Vlak na pogon gorivnim člancima i vodikom kao gorivom

(Hydrogen & Fuel Cell Powered Train)

Frano Barbir
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Voditelj laboratorija za nove energetske tehnologije
Fakultet elektrotehnike strojarstva i brodogradnje
Voditelj istraživačke aktivnosti IC Centar izvrsnosti za znanost i tehnologiju – Integracija Mediteranske regije STIM
Sveučilište u Splitu
Vice-president, International Association for Hydrogen Energy
Chairman, States Representatives Group, Fuel Cells&Hydrogen Joint Undertaking

Vlak na pogon gorivnim člancima i vodikom kao gorivom
(Hydrogen & Fuel Cell Powered Train)

- Što je to gorivni članak?
- Kako radi?
- Gdje se koristi?
- Može li pogoniti vlak?
- Je li to netko već radi?
- Kako to izgleda?
- Koliko vodika treba?
- Je li to sigurno?
- Kako je to u usporedbi s dizel ili električnim?
- Može li se to primijeniti i u Hrvatskoj?

- What is a fuel cell?
- How does it work?
- Where it is used?
- Can it power a (passenger, freight) train?
- Who is doing it?
- How does it look like?
- How much hydrogen will be needed?
- Is it safe?
- Can it compete with diesel or electric?
- Can we use it in Croatia?

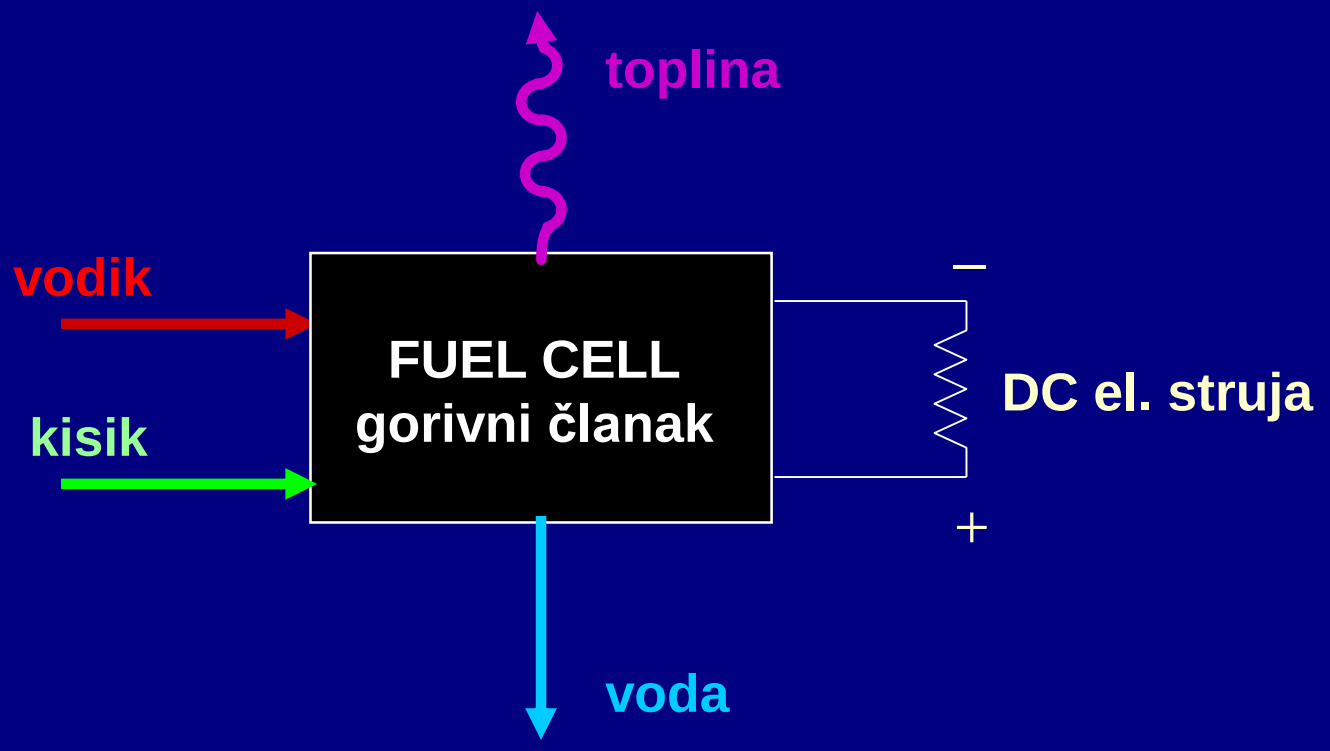
Što je gorivni članak?

Gorivni članak je elektrokemijski pretvarač energije.

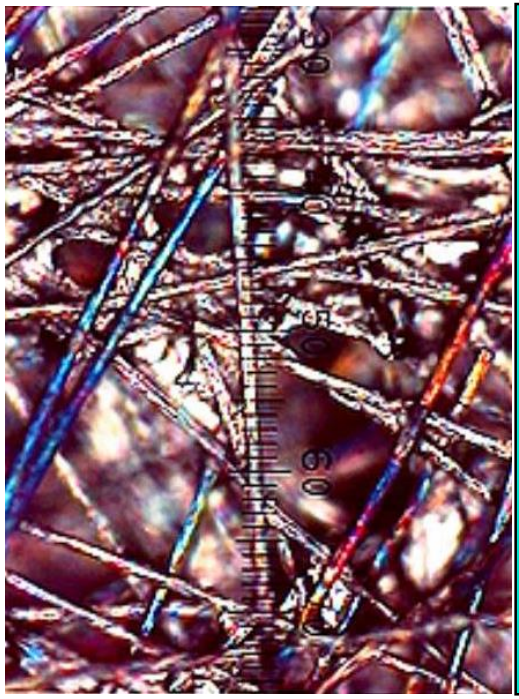
Pretvara kemijsku energiju goriva (H_2) direktno u električnu energiju.

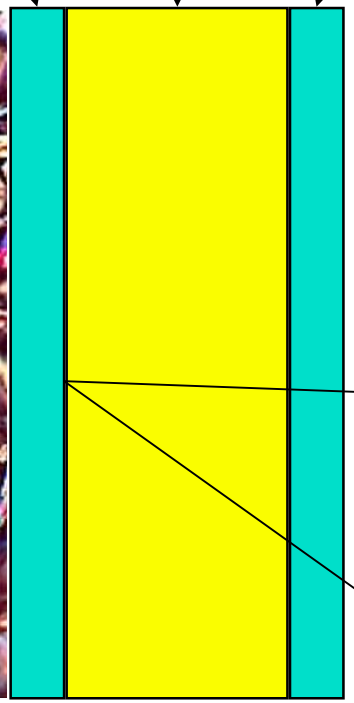
Gorivni članak je poput baterije

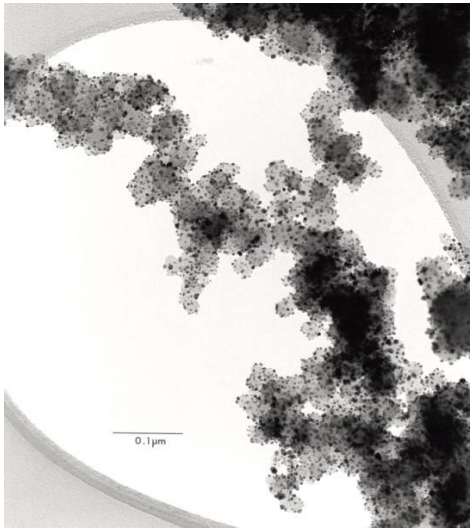
ali s konstantnim dotokom goriva i oksidanta.

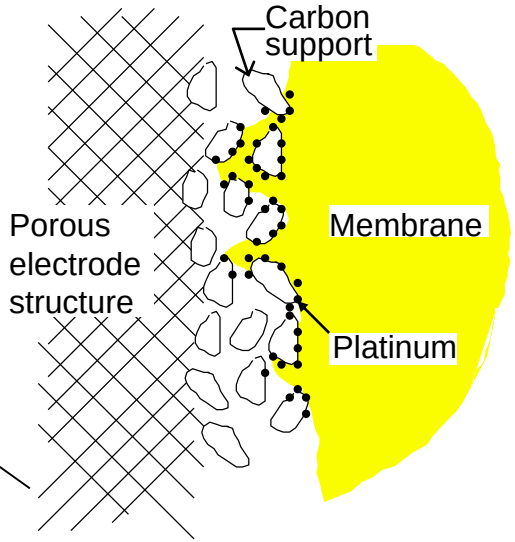


Kako radi gorivni članak?

