Razvojni trendovi – smanjenje emisije CO_2

U V O D

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A European Green Deal

Striving to be the first climate-neutral continent

Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, Europe needs a new growth strategy that will transform the Union into a modern, resource-efficient and competitive economy, where

- there are no net emissions of greenhouse gases by 2050
- economic growth is decoupled from resource use
- no person and no place is left behind

The European Green Deal is our plan to **make the EU's economy sustainable.** We can do this by turning climate and environmental challenges into opportunities, and making the transition just and inclusive for all.

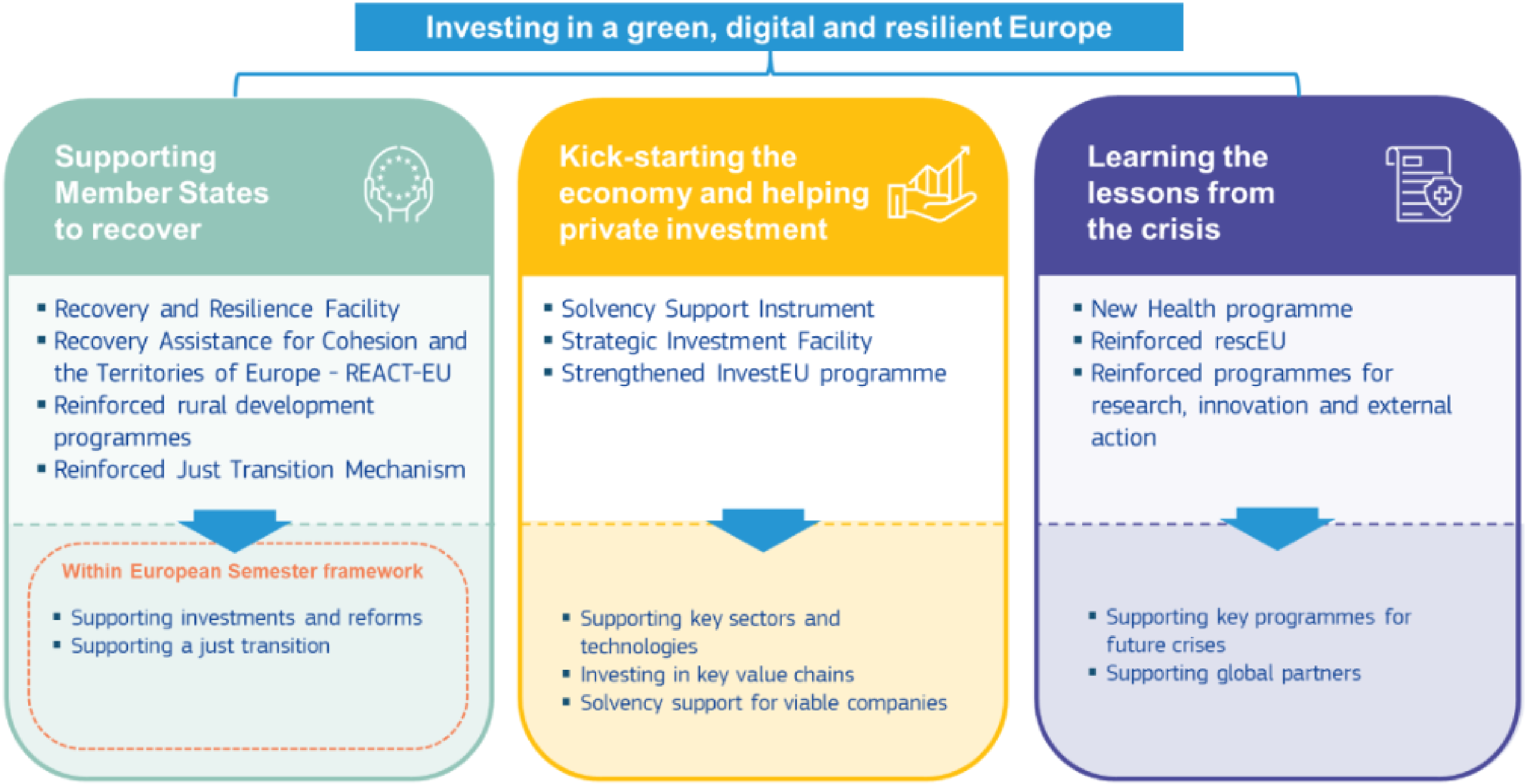
Akcijski plan za poticanje učinkovite upotrebe resursa prelaskom na čisto, kružno gospodarstvo, obnovu biološke raznolikosti i smanjenje zagađenja.
Plan opisuje potrebna ulaganja i dostupne financijske alate.
EU želi biti klimatski neutralan 2050. godine. Predlaže se Europski klimatski zakon za prevođenje političke predanosti u zakonsku obvezu. Postizanje ovog cilja zahtijevat će uključenost i djelovanje svih gospodarskih sektora:

- ✓ ulaganja u ekološki prihvatljive tehnologije
- ✓ podrška industriji za inovacije
- ✓ uvođenje čistijih, jeftinijih i zdravijih oblika privatnog i javnog prijevoza
- ✓ dekarbonizacija energetskog sektora
- ✓ osiguravanje energijske učinkovitosti zgrada

Next Generation EU - a new recovery instrument of €750 billion which will boost the EU budget with new financing raised on the financial markets for 2021-2024

Postizanje samodostatnosti:

- Proizvodnja hrane (površine, voda, gnojivo, sjeme)
- Proizvodnja energije (goriva) i strateških materijala
- Proizvodnja aktivnih komponenti lijekova (povratak proizvodnje iz Azije)



Source: European Commission

Mogućnosti smanjenja emisije CO_2

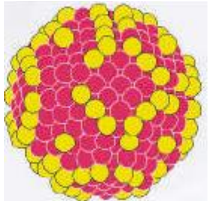
Zeleni vodik

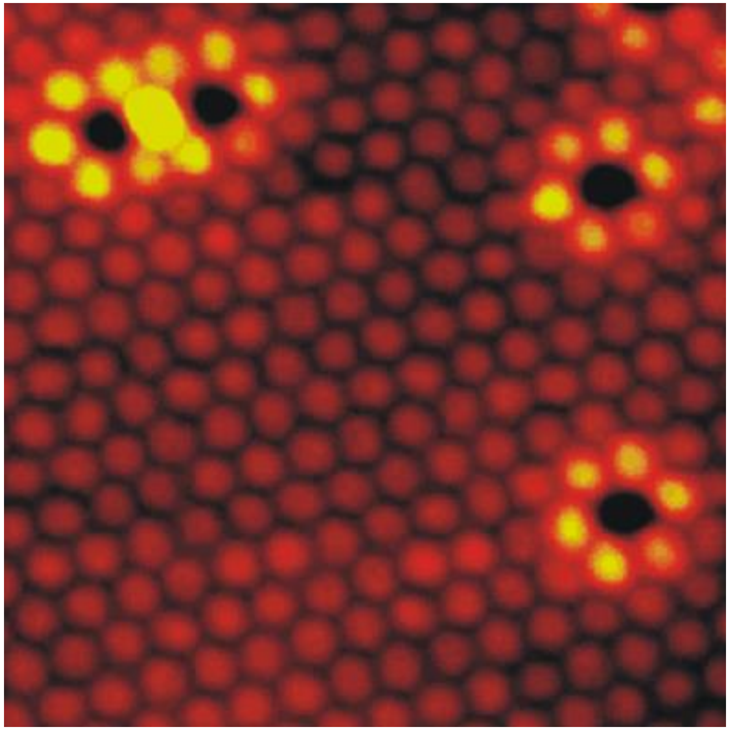
Mogućnosti za smanjenje emisije CO_2

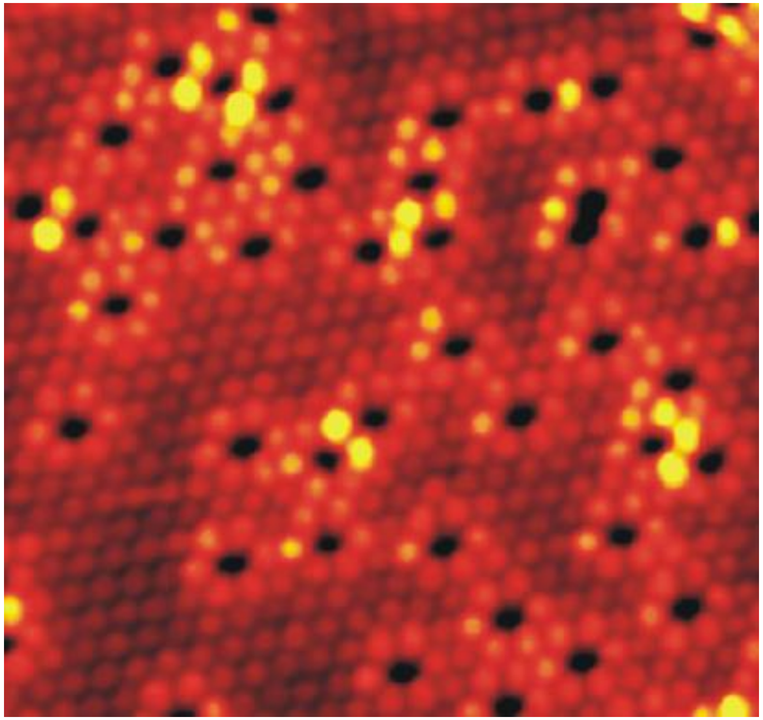
1. TEHNOLOŠKA UNAPRJEĐENJA PROCESA
2. HVATANJE I SKLADIŠTENJE CO_2 – MINERALNO, U PODZEMLJU (VODOTOKOVI, NAFTNA POLJA / EOR)
3. KEMIJSKI PROCESI U RAZVITKU

Design of a new steam reforming catalyst based on nanoscience

- Au-Ni surface alloy







F. Besenbacher, et al., Design of a Surface Alloy Catalyst for Steam Reforming, *Science* 279 (1998) 1913

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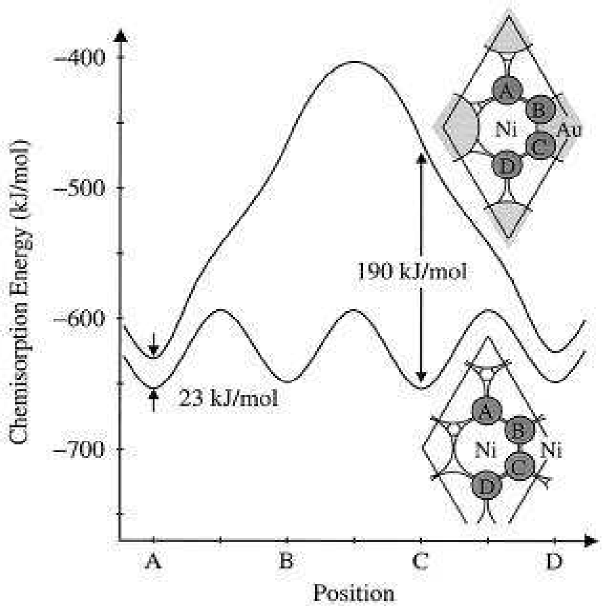

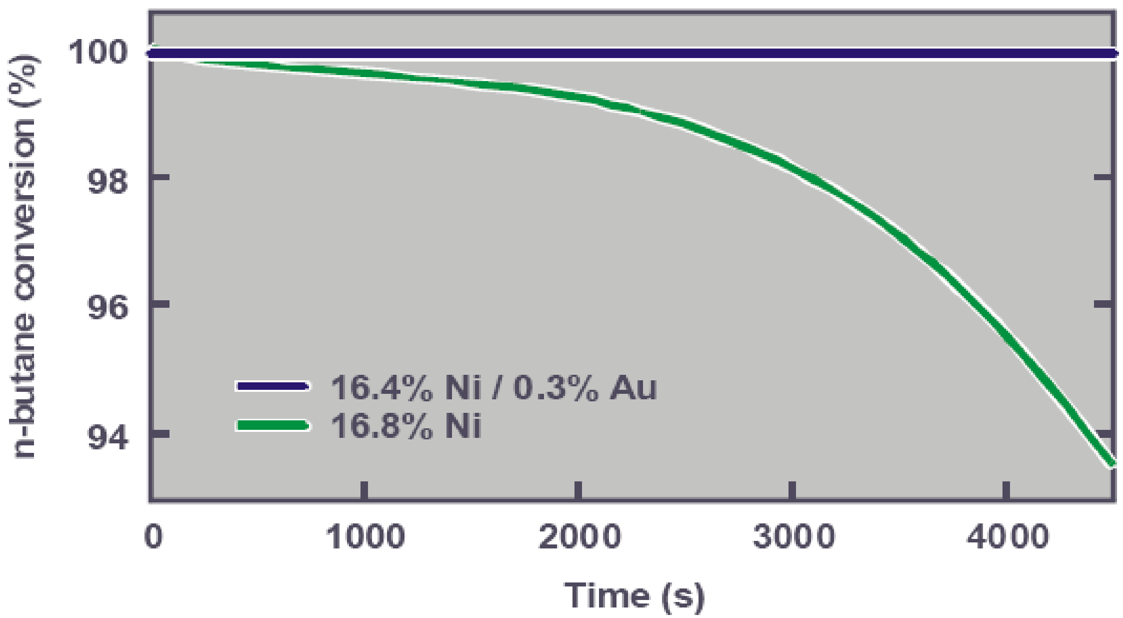

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TEHNOLOŠKA UNAPRJEĐENJA PROCESA

Visokoučinkovito reformiranje bez proizvodnje suvišne pare - Air Liquide SMR-X tehnologija

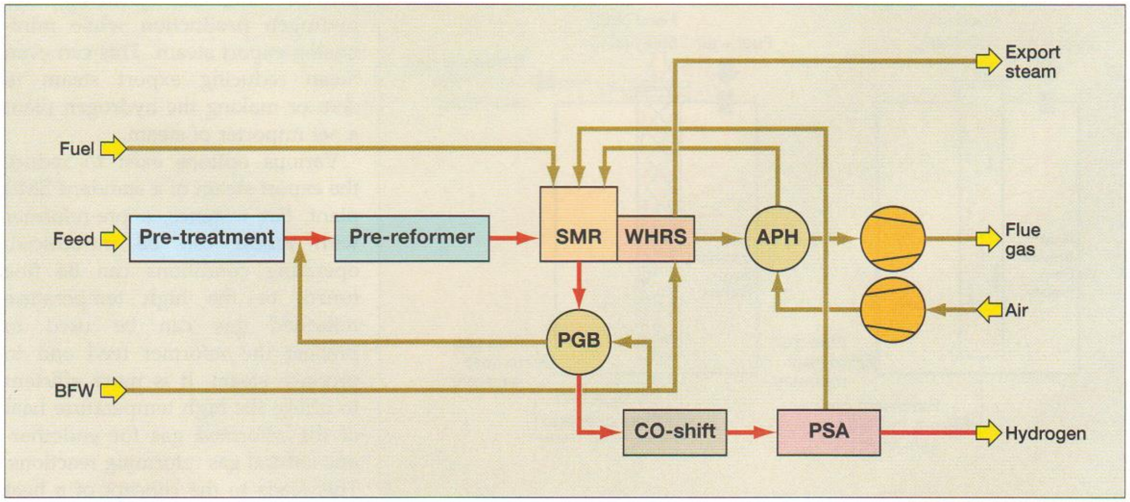


Figure 1 Typical H_2 SMR configuration: WHRS – waste heat recovery section, APH – air preheat, PGB – process gas boiler, PSA – pressure swing adsorption, BFW – boiler feed water

