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Instituto Tecnológico
de Buenos Aires

MTL 2018
Power To Gas: H_2 Technology

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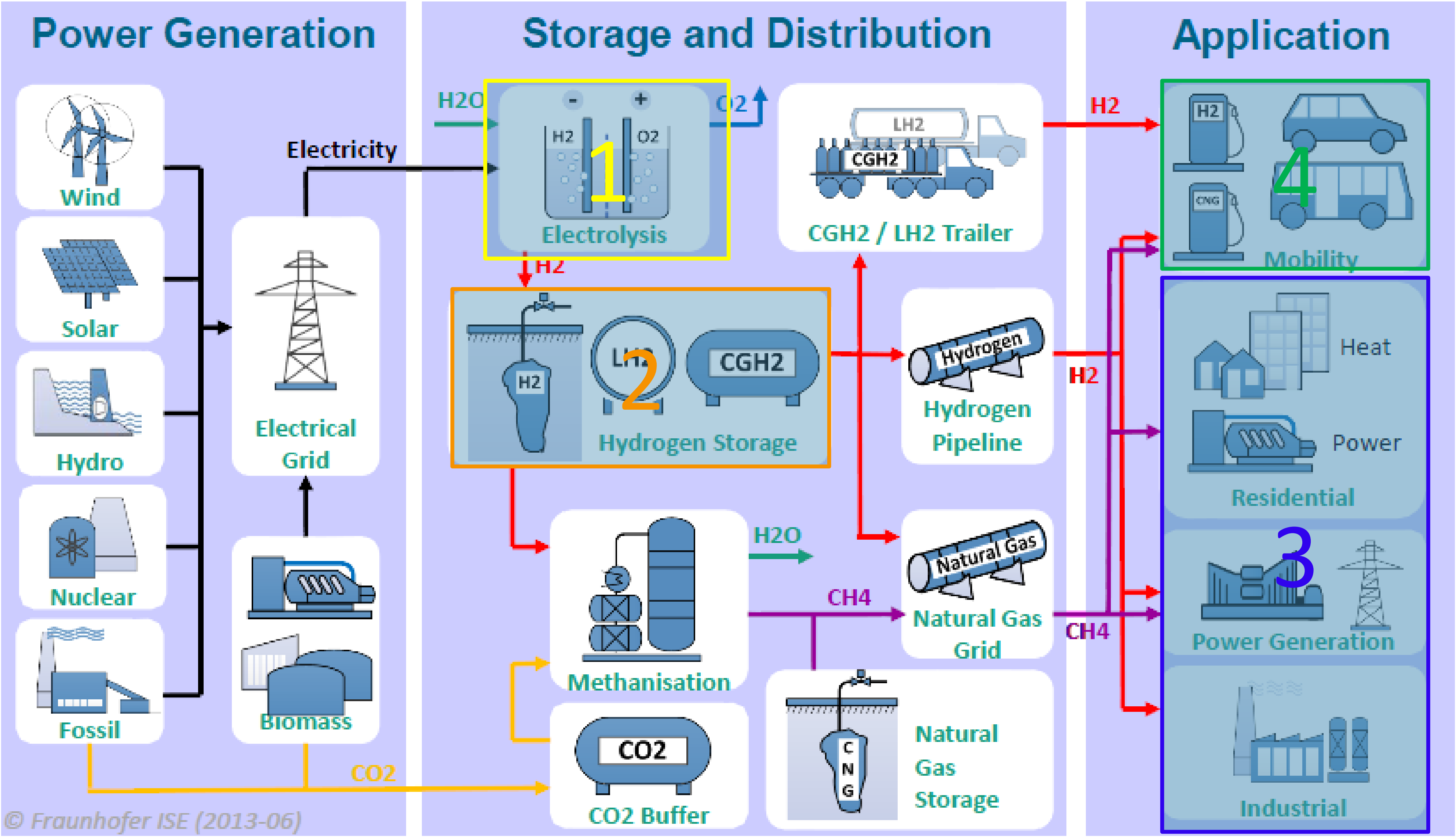
Power to Gas Concept – Hydrogenation of CO_2

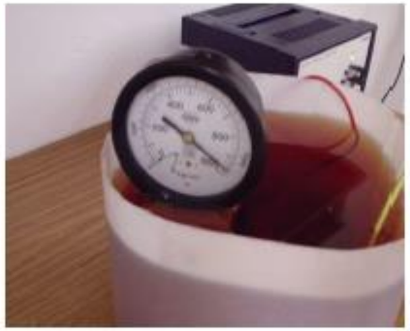
The hydrogen pathway and extension to natural gas



1-High pressure Hydrogen Production

Hydrogen production at 900 bar by means of electrolyzers installed in the fuelling stations. The hydrogen is directly stored at 875 bar without the need of compressors.

a



b

c

a Lab-scale test at 950 bar.

b Prototype for intermittent operation at 750 bar.

c Industrial scale prototype for operation at 200 bar.

Cost comparison of Hydrogen production

	Scenarios	Minimum	Medium	Maximum
1	Cost of production by Steam Reforming, transportation and compression of H_2 [U$D/GGE H_2]	**0,639**	**0,895**	**1,151**
2	Cost of production by storage pressure electrolysis at 900 bar of H_2 and O_2, **[U$D/GGE H_2]**	**0,484**	**1,011**	**1,787**

The system saves the energy consumption for compression, compressor costs of maintenance and capital repayment. The challenge is to develop the technology to reach high pressure safe and reliable operation and producing hydrogen with the specified purity.

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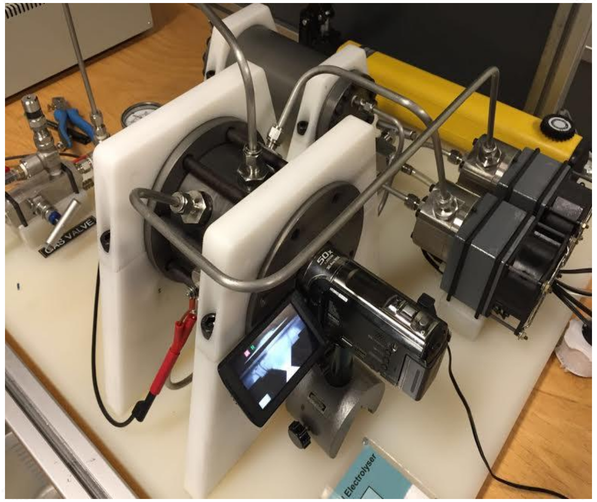
2005

2009

2010

2011

2013



2015

Year	Production capacity		Installation place	Purpose
	Nm^3H_2/h	bar		
2017	??	??	ITBA	Fueling of Green Island Prototype
2016	??	??	ITBA	Fueling of Hybrid Bus Prototype
2015	-	500	Karlsruhe Institute of Technology, Germany	Study bubbles detachment and behavior
2013	2	200	ITBA	Performance test, also at at EnerSystem
2011	5	200	H2 Experimental Plant , P.Truncado, Sta Cruz.	Research and use of H_2 as fuel
2010	1	30	National University of Córdoba	Study of wind mill-electrolyzer interface
2009	0,7	30	Base Esperanza, Antarctica	Use of H_2 as fuel
2005	0,1	700	ITBA	Research

