



@EVSymposium29
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Electric Vehicle Symposium & Exhibition

June 19-22, 2016 | du 19 au 22 juin 2016

Montréal, Québec, Canada

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DRIVE ELECTRIC INNOVATION
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Energy management of multi-storage systems in electric vehicles

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Presentation contents

I. Background

II. Fuel cell system

III. Supercaps system

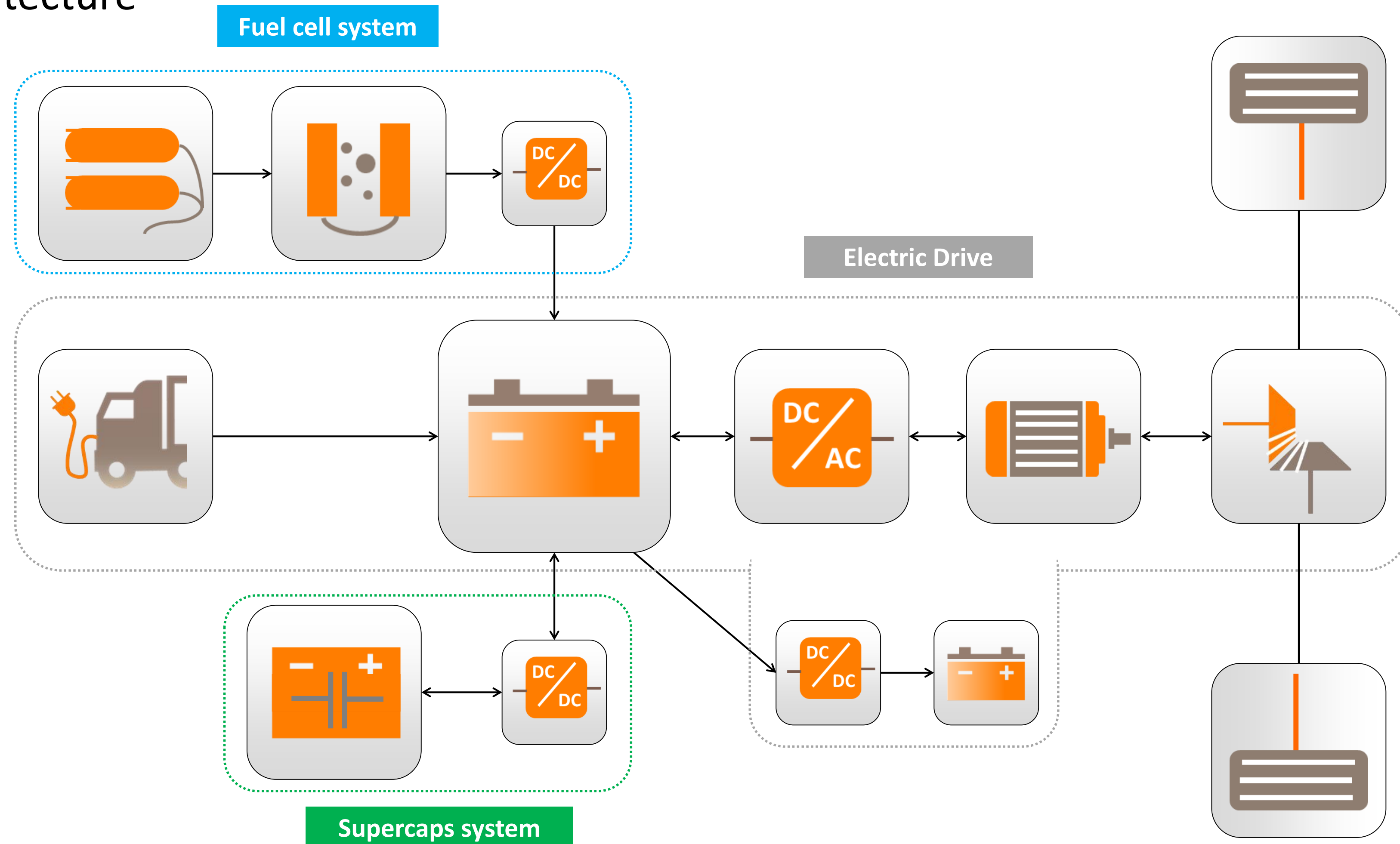
IV. Energy consumption simulation

V. Conclusions

- Project objectives
 - Electrify a vehicle from the ICE version
 - Maintain the key requirements
 - Vehicle speed
 - Hill-climbing
 - General comfort
- Baseline vehicle
 - Project done between 2009 and 2011
 - High voltage battery: 46.6kWh
 - Maximum system power: 100kW
 - Vehicle range: 157km according to NEDC



