Costs and environmental impacts of a cryogenic H2 tank demonstrator

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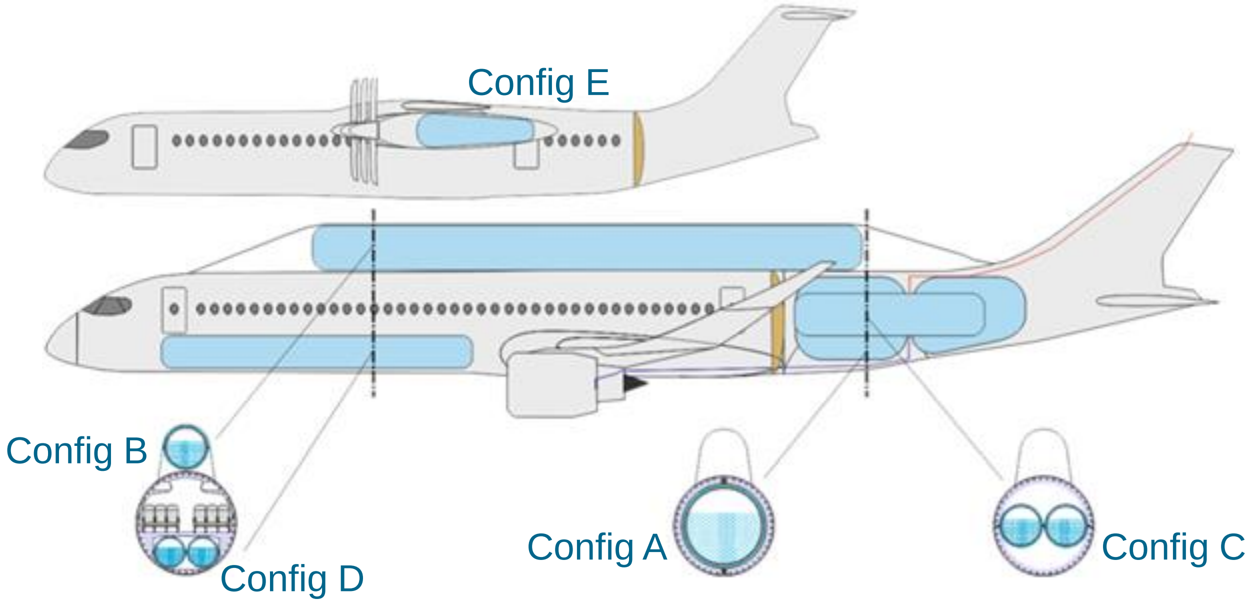
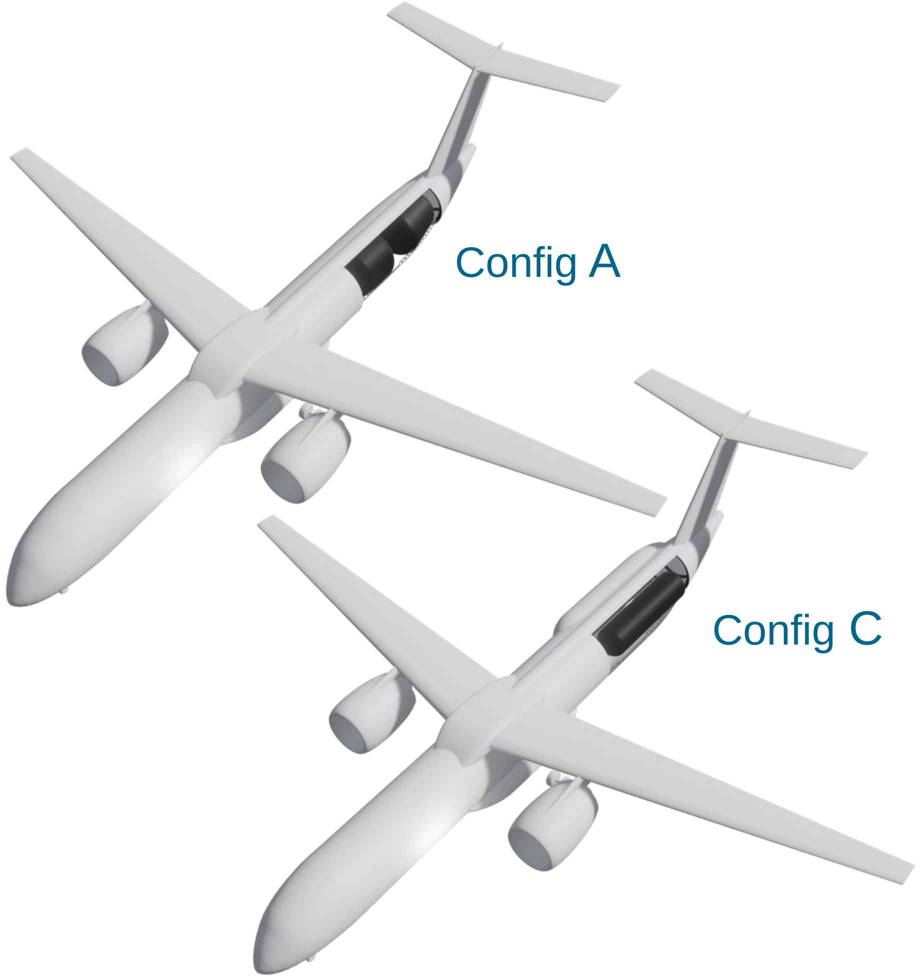
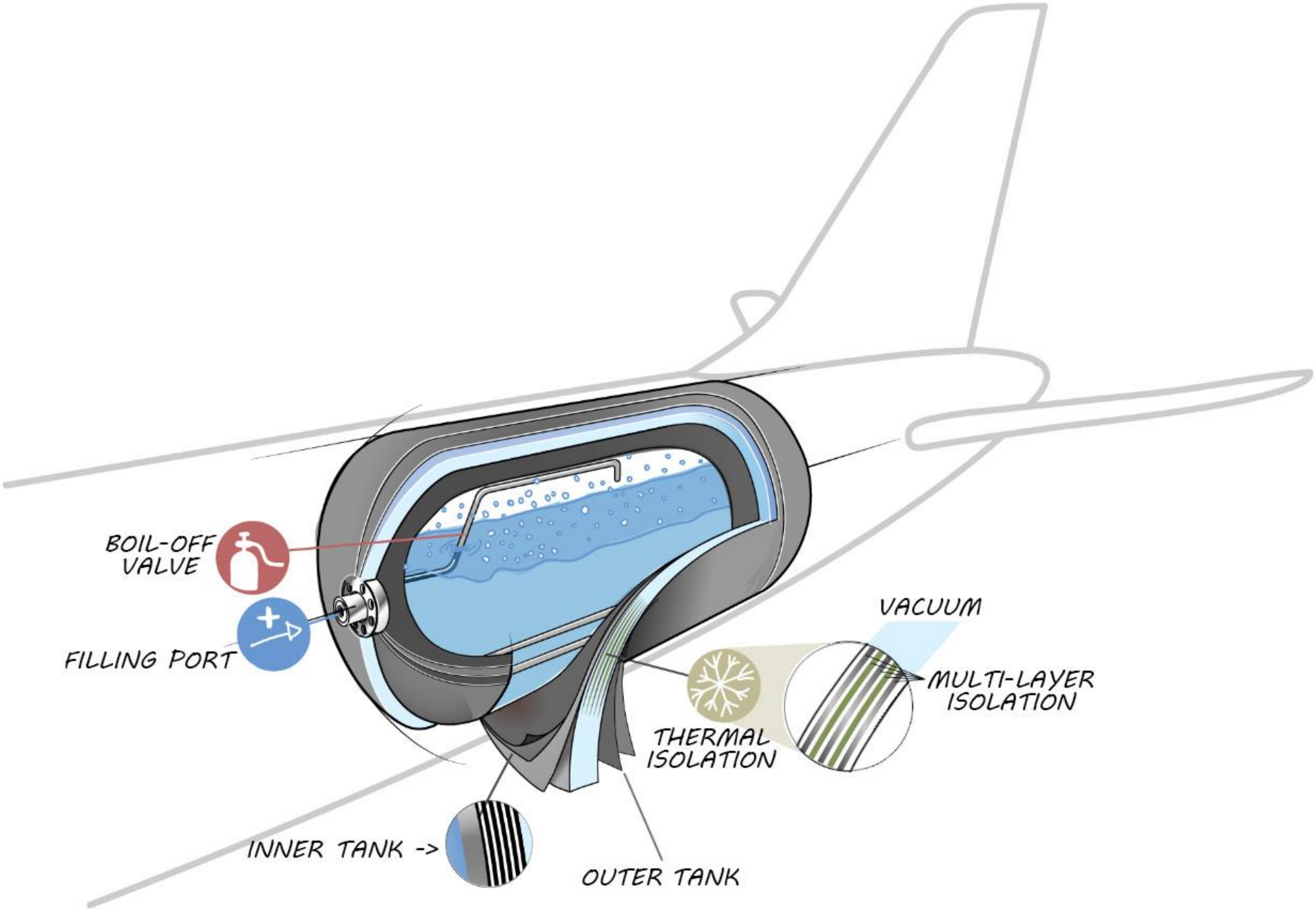
2. Possible tank configurations





