DTU

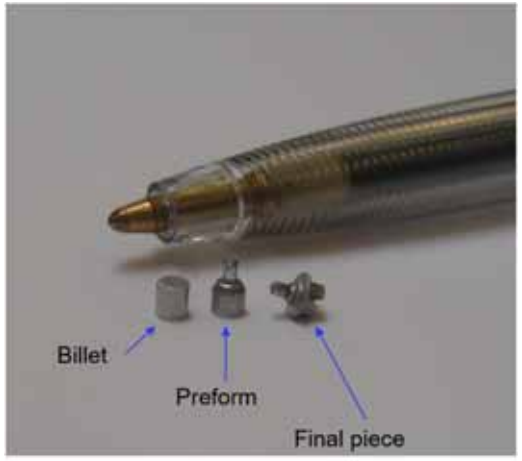
1st General meeting of the EMN AdvanceManu

Challenges and trends in advanced manufacturing - also related to metrology

Hans Nørgaard Hansen
Contributions: Tim McAloone, Jesper Hattel, Giuliano Bissacco, David Bue Pedersen

…a few words about me…

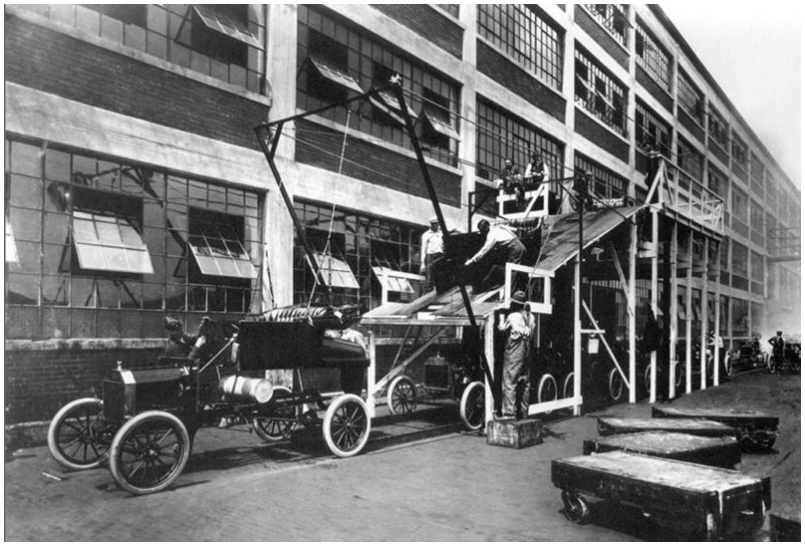
- Professor of Micro Manufacturing, Department of Mechanical Engineering, Technical University of Denmark (2002➔)
- Head of Department Mechanical Engineering, Technical University of Denmark (2016➔)
- Fellow of CIRP (2007➔)
- President of CIRP (2021-2022)
- President of euspen (2015-2017)

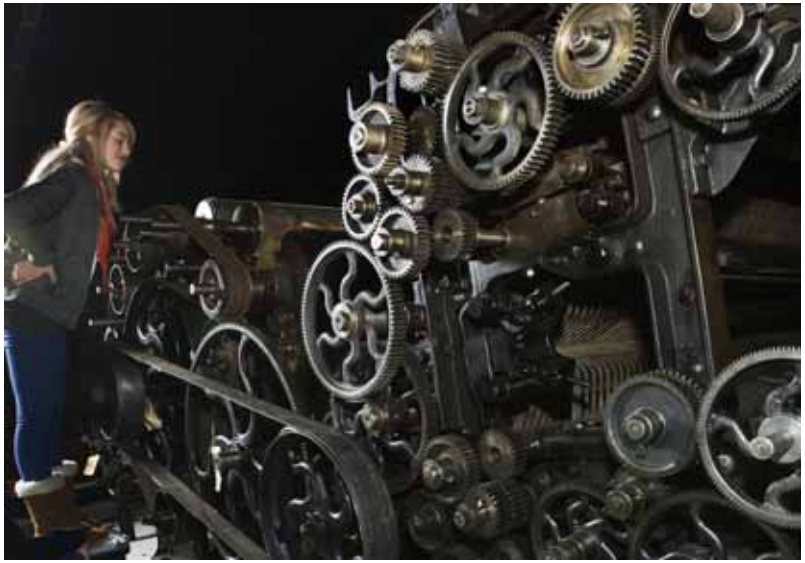


Outline

- Mega trends and manufacturing (and everywhere else)
- Some examples of developments in manufacturing
- What is different from what we are already doing?