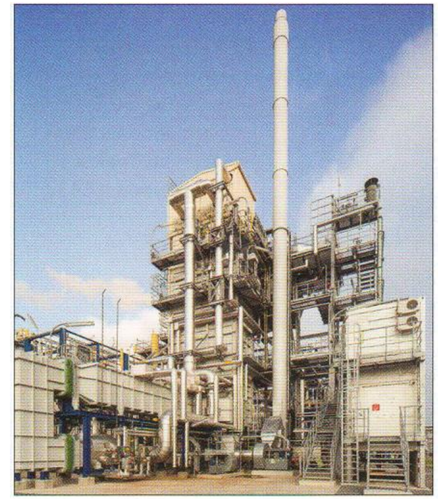


Figure 7 Air Liquide's commercial scale demonstration plant

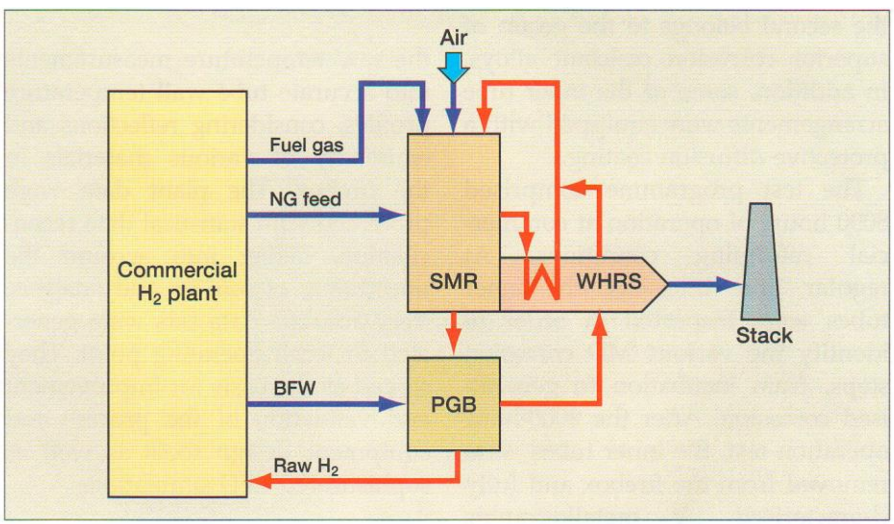


Figure 6 Block flow diagram of the multipurpose SMR demonstration plant; PGB – process gas boiler, WHRS – waste heat recovery section

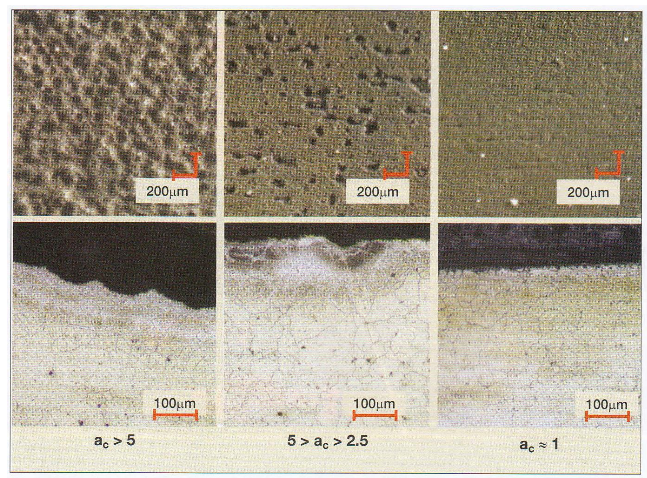
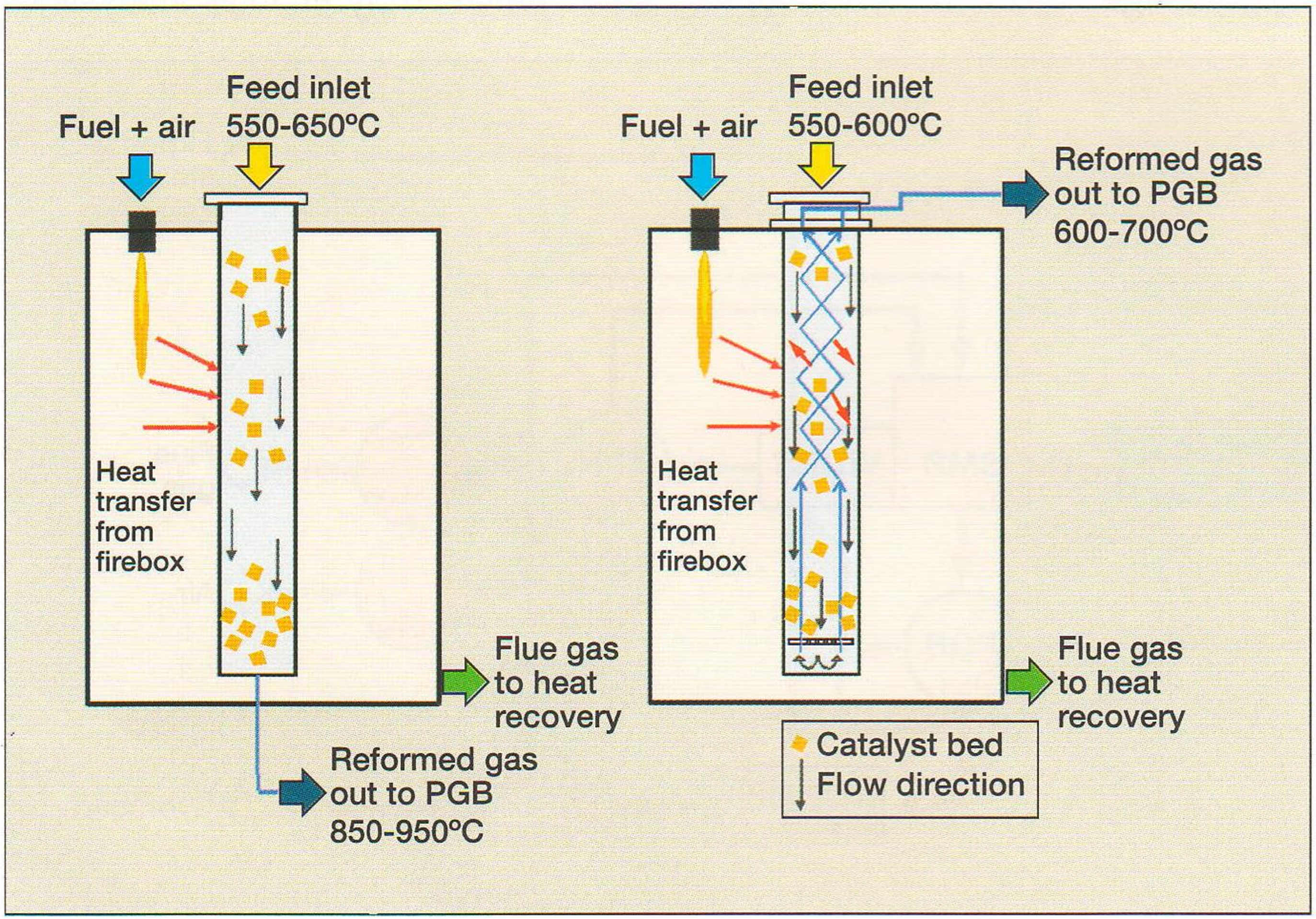


Figure 9 Overview of internal surface morphology (top pictures) and cross-sections after etching (bottom pictures) of the helical tube made in less resisting alloy after 8000 hours of operation as a function of carbon activity

Mogućnosti za smanjenje emisije CO_2

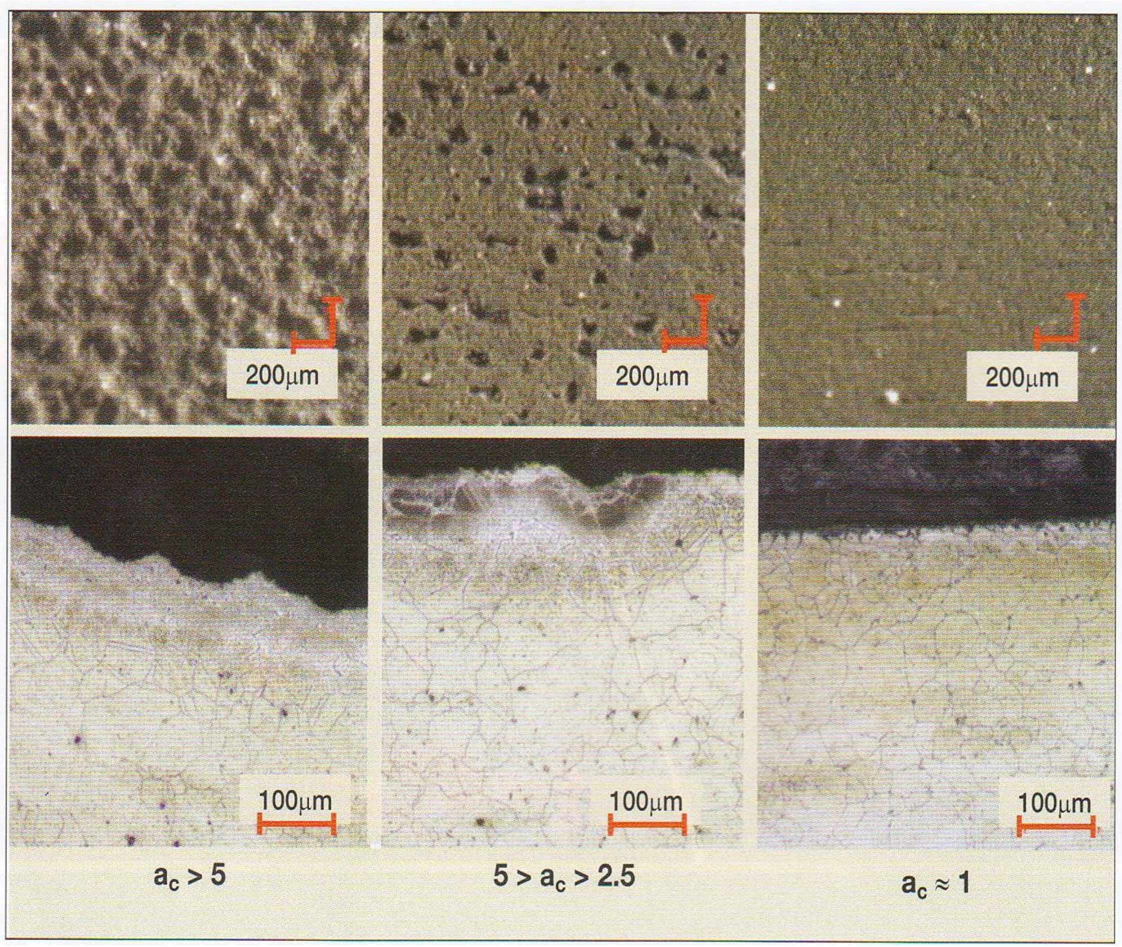
TEHNOLOŠKA UNAPRJEĐENJA PROCESA

Prikaz unutarnje izmjene topline primijenjen kod SMR-X tehnologije (desno) u usporedbi s klasičnim postupkom (lijevo).



Mogućnosti za smanjenje emisije CO_2

TEHNOLOŠKA UNAPRJEĐENJA PROCESA

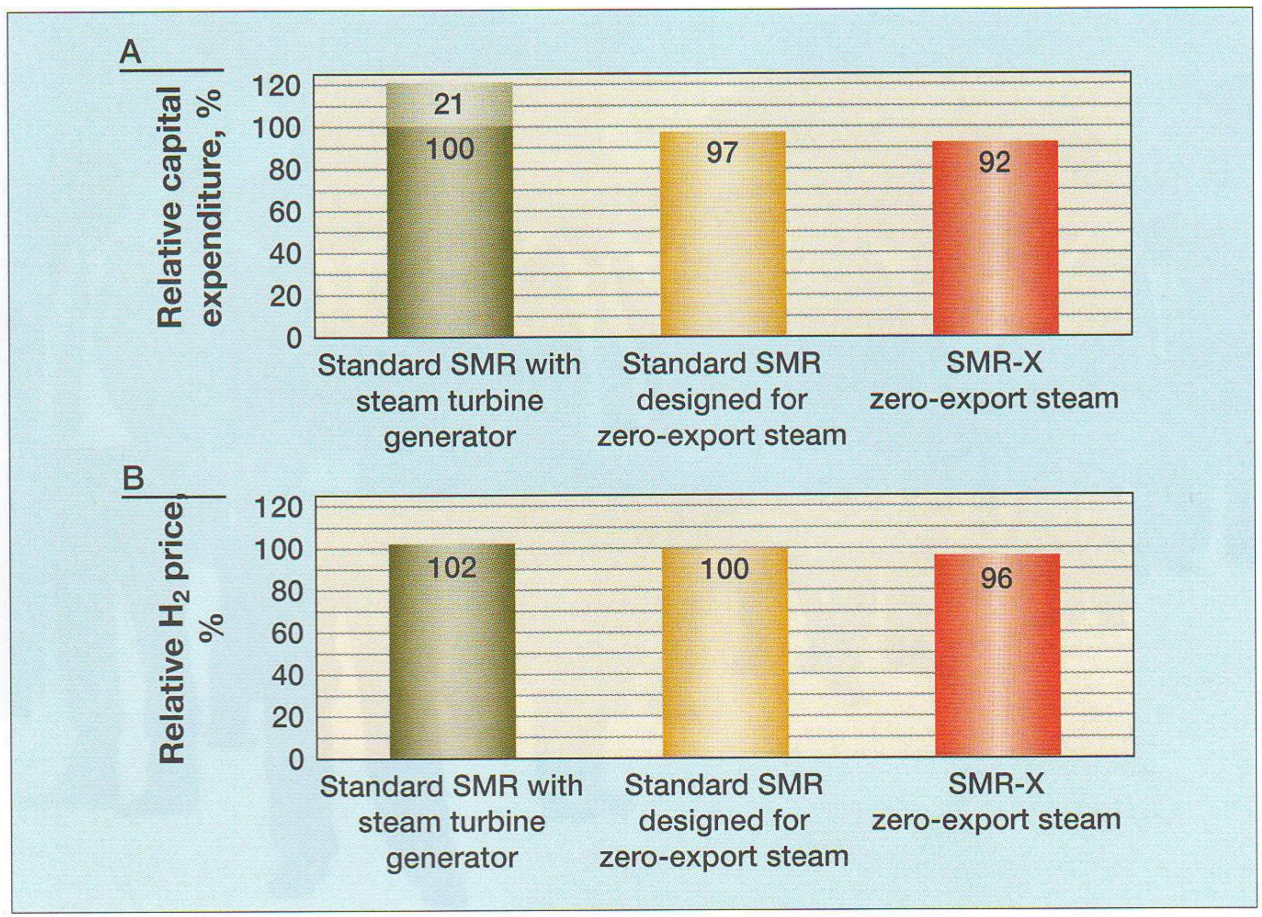


Prikaz morfologije unutarnje površine (gornje slike) i presjeci nakon jetkanja (donje slike) cijevi izrađenih od slabo otporne slitine nakon 8000 sati rada u uvjetima sklonim MD koroziji kao funkcija aktiviteta ugljika, a_c.

