



# Welcome to FS4A

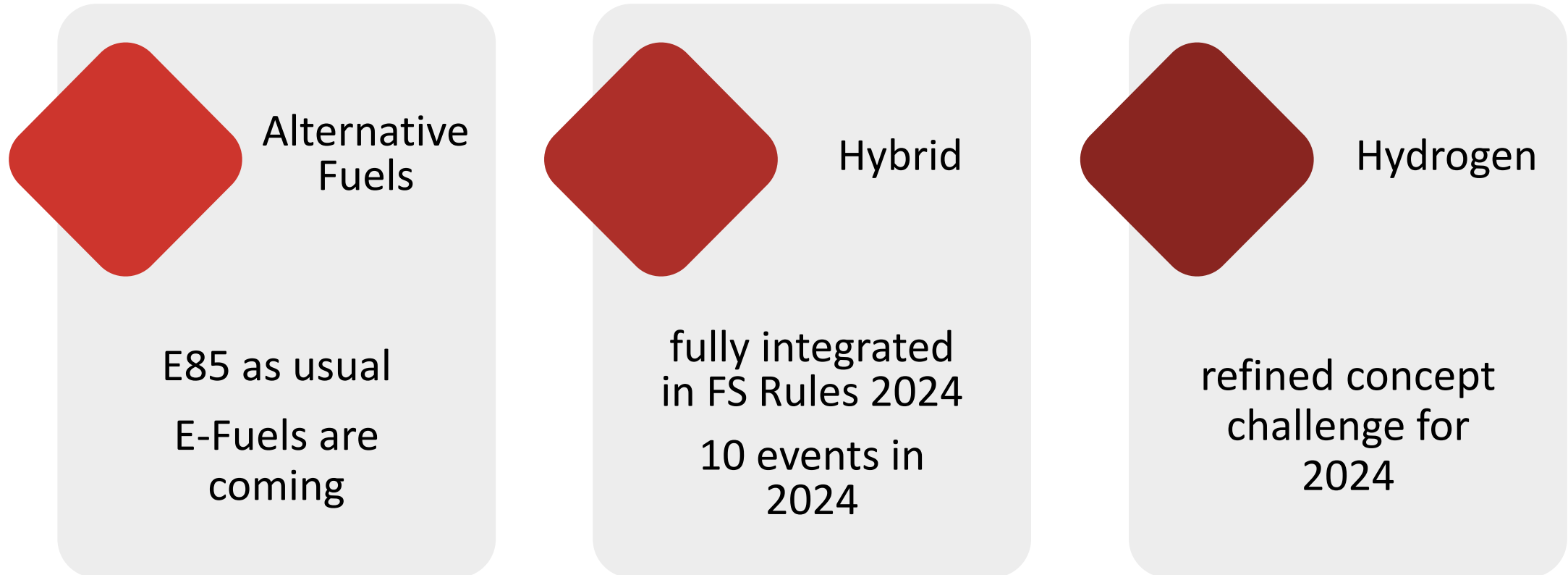
Formula Student Austria &  
Alpe-Adria Academy 2024



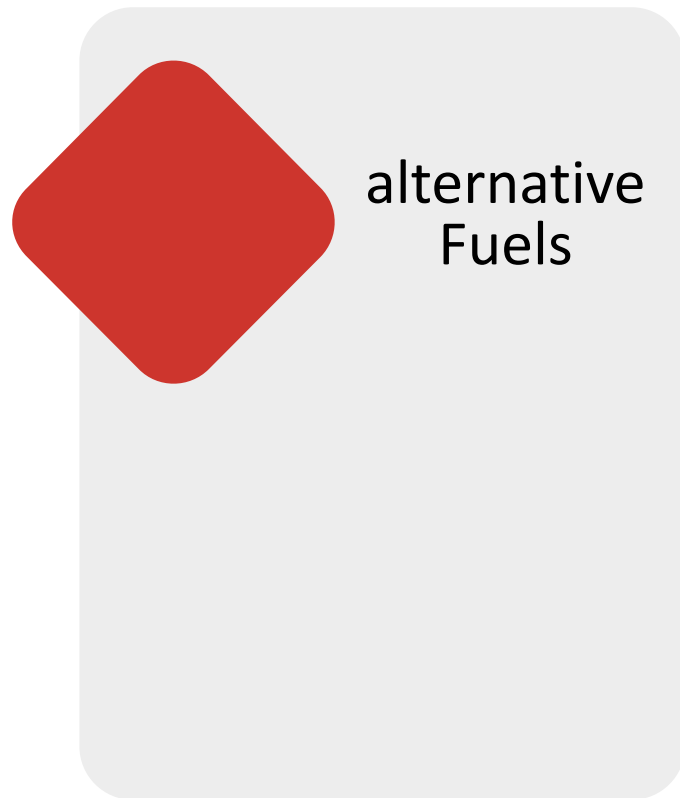
# Alternative Drivetrains (other than Battery-Electric)



