W. Ostwald ja vesiniku tehnoloogiad 2023. aastal

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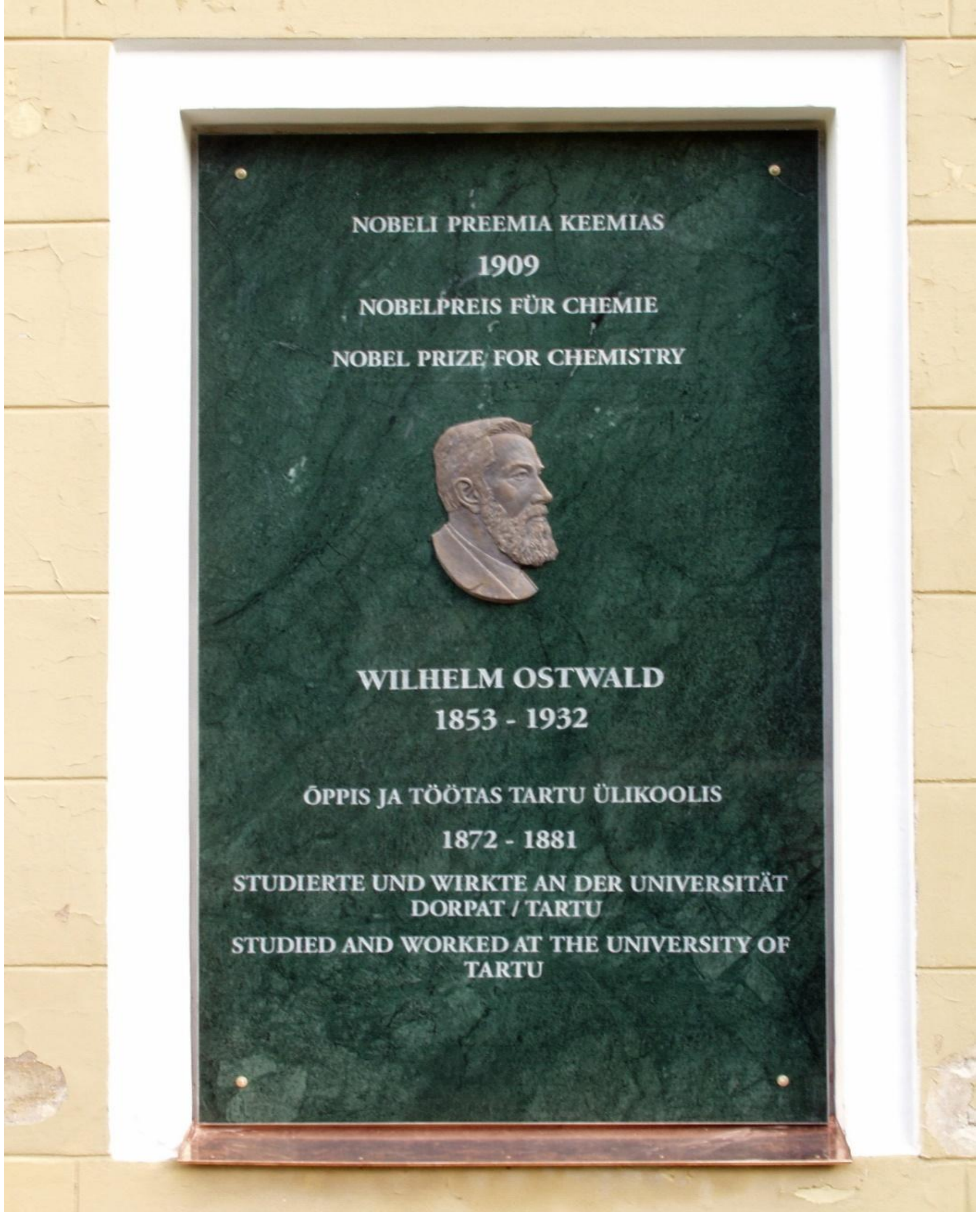
Tartu, 06.10.2023, VII vesinikupäev

170 aastat Nobelisti W. Ostwaldi sünnist!
Füüsikalise keemia ja rohelise 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

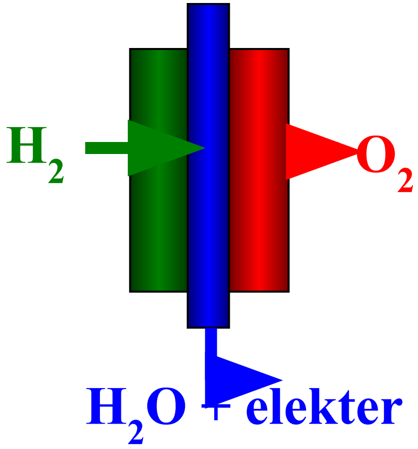
associated prof. at Univ. Tartu (1875-1881), prof. of Leipzig Univ. (1888-1906)

Now: testing the influence of the characteristics of carbon materials on PEMFC energy and power densitity; development of Pt-metals free d-metal-N_2 materials ($Fe\text{-}N_2$; $Co\text{-}N_2$; $Fe\text{-}Co\text{-}N_2$) for PEMFCs

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

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

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



Fuel cell
die
Brennstoff
zelle
Топливни
й

H_2-O_2 kütuseelement, teoreetilised alused W. Ostwald

- H_2-O_2 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

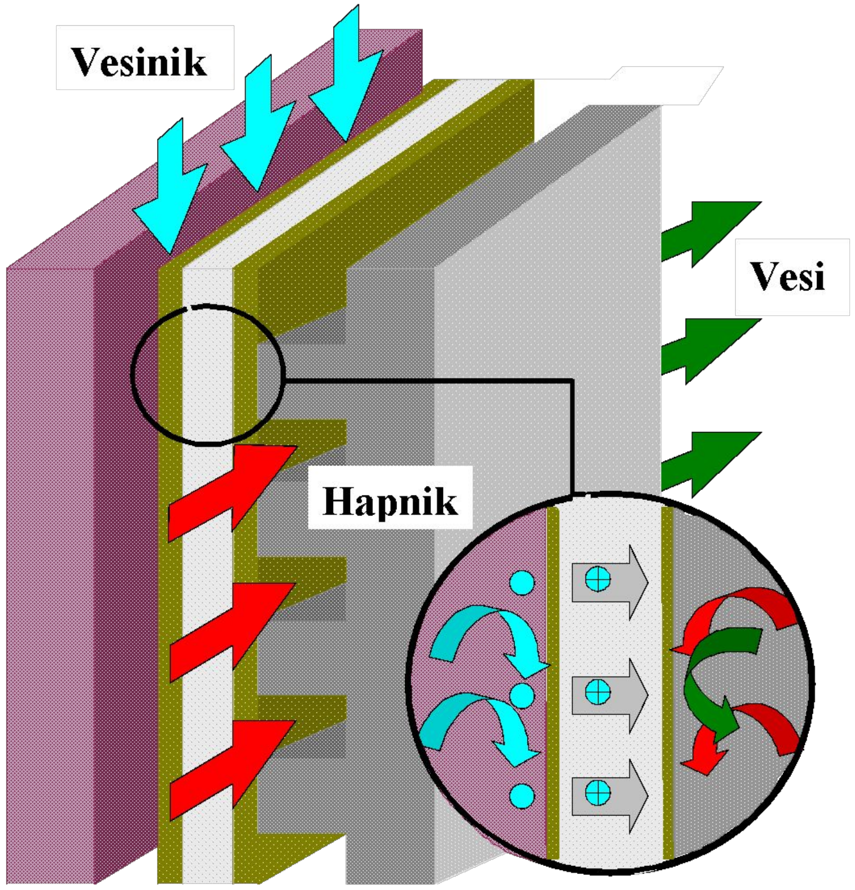
Anoodil vesinik (kütus) oksüdeerub

$H_2 \rightarrow 2H^+ + 2e$ ($E^0 = 0$)

Katoodil hapnik redutseerub

$O_2 + 4e^- + 2H_2O = 4OH^-$ ($E^0 = 1{,}229$ V)

Summaarne ioonreaktsioon: $H^+ + OH^- = H_2O$



- **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

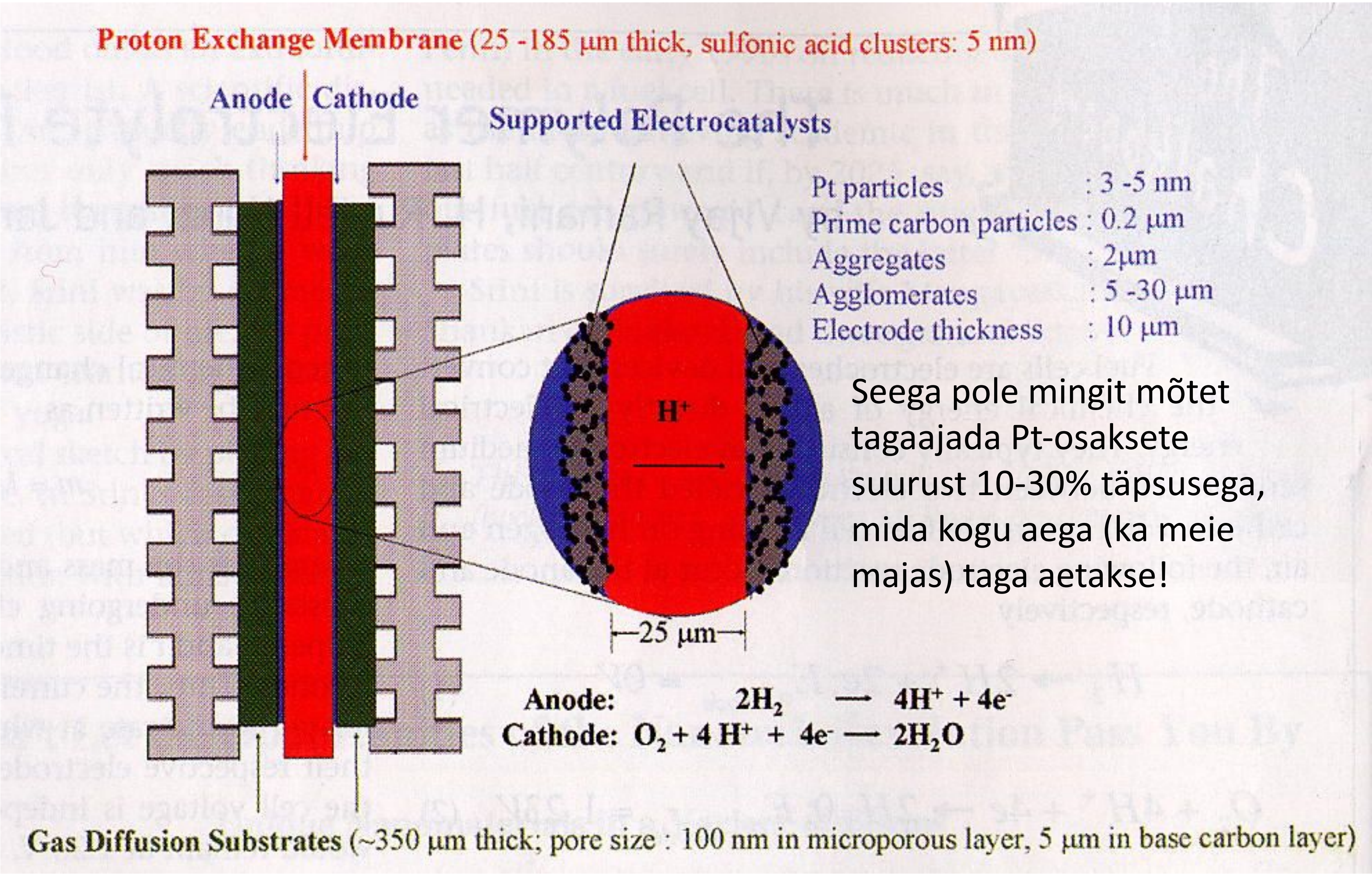
- Carl Claus was born in Russia, Dorpat,
- 1810 a pharmacist at St. Petersburg, 1815 back to Dorpat, passed the pharmacy examination at the Univ. Dorpat, 1815 back to St. Petersburg, 1817 to Saratov
- 1831 became an assistent in the chemistry at the Univ. Dorpat, defended masters degree,
- 1838 established the chemistry laboratory at Kazan University.
- 1839 recieved 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 Platinemetalle. 1856 established formation principles of Pt metals ammines

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(oksohüdroksiidi) moodustumist) ja seega võimalikku lahustumist ja hiljem sadenemist lahusefaasist uude kohta. Selle tulemusel võib osasese suurus kasvada ja katalüsaatori aktiivsus väheneda!