Mogućnosti za smanjenje emisije CO_2

TEHNOLOŠKA UNAPRJEĐENJA PROCESA

Usporedba investicijskih (gore) i proizvodnih (dolje) troškova za visoko-volumnu proizvodnju vodika parnim reformiranjem na osnovi različitih SMR koncepata.



Mogućnosti za smanjenje emisije CO_2

TEHNOLOŠKA UNAPRJEĐENJA PROCESA

Obnova plamenika povećava kapacitet i smanjuje troškove - Zeeco

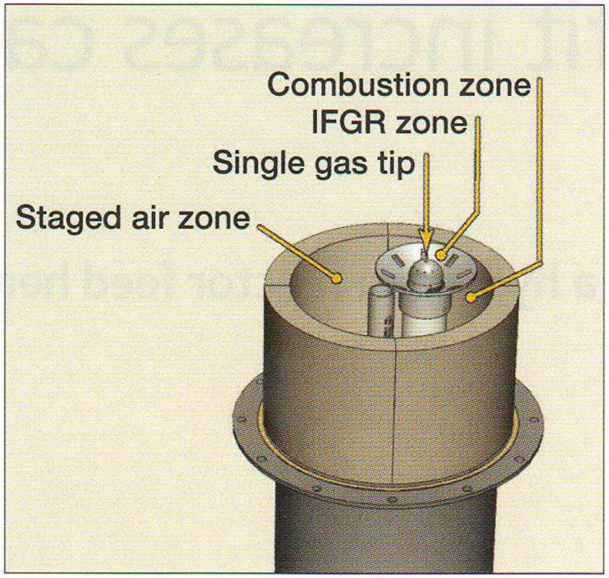


Figure 2 Burner throat of a typical GB Single Jet burner showing the different combustion air and internal flue gas recirculation zones of the burner

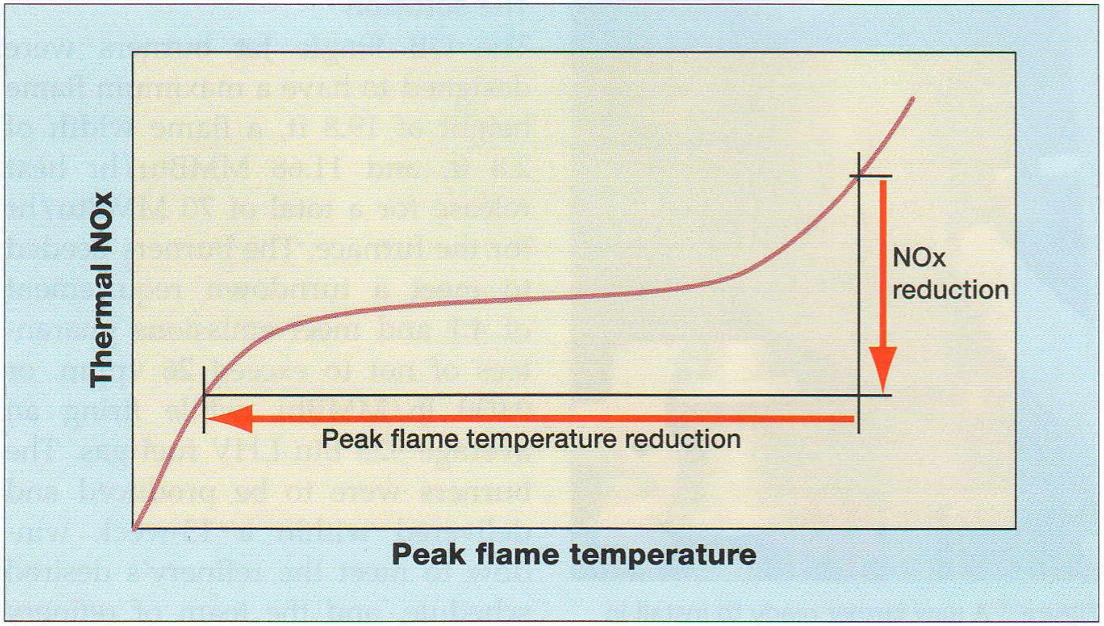


Figure 3 Peak flame temperature versus thermal NOx production

One immediate result of the burner retrofit was the furnace began operating at a significantly lower fuel gas pressure of 18 psig and required only five of the six burners to achieve the desired heat release at that pressure. The new operating pressure was well below the maximum 27.5 psrg and the burners operated as expected with stable flames and low flame interaction. With those operating parameters, the new burners paid for themselves in less than one week of operation.

Mogućnosti za smanjenje emisije CO_2

HVATANJE I SKLADIŠTENJE CO_2 – MINERALNO, U PODZEMLJU (VODOTOKOVI, NAFTNA POLJA / EOR)

Mogućnosti za smanjenje emisije CO_2

HVATANJE I SKLADIŠTENJE CO_2 – MINERALNO, U PODZEMLJU (VODOTOKOVI, NAFTNA POLJA / EOR)

Mineralno skladištenje

Zbrinjavanje CO_2 reakcijom s mineralima koji sadrže Mg i Ca i formiranjem karbonata $MgCO_3$ i $CaCO_3$

$$CaO + CO_2 = CaCO_3 \quad \Delta H < 0$$

$$Mg_2SiO_4 + 2CO_2 = 2MgCO_3 + SiO_2$$

Termodinamički povoljan proces, spontan, ali dugotrajan.

wollastonite	$CaSiO_3 + CO_2 \rightarrow CaCO_3$
olivine	$Mg_2SiO_4 + 2CO_2 \rightarrow 2MgCO_3 + SiO_2$
pyroxenes	$CaMgSi_2O_6 + 2CO_2 \rightarrow CaMg(CO_3)_2 + 2SiO_2$
serpentine polytypes	$Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + 2H_2O$
brucite	$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O$

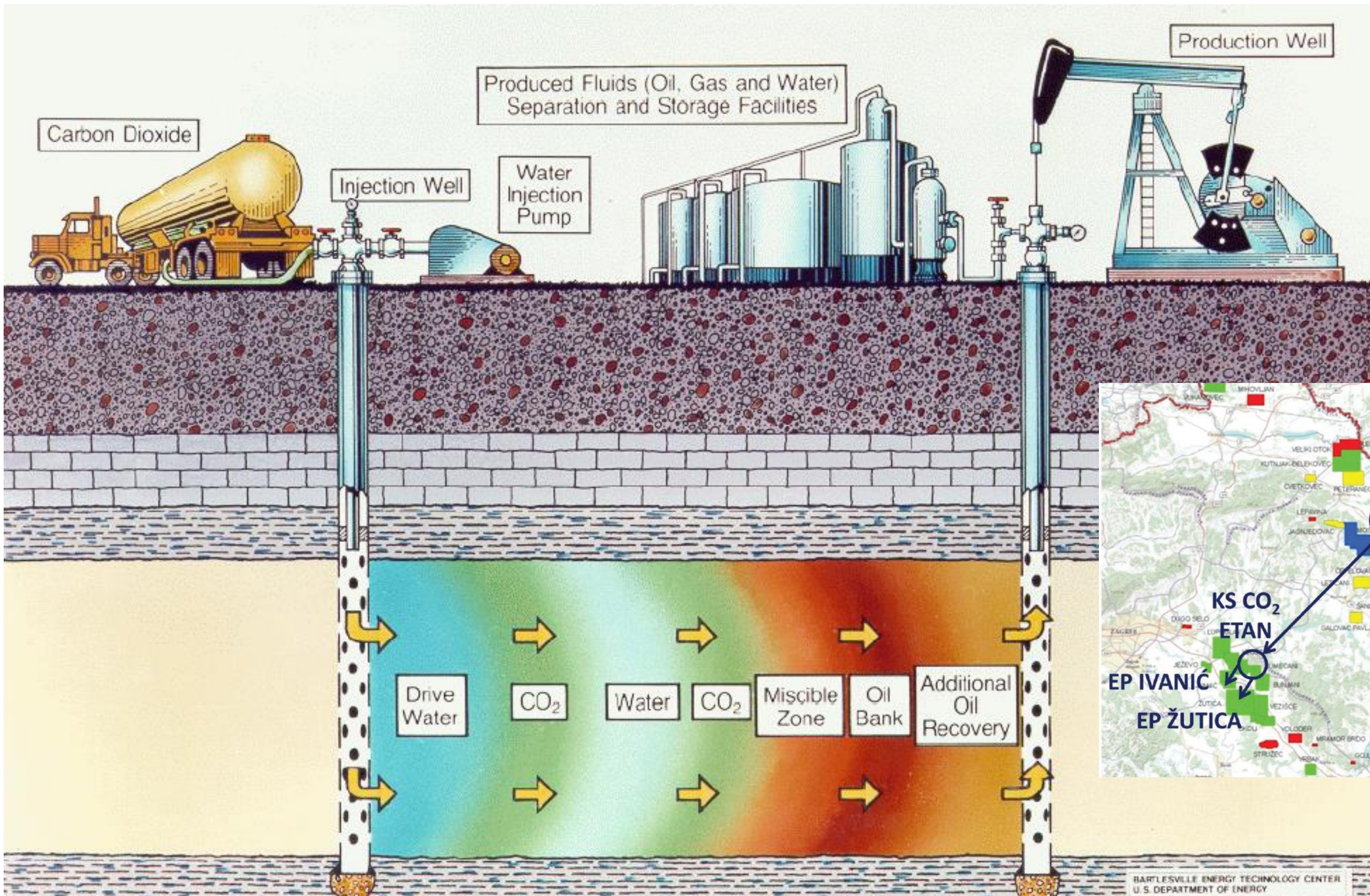
Mogućnosti za smanjenje emisije CO_2

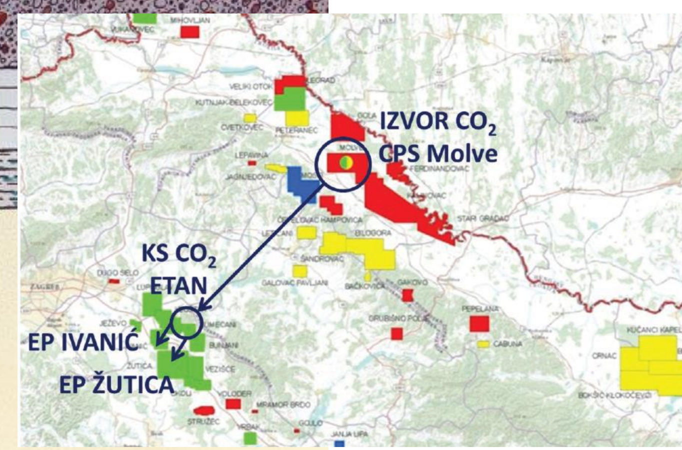
HVATANJE I SKLADIŠTENJE CO_2 – MINERALNO, U PODZEMLJU (VODOTOKOVI, NAFTNA POLJA / EOR)

Utiskivanje CO_2 iz postupka reformiranja u naftna polja

(praktična iskustva – INA: naftna polja Ivanić i Žutica – EOR – povećanje iscrpka ugljikovodika)

= plavi vodik





Mogućnosti za smanjenje emisije CO_2

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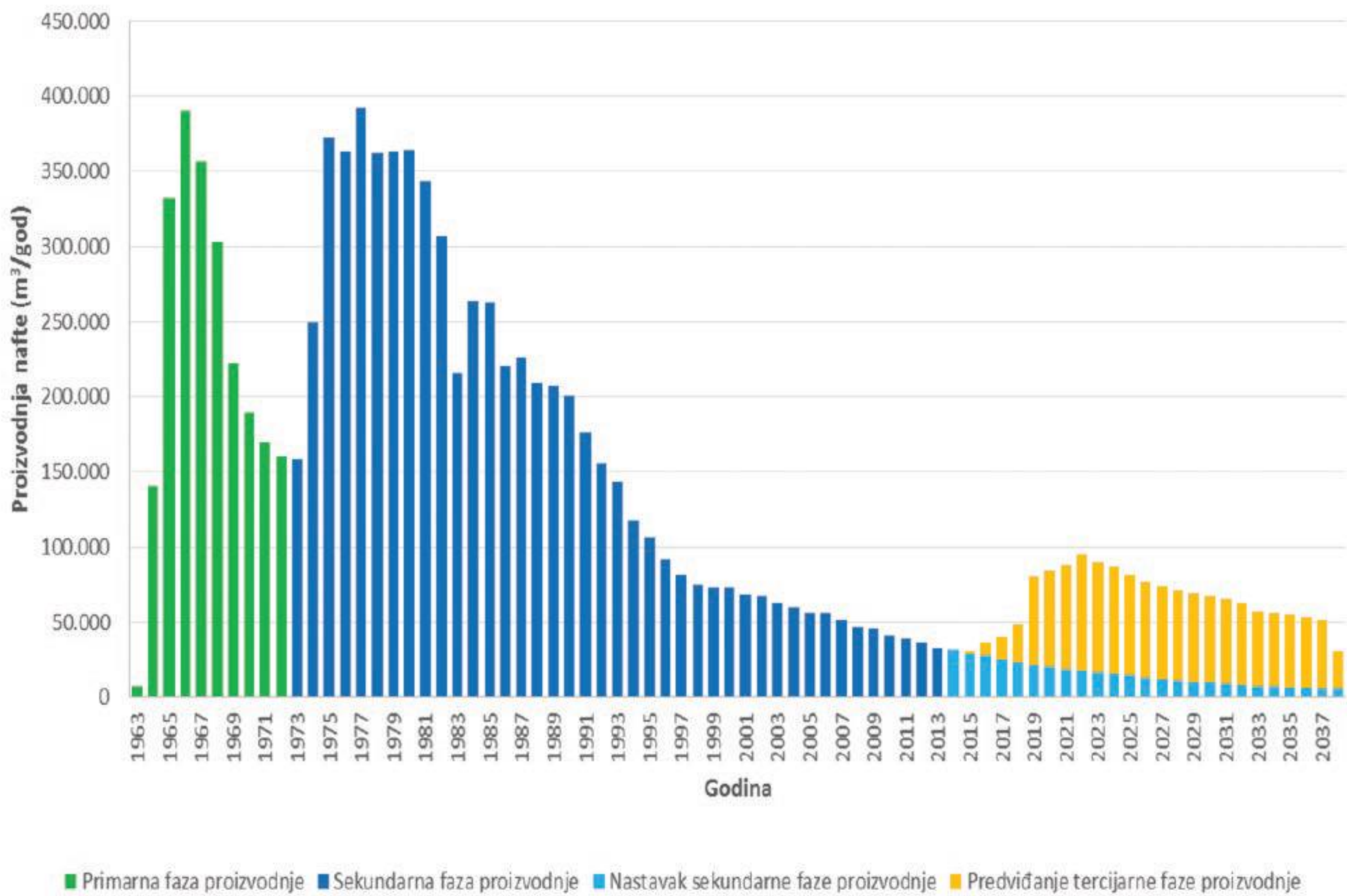


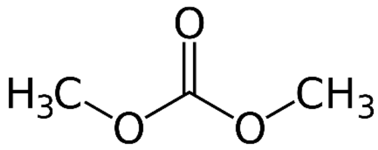
Mogućnosti za smanjenje emisije CO_2

KEMIJSKI PROCESI U RAZVITKU

Dimetil karbonat (DMC) – organski ester formule $OC(OCH_3)_2$. Bezbojna, zapaljiva kapljevina. Upotrebljava se kao otapalo, dodatak gorivima, za procese metilacije. Smatra se zelenim reagensom i ne podliježe EPA restrikcijama za hlapljive organske tvari (VOC) u SAD.

