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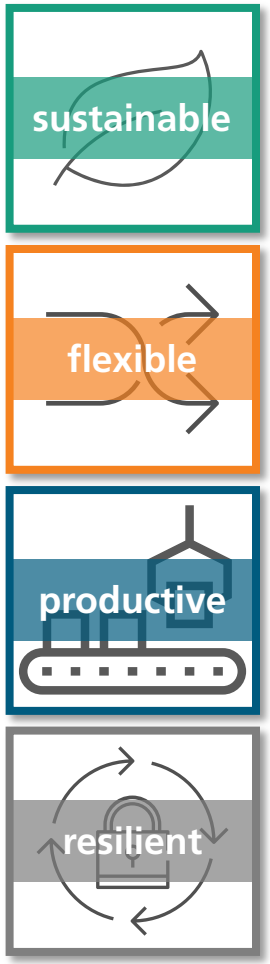
Future-proof production – sustainable, flexible, productive and resilient

Necessary characteristics of future production systems

Production systems should be sustainable, flexible, productive, and resilient



- Climate neutrality by 2030 according to Scope 1-3
- Recyclable products with neutral CO_2 footprint

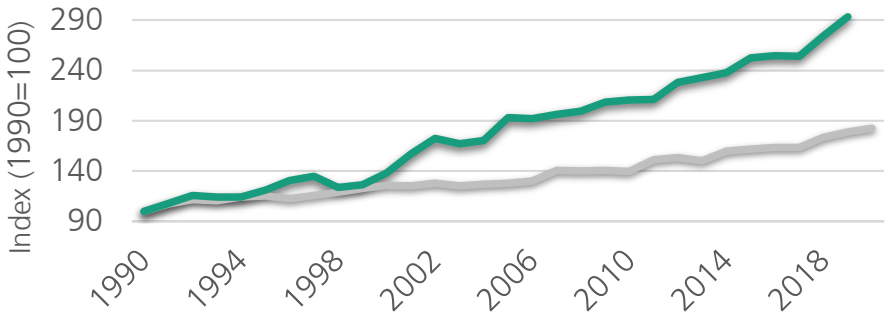
- Flexibility regarding fluctuations in production
- Flexible adaptation of hardware and software to changing conditions

- Transparency about the performance of all business processes => Time is money
- Focus on increasing labor, machine, material and energy productivity => Asset productivity: < +5%/a

- "Performing under adverse conditions"
- Securing value creation (local for local, access to raw materials and semi-finished products, technological sovereignty)

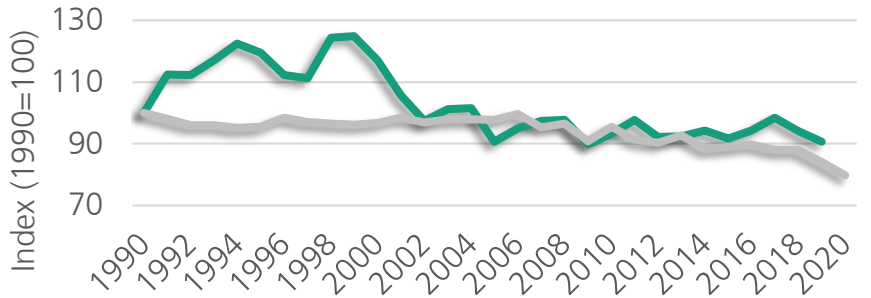
Increasing energy and resource productivity is not enough

Energy & material productivity increase at the example of Germany



Energy productivity: +82%

Material productivity*: +193%



Primary energy consumption: -10%

Raw material consumption (RMC): -9%

Despite an increase in energy and material productivity...

... resource consumption in Germany currently corresponds to **3 earths**.

... global resource consumption is currently equivalent to **1,7 earths**.

sustainable

To face current environmental problems, an increase of energy and resource productivity is not sufficient. We need sustainability on an economic, ecological and social level.

Source: WU Vienna (2022): materialflows.net/visualisation-centre/country-profiles; BMWK (2021); Global Footprint Network (2022): http://data.footprintnetwork.org/#/; Fraunhofer IPA