2. Tank structure



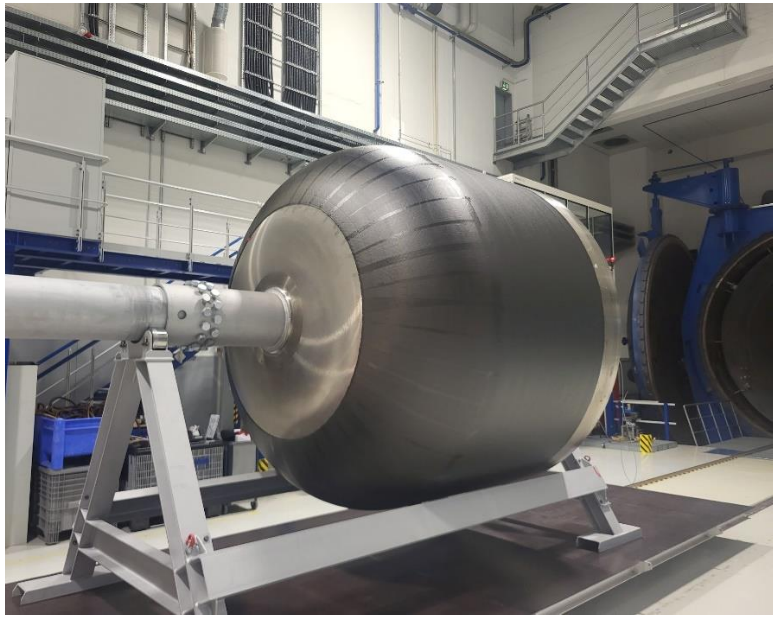
3. HyStor and Tacoma project

HyStor

- Funding by: Federal State of Lower Saxony - NBank
- Duration: 2021 – 2023
- Aim: production demonstrator in the form of a half tank (Config A)
- Provided the LCI data

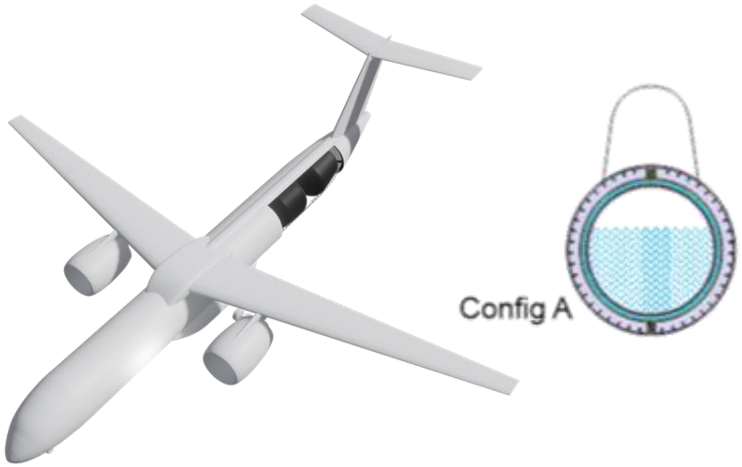
Tacoma

- Funding: National aviation research program of Germany – LuFo
- Duration: 2023 - 2026
- Aim: Development of a cryogenic aviation tank (Config C)
- LCA and cost assessment are performed



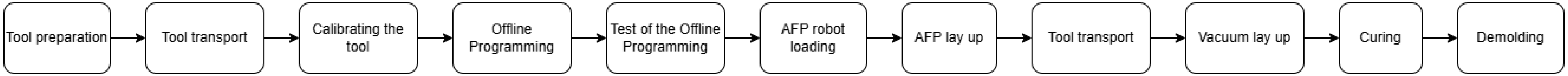
3. Scaling between the configurations A & C

- Fictitious tank geometries served as production demonstrators in the projects HyStor (Config A) and Tacoma (Config C)
- No complete data set yet available for Config C
- Use of Config A production as reference
- Scaling of the Config A results to Config C based on volume → Factor 2



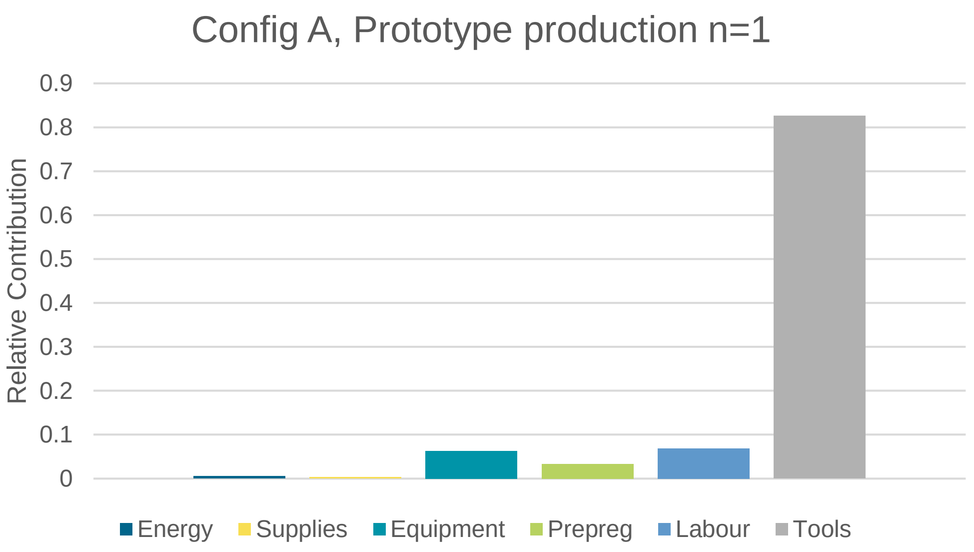
4. Process chain and LCI of the tank production

