CCS ja muud tehnoloogiad, mida on võimalik juurutada põlevkivi kasutamisele

„ESTIS-e koolitus:

Põlevkivi tulevik Eestis“

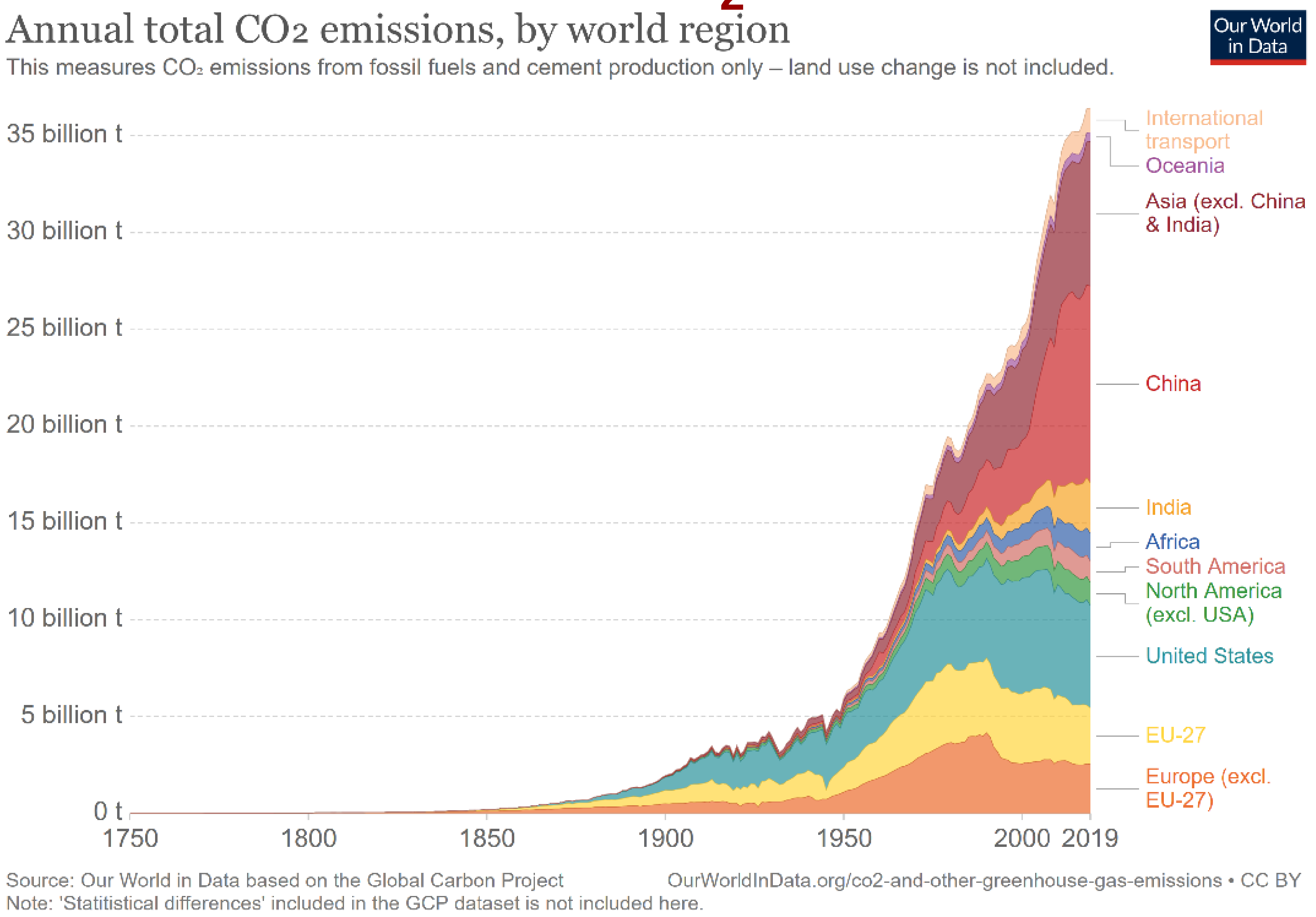
Professor Alar Konist

Energiatehnoloogia instituut

Tallinna Tehnikaülikool

MAAILM

Maailma CO_2 heitmed

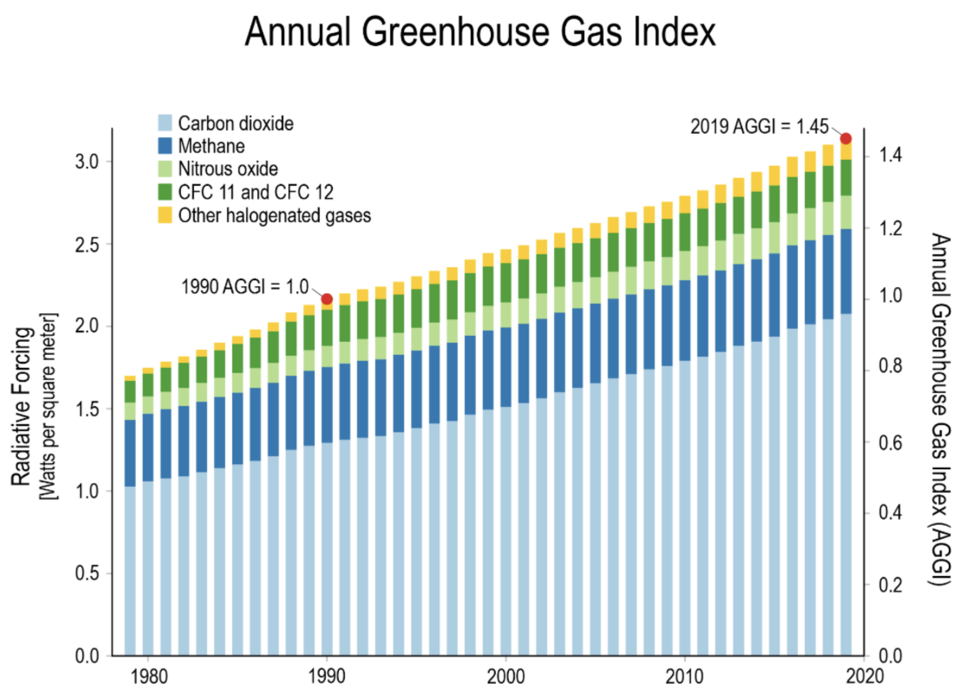


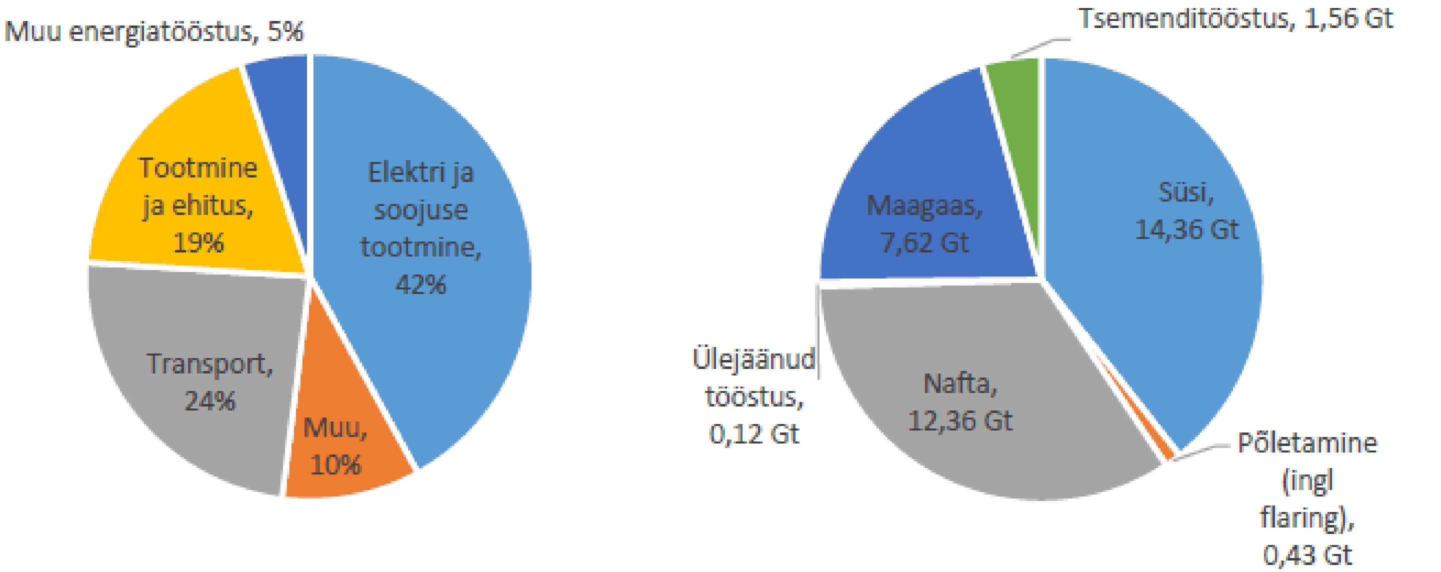
TAL TEC

Joonis 2. Maailma CO_2 heitmed aastate lõikes. Allikas: Our World In Data [6]. Andmete allikas: Global Carbon Project ja Carbon Dioxide Information Analysis Centre [10].

Allikas: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021

CO_2 heitmed





Joonis 3. Maailma CO_2 heitmed aasta 2016 sektori järgi (vasakpoolne diagramm; andmete allikas: IEA [6]) ja aastal 2019 kütuse liigi järgi (parempoolne diagramm; [10])

TAL TECH

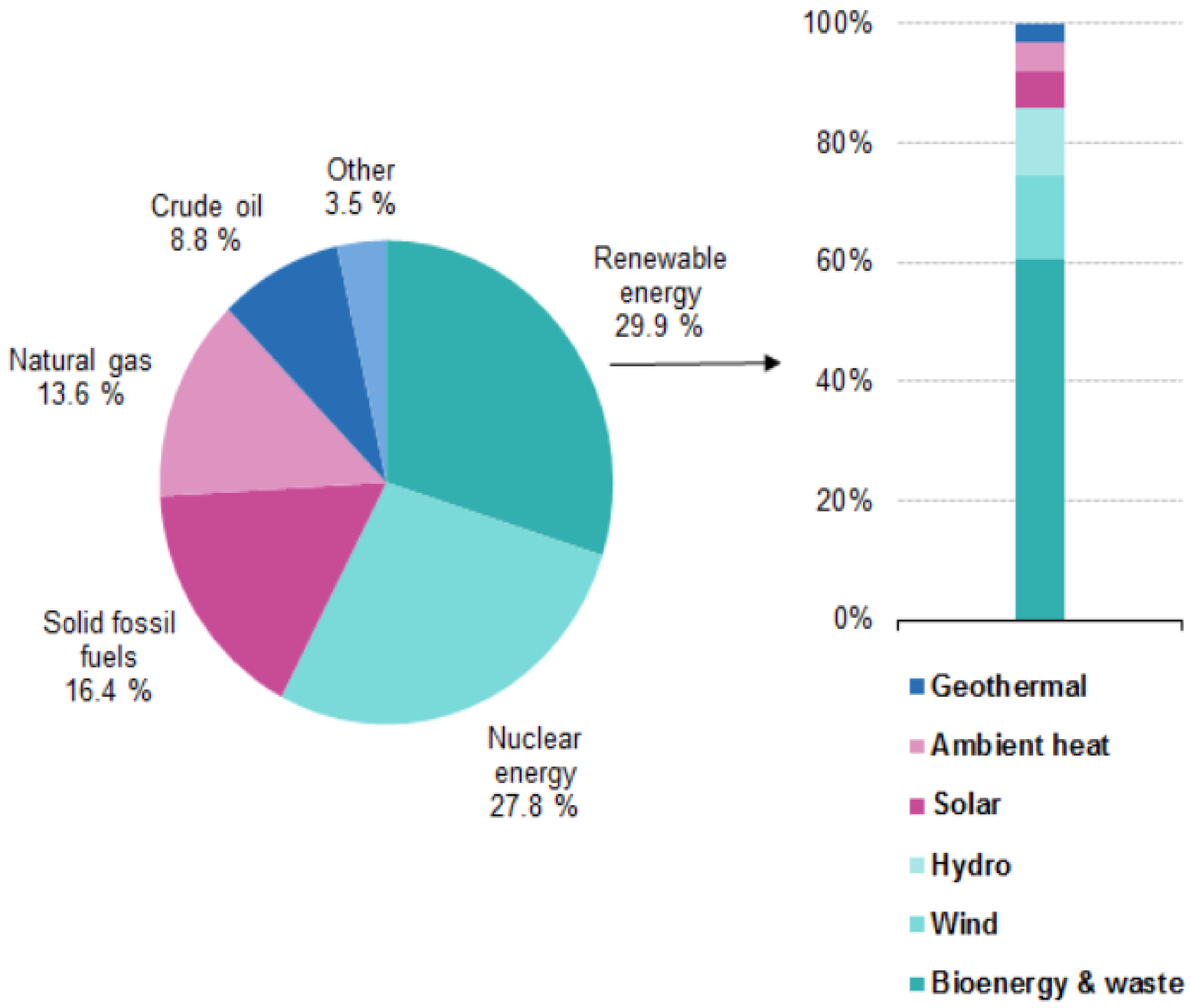
http://www.stat.fi/til/ehk/2019/ehk_2019_2020-12-21_tie_001_en.html

Statistics Finland - Energy supply and consumption

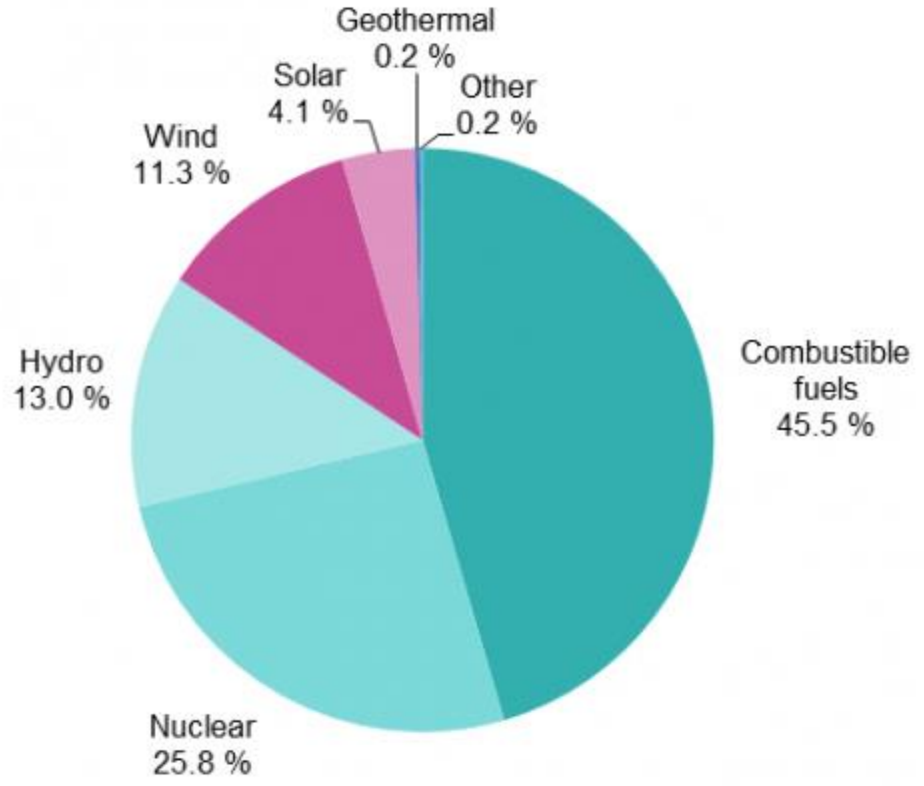
Allikad: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021
https://ccsknowledge.com/what-is-ccs/climate-change

EU-28 primaarenergia tootmine ja neto elektritootmine, (Eurostat, 2017)

Production of primary energy, EU-28, 2017
(% of total, based on tonnes of oil equivalent)

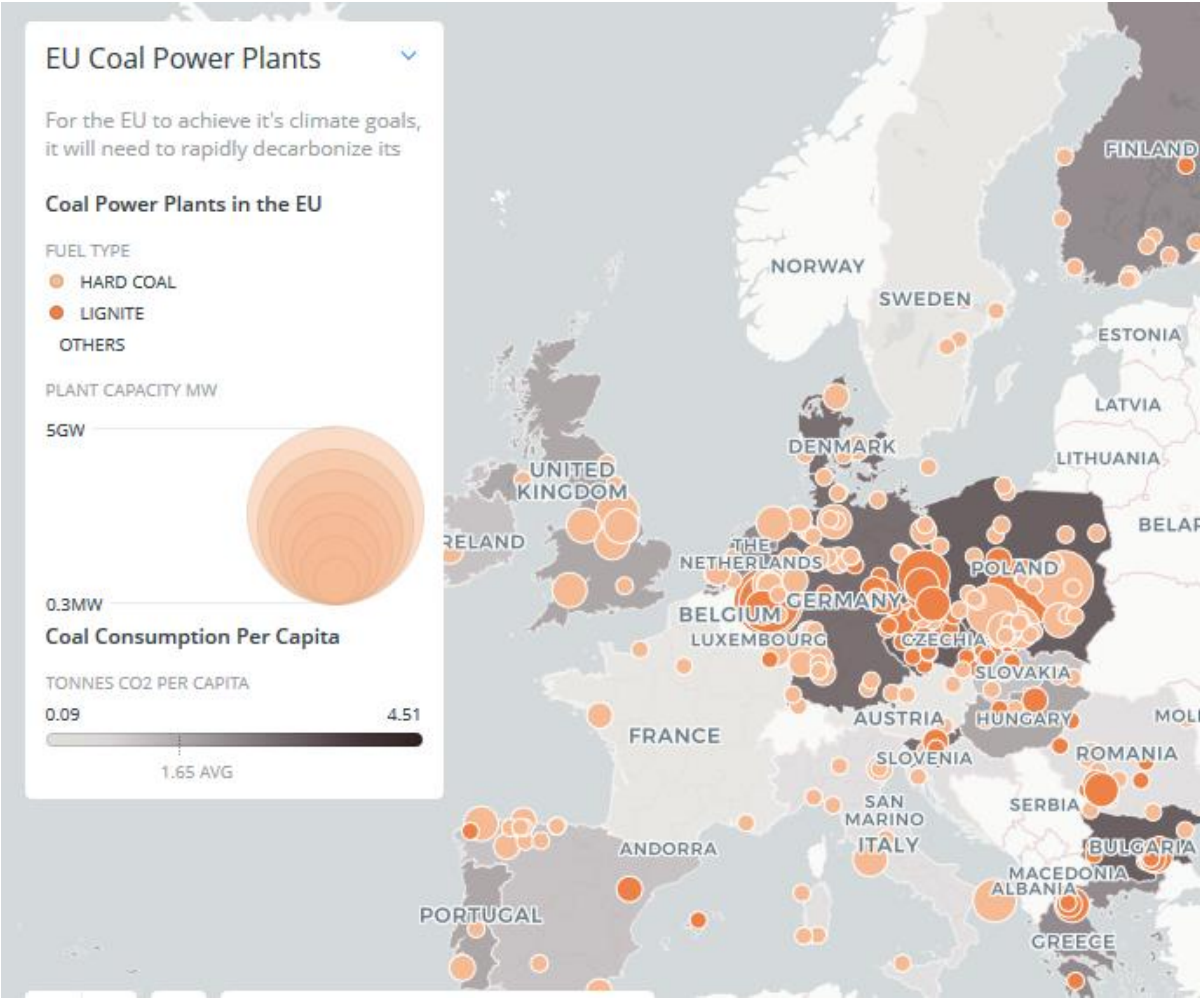


Net electricity generation, EU-27, 2018
(%, based on GWh)



Source: Eurostat (online data code: nrg_ind_peh)

