LIGHTVEHICLE 2025

Hydrogen Tank Demonstrator

Composite Pressure Vessel for Fuel Cell E-vehicles

Dr. Michael Effing, AMAC GmbH

30-11-2021

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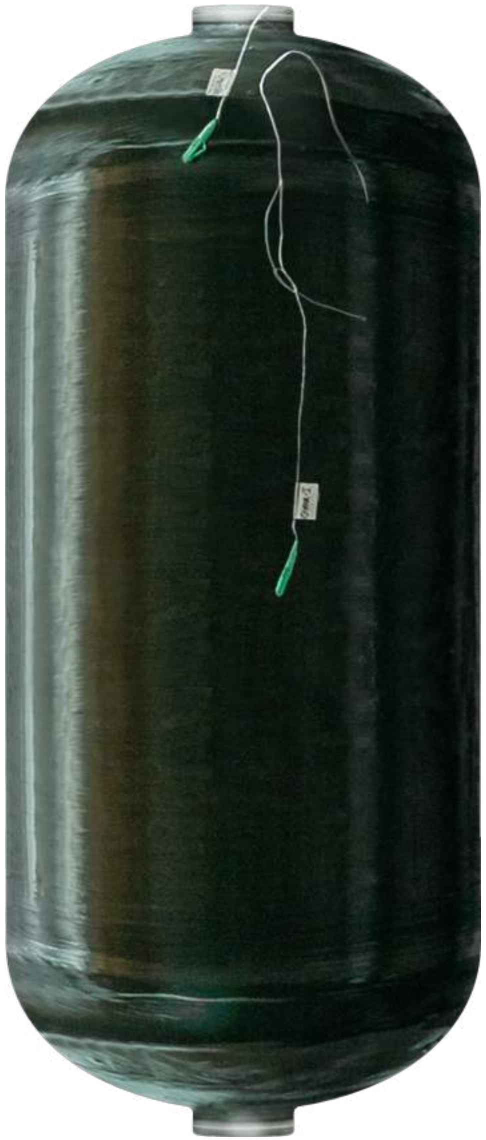
Demonstrator “H2Tank”



Demonstrator “H2Tank”

Dr. Michael Effing
AMAC

PARTNERS

CO-FINANCING PARTNERS

www.lightvehicle2025.eu

The Light Vehicle 2025 project is funded by the European Union within the framework of the Interreg VA programme Euregio Meuse-Rhine (European Fund for Regional Development).

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- High demanding application for EV with Fuel Cells (FCEV)
- Extreme pressures (700 bar). Requires carbon fibers for high strength and weight reduction.
- High volume production expected in 2025.
- Excellent capabilities for production and engineering in our Region EMR.

FCEV technology on New Hyundai

Source: Hyundai Nexo 2020 FCEV

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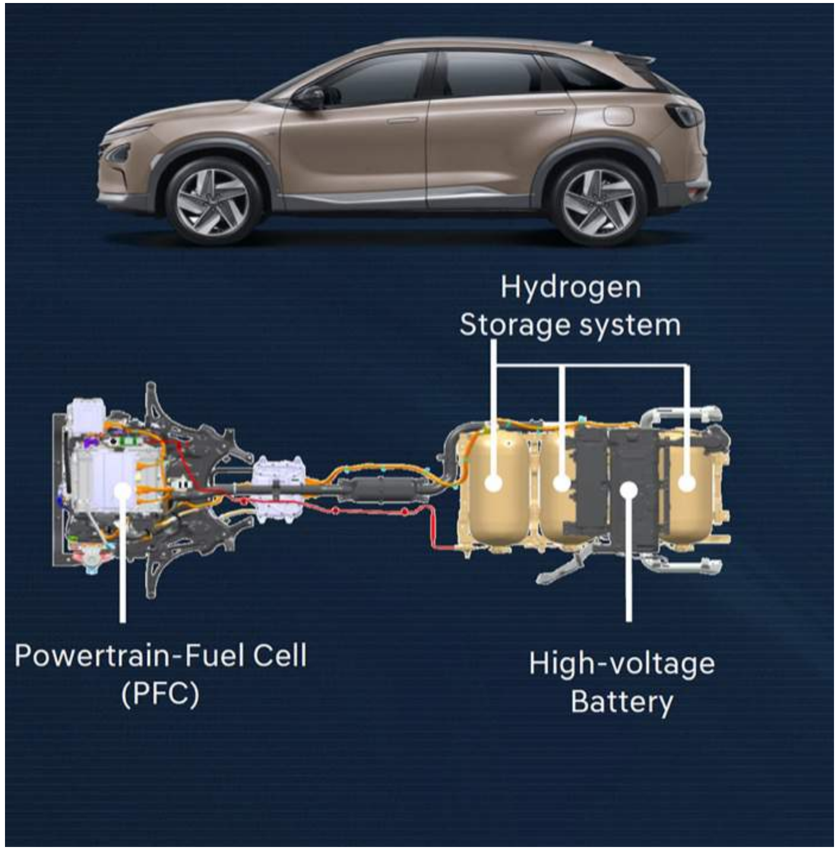
Characteristics:

- Car model: Hyundai Nexo
- Hydrogen tank Type IV (700 bar)
- Lifetime: 15 years
- Number of tanks per vehicle: 3
- Volume: 52 liters
- Capacity: 2kg of Hydrogen



Source: SAE International

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Future Targets for Hydrogen Pressure Vessels

No	Parameter	Unit	State of the art		FCH 2 JU Target		
			2012	International SoA 2017	2020	2024	2030
1	CAPEX- Storage Tank	EUR/kg H2	3,000	1,000	500	400	300
2	Volumetric capacity (at tank system level)	Kg/l	0.02	0.023	0.03	0.033	0.035
3	Gravimetric capacity (at tank system level)	%	4	5	5,3	5,7	6

Source: Hydrogen Europe

The cost for the CPV has to be reduced significantly for mass production

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Objective of Demo Project

Hydrogen technologies are in the early stage of market introduction. They store hydrogen at very high pressures of 700 bars for Fuel Cell driven EV (electric vehicle) the first generation is using thermoset filament winding with standard T700 carbon fiber.

