

**How the Crisis has Shaped the European
Micro
and Nano Landscape – and what will
Help to get on Track again**

Dr. Uwe Kleinkes, IVAM Microtechnology Network

19.04.2010

crisis chance

危機會

2020

Worldwide



European Association for Micro/Nanotechnology and
Advanced Materials

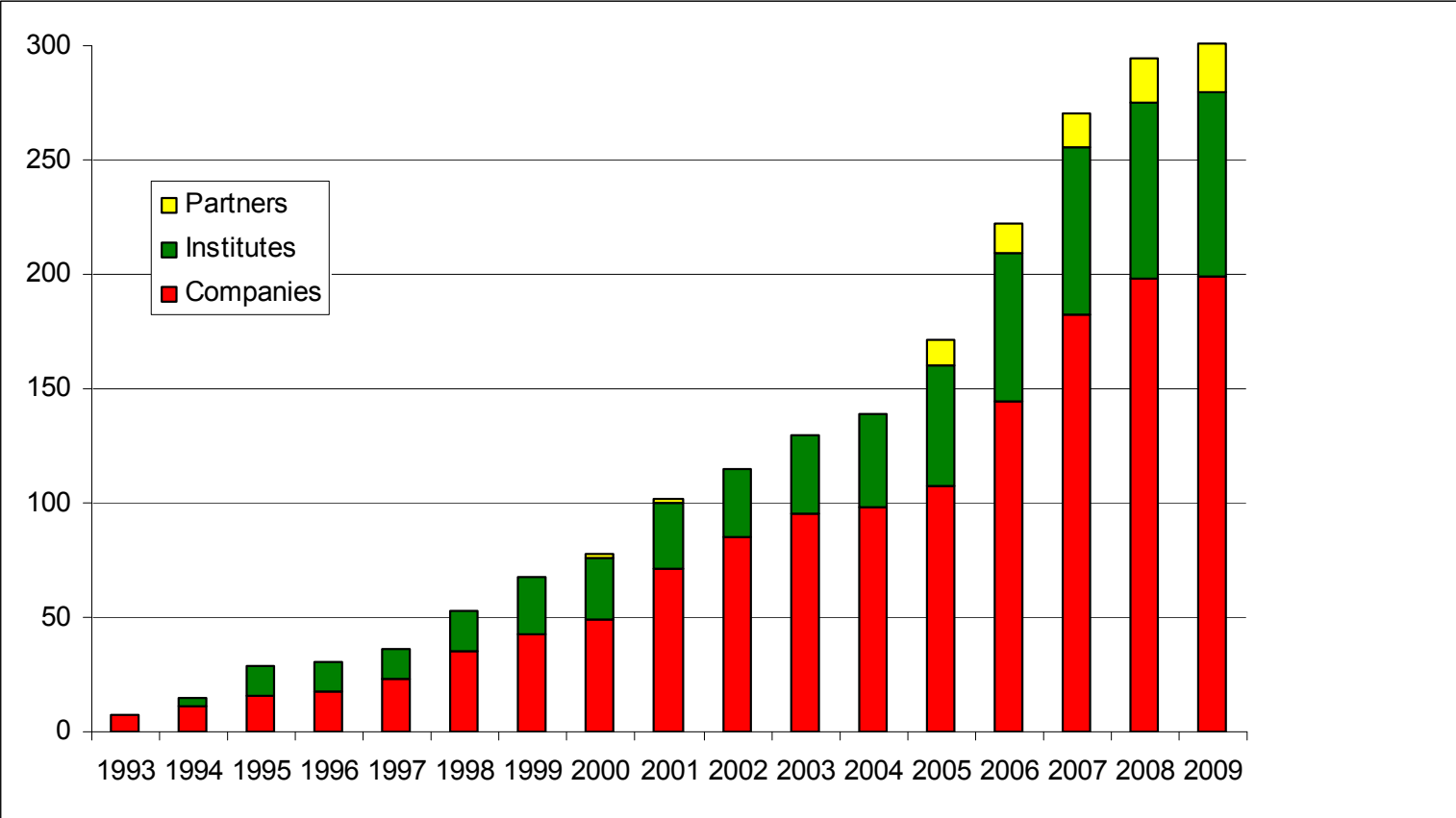


Communicative bridge between users and suppliers of MST/MEMS

- **IVAM is the Microsystems, Nanotechnology and Advanced Materials Network**
 - **Over 280 companies and institutes go for the markets**
 - **Mission of IVAM:**
Connection between users and suppliers of MST/MEMS/Nano
 - **Focus of activities:**
 - Technology marketing
 - International networking
 - Lobbying for high-tech SME
 - Education and training
-

IVAM is a growing European network

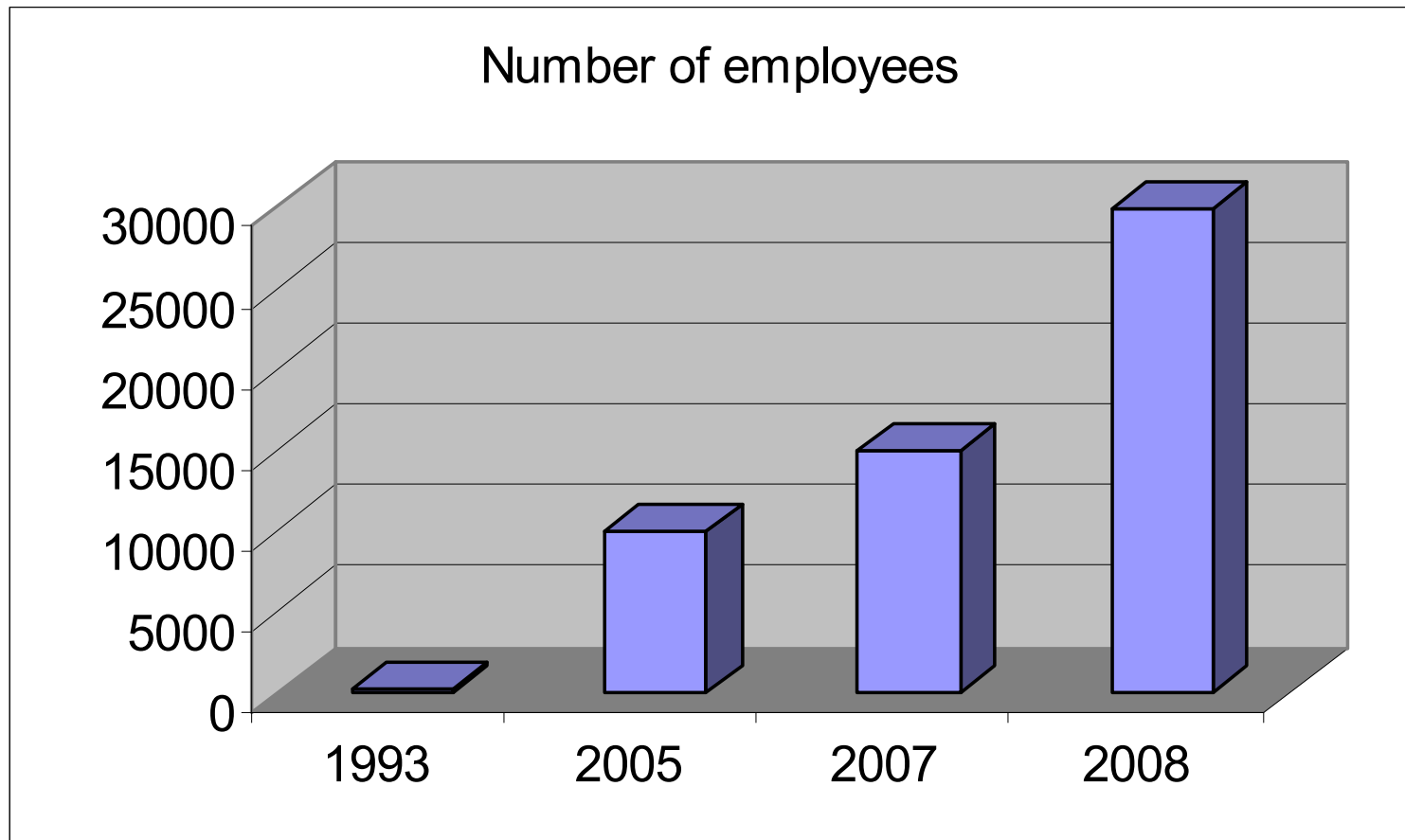
IVAM



We have added new members in 2009 – though there was a crisis in economy

IVAM members

IVAM



Board of IVAM: entrepreneurs

IVAM

The Board

IVAM is represented by the board of directors.



Chairman of the Board:

Dr. Frank Bartels

www.bartels-mikrotechnik.de



Deputy Chairman of the Board:

Dr. Thomas W. Kritzler



Member of the Board:

Dr. Lutz Aschke

www.limo.de



Member of the Board:

Dr. Hans van den Vlekkert

www.lionixbv.nl



Member of the Board:

Dr. Olaf Kiesewetter

www.umweltsensortechnik.de



Prof. Dr. Roland Zengerle

IMTEK Institut für Mikrosystemtechnik
Albert-Ludwigs-Universität Freiburg as well as HSG-IMIT
www.imtek.de/anwendungen/ resp.
www.hsg-imit.de



Dr. Thomas Fries

FRT
Fries Research & Technology GmbH
www.frt-gmbh.com



Prof. Dr. Dieter Jäger

Universität Duisburg-Essen
FB9/Optoelektronik, ZHO/LT 115
www.oe.uni-duisburg.de



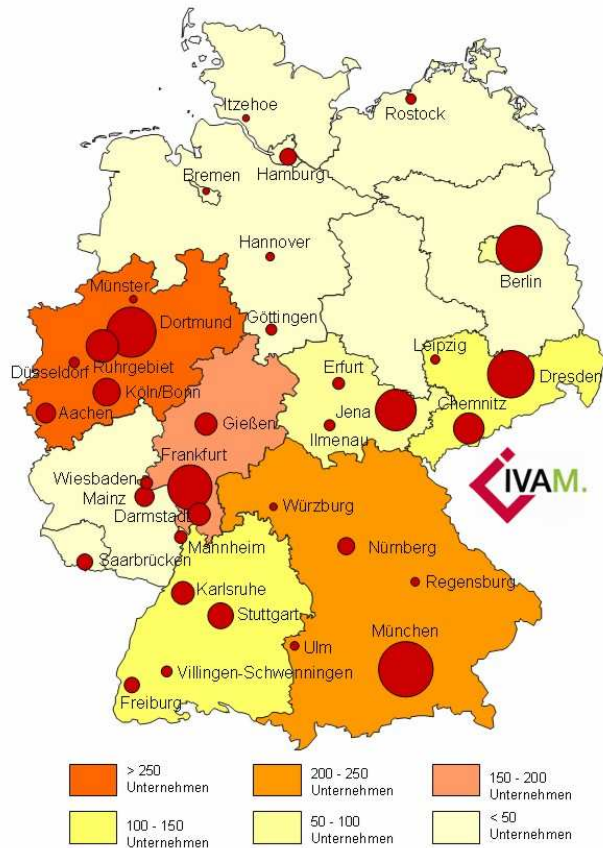
Prof. Dr. Thomas Geßner

Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM,
Abteilung Micro Devices and Equipment Chemnitz as well as
Technische Universität Chemnitz, Zentrum für Mikrotechnologien (ZfM)
www.pb.izm.fraunhofer.de/mdae resp.
www.zfm.tu-chemnitz.de



Prof. Dr. Klaus Meerholz

Universität Köln
Institut für Physikalische Chemie
www.meerholz.uni-koeln.de



MST-Atlas Deutschland:
Cluster von Unternehmen der Mikro- und Nanotechnik und Neuen Materialien.
© IVAM Research, Februar 2007

IVAM is the German competence network for Micro- und Nanotechnology

(s. www.kompetenznetze.de)



- Microsystems Industry Today

IVAM

European Data survey

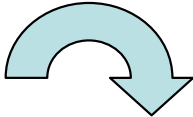
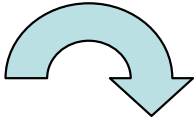
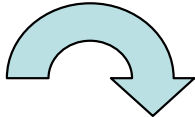
IVAM

-
- Time of survey: December 2009
 - Target group:
 - European SME and R&D institutes dealing with microtechnology, nanotechnology and/or advanced materials throughout Europe
 - Number of addressees: 2,642
 - Number of responses: 251 (192 complete, 61 incomplete)
 - Response rate: 9.5 % (2008/2009: 12.6 %)
 - Low response rate may be due to
 - the time of the survey (end of 2009 instead of early 2010; year-end accounting)
 - a generally lower mood, no inclination to “face” the present economic state
-

Emploment numbers and turnover in 2009 **IVAM**

- The European micro, nano and materials companies employed an average of 119 people
 - Total employment number of the industries: 309.400
 - The companies achieved an average turnover of 16.9 million Euros
 - Total turnover of the industries: 44 billion Euros
 - **1st investigation of its kind !**
-

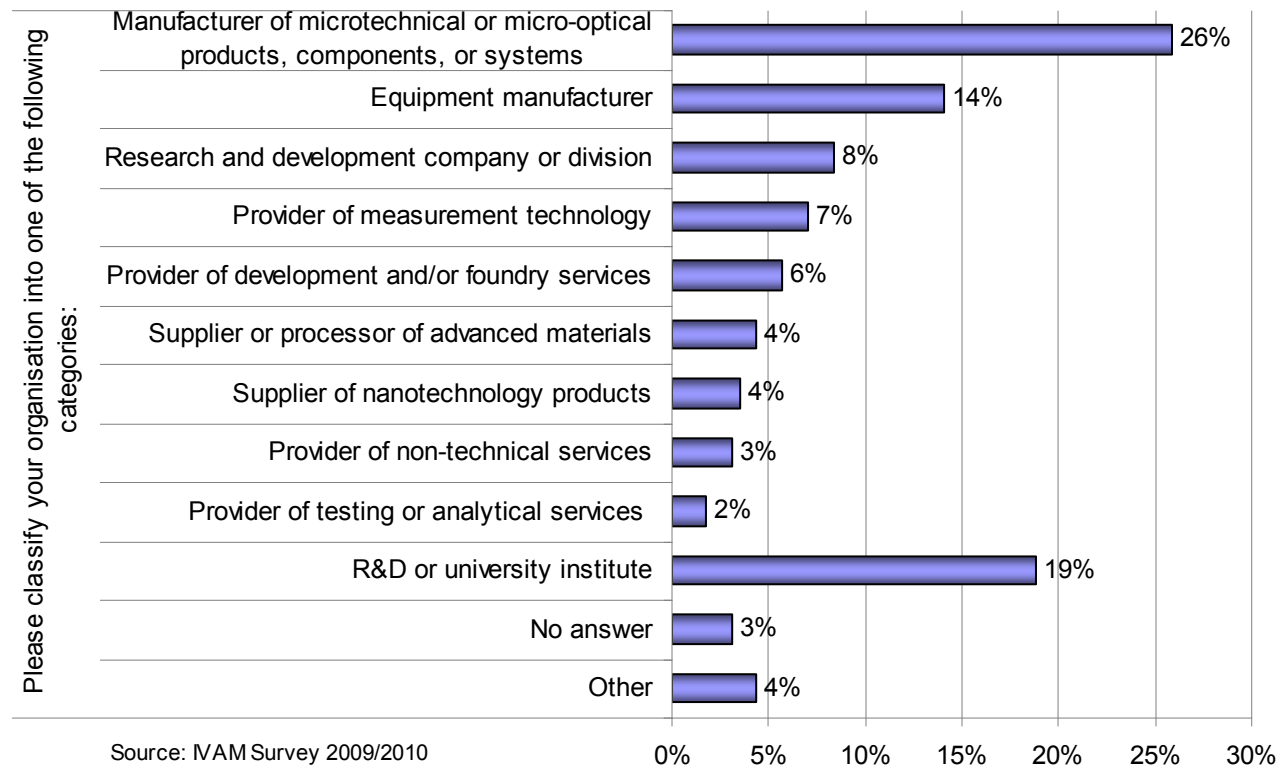
Summary of the most striking results **IVAM**