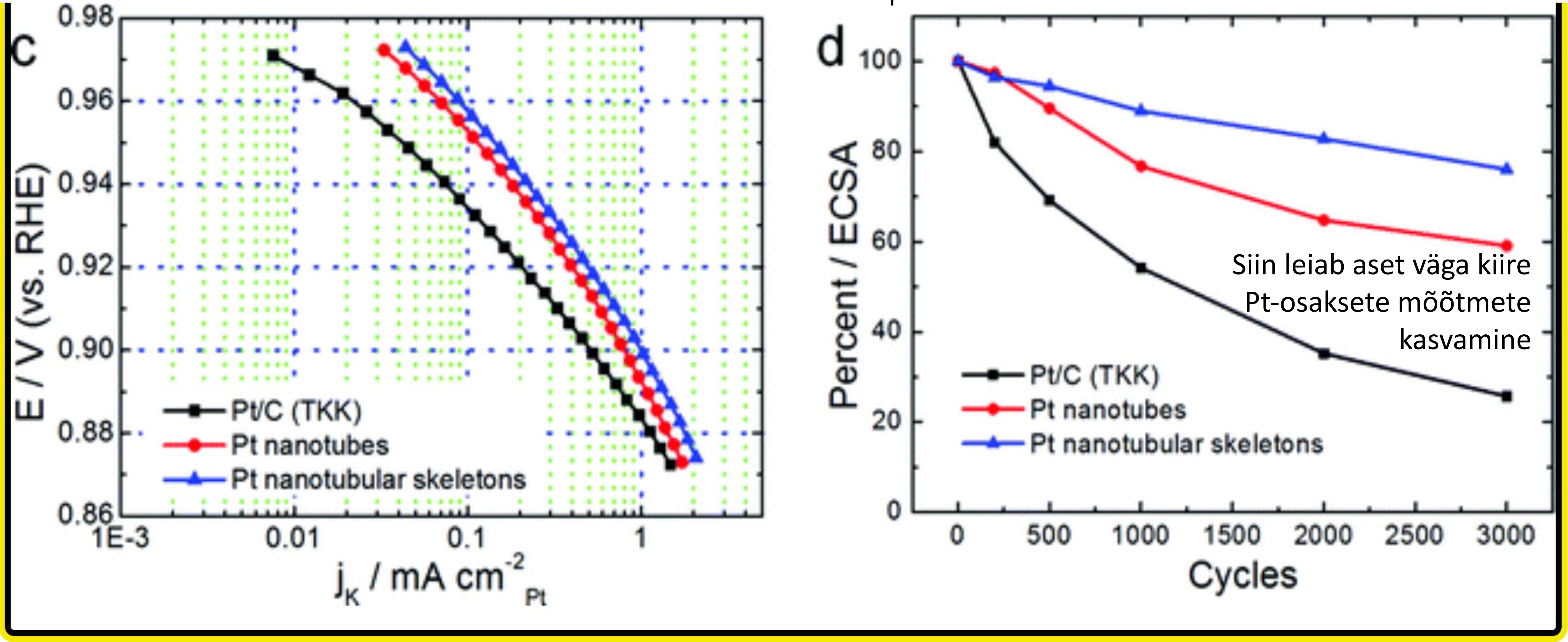


Seega pole mingit mõtet tagaajada Pt-osaksete suurust 10-30% täpsusega, mida kogu aega (ka meie majas) taga aetakse!

V. Ramani et al., Interface 13 (2004) 17.

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.



Vostakola M.F. et al., Energies 2023, 16, 3327.

1887 – Ph.D. thesis on metamerism of metaphosphates
(i.e. HPO3 acid salts $(NaPO_3)_2$, $Mg_6Na_2(PO_3)_{14}$)

Anionic complexes:

$$Na_2[Na_4(PO_3)_6] \xrightarrow{H_2O} 2Na^+ + [Na_4(PO_3)_6]^{2-}$$

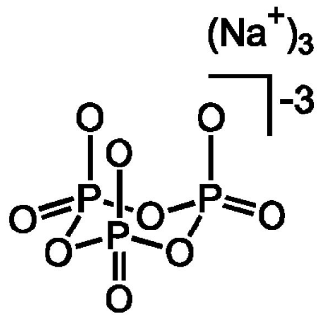
$$Na_4[Na_2(PO_3)_6] \xrightarrow{H_2O} 4Na^+ + [Na_2(PO_3)_6]^{4-}$$

$$NH_4K_4(PO_3)_5 \xrightarrow{H_2O} NH_4^+ + 4K^+(PO_3)_5^{5-}$$

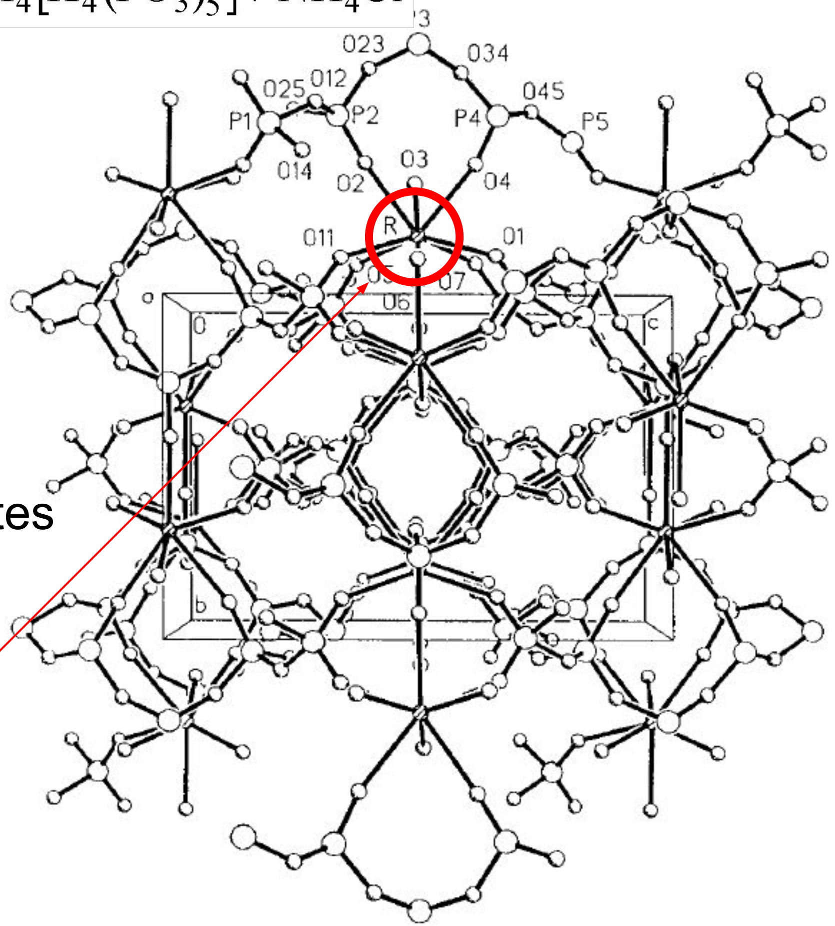
$$NH_4Li_4(PO_3)_5 \xrightarrow{H_2O} NH_4^+ + 4Li^+(PO_3)_5^{5-}$$

$$NH_4[(NH_4)_4(PO_3)_5] + 4KCl \rightarrow NH_4[K_4(PO_3)_5] + NH_4Cl$$

Synthesis of $M_3Na_2(PO_3)_8$ (M = Mg, Co, Zn, Ni)
$M_4Na_4P_2O_7$ (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 MP_5O_{14}
(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

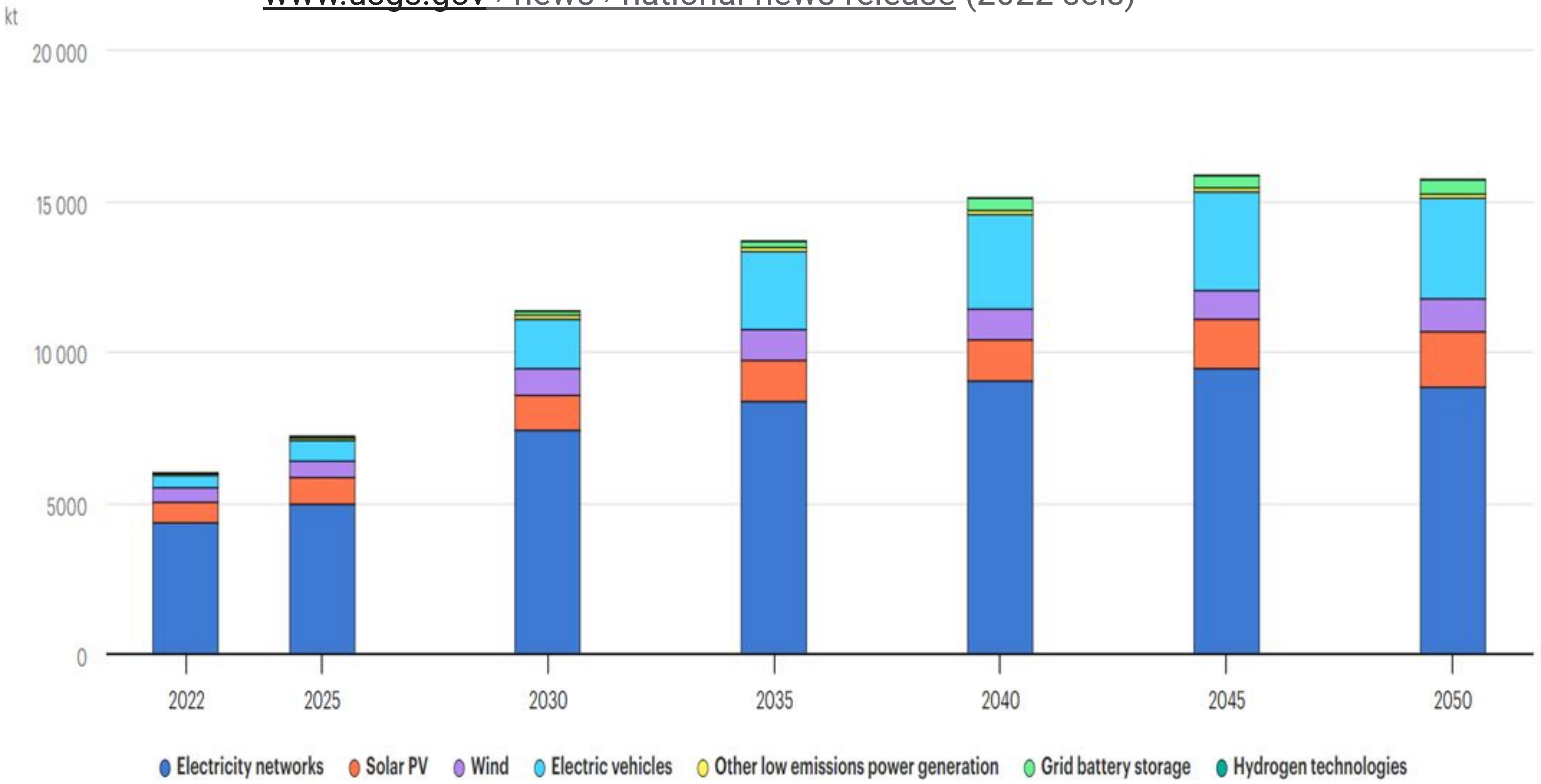
U.S. Geological Survey Releases 2022 List of Critical Minerals (2022) www.usgs.gov › news › national-news-release

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

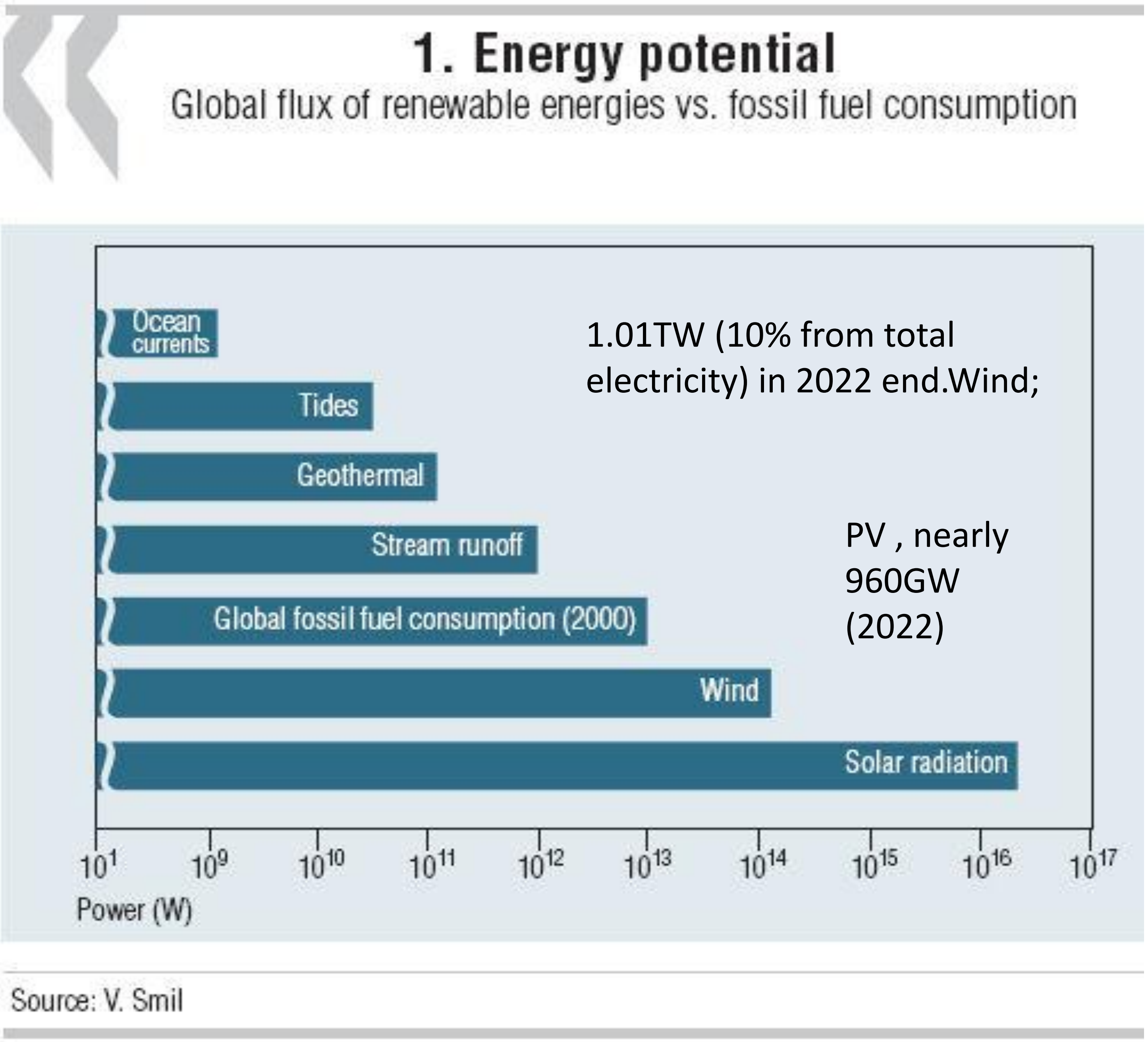
Vase kasutusalad (kogus kilotonnides)

