SCIENTIFIC COMMITTEE WORKSHOP ON SMART CITIES

Chapter Energy

About me

Moritz Loske

M. Eng.

Networked Systems and Applications Department
Fraunhofer Institute for Integrated Circuits IIS

Nordostpark 93 | 90411 Nürnberg, Germany
Phone +49 911 58061-9316 | Fax +49 911 58061-9399
moritz.loske@iis.fraunhofer.de

Chapter Energy

Author: ***Karlheinz Ronge*** *(Fraunhofer IIS)*

Co-author: ***Moritz Loske*** *(Fraunhofer IIS)*

Contributors: ***Holger Kapels*** *(HAW Hamburg)*

Dirk Kähler *(Fraunhofer ISIT)*

Jens Molter *(Fraunhofer ISIT)*

Peter Spies *(Fraunhofer IIS)*

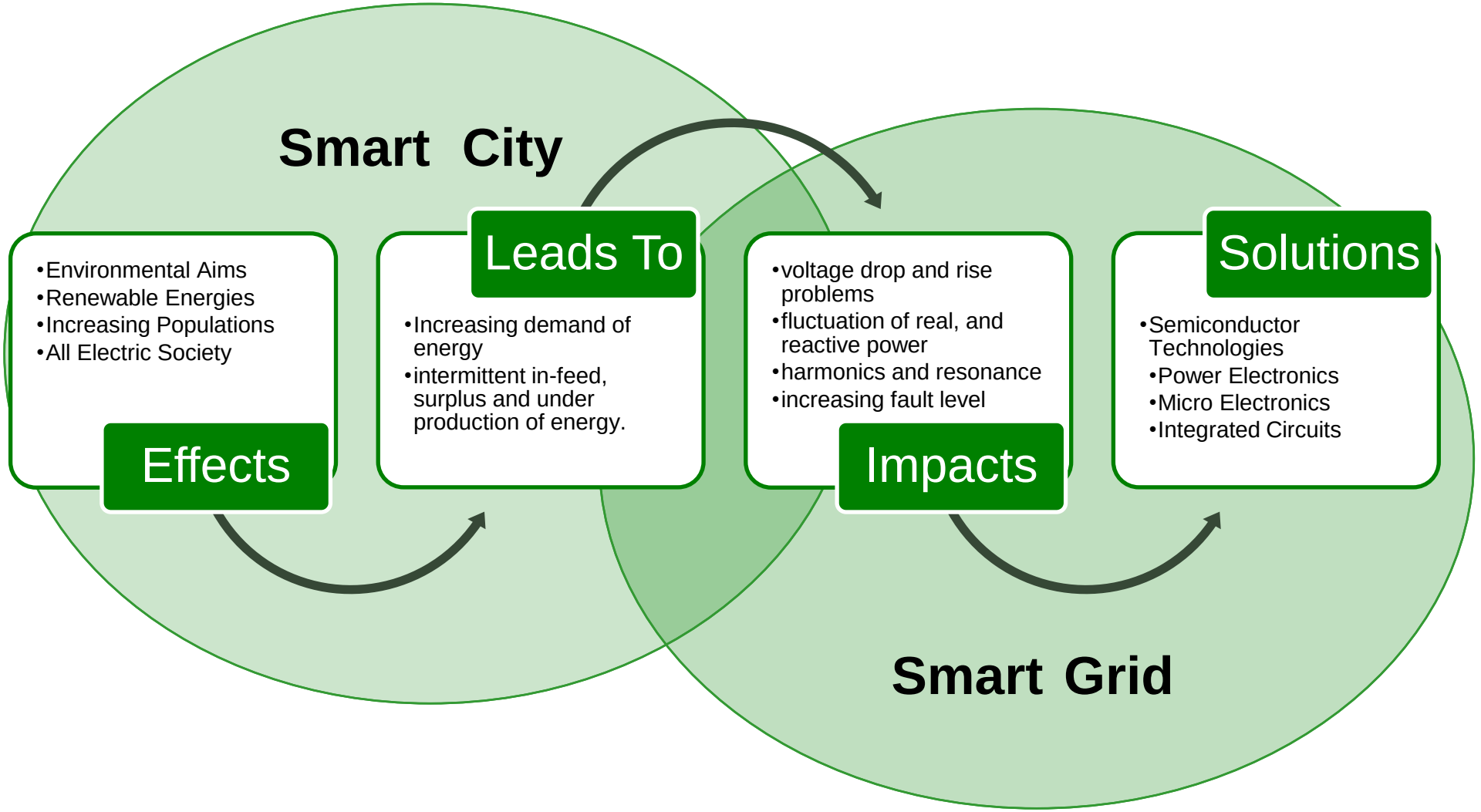
Agenda

- Introduction
- Future Key Products
- Technological Requirements
- Roadmap
- Research Strategy and Economic Impact

Agenda

- **Introduction**
- Future Key Products
- Technological Requirements
- Roadmap
- Research Strategy and Economic Impact

