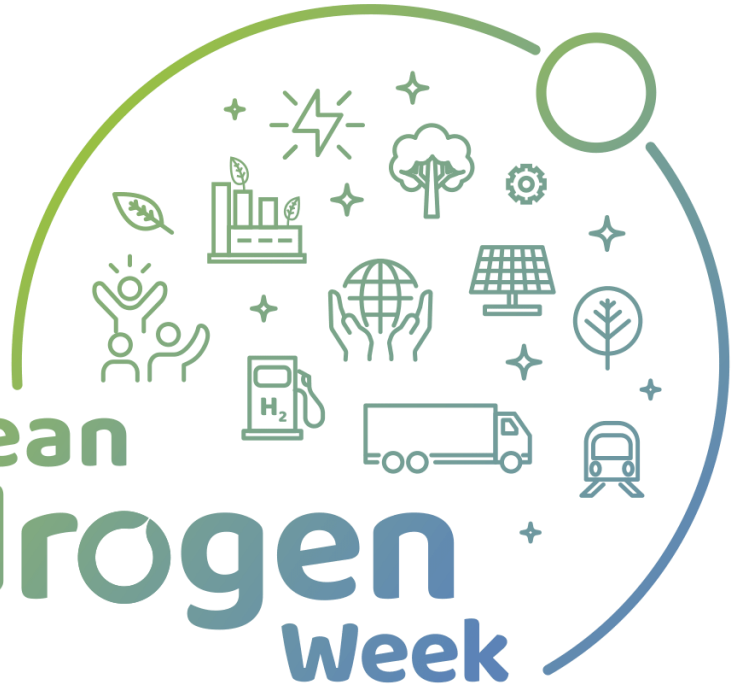
Thermo plastic Hydrogen tank Optimized & Recyclable



Denis RAGOT

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THOR project

JTI-FCH-2018-1-3 – 826262

Thermo plastic Hydrogen tank Optimized & Recyclable

Strengthening of the European supply chain for compressed storage systems for transport applications

Coordinator: **FAURECIA**
Speaker: **Denis RAGOT**

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Internal & Partners

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The project

Call reminder:
2,7 M€ - RIA

- Prepare the H2 market increase for compressed Hydrogen tanks
- Broaden the number of players (tier1 & 2 suppliers) for high pressure H2 vessels
- Decrease the storage costs and increase the performances of the tanks

Consortium response:
2,85 M€, 36+9 months

- Propose a new **thermoplastic H2 tank** technology to allow the recyclability
  - ➢ Solution which could be used for transportation
- Investigate the thermo plastic technology to ensure that it could be applied for high pressure H2 storage systems
- Estimate the manufacturing plant to respond to a 30,000 tanks per year

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The project Consortium

Industrial & Technical partners

- **Faurecia**, France - coordinator,
  - Industrialisation & mass production aspect
- **Air Liquide**, France
  - End user for high pressure Hydrogen distribution
  - Expertise for the fuelling/defueling
- **CETIM**, France
  - Process definition with laser Assisted Tape Winding
  - Modelling and prototyping of tanks
- **CETIM Grand Est**, France
  - Recycling process
- **RINA-CSM**, Italy
  - Testing facilities of tanks

Research partners

- **SIRRIS**, Belgium
  - Modelling, winding definition and optimization
- **NTNU**, Norway
  - Optical fiber instrumentation, data analysis
- **CNRS – PPRIME**, France
  - Thermomechanical modelling and material behaviour in fire

