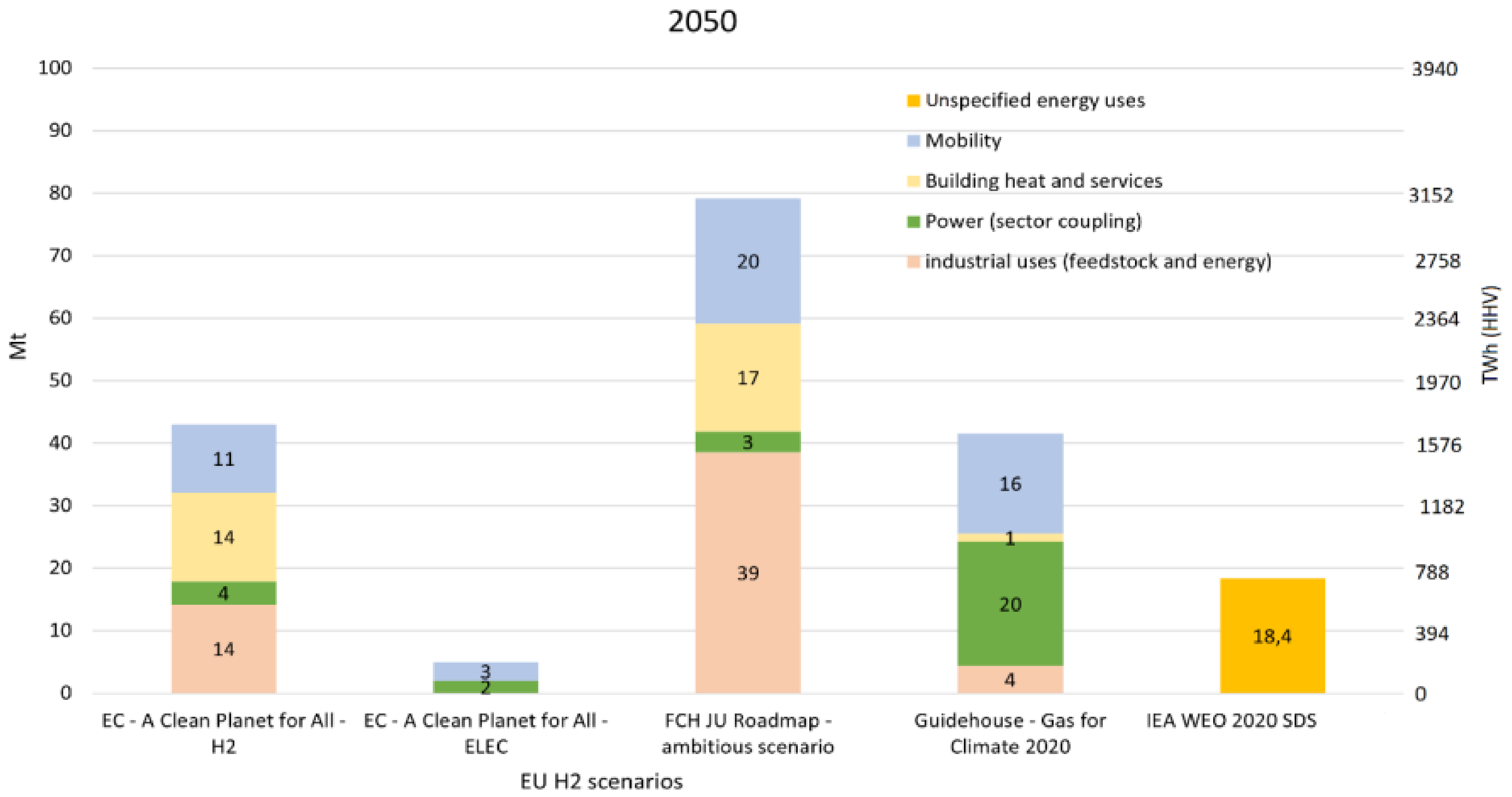




Future Potential Hydrogen usage



https://fsr.eui.eu/wp-content/uploads/2020/11/QM-04-20-535-EN-N.pdf

Empowering **Hydrogen Technologies** by means of Digitalization

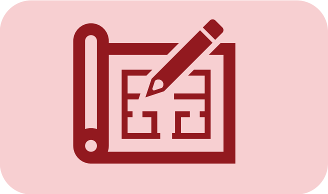
Reliance on Simulation

Reduced Development Time

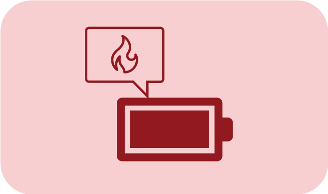
Virtual Testing

Intelligent Technologies

High Performance Computing



Early Design Performance discoveries