The goal of this Project is:

- To further reduce the weight by another 15% using a new higher strength carbon fiber from Mitsubishi and secondly, we like to reduce the cost by using a high filament count of 30K versus a standard of 18K.
- Today liners are made in the traditional injection blow molding Process with high volumen Production. This causes a lot of extra cost for storage and handling.

Our overall target is to demonstrate 15-20% weight saving and also lowering the cost by 20%.

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Partners

- Mitsubishi Chemical
- Key Contact: Denis Boahene
- Webpage: www.eu.mitsubishi-chemical.com
- Email: denis.boahene@mccfc.eu
- Main Resposibility: Material Supplier

- Plastic Omnium
- Key Contact: Axel Seifert
- Webpage: www.plasticomnium.com
- Email: axel.seifert@plasticomnium.com
- Main Resposability: Prototyping and Testing

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Partners

- AMS
- Key Contact: Johan Portangent
- Webpage: www.ams-innovation.com
- Email: johan.potargent@amsbelgium.com
- Main Resposibiliy: Manufacturing of Liners

- 2C-Composites
- Key Contact: Thomas Bäumer
- Webpage: www.2c-composites.de
- Email: t.baeumer@2c-composites.de
- Main Resposibility: Engineering

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Partners

- Conbility
- Key Contact: Kamran Samaie
- Webpage: www.conbility.de
- Email: kamran.samaie@conbility.com
- Main Resposibility: Costing Study

- AMAC GmbH
- Key Contact: Michael Effing
- Webpage: www.effing-aachen.de
- Email: amac@effing-aachen.de
- Main Resposibility: Project Management

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Partners and Targeted OEMs

Engineering/ Cost Analysis	Raw Materials	Equipment/Tooling	Tier 1/ 2	OEM / external	Project Mgmt.
• **P.O./ B** • **2C-C/ D** • **AMS/ B** • **Conbility/D**	• **Mitsubishi/ D** • **AMS/ B** • **P.O./B**	• **P.O./ B** • **2C- C/ D** • **AMS/ B**	• **P.O./ B**	• **E.Go/ D** • **Toyota/ B** • **Hyundai/ D** • **Ford/ D** • **Daimler/ D** • **Etc.**	• **AMAC/ D**

Note: 2C-C/D= 2C- Composites/ D

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Scope of the Project

- 10 Hydrogen tanks Type IV 52 liter (as for Hyundai Nexo) will be fabricated
- 2 modifications on the liner → Blow Molding vs Rotor Molding
- Innovation in liner modification: 2 layer system by combining different materials (PE, PA)
- 2 different carbon fibers types: 18K vs the new 30K carbon fiber for cost/ performance optimisation
- Pressure Vessel (CPV) will be tested at 1050 bar, 700 bar @ 1.5 safety factor
- In addition, 2 benchmarking studies will be conducted
  - Manufacturing of the liner: Pro/ Con for Rotor Molding vs. Blow Molding
  - Winding Process: Thermoplastic tape vs Thermoset epoxy filament winding

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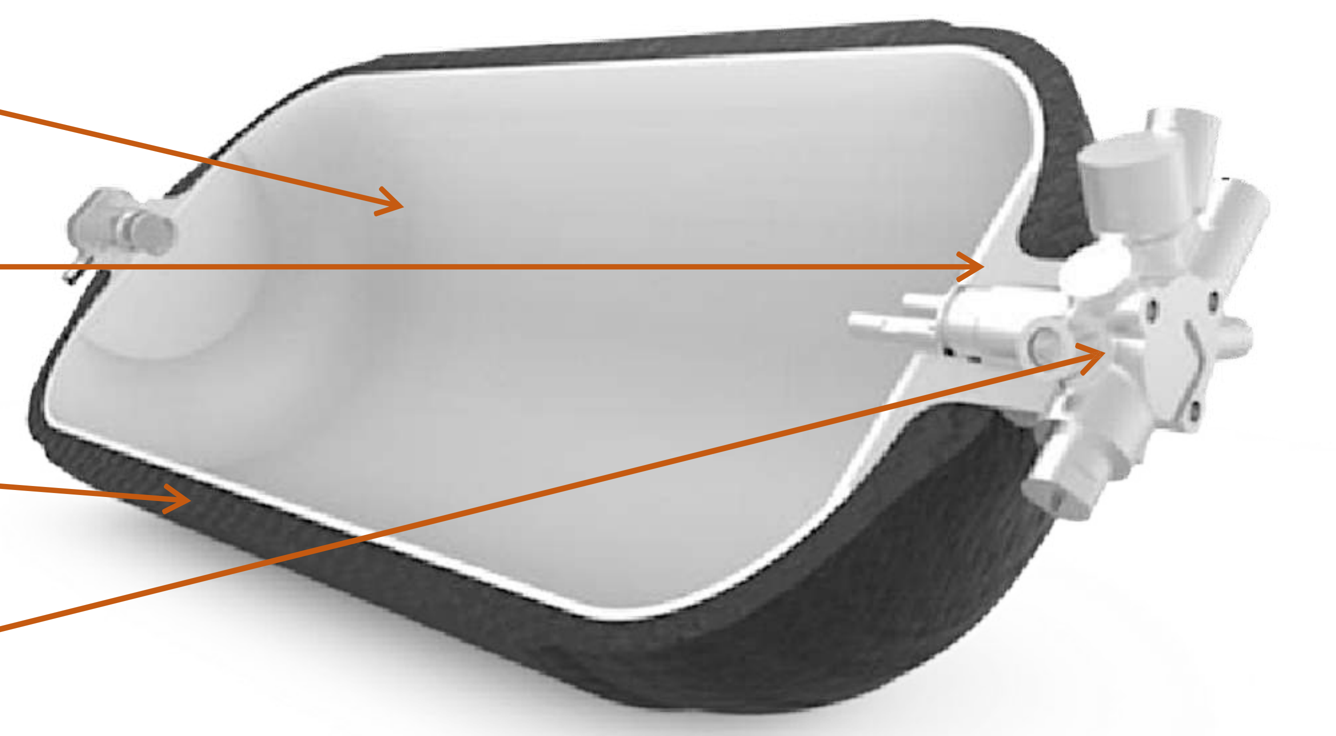
Composite Pressure Vessel Structure