2-High pressure Hydrogen Storage

Intrinsically safe, simple and scalable, high pressure hydrogen storage system

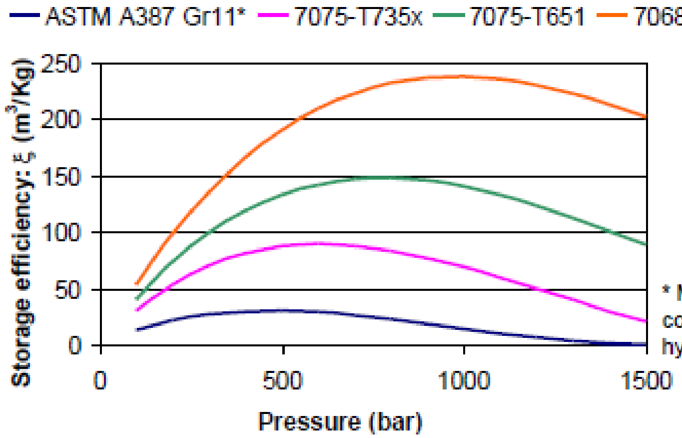
Small prototype coil unit

Al 6063 T6

Total weight:
27 kg

Storage capacity:
2,7 Nm^3 of H_2
at 700 bar

Hydraulic tested
at 1050 bar



Storage efficiency:

$$\xi = \frac{V_n^2}{m\,v}$$

* Material used in conventional steel hydrogen tanks.

Design parameters	
Temperature (C)	25
Storage pressure (bar)	875
Design pressure (bar)	1313
Safety factor *	**1,10**

* Maximum Shear Stress Theory

Material	
Material	7075-T651
Tensile Strength, Yield (Mpa)	503
Density Al (kg/m3)	2810
$/Ton Al tube	3500

1 Kg H_2 Storage System	
Tube length (m)	106
System Weight (Kg)	87
U$S/kg H_2	**303**
H_2(Kg)/System(Kg) (%)	**1,156**

This type of storage system has a high heat transfer capacity, unrestricted shape and is not affected by hydrogen embrittlement.

In case of damage of one or several tubes due to impact, over pressure or material failure, hydrogen would be liberated gradually, avoiding a violent expansion wave.

The challenge is to develop the technology to manufacture aluminum alloy tubes of great length and relatively small circular section.

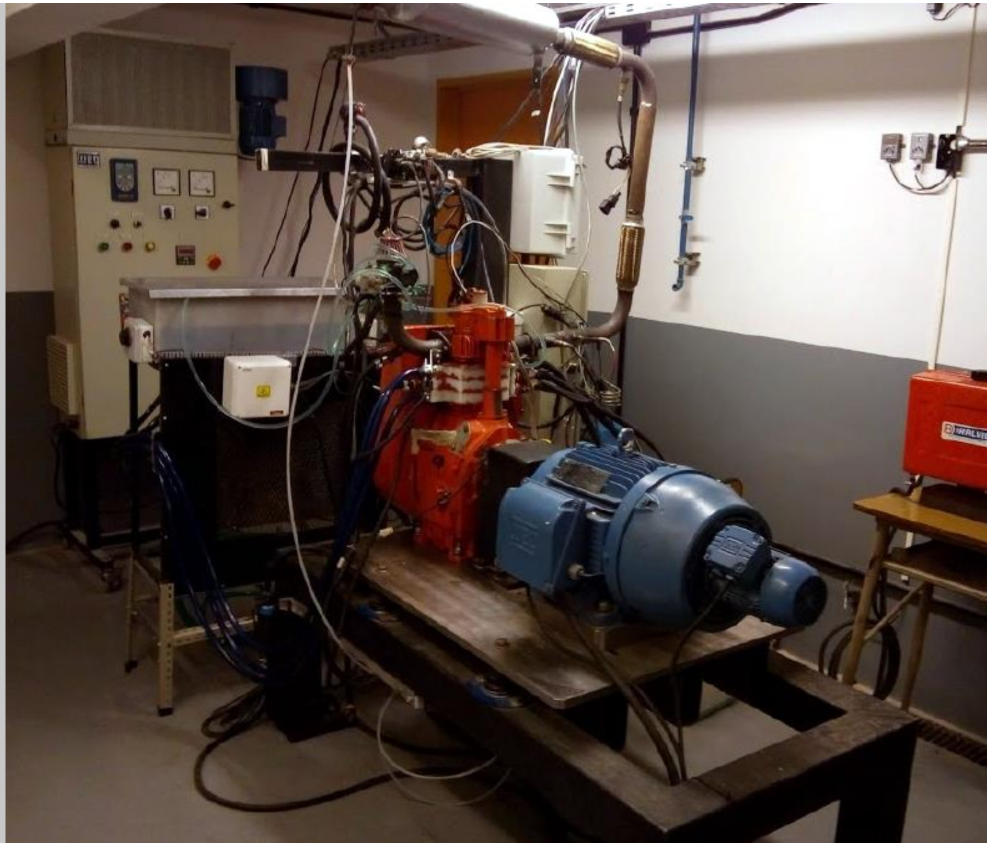
3-Heat&Power Generation

Objective: Study the combustion process of different gaseous fuels, including H_2, to further understand this process in order to design **more efficient gaseous fuelled ICEs**.

Research lines

Heat transfer mechanisms involved in the combustion of gaseous fuels in ICEs.	Incidence of turbulence in the propagation/quenching of lean burn premixed flames in ICEs	Development of engine control strategies to optimise efficiency by varying lambda.

- **10KW R&D Transient engine test cell;**
- **1 cylinder Otto engine and equipped with:**
  - **programmable ECU;**
  - **gaseous fuel injection system;**
  - **In-cylinder pressure transducer.**
  - **Inlet and exhaust gas thermocouples.**
- **Exhaust gas analyzer;**
- **Equipment to be installed shortly:**
  - **Fast response In-cylinder heat transfer sensor;**
  - **Fuel mixing system to generate gaseous fuels of varying compositions (CH_4, CO, CO_2, H_2);**
- **Engine simulation using GT POWER**
- **Engine simulation using CFD**



4-Mobility

Problem

Surface urban transport constitutes a major problem for most big cities:

- Traffic congestions;
- Air pollution (health concerns and climate change);
- Acoustic pollution;

