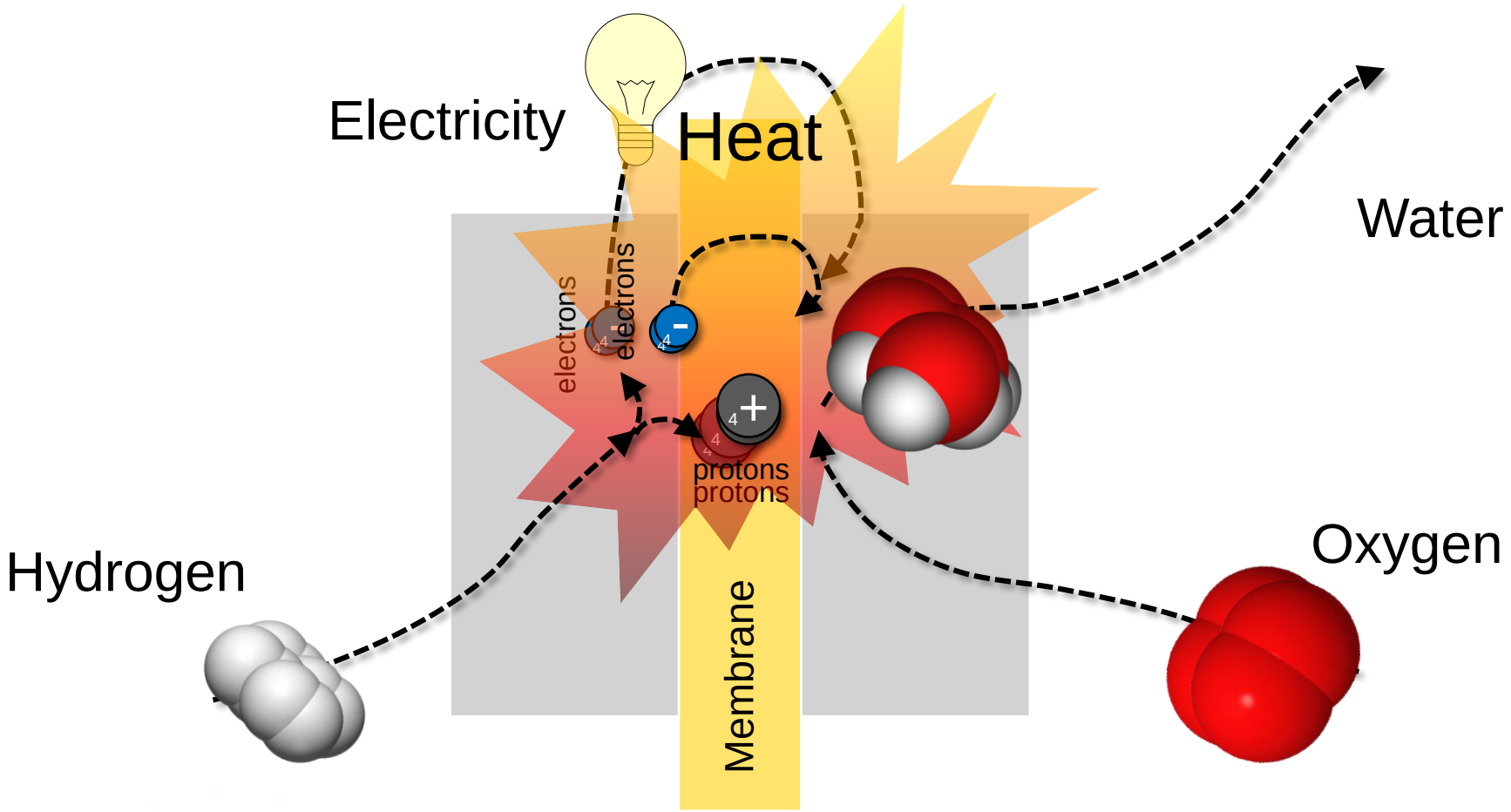
Fuel Cell System and their applications

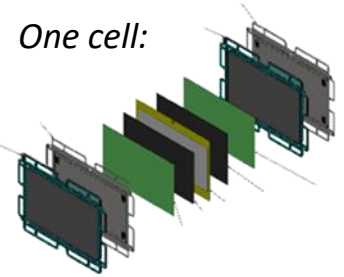
Fuel Cell System

- Fuel Cell stack (different types)
  - PEMFC [Proton Exchange Membrane Fuel Cell]
  - SOFC [Solid Oxide Fuel Cells]
  - MCFC [Molten Carbonate Fuel Cells]
  - PAFC [Phosporic Acid Fuel Cells]
  - AFC [Alkaline Fuel Cell] – The one of Apollo missions