LINER
Permeation Barrier

METALLIC BOSS
Load Transfer & Tightness

CFRP-LAMINATE
Mechanical resistance

ON-TANK VALVE
Pressure relief and safety



Source: Plastic Omnium

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Deliverables: 10 CPV

Source: Plastic Omnium

Fiber Type	With Blow Molded Liner	With Rotomolded Liner	With Rotomolded Liner (PE/PA)
CF 18 K (TRH50 18M)	2	2	1
CF 30 K New (TRH50 30M)	2	2	1
Total CPV :	**4**	**4**	**2**

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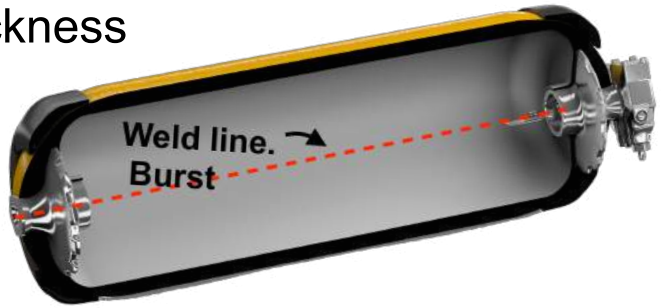
Back-up: Liner Technology

- Liner Concept Blow Molding vs Rotor Molding

Criteria	Blow Molding	Rotor Molding
Choice of Materials	PP, PE	All polymers (PP, PA, PE, combinations)
In-line vs Off-line	Separte to CPV Production. 2-3 min per liner. This Process creates stock	In line with vessel Production. 20-30 min just in time 80ºC of mould. No stock
Shape (thickness)	Constant thickness (4-6 mm) 	No burst/ Weld line Various thicknesses
Investment for tool	High	1/3 low of blow mould tool

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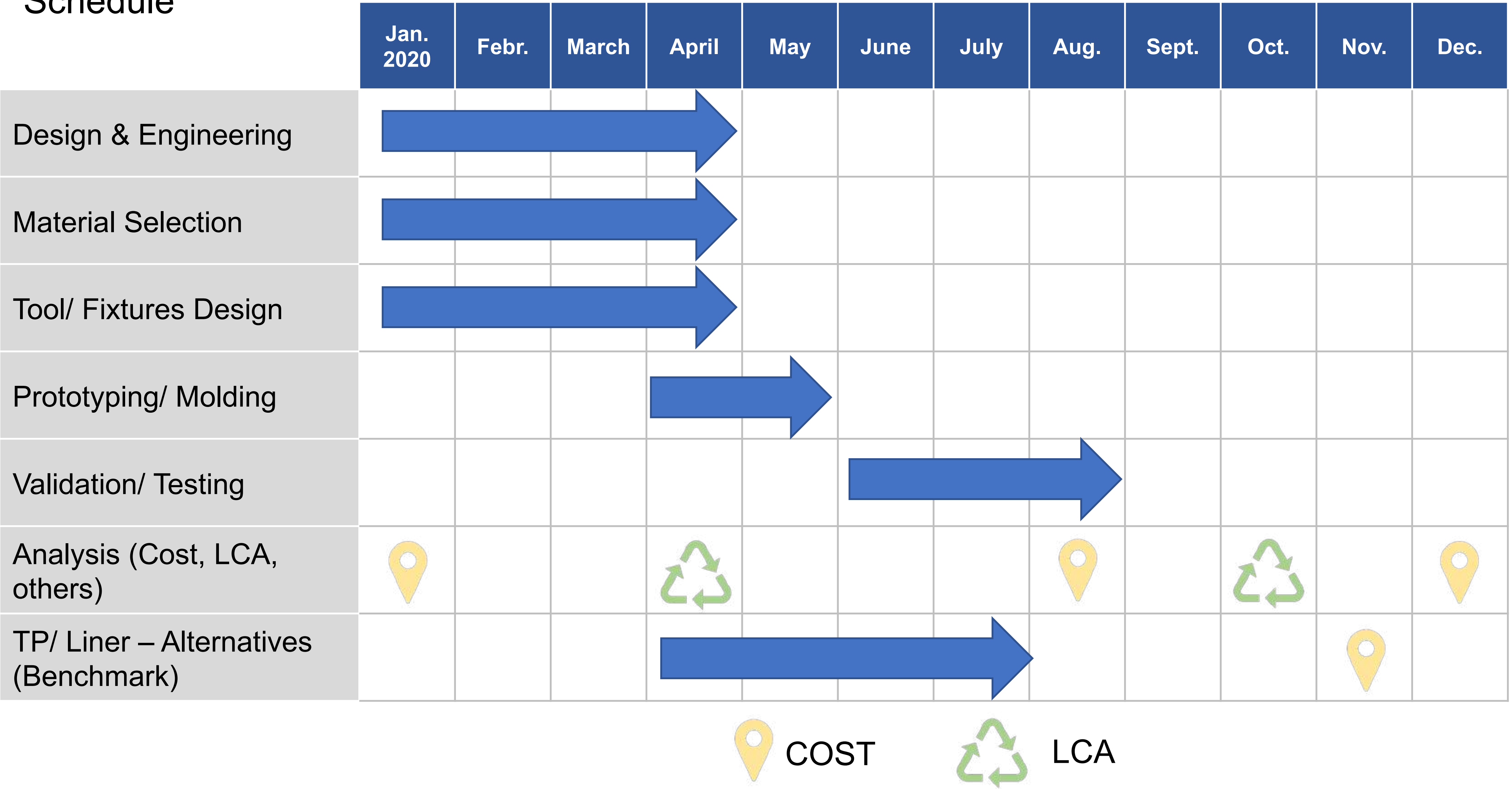
Schedule