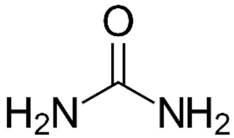
Dobivanje

A. Oksidativna karbonilacija



$$CO + 1/2\ O_2 + 2\ CH_3OH \rightarrow (CH_3O)_2CO + H_2O$$

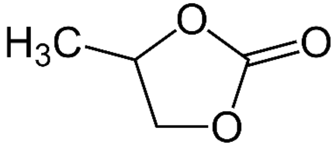
B. Transesterifikacija etilen karbonata ili propilen karbonata i metanola

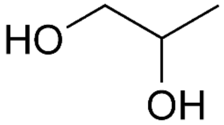


$$CO_2 + 2\ NH_3 \rightleftharpoons \text{urea} + H_2O$$

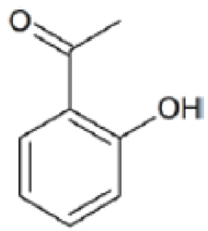
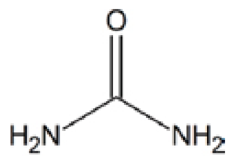
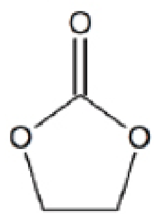
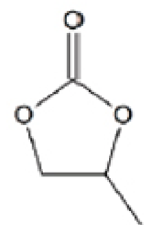
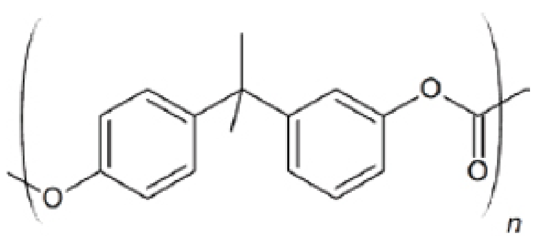
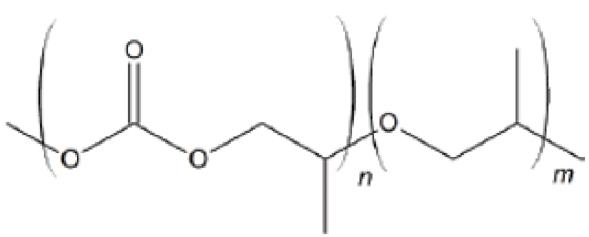
$$\text{urea + propilen glikol} \rightleftharpoons \text{propilen karbonat} + 2\ NH_3$$

$$\text{propilen karbonat + 2 MeOH} \rightleftharpoons \text{DMC + propilen glikol}$$

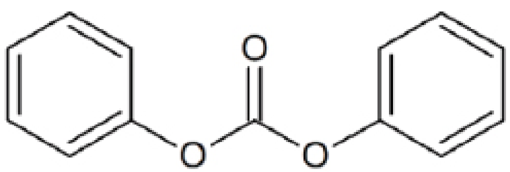
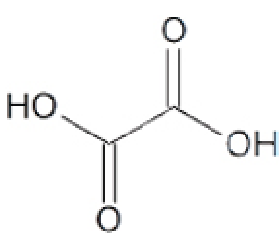




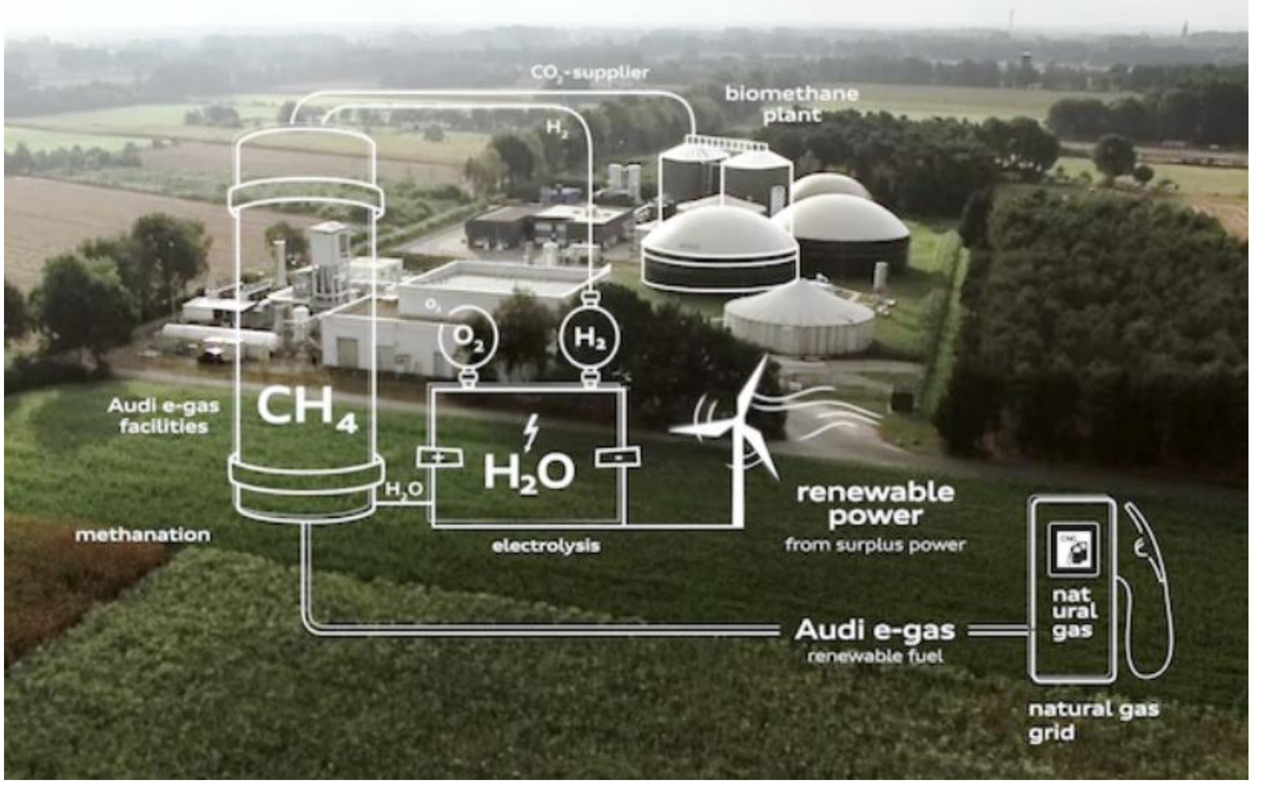
Glavne kemikalije koje se trenutno sintetiziraju iz CO_2 u industrijskim razmjerima.

Strukturna formula i naziv, godišnja proizvodnja postupkom iz CO_2 (doi: 10.1016/j.petlm.2016.11.00351T)	
	Salicilna kiselina 30.000 t
	Urea 112.000.000 t
 	Ciklički karbonati (etilen-karbonat, propilen-karbonat) 40.000 t
	Polikarbonati 600.000 t
	Poli(eter-karbonati) 10.000 t

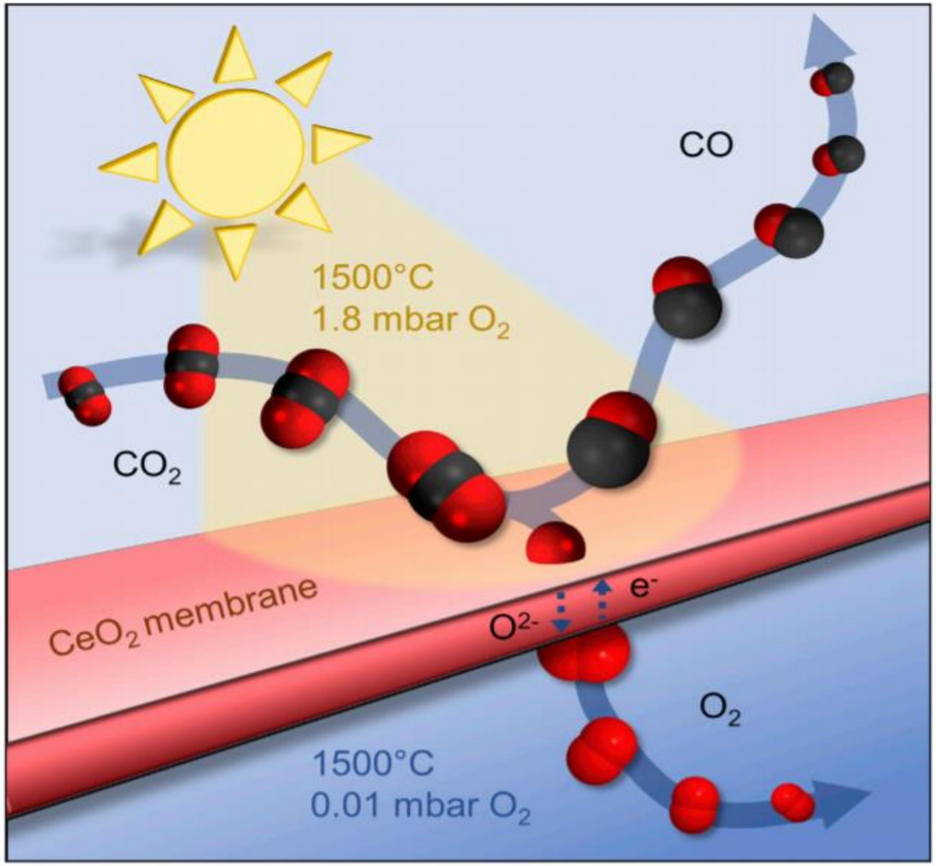
Fine i visoko volumne kemikalije te goriva koje se trenutno sintetiziraju iz CO_2 na pilotskim postrojenjima.

Kemikalija - proizvod	Tvrtka (lokacija)	Godišnja proizvodnja
Metanol	• Carbon Recycling International (Island) • Mitsui Chemical Company (Japan)	4.000 t 100 t
Metan (gorivo)	• Audi (Njemačka)	1.000 t
Ugljikov monoksid (preko SOEC)*	• Haldor-Topsoe (Danska)/Gas Innovations (SAD)	12 Nm^3/h
Sintetska CH goriva (preko CO_2 Fischer-Tropschove sinteze)	• Sunfire (Njemačka) • INERATEC (Finska)	3 t 200 L
 Difenil karbonat	• Shell (Singapur) • Asahi-Kasei	500 t 1.000 t
 Oksalna kiselina	• Liquid Light/Avantium (Nizozemska)	2.4 t

*SOEC = elektroliza/elektrolizer s čvrsto-oksidnim elektrodama

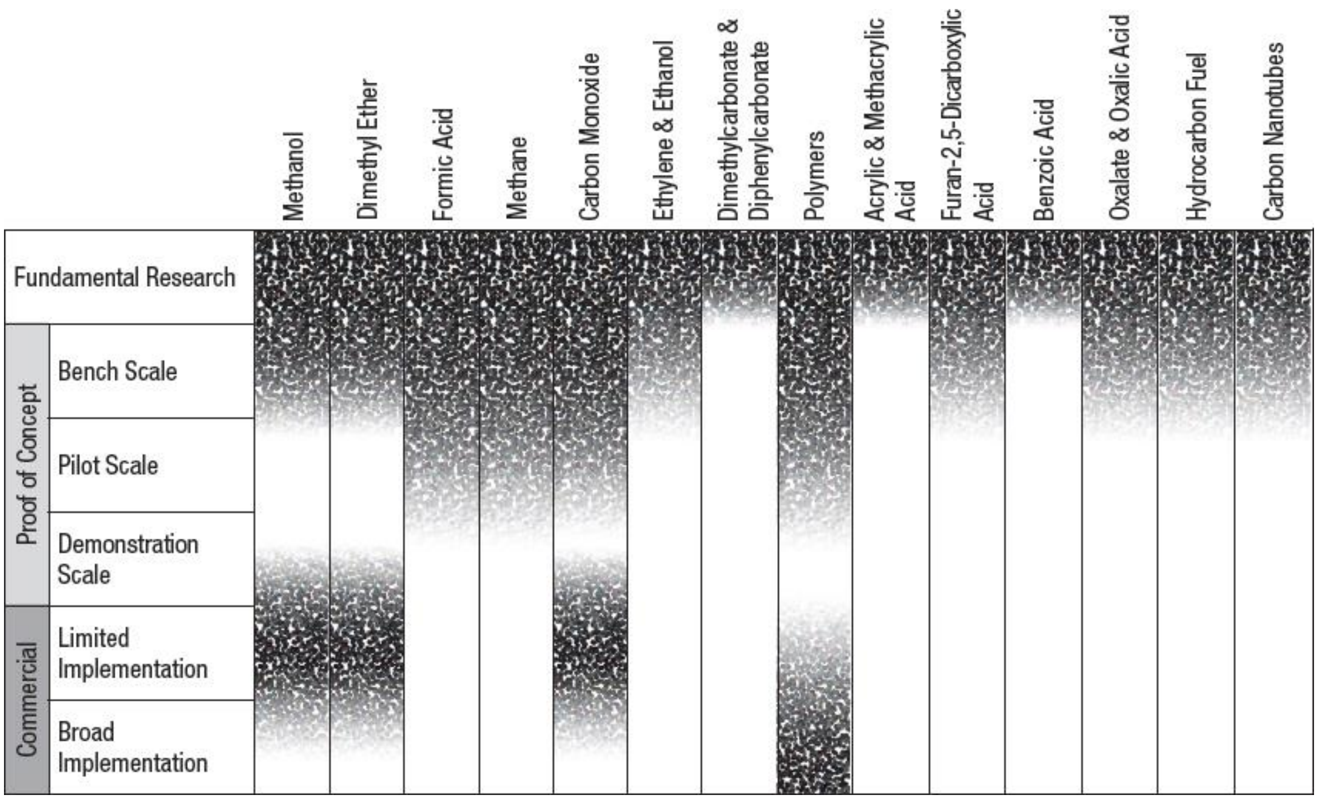


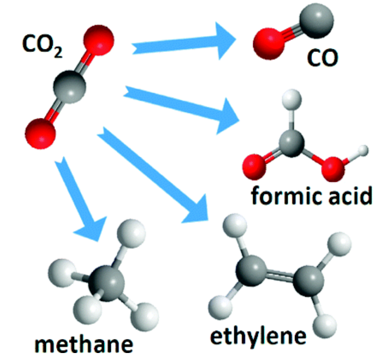
Tehnološka shema procesa proizvodnje sintetskog metana od CO_2 i zelenog vodika dobivenog elektrolizom vode

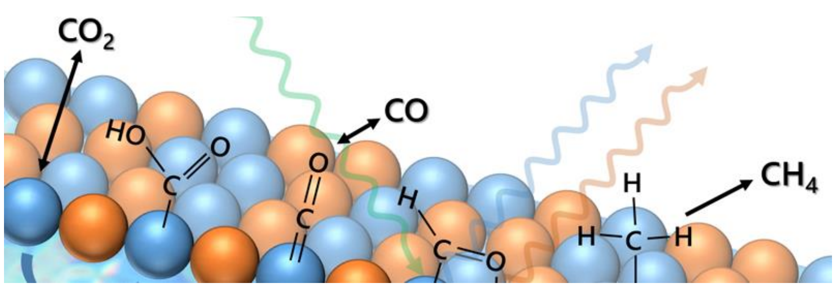


Konverzija CO_2 u gorivo putem termokemijskog procesa na sunčevo zračenje - solarni reaktor kontinuirano cijepa CO_2 preko redoks membrane u odvojene tokove CO i O_2 pomoću koncentriranog sunčevog zračenja (solarni toranj).