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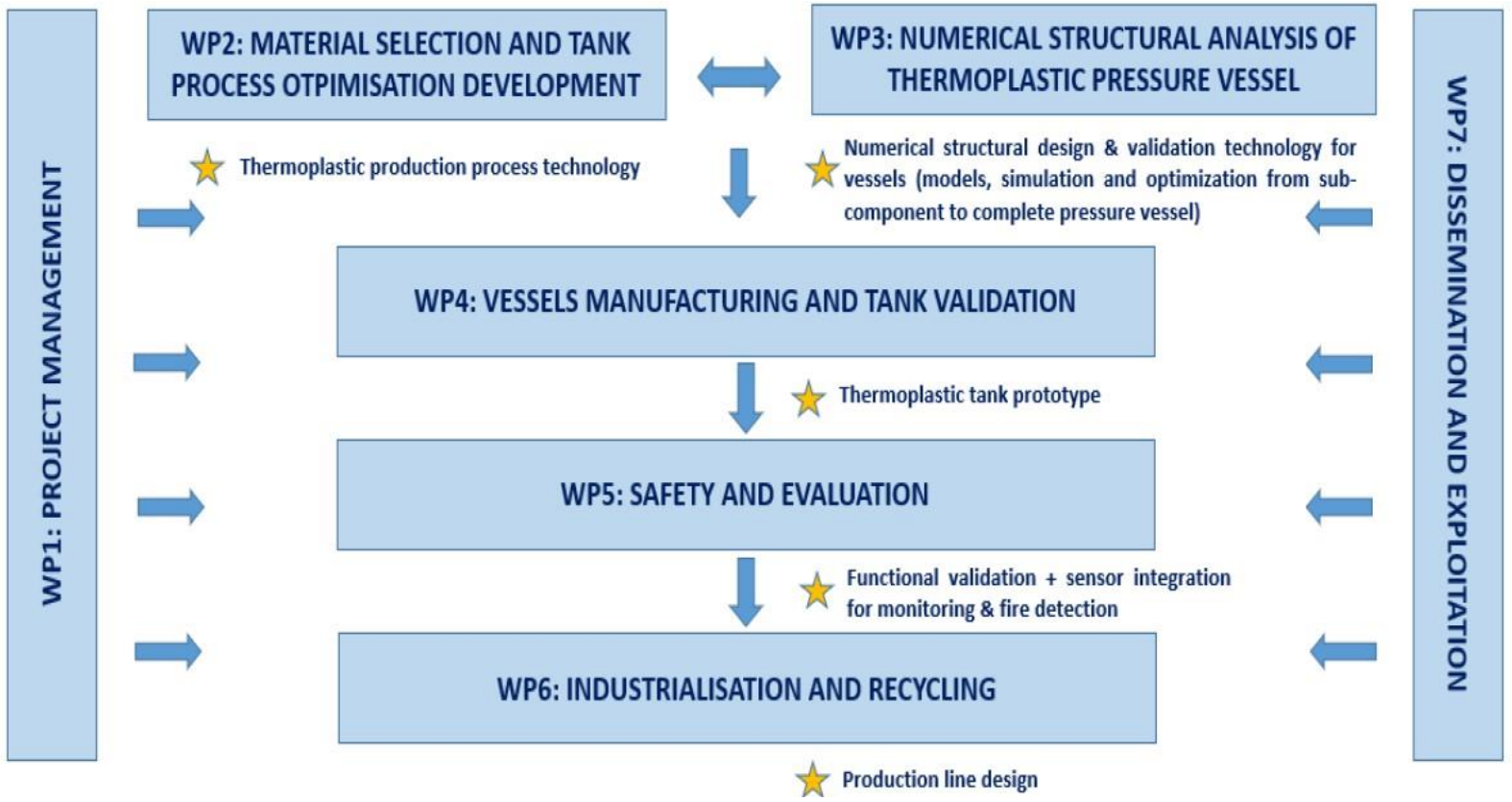
The work plan



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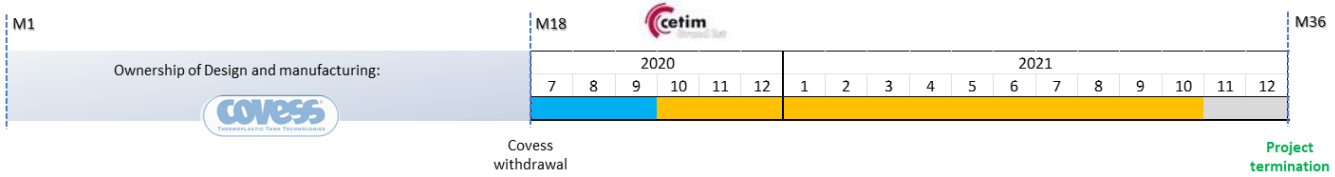
The project overview



