



We are FMD.





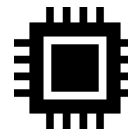
Bringing together research in microelectronics that is spread across many institutes in Germany



Bridging the gap between basic research and customer-specific product development



Providing the broadest range of materials and techniques for innovative solutions



Offering a unique range of expertise and infrastructure



Enabling digital change and future key technologies



Supporting innovators and start-ups



A **single institute** with specific know-how and excellent individual skills.



A **strong cooperation of 13 institutes** with bundled know-how and infrastructure in a **One-Stop-Shop**.



- **Cross-technology and cross-institutional R&D concepts** for optimal cooperation with industry
- **Tailor-made technological and system developments** from a single provider along the entire value chain
- **Joint laboratories and shared production facilities**
- **Organization of combined prototype and pilot fabrication**
- Support of **start-up activities**
- **Industrial contract research**
- **Technology and knowledge transfer**

As a **One-Stop-Shop**, FMD offers customized technology and system developments **along the entire value chain from a single source**.



Hard Facts:

- 13 cleanrooms throughout Germany
- Cleanroom facilities up to class 1
- total size: <19,500 m²
- Over 2,200 modern devices and systems
- Over 10 million movements per year
- wafer sizes: 2" to 300 mm
- 10 of the 13 institutes have committed to unify onto one single MES (Manufacturing Execution System)

State-of-the-Art Cleanrooms:

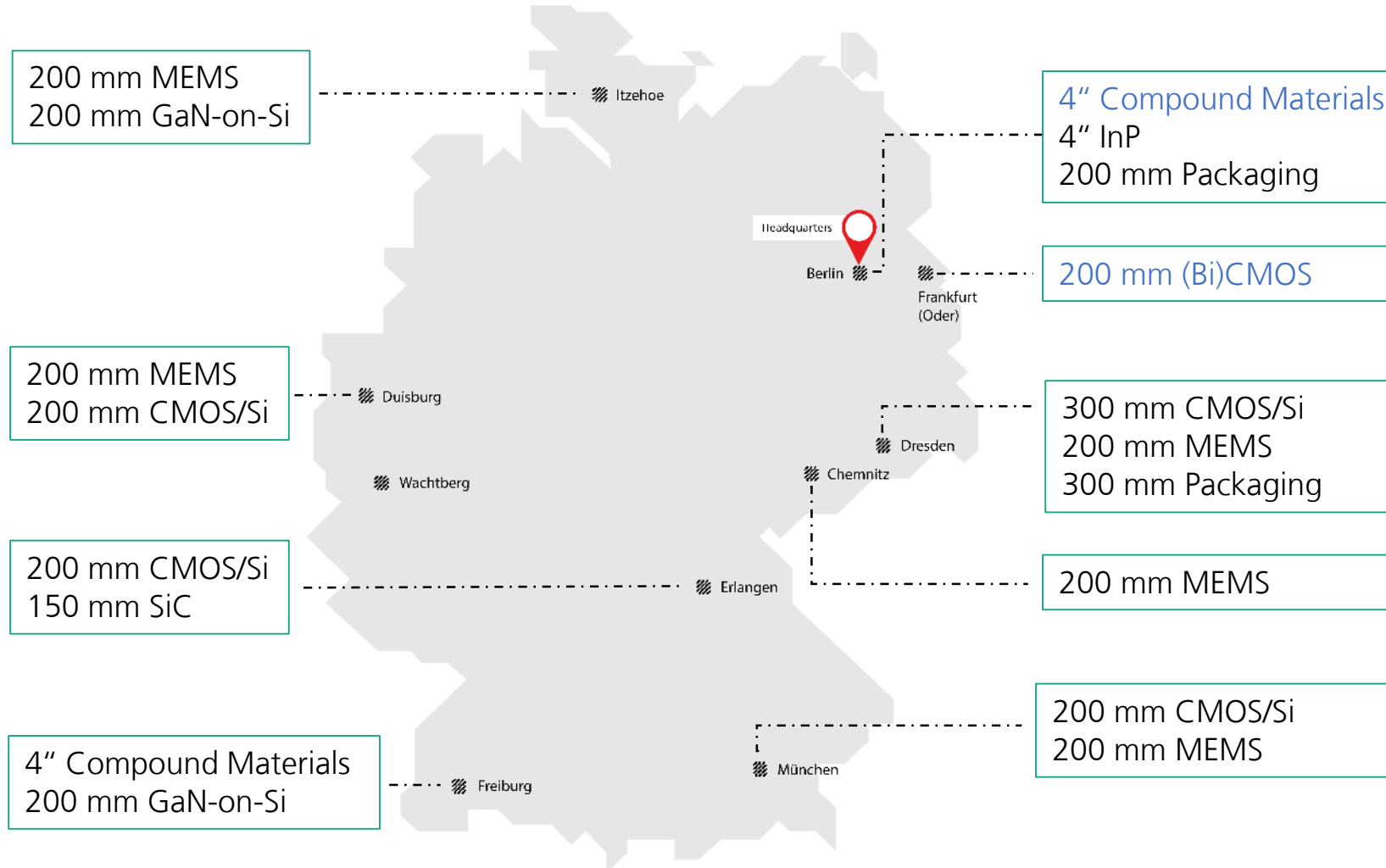
- 200 mm and 300 mm CMOS lines
- 200 mm MEMS and sensor lines
- 100/150 mm SiC line
- 200 mm GaN-on-Si line
- 200 mm and 300 mm 3D integration, assembly and packaging
- In-line and off-line characterization and metrology

Quality Promise:

- ISO 9001 qualified and partial automotive certification
- MES and contamination protocols implemented
- Application of statistical process control
- Protection of customer's intellectual property and compliance with
- Confidentiality



FMD Cleanrooms all over Germany



➤ Operation concepts in alignment

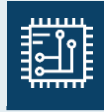
- Over 2.200 equipment in 13 cleanrooms all over Germany
- Over 10 Mio moves per year
- Overall size: appr. 19.500 m²
- Wafersizes: 2" till 300 mm



Our Technology Platforms

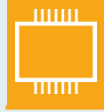
Sensor Systems

Sensor design, fabrication, integration, characterization, and testing within systems.



Microwave & Terahertz

Cutting-edge devices and circuits for frequencies up to and including the THz range.



MEMS Actuators

Design and fabrication, as well as characterization, testing and system integration of MEMS actuators.



Extended CMOS

Design, fabrication and system integration of CMOS circuits.



Power Electronics

Design and fabrication of power electronic devices, including integration in modules and systems.



Optoelectronic Systems

Fully integrated optoelectronic systems for image acquisition and processing, and communication up to Tbit/s speed.





Our Technology Platforms



Extended CMOS



Optoelectronic Systems



Power Electronics



MEMS Actuators

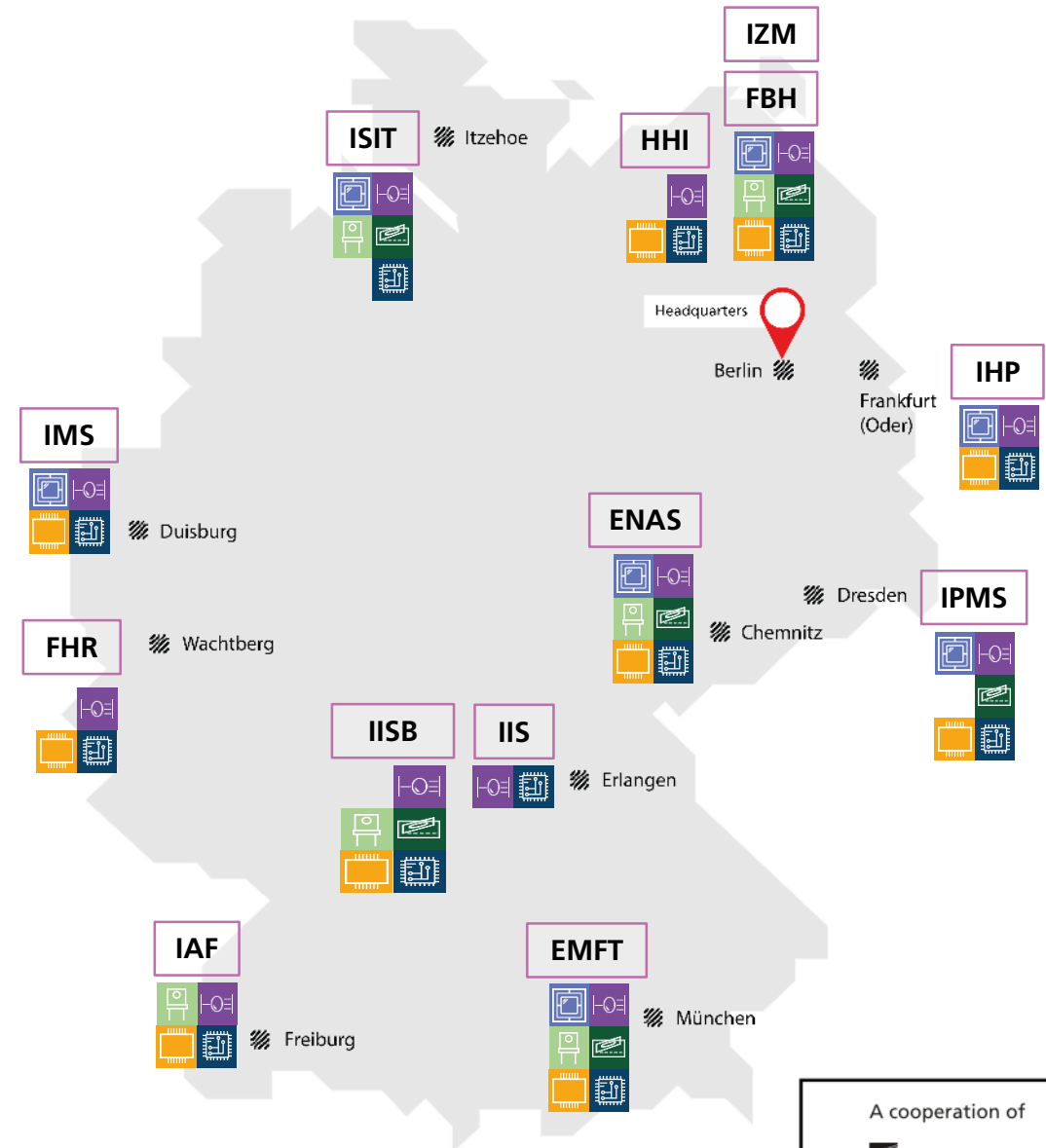


Microwave and Terahertz



Sensor Systems

Two other technology platforms are currently under construction:
Advanced System Integration and **Advanced System Design**



Our Contribution to the Future

Our Research Focus Topics



We conduct research in the field of **networked and automated mobility** to develop sustainable and user-centric mobility concepts for the future.