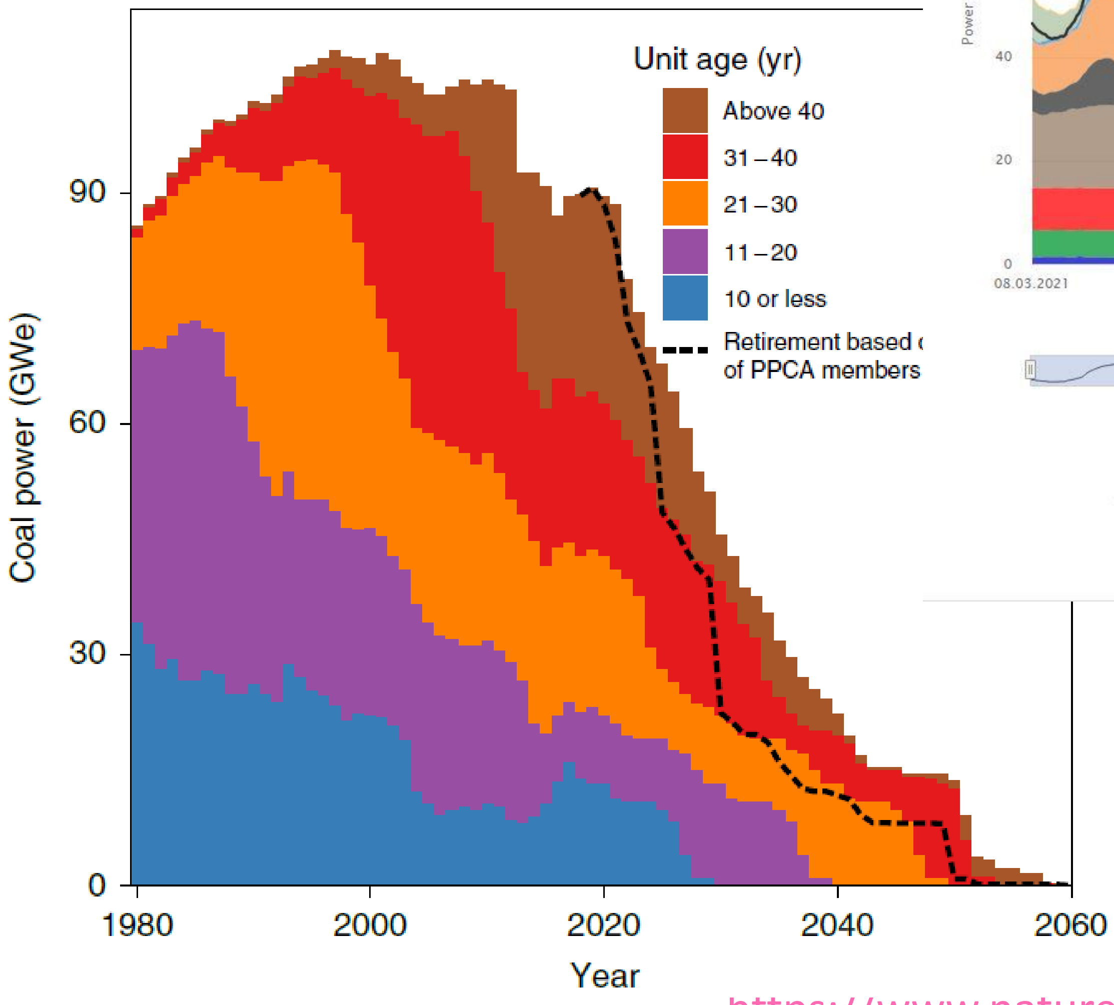
eurostat

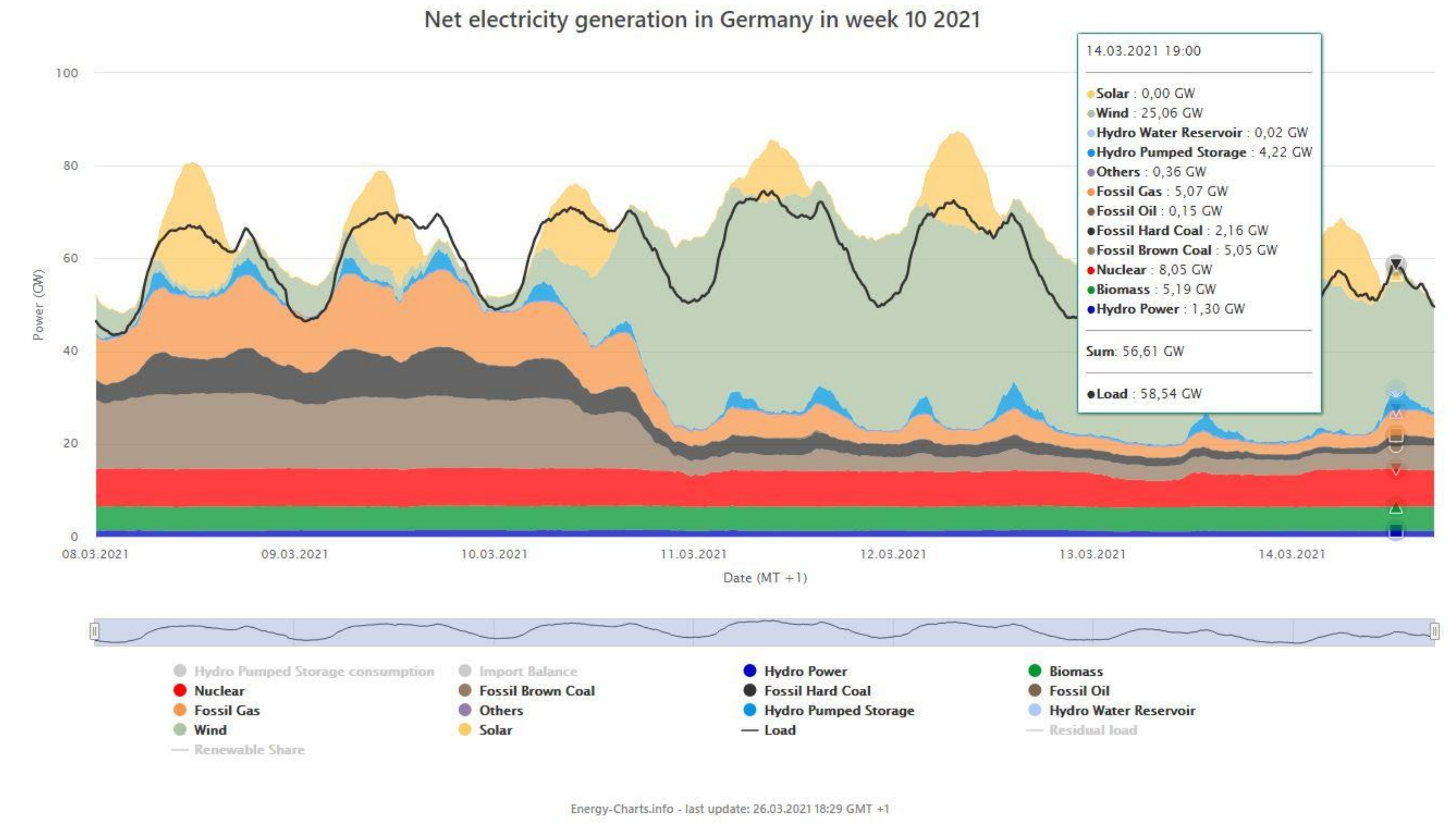


TAL TECH

https://climateanalytics.org/briefings/eu-coal-phase-out/

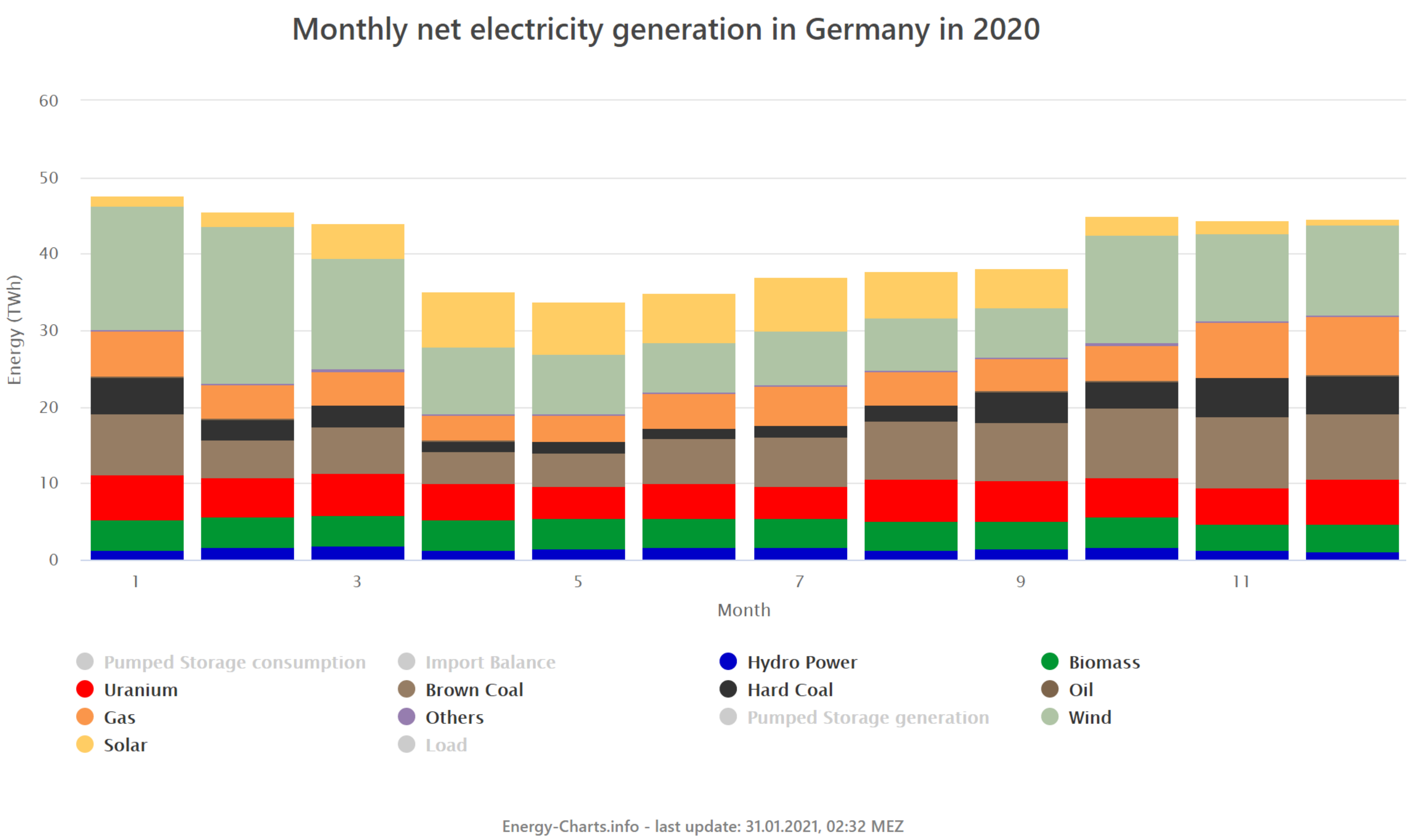
Age of coal firing units





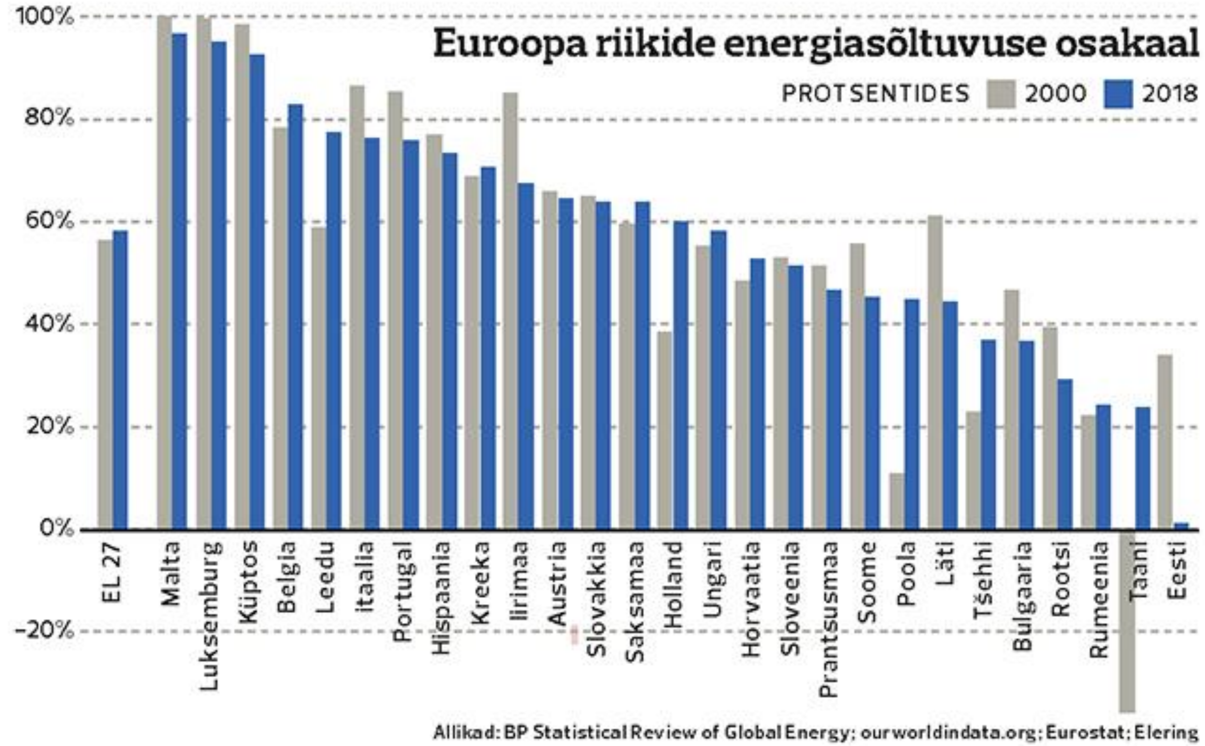
https://www.nature.com/articles/s41558-019-0509-6.pdf

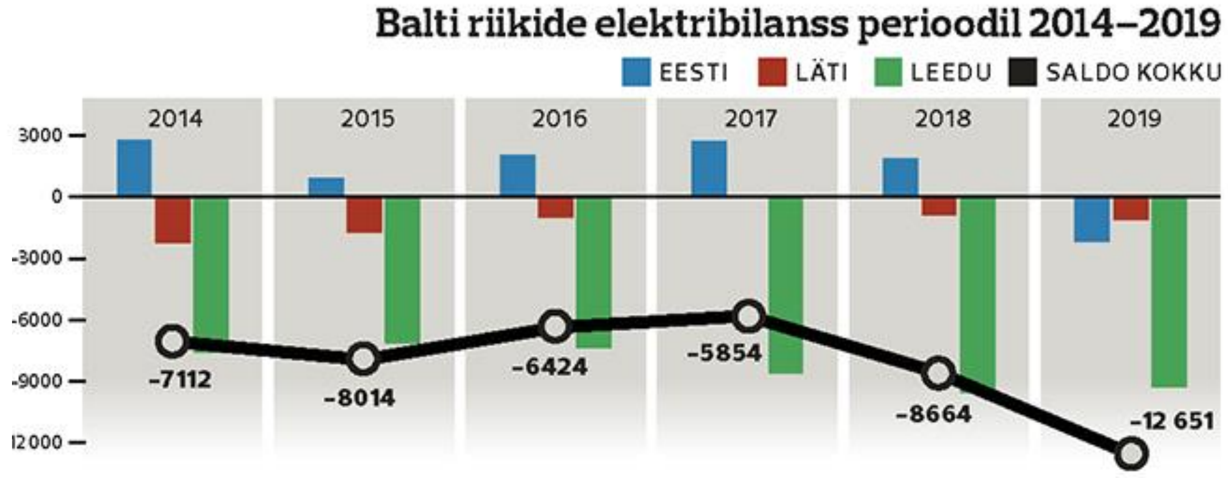
https://energy-charts.info/charts/power/chart.htm?l=en&c=DE

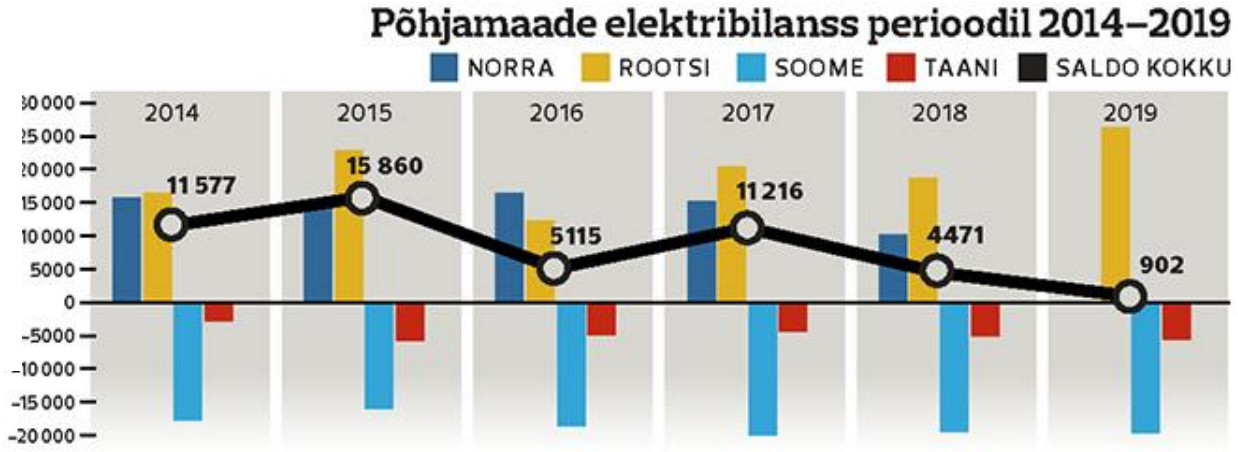


Monthly net electricity generation in Germany in 2020
Energy (TWh)
0
10
20
30
40
50
60
1
3
5
7
9
11
Month
Pumped Storage consumption
Import Balance
Hydro Power
Biomass
Uranium
Brown Coal
Hard Coal
Oil
Gas
Others
Pumped Storage generation
Wind
Solar
Load
Energy-Charts.info - last update: 31.01.2021, 02:32 MEZ

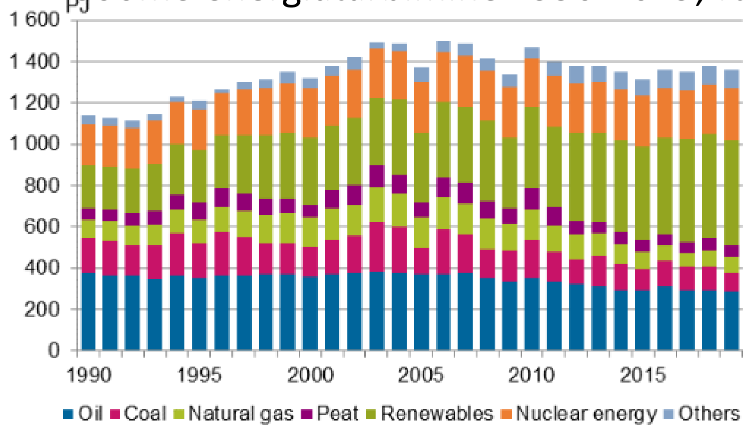
Lähiriikide elektribilanss ja energiasõltuvus







