



# AZL Joint Partner Project

## Thermoplastic Pressure Vessels

Benchmarking of design-for-manufacturing-strategies to optimize material efficiency and cost

In cooperation with:

# Testimonial

## Why Toyota works with AZL and joined the consortium on Thermoplastic PVs



**Dr. Martin Kerschbaum**  
R&D Material Engineering Division

Toyota Motor Europe NV/SA

*“The usage of thermoplastic resins for manufacturing of high-pressure hydrogen storage vessels is of high interest for Toyota. This is due to potential advantages in terms of design, processing, performance, and circularity.*

*It is essential to compare and evaluate the diverse options of design and manufacturing strategies for high-pressure vessels based on thermoplastic composite materials.*

*Gaining additional insights into the key influencing factors on material efficiency, production scalability and realistic cost-structure scenarios is a crucial part of this process.*

*AZL’s structured approach — a combination of know-how in applications, composite materials and production systems with expertise across the entire value chain — provides Toyota with valuable input for the further development of innovative storage systems.”*

# Background

## AZL Pressure Vessel Portfolio

### Partnership Activities

**AZL Workgroup**  
**Composite Pipes & Vessels**  
 Expert & Business Community

Join an extensive partner network from industry and science that develops new solutions and ideas around fiber-reinforced pressure tanks

**AZL** Excellence in Lightweight Production

In four project phases, the AZL conducted an in-depth workshop focus study on the current and emerging FRP production technologies for composite pressure vessels. The study provided a market technology overview and example cost models and analyses is available for all AZL partners and included in the regular AZL Partnership fee.

The AZL conducts frequent workshop focus studies jointly defined by the workshop. The studies provide in-depth insights and broad overview of lightweight technologies and markets and are included in the partnership fee at no additional charge.

Here info:

**Missions of AZL Workgroups**

- Technology-Oriented Networking
- Building Trust in Technology

### Joint Partner Projects

**Final Report | October, 2024**

**Joint Technology & Concept Study: Trends & Design Factors for Hydrogen Pressure Vessels**

Consortium

**Partners:** AOC, ASCEND, BOSCH, CEVOTEC, CONBILITY, EPIC, DOMO, elkamet, EXCELITAS, floleks, Formosa Plastics, HORSE, HUNTSMAN, KANENKA, KLUMPFERS, lasertine, Mitsui Chemicals Group, OP, Polymt Group, Rassini, SWANCOR, tecnalia, TOYOTA, TÜNKERS, unipac

**Pressure Vessels - AZL Partner Network**

Hydrogen Pressure Vessels - AZL Partner Network

Design of a new hydrogen storage tank for a hydrogen-powered truck

Production and testing of hydrogen storage tanks

### Services and R&D-Infrastructure

**Pressure Vessel Design and Prototyping**

With our technology know-how, simulation methods and production capabilities, we analyse the opportunities for your materials and products.

**Related to pressure vessels:**

- Production and testing of filament-wound pressure vessels, including the final winding of the vessel
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**Our Expertise**

As a one-stop shop for market and technology know-how, the AZL brings together experts and decision makers from academia and industry of all disciplines in the relevant business and technology development. Located at the heart of one of the leading high-tech universities, RWTH Aachen University, AZL assists in the development, benchmarking and implementation of complete technical and market strategies. In addition, the AZL Partnership network offers access to an open innovation ecosystem with international companies that provide solutions for industrial implementation and successful market of lightweight technologies in the market.

**Optional services:**

- Production and testing of FRP single
- Placement of lines, top-ups and base parts
- Automated winding and curing of pressure parts
- Build pressure testing
- Compressive and CO<sub>2</sub> impact analysis

**AZL** Excellence in Lightweight Production

# Background - Previous Joint Partner Project

## Trends & Design Factors for Hydrogen Pressure Vessels



FZL  
Aachen GmbH  
Excellence in Lightweight Production

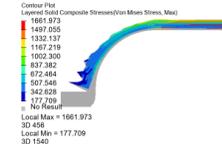
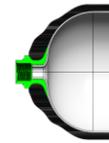
Final Report | October, 2024

Joint Technology & Concept Study:  
Trends & Design Factors for Hydrogen Pressure Vessels

In cooperation with:  
AZL RWTH AACHEN UNIVERSITY

- 12 months study
- 25 companies consortium
- 550 pages report

### Work Packages



**WP1**  
Overview state of the art

Questions to be answered:

- Which are the major players?
- What are typical requirements?
- What are typical layouts and design principles? Information on liners, bosses, valves, sealing, winding patterns, etc.
- What are typical materials?
- What are typical processing routes for liner and shell?
- What are the trends?
- Which concepts for recycling exist?