We set groundbreaking impulses for the **production technology of the future** and rapidly transfer these to industry through diverse knowledge and technology transfer.



We are working to lay the foundation for an **innovation ecosystem for future communications technologies**.



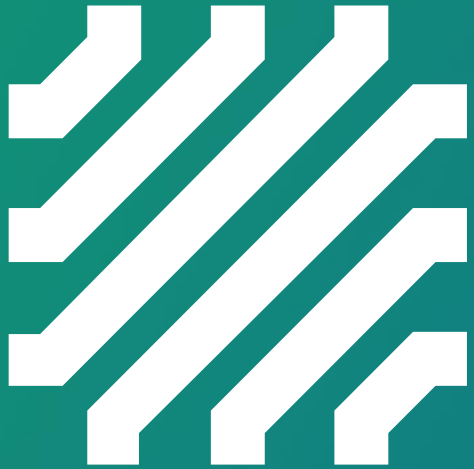
From high-performance, neuromorphic to quantum-based computing, we are driving the **development of hardware and technologies for Next Generation Computing**.



We are working to make **microelectronics**, which contribute to reaching our climate protection goals, **more sustainable** instead of further increasing resource consumption.



We research and develop **microelectronic systems** that we can trust and **which guarantee our security**.



Green ICT @ FMD

A future concept for a resource optimized
Information and Communication Technology



Background and Mission

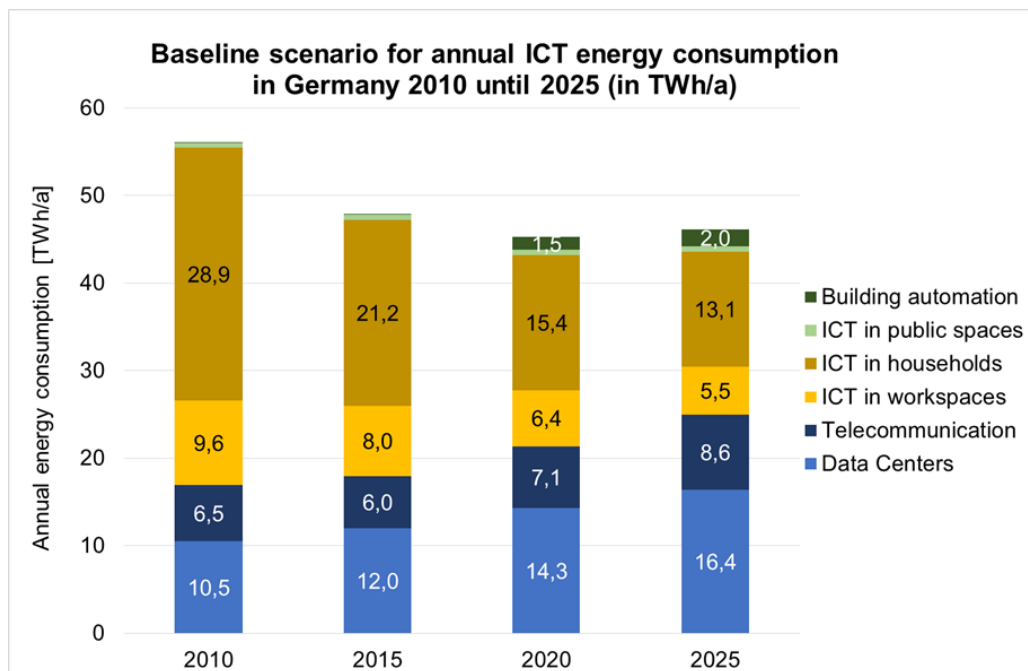
Green ICT is a project that started in August 2022 and is funded by the Federal Ministry of Education and Research (BMBF) to establish ...

- ⌘ An FMD competence center for green ICT developments in the fields microelectronics and microsystems
- ⌘ Testbeds for optimized green solutions in the fields
 - ⌘ Sensor/edge cloud solutions
 - ⌘ Communication networks
 - ⌘ **MEMS/microelectronic fabrication**
- ⌘ An open database for green ICT solutions that forms a basis for LCAs in the fields microelectronics and microsystems
- ⌘ An academy to educate green ICT developments and solutions

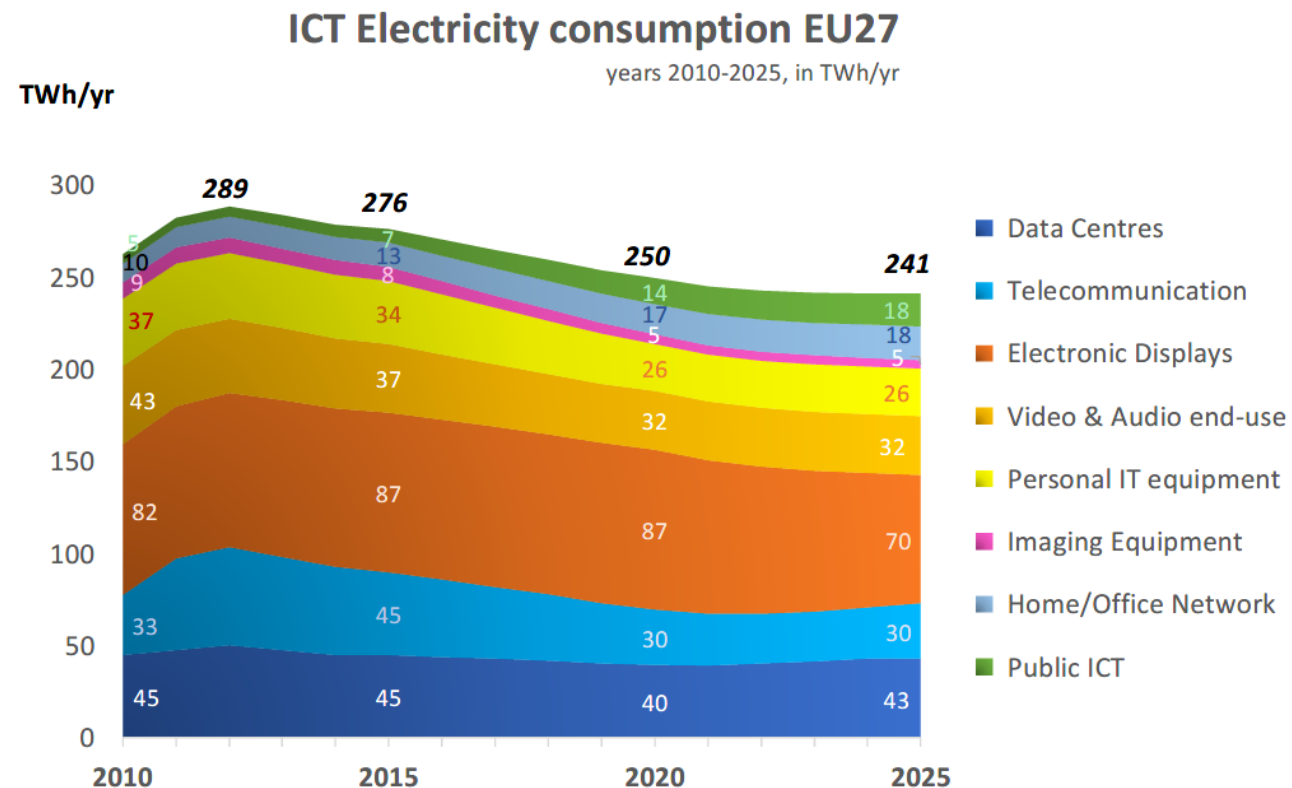
ICT Energy Demand in the European Union 2010-2025



Positive developments due to the European Eco Design Directive



BMWi/IZM (2014): ICT energy consumption in Germany



VHK and Viegand Maagoe (2020): ICT Impact Study

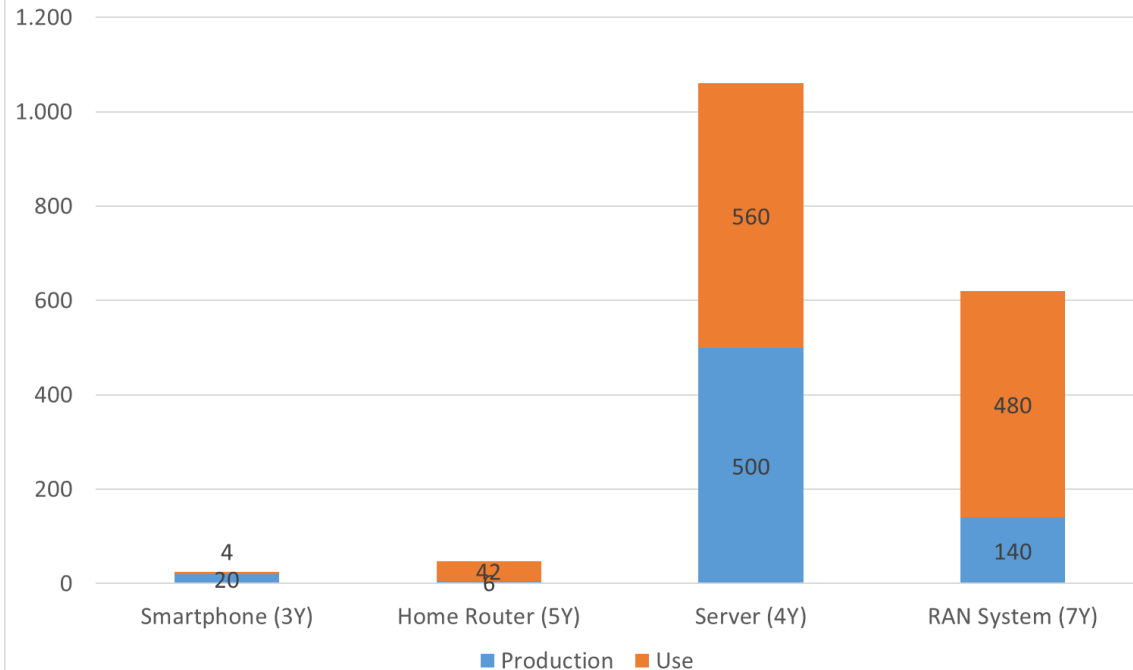
Relative and Absolute Carbon Footprints of Selected ICT Products