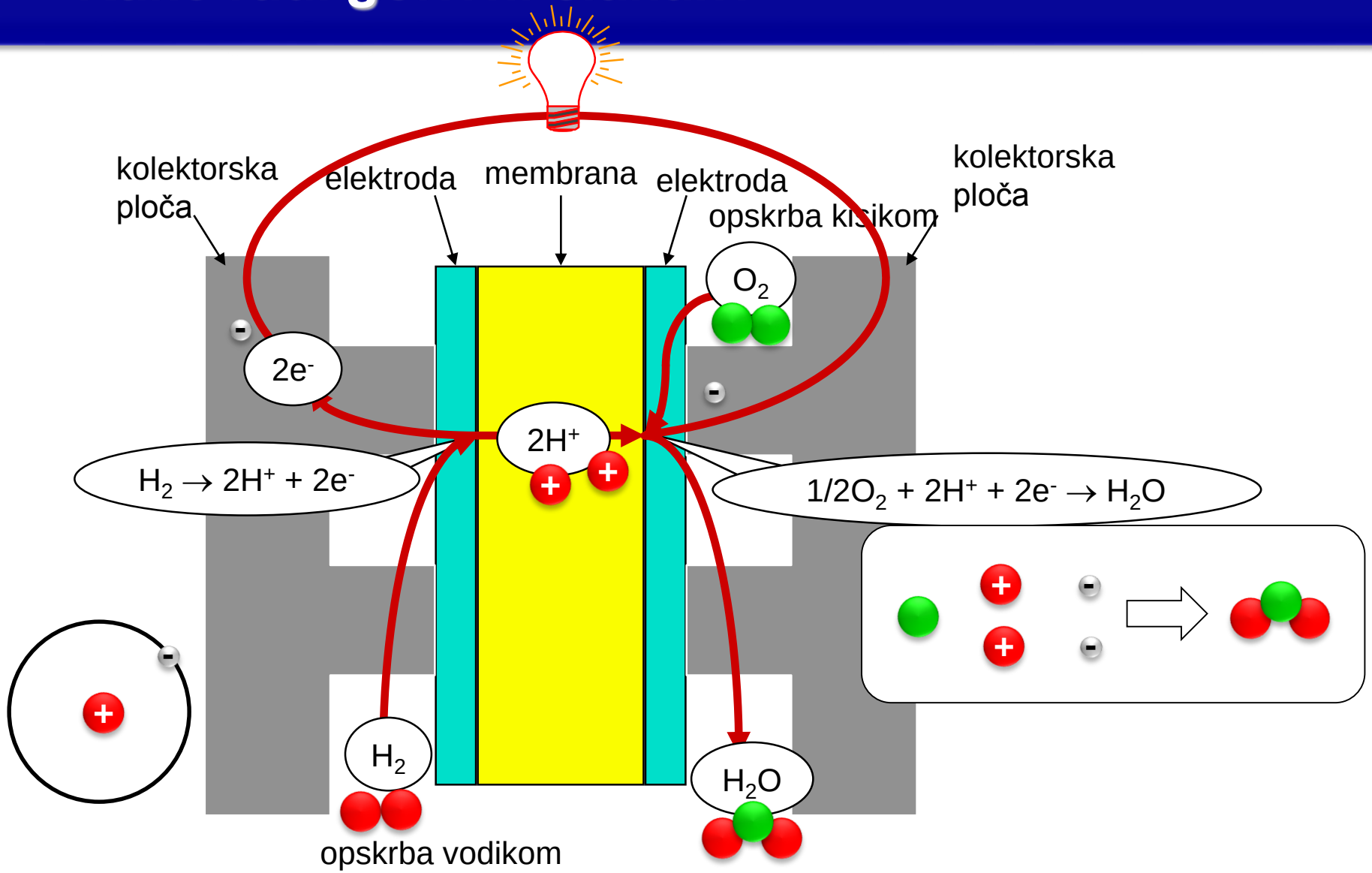








Kako radi gorivni članak?



