Régis HAMELIN

6/11/2013 – Tours - France

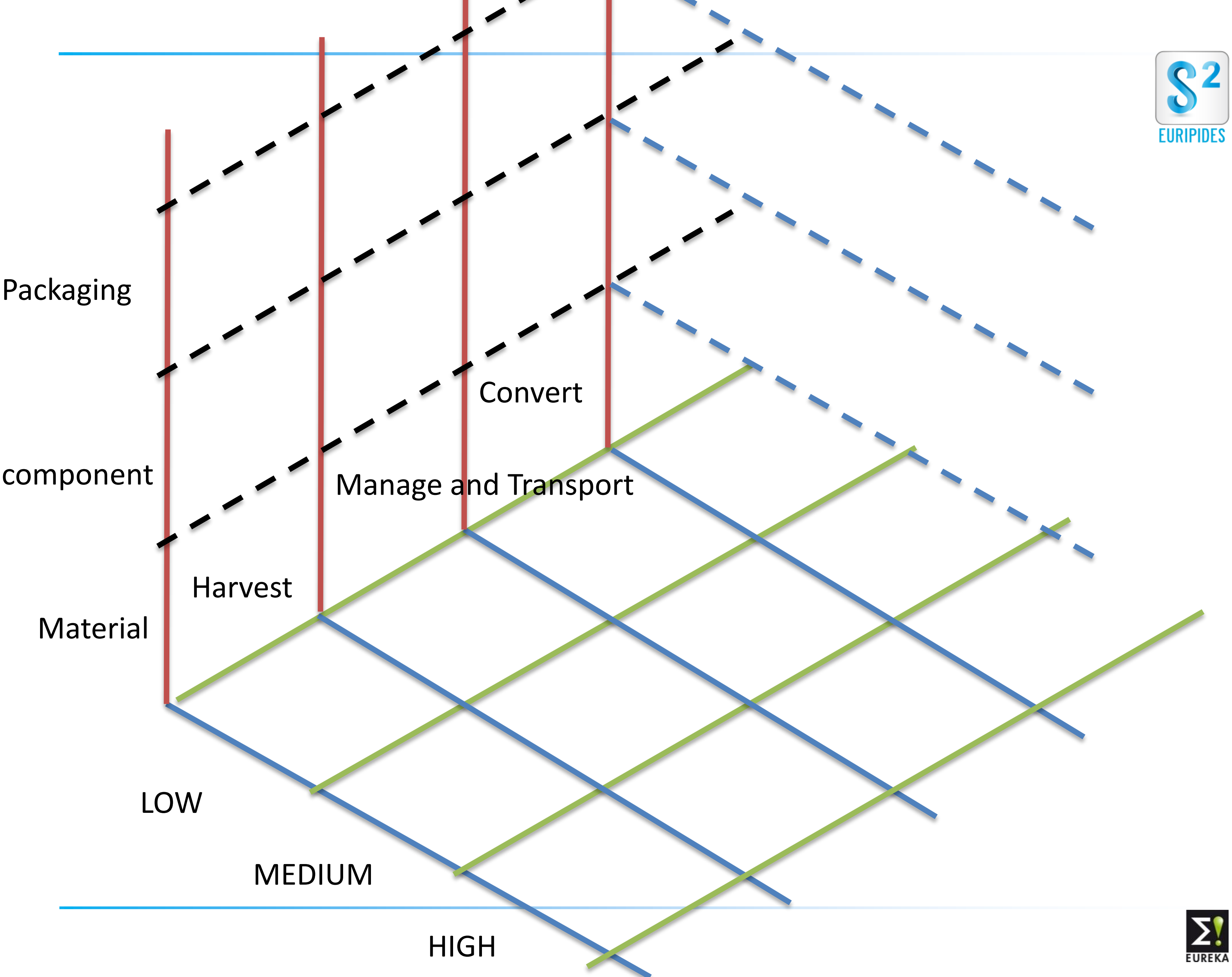
From Nano to Macro Power Electronics: a european perspective

EURIPIDES²

European Smart Electronic Systems

EUREKA

1. SCOPE of THIS PRESENTATION



Packaging

component

Material

Harvest

Manage and Transport

Convert

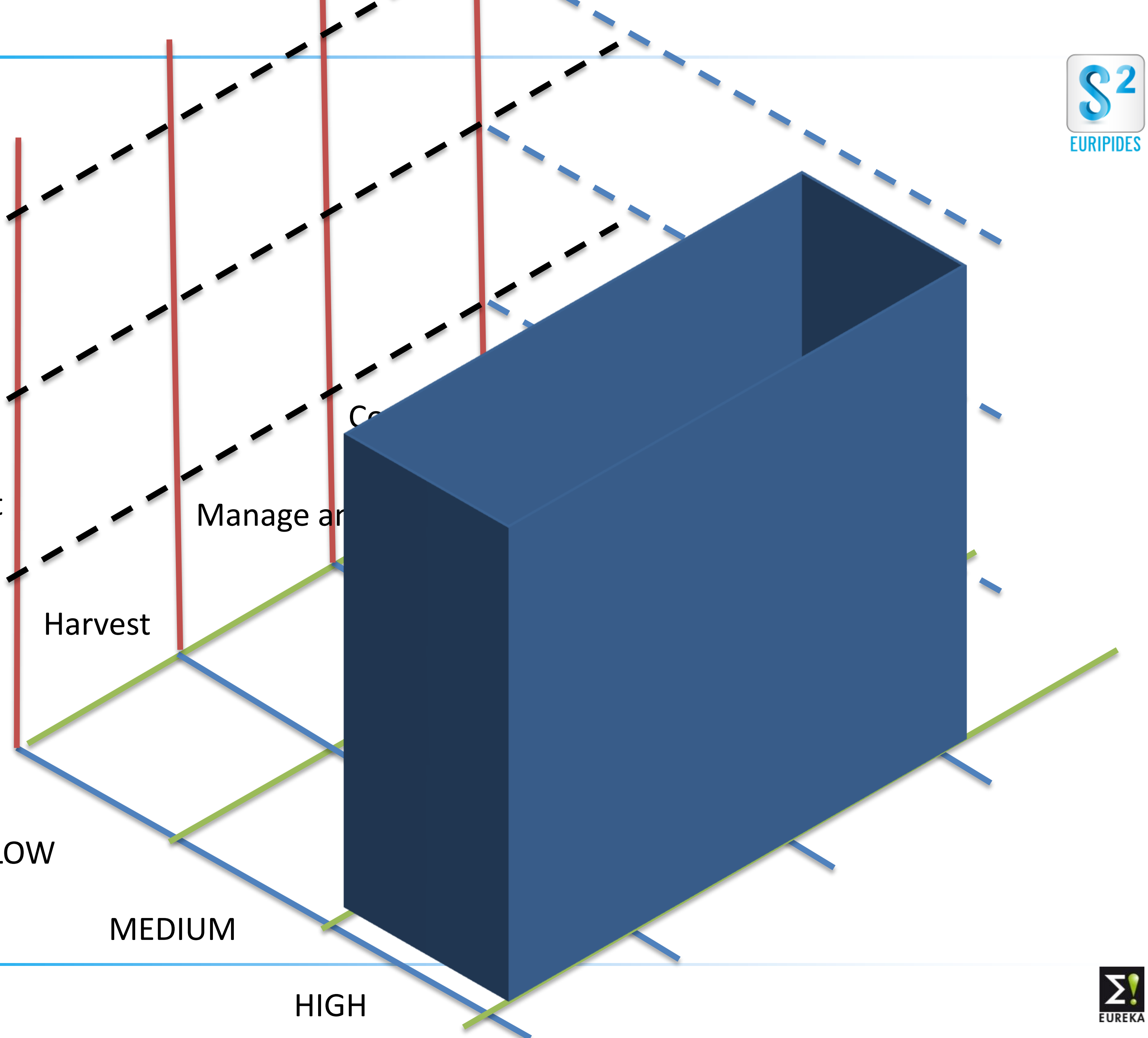
LOW

MEDIUM

HIGH

OUTLINE

1. **SCOPE of THE PRESENTATION**
2. **EUROPEAN INVESTMENT STRATEGY**
3. **THE EUROPEAN COMPETITIVE POSITION**
4. **R&D PROGRAMMES AND PROJECTS**
5. **LOW POWER APPLICATIONS**
6. **CONCLUSIONS**

Packaging
component
Material
Harvest
Manage ar
Co
LOW
MEDIUM
HIGH

2. EUROPEAN INVESTMENT STRATEGY

European Commission support

SOCIETAL CHALLENGES

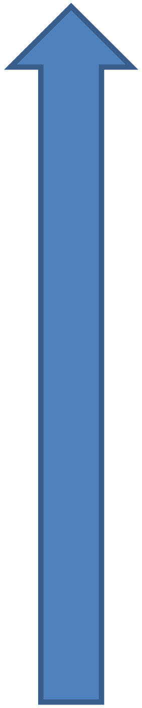
- Living Healthy, Ageing Well
- Efficient use of resources
- Smart, green transport
- Innovative online public services in an inclusive and reflective society
- Living in a secure society

Power Electronics'