Managing Uncertainties

Virtualization of Complete Product Design and Validation

Renaulution | Digital Performance Contribution

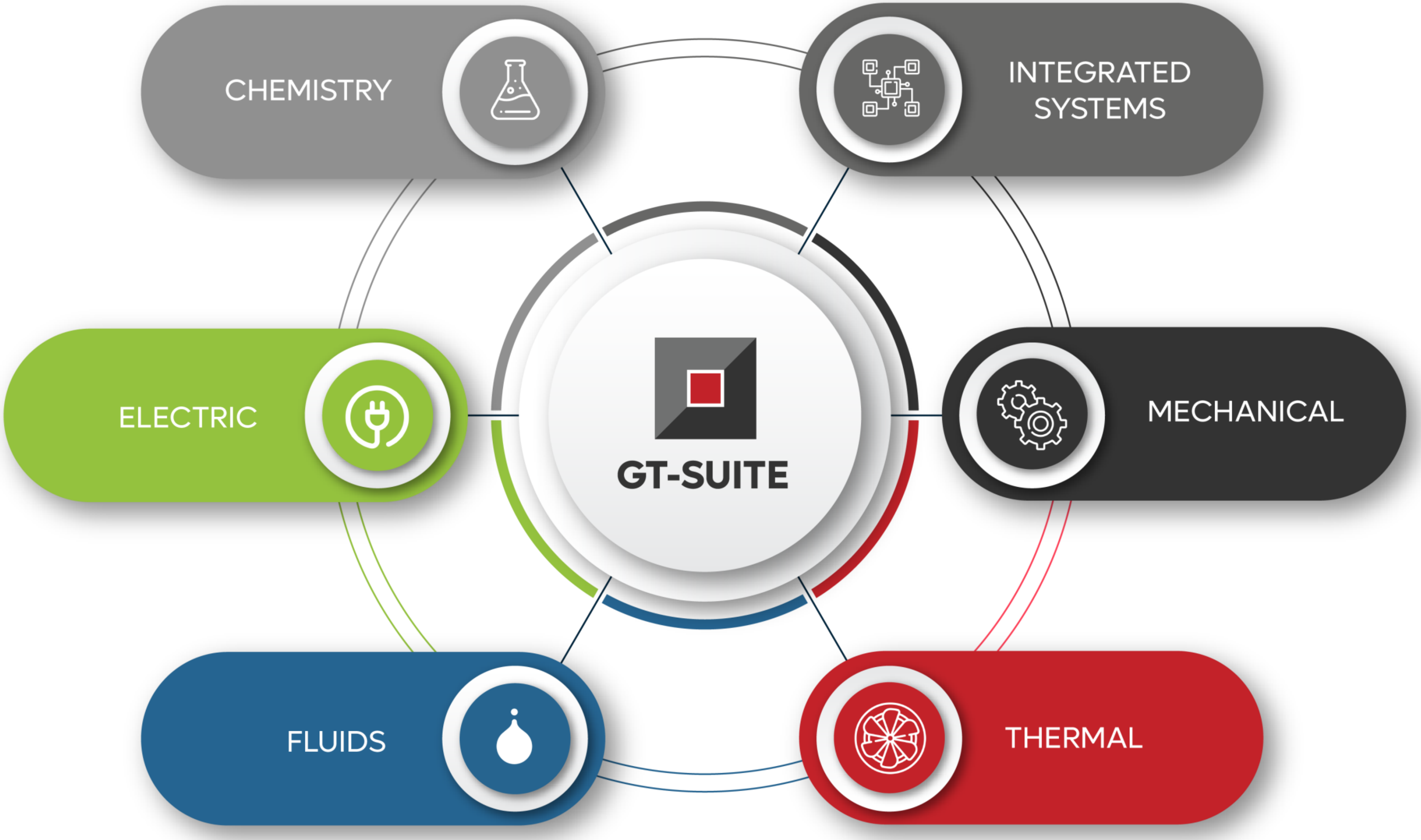
RG

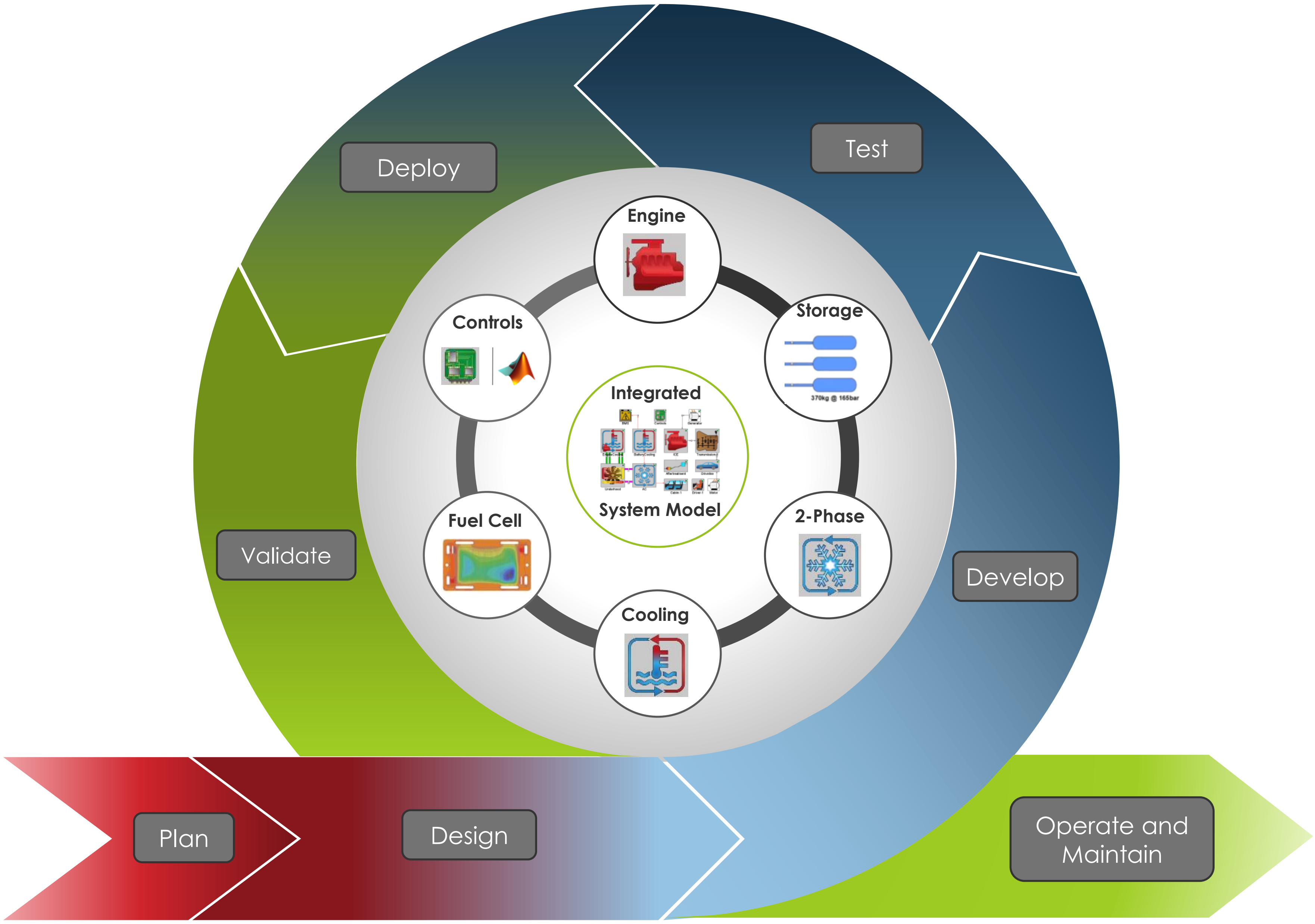
TARGETS

REDUCTION OF COSTS
- **- 1%/veh** COGS
- **- 50%** for physical validation Costs

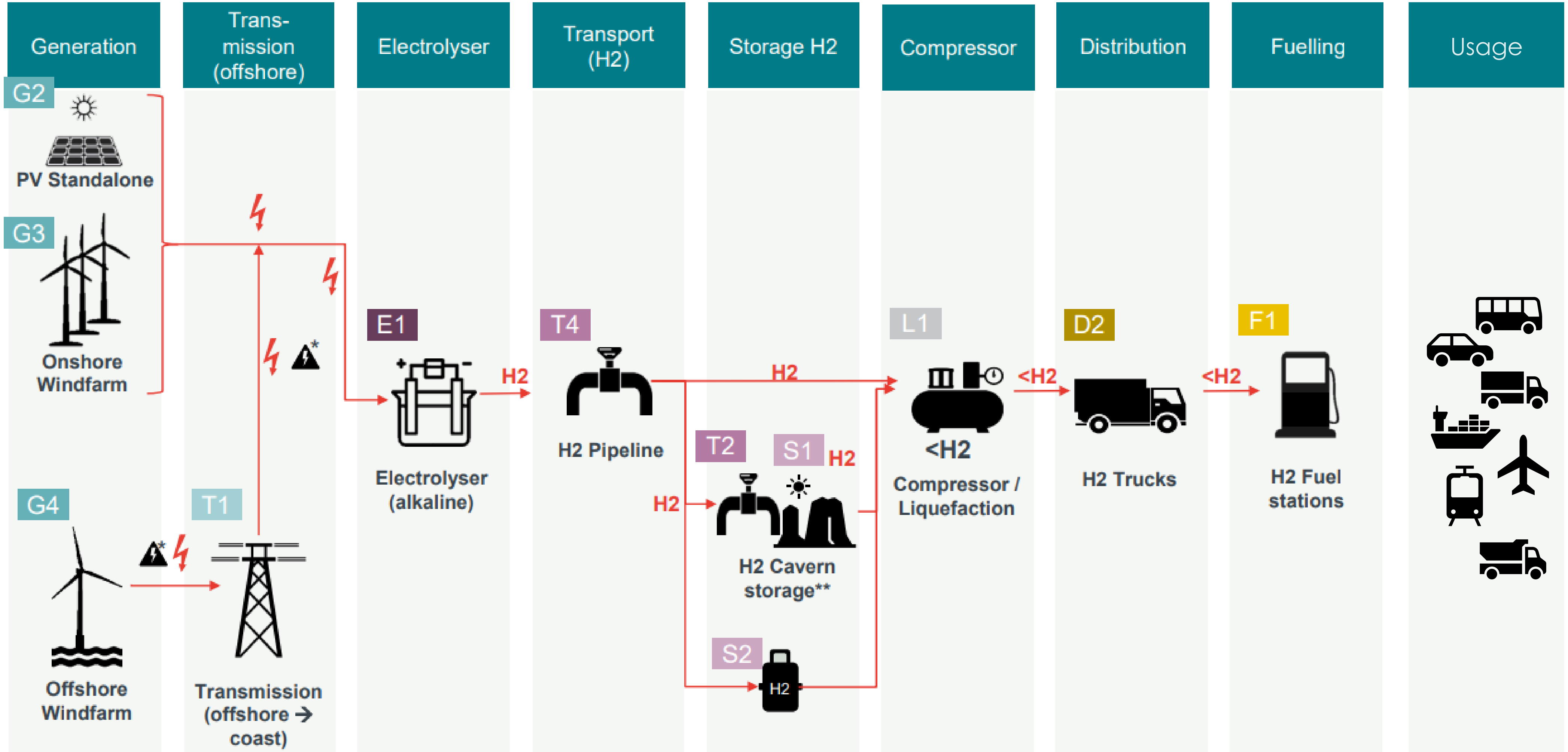
ROBUST VALIDATION OF SYSTEMS & SW
- **0** physical validation for SW
- K°/oo Quality **/ 3**