AKTIESELSKABET
BURMEISTER & WAINS
MASKIN OG SKIBSBYGGERI





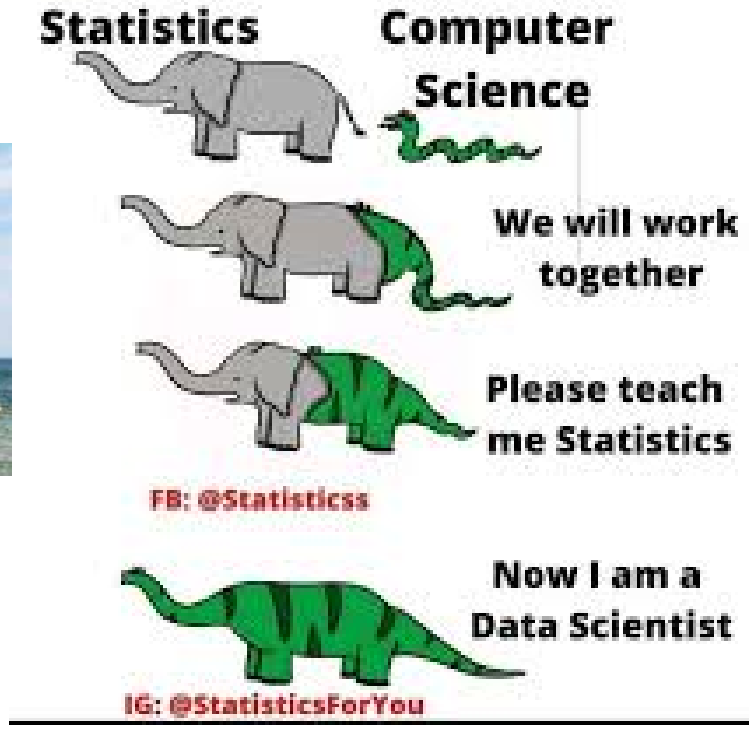
Automotive

Aerospace

Defense

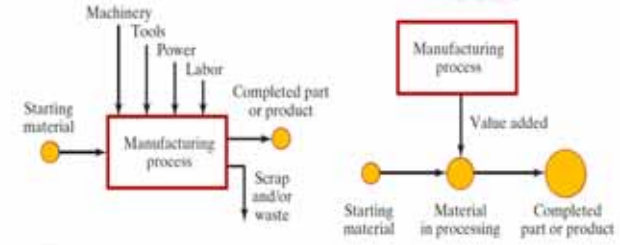
Manufacturing - digital and green

Digitalization



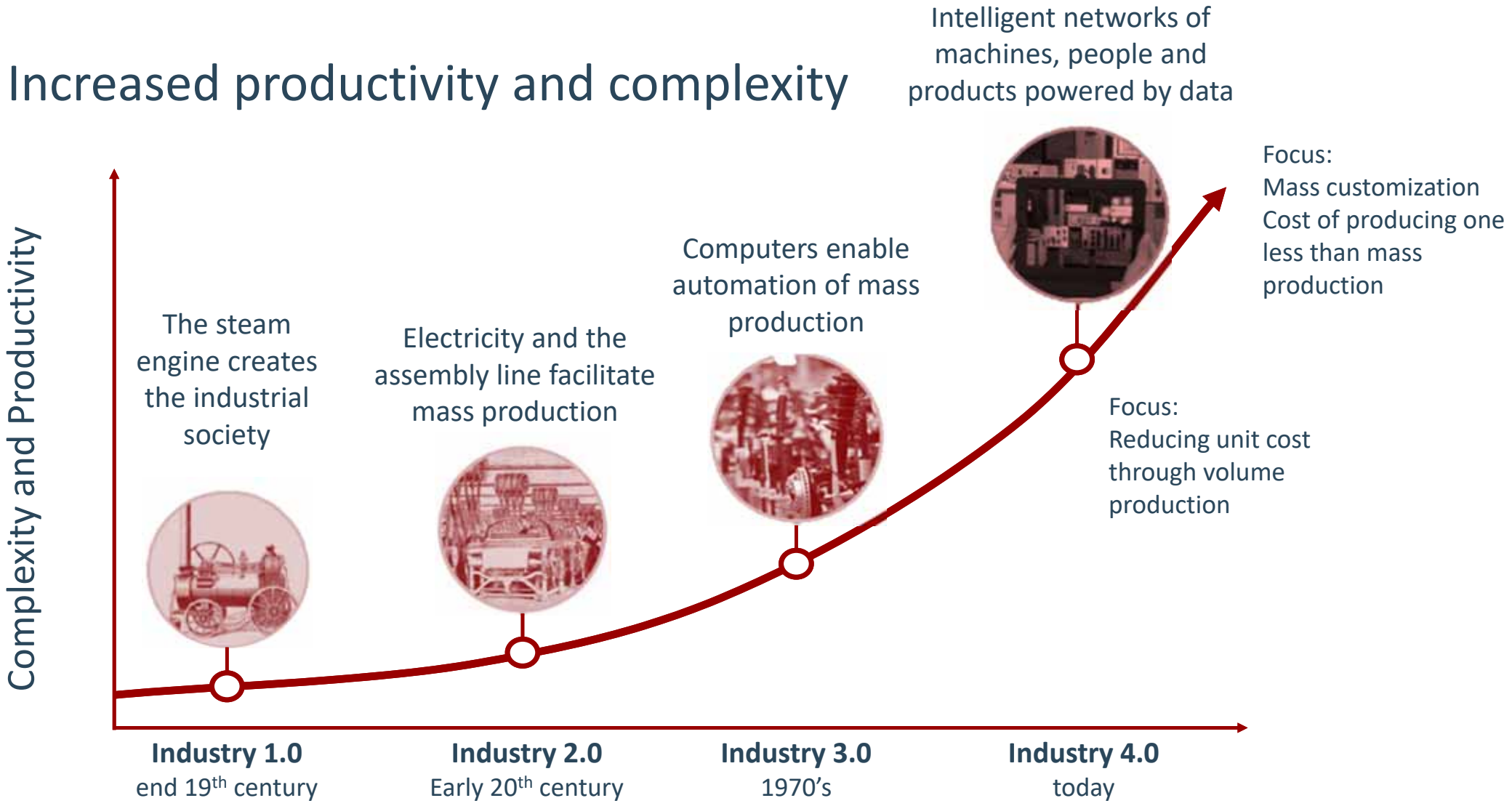
Digitalization

What is Manufacturing?



MADE
Manufacturing Academy of Denmark

Increased productivity and complexity



There are two emerging approaches to Industry 4.0

Fully Automated

Restructuring of PRODUCTS to provide mass customization

Data-Driven Manufacturing
(Industry 4.0/Digitalization)

80/20
Denmark

- High Mix
- Low volume
- High Quality

Fully Manual

Restructuring of PROCESSES to provide mass customization

Industry 4.0 two key components:
- Digital Twins and Digital Automation

Supporting:

- Rapid development cycles
  (experiments)
- Faster time to market
- Customization and quality
- Agile production lines
  (scalability and flexibility)
- Production close to market

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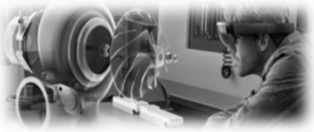
Digital Automation