Soome energiatarbimine 1990-2019, PJ



Süsinikdioksiidi maailm

GLOBAL CARBON CYCLE

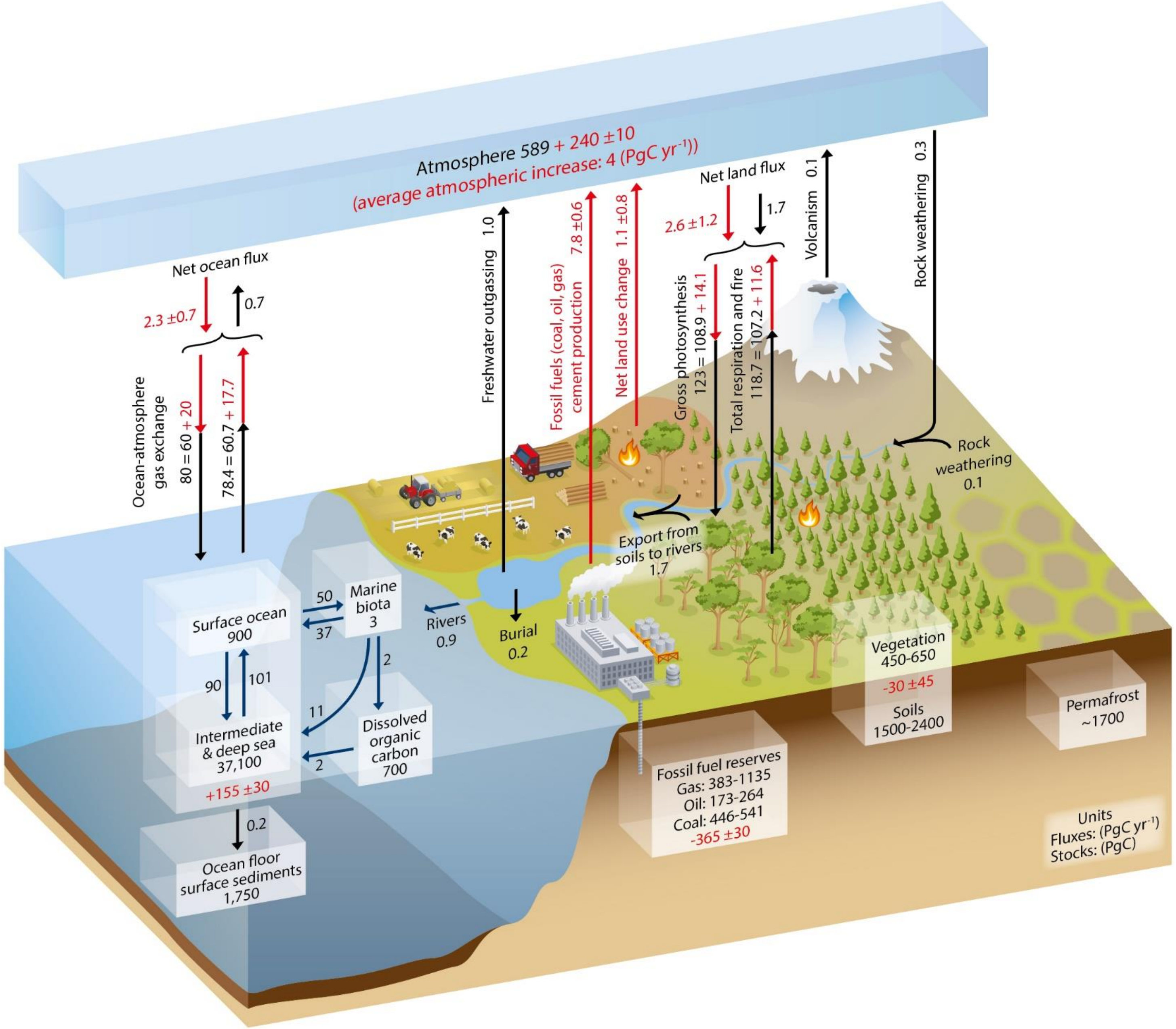
Red lines shows human contribution

Atmosphere: 800 Gt

Hydrosphere: 40,000 Gt

Biosphere: 2,500 Gt

Lithosphere: 65,000,000 Gt



https://www.ipcc.ch/site/assets/uploads/2018/02/Fig6-01-2.jpg

TAL TECH

CO_2 teke, kinnipüüdmise kogused ja hinnad

Table 1 Potential sources of waste CO_2 (most recent available estimates)

CO_2 emitting source	Global emissions[a] (Mt CO_2/year)	CO_2 content[a] (vol%)	Estimated capture rate[b] (%)	Capturable emissions (Mt CO_2/year)	Benchmark capture cost[b] (€ $_{2014}$/t CO_2) [rank]	Groups of emitters
Coal to power	9031[c]	12–15	85	7676	34 [6]	Fossil-based power generation
Natural gas to power	2288[c]	3–10[d]	85	1944	63 [9]	Fossil-based power generation
Cement production	2000	14–33	85	1700	68 [10]	Industry large emitters
Iron and steel production	1000	15	50	500	40 [7]	Industry large emitters
Refineries[e]	850	3–13	40	340	99 [12]	Industry large emitters
Petroleum to power	765[c]	3–8	Not available	Not available	Not available	Fossil-based power generation
Ethylene production	260	12	90	234	63 [8]	Industry large emitters
Ammonia production	150	100	85	128	33 [5]	Industry high purity
Bioenergy[f]	73[d]	3–8[d]	90	66	26 [2]	High purity/power generation
Hydrogen production[f]	54[g]	70–90[h]	85	46	30 [4]	Industry high purity
Natural gas production	50	5–70	85	43	30 [3]	Industry high purity
Waste combustion	60[i]	20	Not available	Not available	Not available	Industry large emitters
Fermentation of biomass[f]	18[d]	100[d]	100	18	10 [1]	Industry high purity
Aluminum production	8	<1[j]	85	7	75 [11]	Industry large emitters

[a] Data from Wilcox (2012) if not indicated otherwise

[b] See Table 2 for literature reference, assumptions, and calculation methods

[c] Data from IEA (2014) based on the largest point sources suitable for capture and not including the emissions of the large amount of emissions that are caused by small decentral point sources in the mobility and residential sector

[d] Data from Metz et al. (2005)

[e] Refineries could include ammonia and hydrogen production. A separate listing is nevertheless interesting to differentiate these two high purity from general refinery CO_2 streams. The capturable emission data based on the estimated capture rates should ensure that emissions are not included twice

[f] Undisclosed technological assumptions for emissions volumes and CO_2 content, if not indicated otherwise. For technological assumptions for cost data see Table 2. For bioenergy and fermentation, emission estimates are only for North America and Brazil

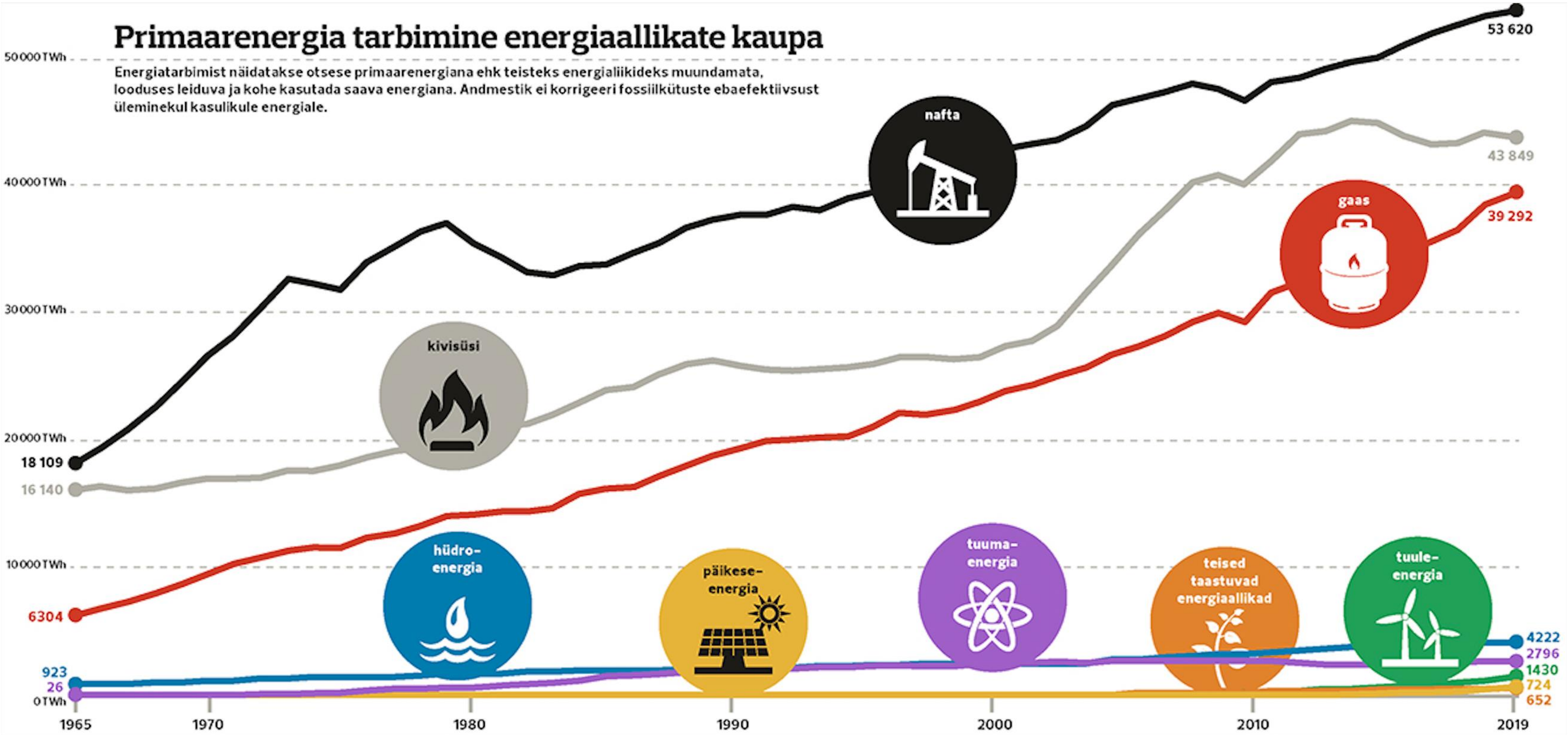
[g] Data from Mueller-Langer et al. (2007)

[h] Data for hydrogen from steam methane reformer from Kurokawa et al. (2011)

[i] Data from Bogner et al. (2007)

[j] Data from Jilvero et al. (2014), Jordal et al. (2014)

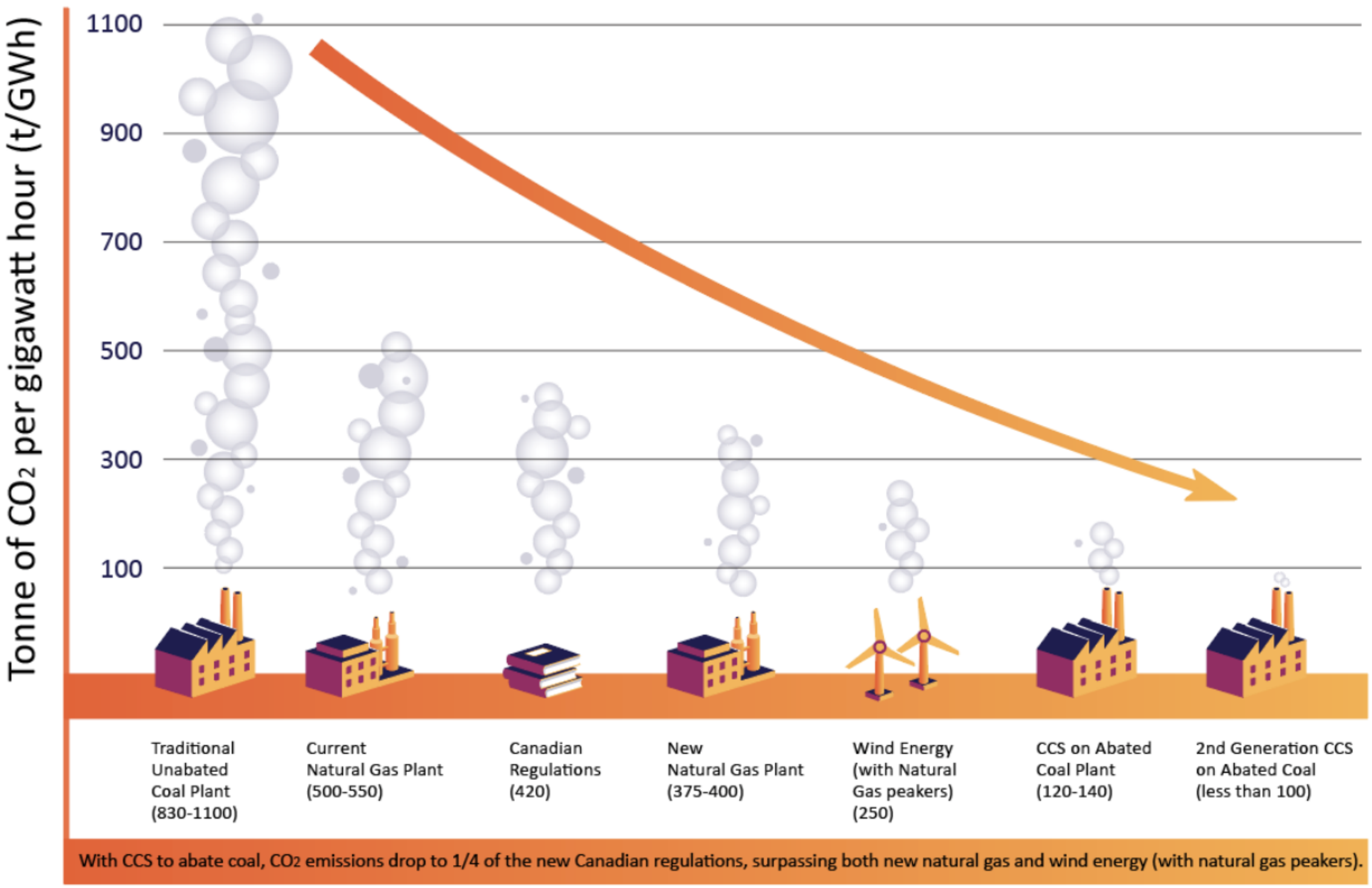
Allikas: https://link.springer.com/content/pdf/10.1007/s11356-016-6810-2.pdf



TAL TECH

Allikas: BP statistical review of Global Energy 2019 ja Postimees 2019

CO_2 Emissions - Significantly Reduced with Carbon Capture & Storage (CCS)



CCS prevents pollution, by capturing:

- 90% CO_2
- 100% SO_2
- 50% NOx
- 92% PM10
- 70% PM2.5

*numbers from Saskpower Boundary Dam 3 CCS Facilty

2nd Generation CCS Abated Coal Plant will reduce the CO_2 emissions to well below 100t\GWh

*based on data from Shand CCS Feasibility Study

INTERNATIONAL CCS KNOWLEDGE CENTRE

FIGURE 1: Greenhouse Gas Emissions Profiles and Performance Standards in Saskatchewan

1100 t/GWh = Lignite Coal Plant
550-500 = Current Natural Gas Plant
420 = Canadian regulations on Coal Plant
375-400 = New Natural Gas Plant
300-325 = Wind (with peakers)
120-140 = CCS on Boundary Dam 3*

TAL TECH

CCS plays a key role in reducing emissions within a diverse energy mix. This graph demonstrates that an abated coal plant with CCS is three times cleaner than new natural gas. Plus, with CCS, CO_2 emissions drop to a quarter of the current Canadian regulations.

Allikas: https://ccsknowledge.com/what-is-ccs/energy-mix

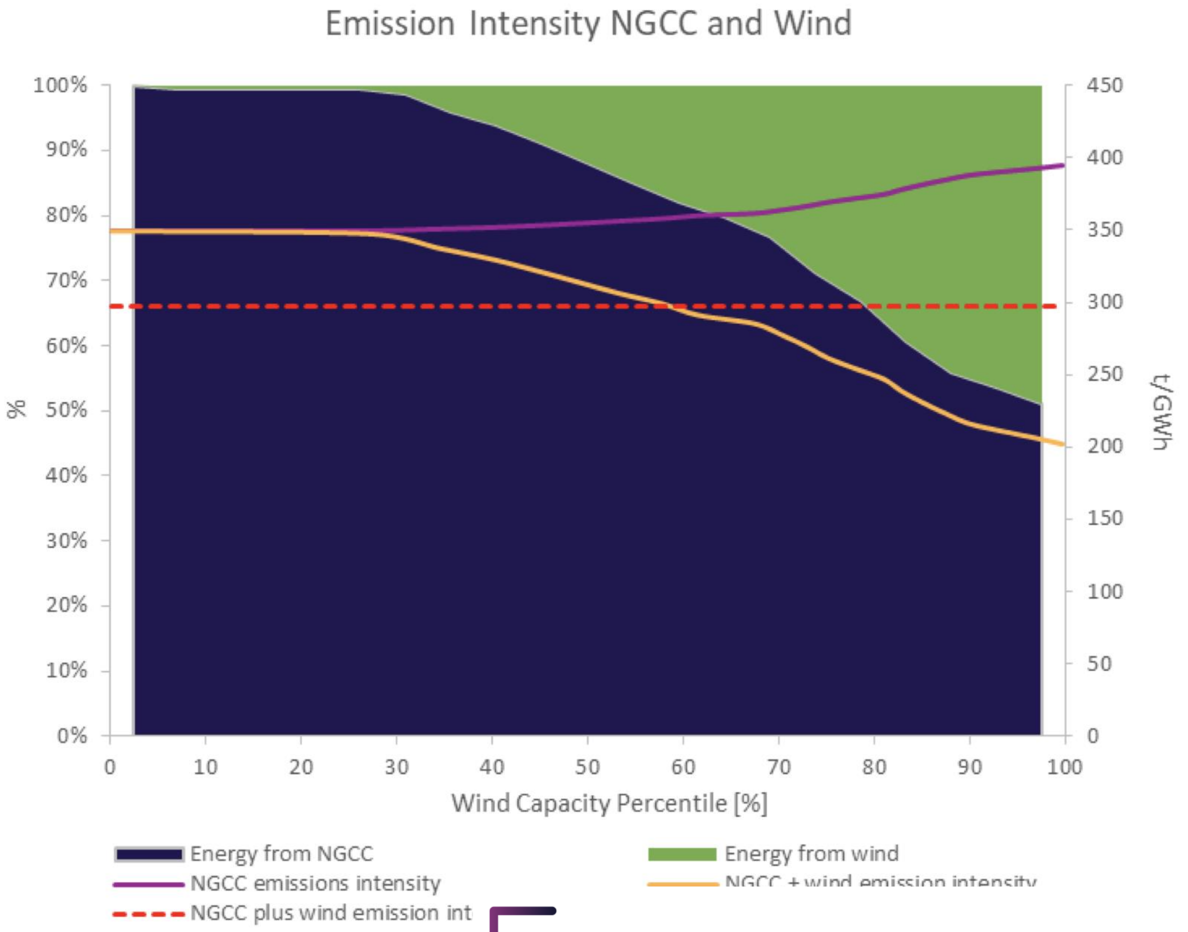
Kliimaneutraalsuse saavutamine 2050

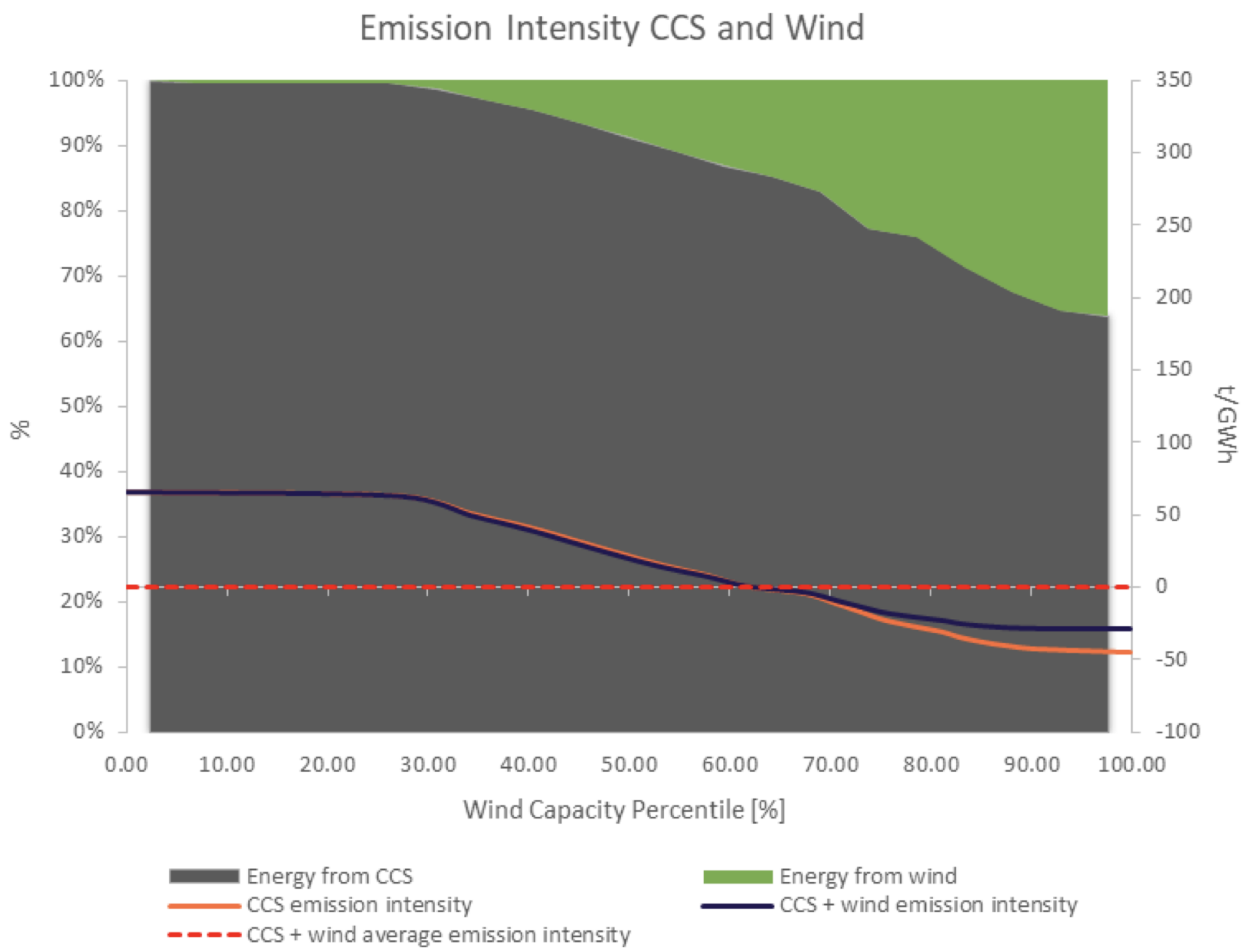
Hetkel ei ole Euroopa Liidul (EL) kindlaid seaduslikke õigusi kehtestada liikmesriikidele spetsiifilisi raamistikke, kuidas energiatootmine peaks toimuma saavutamaks eesmärki olla esimene kliimaneutraalne regioon maailmas 2050. aastaks.
Praxise eelmise aasta lõpul valminud aruandes on välja toodud, et kliimaneutraalsus ei ole 2050. aastal võimalik ilma heidet siduva LULUCF- sektorite või süsiniku püüdmise (CCS) tehnoloogiate kasutuselevõtuta.