PROJECT LEAD TIME REDUCTION
- **- 1 year** (150w vs 210w)


CHEMISTRY
INTEGRATED SYSTEMS
ELECTRIC
GT-SUITE
MECHANICAL
FLUIDS
THERMAL


Deploy
Test
Engine
Controls
Storage
Integrated
System Model
Fuel Cell
2-Phase
Validate
Develop
Cooling
Plan
Design
Operate and
Maintain

Domestic Hydrogen Supply chain



https://www.fvv-net.de/fileadmin/Transfer/Downloads/Publikationen/FVV__Future_Fuels__StudyIV_The_Transformation_of_Mobility__H1269_2021-10__EN.pdf

Technology neutral: Bosch powertrain mix delivers affordable mobility with minimum emissions

Delivery traffic

Urban

Commuters

Extra-urban

Fuel cell

Electric heavy trucks for deliveries to cities

Fuel cells are expected to feature in as many as **20 %** of new electric vehicles by 2030

Battery

Electric cars are at home in the city

At least **20 %** of all new vehicles will be exclusively battery-electric by 2030

+6 % greater range per battery charge thanks to Bosch SiC[1] semiconductors

Hybrid

Efficient over long and short distances

-15 % less consumption with Bosch 48-volt system

By 2030, at least **31 %** of all new vehicles will feature a hybrid powertrain

Combustion engine

More economical and more ecological for frequent long hauls

At least **67 %** of all new vehicles in 2030 will still run on diesel or gasoline, with or without hybrid

Diesel's CO_2 footprint is **15 %** better than gasoline's

New diesel engines have practically stopped emitting nitrogen oxide

Renewable synthetic fuels

Important part of future mobility mix

Roughly **50 %** of the vehicles that will be around in 2030 have already been sold – most of them have a gasoline or diesel engine

-100 % CO_2 Renewable synthetic fuels are a carbon-neutral option for combustion engines