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! (COx, NOx, SOx, VOC, nanoosakesi ja ka H_2S, CO jne.tootvaid tehnoloogiaid)

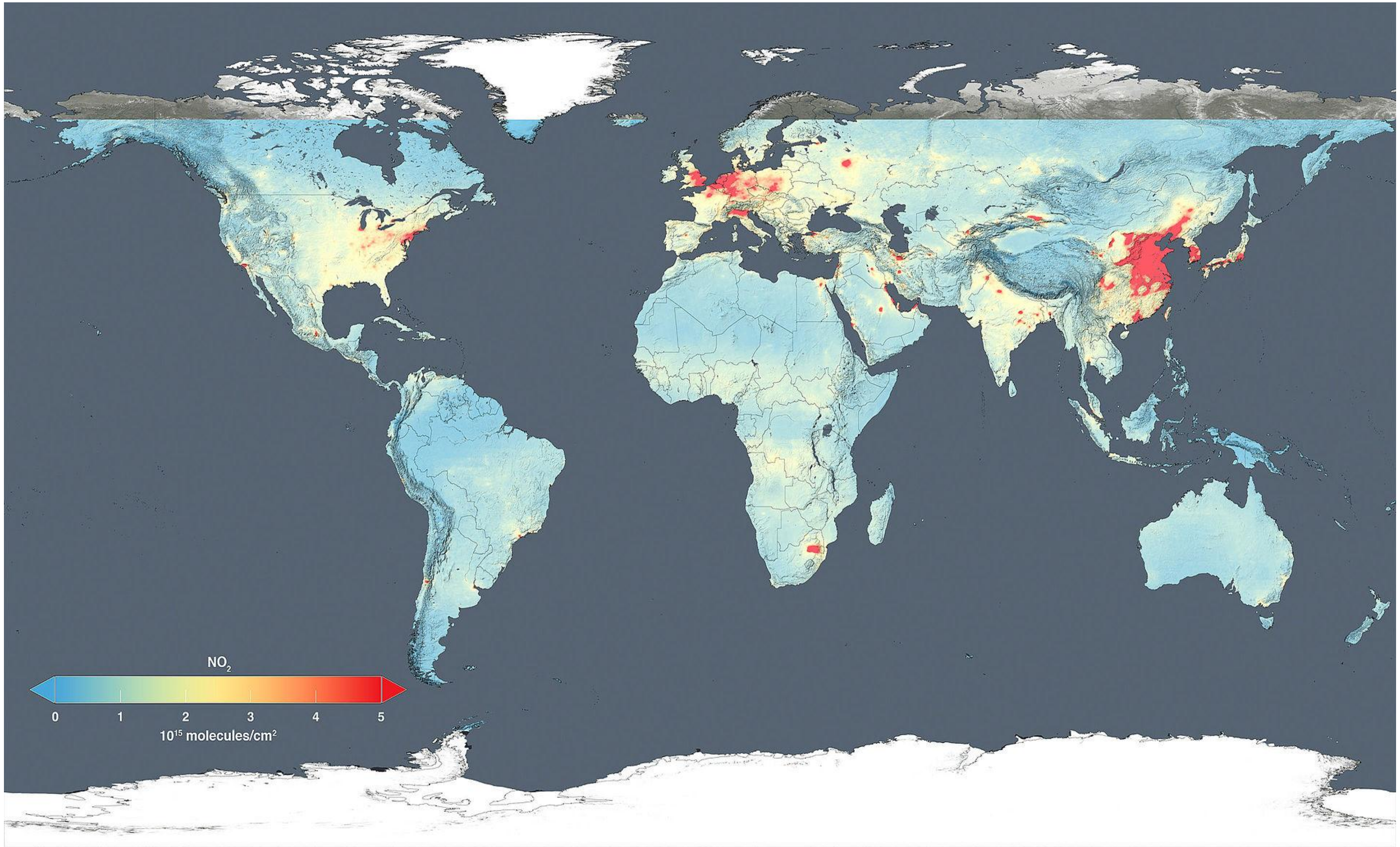


http://www.oecdobserver.org/images/2081.photo.jpg

Saastatus: globaalne probleem, kuid osades kohtades väga kriitiline

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

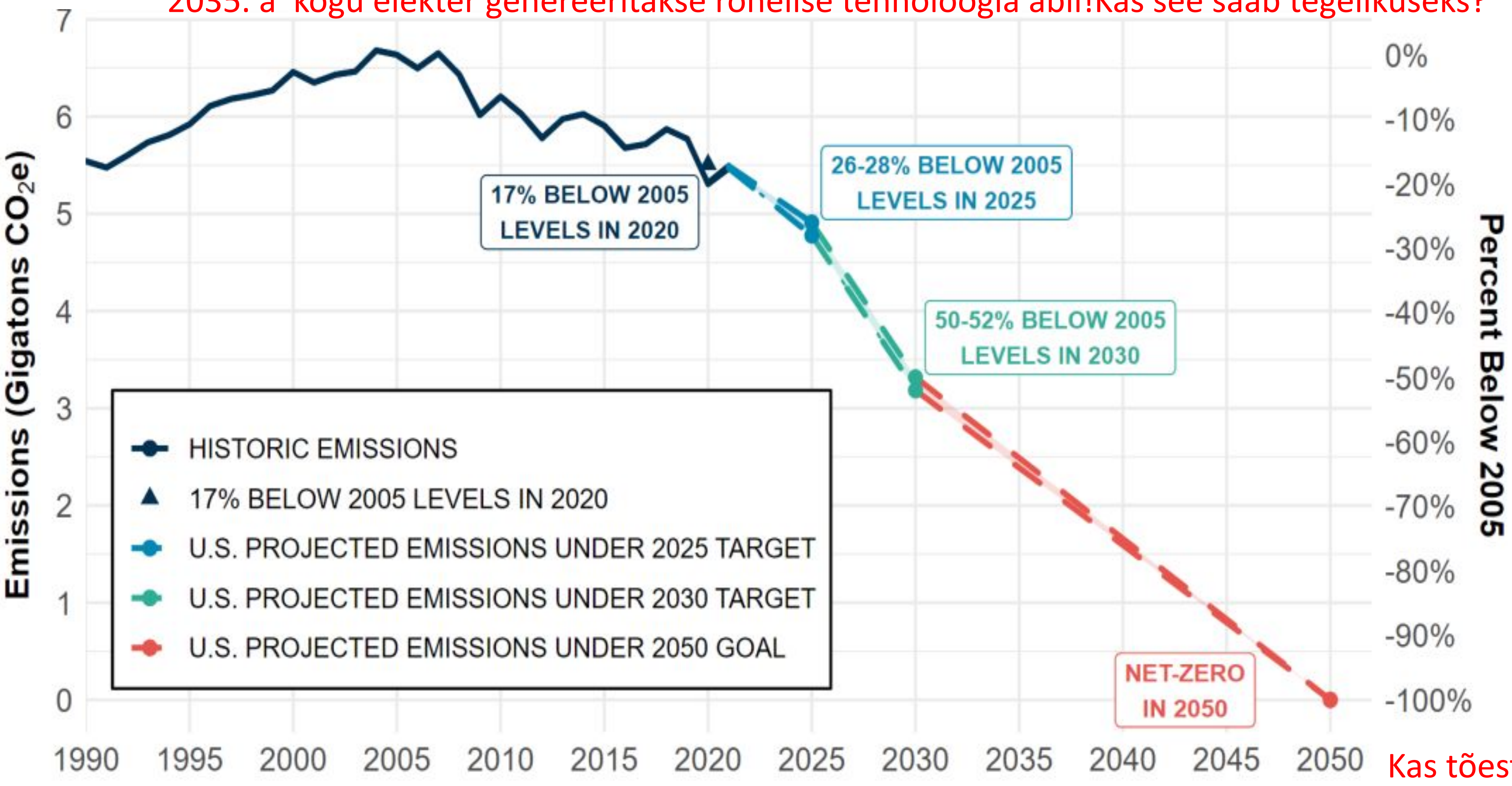
Selleks, et me endid päris ära ei mürgitaks, tuleb otsustavalt vähendada „tossava“ majanduse ja tehnoloogia rakendamist kõigil elualadel!



https://et.wikipedia.org/wiki/Kasvuhoonegaasid#/media/File:15-233-Earth-GlobalAirQuality-2014NitrogenDioxideLevels-20151214.jpg

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]

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

16.65 TWh

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

USA on tegemas väga kiiret „rohelise vesiniku“ elektrolüütilise tootmise kiirendust. Kavatsetakse 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)

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

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

Õnneks ka Euroopa Liidus samad soovitused:2030a 2 (ainult) FC H2 tanklat Eestisse TEN-T koridoridele

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 CO_2 vaba majanduse oletatav paiknemine mandriosal.

