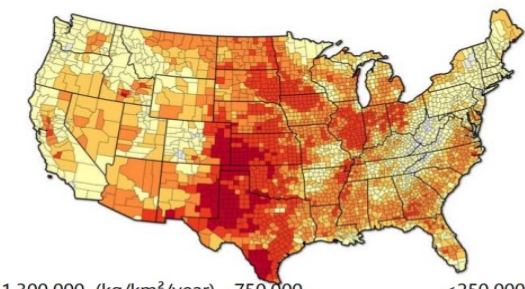
c) *Hydrogen production potential from solid biomass resources, by county land area*



d) *Hydrogen production potential from existing hydropower assets, by county land area*



e) *Hydrogen production potential from concentrated solar power, by county land area*



f) *Hydrogen production potential from utility-scale PV, by county land area*

- 1kg H₂ = 33.3 kWh;
- 1 kg H₂ = 130-180 km (väike auto)
- 1kg H₂ elektrolüüsiks 48-55 kWh elektrit



Lisaks maismaa tuule ja PV elektri genereerimisele ka väga ulatuslikud plaanid avamere (rannikumere) tuuleelektri parkide ehitamiseks, et tasakaalustada maismaal üliharva esineda võivat tuule puudumist.

The pipeline capacity calculated in 2022 was revised to adjust the capacity density of leases areas where specific project dimensions have not been announced **from 3 to 4 megawatts (MW)/km²**. The U.S. offshore wind energy pipeline as of May **31, 2022**, was revised **to 45,772 MW**, from the original reported pipeline of 40,083 MW. 2 South Fork Wind and Vineyard Wind 1 both began wind turbine installation after May 31, 2023.

U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov.)

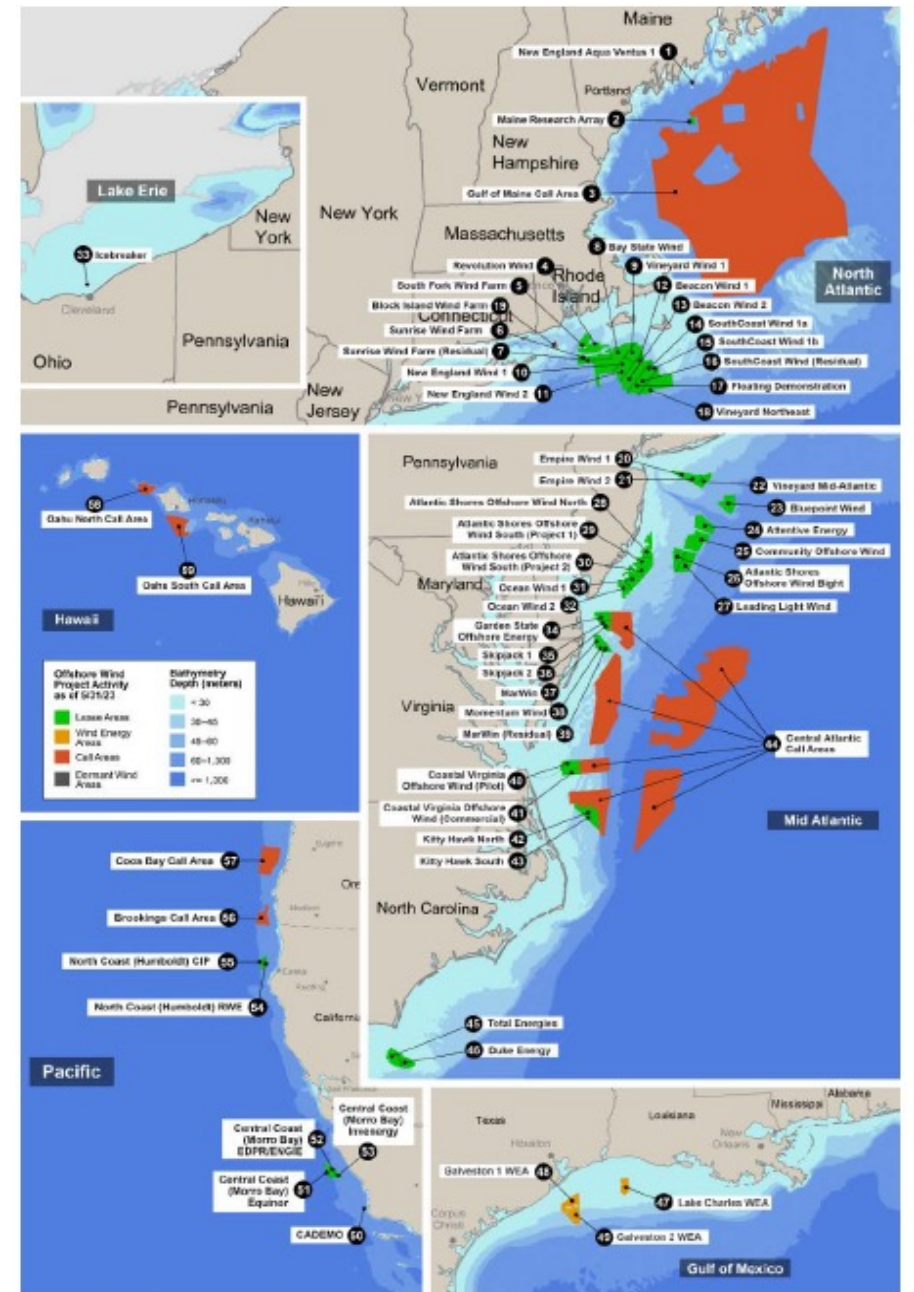


Figure ES-1. Locations of U.S. offshore wind energy pipeline activity and Call Areas as of May 2023. Map created by John Frenzl, National Renewable Energy Laboratory



The production capacity of electrolysers (2021) is between 9 and 13 gigawatts (DOE database)

The growing scale of announced electrolyzer manufacturing capacity, currently estimated between 9 and 13 gigawatts and expected to grow further, suggests progress toward economies at the manufacturing plant; however, manufacturing output has been slow to materialize, with only around 200 MW installed in 2021 and 2022.

The European Commission, for example, set the target to build **40 GW electrolysers within the EU by 2030 to produce up to 333 TWh renewable hydrogen [5]**. According to the EU Commission, up to 25 % of the electricity produced by renewables will be used for electrolysis in 2050 [5],

[www.energy.gov > eere > fuelcells](http://www.energy.gov/eere/fuelcells) **Fuel Cells | Department of Energy**

DOE has set ultimate targets for fuel cell system lifetime under realistic operating conditions at **8,000 hours for light-duty vehicles, 30,000 hours for heavy-duty trucks, and 80,000 hours for**

[www.grandviewresearch.com > fuel-cell-market](http://www.grandviewresearch.com/fuel-cell-market) **Fuel Cell Market Size, Share & Trends Analysis Report, 2030**

Report Overview: The global fuel cell market size was estimated **at USD 6.3 billion in 2022** and is expected to expand at a compound annual growth rate (CAGR) of **19.9% from 2023 to 2030**.

