



Hydrogen ICE - an appealing value proposition for sustainable mobility

PUNCH Torino is a member of

European Clean Hydrogen Alliance

Kick-starting the EU Hydrogen Industry to achieve the EU climate goals



PUNCH Torino is in the Hydrogen group of ANFIA



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Program Manager & Chief Engineer



ENVIRONMENT PARK Parco Scientifico Tecnologico per l'Ambiente

The **SMARTENERGY** six-pack series
Online advanced training & B2B on game changing energy trends

4 topics - 6 online sessions each

Hydrogen

Energy communities

Smart grids

Smart buildings



SMARTENERGY
Digitalising Energy in Europe



Co-funded by the COSME programme of the European Union

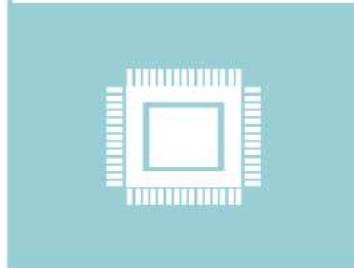
PUNCH Torino – from Design to Manufacturing

Track Records summary 2005-2019

11
Engine
families



3
In-house developed
control families



600+
Vehicle
applications



7
Markets
brands



PUNCH Torino – our capabilities

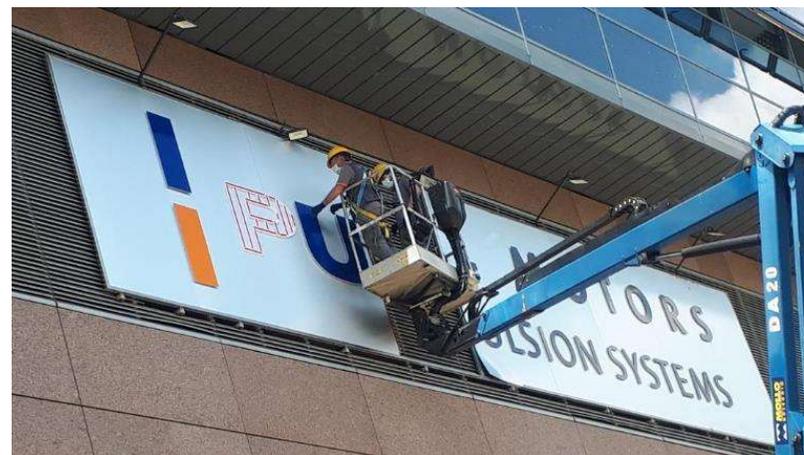
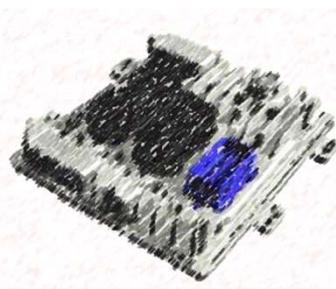
Propulsion Engineering

Developing **'turnkey' Propulsion Systems** from concept to production



Electronics

Hardware, Chip and Software full **In-House** development



AI and Machine Learning

Center of expertise from Fleet monitoring to Human being modeling



Matching domain expertise with analytics competence

Business Innovation

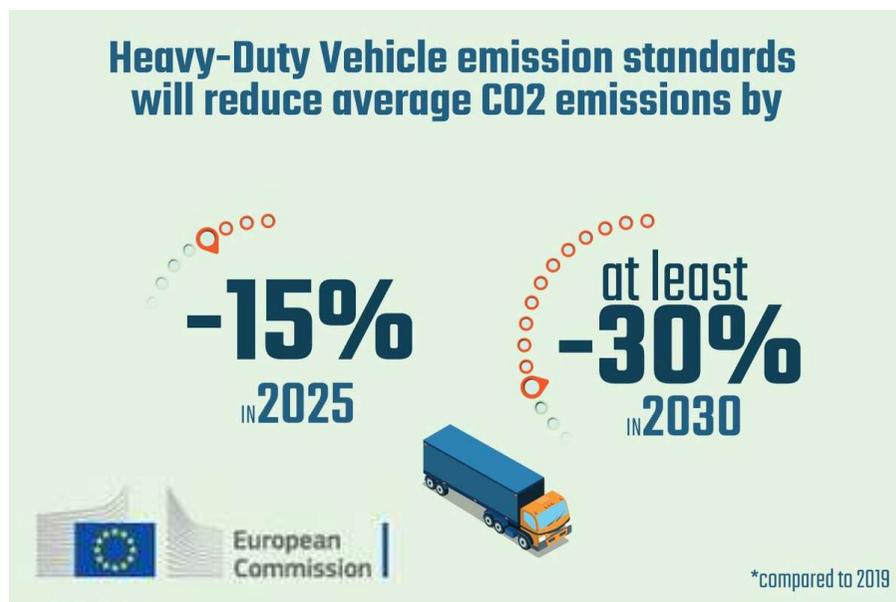
Developing **strategic products** and **new business** leveraging the available **skillset**