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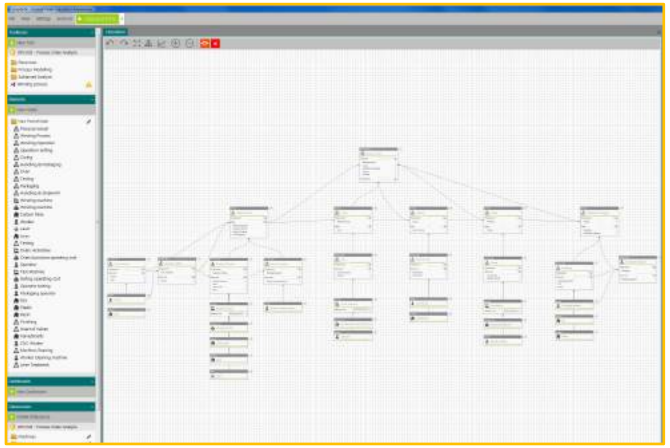
Cost & Process Modeling

- Cost modeling with OPLYSIS software tool
- OPLYSIS supports companies to evaluate, identify and implement cost-efficient lightweight production technologies.



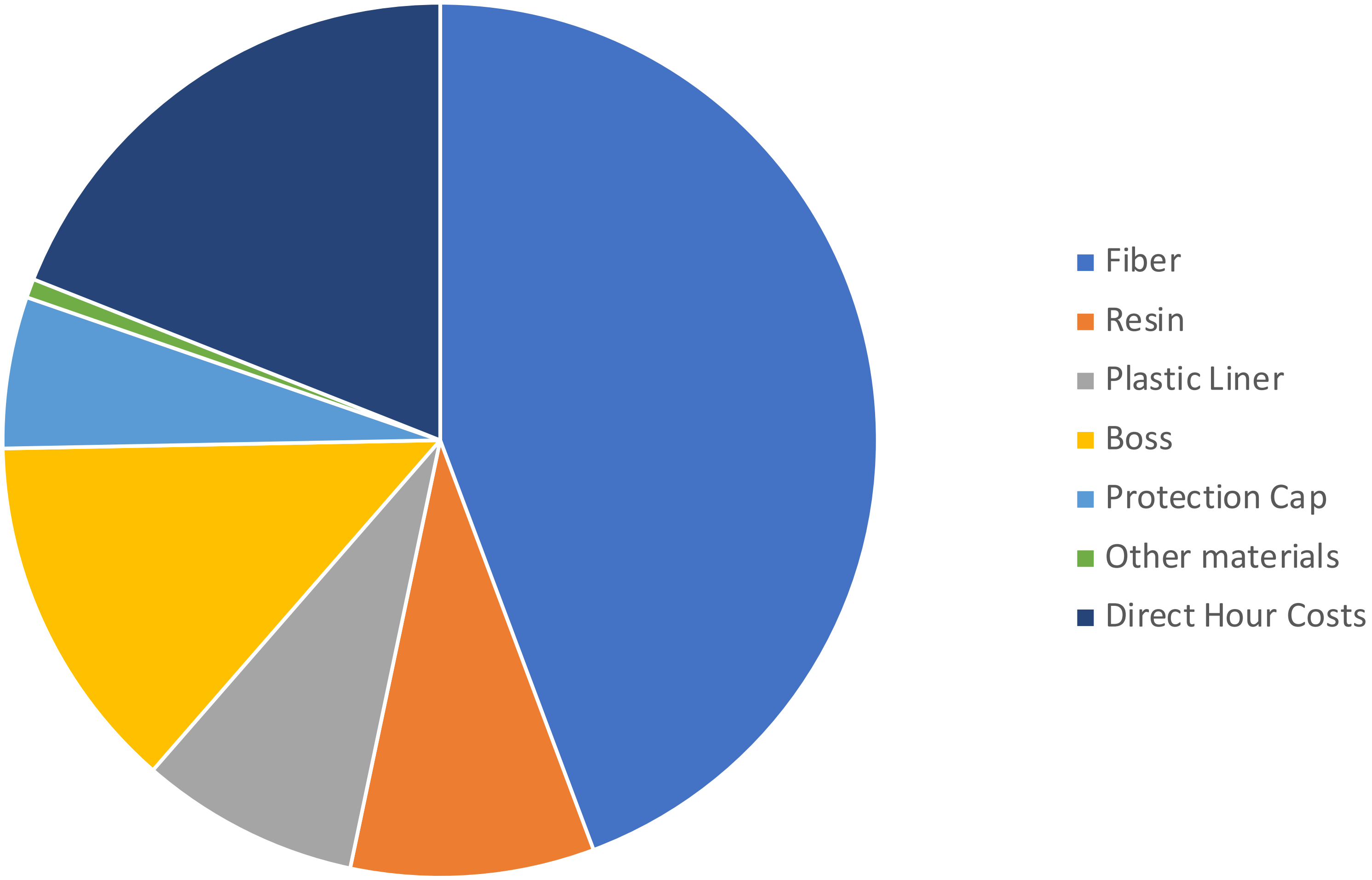
The intuitive drag & drop interface of our job costing software OPLYSIS® allows creating process chains in minutes.

