

# ***PRHYDE-Protocol for heavy-duty hydrogen refuelling***

Call Identifier FCH-04-2-2019:

Refuelling Protocols for Medium and Heavy-Duty Vehicles



01 JAN 2020 - 31 DEC 2021



Horizon 2020  
European Union Funding  
for Research & Innovation



# Acknowledgement



This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 874997.

This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme.



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# Performance Based Heavy Duty Fueling Protocol

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THIS PRESENTATION IS INTENDED TO PRESENT  
ONE APPROACH TO HYDROGEN FUELING AND  
DOES NOT REFLECT POSITIONS OF MY CLIENTS

THE VALUES USED IN THIS PRESENTATIONS ARE  
INTENDED AS EXAMPLES, NOT PROPOSALS

# TABULA RASA: CLEAN SLATE

# Background



- Heavy duty vehicle fueling protocols are challenging because they need to account for a wide range of:
  - Vehicle sizes and configurations
  - Station sizes and configurations
  - Component characteristic (e.g., tanks)
  - Usage
  - Cost
- SAE J2601 tries to optimize fueling for these wide ranges by assuming the worst case
  - Makes developing a fueling protocol restrictive and conservative
- Time for the next generation fueling protocol!

# Goal



- What about a “**performance based**” fueling protocol!
  - Flexible vehicle/station sizes, cost, performance
  - Can react to actual conditions
  - Reliable, protects customer
- But...we need to be careful to ensure that we maintain baseline performance criteria to ensure customer satisfaction



# J2601 Fueling Protocol

- A SAE J2601 station determines ramp rate based upon
  - CHSS volume/pressure
  - Ambient conditions
  - Precooling capabilities

My volume is X1  
and my CHSS is  
at Y1 °C, my  
pressure is a Z1  
MPa

My CHSS is cold.  
Can I get a faster  
fill?

Based upon your 2 vehicle  
conditions, ambient  
temperature, and my station  
precooling level of A1, I will  
give you a fueling rate of 5  
MPa/min

NO!



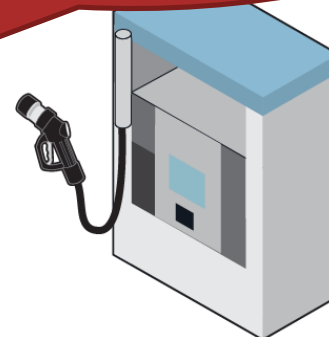
# Advanced formula approach

- You could provide more reliable data from the vehicle
  - Would provide “better” fueling, but would be limited to parameters and their ranges

My vehicle parameters are T4, U7, V3, X2, Y0, Z1

Based upon your vehicle parameters, and my station/ambient parameters of A1, B4, C2, D4, E1 I will give you a fueling rate of 5

(Simple version.... real version would have more parameters)



# Performance Based Fueling Protocol: Simple Example



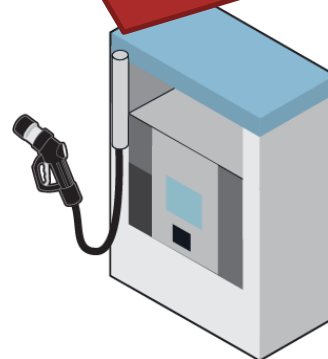
- We can also shift the selection of fueling rate decision to the vehicle
  - Station provides range of fueling rates primarily based upon station conditions
  - Fueling rate calculation moves to vehicle

(Simple version....  
real version would have  
more parameters)