**WP2**  
Design & Analysis

Design and CAE analysis of a nominal 700 bar pressure vessel:

- Definition of material properties to be used
- Liner and boss design
- Winding pattern for thermoset vessel
- Winding pattern for thermoplastic vessel, using tape laying design freedom (non-geodesic, start-stop)
- Effect of process or environment variations: tension, liner pressurization, temperature, moisture variations
- Optimizations for the different materials will be based on the burst pressure load case. Analysis on thermal cycling and drop impact will also be performed.

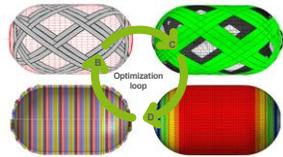
**WP3**  
Processing, Cost and CO<sub>2</sub> analysis

Cost, weight, CO<sub>2</sub> and recyclability evaluation:

- Different processing routes will be modelled for the thermoset design, such as wet winding and towpreg winding. Equipment will be defined, and options to increase the winding speed.
- For the thermoplastic design, the production process will be modelled for both a regular winding path design and a design specifically optimized for thermoplastic tape materials.
- Cost and CO<sub>2</sub>, cradle to gate, will be calculated in Oplysis software
- Recycling options for both thermoset and thermoplastic vessels will be evaluated.

# Background - Previous Joint Partner Project

## Deep dive into thermoset and thermoplastic winding with/without patch designs



**AZL** Applied Center  
Excellence in Lightweight Production

In cooperation with:  
AZL | RWTH AACHEN UNIVERSITY

### Impressions I/IV



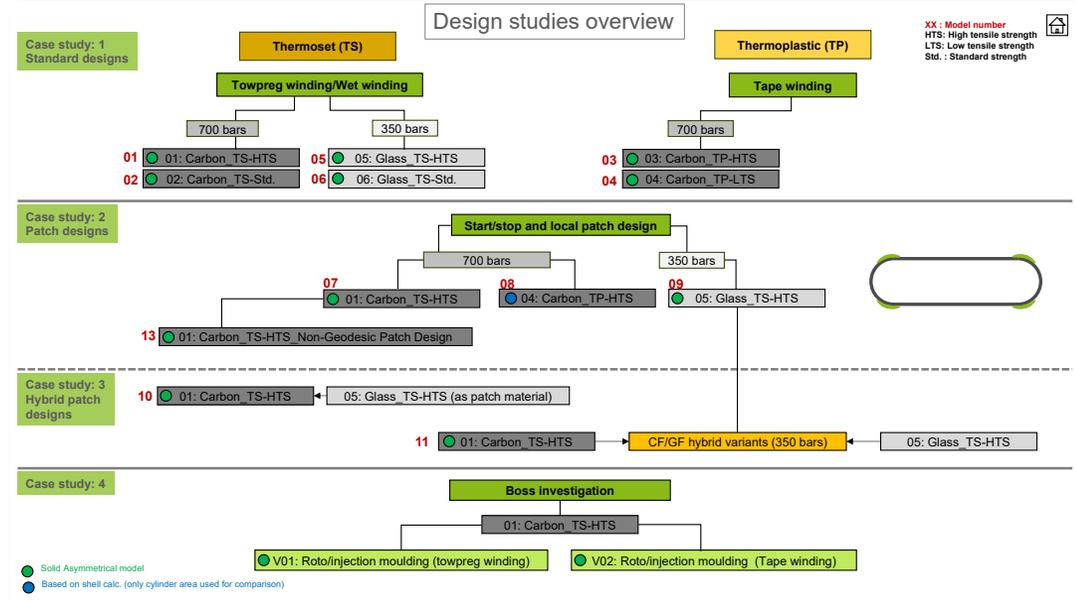
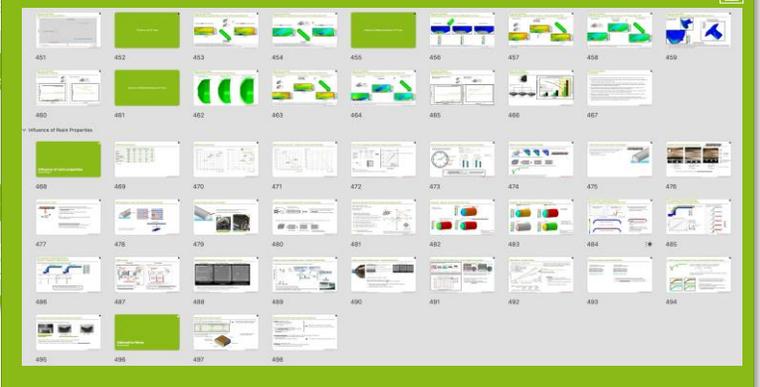
### Impressions II/IV



