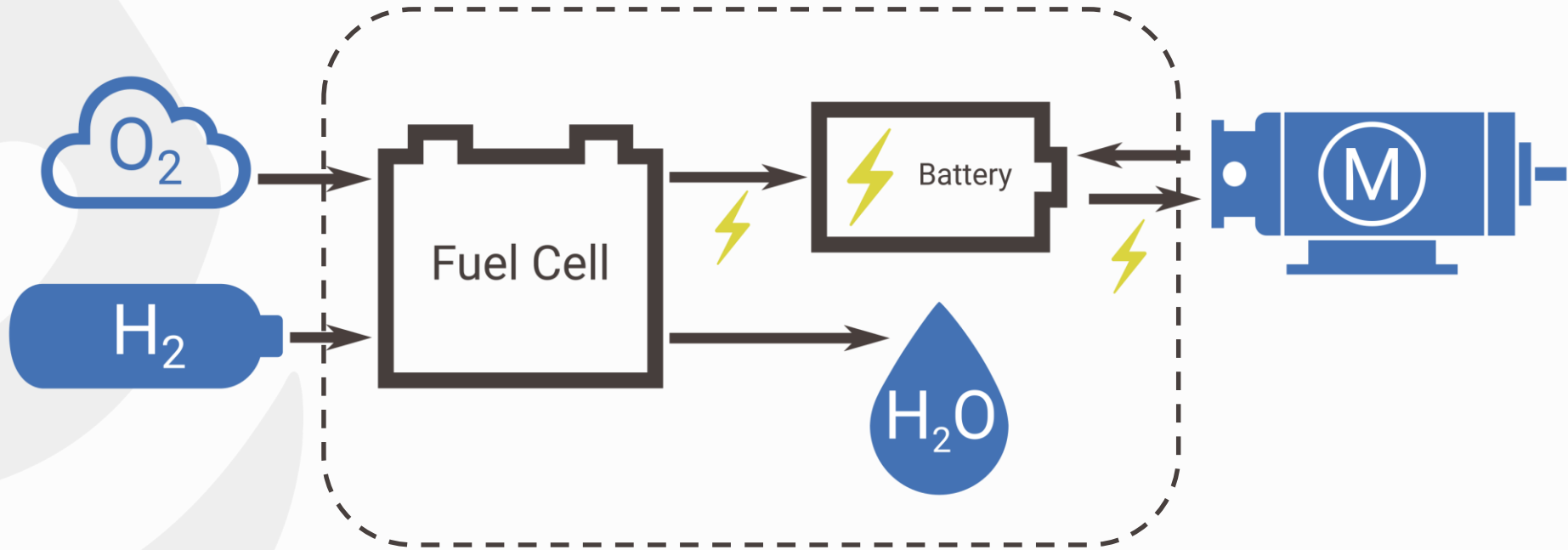




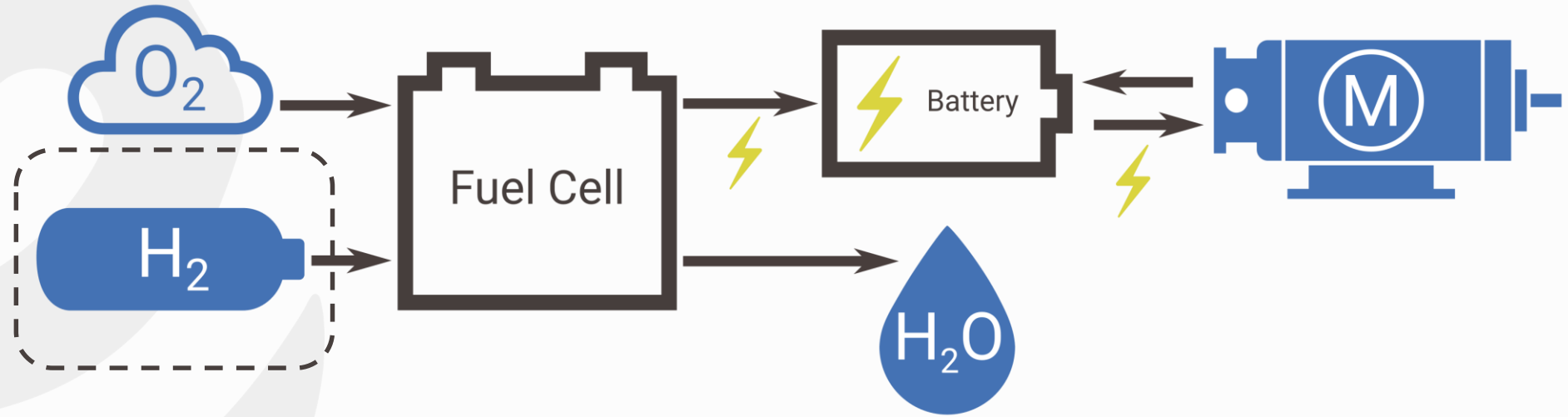
# The energy (storage) solution

Joost Kortleve

# Zepp | Hydrogen fuel cell system



# Energy storage



# Diesel: why do we use it?

- Low cost
- High volumetric energy density
- High energy density
- Fast refuelling time
- Simple storage requirements

# Diesel: we know the disadvantages...

- CO<sub>2</sub> emission
- NO<sub>x</sub>
- Particulate matter (fijnstof)
- Not renewable

	Diesel	Battery	Ammonia (NH3) (Fuel Cell)	Biofuel	Hydrogen (LH2) (Fuel Cell)
Energy efficiency (storage to electricity)	33%eff	90%eff	40%eff	33%eff	45%eff
Volume	1	9	2.5	1	3
Weight	1	27.5	2	1	0.25
CO2 emission	--	++	++	--	++
NOx	--	++	++	-	++
PM	--	++	++	-	++
Refuelling time	++	--	++	++	+
Resources	Not renewable	Little electricy, many material	More electricity	Food production	Electricity

	Diesel	Battery	Ammonia (NH <sub>3</sub> ) (Fuel Cell)	Biofuel	Hydrogen (LH <sub>2</sub> ) (Fuel Cell)
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# Challenge

- Cost: Fuel cell system
- Cost: Infrastructure

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- Cost: Fuel cell system
  - Answer: Production volume
  - DOE: 2018 cost (500k sys/yr) = 45 \$/kW = Diesel engine price
- Cost: Infrastructure
  - Answer: volume and energy storage
  - DOE: 2020 projection = 2 \$/kg = Diesel price (0.60 \$/L)

# Take away

- Hydrogen is a viable energy storage solution
- Challenge = cost → volume → competitive
- Technology is ready



So are we!

10000 L Diesel	Diesel	Natural gas (LNG)	Hydrogen (LH2)	Battery*	Ammonia	Biofuel
	33%eff	25%eff	45%eff	NCA, Tesla 3 pack, 20°C, 90%eff		
Density (kg/L)	0.83	0.43	0.07	2.55		
LHV (kWh/kg)	11.9	13.1	33.3	0.16		
Volume with efficiency	10,000	23,400	31,400	89,700		
Weight (kg) with eff	8,300	10,000	2,200	228,600		
Energy	32.9 MWh	32.9 MWh	32.9 MWh	32.9 MWh		
Charging power (kW)	12 000	12 000	6 000	80		

\*NCA, Tesla 3 pack,