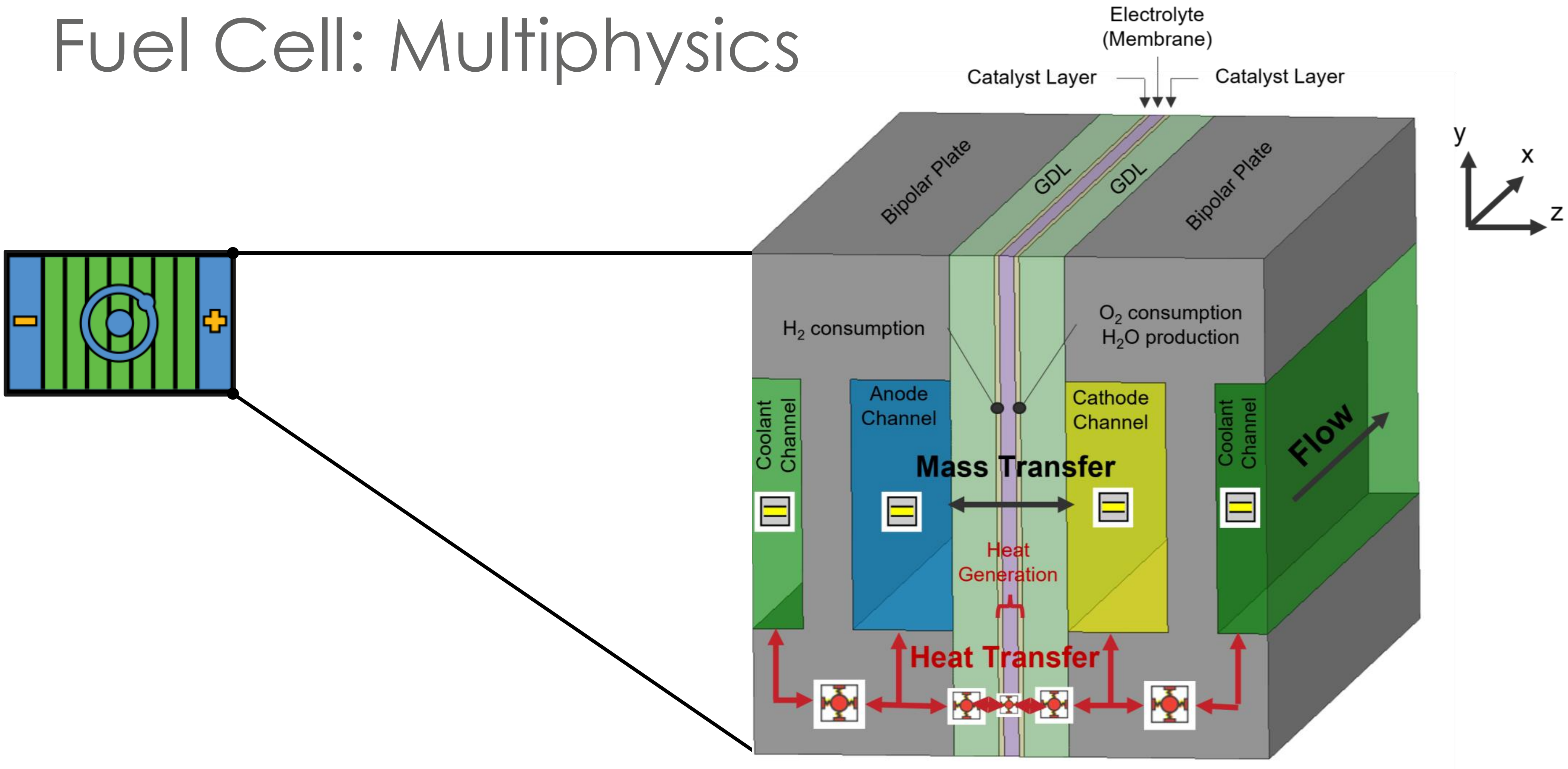
1 Silicon carbide

BOSCH

Fuel Cell Stack and BoP

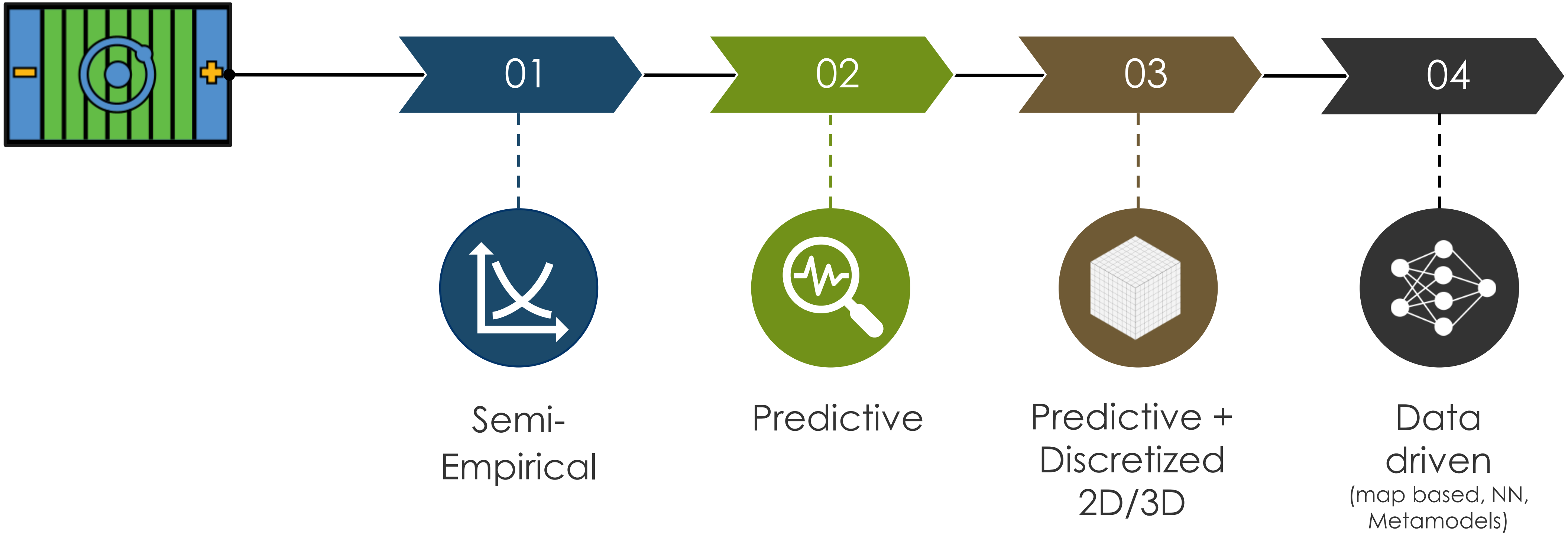
GAMMA TECHNOLOGIES

Fuel Cell: Multiphysics

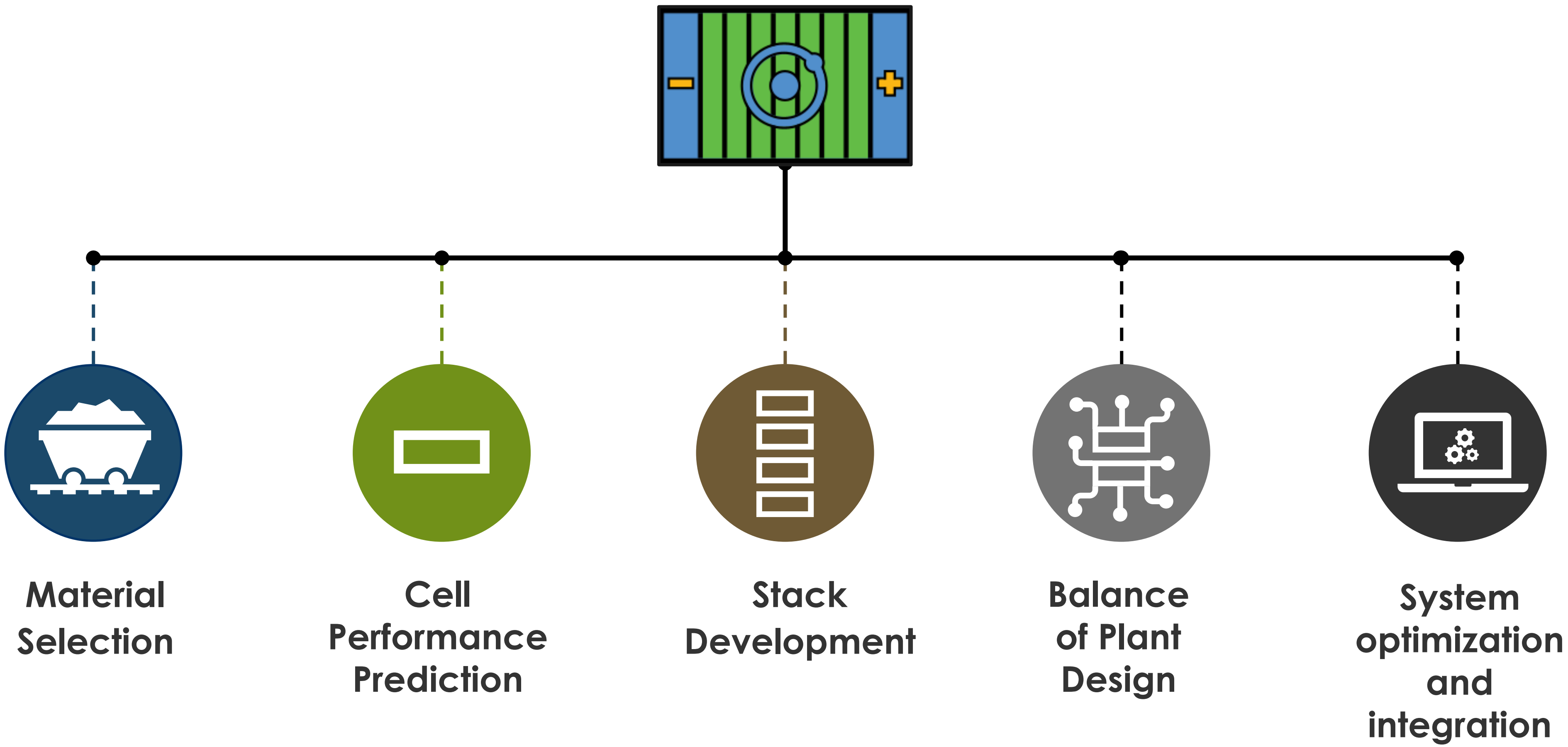


Unit segment within cell

Fuel Cell: Multi Scale



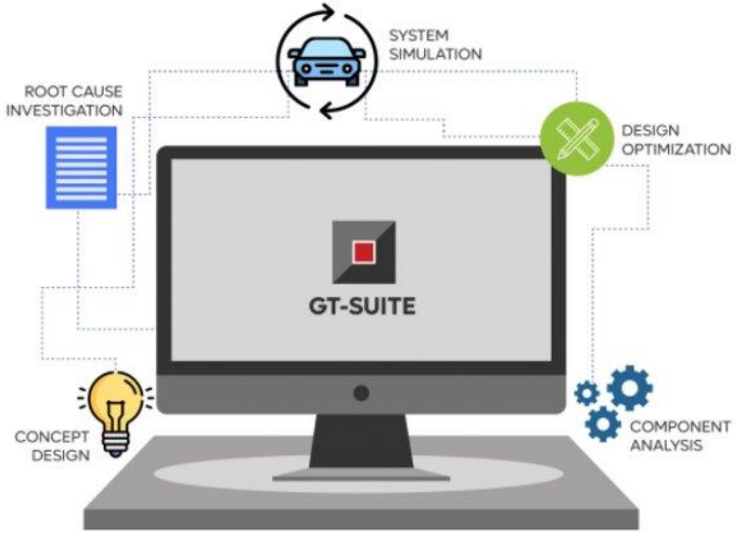
Fuel Cell: Multi Discipline



What ? How ?