# Agenda Session 1

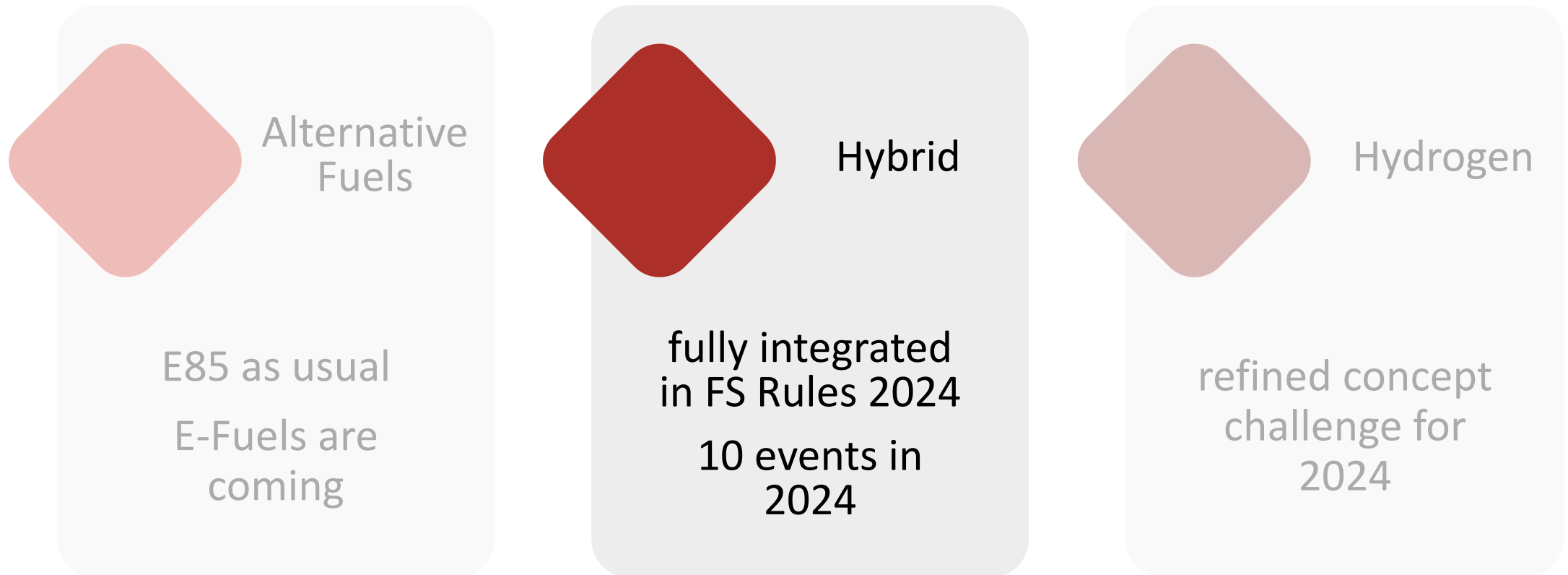


# Alternative Fuels



- E85 remains as usual
- 98 RON to be replaced with E-Fuels soon
  - supply chain needs to be organised
  - E-Fuels have the same normative properties as fossil petrol 98 RON
- other alternative fuels not considered:
  - (bio-) diesel
  - liquified gas
  - etc.