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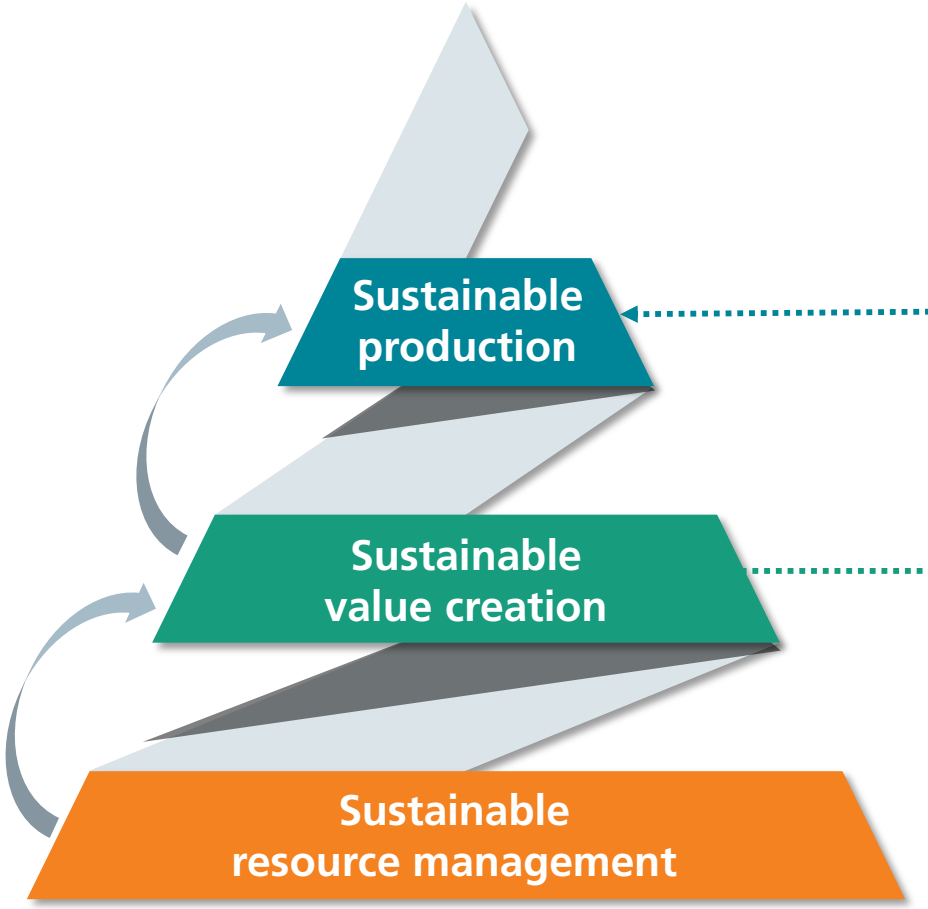
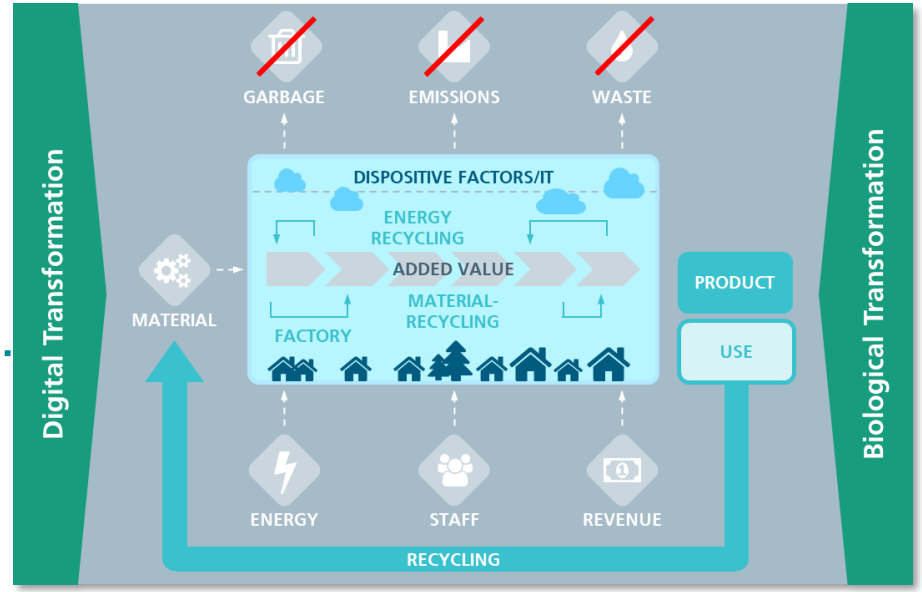
What does sustainable value creation mean?

Efficiency and effectiveness as a basis





Sustainable value creation by

efficiency

- Continuous optimisation of processes
- Reduced material and energy use
- Increased regional material and energy symbiosis

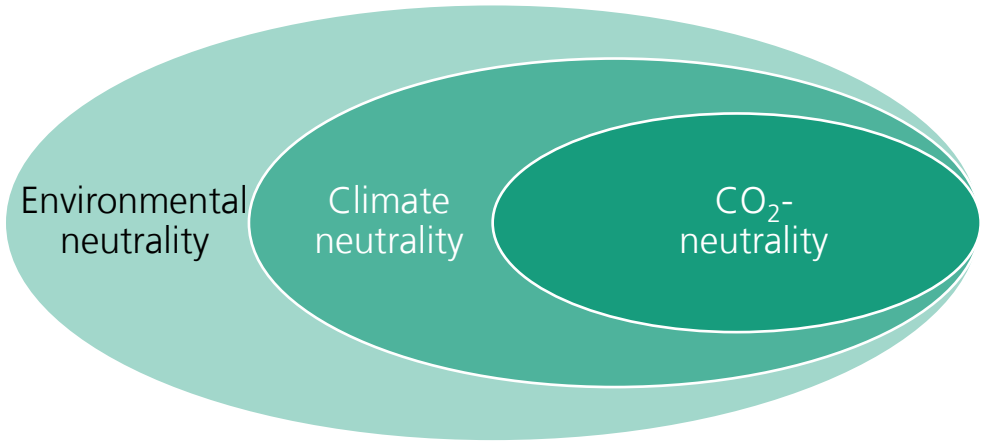
effectiveness

- Waste-free and exergetically favourable processes
- Renewable energies and materials
- Circular economy compatible products and processes

Climate neutrality - first step towards environmental neutrality

Systematic approach and attention to scopes necessary

Different "neutralities"



Corporate Carbon Footprint (CCF)