### Impressions III/IV



### Impressions IV/IV



# Background - Previous Joint Partner Project

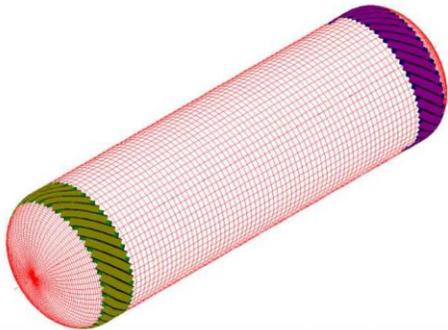
## Cost vs weight for different thermoset and thermoplastic wound vessels



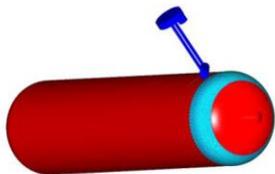
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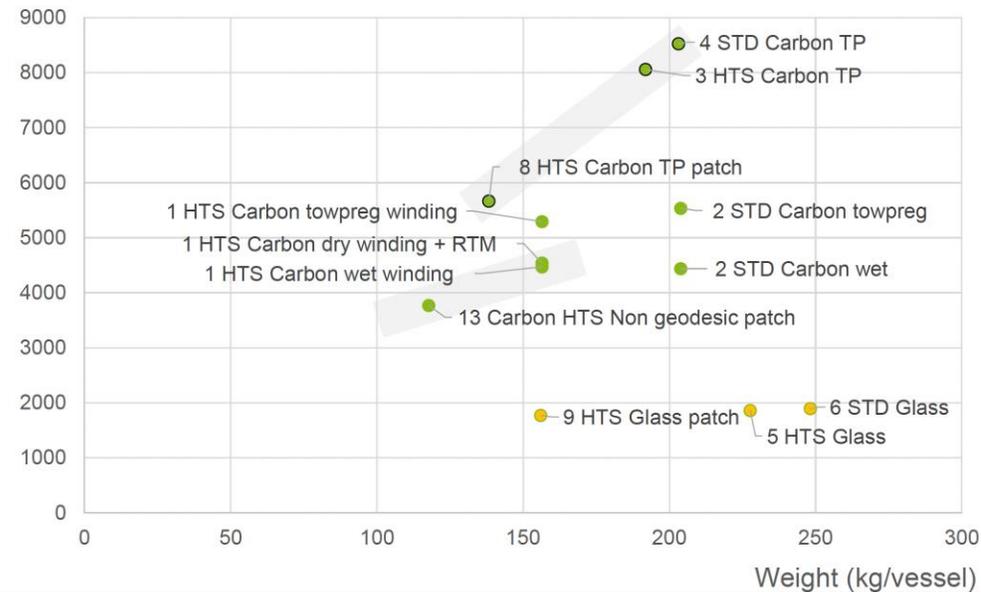


Local reinforcements inserted into a winding sequence  
(Start/stop process)



### Cost versus Weight

Cost (€/vessel)



- When just imitating designs originating from thermoset winding, thermoplastic technologies are not fully able to play out their specific advantages.
- Higher material costs lead to higher production costs