Inputs

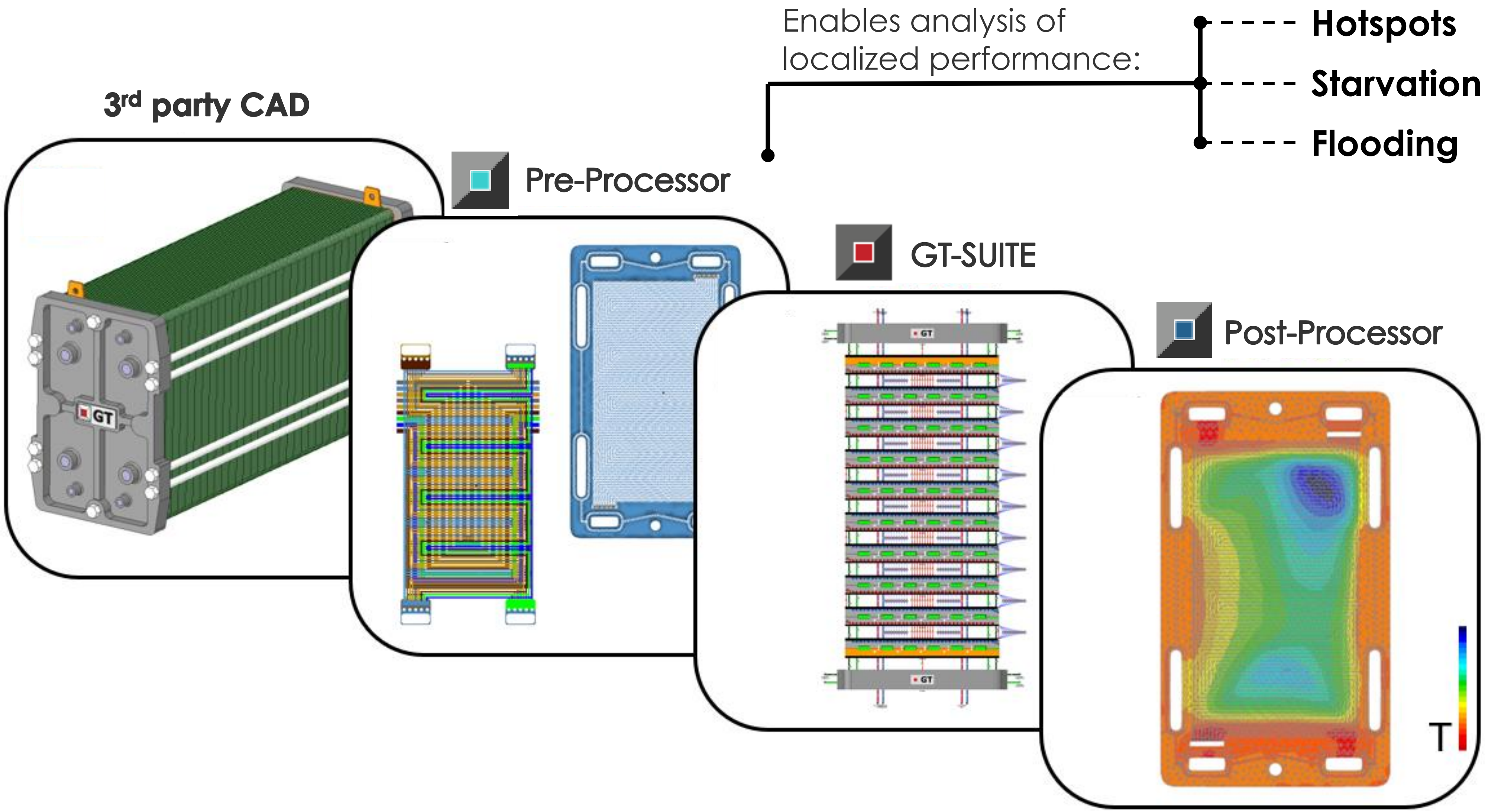
Requirements:
- Range, MPGe
- Towing Capacity
- Cost
- Performance