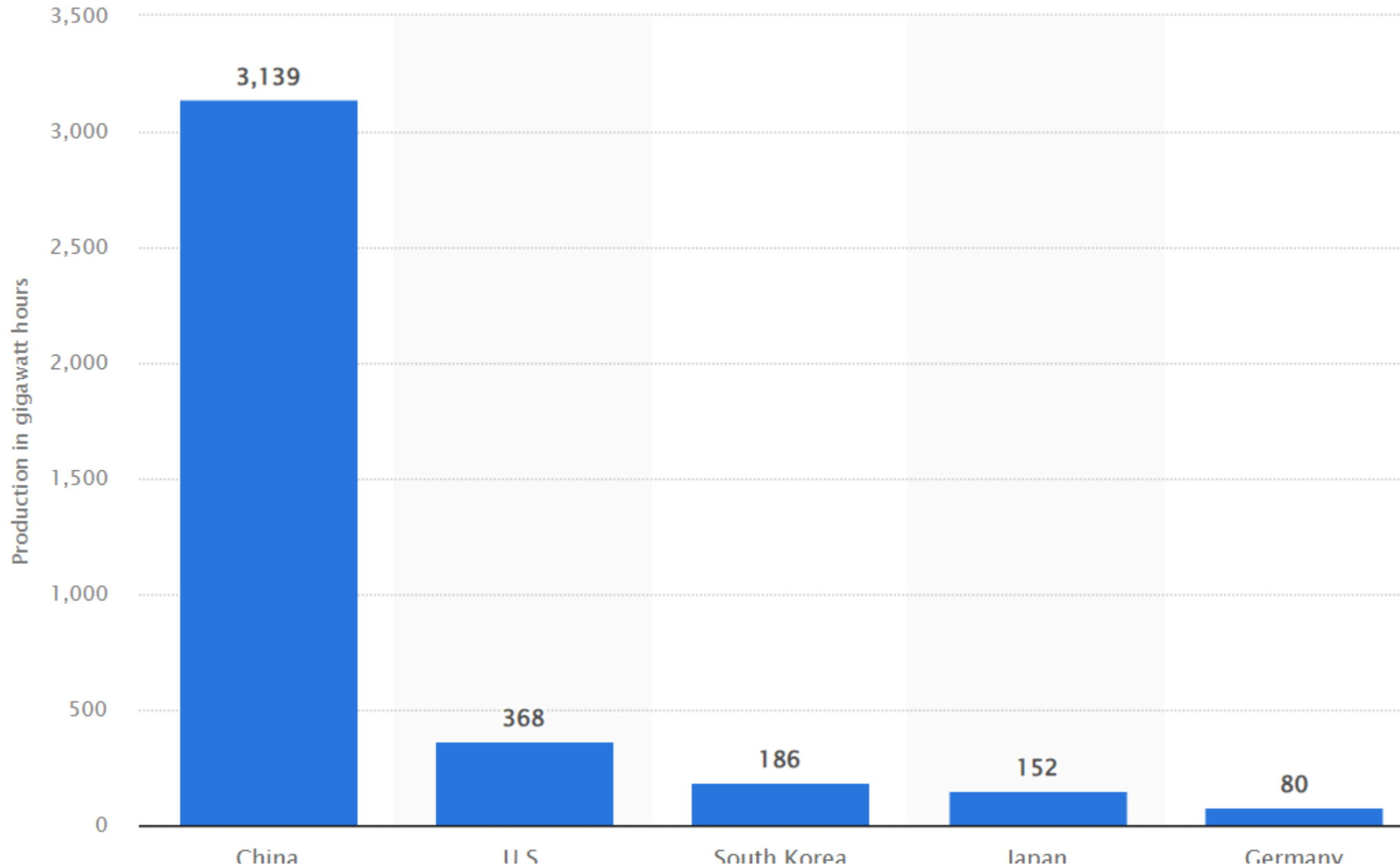


Kütuseelementide ja elektrolüüserite tootmine ja turustamine maailmas 2019 a. ja 2023a. prognoos (Shelli andmed ja hinnangud, ei erine palju DOE ja FCHJU andmetest)
Kütuseelementide tootmine:

- PEMFC 934.2 MW 2023. a 1680 MW
- SOFC 78.1 MW 200 MW
- MCFC 10.2 MW 68 MW
- DMFC 0.4 MW 0.9 MW **Kõik koos ainult 2 GW.**
- Hyundai NEXO tootis/ müüs 680 MW PEMFC süsteeme, millest Euroopas ainult 41 MW; USA+ Canada = 384 MW, seega Aasias ainult 256 MW. Järgmine suurim tootja/müüja Ballard FC systems (180 MW).
- 2050a. toodetakse aastas 113 miljonit FC transpordivahendit, tarbitakse 68 miljonit tonni fossiilseid kütuseid vähem ja välditakse 200 miljoni tonni CO₂ ekvivalendi tootmine.
- 2050. aastal on vaja toota 250 miljonit tonni vesinikku, et toita FC süsteeme (transpordis) ja vähendada fossiilsete kütuste tarbimist 80% võrreldes 2018. a.
- Selleks on vaja **12500 terawatt tundi rohelist elektrit**, st **2.5 korda rohkem kui tuuma + taastuenergia toodang 2018. a.** Lisaks tuleb luua 10-15 % energia salvestuspuhver (1.25 kuni 1.875 tuhat TWh) PV ja tuuleenergia pulsatsioonide silumiseks.
- Elektolüüserite ja kütuseelementide tootmine peab eksponentsiaalselt kasvama, muidu jäävad arendusülessanded täitmata!



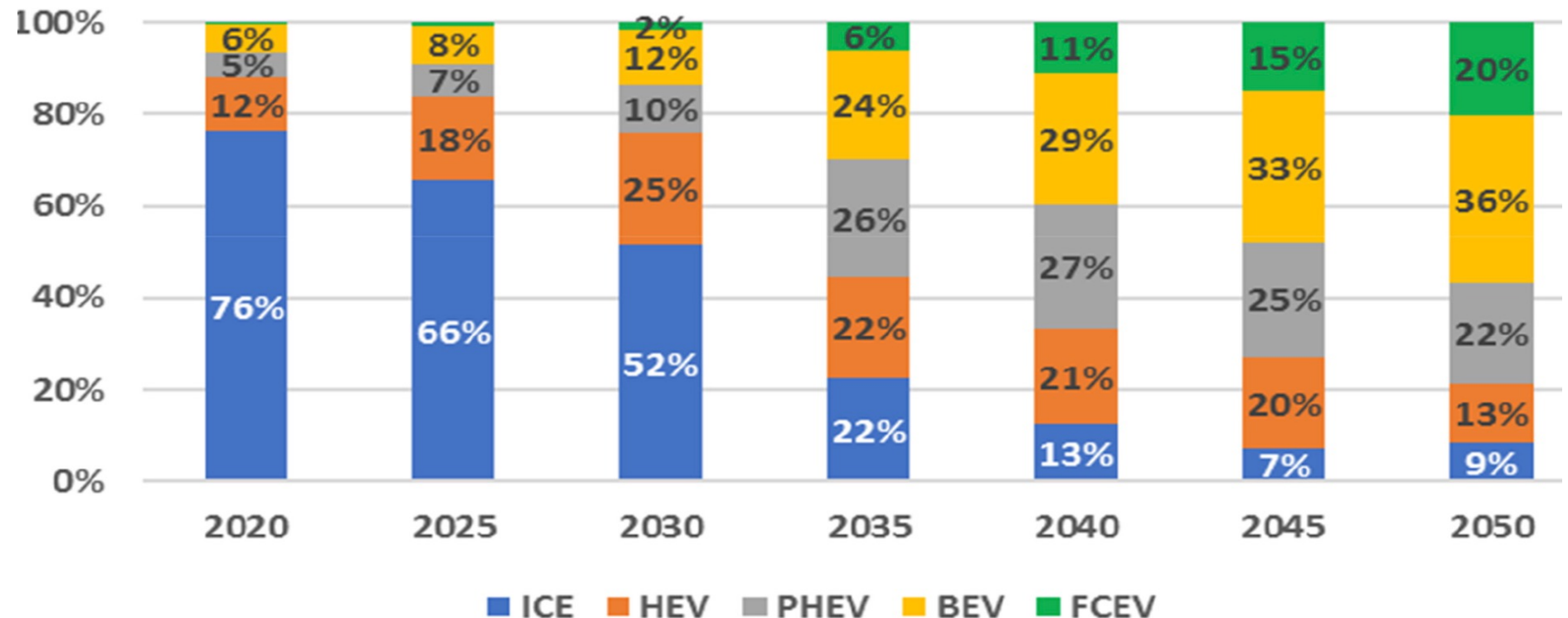
Kütuseelementide tootmine ja kasutamine maade kaupa 2022. a.





Milline võiks välja näha väikeautode turg tulevikus:

The evolution of new vehicle sales by powertrain technology until 2050



ICE –
sisepõlemismootoriga
(bensiin, gaas, diisel
autod);

HEV hübriid (ICE+
patarei)

PHEV- Plug in Hybride EV

BEV-patareidel auto

FCEV vesinik +
kütuseelement

2030. a Californias
1 million FCEV ja 1000
H2 tanklat. (California
Fuel Cell Partnership=
CaFCP)



Jaapanis, Korea Vabariigis, USAs (koolibussid), UK, Itaalias jne, palju rõhku ka busside soetamisele.

