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SUSTAINABLE MANUFACTURING: TRENDS AND RESEARCH CHALLENGES

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ABSTRACT

Sustainability is the only answer for guaranteeing a future to our generations. Natural resources are not infinite and the capacity of regeneration of the environment has been in the last years overestimated. Manufacturing is from one side still one of the most important driving force of our economy but on the other side is one of the main cause of natural resource consumption and CO2 emissions.

The presentation, after having introduced some of the most important social and economical megatrends, will address the most probable technical evolution paths of Sustainable Manufacturing, highlighting the role of the research and innovation in this key area. Roadmapping activities at European level will be discussed.

POLITECNICO DI MILANO

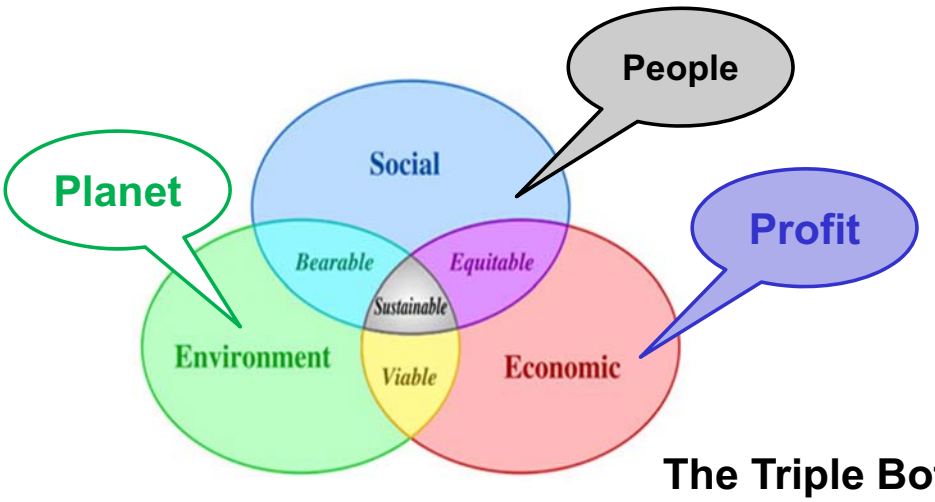
Sustainable Manufacturing: Trends and Research Challenges

Prof. Marco Taisch

TMT Conference, Dubai, 10-12 September 2012

Sustainable Development

"the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland-Commission 1987)

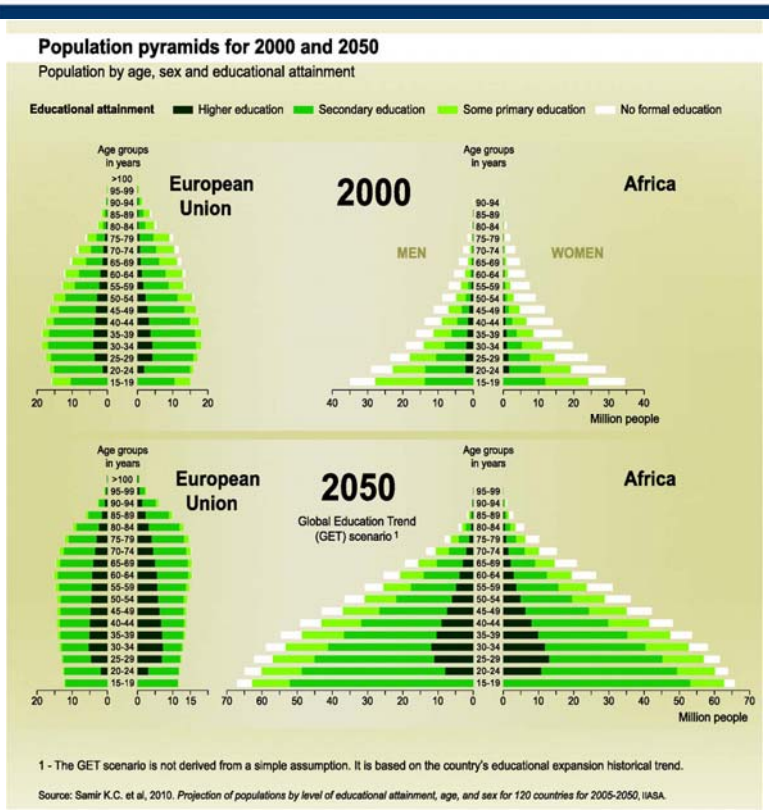


The Triple Bottom Line

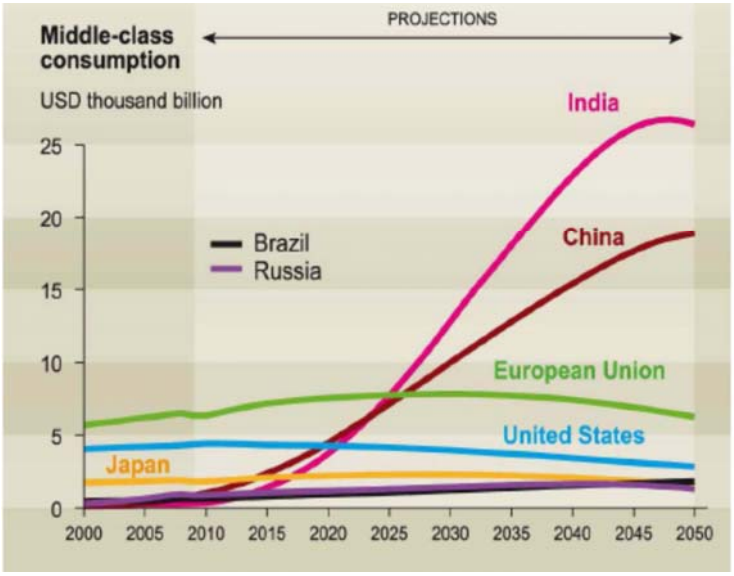
Agenda

1. Social Megatrends
2. Environmental Megaternds
3. Natural resources Megatrends
4. Energy Megatrends
5. The answer from the Manufacturing Industry

What would a future generation look like?

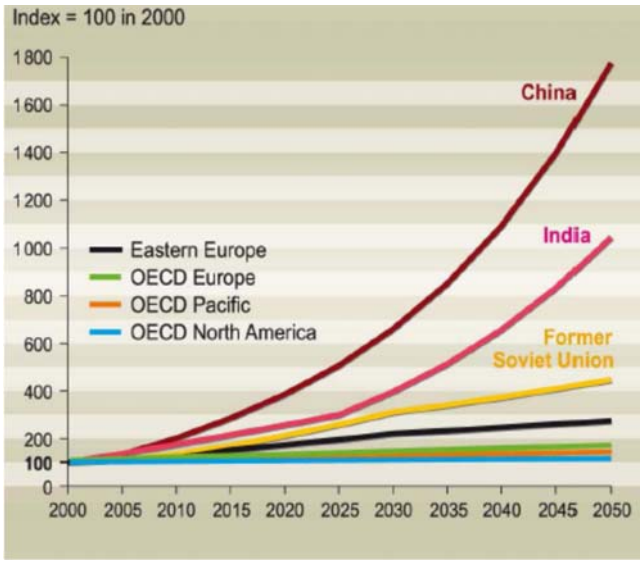


Changing middle class



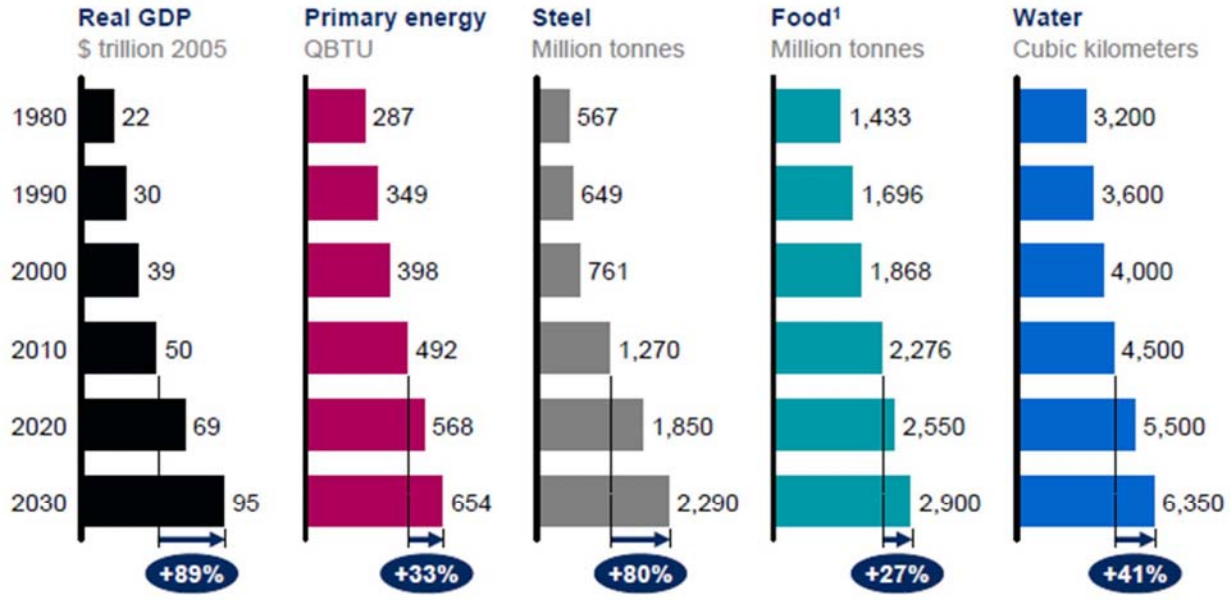
The European environment | State and outlook 2010