Main contribution

EU climate and energy targets for 2020

2020



1990

20%

Reduction of Greenhouse gases

20%

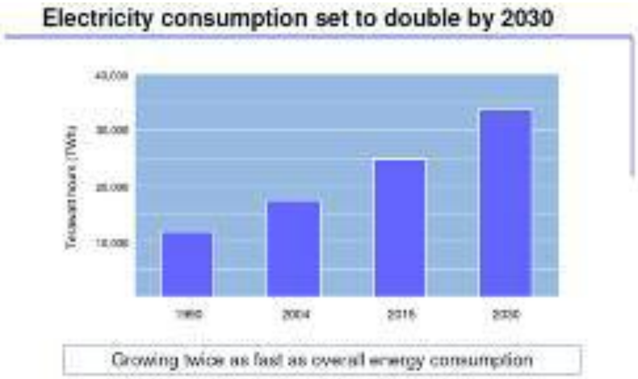
Less Energy consumption

20%

The share of renewable energy

Electrification in progress

Growing Electrification


Electricity consumption set to double by 2030

Growing twice as fast as overall energy consumption

More Electric and all electric Aircrafts

1.6B vehicles in 2030 –
2,5B in 2050

In Western Europe : 60TWh in 2009 to 104TWh in 2020

Servers and datacenters are 2.5% of US electricity consumption

SMART GRID

Power Electronics is Ubiquitous in Smart Grid

Energy Efficiency Improvement

2 approaches

Doing things better

- Less power consumption
- Better efficiency
- Better heat management

A smart management approach

Adopt a context aware approach

LED lighting : 50% savings

Smart management : +20%

Key Enabling Technologies

Micro and nanoelectronics

Advanced Materials

Nanotechnology

Biotechnology

Photonics

Advanced Manufacturing systems

POWER ELECTRONICS is NOT EXPLICITELY IDENTIFIED AS A KEY ENABLING TECHNOLOGY

Photonics is a KET

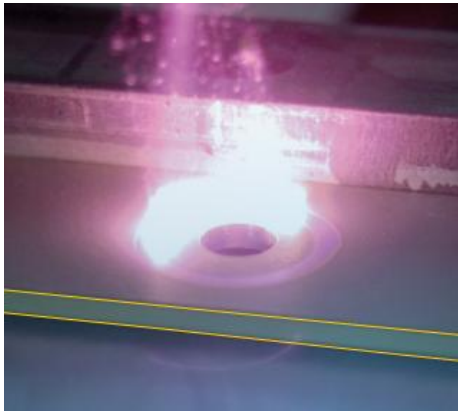
Green Photonics answers societal challenges

- Generate or conserve energy
- Cut Grenhouse gas emissions
- Reduce pollution
- Yield Environmentally sustainble outputs, improve public health

Photovoltaic electricity generation

Highly Efficient Solid State Lighting

Energy efficient communication technology



Clean Manufacturing with Laser processing

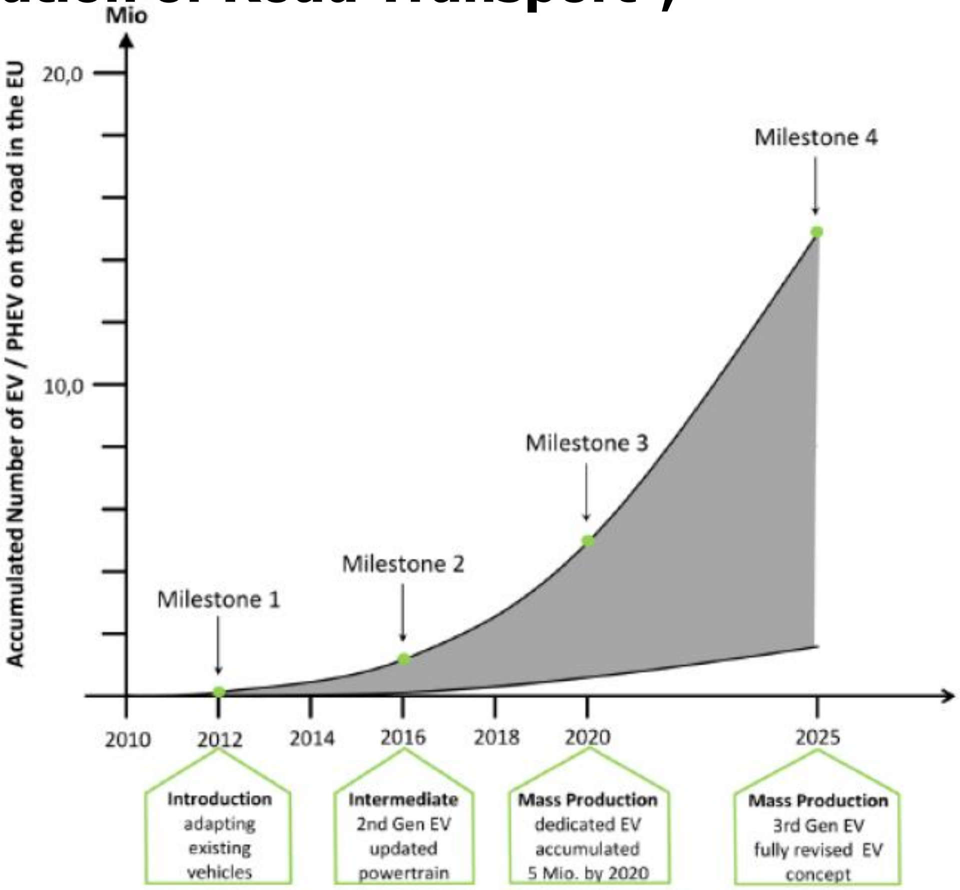
Green Vehicles

“European Roadmap Electrification of Road Transport”,

Mass production of dedicated electric and plug-in hybrid vehicles is feasible by 2020 if fundamental progress is made in six technology fields:

1. energy storage systems,
2. drive train technologies,
3. vehicle integration,
4. safety,
5. road integration
6. grid integration.

require significant increases of energy efficiency reductions of cost



PPP EGVI Roadmap

More Electric Aircraft

Airbus Technology Roadmap– ASD Conference 2012 Lisbon

	Current technologies	Long-term future technologies
Configuration and new Powerplants	Conventional High-By-Pass-Ratio	Non- conventional aircraft concepts / New propulsion concepts
Energy Management	Modular power electronics, more electrical actuation	Scalable energy systems with dynamic thermal management
...	...	...

Roadmaps are in place for all technology streams

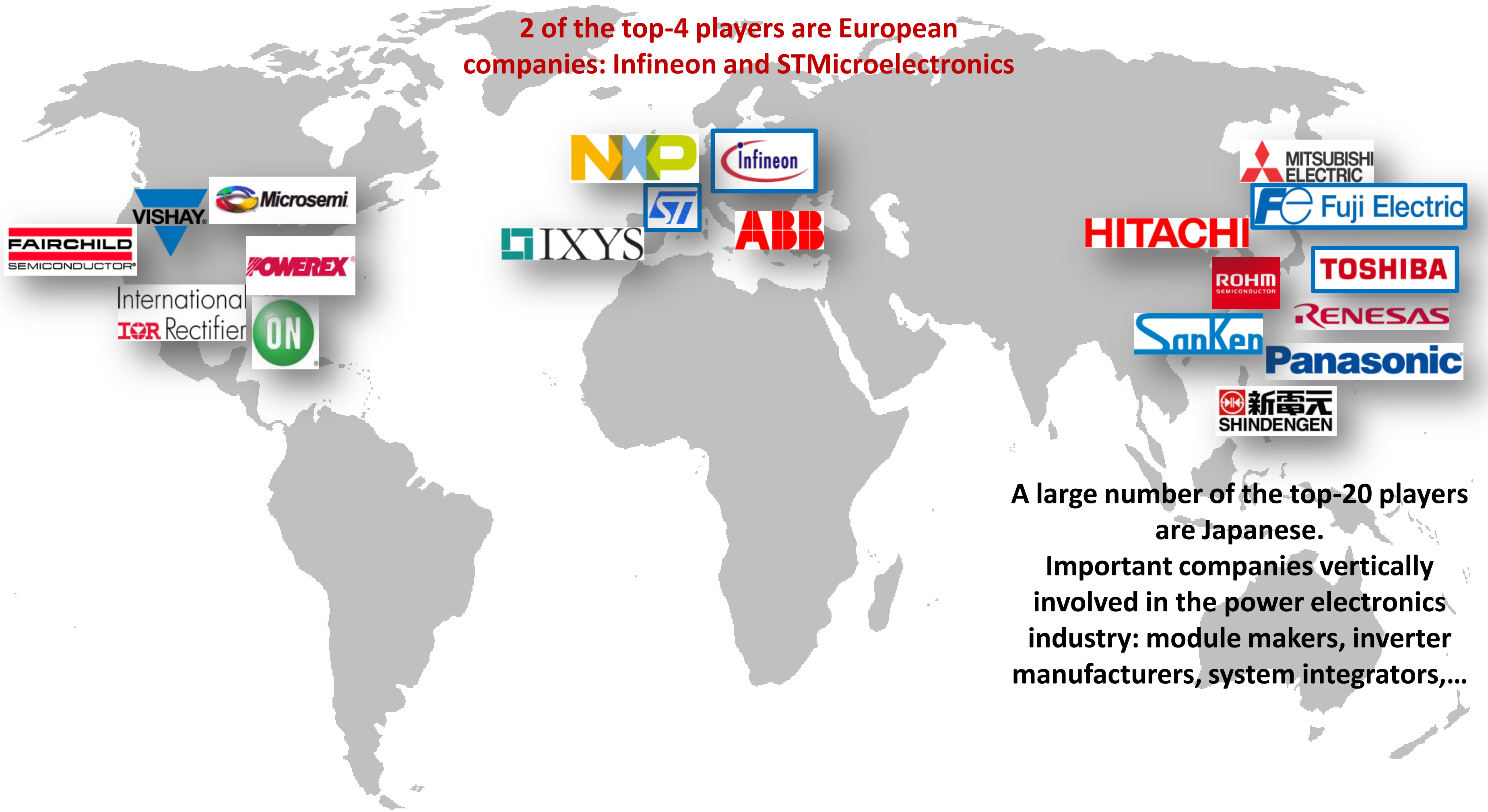
Key Enabling Technologies

NOT EXPLICITELY IDENTIFIED AS A KEY ENABLING TECHNOLOGY BUT TRANSVERSE

Micro and nanoelectronics	→	Semiconductor Power Electronics / packaging
Advanced Materials	→	Heat Management
Nanotechnology		
Biotechnology		
Photonics	→	Electricity Generation
Advanced Manufacturing systems		Industrial applications