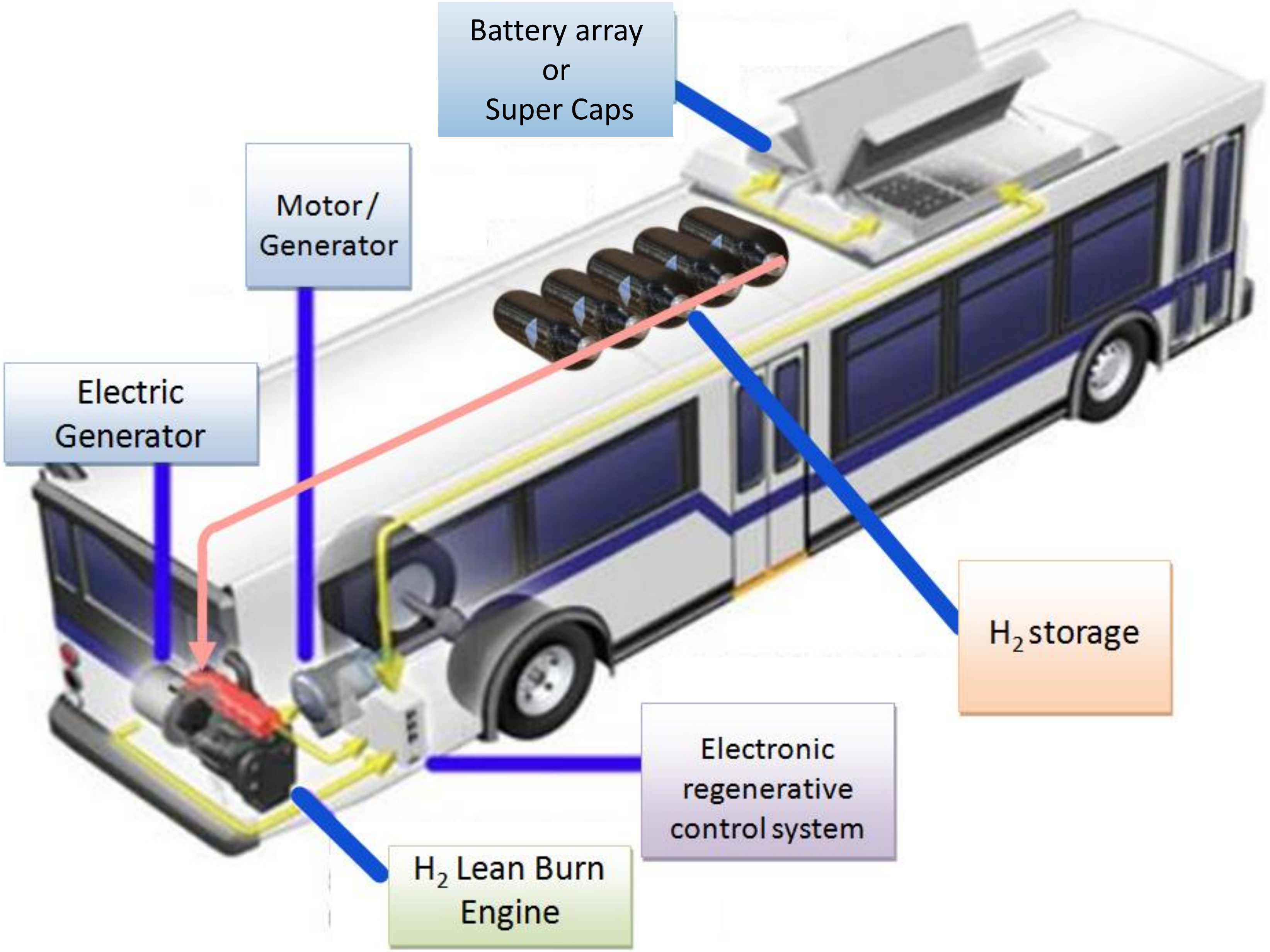
Proposed solution

Background: Collaboration between Mercedes Benz Argentina and ITBA.

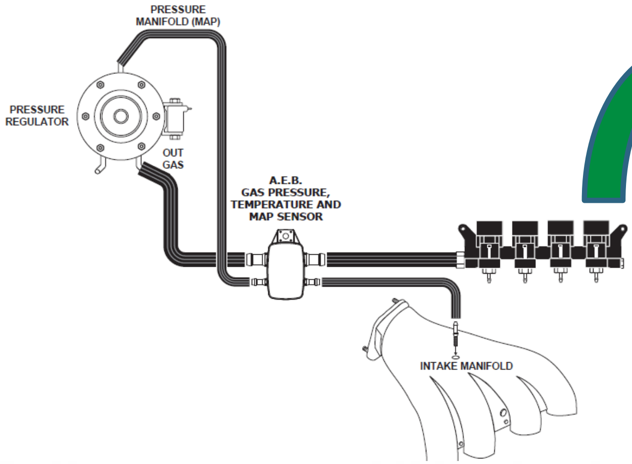
Objective: Convert a MB OH 1618 L-SB Diesel Bus platform to run as a H_2 fuelled series hybrid bus.

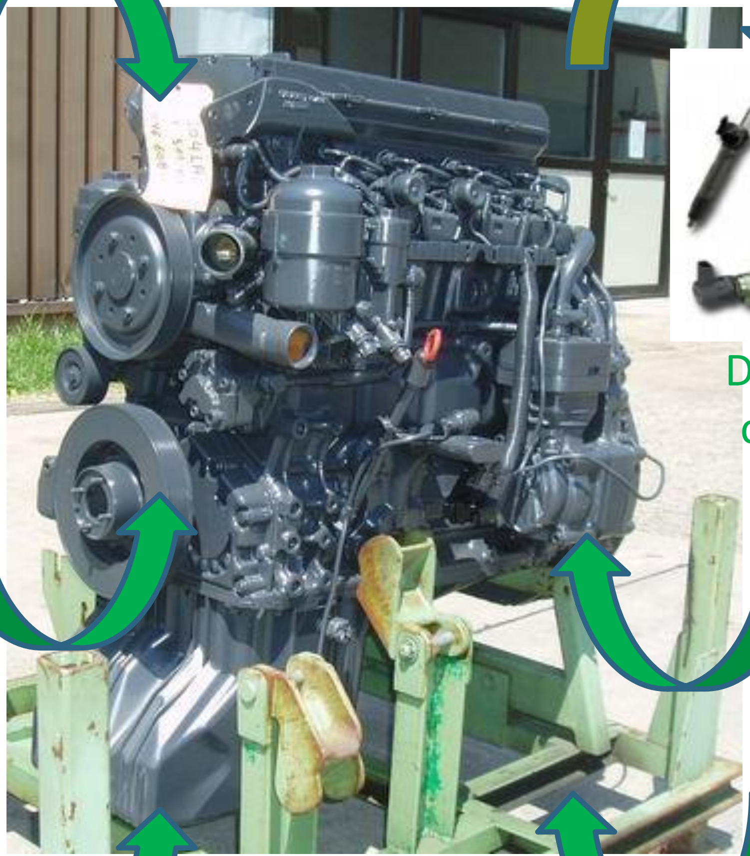
Time frame: 3-4 years

Project description



Conversion & optimization of diesel engine to run on H_2 as a zero emission power unit