- Vehicle architecture



- Objectives
 - Development of a range extender based on hydrogen fuel cell
 - Double the initial range
- System characteristics
 - Maximum fuel cell power: 20kW
 - Control frequency: 10Hz
 - Weight of the complete system (fuel cell, DC/DC converter, piping, etc.): 100kg
 - Hydrogen tank characteristics: 103kg for 110l of hydrogen

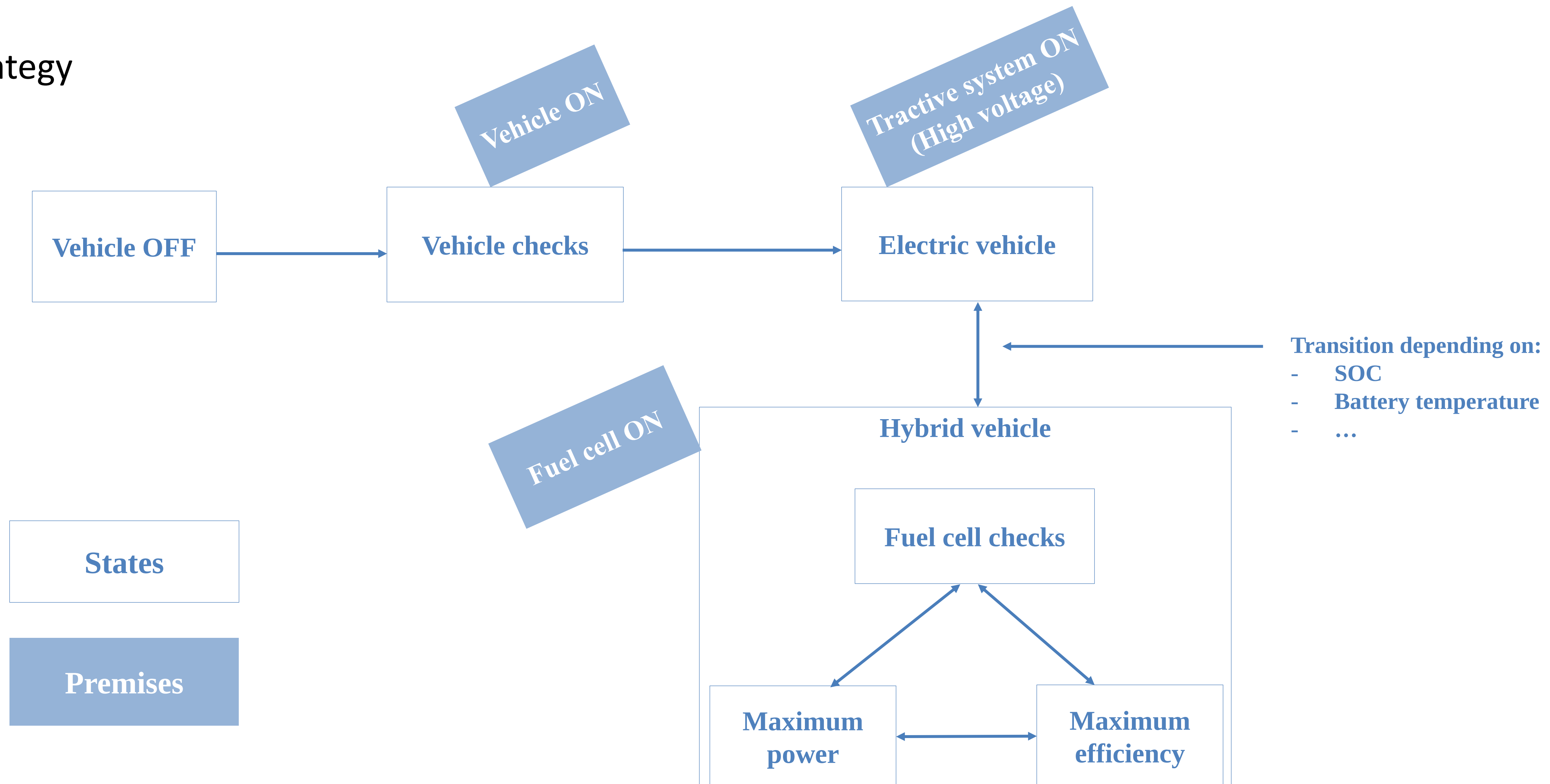


46kWh

≈3kg of H₂

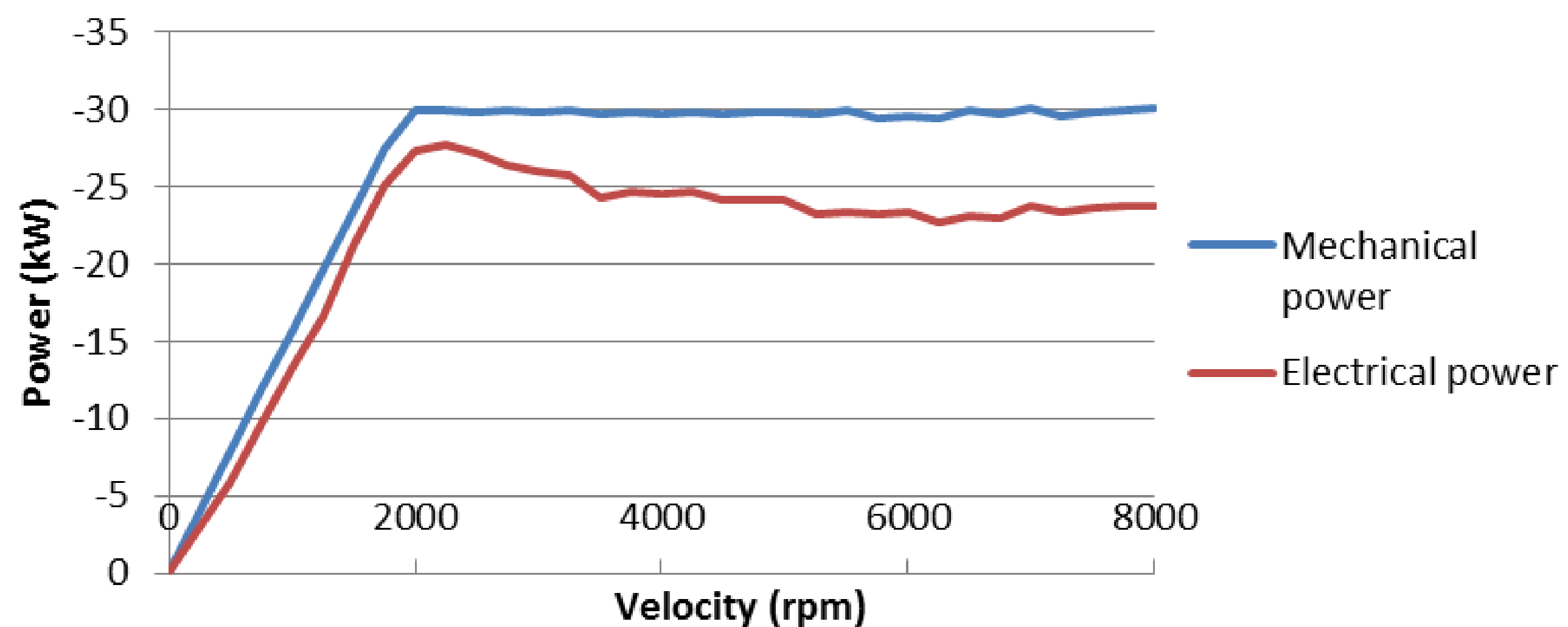
≈110l of H₂

- Control strategy