# Hybrid

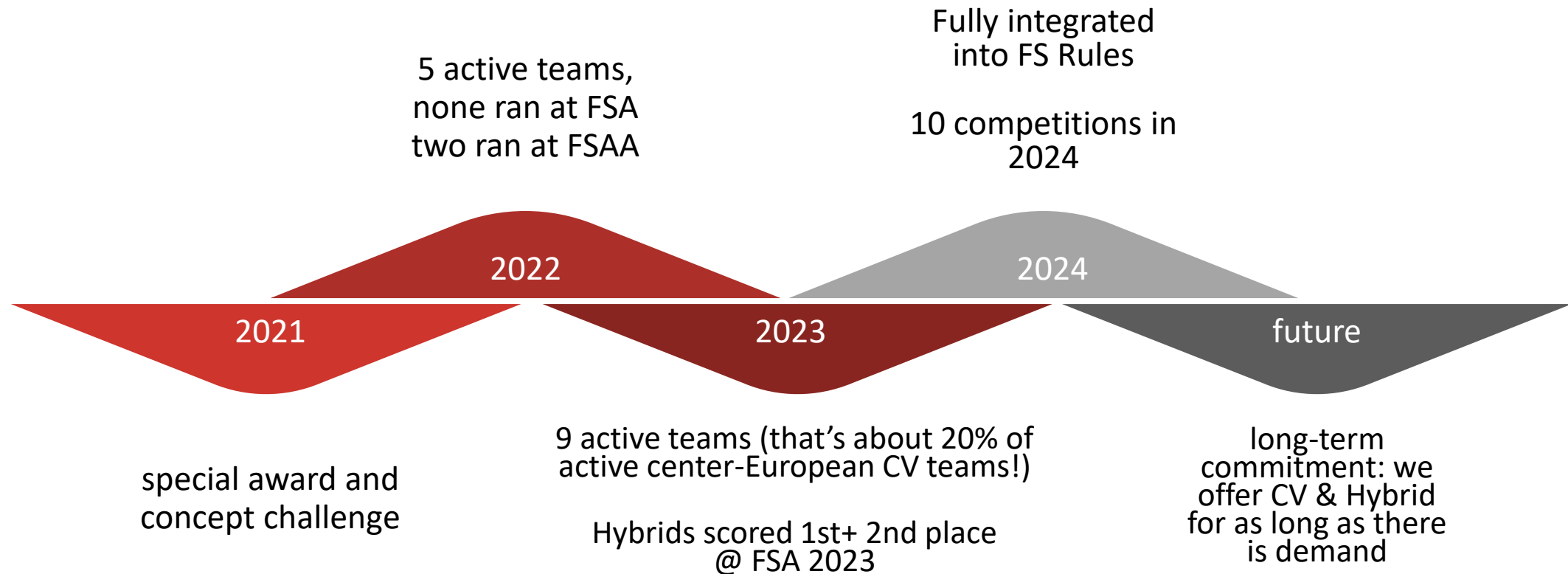


# Hybrid – Motivation

- motivation from our side
  - giving CV teams a green future → makes sponsorship requests easier
  - option to build “green” car without HV system
  - encourage students of CV teams to acquire knowledge in the field of electrical engineering
  - car can still drive, even if Hybrid fails
- similar motivation also for
  - E85 and E-Fuels for standard CV’s
  - Hydrogen-Combustion



# Hybrid - Status



# Hybrid - Status

## 2024 Competitions offering CV & Hybrid according to FS Rules

- FS Alpe-Adria (Croatia)
- FS Austria
- FS Czech
- FS East (Hungary)
- FS Netherlands
- FS Poland
- FS Portugal
- FS Romania
- FS Russia
- FS Spain\*



\*) waiting for confirmation



# Hybrid – Rules Overview

## Organizational

- low voltage system 60V = less danger
- limited power, possible within normal CV class
- limited effort for teams and organizers

## Technical

- energy storage active material max. 3kg
- isolation relay, integrated into shutdown circuit
- otherwise, same rules as for Li-Ion LV batteries
- no limitation on how & where to apply power



# Hybrid – Rules Details 1

- A 1.2.1 The competition is split into the following classes:
- Internal Combustion Engine Vehicle (CV) including Combustion Hybrid Vehicle (HY)
  - Electric Vehicle (EV)

**Changelog Version 1.0:** Included CV Hybrid into CV class

- T 6.1.11 ~~EV only~~ The first 90 % of the brake pedal travel may be used to regenerate brake energy without actuating the hydraulic brake system. The remaining brake pedal travel must directly actuate the hydraulic brake system, but brake energy regeneration may remain active.

**Changelog Version 1.0:** Removed [EV ONLY] label, also valid for HY

- T 7.2.1 [CV ONLY] Water-cooled internal combustion engines must only use plain water as the coolant.

- T 7.2.2 Other cooling systems ~~[EV ONLY] TS components~~ may only use plain water, air or oil as the coolant, see T 1.2.2.

**Changelog Version 1.0:** Changed to accomodate HY

# Hybrid – Rules Details 2

## A 6.8 [CV ONLY] Engine Running

A 6.8.1 Running engines is not allowed in the pits.

A 6.8.2 Engine running is allowed in the engine test area and in the dynamic area, when the following conditions are met:

- The vehicle must have passed mechanical inspection.
- The vehicle must be jacked using the jacks, see T 13.2.
- A driver, wearing required driver equipment, see T 13.3, must be seated in the cockpit.
- A fire extinguisher must be immediately available.
- Driven wheels can only remain fitted to the vehicle if they will not rotate.
- No one is allowed under the vehicle while the engine is running.

A 6.8.3 Cranking engines in the pits is allowed, when the following conditions are met:

- The vehicle has passed mechanical inspection.
- The driven axles are securely jacked up.
- Gearbox is in neutral.
- All driven wheels are removed.
- Connectors to all injectors and ignition coils are detached.
- A fire extinguisher must be placed next to the engine.

CV 5.1.9: Hybrid System may only be activated if engine is running, or during engine start (starter button pressed)

→ testing Hybrid System in the pits only possible when starter button is pressed + conditions from A 6.8.3

→ otherwise testing only possible outside in testing area, driven wheels jacked up and removed

# Hybrid – Rules Details 3

T11.1.5 [CV ONLY] The maximum permitted voltage for motor controller/inverters internal low power control signals is 75 VDC

**Changelog Version 1.0:** Added low power control signal voltage limit for HY

T11.7.7 Battery packs based on lithium chemistry other than lithium iron phosphate (LiFePO<sub>4</sub>) and all hybrid system energy storages regardless of chemistry type:

**Changelog Version 1.0:** Applied rule for all HSC, regardless of chemistry type

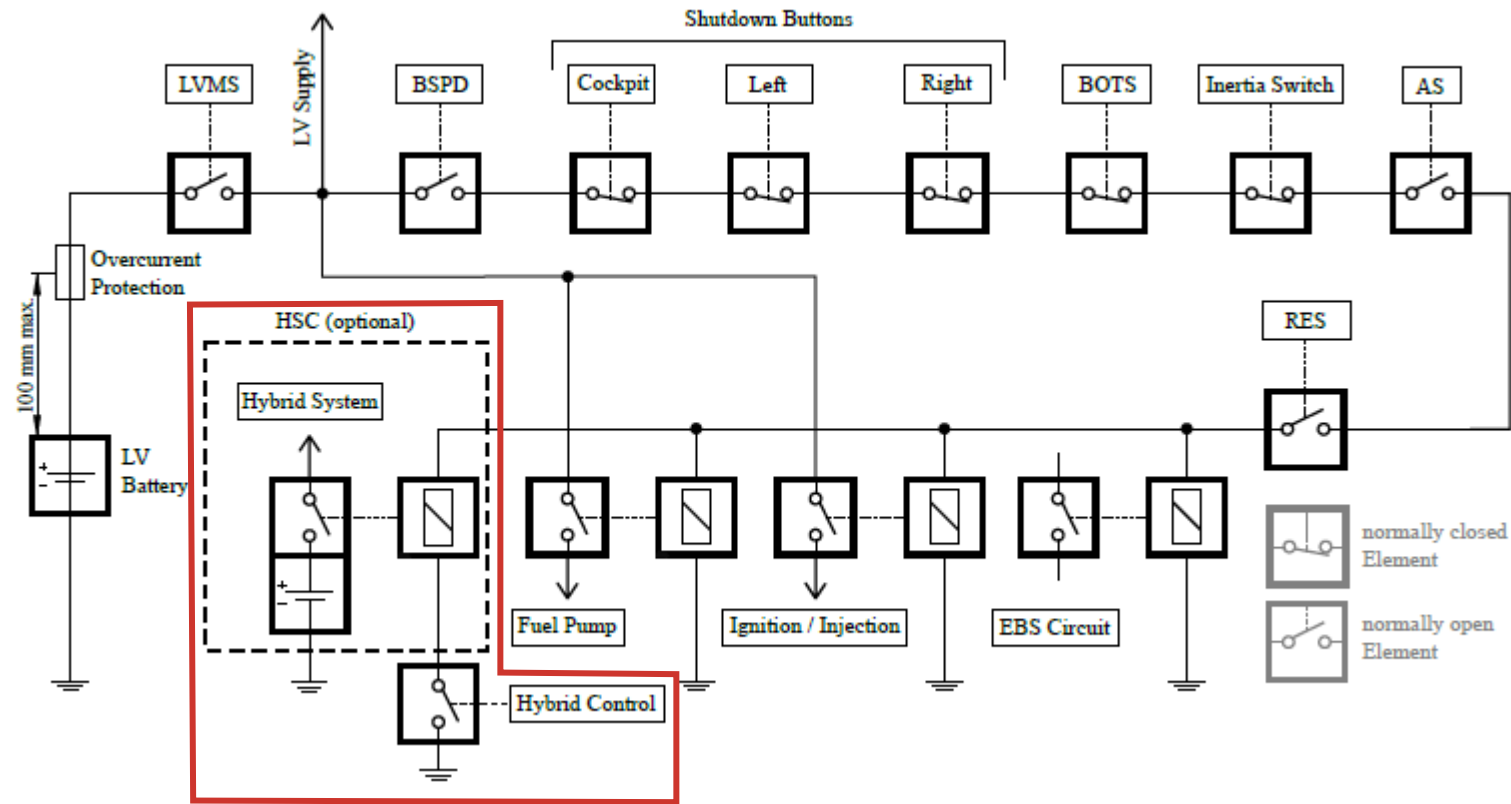
T12.2.1 Combustion Hybrid Vehicles have to be identified by an additional marking next to all three vehicle numbers with the capital letters “HY” in Roman Sans-Serif characters at least 75 mm high in white on a red background.

**Changelog Version 1.0:** Added hybrid vehicle identification requirements

CV 1.1.1 The engine(s) used to power the vehicle must be piston engine(s) using a four-stroke primary heat cycle with a displacement not exceeding 710 cm<sup>3</sup> per cycle. Hybrid powertrains must use a purely electrical energy storage. ~~Hybrid powertrains, such as those using electric motors running off stored energy, are prohibited.~~

**Changelog Version 1.0:** Allowed hybrid powertrains

# Hybrid – Rules Details 4



CV 4.1.4 [HY ONLY] The HSC AIR as per CV 5.2.2 must be part of the SDC in such a way that one side of the relay coil is directly incorporated into the SDC and the other side is controlled by the hybrid control system.

Changelog Version 1.0: Added HSC AIR to shutdown circuit

# Hybrid – Rules Details 5

- CV 5.1.1 The hybrid system must be a LVS, T11.1 and T11.7 are applied for all hybrid system components.
- CV 5.1.2 All electrical parts of the hybrid system except for ground terminals must be covered at least according to IPxxB when energized.
- CV 5.1.3 The Hybrid Storage Container (HSC) is defined as the electric energy storage system, including the AIR and overcurrent protection, that is used in the hybrid powertrain.
- CV 5.1.4 Moving energy into the HSC from a different electrical storage system is prohibited.
- CV 5.1.5 A firewall, see T4.8, must be present between the HSC and the fuel tank.
- CV 5.1.6 The HSC must be positioned according to T11.7.2, all other hybrid system components must be positioned within the surface envelope, see T1.1.18.
- CV 5.1.7 The high current path of the hybrid system must meet EV 4.5.16.
- CV 5.1.8 Motors must meet EV 2.1.
- CV 5.1.9 The hybrid system may only be activated when the combustion engine is running or during engine start.