Design of combustion chamber for H_2 lean burn

Lean burn control strategy

Project description: H_2 ICE, Efficiency

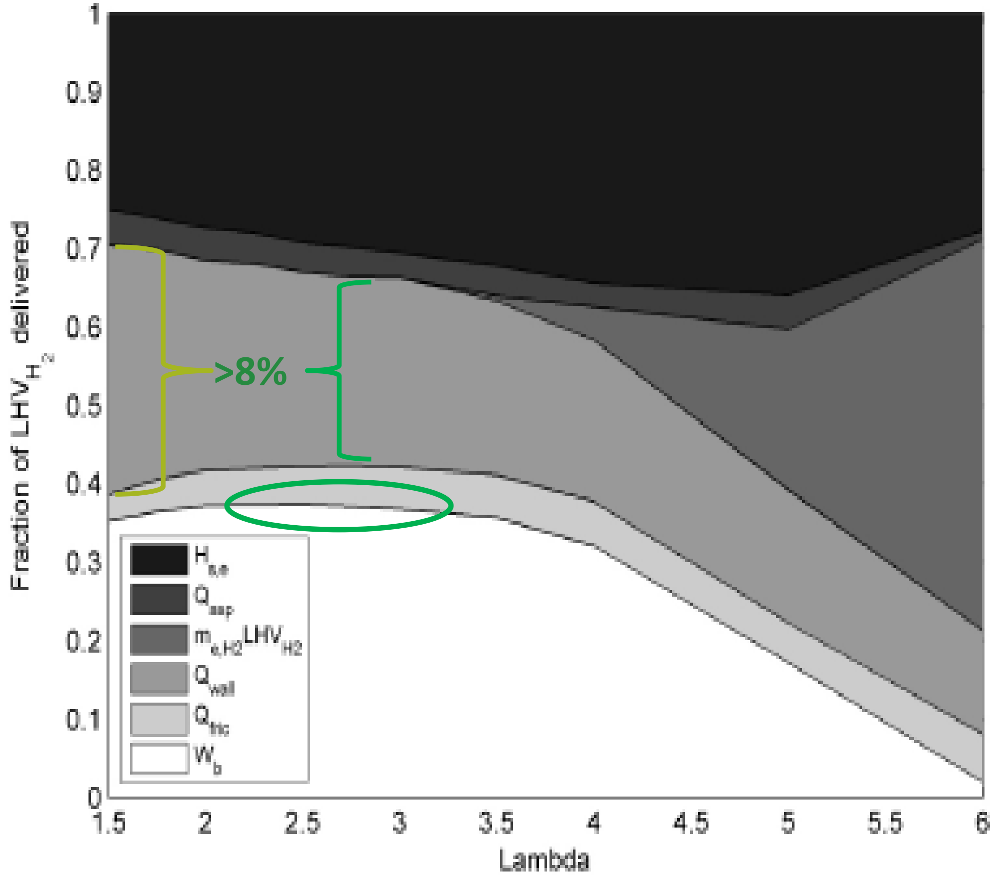


Figure 13. First law energy balance for the naturally aspirated WOT data (fractions of LHV of delivered H_2). Segments show normalised fractions of W_b brake work, Q_{fric} friction losses, Q_{wall} cylinder wall heat transfer, m_{eH2} LHV_{H_2} unburned fuel, Q_{asp} heat transfer to intake and exhaust valves and piping and $H_{s,e}$ the sensible enthalpy of the exhaust leaving the system.

- Peak engine efficiency 38% (2<λ<3)
- Engine efficiency on gasoline 30% (λ=1)
- 8% reduction of in-cylinder heat losses

Room for Improvement

- Increase compression ratio from 10:1►15:1
- Use turbocharger to reduce pumping losses by reusing exhaust gas enthalpy

Expected Max Efficiency 40-45%

CITATION: Dennis, P., Brear, M., Watson, H., Orbaiz, P. et al., "An Integrated Model of Energy Transport in a Reciprocating, Lean Burn, Spark Ignition Engine," *SAE Int. J. Engines* 8(4):2015, doi:10.4271/2015-01-1659.

Project description: H_2 ICE, Emissions

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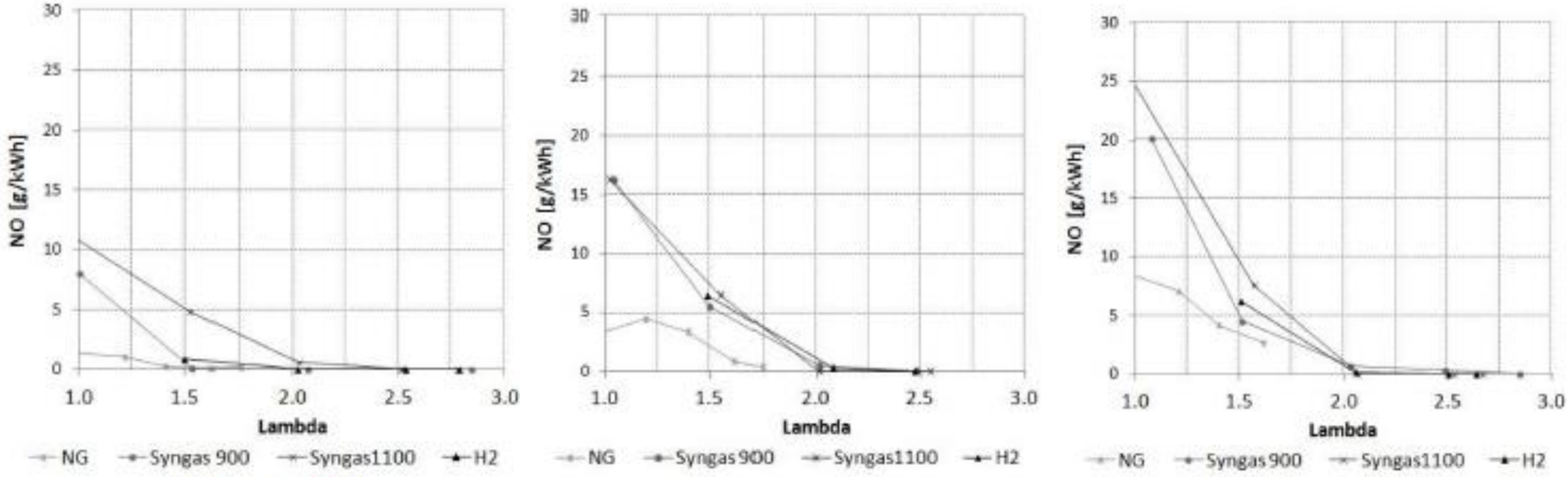


a. 1500rpm and 83Nm

b. 1500rpm and 140Nm

c. 3500rpm and 83Nm

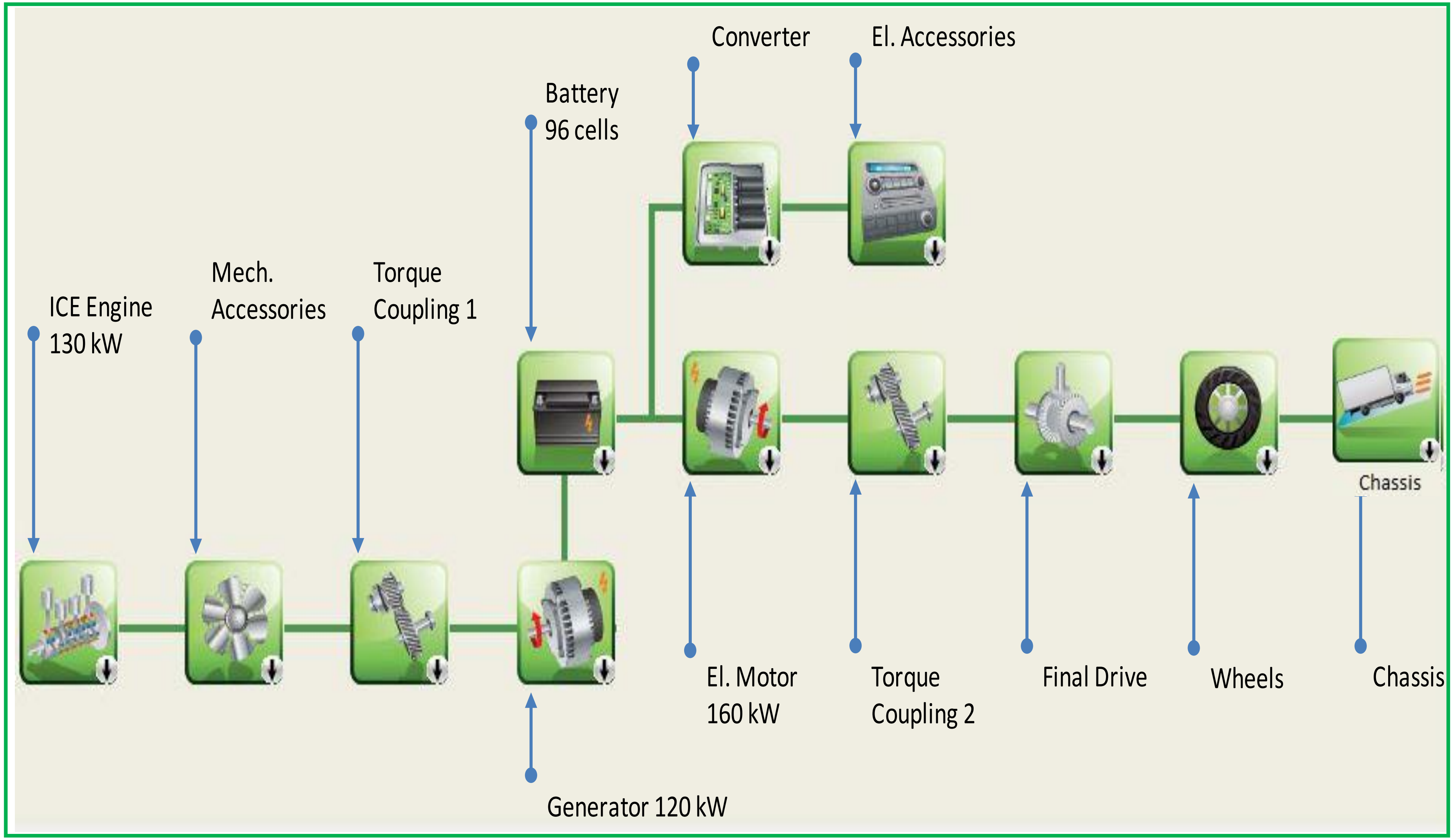
Zeldovich Mechanism for NOx formation Freezes beyond λ>2,
ZERO NOx FORMATION with no after treatment