3. EUROPE COMPETITIVE POSITION

Top 20 Power Semiconductor Players Mapping

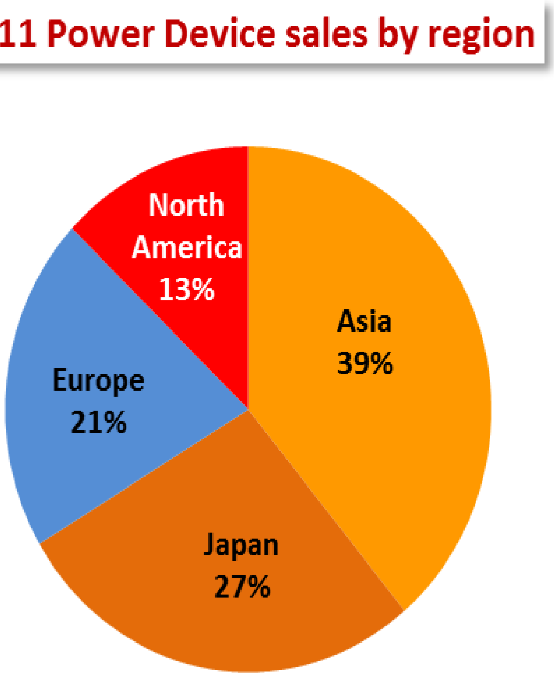


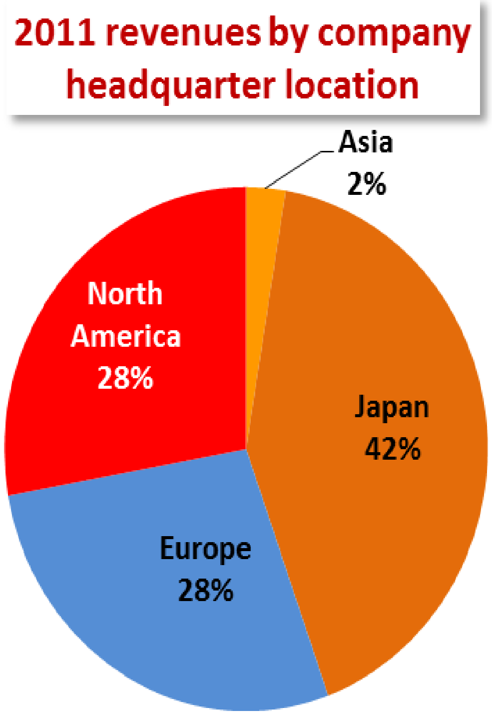
2 of the top-4 players are European companies: Infineon and STMicroelectronics

A large number of the top-20 players are Japanese.
Important companies vertically involved in the power electronics industry: module makers, inverter manufacturers, system integrators,…

Source Yole Developpement report on Power Electronics 2012

Regional analysis



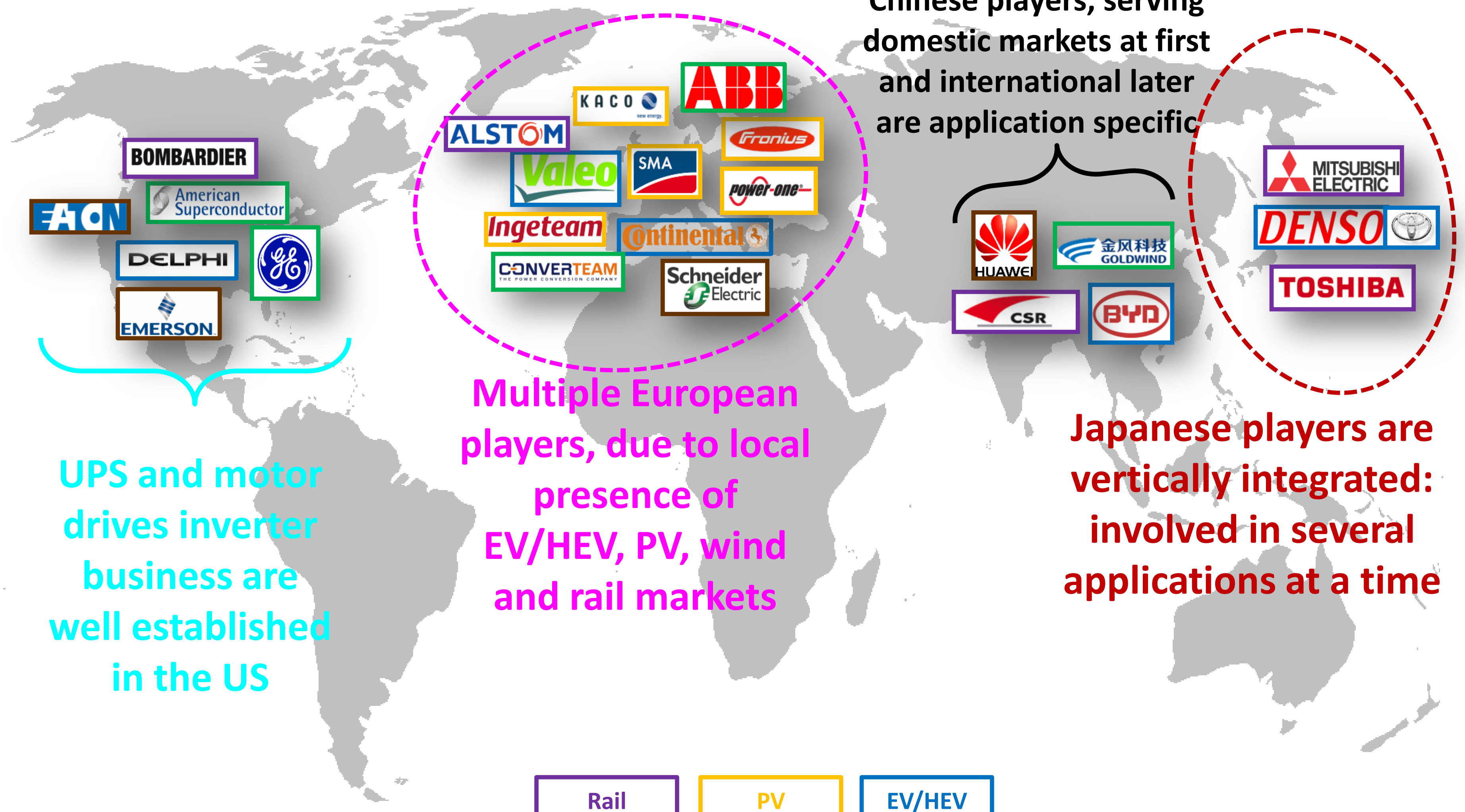


- Overall Asia is still the landing-field for more than 65% of power products. Indeed, most of the integrators are located in China, Japan or Korea.
- Europe is very dynamic as well with top players in traction, grid, PV inverter, motor control…

- The big-names of the power electronics industry are historically from Japan. 9 companies of the TOP-20 are Japanese.
- Very few power manufacturers in Asia out of Japan
- Europe and US are sharing 4 of the TOP-5 companies

Source Yole Developpement report on Power Electronics 2012

Main players in Inverter market



Chinese players, serving domestic markets at first and international later are application specific

UPS and motor drives inverter business are well established in the US

Multiple European players, due to local presence of EV/HEV, PV, wind and rail markets

Japanese players are vertically integrated: involved in several applications at a time

Rail

PV

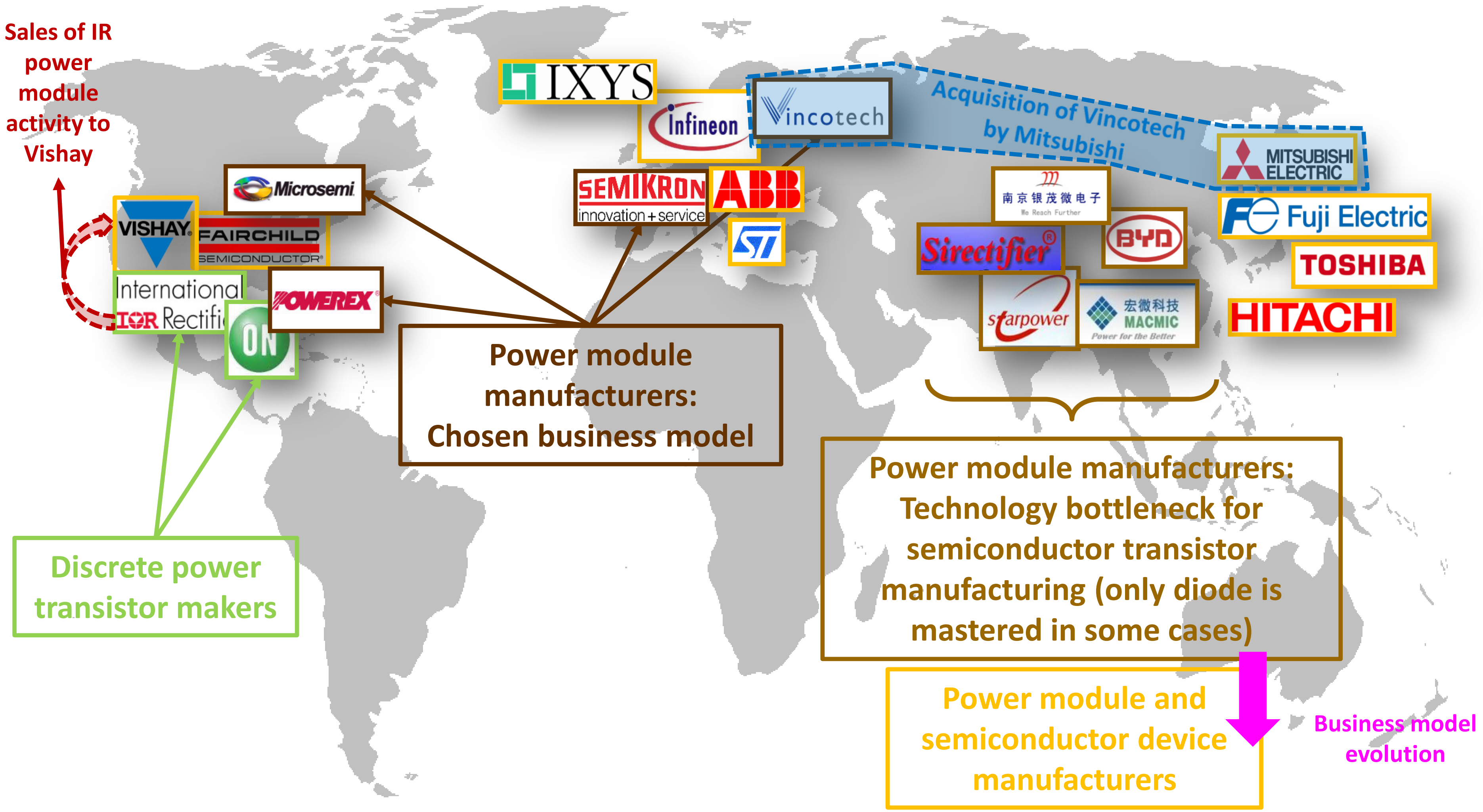
EV/HEV

Wind

UPS/AC drives

Source Yole Developpement

Main players in Power module market



Sales of IR power module activity to Vishay

Acquisition of Vincotech by Mitsubishi

Power module manufacturers: Chosen business model

Discrete power transistor makers

Power module manufacturers: Technology bottleneck for semiconductor transistor manufacturing (only diode is mastered in some cases)