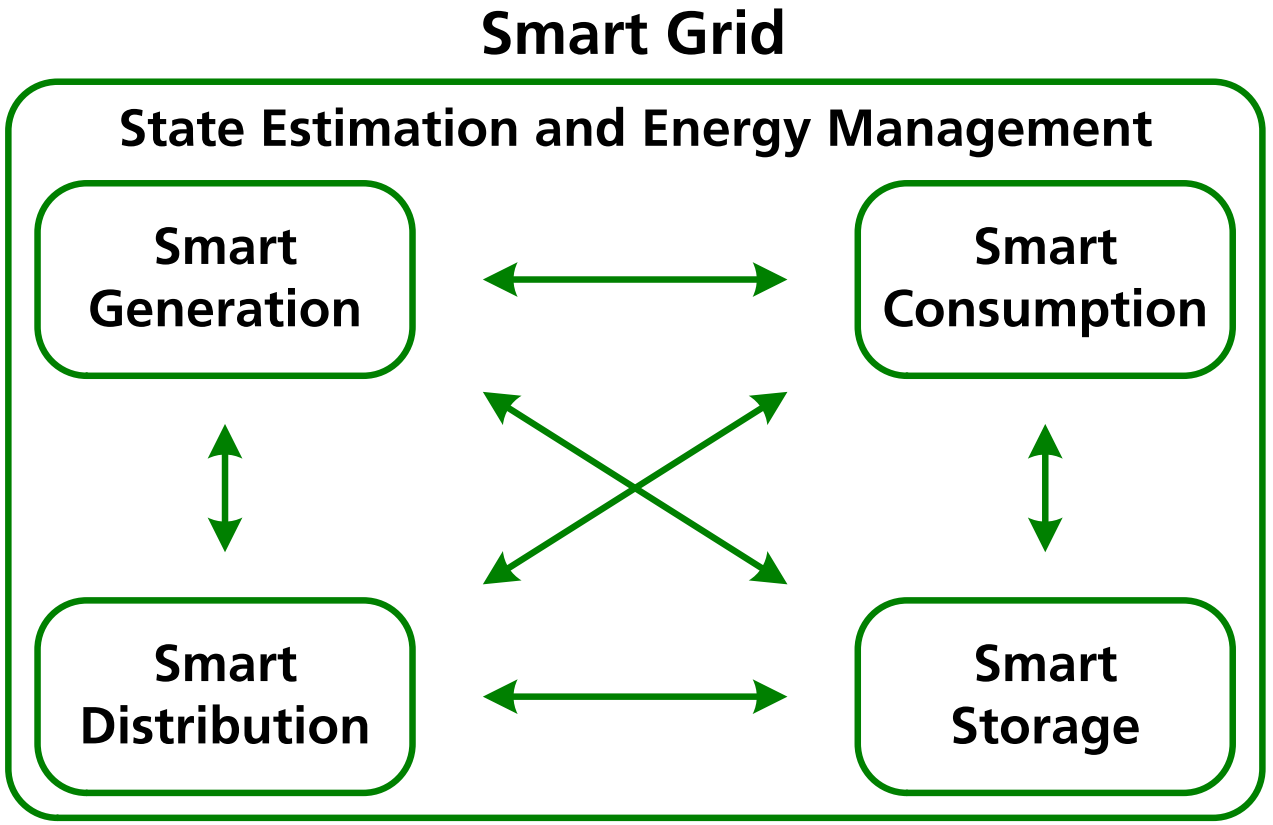
Introduction



Agenda

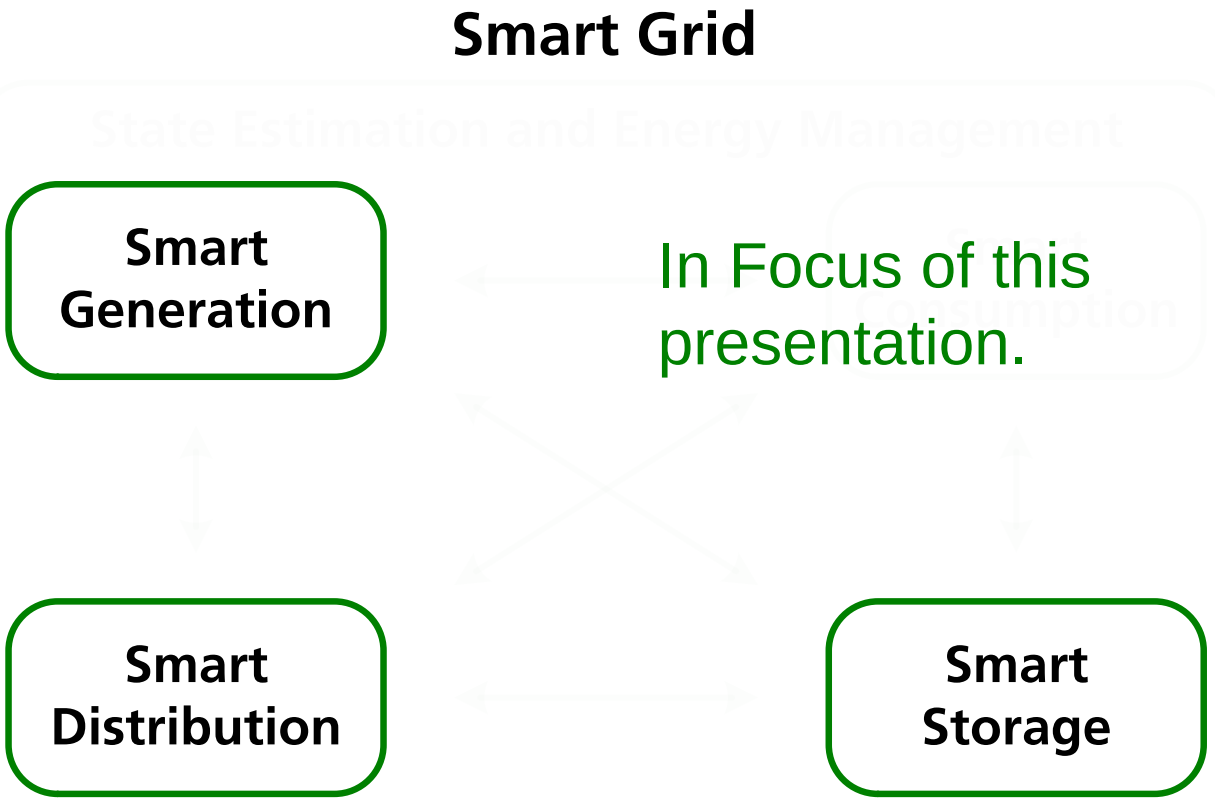
- Introduction
- **Future Key Products**
- Technological Requirements
- Roadmap
- Research Strategy and Economic Impact

Future Key Products



Verband der Elektrotechnik Elektronik Informationstechnik e.V, *Die Deutsche Normungsroadmap: E-Energy / Smart Grid*. Frankfurt am Main: VDE, 2010.