CCS – CO2 sidumise ja ladustamise tehnoloogia (ingl *Carbon Capture and Storage*);
CCU – CO2 sidumise ja taaskasutamise tehnoloogia (ingl *Carbon Capture and Utilisation*).

Mis on CCS ja CCU (CCUS)?
Miks peaks CCSiga tegelema?
Maailma energiatarbimine.

Allikas: http://www.praxis.ee/wp-content/uploads/2020/12/Lopparuanne_Polevkivitoostuse-kahanemise-mojud.pdf
https://keemia.ee/sites/default/files/2020-12/Final_Polevkivioli_rahvuslik_rikkus_0.pdf

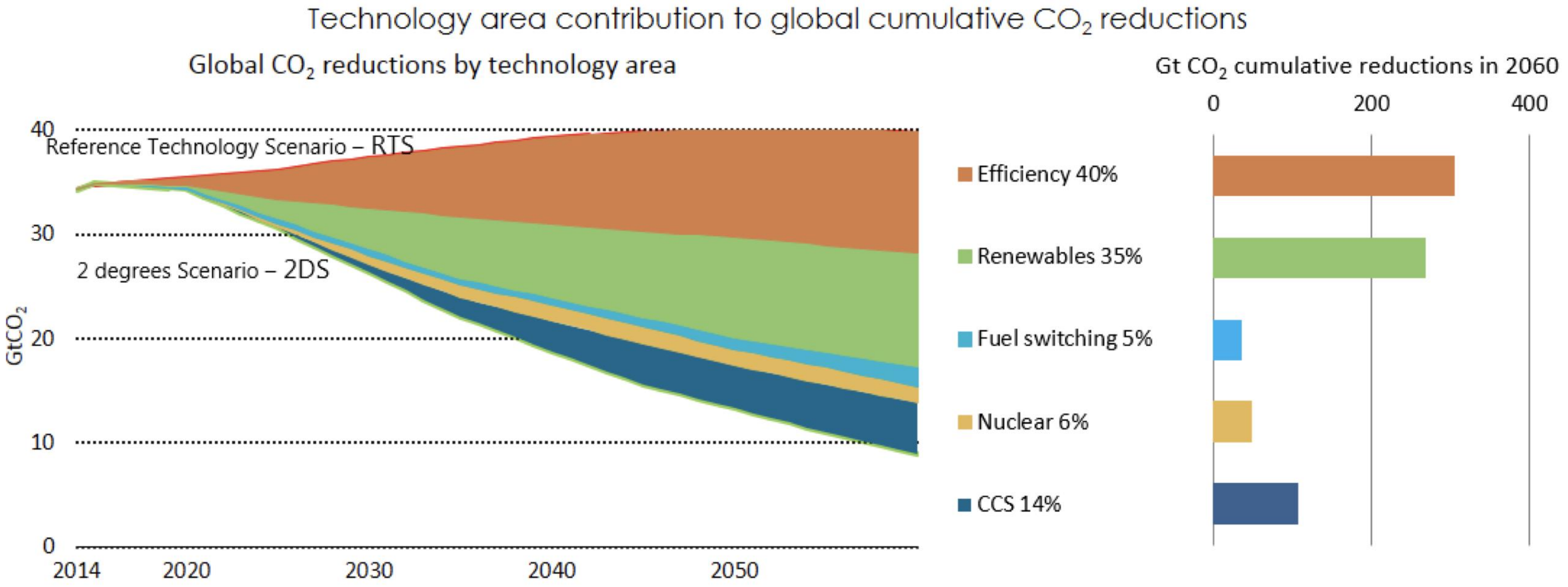




A carbon-neutral coal-fired power plant is clearly within reach.

The International CCS Knowledge Centre (Knowledge Centre) is currently executing a feasibility study with SaskPower to determine if a business case can be made for a post combustion carbon capture retrofit of the 305MW Shand Power Station. This report is therefore titled the Shand CCS Feasibility Study.

CCSil on oluline roll CO_2 heitmete vähendamises

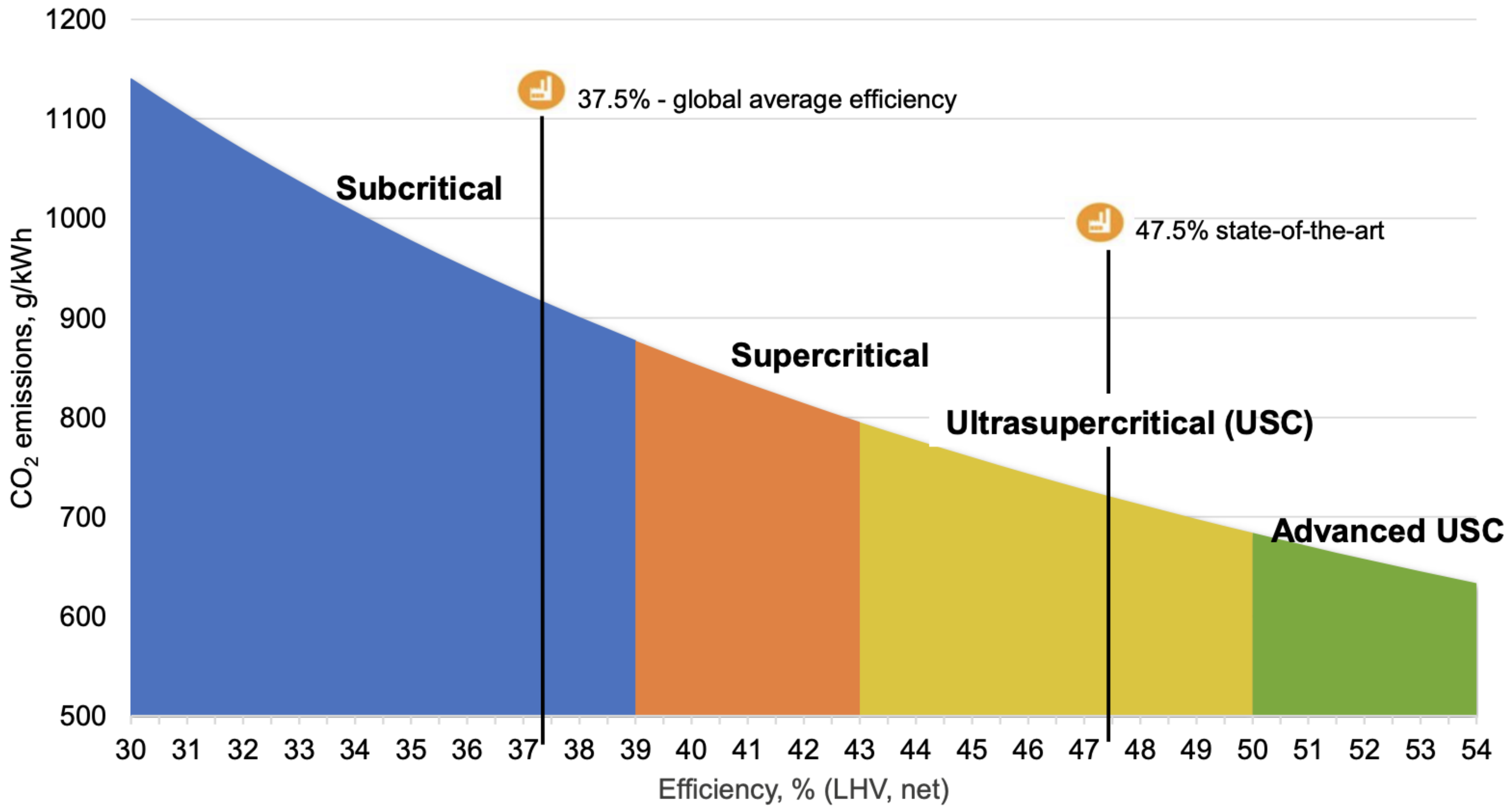


Allikas: https://www.netl.doe.gov/sites/default/files/netl-file/T-Dixon-IEAGG-CCUS-Update.pdf

CCS tehnoloogiate rakendamisega tasub tõsta ka energiatootmiseefektiivsust

Potential for ~2 Gt of CO_2 savings if global average brought to state of the art

USC not strictly defined – broadly refers to use of material advances since the 1990s (P91/92)



TAL TECH

IEA Clean Coal Center, Increasing Efficiency of Pulverized Firing Power Plant

KÜTUSE ELEMENTKOOSTIS

- Kütuse elementkoostise peamised komponendid on ***süsiniku, vesiniku, hapniku, lämmastiku ja väävli suure molaarmassiga keerukad ühendid.***
- Koos huumuskütuste geoloogilise vanuse suurenemisega suureneb nendes oluliselt **süsiniku sisaldus** ning väheneb oluliselt hapniku ja teataval määral ka vesiniku sisaldus. Erandina on vaatamata suurele vanusele põlevkivil kõrge nii **vesiniku** kui ka **hapniku** sisaldus

Kütus	Elementkoostis %				
	C^p	H^p	O^p	N^p	S^p
puit	50...55	6...7	40...45	0,5	0,05
turvas	55...60	6...7	30...35	2...3	0,4...0,6
pruunsüsi	64...77	4...6	15...25	0,8...1,5	0,3...8
kivisüsi	75...90	4...6	3...16	0,5...3	1...3
antratsiit	90...93	2...4	2...4	1...2	0,5...2
põlevkivi	60...80	7...10	8...20	0,1...2	2...15

Kütuse **tarbimisaine** koostis:

$$C^t + H^t + O^t + N^t + S^t_o + S^t_p + A^t + W^t = 100\%$$

Kütuse **kuivaine** koostis:

$$C^k + H^k + O^k + N^k + S^k_o + S^k_p + A^k = 100\%$$

Kütuse **põlevaine** koostis:

$$C^p + H^p + O^p + N^p + S^p_o + S^p_p = 100\%$$

Kütuse **orgaanilise** aine koostis:

$$C^o + H^o + O^o + N^o + S^o_o = 100\%$$

VALDAV OSA EMISSIOONIDEST TEKIB PÕLEMISEL

Aines/kütuses oleva keemilise energia vabanemine kiirete oksüdeerumisreaktsioonide kaudu. Selle käigus ühinevad **kütuses** olevad põlevkomponendid hapnikuga. Näiteks:

- $C + O_2 \rightarrow CO_2$
- $2H + O_2 \rightarrow 2H_2O$
- ...

Oksüdeerija – tavaliselt õhus olev **hapnik** ja ka kütuse orgaanilise osa koostises olev hapnik.

Põlemise käigus vabaneb energia, mis on võrdne kütuse **kütteväärtusega**.

Kütuse põlemine peab tavaliselt olema täielik.

Saasteainete emissioonid on enamasti tingitud järgmistest teguritest:

- Halb õhu ja kütuse segunemine katlas.
- Üldine hapnikupuudus.
- Madal põlemistemperatuur.
- Liiga lühike viibeaeg.

TAL TECH

Mis on CCS, CCU ja CCUS?

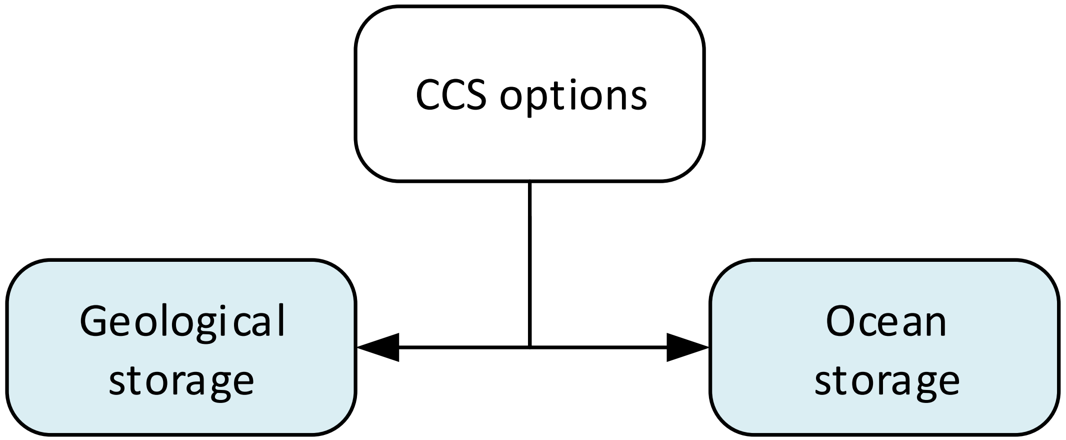
CCS & CCU

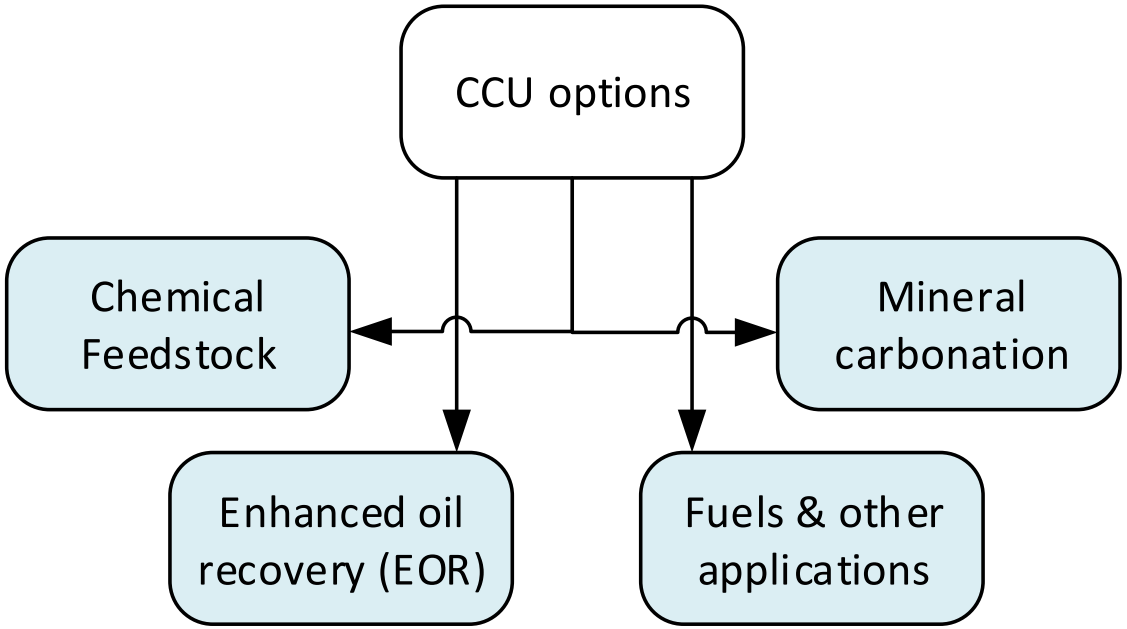
Both aim to capture CO_2 emissions from *point sources* such as power plants and industrial processes, to prevent the release into the atmosphere.

The difference is in the final destination of the captured CO_2.

CCS, captured CO_2 is transferred to a suitable site for long-term storage

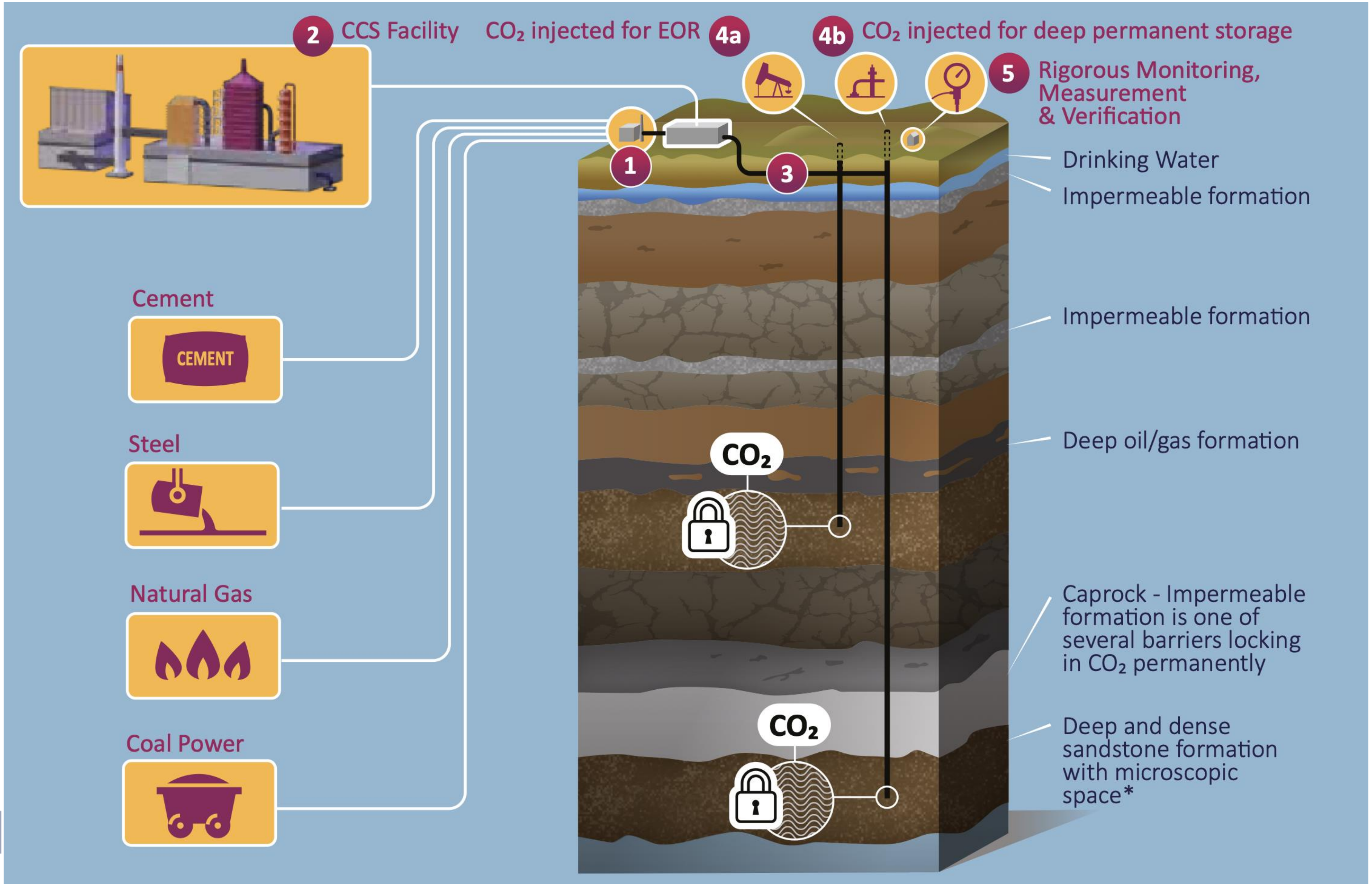
CCU, captured CO_2 is converted into commercial products