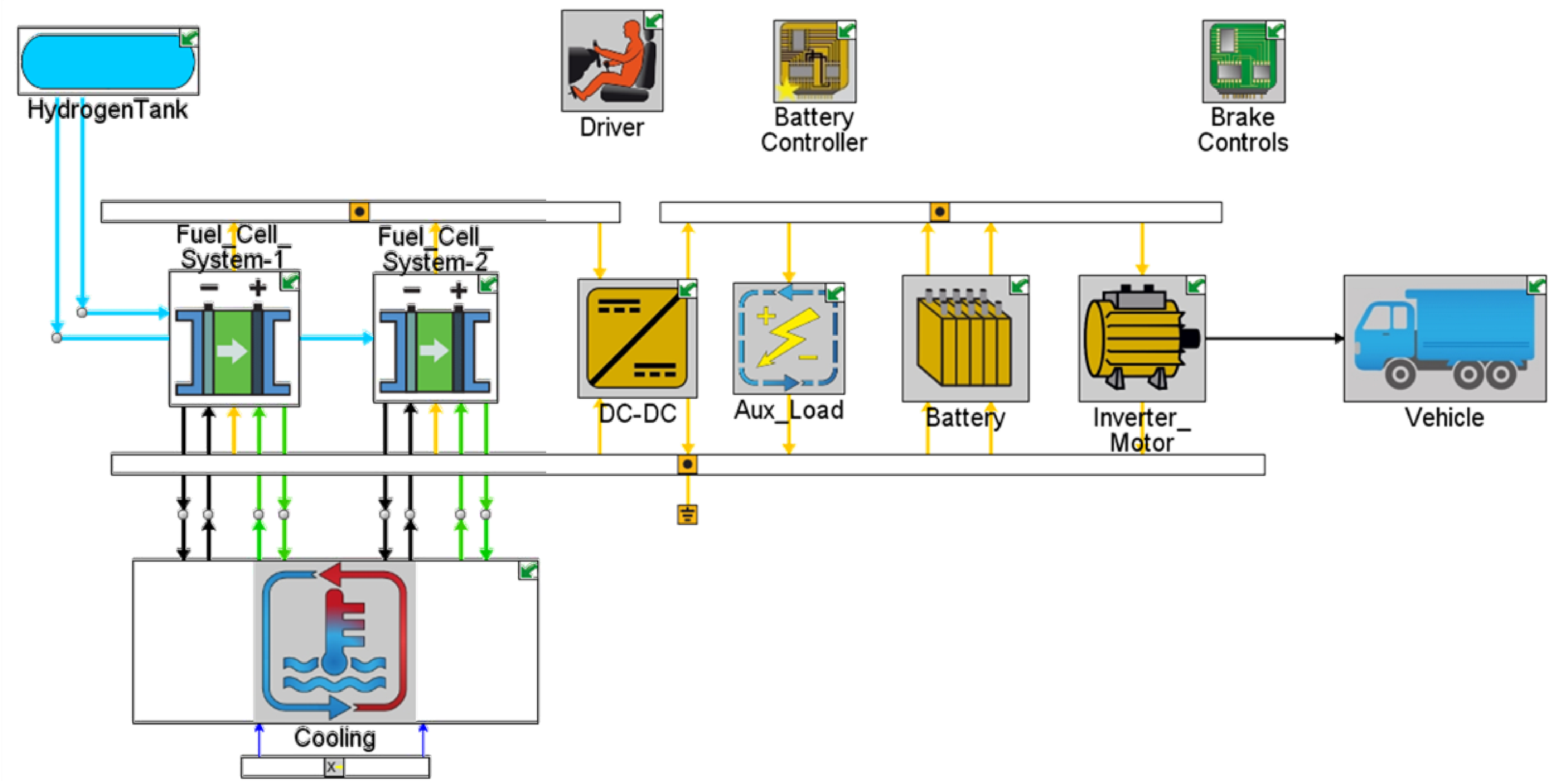


Outputs

Optimal Architectures
Req. For Subsystems

Fuel Cell: 3D-1D synergy




HydrogenTank
Driver
Battery Controller
Brake Controls
Fuel_Cell_System-1
Fuel_Cell_System-2
DC-DC
Aux_Load
Battery
Inverter_Motor
Vehicle
Cooling

SYMBIO
A FAURECIA MICHELIN HYDROGEN COMPANY

Hydrogen recirculation system optimization for PEMFC

SYMBIO - Emilien Sopetti

GTTC 2022

1/ Context

Area of study: focus on anode loop

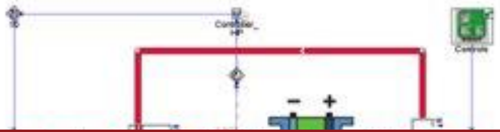
1) Recirculation is needed to raise the anode stoichiometric ratio & ensure water management.

2) Ejector (venturi):
   - ✅ Compact, passive.
   - ⚠ Sizing adapted to stack power range.

3) Purge
   → Necessity to purge N2 and H2O.

2/ Recirculation loop system modeling

System presentation: model features



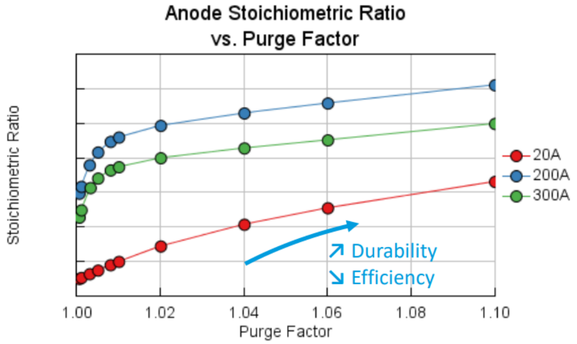
Key features:

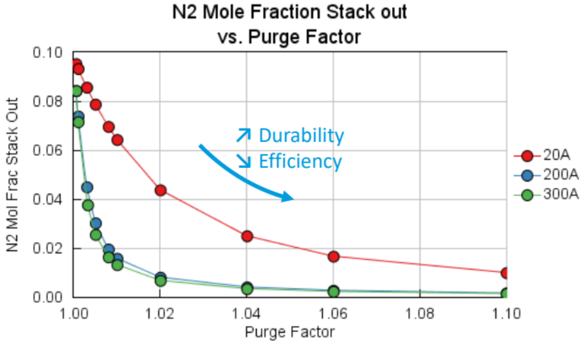
- Multispecies: H_2O and N_2 crossover prediction, impact on recirculation performance.

3/ Architecture exploration

Purge factor = overconsumption factor due to H2 loss at the purge

Purge calibration (1/2): sensitivity study





The purge strategy is a trade-off:

→ High purge factor to limit N2 concentration / raise the stoichiometry.

→ Low purge to avoid rejecting H2 and to lower the consumption.

H2 Combustion

GAMMA TECHNOLOGIES

H2 Combustion

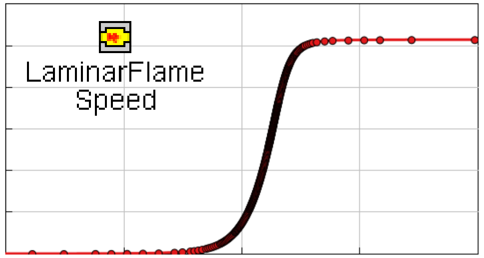
Model Flame Properly for unconventional Fuel

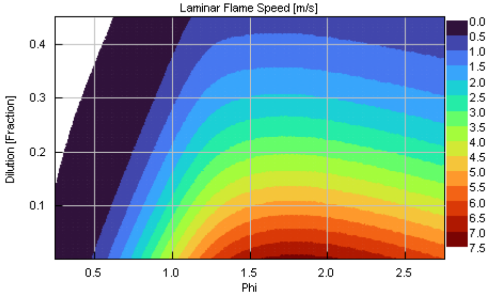
Laminar Flame Speed & Knock model

High accuracy at lean conditions

Predictive H2 Combustion

- **Spark-Ignited Engines**
- **Dual Fuel Engines**
- **Pre-Chamber Engines**





PUNCH | Torino

CALIBRATION OPTIMIZATION OF A DUAL FUEL (DIESEL + HYDROGEN) ENGINE USING GT-SUITE

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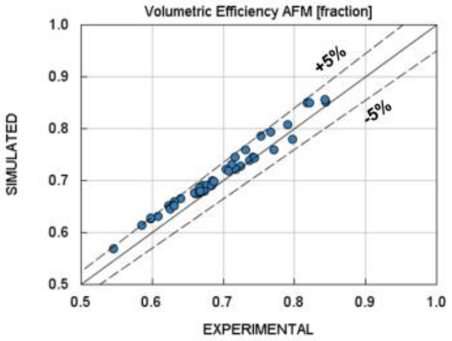
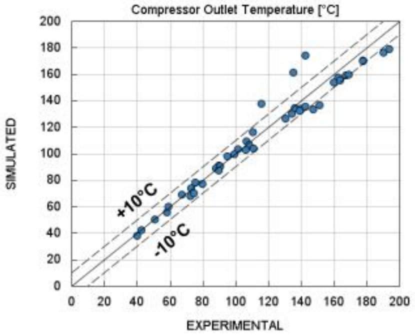
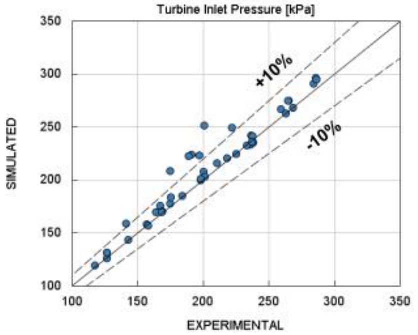
ENGINE MODEL TUNING

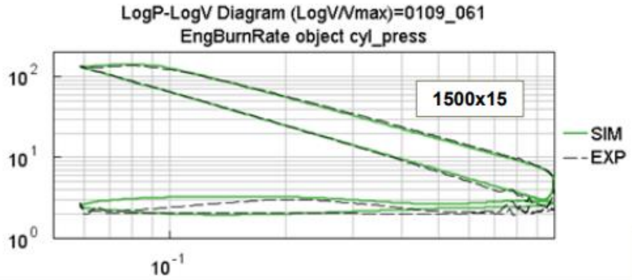
MODEL CORRELATION

Below some plots showing the GT-POWER model accuracy before the tuning of predictive combustion model (TPA analysis):