Future Key Products

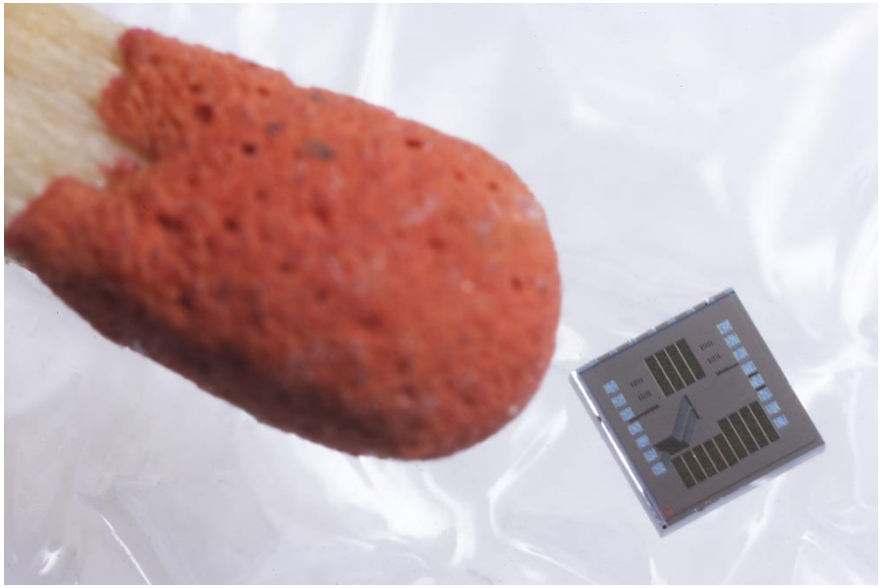


Future Key Products

Power-Electronics
for varying load conditions
- Power Converter/Inverters
- Power Switches

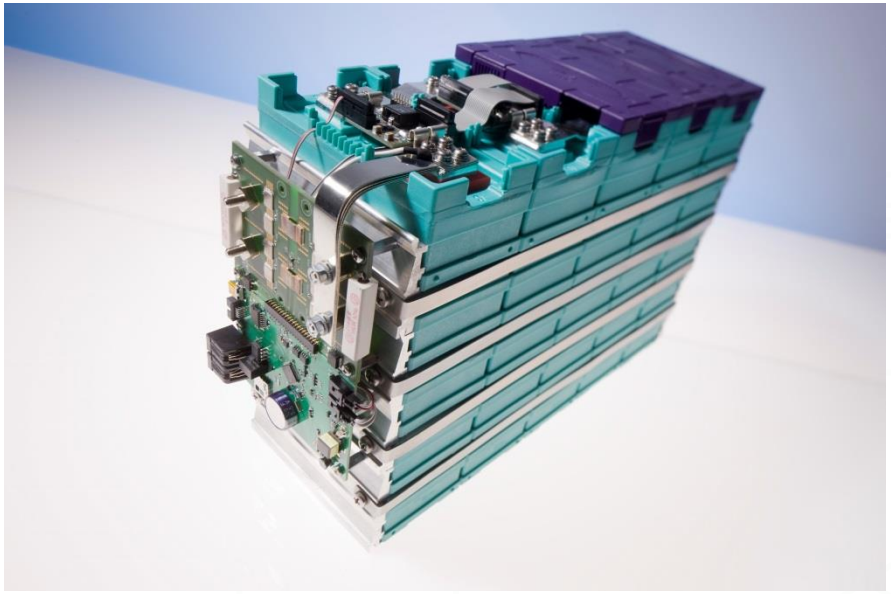
Smart Generation

Micro-Electronics
- Energy Transducer for Energy Harvesting
- PMIC



DC-DC Wandler ASIC für Thermogeneratoren © Fraunhofer IIS/Kurt Fuchs

Future Key Products



© Fraunhofer IIS/ Kurt Fuchs

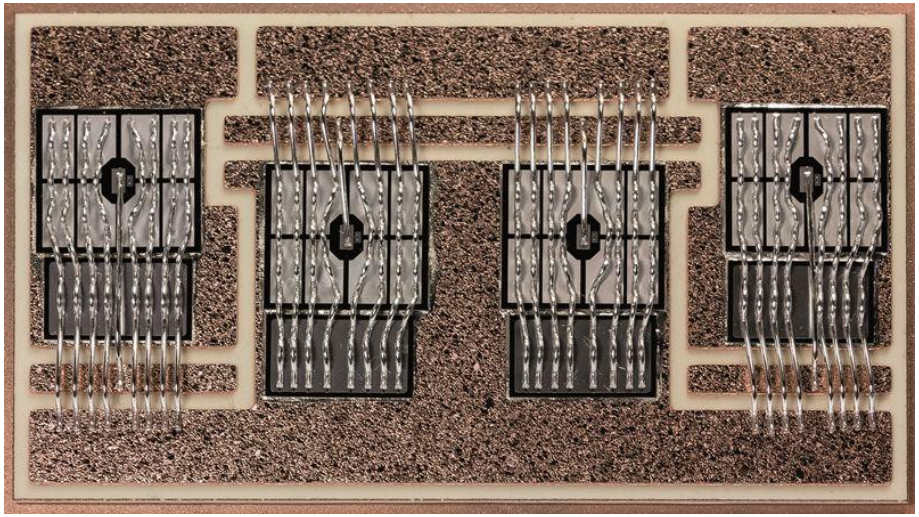
Power-Electronics
for varying load conditions
- Power Converter/Inverters
- Power Switches