Technical side

- Thermoplastic solution was not used for high pressure gaseous H2 storage
  - Materials had to be selected (PA11 & PA12 tapes with PA11 liners)
    - 6 different tapes used
  - Design to be adapted (based on a 63l inner volume tank, 2 type of liners)
  - Winding process with tow preg to be used

Project run out

- CO2 issues
  - COvid has slowed down the project
  - COvess, which was initialy in the Consortium, decided to leave the project
    - Consortium had to redo completly the work and the material selection

<u>-> +9 months accepted by Project Officer</u>

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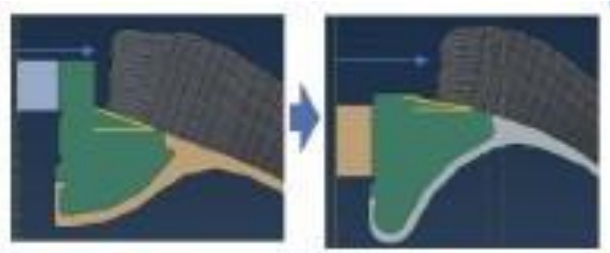
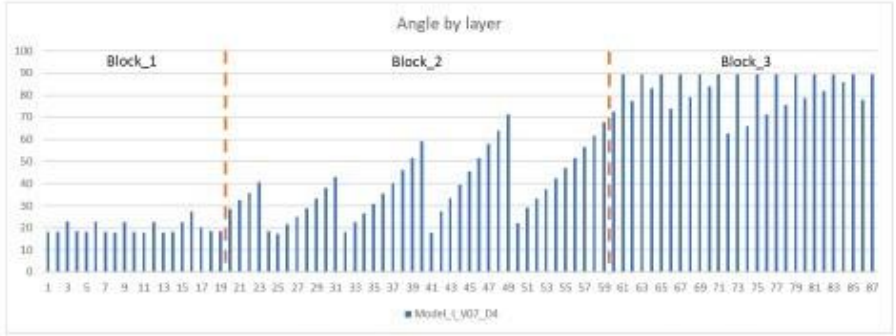
The project results - WP2 & 3

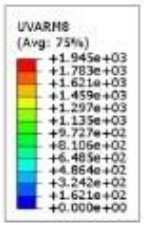


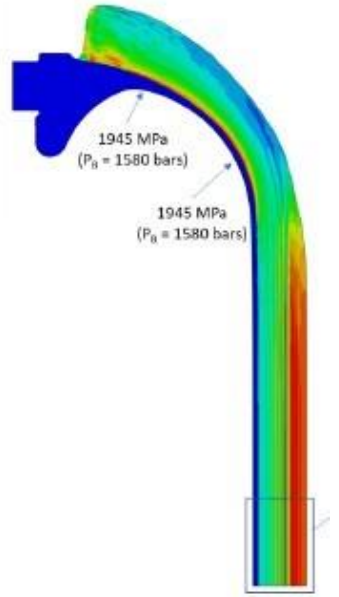
Boss optimization

Tank design, modeling *SIRRIS*

- Woundsim & Abaqus used for the winding pattern & bosses optimization
- Correlation with iterative experimental results has shown that out-of-plane stiffness value is of prime importance to predict the burst value and the failure mode (also seen with CETIM software Optitank)
- New design was optimized to respect the expected performance (1575 Bars minimum burst pressure)







	#layers	Weight	Pburst (bar)					
	(-)	(kg)	End (Top-Boss)	Dome_1	Dome_2	Cylinder_1	Cylinder_2	GLOBAL
Model H3	82	52,62	1648	1476	1507	1454	1510	**1476**
Model_I_V05	82	52,27	1639	1585	1533	1729	1451	**1451**
Model_I_V06_A	78	48,40	1614	1517	1517	1504	1508	**1504**
Model_I_V06_V2	84	53,61	1699	1558	1558	1565	1557	**1557**
Model_I_V07_D4	***87***	55,91	1731	***1580***	***1580***	***1596***	***1582***	**1580**