Smartphone, home router, enterprise server, and mobile station

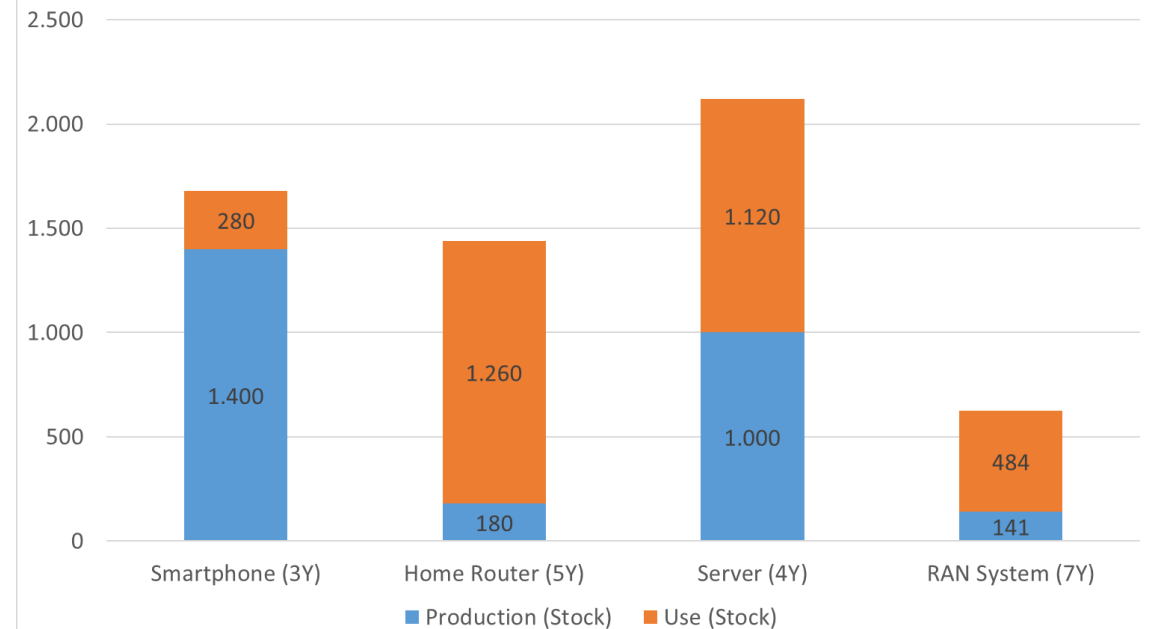
relative environmental impact (kg CO₂e)

Annual Product Carbon Footprint - Single Device (kgCO₂e)



absolute environmental impact (kt CO₂e)

Annual Product Carbon Footprint - Total Stock of Devices in Germany (ktCO₂e)



- Relative: single product annual carbon footprint
- Absolute: product stock annual carbon footprint

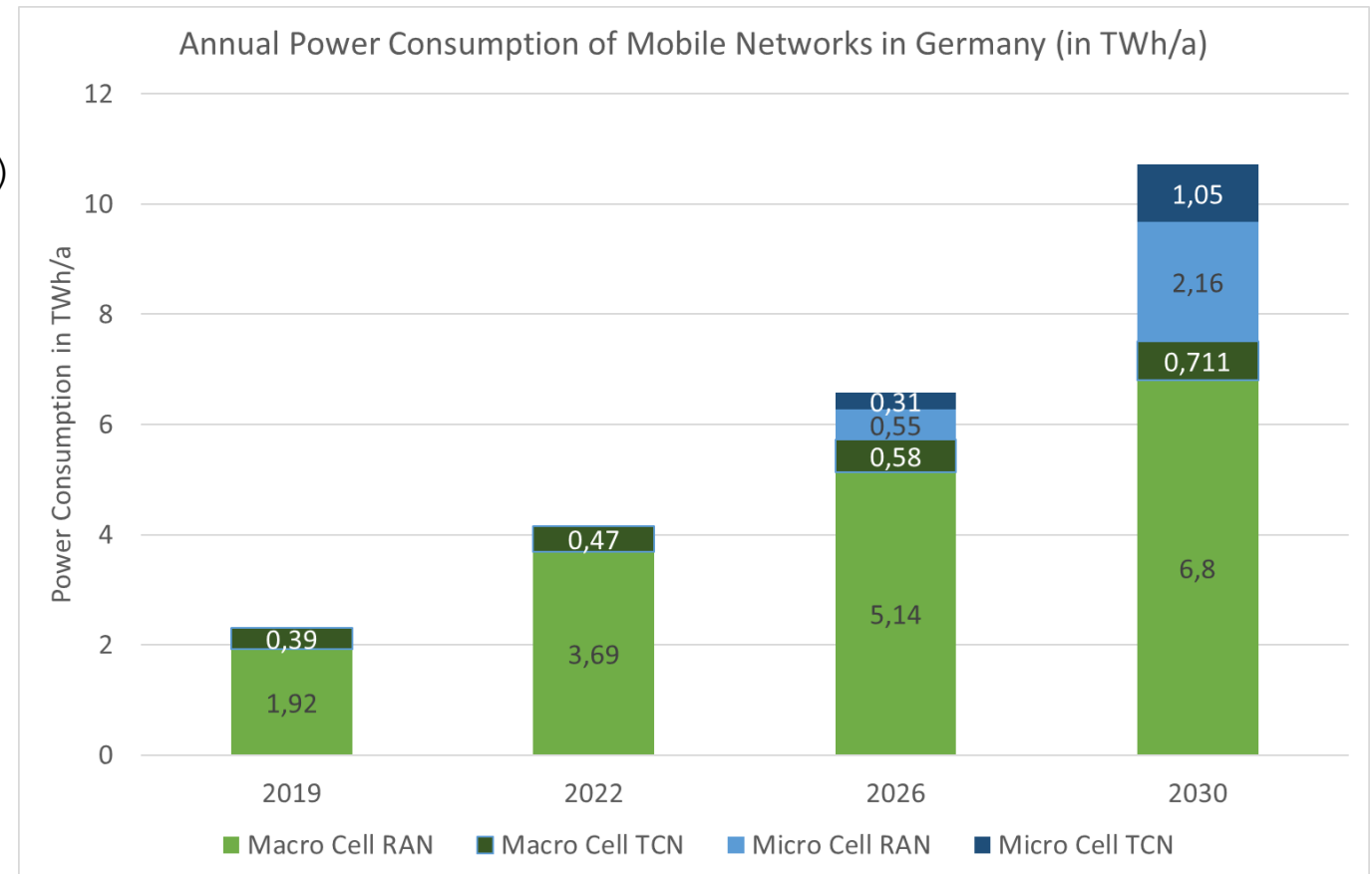
Stock Germany	Devices
70,000,000	Smartphone (3Y)
30,000,000	Home Router (5Y)
2,000,000	Server (4Y)
1,008,000	RAN System (7Y)

Macro Cells (cm-wave):

- Outdoor antenna sites (DTAG, Vodafone, Telefonica)
- Existing spectrum 700 MHz – 3.6 GHz (2G – 5G)
- Increase from 85,000 to 120,000 antenna sites
- 100% area coverage (357,386 km²)**

Micro Cells (mm-wave):

- Outdoor use in public spaces (eMMB/hotspot)
- New spectrum 26 – 28 GHz (5G) with an average range of around 150 meters
- 245,000 sites with two 60° sectors
- 1% area coverage (3,573 km²)**



RAN (Radio Access Network) TCN (Transport Core Network)

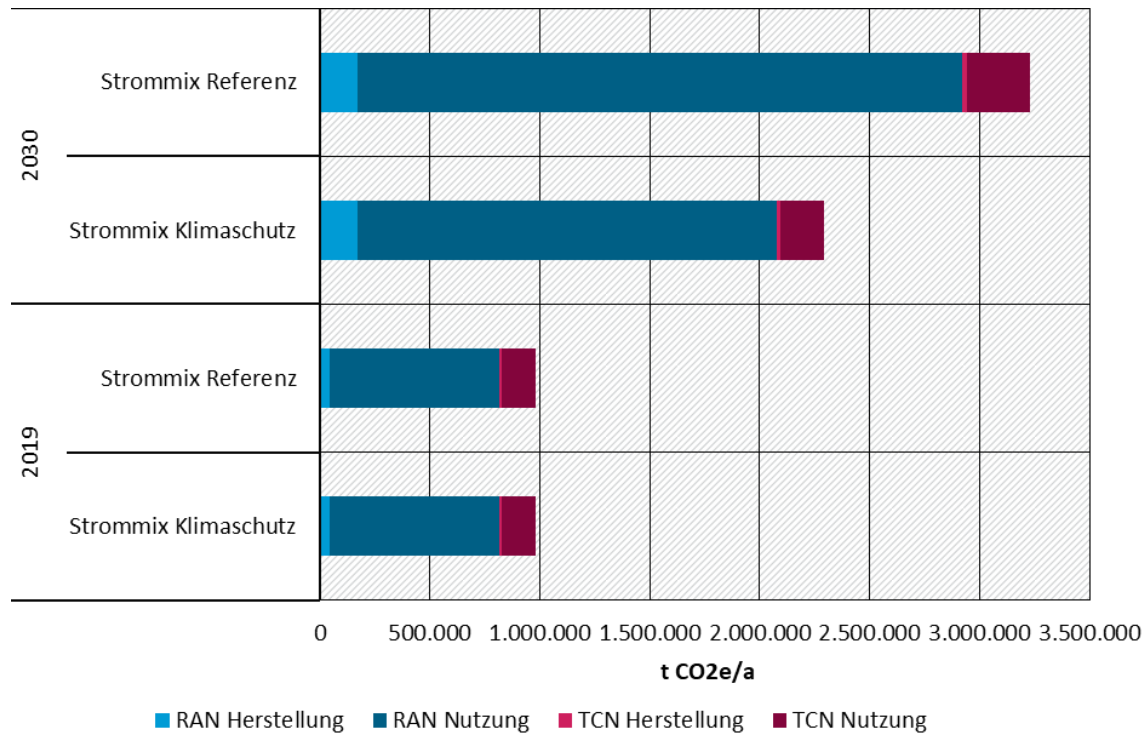
Saving Potentials in Mobile Communications