Scopes according to Greenhouse Gas Protocol

Scope 1

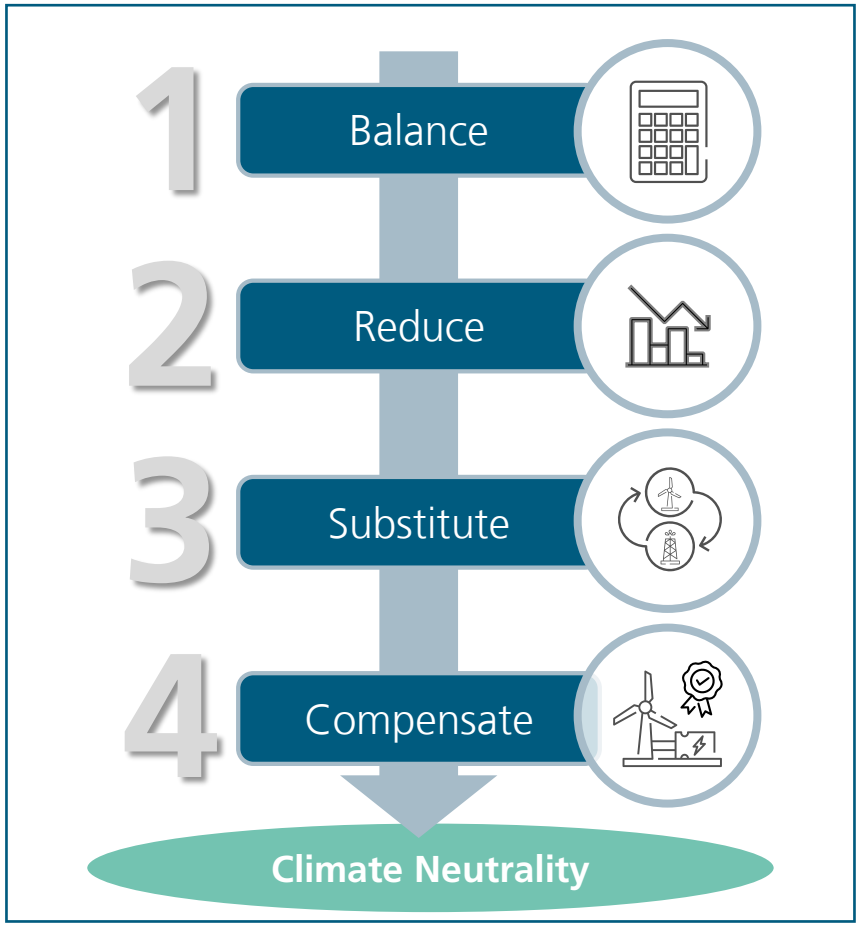
- Direct emissions (e.g. oil heating)

Scope 2

- Indirect emissions
- Purchase of electricity, heat, steam, cooling

Scope 3

- Indirect emissions
- Upstream & downstream activities
- 15 categories (e.g. shuttle traffic, purchased goods...)



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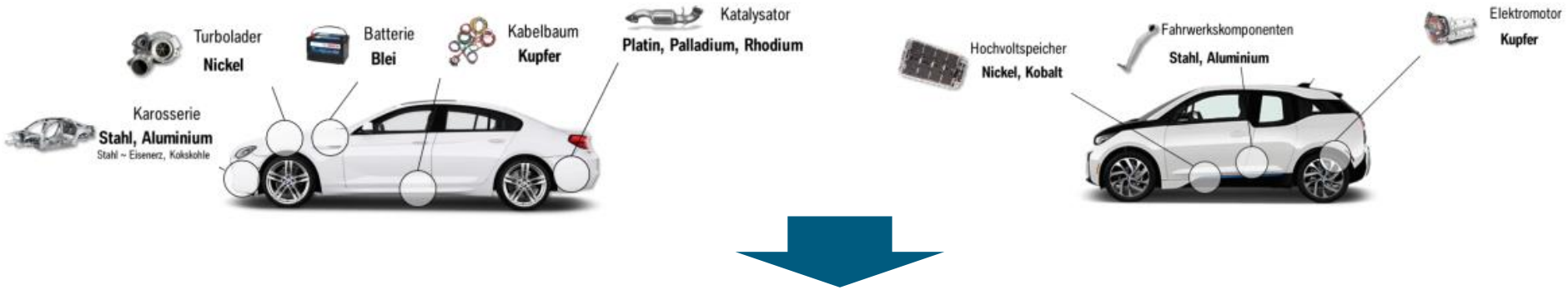
Catena-X Automotive Network

Building the First Operating System for a Data Driven Value Chain

Premise:
Without Catena-X, the targets for secondary materials and the associated CO_2 targets will not be achieved.