Modular Production

Additive Manufacturing

Collaborative robots

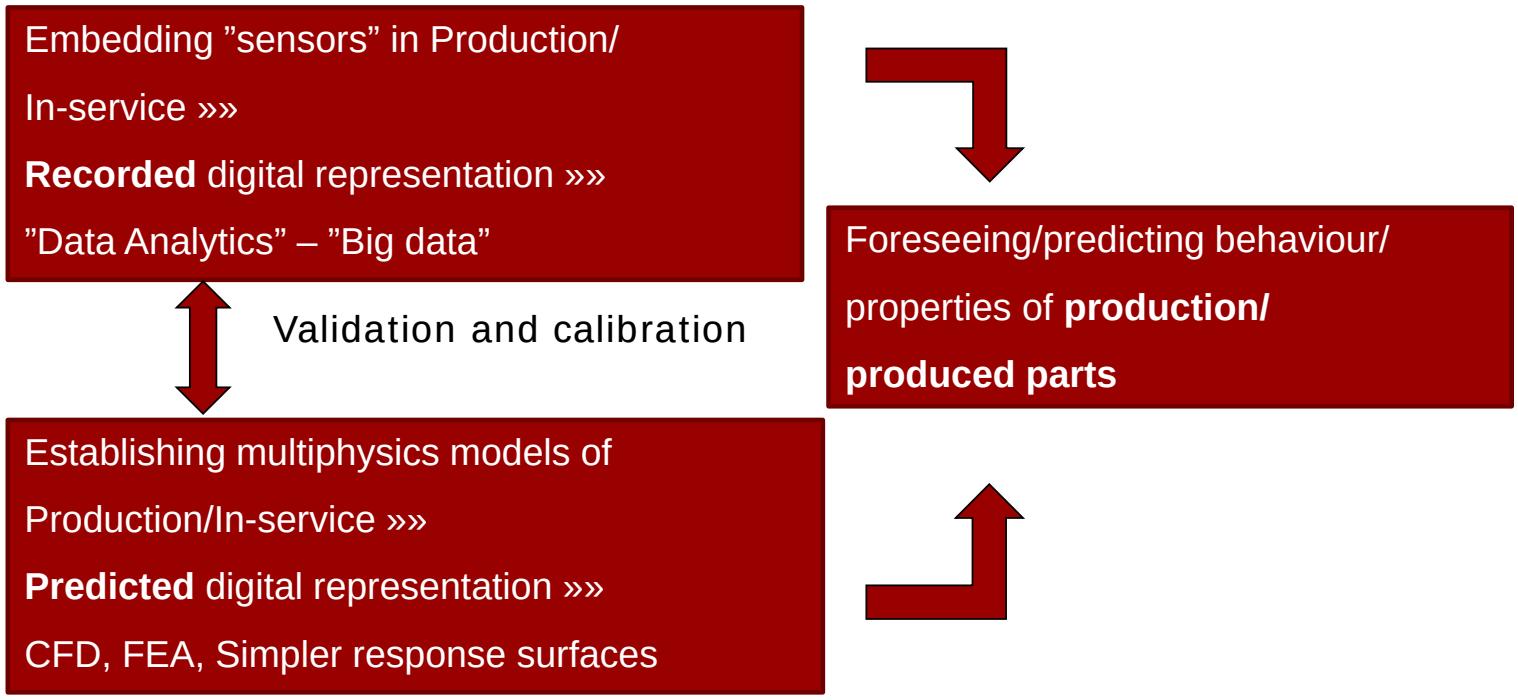


"Augmented Reality"

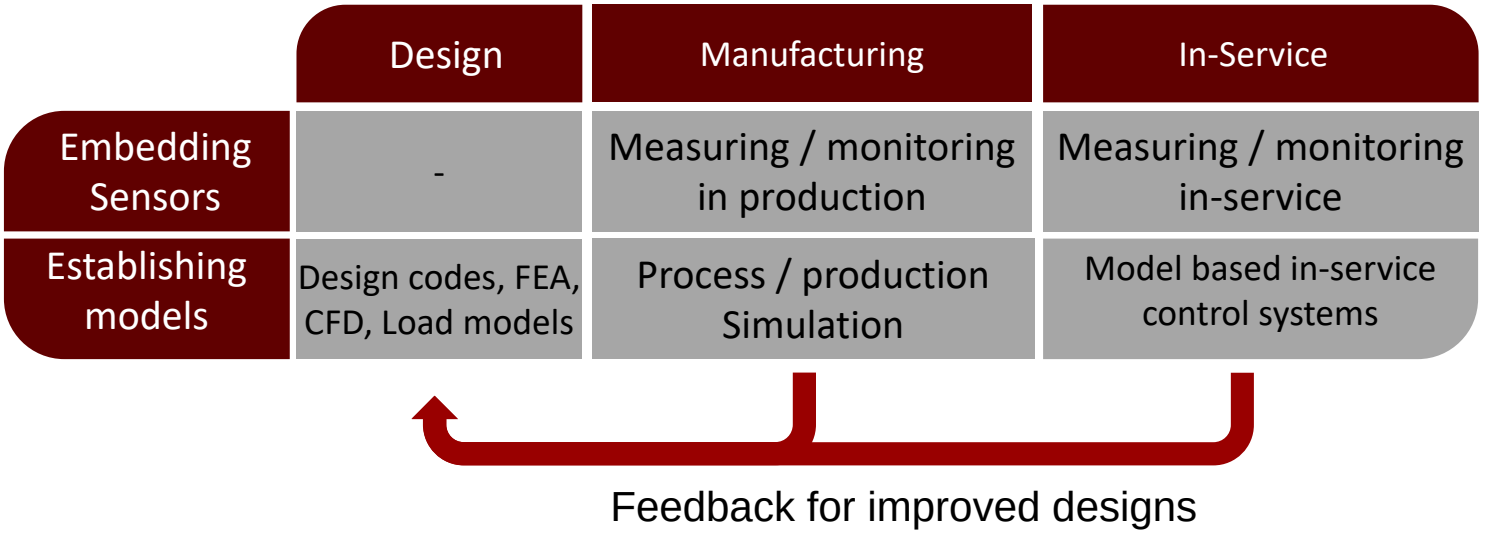
IoT
- Supply chains from production to customer

Simulering
& "Digital Commissioning"

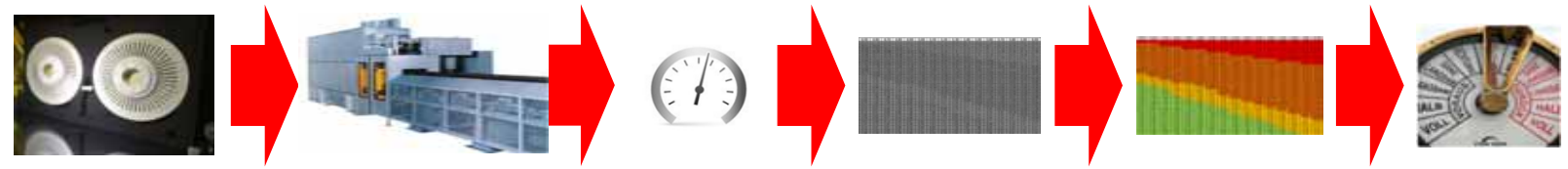
Digital representation of Production and Products - Stands on two legs….