Technology modernization, energy management, and use of renewable energies



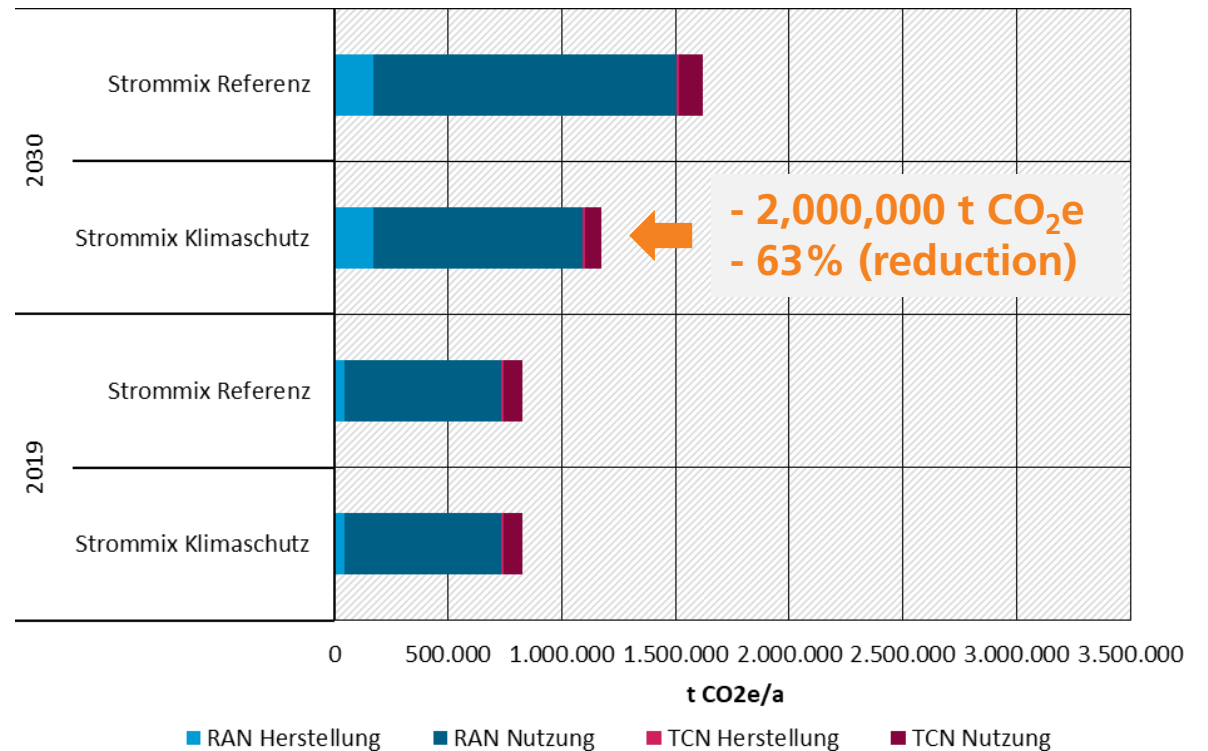
Baseline scenario

- 2030 scenario provides 45x higher performance
- Two energy mixes (0.4 kg/CO₂e and 0.28 kg/CO₂e)



Eco efficiency scenario

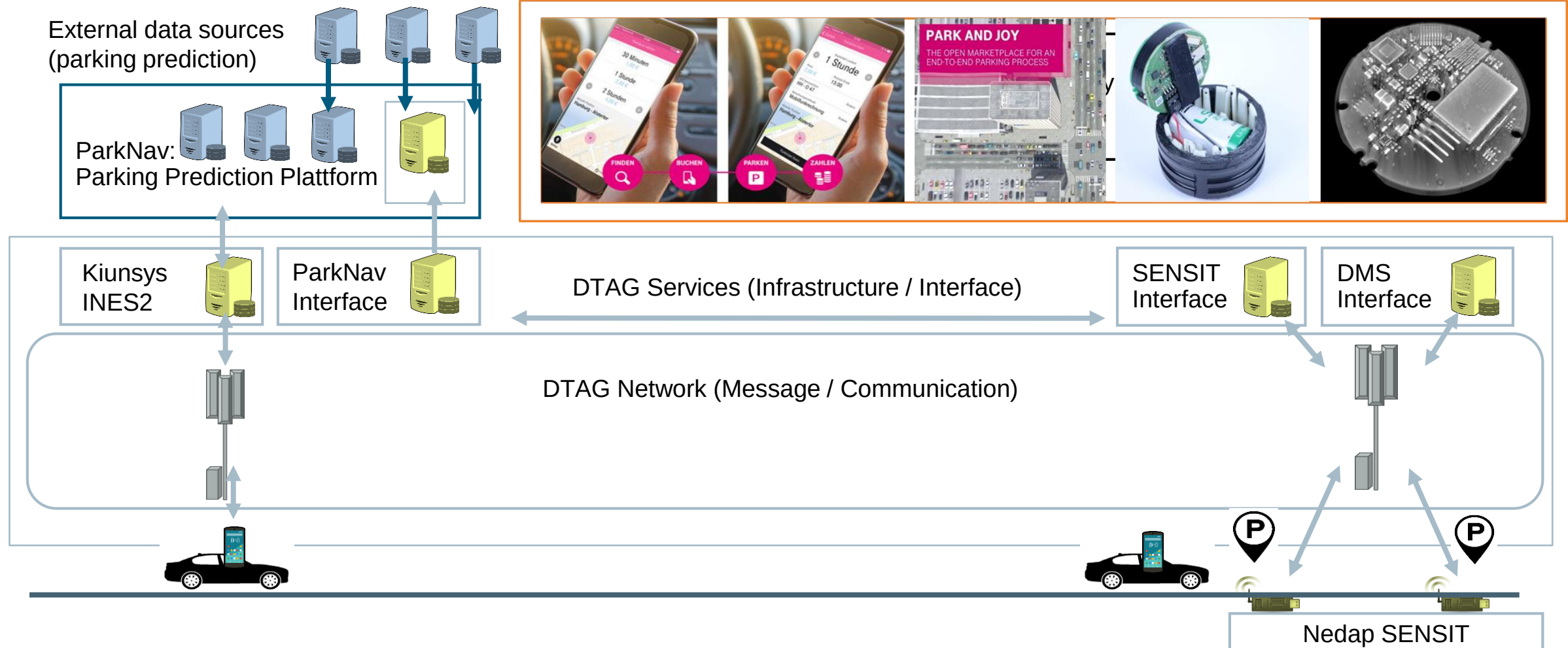
- Latest technology (reduced power losses)
- Load adaptive power management



Sensor-Cloud-Based Emission Savings for Parking Search

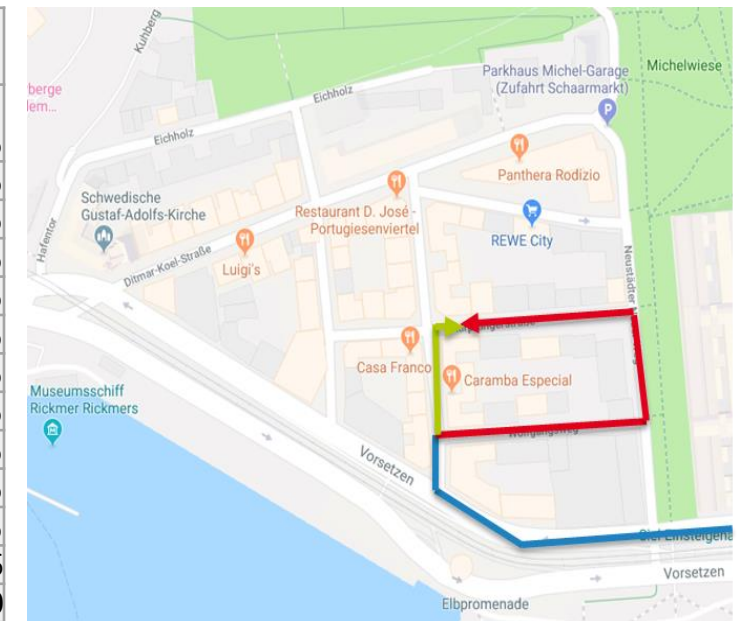


Park&Joy by Deutsche Telekom AG



- ⌘ Max. savings potential per parking operation: 0.240 kg CO₂e (63%)
- ⌘ 16% additional CO₂e reduction by using sensors (compared to cloud-only solution)

		Park&Joy mit Sensoren	Park&Joy ohne Sensoren	Ohne App		
Fahrstrecke						
Parkvorgang [m]	500	96%	78%	50%	33%	25%
Parkversuch	1	96,0%	78,0%	50,0%	33,0%	25,0%
Parkversuch	2	3,8%	17,2%	25,0%	22,1%	18,8%
Parkversuch	3	0,2%	3,8%	12,5%	14,8%	14,1%
Parkversuch	4	0,0%	0,8%	6,3%	9,9%	10,5%
Parkversuch	5	0,0%	0,2%	3,1%	6,6%	7,9%
Parkversuch	6	0,0%	0,0%	1,6%	4,5%	5,9%
Parkversuch	7	0,0%	0,0%	0,8%	3,0%	4,4%
Parkversuch	8	0,0%	0,0%	0,4%	2,0%	3,3%
Parkversuch	9	0,0%	0,0%	0,2%	1,3%	2,5%
Parkversuch	10	0,0%	0,0%	0,1%	0,9%	1,9%
Fahrstrecke Gesamt [m]		521	641	994	1396	1606
Emissionen [kg CO₂e]		0,143	0,176	0,273	0,383	0,440