Link: http://conbility.de/geschaeftsbereiche/2-costing-software/?lang=en

Examine your current production with a multitude of analysis functions and find hidden costs in your processes.

Simulate alternate production scenarios by varying process elements or resources within seconds and use to e.g. assess investments.

Cost Structure Pressure Vessel



Potentials for Pressure Vessel Development

- Optimised of the laminate
- Targeted pole cap reinforcement
- Increased throughput through the use of towpregs
- Optimised Liner and Boss

Conclusion: there is still much to do

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Hydrogen Manufacturing process and testing procedure

Extrusion blow-molding
Robotic winding

Proof tests up to 1050 bar
Burst tests up to 2000 bar
Extreme temp. cycling

Permeation
Extreme temp. cycling
Fueling / Defueling

Source: Plastic Omnium

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Laminate Sequence

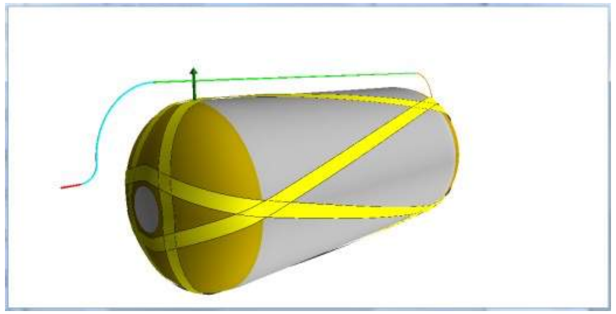
Tank/Vessel Laminate

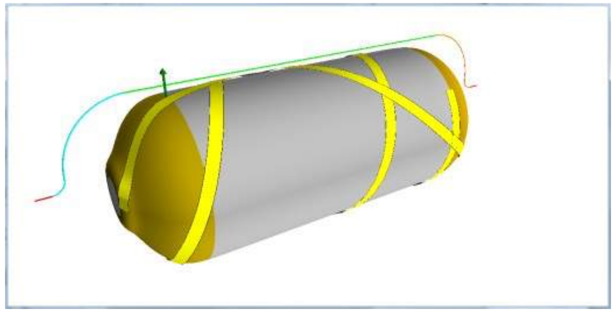
	Lamina	Error	Description	WA (deg)	BW (mm)	Thickness (mm)	Weight (kg)	Time (min)	Cost (€)	OD (mm)
1	Circ		SP=0.00mm, EP=578.30mm	88.52	25.50	2.449	2.24		0.00	319.50
2	Connector		Auto Stop : Auto Stop			0.000	0.08		0.00	319.50
3	Helical		NC=43, R=+4, HP=111.00mm, TP=111.00mm	13.90	23.00	0.918	1.42		0.00	321.33
4	Helical		NC=44, R=+17, HP=111.00mm, TP=111.00mm	13.80	23.00	0.913	1.47		0.00	323.16
5	Helical		NC=74, R=+23, HP=118.50mm, TP=118.50mm	21.50	23.00	1.587	2.53		0.00	326.33
6	Helical		NC=47, R=+22, HP=111.00mm, TP=111.00mm	12.50	23.00	0.916	1.61		0.00	328.17
7	Connector		Auto Stop : Auto Stop			0.000	0.08		0.00	328.17
8	Circ		SP=576.30mm, EP=2.00mm	88.58	25.50	2.449	2.26		0.00	333.06
9	Connector		Auto Stop : Auto Stop			0.000	0.07		0.00	333.06
10	Helical		NC=43, R=-9, HP=130.16mm, TP=130.16mm	23.00	23.00	0.909	1.51		0.00	334.88
11	Helical		NC=46, R=-3, HP=114.00mm, TP=114.00mm	13.20	23.00	0.915	1.60		0.00	336.71
12	Helical		NC=47, R=+22, HP=116.00mm, TP=116.00mm	13.20	23.00	0.910	1.64		0.00	338.53
13	Helical		NC=44, R=+21, HP=132.28mm, TP=132.28mm	23.00	23.00	0.915	1.58		0.00	340.36
14	Connector		Auto Stop : Auto Stop			0.000	0.04		0.00	340.36
15	Helical		NC=41, R=-11, HP=200.66mm, TP=200.66mm	36.00	23.00	0.914	1.53		0.00	342.19
16	Connector		Auto Stop : Auto Stop			0.000	0.09		0.00	342.19
17	Circ		SP=572.30mm, EP=6.00mm	88.65	25.50	1.632	1.53		0.00	345.46
18	Connector		Auto Stop : Auto Stop			0.000	0.07		0.00	345.46
19	Helical		NC=43, R=-15, HP=162.65mm, TP=162.65mm	28.00	23.00	0.911	1.56		0.00	347.28
20	Helical		NC=38, R=-7, HP=214.42mm, TP=214.42mm	38.00	23.00	0.920	1.47		0.00	349.12