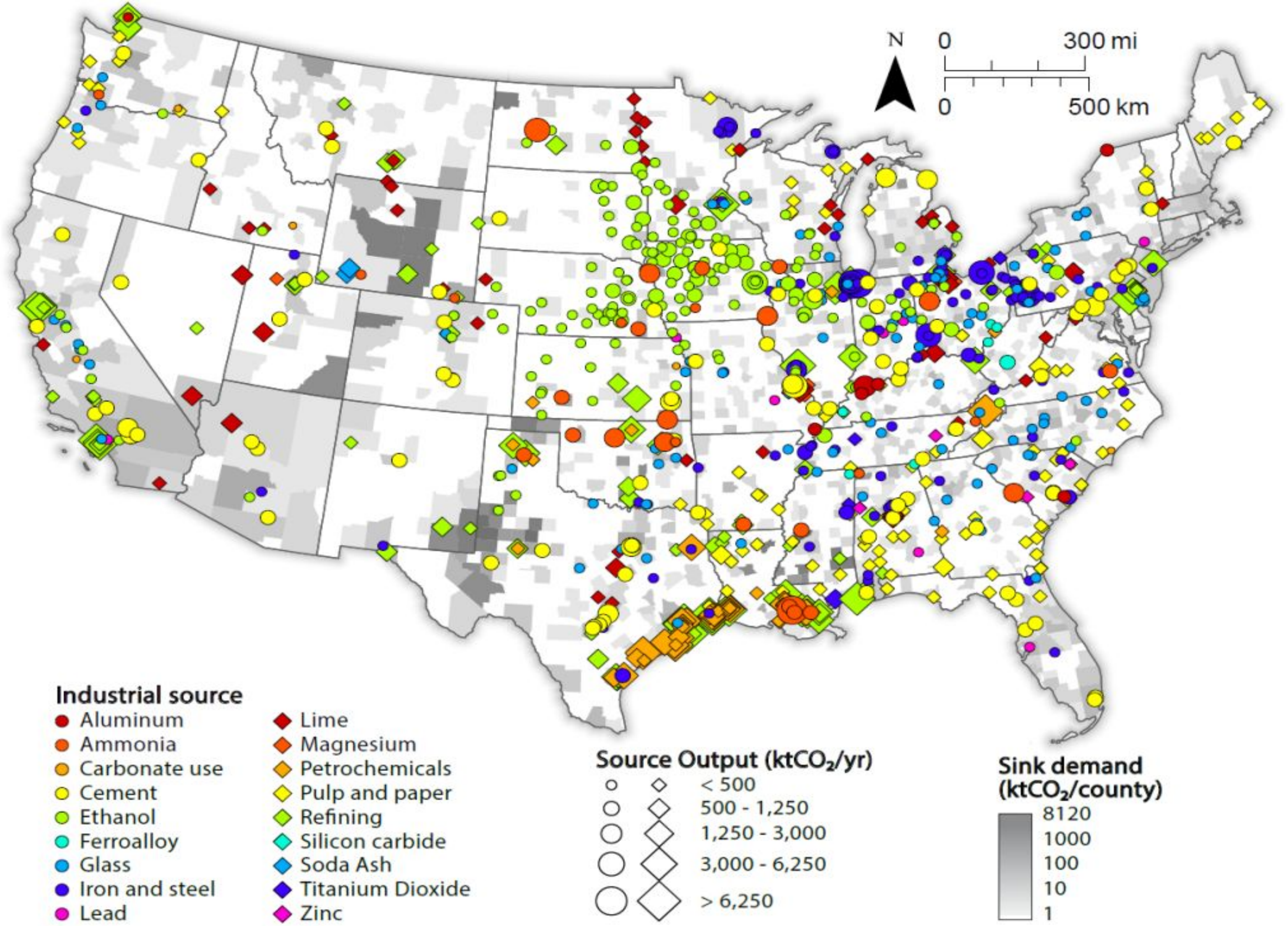


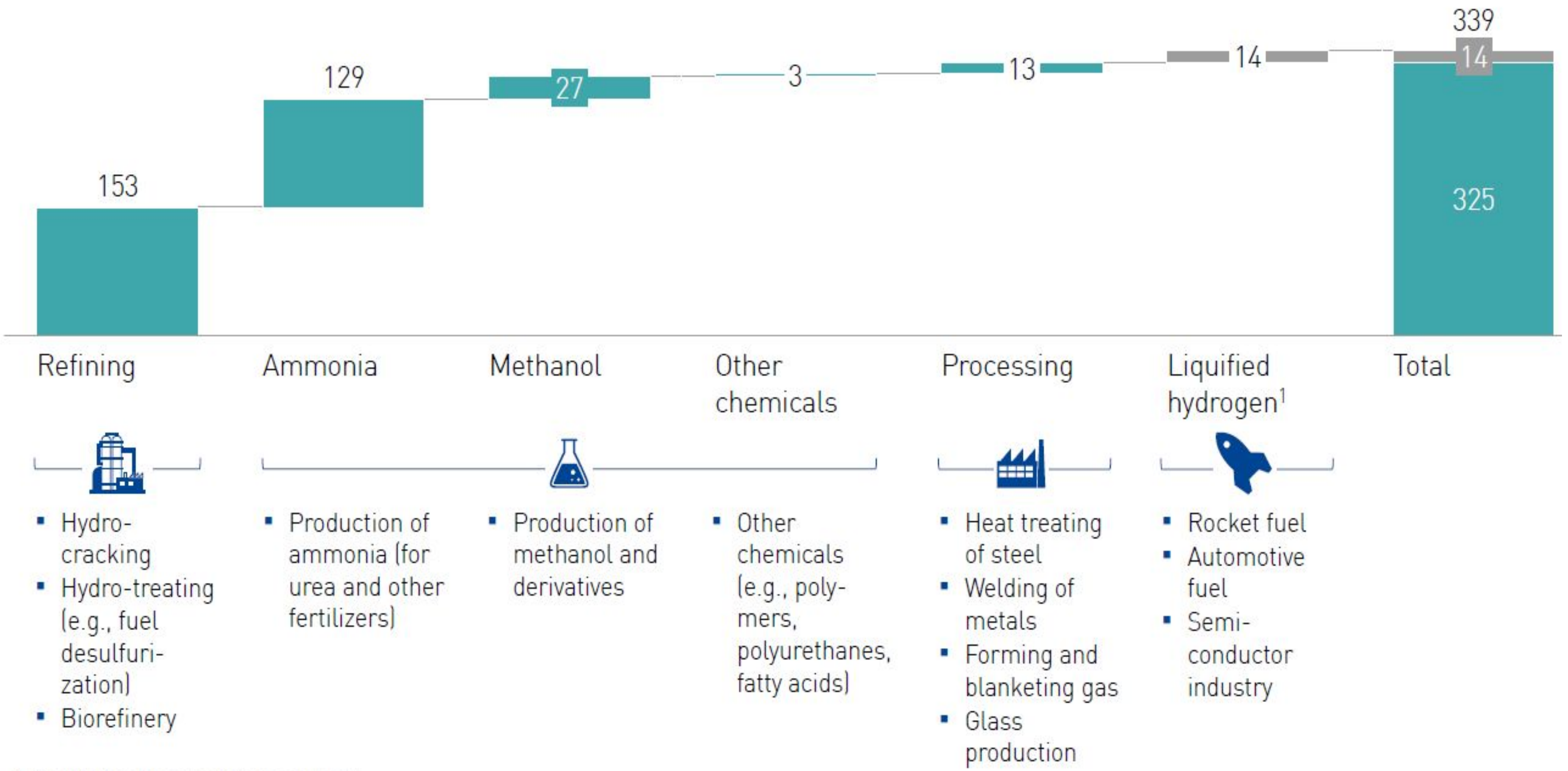
Figure 33: Industrial clusters in the United States create potential regions for decarbonization hubs. (Source Psarras et al.[183])

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

Et saavutada kiire CO_2 ekvivalendi vähenemine, on lähema 10-ne aasta jooksul vaja teostada nn neljas tehnoloogiline revolutsiooon. Põhilised arengumootorid on: roheline elekter ja vesiniktehnoloogiad.
Lisaks erinevad tsüklilise ja taastuva materjalidetehnoloogia lahendused.

EXHIBIT 17: USE OF HYDROGEN TODAY

Total hydrogen use in the EU, in TWh



1 Counted in transportation segment

https://fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

Rohelise vesiniku kasutusalad

Rohelise vesiniku mõningad kasutusalad:

- Tööstus (kõik koos nii keemia, kütuste puhastamise tööstus, metallurgia, biokeemia jne) 50%,
- transport 25%
- küttemajandus 15%
- kõik ülejäänud 10%

kogu toodetud rohelisest vesinikust.

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

M.F. Vostakola et al., Energies 2023, 16, 3327.

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

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

60.0 kW PV demo system developed at TU IC;

Capacitor (Skeleton, NT Bene)
Li- ion and Na-ion batterieS;
Lead/acid batteries, 24x208Ah installed

E

Electrolyser, 6.3kW installed

H_2

H_2 storage,12x50L 350bar

H_2

PEMFC, installed; SOFC- in progress

Q

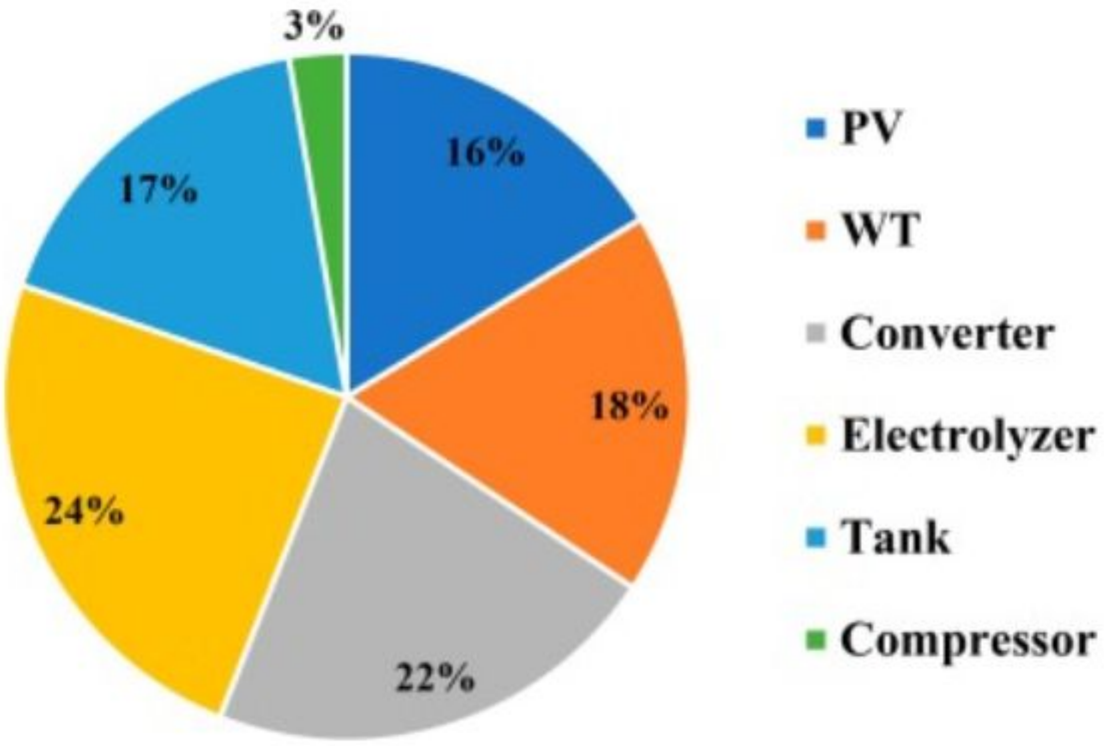
Synthetic fuel synthesis reactor (CO2+H20);

SOFC (Elcogen) SOEL, under development

E

Ülevaade DOE poolt arvutatud 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

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

, ,

Miks just tuuleelekter ja PV: sest

pikemaaegsed prognoosid annavad 2030. aastaks kõige odavamad hinnad PV- ja tuuleelektrile.

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.

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 CO2 , NOx ja NP saastemaksud siis

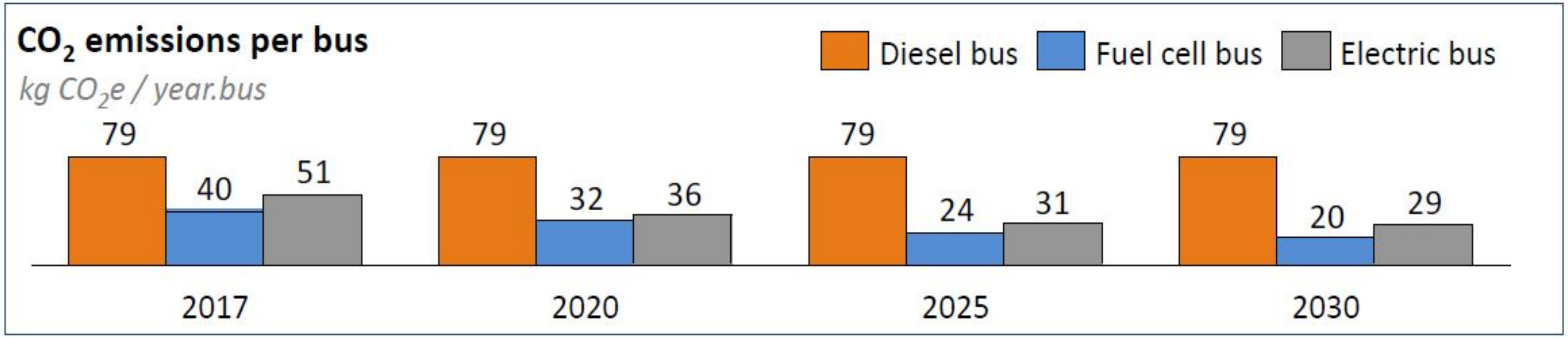
COx, NOx ja NP üks aasta	7271,6€	1752€ (NB! Arvestatud tootmisel eralduvaid gaase)
, 12 aastat COx, NOx ja VNP trahve	87252€	21024€

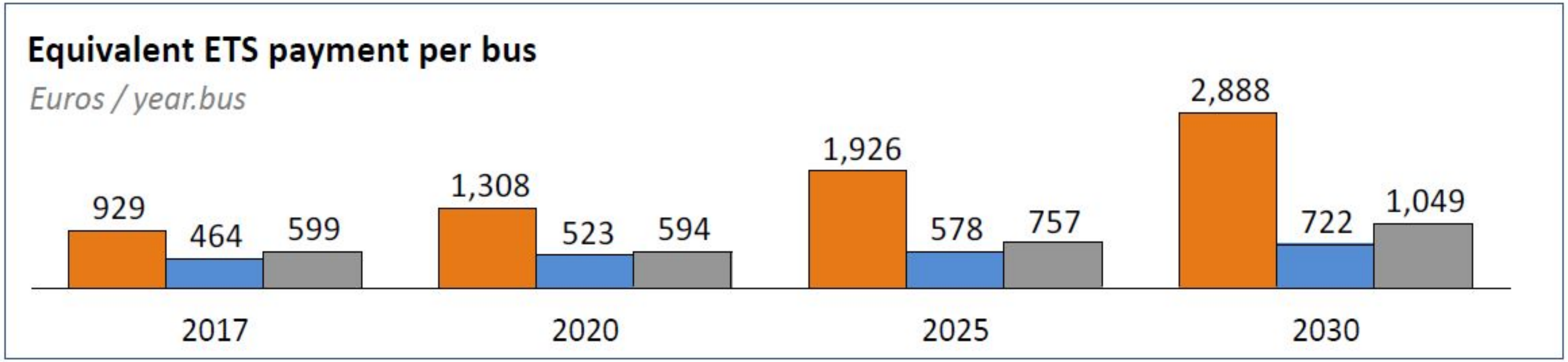
Siis on vahe veelgi suurem 376508 €

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 CO_2 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 CO_2 emissions than an equivalent diesel bus.
- This translates into ETS savings of thousands of Euros per year per bus.





Kui arvestame CO_2 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 NOx, SOx, VOC ja nanoosakeste ohtlikkust arvestav maks, siis on küll targem diiselbussid garaaži jätta!

Kütuseelementide ja vesiniktehnoloogia maksumuse alandamiseks on tegelikult veel palju võimalusi:

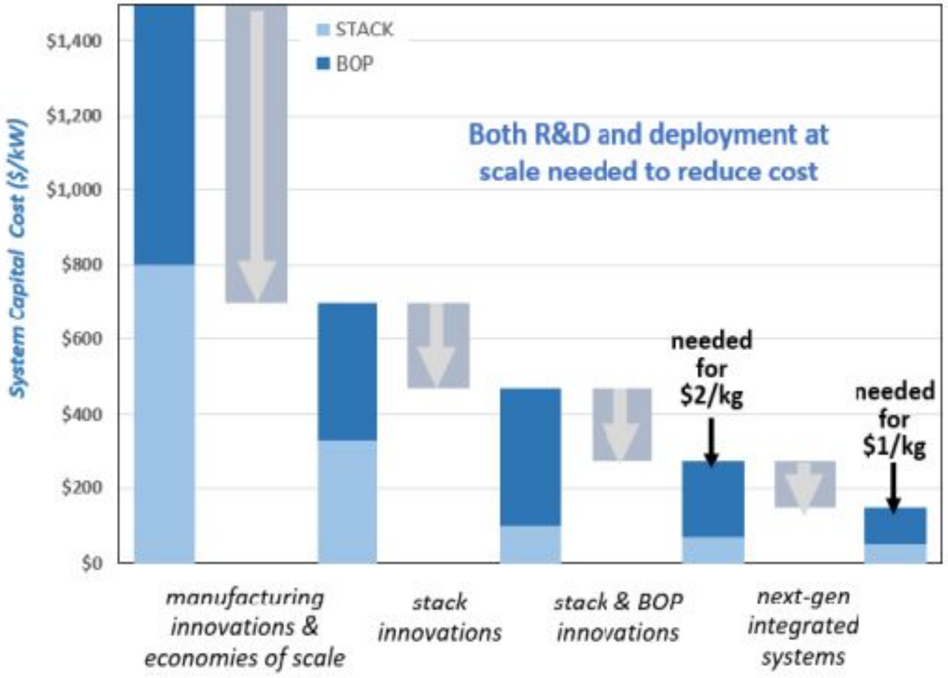


Figure 21: Reducing electrolyzer capital costs will require reaching economies of scale and innovating the electrolyzer stack and balance-of-plant components.