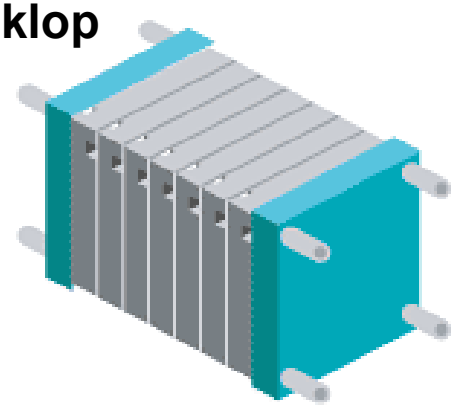
Ukupno: $H_2 + 1/2O_2 \rightarrow H_2O$

Teoretski napon: 1,23 V

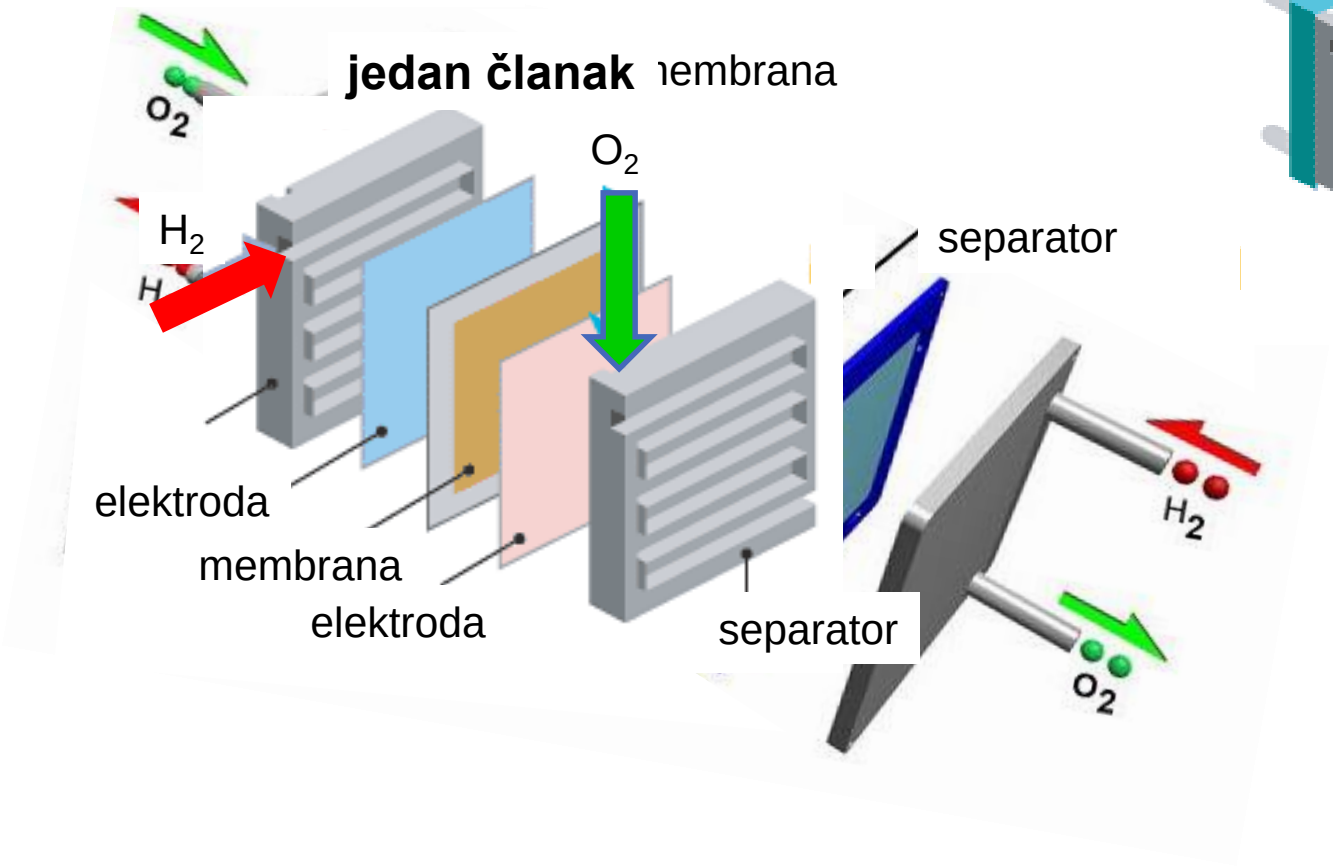
Praktički napon: 0.6-0.7 V

Da bi se dobilo veći napon i više snage članci se slažu u seriju

nakupina, svežanj, sklop



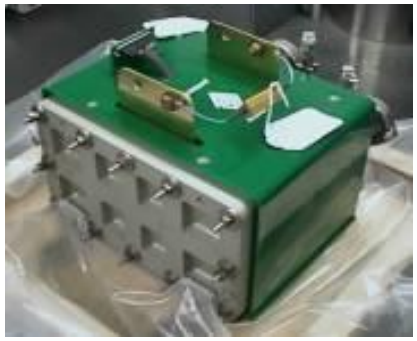
tri članka u seriji



Jedan članak ima napon manji od 1 Volta

Jedan svežanj može imati više od 300 članaka

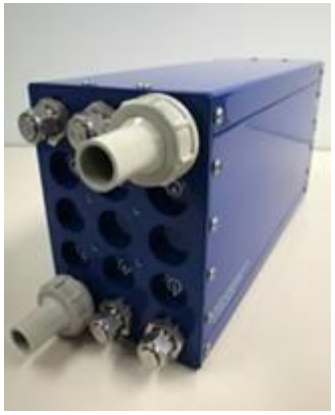
Neki gotovi svežnjevi gorivnih članaka



Teledyne

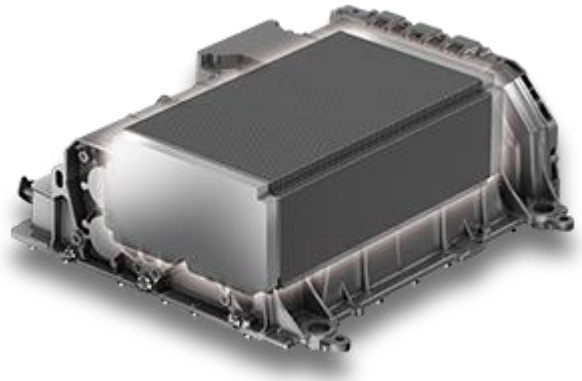
Ballard

Honda



Nedstack

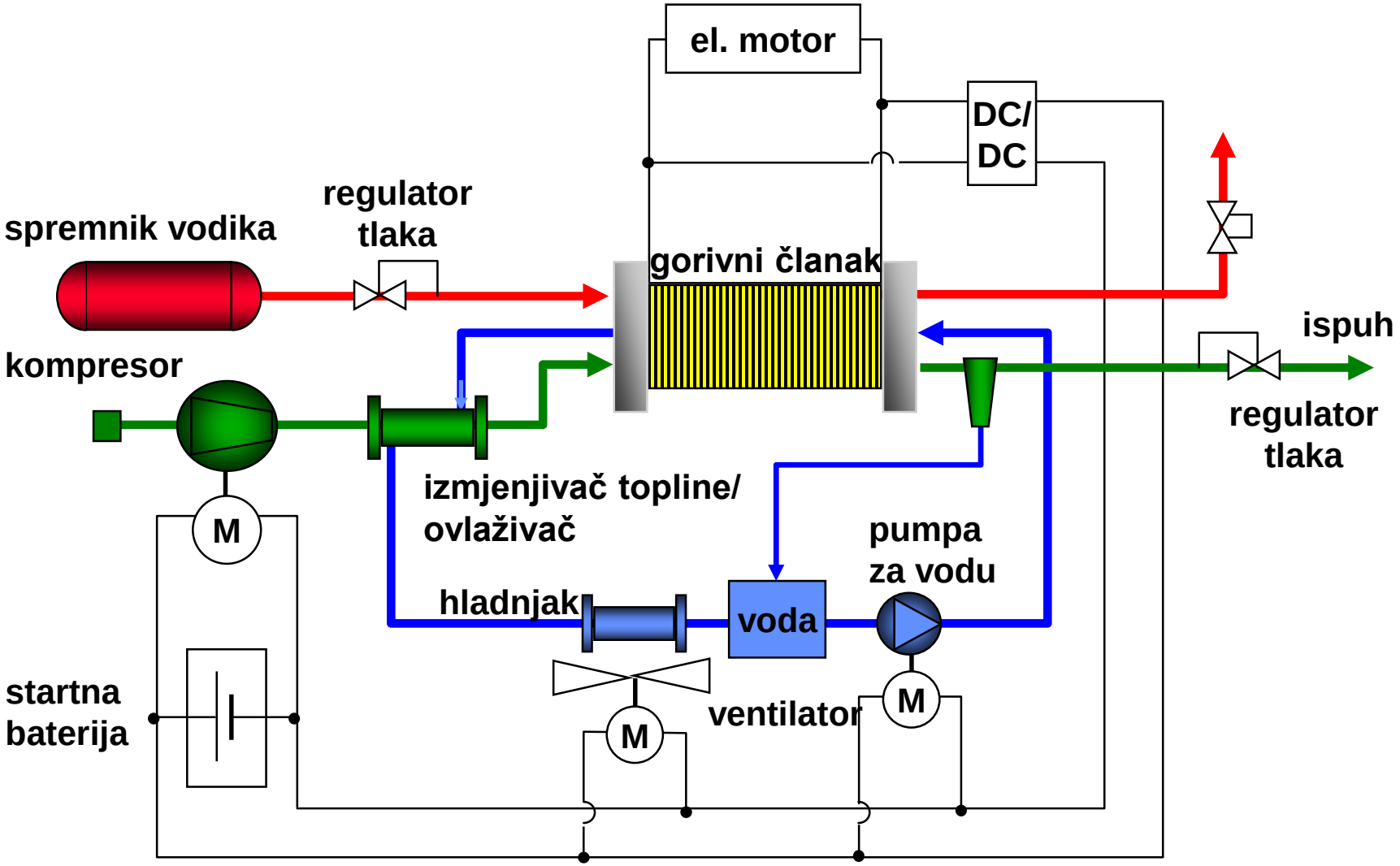
Hydrogenics



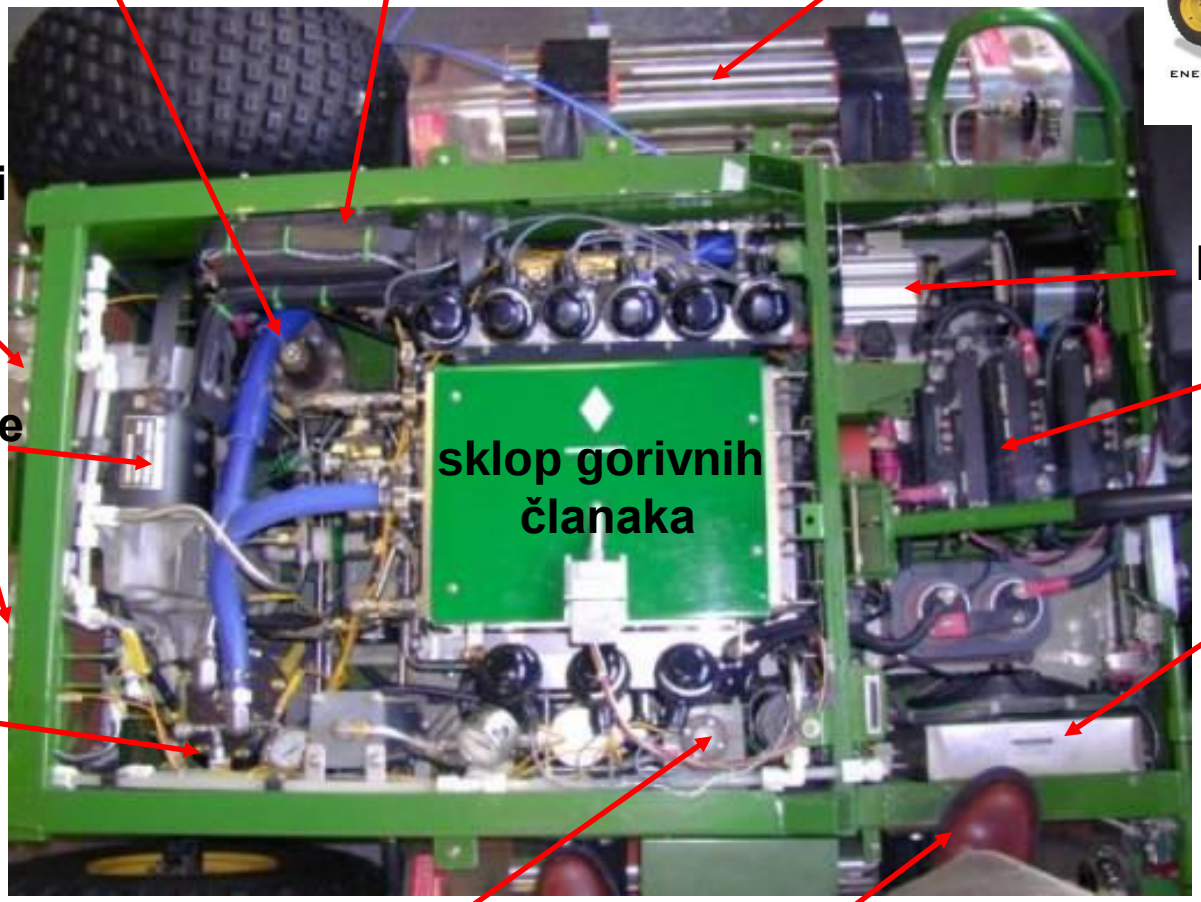
Toyota

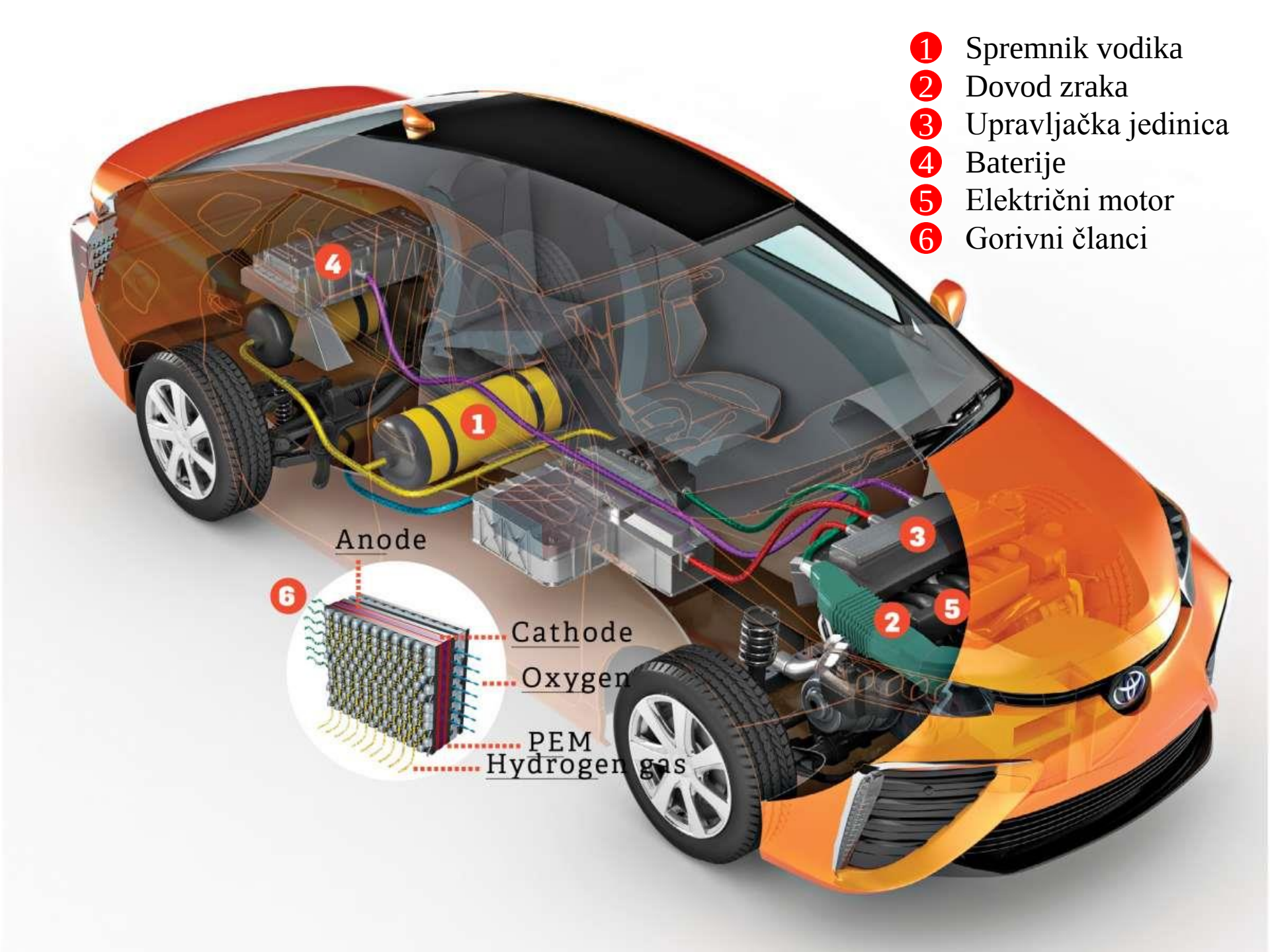
Gorivni članak treba pomoćne uređaje

Primjer sustava za pogon vozila



Stvarni sustav gorivnih članaka




1 Spremnik vodika
2 Dovod zraka
3 Upravljačka jedinica
4 Baterije
5 Električni motor
6 Gorivni članci
Anode
Cathode
Oxygen
PEM
Hydrogen gas

Popular Mechanics

HYUNDAI

NOW | MARCH 2014

Speed Lab

BYE-BYE GASOLINE!

The First Mass-Produced Hydrogen Car

Hyundai Tucson Fuel Cell
Range 300 miles
Top speed 100 mph
Lease terms $500/month; $3,000 down

When it comes to alternate energy sources, most automakers think simply—battery power or bust. That's what makes the Hyundai Tucson Fuel Cell an outlier. The SUV will be the first mass-produced hydrogen car in the U.S. when it debuts this spring.

Because hydrogen fuel infrastructure is more or less nonexistent, Hyundai's rollout will be small. The car will be available at select dealers in Southern California, all within range of the company's sources of hydrogen, which include a nearby waste water treatment plant. Local drivers will be able to "gas" up for free at any of seven distribution stations. A fill-up takes less than 10 minutes and lasts for up to 300 miles. The company claims that the Tucson charges more quickly and has a longer range than traditional EVs. It's also clean: The only exhaust is water vapor. DANIEL DUMAS

10 MINUTES

Maximum time needed to replenish the Tucson's hydrogen fuel cell.

Sales
2016 242
2018 3000 (goal)

Toyota Mirai – first commercial fuel cell automobile being sold since 2015

Sales	U.S.	World
2015	72	
2016	1034	
2017	1838	
Total	2944	5300

engadget

Honda's hydrogen-powered FCX Clarity goes on sale

The longest-range zero-emissions vehicle can also power your house for seven days.

Steve Dent, @stevetdent
03.10.16 in Transportation

40
Comments

U.S. Sales

2016	**8**
2017	**450**
2018	**410 (until March)**

Najnoviji model na tržištu – Hyundai Nexo (2018)

Viličari na pogon gorivnim člancima i vodikom su već u komercijalnoj primjeni

Coca-Cola Officially Unveils its Fuel Cell Forklift Fleet

10 FEB 2012

Coca-Cola® will unveil its fleet of 37 fuel cell forklifts and 19 fuel cell pallet jacks at its San Leandro bottling plant at a 'green ribbon-cutting' ceremony today.