Power module and semiconductor device manufacturers

Business model evolution

Source Yole Developpement report on Power Electronics 2012

SWOT

HELPFUL
To achieving the objectives

HARMFUL
To achieving the objectives

INTERNAL FACTORS

STRENGTHS

- **Strong silicon Power Semiconductors and Modu Industry**
- **High Quality research groups**
- **Networks and Association : ECPE, EPE, EPSMA, EPIA…**

WEAKNESSES

- **High Labor costs**
- **P.E. not recognized as a Key enabling technolgy**

EXTERNAL FACTORS

- **Sustainable energy trend : energy efficiency**
- **Fast growing market for renewable energy**
- **Decentralised power generation**
- **Nomad behaviours**
- **Mobility**

OPPORTUNITIES

- **Shortage of students specialising in P.E.**
- **China and India have identified P.E as a K.E.T**
- **Outsourcing of research**
- **European industries taken over by competitors**

THREATS

Adapted from e4u

4. Programmes and projects

TRENDS in SEMICONDUCTOR POWER ELECTRONICS

SiC :

Better at > 600V

Runs at higher temperature

100M$ annually and sells in Photovoltaics and Hybrid Vehicle markets

is getting « cheaper » : moving from 2 to 3 inches

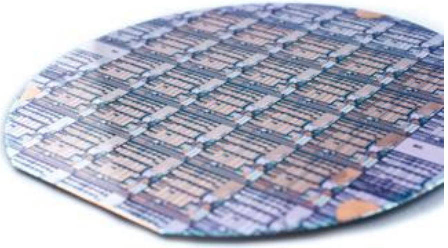
- CREE MOSFET 1200V 20A
  - 144€ in 2011
  - 21€ in 2013 (Farnell)
- IGBT 1200V 33A
  - 6€ in 2011
  - 5€ unit price, 3€ >100pcs

GaN

Has strong potential for fast switching at 600V :

Servers, network base stations

Cheaper than SiC



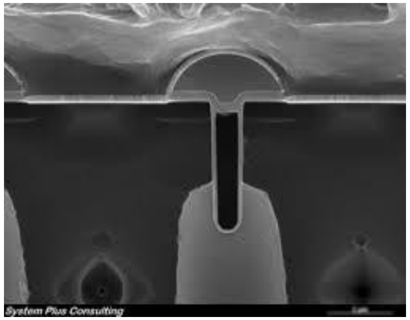
Source IMEC

Silicon

Super Junction MOSFETS

Improved trench technology

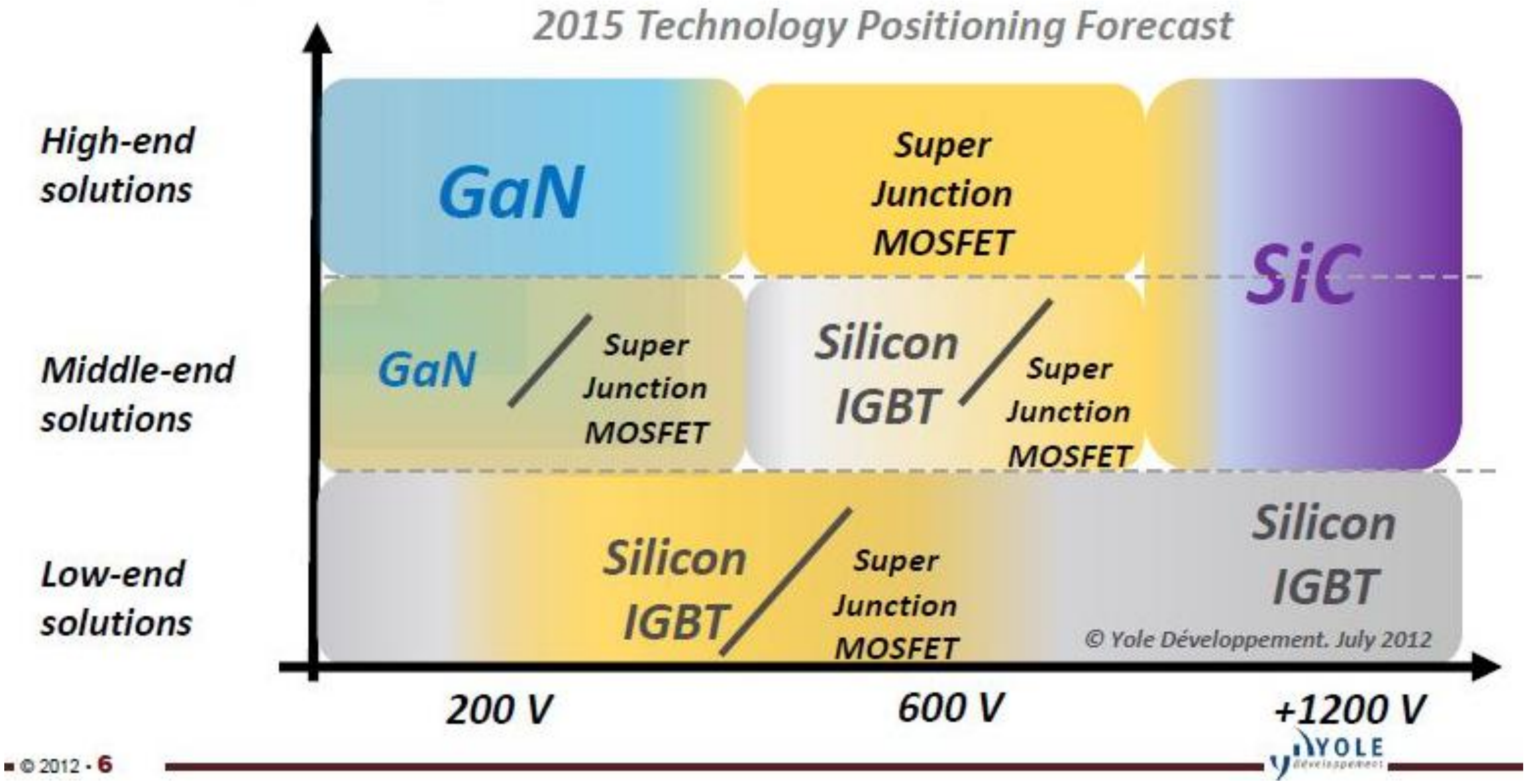
Targets > 600V



Toshiba DTMOS 4 600V MOSFET
Source System Plus consulting/Yole
Innovative trench gate

Forecast in 2015

Yole développement report on Power electronics 2012



CHALLENGES IN GRID AND MOBILITY

- **LOWER LOSSES**
- **HIGH POWER DENSITY**
- **HIGHER SWITCHING FREQUENCY**
- **HIGHER OPERATING TEMPERATURE**
- **LONGER LIFETIME and HIGHER AVAILABILITY in HIGH POWER APPLICATIONS**
- **COMPACTNESS,WEIGHT REDUCTION , HEAT MANAGEMENT**
- **AND AFFORDABLE**