700 FC bussi 2024 aastal Incheon linnas Korea Vabariigis 180 kW (üle laadimisega 500km läbisõit)



South Korean city to get 700 hydrogen buses by the end of 2024 – powered by dirty H2 from fossil fuel

[www.electrive.com/2023/02/24/hyundai-to-deliver....](http://www.electrive.com/2023/02/24/hyundai-to-deliver...)



Mandri-Euroopas ollakse veidi tagasihoidlikumad, kuid miks?

Solaris has won the largest European H2 bus tender so far. 130 Urbino hydrogen for TPER

Solaris has secured a contract to provide 130 hydrogen-powered Urbino 12 buses to the municipal public transport operator TPER in Bologna. This represents one of the largest fuel cell bus orders in Europe and aligns with Bologna's goal of transitioning to a fully zero-emission urban public transport system by 2030. The tender was issued in [...]

www.sustainable-bus.com>fuel-cell-bus>Solaris

11 September 2023 by Editorial Staff



Eksplutatsiooni andmed on ju suurepärased! Testandmed olemas 3000 bussi kohta .Enamus läbisõitnud ilma remondita 2x rohkem km kui diiselbussid. Lisaks ju veel ka odavam kütus ja COx, NOx, SOx, VOC ja NP puudumine!

Across the globe, we continue to see good news about fuel cell electric buses (FCEBs) in North America, China, Japan and Europe.

In California, we have 21 FCEBs in operation, more than 15 years of service and more than 2.5 million miles of experience; they perform as well as any conventional bus. In the next few years, California will more than double its fuel cell bus fleet, adding 32.



<https://www.linkedin.com/company/80744/>

<https://www.facebook.com/cafcp/>

<https://twitter.com/CaFCP>



Department of Energy Releases Request for Information on Building Supply Chains to Meet Sustainable Aviation Fuel Grand Challenge Goals

Varsti lendavad lennukid kas vesinikkütusel, NH₃ või sünteeskütusel. Sama lugu on laevanduses teoksil.



Image from istock.com

Image from istock.com



Kuna Jaapanis pole ruumi rohelist vesinikku kogu vajaminevas koguses toota, siis koostööleping Austraaliaga vesiniku tootmiseks transportimiseks spets laevadega Jaapanisse!

2030 more than 100,000 FC vehicles in Japan



5.3 million homes may have their own fuel cell system by 2030

Japan is home to a relatively large fuel cell system that was able to provide electrical power to homes in the wake of the 2011 Fukushima nuclear disaster. Fuel cells have proven that they can be effective as residential energy systems and the Japanese government is ready to support their adoption as such. Several large fuel cell manufacturers, including Panasonic, are beginning to develop small, inexpensive fuel cell systems for home. The Japanese government currently has a goal of installing 5.3 million homes with [fuel cell systems](#) by 2030.

Fuel cells may be a useful energy efficiency solution



Australia to make world's-first liquefied hydrogen shipment to Japan

The Suiso Frontier cargo vessel docked at Victoria's Port of Hastings on Friday to take on the world's first shipment of liquid hydrogen. The ship's arrival is a landmark for the Japanese-Australian Hydrogen Energy Supply Chain pilot project, which sees liquefied hydrogen generated from brown coal, and an engineering milestone in itself. But while the Australian government describes the product as "clean", experts maintain that carbon capture and storage technology has proven only to be an expensive failure.

JANUARY 21, 2022 **BLAKE MATICH**

HIGHLIGHTS HYDROGEN MARKETS MARKETS & POLICY POLICY TECHNOLOGY TECHNOLOGY AND R&D
AUSTRALIA JAPAN

Kuna Jaapanis pole rohelise vesiniku genereerimiseks piisavalt häid looduslike tingimusi, siis on Austraalia kõrbetes alanud PV (aga ka fossiilsetest energiaallikatest koos CCS) vesiniku tootmine ja veeldatud vesiniku transport Jaapanisse!

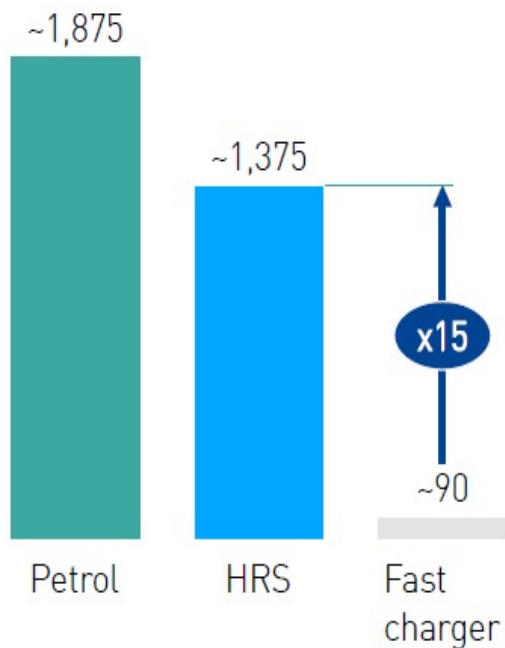


Image: HySTRA

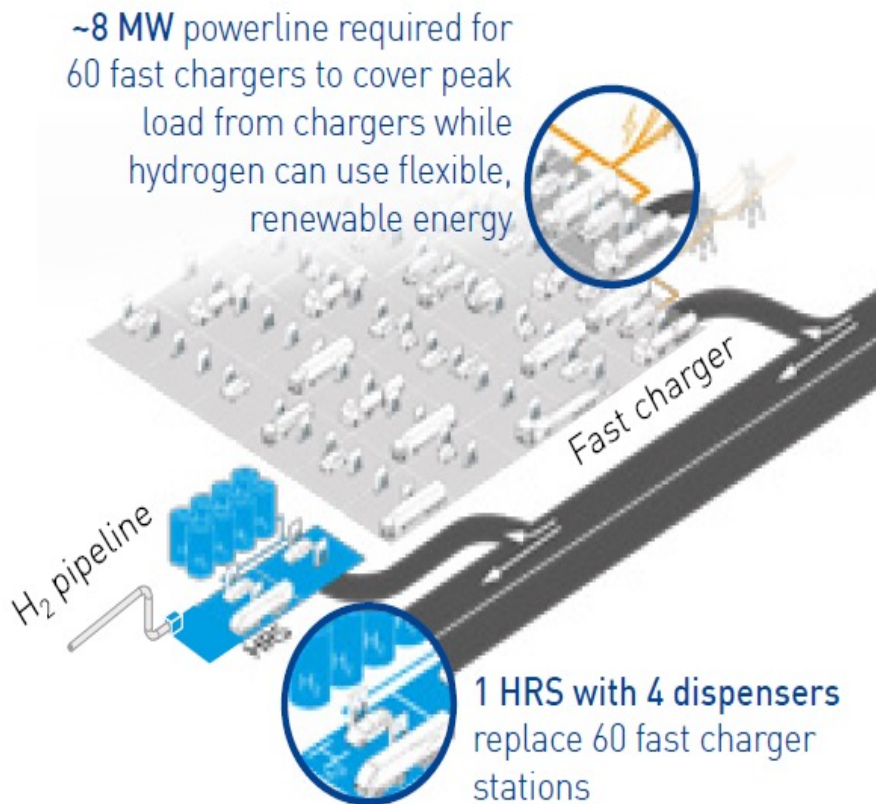
EXHIBIT 11: IMPLICATIONS OF REFUELING SPEED ON SPACE REQUIREMENTS AND INVESTMENTS