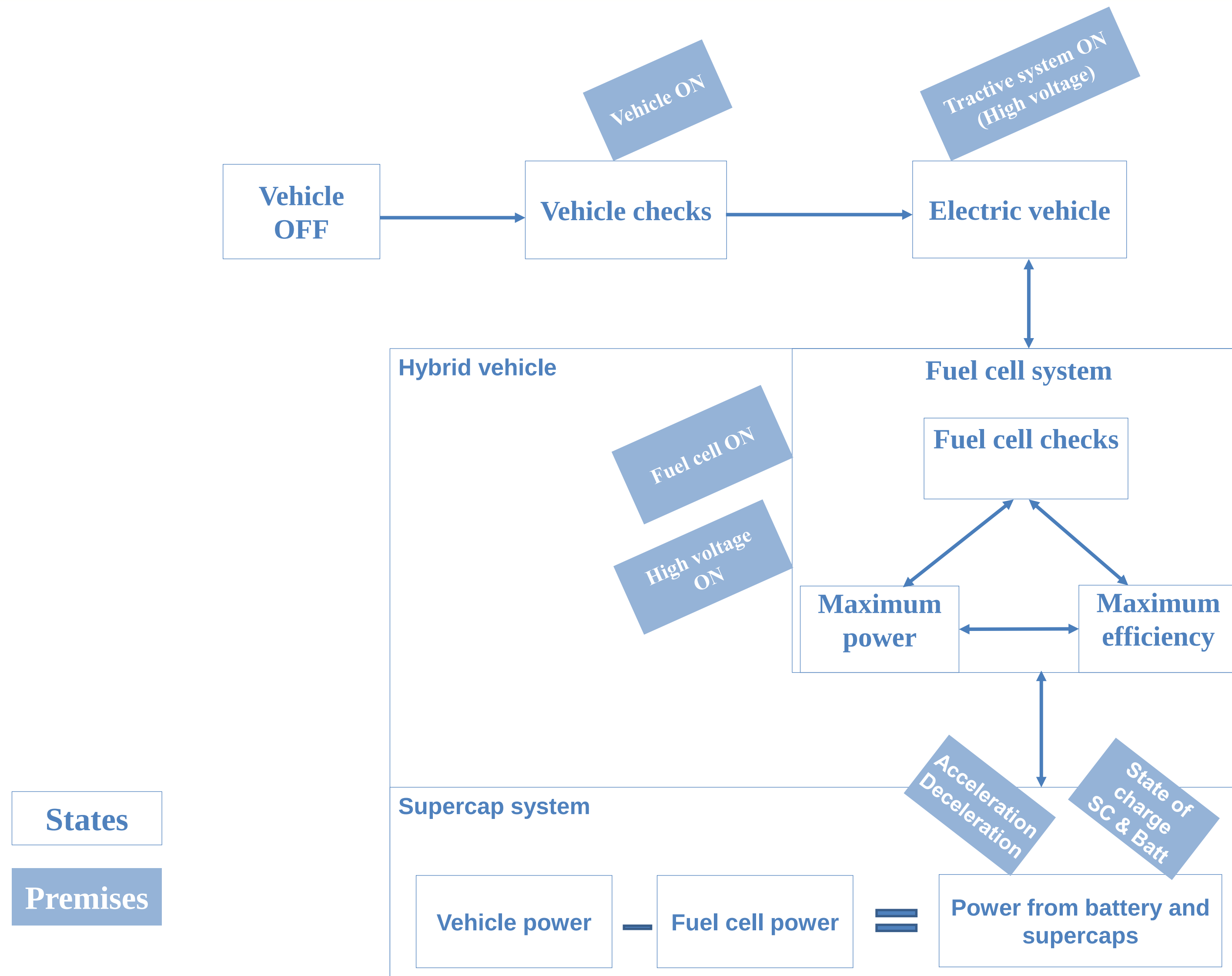


- Objectives
 - Increase the battery lifecycle
 - Recover/provide high power
- System characteristics
 - Maximum supercap power: 20kW
 - Control frequency: 100Hz
 - Supercaps capacity: 150Wh