CHALLENGES IN PACKAGING

IN TOUGH ENVIRONMENT : OFF SHORE WIND TURBINES, GRID OR AUTOMOTIVE

INCREASED CURRENT DENSITY

- **LOW ELECTRICAL RESISTANCE IN LEADS**

INCREASED POWER DENSITY INDUCE SHEAR STRESS

- **HEAT EXTRACTION**

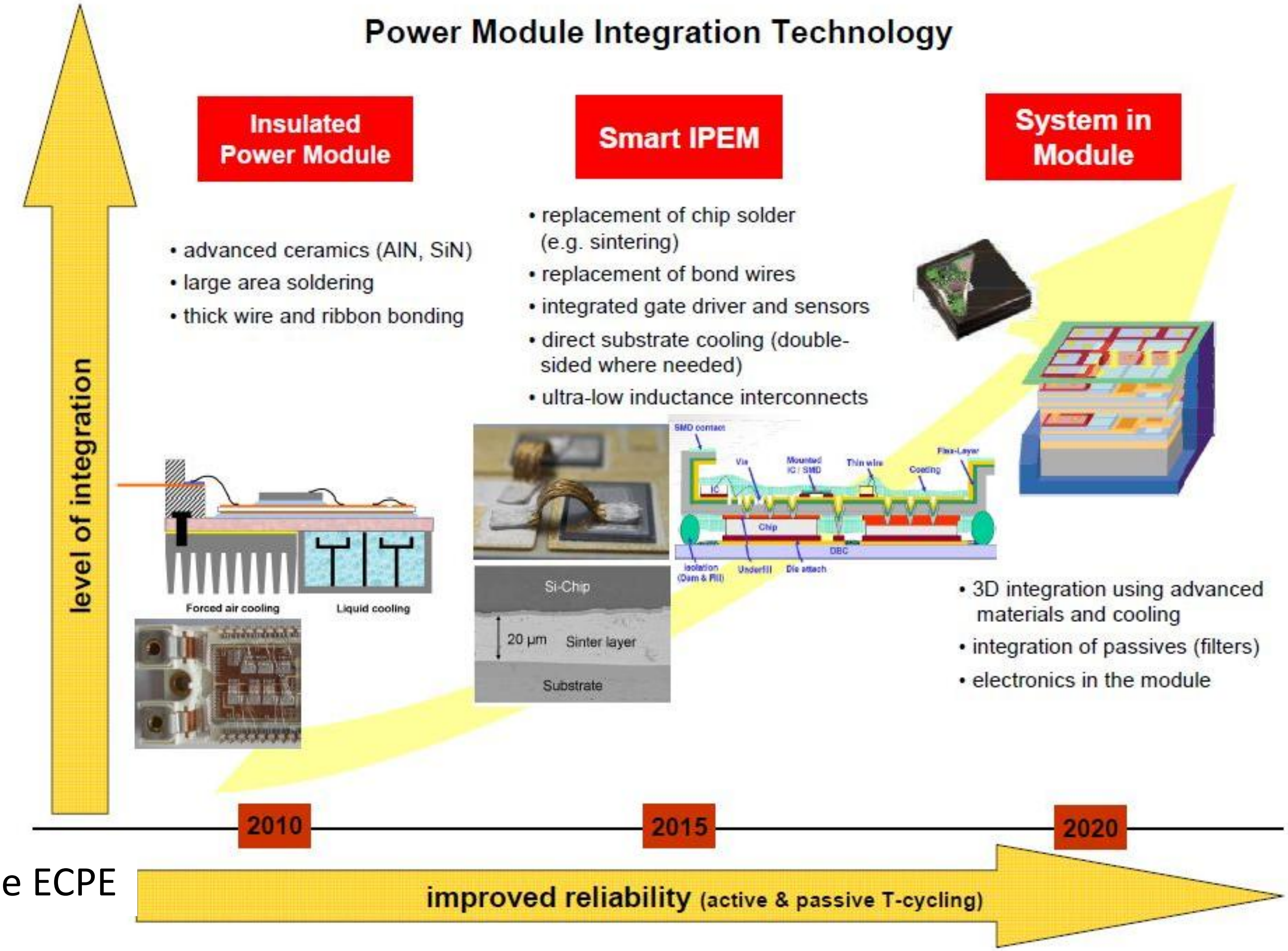
FAST SWITCHING

- **REDUCED PARASITICS**

HIGH TEMPERATURE OPERATION

- **RELIABILITY AT > 200°C and CYCLING**

Packaging roadmap for integration



Power Module Integration Technology

Insulated Power Module

- advanced ceramics (AlN, SiN)
- large area soldering
- thick wire and ribbon bonding

Smart IPEM

- replacement of chip solder (e.g. sintering)
- replacement of bond wires
- integrated gate driver and sensors
- direct substrate cooling (double-sided where needed)
- ultra-low inductance interconnects

System in Module

- 3D integration using advanced materials and cooling
- integration of passives (filters)
- electronics in the module