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The project results - WP4

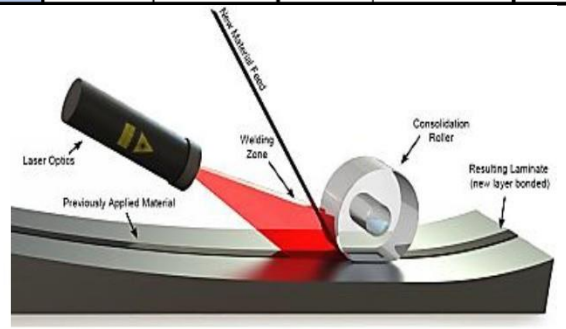
Tank #	Liner		Tape		Stacking model
	Material	Type	% CF	Matrix mate	
#C1	PA11	Hyphone	55	PA11	F - 74 layers
#C2	PA11	Hyphone	55	PA11	F - 74 layers
#C3	PA11	Hyphone	55	PA12	F - 74 layers
#C4	PA11	Hyphone	57	PA12	G - 82 layers
#C5	PA11	THOR	57	PA12	G - 82 layers
#A6	PA11	THOR	57	PA12	G - 82 layers
#A7	PA11	THOR	57	PA12	G - 82 layers
#A8	PA11	THOR	57	PA12	G - 82 layers
#A9	PA11	THOR	57	PA12	G - 82 layers
#A10	PA11	THOR	57	PA12	G - 82 layers
#A11	PA11	THOR	57	PA12	G - 82 layers
#A12	PA11	THOR	57	PA11	G - 82 layers
#A13	PA11	THOR	57	PA11	G - 82 layers
#A14	PA11	THOR	57	PA11	G - 82 layers
#A15	PA11	THOR	57	PA11	G - 82 layers

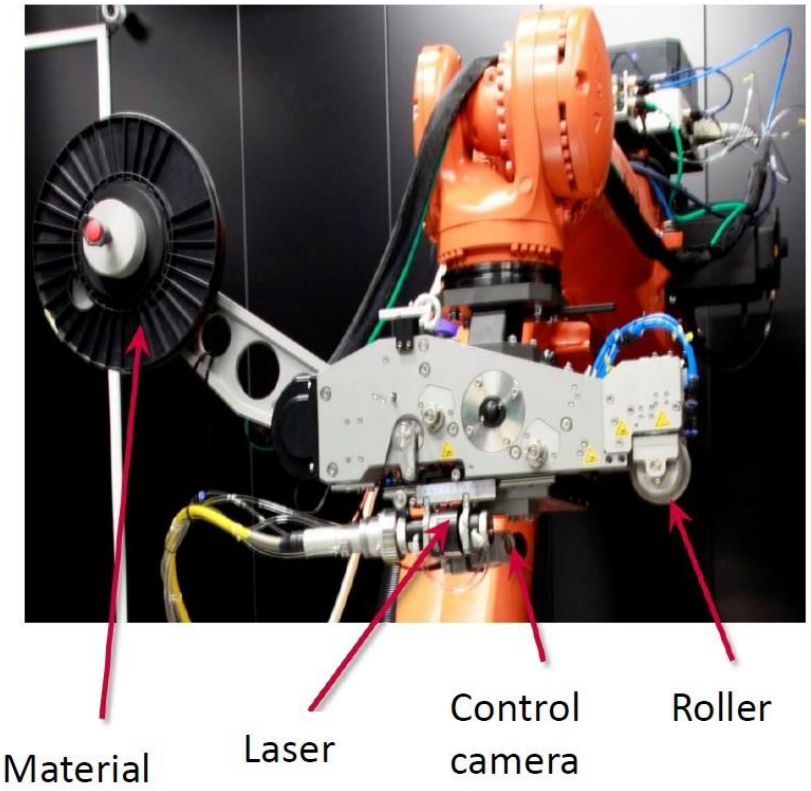
Tank manufacturing *CETIM*

Process: Automated Laser Placement

- Process parameters optimized to enhance the production time & the composite cohesion
- 2 different means used (new one from tank#6)
- Total of 15 tanks produced