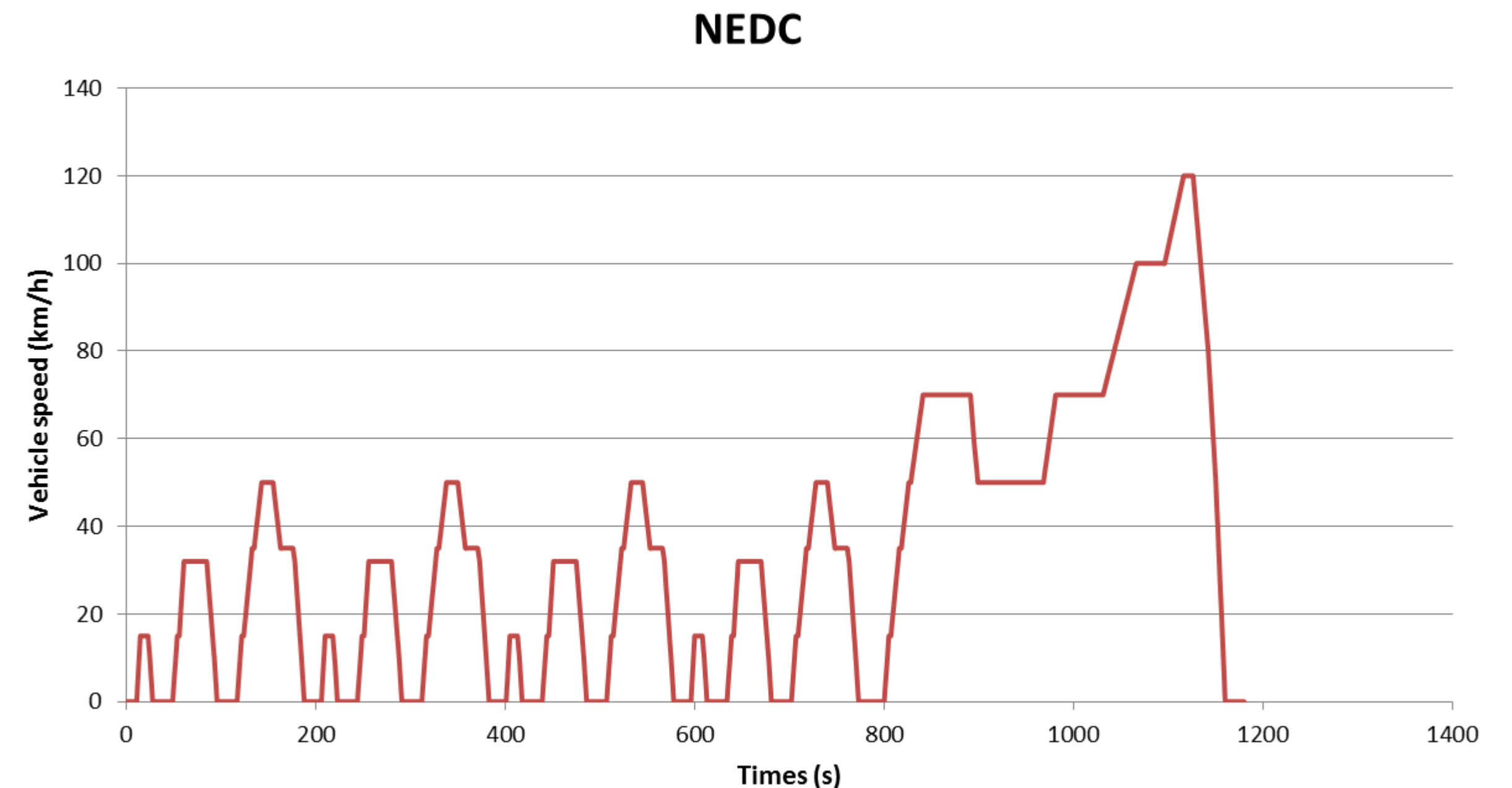
Dimensioning of supercap system
according needs of regenerative braking