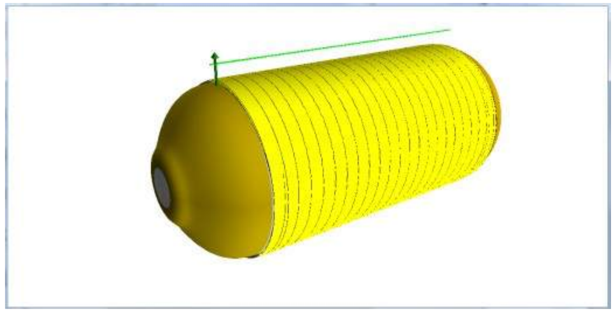
Original Mandrel

	Headstock		Cylinder		Tailstock	
Diameter	72.00		314.60		72.00	mm
Position	-94.30	0.00		578.30	672.60	mm

Total Thickness	22.61	mm
Total Weight	30.94	kg
Total Winding Time		min
Total Material Cost	€ 0.00	







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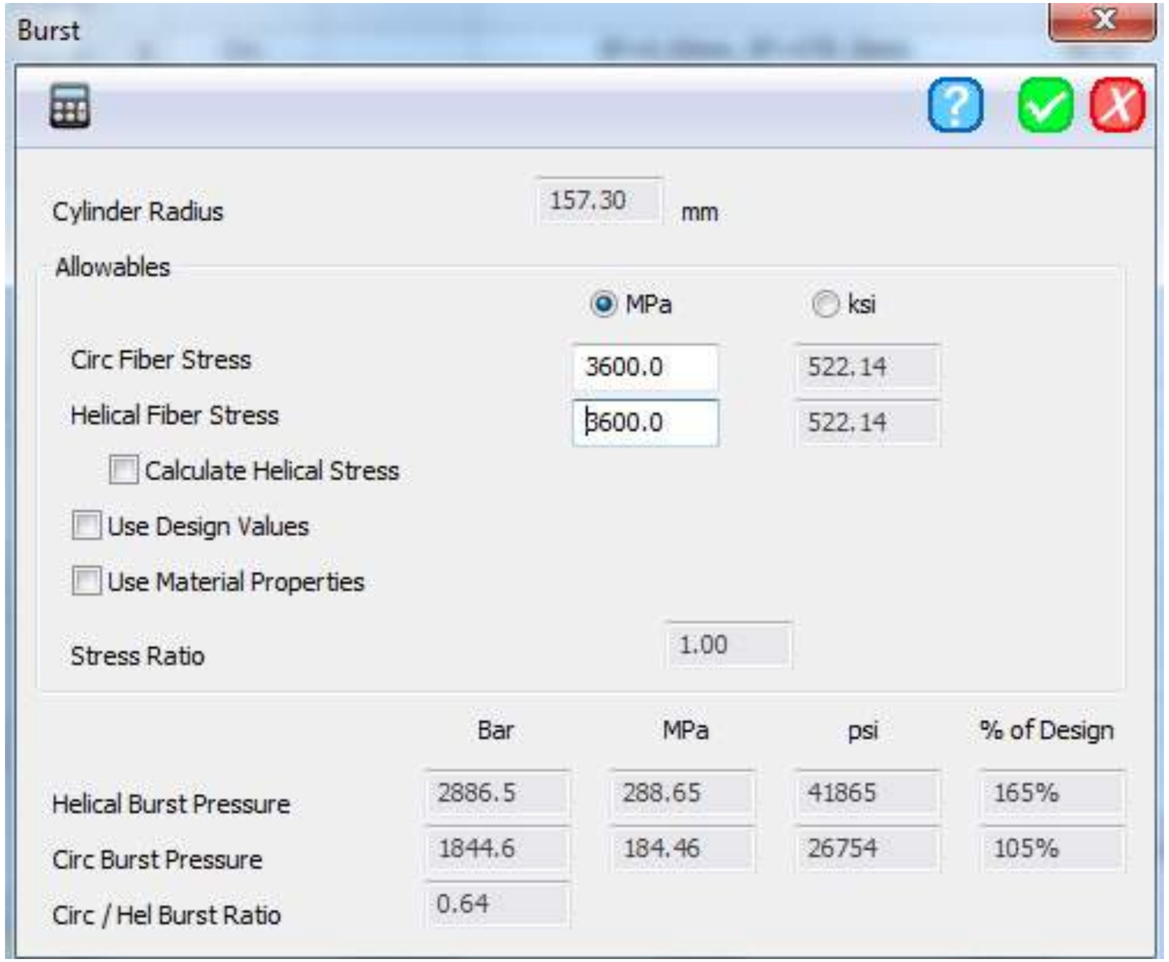
Estimated Burst Performance



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Laminate optimization on 50L vessel