- Turnover  Germany  
 - In Germany, the automotive industry has replaced the medical industry as the major target market during 2009 > effect of „Abwrackprämie“?
 - German companies have more often been able to keep their staff numbers steady > possible effect of „Kurzarbeit“
 - In Germany, the crisis has most significantly affected the export rates; even stronger decreases are expected for 2010
> German companies are no longer export champions
-

Categories of respondents

IVAM

Almost 80 % of the respondents are industry enterprises;
19 % are R&D or university institutes



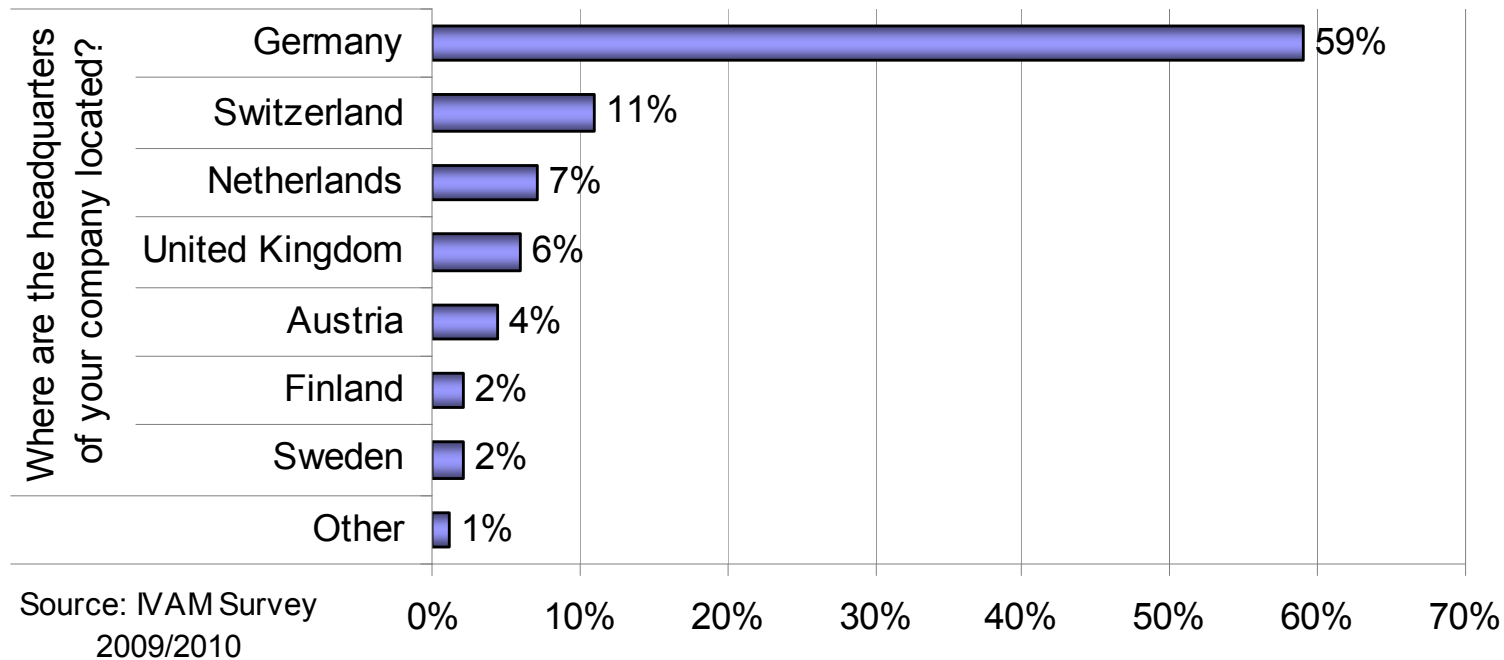
A large proportion of the responding enterprises manufacture micro/nano components or systems.

Others:
microelectronics, software,
cleanroom products

R&D institutions are not included in the evaluation of the economic data !

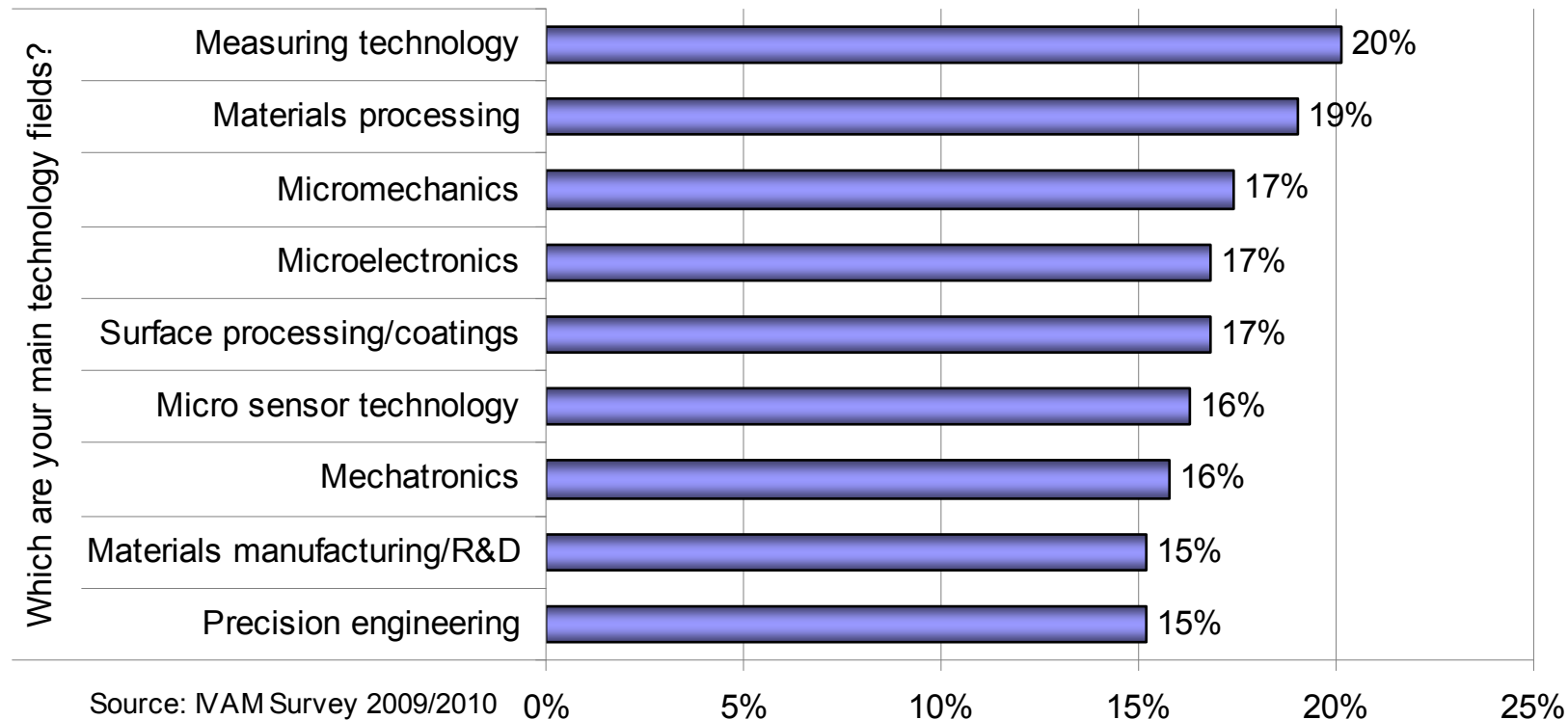
Nationality of the respondents

Almost 60 % of the respondents are based in Germany



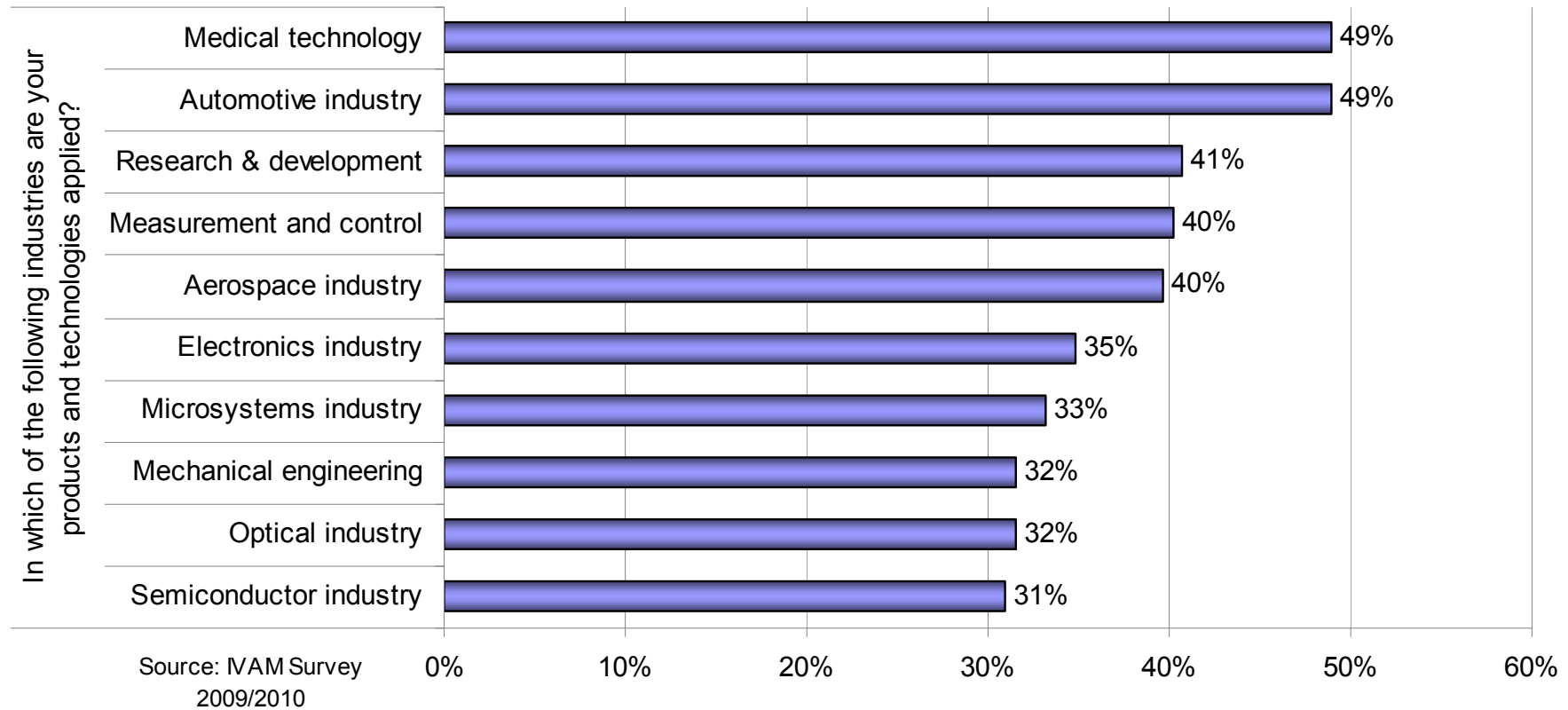
Applied technologies

A fifth of the European companies are offering measurement technology



Target markets

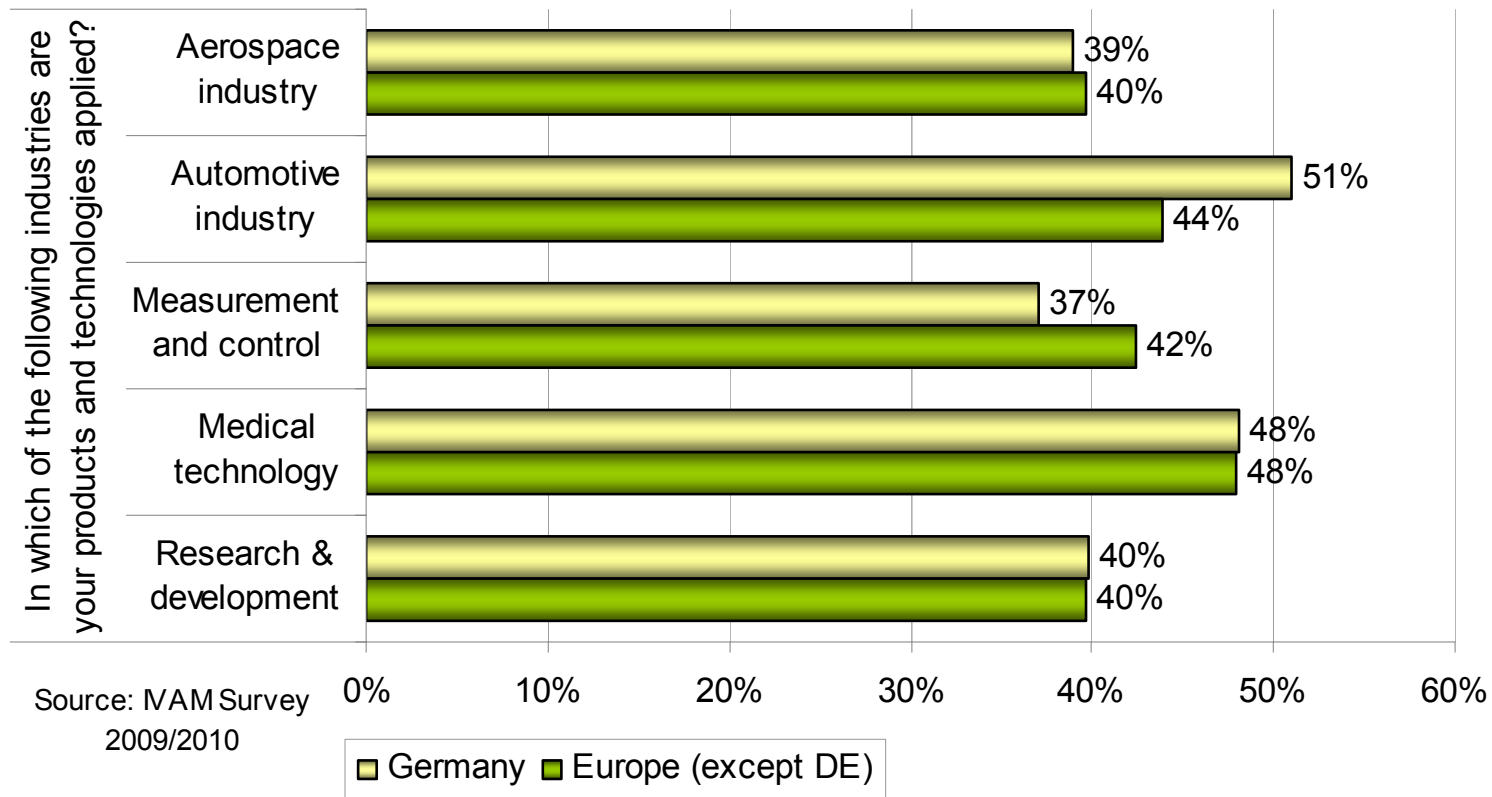
The medical technology market has lost shares as compared to 2008/2009 (57 %). Medical technology shares its top position with the automotive industry