I need 80 kg and  
my CHSS is at  
X1 °C, my  
pressure is a Y1  
MPa

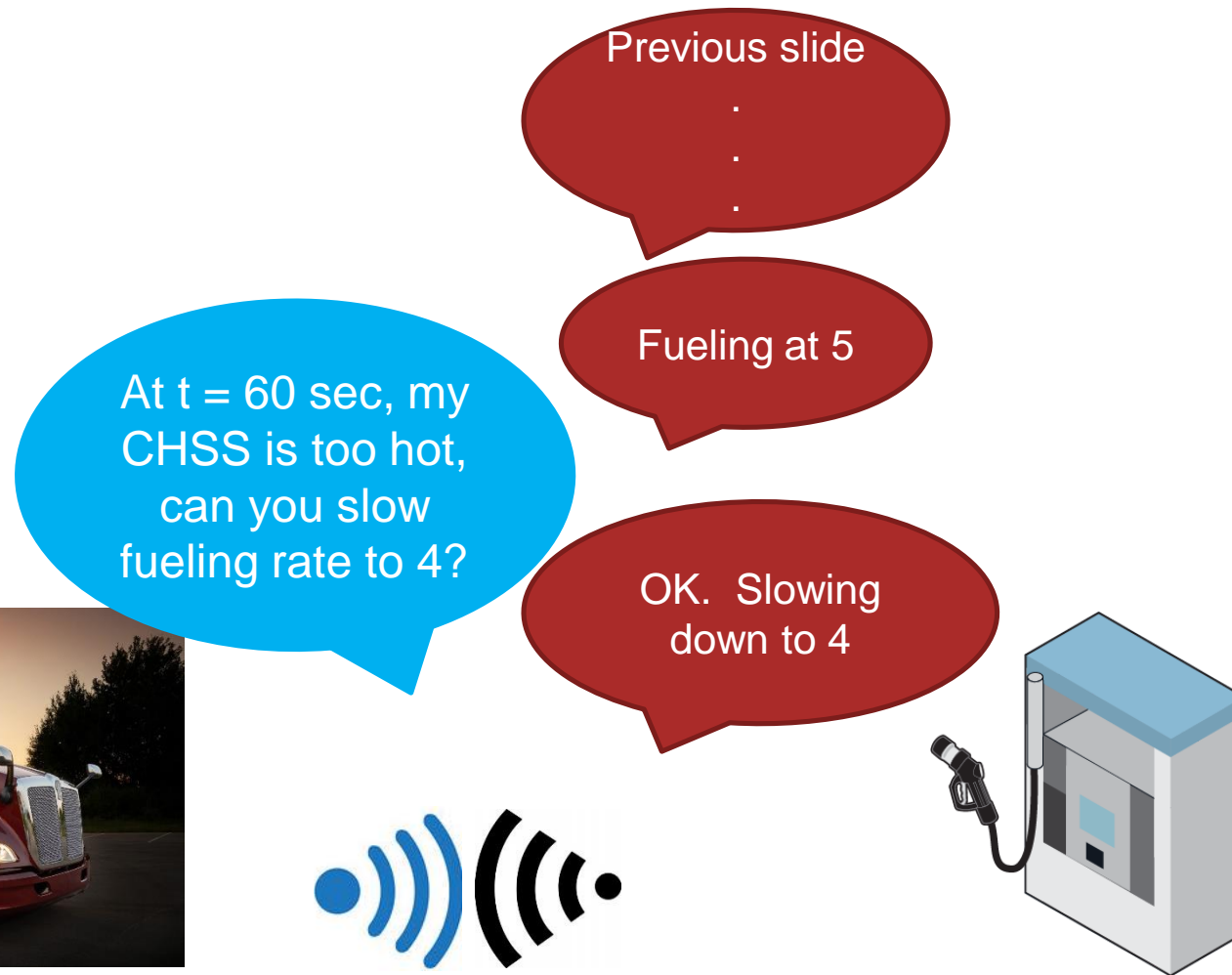
Based upon my  
CHSS temp, my tank  
design, and your  
data, please give me  
a fueling rate of 5

Based upon your request, my  
storage and ambient conditions,  
I can provide you a range of  
fueling rates from “2 to 7” at “T1”  
precooling levels



# Performance Based Fueling Protocol: Vehicle Feedback Loop

- In a performance based approach, the vehicle can provide feedback during the fill