→ Boss design was adapted to the head trajectory (new liner from tank#5)





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The project results - WP5

Testing & validation *RINA-CSM*

Burst, ASR, ATPC & ETPC testing devices

- 7 burst tests done
  - 1 burst on tank equiped with strain gages
  - 1575b never reached, with burst always in the dome

  → **No acceptance to perform H2 tests**
- ASR tests on 2 tanks (last one still on going)
- ATPC test stopped at 1836 cycles
- ETPC test on going

→ **Good first experience on testing for pressure vessels**

Tank #	Test target	Results
#C1	Burst 1575b	NOK - 738,3b
#C2	ASR + Burst	NOK - 350b
#C3	Burst 1575b	No test
#C4	Burst 1575b	NOK - 1466,3b
#C5	Burst 1575b	NOK - 1476,2b
#A6	Burst 1575b	NOK - 1250b
#A7	ATPC- 22kcycles RT	NOK - 1836 cycles
#A8	ASR & Burst	Ongoing
#A9	Burst 1575b	NOK - 1198b
#A10	ETPC	Canceled
#A11	H2 fuelling/defueling	No H2 tests
#A12	Burst 1575b	NOK - 1371b
#A13	Bone fire tests	No H2 tests
#A14	Bone fire tests	No H2 tests
#A15	Bone fire tests	No H2 tests

Example of burst test

Tapes characterization *CETIM*

- New tools developed to characterize tapes
- Specifications for tapes more complete

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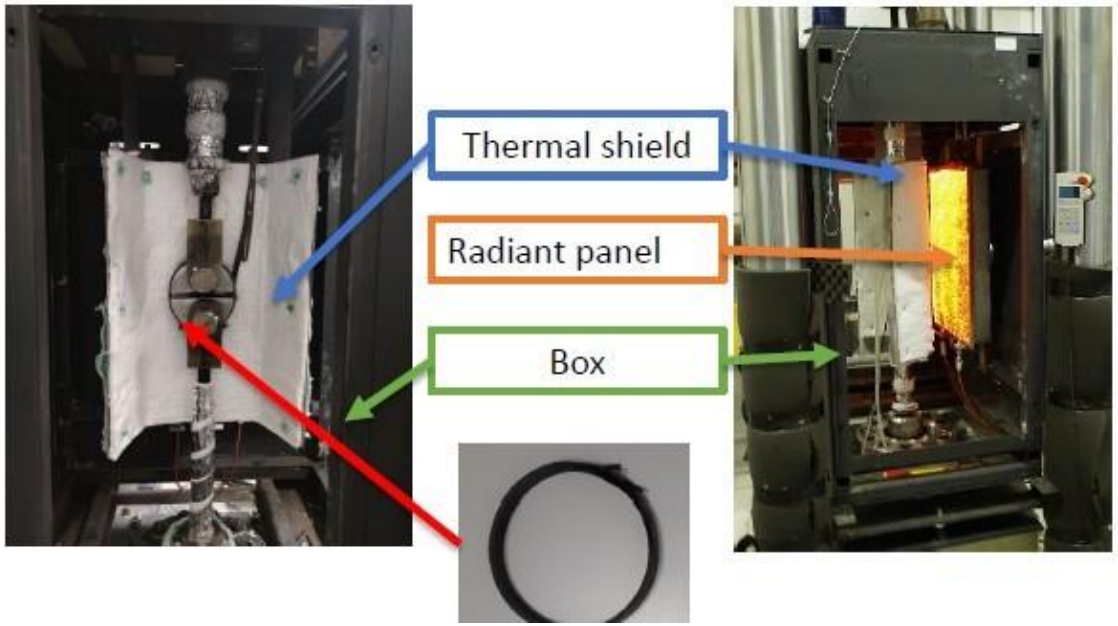
The project results - WP5