ZERO emission power unit!!!

CITATION: Orbaiz, P., Brear, M., Abbasi, P. and Dennis, P., "A Comparative Study of a Spark Ignition Engine Running on Hydrogen, Synthesis Gas and Natural Gas," *SAE Int. J. Engines* 6(1):2013, doi:10.4271/2013-01-0229.

Life Cycle Assessment (LCA)

Hybrid H_2 Vehicle (HH2V)



"Life Cycle Analysis"

- Minimize "Total cost of ownership" (TCO):

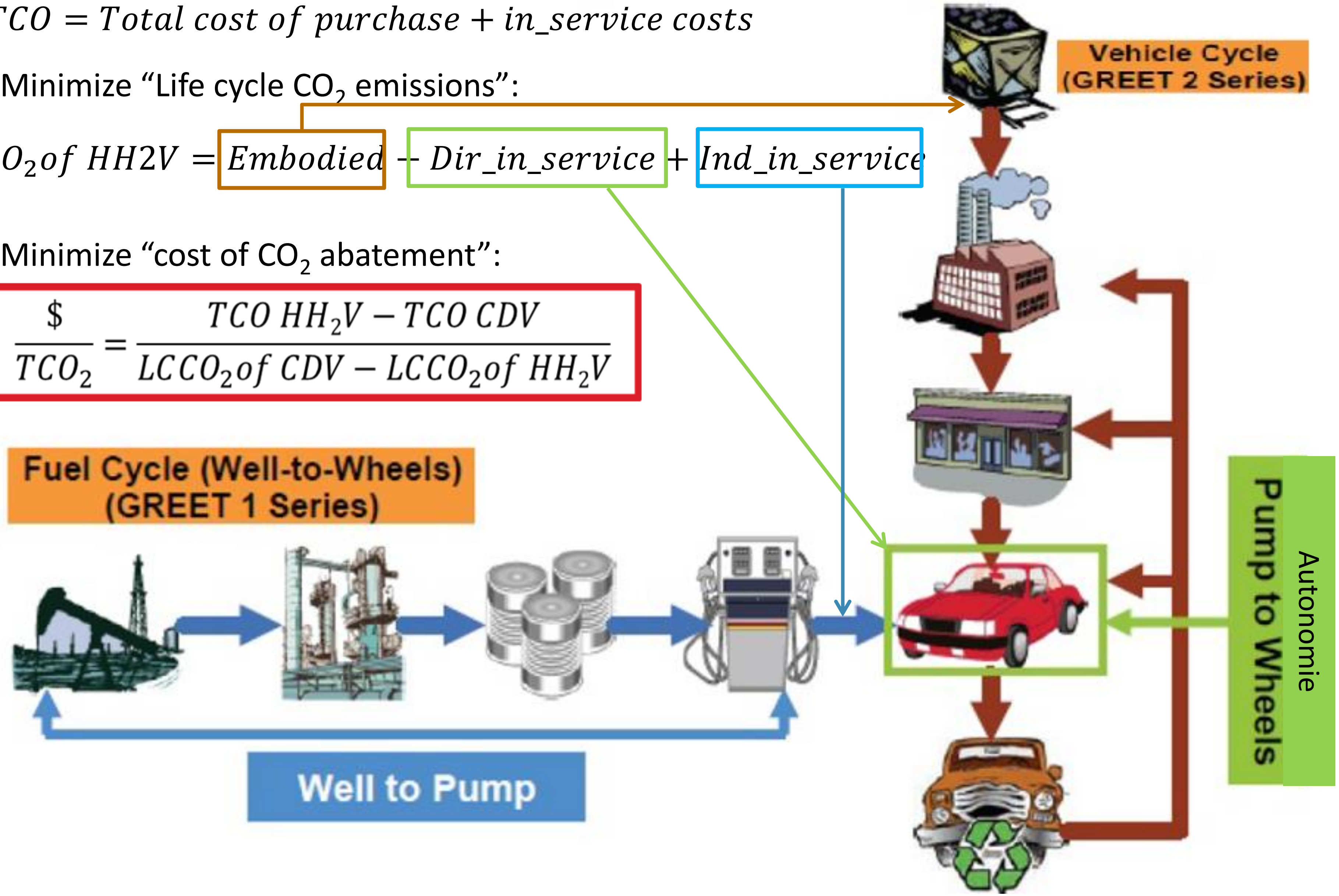
$$TCO = Total\ cost\ of\ purchase + in\_service\ costs$$

- Minimize "Life cycle CO_2 emissions":