- Control strategy

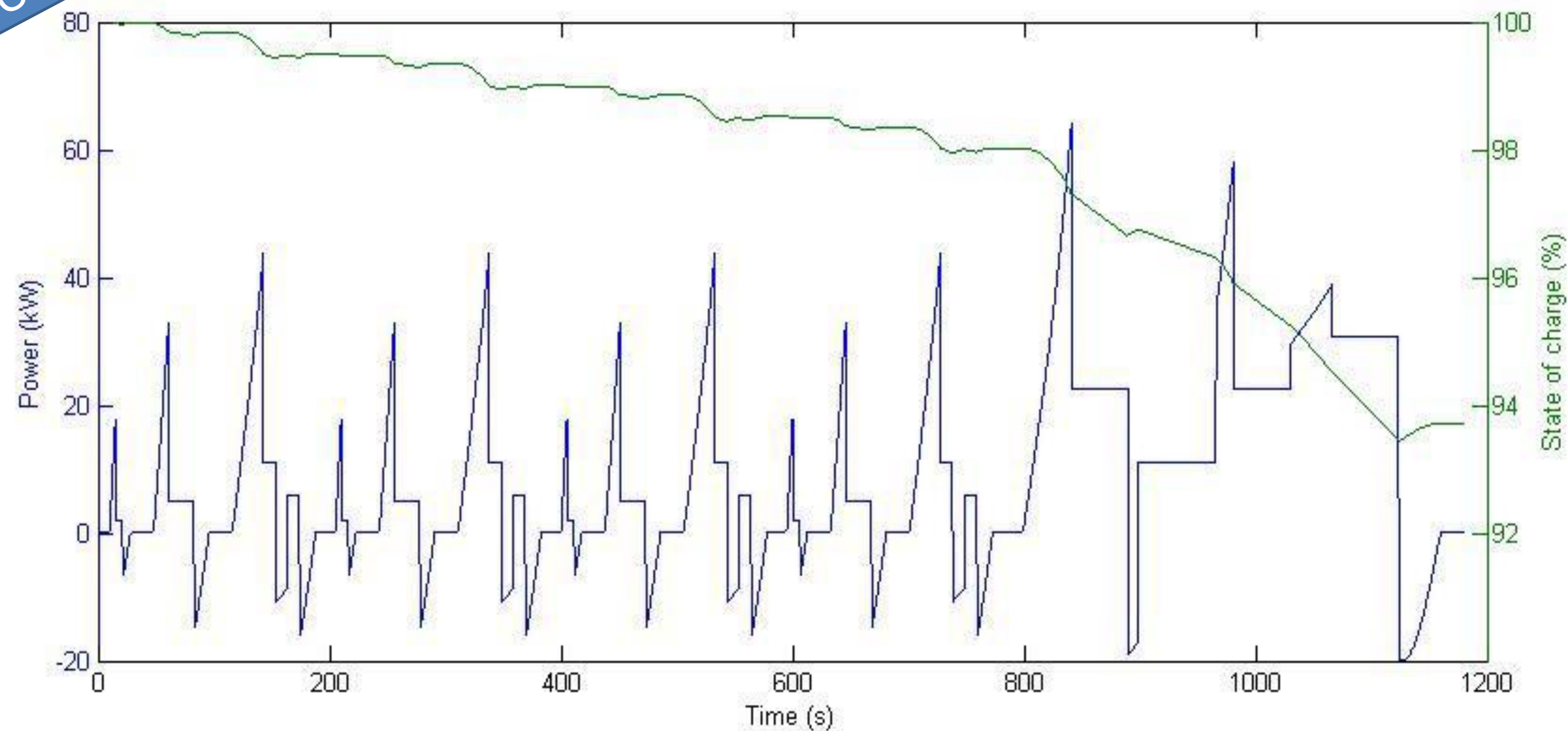


- Energy consumption basis
 - Result of the control strategies of different multi-storage systems.
 - Initial and final conditions taken into account.
 - Specific and /or restrictive premises of each storage system considered.
 - Three different configurations:
 - EV
 - HEV (Fuel cell)
 - HEV (Fuel cell + supercaps)
 - Configurations evaluated during NEDC



