

# „ The DLR´s Modular, Shape-Adaptable Cellular CNG-tank – Validation of a Customer-Oriented Solution“

## Current State

Dipl.-Ing. Diego Schierle  
Prof. Dr. Horst E. Friedrich  
DLR Institute of Vehicle Concepts  
Stuttgart



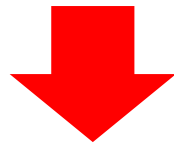
# Contents

1. Megatrends
2. Technology – DLR-Wabentank
3. History of the DLR-Wabentank
4. New Production Approach DLR-Wabentank
5. Subsystem
  1. Cell
  2. Gas-Connector
  3. 3D-Winding
6. DLR-Wabentank Potential



# 1. Megatrends

- We are reaching the limits of oil extraction
- Climate change is taking place
- Growing population, concentrated in megacities



## Vehicle Concepts

- Lower energy consumption
- Reduced CO<sub>2</sub> emissions
- Alternative and renewable energy sources
- Automated driving / connectivity
- ...



Source: <http://www.fotocommunity.de/pc/pc/mypics/1438338/display/18369424>



Source: DLR



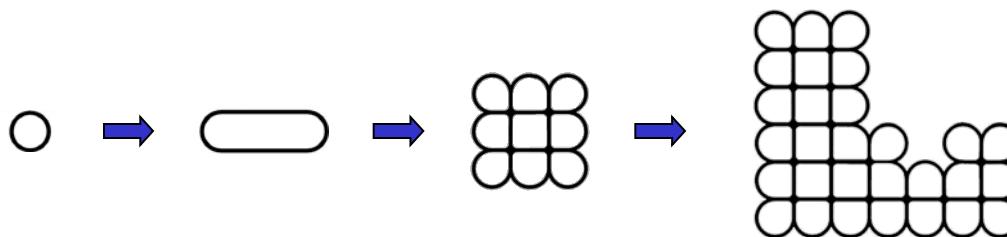
Source: versust.blogspot



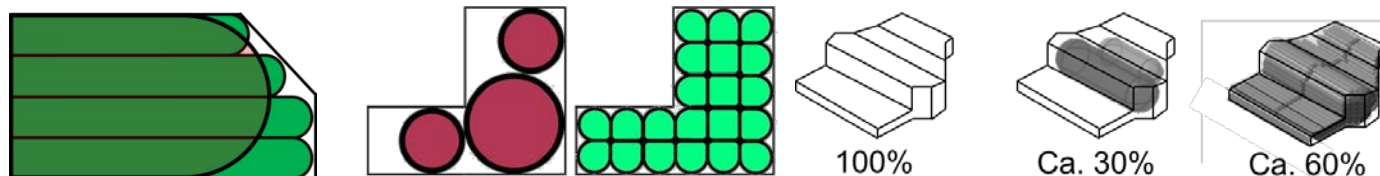
## 2. Technology – DLR-Wabentank

Tanks with a wide range of packaging possibilities are an enabler for CNG-Vehicles

**Basic Concept –  
DLR-Patent**



**Variability in the  
use of the  
available space**

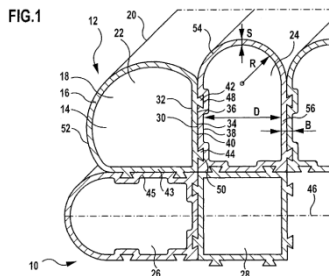


**Mercedes Benz E-Class:  
ca. + 38% demonstrated**



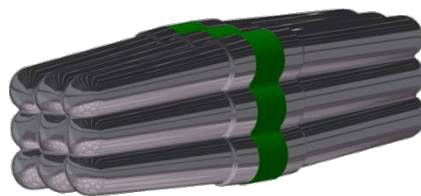
### 3. History of the DLR-Wabentank

- DLR-Wabentank as an idea ca. 10 Years old
- Different stages of development:



[Kö03]

metal



[LLBT09]

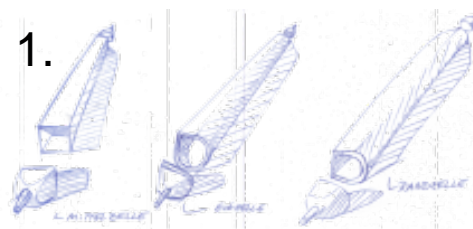
thermoplast



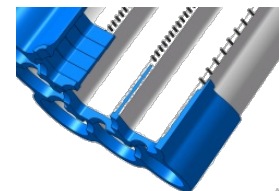
[Str11]

thermoset

- Project to develop the automated production steps for a thermoset „DLR-Wabentank“
- Dividing the complexity in 3. subsystems:



2.