Car ownership rates projections



The European environment | State and outlook 2010

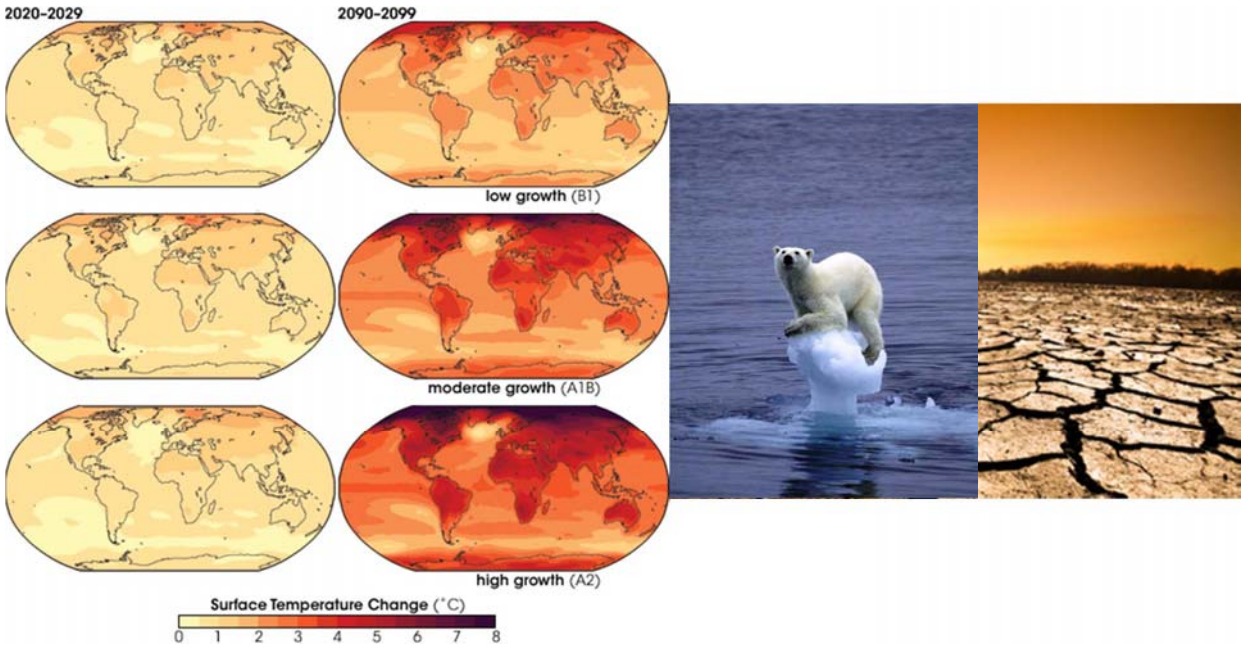
Demand for most resources has grown strongly since 2000, a trend that is likely to continue to 2030



1 Only cereals.

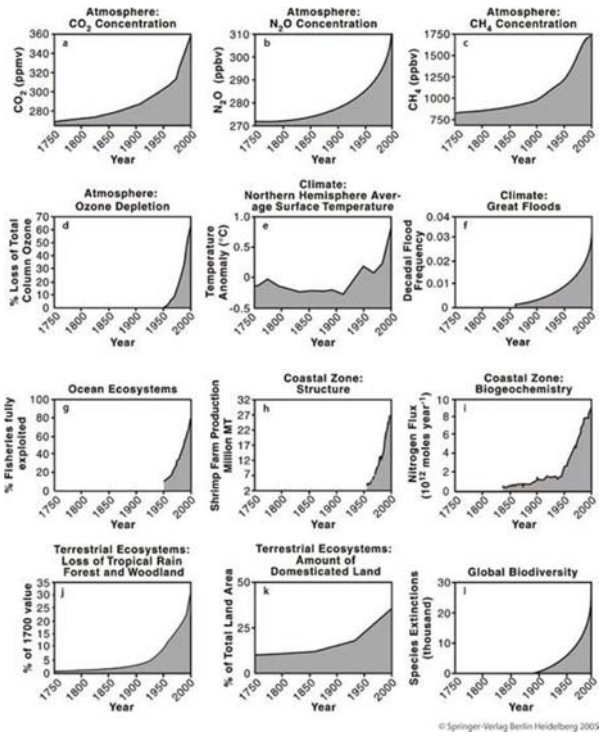
SOURCE: Global Insight; IEA; UN Environment Program (UNEP); FAO; World Steel Association; McKinsey analysis

Clean and healthy place to live …



Source: IPCC 2007

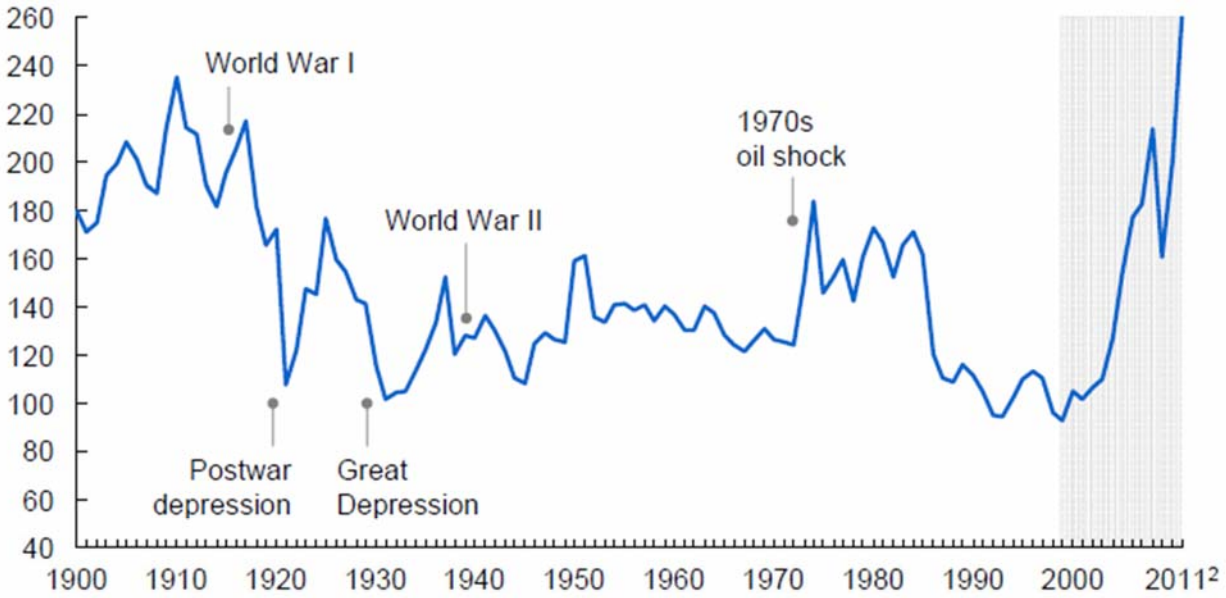
Clean and healthy place to live …



Source: http://rs.resalliance.org/2008/12/04/visualizing-the-great-acceleration-part-ii/

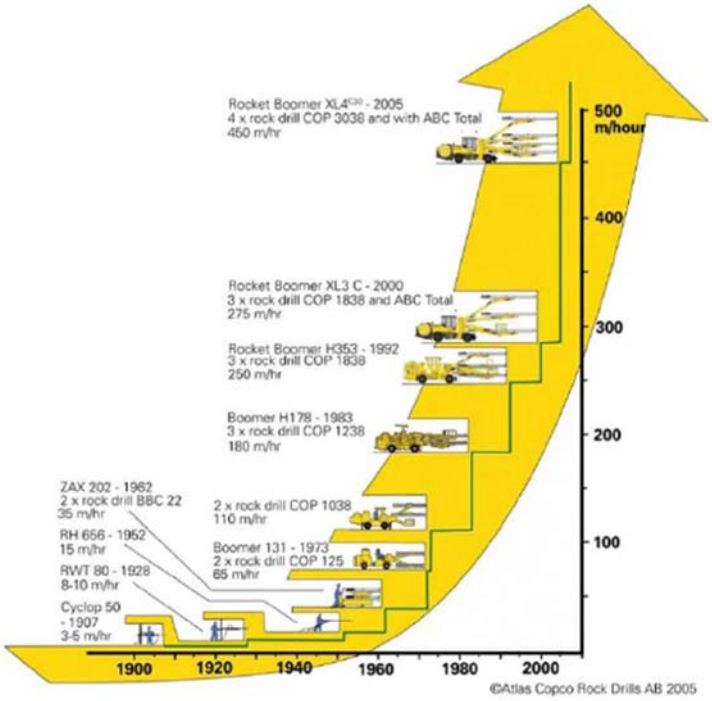
Commodity prices have increased sharply since 2000, erasing all the declines of the 20th century

MGI Commodity Price Index (years 1999–2001 = 100)[1]



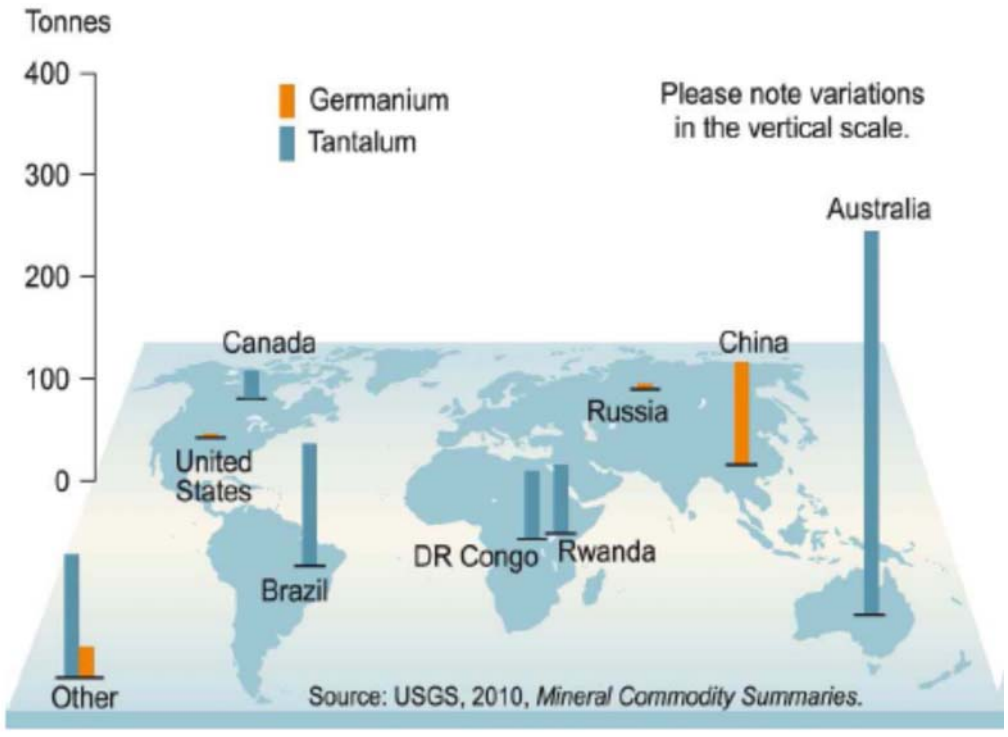
1 See the methodology appendix for details of the MGI Commodity Price Index.
2 2011 prices are based on average of the first eight months of 2011.
SOURCE: Grilli and Yang; Stephan Pfaffenzeller; World Bank; International Monetary Fund (IMF); Organisation for Economic Co-operation and Development (OECD); UN Food and Agriculture Organization (FAO); UN Comtrade; McKinsey analysis