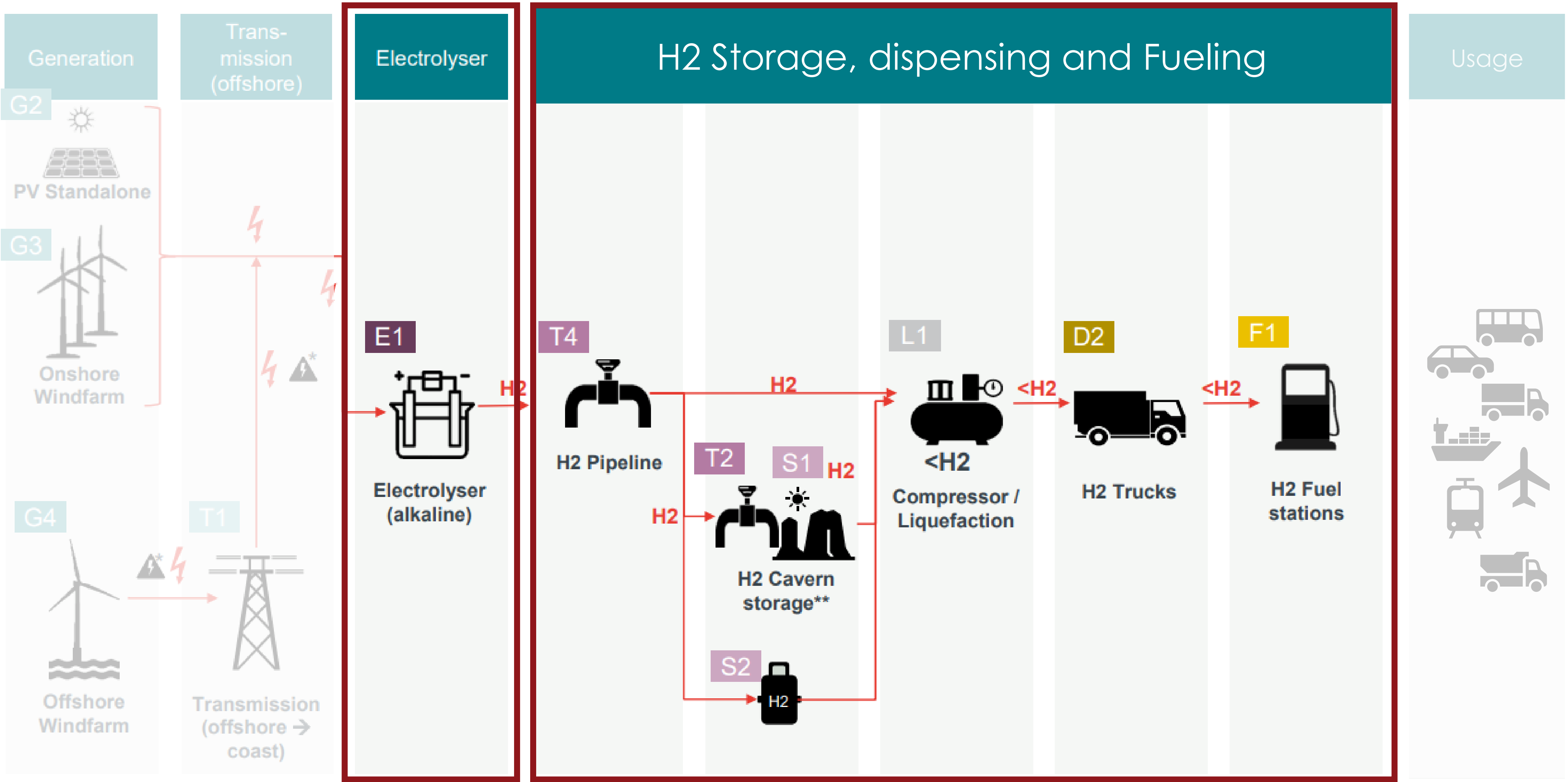






All those plots highlight proper modeling assumptions for valve profiles & timing, hardware geometries, turbocharger maps, heat exchanges and pressure losses models.

Domestic Hydrogen Supply chain



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H2 Supply Chain

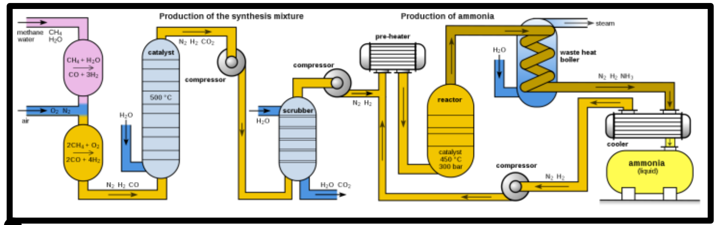
Electrolyzer and reformers

Electrolyzer

Flow, thermal and electrochemical domain combined

Empirical electrochemistry and Predictive H&O crossover

Polarization curve fitting



Reformers

CH_4 — Conversion of Methane to H_2

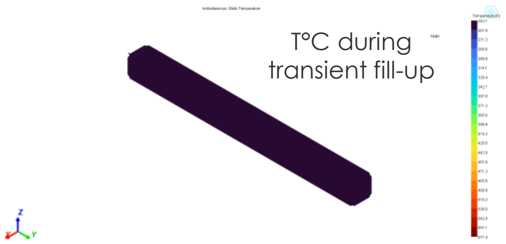
CH_3OH — Conversion of Methanol to H_2

NH_3 — Conversion of Ammonia to H_2

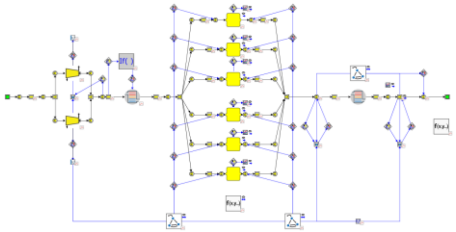
GT

H2 Storage and Fuelling

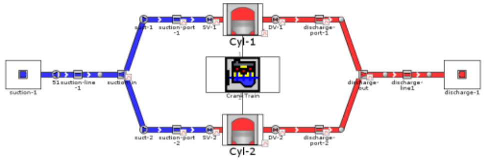
Tank Modeling



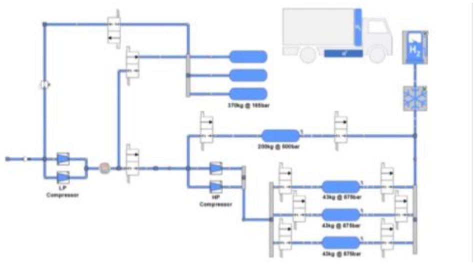
Hydrogen Filling Station



Hydrogen Compressors



Hydrogen Integrated Fueling Systems



PowerCell Group

Integration of Fuel Cells and Electrolysers in Powergrid Applications

Customer Case:

2.5 GWp Solar plant in southeast Europe; calculated total energy output: 1500 hours, 2.5 MW = 3.75 GWh / year

- Total electricity upload: 2 MW @1500 hrs / year → ~4 hrs/day
- Max. continuous Power Supply: 2 MW for max. 8 hrs / day

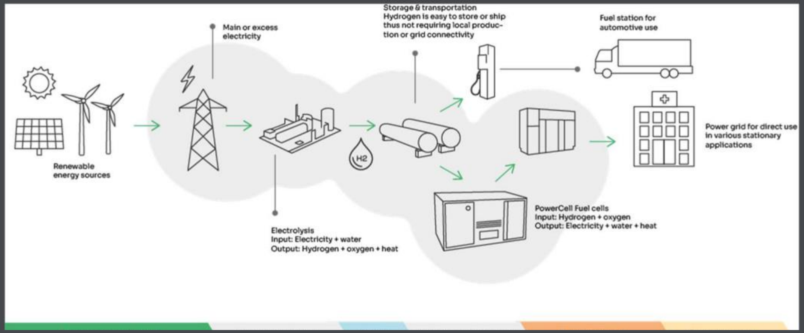
→ Fuel Cell Capacity?