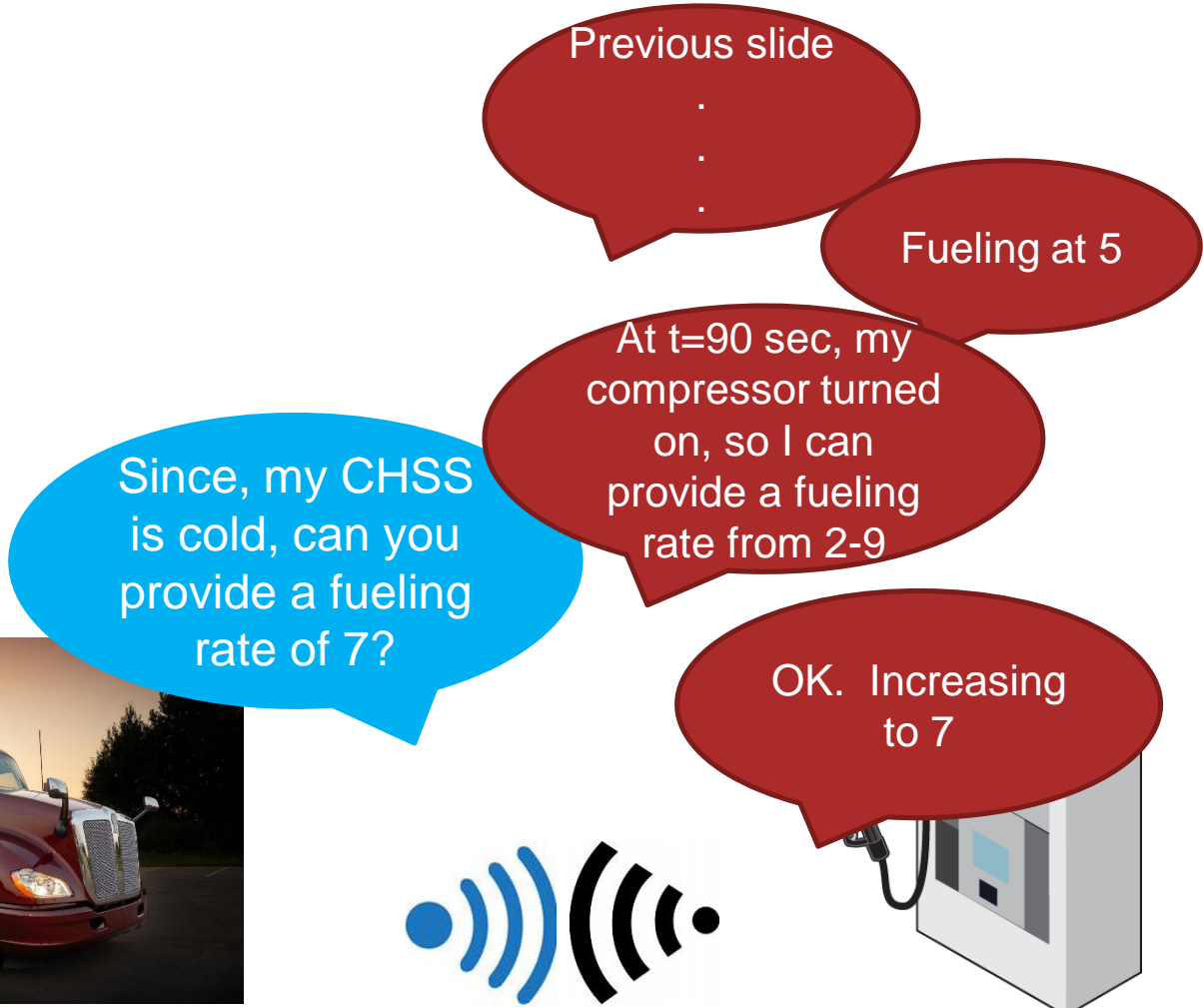


(Simple version....  
real version would have  
more parameters)



# Performance Based Fueling Protocol: Station Feedback Loop

- The station can also provide feedback



(Simple version....  
real version would have  
more parameters)

# Performance Based Fueling Protocol: Conservative option



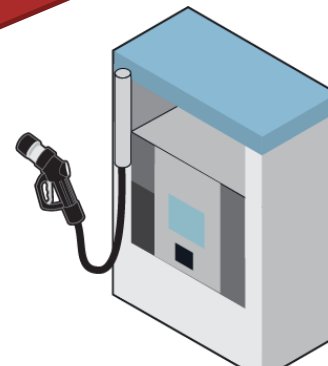
- Vehicle can opt not to fill or provide conservative default fueling