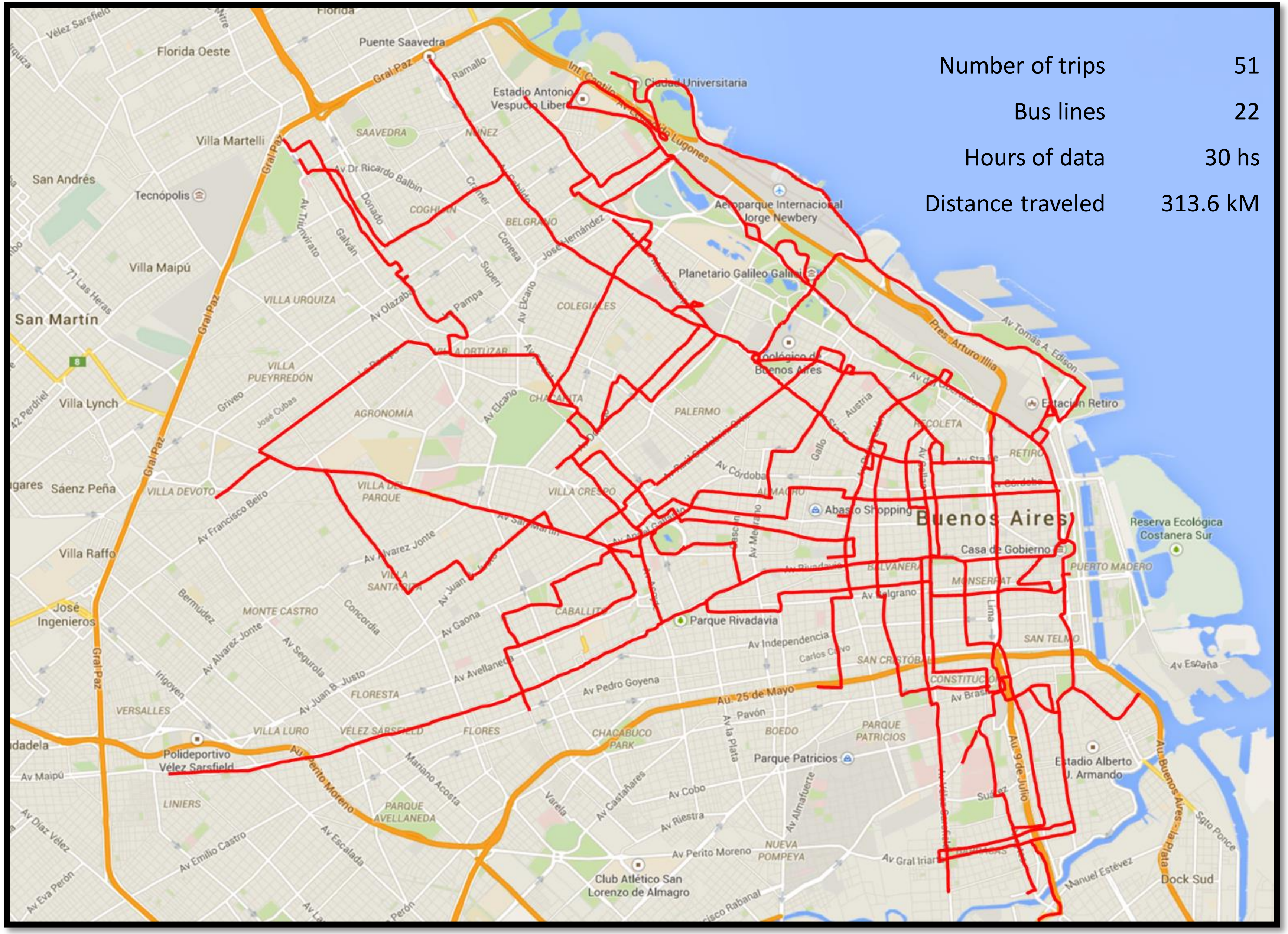
$$LCCO_2 of\ HH2V = Embodied + Dir\_in\_service + Ind\_in\_service$$

- Minimize "cost of CO_2 abatement":

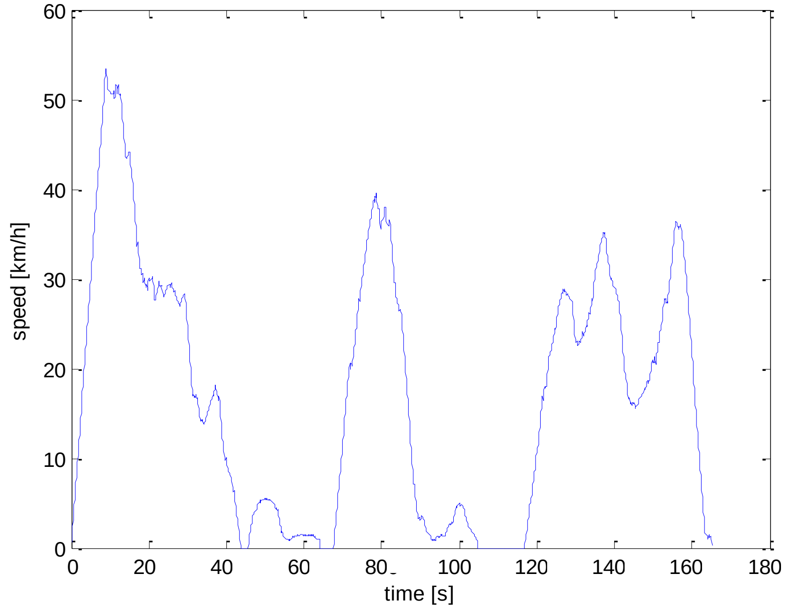
$$\frac{\$}{TCO_2} = \frac{TCO\ HH_2V - TCO\ CDV}{LCCO_2 of\ CDV - LCCO_2 of\ HH_2V}$$



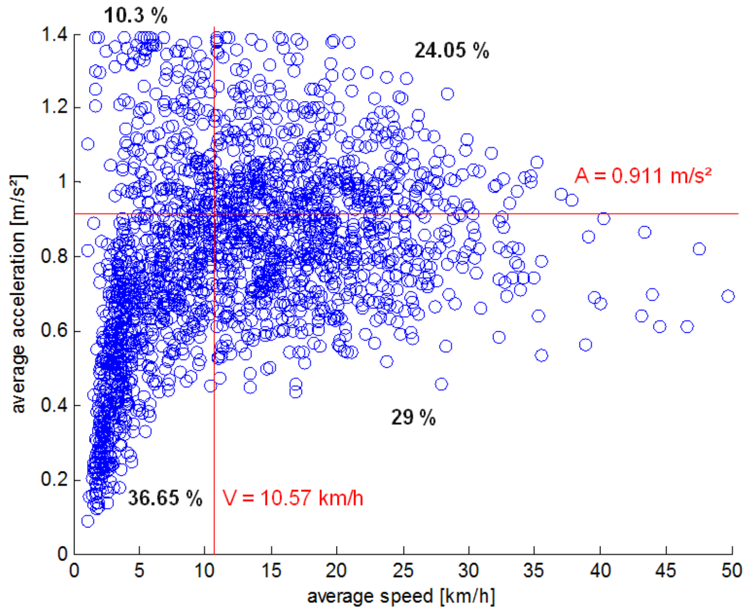
Operation Costs and Emissions. Buenos Aires Drive Cycle



Number of trips	51
Bus lines	22
Hours of data	30 hs
Distance traveled	313.6 kM



“Micro trips”