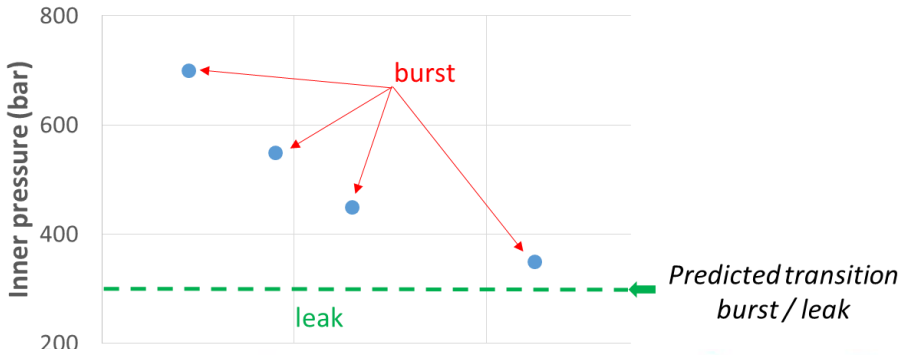
Safety & fire characterisation *CNRS*

Develop a numerical approach to predict fire resistance of tanks

- Development of testing means to measure mechanical performance of composite in fire
- Model developed at tank scale with new measured data and material degradation factors

→ No full correlation possible as no bone fire tests were performed





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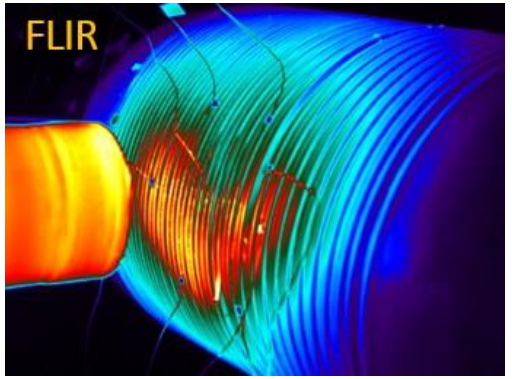
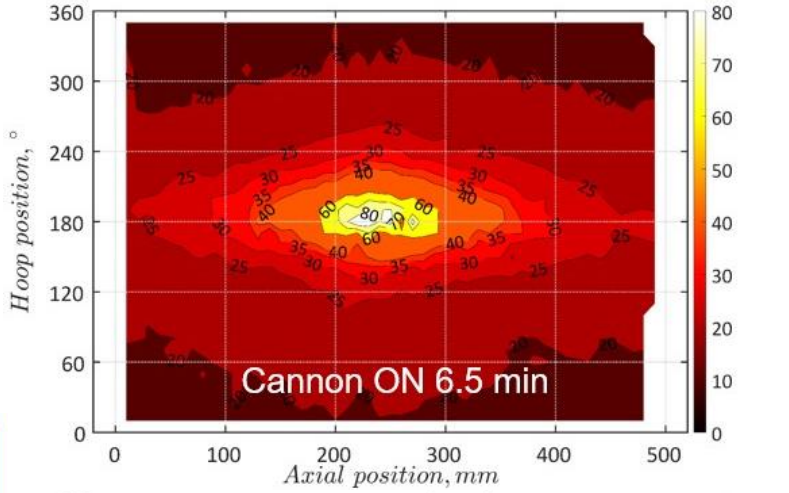
The project results - WP5

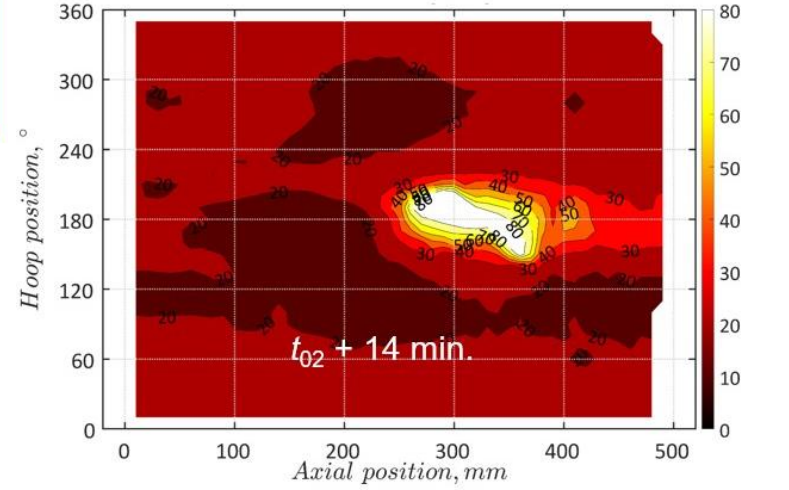
Optical fiber (OF) as fire sensor *NTNU*