Refueling speed

Km/15 minutes of refueling

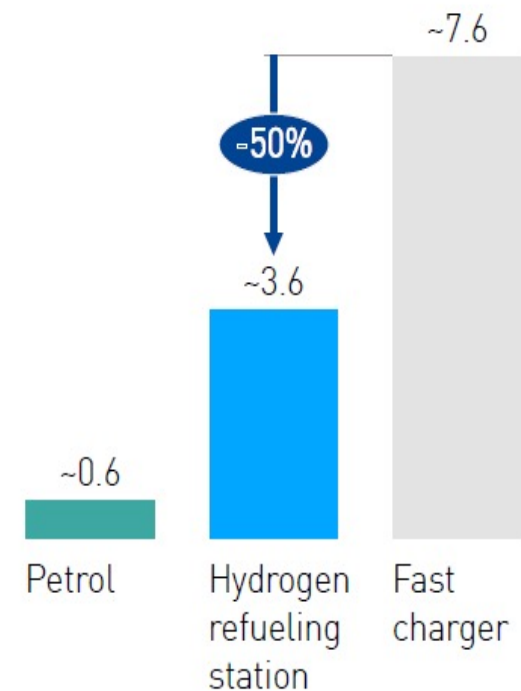


Space requirements



Investment costs per refueling

EUR/refueling



Hydrogen refueling is 15x faster than fast charging

Hydrogen refueling is half as capital-intensive as fast charging

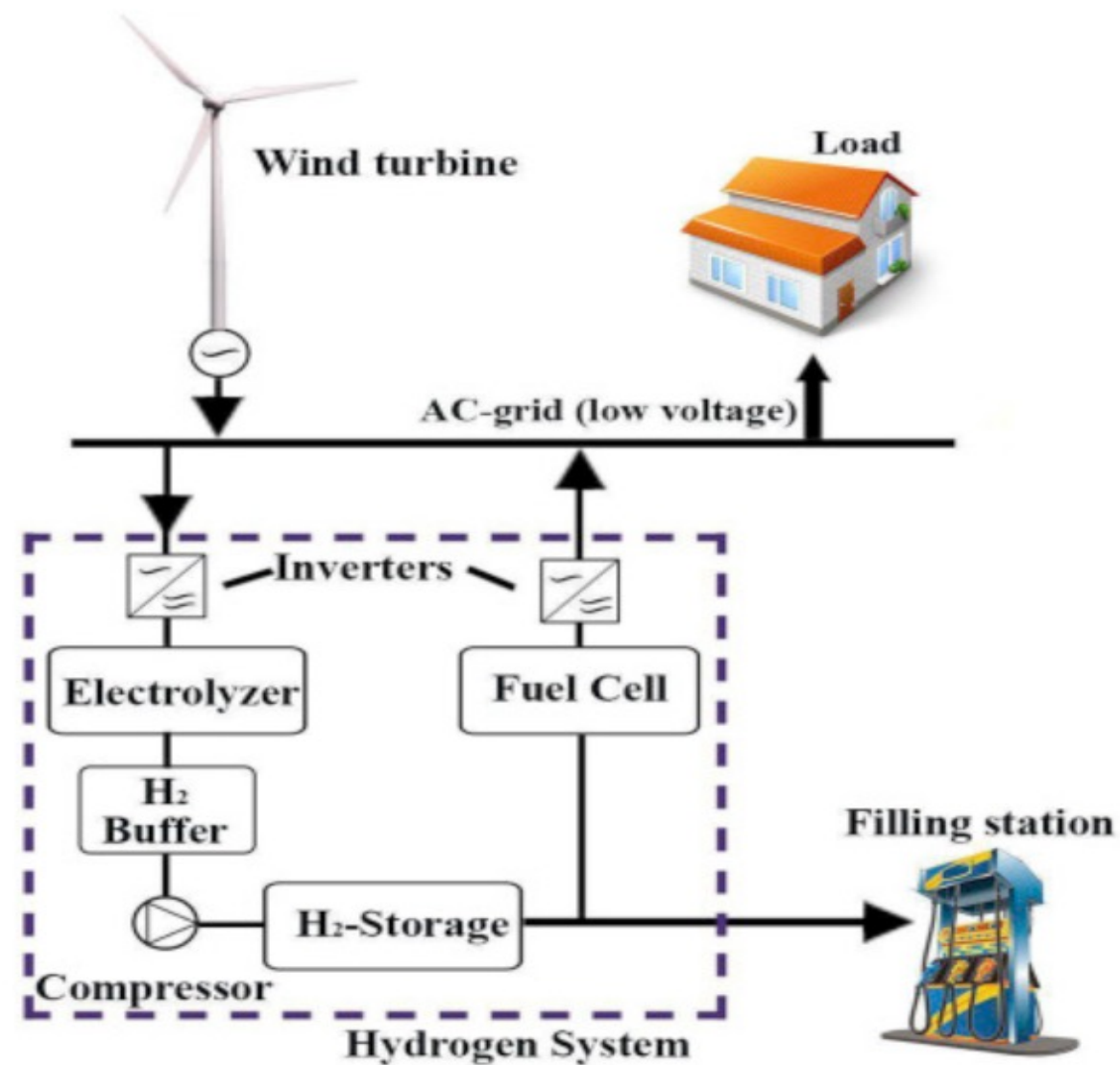
Assumptions: Average mileage of passenger car = 24,000 km; number of PCs in EU in 2050: ~180 million; ICE: range = 750 km/refueling, refueling time = 3 minutes; FCEV: range: 600 km/refueling, refueling time = 5 minutes, fast charger = 1,080 km²; BEV: range = 470 km/refueling, refueling time = 75 min, gas station = 1,080 m²; WACC 8%; fast charger: hardware = USD 100,000, grid connection = USD 50,000, installation costs = USD 50,000, lifetime = 10 years; HRS: capex (1,000 kg daily) = EUR 2,590,000, lifetime = 20 years, refueling demand/car = 5 kg; gas: capex = EUR 225,750, lifetime = 30 years, 1 pole per station

Vesiniku transport võrreldes elektriga on palju kiirem ja odavam. 1 standartne H₂ tankla, milles 4 H₂ tankimise püstolit, asendab 60 kiirlaadimisseadet kogu võimsusega 8 MW! H₂ tankla ehitamine on 50% odavam kui sama tankimisvõimsusega kiirlaadimissüsteemi ehitamine. Põhiline probleem on seotud võrkude puudumisega.

Tulevikus oleks kõige
ökonoomsem ühildada oma
energia (elekter , soojus ja
autokütus (vesinik) üheks
terviklikuks kompleksiks.

Kui liita ka veel PV süsteem, siis
on võimalik täielik sõltumatus
tsentraalsetest elektri
tootjatest.

Kuna bensiini ja diiselkütuste
hinnad on väga kõrged, siis
autoga (FC) ühildamine
muudab kesk-(3-5 a.) ja
pikemaajalise (5-12) tasuvuse
väga heaks.



[Download : Download high-res image \(386KB\)](#)

[Download : Download full-size image](#)

Fig.1. Schematic of hydrogen production through wind energy.



Kokkuvõte:

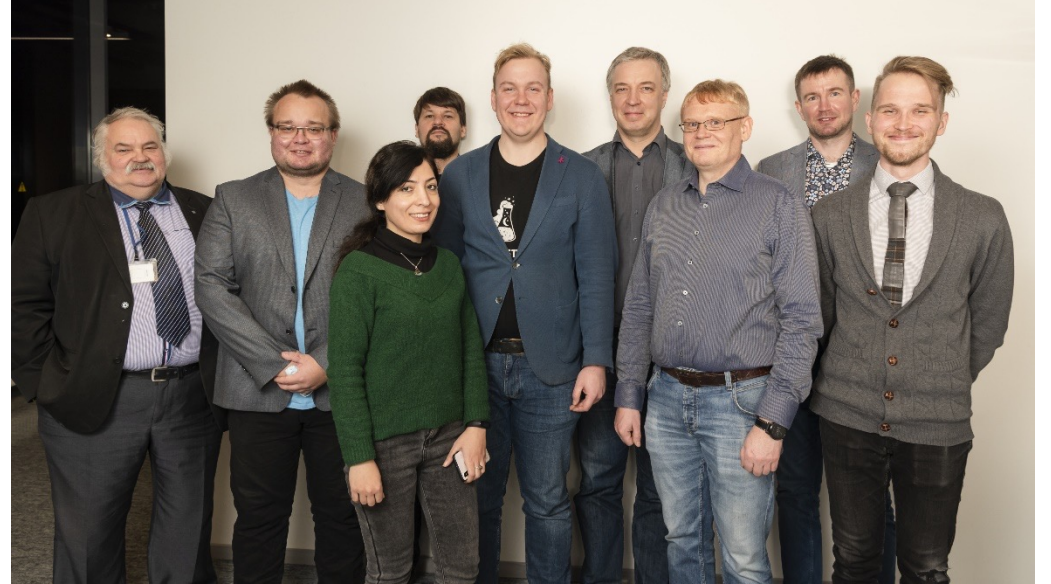
Peamised vesinikutehnoloogia arendussuunad Eestis ja Läänemere regioonis:

- Intensiivistada vesiniku- ja taastuenergeetika spetsialistide ettevalmistamist (magistrid, doktorid, järeldoktorid) uue komplekteeritava aineprogrammi alusel ja võimaldada elukestvat taastuenergeetika täiendõppet soovijatele
- **Projekteerida ja välja ehitada tuule- ja päiselektri (PV) tootmise väljad ja luua ühendused alalisvoolu elektrivõrguga ja vesinikutrasside või loodusliku gaasi võrguga (kui viimase tehniline tase võimaldab)**
- **Varustada elektrit tootvad kompleksid elektrit salvestavate patareidega, et salvestatud elektrit kasutada elektrolüüsi toimimiseks tuule- ja päikesekiirguse puudumisel (vähendab CAPEX kulutusi 1 kg toodetava vesiniku kohta)**
- **Ehitada elektrolüüsi kompleksid PV (umbes 20-25% max. võimsusest või kuni 50%, kui salvestus) ja juurutada vesiniku tootmine**
- Luua vesiniku salvestamise võimalus ka meretuuleparkide juurde (vee alla) ja ehitada vesinikutrassid maismaale
- **Ehitada välja kolmerõhulised (350, 700 ja 1040 bar tankimispositsioonid, kasutades üht tsentraalset hoiupaaki) vesinikutanklad busside, tänavakoristusautode, prügiveomasinate, päästeautode, sõiduautode, laevade, rongide, väikeautode jne varustamiseks vesinikkütusega**
- Soetada vesinikubussid, eriotstarbelised autod, vedurid, laevad ja alustada nendega opereerimist/kogemuste kogumist
- **Kaaluda vesiniku kasutamise võimalusi energiamahukas tööstuses (kustutamata lubja tootmine, klaasitööstus, tsemenditööstus, ammoniaagi ja lämmastikväetiste tootmine, haruldaste rasksulavate pulbermetallide tootmine jne).**
- **Kaaluda biogaasi (60-65 % CH₄ ja 30-35% CO₂) metanogeense väärindamise võimalusi Eesti erinevate biogaasi tootjate juures täiendavaks koguseks metaaniks (lõpptulemusena 90-95% metaani) ja metaani kasutamine ainult kütuseelementides**
- **Toetada nn targa asumi (toodab endale ise elektrit ja soojust) arendamise võimalusi, installeerides kütuseelemendid ja elektrolüüserid ning energiasalvestid, ühildades need ilmastikuprognosidega ja elektrienergia börsihindadega**

Täna tähelepanu eest!

Täname:

- ETAG (IUT20-13, PRG676)
- Europea Structural fund
Struktuurifond
 - Estonian Centers of excellence TK 117 and TK 141, ESS, NAMUR, NAMUR+,
 - Energy technology project SLOKT10209T,
 - Materials technology projects SLOKT12180T and SLOKT12181T), ESS Estonian participation development project
- Iseauto contract AuveTECH OÜ; SOEL (300W) contract with H2Electro, contract with Stargate Hydrogen for testing of novel materials, etc.



Fotode autor: Viivi Järve

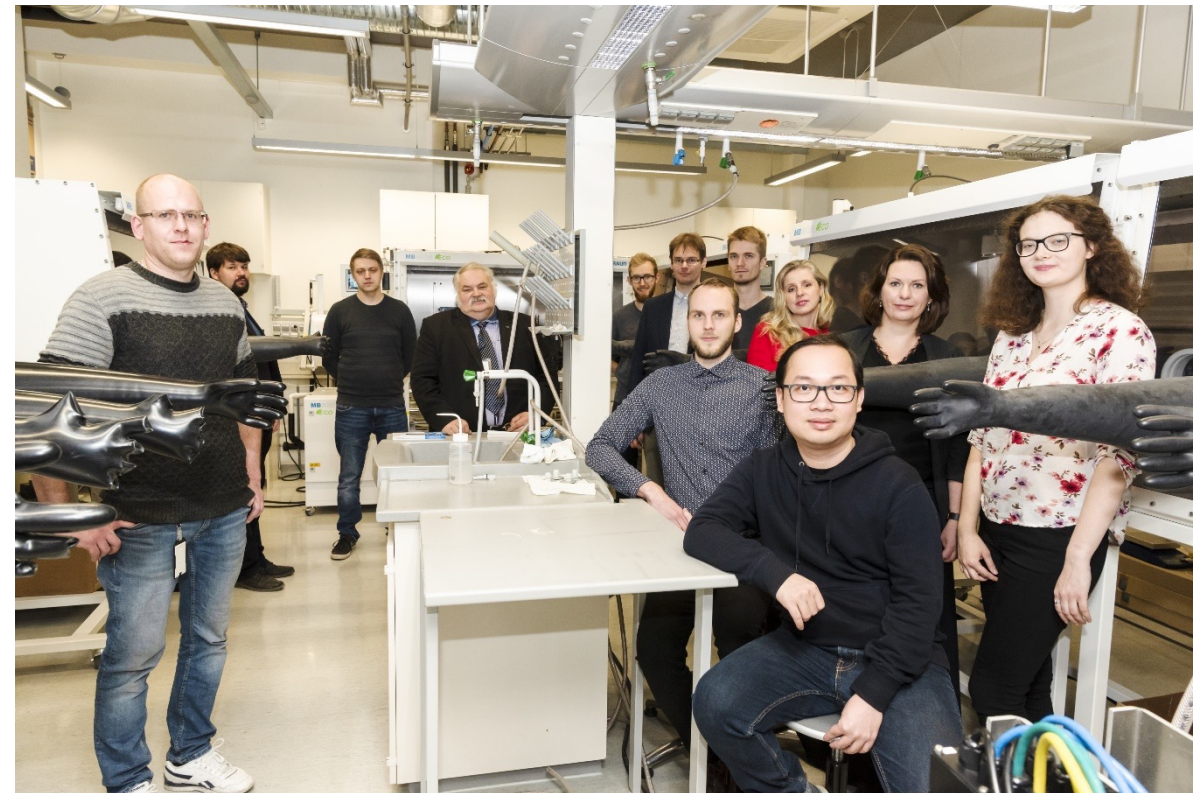


TABLE I Parameters Used In Case Studies*

Need
võiksid
olla
arvestusli-
kud
hinnad
2023.

LCOE of Wind ^[5]	68\$/MWh
LCOE of Solar ^[5]	39\$/MWh
Hydrogen Market Price ^[5]	4.2\$/kg = 138\$/MWh
Capital Cost of Wind Farm ^[20]	2347\$/kW
Capital Cost of Solar Farm ^[20]	1555\$/kW
Capital Cost of Electrolyser ^[20]	938\$/kW
Electrolyser Efficiency ^[21]	75%
Technical Life of Wind/Solar Farm ^[20]	25 Years
Technical Life of Electrolysers ^[20]	20 Years