Target markets Germany vs Europe

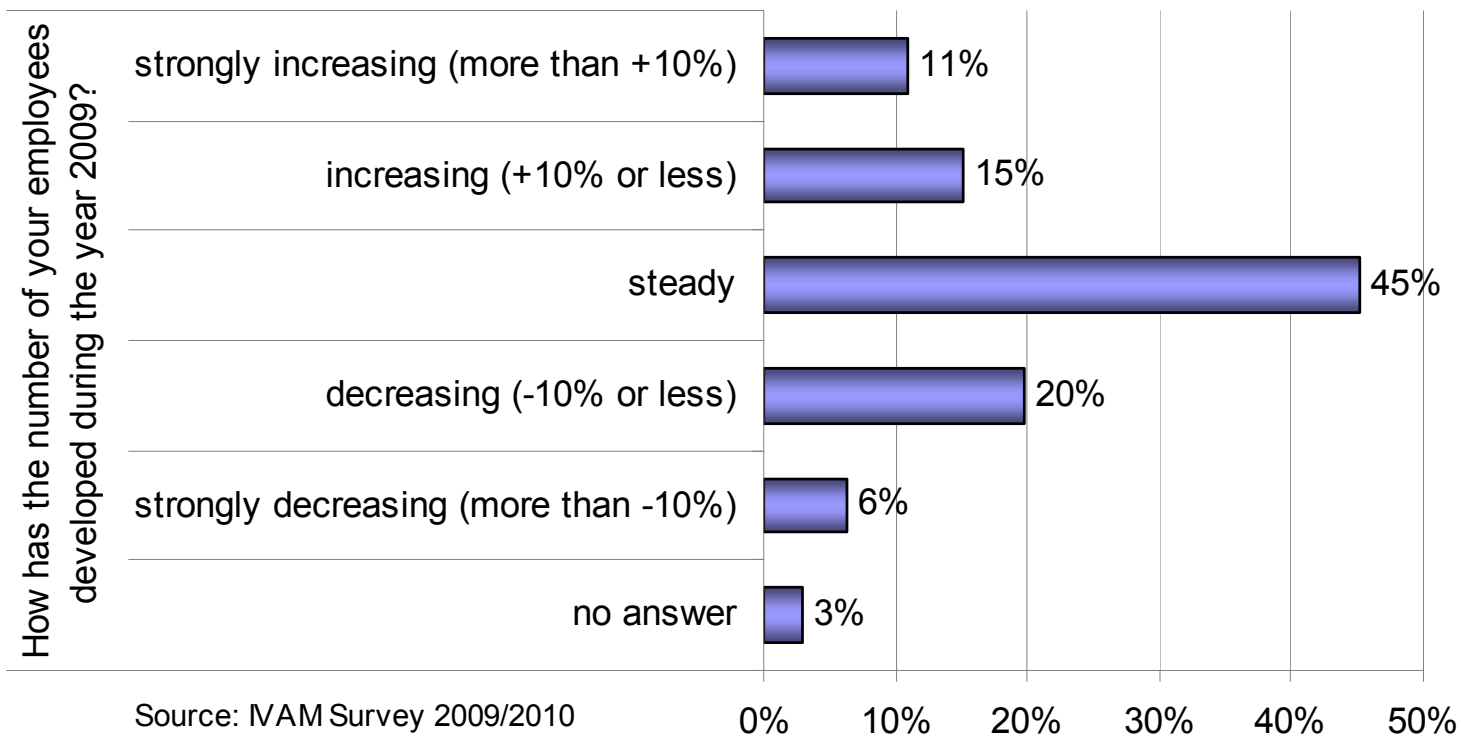
In 2009, the automotive industry has replaced medical technology as the top market in Germany

→ positive effects of the “Abwrackprämie”?



Staff development in 2009

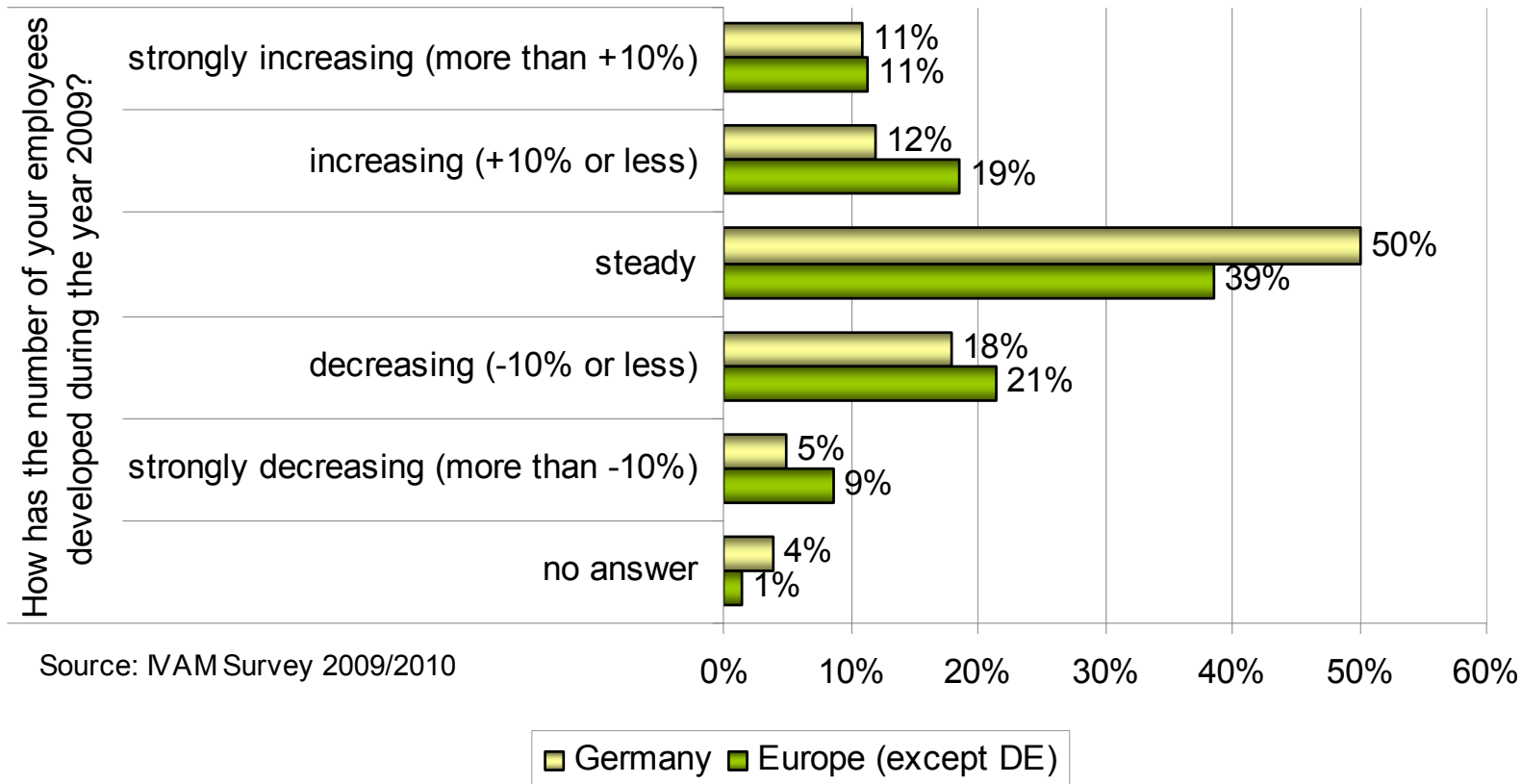
Staff numbers have been steady in almost half, but decreasing in more than a quarter (26 %) of the companies/institutes in 2009. In 2009, the decrease has been stronger than it was in 2008.



Staff development in 2009 Germany vs Europe

In Germany, more companies than in the rest of Europe have been able to keep staff numbers steady in 2009

-> effects of “Kurzarbeit”?

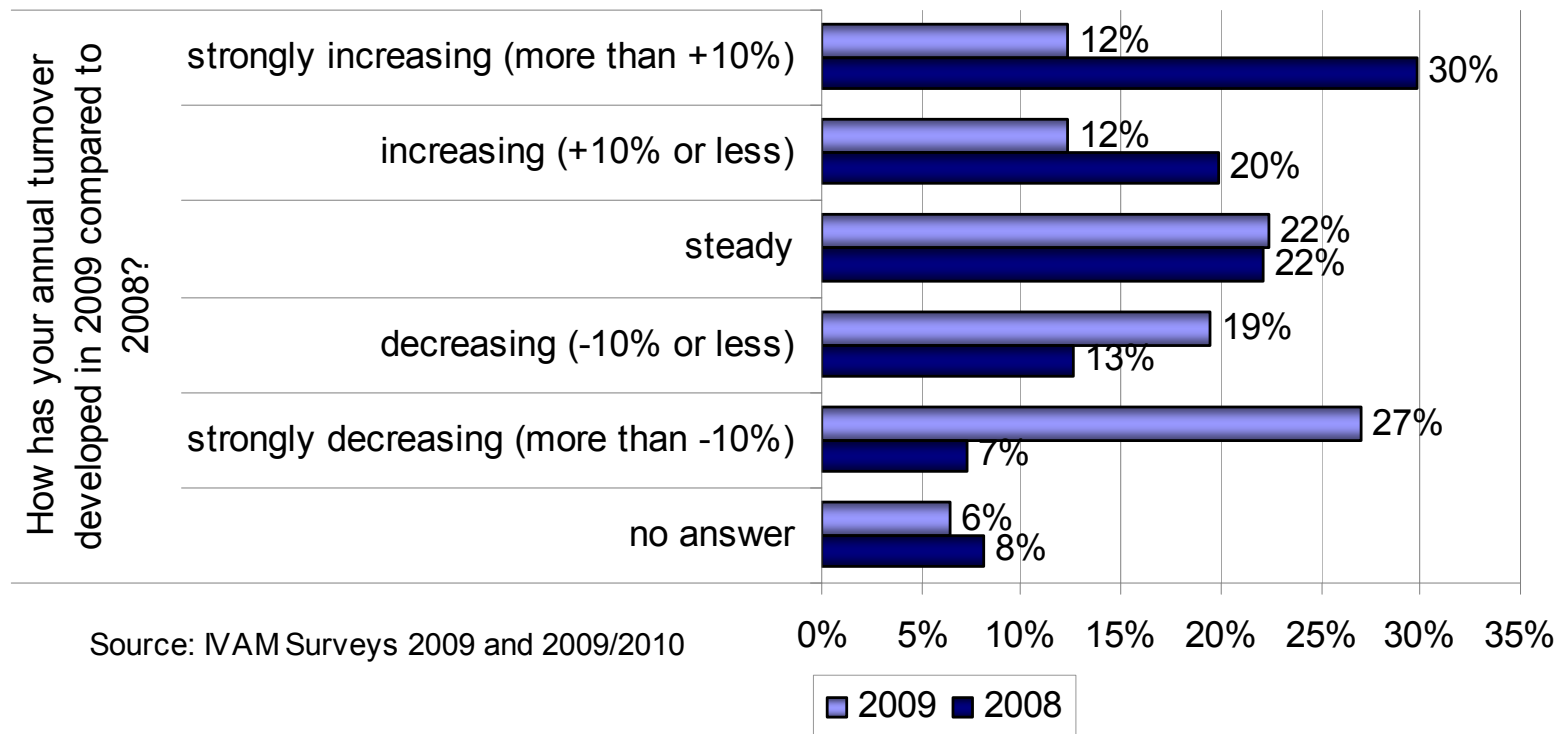


Turnover development in 2009 (and 2008)

46 % of the respondents have experienced a decrease or strong decrease in their turnover in 2009

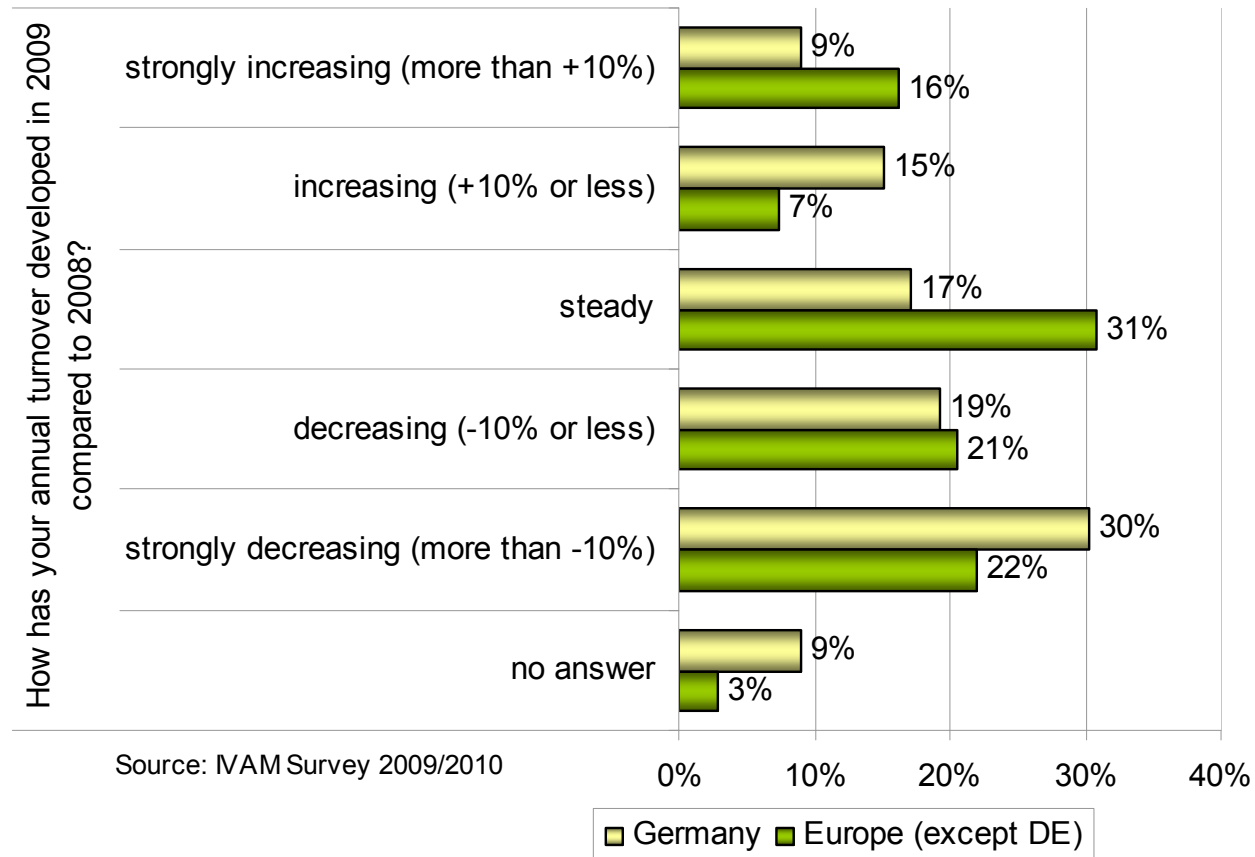
In 2009, the decrease has been stronger than during 2008