Stanje istraživačkih aktivnosti za dobivanje kemijskih proizvoda iz otpadnog CO_2 - veća gustoća na dijagramu ukazuje na znatne istraživačke aktivnosti, a prazna područja označavaju odsustvo ili male istraživačke aktivnosti.







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France backs green hydrogen as part of €30bn green energy package

By Jules Scully | Sep 07, 2020 11:16 AM BST | 0

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„With energy consumption representing nearly 70% of France's greenhouse gas emissions, the government said the scheme should be an opportunity for the country to spearhead low-carbon hydrogen production. A total of €7 billion will be spent by 2030 to develop green hydrogen, including funding for research projects focused on carbon-free solutions based on hydrogen for the maritime and aviation industries."

Image: Twitter/LANGA Group.

Almost a third of France's €100 billion (US$118.2 billion) coronavirus recovery package will be directed towards greener energy policies, as the country ramps up expenditure on hydrogen production.

Some €30 billion of the plan will be spent on an "ecological transition", including efforts to make buildings more energy efficient and ensure France is at the forefront of green hydrogen, the country's prime minister, Jean Castex, noted. "Relaunch France is first and foremost a plan intended to serve the climate and biodiversity," he said.

Announcing the package – which has employment, environment and competitiveness as its three pillars – last week, Castex said the money would be spent over the next two years to help the economy to recover to its pre-crisis level by 2022.

Air Liquide

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€21,920 M

2019 Group revenue

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[Report - 1/3] Let's talk hydrogen!

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Trenutne industrijske potrebe za vodikom:
1,2 mil. t/god. uz očekivani porast potražnje zbog novih tržišta (promet)

Za zeleni vodik: > 10 GW_{el}

- vjetroturbine u Sjevernom moru
- proizvodno-distributivna mreža u 5 regionalnih područja > > >

11
JUN 2020

The Netherlands Preparing for GW-Scale Hydrogen Production

5 potential industrial regions have been designated for large-scale green hydrogen production.

Currently the Dutch annual industrial hydrogen demand is 1.2 million ton. This demand will significantly increase in the coming decade and the production methods need to be "green", fueled by renewable electricity. New markets like transport will need to be serviced. More than 10 GW electricity will be needed as input and most will come from offshore North Sea wind. Currently electrolyzers are in the MW range, not GW. The GW-hydrogen plant will need up to 8 hectare. In all 5 regions locations with sufficient space can be found. Bottleneck is the electricity infrastructure, not so much the gas infrastructure. Bringing renewable electricity from all those turbines and panels to the hydrogen plants will be more costly than handling the resulting hydrogen.

Next stop, hydrogen-powered trains

‘World’s first’ hydrogen-powered train enters into service

PUBLISHED MON, SEP 17 2018 5:29 AM
UPDATED TUE, APR 21 2020 5:41 AM

European railway manufacturer Alstom has launched what it says is the world’s first hydrogen fuel cell train. Alstom’s Coradia iLint uses fuel cells that turn hydrogen and oxygen into electricity, and can travel up to 140 kilometers per hour. Two models of the low-noise, zero-emissions train will enter commercial service in Lower Saxony, Germany, today.

Engineers working on the Hydroflex say that hydrogen-powered trains could be the answer to decarbonising the UK’s rail system without incurring the high cost of electrifying its track. According to an [assessment of 20 lines] in Britain and mainland Europe, electrifying a single kilometer of track can cost £750,000 to £1m ($965,000 to $1.3m). Hydrogen-powered trains are less expensive, because they don’t require massive track overhauls and they can be created by retrofitting existing diesel trains. This is especially beneficial in rural areas where there are more miles to cover, but fewer passengers to justify the expense.

https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-change

KONČAR
Končar - Električna vozila d.d.

FORBES / EDITORS' PICK|23,342 views|Dec 29, 2019,08:00am EST

Heavy-Duty Hydrogen: Fuel Cell Trains And Trucks Power Up For The 2020s

The first zero-emission “hydrail” project in the U.S. will be in southern California, where the San Bernardino County Transportation Authority plans to operate a FLIRT H2 train from Swiss supplier Stadler from 2024. The first train, with two cars and a rooftop power pack containing fuel cells and hydrogen tanks, will run on a 9-mile commuter rail line between San Bernardino and Redlands, under a contract worth $23.5 million, according to the SBCTA, with an option to purchase four more trains.

www.upi.com/Big-oil-big-auto-tout-hydrogen-as-next-clean-fuel-choice/6341484736047/

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Big oil, big auto tout hydrogen as next clean fuel choice

Thirteen-member council calls for governments to put forward large investments.

By Daniel J. Graeber | Jan. 18, 2017 at 6:04 AM Follow @crudeoilprices

Naftaši i auto industrija žele vodik kao čisto gorivo

Na marginama gospodarskog foruma u švicarskom Davosu veliki predstavnici automobilske i naftne industrije su formirali tijelo pod nazivom **Hydrogen Council** čiji je cilj *da se usmjeri i ostatak industrijskih proizvođača te zakonodavce prema vodiku kao čistom energentu*.

Prema izjavi izvršnog direktora velike francuske plinske tvrtke Air Liquide B. Potiera, cilj ovog savjeta je da objasni „zašto se vodik izdvojio kao ključno rješenje za energetsku tranziciju, mobilnost kao i za energiju za industrijski sektor i stanovanje“.

Savjet za vodik osim te francuske kompanije čine još Toyota i 12 drugih europskih i azijskih proizvođača automobila i nafte.

Izvor: United Press International, 18.1.2017.

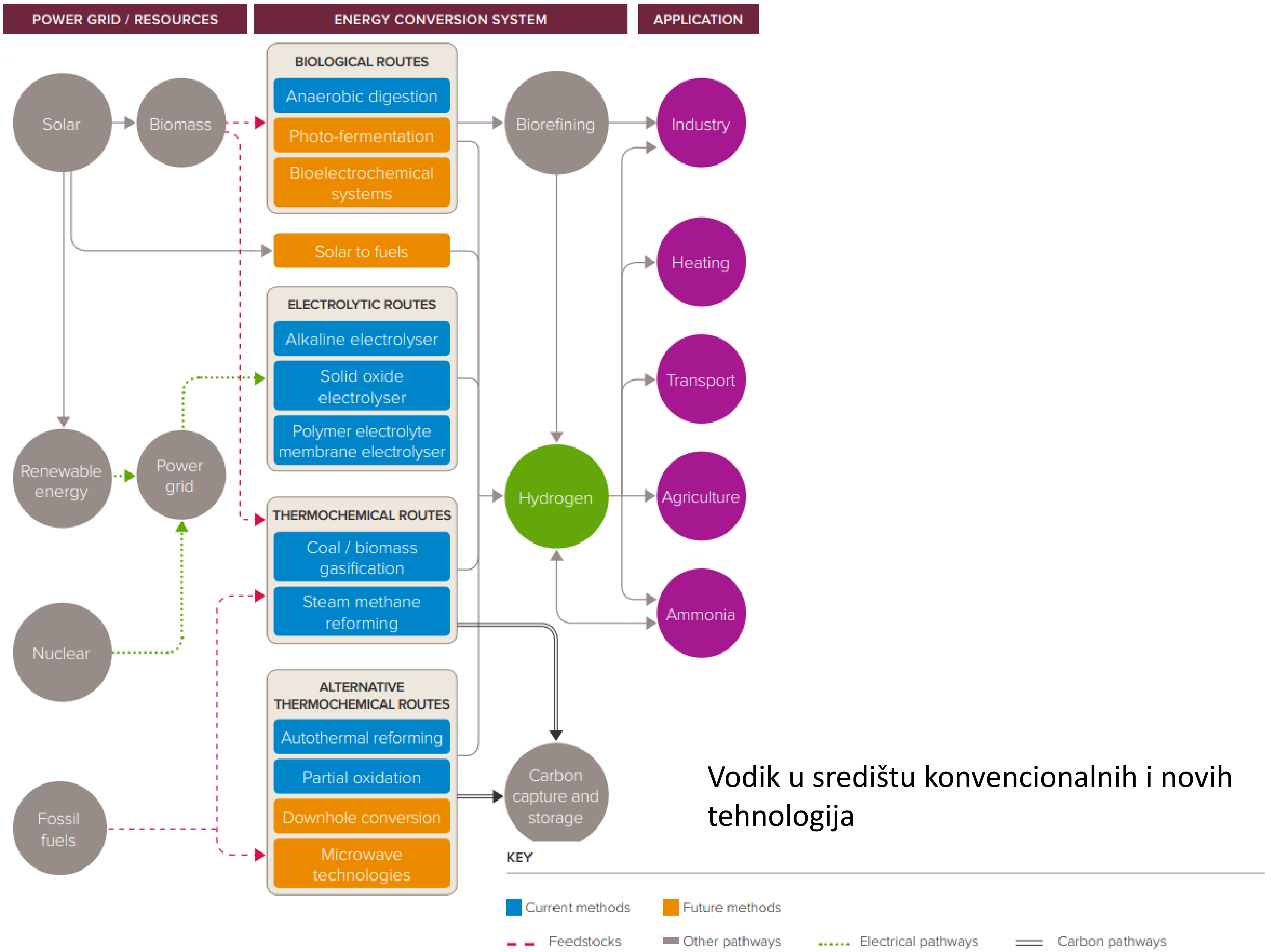


Fuel cell vehicles are limited in availability and depend in part on access to refueling stations for hydrogen.

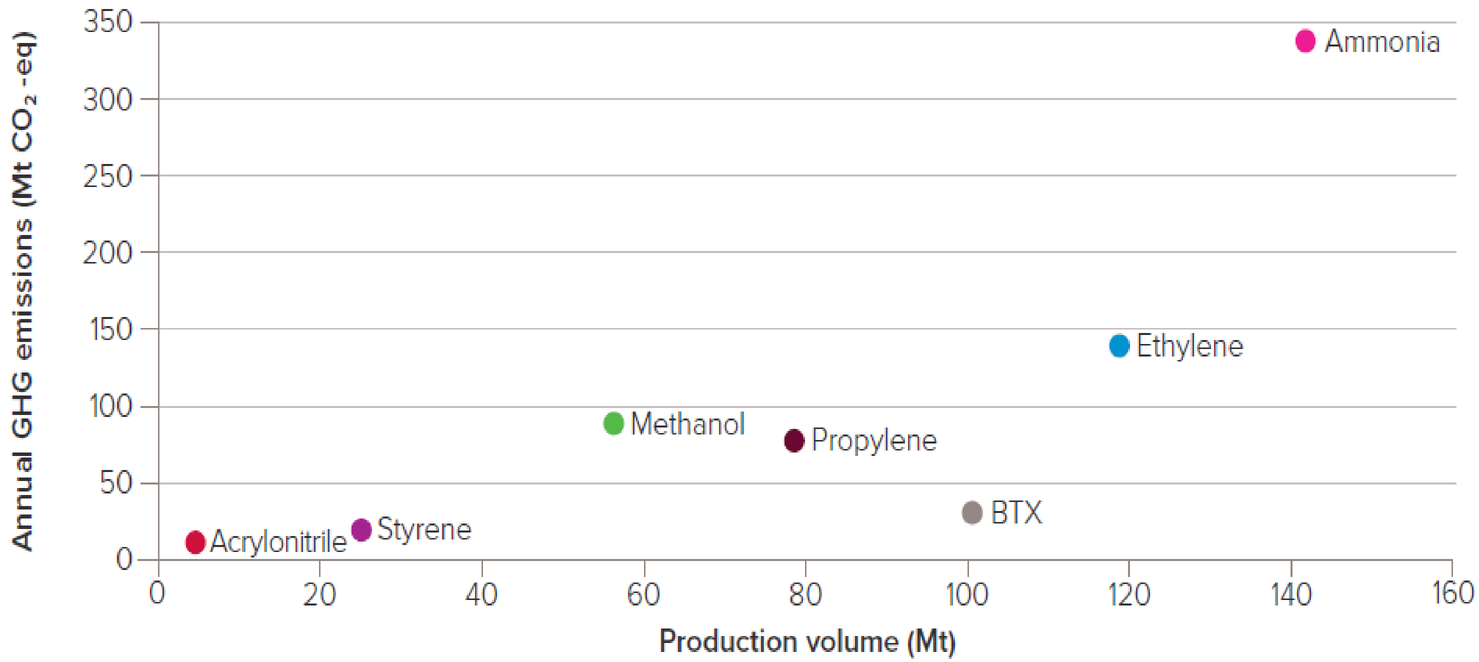
"We need governments to back hydrogen with actions of their own – for example through large-scale infrastructure investment schemes," Potier said.

The council collectively aims to invest nearly $11 billion during the next five years in hydrogen-related energy products.