- **Catena-X enables access to life-cycle data of vehicles.**
- **Catena-X enables the reduction of overhead costs through a data ecosystem.**
- **Catena-X enables the certification and transparency of material cycles for CO_2 reduction.**
- **Catena-X directly affects CO_2 targets and enables new sourcing models.**
- **Catena-X structures fragmented markets, sets standards and enables economic dismantling**

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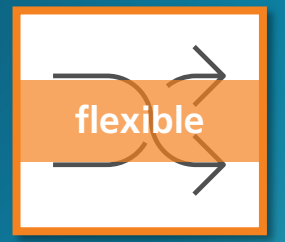
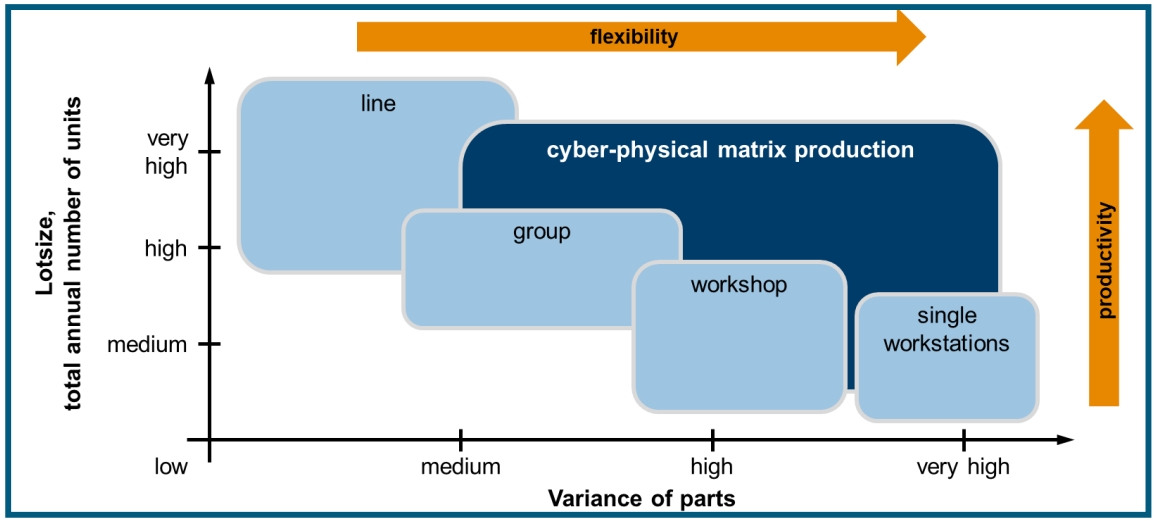
Source: Catena-X or an Catena-X affiliate company.

Flexible production as a response to short-term changes

Cyber-physical matrix production systems as one flexibility possibility



- Production systems must be planned, built and managed flexibly to react quickly to changes at short notice (i.e. order fluctuations, supply chain problems, new or changed products, …)
- Today's technologies enable high flexibility on both the hardware and software side, for example automated guided vehicles, factory operating systems or flexible automations
- Cyber-physical matrix production systems enable the production of variable lotsizes as well as variable number of parts



High flexibility must be one of the goals in planning and designing future-proof productions. This can become a major competitive advantage in the event of short-term fluctuations.

Source: own representation, inspired by Eversheim 1996, S. 103, 135, Wöhe/Döring 2000, S. 442, Spath et al. 2014, S. 10.10, extended by matrix production systems.

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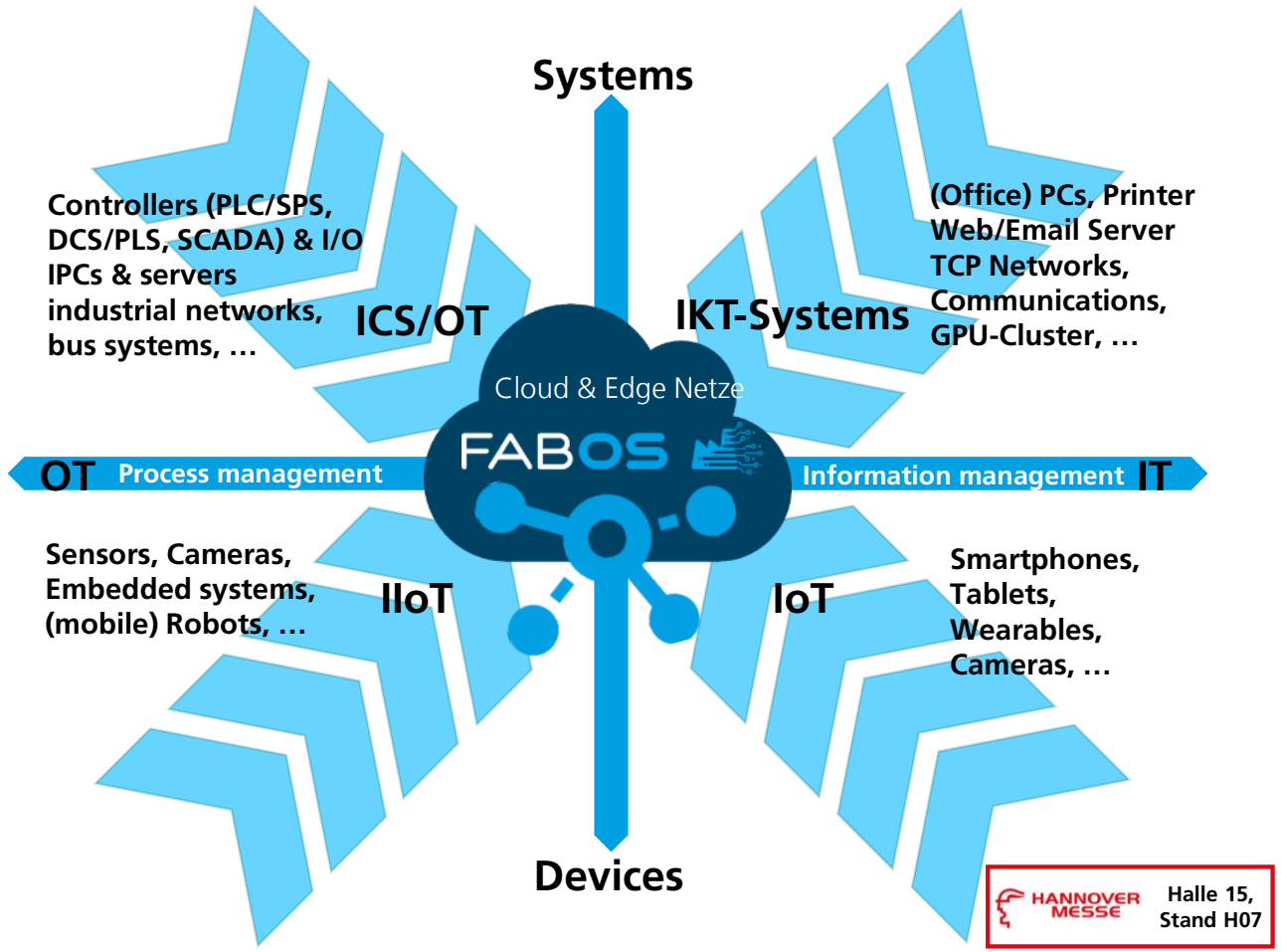
Example FabOS: Industrie 4.0 Drives the Convergence of ICT and OT