Use of **Optical fiber grid** as safety device on fire

- OF integrated to a TypeV cylinder
- OF can measure local temperature
  - Visual mapping of temperatures for monito and decision making
- Flame localization is reliable
  - OF withstanded 17’ in direct flame
  - Flame localization well positioned
  - For accurate temperature value in flame, a higher-cost sensor is needed







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The project results - WP6

Tank recycling *CETIM-GE*

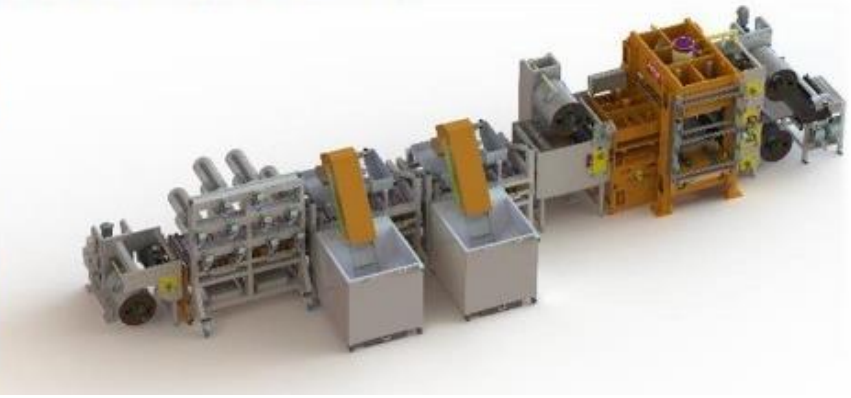
Define the recycling process and the recycled products coming from thermoplastic tanks

- Selection of the delamination process
  - Hobbing has been selected
- Several recycled composite ratio tested to obtain thermoplastic sheets reinforced with carbon fiber
  - Sheets to be used for final application
  - Tested for 2 & 3 mm thickness

→ Bending performance (with 37 % PA11 with 37% CF) are closed to current SMC

- ➢ Density 1,25
- ➢ 150 to 180 MPA bending

Pilot line in Cetim Grand Est



➢ Trials with different fiber ratios

58%vol FC = tape only

47%vol FC = tape + liner

37%vol FC

Best aspect & quality surface

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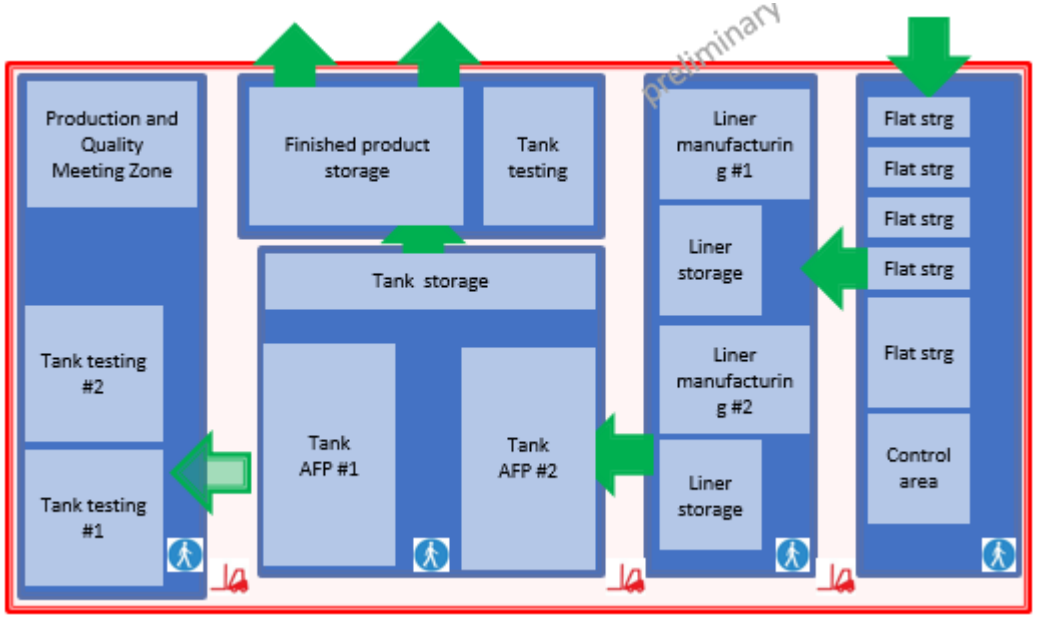
The project results - WP6