Savings Potential for DTAG Product Park&Joy

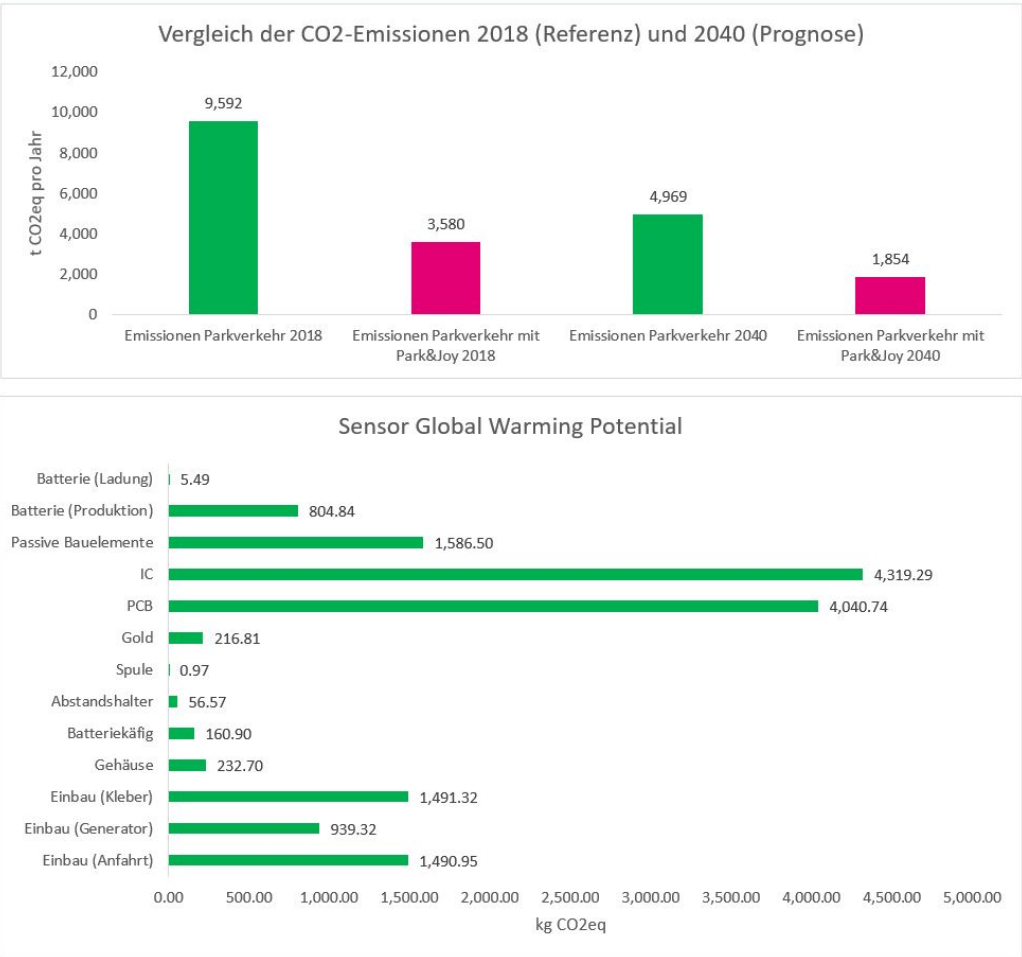


Calculation tool for various city and market penetration scenarios

Park&Joy Emissionstool

zur Bedienungshilfe

- Stadt
- Frankfurt am Main
 - Freiburg im Breisgau
 - Fürth
 - Gelsenkirchen
 - Göttingen
 - Hagen
 - Halle (Saale)
 - Hamburg**
 - Hamm
 - Hannover
 - Heidelberg
 - Heilbronn
 - Herne
 - Hildesheim
 - Ingolstadt
 - Jena
 - Karlsruhe
 - Kassel
 - Kiel
 - Koblenz
 - Köln
 - Krefeld
 - Leipzig



Environmental Benefits of AI-supported Mobile Communications Control

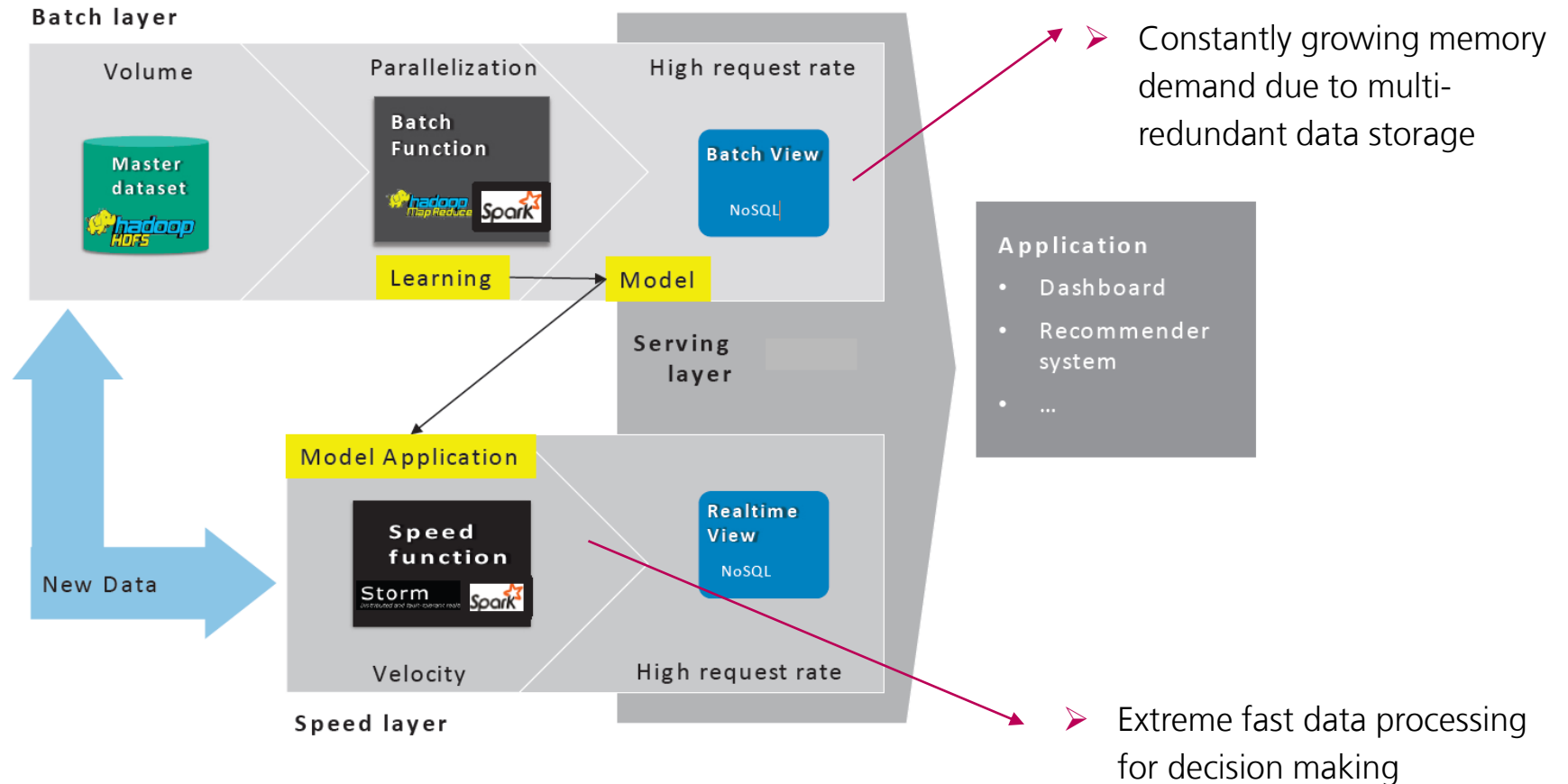


Determination of additional sensor expenditure (condition monitoring) and AI (learning, model)

Components

AI server/cloud:

- CPU: COTS [x86], FPGA [with accelerators], ASICs
- In-memory computing (DRAM, scaled NAND)
- Broadband, low latency communication



laMDA AI architecture

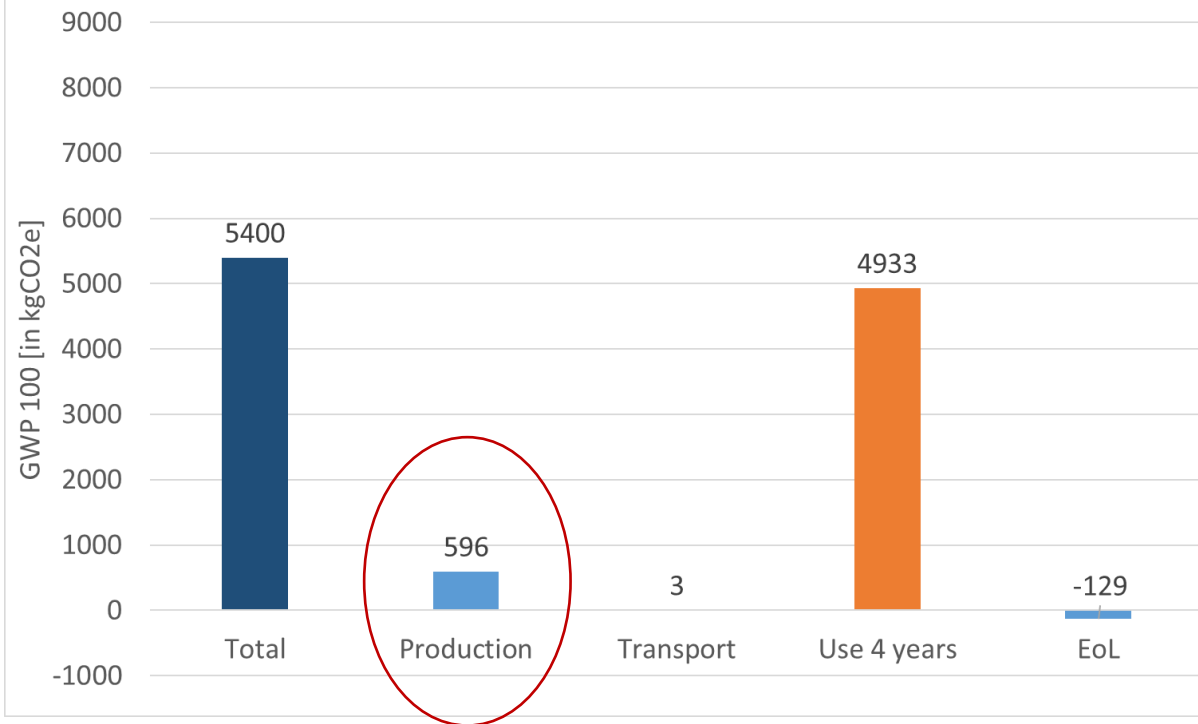
Server Life Cycle Assessment Comparison of 2014 and 2019