Viličari na pogon gorivnim člancima i vodikom su već u komercijalnoj primjeni

CASE STUDY - WALMART CANADA FUEL CELL FORKLIFT FLEET

The entire fleet of material handling equipment at the new Walmart Perishable Distribution Centre (PDC) in Balzac Alberta is powered by hydrogen fuel cells.

Aargau, CH

Bolzano, IT

Oslo, N

London, UK

Milano, IT

Köln, D

Hamburg, D

H2 Aberdeen

Aberdeen HydrogenBusProject

40 Van Hool fuel cell bus in Cologne and Wuppertal

The **new A330 FC will be delivered in 30 units to Cologne** (that is tendering 53 battery electric buses), and other 10 vehicles will be deployed in **Wuppertal** through Jive 2 EU funded program. The vehicle, when deployed on flat urban service lines, will be equipped with 24 kWh traction battery and 85 kW hydrogen fuel stack. The version of the bus for regional and hilly city services is fitted with a 36 kWh traction battery.

Van Hool towards the launch of the new A330 FC and Exqui.City 18 FC. A fuel cell future

Electric Hydrogen Truck is coming!
And it’s not Tesla – it’s Nikola!

Anheuser-Bush ordered 800 hydrogen trucks from Nikola!

1,000 Hyundai Fuel Cell Electric Trucks Headed for Switzerland

September 21, 2018 by Ryan ZumMallen, @Zoomy575M

Market Updates

CSR Sifang to Deploy 8 Fuel Cell Trams in Foshan, China Powered by Ballard

March 17, 2017

VANCOUVER, CANADA – Ballard Power Systems (NASDAQ: BLDP; TSX: BLDP) today reported that CRRC Qingdao Sifang Company ("CSR Sifang") recently announced the final contract with its customer for the planned deployment of eight (8) hydrogen fuel cell trams for a route being developed in the City of Foshan, China. All of these trams are to be powered by Ballard FCveloCity® fuel cell engines.

CRRC fuel cell tram planned for deployment on the Gaoming Line in the City of Foshan

CSR Sifang is a Chinese rolling stock manufacturer based in Qingdao, Shandong province. Established more than 100-years ago, CSR Sifang has a yearly production capacity of 200 high-speed electric multiple units (EMUs), 1,000 mass transit vehicles and 300 high-grade passenger cars. An initial demonstration of a fuel cell-powered tram, using Ballard technology, was successfully completed by CSR Sifang in March 2015.

In that same year Ballard announced we had signed a joint development agreement and a supply agreement with CSR Sifang to develop and commercialize a fuel cell engine specifically designed for integration into that company's low floor trams. The agreements included 2016 delivery of ten (10) customized FCveloCity® modules.

At the same time, Ballard also announced our plan to develop a new prototype configuration of the FCveloCity® fuel cell module to deliver 200 kilowatts (kW) of net power for use in powering trams in urban deployments, including the initial deployment of 8 fuel cell-powered trams on the Gaoming Line in the City of Foshan.

