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Sustainability in highly automated production systems: Methodology and algorithm for assessing production lines in the planning phase

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INTRODUCTION

- ***Trends in Manufacturing:***
  - Automation & Sustainability are key[(a)]
  - Burden shifting from use stage (e.g. e-Mobility)
  - New ISO 14001/2015: Life cycle perspective in production
- **Automotive Manufacturing:**
  - Car Body production is highly automated (up to 1.200 robots ≈ 95%)

[(a)] Roadmap for Factories of the Future in 2030 developed by European Commission & European Factories of the Future Research Association (EFFRA)

CHALLENGES

I = P x A x T [(b)]

- Environmental **Impact (I)** of car sector rises due to **population (P)** and **affluence (A= ↑prosperity ↑mobility)** increase → **Technology (T)** the only lever to decrease impacts
- **Increase** in car variants, production life-time, infrastructure costs and complexity
- **Decrease** of time for planning & ramp-up
- **Economic data** main industry interest
- **Life cycle thinking** hardly exists in production

[(b)] T. Graedel and B. R. Allenby, "Industrial ecology," vol. 20, no. 4. Prentice Hall, 1995

OBJECTIVES

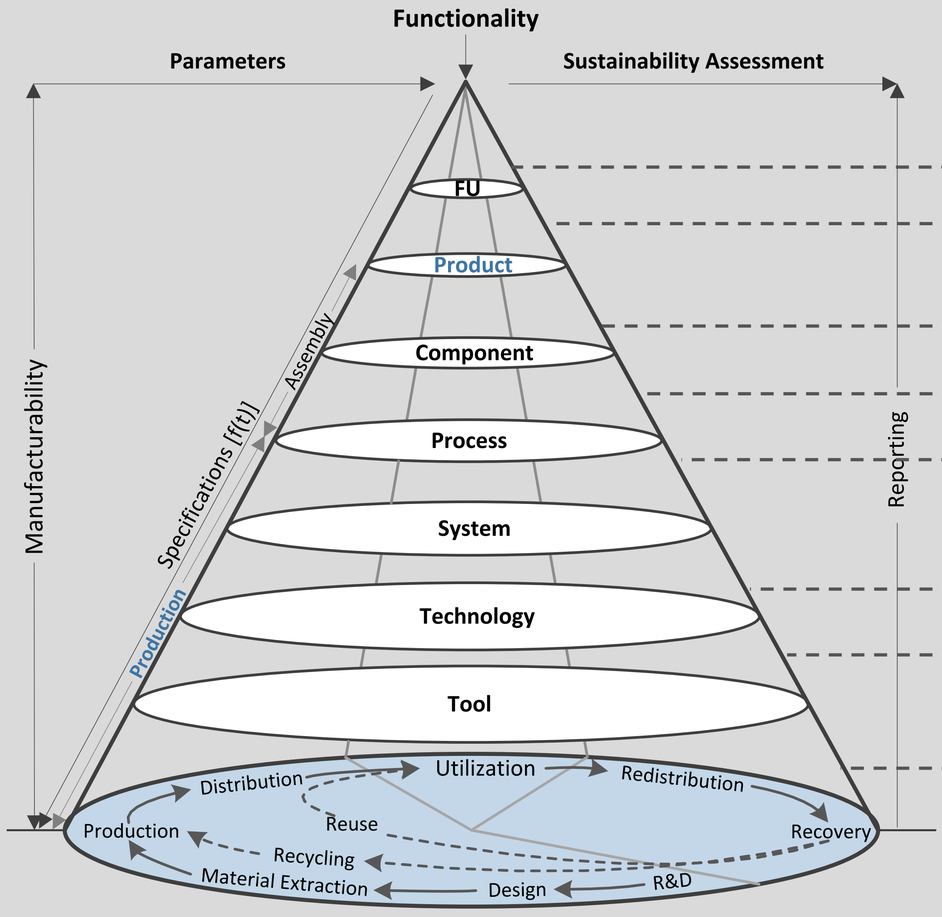
Sustainable Manufacturing:

- Assess Sustainability in relation to the final product incl. rebound effects & planetary boundaries

Sustainability in Highly Automated Manufacturing:

- Sustainability Assessment ***Algorithm*** for ***production planning*** targets to be applied in an economically ***feasible way***
- Identification of ***when***, ***how*** and ***where*** to implement