  - Direct Methanol (typically PEM)
- Fuel Cell system BOP (Balance Of Plant)
  - Air (or oxigen) loop
  - Fuel (Hydrogen) loop
  - Coolant loop
  - Power Electronics
  - Control
  - Fuel reservoir (hydrogen cylinders)
  - Energy/Power Buffer (batteries or similar)

Fuel Cells ‘controlling the power of hydrogen’

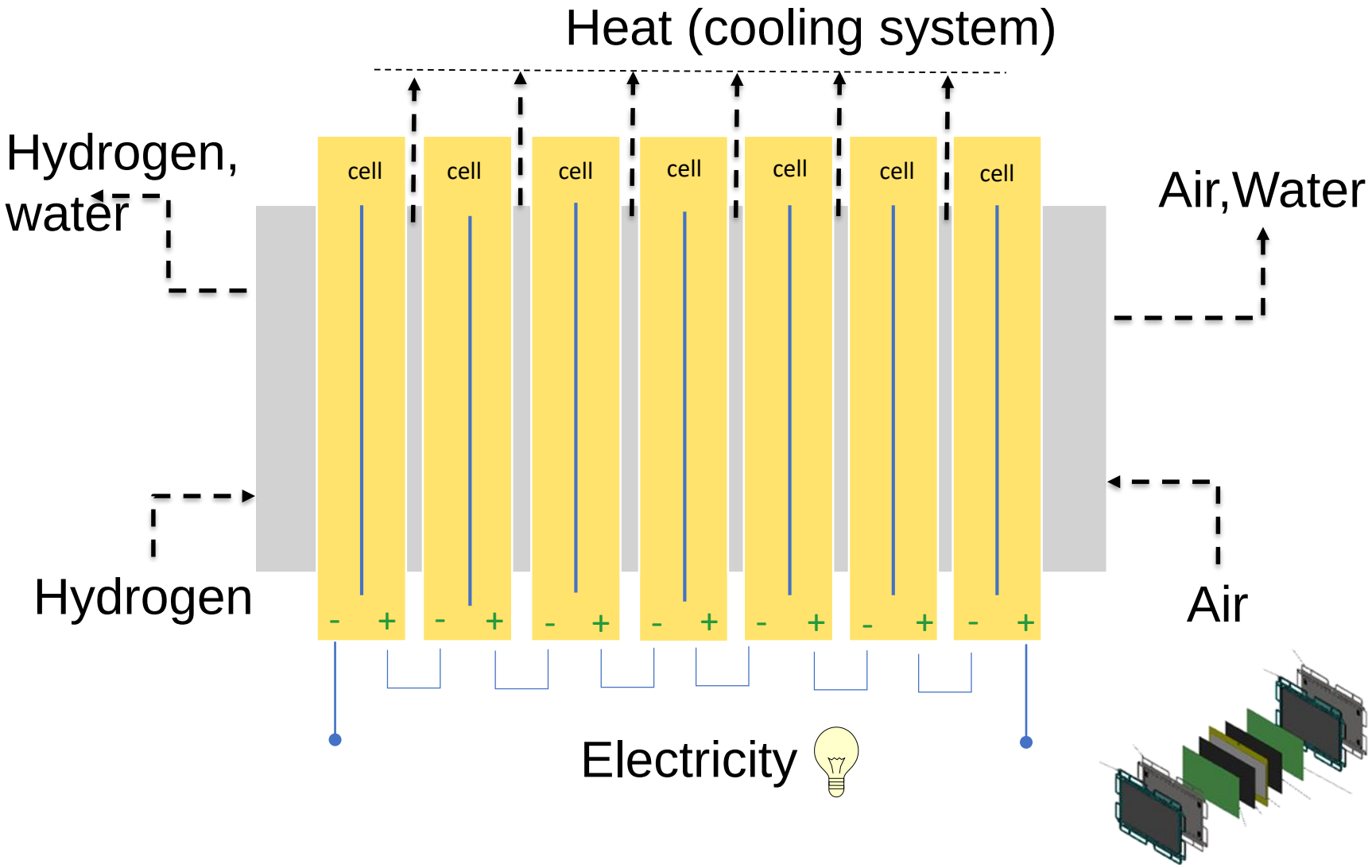


One cell:

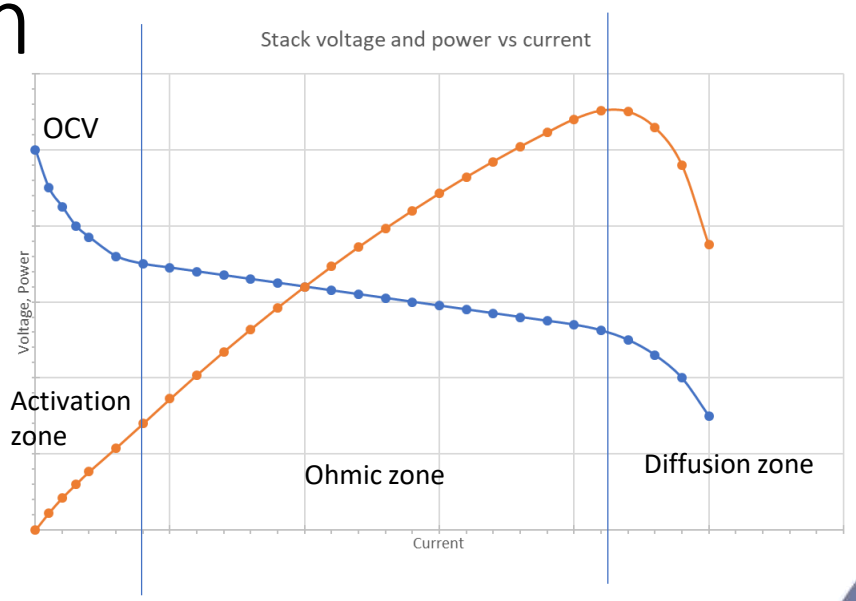


PEM fuel cell stack / system

- Membrane
- Electrode (Pt based catalyst)
- GDL (Gas diffusion Layer)
- Membrane must be humid
- Cell must not be flooded
- Supply hydrogen and oxygen(Air) in the right quantity, temperature, humidity and pressure and evacuate the excess
  - Air compressor, filter, intercooler, exhaust
  - Hydrogen loop
- Evacuate water produced by the reaction
  - Exhaust system
- Maintain temperaure control
  - Cooling system (radiators or similar)
- Maintain water balance (not dry, not flooded)
  - Control system
- Manage Power
  - Power Electronics, battery
- Manage safety
  - Safety features