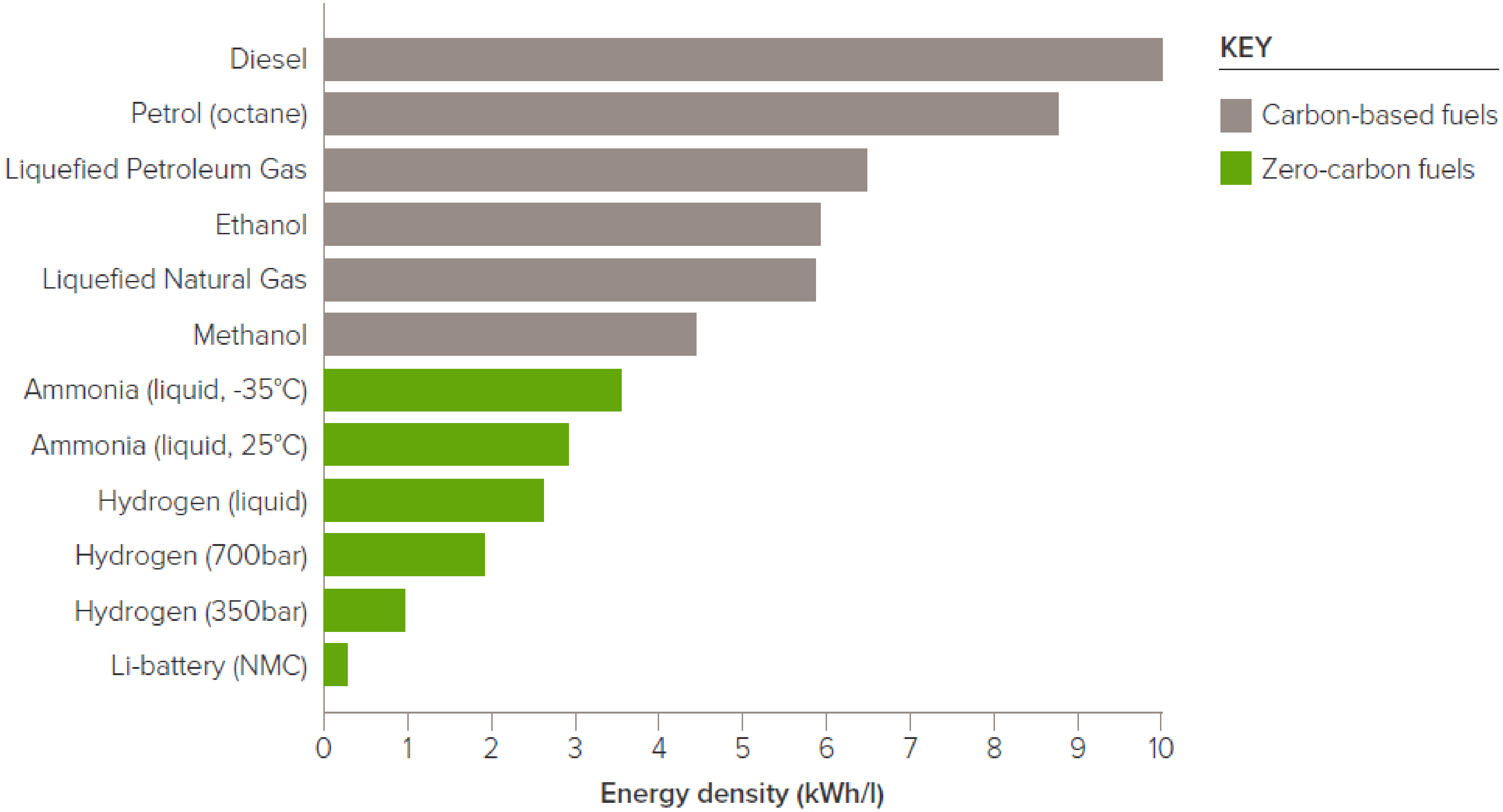
Outside of the 13-member group, the United States has committed at least $3 million to advance fuel-cell research with the aim of increasing market competition. Austria, meanwhile, already has infrastructure in place to support hydrogen-powered vehicles and energy company OMV said it's a partner in an initiative in Germany, which envisions 400 hydrogen filling stations by 2023.



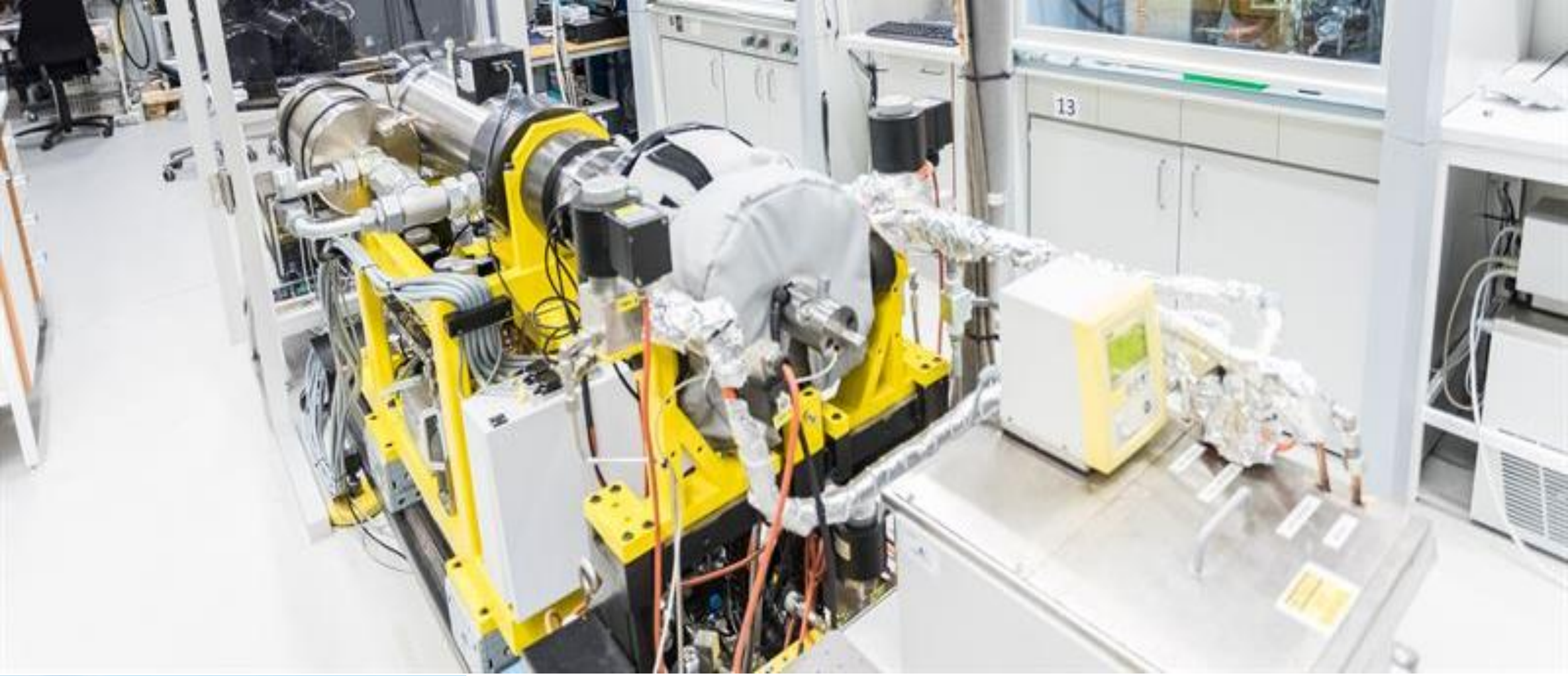
Vodik u središtu konvencionalnih i novih tehnologija



Emisije stakleničkih plinova u industrijskoj proizvodnji visoko volumnih kemikalija (podaci za 2010. godinu; BTX = benzen, toluen, ksilen – bazni aromatski ugljikovodici).



Volumetrijska gustoća energije raznih goriva

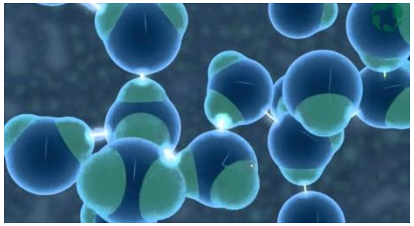


Sustav za ispitivanje izgaranja amonijaka finske tehnološke grupe Wärtsilä

Proizvodnja zelenog vodika

SIROVINE I PROCES

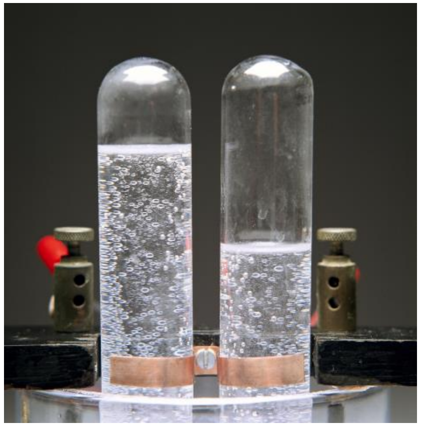
- sirovina: voda



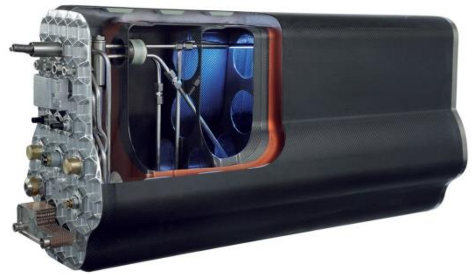
- izvori energije: obnovljivi (hidroelektrane, vjetroelektrane, fotoelektrane)

- proces: elektrokemijski - elektroliza vode

$$2\ H_2O\ (l) \rightarrow 2\ H_2(g) + O_2(g)$$



Proizvodnja zelenog vodika



PROIZVODI

- proizvod: zeleni vodik

- suproizvod: čisti kisik
  (za kemijske procese, za izgaranje CH goriva umjesto zraka – produkti: voda + CO_2, bez dušika)

ELEKTROLITIČKI PROCESI

PROIZVODNJA VODIKA ELEKTROLIZOM VODE

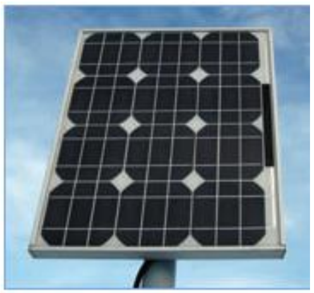
Katodna reakcija (+): $2\ H_2O\ (l) + 2\ e^- \rightarrow H_2\ (g) + 2\ OH^-\ (aq)$

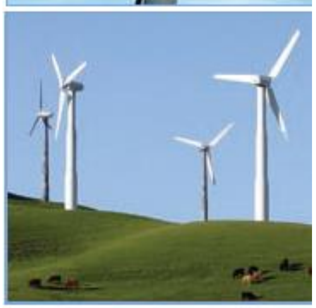
Anodna reakcija (-): $4\ OH^-\ (aq) \rightarrow O_2\ (g) + 2\ H_2O\ (l) + 4\ e^-$

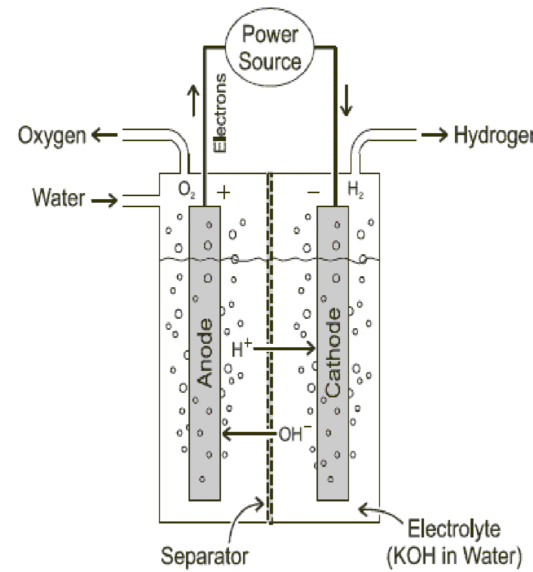
$E^o = -1{,}23\ V$

Elektrolit: KOH

Elektrode (elektrokatalizator): Ni







Elektroliza je elektrokemijski proces razdvajanja vode na vodik i kisik upotrebom električne energije. Zbog visoke cijene električne energije, učinkovitost je vrlo važan parametar kod elektrolize.

Visoka učinkovitost postiže se provođenjem elektrolize pri višim temperaturama i pri višim tlakovima. Iako je elektroliza skup proces, cijena dobivenog vodika može biti znatno niža ako je korištena vršna električna energija i ako su postrojenja visokovolumna.

ELEKTROLITIČKI PROCESI

PROIZVODNJA VODIKA ELEKTROLIZOM VODE

Visokotlačni PEM elektrolizer
(PEM – proton exchange membrane)

- izlazni tlak vodika oko 120-200 bar na 70 °C
- nema potrebe za vanjskim kompresorom

Tip	Alkalne otopine	Kisele otopine	PEM	SOEC
Nosilac naboja	OH^-	H^+	H^+	O^{2-}
Reaktant	Voda	Voda	Voda	Voda, CO_2
Elektrolit	NaOH, KOH	H_2SO_4, H_3PO_4	Polimer	Keramika
Elektroda	Ni	Pt	Pt, Ir	Ni
Temperatura	40-90 °C	150 °C	20-150 °C	700-1000 °C
Reakcija na anodi	$2OH^- \rightarrow ½\ O_2 + H_2O + 2e^-$	$H_2O \rightarrow ½\ O_2 + 2H^+ + 2e^-$	$H_2O \rightarrow ½\ O_2 + 2H^+ + 2e^-$	$O^{2-} \rightarrow ½\ O_2 + 2e^-$
Reakcija na katodi	$H_2O + 2e^- \rightarrow H_2 + 2OH^-$	$2H^+ + 2e^- \rightarrow H_2$	$2H^+ + 2e^- \rightarrow H_2$	$H_2O + 2e^- \rightarrow H_2 + O^{2-}$

Technical data

Hydrogen production:
100 – 2,000 kg per hour

Plant efficiency: ~75%

Startup time: < 1 minute

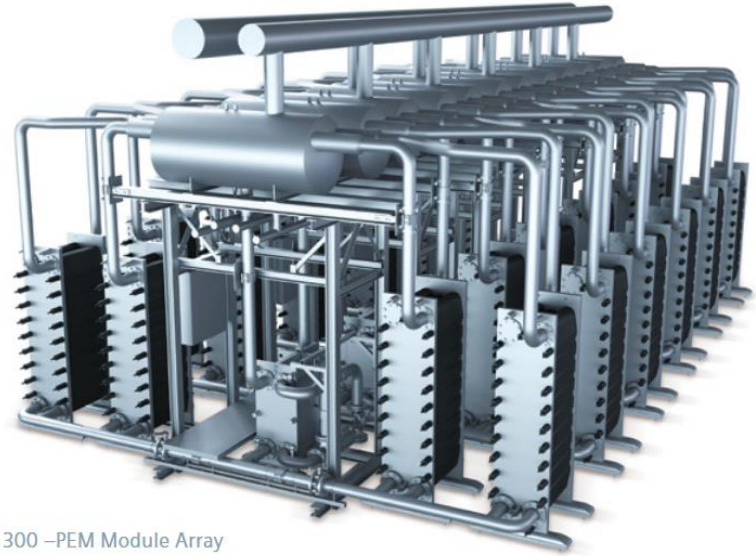
Dynamics: 0 – 100% in 10% / s

Minimum load: ≥ 5%

Water consumption (DI):
10 l per kg hydrogen

Hydrogen quality:
Ultra high purity 5.0

(2,4 – 48,0 t/dan)



SILYZER 300 –PEM Module Array

Siemens / Hydrogen Renewables Australia (HRA) has proposed the Murchison Renewable Hydrogen Project – a large scale (up to 5,000 MW) combined solar and wind farm to produce low-cost renewable hydrogen or 'green hydrogen' on Murchison House Station in Western Australia (WA).