System landscape in manufacturing companies inhibits efficient use of new technological possibilities

- ICT & OT are increasingly converging, do not fit together due to different genesis (e.g. reliability vs. flexibility)
- IoT & IIoT approaches are increasingly being used
- New possibilities
  - Better communication technology, Computing power and AI tools
- New challenges
  - Efficient use of domain knowledge while maintaining technological sovereignty
  - Use of the flexiblity of ICT in OT
  - Widespread use of artificial intelligence for production optimization



DCS Distributed Control System, ICS Industrial Control System, industrielle Kontrollsysteme

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Example of application of matrix prouction systems – SEW Eurodrive Bruchsal

Achieved: High productivitiy independent of variance and short lead time of 5 days

Starting point:

- Offer of customizable products leads to high variance

Goal:

- Produce high variance efficiently and with short delivery times

Solution:

- Continuous matrix production system across al production stages
- Production in one-piece flow

Result:

- Number of employees: lower
- Number of operating resources: lower
- Lead time: lower
- Stocks: lower
- Degree of automation: higher
- Space requirement: slightly higher

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Source: SEW-Eurodrive; Forschungsbeirat der Plattform Industrie 4.0/acatech - Deutsche Akademie der Technikwissenschaften (Hrsg.): Umsetzung von cyber-physischen Matrix-Produktionssystemen, 2022.

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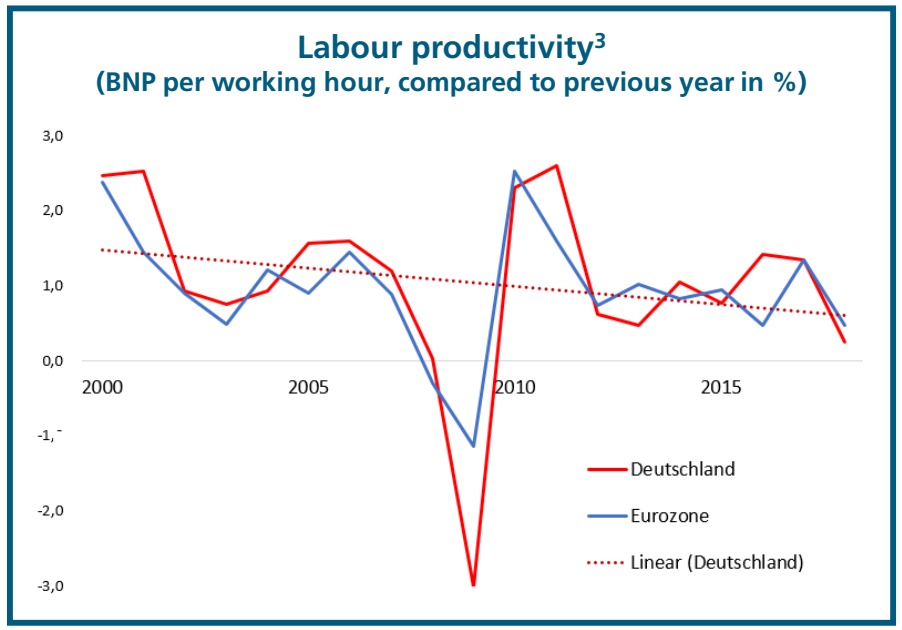
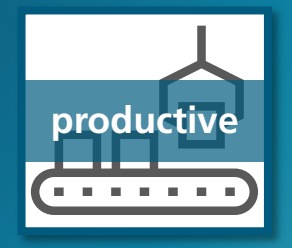
Productivity paradox exacerbates skills shortage

Skilled labour shortage and demographic change require higher productivity

- Demographic change and the shortage of skilled workers are leading to a sharp rise in the number of job vacancies in Germany despite the risk of recession.
- Despite Industry 4.0 and technologies such as artificial intelligence, there is a negative trend in labour productivity in Germany and the EU[1]





Companies in global competition need a big leap in productivity due to demographic change and the shortage of skilled workers.