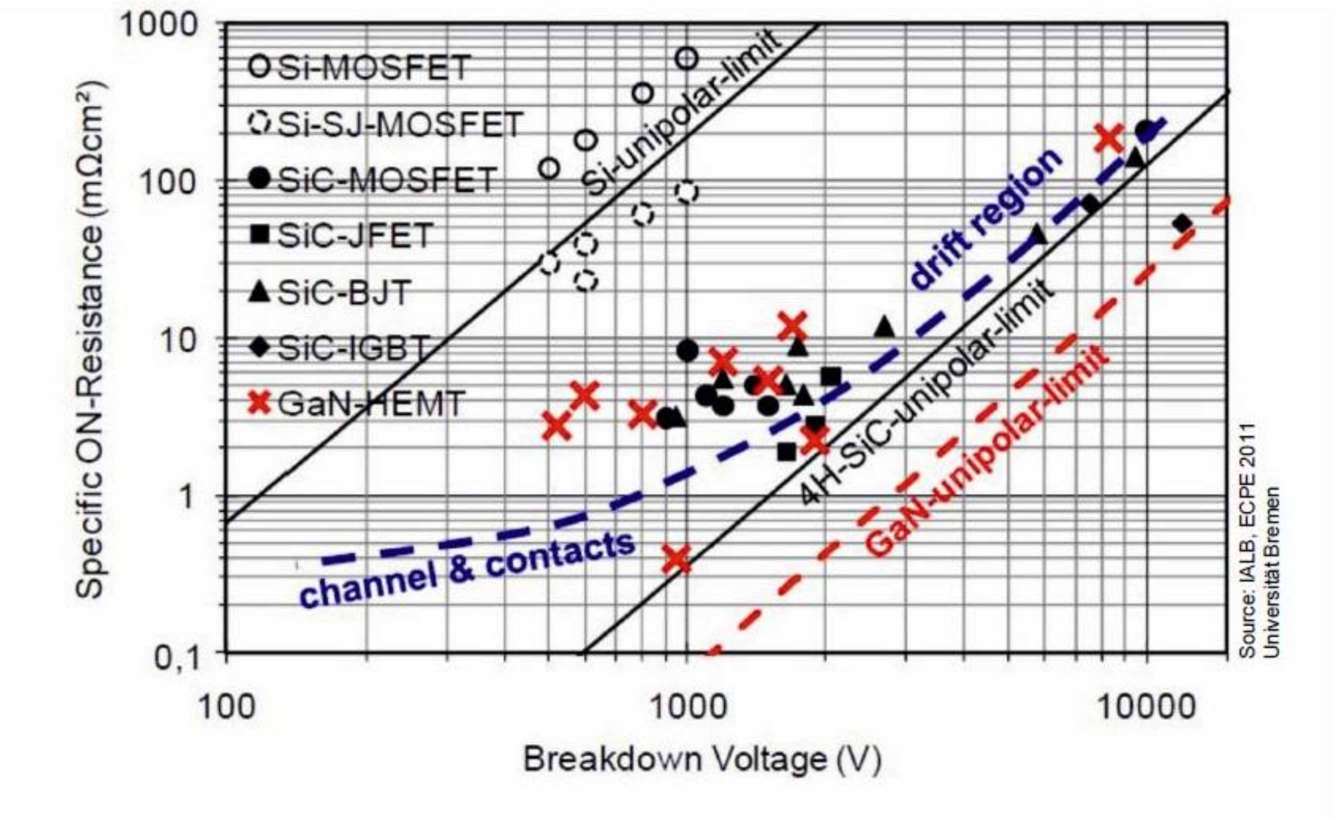
Source ECPE

AN OPPORTUNITY FOR WIDE BANDGAP MATERIAL

In Tough environment specifications

Higher Breakdown Voltage enables Faster Switching

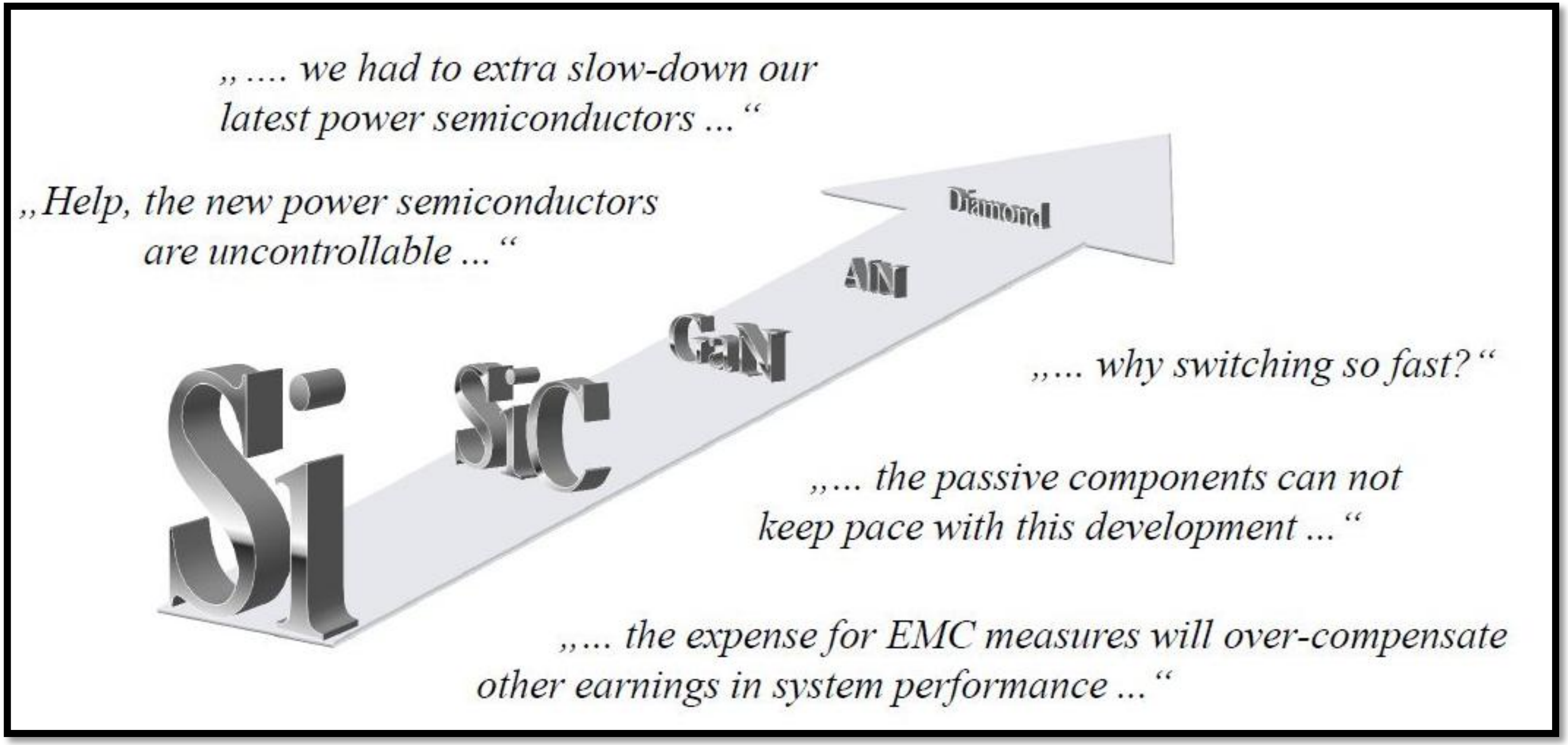
Allow Higher Junction temperatures



Source: IALB, ECPE 2011
Universität Bremen

FAST SWITCHING PACKAGING

Hurdles for GaN and SiC



„ …. we had to extra slow-down our latest power semiconductors … “

„Help, the new power semiconductors are uncontrollable … “

„… why switching so fast? “

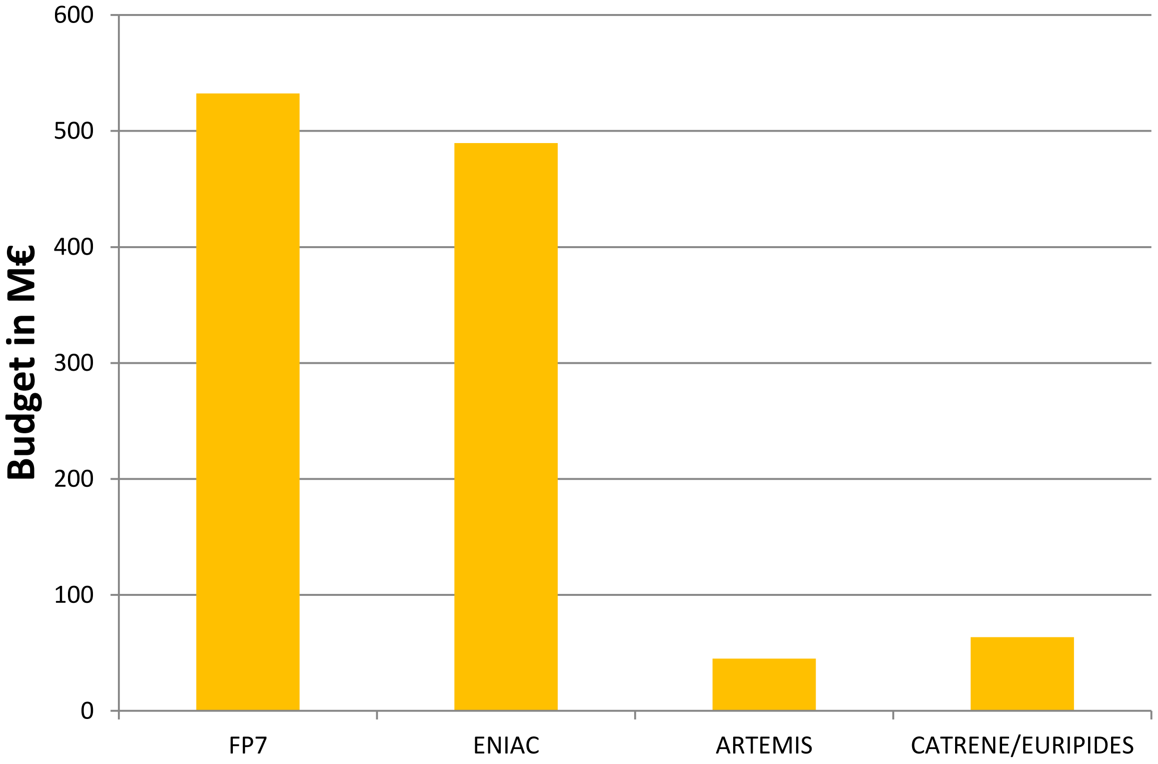
„… the passive components can not keep pace with this development … “

„… the expense for EMC measures will over-compensate other earnings in system performance … “

Dr Martin März Fraunhoffer IISB

European investment in Power Electronics

From 2004 to 2013: 1,13B€ of collaborative and co-funded R&D in EUROPE for POWER Electronics



What FP7-Cooperation does

EURIPIDES

Support Excellence in Science

FUNDING : EU

SEVENTH FRAMEWORK
PROGRAMME

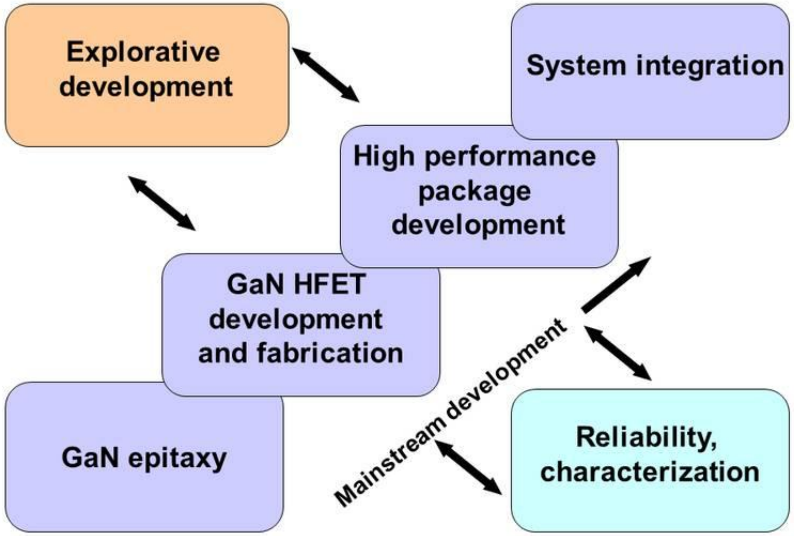
Material Science Components	*Thermal Management*	*Packaging and systems*
HIPOSWITCH 5,57M€	THEMA – CNT 3,46M€	HERMES 14,37 M€
GaN-based normally-off high power switching transistor for efficient power converters	Thermal Management with Carbon Nanotube Architectures	High density integration by embedding chips for reduced size modules and electronic systems

EUREKA

FP7- HIPOSWITCH

200 mm GaN on Silicon

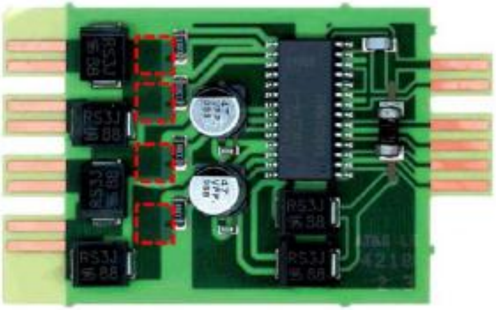
- Telecom power converter working at frequency targeting 300-500kHz , 600V capable package: reduced passive size, heatsinks and weight
- 10x smaller chip footprint
- Thin wafer technology

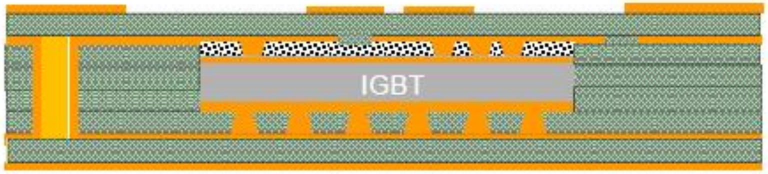


FP7- HERMES

FP7- HERMES : from H. Stahr AT&S

- Power module





Stack up

Cross section

Applications
- Motor control
- Air conditions
- Washing machines

Key features
- Reliability
- Footprint reduction
- Electrical isolation

Benefits
- Encapsulation
- Higher power rates
- Remove wire-bond connections

What JTI like ENIAC does

Supports more maturetechnologies and Pilot Lines

Funding : EU + Member States

EPPL :	**AGATE :**	**EPT 300 :**
74,8M€	59,6 M€	43,6 M€
Enhanced Power PILOT Line	Development of Advanced GaN Substrates and Technologies:	Enabling Power Technologies on 300mm
300mm Pilot line	Demonstrate processing on 6 and 8 inches wafer.	

What EUREKA does

Supports Higher TRL technology closer to market

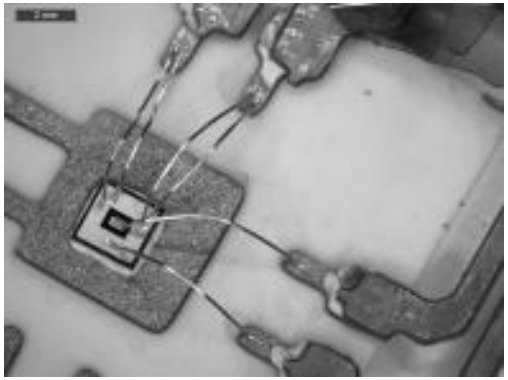
FUNDING : Member states

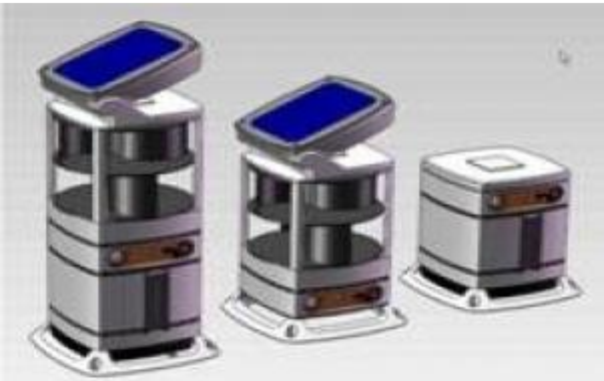
CATRENE
RELY : 7,4M€

CATRENE/EURIPIDES
THOR 32,6M€

EURIPIDES : ENERPACK
2,88M€

RELY - Design for RELIABILITY of SoCs for Applications like Transportation, Medical, and Industrial Automation





EURIPIDES^2 Smart Electronics Systems

Smart system functionalities

Sensing, Metering, Measuring

Actuating, incl. smart power electronics and LED, laser, light

Data storage and processing, artificial intelligence

Communication and data transmission (incl. wired and wireless communication), communicating objects

Man-machine **interface**, e.g. displays, key pads, machine to machine, …

Energy storage, management and harvesting (smart grids, smart building, ...)