Micro-Electronics
- Battery Management Systems

Smart Storage

Future Key Products

Flexible AC Transmission Systems (FACTS)
- Super Junction MOSFETS
- High Power Thyristors



Power modul © Fraunhofer IISB

High Voltage DC (HVDC)
- High Power Switches
- Power Converter/Inverters
- Solid State Circuit Breaker
  - High Voltage Tyristors
  - High Power IGBTs

Smart Distribution

Summary of Future Key Products

- Power Converters (AC,DC)
  - Diodes
  - Thyristors / Thyristor-Valves; GTOs
- High Power Switches
  - SJ-MOSFETs
  - IGBTs / HEMTs
- Solid State Circuit Breakers
- Power Management Integrated Circuits (PMIC)
- Battery Management Systems

Agenda

- Introduction
- Future Key Products
- **Technological Requirements**
- Roadmap
- Research Strategy and Economic Impact

Technological Requirements - 1

Power-Electronics

- high Power Density

$$\text{Power Density}^{\uparrow} = \frac{\text{Power Capability}^{\uparrow}}{\text{Volume}_{\downarrow}}$$

  - miniaturization/ size reduction
  - high power handling capabilities
    (wide-bandgap semiconductors [SiC, GaN])
  - increasing power rating performance

Technological Requirements - 2

Power-Electronics

- voltages ratings above 10kV
- switching frequencies exceeding 10 kHz
- efficiency *(reduction of inner resistance* $R_{DS,ON}$*)*
  - superjunction components
- sophisticated thermal design and reliable packaging