RESULTS: *SUSTAINABILITY CONE* APPLIED IN HIGHLY AUTOMATED PRODUCTION



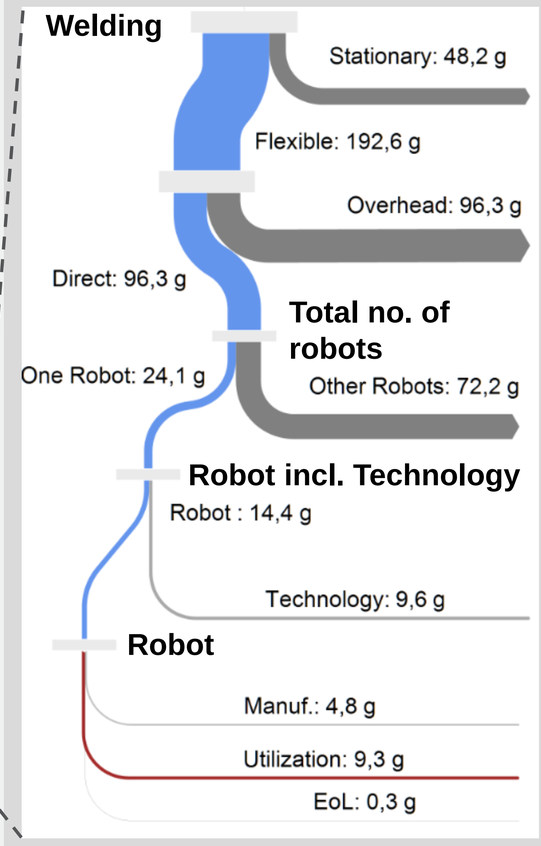
Sustainability Cone: Merging life-cycle perspective, product and production planning (Rödger et al., submitted)

Applied algorithm: Greenhouse Gas (GHG) targets for the different levels of the Sustainability Cone

	Mobility		GWP_{100} (Today)	GWP_{100} (Scenario)
	200.000 km/10yr		38,3 t	29,0 t
	Car	Manuf.	6,7 t	4,0 t
		Use	31,6 t	25,0 t
		EoL	0,0 t	0,0 t
	Car Body		2,0 t	1,2 t
	Body-Shop		105,7 kg	63,4 kg
	Underbody		51,8 kg	31,1 kg
	Side Member		7,5 kg	4,5 kg
	Spot-Welding		0,2 kg	0,1 kg
	Robot	Manuf.	4,8 g	2,9 g
		Use	9,3 g	5,6 g
		EoL	0,3 g	0,2 g

Assumptions for this scenario:

- Total GHG emissions of car sector remain stable
- 40% sales increase until 2024 (worldwide)
- 21% less fuel consumption (EU no. 333/2014)



Allocation of GHG emissions from the technology level in the sustainability cone downwards to the tool level

METHODOLOGY

Vertical perspective in Sustainability Cone:

- ***Market*** developments and ***demands*** for functionality
- ***Top-down*** approach for economic, social and environmental goals, determining choice of process layout, system, technology and tools
- Reflects iterative product and production planning
- ***Bottom-up*** approach for reporting sustainability assessment results

Horizontal perspective in Sustainability Cone:

- Sustainability aspects determine choice of different options (e.g. technology…)

SUSTAINABILITY ALGORITHM

- Algorithm combines specific ***resource***, ***product*** and ***process*** parameters (e.g. car body)
- ***Allocation*** method for ***each level*** in the Sustainability Cone
  - Cycle time per system, cell and technology
  - Vertical integration and degree of mechanization
  - Production components and PLC systems
- Overhead and indirect consumptions
- **Sustainability target calculation for**
  - Technology
  - Robotics (Manufacturing, Use and EoL)

DISCUSSION & CONCLUSION

- **Sustainability Cone** and Algorithm allows
  - ***combination*** of ***product*** and ***production***,
  - ***target setting*** and ***implementation*** in an early planning phase
- Production component data currently lacking
- Algorithm and life cycle data should be implemented in ***industrial planning software***

Future Work:

- More impact categories will be investigated:
  - Environmental + Resources + Social
- Application in case studies

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AREUS Automation and Robotics for EUropean Sustainable manufacturing

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