I need 80 kg and  
my CHSS is at  
X1 °C, my  
pressure is a Y1  
MPa

Based upon your  
precooling level of  
A42 and my CHSS  
temp, please do  
not fuel me

Based upon your request,  
my storage and ambient  
conditions, I can provide  
you a range of fueling rates  
from “2 to 7” at “T+35”  
precooling levels

(Simple version....  
real version would have  
more parameters)



# Performance Based Fueling Protocol: Conservative option



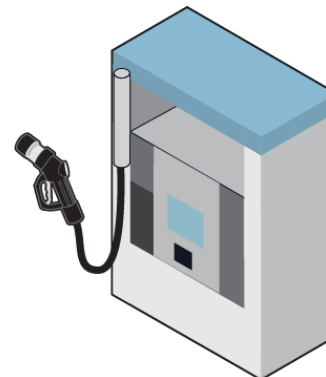
- Station can opt not to fill or provide conservative default fueling

I need 280 kg  
and my CHSS is  
at X1 °C, my  
pressure is a Y1  
MPa

Please give me  
conservative  
default fueling

Based upon your request  
of 280 kg, my storage and  
ambient conditions, I only  
provide a conservative  
default fueling

(Simple version....  
real version would have  
more parameters)



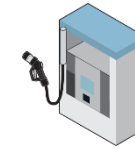
# Performance Based Fueling Protocol: Implementation

- There are going to be many vehicle and station sizes/designs
- Usually, the “base” station will be optimized for the types of vehicles they are fueling

Local Truck/Bus  
H50 A kg



10 min to 100% SOC

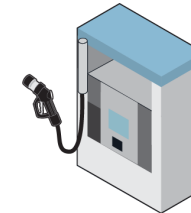


Small Station  
H50 Tamb

Medium Haul Truck  
H70 B kg



10 min to 100% SOC

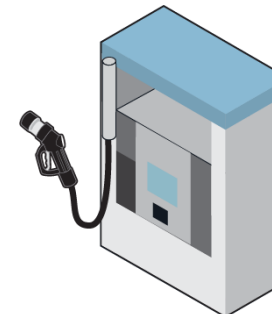


Medium Station  
H70 T20

Long Haul Truck  
H70 C kg



10 min to 100% SOC



Large Station  
H70 T40

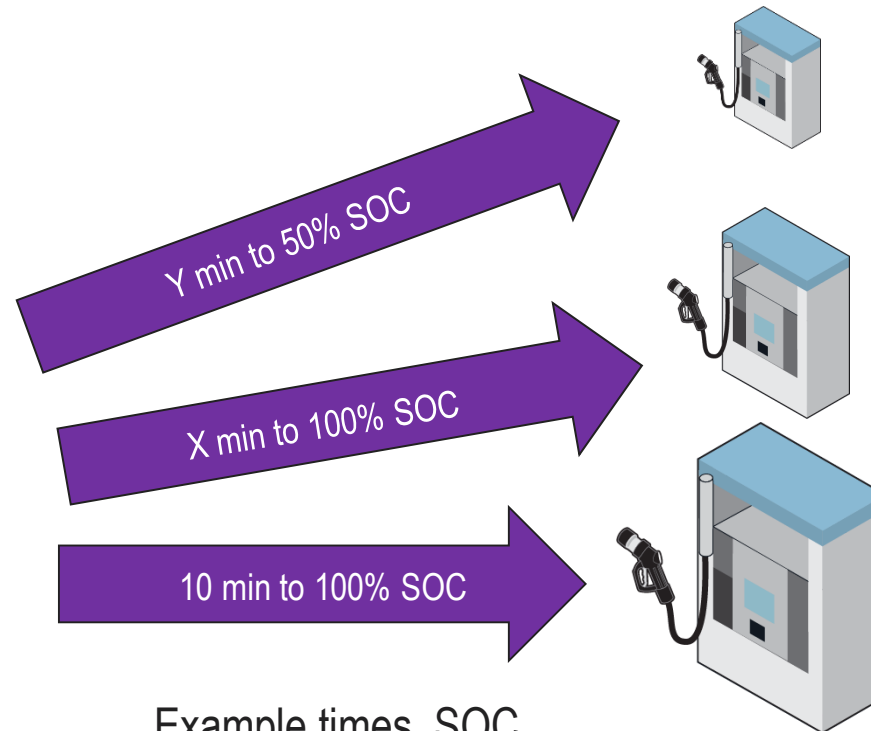


# Performance Based Fueling Protocol: Implementation



- We will want the flexibility to be able to fuel different size vehicles at the different sized stations