8.876 t/god. (H_2)
26,9 t/dan

$$n = \frac{Q}{z * F} = \frac{I * t}{z * F}$$

$$E = P * t = U * I * t$$

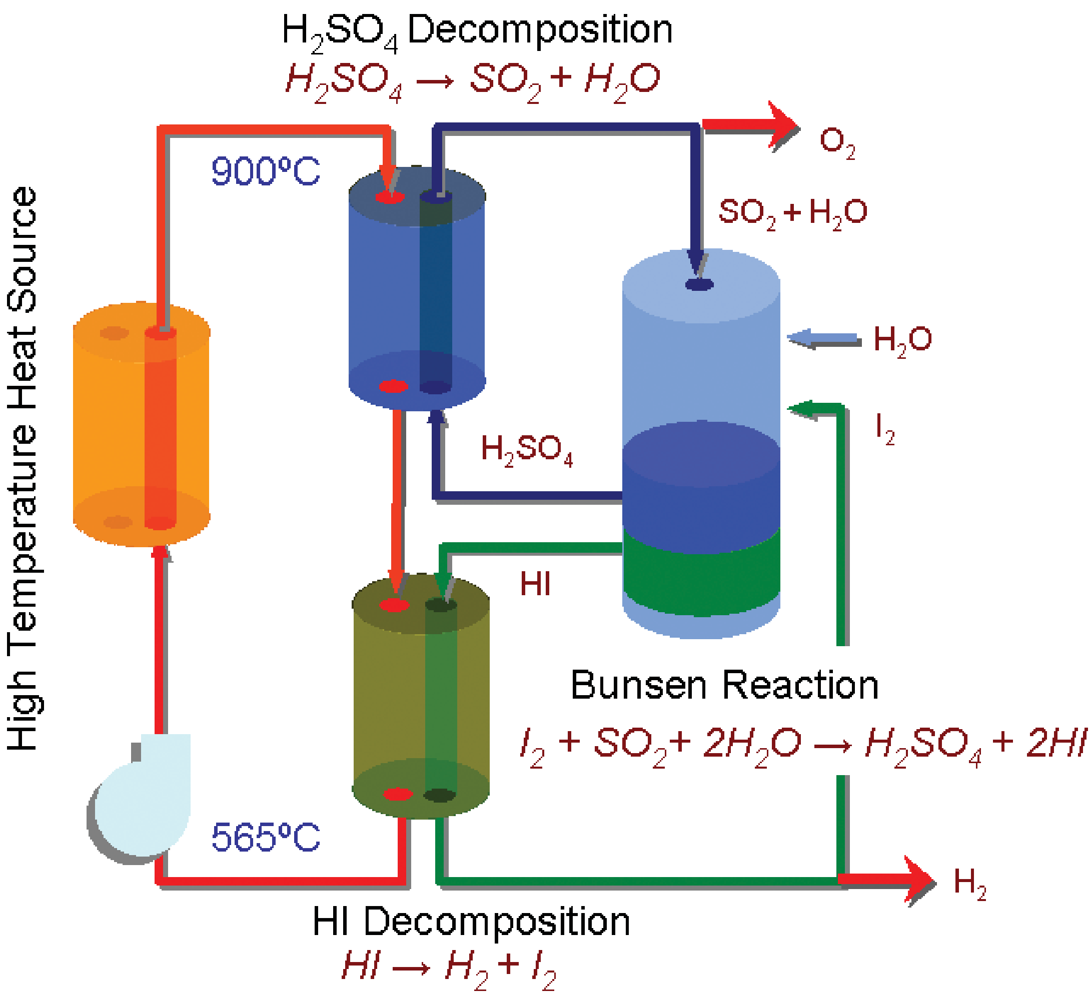
η = 75 - 80 % (> 80 %)

Jedna od temeljnih **termokemijskih reakcija za proizvodnju vodika** je sumporojodični (S-I) ciklus cijepanja vode, koji koristi toplinsku energiju iz izvora topline visoke temperature kao što su nuklearni reaktor ili *solarni toranj*.

Ciklus se sastoji od tri dijela: Bunsenove reakcije, raspada sumporne kiseline te raspada HI. Toplinske je djelotvornosti od 47 %, što ga čini jednim od gospodarski najpoželjnijih za industrijsku visokovolumnu proizvodnju vodika.

Prednosti S-I ciklusa: odsutnost otpadnih voda, laki prijenos reaktanata u tekućem ili plinovitom obliku.

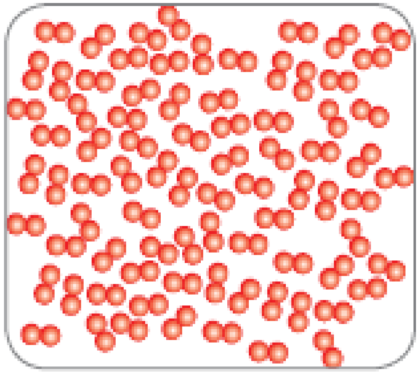
Glavni problem: korozivna priroda kemikalija koje su uključene u reakciju.

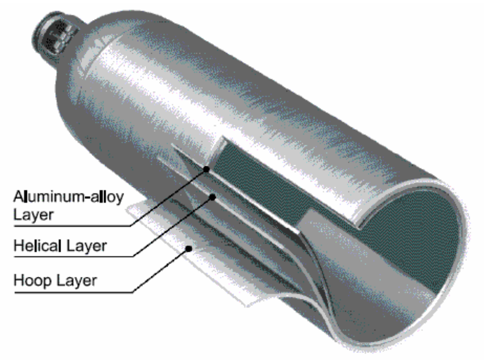


Skladištenje vodika

- Stlačeni plin

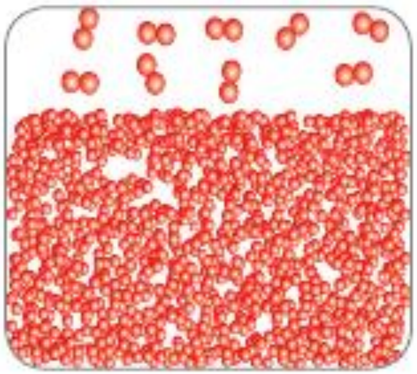
  - čelični i kompozitni spremnici; 150 bar // 350-700 bar – razvitku





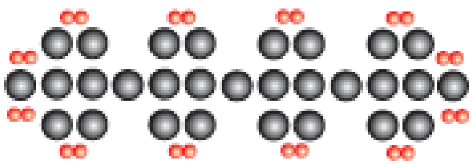
- Ukapljen

  - kriogeni spremnici, -253 ^{o}C

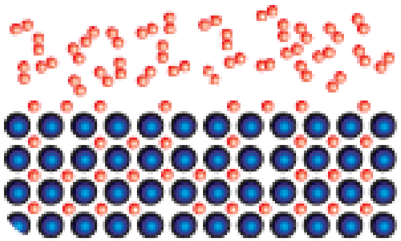


Skladištenje vodika

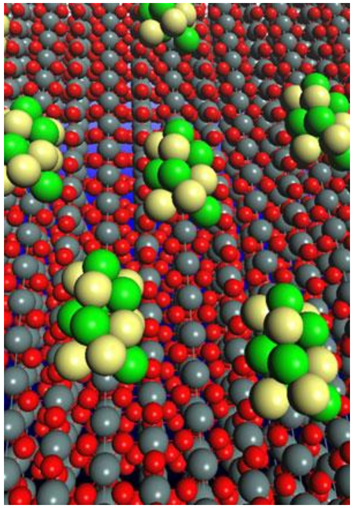
- U čvrstoj fazi / materijalu

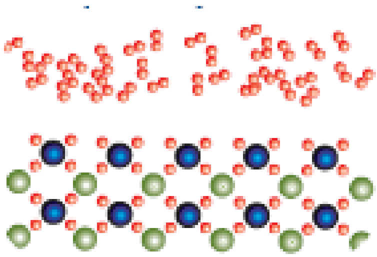


Površinska adsorpcija

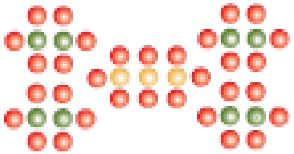


Metalni hidridi

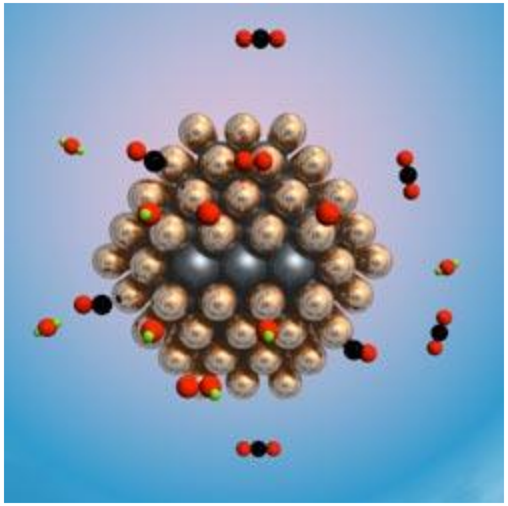




Kompleksni hidridi



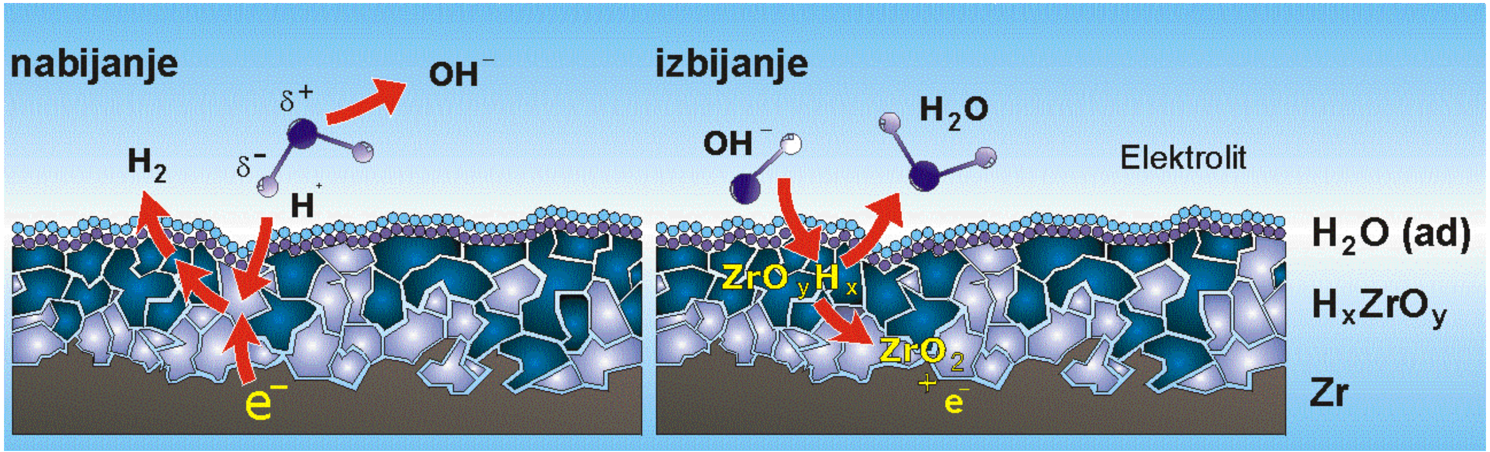
Kemijski hidridi



Vozila - ključni zahtjevi za skladištenje vodika

- Visoka gravimetrijska i volumetrijska gustoća
  (mala masa i zauzeće prostora)
- Brza kinetika punjenja i pražnjenja
- Prikladna termodinamika
  (toplina adsorpcije i desorpcije vodika)
- Dugi uporabni vijek i izdržljivost u broju ciklusa punjenja i pražnjenja
- Otpornost na nečistoće
- Mala cijena sustava i niski radni troškovi
- Minimalne energijske potrebe i utjecaj na okoliš
- Sigurnost

Po sadržaju energije: 1 kg H_2 = 1 galon (3,8 L) benzina;
450 km = 5 – 13 kg H_2, ovisno o vrsti osobnog vozila

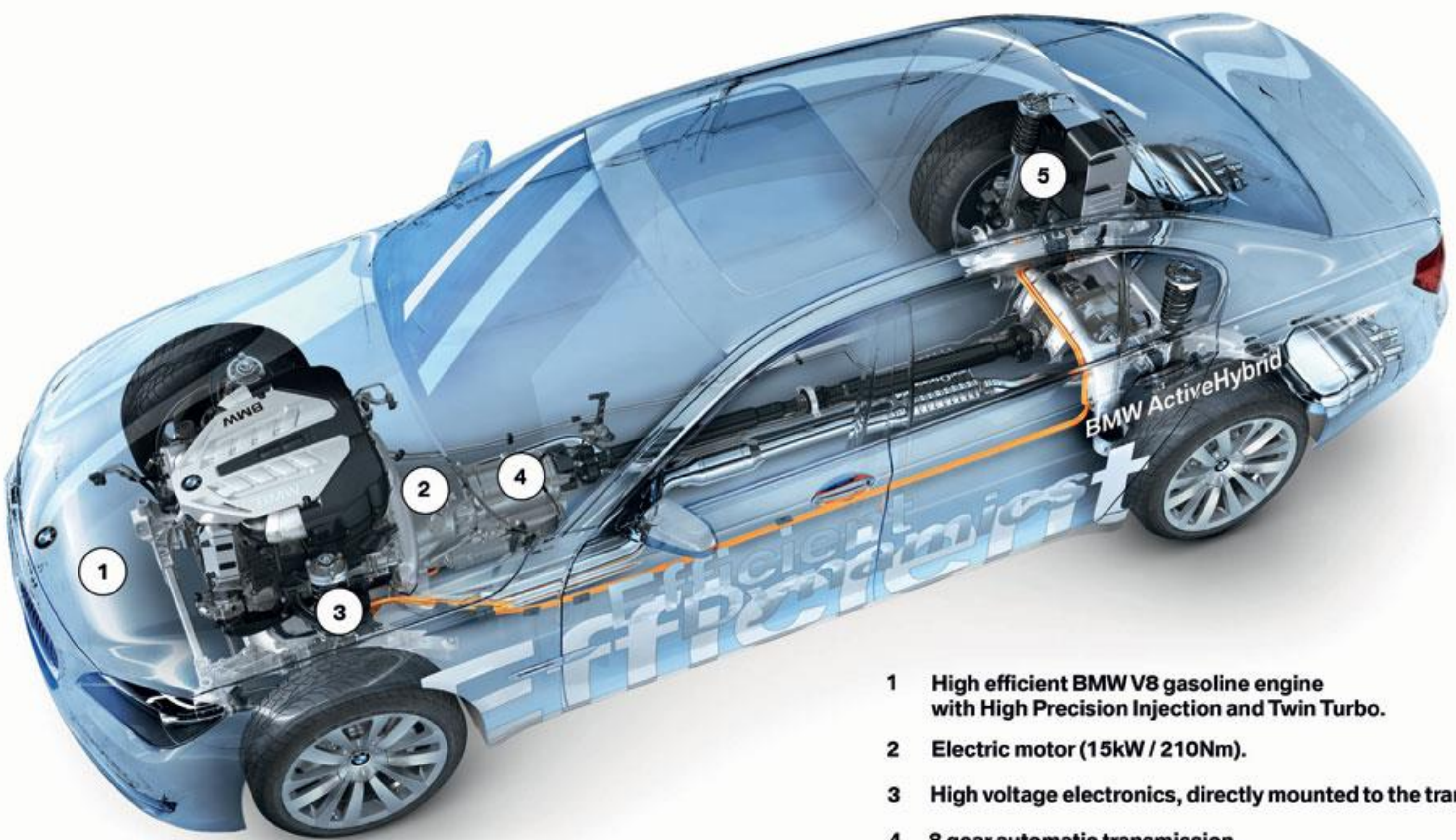


Vehicle Model: Citaro City-bus
H2 Storage Capacity: 43 kg
Service Pressure: 350 bar /5075 psi
Approx. Driving Range: 300km
Number of Vehicles: 30
Location: Europe, North America, Australia