Technological Requirements - 3

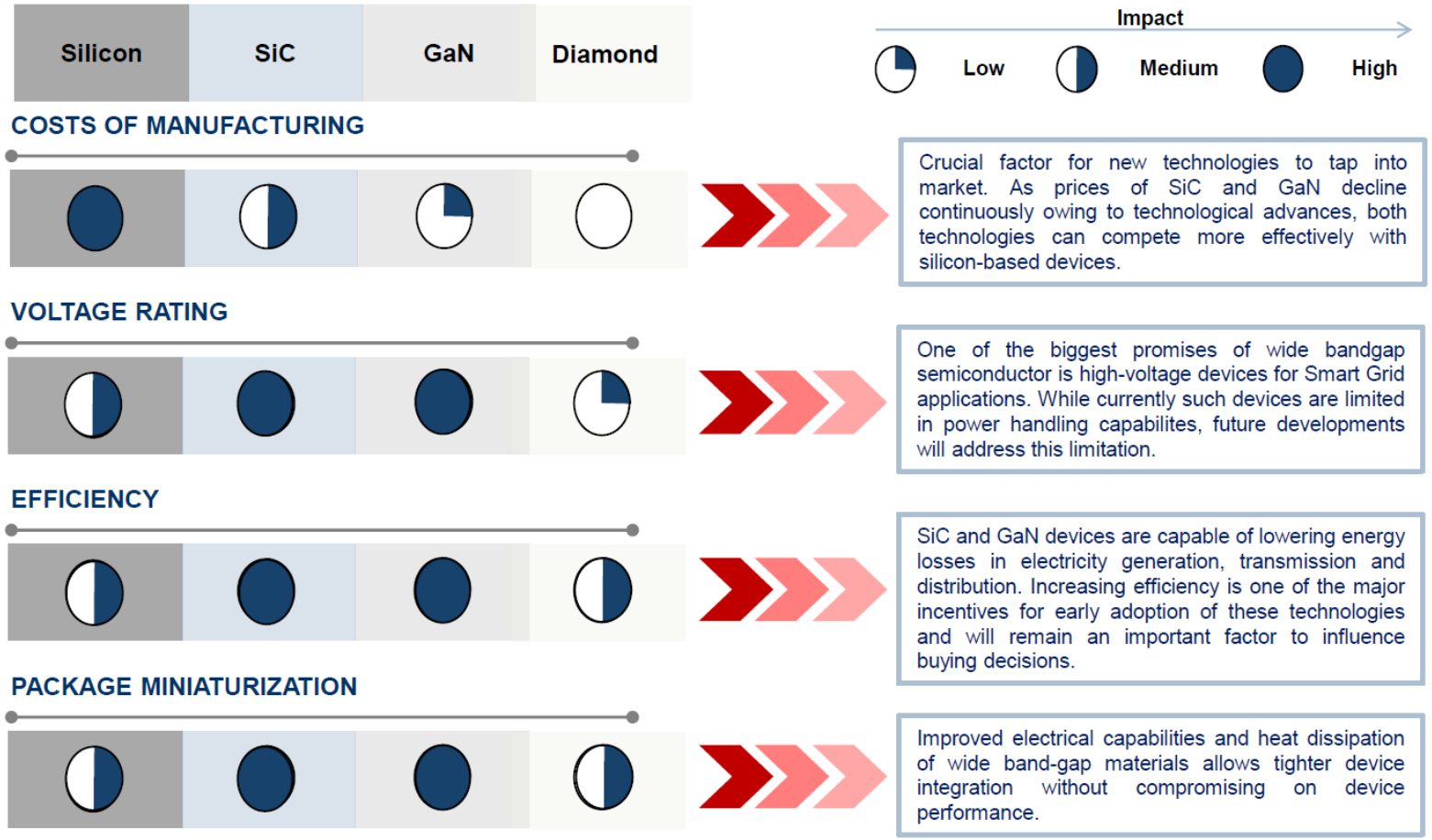
Micro-Electronics

- high performance with small amount of energy ratio
- smart IC design and packaging (single chip solutions)
- low start-up voltage (several mV), without increasing leakage currents
- high efficiency within dynamic input voltages (energy harvesting)

Agenda

- Introduction
- Future Key Products
- Technological Requirements
- **Roadmap**
- Research Strategy and Economic Impact

Roadmap – Technology Overview



"Advances in Power Electronics Enabling Future Smart Grid: Advanced Power Electronics Driving Next-Generation Power Grid," Technical Insights D4CE-TI.