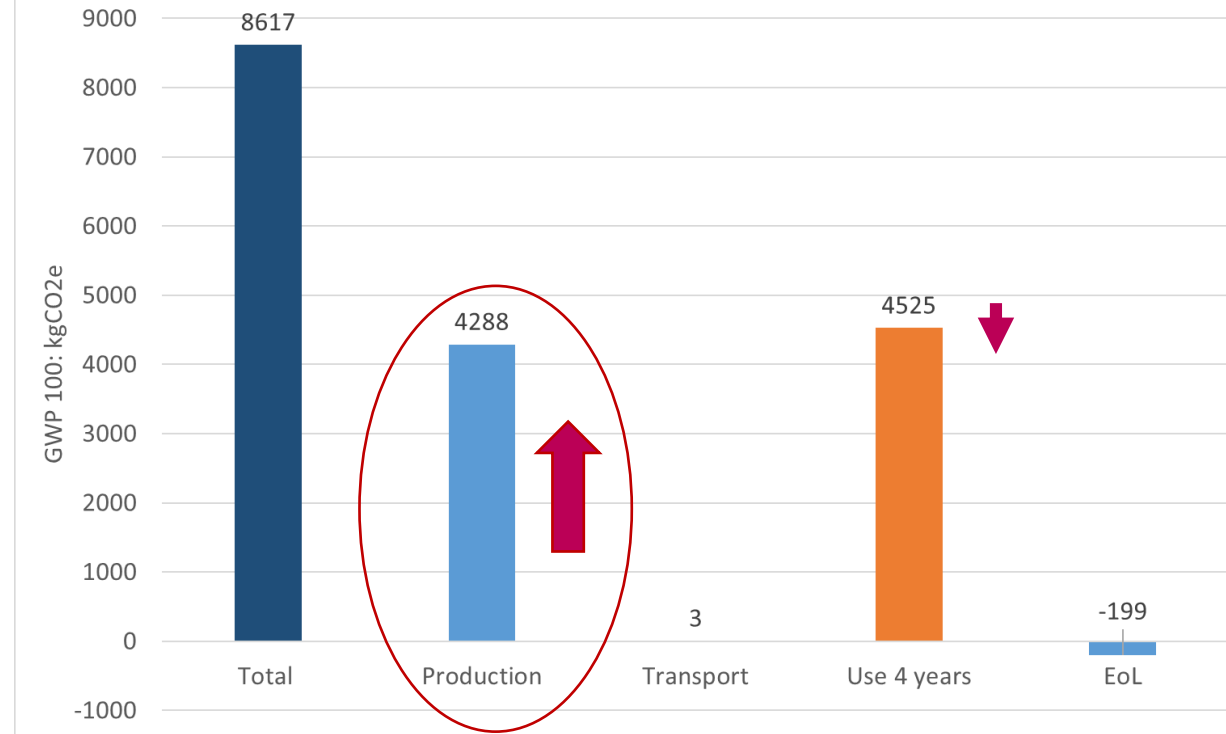
The environmental impact of microelectronics production accelerates



Dual CPU Rack Server (ErP Lot 9 Study 2014)



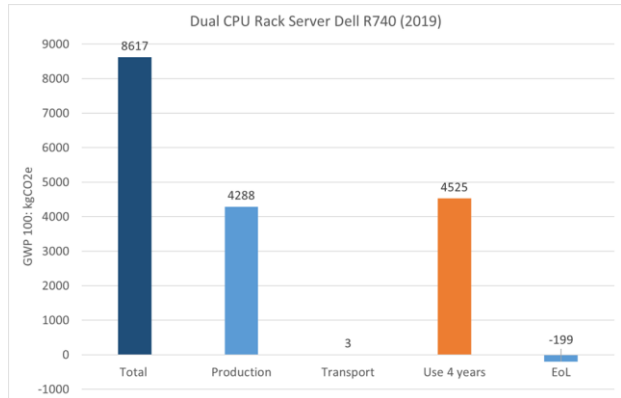
Dual CPU Rack Server Dell R740 (2019)



Chip Production Has a High Share of the Product Carbon Footprint



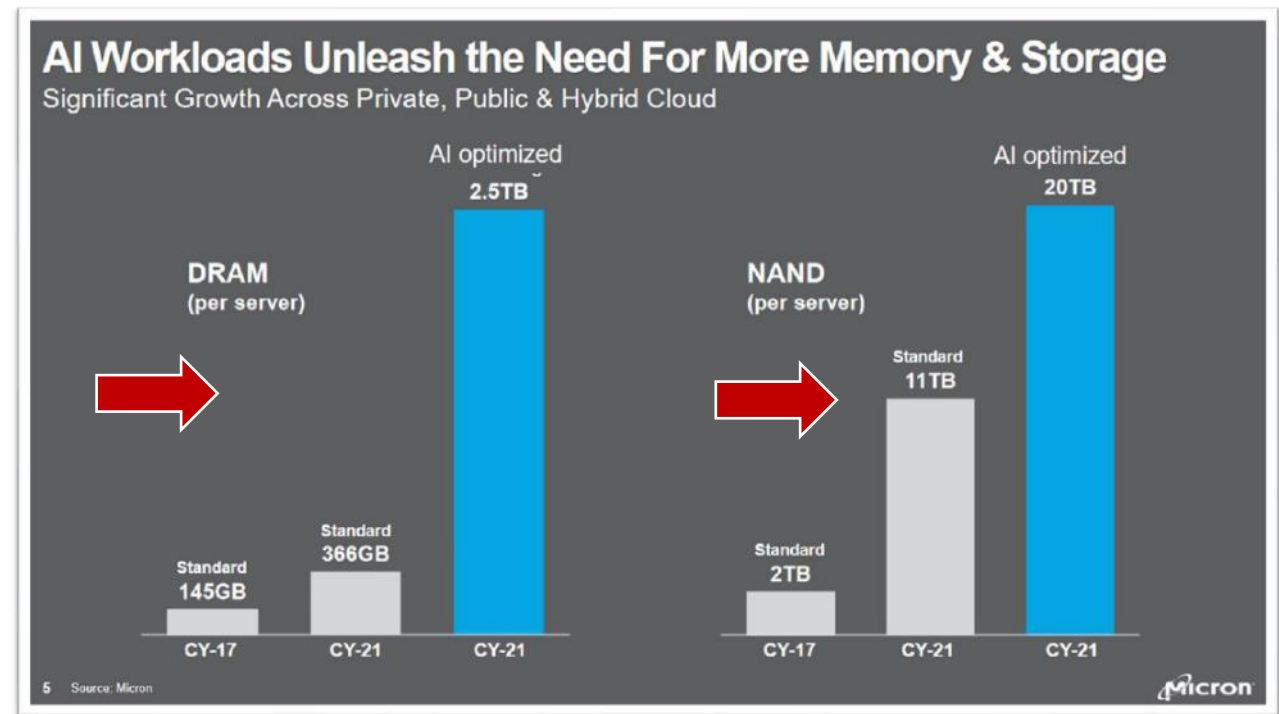
NAND account for up to 40% of the carbon footprint for AI servers



■ DRAM and NAND per server increases 3 to 5 times in memory artificial intelligence (AI) computing