# Joint Partner Project Thermoplastic Pressure Vessel

## Why a dedicated project for Thermoplastic Composites for Pressure Vessels?

### Strong industry Interest for thermoplastic resin systems:

- **Clean and fast processing:** No curing required, enabling short cycle times and specific automation
- **Repairability and reshaping:** Thermoplastics allow post-processing through controlled reheating
- **Recyclability at end-of-life:** Material can be remelted and reused, supporting circular economy goals

### Strategic Imperative: Design Rethink

- **Conventional designs are cost-inefficient** when applied to thermoplastic-based vessels
- **Rethinking design & production** is critical to fully exploit thermoplastics' unique processability
- **Targeted optimizations** unlock material efficiency, reduce carbon fiber usage, and cut manufacturing costs
  - **Design variants:** integral vs. differential design,
  - **Hybridisation:** thermoset/thermoplastic/continuous fibre/non-continuous fibre composites combined in one vessel

## What are the specific features of Thermoplastics?

### Specific materials and technologies of interest:

- Type IV and Type V tanks can be manufactured integral and differential
- Thermoplastics can be joined by welding or overmoulding (shells, dome caps, reinforcement sections or profiles)
- Tapes can be positioned “highly non-geodesic”
- Functions can be separated, offers potential for multi-material/technology combinations (e.g. carrying hoop/axial stresses, geometrical stiffening, valve integration)
- (Re)consolidation by melting possible
- Advantages brought by molecular bond between liner and overwrap

**Simultaneous engineering approach** for designing production systems, production chains and component configuration facilitate **benchmarking of technical and economical KPIs**

# Joint Partner Project Thermoplastic Pressure Vessel

## Project Objectives

### Objectives:

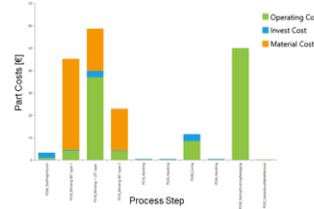
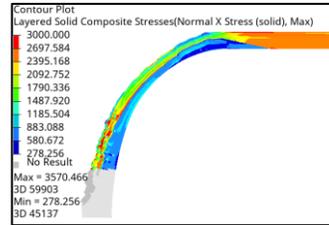
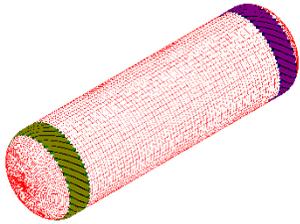
- Map the current state-of-the-art and IP-landscape in thermoplastic pressure vessel technologies across sectors such as hydrogen (Type 4, 4.5, 5), liquefied hydrogen (LH<sub>2</sub>), and CNG storage
- Engineer pressure vessel designs optimized for thermoplastic materials and to explore material- and application specific manufacturing approaches
- Assess the technical and economic feasibility of the developed concepts, with special focus on manufacturability, sustainability, and industrial scalability, and potential routes to achieve a viable business case

### Results:

- Structured report highlighting key technology insights, design principles, material systems, manufacturing routes, and relevant benchmarking criteria
- Engineering documentation of selected vessel and production concepts, including CAD models, process steps, material configurations, and draft layouts for industrialization
- Comprehensive benchmarking matrix comparing the developed concepts, with visualizations of performance-cost trade-offs and production efficiency metrics
- Network with potential partners & customers at events

# Joint Partner Project Thermoplastic Pressure Vessel

## Work Packages



### WP1 Market & Technology Landscape

Identification of on all aspects related to performance and production of TP pressure vessels

- Existing products,
- Ongoing developments,
- Research initiatives and related scientific studies
- Review of applicable standards, certification protocols, and IP landscape
- Application-specific requirements across transportation, aerospace, heavy machinery, and energy infrastructure

### WP2 Conceptual Design & Manufacturing Strategies

Simultaneous engineering approach

- Definition of representative use cases with high technological and economical potential (choice of H<sub>2</sub> tanks, stationary tanks, CNG tanks, LH<sub>2</sub> tanks, as following from participant interests)
- Innovative structural designs, specific for thermoplastics, and optimization of all elements relevant for the specific component designs (type IV, type V)
- CAE simulations for deriving concept-specific reinforcement configuration and material (combinations)
- Evaluation of manufacturing technologies: integral vs. fused multi-component approaches, filament winding, AFP, patch placement, braiding, forming, thermoforming, compression/injection molding, welding, etc.
- Development of production system concepts (line layouts, sub-modules, automation)