Alstom's hydrogen train Coradia iLint first successful run at 80 km/h

14/03/2017

ALSTOM

EVERSHOLT
UK RAILS GROUP

‹ Press releases and news 07 Jan 2019

Alstom and Eversholt Rail unveil a new hydrogen train design for the UK

SIEMENS
Ingenuity for life

Mobility

Siemens receives funding approval for developing fuel cell drive for trains

Munich, 2018-Feb-26

- **Siemens and Ballard jointly develop fuel cell drive for trains**
- **German Federal Ministry for Transportation and Digital Infrastructure funds project with around €12 million**
- **Mireo regional and commuter train platform to be reference**
- **Zero-emission operation without overhead lines**

SIEMENS
Ingenuity for life
POWERED BY
BALLARD

A

Fuel cell hydrogen trains ("Hydrails") are a future zero-emission alternative for non-electrified regional train connections

Fuel cell electric trains[1]

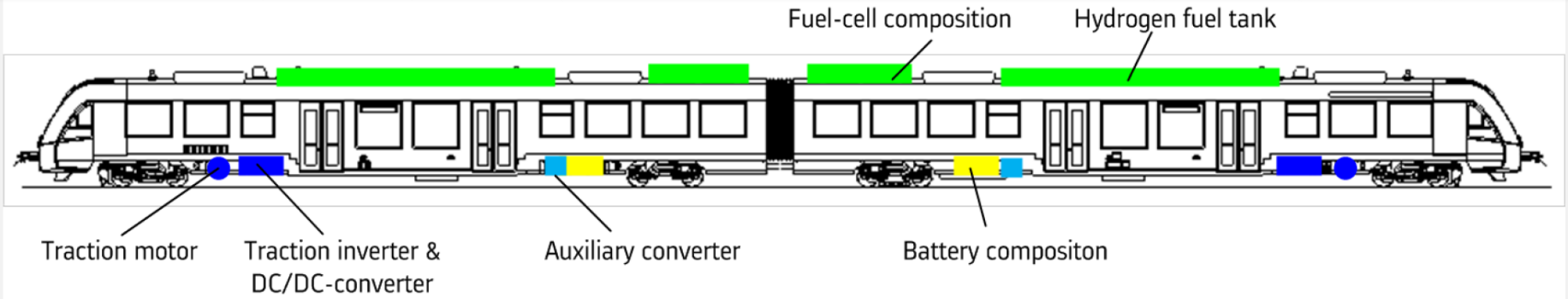
Brief description: Hydrails are hydrogen-fuelled regional trains, using compressed hydrogen gas as fuel to generate electricity via an energy converter (the fuel cell) to power traction motors or auxiliaries. Hydrails are fuelled with hydrogen at the central train depot, like diesel locomotives

Use cases: Cities and regions can especially deploy hydrails on non-electric tracks for regional train connections to lower overall and eliminate local emissions (pollutants, CO_2, noise); cities and regions can – for example – promote FCH trains through demo projects or specific public tenders

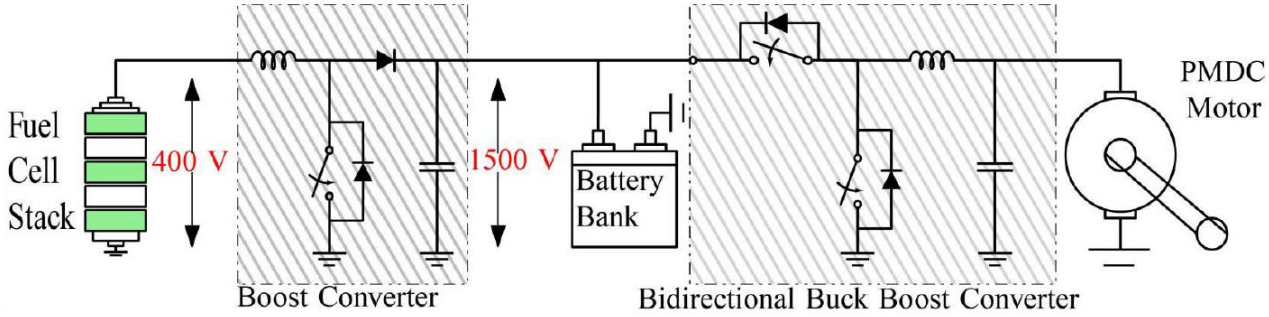
Fuel cell electric trains – Hydrails (based on Alstom prototype)

Key components	Fuel cell stacks, air compressor, hydrogen tank, electronic engine, batteries
Output	400 kW FC, hybridized with batteries
Top speed; consumption; range	140 km/h; 0,25-0,3 kg/km; 600-800 km
Fuel	Hydrogen (350 bar)
Passenger capacity	300 (total) / 150 (seated)
Approximate unit cost	EUR 5.1-5.5 m (excl. H_2 infrastructure)
Original equipment manufacturers	Alstom
Fuel cell suppliers	Hydrogenics
Typical customers	Public transport authorities, regional train operators
Competing technologies	Diesel, diesel-electric hybrid, pure battery trains

Kako to izgleda?



- The trains are powered by an electrical traction drive. Electrical energy is generated on-board in a fuel cell and intermediately stored in batteries.
- The fuel cell provides electrical energy by combining hydrogen stored in tanks on-board with oxygen from environmental air. The only exhaust is water steam and condensed water.
- The battery stores energy from fuel cell when not needed or from kinetic energy of the train during (electrical) braking and allows to support (boost) energy delivery during acceleration phases.



Koliko vodika treba?

100 kW = 5-6 kg/h

1 kg H2 = 1 galon benzina = 3.785 l benzina = 3.6 l dizela

0.25–0.30 kg/km x 600-800 km = 150-240 kg

Odakle vodik?

Vodik se može:

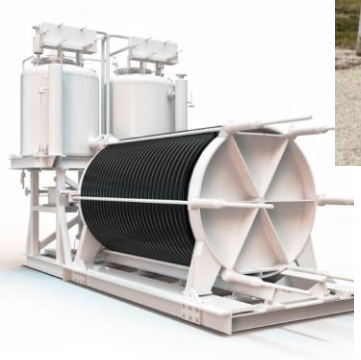
dovoditi do postaje za natakanje

- kamionima
- vlakom
- cjevovodom

} tekući / komprimirani plin

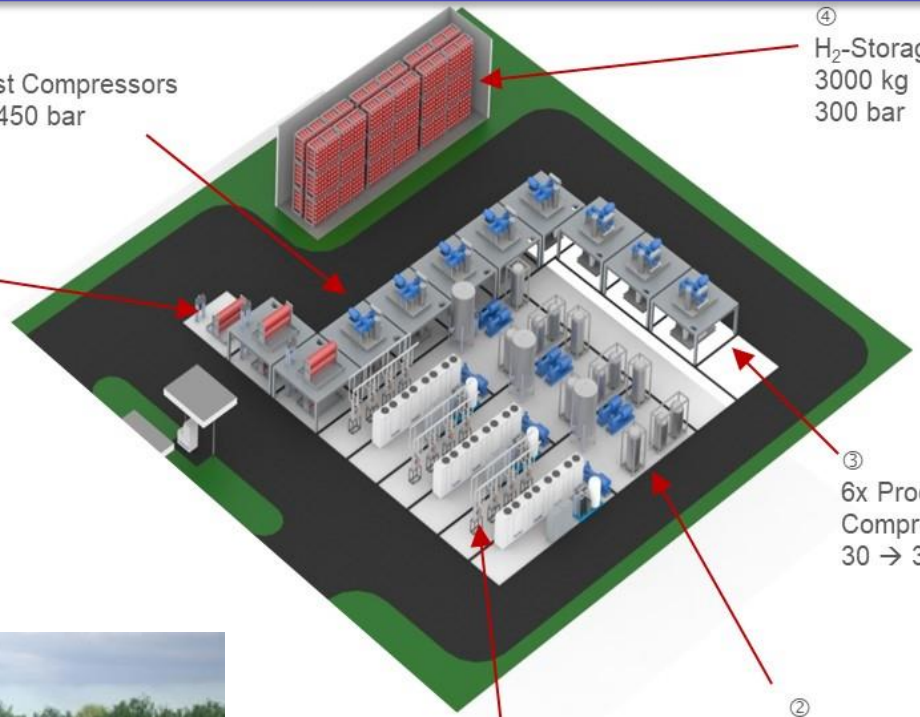
proizvoditi na samoj postaji za natakanje