Drilling technology during 100 years

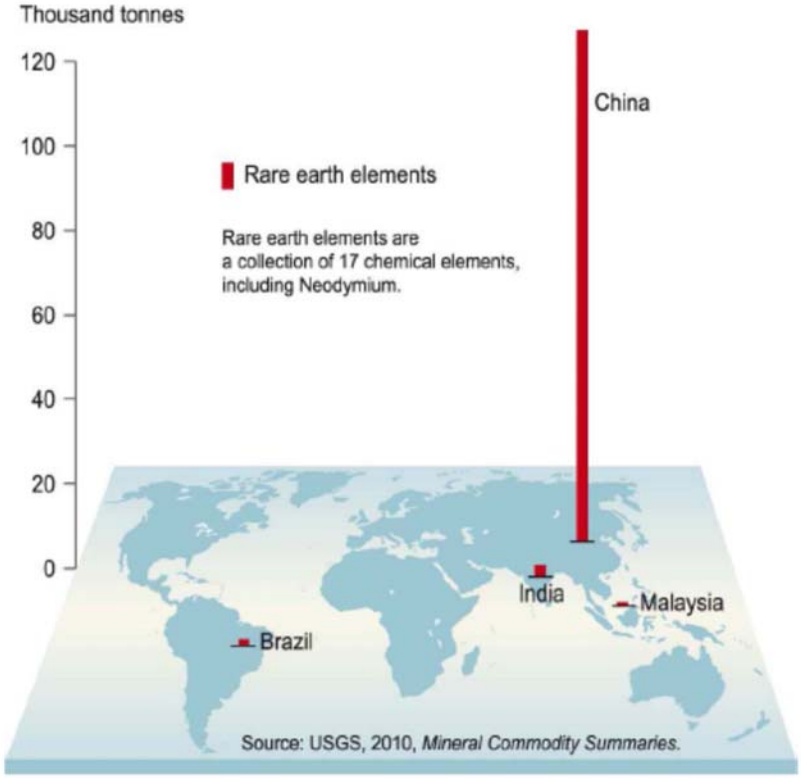


Source: Stichting Materials innovation institute (M2i) 2009

Rare earth elements



Rare earth elements



Cell phones

A ton of cell phones would have:

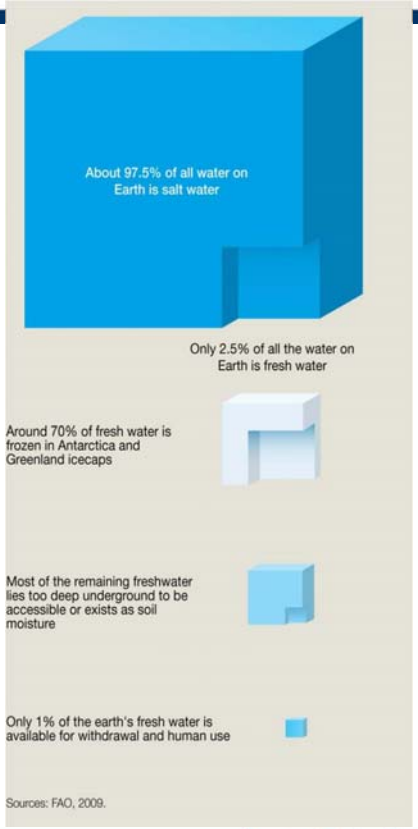
- 3.5kg of silver
- 340 g of gold
- 140 g of palladium
- 130 kg of copper

(Hagelüken and Meskers 2008).

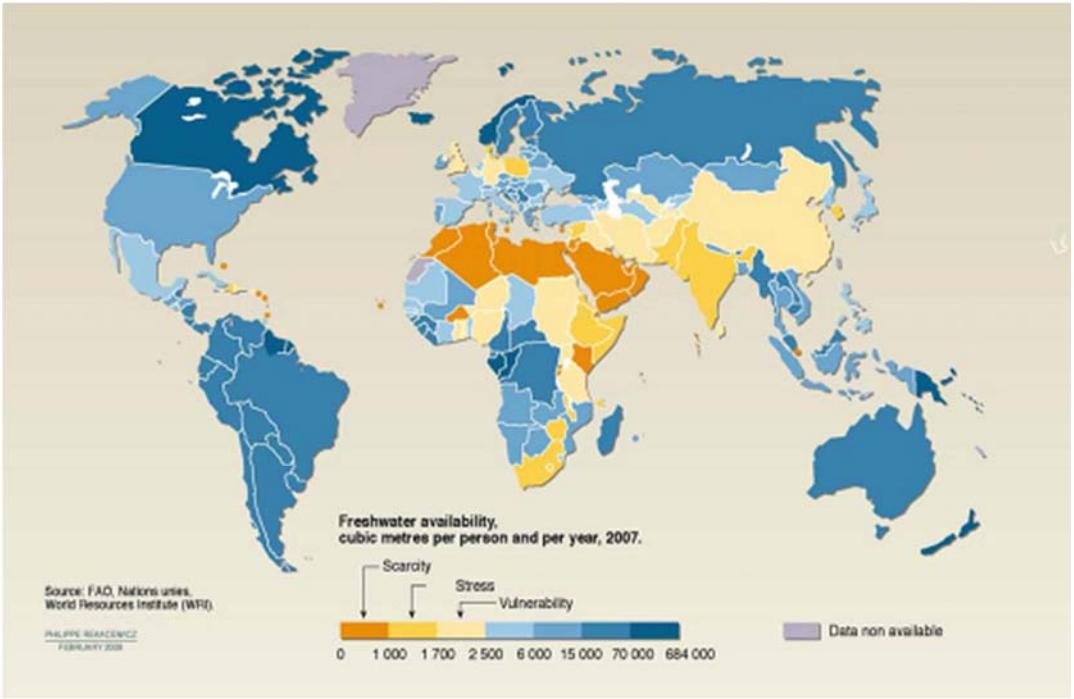
Cutaway image of a cellular phone showing the interior components, many of which contain and depend on minerals and mineral products to function. SOURCE: CAP-XX Ltd.

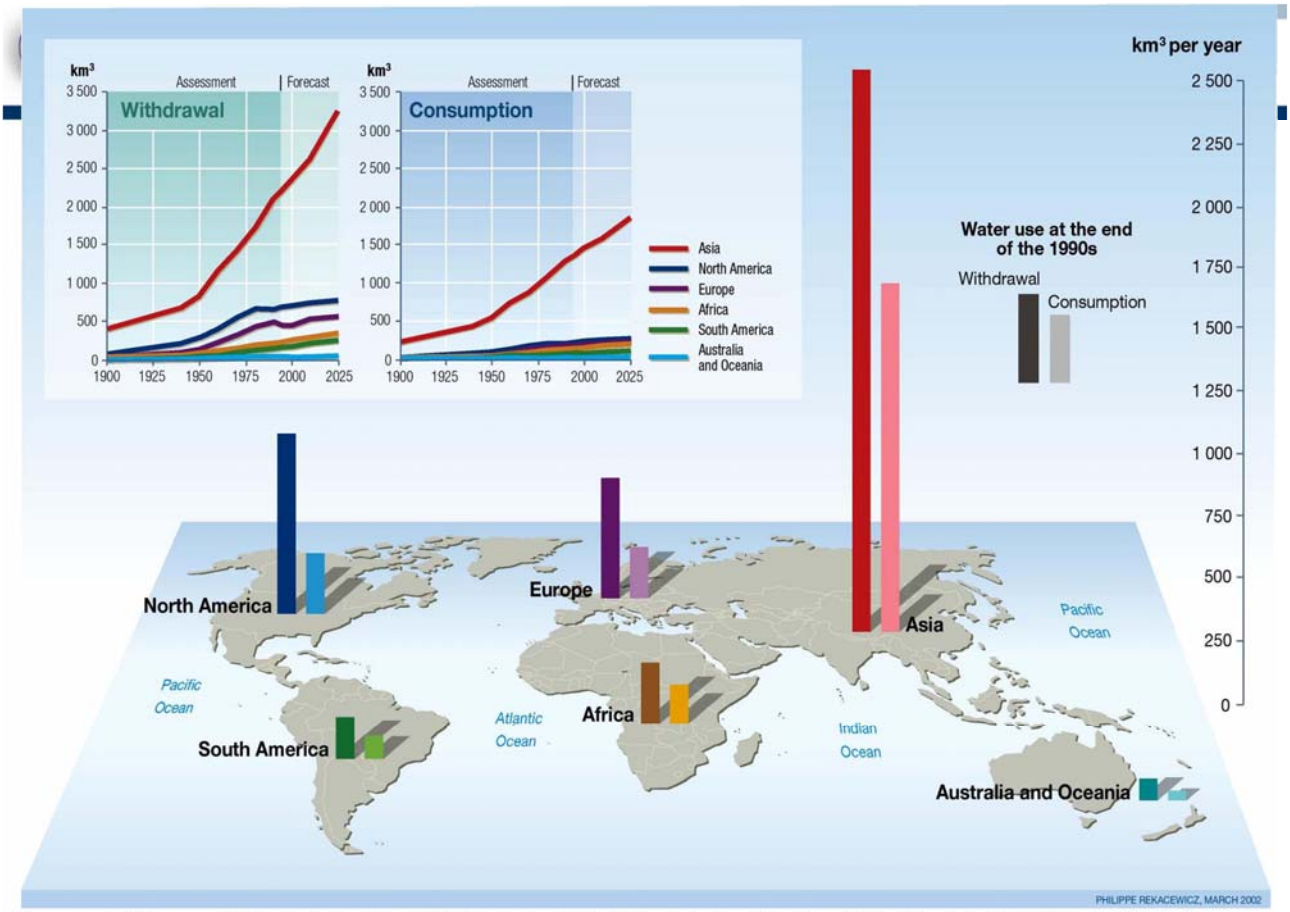
Source: US NRC "Minerals, Critical Minerals, and the U.S. Economy," 2008