Coupling to the entire chain: Design, Manufacturing and In-Service



THE DIGITAL SHADOW: Recorded from real production
THE DIGITAL TWIN: Based on models



Real Foundry– Digital Shadow

Digital Foundry– Digital Twin

Digitalization and industry 4.0 in German foundries. Courtesy: MAGMA GmbH, Aachen, Germany, Dr. Jesper Thorborg

What are the Differences between digital Shadow and digital Twin?

Digital Shadow

- Data come from real production conditions
- Data can only be created during production
- Processes have natural variations and scatter
- Large amount of data required to get evidence
- Many quality criteria cannot be retrieved directly
- Often weak correlation to quality

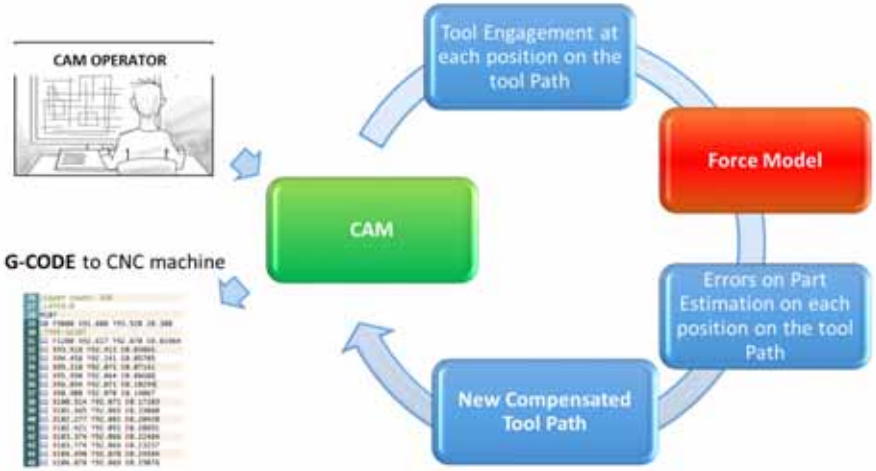
Digital Twin

- Process window and measures can be determined during planning
- Multiple quality criteria are available which cannot be directly measured during production
- No scatter → reduced number of experiments → easy statistics possible
- Feasibility studies can be substituted to a large amount
- Modell to describe the process must be available
- Identification of process conditions, robustness and quality and optimal operating conditions…

Digitalization and industry 4.0 in German foundries. Courtesy: MAGMA GmbH, Aachen, Germany, Dr. Jesper Thorborg

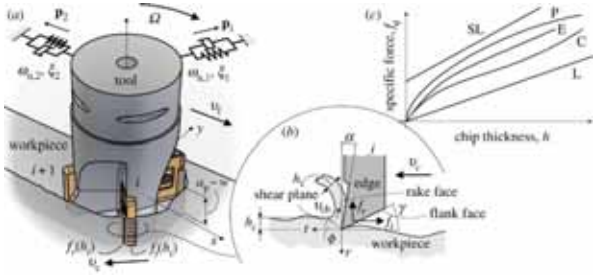
Compensation strategies for precision machining of large structures

Assoc. Professor Giuliano Bissacco (DTU)
PhD Student Alessandro Checchi (DTU)
Christian Haastrup Merrild (DAMRC)