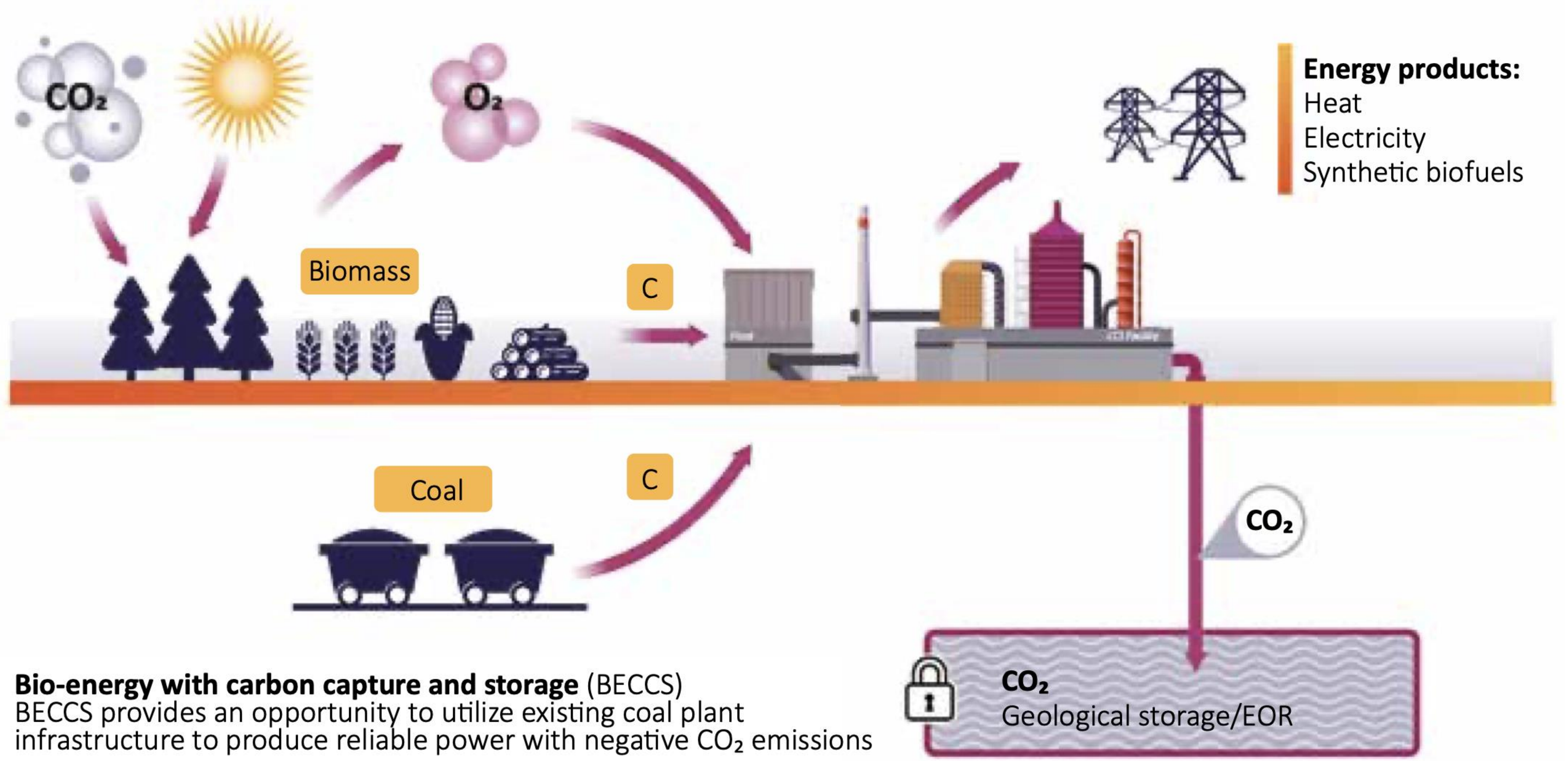
TALTECH

(Rosa, M. et al., 2015)



TAL TECH

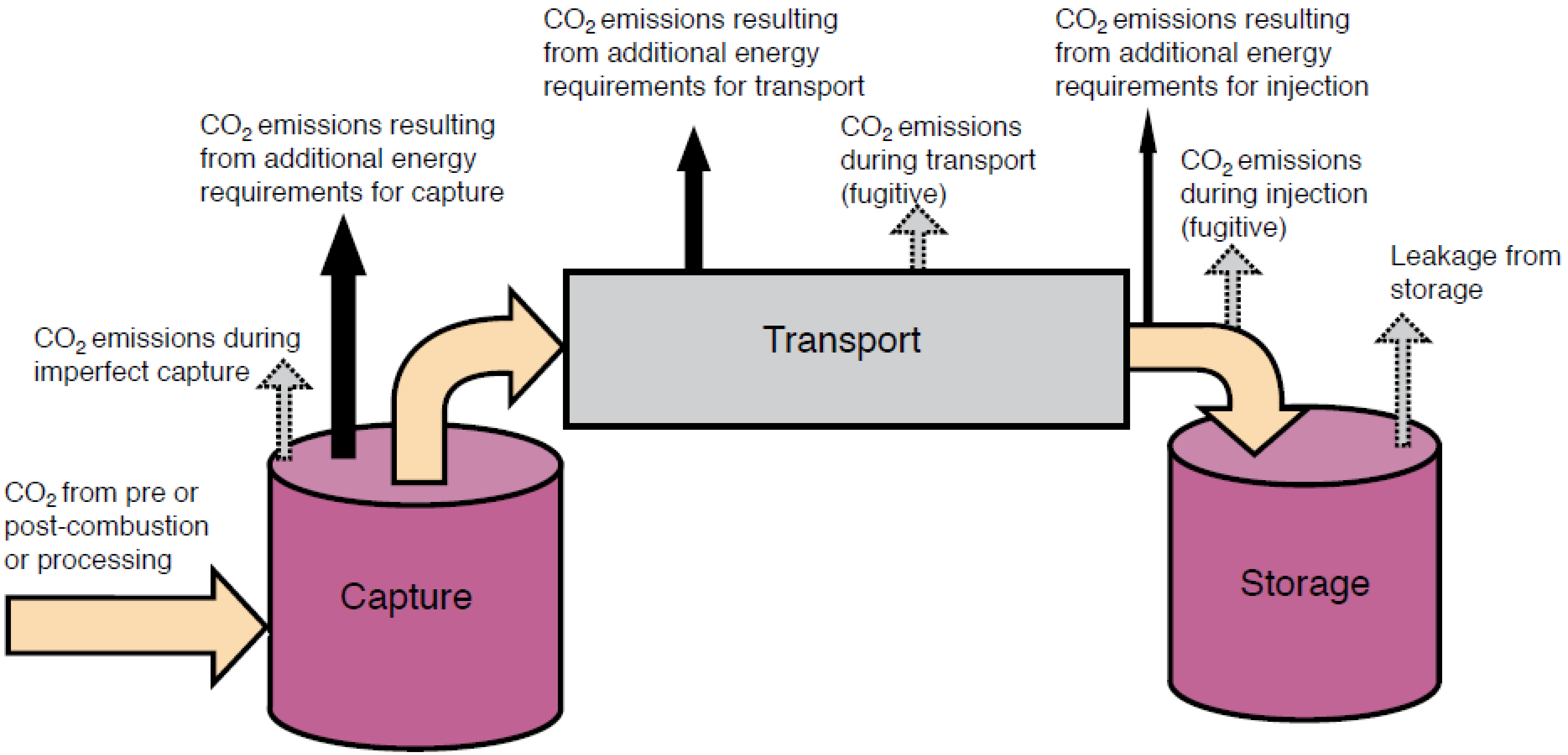
https://ccsknowledge.com/pub/Publications/CIAB_CCUS_Coal_Nov2019.pdf



Source: International CCS Knowledge Centre

https://ccsknowledge.com/pub/Publications/CIAB_CCUS_Coal_Nov2019.pdf

Mis on CCS?



Allikas: *IPCC Special Report on Carbon dioxide Capture and Storage*

CCS tehnoloogiate valmidustasemed

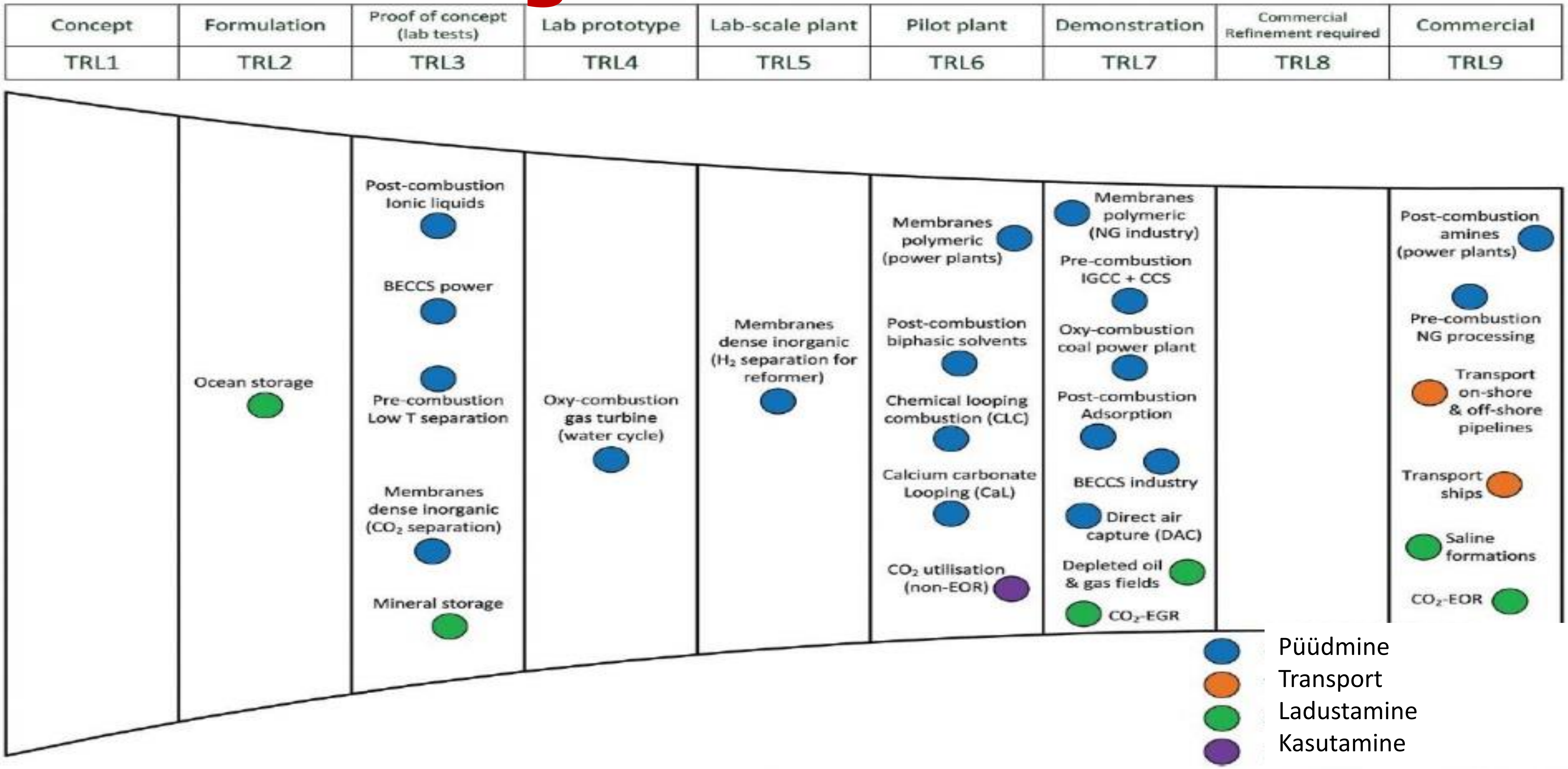
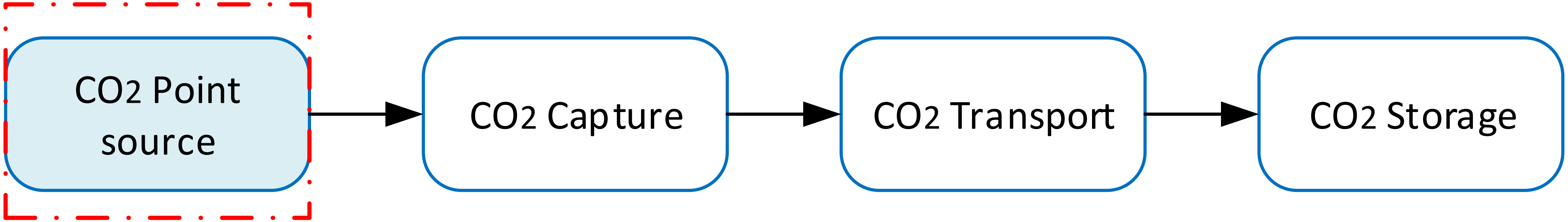


Fig. 1 Current development progress of carbon capture, storage and utilisation technologies in terms of technology readiness level (TRL). BECCS = bioenergy with CCS, IGCC = integrated gasification combined cycle, EGR = enhanced gas recovery, EOR = enhanced oil recovery, NG = natural gas. Note: CO_2 utilisation (non-EOR) reflects a wide range of technologies, most of which have been demonstrated conceptually at the lab scale. The list of technologies is not intended to be exhaustive.

Allikas: Carbon capture and storage (CCS): The way forward; Bui M Adjiman C Bardow A Anthony E Boston A Brown S Fennell P Fuss S Galindo A Hackett L Wilcox J Mac Dowell N. Energy and Environmental Science. 2018 vol: 11 (5) pp: 1062-1176

CCS PATHWAY AND TECHNOLOGIES

1. CO2 Point source



40% of the w CO_2 emissions are caused by electricity generation in fossil-fuel power plants *(Peter Markewitz, et. al, 2012)*

A significant proportion of GHG emissions can be attributed to industrial processes, contributing 25% of the global CO_2 emissions. *(GCCSI, 2016)*

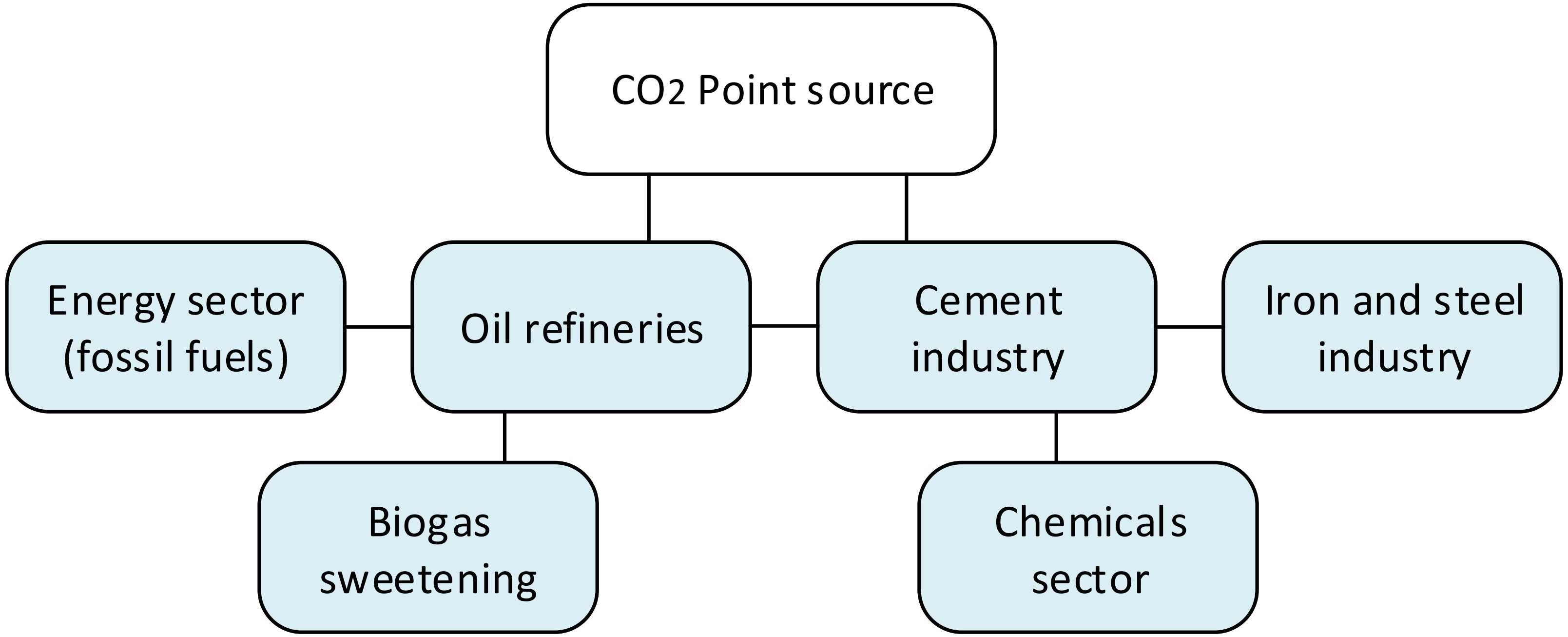
TAL TECH

CO_2 POINT SOURCE

5% of global CO_2 emissions are caused by its manufacture. Approximately 60% of CO_2 emissions from cement production *(C. C. Dean, et. al, 2011)*

petrochemicals and oil refining sector is responsible for approximately 6% of total global CO_2 emissions *(S. Nyquist and J. Ruys, 2010)*

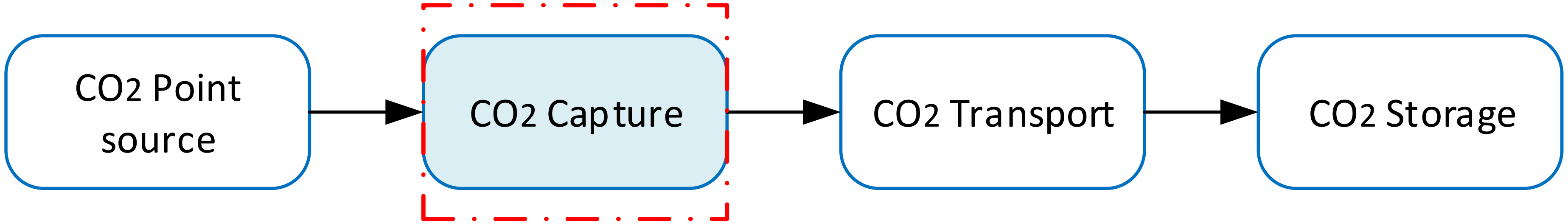
To determine the carbon footprint of the energy system requires a Life Cycle Assessment (LCA)



TAL TECH

CARBON CAPTURE TECHNOLOGIES

2. CO_2 Capture



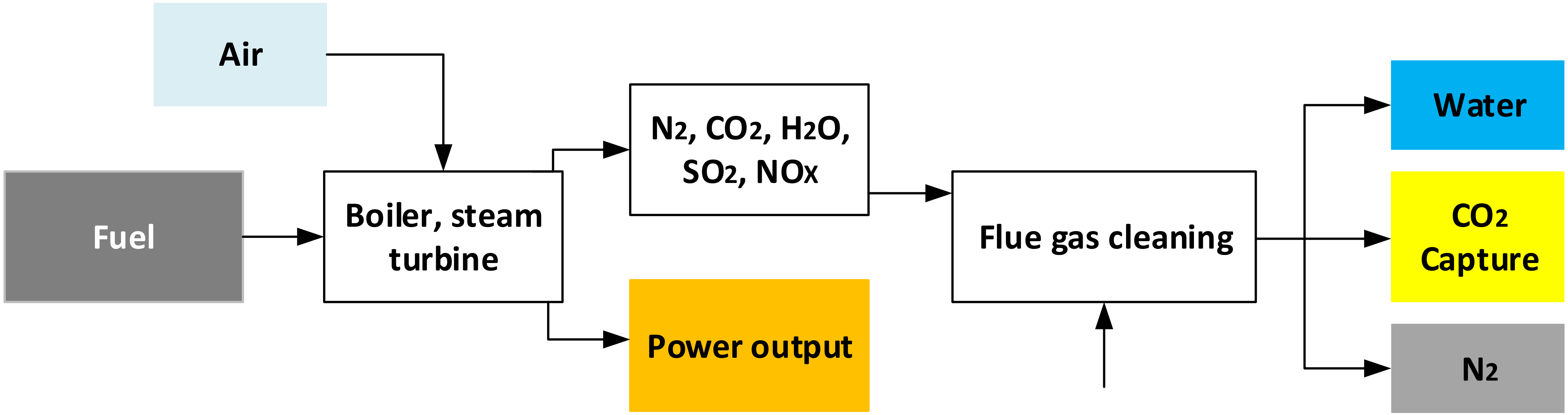
1. CO2-capture from the flue gas stream after combustion (Post-combustion)

2. Use of nearly pure oxygen for fuel combustion instead of air, which increases the CO2-concentration of the flue gas (Oxy-fuel)