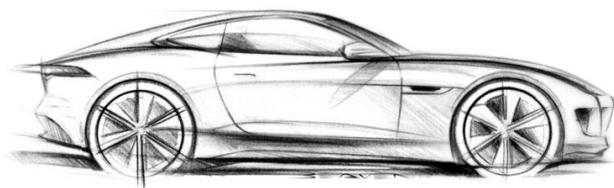
Developing new opportunities and skillset breaking the silos, fostering the innovation culture

700+ Employees
400+ granted patents

The CO₂ challenge, the BEV pain point, the Hydrogen solution



- CO₂ target for Heavy Duty (EU reg. 2019/1242)
- ZERO EMISSION VEHICLES procurement target, e.g. City Bus (EU directive 2019/1161)
- Long charging time & payload reduction: pain point of BEV's for Commercial & Heavy Duty
- Hydrogen is the viable solution, but high cost is one of the pain points of Fuel Cell



- Also sport cars may be challenged by CO₂

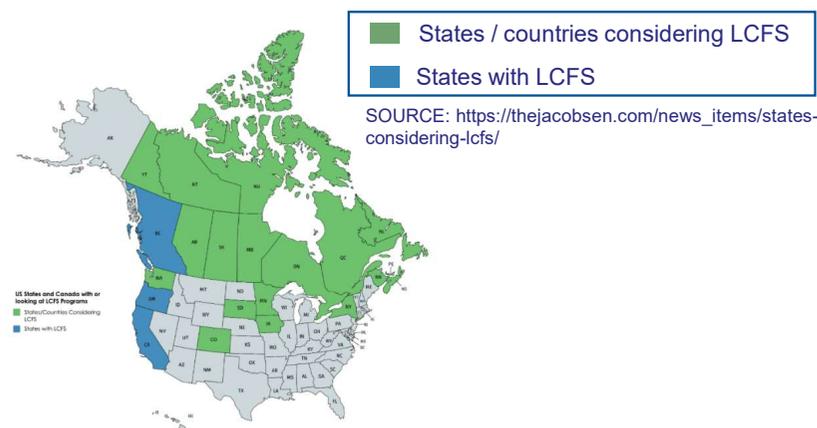
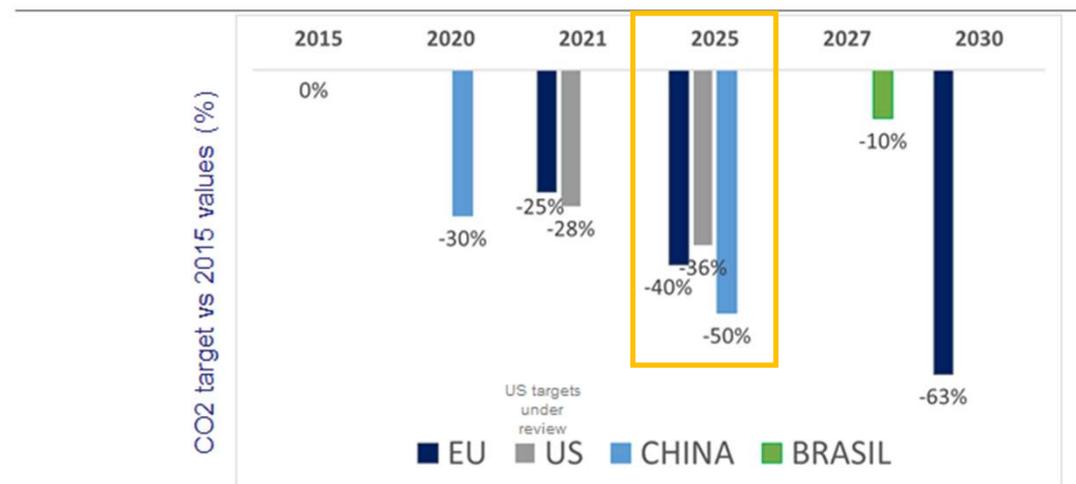
The CO₂ challenge, the BEV pain point, the Hydrogen solution