Vertical-Axis Wind Turbines Work Well Together

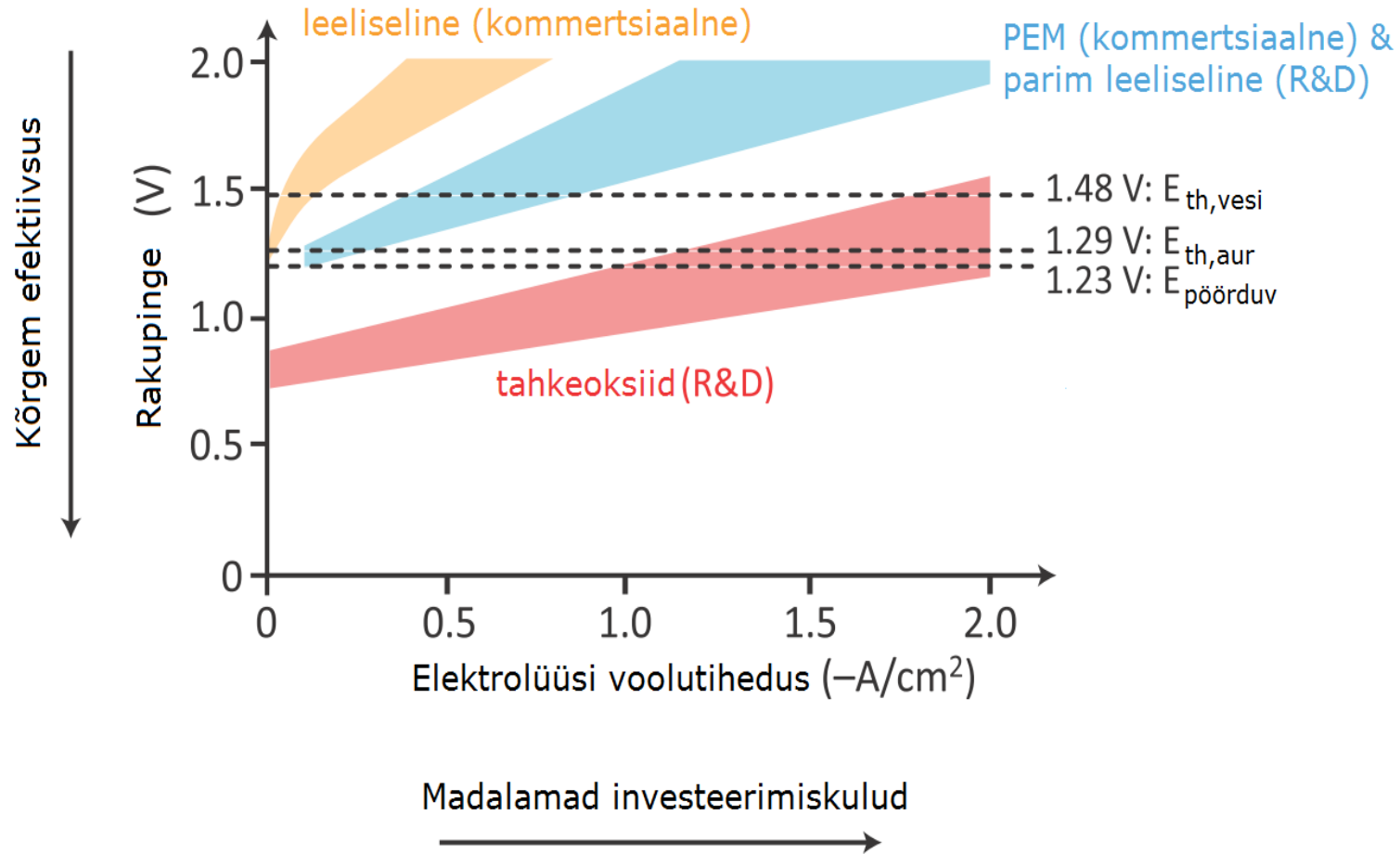
Üks
võimalus
on: uued ja
odavamad
suurema
tootlusega
tuulegener-
-aatorid



Erinevate kaasaegsete elektrolüüserite polarisatsioonikõverate vahemikud.

Kui soovime elektrolüüsitud vesiniku hinda alla saada, siis põhitähelepanu tuleb koondada kõrgtemperatuursete tahkeoksiid elektrolüüserite arendamisele!

Seda ütlevad meile loodusseadused, seega vaja on intensiivistada materjaliteaduslike uuringuid!



$E_{th,vesi}$ ja $E_{th,aur}$ tähistavad vastavalt vee ja auru termoneutraalse elektrolüüsi pingeid.
 $E_{pöörduv}$ on vee elektrolüüsi pöörduv potentsiaal standardolekus.

Solar Energy Technologies Office

USAs kuulutatakse peaaegu iga nädal välja mingi järgmine projektide esitamise kogumise võistlusvoor!

Projektid 0.5 kuni 10-20ne Miljoni USD.



Solar Funding OPPORTUNITY

U.S. DEPARTMENT OF **ENERGY** | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
SOLAR ENERGY TECHNOLOGIES OFFICE

Silicon Solar Manufacturing and Dual-use Photovoltaics Incubator

Mandatory concept papers for the U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) [Bipartisan Infrastructure Law Silicon Solar Manufacturing and Dual-use Photovoltaics Incubator](#) are due **September 27 at 5 p.m. ET**. DOE is interested in solutions that will accelerate manufacturing innovations that are part of the silicon solar module supply chain. Other projects will develop products that can open new markets for the emerging dual-use photovoltaic (PV) sectors, in particular agricultural PV, building-integrated PV, floating PV, and vehicle-integrated PV.

DOE expects to make between five to twelve awards ranging from \$400,000 to \$10 million.

Domestic Manufacturing Conversion Grants Funding Opportunity: Biden initiatives:

The \$2 billion [funding opportunity](#), announced on August 31, 2023, will spur the conversion of long-standing facilities to manufacture electric vehicles and components. Supported by President Biden's Inflation Reduction Act, the **[Domestic Manufacturing Conversion Grants](#)** for electrified vehicles program will provide cost-shared grants for domestic production of efficient hybrid, plug-in electric hybrid, plug-in electric drive, and hydrogen fuel cell electric vehicles.

This program will expand manufacturing of light-, medium-, and heavy-duty electrified vehicles and components and support commercial facilities including those for vehicle assembly, component assembly, and related vehicle part manufacturing. The program aims to support a just transition for workers and communities to an electrified transportation future, with particular attention to communities supporting facilities with longer histories in automotive manufacturing. Preference will also be given to projects that commit to paying high wages for production workers and maintaining collective bargaining agreements.

Projects selected for this funding must also contribute to the president's Justice40 Initiative, which aims to advance diversity, equity, inclusion, and accessibility in America's workforce and ensure every community benefits from the transition to a clean energy future.



5.2. Energy and exergy of the system

Table 4 illustrates the yearly energy/exergy flow results from a year-long simulation. This table demonstrates that the PV and WT have nearly the same energy efficiency while the PV exergy efficiency is higher than WT. Additionally, the inverter has the highest energy and exergy efficiency of 95% because of its very low loss. Moreover, the electrolyzer's exergy (64%) and energy (77%) efficiency are higher than the energy and exergy of PV and WT. Furthermore, Fig. 10 illustrates the Grassmann diagram – an essential tool for depicting exergy flows and losses – of the hybrid renewable energy system. As shown, the majority of the exergy is lost via PV panels and WT. Overall, only a small fraction of the exergy input is transformed into usable exergy output. Table 5 summarizes the system's average energy and exergy efficiency.

Table 4. Energy and Exergy flow values of the system components.