Burst : Dome section

Burst : Cylindrical section

Laminate optimization on 50L vessel

- Burst testing on 50L vessels
  - Burst 5: 1747 bar, cylindrical section

  - Good burst result
  - Laminate thickness is larger than expected

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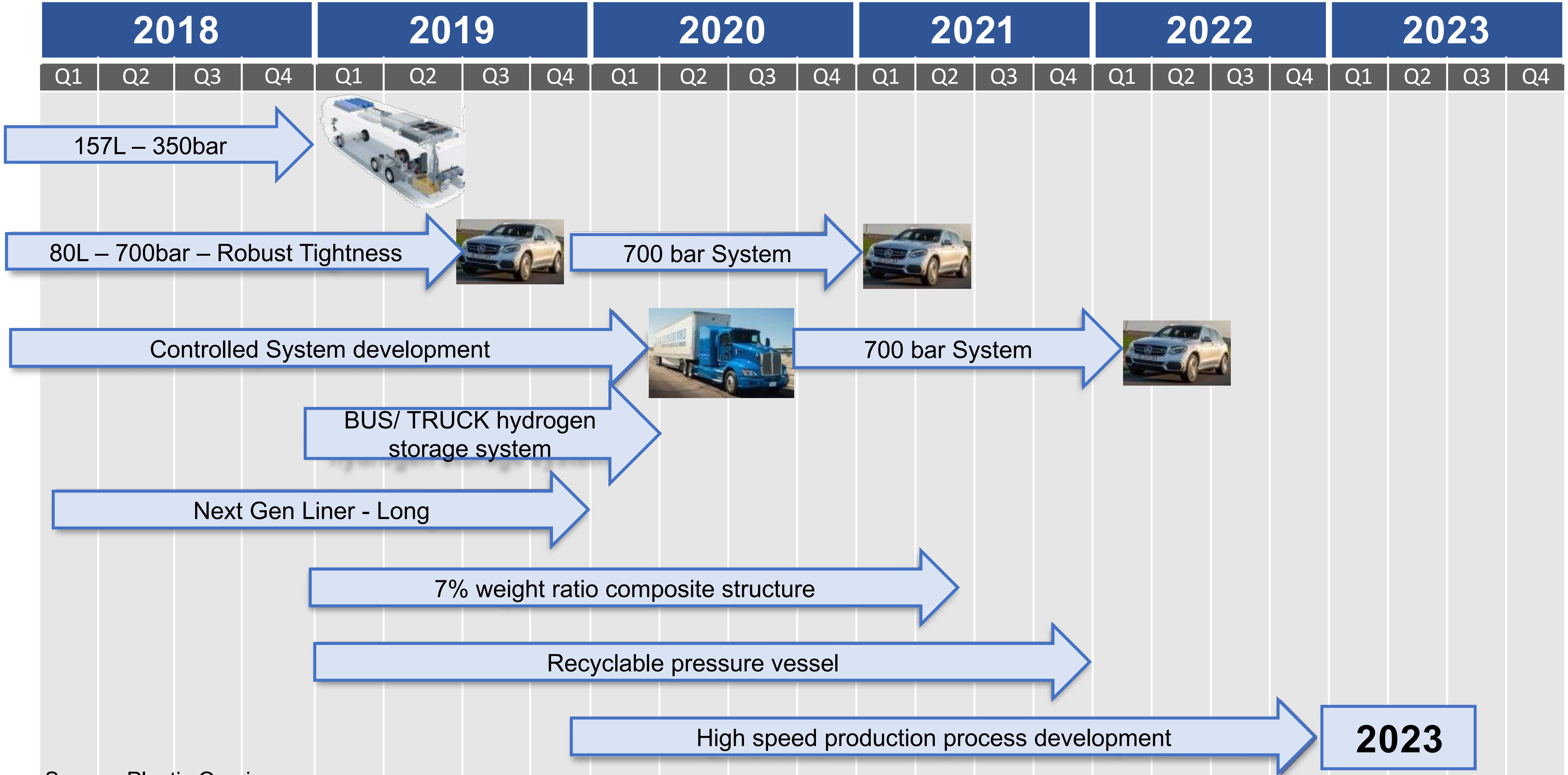
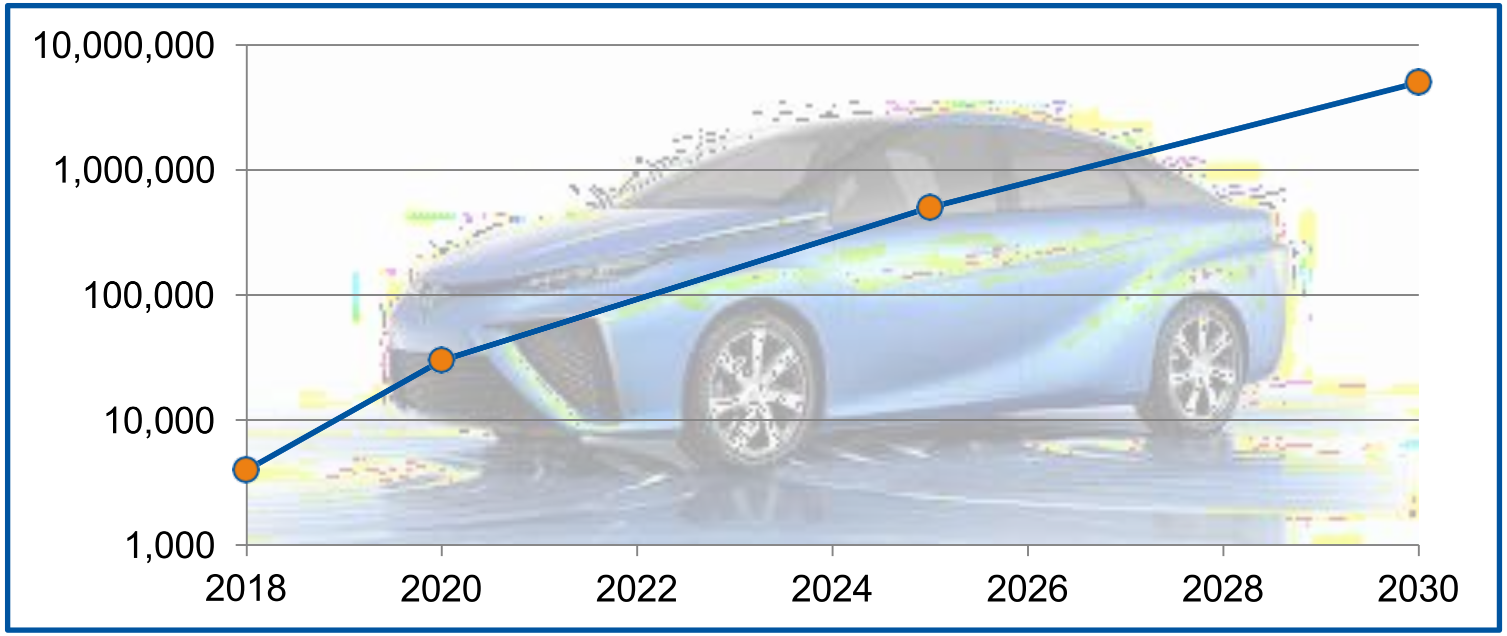
Plastic Omnium Vessel technology Roadmap