Process and component technologies

Materials and Process technologies

Component technologies including MEMS, optoelectronics, printed, flexible electronics and bioelectronics

Packaging technologies, housing

System integration technologies

Reliability

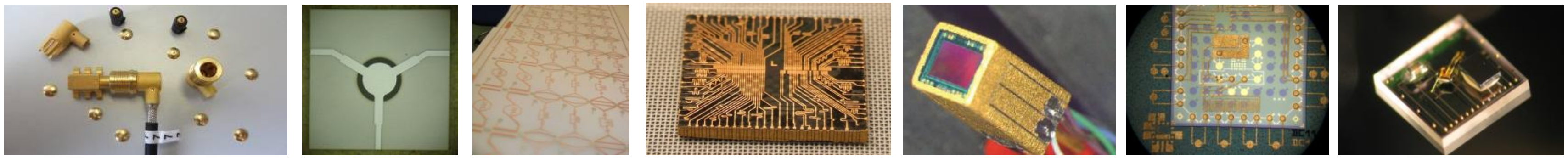
EURIPIDES^2 industrial value chain

LEVEL 1 | Processes, equipment and tools, materials, substrates, packages

LEVEL 2 | Interconnection and passive components as well as MEMs and advanced packaging activities (excluding other semiconductor devices)

LEVEL 3 | Subsystem assembly, boards and modules including SiP, MCM and other 3D assemblies...

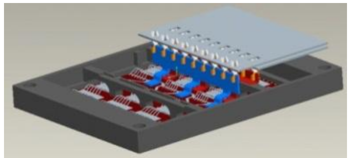
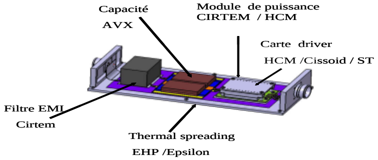
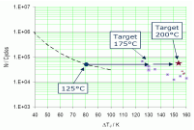
LEVEL 4 | Electronic products, systems, stand-alone (e.g. smartphones, PCs...), embedded (e.g. engine control unit...), “enmeshed” or “implanted” (e.g. intelligent clothes, building materials, medical implants, ...)



THOR – EURIPIDES/CATRENE

Economy of Scales

From Nano to Macro Power Electronics

THOR levels	*Automotive*	*Aeronautics*	*Healthcare*
power system			
module		 	
component	 	**Common power devices**	
process technology		**Common process technology**	