The World's Water Supply

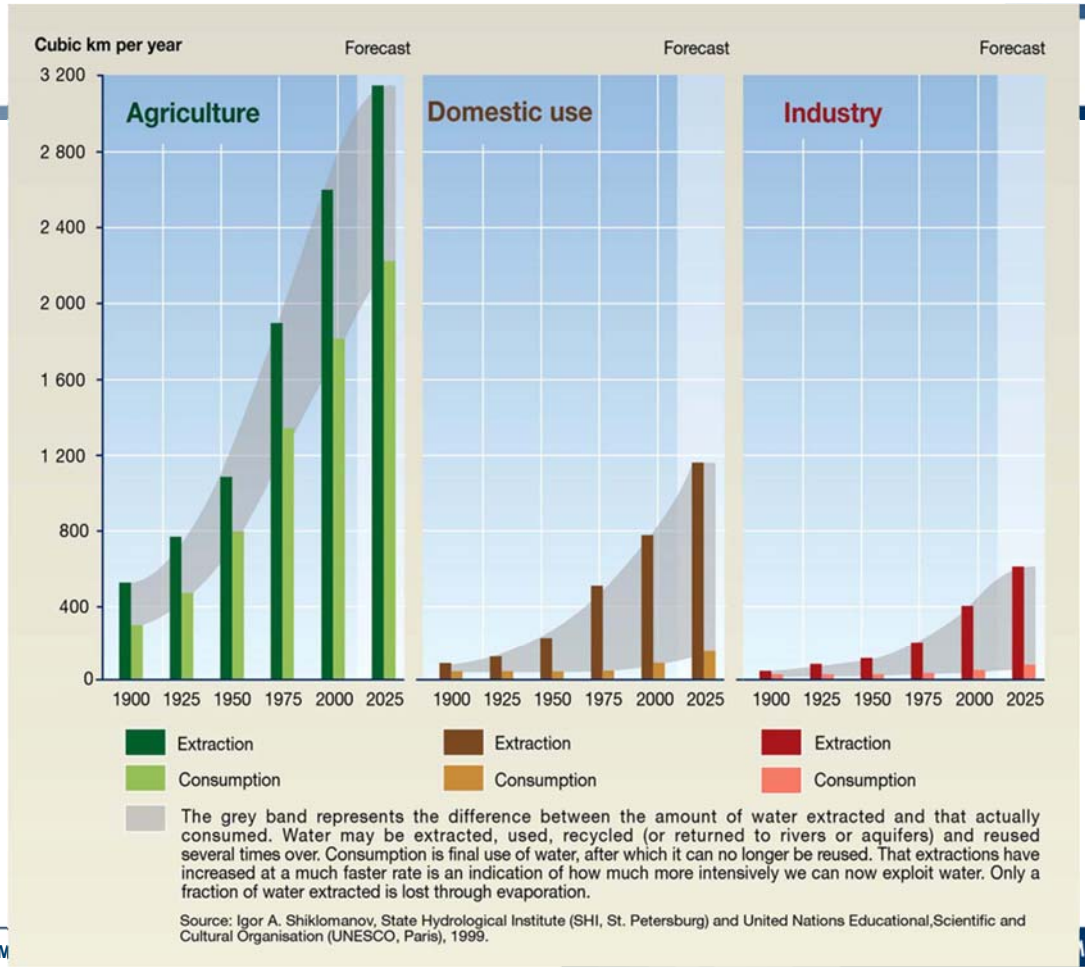


Freshwater availability





Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999; *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000; Paul Harrison and Fred Pearce, *AAAS Atlas of Population 2001*, American Association for the Advancement of Science, University of California Press, Berkeley.



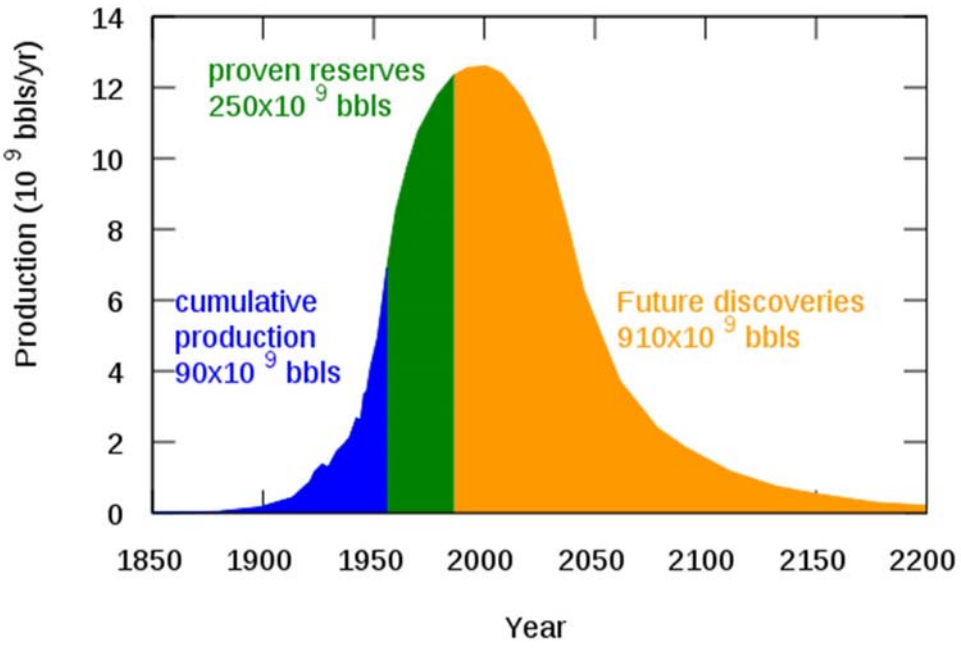
Source: GE Citing Blue Planet Run, Smolan, Erwitt

Water/Energy Nexus

1. About 6-18% of a city's energy demand is used to produce, treat & transport water
   - At times 60% of this water leaks and never reaches the end user!
2. Higher technology to treat impaired water requires higher energy demand
3. Declining reservoir levels reduce hydro generating capacity
4. Power generation requires large quantities of water
   - >50% of global industrial water consumption is used to generate power
5. Energy exploration & production generates large quantities of wastewater

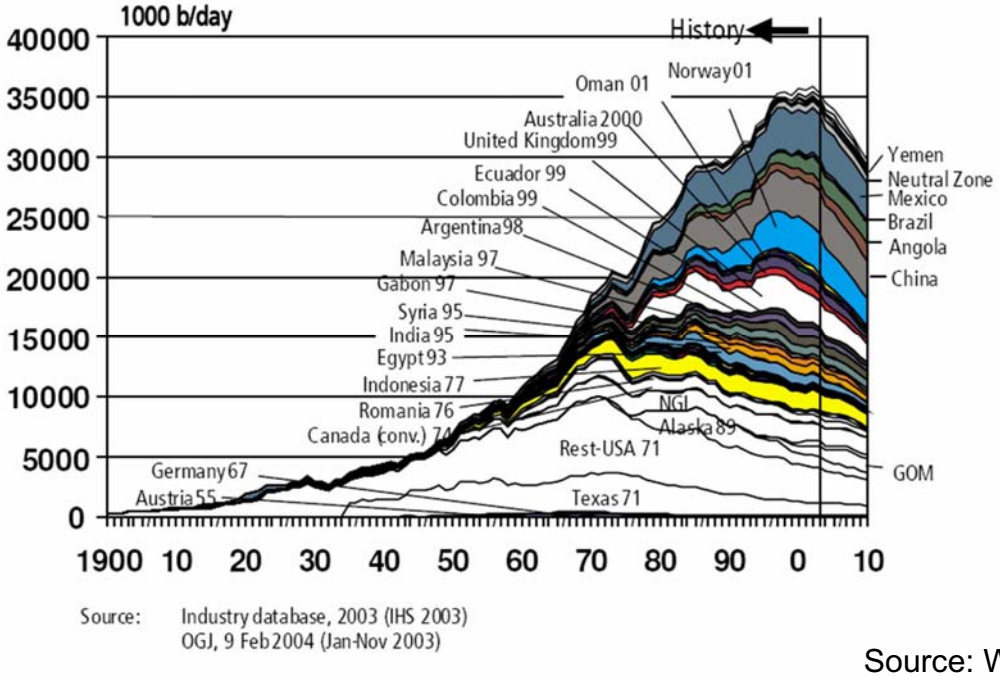
Source: GE

Oil: Hubbert Peak



Source: Wikipedia

Hubbert Peak



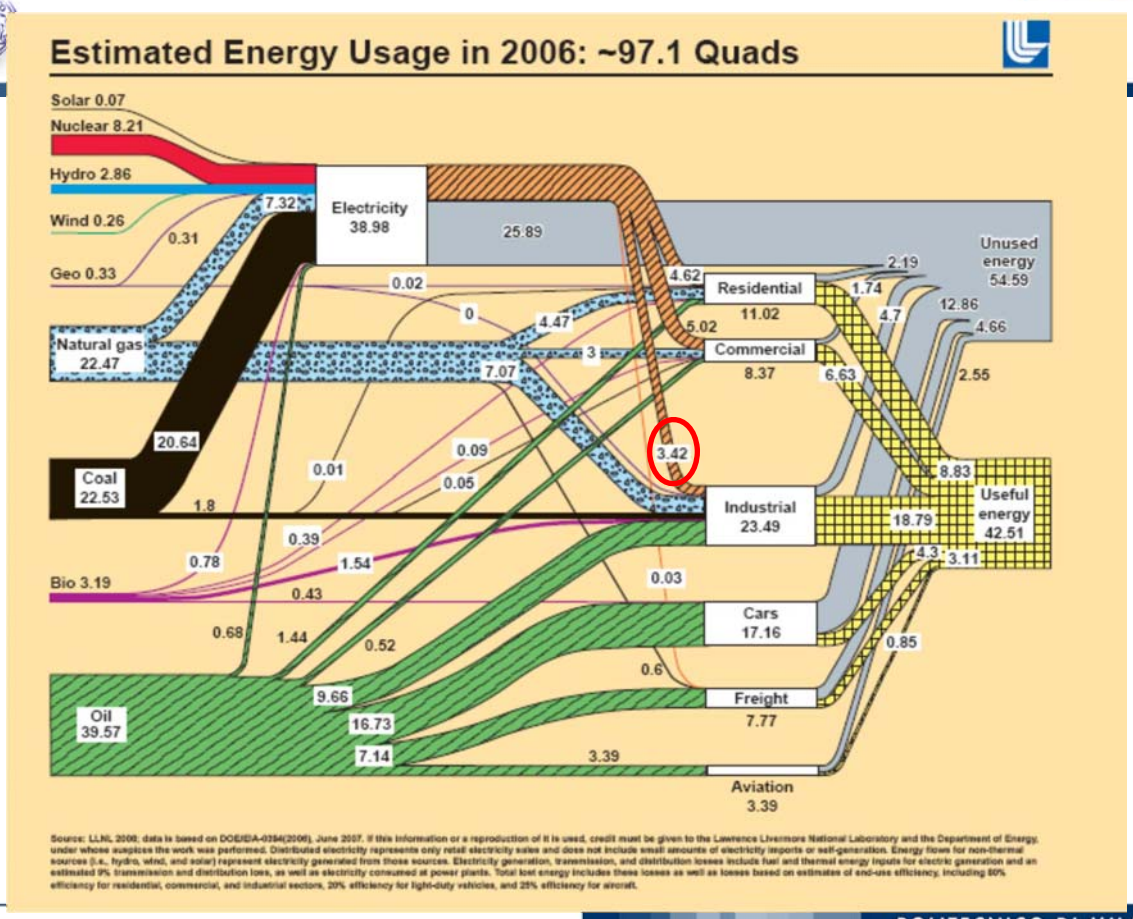
Source: Wikipedia

Every year for the past 30 years, the world-wide oil industry has pumped more oil than it has discovered.

In the last 5 years, 15 billion barrels of new oil were found world-wide.