Source: [1]Produktivitätsparadoxon im Maschinenbau, IMPULS-Stiftung 2018; Deutscher Gewerkschaftsbund; Shollo et al. 2022, Shifting ML value creation mechanisms: A process modle of ML value creation in Journal of Strategic Information Systems; [2]Bundesagentur für Arbeit, Darstellung KFW; [3]OECD 2019, Deutscher Gewerkschaftsbund

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Example for assist systems

Increasing productivity with assist systems

Photo: Rainer Bez, Fraunhofer IPA

Visual worker assistance for error-free assembly

Photo: Rainer Bez, Fraunhofer IPA

Human-robot collaboration for the optimal linking of man and machine

Photo: Valentina Klepikova, Fraunhofer IAO

VR-/AR-Applications, e.g. for error recognition

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Example: Intelligently automated assembly planning

Assistance of human workers

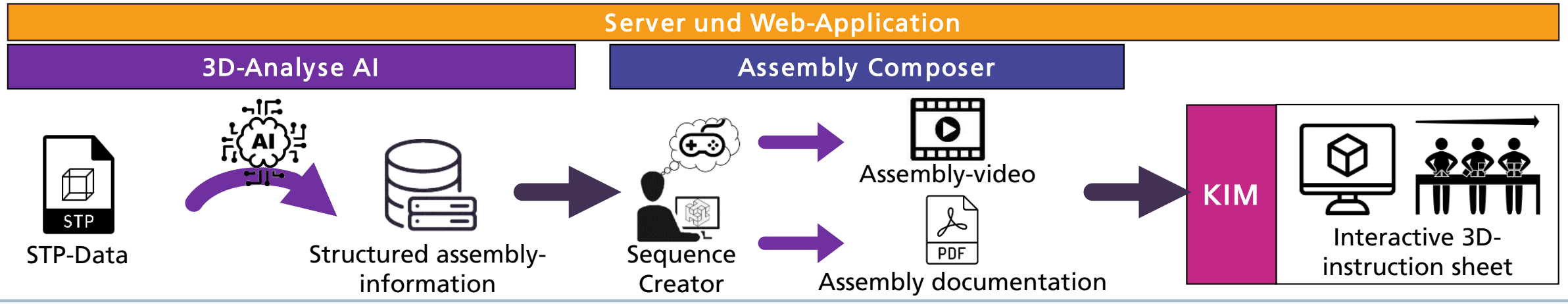
Assemblio
Montageplanung, Intelligent Automatisiert.

- Editor for assembly planning that uses CAD models generated in advance
- Intuitive assembly plan generation using artificial intelligence
- Video and assembly instructions are automatically generated with the graphic planning tool Assembly Composer
- KIM: Automatic and intelligent generation of assembly assists from existing CAD models

up to **73%** less preparational effort

up to **92%** faster assembly planning

up to **55%** less planning errors



Source: assemblio.com

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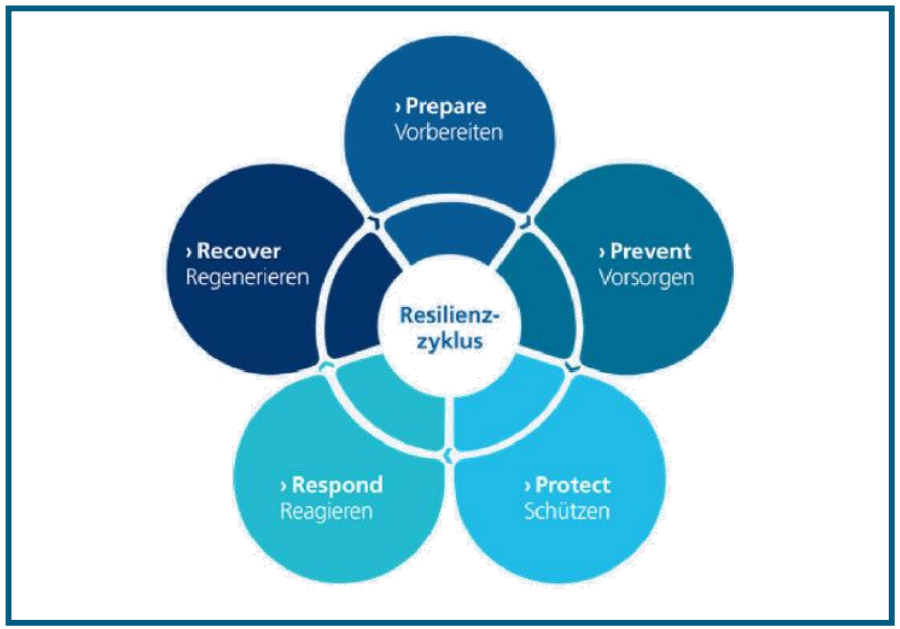
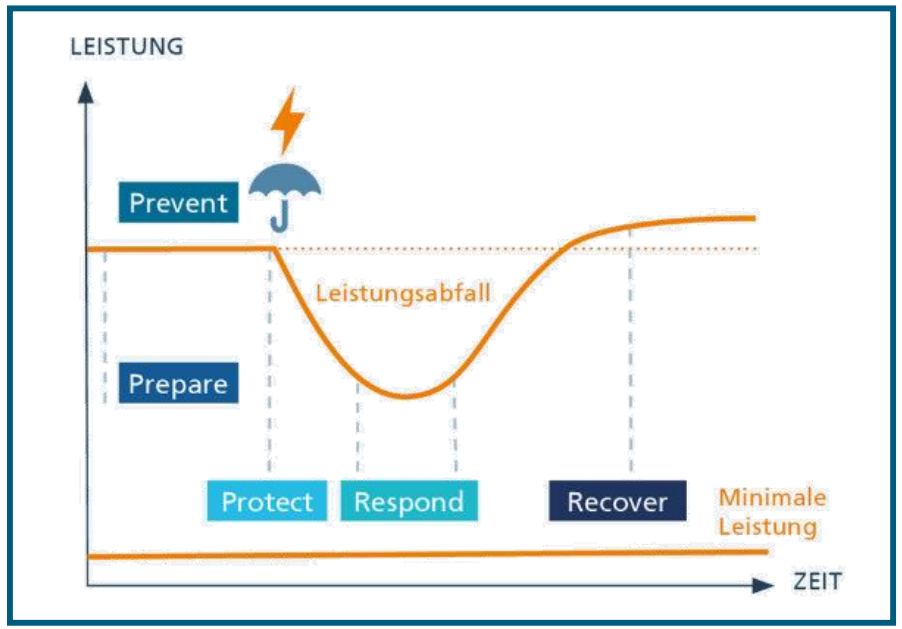
Resilience in production