Development of annual turnover



Turnover development in 2009 Germany vs Europe

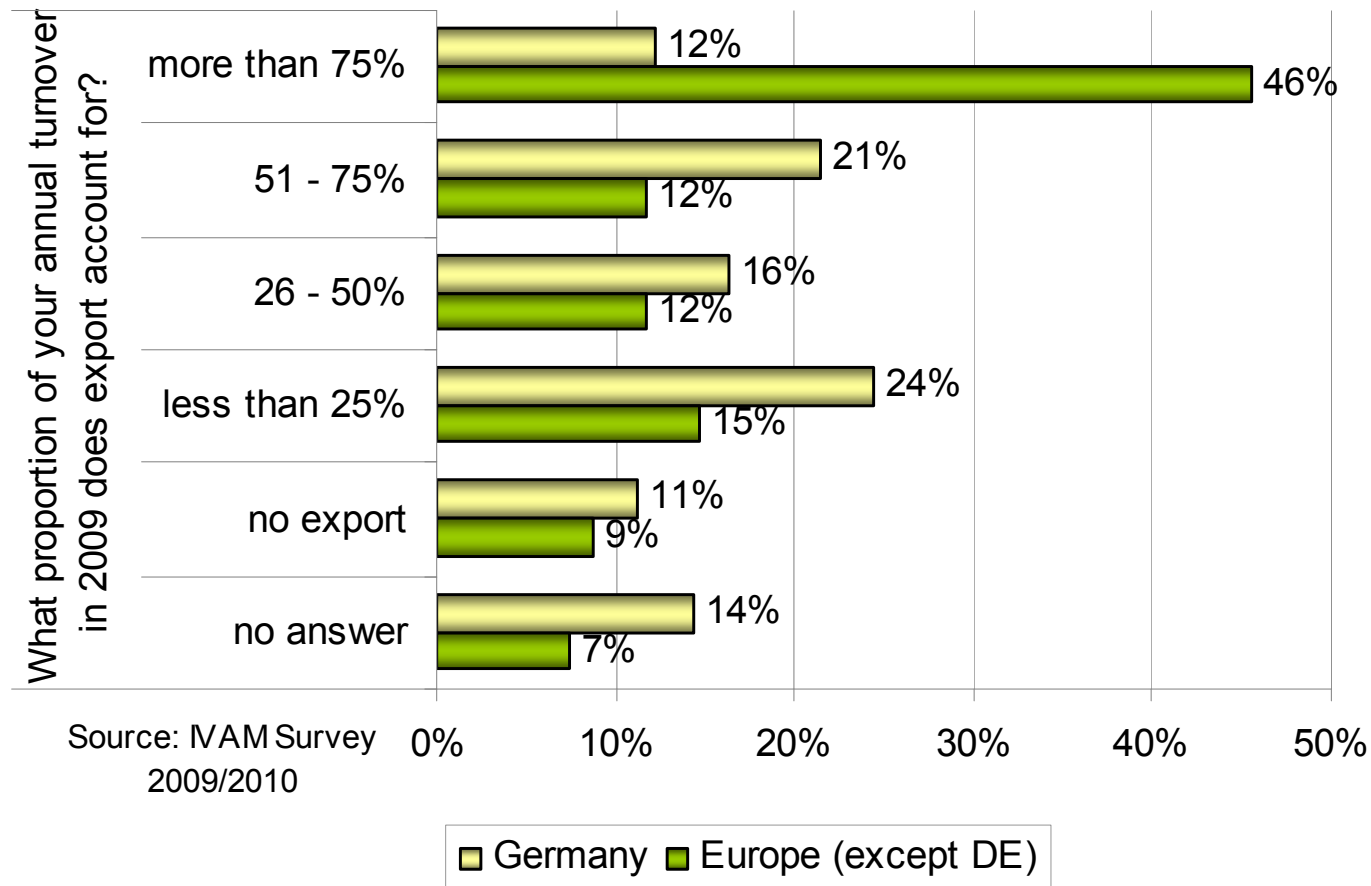
In spite of experiencing a more steady staff development than the rest of Europe, the German enterprises had to face a stronger decrease in their turnover in 2009



Export share Germany vs Europe

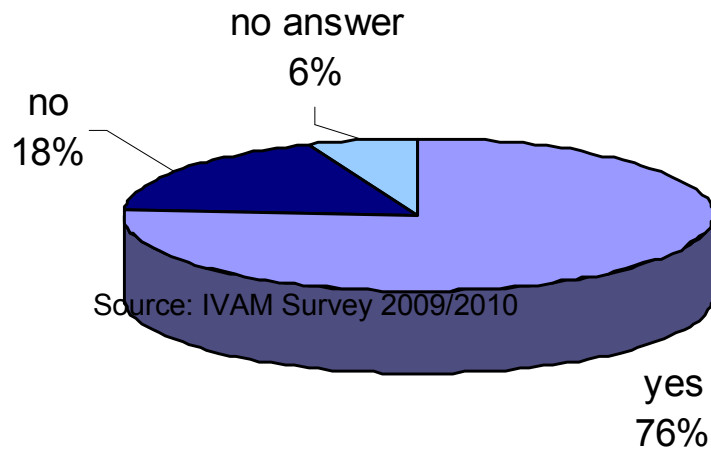
IVAM

German enterprises are no longer export champions
in Europe



Effects of financial and economic crisis in 2009

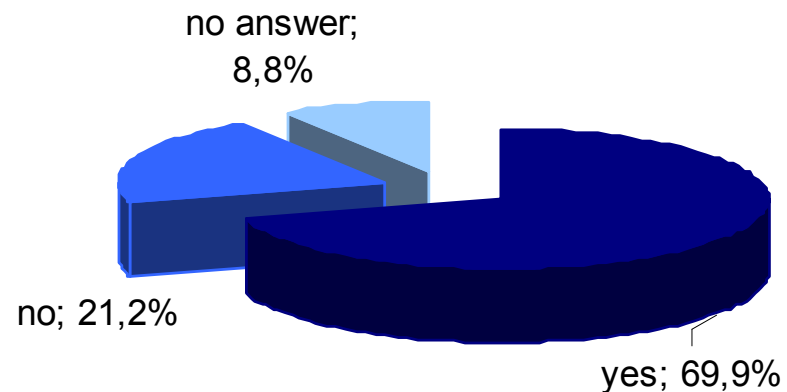
Has the financial and economic crisis affected your business in 2009?



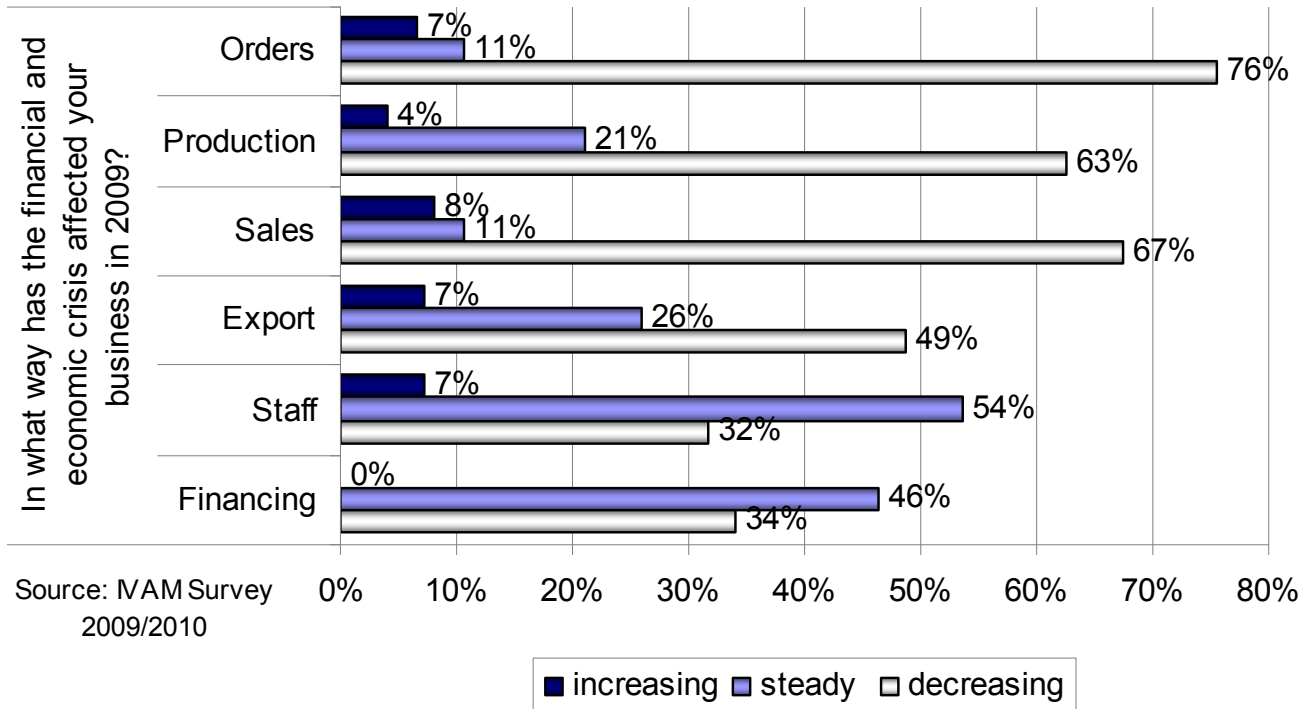
In the beginning of 2009, fewer companies expected to be affected by the crises in the course of the year

More than three quarters of the respondents were affected by the economic crisis in 2009

**Do you expect the financial and economic crisis to affect your business in 2009?
Companies only**



Effects of financial and economic crisis in 2009

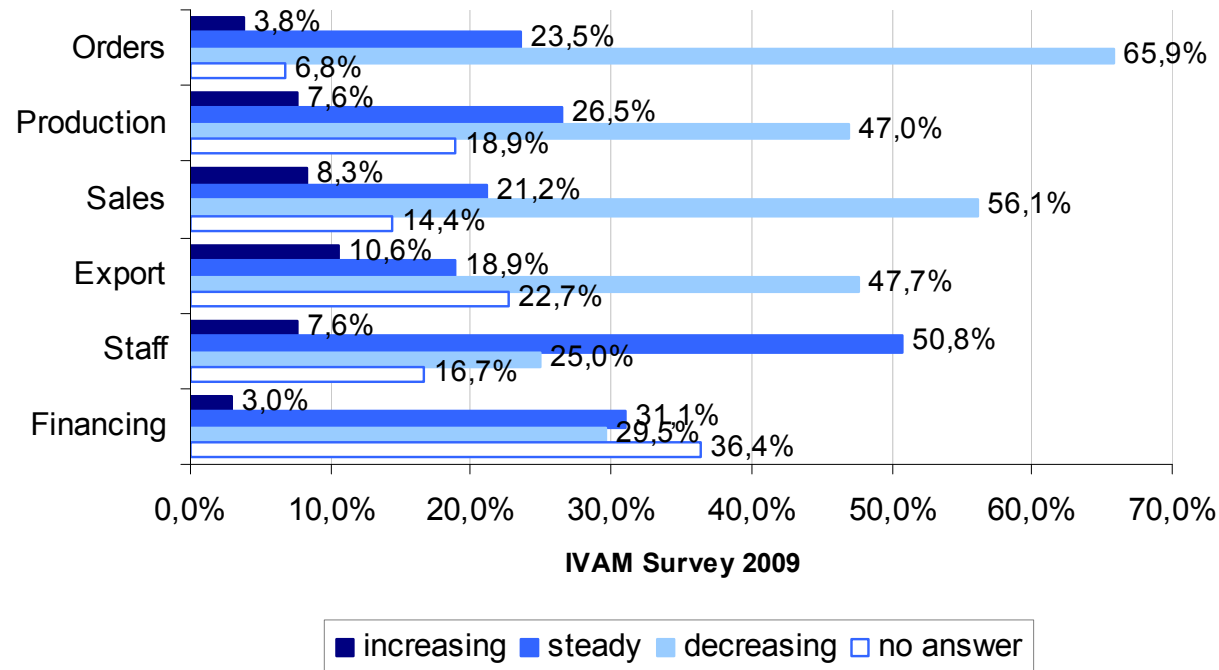


The effects of the economic crisis in 2009 have been worse than the companies predicted in the beginning of 2009.

There is still uncertainty.

Effects of financial and economic crisis in 2009

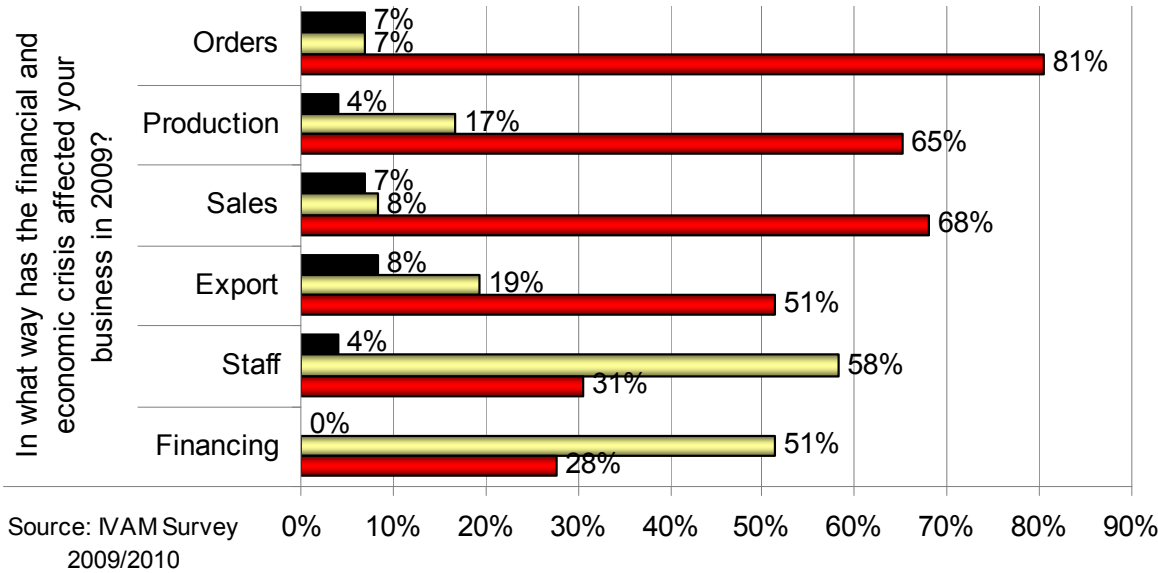
In what way do you expect the financial and economic crisis to affect your business in 2009?



A larger proportion of the companies have suffered decreases in each business area – from orders to financing

Effects of financial and economic crisis in 2009

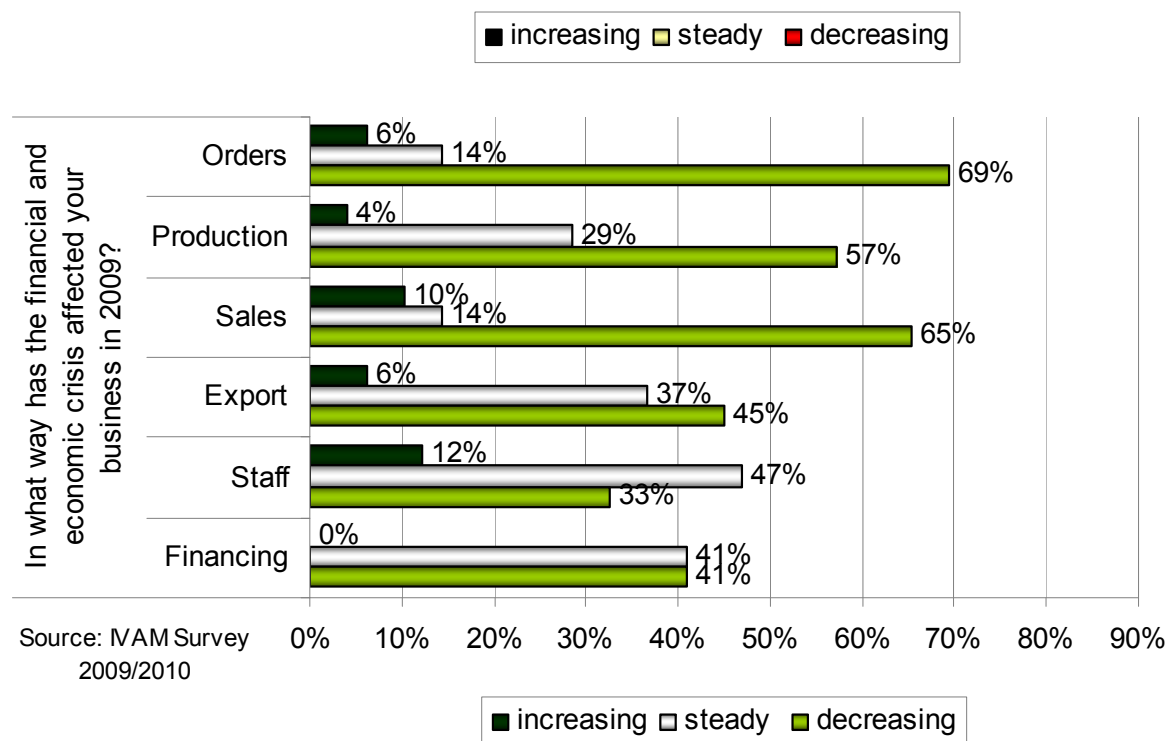
IVAM



ie

In Germany, a larger proportion of the companies suffered a decrease in orders, production, sales, and export,

but German companies have more often been able to keep staff numbers and financing steady than companies in the rest of Europe

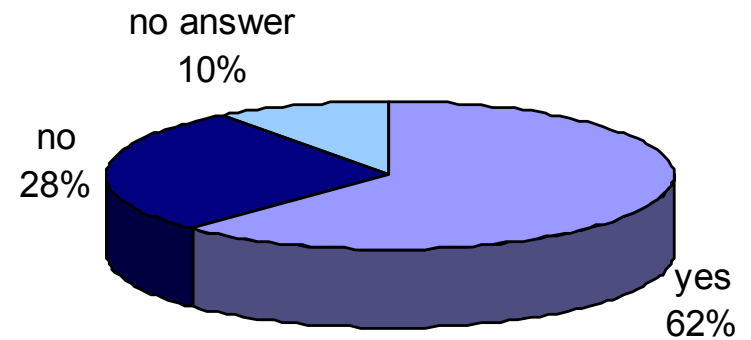


Effects of financial and economic crisis in 2010

The respondents expect the effects of the crisis to abate in 2010

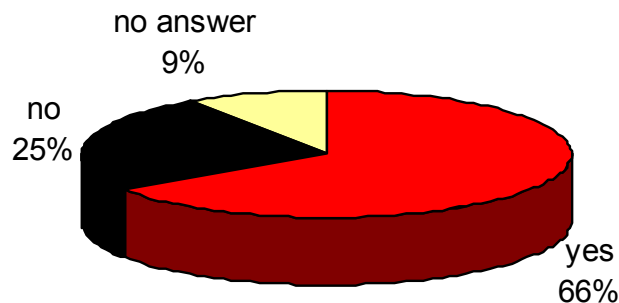
At first sight, German companies seem to be less optimistic than those in other European countries ...