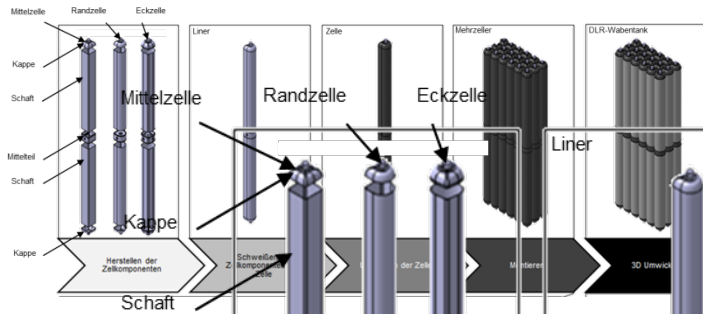


3.





## 4. New Production Approach DLR-Wabentank



- DLR-Wabentank Stand 2013:

- Automatische Produktion

- Modular Expansion

- 18%  $\Delta$  / o. m. n

- Automated Production starts

Kappe

at 201

Aluminum  
production

Welding each  
cell

Winding each  
cell

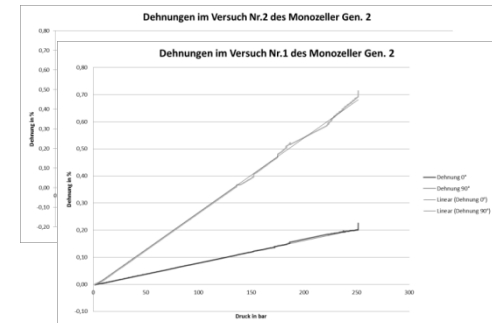
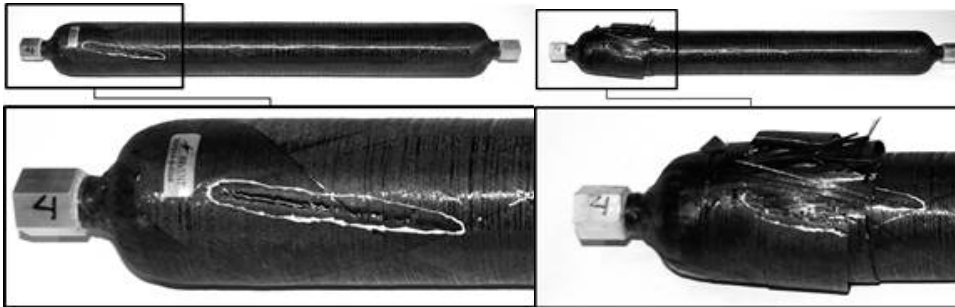
Assembly