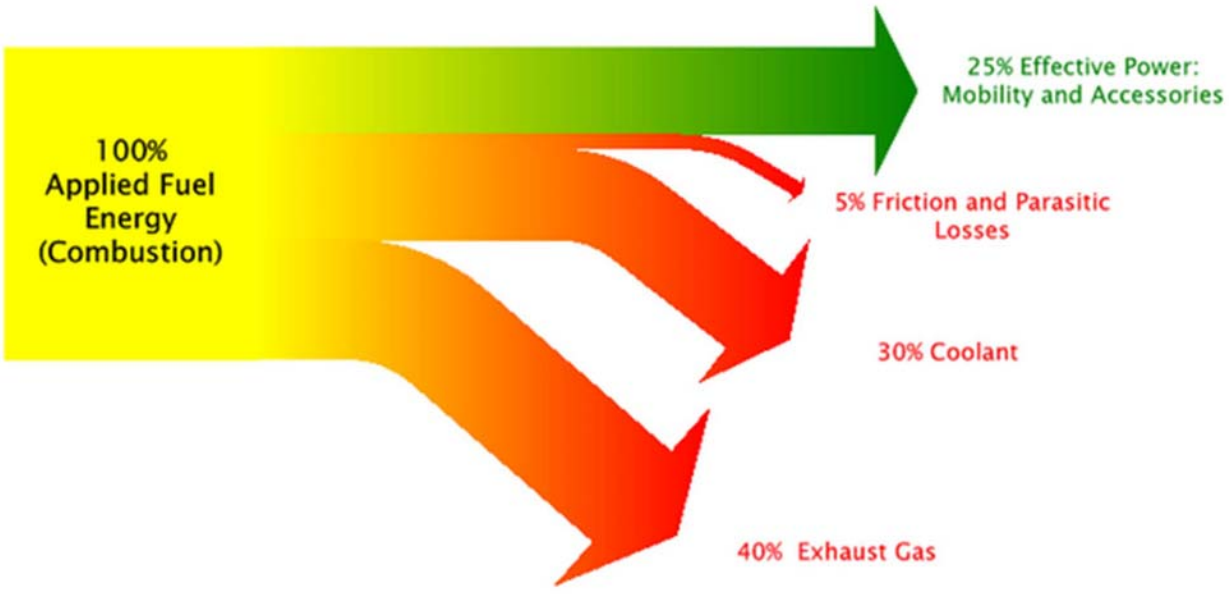
During the same 5 years, how many billions of barrels of oil were pumped out of the ground?

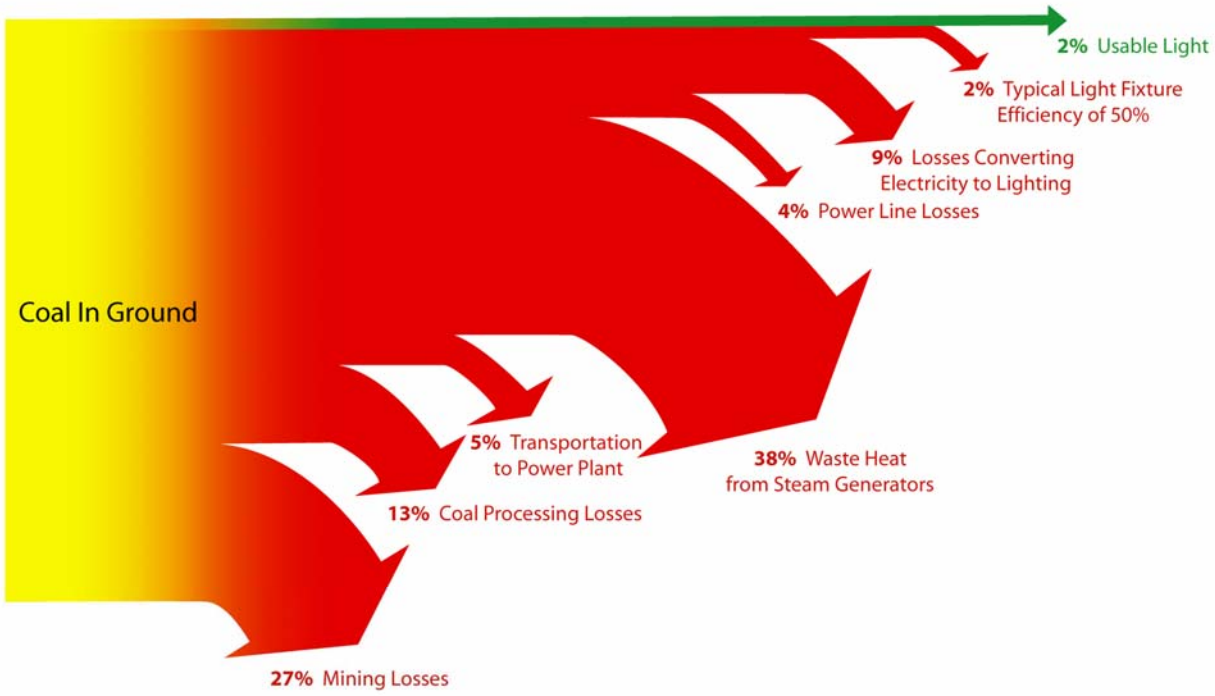
135



Source: LLNL 2008; data is based on DOE/EIA-0384(2006), June 2007. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include small amounts of electricity imports or self-generation. Energy flows for non-thermal sources (i.e., hydro, wind, and solar) represent electricity generated from those sources. Electricity generation, transmission, and distribution losses include fuel and thermal energy inputs for electric generation and an estimated 9% transmission and distribution loss, as well as electricity consumed at power plants. Total lost energy includes these losses as well as losses based on estimates of end-use efficiency, including 80% efficiency for residential, commercial, and industrial sectors, 20% efficiency for light-duty vehicles, and 25% efficiency for aircraft.

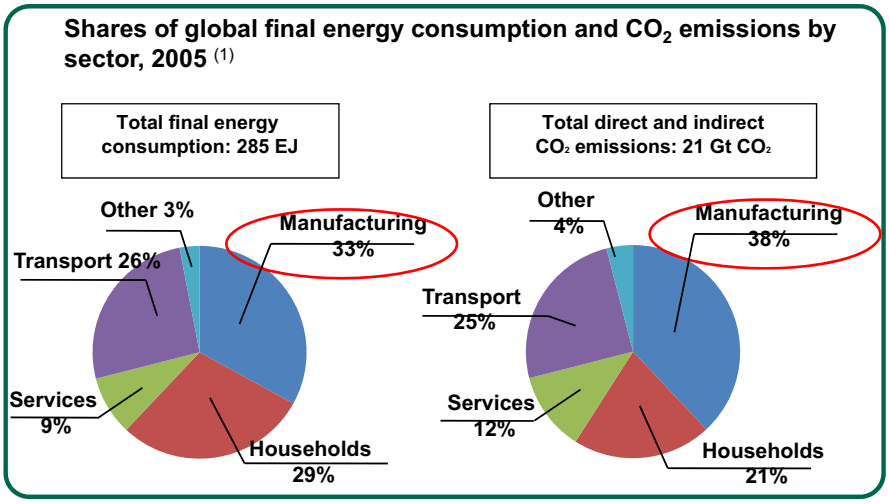
Typical Energy Split in Gasoline Internal Combustion Engines





Sustainability in the Context of Manufacturing

Shares of global final energy consumption and CO_2 emissions by sector, 2005 (1)



"technologies and best practices could save between 18% to 26% of current primary energy use in global industry" (1)

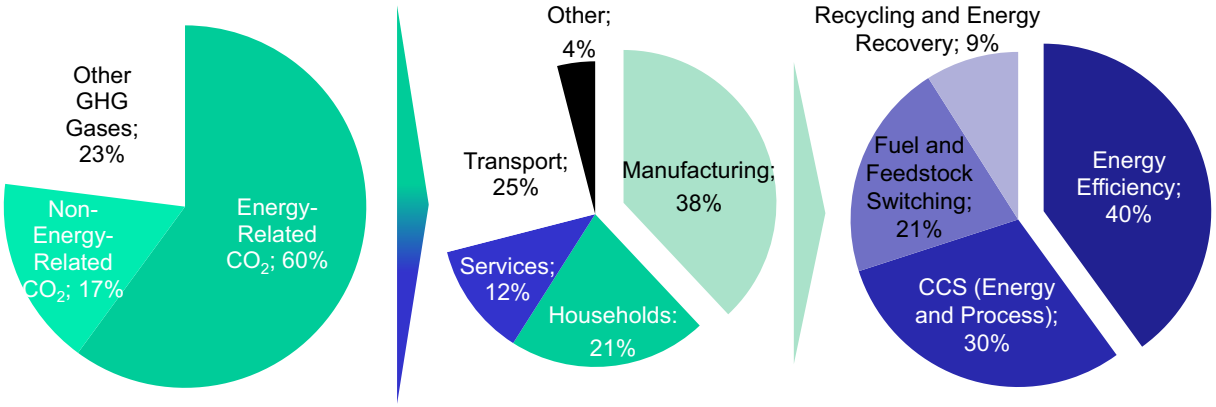
(1) IEA, Worldwide trends in Energy Use and Efficiency ,Energy Indicators, 2008

Why Energy Efficient Manufacturing? – The Global Perspective

77% of GHG emissions are CO_2 emissions

38% of CO_2 emissions from manufacturing sector

40% of reduction potential in industry from energy efficiency



Global GHG Emissions 2005

Global CO_2 Emissions 2005 per Sector

Technology for reducing direct CO_2 emissions from industry, 2006-2050

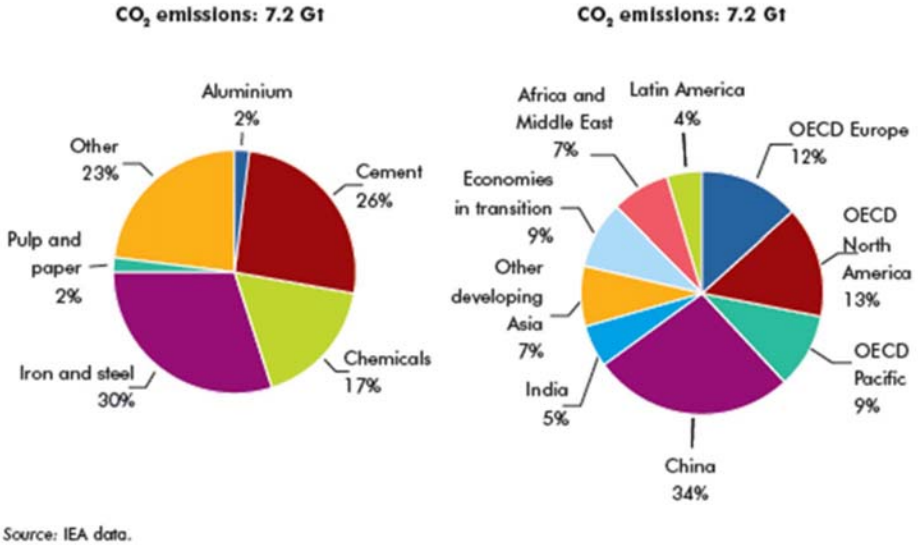
GHG – Greenhouse gas, CCS – Carbon Capture and Storage

Source: IEA 2008d, World Resource Institute 2011; data from 2005

Source: IEA 2009a

Direct CO_2 emissions in industry by sector and region

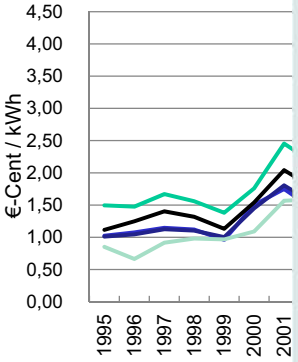
Figure 1.1 ▶ Direct CO_2 emissions in industry by sector and by region, 2006



Source: IEA data.