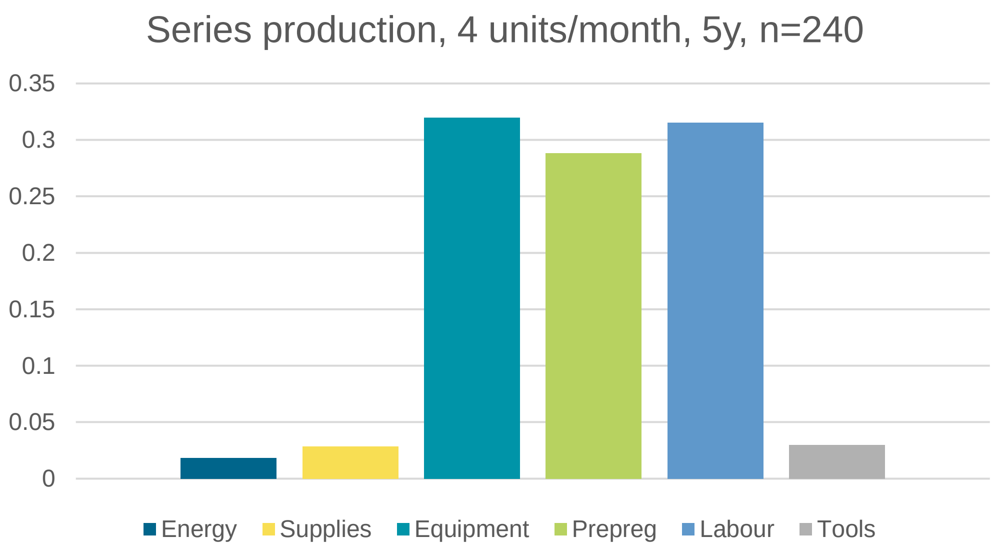
- Definition of the system boundaries
- Setting up the process chain
- Common LCI for economic & ecological evaluation



4. Cost assessment

- Cost estimation of Config A production based on DLR costs
- Estimation of the costs of series production