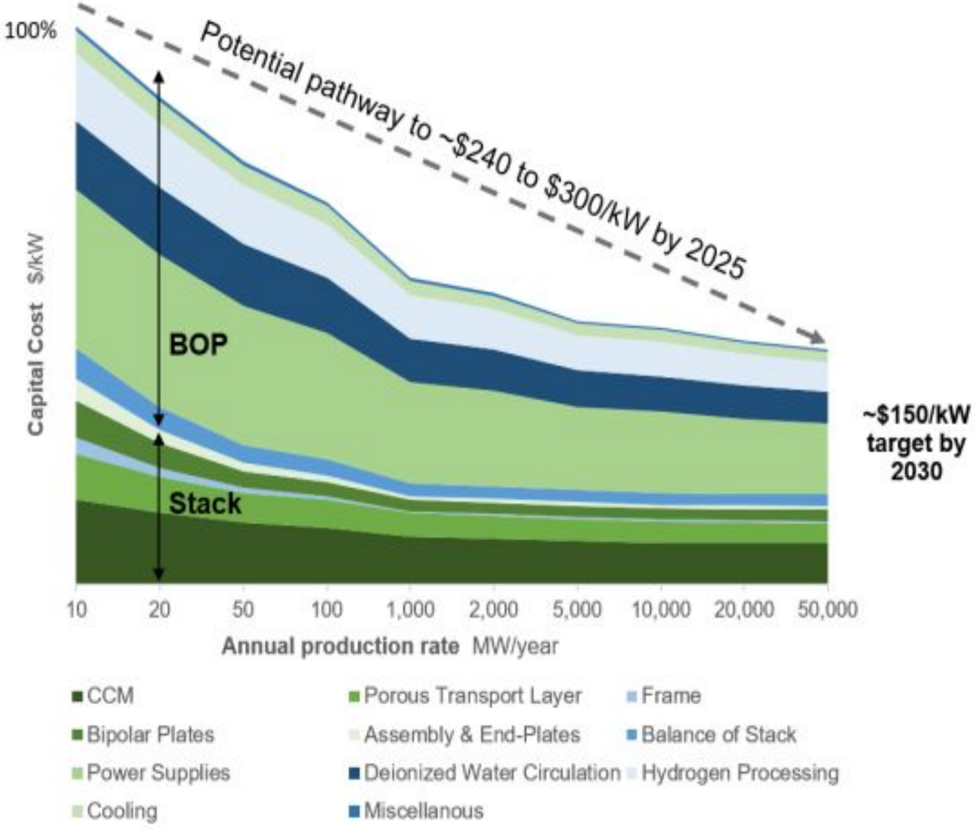


Figure 22: There are many drivers for electrolyzer stack and balance-of-plant capital cost reductions.

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

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

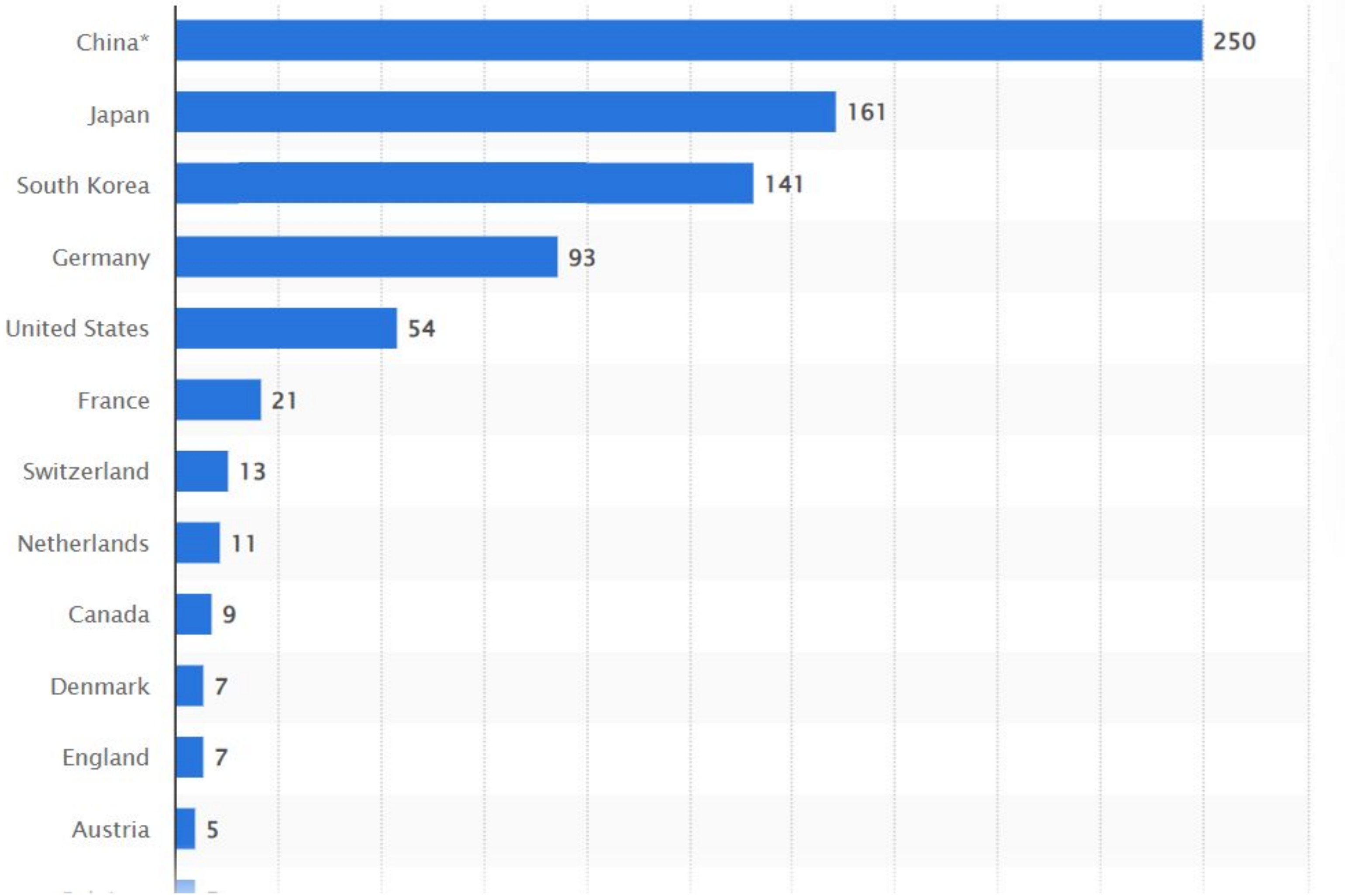
Table 6. Costs in USD per concept for the case study.

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	$\sum \left(E_k^{grid} \cdot PPA \right)$	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	$\sum \left(C^{H2O} \cdot C^{sp.H2O} \cdot \dot{m}_k^{H2} \right)$	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)

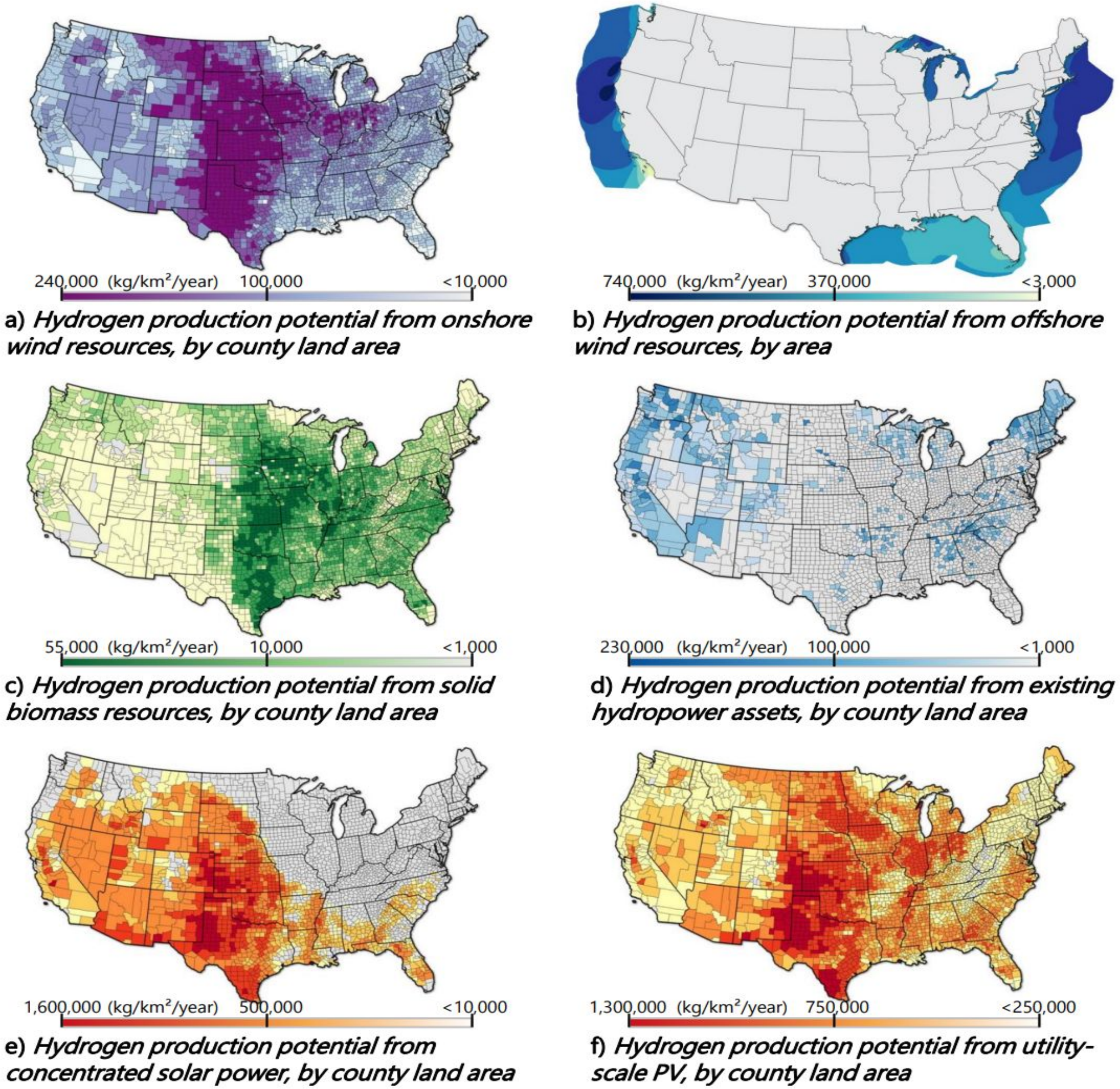
In 2022, there was nearly 1000 RHS in World.
More than 60 countries have at least 1 RHS with 4 positions.
Estonia????



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

USA keskosa on sobilik nii tuule-, biomassist, kontsentereeritud päikeseenergia kui ka otse PV-elektri ja vesiniku tootmiseks ilma, et oleks vaja pikemaaegseid salvestusvõimsuseid rakendada.

Ainult ida- ja läänerannik aga sobivad meretuuleparkide ja hüdroenergia abil elektri ja vesiniku tootmiseks. Rannikualadel arendatakse laineenergia ja tõusude –mõõnade kasutamist.



- 1kg H_2= 33.3 kWh;
- 1 kg H_2 = 130-180 km (väike auto)
- 1kg H_2 elektrolüüsiks 48-55 kWh elektrit

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

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)/km^2. 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.