Long Haul Truck  
H70 C kg  
X1, Y1, Z1 parameters



Small Station  
H35 Tamb  
A1, B1, C1 parameters

Medium Station  
H70 T20  
A2, B2, C2 parameters

Large Station  
H70 T40  
A3, B3, C3 parameters

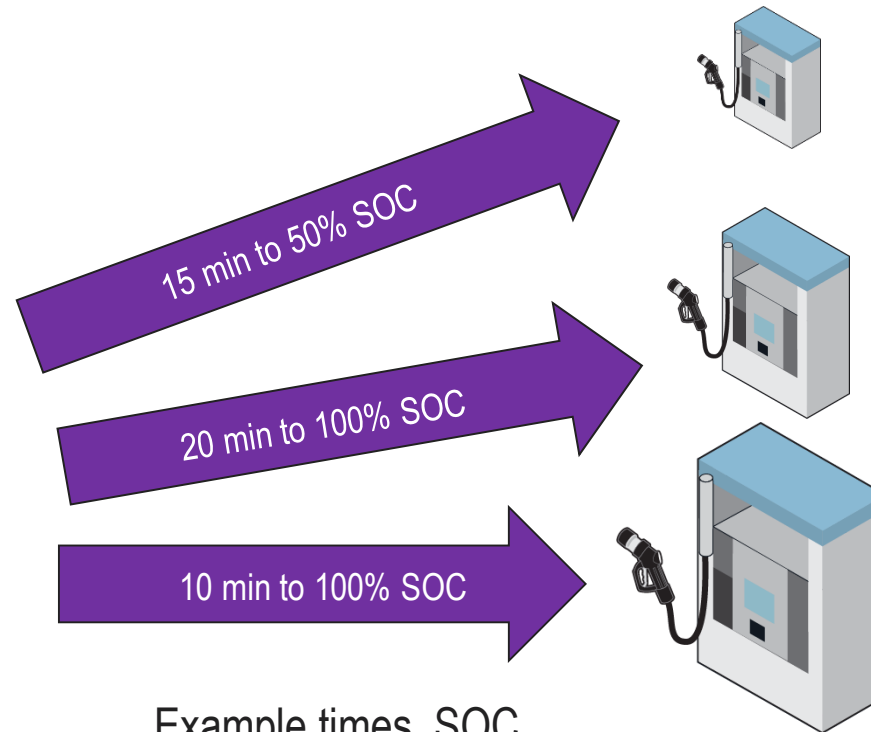
Example times, SOC

# Performance Based Fueling Protocol: Implementation



- If we know the key parameters, we can estimate the performance of a vehicle at different sized stations
- It will be important to set performance targets to meet customer expectations