### WP3 Performance, Cost & Production Benchmarking

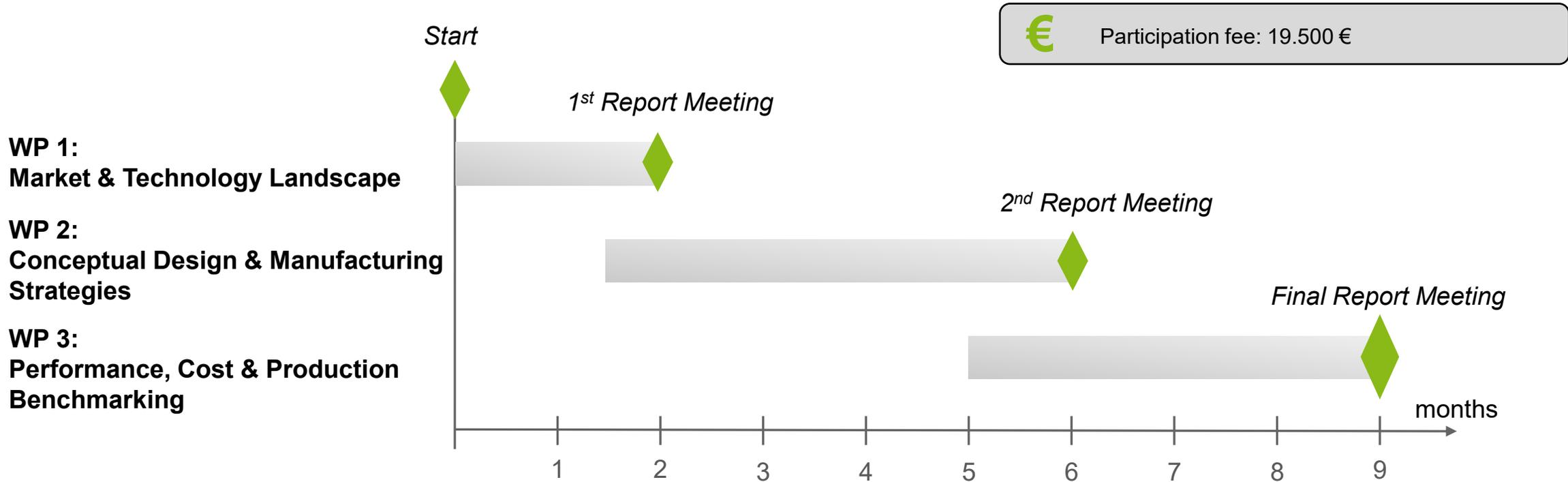
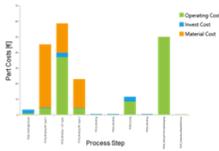
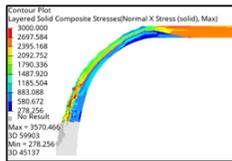
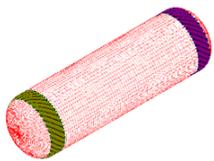
Cost, weight, CO<sub>2</sub> and recyclability evaluation:

- Estimation of material usage, component-specific KPIs (weight, volume, storage efficiency), cycle times, energy consumption
- Evaluation of environmental metrics and recycling potential
- Quantification of manufacturing-specific KPIs (throughput, cost/unit, equipment utilization)
- Identification of potential routes towards viable business cases

# Joint Partner Project Thermoplastic Pressure Vessel

## Estimated Timeline

Open to join!



# Joint Technology Development through Cost-Sharing

## Efficiently drive your development!

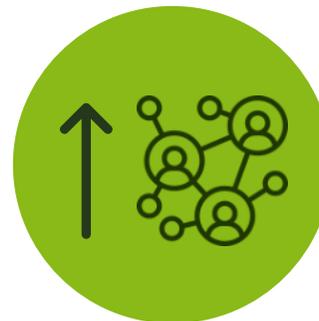
### What it is

Within the AZL Joint Partner projects, international companies come together to improve their understanding of trend topics & their markets, to optimize technology and business development strategies and to develop approaches to solve future challenges.

### How it works



### How you benefit





# CONTACT US WITH YOUR REMARKS AND QUESTIONS



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