- **Restrictions on CO₂ target** for transportation on-going
- Increasing number of **US states** considering **Low Carbon Fuel Standard**

Multiple decarbonization choices for different purpose:

- **Batteries suitable** for High power short duration
- **Fuel Cell + Hydrogen** suitable for low power long duration
- **H₂ ICE closing** the gap between BEV and FC thanks to low \$/kW

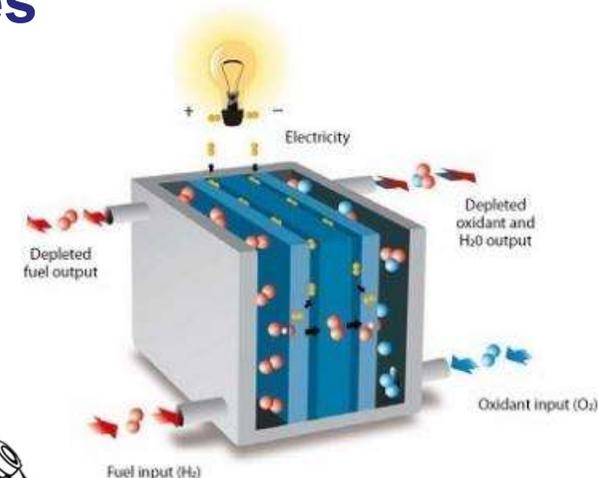
Fuel Economy & CO₂: new targets vs 2015 values



PUNCH Torino – our vision on Hydrogen technologies

“Hydrogen Ecosystem”

- H₂- Fuel Cells
- H₂- Internal Combustion Engines
- H₂- Production, Storage, Distribution



PUNCH Hydrocells

Feb 25th : PUNCH Torino announces the creation of **PUNCH Hydrocells**

PUNCH Hydrocells, based in Turin, will be targeting the **development, supply and integration of hydrogen-based propulsion and energy storage systems**. The new business will have a team with a wide range of skills that will go from Artificial Intelligence, to control electronics, to mechanical and electrical engineering, with **particular attention to the use of renewable energy**.

This is a long-term project, as evidenced by the allocation of over two million euros which will be used to **convert two engine test benches** currently in force at the engineering center into as many test benches dedicated to the **development of H₂ technologies**.

Hydrogen ICE strengths



H₂-ICE for Commercial & Heavy Duty at **similar cost of Diesel engines** (<< of Fuel Cell or Battery)



H₂-ICE considered as **"zero-emission vehicle"**



No compromise in driving range, payload and reliability
Retrofitting of existing vehicles & engines



Keep / Improve **sound experience** of existing engines



Reuse of existing footprints & skills, with positive LCA (production & recycle) **quick time to market**



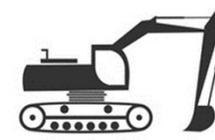
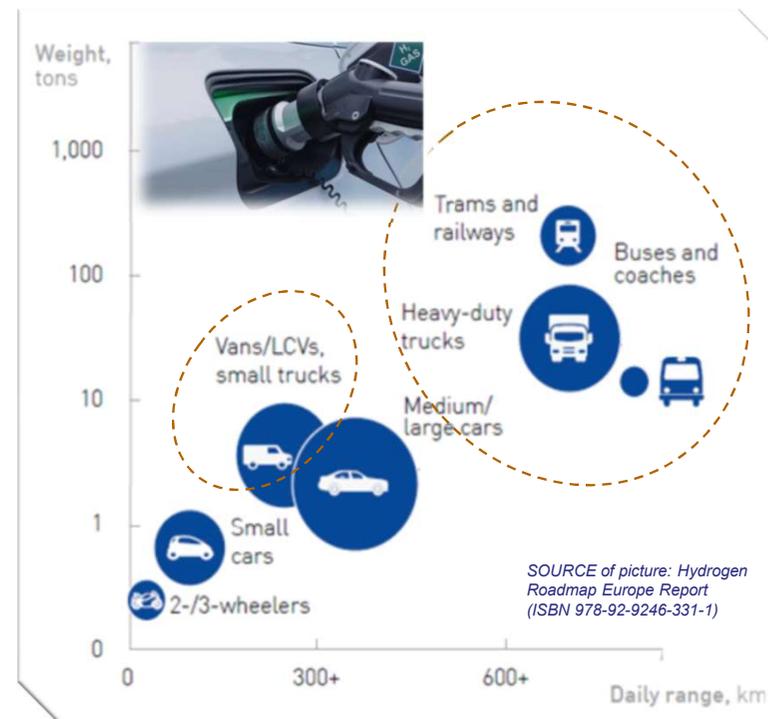
Capability to operate at **Heavy Duty** conditions for prolonged time