Do you expect the financial and economic crisis to affect your business in 2010?



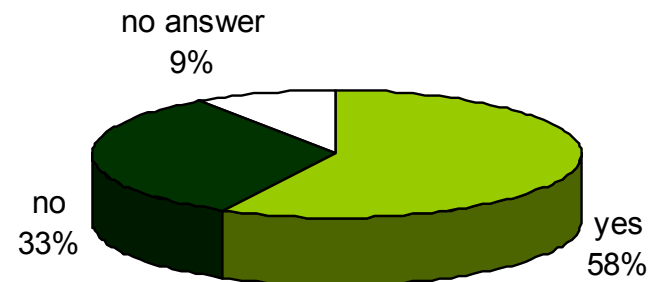
all European companies

Do you expect the financial and economic crisis to affect your business in 2010?



Germany

Do you expect the financial and economic crisis to affect your business in 2010?

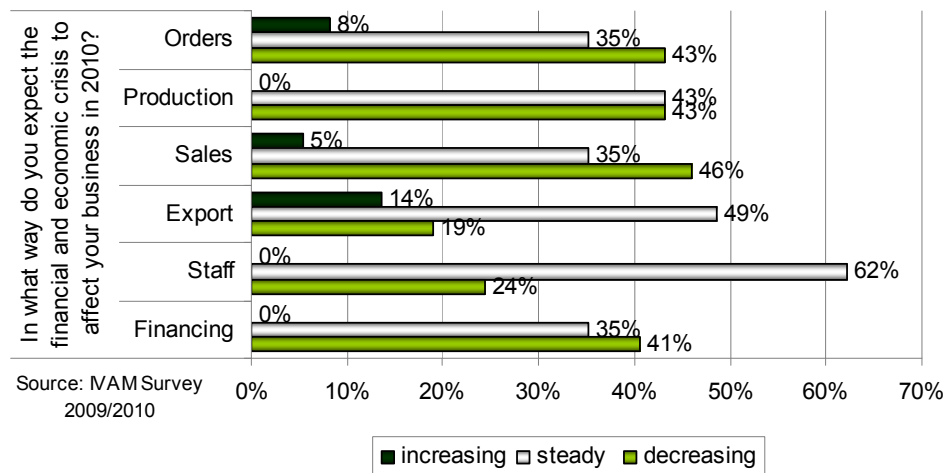
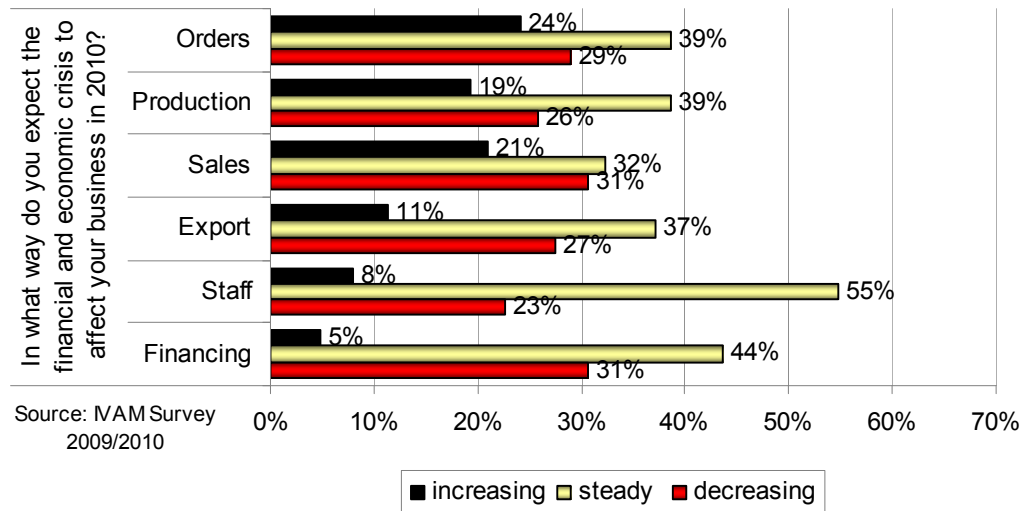


Europe (except DE)

Effects of financial and economic crisis in 2010

IVAM

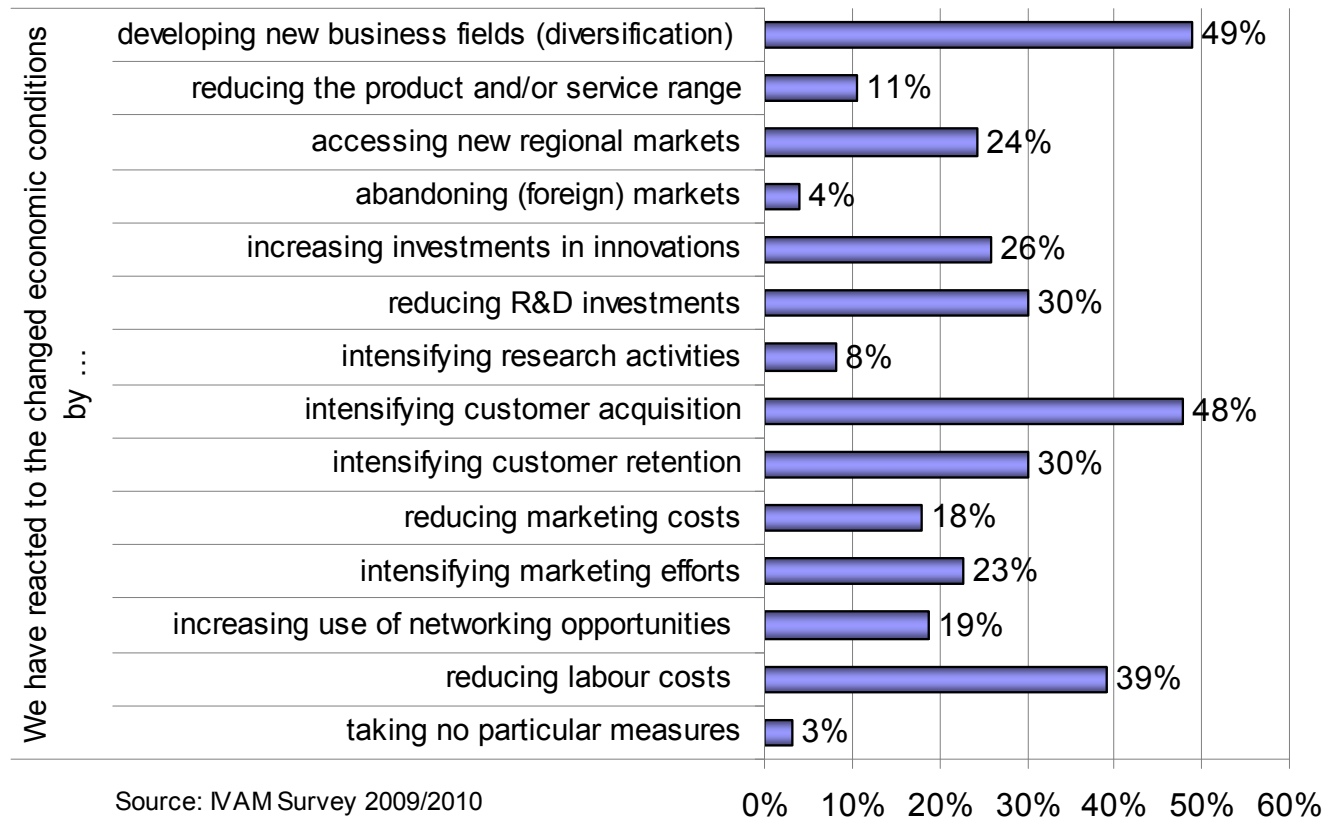
Germany vs Europe



... but in fact, a smaller proportion of the German companies is expecting decreases in most business areas – except export

measures

A majority of the respondents have reacted to the crisis in a “positive” way – e.g. by diversification or by intensifying acquisition efforts.



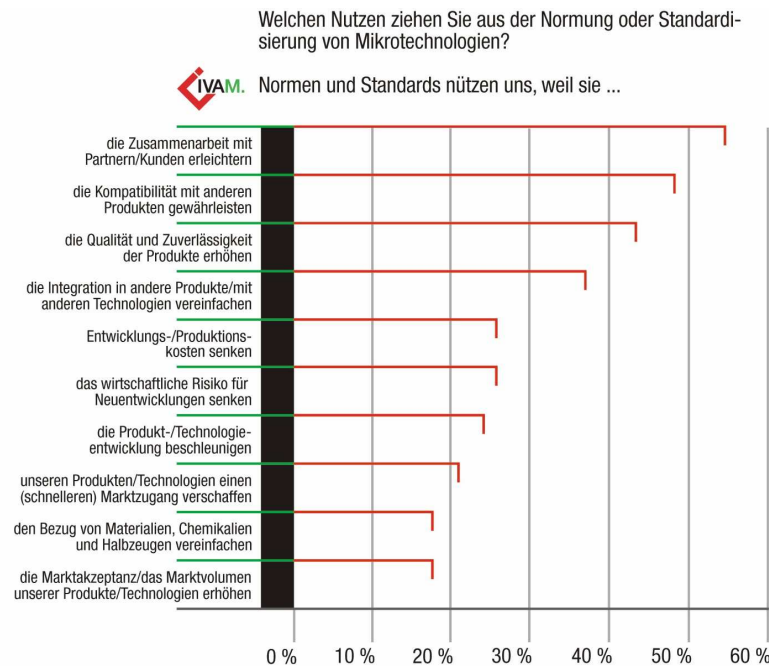
Standards in MST:

IVAM

Germany is too complicated, too slow

Project NOSTA : One product, one process, one package,

Standards are a problem esp. for SME -> no mass markets



- IVAM Research: Iris Lehmann



**„There is more turn over with catering at
Micro and Nano events than with products
from Mikro- und Nanotechnologie.“**

Kurt Demmer, Chefvolkswirt der IKB-Bank,

Dortmund, Technologie- und Branchentag 2001



- Bosch Fab (550 Million €)



microParts (70 Million €)