3D-Winding

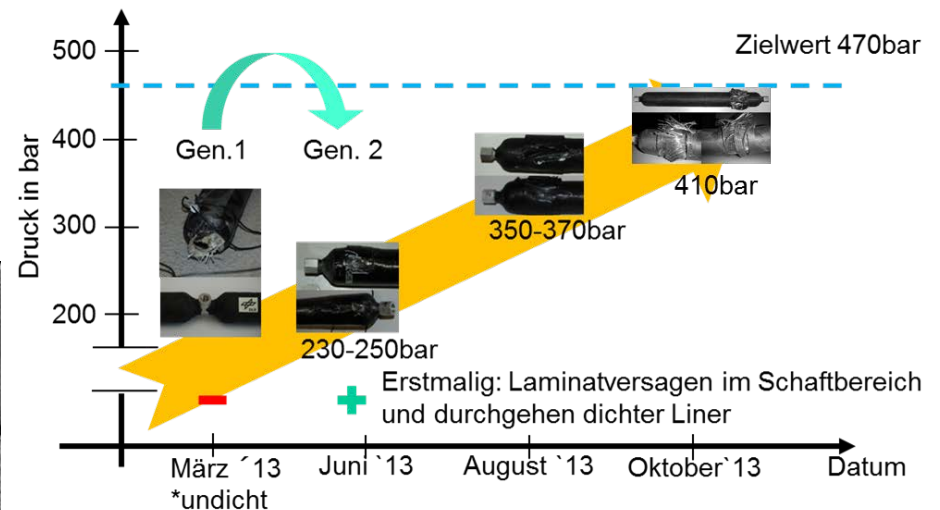
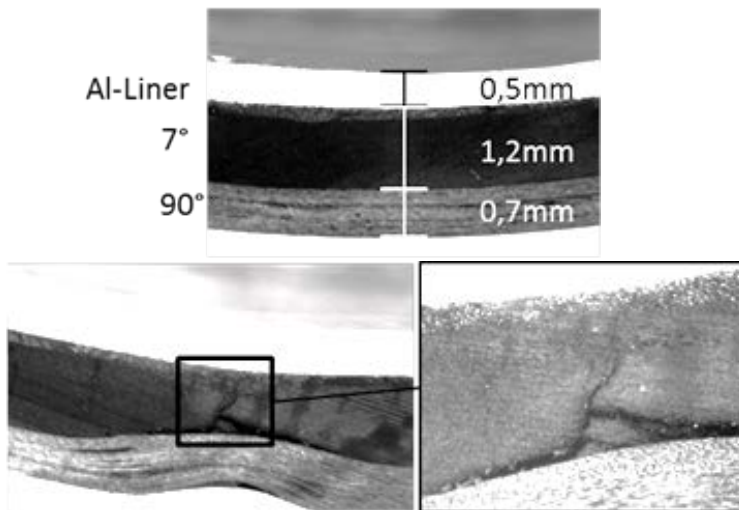


## 5. Subsystem: Cell

- Burst pressure tests on rotationally symmetric liners

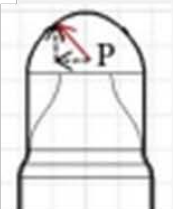
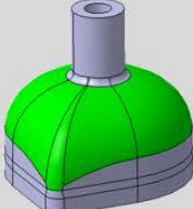

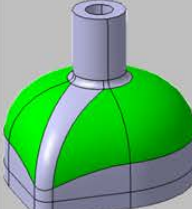











- Indentation having a negative impact



## 5. Subsystems: Cell

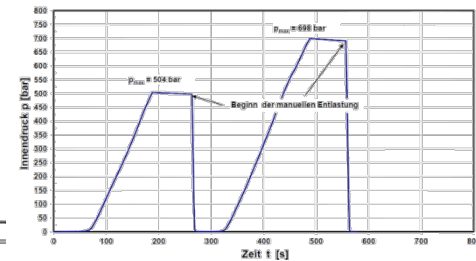
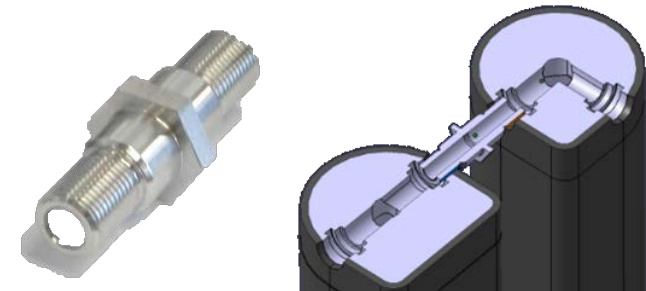
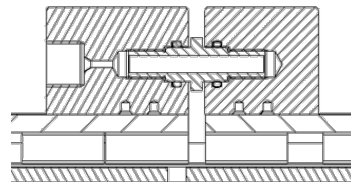
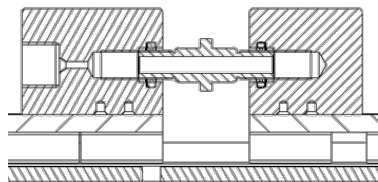
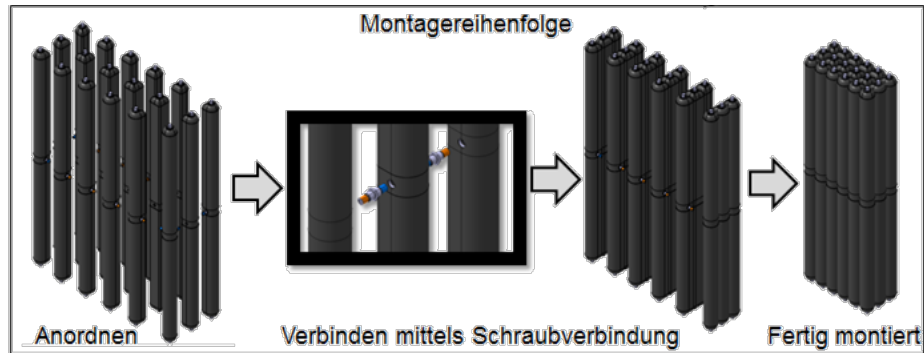
- 0,5mm Aluminum Liner
- **Non-rotation-sym. Liner** full winding