Components	Input (MWh)	Output (MWh)	Loss (MWh)	Efficiency	Exergy
PV panels	313.9	69.05	244.85	22%	22.62%
WT	168.868	39.36	129.508	23.31%	13.1%
Converter	108.41	102.99	5.42	95%	95%
Electrolyzer	97.4	74.9	22.5	77%	64%

Energy and exergy:
A system's exergy analysis measures the

degradation of energy or material in the system,

while energy information only quantifies the transfers and conversions of energy inside a system or process

Analysis of the CO₂ emissions from different bus types

The CO₂ emissions and equivalent ETS price analysis is based on the following assumptions

CO ₂ emissions analysis					
Parameter	Units	2017	2020	2025	2030
Diesel CO ₂ content	kg CO ₂ e / l	2.68	2.68	2.68	2.68
Hydrogen CO ₂ content assuming UKH2M targets	kg CO ₂ e / kg H ₂	4.17	3.34	2.50	2.09
Grid electricity co ₂ content	kgCO ₂ e / kWh	0.32	0.30	0.26	0.24
Annual fuel consumption					
Diesel bus	l / year	29,600	29,600	29,600	29,600
Fuel cell bus	kg / year	6,400	6,000	5,200	5,200
Electric bus	kWh / year	160,000	120,000	120,000	120,000
Annual CO ₂ emissions					
Diesel bus	Tonnes CO ₂ / year.bus	79	79	79	79
Fuel cell bus	Tonnes CO ₂ / year.bus	39.66	31.73	23.80	19.83
Electric bus	Tonnes CO ₂ / year.bus	51	36	31	29
Cost of CO ₂ emissions per bus at ETS price					
Diesel bus	EUR / year.bus	929	1,308	1,926	2,888
Fuel cell bus	EUR / year.bus	464	523	578	722
Electric bus	EUR / year.bus	599	594	757	1,049

NOx NP Sum
2,571 1,78 7,241

Analysis of the pollution emissions due to EURO VI standard buses

The following assumptions underlie the air quality analysis

Pollutant emissions analysis		CO	HC	NOx	PM
Euro VI standard	<i>g / kWh</i>	1.50	0.13	0.40	0.01
Bus efficiency	<i>kWh / 100km</i>	396	396	396	396
Bus mileage	<i>km / year</i>	80,000	80,000	80,000	80,000
Pollution over 12 year lifetime	<i>Tonnes</i>	5.70	0.49	1.52	0.04
Marginal cost of pollutant	<i>EUR / tonne</i>	-	-	1,000	67,650
Cost per bus	<i>EUR / bus</i>	-	-	1,520	2,571

Energies, Vostakola MF, etc.,
2023, 16 ,3327
Miks vesinik?, sest kõige
parem kaaluline
energiatihedus! JA eiteki FC
kütusena kasutanisel NOX,
SOx, COx, Voc ja nanoosakesi
1kg H2energia =1galloni (3.68
kg) bensiiniga

1MJ =0.27778kWh;
1Therms=29.307 kWh

Table 1. Energy content of several fuels [14].

Fuel	Energy Content (MJ.kg ⁻¹)
Hydrogen	120
Liquefied Natural Gas (LNG)	54.4
Propane	49.6
Gasoline	45.6–46.8
Ethanol	29.6
Methanol	19.7
Coke	27
Dry wood	16.2
Bagasse	9.6

DOE ja USA
pööravad üha
rohkem
tähelepanu
energia
salvestamisele
kas pataterides
(Li-ioon, Na-
ioon, Zn-ioon.
Ni-
metallhüdriid
või redoks ,
vähemal
määral
metall/õhk) või
siis vesinikuna.

Alliant Energy (NASDAQ:[LNT](#)), NextEra Energy (NYSE:[NEE](#)) and Xcel Energy ([XEL](#)) are among potential grant recipients from the Department of Energy, which plans to give a total of \$325M to 15 long-duration storage projects.

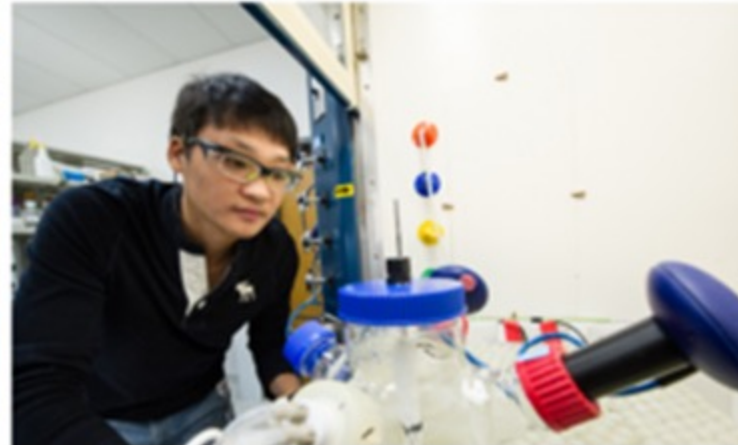
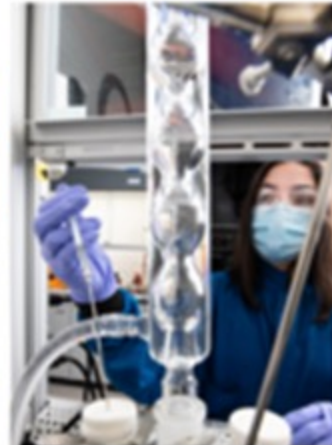
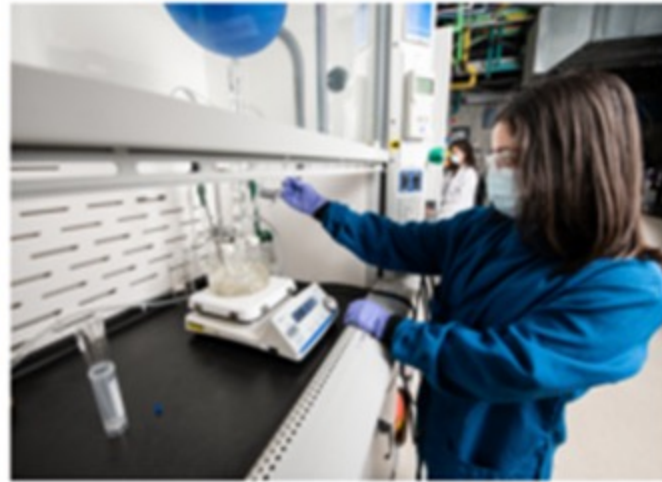
The funding includes up to \$286M for operating storage projects and up to \$39M for six projects that will be tested at DoE's national laboratories, UtilityDive.com reported Tuesday.

The DoE said the projects will help realize its Long Duration Storage goal of lowering long-duration energy storage costs by 90% by 2030.

Alliant ([LNT](#)), WEC Energy ([WEC](#)) and Madison Gas & Electric plan to build the 200 MWh Columbia Energy Storage Project in Wisconsin, which would be the first commercial scale project demonstrating a closed-loop carbon dioxide-based energy storage system; Alliant said the project is in line to receive \$30M from DoE.

September 29, 2023

The U.S. Department of Energy Announces \$16.7 Million to Advance Production of Affordable Biofuels and Biochemicals



DOE Announces \$38 Million for 13 Tribal Clean Energy Projects

New Clean Energy Investments Will Reduce Energy Costs and Improve Energy Security and Resilience

September 28, 2023

Today the U.S. Department of Energy (DOE) announced \$38 million in funding to advance clean energy technology deployment in 13 American Indian and Alaska Native communities. This funding will bolster ongoing efforts to reduce and stabilize energy costs, increase energy security and resilience, and provide electric power to Native communities. These investments align with the Biden-Harris Administration's goal to enhance Tribal energy sovereignty, while achieving an equitable clean energy future.

These cost-shared clean energy projects, valued in total at over \$55 million, are the result of the [funding opportunity announcement released February 17, 2023](#). The 13 projects are estimated to result in more than 9.6 megawatts of new clean energy generation and over 2,600 megawatt-hours of battery storage, affect over 1,300 Tribal buildings, and save these communities more than \$125 million over the life of the systems.

Green H₂ is an emerging sector with market sizing potential forecasted to reach between 450 MMtpy and 600 MMtpy by 2050. InterContinental Energy's portfolio of projects is among the largest in the world and is projected to produce more than 5 MMtpy of green H₂ to help offset more than 50 MMtpy of CO₂.

InterContinental Energy announced its next phase of growth following continued strategic equity investment from GIC and a new investment from Hy24, totaling \$115 MM in equity investment.