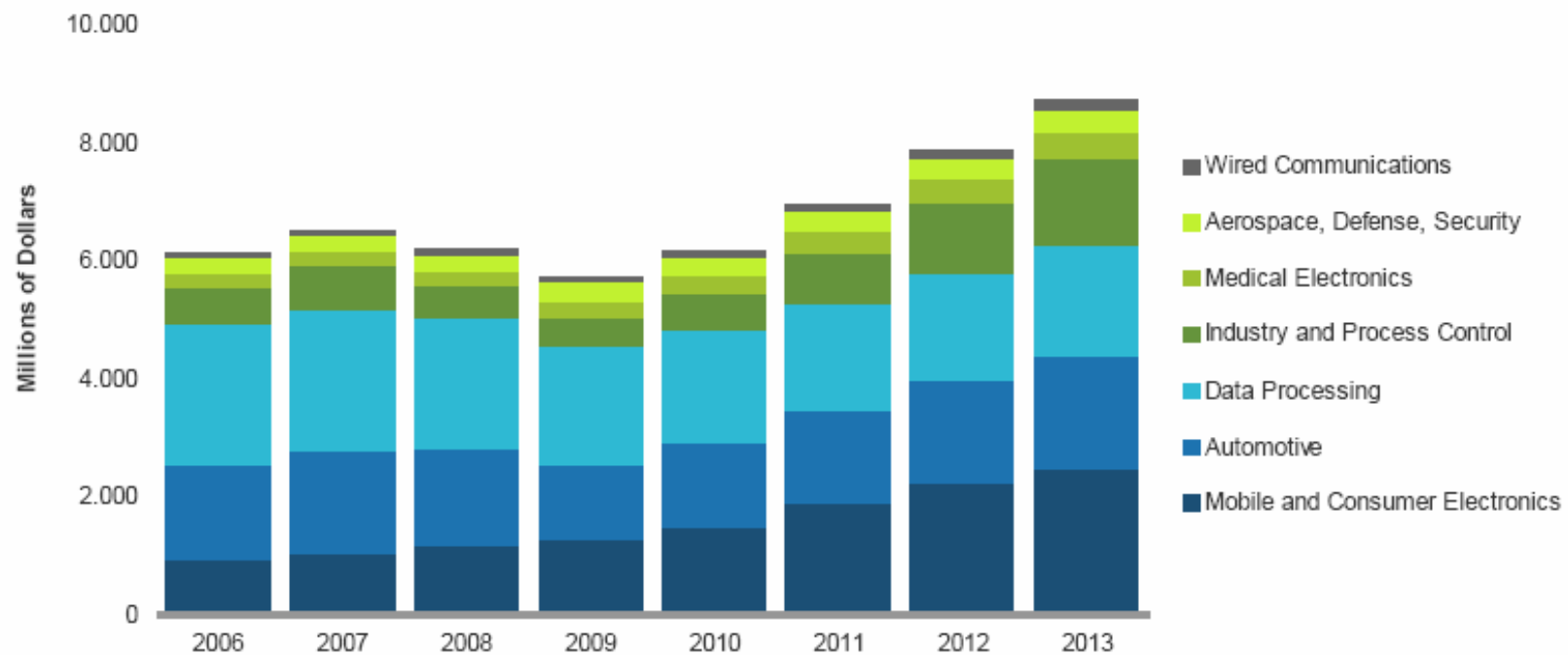


Markets for Microsystems

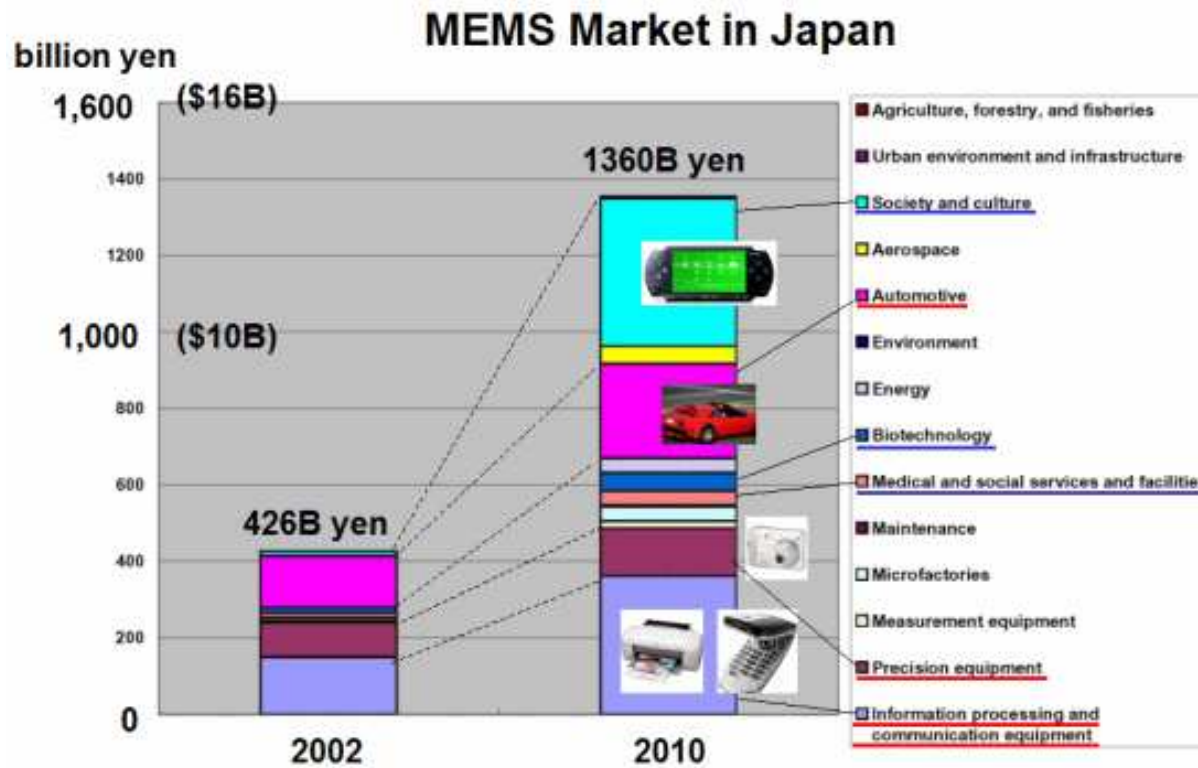
IVAM

MEMS Market by Application, 2006-2013

iSuppli



Note: emerging MEMS categories not counted in this breakout (\$180 M in 2013 up from \$30M in 2009)



11 Billion €

15 Billion US \$

as of March
10th 2010

-
- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

Miniaturisation

IVAM



First cell phone and
its inventor Martin
Cooper (1973)

picture: Wikipedia

Miniaturization

IVAM



Let's Go Digital

MEMS Microphones for Smartphones

IVAM



The Economist

Log in | Register | My account | News letters | RSS | Subscribe

Home | World | Business & finance | Science & technology | Markets & data

Print Edition

Noise-cancelling technology

Opting for the quiet life

Tiny microphones provide a new way to eliminate background noise

Feb 11th 2010 | From The Economist print edition



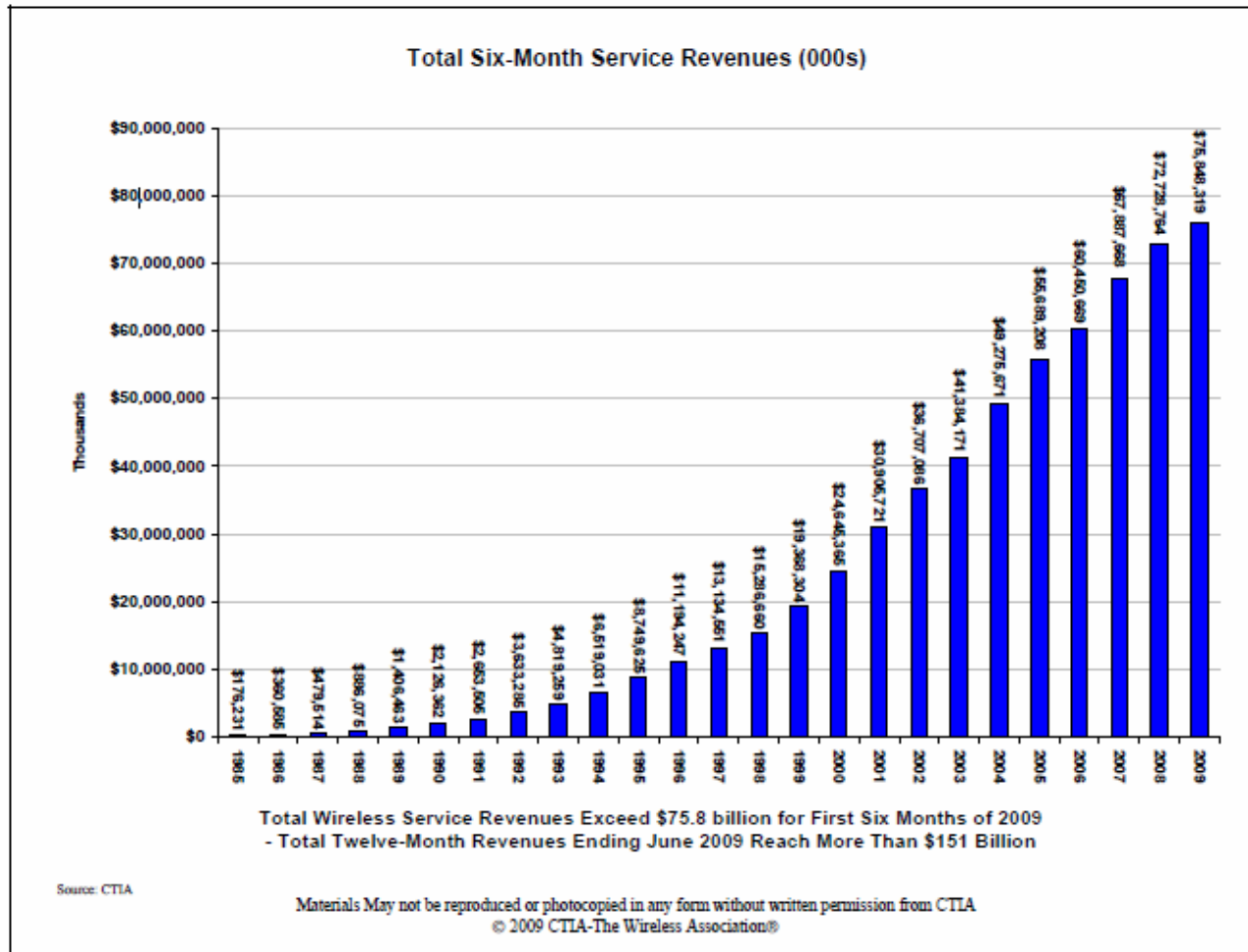
A cartoon illustration depicting a man sitting at a desk with a laptop, shouting loudly into a mobile phone. A woman in a white dress is aiming a rifle at him, suggesting a need for noise cancellation. The background shows a window with a view of a city.

- Long way from automotive into consumer electronics, for some years predicted from the people with the glass ball, now the race is on
 - Bosch -> Bosch Sensortec
 - Mems MicroPhones (Economist)
 - Smartphones, consumer electronics ST Microelectronics
 - -> no added value in Europe (except Nokia)
-

- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

- Wireless/ Mobile (Energy Harvesting)







mLearning
Preparing the next generation to be more competitive and better educated through broadband.

[READ MORE](#)

- Smart Energy
- Wireless Health
- Intelligent Transportation
- Retail Solutions
- **mLearning**
- Mobile CE
- Cloud Computing
- Mobile Applications
- Mobile Marketing & Advertising
- Social Networking
- Mobile Money

MobileLife

It's just the beginning!



March 23-25, 2010
Las Vegas Convention Center
Las Vegas, Nevada, USA

Energy Saving/ CO₂ reduction

IVAM

> Self-powered Radio Systems in Practice

Case Study:
Torre Espacio - Madrid



- **4200 Wireless & Battery-less Light Switches**
- **Occupancy Sensors**
- **Daylight Sensors**

- **Savings**
 - **40% Lighting Energy Costs**
 - **20 miles Cable**
 - **42.000 Batteries (over 25 years)**
 - **80% cost of retrofitting**

➔ ENERGY-EFFICIENCY & FLEXIBILITY "ENABLED BY ENOCEAN"





Nokia files patent for piezoelectric powered cell phone battery

While other big phone manufacturers (like [Samsung](#)) are using solar energy as an alternative to charge their phones' batteries, [Nokia](#) intends to use [piezoelectricity](#) and [kinetic energy](#).

The Finnish giant has filed a patent for a "Piezoelectric Kinetic Energy Harvester" – which is actually a cell phone battery that's "contained within a first frame that is coupled to a second frame by one or more piezoelectric elements."

Said battery should be included into a phone with the r would gather electrical energy resulted from the phone's

Thermoelectric effect



BMW aims to put rocket science in your car



(Reuters) - Germany's BMW wants to use NASA technology to boost the fuel efficiency of its luxury cars and lower emissions of harmful greenhouse gases.

Christiaan Hetzner
GENEVA
Mon Mar 9, 2009 5:29pm EDT

LIFESTYLE

Engineers at the BMW's high tech experimental lab in



Energy Harvesting Basics

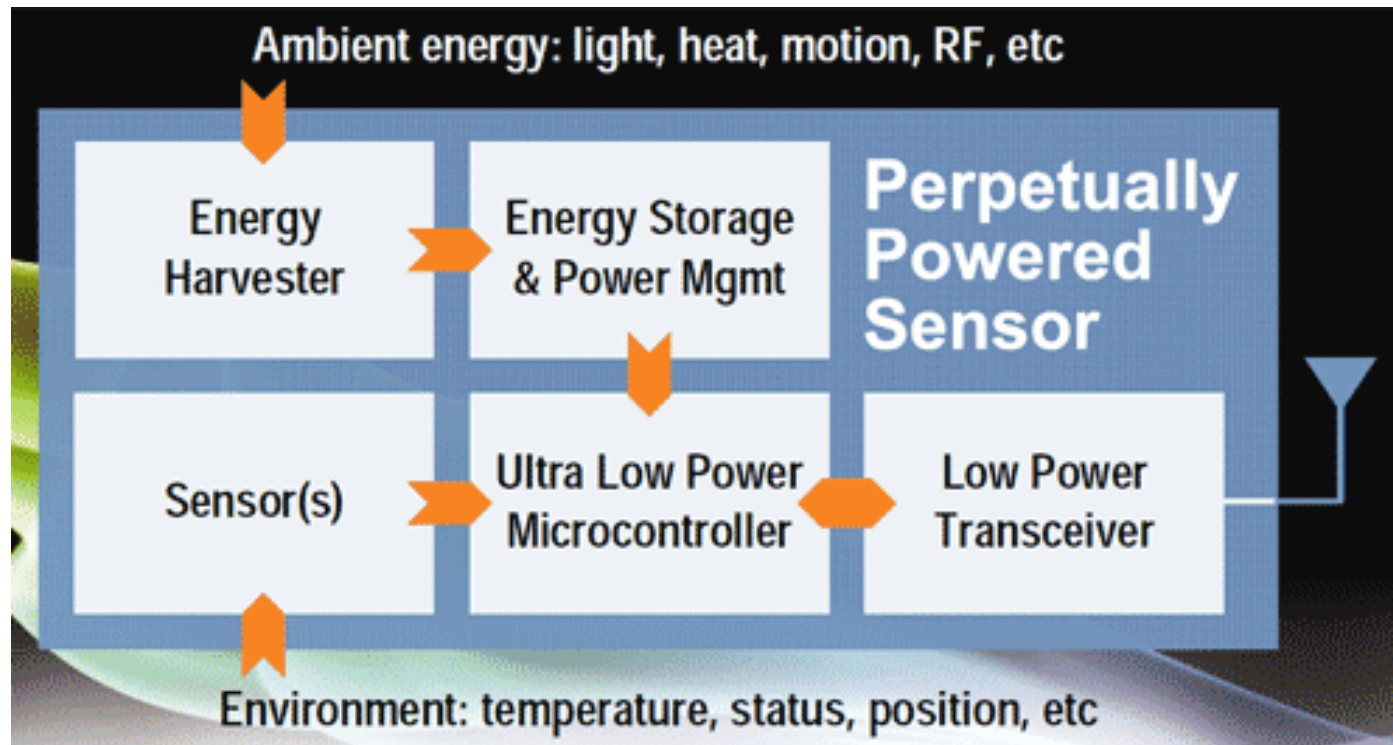
Energy harvesting is the process by which energy readily available from the environment is captured and converted into usable electrical energy

This term frequently refers to small autonomous devices, or micro energy harvesting

Ideal for substituting for batteries that are impractical, costly, or dangerous to replace

Industry Applications

- Remote patient monitoring
 - Efficient office energy control
 - Surveillance and security
 - Agricultural management
 - Home automation
 - Long range asset tracking
 - Implantable sensors
 - Structural monitoring
 - Machinery/equipment monitoring
-



- Advantages Microsystems
 - Small by design
 - Complex functions
 - Low power consumption
 - Wikipedia mentions MEMS in connection with energy harvesting
-

Donnerstag/Thursday, 22.04.2010

Session: Energy Harvesting & Wireless Sensor Networks

<u>Moderation:</u>	Bernd Folkmer, HSG-IMIT, Villingen-Schwenningen, (DE)
10:00–10:30	Keynote: Micro Energy Harvesting – Power Supply for Distributed and Embedded Systems Prof. Dr. Peter Woias, IMTEK, Graduiertenkolleg Energy-Harvesting, Freiburg, (DE)
10:30–10:50	Self-powered Radio Systems in Practice: Concepts, Products & Prospects Frank Schmidt, EnOcean GmbH, Oberhaching, (DE)
10:50–11:10	Practical Energy Harvesting Roy Freeland, Perpetuum Ltd, Southampton, (GB)
11:10–11:30	Power-Energy-Harvesting in Harsh Environments! Andreas Wörtz, RAMPF FORMEN GmbH, (DE) Heinrich Walk, CADWalk, Allmendingen, (DE)
11:30–11:50	Process-oriented Application of Energy Harvesting Technology: Energy Autonomous Wireless Temperature Transmitter Dr. Marco Ulrich, ABB AG Corporate Research Center Germany, Ladenburg, (DE)
11:50–12:10	Piezo Energy Harvesting by Arveni, an Emerging Standard Product for Batteryless Wireless Applications Jean-Frederic Martin, Arveni, Cremieu, (FR)
12:10–12:30	Energy Harvesting Aided Bridge Monitoring Prof. Dr. Thomas Schmidt, Hochschule Magdeburg, Magdeburg, (DE)
12:30–12:50	Optimum Design Strategies for Electromagnetic Vibration Transducers Dirk Spreemann, HSG-IMIT, Villingen-Schwenningen, (DE)
12:50–13:10	Thermal Energy Harvesting – Energy Budgets and their Practical Exploration Burkhard Habbe, Micropelt GmbH, Freiburg, (DE)
13:10–13:40	Break
13:40–14:00	Energy Harvesting: Quo Vadis? Dr. Andreas Rampe, Endress+Hauser Process Solutions

15:00–15:20	„Sensors Unplugged“ Miniaturised Components for the Automation Industry Bernd Kärcher, Festo AG, Esslingen, (DE)
15:20–15:40	Wireless Soil Moisture Sensor Networks for Environmental Monitoring and Agricultural Irrigation Prof. Dr. Ch. Hübner, Hochschule Mannheim, Mannheim, (DE)
15:40–16:00	Wireless Autonomous Transducer Solutions Nicolas Lallemand, Holst Centre/ IMEC-NL, Eindhoven, (NL)
16:00–16:20	Integrated Radio Systems for Energy Harvesting Robert Saurug, SensorDynamics AG, Lebring, (AT)
16:20–16:30	Break

Japan Session



<u>Moderation:</u>	Bernhard Wybranski, VDI/VDE Innovation + Technik GmbH, Berlin, (DE)
16:30–16:50	Research on Energy Harvesting in BEANS Project Junji Adachi, BEANS Laboratory, Tokyo, (JP)
16:50–17:10	Efficient and Reliable Organic Solar Cell Kenji Kawano, Panasonic Electric Works, Ltd., Fukuoka, (JP)
17:10–17:30	Highly Efficient Capacitor Utilizing Super Critical Fluid Deposition Hideo Yamada, BEANS Laboratory, Tokyo, (JP)

**ICT Call Information Session
Halle/hall 6, Stand/booth H32
Freitag/Friday, 23.04.2010
12:30–15:00 Uhr/hrs**

Im Rahmen des Forums „Innovationen für die Industrie“ auf der HANNOVER MESSE 2010 organisiert die Nationale Kontaktstelle Mikrosystemtechnik am 23. April 2010 Beratungsgespräche, die speziell auf IuK-Themen im 7. Forschungsrahmenprogramm und Ergebnisse des 5. Anrufs im Programm zugeschnitten sind. Das betrifft vor allem elektronische Komponenten und Systeme, Mikrosysteme und miniaturisierte Smart Systems.