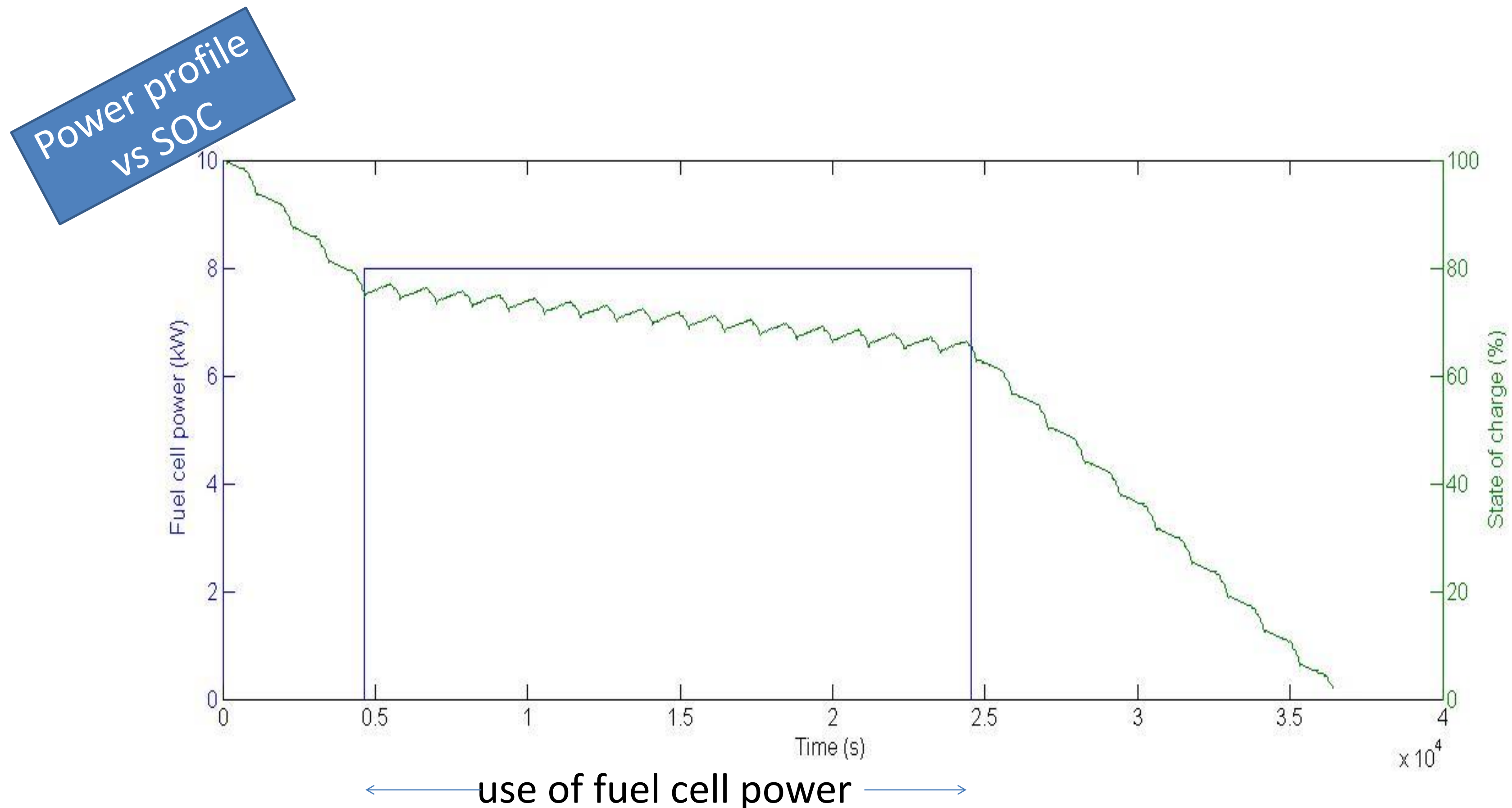
- Baseline vehicle (EV)

Power profile
vs SOC



- Starting point:
 - 100% of SOC
- Final point:
 - 1% of SOC
- Final results:
 - 297Wh/km
 - 157km