Quick refueling time (like for actual engines)



Reduced recharging footprint & no grid peak load vs BEV
Few H₂ stations sufficient for hub based specific fleets

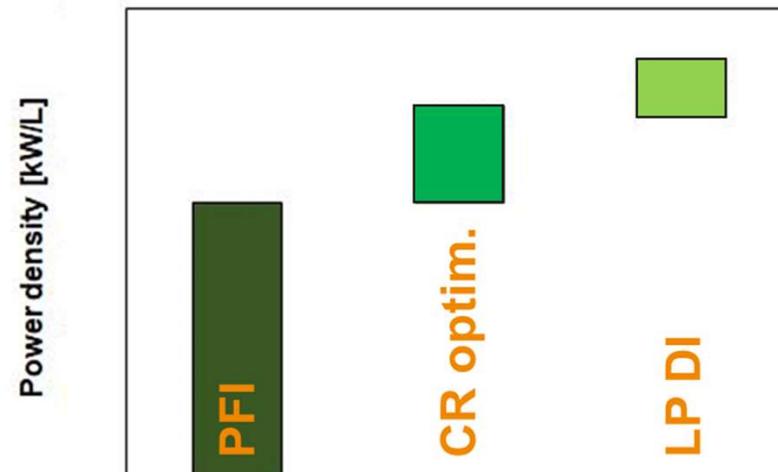


Hydrogen ICE derived from Diesel engine

- Injection
- Ignition
- Specific SW
- Charging
- Intake Manifold
- Piston & Rings
- Blow By
- EGR
- Valves and Valve Seats



Specific Power walk chart



PFI injection with specific piston geometry featuring **optimized CR** can already meet typical power requirements of industrial application.

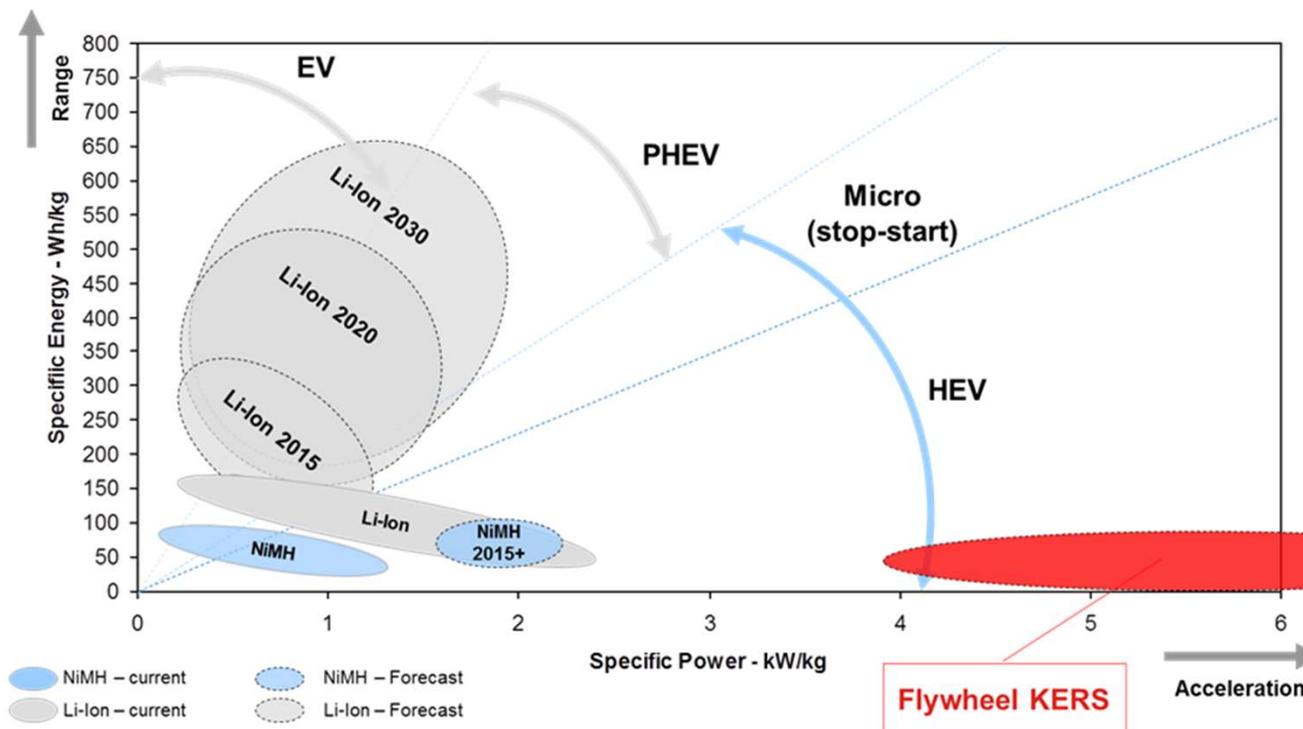
DI injection provides additional edge where needed.