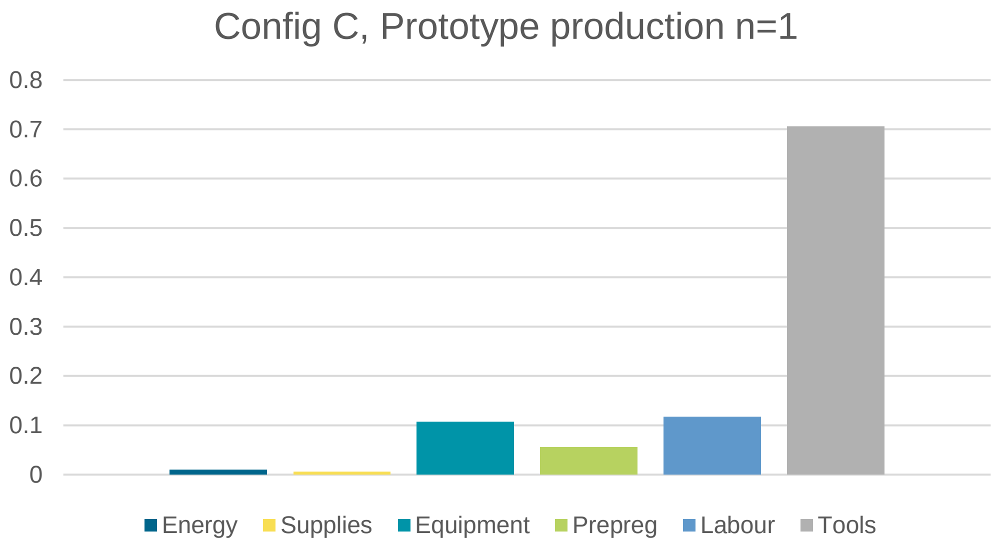


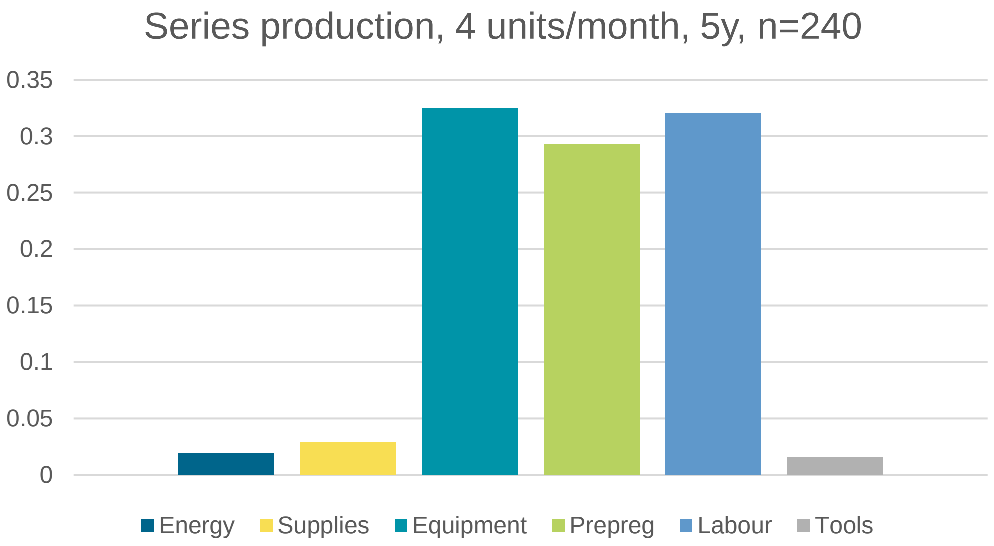


→ Cost reduction of **89%** compared to prototype production

4. Scaling the costs to Config C

- Scaling the HyStor costs to Tacoma tank configuration
  - Factor 2 -> Tank cost in series production ~2x