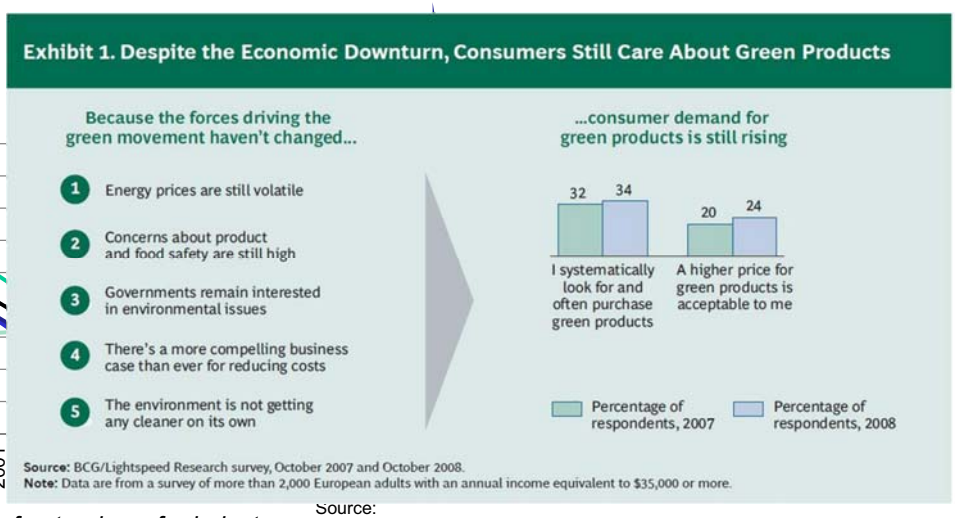
Source: IEA 2009a

- Environmental regulations
- Customer demands
- Rising energy prices



Development of prices of natural gas for industry

Source: BMWi 2011



Motivation for Sustainable Manufacturing

We, as a species, are depleting many resources at a very rapid rate

Fresh water efficiency ~ 40%

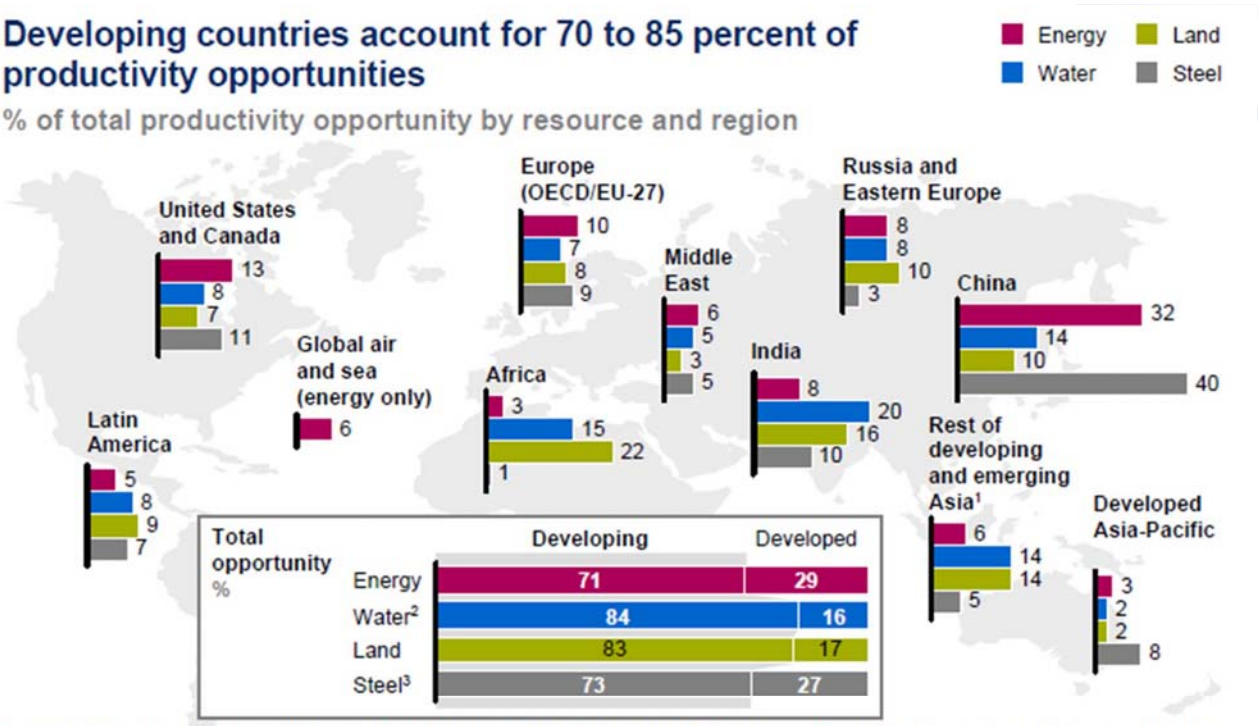
Car efficiency ~ 25%

Light bulb efficiency ~ 2%

We, as engineers and managers, can have a significant impact on sustainability

Developing countries account for 70 to 85 percent of productivity opportunities

% of total productivity opportunity by resource and region



1 Rest of developing Asia includes Central Asia (e.g., Uzbekistan), South Asia (e.g., Bangladesh), Southeast Asia (e.g., Laos), and North Korea.
2 Includes water savings from water-specific levers as well as water savings from improved agricultural productivity.
3 For steel, the chart represents all the demand-side levers and the scrap recycling lever but excludes supply- and conversion-side levers.
NOTE: Numbers may not sum due to rounding.
SOURCE: McKinsey analysis

But what is really Sustainable?

Toyota Prius	Seat Leon	WV Polo
104 gCO2/Km	100 gCo2/Km	108 gCo2/Km
4,7L/100Km	6,2L/100Km	4,0 L/100Km

Which one is the most sustainable?

What about the production process?

And beyond the environmental impact?

The Three Major Dimensions of Sustainability

New engineering focus

Traditional engineering focus

Environmental sustainability	Social sustainability	Economical sustainability
- Materials - Energy - Water - Bio-diversity - Emissions - Waste - Product and services - Compliance - Transport	- work practices and adequate working conditions - diversity and equal opportunities - relations with the community - social policy compliance - consumer health and safety - human rights	- economic performance - market presence - indirect economic impacts

Future engineering focus?

Source: N. DUQUE CICERI 2011

So far…

Population increasing rapidly

Resource (minerals, water, oil, energy) consumption increasing too fast

Not enough supply! Prices will sky rocket!

We need to be much more productive

Engineers and managers should take a holistic perspective of products/services from design, manufacturing, operation, transportation, and recylcing

Value Chain for Sustainable Innovation

Design	Industrialization	Procurement	Production	Distribution	Use	Recycle	Dismiss
✓Green Marketing ✓ LCA ✓ Environmental break even point ✓ Design for Assembly ✓ Design for Disassembly ✓ Design for Maintenance ✓ Packaging Design	✓ GSCM ✓ Supply Chain Collaboration ✓ Closed loop supply chain ✓ Reverse Logistics ✓ Eco fleet	✓ Energy Efficiency ✓ Production Planning ✓ Quality Management ✓ New Technologies	✓ Combined Transport ✓ Transport Improvement ✓ Delivery Routes ✓ Logistic plants sharing	✓ Sensitization ✓Communication ✓ Training	✓Recycle ✓Remanufacturing ✓ Reconditioning ✓ Repair ✓ Reuse	✓ Prevention ✓ Recycling ✓ Disposal technologies	

Information System

✓ EDI ERP CRM
✓ Knowledge management
✓ LCDA + Embedded technologies

Organization and Human Resources

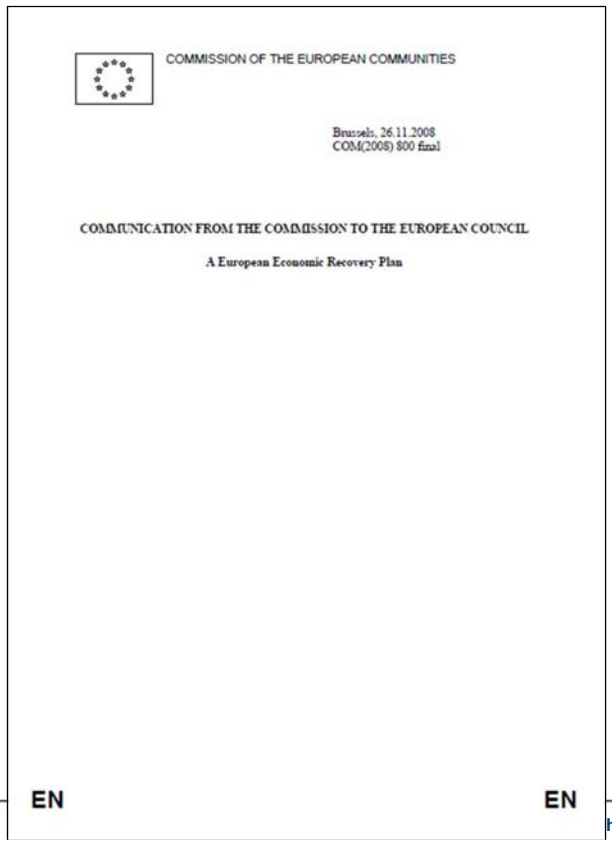
✓ Empowerment
✓ Sensitization, Corporate culture
✓ Commitment, Premium system
✓ Functional integration

Planning and Control

✓ Supply chain integration
✓ Environmental monitoring
✓Localization
✓ Servitization
✓Certifications, Ecolabelling, Reporting
✓Green Image, Environmental impact evaluation methods, Focus on environmental costs and benefits

THE FACTORY OF THE FUTURE

The Strategy of the EU and the USA



COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 26.11.2008
COM(2008) 800 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN COUNCIL

A European Economic Recovery Plan

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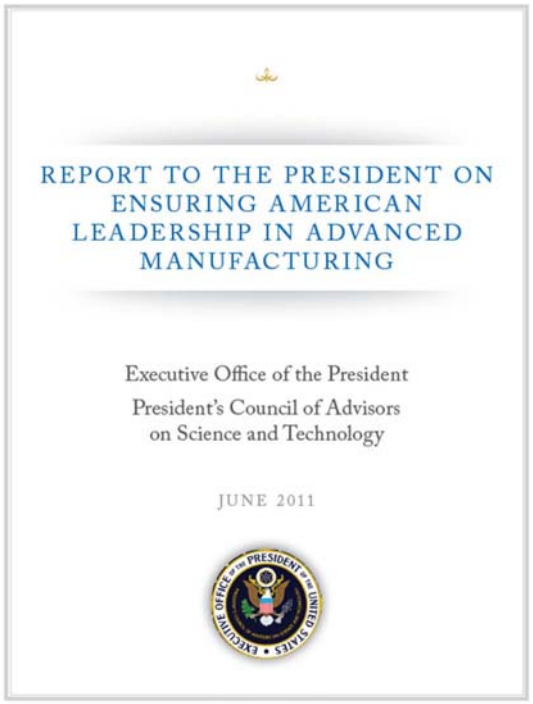