Definition of hybrid system:  
analogue to EV 1.1.1:

every part that is electrically  
connected to the HSC and  
the hybrid motor(s),  
including HSC and motors(s)  
themselves

# Hybrid – Rules Details 6

## CV 5.2 Hybrid Storage Container

CV 5.2.1 The HSC must be attached to the primary structure, see T 1.1.12, and meet EV 5.5.8.

CV 5.2.2 A disconnection mechanism, designed as an AIR must be integrated into the HSC, disconnecting the positive pole of the HSC. The AIR must be compliant with EV 5.6.3.

CV 5.2.3 The maximum accumulated weight of all elements in the hybrid system that store the electrical energy, e.g. battery cells or supercapacitors, including all casings and tabs that are integral to them, is 3 kg.

CV 5.2.4 The HSC must be removable to be inspected at the mechanical inspection and it must be possible to easily check the weight limit.

## CV 5.3 Hybrid System Form

CV 5.3.1 A Hybrid System Form (HSF) has to be submitted using the HSF template

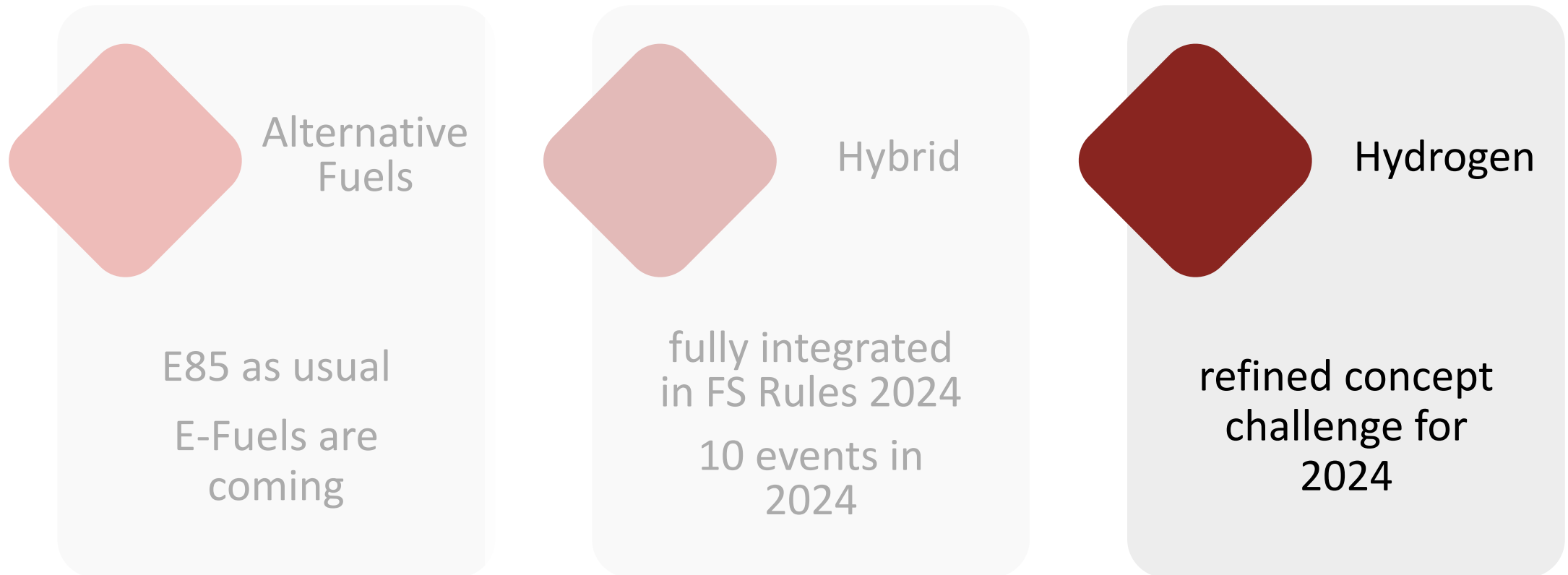
CV 5.3.2 The HSF template will be available on the competition website

CV 5.3.3 If no HSF is submitted, the team must not use the hybrid system at the competition. A 5.4.2 will not be applied for the HSF

HSF Template:  
currently work in progress

Based upon 2023 template  
from FS East & Netherlands

# Hydrogen





# Hydrogen - Motivation

- Promotion of new and diverse alternative technologies and innovative drivetrain concepts
- Option to build a “green” car without a HV system
- Encourage students to acquire knowledge in the field of hydrogen and fuel cells, Hydrogen will be important in future industrial applications
- New challenge for established EV teams
- Giving CV teams a green future → sponsorship requests easier

# Hydrogen – Status 2023

- Special award and concept challenge in 2023 at FS Austria, FS Alpe Adria and FS East
- Positive feedback from sponsors
- There have already been concepts with Hydrogen
  - Greenteam Twente
  - Forze Hydrogen Racing



# Hydrogen in other Racing Series

... with fuel cell:

- Prototypes from mission H24 project, should drive 2025, new hydrogen class for the 24 Hours of Le Mans

.... with combustion:

- Concept-Car "GR H2 Racing"
- GR Corolla H2 Concept at 24-hour race in Fuji 2023
- GR Yaris H2 at Rallye Ypres 2022