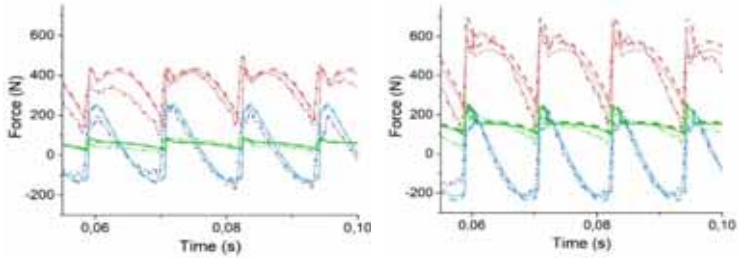


Problem: Geometric Errors Generation

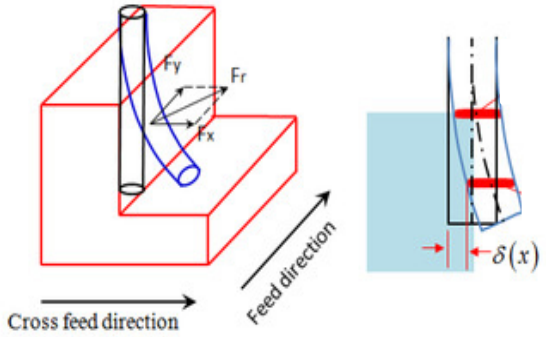
Cutting Process



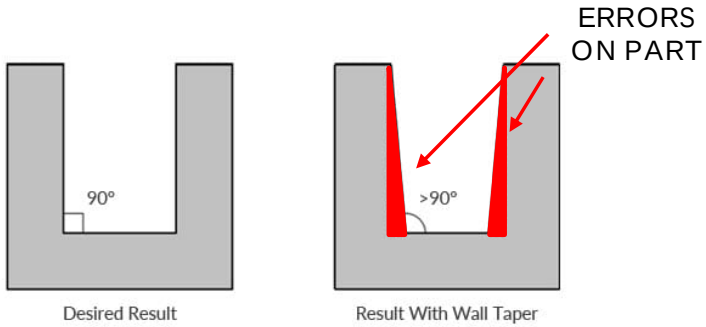
Cutting Forces



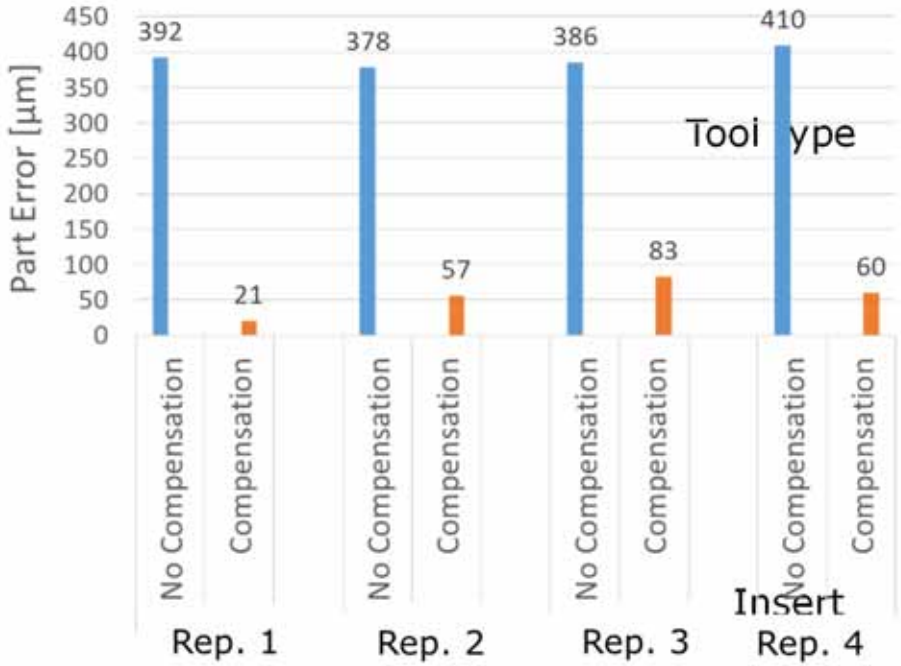
Machine-Tool Deflection



Geometric Errors on the Final Part

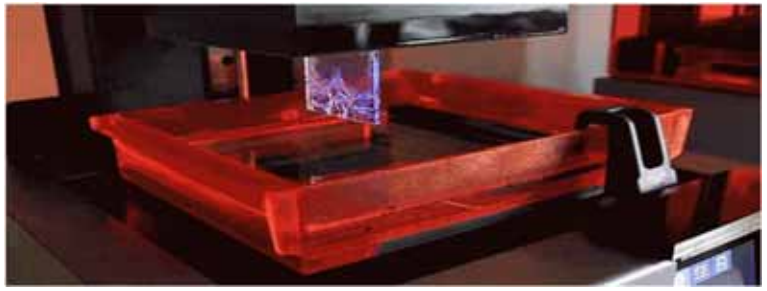