5 steps for resilient systems

- Current crises increase the need for resilient systems
- “Prepare", "Prevent", "Protect", "Respond" and "Recover" can help dampen a drop in performance after a shock occurs
- Focus on raw materials and commodities and local for local (e.g. Inflation Reduction Act)





It needs a clear strategy to be resilient to unpredictable shocks and to minimise their impact.

Source: Kohl, Holger, et al.: White Paper »RESYST« - Resiliente Wertschöpfung in der produzierenden Industrie – innovativ, erfolgreich, krisenfest. Hrsg. Fraunhofer-Gesellschaft e.V., München 2021

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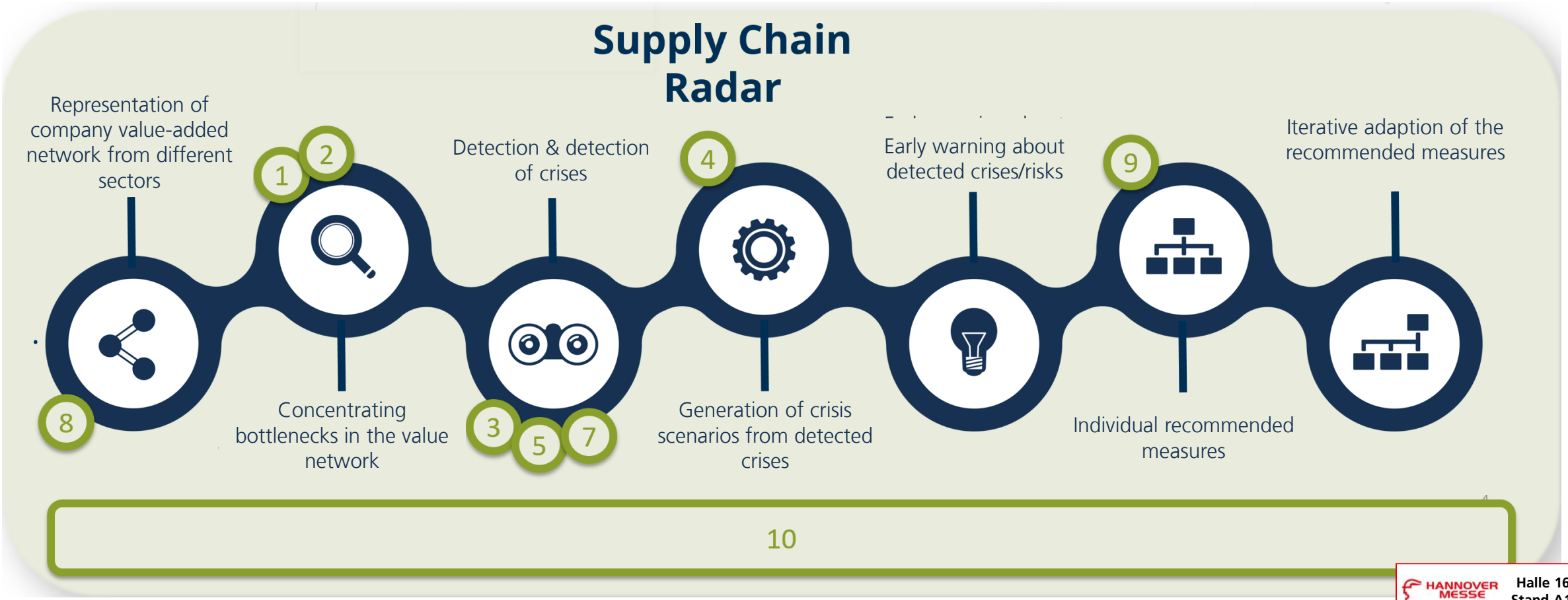
Project PAIRS (Privacy-Aware, Intelligent and Resilient Crisis Management)

Development of a risk & crisis management platform for decision-makers based on AI-tools