Diese Beratungen sollen besonders die Antragssteller ansprechen, die die Einreichung von Projektvorschlägen im 7. Forschungsrahmenprogramm planen. Die Gespräche sind geeignet Teilnehmern zu helfen, das aktualisierte

Ticket from IVAM for free:
Alternative:
Energy Harvesting conference in Munich for (3000 € for admision)

- Energy efficiency/ saving (Green MST )



ENERGIE UND EFFIZIENZ

Einsatz von Mikro- und Nanotechnologien für
effiziente, energiesparende Produktion und Produkte



www.ivam-research.com

www.ivam-research.com

Beispielrechnung

Die mikrofluidischen Displays bringen bis zu 90% Leistungsvorteile im Vergleich zu herkömmlichen LED-Anzeigen. Bei dem Einsatz von einer 7-Segment Anzeige mit einer Spannungsversorgung von 20V und einem Stromverbrauch von bis zu 300 μA ist der Leistungsverbrauch von 6mW um Faktor 6 kleiner als bei herkömmlichen LEDAnzeigen (Spannungsversorgung 2V, Stromaufnahme 20mA). Wird die Information dauerhaft angezeigt, geht die Leistungsaufnahme der Anzeigen auf Null zurück, während die herkömmliche LEDAnzeige eine permanente Leistungsaufnahme aufweisen.

- Green MST with IVAM
- March 25th 2010, working Group
- Hannover Fair, April 19th-23rd 2010
- Regionalkonferenz Mikrotechnik in Dortmund
(June 30th 2010)

.

- Standards for building automation 50 Bus-Systems in Lab of Prof. Aschendorf
 - In fact: standards are missing
Americans are again faster !
 - Continua Health Alliance
(<http://www.continuaalliance.org>)
 - Nokia, Roche, IBM, Panasonic, Philips
-

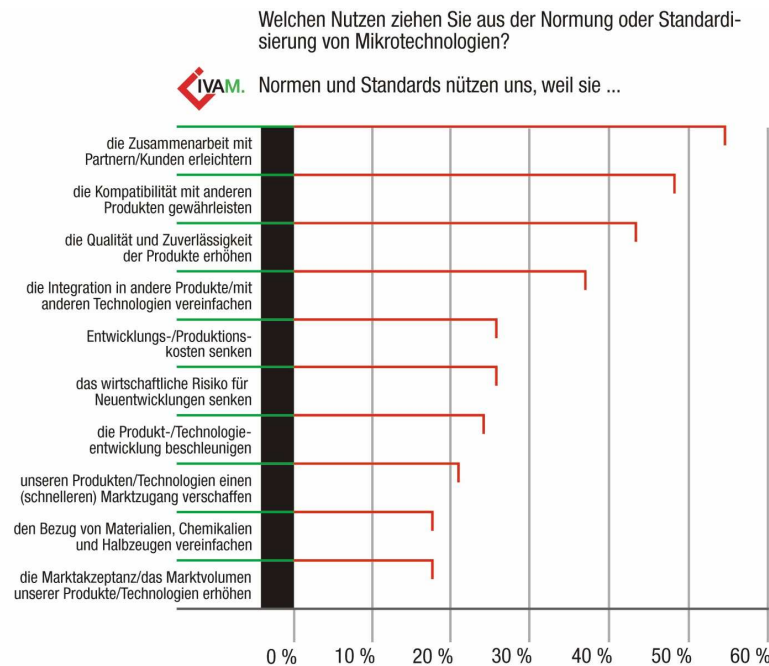
Standards in MST:

IVAM

Germany is too complicated, too slow

Project NOSTA : One product, one process, one package,

Standards are a problem esp. for SME -> no mass markets



- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

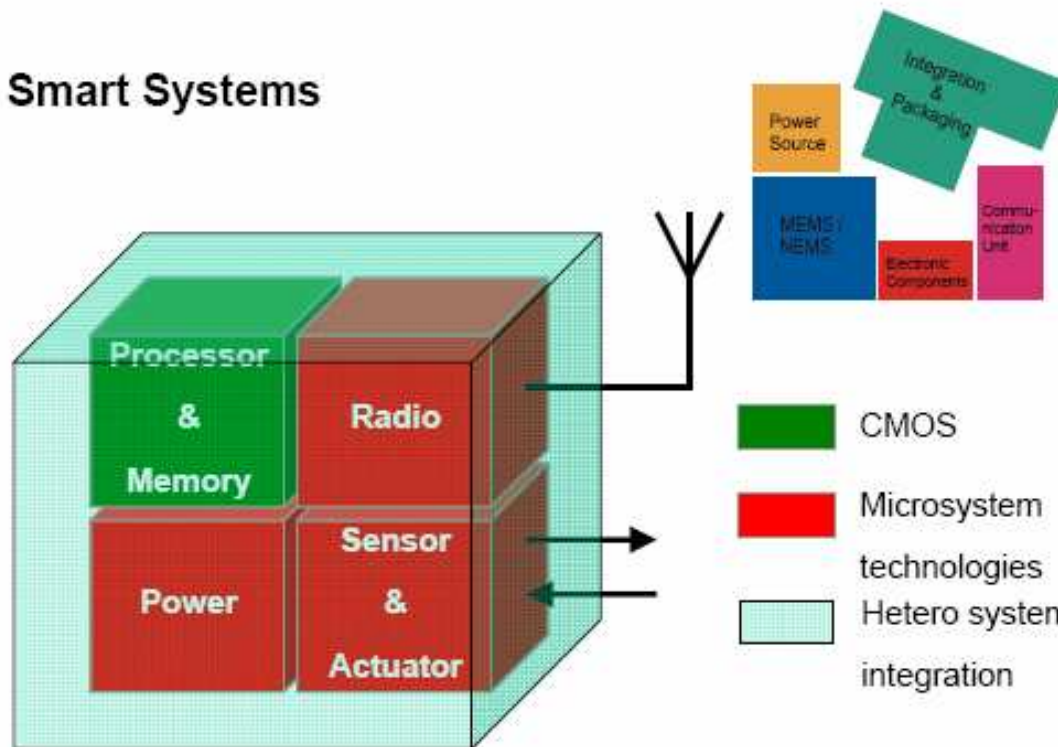


Prof. Dr. Thomas Geßner

Fraunhofer ENAS

IVAM

Smart Systems



Smart System Integration

Tokio,
February,
17th, 2010

Trends

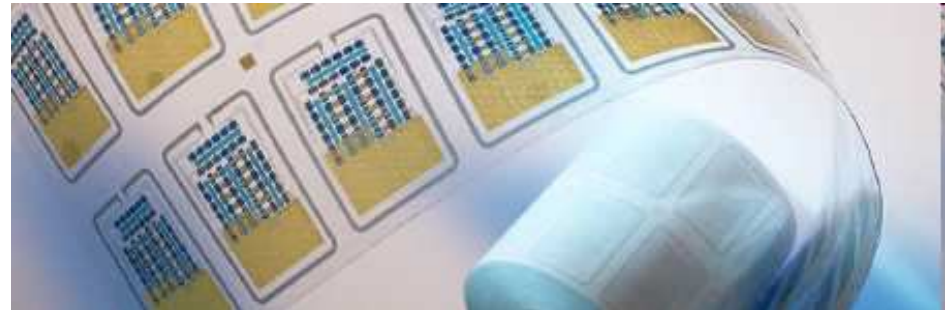
IVAM

- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

Printed Electronics

IVAM

- Only Niche Applications in Printed /Display for Europe?



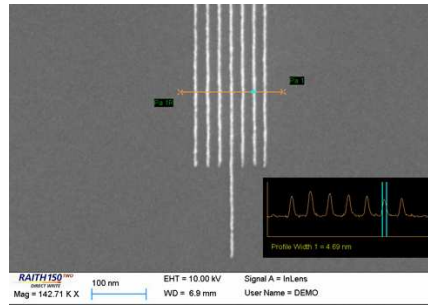
Source: www.oe-a.org

- German Printing Industry is world leader
 - Heidelberg, Dresden, Cologne
-

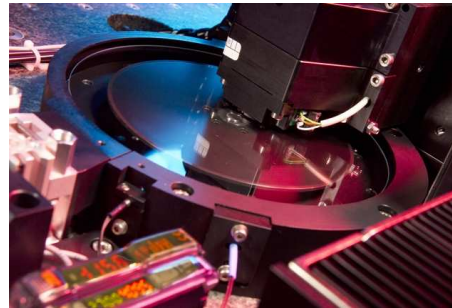
What has microsystems to do with that ?

IVAM

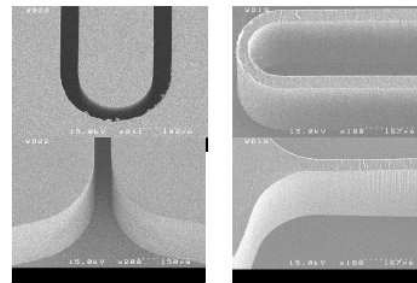
Mastering/ Litho Raith



SINGULUS
MASTERING

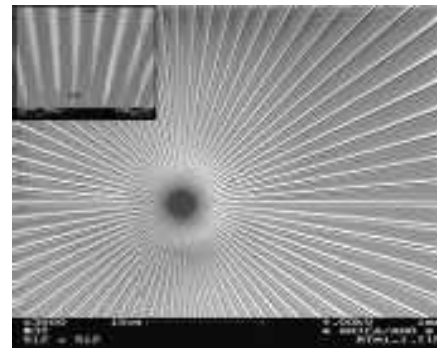


Nanoimprint Hot Embossing



50 micron channels, aspect ratio~10
Dr. Jost Goettert – Louisiana State University - CAMD

Nanoimprint

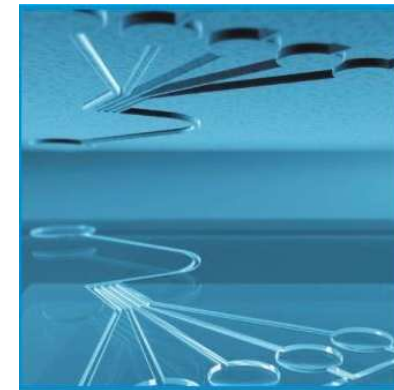


Electroforming

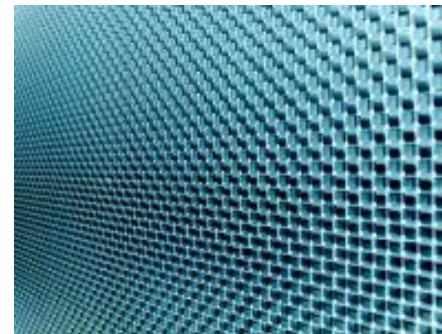
TECAN



temicon



technotrans



- Miniaturisation
 - Wireless / Mobile Application
 - Energy Efficiency/ Green MST
 - Complex, integrated microsystems
 - New production technologies
 - Printed Electronics/ Lighting, Display Technologies
 - Smart living / Ambient Assisted Living
 - Automotive (?)
-

Automotive is the mother of microsystems in Germany

IVAM

Comfort

- Atmospheric pressure sensor (transmission control, motronic) @ Bosch
- Manifold absolute pressure sensor (Electronic diesel control, motronic) @ Bosch
- Knock sensor (Motronic) @ Bosch
- Mass air flow sensor (Motronic – air intake) @ Continental Teves
- Angular position sensor (Motronic – cam and crankshaft position)
- Piezo actuator (Fuel injection) @ DaimlerChrysler
- Rotational speed sensor (Electronic transmission control, motronic) @ Bosch
- Oil quality sensor (Transmission and engine) @ Bosch
- Soot sensor (Motronic – exhaust) @ Bosch
- High pressure sensor (Fuel injection system, common rail) @ Bosch
- Oxygen sensor (Motronic - lambda) @ Bosch
- Pedal position sensor (Electronic accelerator, electro-hydraulic brake) @ Bosch

Powertrain

- Radar 77 GHz (longitudinal control, obstacle detection) @ Bosch
- Infrared (Night vision system) @ Bosch
- Radar 24 GHz (Pre-crash, parking aid) @ IBEO
- Steering wheel angle sensor (Vehicle dynamics) @ Continental Teves
- Rotational speed (Antilock braking system) @ Hella
- Pressure sensor (Vehicle dynamics, crash detection) @ Hella
- Yaw rate (Electronic stability program) @ uCam
- Angular rate sensor (Roll over)