Long Haul Truck  
H70 C kg  
X1, Y1, Z1 parameters



Example times, SOC

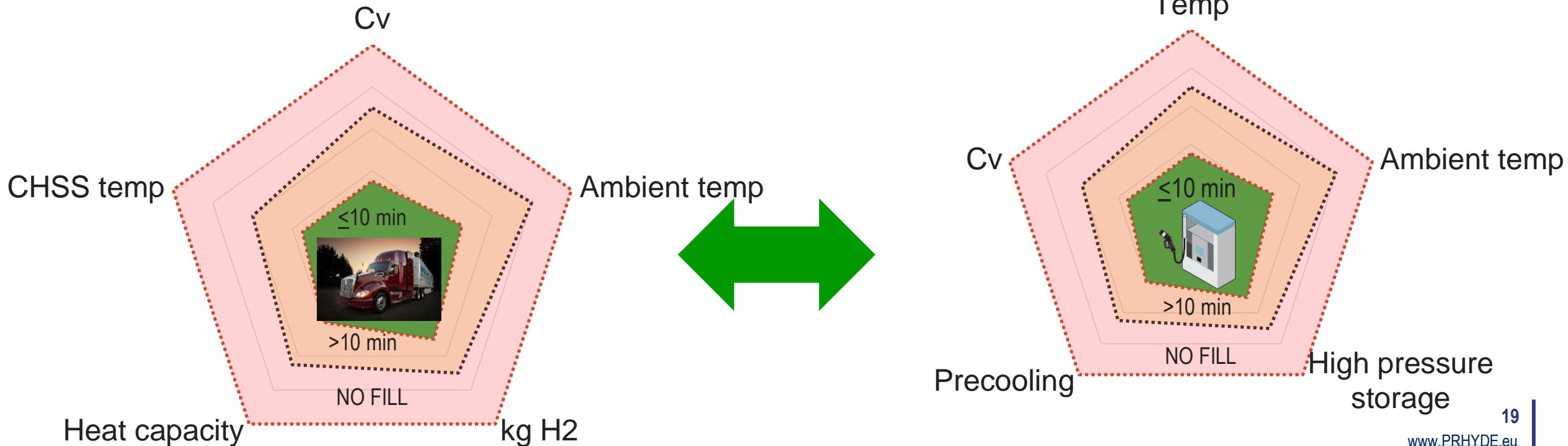
Small Station  
H35 Tamb  
A1, B1, C1 parameters