→ Cost reduction of **81%** compared to prototype production

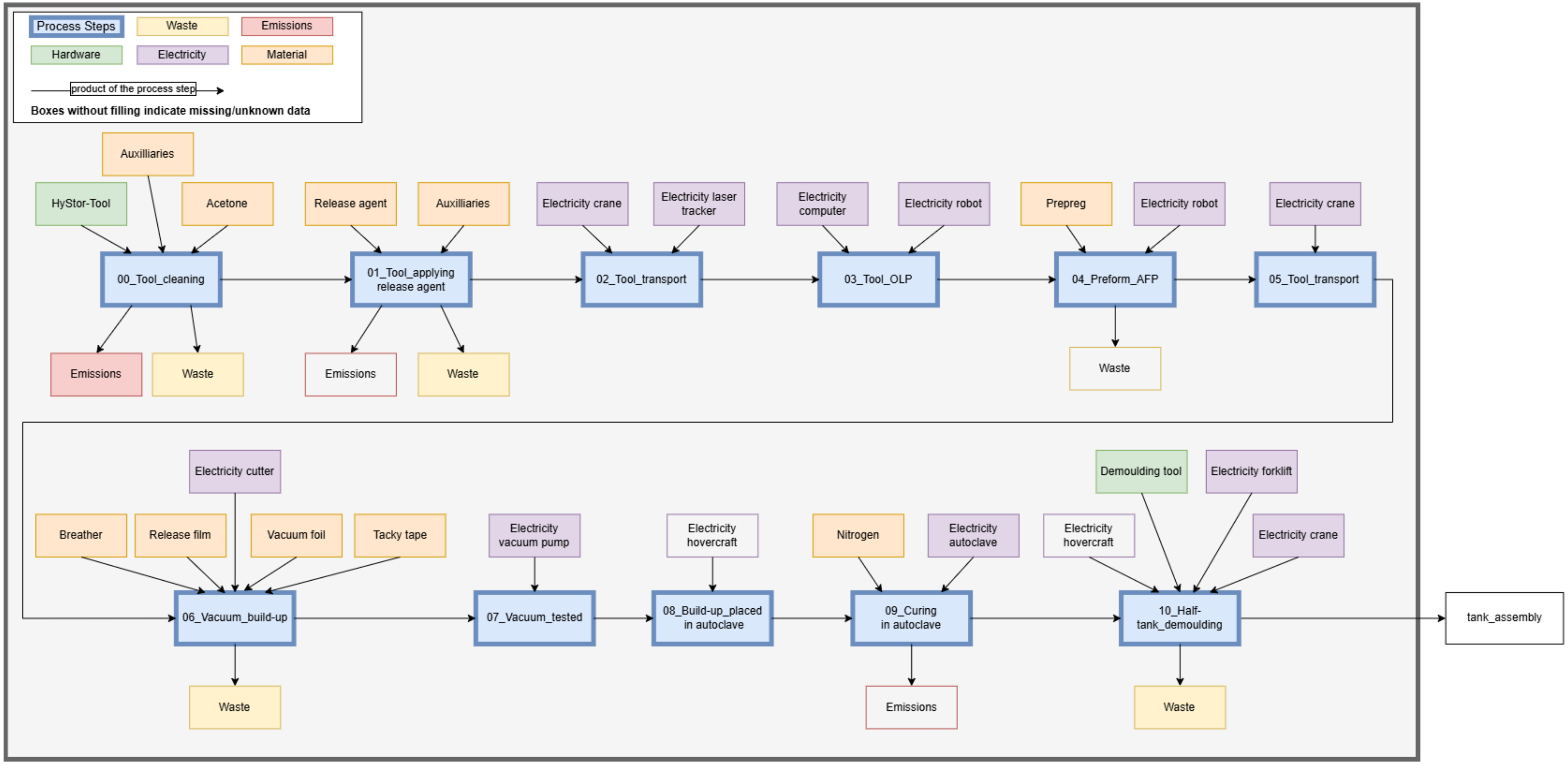
5. Life Cycle Assessment - LCA

- Intended application:
  - Preliminary LCA of LH2 CFRP tank shell for Tacoma
- Product system:
  - Production of the inner CFRP shell of the Tacoma LH2 tank
- Declared Unit
  - 1 unit of a CFRP shell for a LH2 tank
- System boundaries:
  - Cradle to gate
  - Included:
    - manufacturing processes of CFRP layers (primary lab data, assumptions)
    - Tool and demoulding device
    - Materials (secondary data based on literature and LCA databases)
  - Excluded in this version:
    - Assembly (merging of half-tank segments to one layer)
    - detailed material composition of the hydrogen tank including isolation and systems
    - Autoclave production and infrastructure
    - transportation of manufactured tank to the assembly line
    - manufacturing and maintenance of equipment
    - mechanic-related impacts (e.g. lunch, commute, …)

5. LCA background

- Allocation procedures:
  - Based on masses
- LCIA methodology:
  - Environmental Footprint (EF 3.1)
- Database:
  - EcoInvent 3.9.1. cut-off is used as a background database
- Software:
  - Open-source software brightway2/Activity-Browser
- Modelling approach:
  - Attributional
- Assumptions:
  - Production activities are assumed to take place in *Europe* or in Germany depending on the available inventory data
- Limitations:
  - There is a lack of reliable data for certain impact categories (e.g. water demand).
  - The impacts from the design and development of the aircraft concepts are not considered.