→ Electrolyser Capacity?

→ Storage Capacity?

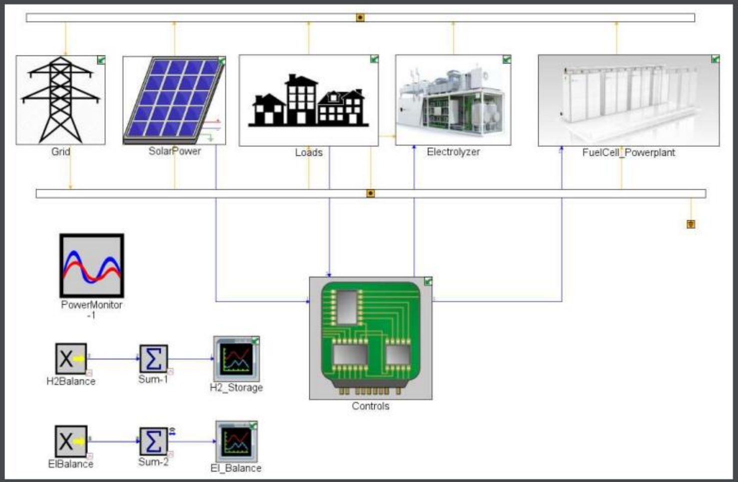
→ Feasibility?

Powergrid Integration



Use Cases:

- Power Supply Regulation (up & down)
- Grid Stabilization
- Peak Shaving
- Off-Grid Applications (stationary & mobile)
- Backup Power



Summary

→ The Powergrid model helps us and our customers to understand the situation

→ Analysis of different potential scenarios

→ Biasing expectations and possibilities

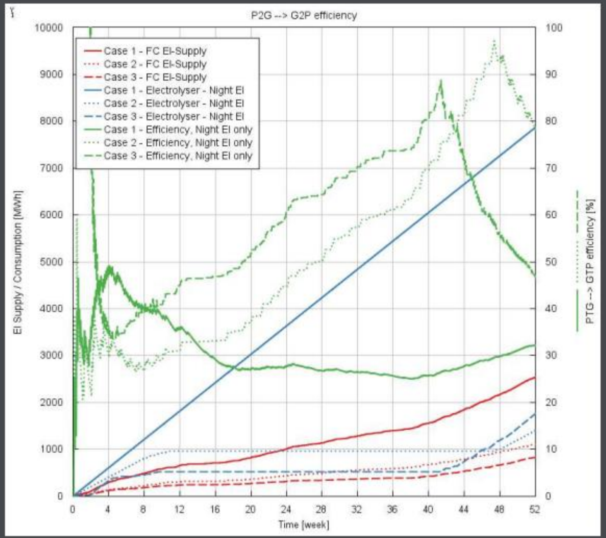
Learnings:

→ Onsite hydrogen storage is challenging

→ There is no standard use case – solutions need to be adapted to customer and market prerequisites

→ There is no easy way to evaluate the results

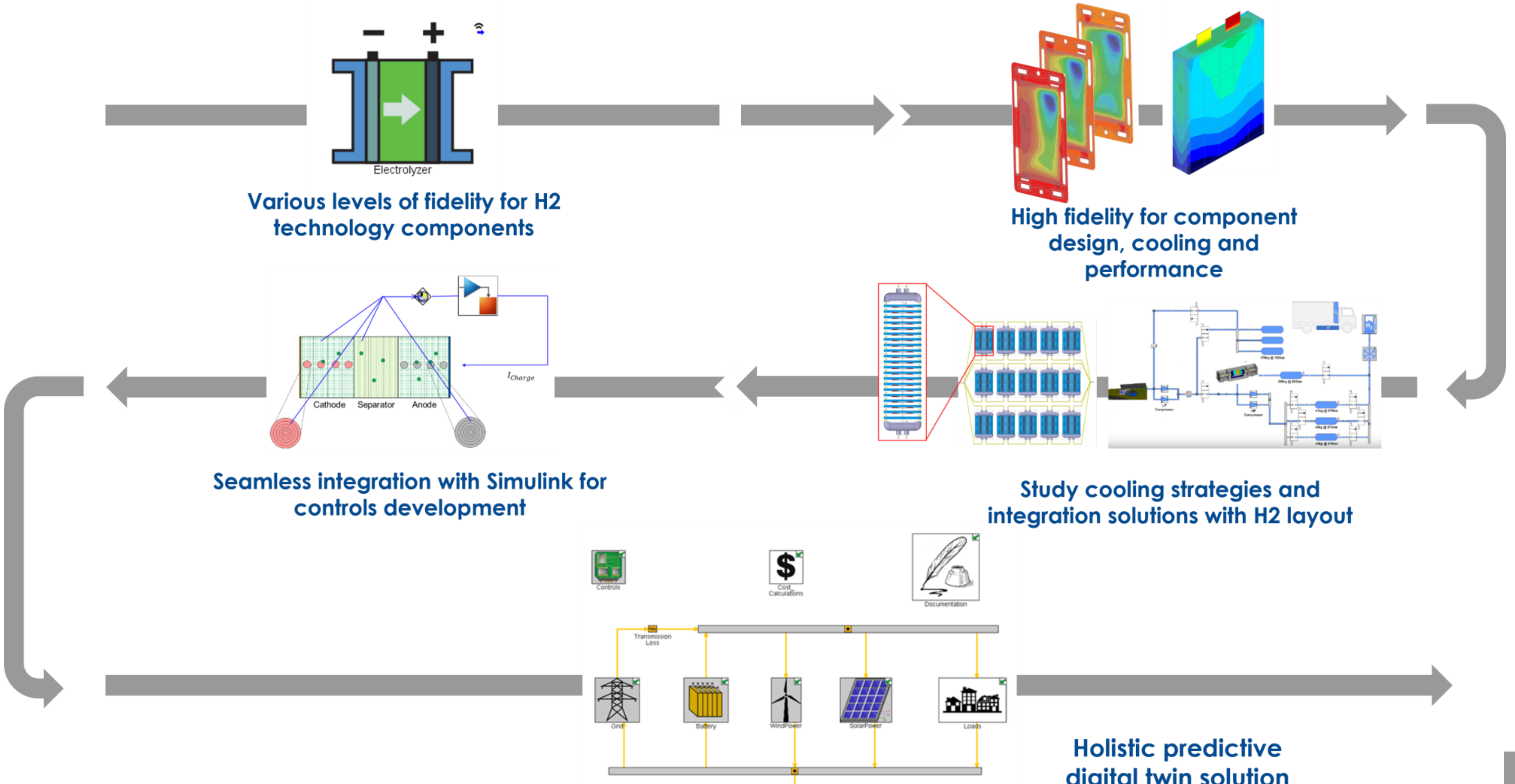
→ Electricity prices and available energy are always based on historical data – may change in the future and impact operating strategy and configuration of the proposed solution



Summary

GAMMA TECHNOLOGIES

Multi Physics ››› Multi Scale ››› Multi Disciplines



Thank You

Hanna Sara
Simulation Solutions Consultant
h.sara@gtisoft.com

Website
www.gtisoft.com

Meet us @ Stand C07

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