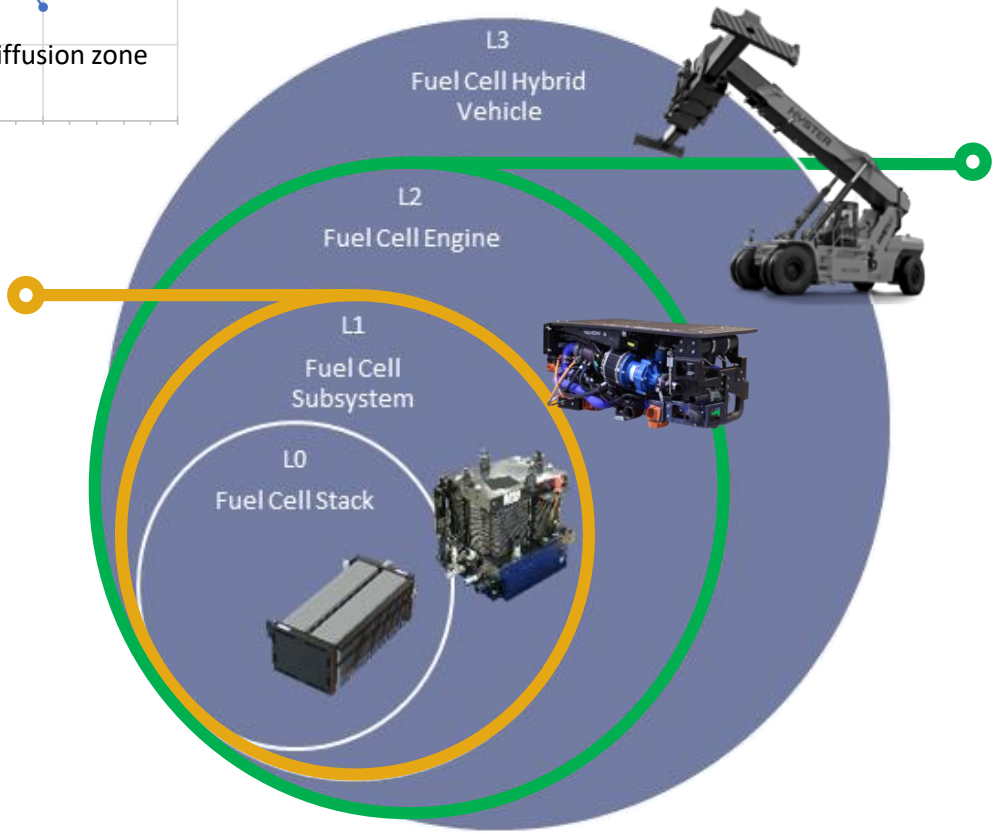
Fuel Cell system



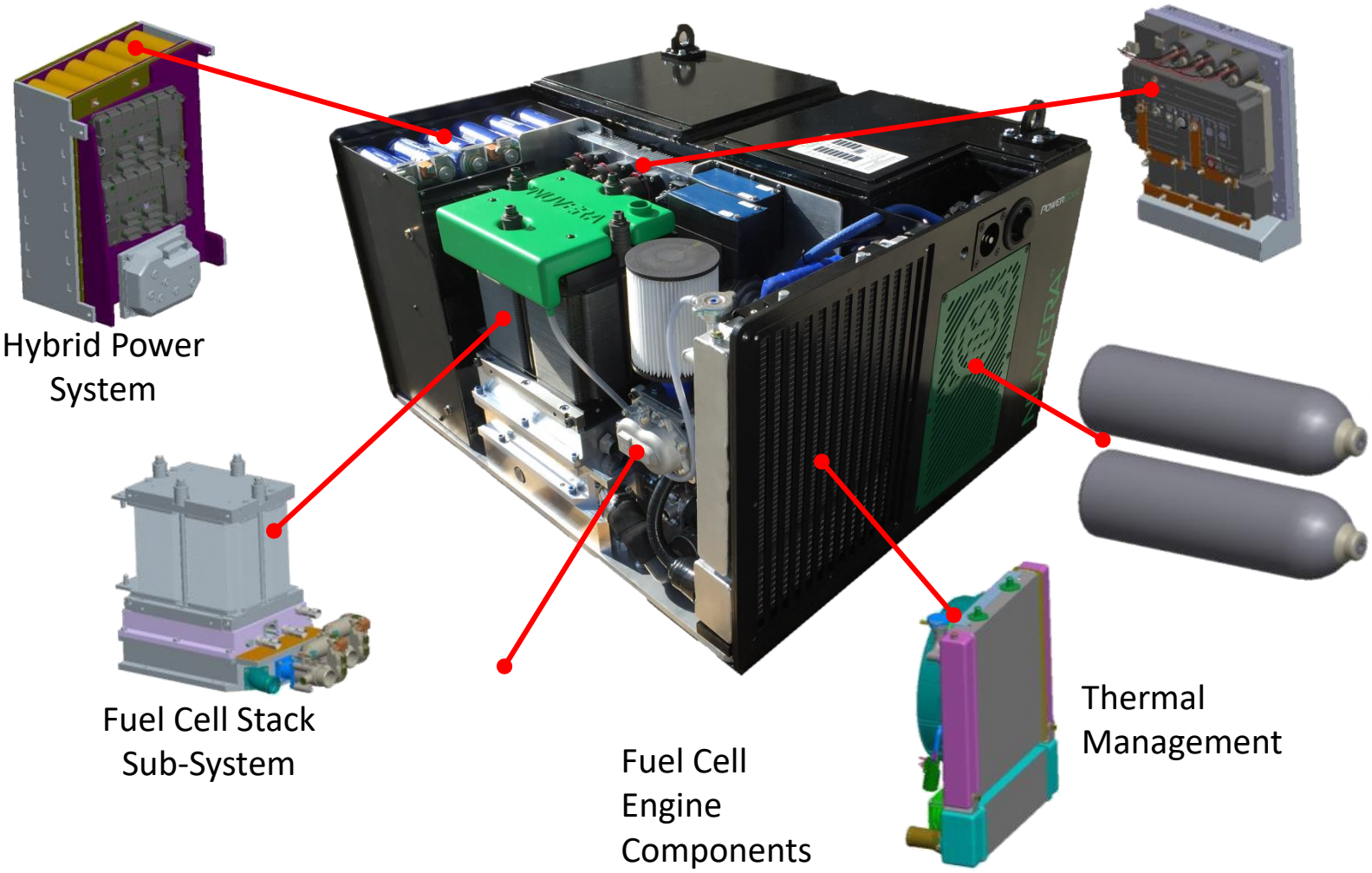
Stack efficiency = Cell voltage / 1.25

System eff < Stack eff

Because of parasitic losses (compressor, etc)