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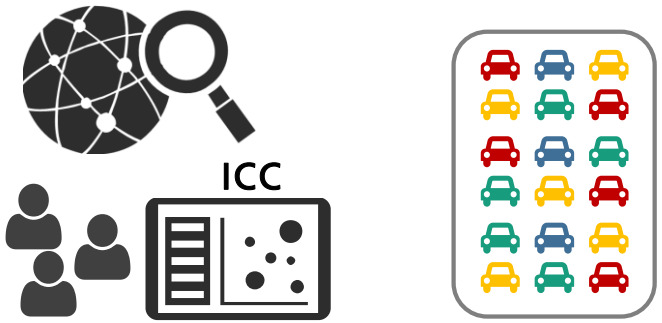
Example for resilient production via AI

Order planning for car manufacturers

Configuration generator

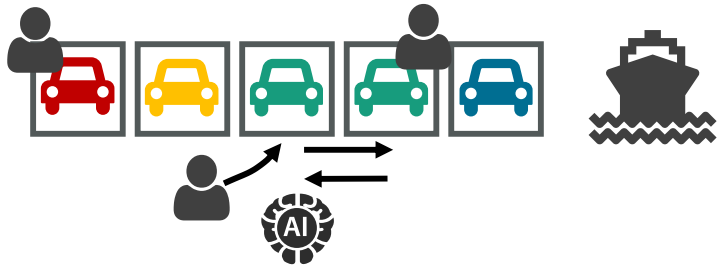


- Anticipation of the customer's request with AI methods
- Creation of market-specific and buildable planned orders

Initial planning order book

- Scheduling of planned orders and creation of the production programme
- Automated and data-based derivation of all option and material requirements

Matching & Recalibration

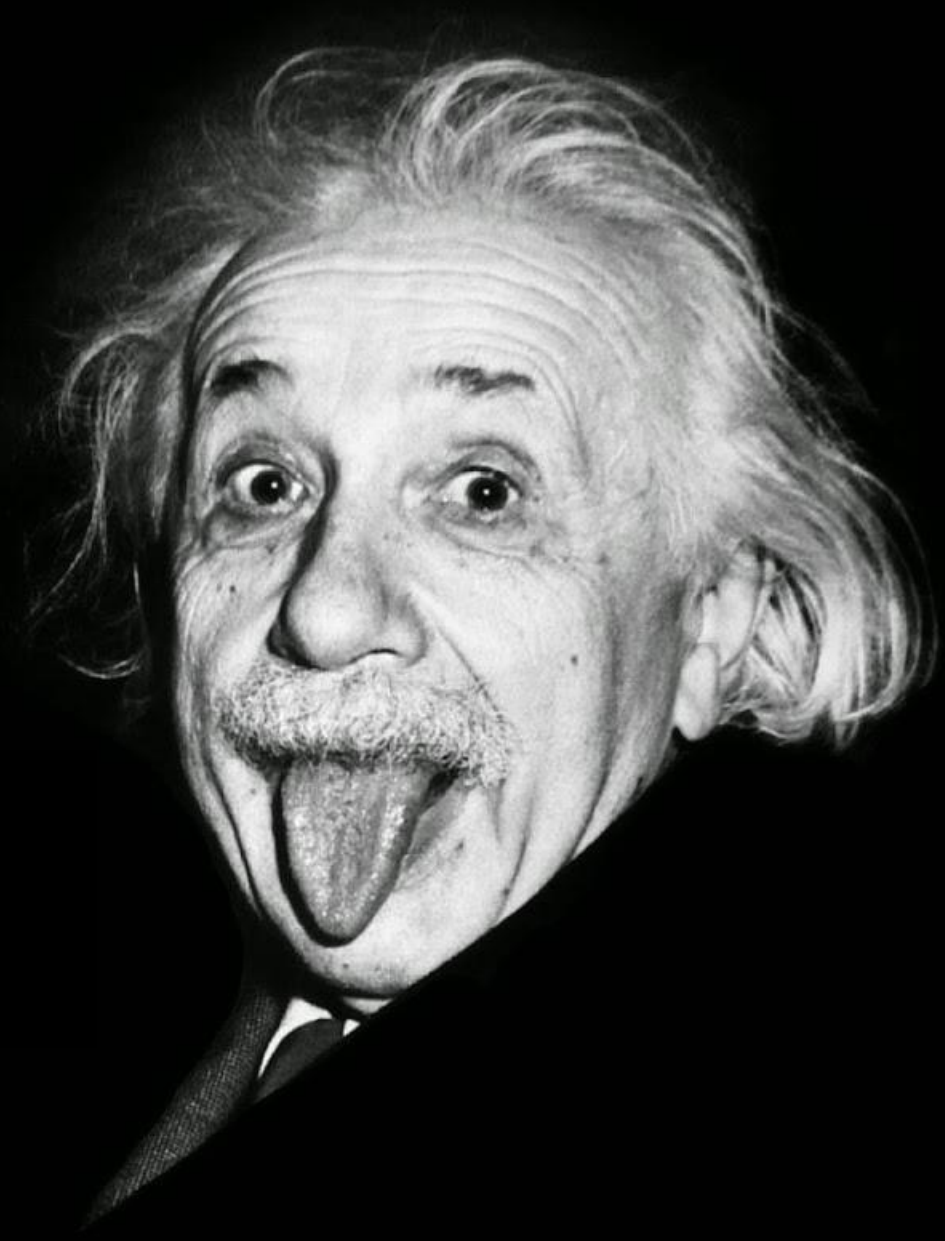


- Assignment of real customer orders to optimal planned orders
- Automated control of option swaps

ICC: Internet Car Configurator

The definition of insanity is
doing the same thing over and over again
and expecting different results.

Albert Einstein



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