REPORT TO THE PRESIDENT ON ENSURING AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING

Executive Office of the President
President's Council of Advisors on Science and Technology

JUNE 2011

The ActionPlanT Roadmap for Manufacturing 2.0

Main Components

Vision

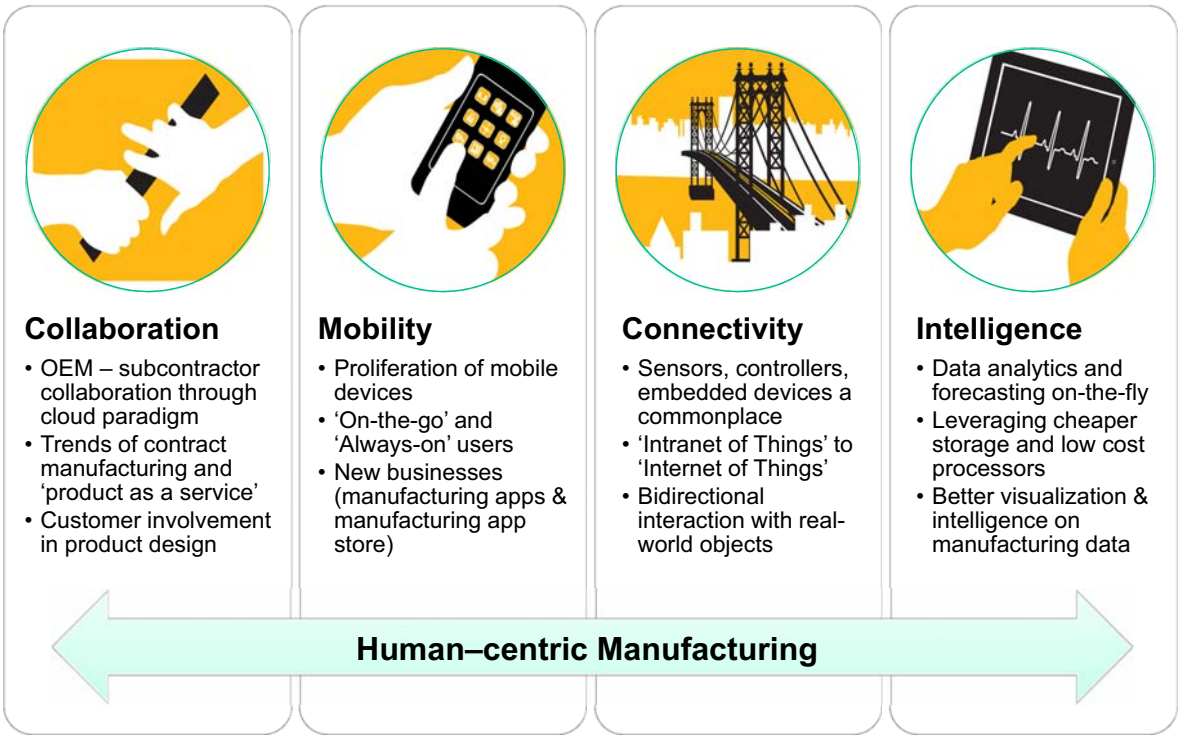
- Based on 4 socio-economic and 4 ICT megatrends
- Proposes 5 ambitions for future enterprises
- Defines Manufacturing 2.0 vision with 5 R&D clusters

ICT Recommendations

- Takes a technology push view
- Expands 4 megatrends into 15 key ICT recommendations for implementation

Research Priorities

- 40 Research Priorities grouped according to 5 R&D clusters
- Integrated in the EFFRA FoF Roadmap



(C) ActionPlanT 2012

Ambitions for Manufacturing Enterprises

On-demand
- Accommodate changing demands & deliver customized products
- Make supply networks agile, interoperable, and manageable

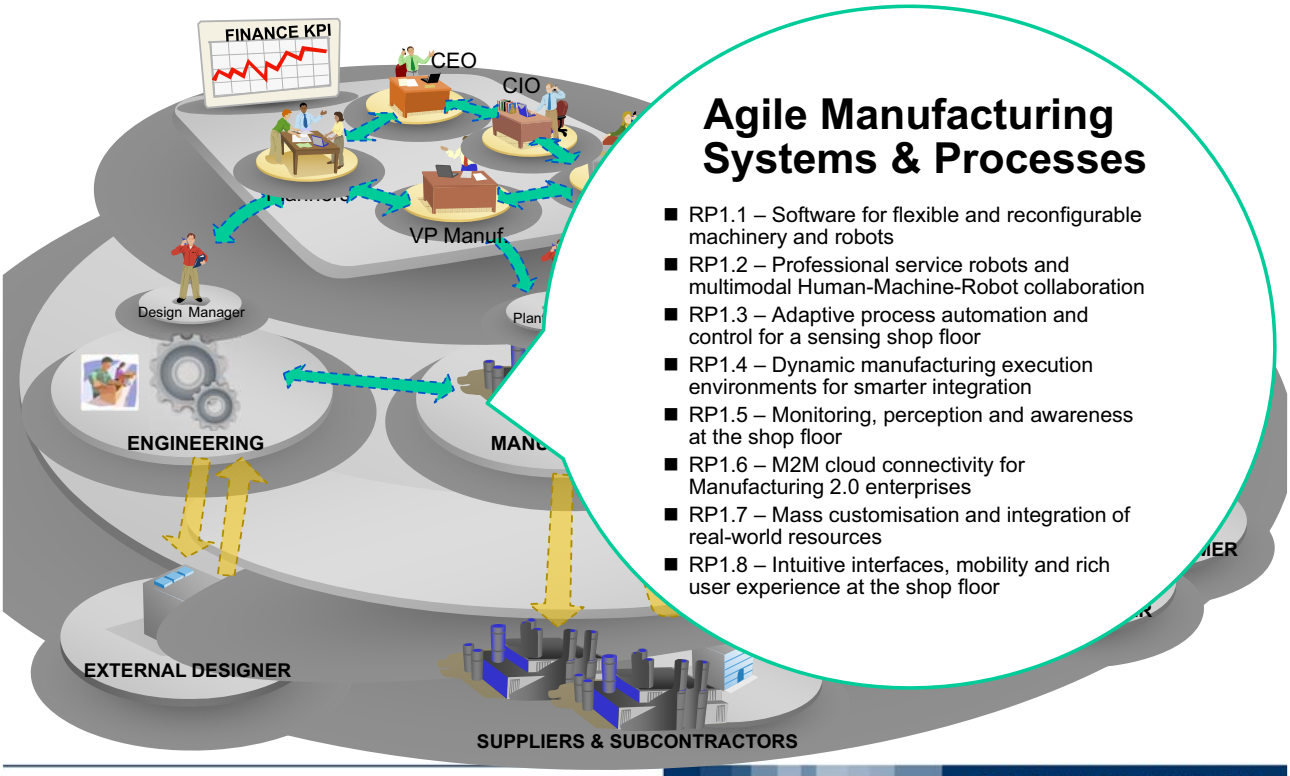
Optimal
- Deliver high quality products that are durable and competitively priced
- Focus not only on the design but also on after-sales services

Innovate
- Faster introduction of collective innovation
- Short turnaround – from laboratory prototype to full-scale production

Green
- Reduce energy footprints on shop floors and increase End-of-Life (EoL) use
- Be compliant with new regulations

Human-centric
- Change perception from being production-centric to human-centric
- More accommodating towards needs of the workforce and customers

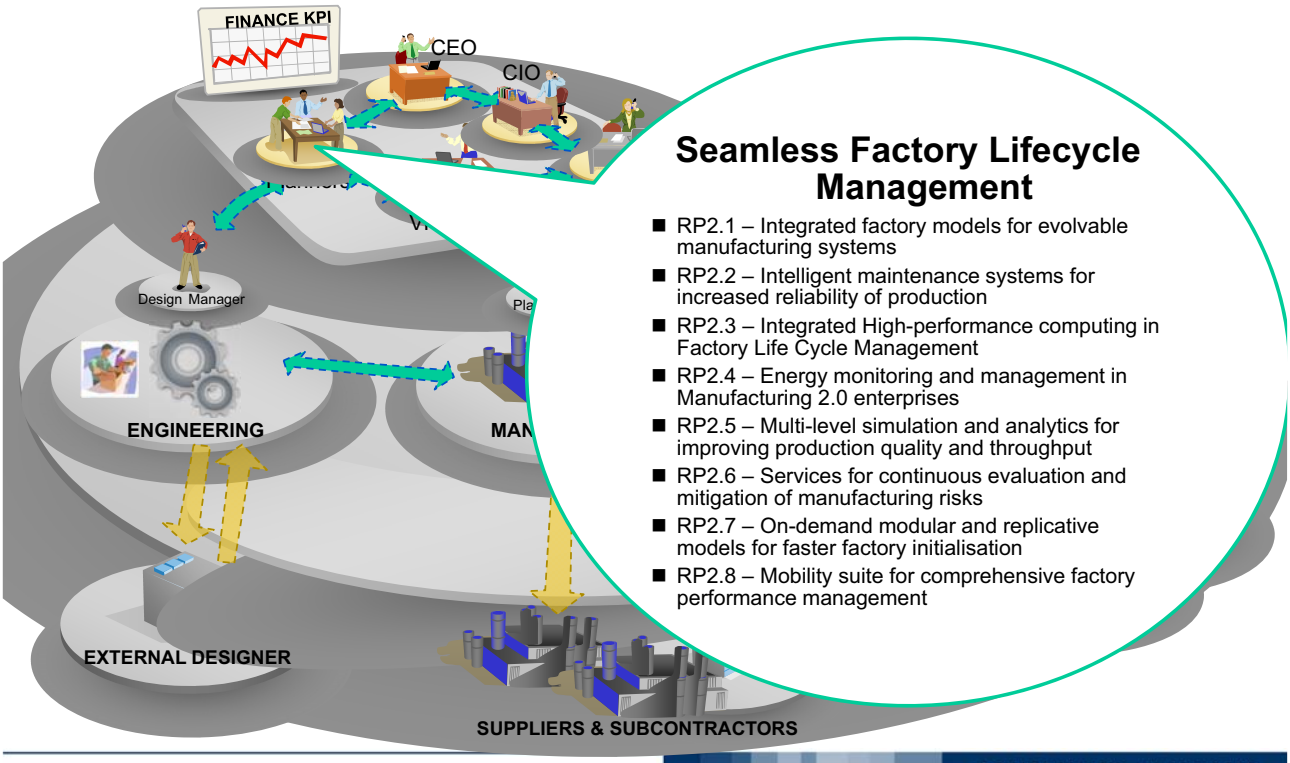
Beyond the Shop Floor
A Manufacturing 2.0 Enterprise