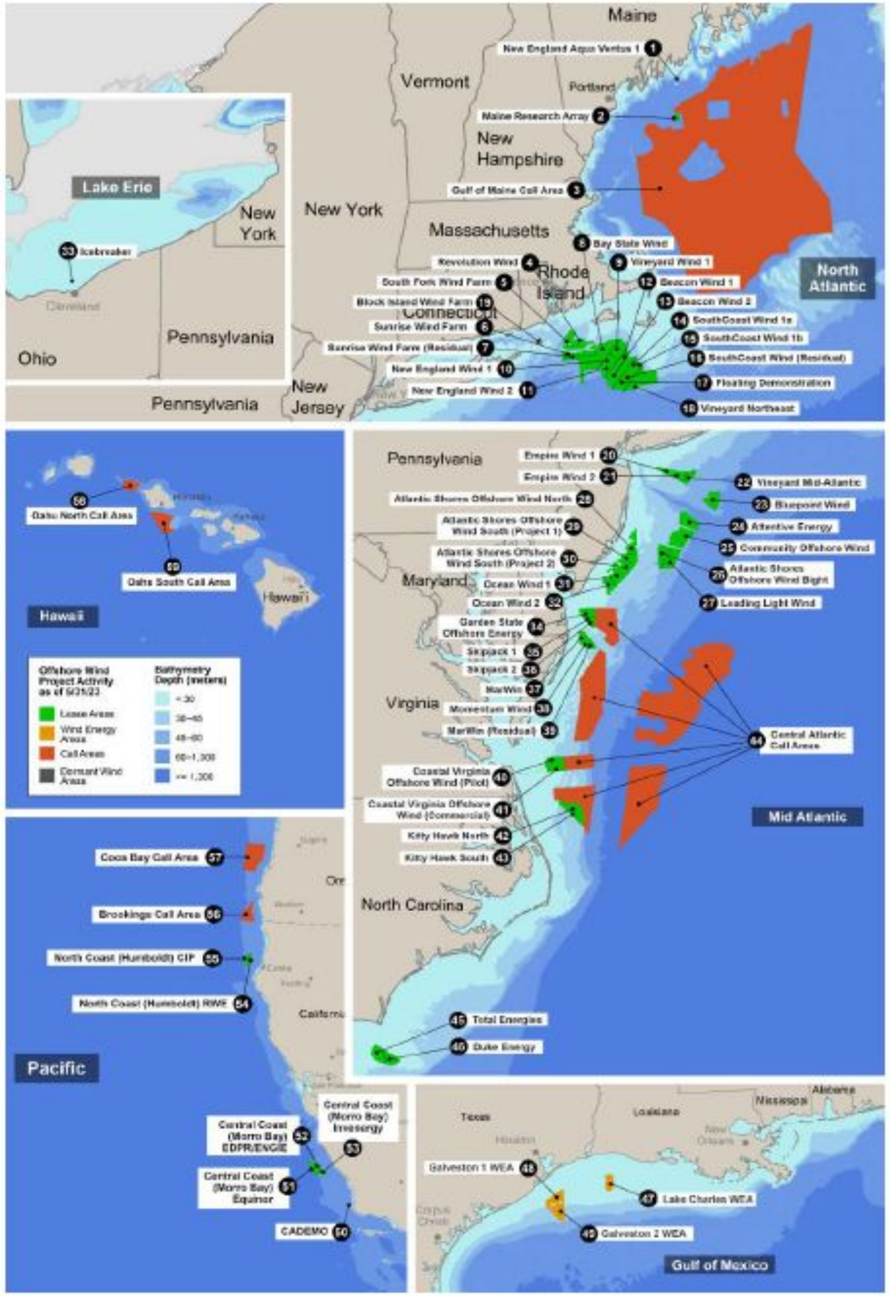
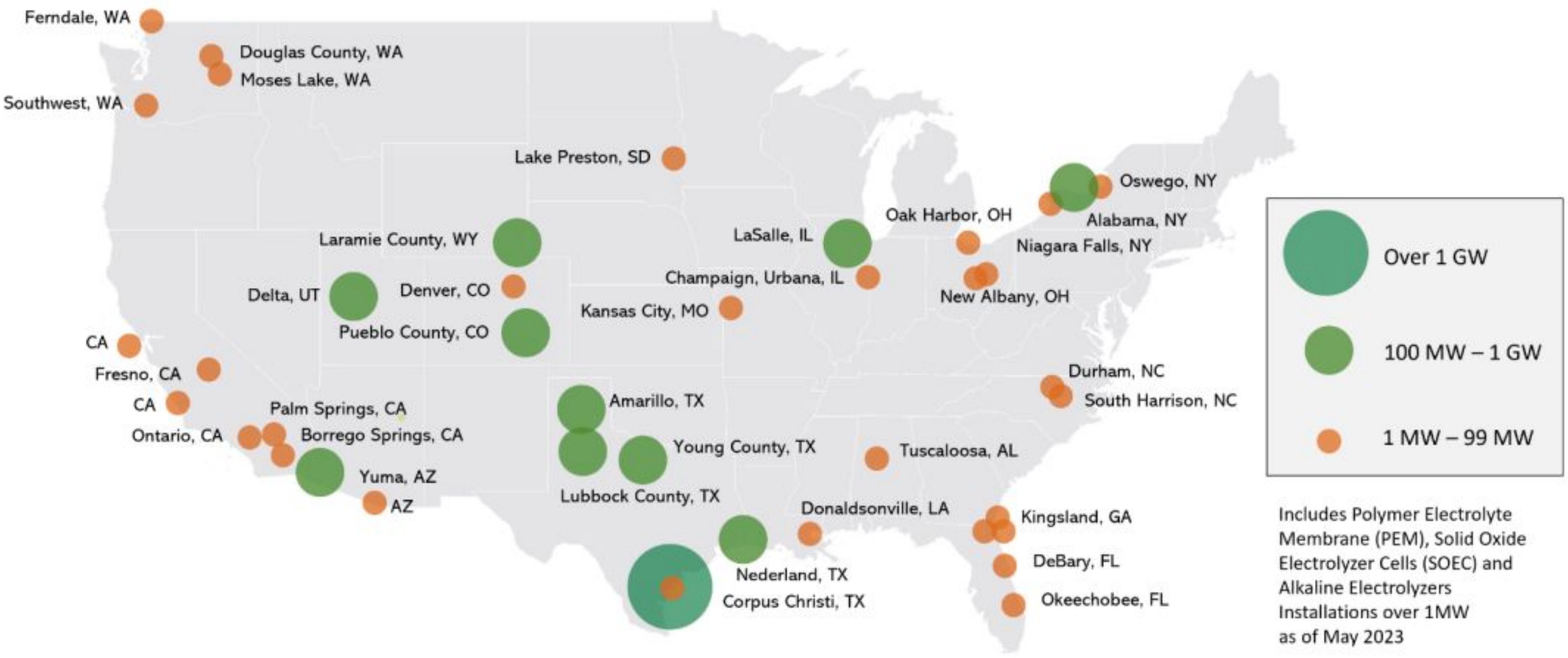


Figure ES-1. Locations of U.S. offshore wind energy pipeline activity and Call Areas as of M
2023. *Map created by John Frenzl, National Renewable Energy Laboratory*

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

Lisaks Jaapanile ja Koreale Ostwaldi ideed elavad ka USAs ja EL arenenud riikides:ehitatakse elektrolüüsi jaamu

NB! 1GW EL
10 100 MW EL;
35 1-99 MW EL,
1kg H_2 nõuab 50 kWh elektrit.
Seega 1h jooksul 1GW EL toodab 20 tonni H_2.
1kg saab Toyota Mirai sõita 130-180 km.
12m buss 15-20km.



(b) Planned and installed PEM electrolyzer capacity over 1 MW. Bubbles are for illustrative purposes only and not drawn to scale. [49]

Figure 8: Examples of announced clean hydrogen technology deployments in the United States.

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

The producion 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],

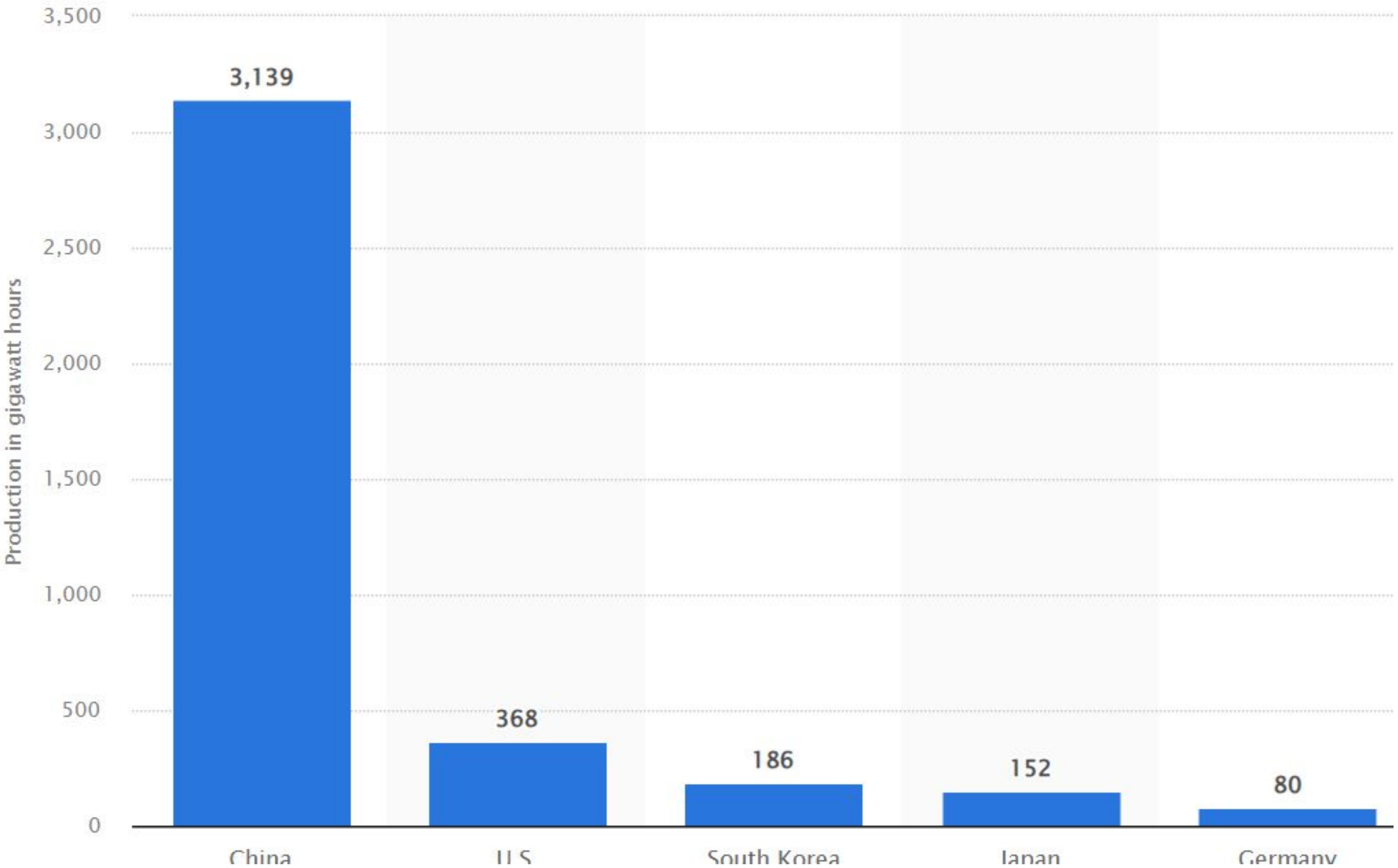
www.energy.gov › eere › fuelcellsFuel Cells | Department of Energy
DOE has set ultimate targets for fuel cell system lifetime under realistic operating conditions at 8,000 hours for light-duty vehicles, 30,000 hours for heavy-duty trucks, and 80,000 hours for

www.grandviewresearch.com › fuel-cell-marketFuel 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.
- Hyndai 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 CO_2 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 + taastuvenergia 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:

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

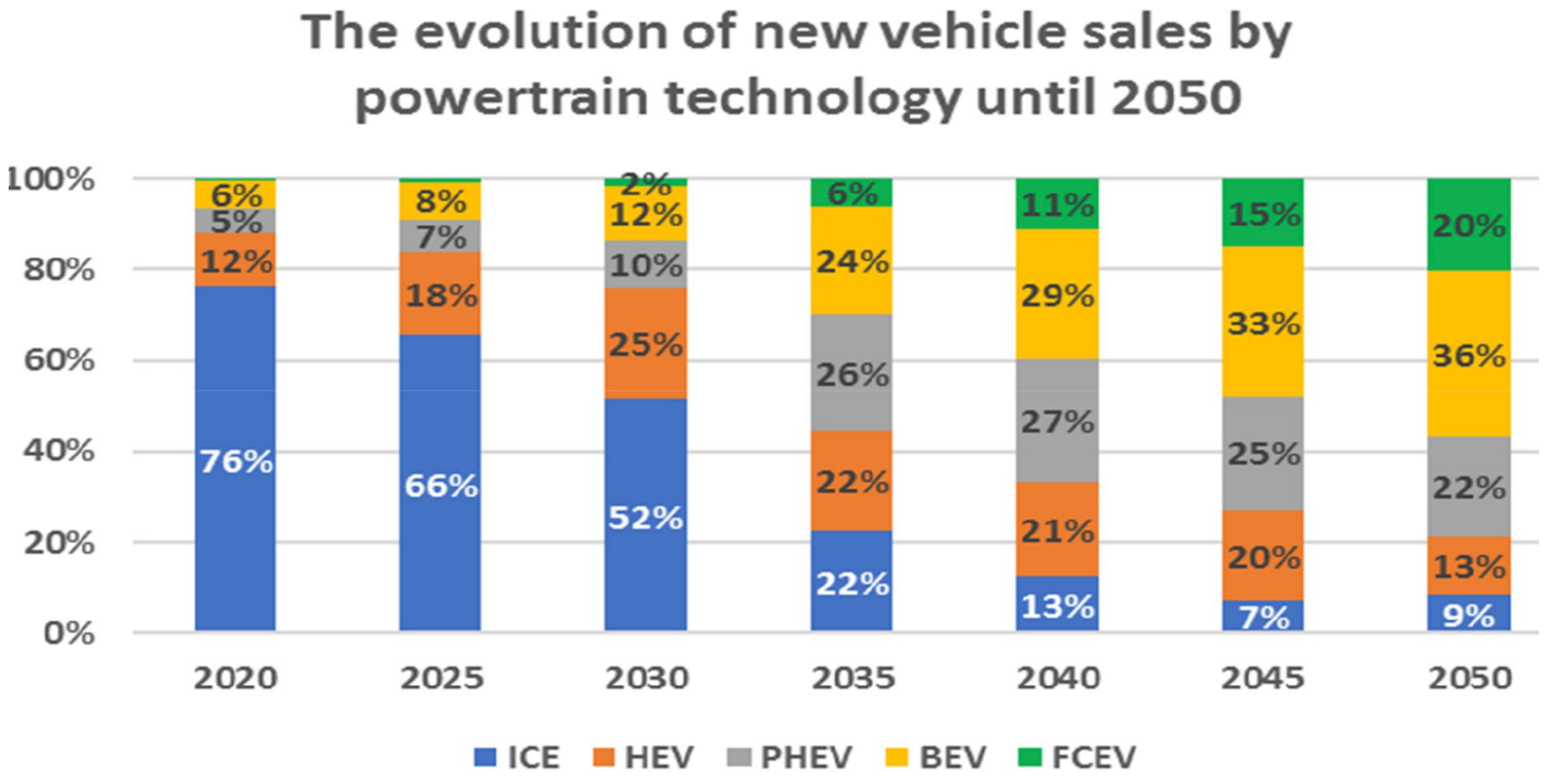
HEV hübriid (ICE+ patarei)

PHEV- Plug in Hybride EV

BEV-patareidel auto

FCEV vesinik + kütuseelement

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



Int.J.of Hydrogen Energy, 2022, 44,9121.9142

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>2023/02724>hybdai 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

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

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!