Mass production manufacturing *Faurecia*

Define **a process and recycled product** coming from thermoplastic with big thickness tanks

- Shop floor simulation for the manufacturing means installation
- Process flow chart estimated
- Cost calculation for a tank

→ Target of 400 €/kg can be achieved, but thermoplastic tapes reinforced with carbon fibers is the key elements for the price of the tank



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Conclusions

A warm thank you to the FCH2-JU & Clean H2 JTI team for their support

Another one for the consortium team

Technical side

- **The Thermoplastic reinforced with carbon fiber can be used for high pressure gaseous H2 storage**
  → **Further R&D developments on mono material Thermoplastic tank reinforced with carbon fiber are needed**
- **Clean H2 tanks price target can be achieved**
  → **Price of the tapes is the major part of the total price. Thermo-plastic tapes reinforced with carbon fibers must become more competitive**

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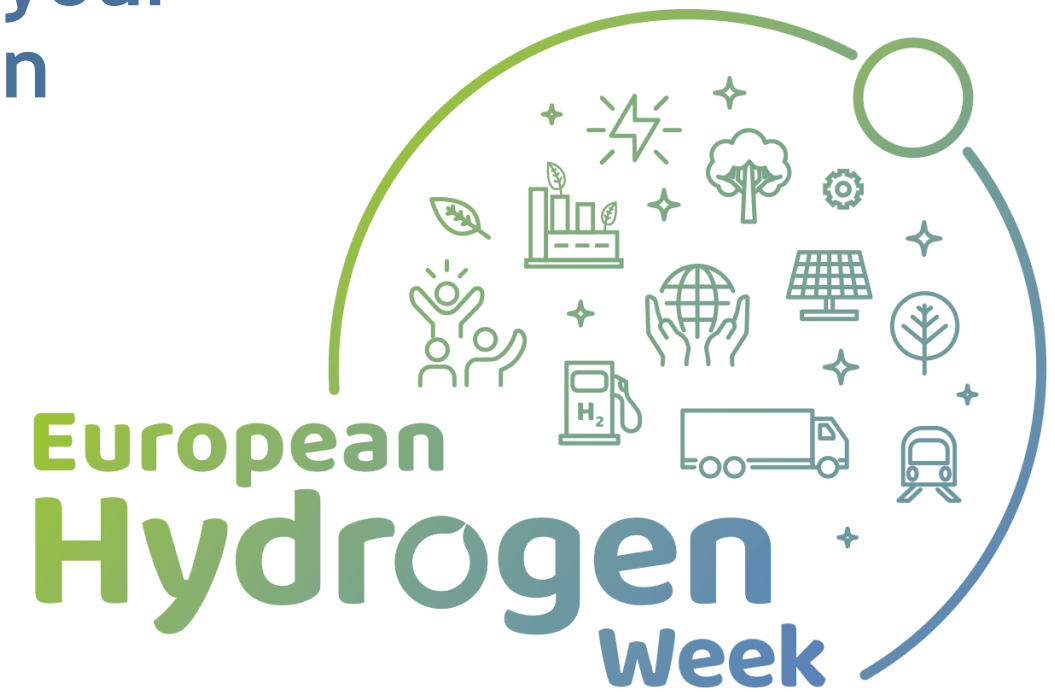
Thanks for your attention



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