5. Process description for the LCA



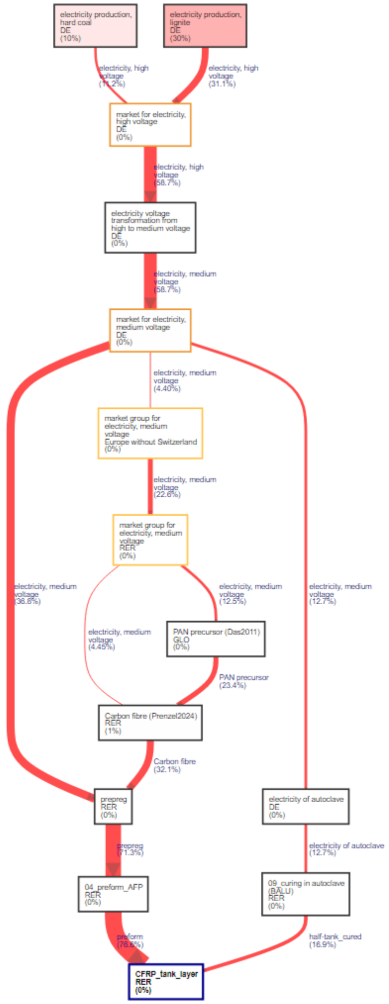
5. Absolute impacts EF 3.1

reference product		CFRP_tank_layer_total	tool_clean	tool_prepared	tool_placed	tool_tested	preform	preform_placed	vacuum build-up	vacuum build-up_tested	vacuum build_up_placed	half-tank_cured
name		CFRP_tank_layer_total	00_tool_cleaning	01_tool_applying release agent	02_tool_transport to GroFi facility	03_tool_OLP	04_preform_AFP	05_preform_transport to the autoclave wagon	06_vacuum build-up	07_vacuum build-up_tested	08_vacuum build_up_placed in autoclave	09_curing in autoclave (BALU)
location		RER	RER	RER	RER	RER	RER	RER	RER	RER	RER	RER
	unit											
Acidification	mol H+ eq	27.07016658	0.124678054	0.153067481	0.003341934	0.020631712	21.40819946	0.003278878	0.81302138	0.006809978	0	4.537137701
Climate Change (GWP100)	kg CO2 eq	9412.349812	22.00549043	17.1057381	1.166209167	7.199691308	7214.287941	1.14420522	560.2564688	2.376426226	0	1586.807642
Ecotoxicity Freshwater	CTUe	39198.55474	126.3021817	253.055955	2.774904164	17.13110646	35601.39427	2.722547482	770.5821109	5.654521693	0	2418.937144
Resource Use Fossil	MJ	158511.5455	347.58887	507.6764631	17.7071209	109.3164143	126497.5807	17.37302428	3538.507429	36.08243505	0	27439.71305
Aquatic Freshwater Eutrophication	kg P eq	9.488012467	0.005776446	0.002106089	0.001666203	0.010286446	7.365747528	0.001634765	0.03407705	0.003395282	0	2.063322657
Marina Eutrophication	kg N eq	7.549657323	0.031636097	0.039841563	0.000872401	0.005385844	6.082737246	0.000855941	0.193522942	0.001777724	0	1.193027565
Terrestrial Eutrophication	mol N eq	57.51029054	0.310396833	0.416124791	0.006653835	0.041078013	46.08589001	0.006528291	1.457286538	0.013558757	0	9.172773465
Human Toxicity Cancer Effects	CTUh	3.37305E-06	4.22417E-08	1.01775E-08	5.08732E-10	3.1407E-09	2.36401E-06	4.99133E-10	4.81162E-07	1.03666E-09	0	4.70266E-07
Human Toxicity Non-cancer Effects	CTUh	7.42208E-05	2.56838E-07	1.74233E-07	1.95166E-08	1.20488E-07	5.83167E-05	1.91484E-08	2.00425E-06	3.97697E-08	0	1.32698E-05
Ionising radiation	kBq U235	2614.912883	1.349414845	0.354136222	0.267735436	1.652887449	2063.918982	0.262683824	8.285148509	0.545574097	0	538.2763208
Land Use	pt	20860.53871	99.74441634	107.8366021	4.221373028	26.06100481	16380.72226	4.14172448	340.5554874	8.602043151	0	3888.653805
Resource Use Minerals and Metals	kg Sb eq	0.027434871	9.3659E-05	8.25718E-05	1.28206E-05	7.91491E-05	0.018769062	1.25787E-05	0.00551596	2.6125E-05	0	0.002842945
Ozone Depletion	kg CFC-11 eq	0.010556409	3.21634E-07	1.87869E-06	1.33318E-08	8.23049E-08	0.000139906	1.30802E-08	0.010396328	2.71667E-08	0	1.78386E-05
Particulate Matter	Disease incidents	0.00013013	1.25658E-06	9.76582E-07	1.65258E-08	1.02024E-07	0.000101837	1.6214E-08	7.79727E-06	3.36753E-08	0	1.80943E-05
Photochemical Ozone Formation	kg NMVOC eq	17.67674969	0.757836337	0.178062546	0.00189494	0.011698576	13.47657522	0.001859187	0.558481251	0.003861388	0	2.686480252
Water Scarcity	m3 world eq deprived water	3507.355744	7.241822111	4.5082968	0.265683412	1.640219099	2213.171517	0.260670517	133.7846553	0.541392612	0	1145.941487

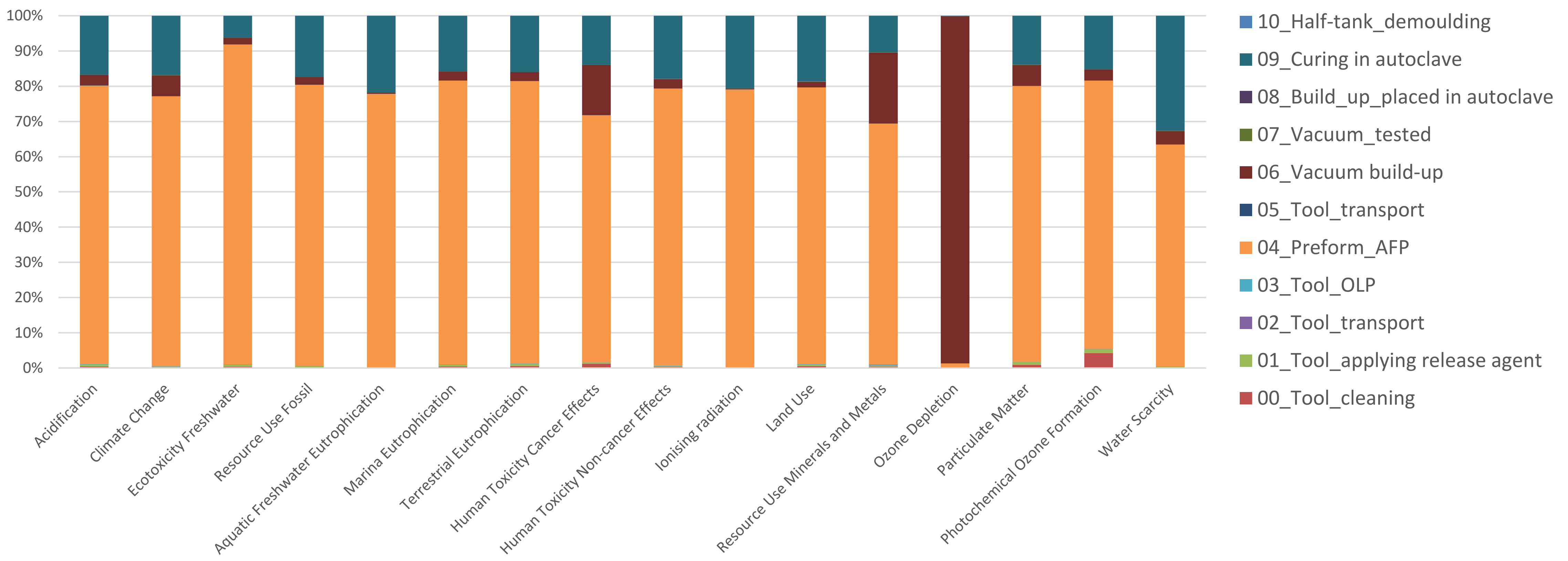
= 0 because data for electricity hovercraft missing

GWP100_ConfigA = 5003 kg CO2 eq.