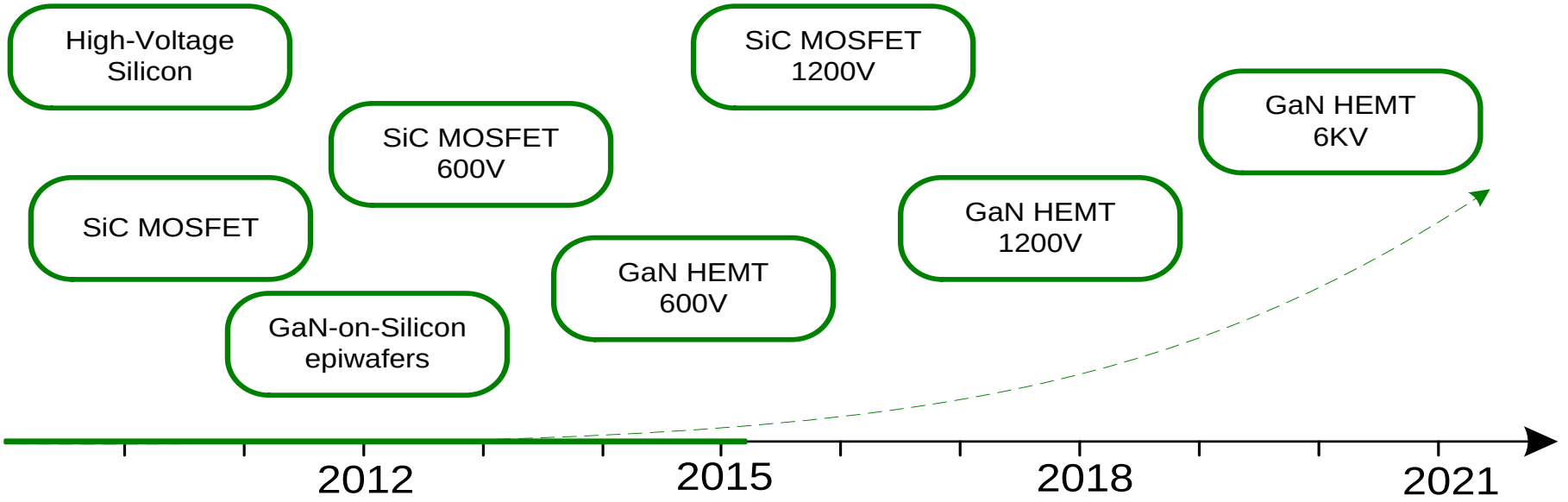
Roadmap – Power-Electronics - 1

- SiC MOSFETs
  - Improving of wafer size and defect control to achieve larger device areas and output currents
  - Reducing of channel resistance for MOSFETs together with improved gate-oxide quality

Roadmap – Power-Electronics - 2

- GaN HEMTs
  - Improved defect control to achieve larger device areas and output currents
  - optimization to reduce costs to be competitive to Si-based Technology (e.g. GaN-on-Si)
  - Monolithic normally-off transistor concepts in 600V and 1200V
  - improvement of packaging and thermal design

Roadmap – Power-Electronics - 3



Increased performance is a major driving factor for early adoption of GaN and SiC power electronics

Further improvements in efficiency, speed and voltage handling capabilities are expected to accelerate growth of GaN and SiC power electronics

High-voltage rated GaN power electronics are expected to provide a stronger alternative to conventional silicon devices, such as thyristors, for demanding Power Grid applications.

Frost & Sullivan - "Advances in Power Electronics Enabling Future Smart Grid: Advanced Power Electronics Driving Next-Generation Power Grid," Technical Insights D4CE-TI. - 2012

Roadmap – Micro-Electronics

- decreasing supply voltage
- increasing on-chip clock
- enhancement in performance, size and efficiency
- specialized ICs for energy, power and battery management (BMS, PMIC)

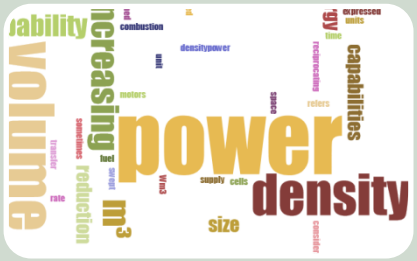
	2015	2017	2019	2021	2023
Power supply voltage [V]	0.83	0.80	0.77	0,74	0.71
On-chip local clock [GHz]	5.95	6.44	6.69	7.53	8.18

"INTERNATIONAL TECHNOLOGY ROADMAP FOR SEMICONDUCTORS: 2013 Edition," Executive Summary, 2013.

Agenda

- Introduction
- Future Key Products
- Technological Requirements
- Roadmap
- **Research Strategy and Economic Impact**