- reformiranjem zemnog plina
- elektrolizom vode

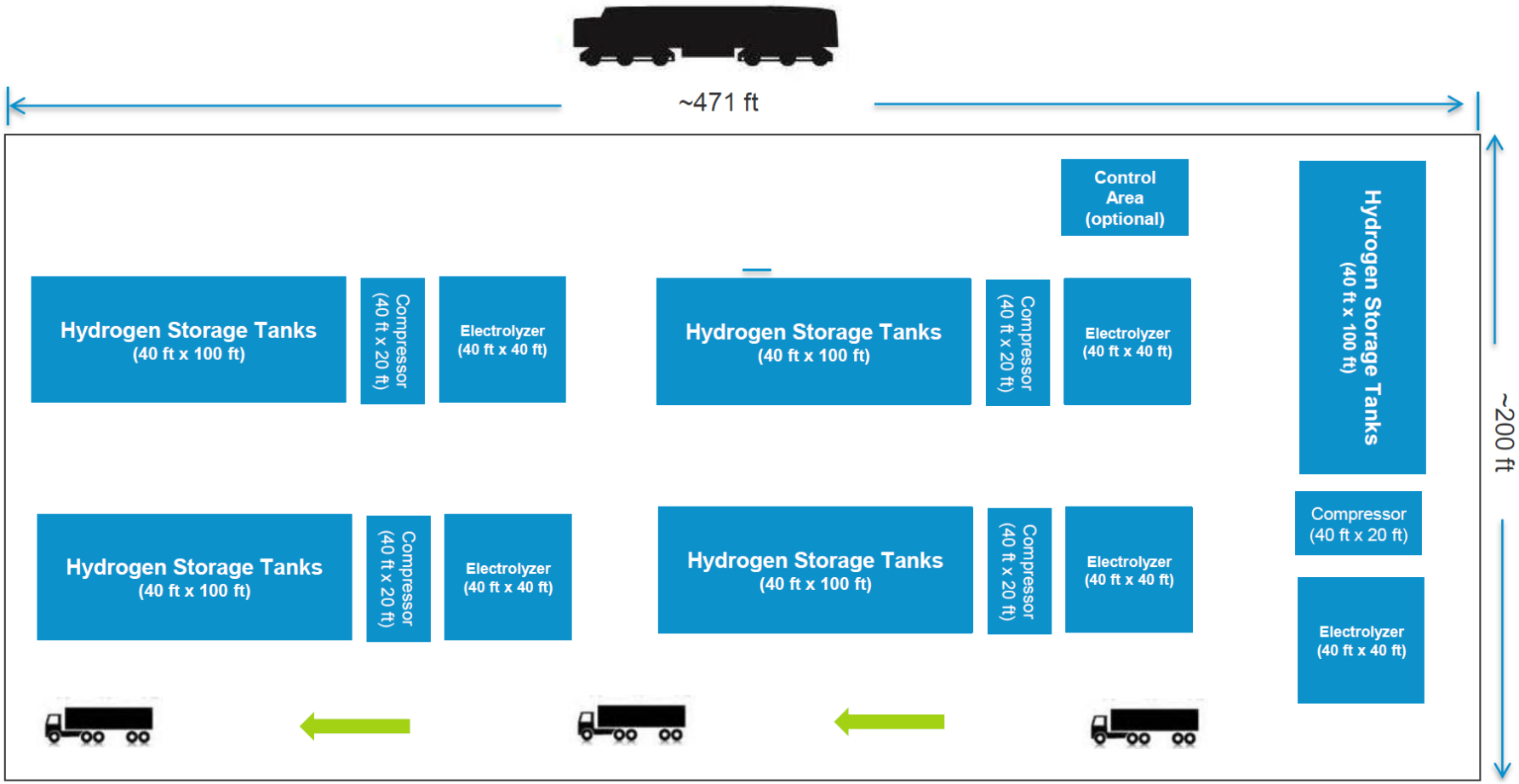


Punjenje vodikom

HYDROGENICS
Advanced Hydrogen Solutions



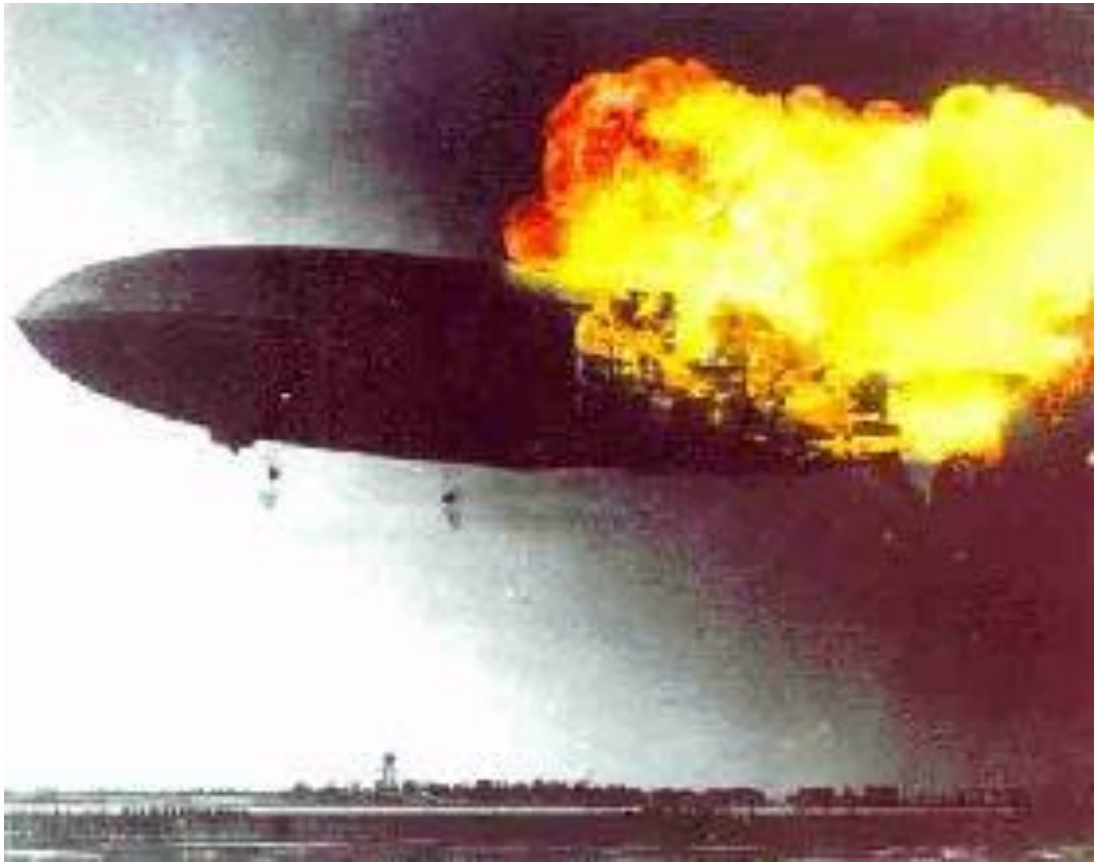
Preliminary Hydrogen Infrastructure Footprint Estimation: 4000 kgpd Hydrogen for 5 Locomotives per 1 Line Haul Train



Disclaimer: Above layout is conceptual. Actual space and layout will depend on local codes/standards and other requirements.

Je li to sigurno?

Sigurnost vodika: stvarna ili percepcijska



Hindenburg nesreća (1937) je primjer kako je vodik, zapravo siguran a ne opasan!

Je li to sigurno?

Vodik nije opasniji od benzina!

Je li to sigurno?

Vodik na krovu autobusa (ili vlaka) ne predstavlja opasnost!

Svojstva vodika s obzirom na sigurnost

- vjerovatnost propuštanja ↑
- volumen ispuštenog goriva ⇧
- energija ispuštenog goriva ↓
- difuzivnost i uzgon ↑
- donja granica zapaljivosti u zraku ↑ ▯
- minimalna energija zapaljenja ⇩
- energija zapaljenja na DGZ ▯
- brzina plamena ↑
- donji omjer gorivo/zrak za detonaciju ↑
- explozivna energija u odnosu na spremljenu energiju ↓
- vidljivost plamena ↓
- emisivnost plamena ↓
- toksičnost plinova izgaranja ↓
- toksičnost goriva ↓

Legenda

⇧ veće nego druga goriva

▯ ~isto kao druga goriva

⇩ manje nego druga goriva

Rizik

■ potencijalno opasnije

■ sigurnije

□ isto kao druga goriva ili irelevantno

Kako je to u usporedbi s dizel ili električnim?

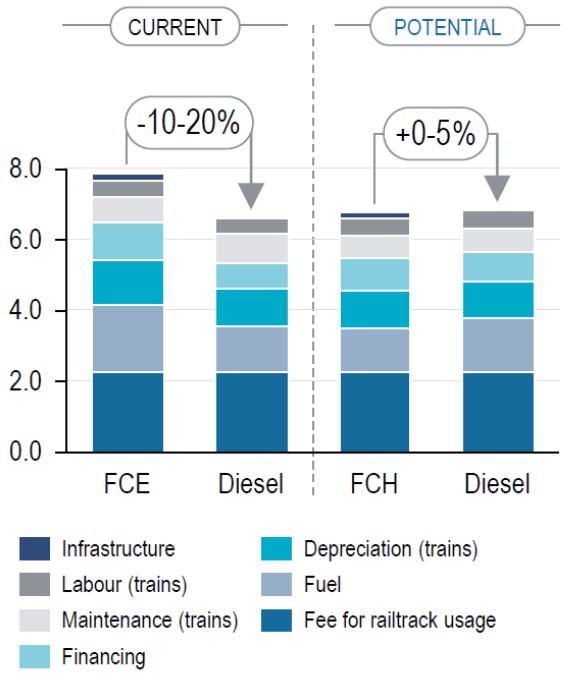
B

Hydrails might almost reach cost parity with diesel trains in the medium run, while reducing CO_2 and putting NO_x emissions to 0

Business case and performance overview – PRELIMINARY / INDICATIVE EXAMPLE

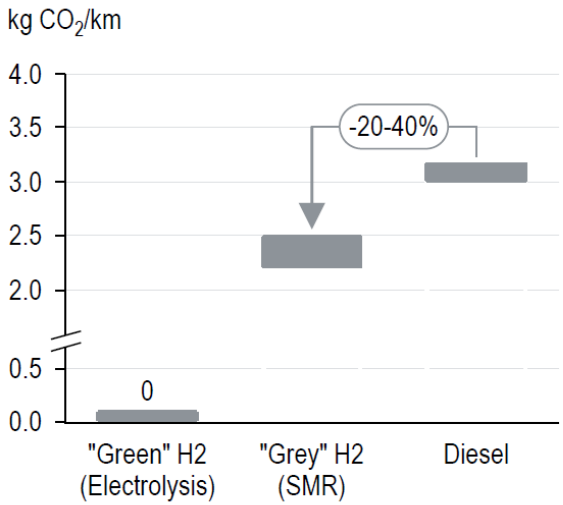
Economic

Estimated annualised Total Cost of Ownership (TCO) [EUR/km], 2017 prices



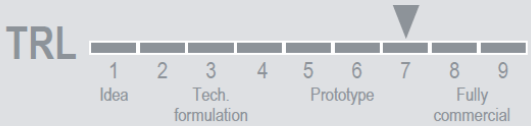
Environmental

- Zero tailpipe emissions of CO_2, pollutants such as NO_X and fine dust particles, e.g. saving ~15-25 t NO_X/year
- Well-to-wheel CO_2 emissions depend on fuel source, use case characteristics and efficiency (i.e. fuel consumption)