Hydrogen ICE & Flybrid



Battery:

- Long term energy storage
- Large energy capacity
- Low power charge & discharge
- Suitable for infrequent full charge & discharge



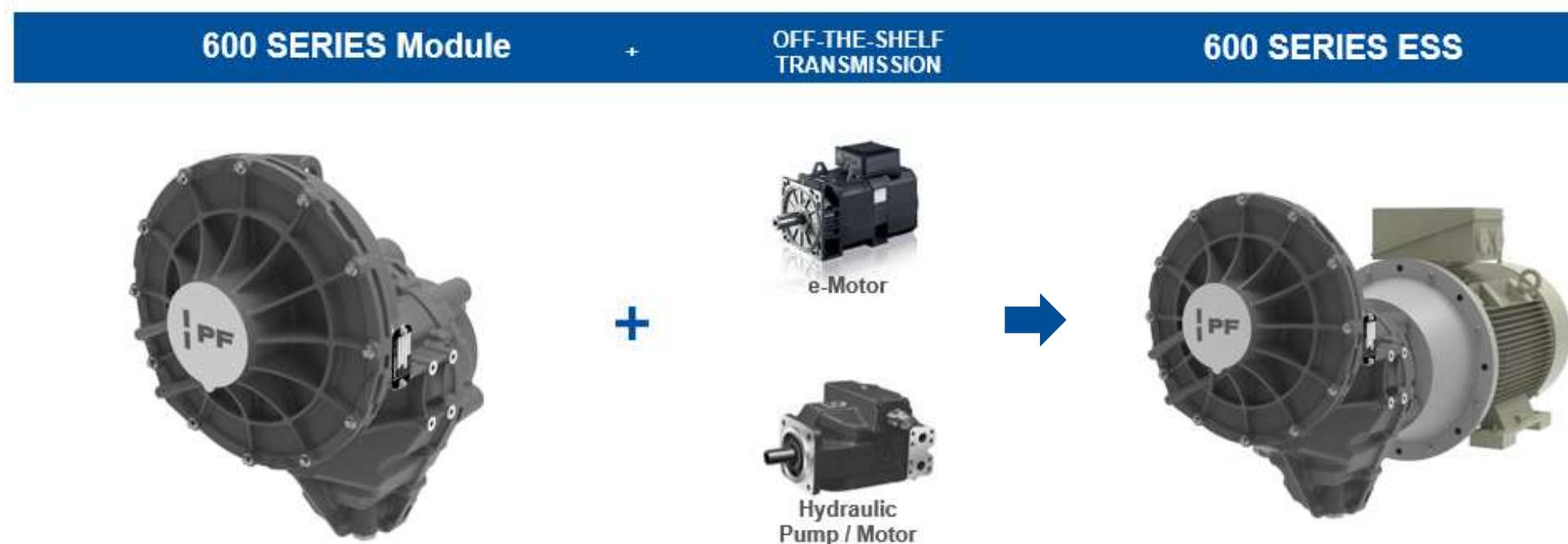
Flywheel:

- Short term energy storage
- Small energy capacity
- High power charge & discharge
- Suitable for very frequent full charge & discharge