Source: Plastic Omnium

Possible market evolution for the yearly production of FCEV's (world-wide)

- 2018:
  - Several premium cars on the roads
  - Estimated yearly production of a few thousand units, mainly by Japanese and Korean manufacturers
- 2020:
  - Start of small series for OEM pilot projects (US & EU)
  - Fast start production : China, Japan, Korea
  - Tokyo Olympics involves TOYOTA as major sponsor to promote FCEV's
- 2025:
  - EU, US and Asian car makers foresee significant increase in production and sales
  - China, Japan and Korea remain the main markets
- 2030:
  - Out of the 100 million passenger cars produced world-wide, 30% might be full-electric (BEV + FCEV) in order to meet the targets related to the reduction of CO_2 emission
  - Studies by leading organizations (e.g. Hydrogen Council, Hydrogen Europe, …) estimate that up to 5 million FCEV's might be produced every year



Source: Plastic Omnium

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Main Risk: Carbon Fibre requirements for automotive applications

- ± 10 kg of Carbon Fibres are required to store 1 kg of Hydrogen
- Today‘s FCEV‘s store 5 kg to 6 kg of Hydrogen
- 5.000.000 FCEV‘s would require around 250.000T of Carbon Fibre
- Today‘s annual worldwide production is only 80.000T, of which more than 60% is used for areospace and wind power applications

Source: Plastic Omnium

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Conclusion

- Around 9% better performance than standard fiber (e.G. T700)
- Nominal performance is 14% more than standard fiber (5600MPA vs 4900MPA) which leads to believe that further optimization is possible by adjusting the processing parameters
- Further technical validation should include:
  - Cycle testing
  - Permeation
  - Low temperature behavior of liner

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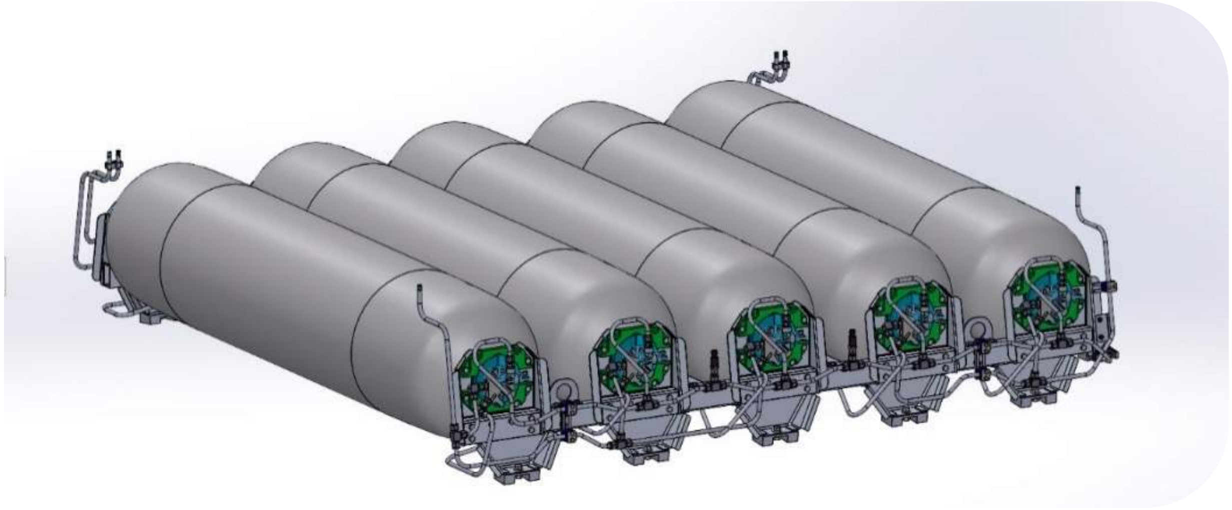
Project - Major German OEM

- Plastic Omnium will supply 6 certified tanks, system at the top of the bus
- Tanks certified in 2020
- New Facility – fully certified, in Belgium



Growing market through European funding

THANK YOU

DRINKS UNTIL 15:30 HOURS