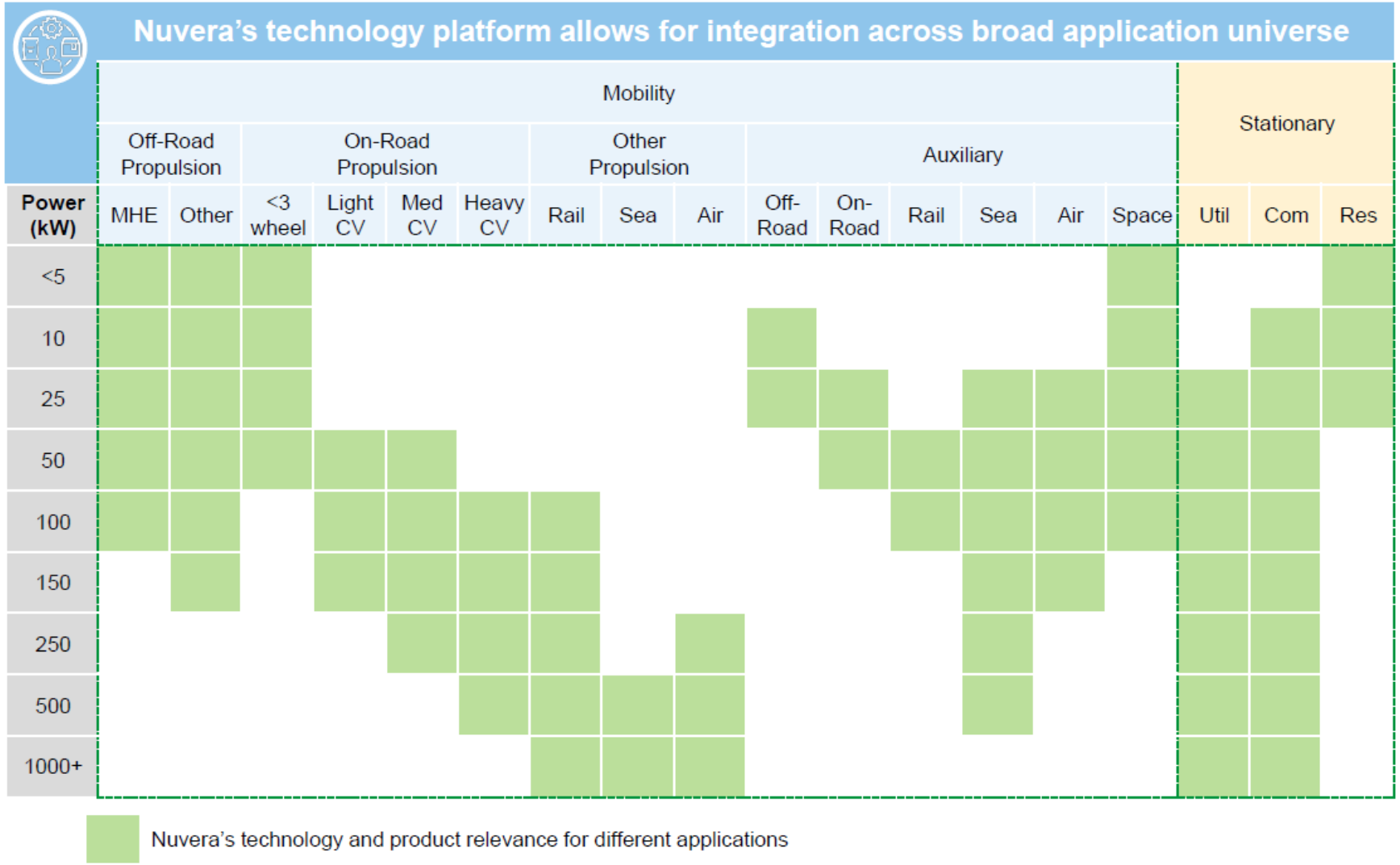
Fork-lift truck Application



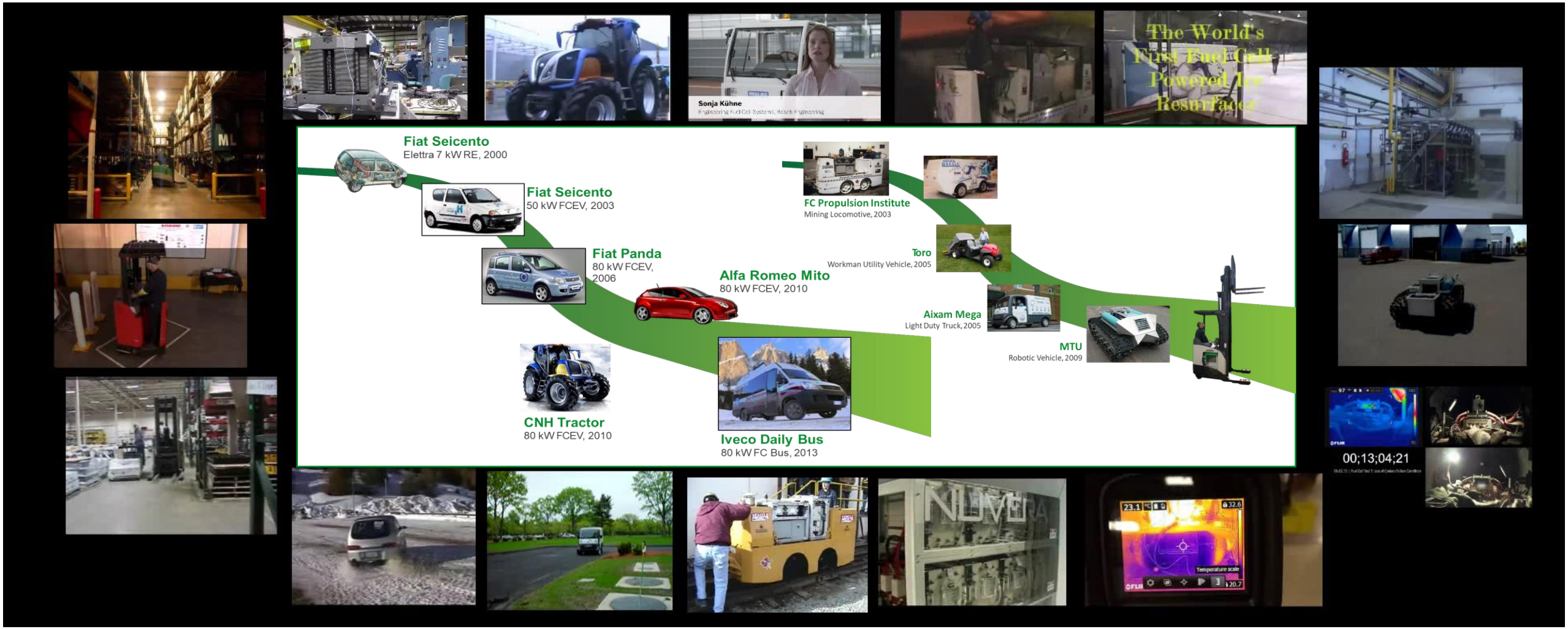
Power for a Full Range of Vehicles

If it moves, it needs a fuel cell engine.