Medium Station  
H70 T20  
A2, B2, C2 parameters

Large Station  
H70 T40  
A3, B3, C3 parameters

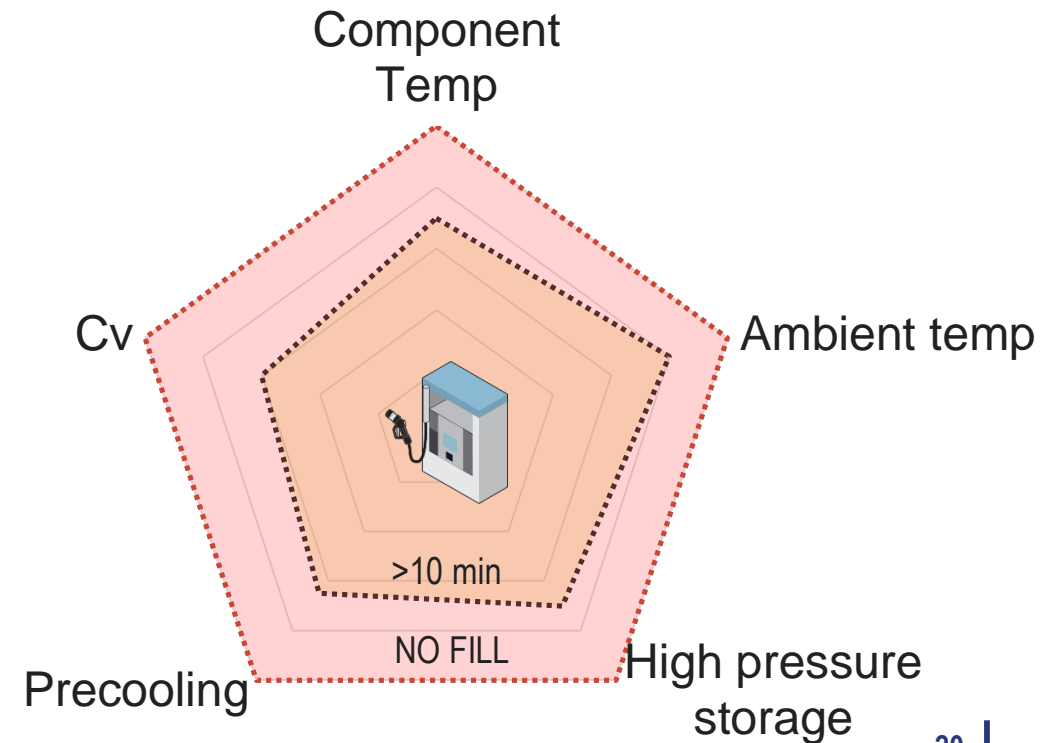
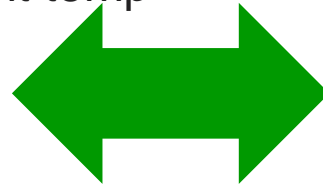
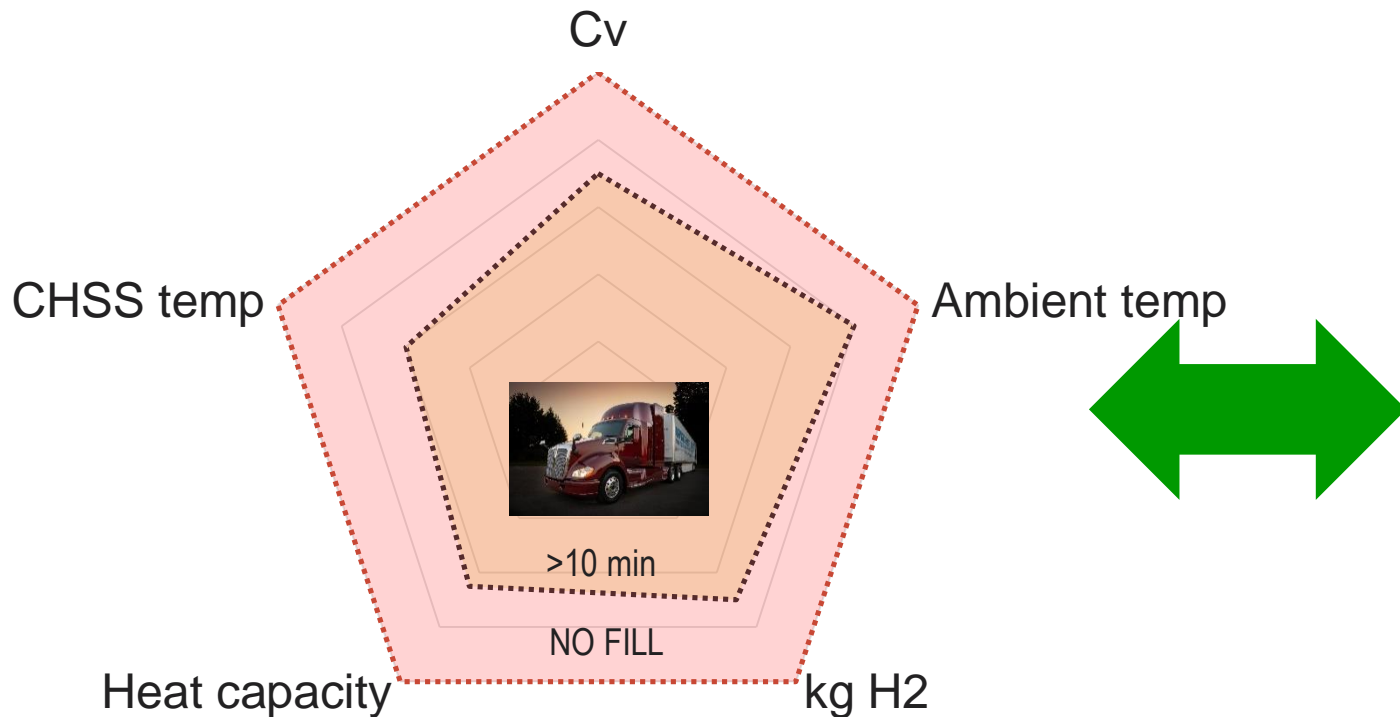
# Performance Based Fueling Protocol: Performance Targets

- For each vehicle and station size combination, we can define performance targets
  - **Green:** Best performance (equal to conventional fueling)
  - **Yellow:** Reduced performance
  - **Red:** No fueling