Technical/operational

- Rising technical maturity of larger-scale fuel cell modules to be used in trains or tram cars; roll-out in Germany in first major "real-life" projects under way, tech. moving towards commercialisation for trains starting operations over the medium term (tender processes in part already ongoing)
- Once deployed, Hydrail OEMs would (feel compelled to) guarantee same availabilities of conventional diesel trains (e.g. approx. 97%), not withstanding initial deployment challenges
- Range of a fully fuelled Hydrail at 600-800 km, aiming to reach parity with diesel at up to 1,000 km



The Nordland Line

Freight train at Saltfjellet
(not a winter picture)

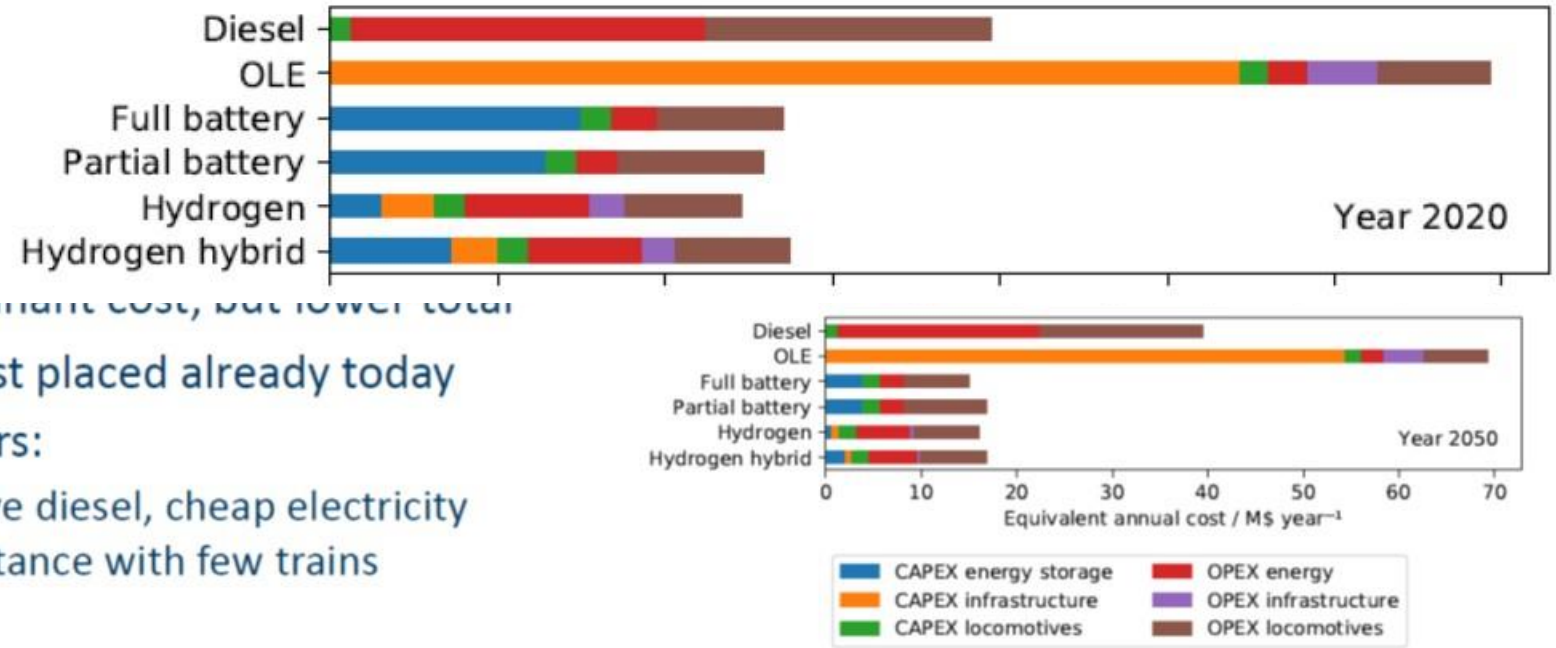
SINTEF

- Single-track line, 731 km
- Passing loops: 600 m
- About 3000 train movements a year
- CO_2 emissions: 37 800 t
- Over 150 tunnels
- Crosses polar circle
- Strong winds (few or no trees)
- Ice formation

Kako je to u usporedbi s dizel ili električnim?

Nordland Line

- Large diese
- Diesel locor
- Large OLE c
- Battery dominant cost, but lower total
- Fuel cells best placed already today
- Critical factors:
  - Expensive diesel, cheap electricity
  - Long distance with few trains



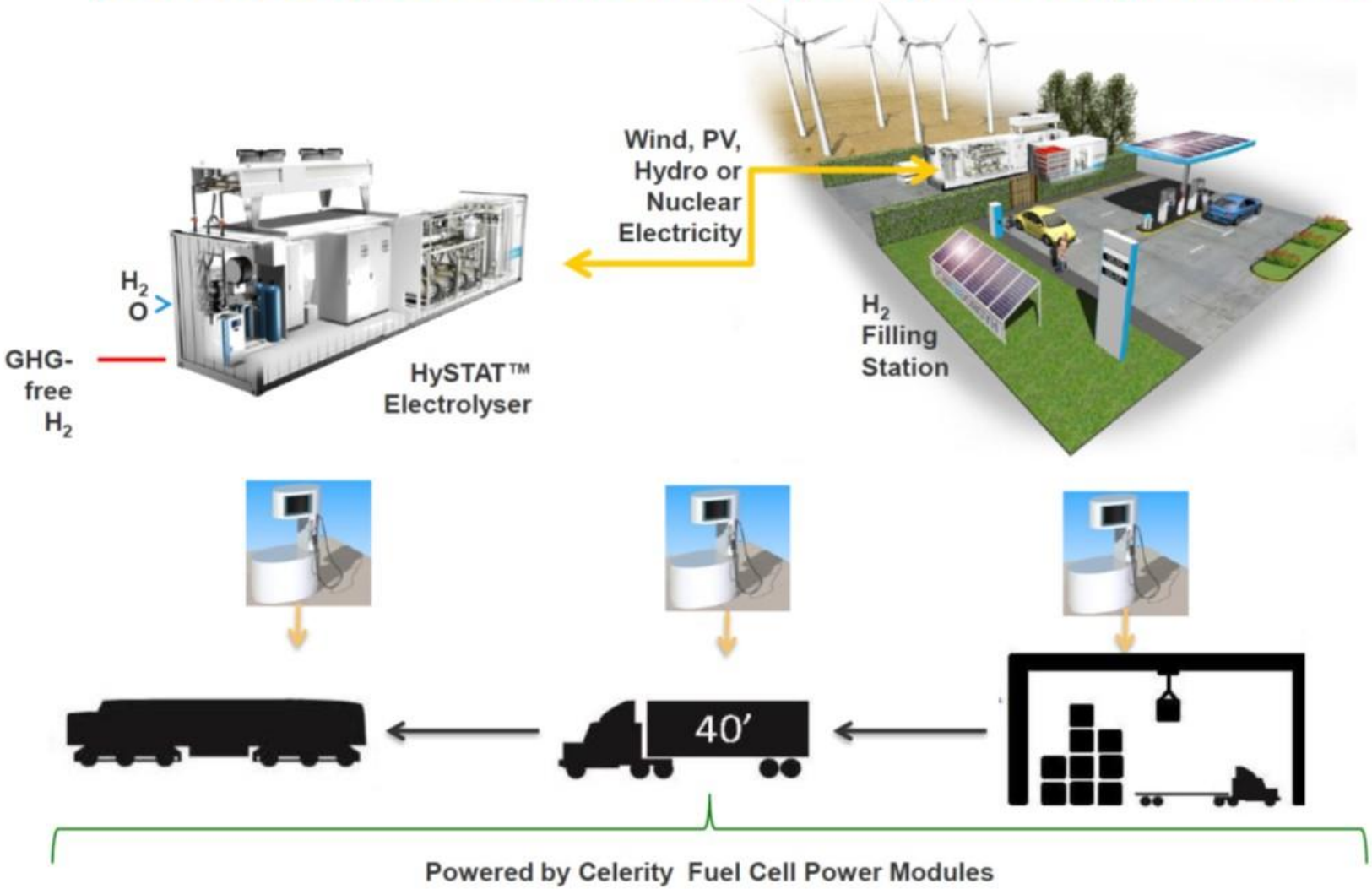
SINTEF

Kako je to u usporedbi s dizel ili električnim?