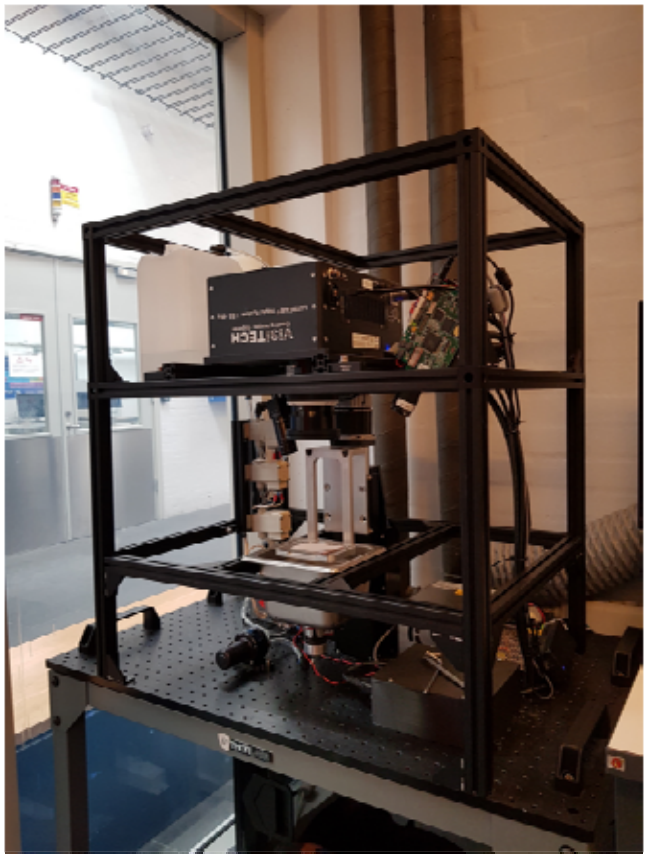
Error reduction by compensation

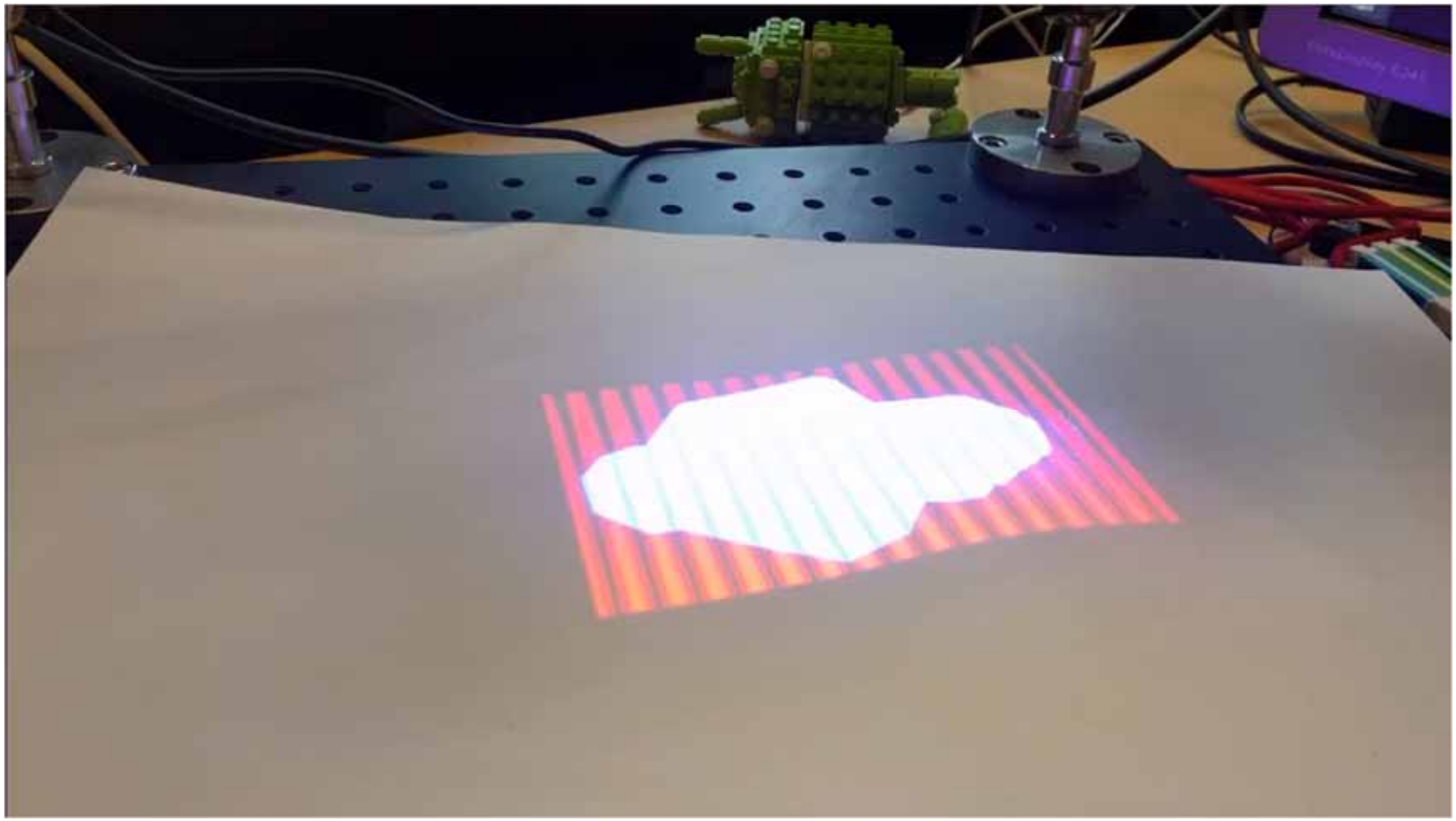


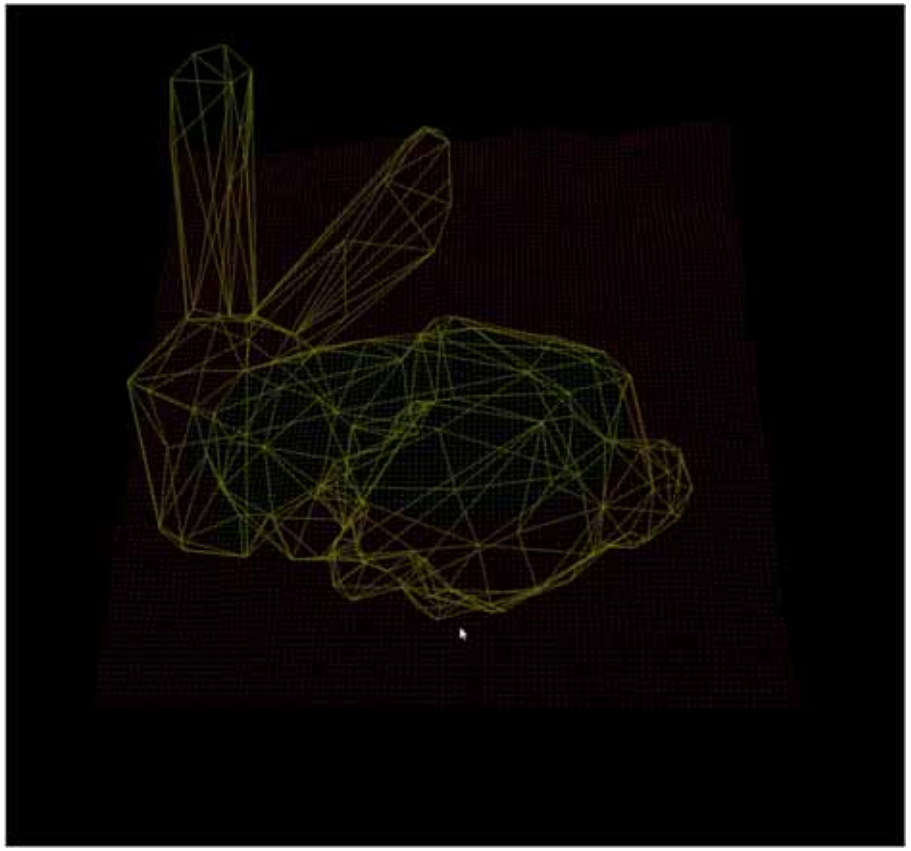
Advanced process control by in-line sensoring and optimization in additive manufacturing

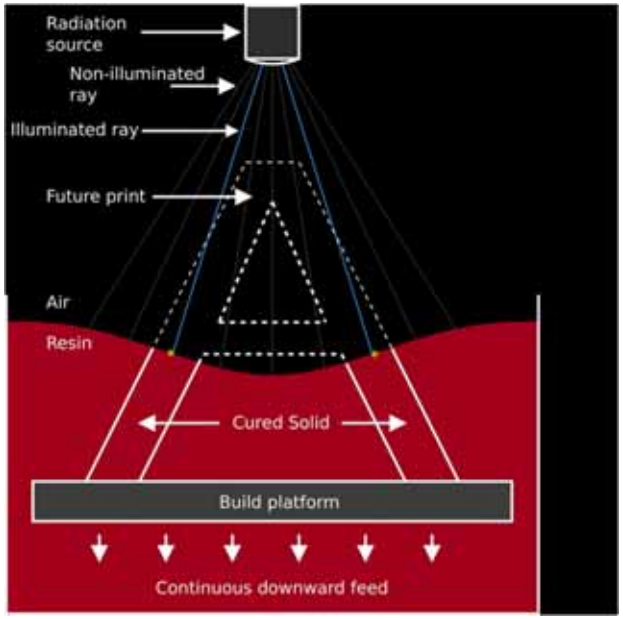
PhD Eyþór Rúnar Eiríksson (DTU)
Senior Researcher David Bue Pedersen (DTU)