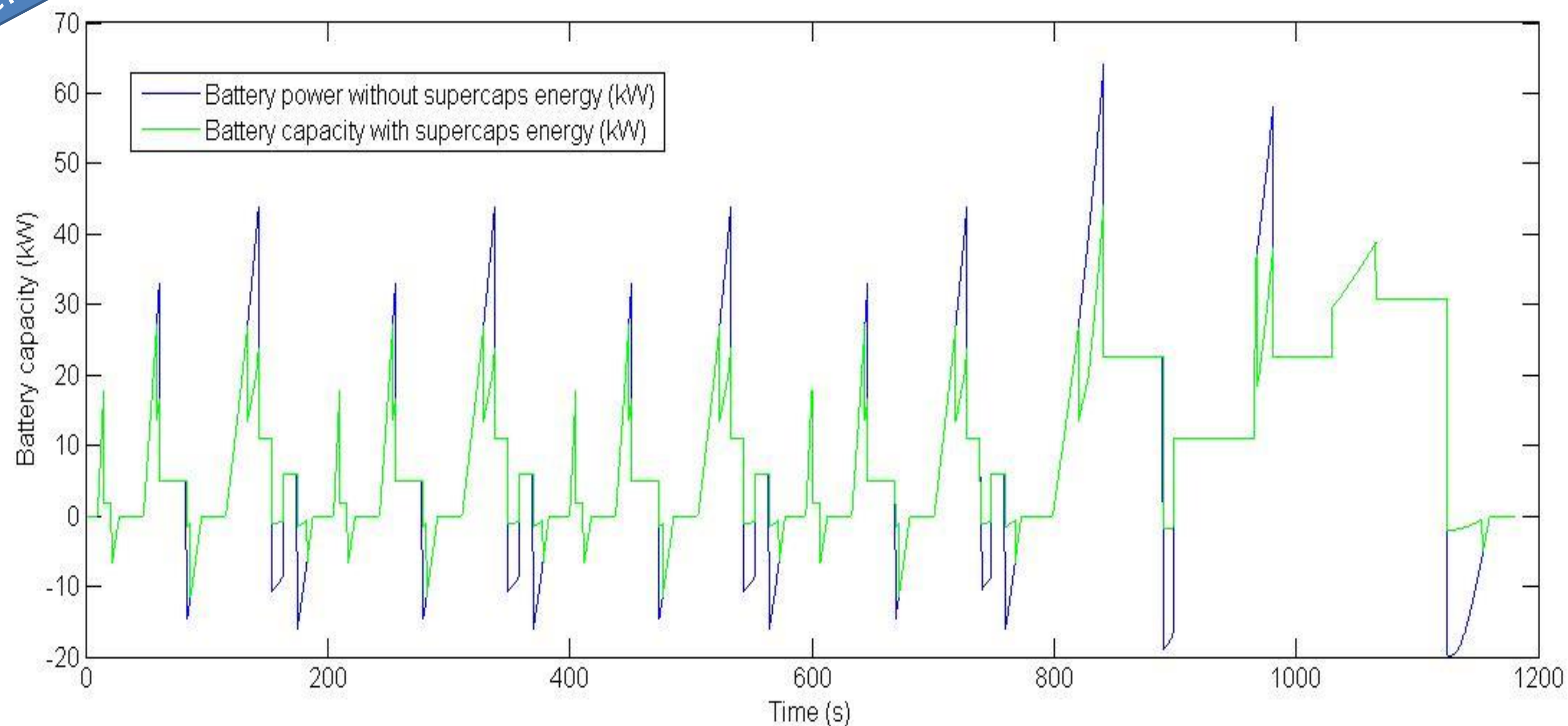
- Baseline vehicle with fuel cell system (FC-HEV)



- Starting point:
 - 100% of SOC
 - 100% of hydrogen tank capacity
- Final point:
 - 1% of SOC
 - 5% of hydrogen tank capacity
- Final results:
 - 151Wh/km (battery only)
 - 309km

- Baseline vehicle with fuel cell and supercap system (FC-HEV + supercaps)

Battery power
behaviour



- Starting point:
 - 100% of SOC
 - 100% of hydrogen tank capacity
 - 100% of supercaps capacity
- Final point:
 - 1% of SOC
 - 5% of hydrogen tank capacity
- Final results:
 - 151Wh/km (battery only)
 - 309km

- Simulation comparison

	EV	HEV (fuel cell system)	HEV (fuel cell system + supercaps)
Total range	157km	309km	309km
Battery energy consumption	297Wh/km	151Wh/km	151Wh/km
Maximum battery power	64kW	64kW	44kW
Minimum battery power	-19.8 kW	-19.8 kW	-11.5 kW
Energy throughput until battery empty	53.7 kWh	82.7 kWh	73.3 kWh
Battery cycles required for the vehicle lifetime	2931	2296	2035

- Successful demonstration of advantages of multi-energy sources
 - Fuel cell technology increases the vehicle range
 - Supercap technology prolongs the lifespan of high voltage battery
- Initial premises to double the initial range of the baseline vehicle: 157km
 - Target fulfilled , range successfully increased up to 309km with FC system
- Impacts of supercaps system
 - Prolongation of battery lifecycle by reducing the battery energy throughput
 - Absorbing the peaks of power to avoid battery over-heating
 - Target fulfilled: maximum and minimum battery powers were reduced to 44 kW and -11.5 kW
 - Energy throughput required to reach the vehicle lifetime reduced from 2931 (baseline vehicle) to 2035 cycles (fuel cell system + supercaps)

- Further studies
 - Review the basis of the project: starting from scratch instead of using a baseline vehicle
 - Possible scenario
 - Virtual vehicle developed from the beginning
 - Selection and definition of the 3 energy sources without restriction of an existing vehicles
 - Capacity
 - Power
 - Dimensions

MANY THANKS FOR YOUR ATTENTION