⇒ Battery & Flywheels suitable for different usage cases

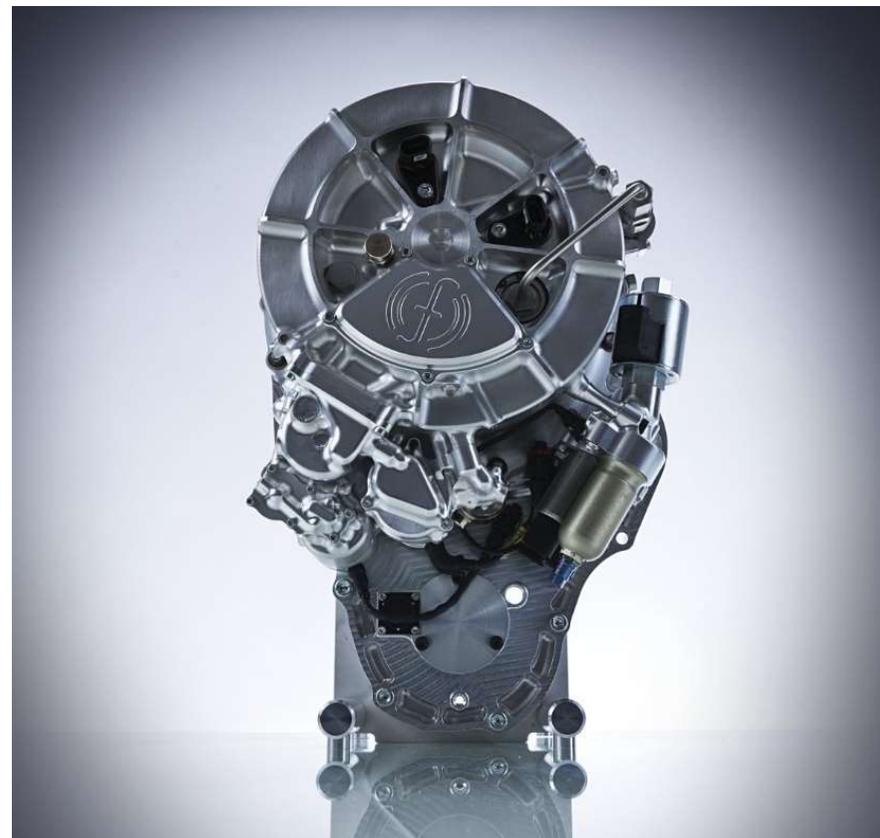
Flybrid 600 Series Energy Storage System (ESS)

The 600 Series Module can be connected to various energy transmission options



Flywheel Energy Storage – Advantages

- High power density → low weight
- Insensitive to high number of charge & discharge events → no degradation even in harsh duty cycles
- High robustness against vibration and shock loads → long life
- Low cooling requirements → Beneficial for vehicle integration
- Insensitive to the ambient temperature (-30 to +130°C) → insensitive to installation location
- Easy to repair → low operating cost
- Great recyclability & low full life cycle emissions