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

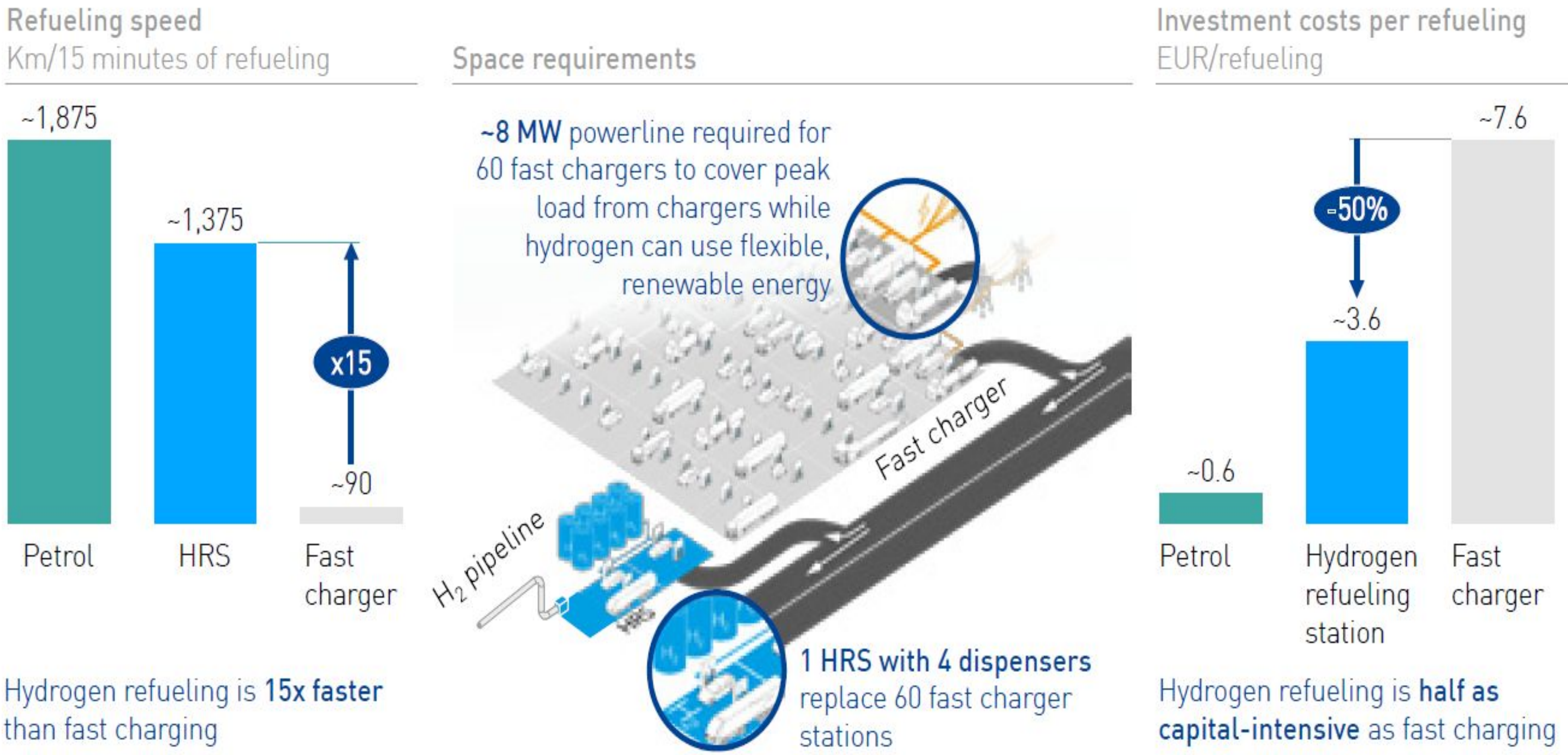
HIGHLIGHTS | HYDROGEN | MARKETS | MARKETS & POLICY | POLICY | TECHNOLOGY | TECHNOLOGY AND R&D | AUSTRALIA | JAPAN

Image: HySTRA

https://www.pv-magazine.com/2022/01/21/australia-to-make-worlds-first-liquefied-hydrogen-shipment-to-japan/

Vesiniku transport võrreldes elektriga on palju kiirem ja odavam. 1 standartne H_2 tankla, milles 4 H_2 tankimise püstolit, asendab 60 kiirlaadimisseadet kogu võimsusega 8 MW! H_2 tankla ehitamine on 50% odavam kui sama tankimisvõimsusega kiirlaadimissüsteemi ehitamine. Põhiline probleem on seotud võrkude puudumisega.

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



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

https://fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

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.

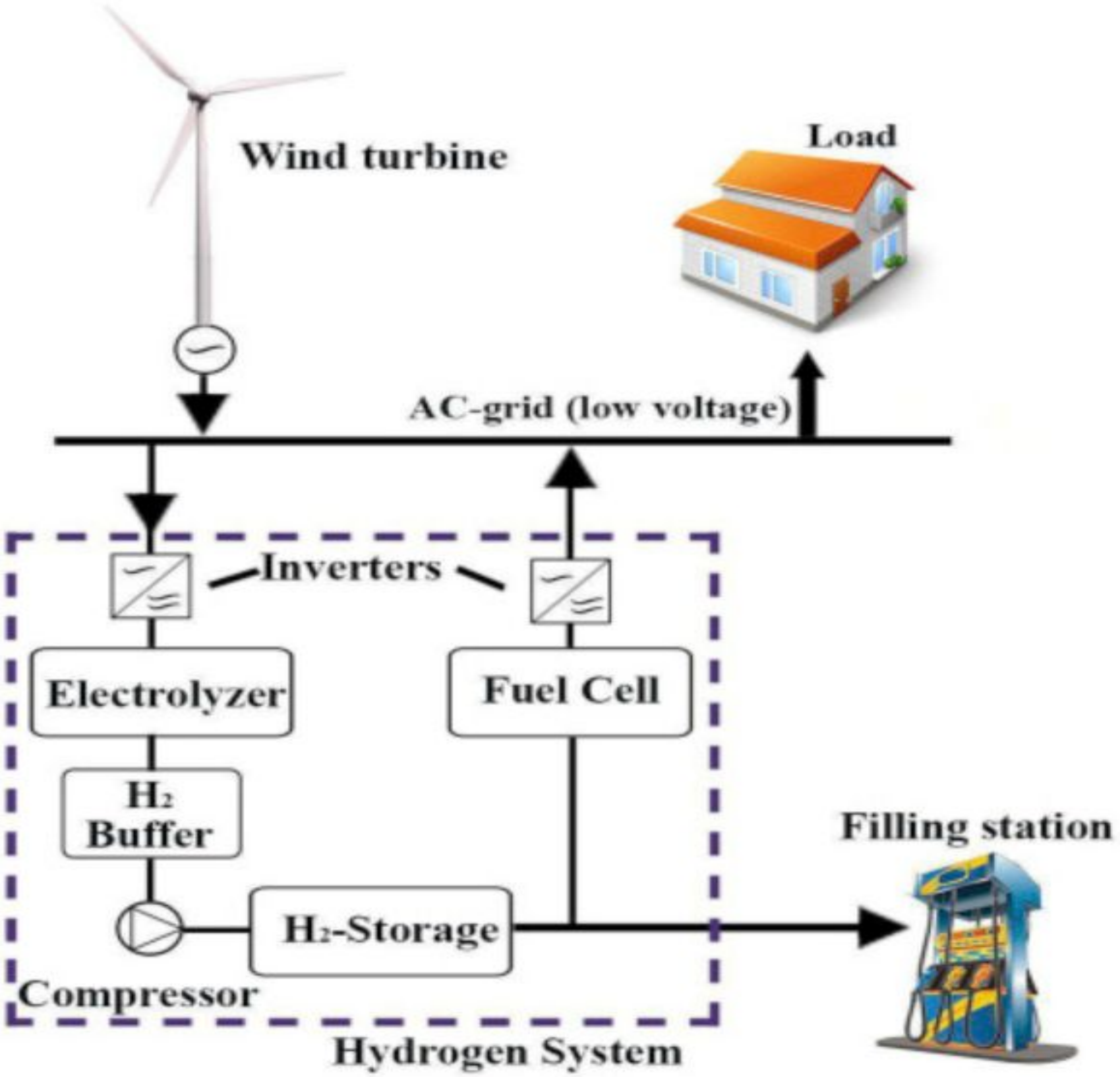


Fig. 1. Schematic of hydrogen production through wind energy.

O. Nematollahi, Energy 175 (2019) 914-930

Lõpetuseks:

Vesiniktehnoloogia on osades kohtades juba momendil majanduslikult väga tasuv, osade elualade jaoks aga vaja olulist H_2 maksumust vähendada, et H_2 kasutamine oleks kasumlik.

Rohelise vesiniku massiline kasutamine tööstuses (metallide tootmine, NH_3 ja MeOH) eriti aga küttemajanduses nõuab rohelise H_2 hinna väga olulist alandamist.

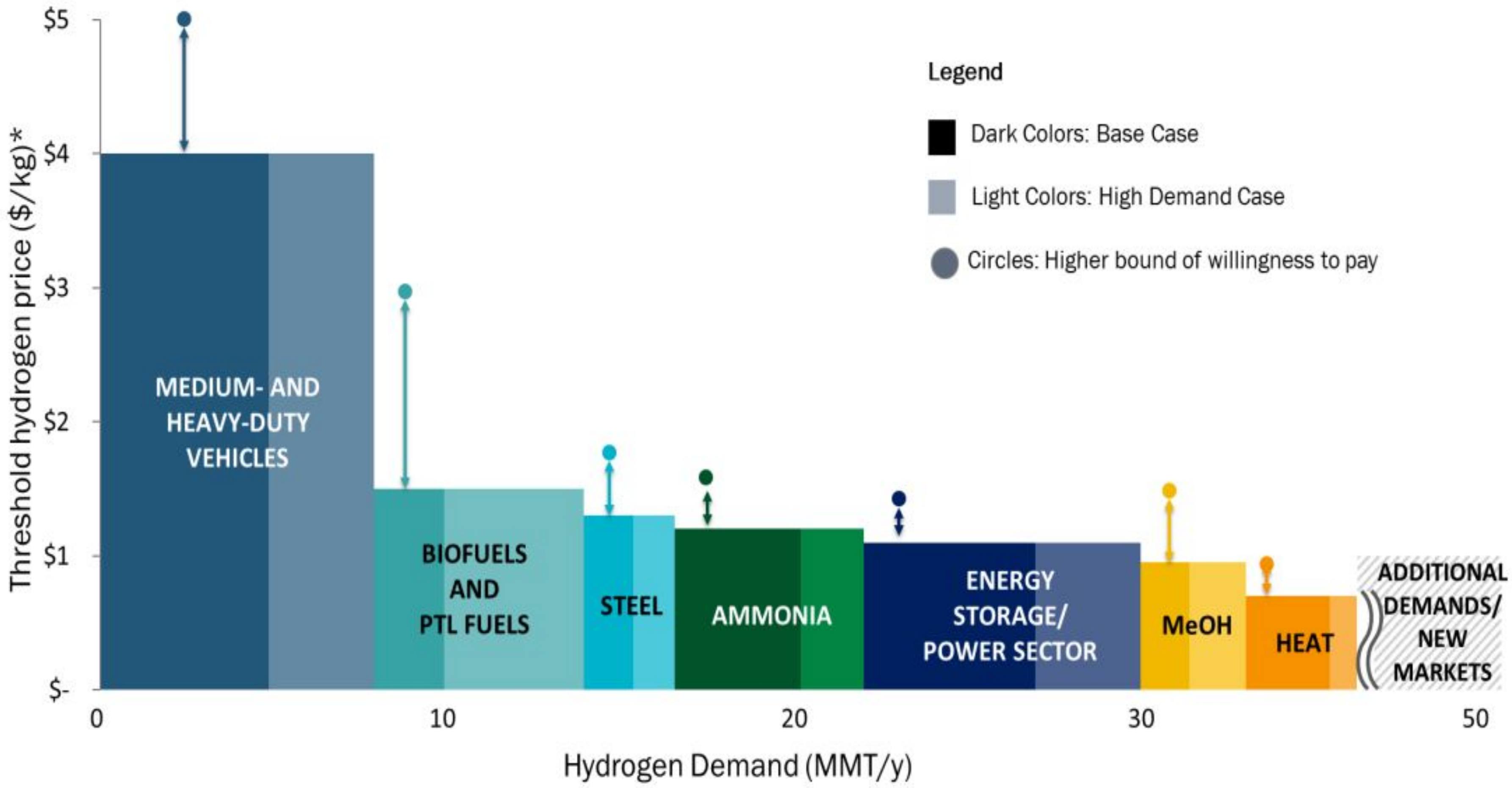


Figure 11: Scenarios showing estimates of potential clean hydrogen demand in key sectors of transportation, industry, and the grid, assuming hydrogen is available at the corresponding threshold cost.