Research Strategy



Research Strategy

reduction of costs

- improvement of production techniques
- new substrates

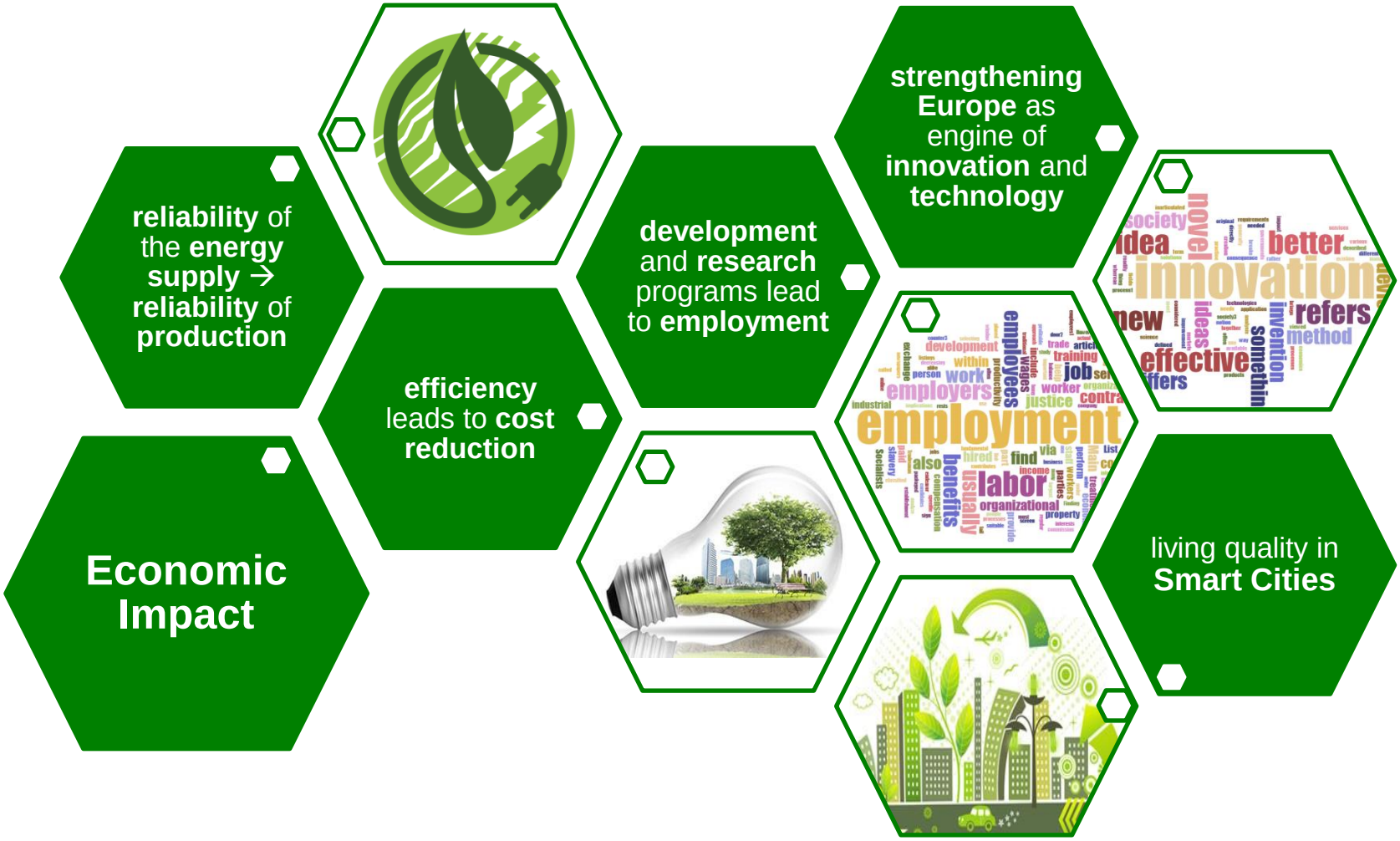
increasing power density

- reduction of size
- increasing power handling capabilities

increasing efficiency

- reduction of on-state losses
- Packaging and thermal design

Economic Impact



Any Questions?

Moritz Loske

M. Eng.

Networked Systems and Applications Department
Fraunhofer Institute for Integrated Circuits IIS

Nordostpark 93 | 90411 Nürnberg, Germany
Phone +49 911 58061-9316 | Fax +49 911 58061-9399
moritz.loske@iis.fraunhofer.de

Roadmap – Power-Electronics

- Si-based MOSFETs
  - Further reduction of specific on-resistance $R_{DS,ON}$
  - Reducing output capacitance C_{oss} to improve the efficiency of hard-switching circuits
  - Reducing gate charge Q_g and gate resistance R_g to enable higher switching frequency operation

Roadmap – Power-Electronics

- Si-based IGBTs
  - Further reduction of wafer thickness→ cost reduction
  - Improvement of the efficiency (Trench superjunction structures)
  - increase working temperature
    - improving and simplifying heat exchangers and cooling systems
    - applications in high temperature environments
  - Improved soldering techniques and reduce back- and top-side thermal resistance