InterContinental Energy is developing a portfolio of green H₂ projects in Australia and the Middle East, located in exceptional coastal deserts with the best complementary wind and solar resources to deliver cost competitive green fuels at scale for domestic and export markets. The projects, which are among the most advanced, will be developed in phases, with an overall ambition of nearly **100 GW** of total installed renewable capacity. **Up to 10 GW of capacity is targeted for delivery in the first phases before the end of 2030**

23rd Annual

Advanced Automotive Battery Conference

December 11-14, 2023 | San Diego, CA + Online

AdvancedAutoBat.com/US

Põhilised patareide arendajad;

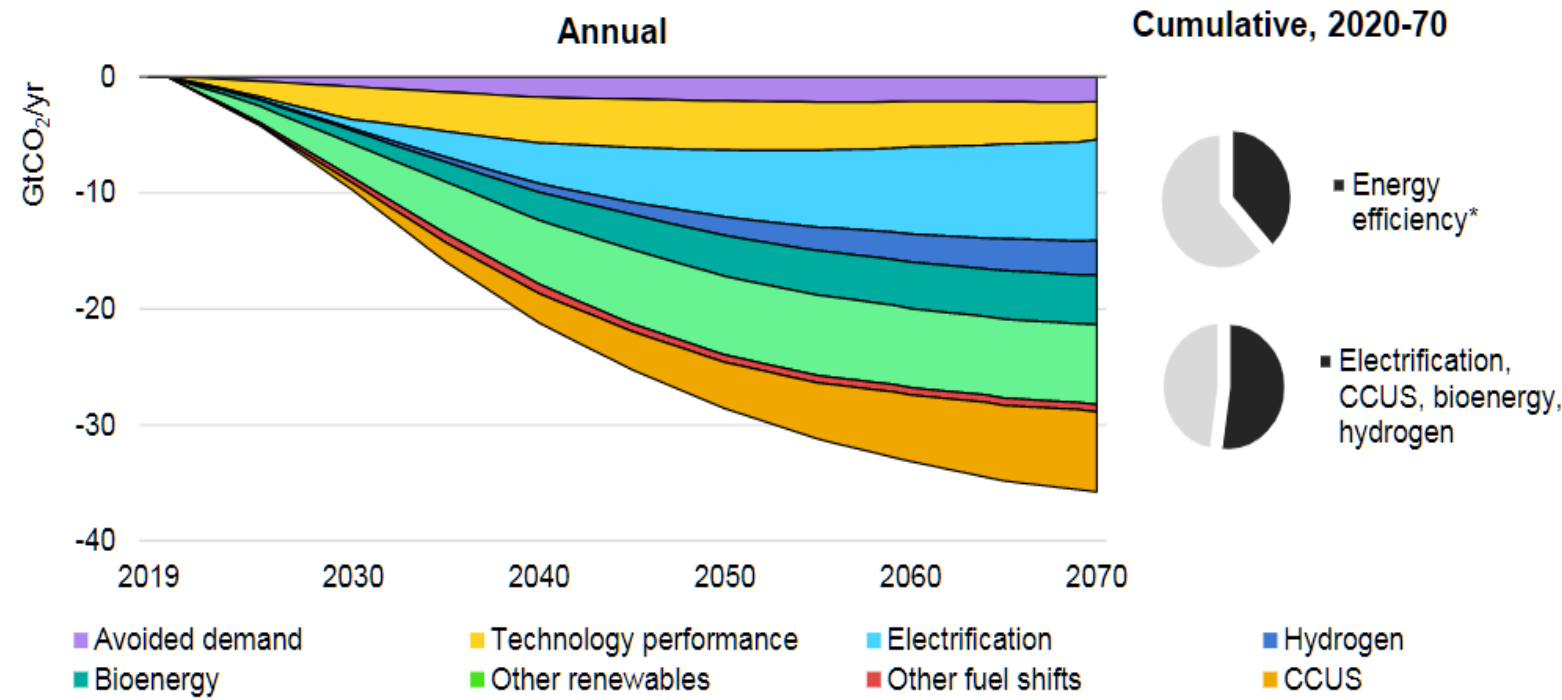
Lisaks H2
tehnoloogiale tuleb
arendada ka
Patareide
mahtuvust ja ajalist
vastupidavustm
(laadimistsükli
arvu), ning
võimsustihedust
kõrgetel
energiatiheduse
väärtustel(vähenda
da patareide
sisetakistust!).

Here are just a few of the OEMs and battery developers that will present this year:

Accelera by Cummins, Amionx, Blue Solutions, BMW, BYD, CATL, Daimler, EC Power, Enovix, EnPower, Factorial, Ford Motor Co., FREYR, General Motors, LG Energy Solution, Lyten, Mercedes-Benz, Nanoramic Laboratories, Nanotech Energy, Nissan, ProLogium, Rivian, Sakuu Corp., Sepion Technologies, Skeleton Technologies, Stellantis, Toyota, Volta Trucks, Volvo, and many more.



Figure 2.2 Global energy sector CO₂ emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-70



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* Energy efficiency includes enhanced technology performance as well as shifts in end-use sectors from more energy-intensive to less energy-intensive products (including through fuel shifts).

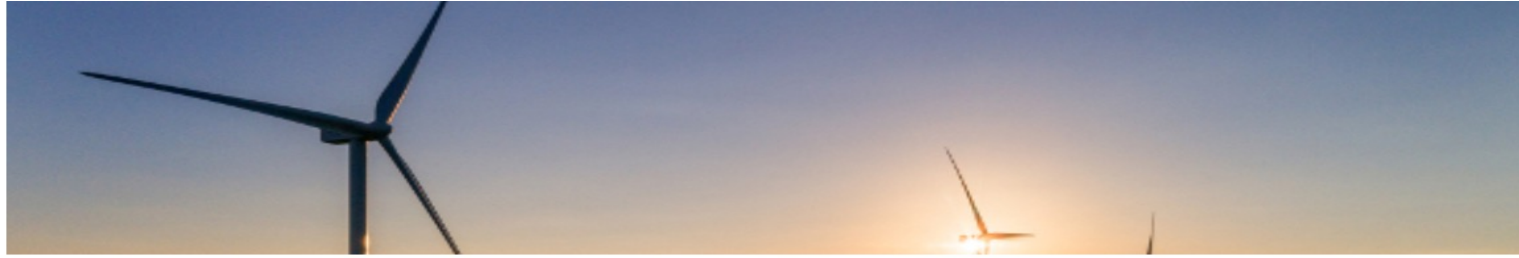
Notes: CCUS = carbon capture, utilisation and storage. See ETP model documentation for the definition of each abatement measure. *Hydrogen* includes low-carbon hydrogen and hydrogen-derived fuels such as ammonia.

Electrification, CCUS, bioenergy and hydrogen-derived fuels contribute to more than half of cumulative emissions reductions from 2020 to 2070 in the Sustainable Development Scenario relative to the Stated Policies Scenario.

Seega CO₂ tootmise vältimise põhilised võimalused/suunad on:

- roheline elekter,
- vesiniktehnoloogiad,
- bioenergia,
- muud taastuenergia liigid (hüdro-, pumphüdroenergia, tõusud/mõõnad, ookeanide laineenergia, geotermaalenergia)
- Suunad, millega intensiivselt tegeleda:
- süsteemide energiaefektiivsuse tõstmine:
- hoonete soojustamine,
- ekso-ja endotermisiste protsesside kombineerimine (paralleelne toimumine/läbiviimine soojuse keskkonda levimise vältimiseks)

Lääne Austraalias
läheb maismaa
tuuleparkide
(2.4GW) ehitamine
hoogu.



Macquarie Asset Management has revealed its partnership with Perth-based Green Wind Renewables Pty Ltd (GRW) to collaboratively build up to 2.4 GW portfolio of onshore wind projects in Western Australia. The companies will collaborate on the projects as a joint venture, which might eventually grow to include more projects. Moreover, the partners have already negotiated land contracts for the projects and will now begin resource monitoring work.

Reportedly, the projects are currently in the early phases of construction, with community consultation sessions to be held as the development process proceeds. The scheduled capacity is planned to be connected to the South West Interconnected System.

In September 2022, Macquarie Asset Management agreed to sell a 15.5 per cent stake in the Lincs Offshore Wind Farm (Lincs) to Octopus Energy Generation funds. The asset manager held the stake through Macquarie European Infrastructure Fund V. No financial details were disclosed. The 15.5 per cent stake was acquired by Octopus Renewables Infrastructure Trust and Sky, funds managed by Octopus Energy Generation.

REGlobal's Views: Western Australia is expected to witness tremendous capacity additions in the renewables space as the region plans to build 50 GW of renewables in just two decades. Thus, this is the right time to enter this highly attractive market which has ample untapped potential.