# Hydrogen – FS Drivetrain General

## Hydrogen tank and regulator standardized

- Only feasible way to ensure a safe 350 bar H2 system
- Quick connect allows removal of tank and regulator
- Instead of fueling the car, the tank is replaced
- There is no Hydrogen in the car for working on the car

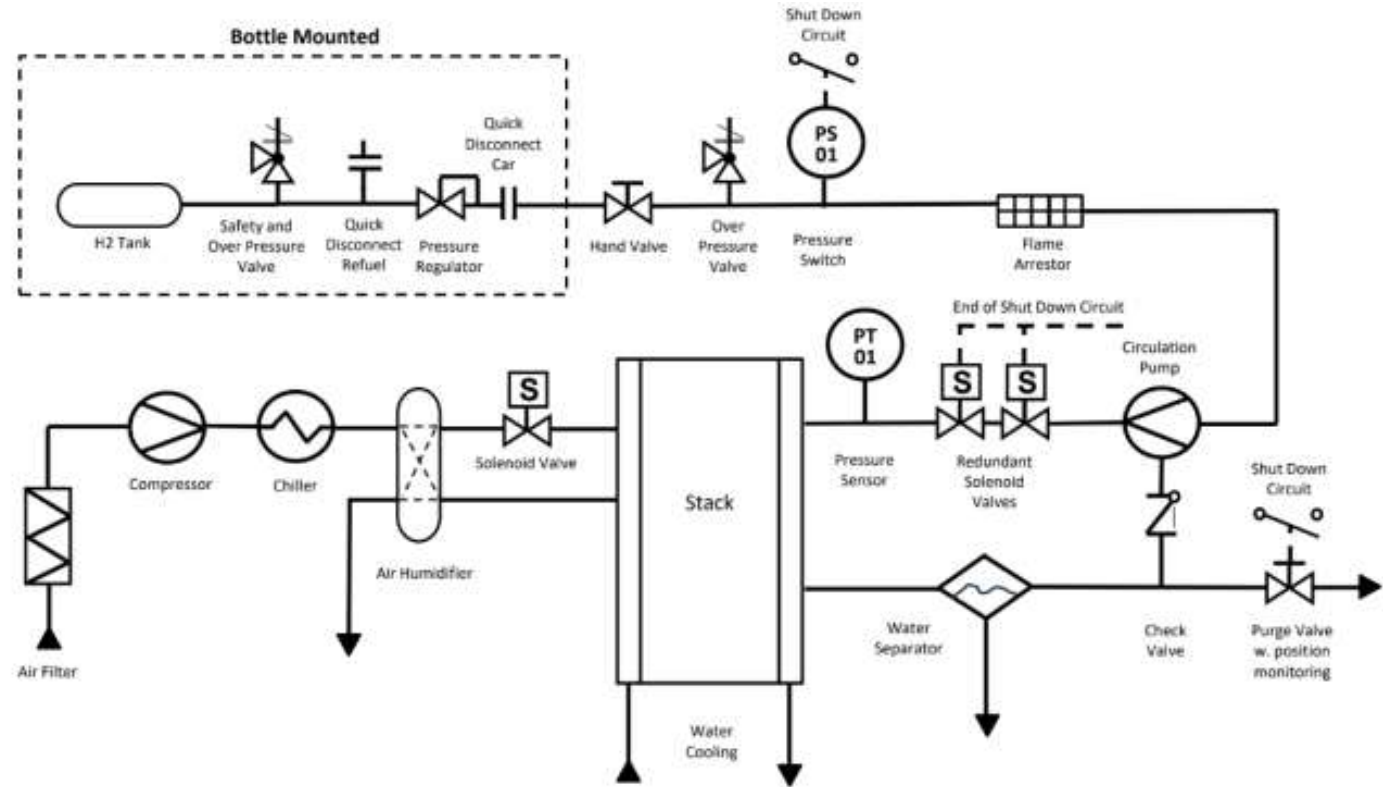
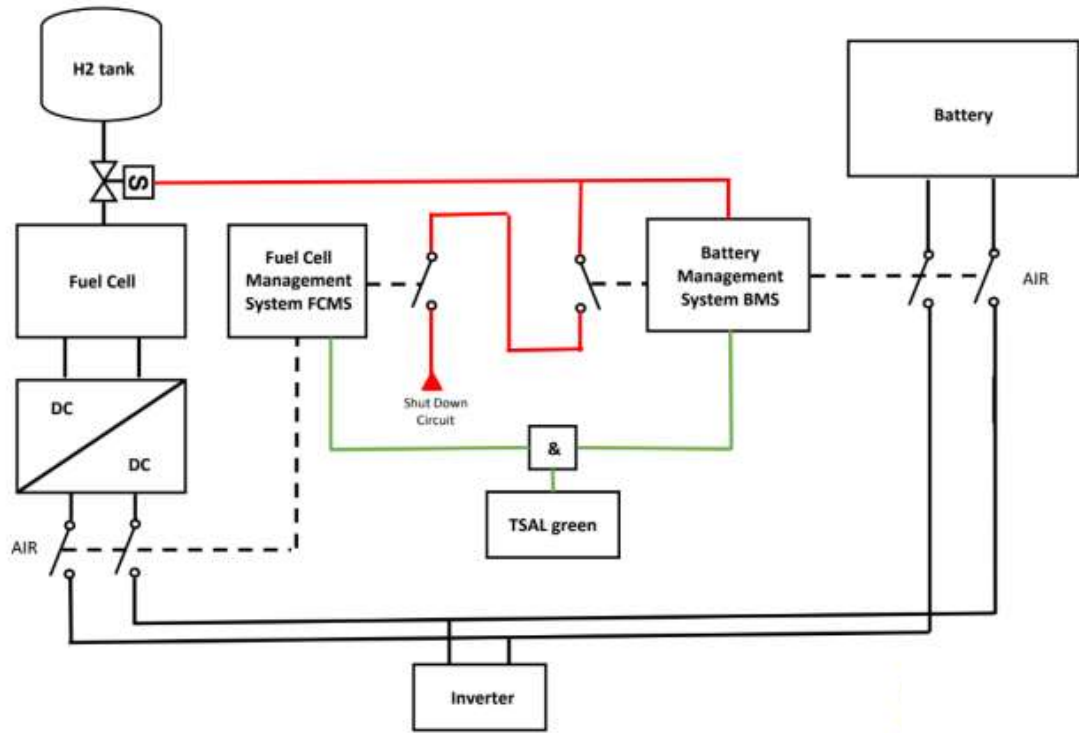
## Combustion