Prednosti vlaka na pogon vodikom

- Dugoročno predstavlja transport bez emisija
- Tihi rad
- Fleksibilnost elektrifikacije bez žica
- Brzo punjenje kao i dizel
- Mogućnost integracije s obnovljivim izvorima energije

Long Term Goal:
Renewable Zero Emission Hydrogen Freight Network



Zaključak

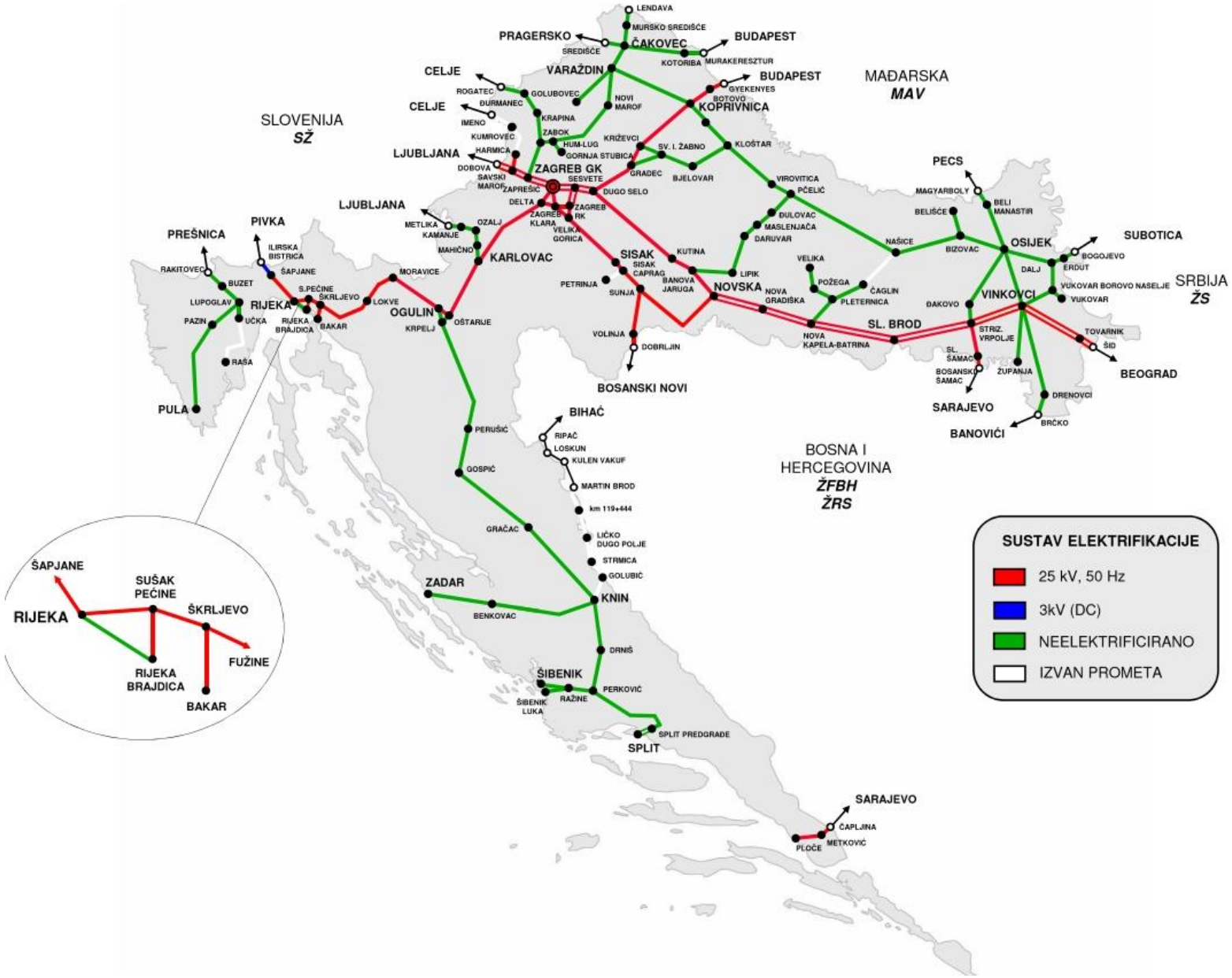
Vlak na vodik je za dizel

HYDRAIL IS TO DIESEL

AS DIESEL WAS TO STEAM

ono što je dizel bio za ugljen

Može li se to primijeniti i u Hrvatskoj?



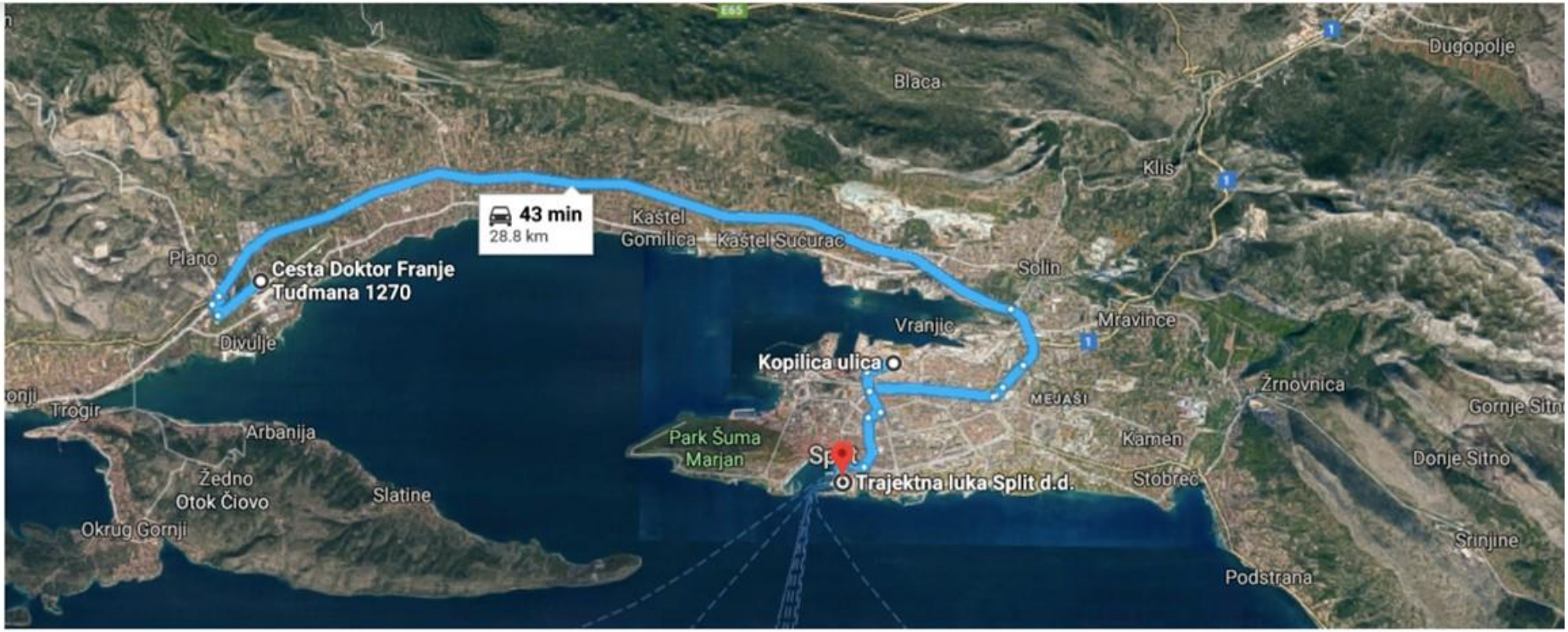
VIJESTI

Vlakom od zračne luke do Splita

30. travnja održan okrugli stol Razvoj željezničke infrastrukture u Splitsko-dalmatinskoj županiji

VIJESTI

Vlakom od zračne luke do Splita



Tako će već iduće ljeto Kopilica će biti povezana vlakom s gradskom lukom koji će voziti svakih 15 minuta, i to već u siječnju 2019. godine prema planu.

22 Svi 2017

Tramvajem ili vlakom do “Franje Tuđmana”

Ivo Gračanin.

Trenutačni gradonačelnik grada Zagreba najavljuje izgradnju tramvajske pruge od Kvaternikovog trga do Međunarodne zračne luke Zagreb.

Zašto to ne bi bio vlak na vodik?

Zašto to ne bi bio vlak na vodik?

Zašto to ne bi bio vlak na vodik?

Hvala na pozornosti!

HYDRAIL 2019 | 19-22 JUNE 2019 | HAMBURG, GERMANY

14th International Hydrail Conference | Hamburg, Germany | 19-22 June 2019

The 14th International Hydrail Conference will be held in Hamburg, Germany on the 19-22 of June 2019. The event will feature an excursion on hydrogen fuel cell-powered light rail and behind-the-scenes tour of rail facilities, presentations and round table discussions on the latest hydrail developments, and discussions with energy and transport leaders from the Schleswig-Holstein Parliament.

Download Conference Presentations from the 13th International Hydrail Conference held in Rome, Italy on 6-8 June 2018

The 13th International Hydrail Conference was held 6-8 June 2018 at the Congress Centre of Engineering Faculty, University of Rome Tor Vergata in Rome, Italy. Additional conference information is available on the University of Rome's conference website at http://hydrail-conference-2018.uniroma2.it/.

ImechE Report on the future of Hydrogen Trains in the UK

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