3. CO2-capture from the reformed synthesis gas of an upstream gasification unit (Pre-combustion).

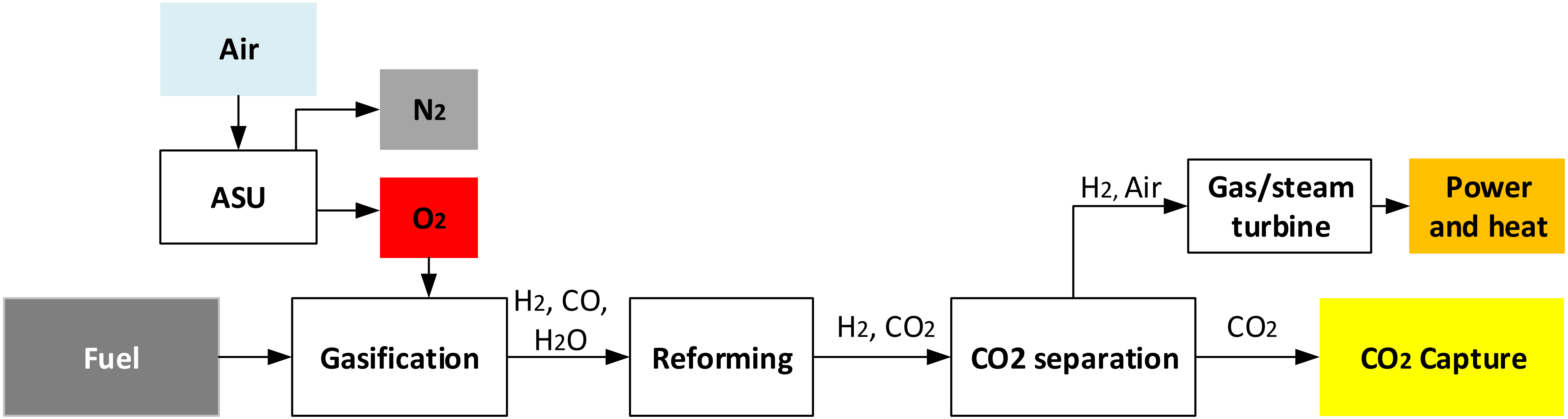
TAL TECH

1. Post-Conversion CO_2 capture: post-combustion capture

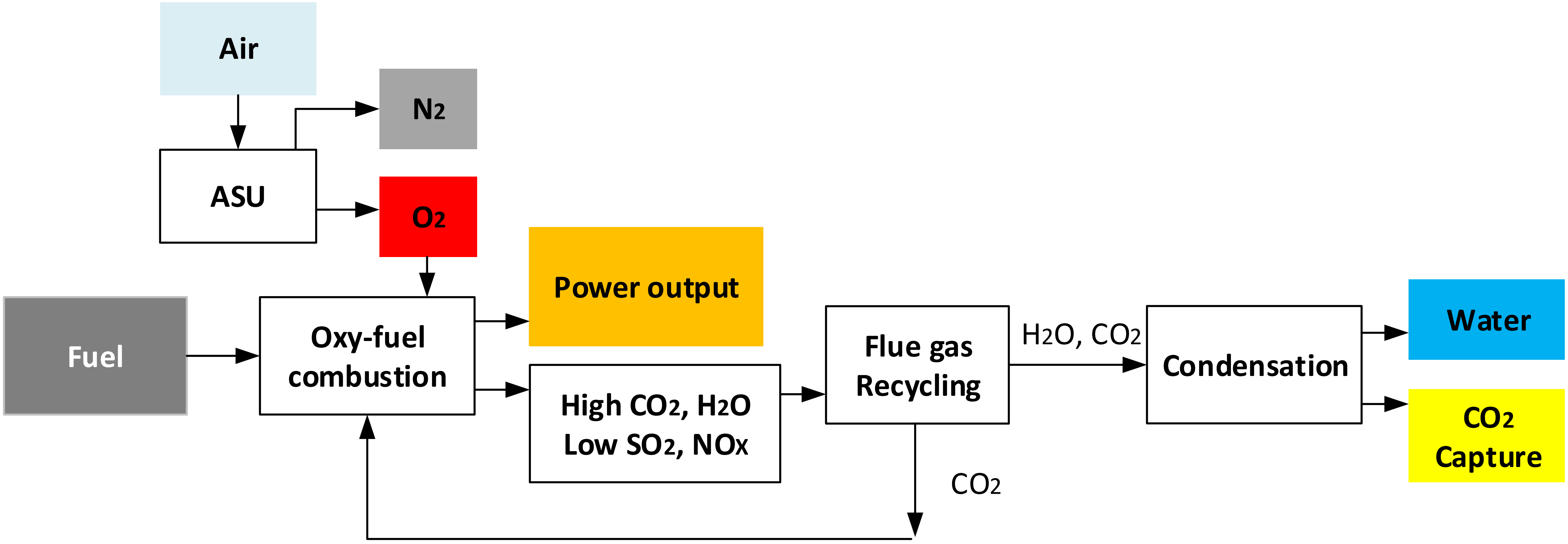


1. Absorption by chemical solvents
2. Adsorption solid sorbents
3. Membrane separation
4. Cryogenic separation
5. Pressure/vacuum swing adsorption

2. PRE-CONVERSION CO_2 CAPTURE



3. OXY-FUEL COMBUSTION CO_2 CAPTURE



TAL TECH

3. OXY-FUEL COMBUSTION CO_2 CAPTURE

Separation of oxygen from air

Applications;

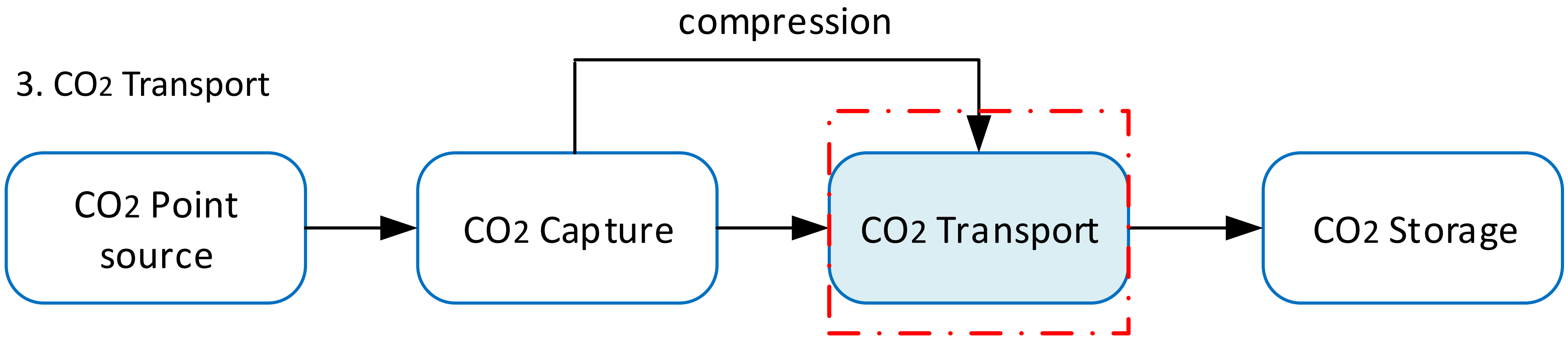
- iron and steel industry;
- cement industry
- Power plants; syngas production and upgrading

Methods;

- Oxy-fuel process
- Chemical looping combustion
- Chemical looping reforming

TAL TECH

CO_2 COMPRESSION AND TRANSPORT



CO_2 is compressed and shipped or pipelined to be stored either in the ground, ocean or as a mineral carbonate

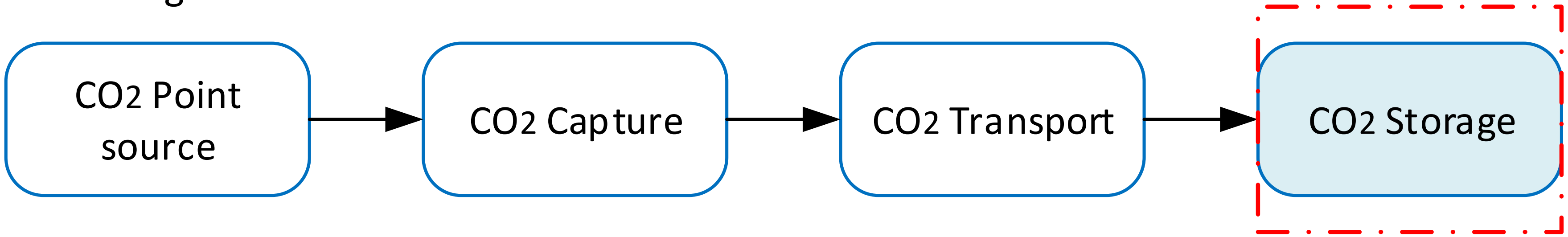
The technologies for CO_2 transport are well established. Around 46500 km of CO_2 pipelines worldwide (both on-shore and off-shore), most of which are associated with EOR operation in the United States.

The technology for CO_2 transport with ships is also relatively mature.

TAL TECH

CO_2 STORAGE

4. CO_2 storage



CO_2 can be stored through different trap mechanisms, including impermeable layers known as "caprock" (e.g. mudstones, clays, and shales) which trap CO_2 underneath as well as in situ fluids and organic matter where CO_2 is dissolved or adsorbed

Subject to the reservoir pressure and temperature, CO_2 can be stored as compressed gas, liquid, or in a supercritical condition

geological storage, involves injecting CO_2 into geological formations such as depleted oil and gas reservoirs

deep saline aquifers and coal bed formations, at depths between 800 and 1000 m

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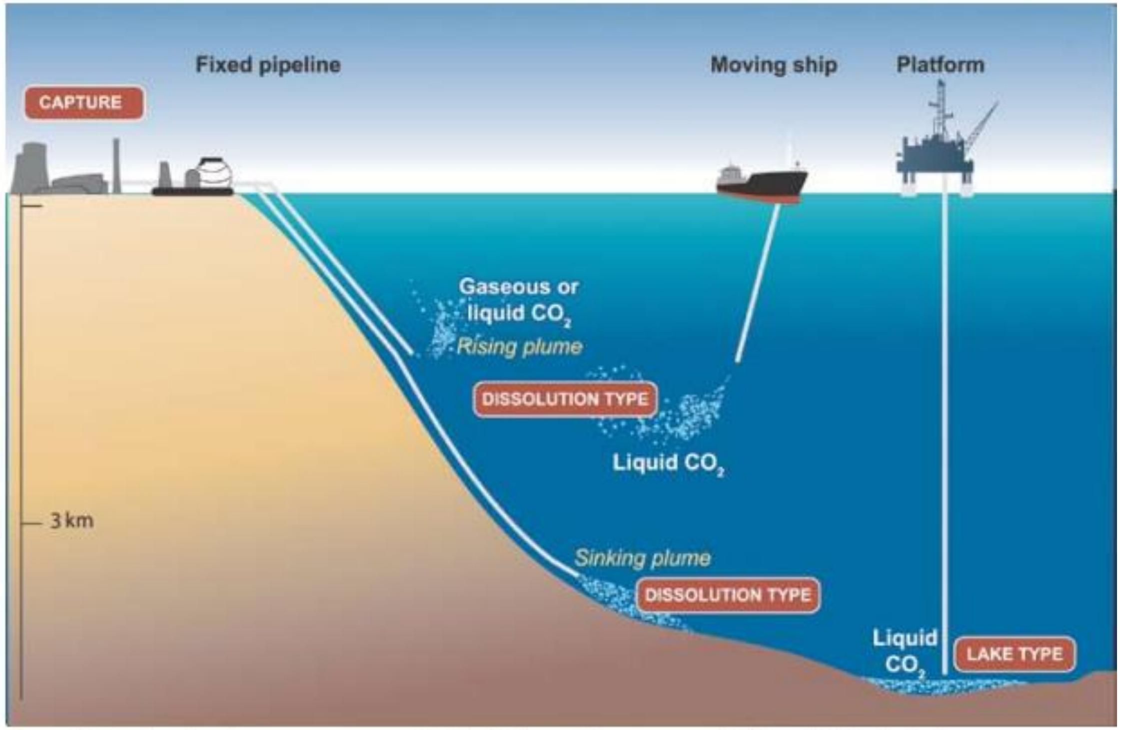
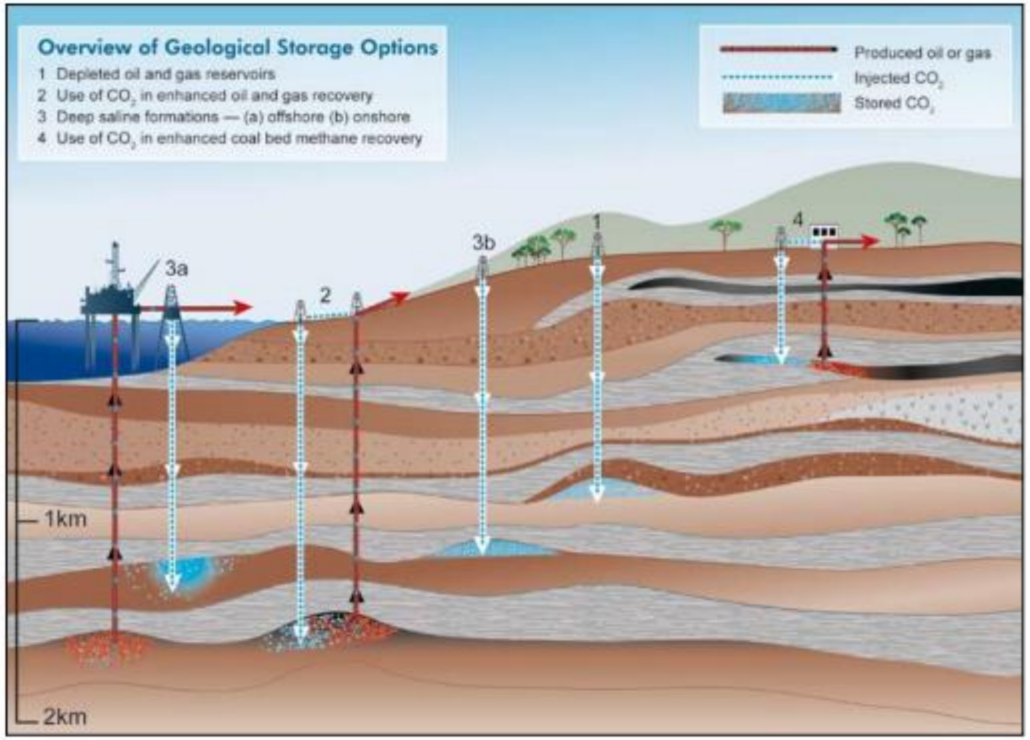
OCEAN STORAGE & GEOLOGICAL STORAGE

“dissolution type” ocean storage, the CO_2 rapidly dissolves in the ocean water, whereas in “lake type” ocean storage, the CO_2 is initially a liquid on the sea floor



CO_2 in deep underground geological formations. Two methods may be combined with the recovery of hydrocarbons: EOR and ECBM .



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(IPCC Special Report, Carbon Dioxide Capture and Storage 2005)

Püüdmise hinnanguline maksumus

Fig. 3 CO_2 supply curve: fossil power and large industrial sources

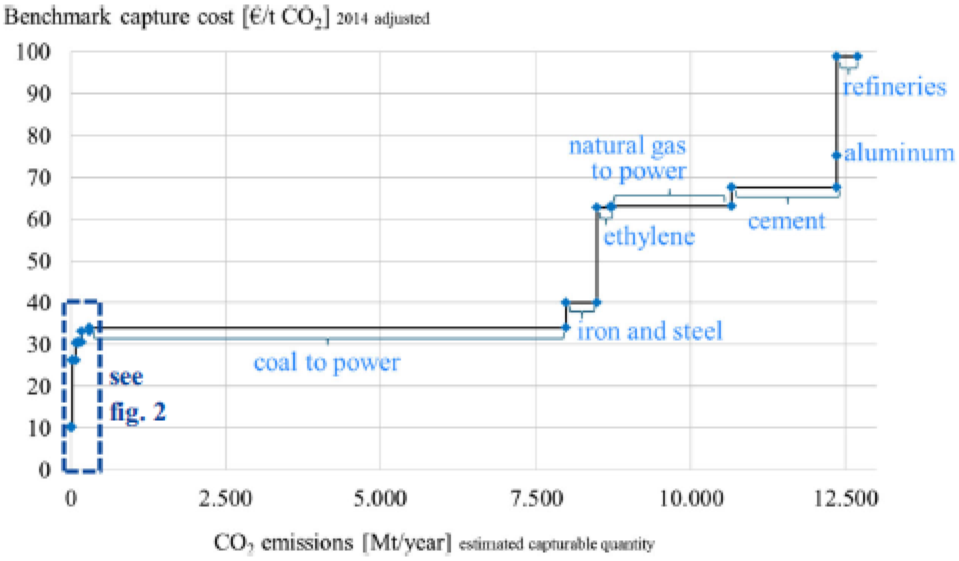
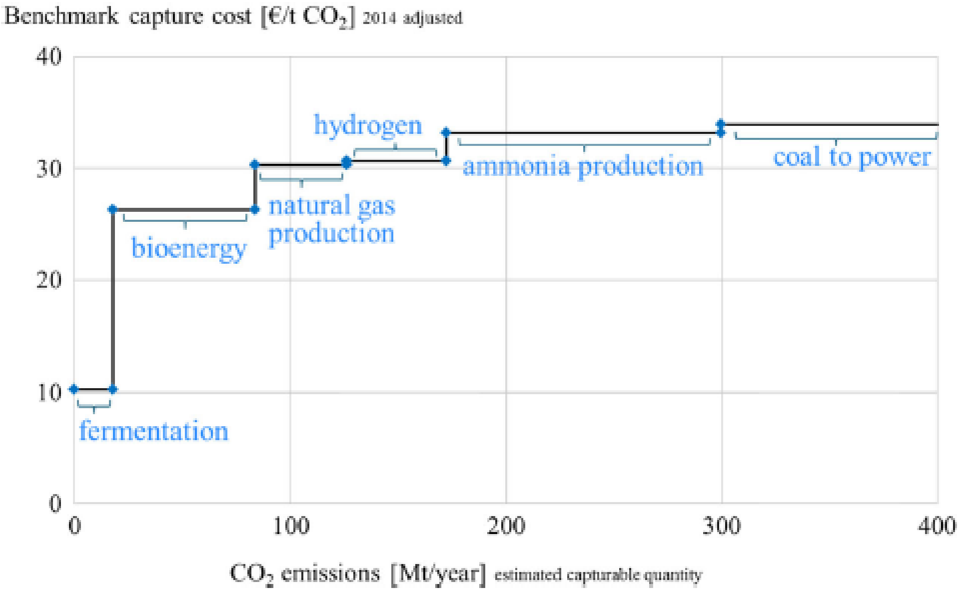