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

Kokkuvõte:
Peamised vesinikutehnologia arendussuunad Eestis ja Läänemere regioonis:

- Intensiivistada vesiniku- ja taastuvenergeetika spetsialistide ettevalmistamist (magistrid, doktorid, järeldoktorid) uue komplekteeritava aineprogrammi alusel ja võimaldada elukestvat taastuenergeetika täiendõppet soovijatele
- Projekteerida ja välja ehitada tuule- ja päiseelektri (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 elektrolüüseri 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 kasutamisvõimalusi energiamahukas tööstuses (kustutamata lubja tootmine, klaasitööstus, tsemenditööstus, ammoniaagi ja lämmastikväetiste tootmine, haruldaste rasksulavate pulbermetallide tootmine jne).
- Kaaluda biogaasi (60-65 % CH_4 ja 30-35% CO_2) 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 elektit ja soojust) arendamise võimalusi, installeerides kütuseelemendid ja elektrolüüserid ning energiasalvestid, ühildades need ilmastikuprognoosidega ja elektrienergia börsihindadega

Tänan 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 developmemt project
- Iseauto contract AuveTECH OÜ; SOEL (300W) contract with H2Electro, contract with Stargate Hydrogen for testing of novel materials, etc.

Fotode autor: Viivi Järve

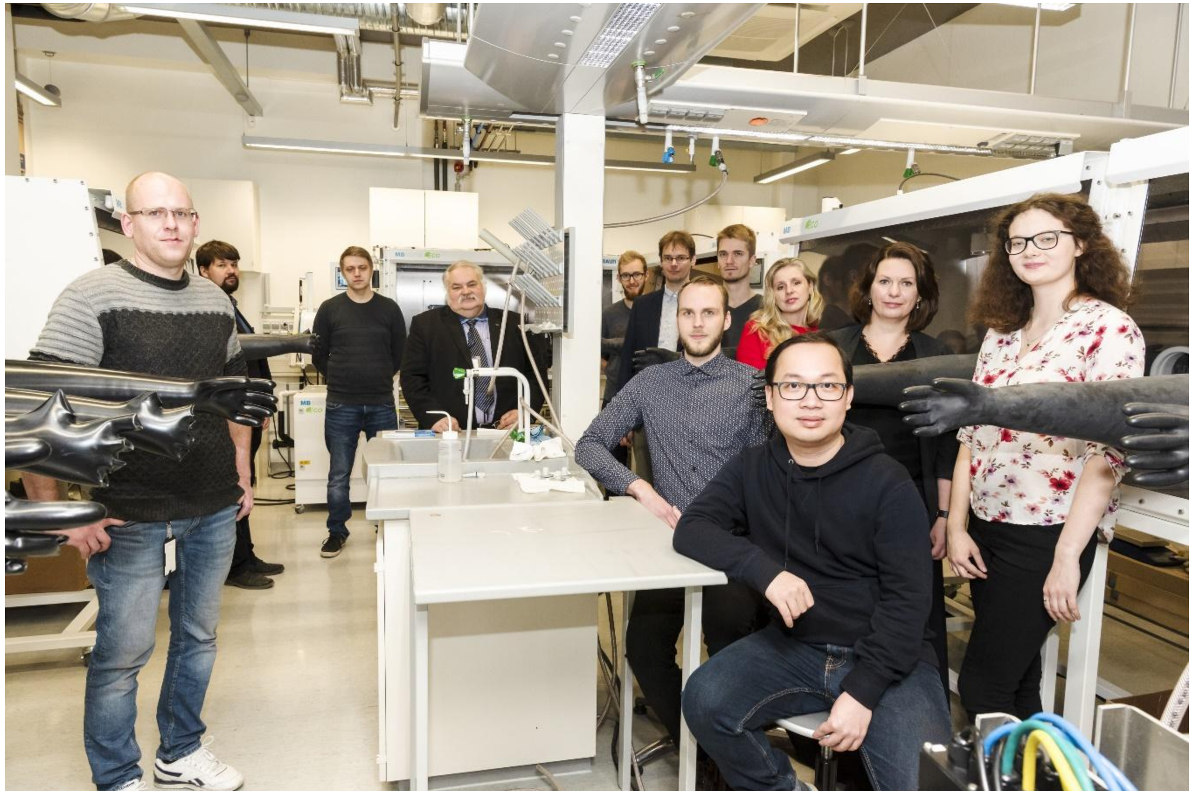


TABLE I Parameters Used In Case Studies*

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

Need võiksid olla arvestusli-kud hinnad 2023.

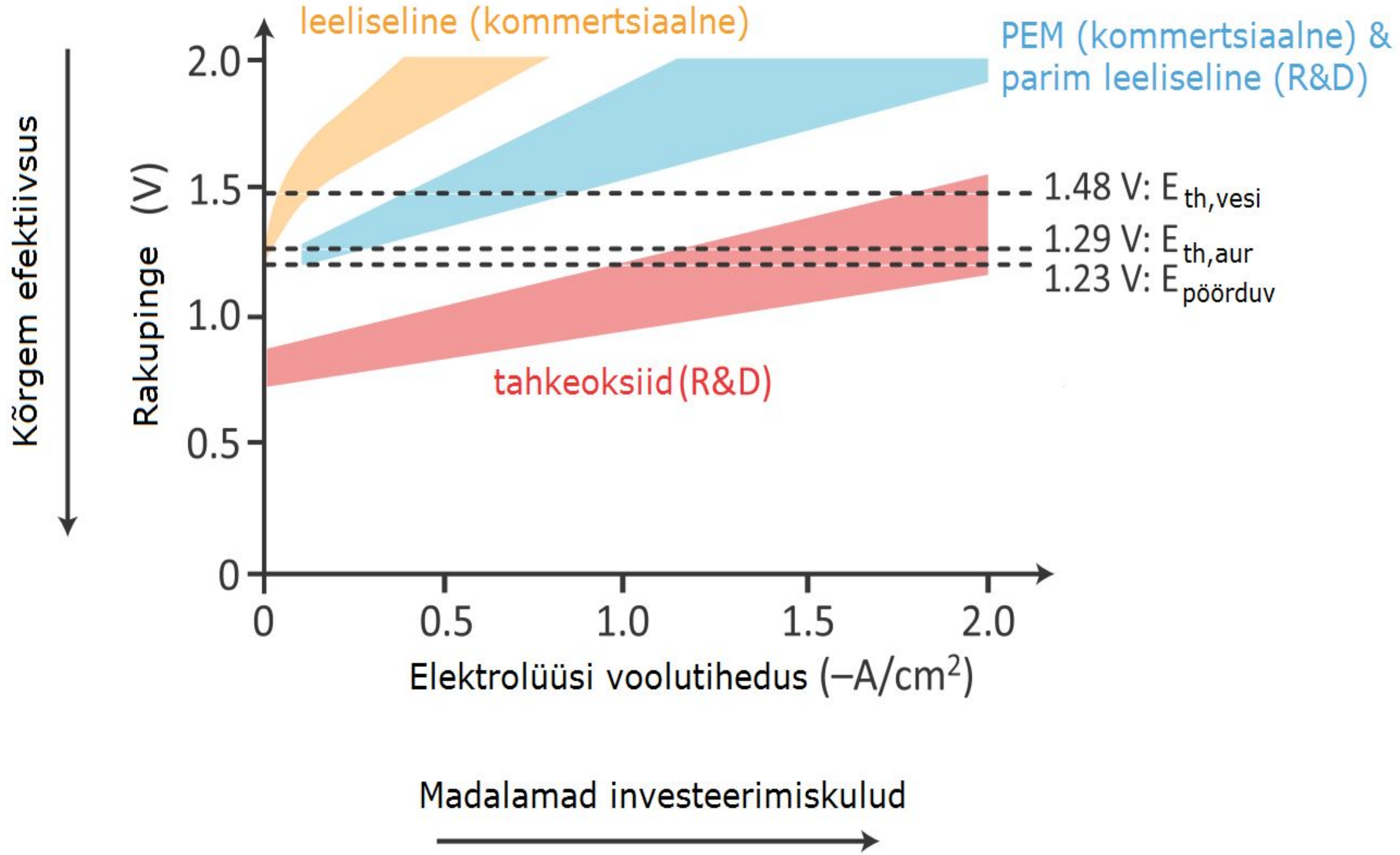
Vertical-Axis Wind Turbines Work Well Together

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 potensiaal standardolekus.

USAs kuulutatakse peaaegu iga nädal välja mingi järgmine projektide esitamise kogumise võistlusvoor!
Projektid 0.5 kuni 10-20ne Miljoni USD.

Solar Energy Technologies Office

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.

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

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%

Analysis of the CO_2 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 CO2 content	*kg CO2e / l*	2.68	2.68	2.68	2.68
Hydrogen CO2 content assuming UKH2M targets	*kg CO2e / kg H2*	4.17	3.34	2.50	2.09
Grid electricity co2 content	*kgCO2e / 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 CO2 emissions					
Diesel bus	*Tonnes CO2 / year.bus*	79	79	79	79
Fuel cell bus	*Tonnes CO2 / year.bus*	39.66	31.73	23.80	19.83
Electric bus	*Tonnes CO2 / year.bus*	51	36	31	29
Cost of CO2 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

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

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	*g / kWh*	1.50	0.13	0.40	0.01
Bus efficiency	*kWh / 100km*	396	396	396	396
Bus mileage	*km / year*	80,000	80,000	80,000	80,000
Pollution over 12 year lifetime	*Tonnes*	5.70	0.49	1.52	0.04
Marginal cost of pollutant	*EUR / tonne*	-	-	1,000	67,650
Cost per bus	*EUR / bus*	-	-	1,520	2,571

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

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 patatерides (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 H_2 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 H_2 to help offset more than 50 MMtpy of CO_2.

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 H_2 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

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

23rd Annual

Advanced Automotive Battery Conference

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

AdvancedAutoBat.com/US

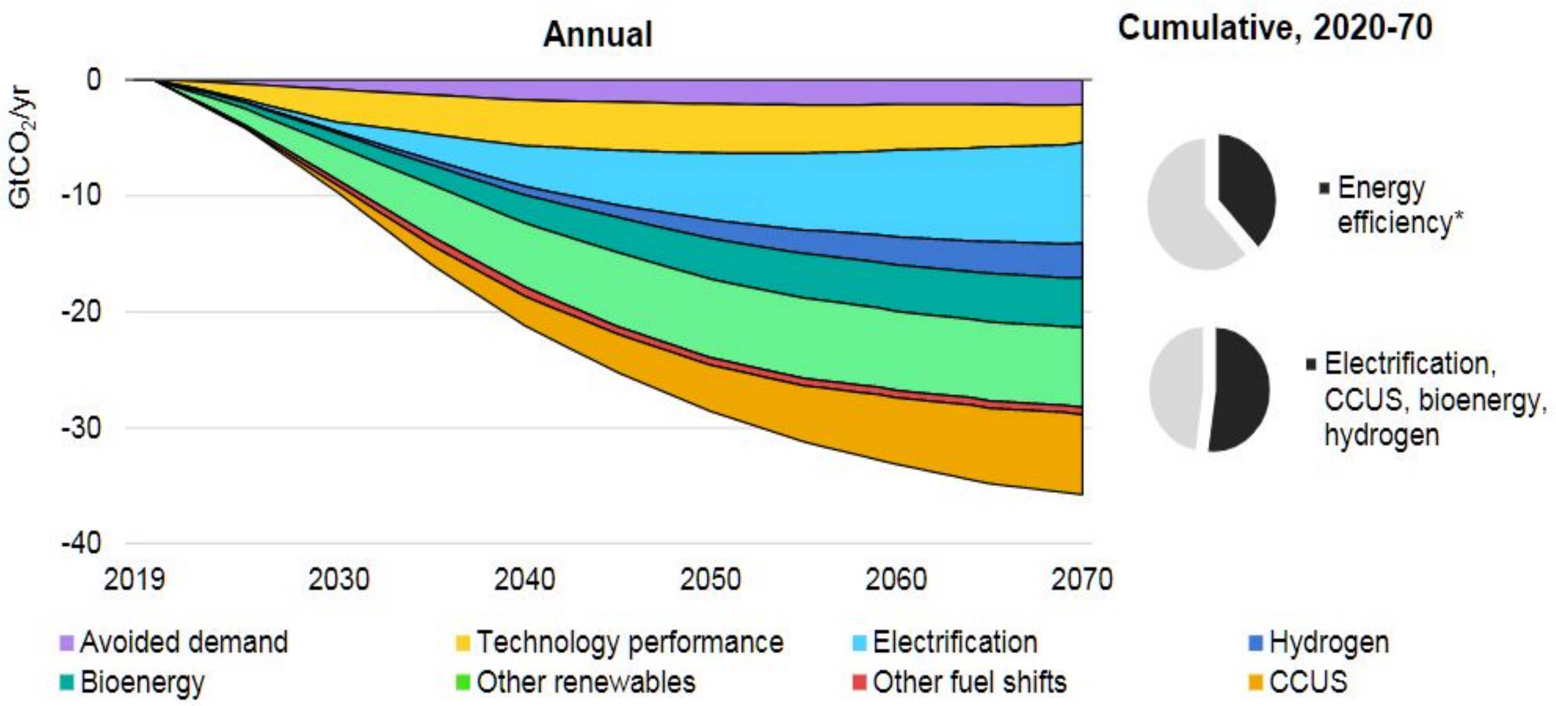
Põhilised patareide arendajad:

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.

Seega CO_2 tootmise vältimise põhilised võimalused/suunad on:

- roheline elekter,
- vesiniktehnoloogiad,
- bioenergia,
- muud taastuvenergia 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)

Figure 2.2 Global energy sector CO_2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-70



* 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.

https://www.iea.org/reports/energy-technology-perspectives-2020?utm_campaign=IEA%20newsletters&utm_source=SendGrid&utm_medium=Email

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.