Photo: Ford Hydrogen Tank – from National Hydrogen Association media downloads


LIQUIFIED HYDROGEN
FLAMMABLE GAS


LIQUIFIED
FLAMMABLE GAS



1 High efficient BMW V8 gasoline engine with High Precision Injection and Twin Turbo.

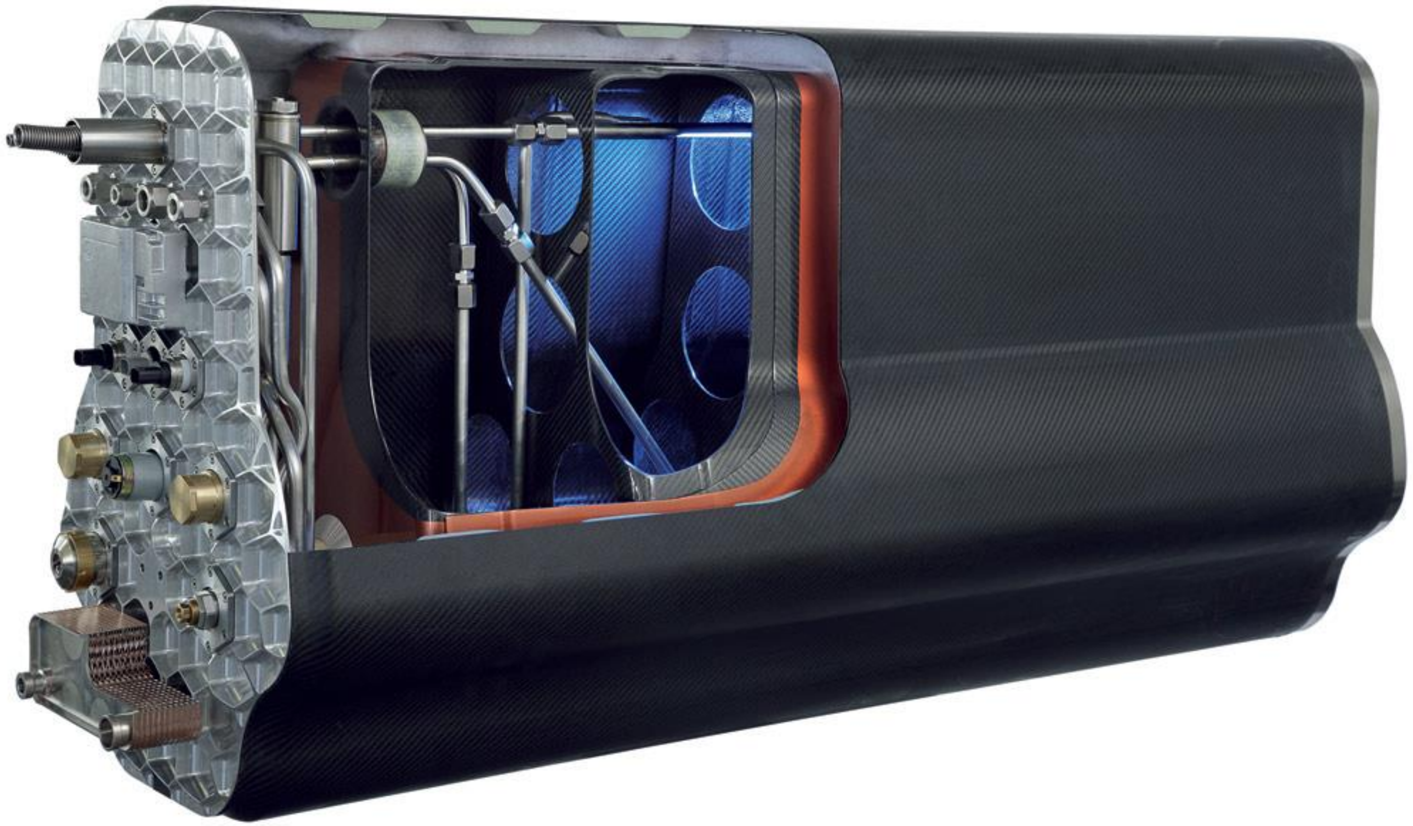
2 Electric motor (15kW / 210Nm).

3 High voltage electronics, directly mounted to the transmission box.

4 8 gear automatic transmission.

5 Lithium-ion battery (120 Volts).

BMW LH2 hydrogen storage tank



The BMW LH2 hydrogen storage tank, developed in collaboration with partners from the European aerospace industry, is made of composite materials and its weight is up to a third of the weight of a conventional cylindrical steel tank.

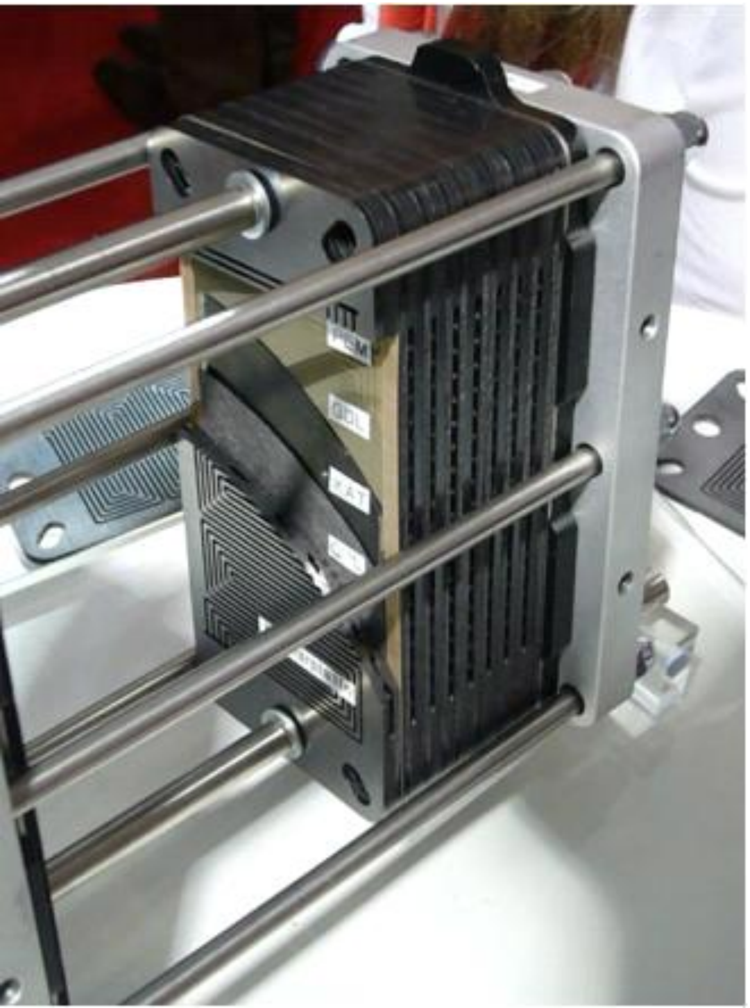
The subsidiary systems of the BMW LH2 storage tank are integrated inside the casing, taking up less room in the car and making the maintenance much easier.

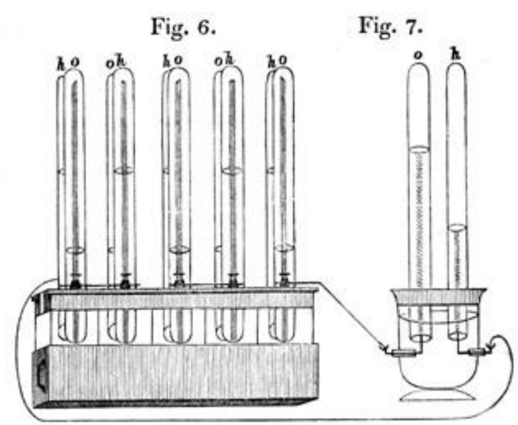
- with 10 kg of hydrogen, it could allow a range well in excess of 500 km in a future vehicle

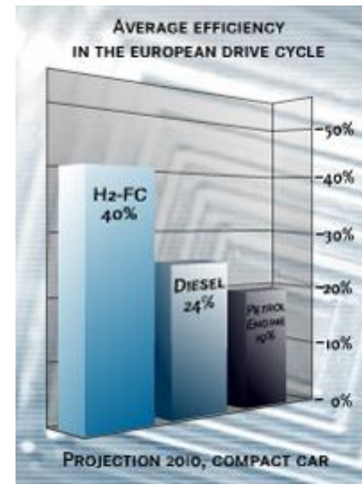
Proizvodnja zelenog vodika

KONVERZIJSKI UREĐAJ

- energijski pretvornik kemijske u električnu energiju: gorivni članci ili elektrokemijski motori (visoka energijska učinkovitost) (PEMFC, AFC, DMFC, PAFC, SOFC)
- produkt izgaranja: voda







Mercedes-Benz Company

Groveova "plinska baterija" – prvi gorivni članak
W. Grove: "On the Gas Voltaic Battery",
Philosophical Magazine and Journal of Science (1843), str. 272.

Svežanj gorivnih članaka u presjeku - Izložbeni uzorak tvrtke 3M

Gorivni članak VODIK - KISIK

Anodna reakcija: $2\ H_2 \rightarrow 4\ H^+ + 4\ e^-$

Katodna reakcija: $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$

Ukupna reakcija: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

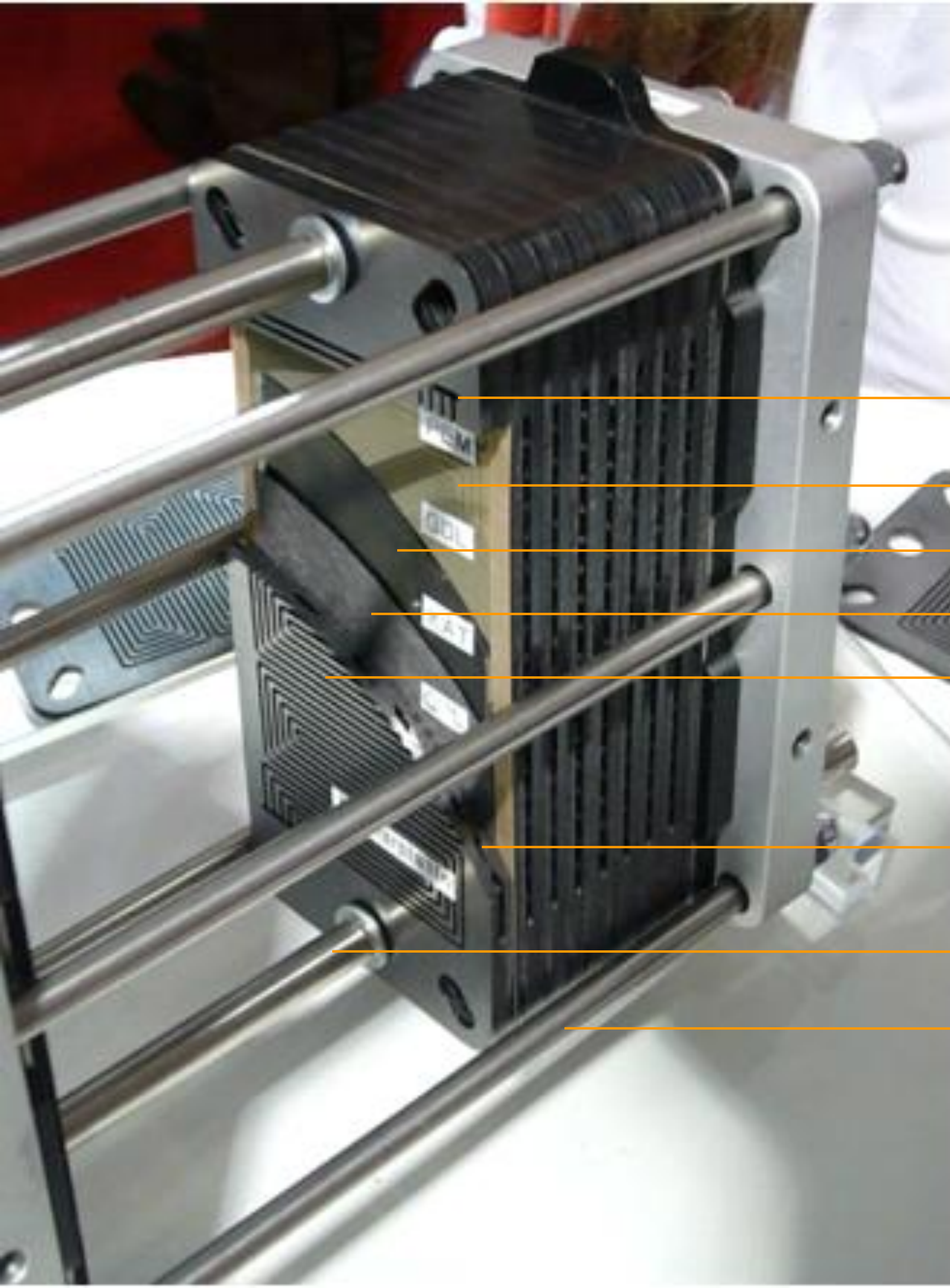
katalizator (Pt)

$H_2\ (g) + O_2\ (g) \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow$ električna struja, E_{MS} + H_2O + toplina

REAKTANTI PRODUKTI

Svežanj gorivnih članaka u presjeku

(Izložbeni uzorak tvrtke 3M)



Proizvodnja zelenog vodika

PRIMJENA

- proizvodnja električne energije; stacionarna, za pogon vozila
- smanjenje emisije stakleničkih plinova u proizvodnji energije izgaranjem CH