- Only boosted 4-stroke engine technically feasible

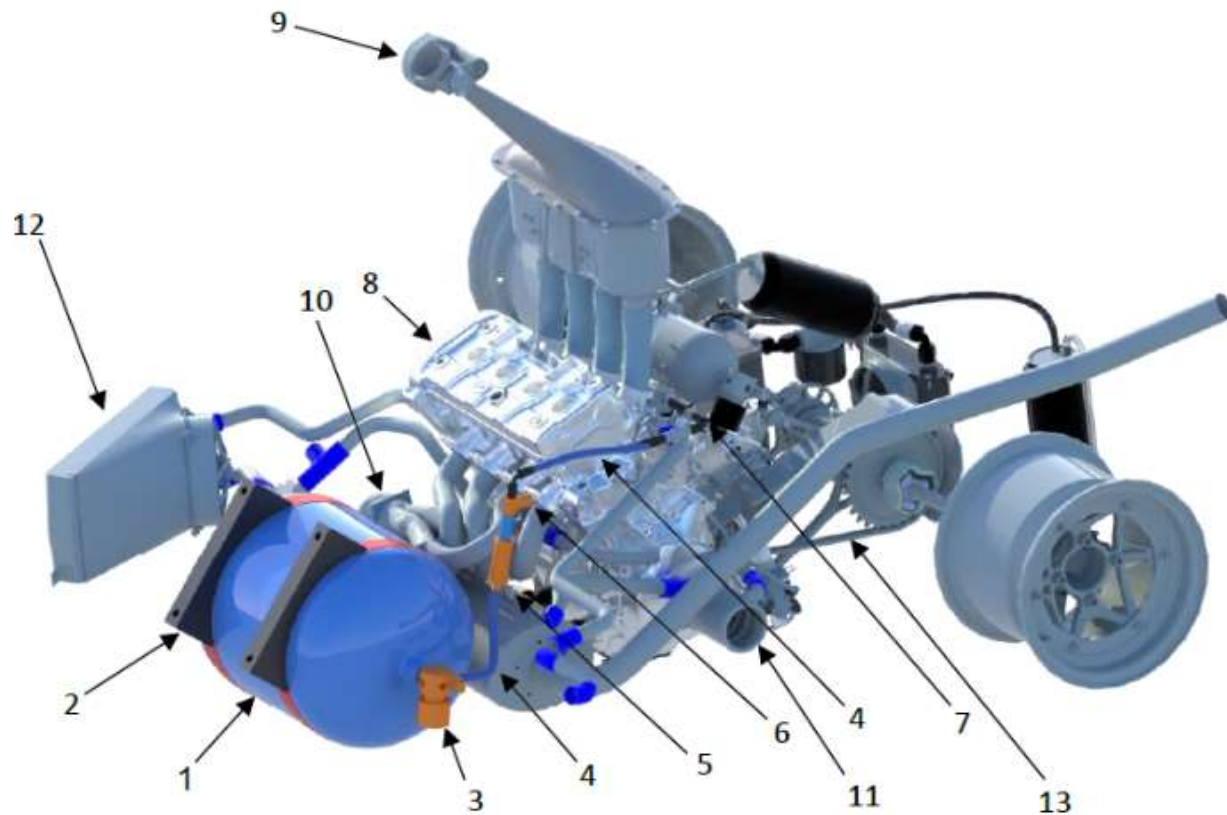
## Electric

- Fuel cell
- Only feasible with additional electrical energy storage

# Hydrogen – EV Drivetrain



# Hydrogen – CV Drivetrain



1. fuel tank with 280 mm diameter and 400 mm length
2. fuel tank attachment with included shock absorber
3. directly attached pressure regulator
4. fuel line
5. self checking dual safety valves
6. pressure sensor
7. intake manifold injection with fuel injectors
8. 4-stroke internal combustion engine
9. airbox
10. turbocharger
11. electric motor
12. water cooling and intercooler
13. battery