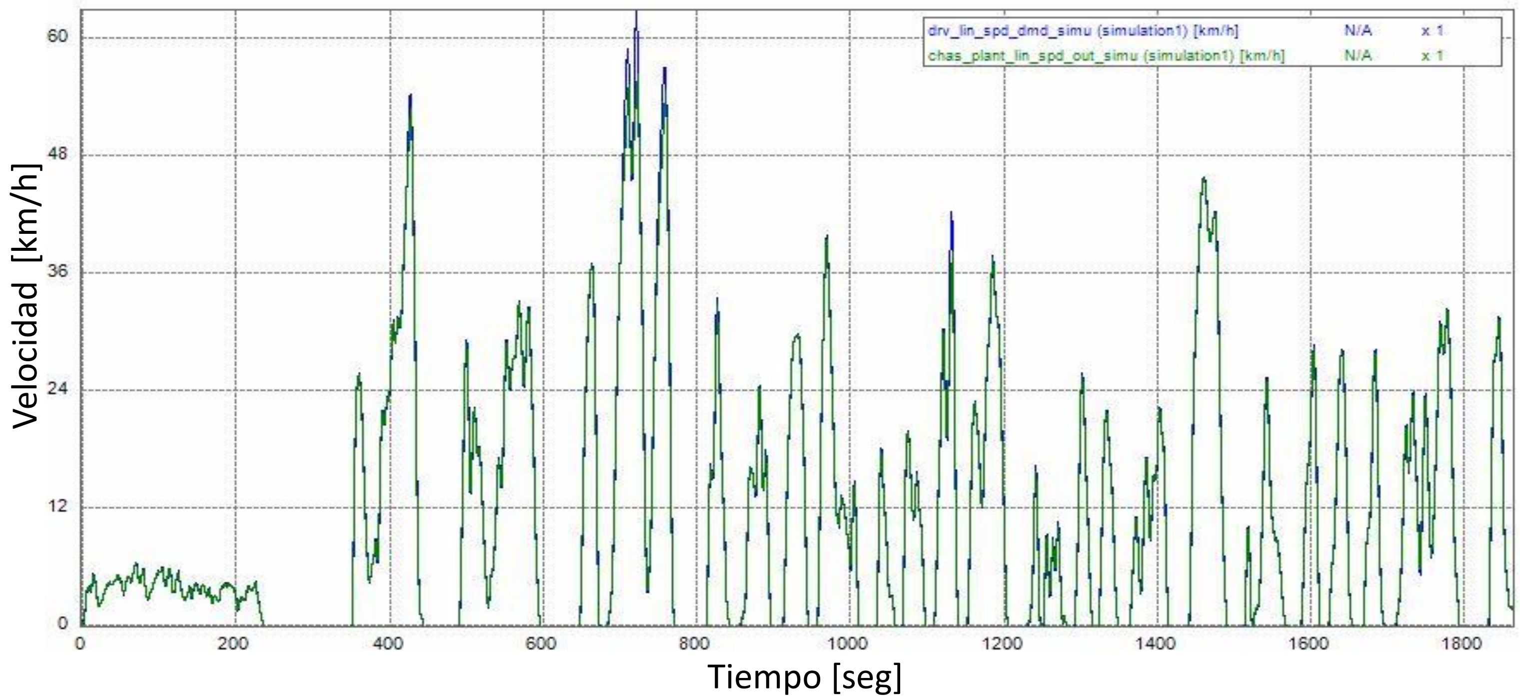


Statistic distribution

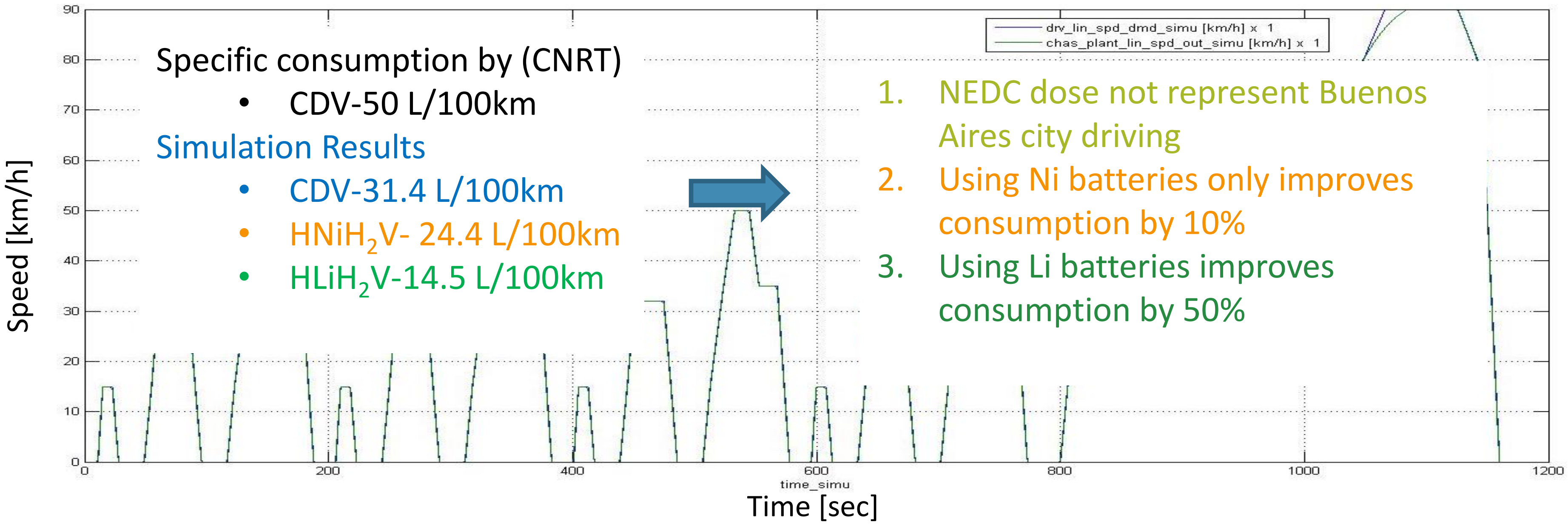
Average Acceleration $0.91 m/s^2$

Average speed 10.57 km/h

Statistic distribution



New European Standard Driving Cycle (NEDC)



Specific consumption by (CNRT)

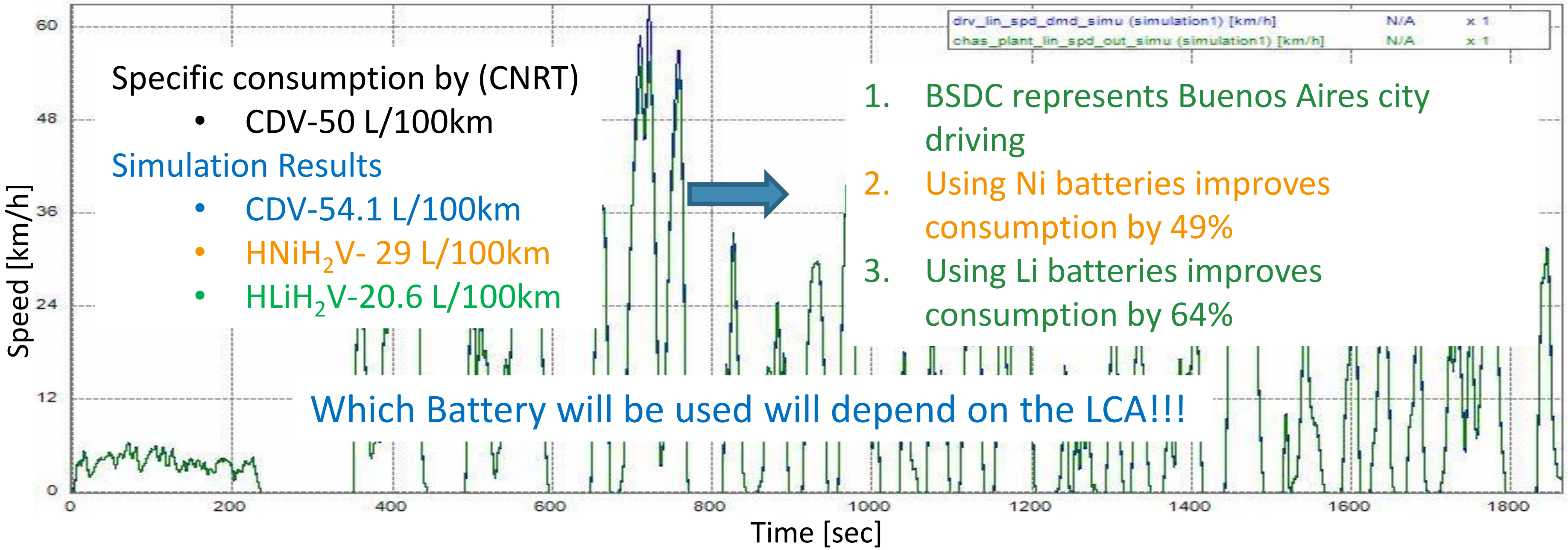
- CDV-50 L/100km

Simulation Results

- CDV-31.4 L/100km
- $HNiH_2V$- 24.4 L/100km
- $HLiH_2V$-14.5 L/100km

1. NEDC dose not represent Buenos Aires city driving
2. Using Ni batteries only improves consumption by 10%
3. Using Li batteries improves consumption by 50%