3. Broadest potential application set



25+ Years of Mobility Experience



Supporting Volume Growth

Automated assembly and control equipment

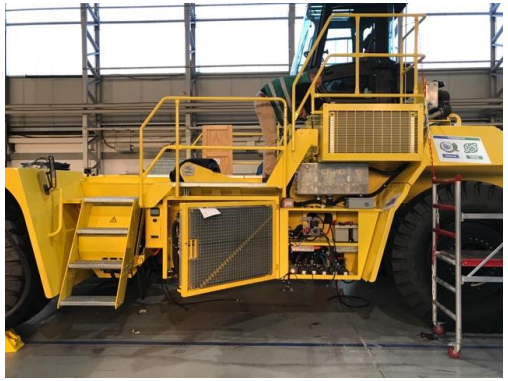
- ✓Low-cost / high-volume manufacturing capability
- ✓High quality assurance
- ✓Manufacturing processes developed at Nuvera HQ for duplication at other plants
- ✓Expandable production capacity build-up

Versatile Applications

Hyster® Top Loading Container Handler
Twin E-45 Fuel Cell Engine Configuration
90 kW Total Power

Flexible Configuration

Multiple fuel cell engines can be integrated into a single drivetrain or power system to deliver **higher power**



Certification Awarded

Nuvera fuel cell motive power solutions certified by Chinese national motor vehicle inspection center

SMVIC

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CNAS 中国认可 检测 TESTING CNAS L1466