GWP100_ConfigC = 9412 kg CO2 eq.



5. Preliminary relative results for Tacoma LH2 CFRP layer



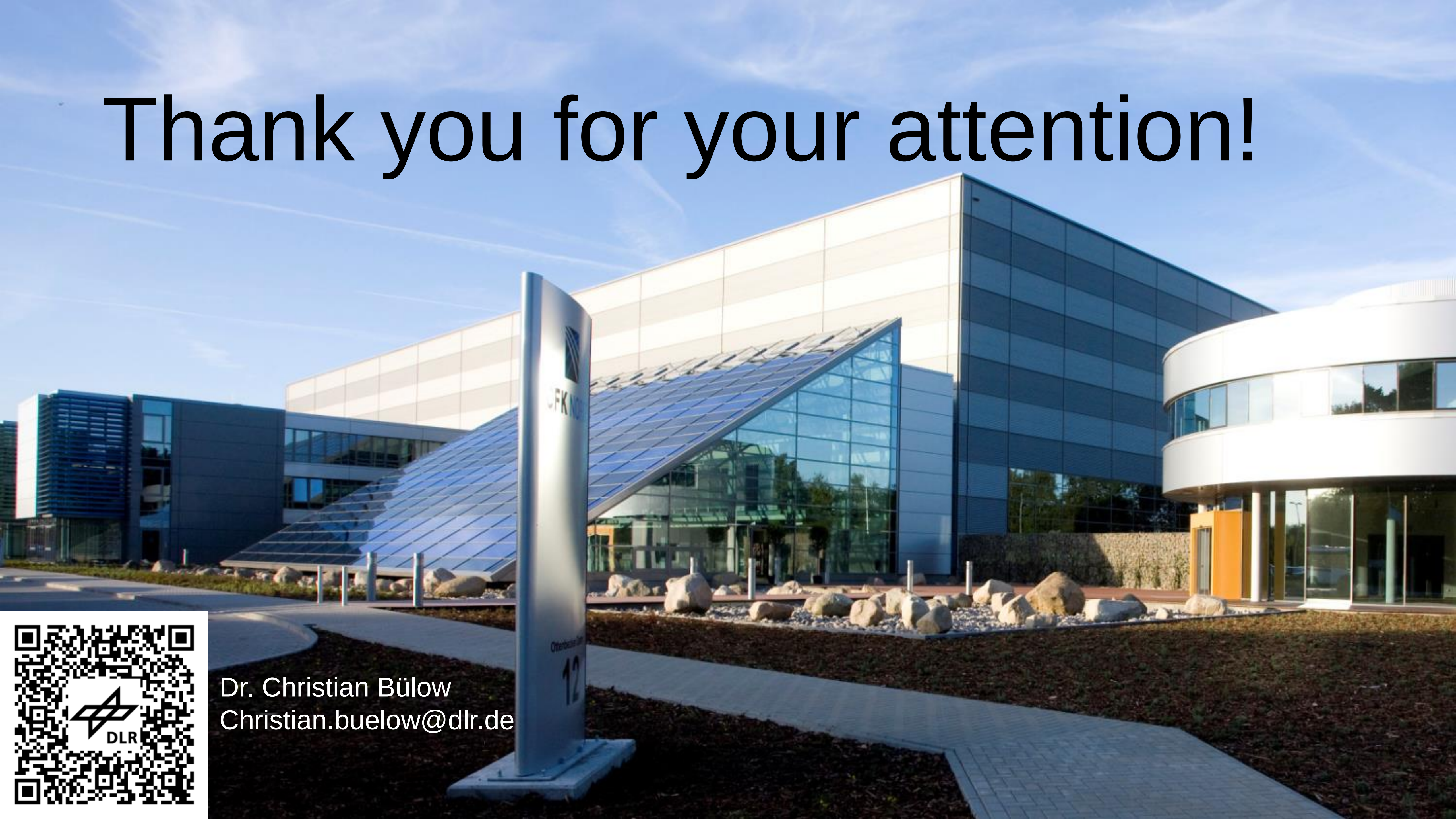
- Main Process drivers
    - Preforming
    - Curing in the autoclave
    - Vacuum build-up

6. Conclusions and Outlook

- Consideration of 2 tank configurations for cost and ecological assessment
- Main cost factors in the series production: equipment, material and labour
- Main ecological process drivers: preforming, curing and vacuum build up

- LCI of dome and cylinder in Tacoma
- Economical and ecological assessment on a broader data base

Thank you for your attention!



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