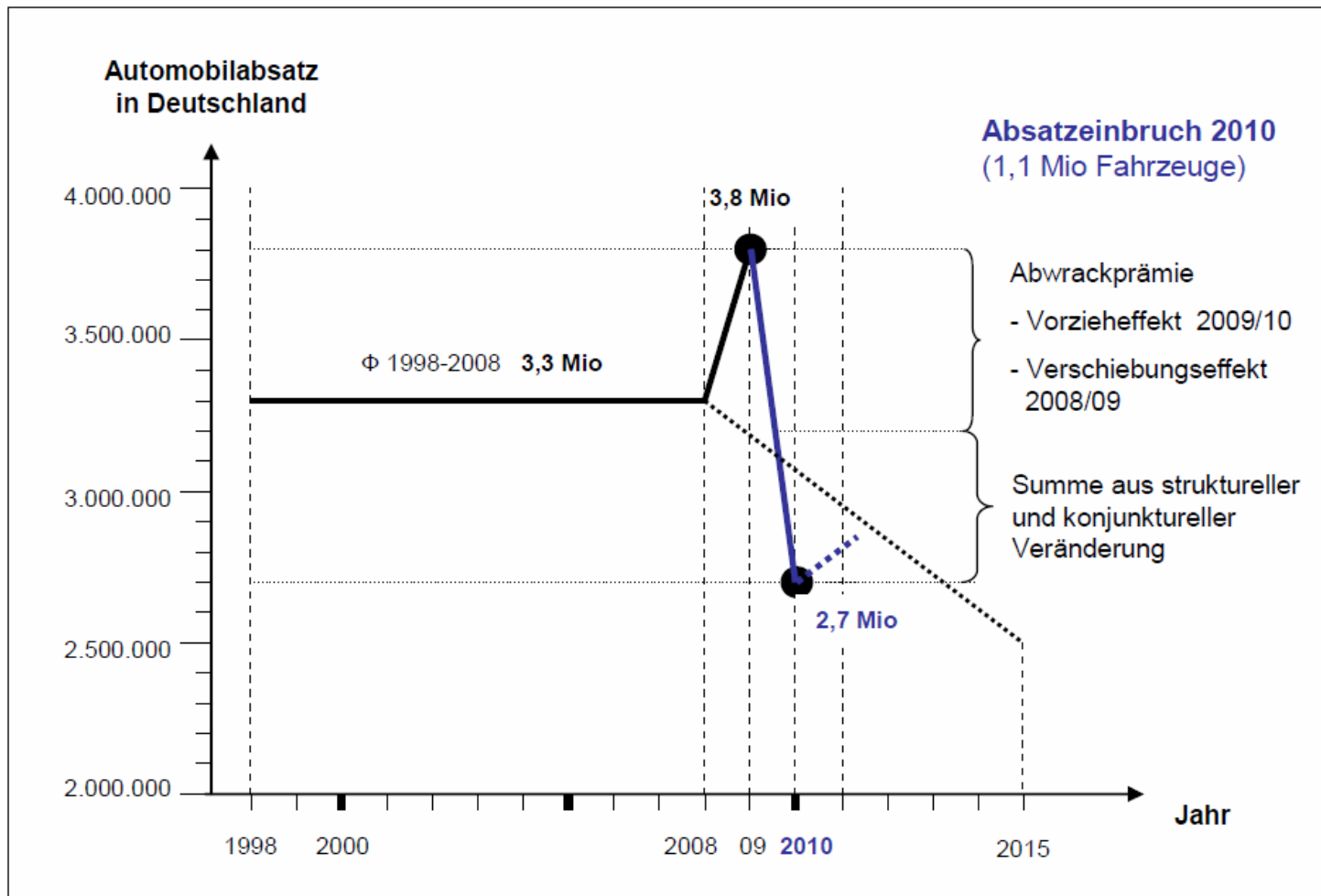
Safety

- Humidity/temperature (Air condition)
- Air quality sensor (Air condition)
- Angular rate (Navigation, pitch, chassis)
- Light sensor (Automatic light, air conditioning)
- Rain sensor (Wash/wipe control)
- Microphones/displays (Communication)
- Inertial/pressure (Central locking, theft protection)
- Tank/tire pressure (On board diagnostics)
- Tilt sensor (headlamp aiming, security)
- CMOS camera (parking aid)
- Inertial sensors (airbag and stability control)
- Out of position sensor (Airbag)
- Seat occupancy sensor (Airbag)

Fahrzeug: DaimlerChrysler (only for demonstration) @ VDI/VDE-IT

Prof. Dudenhöfer says

IVAM



UNIVERSITÄT
DUISBURG
ESSEN

Automotive

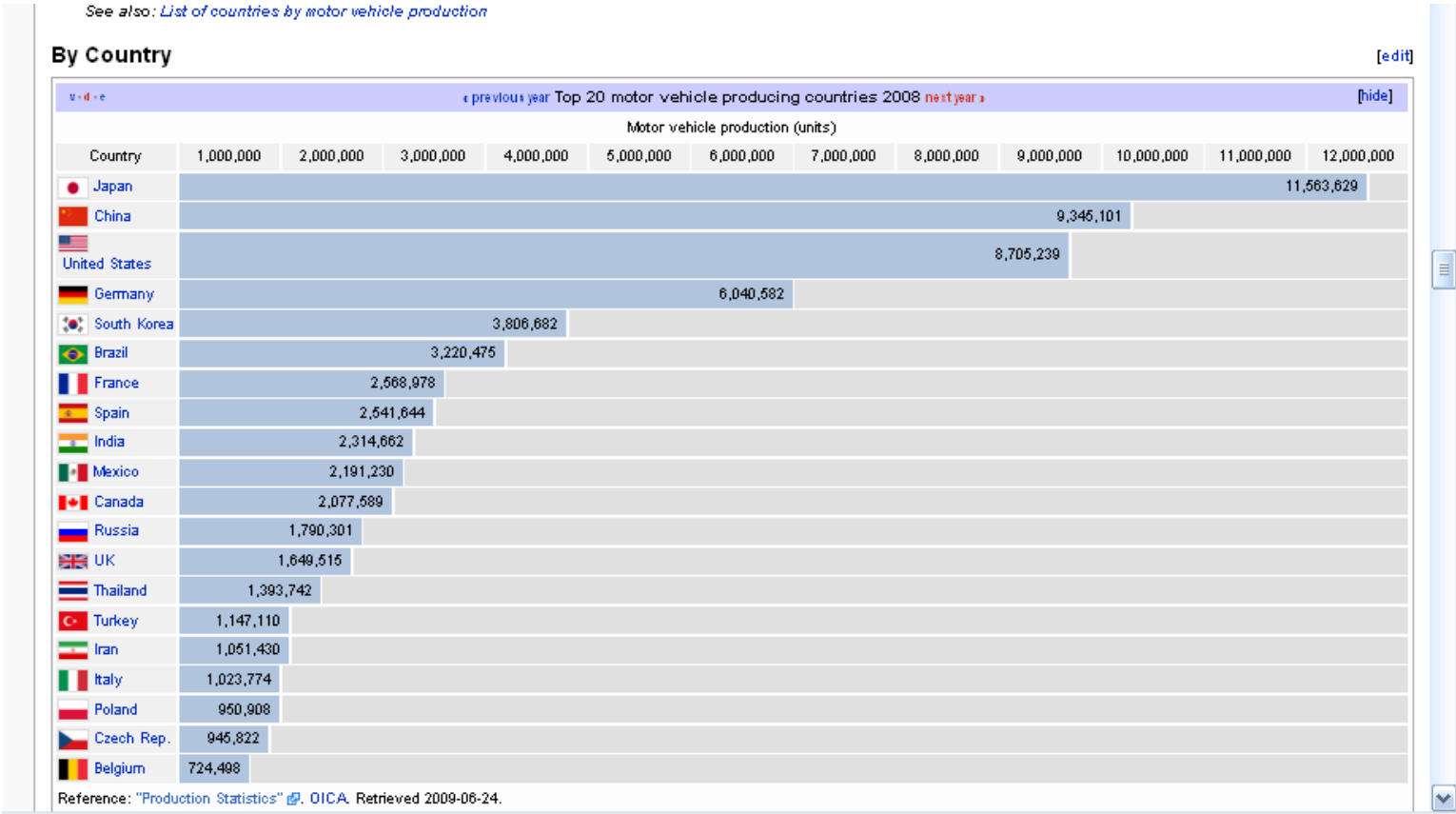
IVAM

- Shrinking markets in Europe (saturated markets, overcapacities, demographic change)



- Rising markets in Asia (Korea is catching up very fast)
 - Electromobility
-

Automotive world will change – supply chains, too !



Still advantages with MEMS

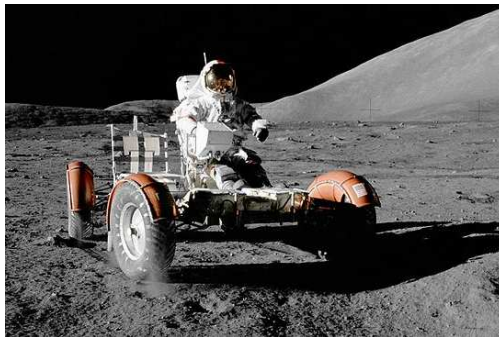
IVAM



VDI Nachrichten, 12.3.2010

New Bosch-Sensor-Cluster for Automotive

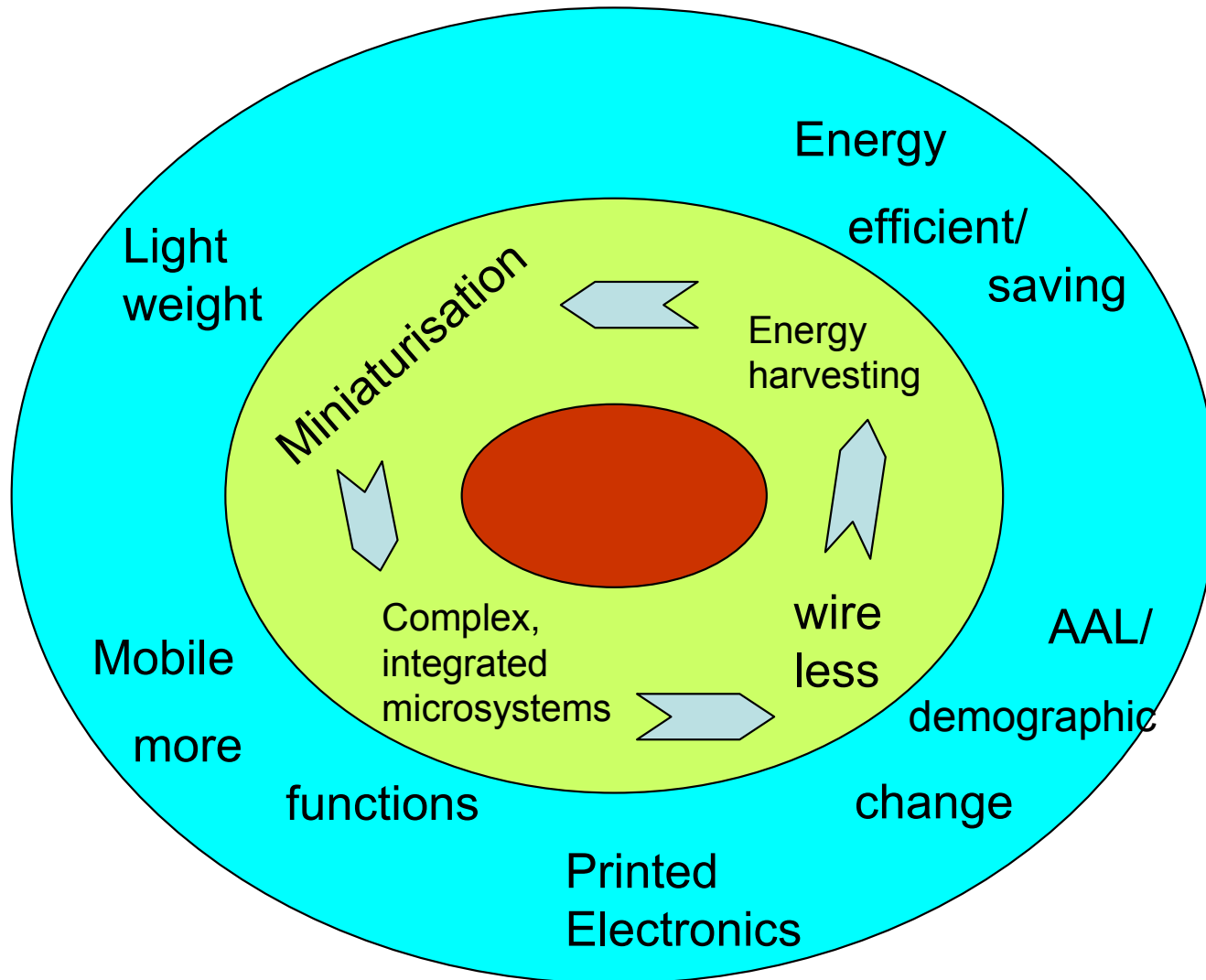
New mobility trends in Europe, Asia
-electromobility, aging society



Lunar Module, Tesla Roadster
-> No mass production

Byd: Made in China

Drivers: Technology core and market shell **IVAM**



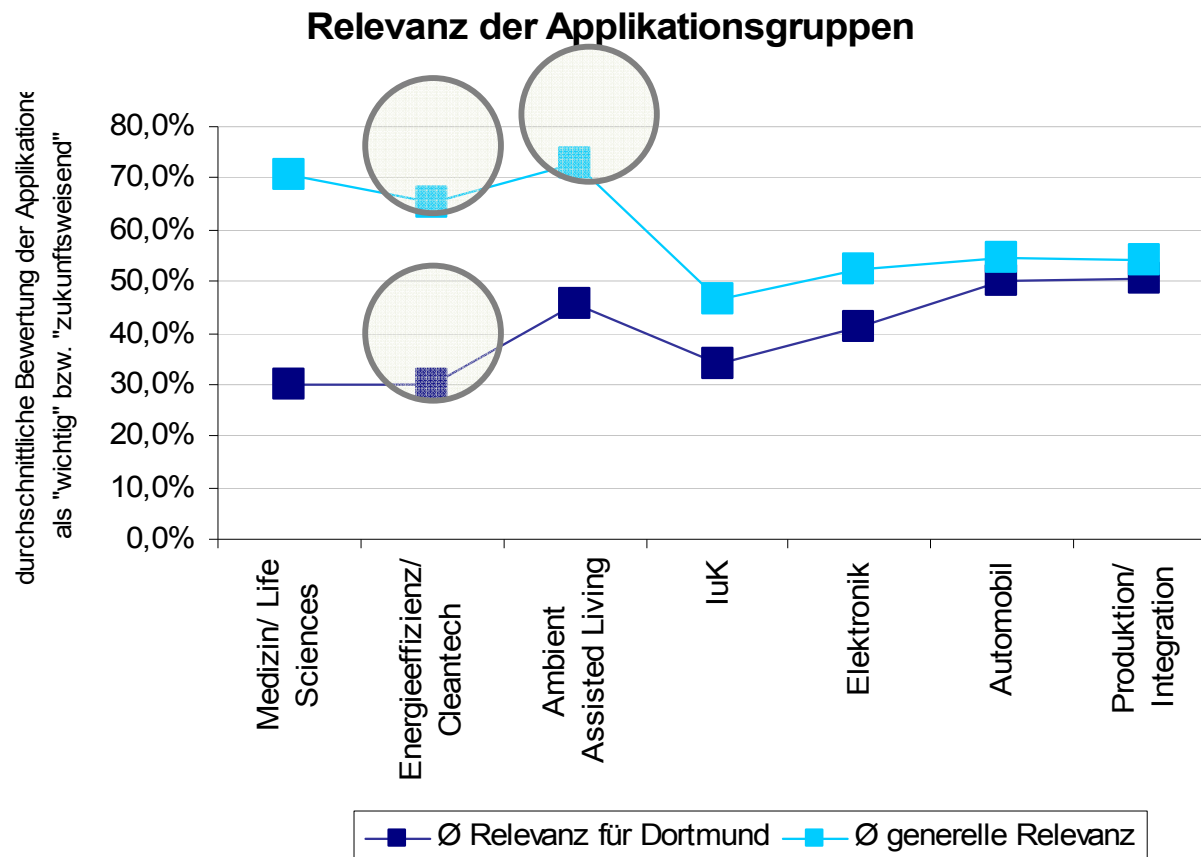
- AAL/demographic change/ Aging society in Europe, Asia !!
 - mobile/wireless services (health, comfort)
 - Changing automotive market in Europe
 - Car with blood pressure sensing device ? Can Apple make a car and how would it look like ?)
 - Energy
 - saving/monitoring -> new processes, wireless, energy harvesting
-

- Technology
 - Miniaturisation is still hot
 - Printed electronics is something to look on
-

New markets hard to reach even for High-tech companies

IVAM

65 % of the micro- and nanotechnology companies and institutes in Dortmund consider energy/efficiency/cleantech applications to be sustainable – only 30 % actually develop applications



energy/efficiency/cleantech and AAL applications are considered to be important in the future, but only a few companies/institutes are already working in these fields

Source: IVAM Survey, June 2008

Thank you !

IVAM

- Dr. Uwe Kleinkes
- uk@ivam.de
- phone: 0049 231 9742 148
- Fax: 0049 231 9742 150
- www.ivam.com



MST-Atlas Deutschland: Überblick über die
MST-Cluster © IVAM, Oktober 2004