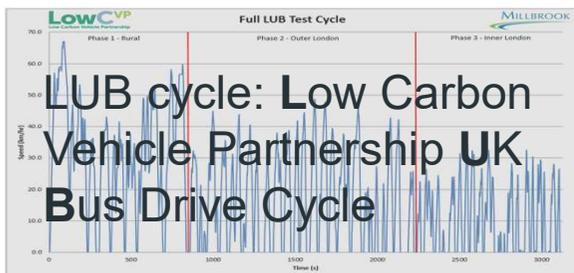
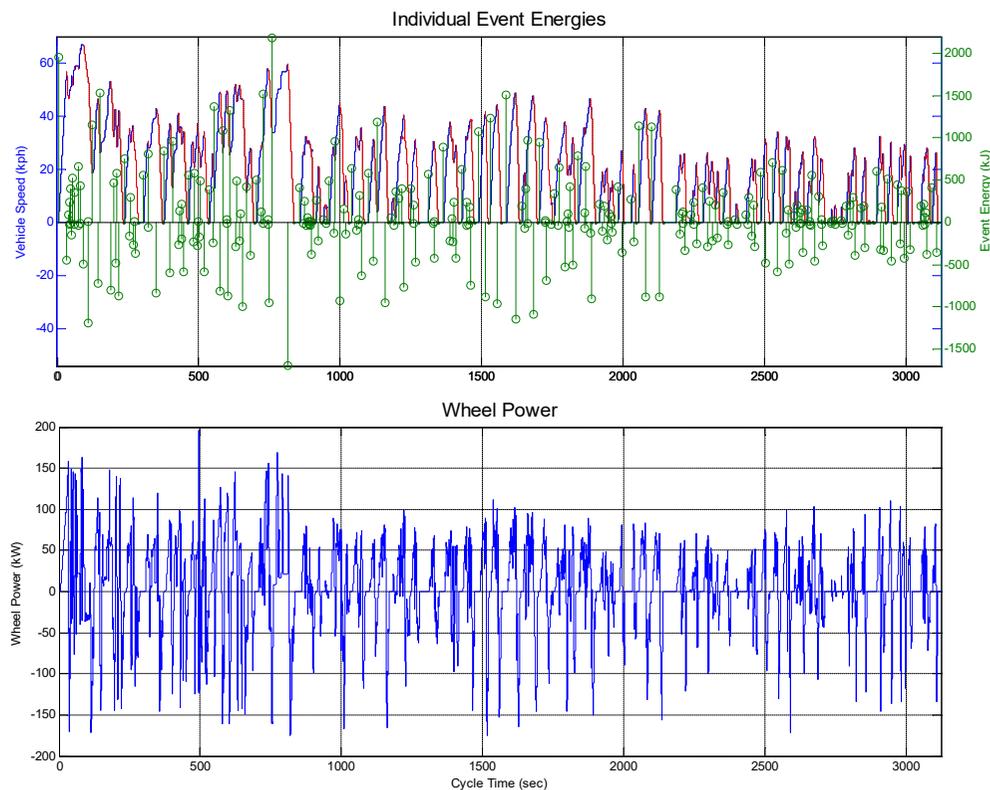
Flybrid City BUS case study

Results:

The simulated fuel consumption benefit for the electrically connected flywheel is **19%** on the **LUB** cycle.

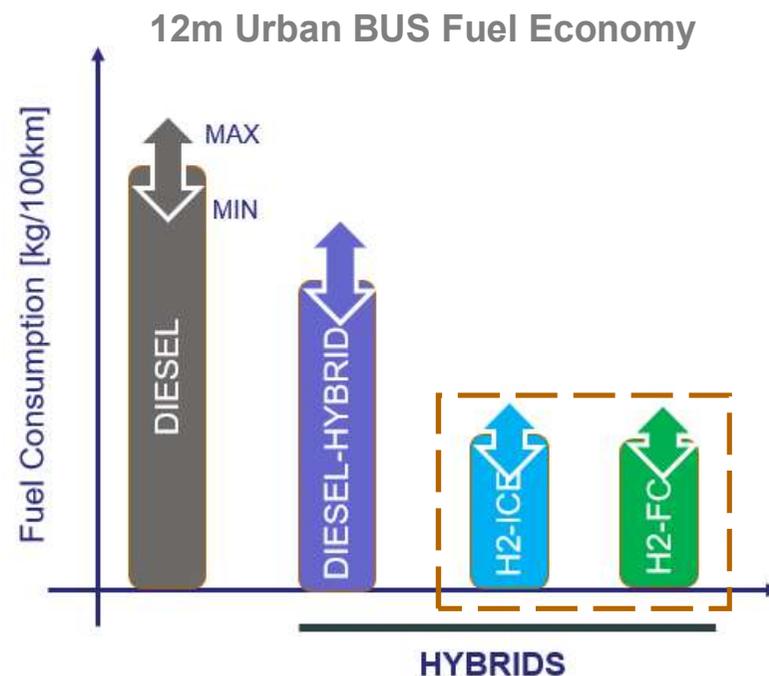
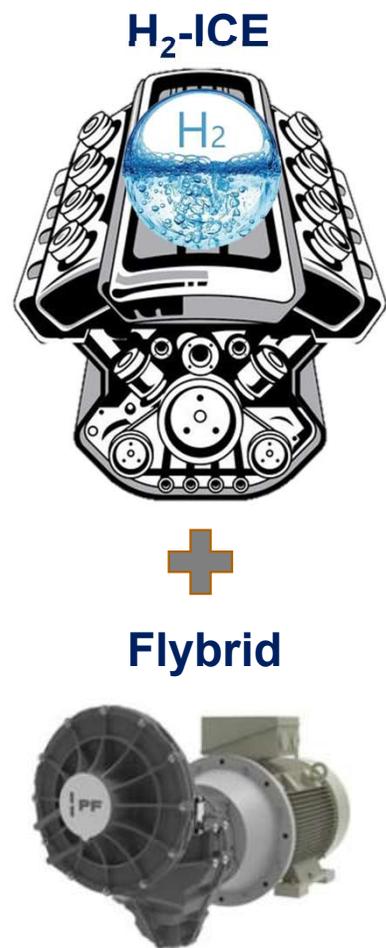
Additional benefits to be considered:

- Direct drive motor eliminates gear windage losses
- Electrical ancillaries can be driven from the flywheel when the bus is stopped enabling start stop
- Bus pull-away from rest is possible using only the flywheel



Weight	Static Rolling Force [N]	Frontal Area [m ²]	Drag Coefficient
13.9t	682	5.97	0.7

Hydrogen ICE & Flybrid: appealing value proposition



CO₂ FREE BUS
at appealing
Total Cost of Ownership



Hydrogen ICE – summary

- ✓ **Hydrogen** is key technology for **decarbonizing** specific applications
- ✓ **Hydrogen ICE & Fuel Cell** technologies offer an holistic **approach** to the **decarbonization goal**
- ✓ **Converting existing Diesel engine architecture with minimal effort, & Port Fuel Injection** can already provide viable products
- ✓ **Hybrid Hydrogen ICE** can achieve **similar efficiency of FCEV** for specific application
- ✓ **Optimized design** including **Direct Injection** is a **next step** for **Power & Efficiency improvement**
- ✓ **Need social & political consensus on H₂-ICE** as complementary solution to other green technologies

PUNCH Torino & H2-ICE alliance



The H2-ICE alliance has been established: an Italian partnership for the development of sustainable mobility driven by hydrogen-powered engines.

The scope of the alliance is to drive the evolution of the industry, supply chain and transportation footprint towards the transition to a green-energy society.

Leading partners: **PUNCH Torino**, **AVL in Italy**, **Industria Italiana Autobus S.p.A.**, **Landi Renzo S.p.A.** and **TPER SPA**

[#energy](#) [#sustainable](#) [#hydrogen](#) [#alliance](#)

<https://www.linkedin.com/feed/update/urn:li:activity:6757296221624291328>

PRESS ARTICLES

<http://hydronews.it/nasce-h2-ice-alleanza-made-in-italy-per-il-trasporto-pubblico-a-idrogeno/>

http://www.ansa.it/canale_motori/notizie/industria/2021/01/19/auto-nasce-h2-ice-alleanza-made-in-italy-per-lidrogeno_88a2d614-e17b-44bc-95db-974e06555889.html

<https://www.industriaitaliana.it/punch-torino-avl-italia-industria-italiana-autobus-landi-renzo-automotive-idrogeno/>

<https://www.autobusweb.com/nasce-h2-ice-lalleanza-made-in-italy-che-spinge-sullidrogeno/>

<http://www.trasporti-italia.com/autobus/autobus-in-via-di-sviluppo-un-motore-a-combustione-interna-alimentato-a-idrogeno/45402>



Nasce H2-Ice, l'alleanza italiana con lo scopo di promuovere l'utilizzo dell'**#idrogeno** per la trazione di veicoli nel trasporto pubblico! Oltre a IIA, hanno aderito alla partnership **PUNCH Torino**, **AVL in Italy**, **Landi Renzo S.p.A.** e **TPER SPA**.

Le parole del nostro CEO **Giovanni De Filippis**: "Un altro tassello nel consolidamento della leadership di Industria Italiana Autobus nella costruzione di autobus.

Già impegnata con un importante piano d'investimenti per il rinnovo della gamma, attraverso questo accordo svilupperemo e testeremo in operatività un autobus ad idrogeno, consentendo così ad IIA di essere pronta al momento in cui il mercato chiederà veicoli green.

IIA crede fortemente nel prodotto eco sostenibile, con la presenza nella sua gamma di veicoli a trazione a LNG e CNG, questo sarà un ulteriore passo avanti verso il trasporto a basso impatto ambientale."

[See translation](#)





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*“We provide our partners
with innovative engineering solutions
and affordable products for a sustainable mobility,
building our excellence around people.”*

