Digital Twins and Circular Economy challenges and an up-coming Project

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The **transition towards a circular economy** is estimated to represent a $4.5 trillion global growth opportunity by 2030 [Accenture Strategy, 2015, Waste to Wealth]


The **digital twin** market was valued at $3.8 billion in 2019, $7.5 billion in 2020, and is estimated to reach a value of $46.08 billion by 2026 [Mordor Intelligence 2022, Digital Twin Market, Growth, Trends, and Forecasts]
The pivotal role of DT raises significant questions related to its development within the present technological framework, needed skill sets, and implementation costs.
Minimized waste

Minimized raw material

Reprocessing

Repair

Refurbish

Share

Re-use

Use

Re-use

Refurbish

Repair

Reprocessing

Minimized waste
Challenge 1 - **Creation and update** of DT still requires high level of skills

Challenge 2 – The **silo effect** has not been actually relieved, and interfaces are only partially developed

Challenge 3 – Too many **overlapping standards** and vendor-specific platforms make interconnections laborious

Challenge 4 – **Lack of secure exchange** of data and clear data ownership

Challenge 5 - No effective and reliable **LCA data sources**

Challenge 6 - Poor use and exploitation of **IoT-enabled data streams**

Challenge 7 - **Implementation costs** constitute a significant barrier
AS IS

AN EXAMPLE!
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To integrate novel hardware technologies into the digital thread, to unleash their full potential for actual Circular Economy and reduced dependency from raw materials.

To set up an adequate sensors layer, where data, collected on the shop floor along the supply chain, are gathered and managed. The need of a common data space arises, to promote and facilitate the secure and seamless exchange of manufacturing / product / business data within value-networks in a circular-economy ecosystem.
The data across the value network needs to be exploited by data-driven methods for the generation and adaptation of multi-fidelity digital twins.
The digital twin emerges from the data collected.
Circular value chain

1. Digital Twin + AI
2. Data space
3. HW enablers for CE

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Analytics

AI
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Data space

Digital Twin + AI

Do we really need the AI?
GWP [kg eq. \( CO_2 \)/kg]

AN EXAMPLE!
GWP [kg eq. CO₂/kg]

GWP_{Ext} + GWP_{M.P.} + GWP_{Manuf.} + GWP_{Ass.} + GWP_{Use} + GWP_{Repair} + GWP_{EoL} + GWP_T

(1+SRC) \cdot (\sum_m f_m \cdot C_{S_m} \cdot GWP_{man,m}) +
+ SRC \cdot (\sum_i \sum_j f_{ij} \cdot V_{ij} \cdot \rho_j \cdot GWP_{ext}) +
+ \sum_i \sum_j \sum_p f_{ip} \cdot \chi_{p,i,j} \cdot V_{ij} \cdot \rho_j \cdot GWP_{mp,p,j} +
+ \sum_i \sum_j \sum_{f_{SRC}} f_{SRC,i,j} \cdot V_{ij} \cdot \rho_j \cdot GWP_{EOL,i,j} +
+ \sum_i \sum_j \sum_{f_{SRC}} f_{SRC,i,j} \cdot V_{ij} \cdot \rho_j \cdot f_{i,j,q} \cdot d_{i,j,q,z} \cdot GWP_{tra,z} +
+ \sum_i \sum_j \sum_{f_{SRC}} f_{SRC,i,j} \cdot V_{ij} \cdot \rho_j \cdot f_{SRC,i,j,r} \cdot d_{EOL,r,z} \cdot GWP_{tra,z} +
+ (1+SRC) \cdot (\sum_m f_m \cdot Q_{aux,w,m} \cdot GWP_{ext,w} +
+ \sum_m \sum_{w} \sum_{p} f_{m} \cdot \chi_{p,w} \cdot Q_{aux,w,m} \cdot GWP_{mp,p,w} +
+ \sum_m \sum_{w} \sum_{i} f_{m} \cdot f_{w,i} \cdot Q_{aux,w,m} \cdot GWP_{EOL,w,i} +
+ \sum_m \sum_{w} \sum_{q} f_{m} \cdot f_{w,q} \cdot Q_{aux,w,m} \cdot d_{w,q,z} \cdot GWP_{tra,z} +
+ \sum_m \sum_{w} \sum_{r} \sum_{z} f_{m} \cdot f_{w,r} \cdot Q_{aux,w,m} \cdot d_{EOL,r,z} \cdot GWP_{tra,z} +
+ (1+SRC) \cdot (\sum_m \sum_{j} f_{m} \cdot Q_{w,m,j,m} \cdot GWP_{ext,j} +
+ \sum_m \sum_{j} \sum_{p} f_{m} \cdot \chi_{p,j} \cdot Q_{w,m,j,m} \cdot GWP_{mp,p,j} +
+ \sum_m \sum_{j} \sum_{f_{SRC}} f_{j,l} \cdot Q_{w,m,j,m} \cdot GWP_{EOL,j,l} +
+ \sum_m \sum_{j} \sum_{q} \sum_{z} f_{m} \cdot f_{j,q} \cdot Q_{w,m,j,m} \cdot d_{q,z} \cdot GWP_{tra,z} +
+ \sum_m \sum_{j} \sum_{r} \sum_{z} f_{m} \cdot f_{j,r} \cdot Q_{w,m,j,m} \cdot d_{EOL,r,z} \cdot GWP_{tra,z})
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Data space

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3 HW enablers for CE

analytics

Circular TwAIn

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CIRCULAR TWAIN