# Hydrogen - Future

- Repeating concept challenge in 2024
- Hydrogen Rules Extension feasible for 2025
- Draft version will be published as input for the 2024 Concept Challenge
- This allows Teams to gear up for actual Hydrogen cars starting 2025
- The events have to guarantee for the infrastructure and safe working conditions, which is a significant challenge
- Safe working and testing conditions have to be implemented for the rest of the season as well

# Hydrogen – Open Challenges

- Allow retrofit of old cars (like start of EV-class)
- CV - one tank per car, size unclear
  - Air restriction not feasible; has to have fuel flow limiter
  - Balance of performance with EV/CV - engine size up to 1.000cc
  - Consumption via tank weight or flowmeter (could also monitor max flow)
- EV - one tank per car, size unclear
  - Electrical Energy storage type and size unlimited
  - Energy meter for accumulator “as usual” <85kW
  - Additional energy from the fuel cell is unlimited
  - Allow more peak power to make it attractive or own class?



# Polling Time!

- please answer the slido polls
- only once per team, answering both questions



# Q&A

## Session 1 Alternative Drivetrains

# Q&A for CV & Hybrid

Question	Answer
Is there any guarantee or plan for how many years (at minimum) the hybrid category will be around?	Yes, FS Austria will definitely keep the CV & Hybrid class running for as long as there is reasonable demand for it! FS Austria has now officially overtaken the "CV" chapter of the FS Rules and as you know we have now implemented the Hybrid Extension into it, it is definitely going to stay there!
Do you think removing CV class will improve Formula Student in any way? Why? Wouldn't it be much better if students had more options to choose?	We believe that Formula Student should first and foremost be a challenge for aspiring students. For that an exiting topic is needed, a race car just happens to "fit the bill". But for the purpose of the challenge it really does not matter which powertrain it has, which is why we want to stay as open as possible. We clearly distance ourselves from the course that FSG has taken in this regard - you as a team should be able to choose.
Are E-Fuels going to be implemented as an option for standard CVs?	Yes, most definitely! It is simply a matter of sourcing, logistics and safety at this point. Maybe even already for 2024, lets see.
T 4.6.2 If a heat-resistant material is in the firewall and temp is always below 60 degrees, why is there the convection part (25mm air gap) of the rule?	From my understanding of the rule, the 25mm requirement is only necessary if there are hot parts like exhaust manifold. But if you are not sure, please post a FSG Rules question with more information about your design.
Are you planning to increase the CV hybrid accumulator active material weight in the next years?	No, we believe the 3kg limit is a good size and it allows us to have Hybrid within the CV class.
What are the most common mistakes first year teams make and how do we avoid them?	Looking at the fastest car in the competition and trying to copy that is not a good starting point, instead you should start with a very simple concept, get that running and then improve from there. The biggest mistake you can make is making the challenge to hard for yourselves and then fail at delivering a working vehicle - a FS team will only stay together, when there is a working output which allows you to actually participate in competitions.

# Q&A for Hydrogen

Question	Answer
In which ways do you think should Formula Student go towards a path of standardized parts? (for example hydrogen tanks, should that be part of FS's future)	We believe standardized hydrogen tanks are the only feasible way of getting hydrogen started in Formula Student because of the safety concerns of everybody involved. Apart from that, we don't think that standardized elements help the cause. Rather we want to provide "how-to-guides" and "best practice examples".
Is there any chance that we will see an implementation of eFuels or Hydrogen?	E-Fuels: 95% likely, Hydrogen Combustion: 80% likely, Hydrogen Fuel Cell 66% likely at this point in time
Plans to accommodate hydrogen-electric or hydrogen combustion powertrains, or perhaps plans to create an umbrella category of "alternative powertrains"?	Yes, that is definitely the idea behind our Hydrogen Concept Challenge! The endgame is to fully implement Hydrogen into Formula Student just as it has been done with Hybrid - but it will take a little longer because of all the safety issues and other uncharted issues.
Is there any development path teams can take to develop a hybrid powertrain?	This is basically the core of the engineering challenge: you have to see what gives you the most advantage with the resources and possibilities that you have access to.
Will there be events dedicated to hydrogen single-seaters in the future?	Yes, but it is planned as integral part of Formula Student Competitions!
Do you have any contact with fuel cell manufacturers? We are designing a hydrogen car, but nobody seems interested in selling us a fuel cell	Yes, this is definitely a big part of the challenge, the whole industry is in a "start-up" phase and there are not yet off-the-shelf solutions for FS cars.
CV 2.3.4 Can the fuel tank container be not closed, but have holes in its outer surface/structure?	The fuel tank needs to be fully closed, it must prevent spilling of fuel under any circumstances. There can only be a small venting line, but even that needs a check valve in case of the vehicle being upside down after an accident. If you have a flexible fuel tank, it also has to be fully contained within a rigid container.
Where can a team fuel up the hydrogen tanks during testing? Seems to be quite difficult and expensive	Yes, that is definitely a challenge to be solved, We believe having "cartridge" style fuel tanks which can be easily replaced can solve the problem, but then of course they have to be rather cheap.