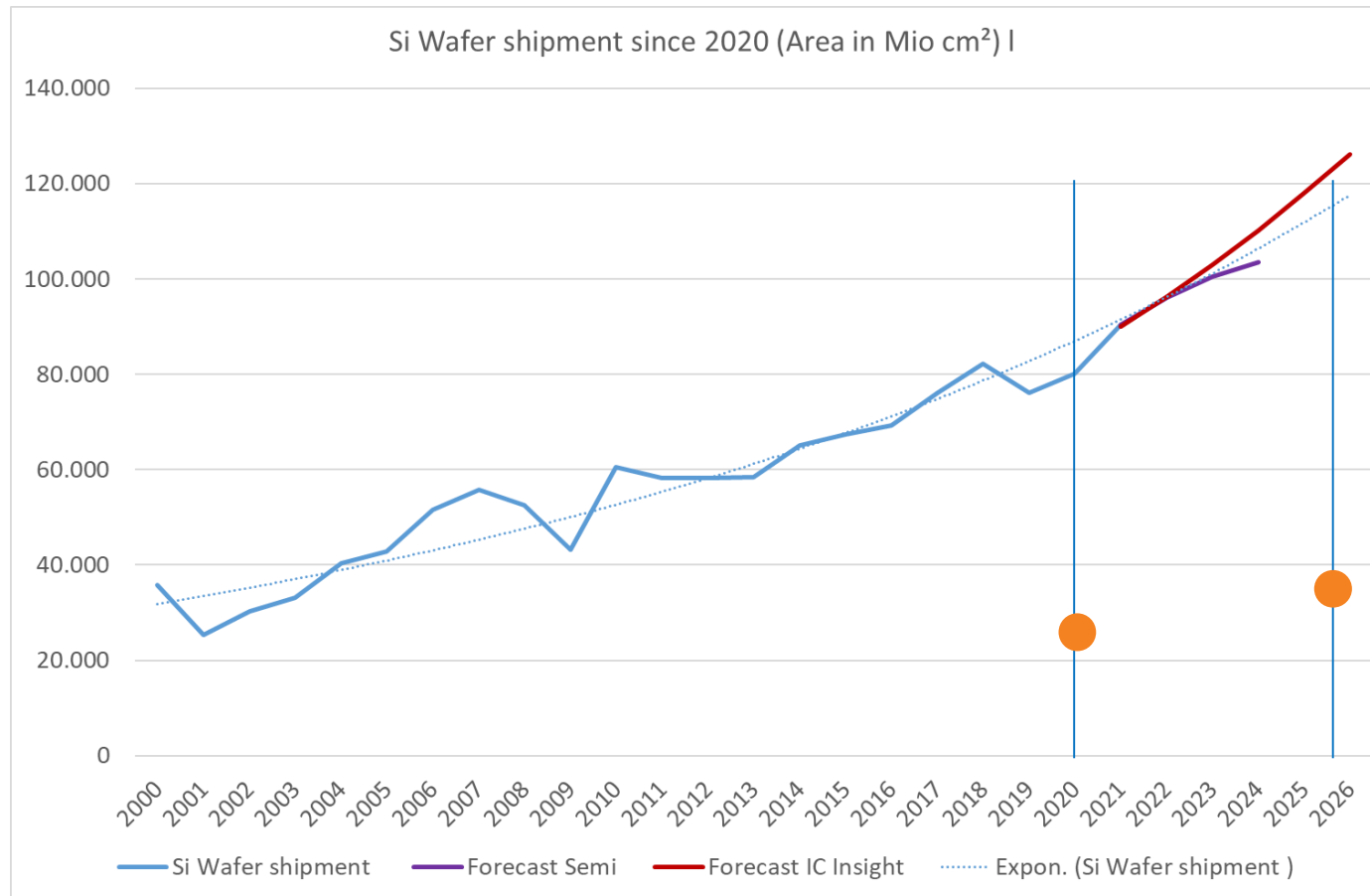


Main Components	Global Warming Potential (GWP 100 years) [kg CO ₂ e]
Chassis	34.1
Fans	11.1
3.84TB Solid State Drives	3373.5
400GB Solid State Drives	64.1
Mainboard	175.3
Packaging	1.9
PSU	31.3
PWB Mixed	591.8
Total	4283.1



Annual Silicon Wafer Shipment

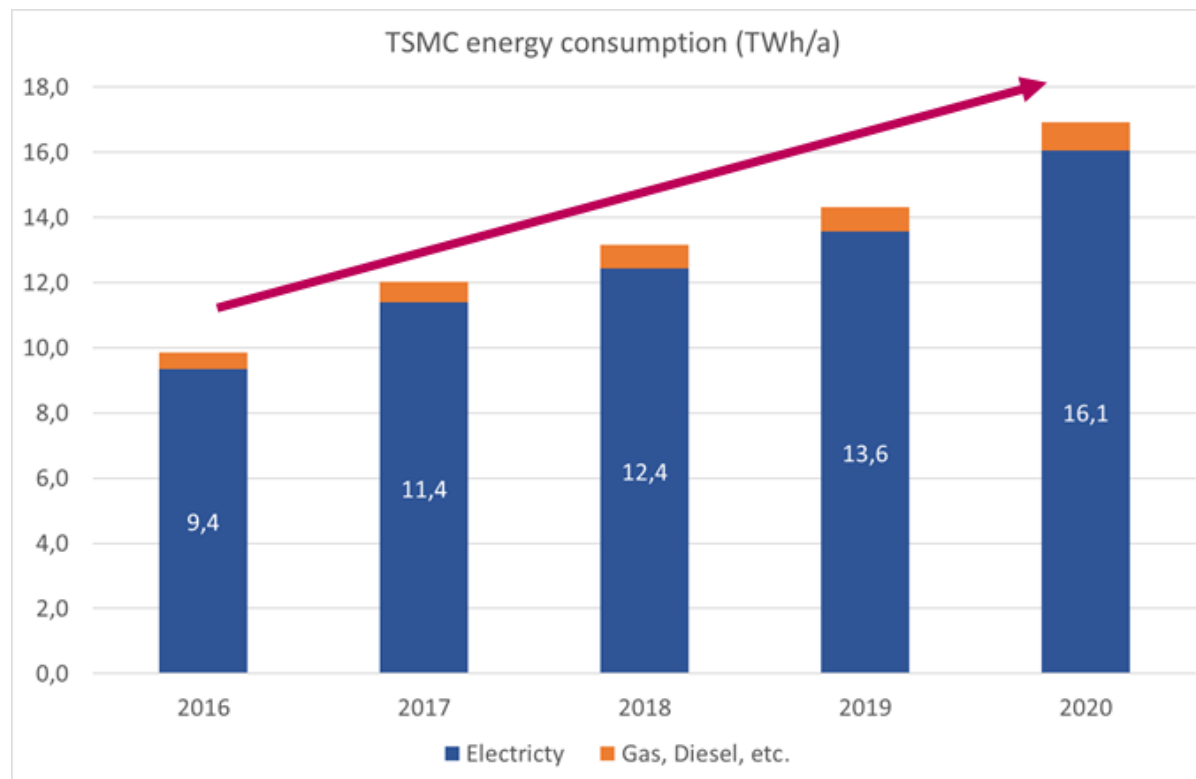
A significant growth is anticipated



<https://www.semi.org/en/products-services/market-data/materials/si-shipment-statistics>

Breakdown of the Chip Production Carbon Footprint

TSMC Environmental Report



/// The CF does not merely consist of energy

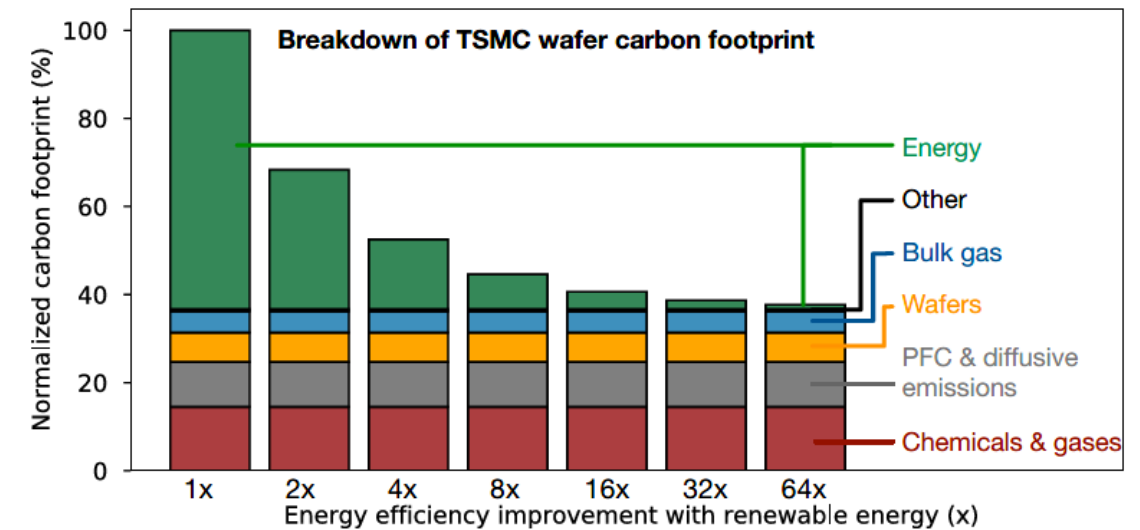


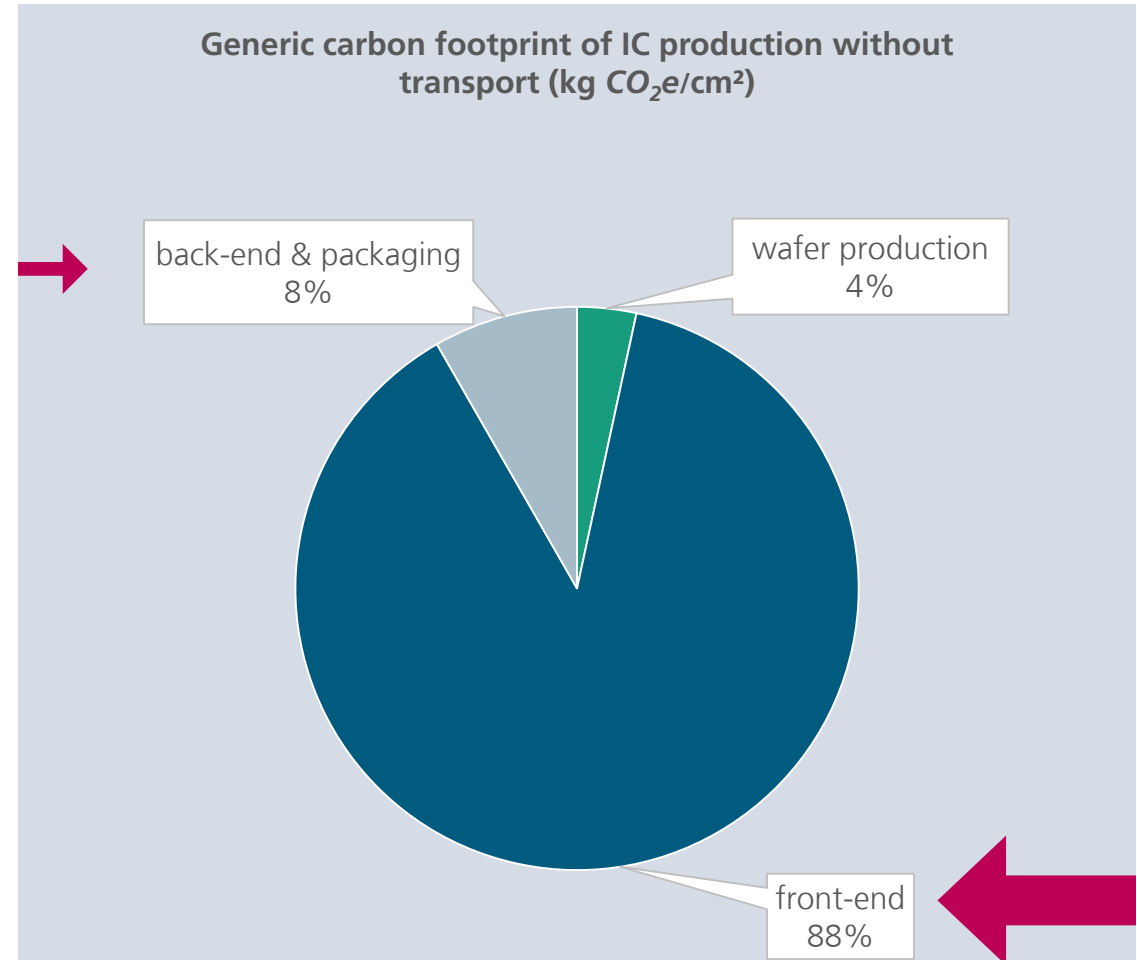
Fig. 14. Carbon-emissions breakdown for TSMC wafer manufacturing.