# Performance Based Fueling Protocol: Performance Targets

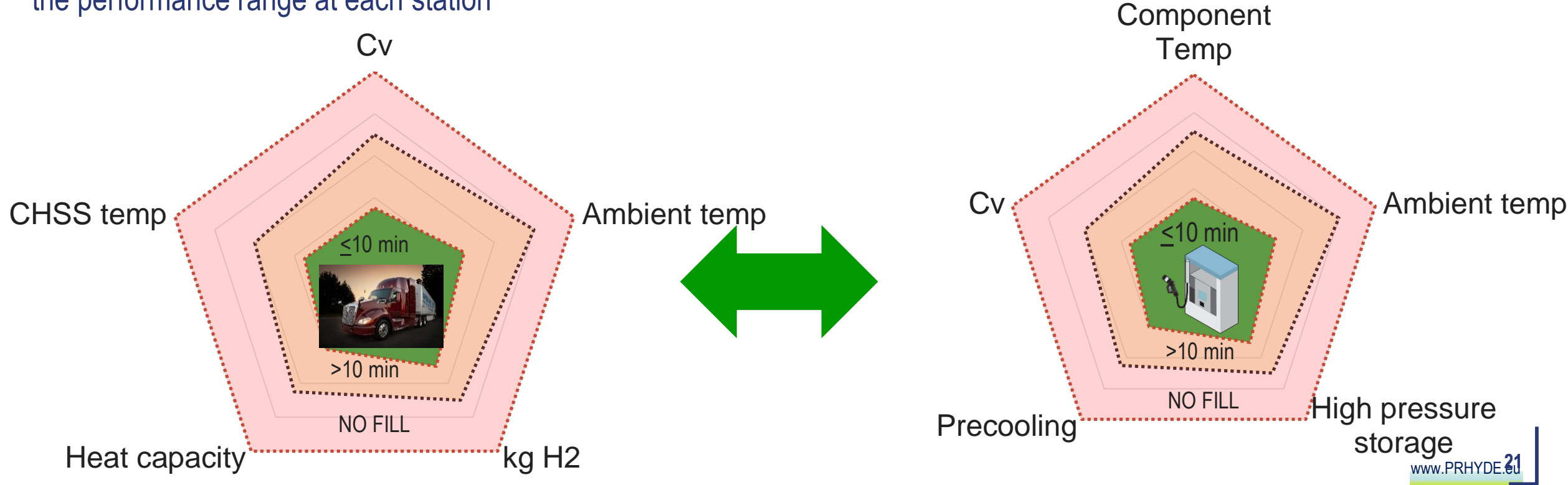
- In some cases, **Green** performance cannot be achieved
  - Large truck at small station
  - Station under high use
  - Poor ambient conditions (hot days)
- **Reduced performance but, the vehicles will still be able to fuel!**



# Performance Based Fueling Protocol: Performance Targets



- Need to define parameters to meet varying performance “targets”.
  - If vehicle (X1, Y1, Z1) and station (A1, B1, C1) parameters are within green box, then 10 min fill
  - If vehicle (X3, Y3, Z3) and station (A3, B3, C3) parameters are outside red box, then no fill
- Then, the vehicle and station provider knows if they design their system to meet these parameters, then they will know the performance range at each station



# Performance Based Fueling Protocol: Benefits



- Flexible: Will allow inter-operation of wide range of vehicles and stations
- Future proof: Does not limit future technologies (e.g., Type V CHSS or different nozzle designs)
- Feedback loops: Can modify fill based upon changing conditions
- No worst case scenario: Allows vehicle and station manufacturers to use their known design to optimize fueling
- Based upon real world conditions: Not defined by tables or equation
- Simpler: Fueling protocol will not need intensive on-board calculations
  - Lookup tables can be used ensure parameters are within **Red** “no fill” target
  - Station: Primarily needs to know capacity requested and station/ambient conditions
  - Vehicle: Primarily needs to know fueling rate range, precooling, and already knows vehicle/ambient conditions
  - Vehicle/Station manufacturers can do as simple or complex modeling as they want

# Fueling Protocols are “EASY”



- If we use a “**performance based**” fueling protocol, then “all we need to do” is
  - Determine rules, baseline performance, and vehicle/station size categories
  - Determine parameters which most affect fueling (i.e., sensitivity study)
  - Create “predictor” calculator that can be used by vehicle and station manufacturers
  - Use the calculator to define performance targets
- Similar to formula approach, but implementation different

# Contact



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