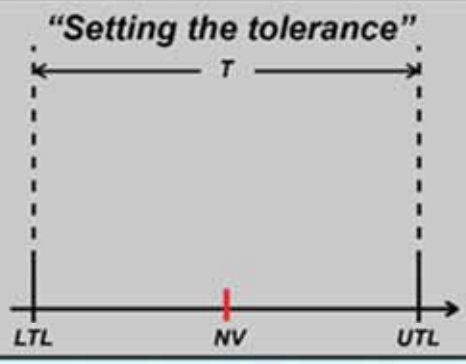
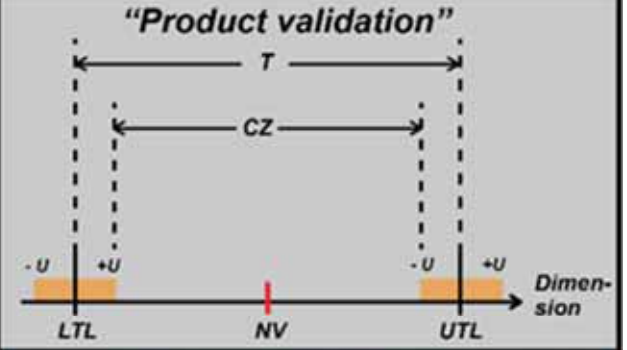
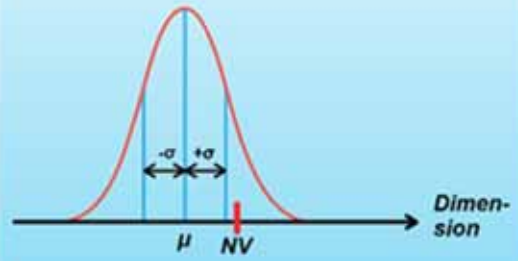
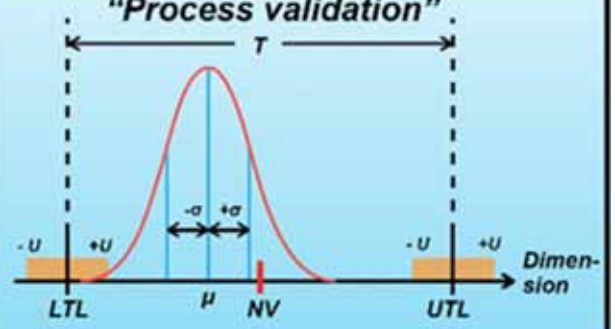



Radiation source
Non-illuminated ray
Illuminated ray
Future print
Air
Resin
Cured Solid
Build platform
Continuous downward feed

It all comes down to……

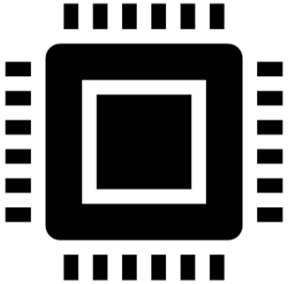
	Specification	Process chain definition	Validation
Product		N/A	
Process	N/A		

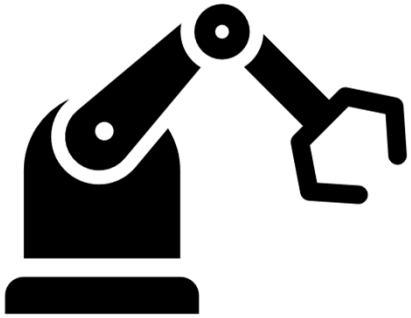
…and here metrology plays an important role

	Specification	Process chain definition	Validation
Product	"Setting the tolerance" 	N/A	"Product validation" 
Process	N/A	"Process stability" 	"Process validation" 

Observations

- Data collection is not new (temperatures, pressures, forces..)
- Dimensional metrology applied to manufacturing is not new (in-line, off-line)
- Simulation of process-material interaction is not new



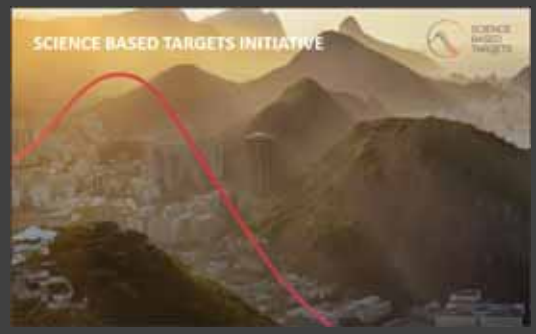


What could be relatively new….

- Modelling of process chains based on a combination of multi-physics models and statistical models (integrating the digital shadow and digital twin)
- Feed-back of data along the value chain (design – manufacturing – use)
- Using measurements to update 3D models of components as they are produced (”traceability”)
- (Automatic) optimization of product and manufacturing design
- Virtual and fact based product development

SUSTAINABILITY TRENDS

- THAT ARE RESHAPING THE WORLD



RESOURCE EFFICIENCY

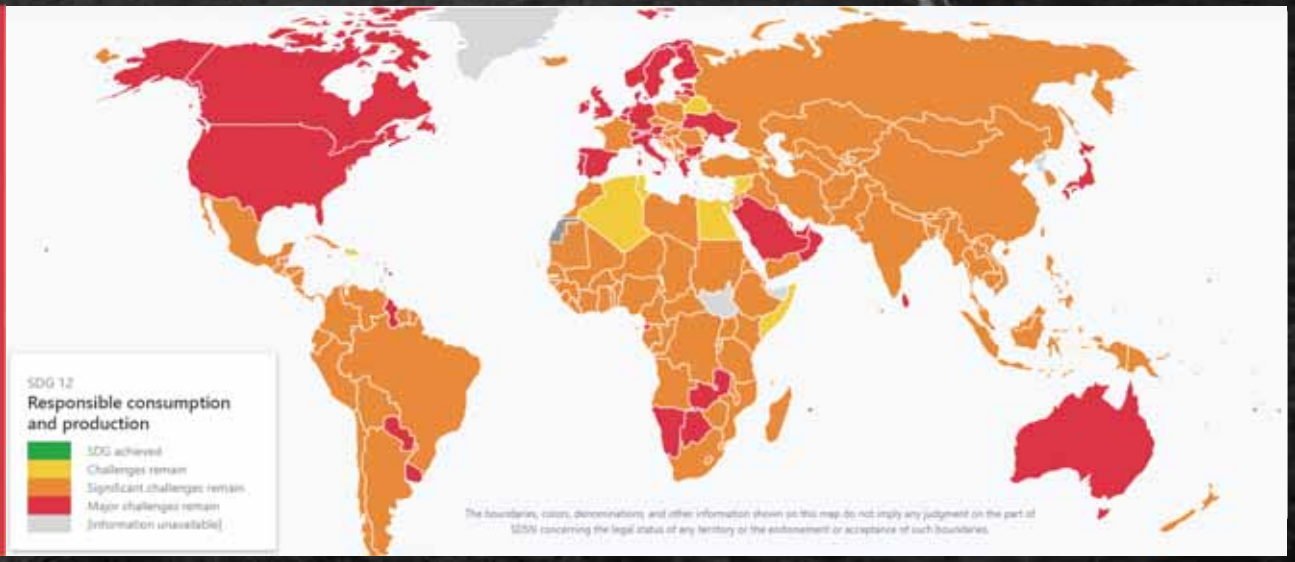
- Huge potential in the installed base
- Savings of both money and environment
- Necessary measures in a growing population
- Risk minimisation