Buenos Aires Driving Cycle (BADC)



Specific consumption by (CNRT)

- CDV-50 L/100km

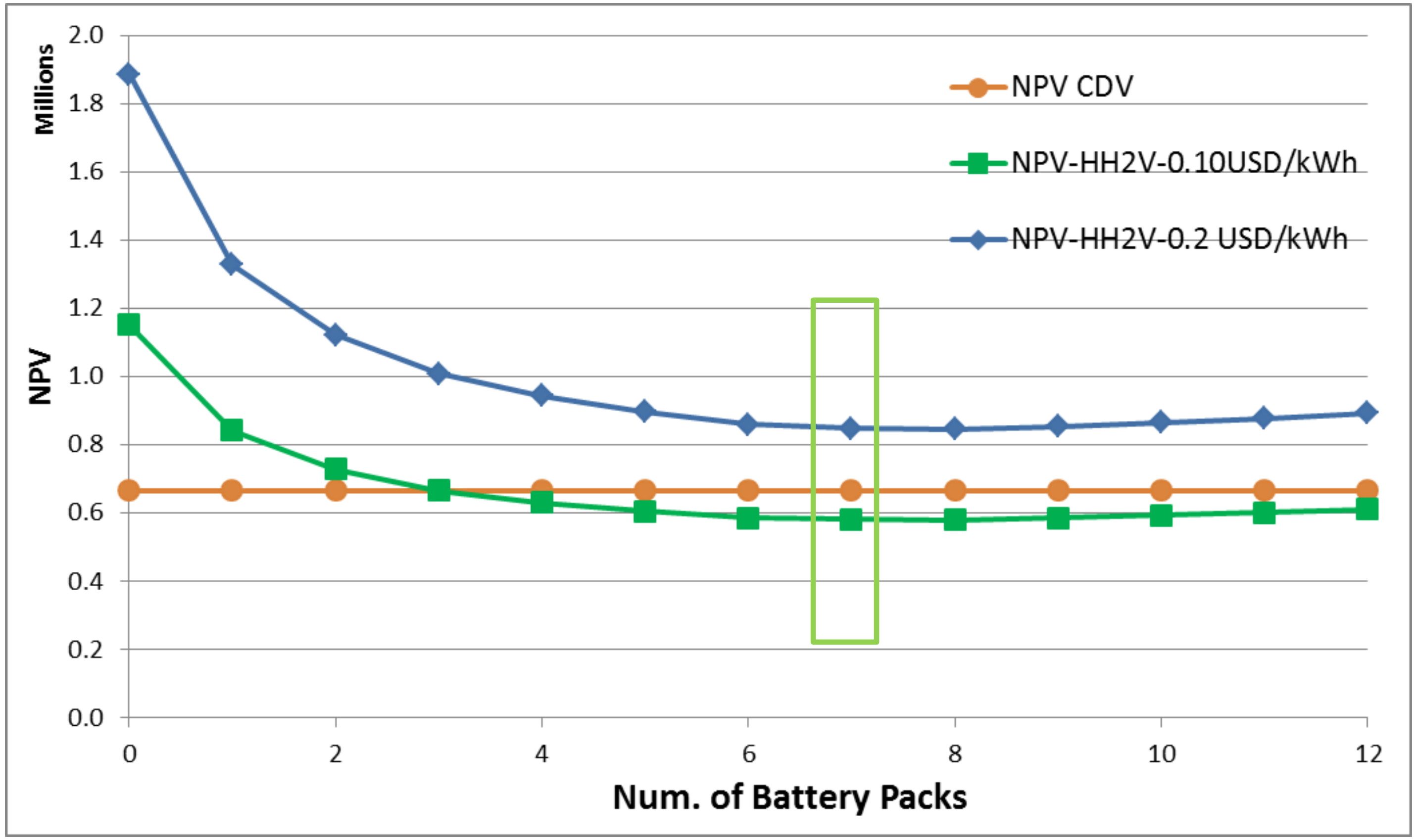
Simulation Results

- CDV-54.1 L/100km
- $HNiH_2V$- 29 L/100km
- $HLiH_2V$-20.6 L/100km

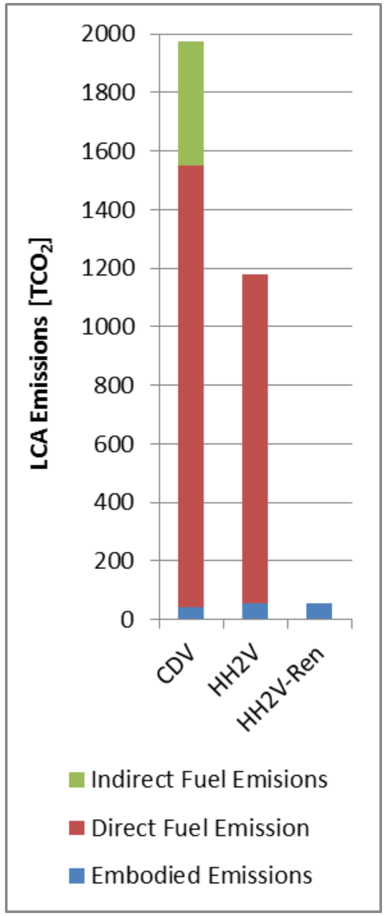
1. BSDC represents Buenos Aires city driving
2. Using Ni batteries improves consumption by 49%
3. Using Li batteries improves consumption by 64%

Which Battery will be used will depend on the LCA!!!

"Cost of Abatement per Ton of CO_2"



Grid Emissions [TCO2/GJ] 0.092
Direct Diesel Emission [TCO2/GJ] 0.0741
Indirect Diesel Emissions [TCO2/GJ] 0.0208



$$\frac{\$}{TCO_2} = \frac{TCO\ HH_2V - TCO\ CDV}{LCCO_2 of\ CDV - LCCO_2 of\ HH_2V}$$

	Cost of Abatement [$/TCO$_2$]	
	HH2V-0.1 USD/kWh	HH2V-0.2 USD/kWh
Elec de la red	-$ 106.81	
Elec. Renovable		$ 93.79

H_2 ICE Hybrid Bus

If well dimensioned and designed to fit the environment in which it will be operated the proposed solution could:

- Have a total cost of ownership lower than the technology it displaces.

CHEAPER

- It is as versatile as the technology it displaces
  - Same refueling times
  - Same autonomy
  - Same life duration

VERSATILE

CLEANER

- Even using electricity from the interconnected grid to produce hydrogen it has Lower life cycle emissions that the conventional technology.

Overall Summary

- We believe H_2 is viable energy vector that will enable further amounts of renewable energy into the sectors of the energy market.
- Further H2 systems can provide auxiliary capability for grid frequency control.
- We are working on the development of cost-effective versatile solutions to promote the inclusion of H_2 technologies throughout the entire energy sector.
- We promote collaboration with both industry and other R&D institutions.

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