	Proof-of-Concept	Variante 1	Versuch Var. 1	Variante 2	Versuch Var. 2	Variante 3	Versuch Var. 3
							
Eigenschaft	Halbkugel mit „S-Schlag“	Isotensoider Ansatz (IA) im gesamten Oberflächenbereich		Eckbereich läuft nach außen hin auf. Rest IA.		IA im rotations-symmetrischen Bereich. Ansonsten Tangenten- und Krümmungs-stetig	
Erkenntnis	Halbkugel nur für isotrope Werkstoffe	Abrutschen und Spleißen des Rovings an der Kante		Abrutschen und Spleißen des Rovings an der Kante		Erstmalig vollumwickelte nicht rotationssym. Liner	





## 5. Subsystem: Gas-Connector



Validated:

- Burst pressure (500bar & 700bar)
- Pressure cycles  
(10bar-250bar→500 000cycles)



## 5. Subsystem: 3D-Winding



- Tool with a max. width of 2mm and a length of 500mm
- Undergoing trials



## 6. DLR-Wabentank Potential

- The production of a “Modular-Free-Shapeable CNG Tank” as the DLR-Wabentank could enable further CNG-Vehicles
- 18% > Volume → increasing range of CNG-Vehicles
- Customer benefits
- DLR-Wabentank is able to be incorporated at any stage in the vehicle development process



# Thank you for your attention!


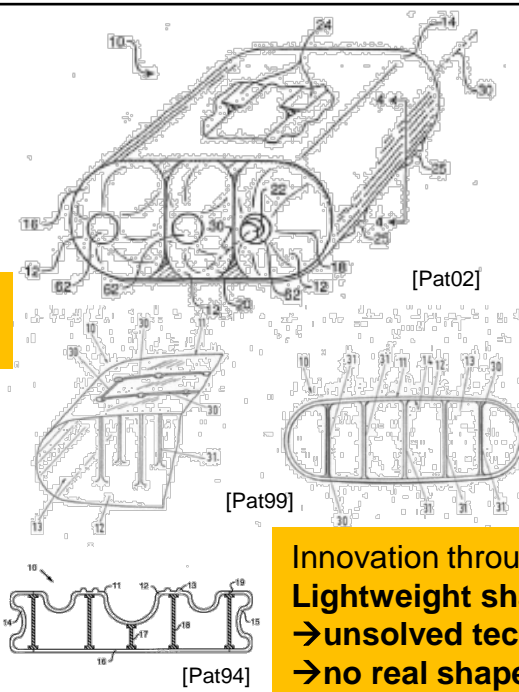
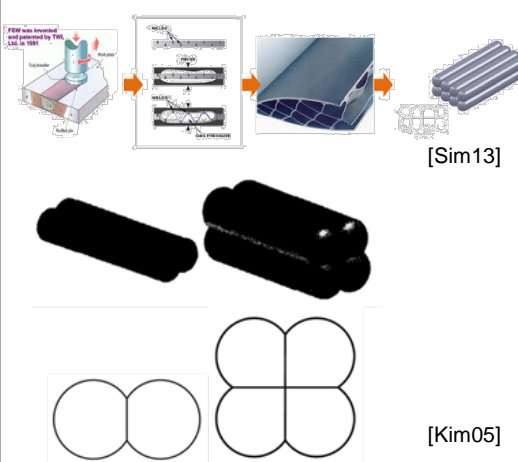