Fig. 2 CO_2 supply curve: high purity and low capture cost sources



Allikas: https://link.springer.com/content/pdf/10.1007/s11356-016-6810-2.pdf

CO_2 kasutamine ehk CCU

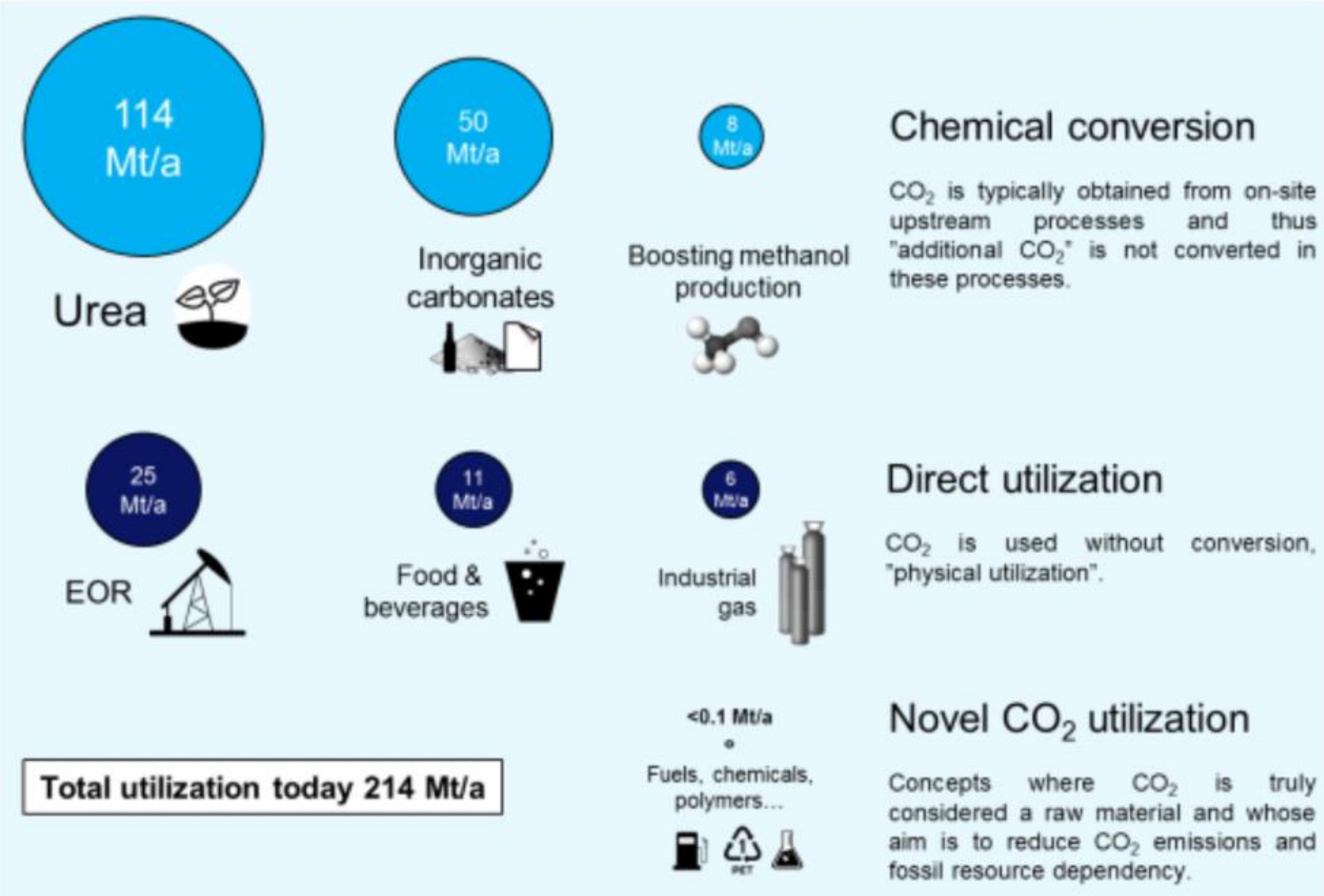


Figure5 Global use of CO2 today. Adapted from [9] based on [5,6,7]

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Allikas: http://makingoftomorrow.com/wp-content/uploads/2017/06/EB_web_28.6_vs6.pdf

CO_2 kasutamise võimalikud viisid

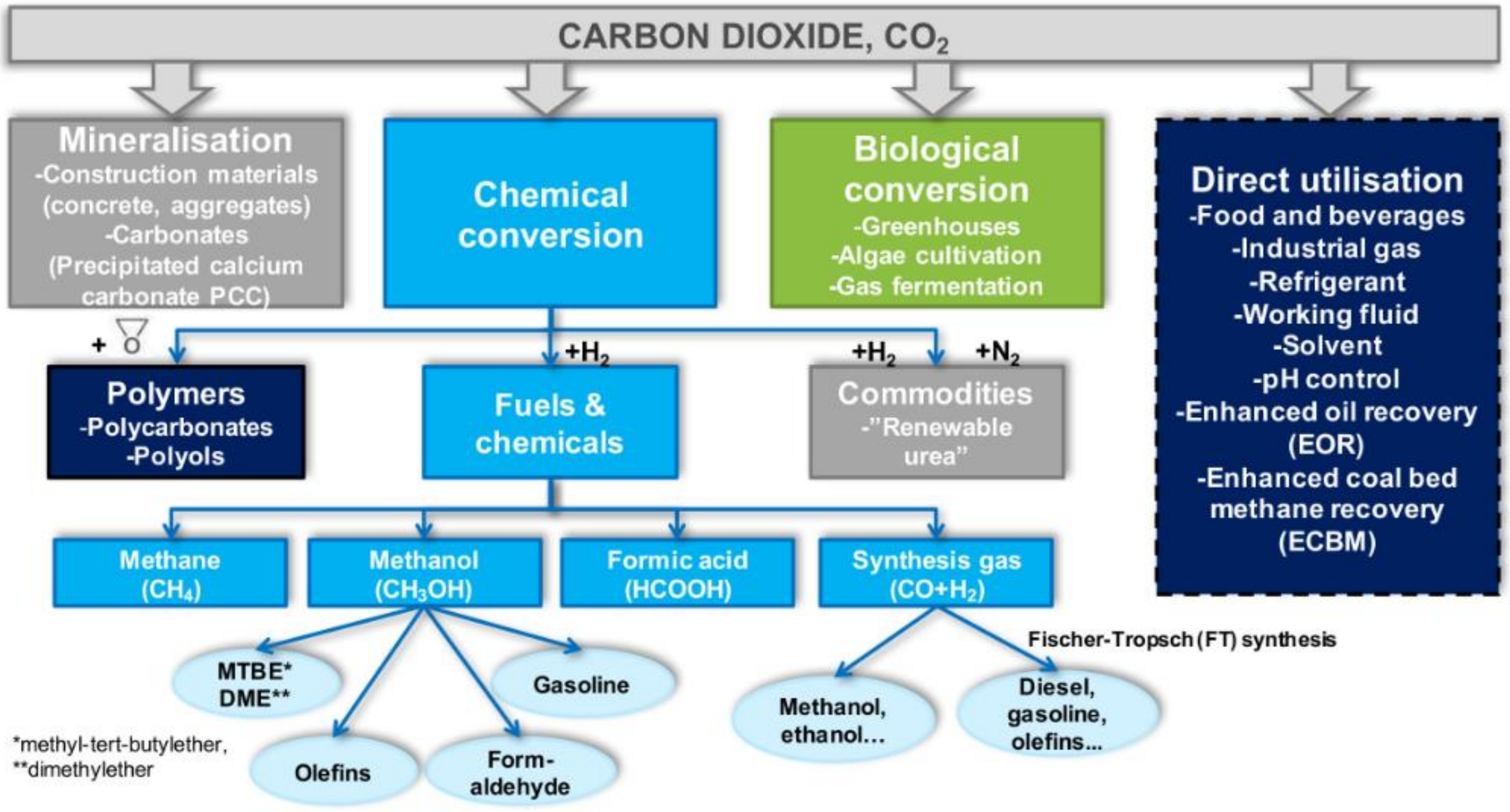

Figure 6 Main CO_2 utilization routes and options for the current and future operations

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Allikas: http://makingoftomorrow.com/wp-content/uploads/2017/06/EB_web_28.6_vs6.pdf

CO_2 kasutamise võimalikud viisid

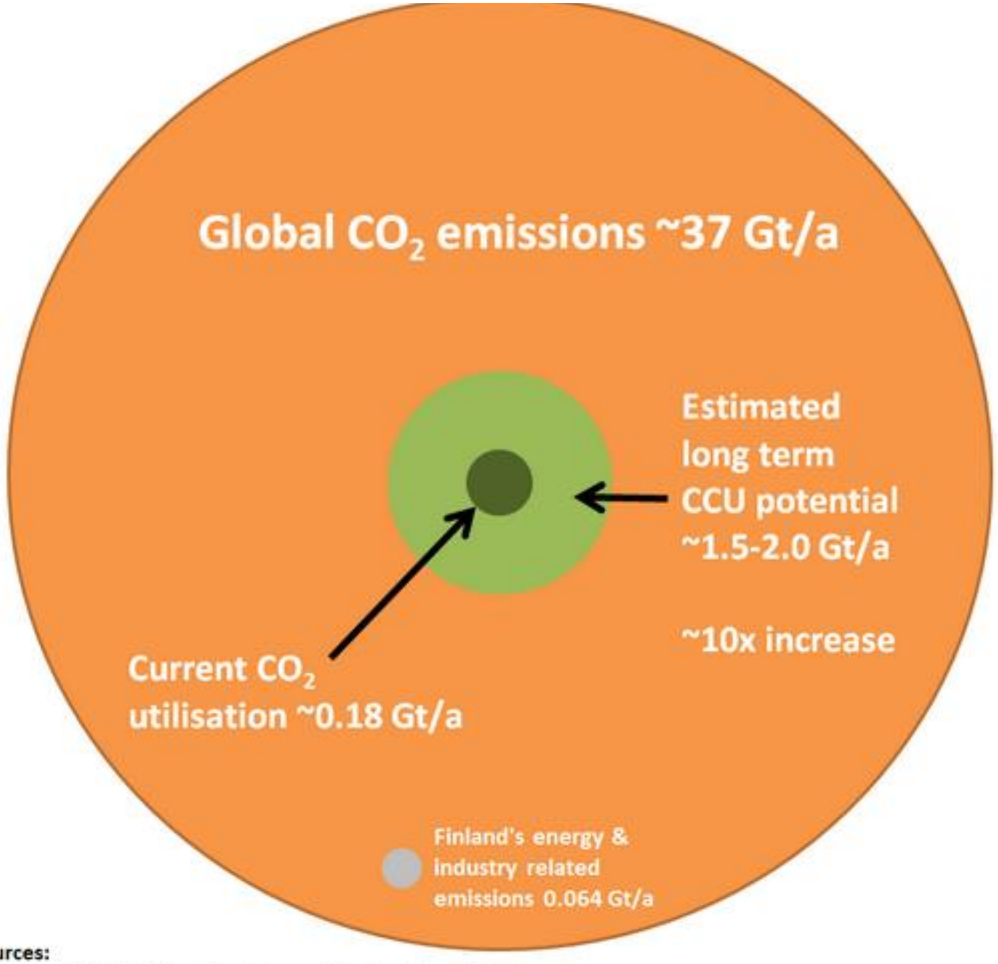
Tabel 11. Erinevate CCU tehnoloogiate kasutatavus erinevatele puhtusastmetele puhastatud CO_2 korral

Tehnoloogia	Kemikaalipuhtussega CO_2	Toidupuhtusega CO_2
Salitsüülhappe tootmine	Pigem ei ole kasutatav	On kasutatav
Uurea tootmine	Pigem ei ole kasutatav	On kasutatav
Dimetüülkarbonaadi tootmine	Pigem ei ole kasutatav	On kasutatav
Polükarbonaatide tootmine	Pigem ei ole kasutatav	On kasutatav
Metanooli tootmine	Pigem ei ole kasutatav	On kasutatav
Polüoolide tootmine	Pigem ei ole kasutatav	On kasutatav
Puhta CO_2 elektrolüüs	Ei ole kasutatav	On kasutatav*
CO_2 ja H_2O kaaselektrolüüs	Ei ole kasutatav	On kasutatav*
Vedelkütused CO_2-st ja elektrolüüsitud H_2-st	Ei ole kasutatav	On kasutatav*
Elektrolüüsi ja gaasfermentatsiooni koosrakendamine CO_2-st kütuste ja kemikaalide tootmiseks	Ilmselt on kasutatav	On kasutatav
Elektrolüüsi ja gaasfermentatsiooni koosrakendamine CO_2-st metaani ja soojuse tootmiseks	Võib-olla sobib (vaja testida konkreetse gaasisegu korral)	Võib-olla sobib (vaja testida konkreetse gaasisegu korral)
CO_2 fototroofiline konverteerimine kütusteks ja kemikaalideks	On kasutatav, kui segada juurde õhku nii, et CO_2 kontsentratsioon oleks 12% või väiksem	On kasutatav, kui segada juurde õhku nii, et CO_2 kontsentratsioon oleks 12% või väiksem
CO_2 kasutamine taimekasvatuses	Ei ole kasutatav	Ei ole kasutatav
F-gaaside asendamine CO_2-ga	Ei ole kasutatav	Kasutatav

*ilmselt vajalik veel täiendav väävliärastus

Allikas: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021

CO_2- CCS ja/või CCU



Sources:
Aresta et al (2013). The changing paradigm in CO_2 utilization
von der Assen et al (2016). Selecting CO_2 Sources for CO_2 Utilization by Environmental-Merit-Order Curves
Statistics Finland

[1] von der Assen, N. et al (2016). Selecting CO2 Sources for CO2 Utilization by Environmental-Merit-Order Curves, Environmental Science & Technology, 50 (3), pp. 1093-1101.

[2] Aresta, M. et al. (2013). The changing paradigm in CO2 utilization, Journal of CO2 Utilization, 3–4, pp. 65–73.

Allikas: http://makingoftomorrow.com/wp-content/uploads/2017/06/EB_web_28.6_vs6.pdf

PÕLEVKIVI KASUTAMINE CO_2 NEUTRAALSUSES – ÜLETAMATU PROBLEEM VÕI VÕIMALUS

CCUS?

Kaevandamine

Põlevkivi

Põlevkiviõli tootmine

Põlevkiviõli

Tuhk

Suitsugaasid

Uttegaas

Uttevesi

Elektritootmine

Soojus/elekter

Suitsugaas

Tuhk

Tooted, jäätmed, emissioonid

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Võimalikud CCS tehnoloogiad ja nende valmidustasemed

Tehnoloogia	Sobivus olemasolevale põletussead-mele*	Efektiivsuse langus‡, %	Saadava CO_2 oodatav puhtus	Ligikaudne kulu (2019 EUR/t CO_2)**	TVT
Membraanprotsess	jah	8-14	50–99%***	45–90	7
Hapnikus põletamine	jah	5-12	70%	25–70	7
Absorptsioon	jah	6-14	>98%	30–90	9
Mitmefaasiline absorptsioon	jah	~9	>98%	25–70	7
Adsorptsioon	jah	~10	50–99%***	40–70	7
Hapnikukandja ringlus	ei	~2	~75%	15–30	6
Kaltsiumi ringlus	jah	3-11	~70%	15–40	6
Krüogeenne püüdmine	jah	5-14	>99%	20–60	6

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* Tehnoloogiat saab rakendada olemasoleva põletusseadme korral ilma, et oleks vaja seadet ennast muuta
** Kulu ei sisalda transpordi ja ladustamise kulu, aga sisaldab seadmete kulu ja kokkusurumise/komprimeerimise kulu
*** Kõrgem puhtus saavutatakse separatsiooniastmete lisamisel
‡ Energialõiv näitab, kui palju rohkem energiat tuleb lisada, et toota sama palju elektrit kui toodetakse ilma CO_2 püüdmiseta; suhteline kasuteguri vähenemine

Allikas: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021

Võimalikud CCS tehnoloogiad ja nende valmidustasemed

Tabel 12. CO_2 püüdmistehnoloogiate sobivus põlevkivitööstusele

Tehnoloogia	Peab saasteainetele vastu	Valmis tööstuses kasutamiseks	Saab kasutada olemasoleval põletusseadmel
Membraanid			X
Hapnikus põletamine	X	*	X
Absorptsioon	X	X	X
Mitmefaasiline absorptsioon	X		X
Adsorptsioon			X
Hapnikukandja ringlus	X		
Kaltsiumi ringlus	X		X
Krüogeenne püüdmine	X		X

*põlevkivi puhul vajab lisaandmeid

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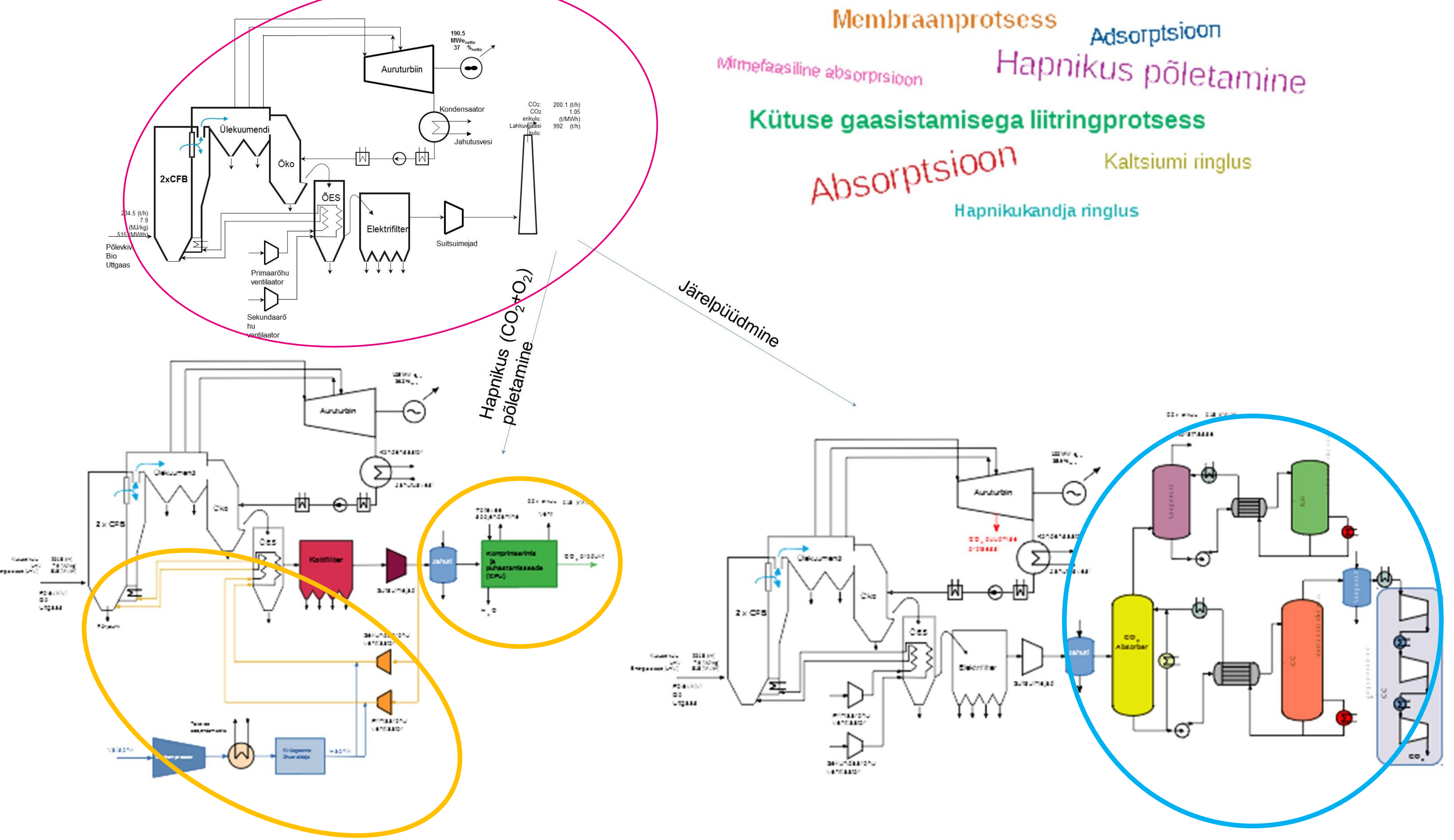
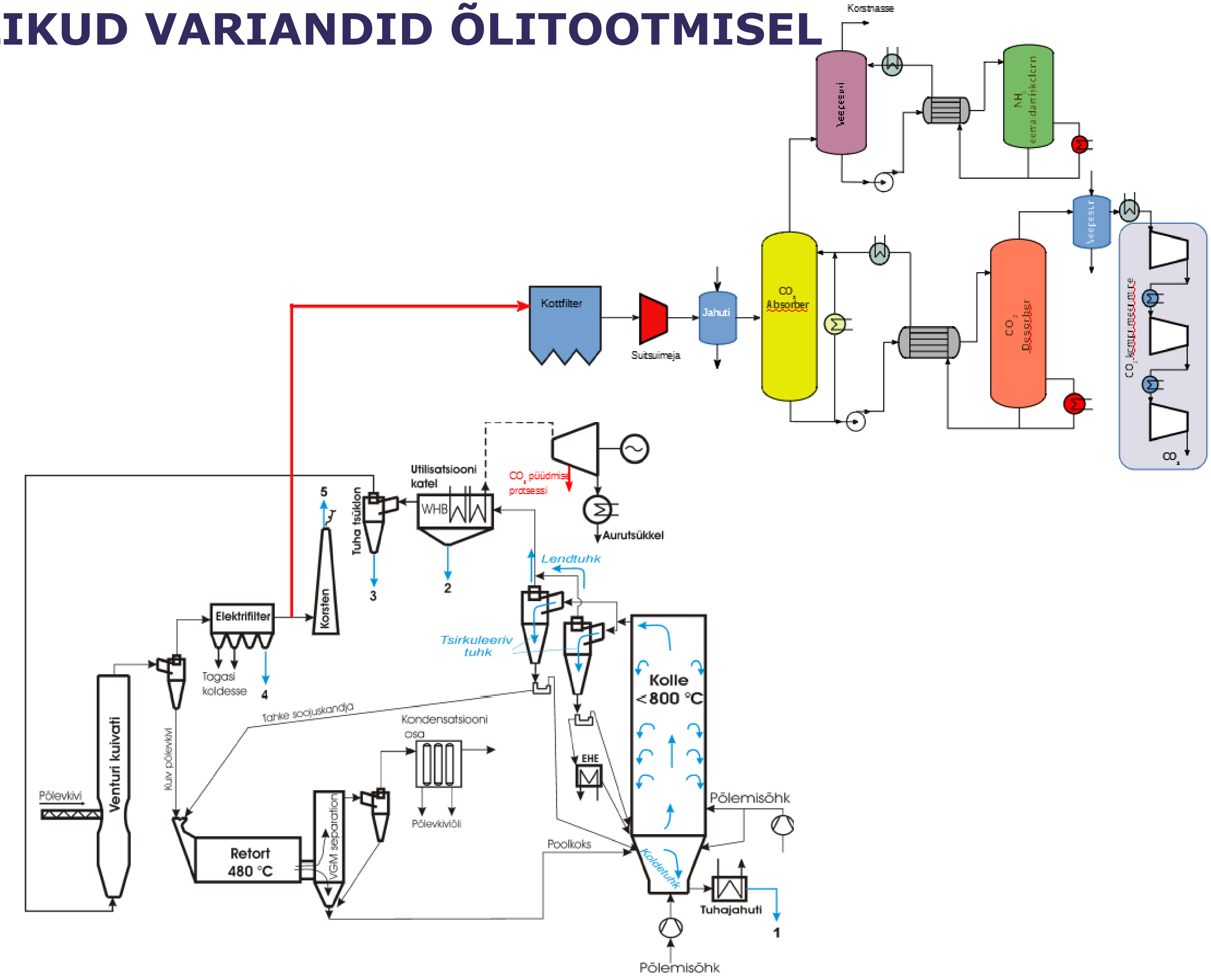
Allikas: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021