SUSTAINABLE DEVELOPMENT GOALS

Tim McAloone

SUSTAINABLE DEVELOPMENT GOALS

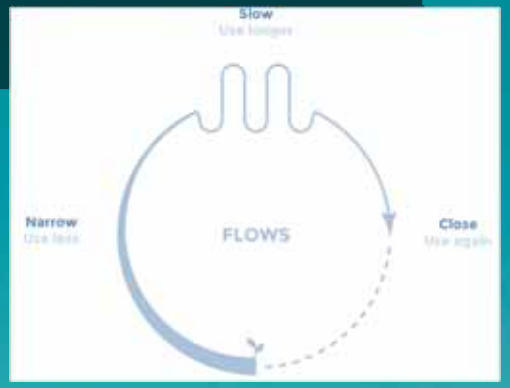
Where Denmark is lagging behind…



Rethink design processes, production processes, consumption patterns

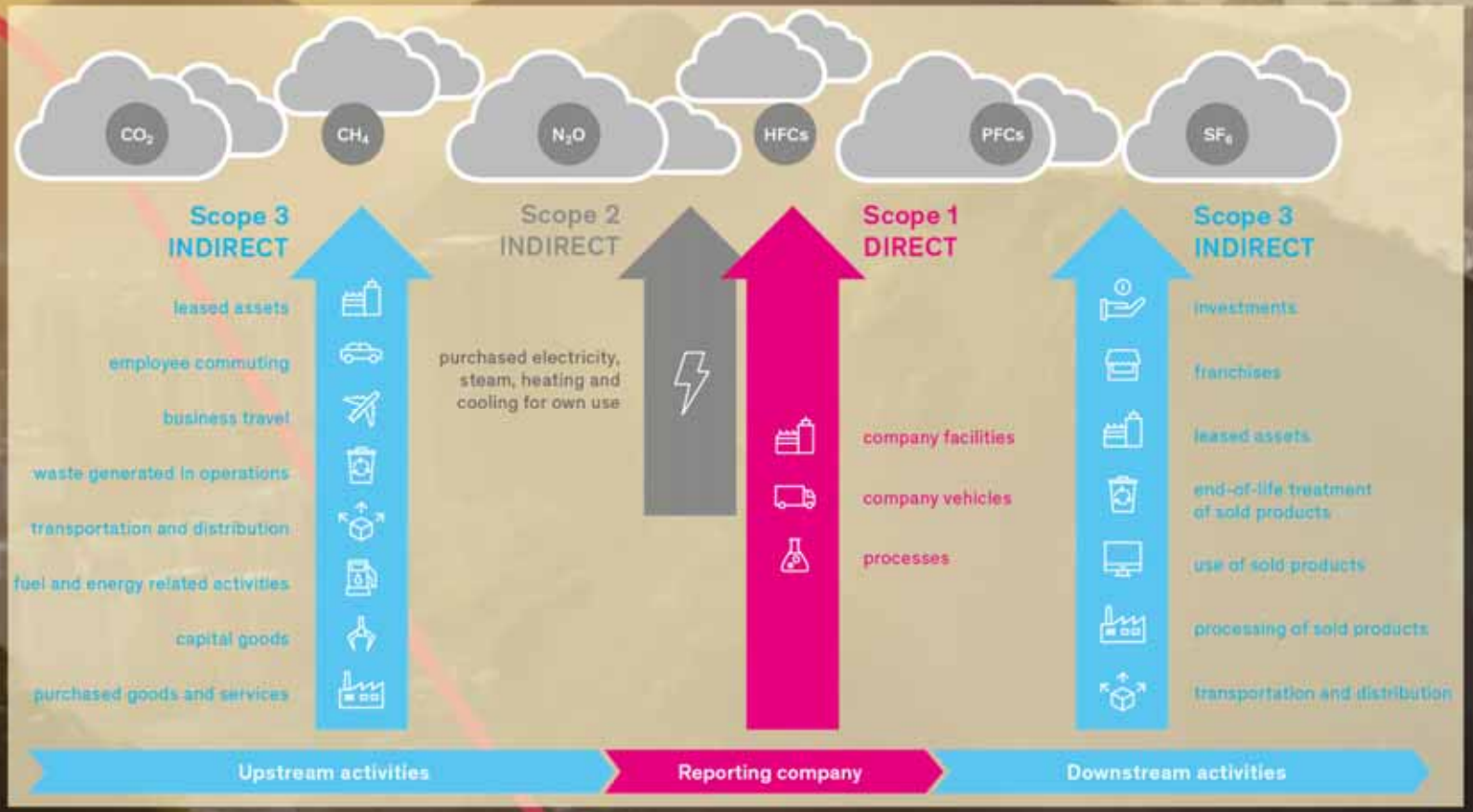
CIRCULAR ECONOMY

- Fastest growing business strategy area in Europe
- Closing the loops
- 1.8 trillion Euro per year in Europe
- Decoupling value creation from resource consumption
- Requires a systemic approach



SCIENCE BASED TARGETS INITIATIVE

SCIENCE BASED TARGETS



[Image: myclimate]

Thank you for your attention!