# Backup



# State of the Art for CNG-Tanks

Industry	Patents	Research																																				
 <p><b>Innovation through Lightweight material</b></p> <table border="1"> <thead> <tr> <th>Hersteller</th><th>Ansatz</th><th>Quelle</th></tr> </thead> <tbody> <tr> <td>CNG Cylinders International</td><td>CNG 3</td><td>www.cng.us.com</td></tr> <tr> <td>Dynetek Industries Ltd.</td><td>CNG 3</td><td>www.dynetek.com</td></tr> <tr> <td>ENK</td><td>CNG 3</td><td>www.enkcf.com</td></tr> <tr> <td>Faber Industrie</td><td>CNG 3</td><td>www.fiber-italy.com</td></tr> <tr> <td>Gastank Sweden</td><td>CNG 3</td><td>www.gastank.se</td></tr> <tr> <td>Lincoln Composites</td><td>CNG 3/4</td><td>www.lincolncomposites.com</td></tr> <tr> <td>Luxfer Gas Cylinders</td><td>CNG 3</td><td>www.luxfercylinders.com</td></tr> <tr> <td>Quantum Technologies</td><td>CNG 4</td><td>www.qtw.com</td></tr> <tr> <td>Ragasco</td><td>CNG 4</td><td>www.hexagonragasco.com</td></tr> <tr> <td>Xperion</td><td>CNG 4</td><td>www.xperion.energy.de</td></tr> <tr> <td>3M</td><td>CNG 4</td><td>www.3m.com</td></tr> </tbody> </table>	Hersteller	Ansatz	Quelle	CNG Cylinders International	CNG 3	www.cng.us.com	Dynetek Industries Ltd.	CNG 3	www.dynetek.com	ENK	CNG 3	www.enkcf.com	Faber Industrie	CNG 3	www.fiber-italy.com	Gastank Sweden	CNG 3	www.gastank.se	Lincoln Composites	CNG 3/4	www.lincolncomposites.com	Luxfer Gas Cylinders	CNG 3	www.luxfercylinders.com	Quantum Technologies	CNG 4	www.qtw.com	Ragasco	CNG 4	www.hexagonragasco.com	Xperion	CNG 4	www.xperion.energy.de	3M	CNG 4	www.3m.com	 <p>[Pat02]</p> <p>[Pat99]</p> <p>[Pat94]</p> <p><b>Innovation through Lightweight shape →unsolved technical challenges →no real shape adaptivity</b></p> <p>[Pat02] DE69622022T2, 2002 [Pat99] DE19749950A1, 1999 [Pat95] EU 0633422A1, 1994</p>	 <p>[Sim13]</p> <p>[Kim05]</p> <p>[Sim13] Simmons, K.: Low-Cost Efficient manufacturing of pressurized conformal compressed natural gas storage tanks, Pacific Northwest National Laboratory, 2013 [Kim05] Kim Y.H. et.al.: A conceptual design and structural efficiency evaluation of 20ft container shape CNG tank, Journal of Society of Naval Architects of Korea, 2005</p>
Hersteller	Ansatz	Quelle																																				
CNG Cylinders International	CNG 3	www.cng.us.com																																				
Dynetek Industries Ltd.	CNG 3	www.dynetek.com																																				
ENK	CNG 3	www.enkcf.com																																				
Faber Industrie	CNG 3	www.fiber-italy.com																																				
Gastank Sweden	CNG 3	www.gastank.se																																				
Lincoln Composites	CNG 3/4	www.lincolncomposites.com																																				
Luxfer Gas Cylinders	CNG 3	www.luxfercylinders.com																																				
Quantum Technologies	CNG 4	www.qtw.com																																				
Ragasco	CNG 4	www.hexagonragasco.com																																				
Xperion	CNG 4	www.xperion.energy.de																																				
3M	CNG 4	www.3m.com																																				