VÕIMALIKUD VARIANDID ELEKTRITOOTMISEL

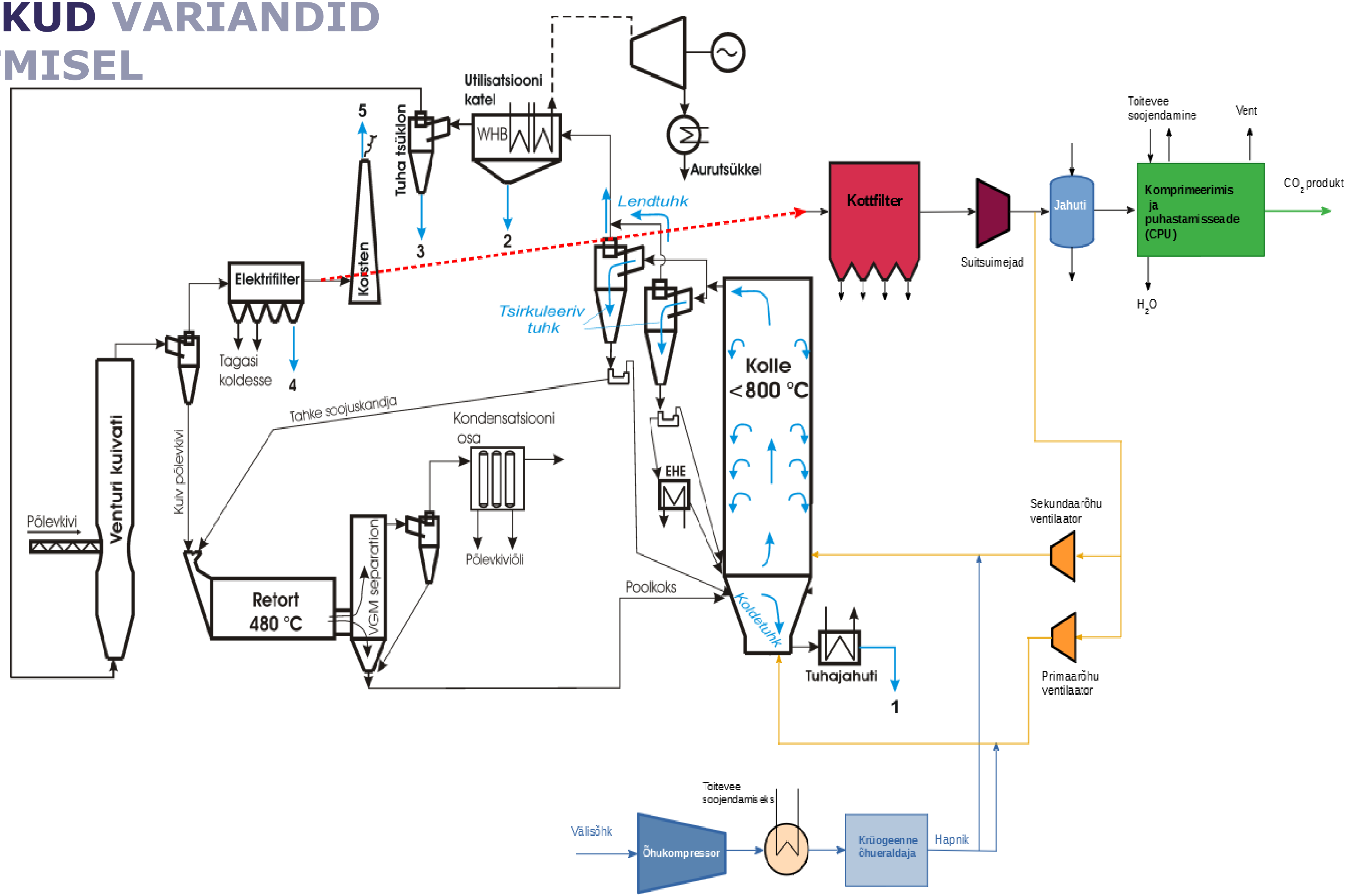


VÕIMALIKUD VARIANDID ÕLITOOTMISEL

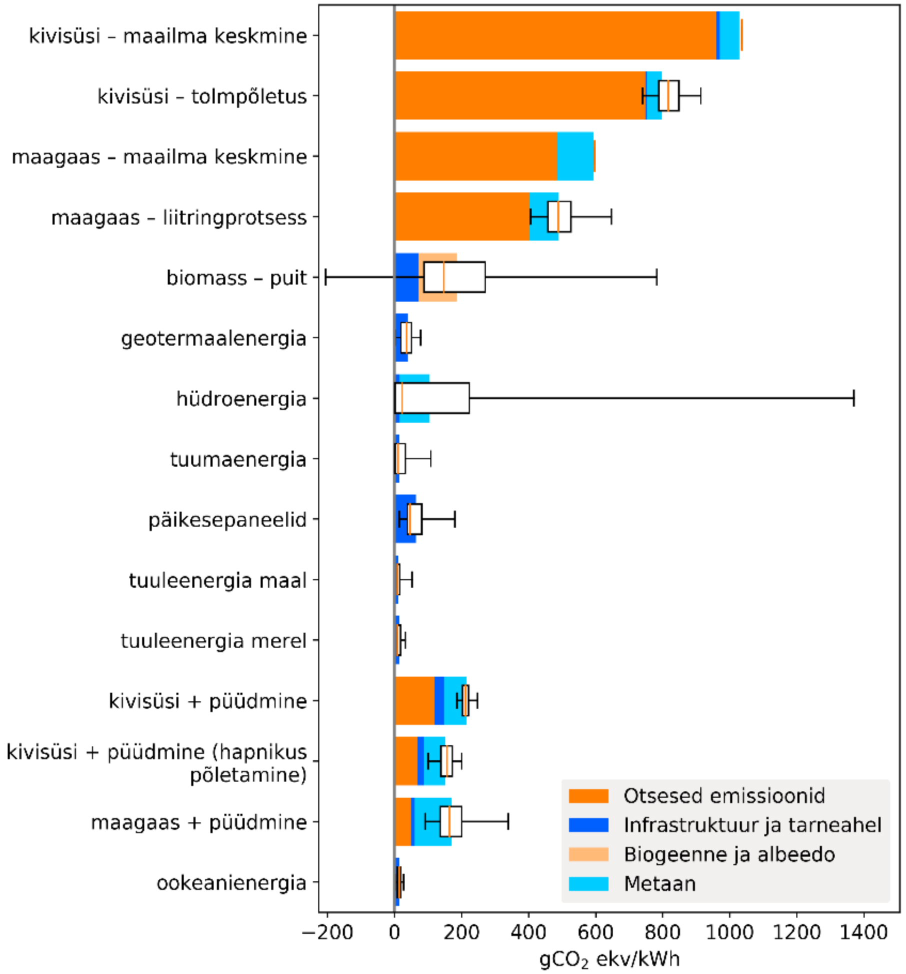


Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) vahearuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, detsember 2019

VÕIMALIKUD VARIANDID ÕLITOOTMISEL



Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) vahearuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, detsember 2019

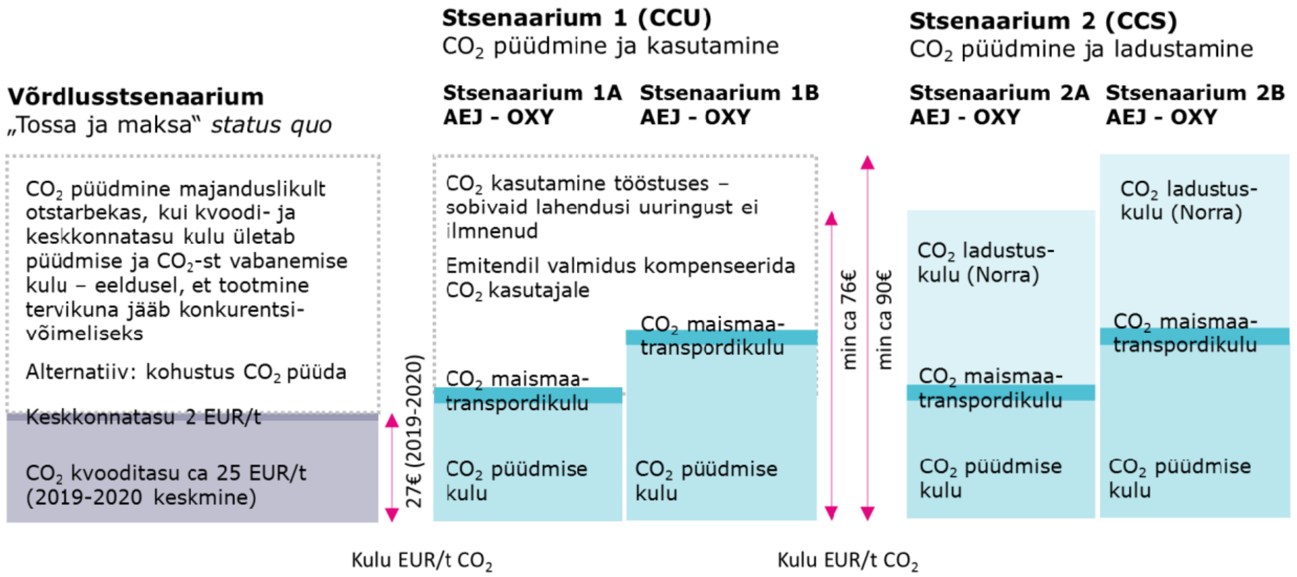


CO_2 eriheitmed toodetud elektrienergia kohta, t CO_2/Mwh_e, (2017)

	TP-101 (PC)	Sumitomo FW (CFBC)	General Electric (CFBC)
CO_2	1,31	0,99	0,91

Suurus	Hetkeolukord	Järelpüüdmine	Hapnikus põletamine
Emiteeritav mass, t CO_2 /MWh	0,988	0,169	0,146
Püütav CO_2 kogus aastas, mln t	0	1,83	1,83
Ploki võimsus (neto), MW_{el}	275,5	198,0	201,6
Hinnanguline CO_2 püüdmise kulu, €/t CO_2*	-	34	29
CAPEX, M€*	-	257,1	214,1

* Alstom ploki puhul, kulu sisaldab ka püüdmisseadmetesse investeeringu kapitalikulu



Joonis 7. Põlevkivitööstuses CO_2 püüdmise majanduslik ja regulatiivne koondvaade

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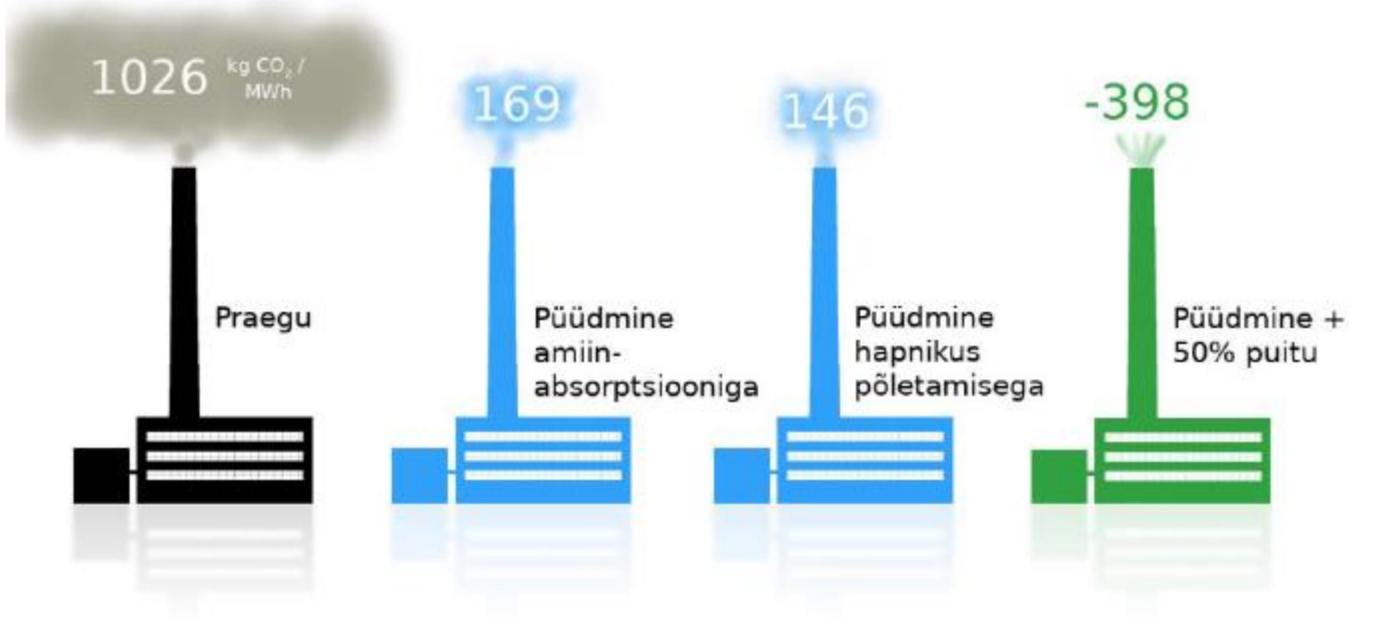
Vajadus kompleksseks uuringuks Eesti energeetika pikaajalise strateegia kujundamiseks

CCS tehnoloogia rakendamisel tekkivad CO_2 heitmed

Uus 275 MW_e netovõimsusega hapnikus põletamise tehnoloogiat rakendava elektrijaama korral, kus kütusena kasutatakse hakkepuitu (50%) ja põlevkivi (50%), oleks summaarne CO_2-ekvivalendile taandatud emissioon on -398 kg CO_2 ekv ühe MWh toodetud elektrienergia (neto) kohta.



Joonis 8. CO_2 jalajäg (kg CO_2 MWh) erinevate elektri tootmise stsenaariumite korral

Hapnikus põletamist võib rakendada põlevkivikatlas ilma suurte muudatusteta

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CO_2 püüdmise ja ladustamise kulu oleks elektritootmises vähemalt ca 76 EUR CO_2 tonni kohta

Allikas: Kliimamuutuste leevendamine läbi CCS ja CCU tehnoloogiate (ClimMIT) lõpparuanne, RITA1, Tallinna Tehnikaülikool, Tartu ülikool, märts 2021

Kokkuvõtteks

- Põlevkivi saab edasi kasutada ka kliimaneutraalsuse/roheleppe valguses.

- Kas me põlevkivi ka tulevikus kasutame on vaid meie enda otsustada, sest tehnoloogiad CO_2 püüdmiseks on olemas
- Tuleb panustada TjaA-sse ja uurida CCS ja CCU tehnoloogiaid TVT 3-7 tasemel
- Tuleb uurida tuha kivinemiskineetikat jt vajalikke omadusi, võtmaks kasutusele seda ehitustööstuses ja seeläbi dekarboniseerima tsemenditööstust

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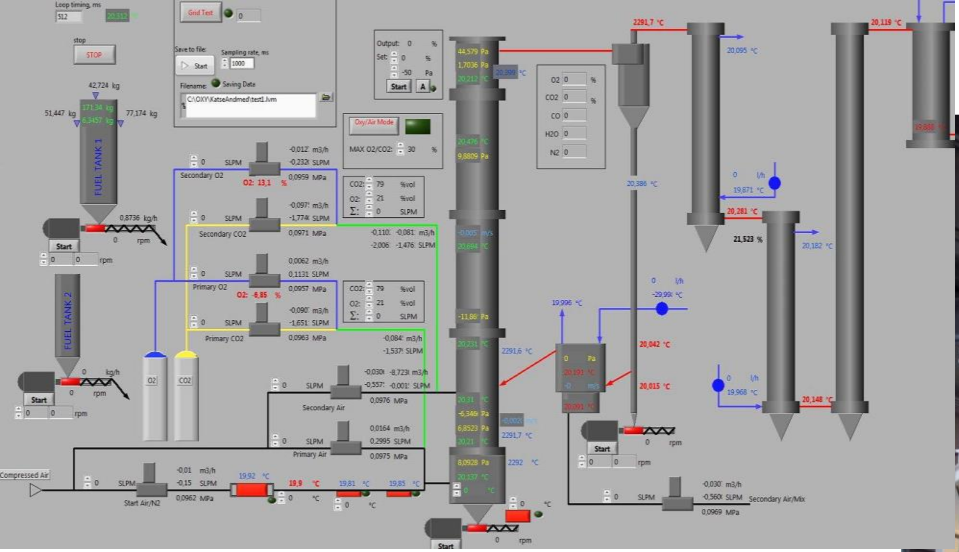
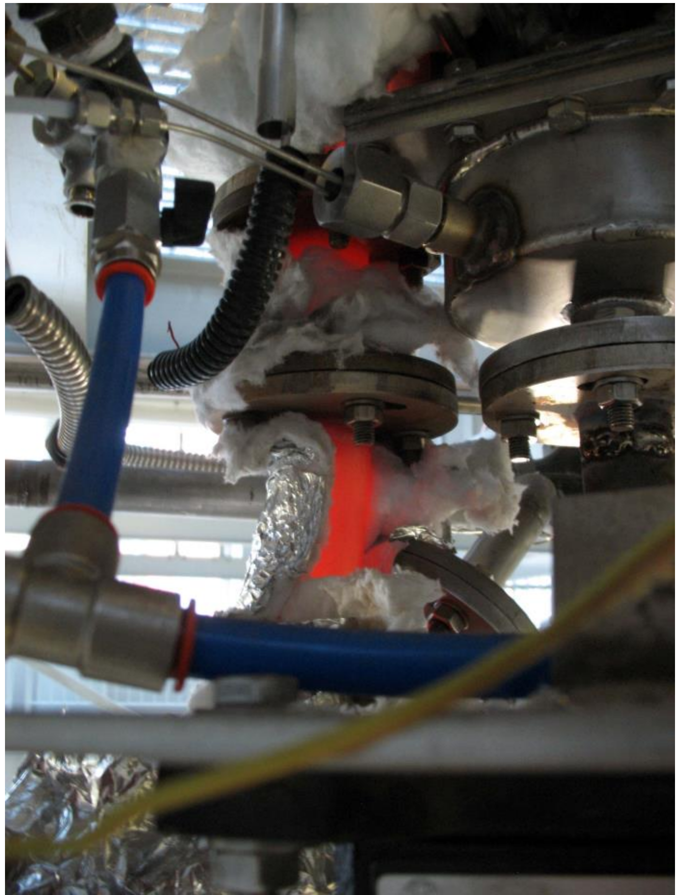
CCUS - 60kW$_{th}$ CFB Test Facility





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