Back-end processes determine overall efficiency

- /// Emissions related to back-end processes are notably low in comparison to front-end related emissions
- /// Challenges of packaging technologies:
 1. Sustaining the high value of chips (cost and carbon footprint) with high yield and reliability
 2. Supporting resource/energy efficiency in manufacturing

*Carbon footprint of IC production ~ 2 kg CO₂e/cm²
Estimation based on Intel environmental reports for CPU*



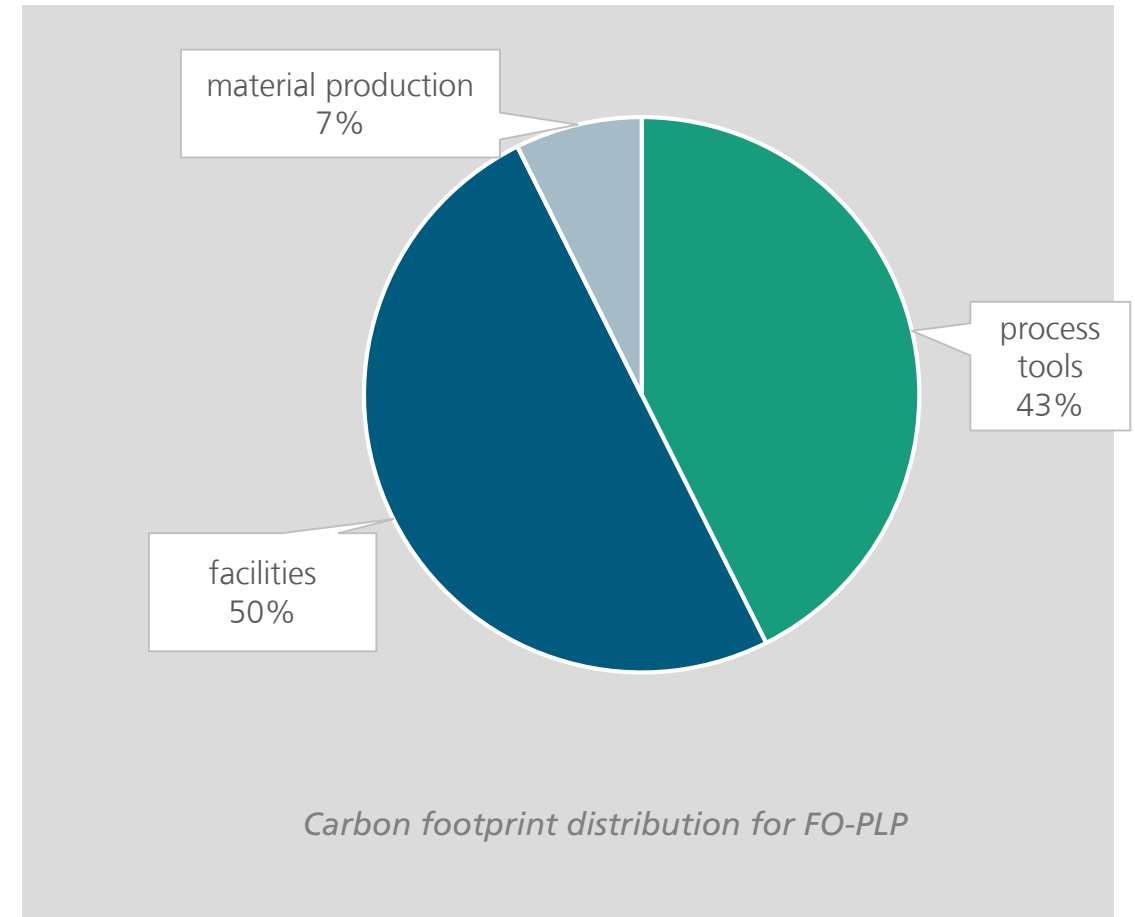
„Green Cloud Computing“ for the German Environment Agency, 2021



Source of emissions	Emissions per panel (kg CO ₂ e/panel)	Emissions per cm ² (kg CO ₂ e/cm ²)
Material production	6	0.002
Facilities	34	0.014
Process tools	47	0.012
TOTAL	81 kg CO₂e/panel	0.030 kg CO₂e/cm²

A significant proportion of emissions is attributable to energy consumption

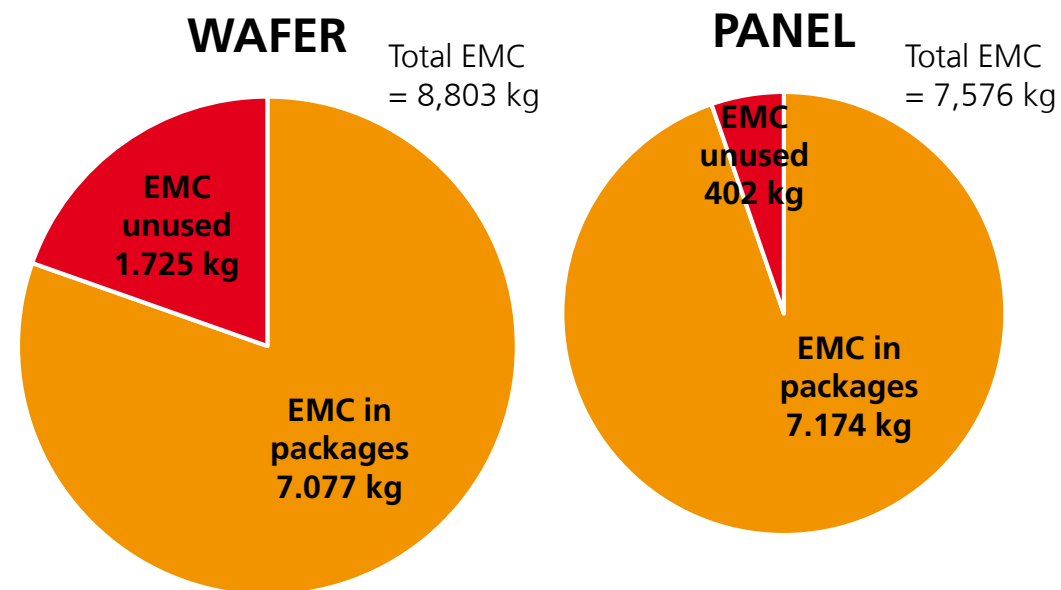
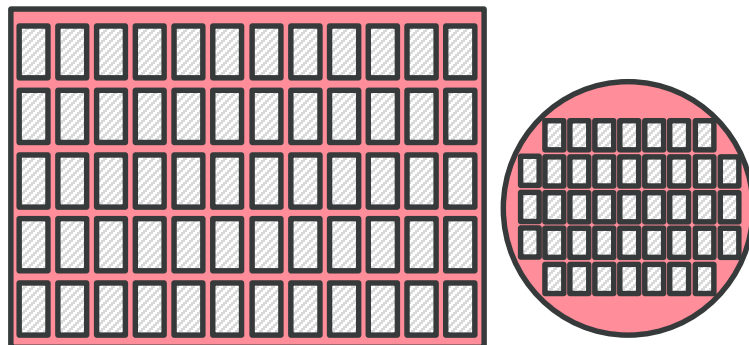
- ▮ Room for improvement with equipment/process optimization
- ▮ Decarbonization through increased renewable energy use



Comparison of Wafer and Panel Resource Efficiency



Rectangular panels have a significantly higher area yield, specifically with large packages



Depending on the scenario:

- /// **PLP saves up to 15% of EMC material** and reduces the environmental impact of manufacturing
- /// **PLP produces less waste** that needs treatment (overall cost reduction)

Estimation of EMC amount required for the production of **50M packages** (20x20 mm²) on wafer and panel

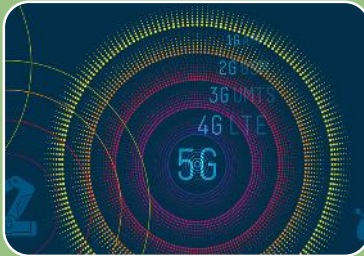


Green ICT Testbeds



Hub 2: Sensor-Edge Cloud

- Embedded green AI
- Energy independent IoT-sensor nodes
- Multi-sensor platform
- Green edge computing and edge cloud systems



Hub 3: Communication Networks

- 5G testbed
- X-haul wireless network
- X-haul optical network



Hub 4: Microelectronic/MEMS fabrication

- Processing
- Cleanroom infrastructure
- Energy optimization
- Back-end technologies
- Material reduction and replacement



Services for manufacturers

- /// Development of demonstrators and prototypes
- /// Technology services



Industrial contract research

- /// R&D projects
- /// Technology consulting
- /// Feasibility studies
- /// Technology and process development
- /// Pilot production



Cooperation projects

- /// R&D projects jointly funded by public authorities and industry



Technology Transfer

- /// Licensing of technologies and processes



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The Office Team

**Thanks for your
attention!**