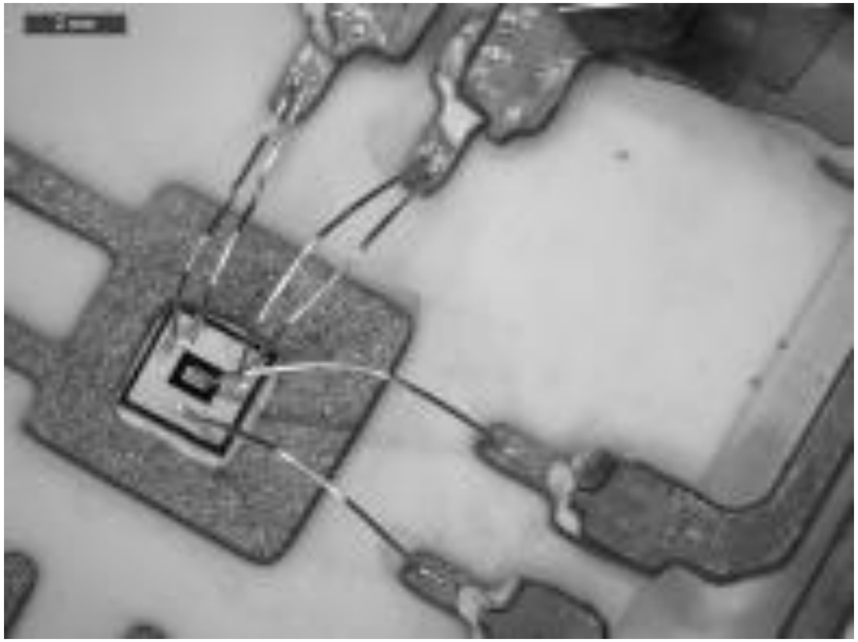
THOR - Selected highlights

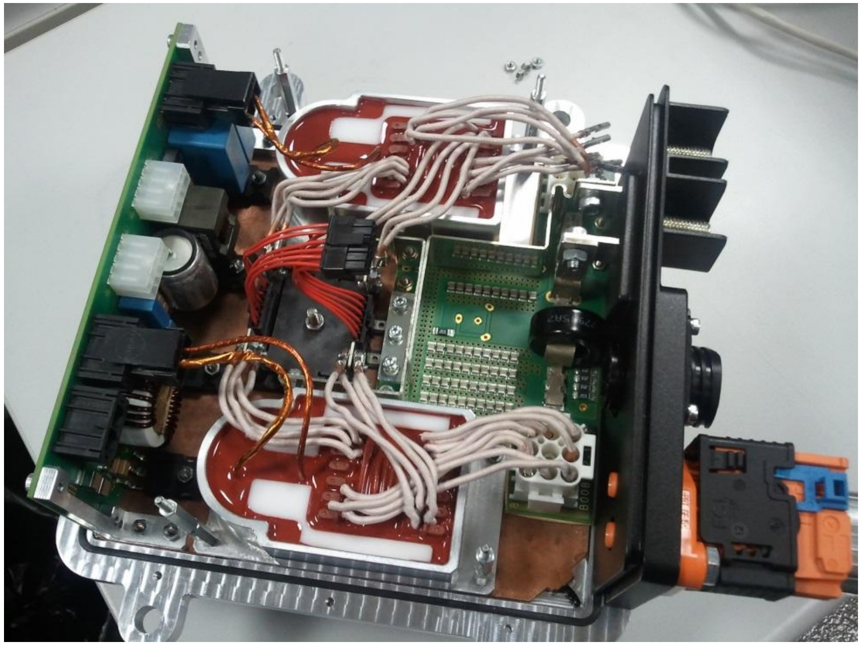
SiC Thermal Runaway

- Effect exists in VJFETs
- Optimization is possible

LLC resonant converter

- 2.5 kW, 150kHz-250 kHz HV/LV
- 1 W/cm^3

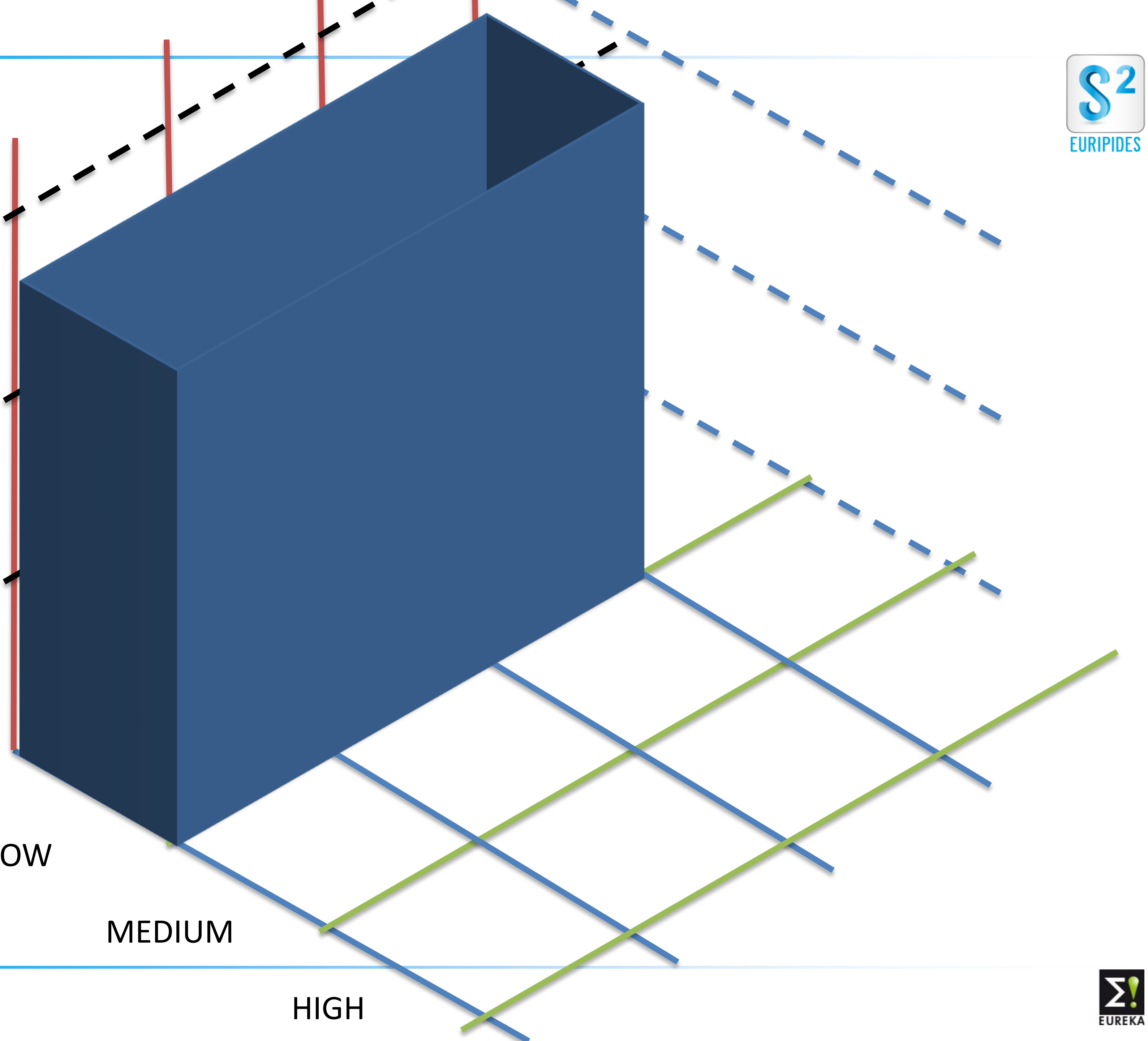




THOR - Selected highlights

Early exploitation of THOR technology

5. Nano-domain



Packaging

component

Material

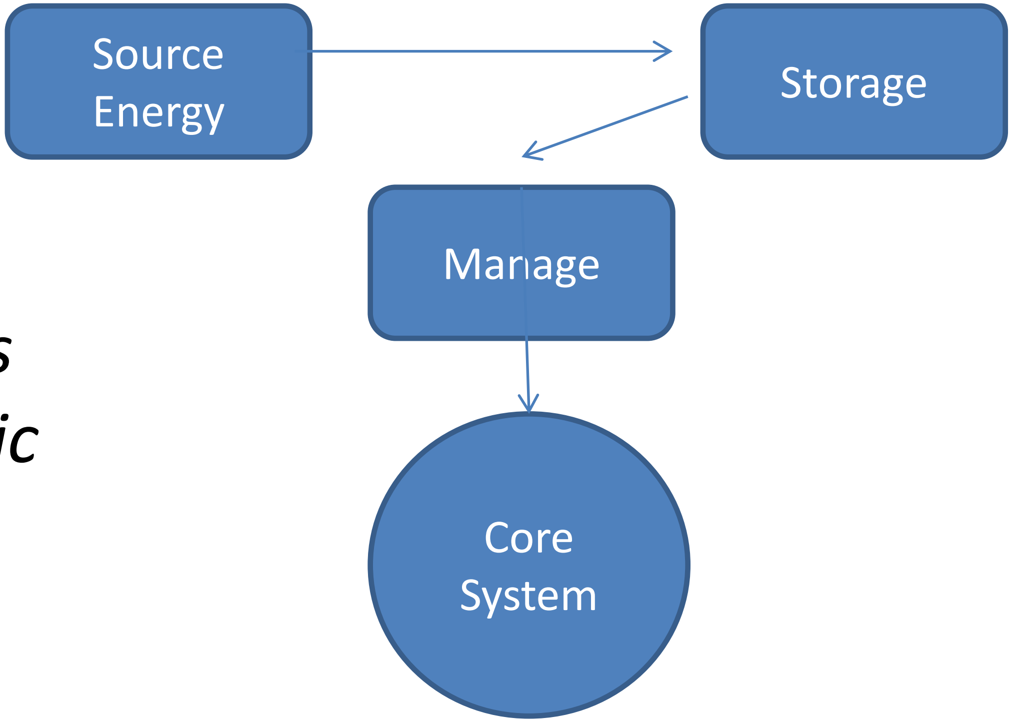
LOW

MEDIUM

HIGH

Low Energy Power Management

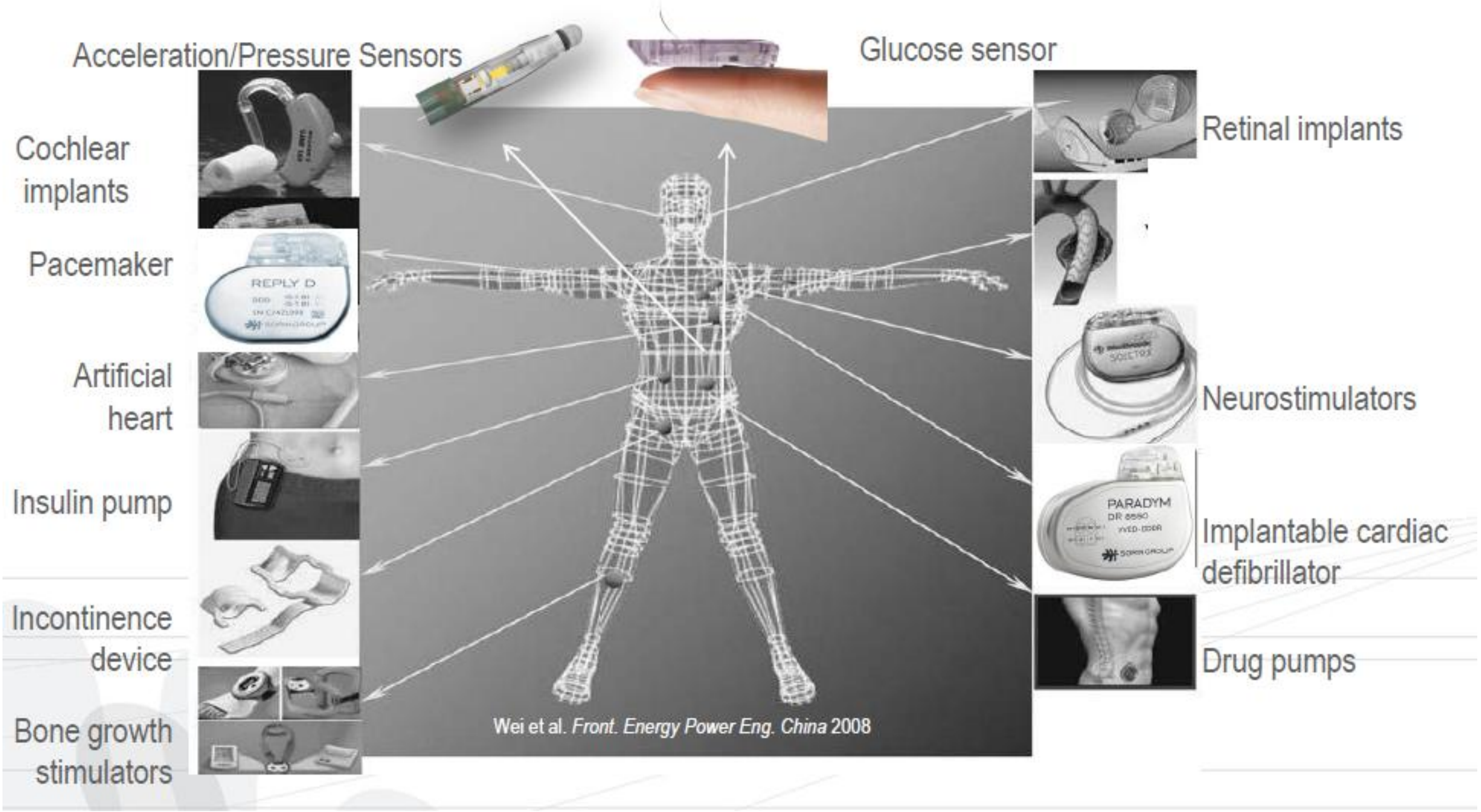
Autonomous Systems and Autonomous Wireless Sensor Networks



*Requires
a hollistic
analysis*

Many technical options, no standard solution !

Low Energy Power Management



Acceleration/Pressure Sensors

Glucose sensor

Cochlear implants

Pacemaker

Artificial heart

Insulin pump

Incontinence device

Bone growth stimulators

Retinal implants

Neurostimulators

Implantable cardiac defibrillator

Drug pumps

Wei et al. *Front. Energy Power Eng. China* 2008

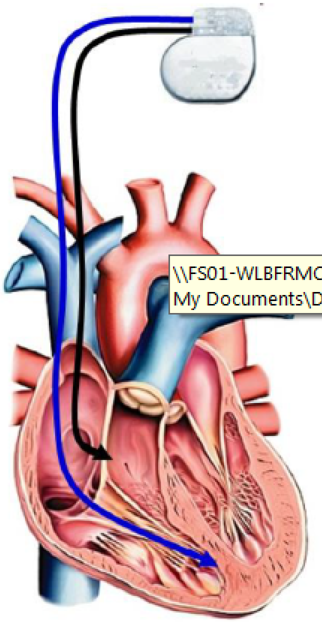
Energy Scavenger in Cardiac Implants

EURIPIDES

Financement FUI FEFER OSEO
09-2010 -> 09-2013

HBS

Heart Beat Scavenger



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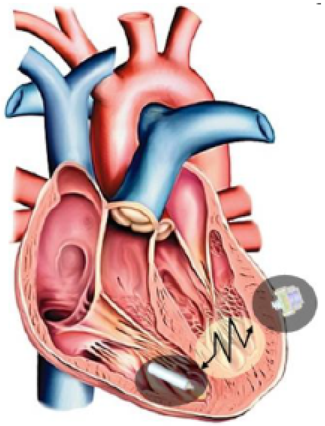
My Documents\Downloads\HBS_slide.png

Stimulateur actuel

Futur stimulateur HBS



8 cm^3	**Taille du stimulateur**	40 µW < 1 cm^3
Pile 2.5 cm^3	**Source d'énergie**	µ-générateur < 0.5 cm^3
1.5 cm^3	**Circuit électronique**	< 0.3 cm^3
2 x 1D	**Accéléromètre**	1 x 3D
Sonde	**Interface avec le cœur**	capsule

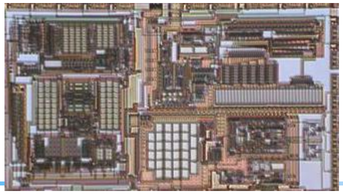
SORIN

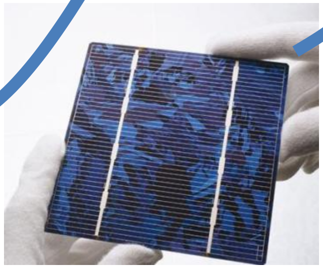
EUREKA

GEMALTO: Self Powered Display Card;

- OBJECTIVE: 5 years energetically self sufficient display card
- Looking for technology partner ship on:
  - Power management
  - Energy storage
    - Green battery
    - supercapacitor
  - Energy harvestiing
    - PV
    - Piezo
    - Vibration
    - ...
  - Very low power Display (B stable if possible)

1234





SPECIAL THANKS

ECPE : Jochen Koszescha

Yole Développement : Philippe Roussel

TYNDALL : Michael Hayes

THOR project : Mark Van Helvoort, Patrick Dubus

SORIN : Renzo Dal Molin

GEMALTO : Béatrice Dubois

Thank you for your attention

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EURIPIDES²
European Smart Electronic Systems

EUREKA