检 验 报 告

燃料电池发动机性能

产品名称: 燃料电池发动机

产品型号: Nuvera E-60-HD-L3

受检单位: 纽威莱燃料电池（浙江）有限公司

检验类别: 强制性试验

国家机动车产品质量监督检验中心（上海）

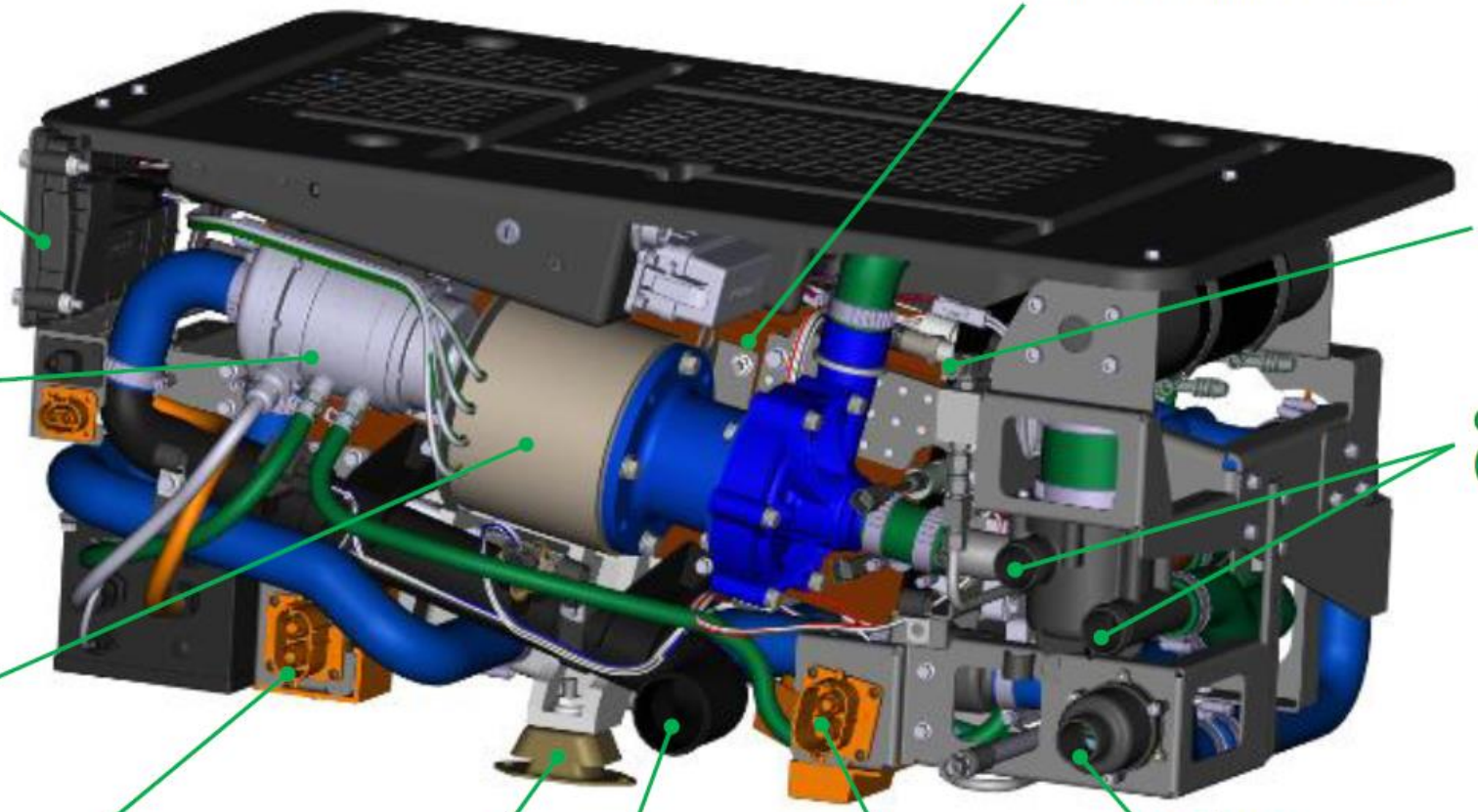
试验专用章 107

检验检测专用章

Customization to meet local market requirements

Access the SMVIC portal at miit.gov.cn for additional details

Fuel Cell Engine Layout



FC Stack
Compact Nuvera® Fuel Cell Stack provides **high efficiency**

Embedded Controller
Simplified vehicle integration and engine operation

Hydrogen Supply
Proprietary ejector circulates hydrogen without electricity and further boosts efficiency

Air Compressor
Fully integrated. No additional sourcing, packaging, or cost.

Coolant Connections (Radiator)

Coolant Pump
Fully integrated. No additional sourcing, packaging, or cost.

Power Out (+)

Vibration Isolation

Air Supply

Power Out (-)

Exhaust
Standardized inputs and outputs simplify interconnection to vehicle powertrain

Nuvera enabling customer success

Experienced and highly responsive global customer application engineering team

Customer Access and Product Influence

- ✓ Participates in customers' product design reviews and planning
- ✓ Provides customers access to decades of knowledge resulting in continued hydrogen and fuel cell innovation

Documentation and Training

- ✓ Tailor-made customer-facing integration documentation
- ✓ Customized training material and presentation
- ✓ Product manuals

Matching high-performance products with knowledge and expertise

- ✓ Highly-trained global support team
- ✓ Remote and on-site support
- ✓ Direct service and aftermarket support

Top Loader
Port of Los Angeles

Reach Stacker
Port of Valencia, Spain (forthcoming)

Passenger Bus
Chinese Cities

Some numbers

- Fuel Cell car
  - Typically 0,75-1 kgH_2 / 100 km
  - Hydrogen tanks 4-6 kgH_2
- Fuel Cell Bus
  - Typically 5-7 kgH2 / 100 km
  - Hydrogen tanks 20-30 kgH_2
- Fuel Cell counterbalance lift truck
  - Typically 1 kgH2 / shift
  - Hydrogen tank 1 kgH_2

- Hydrogen energy content 120 MJ/kg – (Gasoline 43 MJ/kg)
- A fuel cell system @50% electrical efficiency 1 kgH_2 -> 60 MJ (16,67 kWh) of electrical energy (in the same ballpark of a battery car)

Summary

- Anything that requires energy could use an hydrogen fuel cell
- Feasibility and advantageous are intended vs competing technologies on technical, economical and environmental point of view.
- At this stage of development we believe intense and heavy duty mobility applications are the most promising in a near near/medium term horizon
- Green hydrogen and fuel cell application can heavily contribute to the EU neutral carbon emission goal by 2050.