Agile Manufacturing Systems & Processes

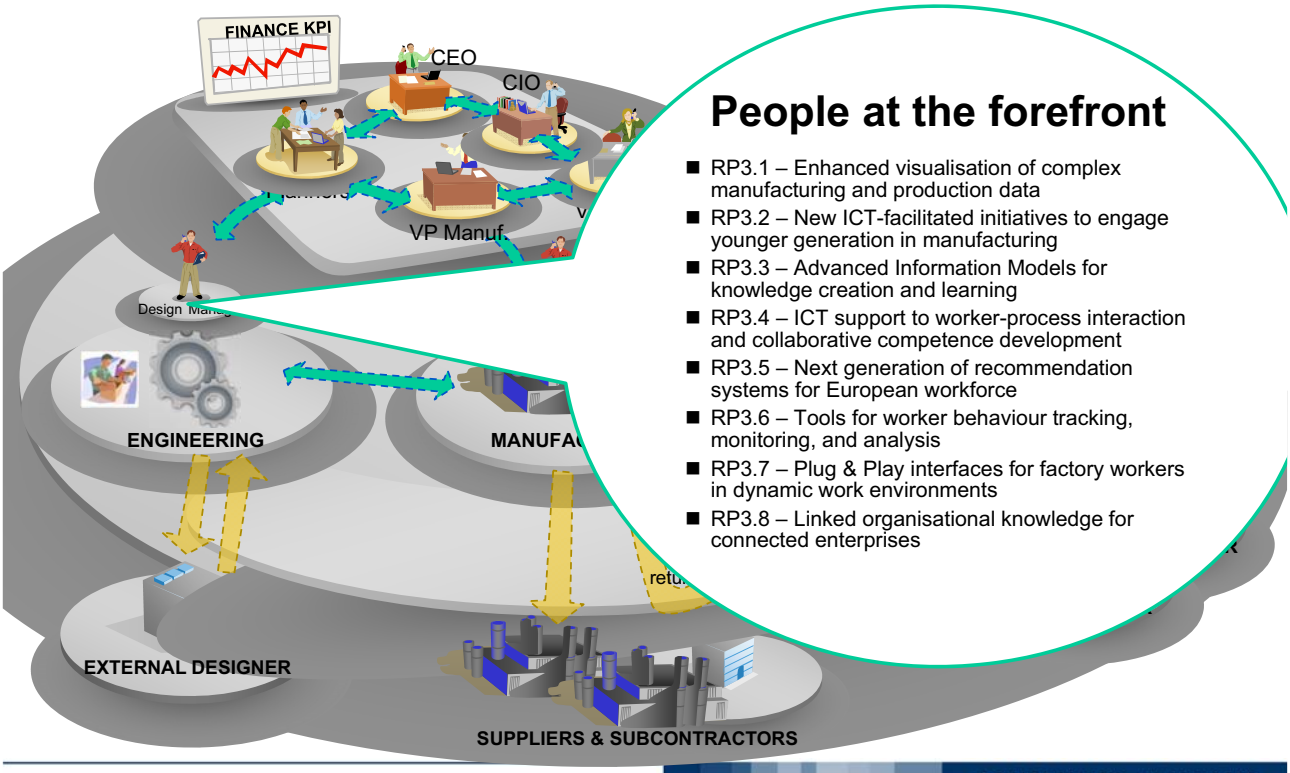
- RP1.1 – Software for flexible and reconfigurable machinery and robots
- RP1.2 – Professional service robots and multimodal Human-Machine-Robot collaboration
- RP1.3 – Adaptive process automation and control for a sensing shop floor
- RP1.4 – Dynamic manufacturing execution environments for smarter integration
- RP1.5 – Monitoring, perception and awareness at the shop floor
- RP1.6 – M2M cloud connectivity for Manufacturing 2.0 enterprises
- RP1.7 – Mass customisation and integration of real-world resources
- RP1.8 – Intuitive interfaces, mobility and rich user experience at the shop floor

Beyond the Shop Floor
A Manufacturing 2.0 Enterprise



Seamless Factory Lifecycle Management

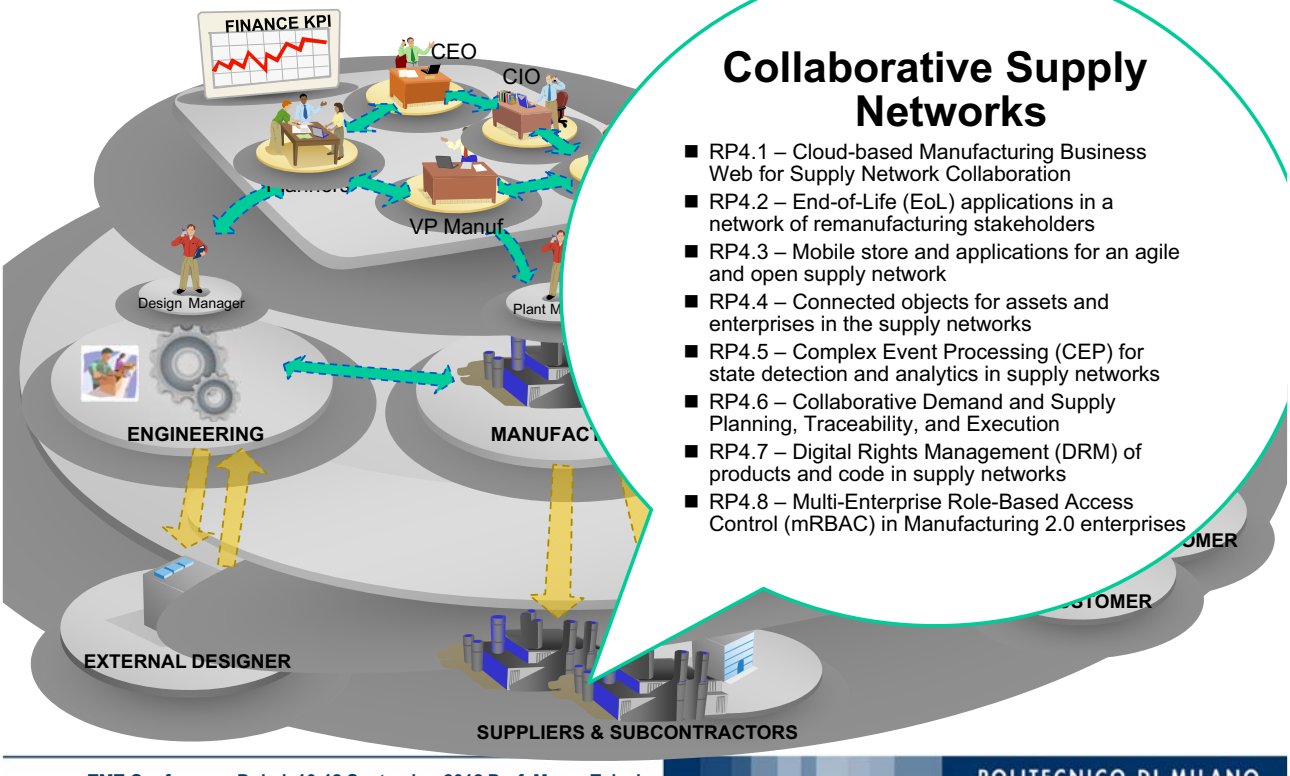
- RP2.1 – Integrated factory models for evolvable manufacturing systems
- RP2.2 – Intelligent maintenance systems for increased reliability of production
- RP2.3 – Integrated High-performance computing in Factory Life Cycle Management
- RP2.4 – Energy monitoring and management in Manufacturing 2.0 enterprises
- RP2.5 – Multi-level simulation and analytics for improving production quality and throughput
- RP2.6 – Services for continuous evaluation and mitigation of manufacturing risks
- RP2.7 – On-demand modular and replicative models for faster factory initialisation
- RP2.8 – Mobility suite for comprehensive factory performance management



People at the forefront

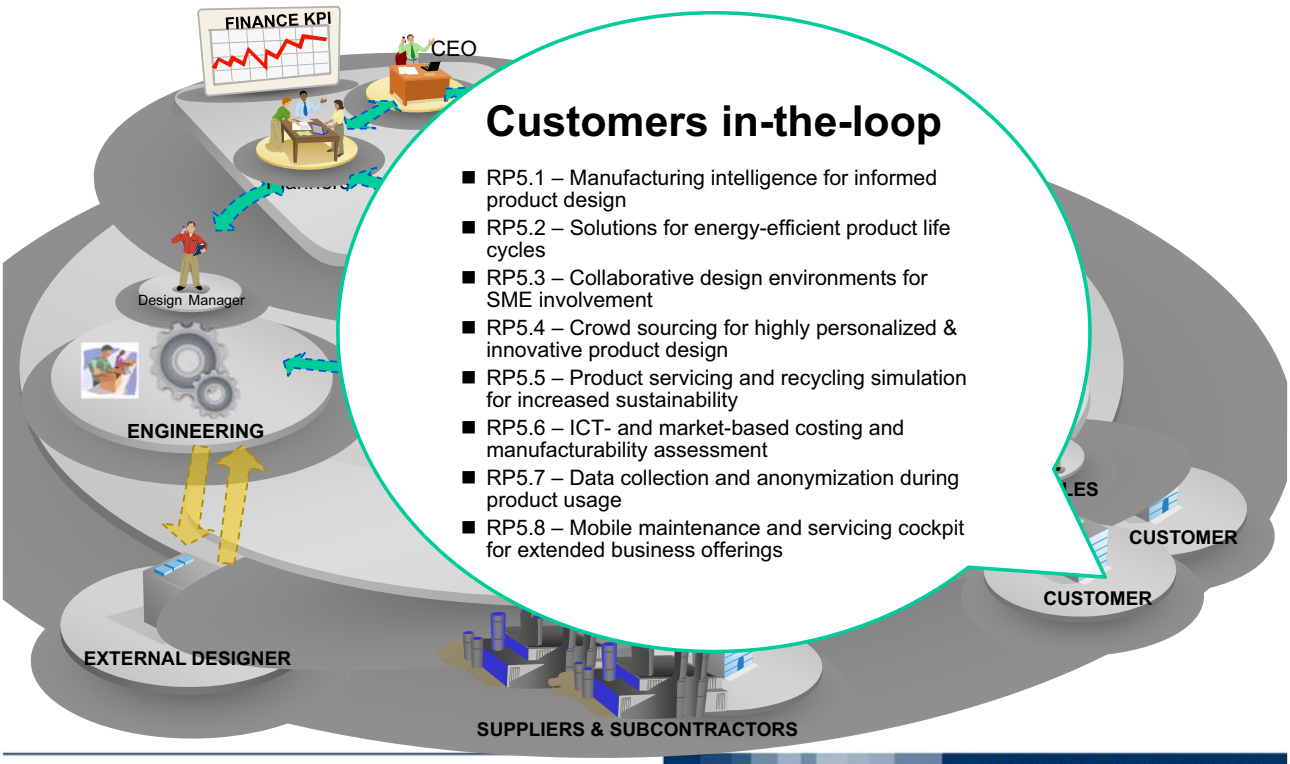
- RP3.1 – Enhanced visualisation of complex manufacturing and production data
- RP3.2 – New ICT-facilitated initiatives to engage younger generation in manufacturing
- RP3.3 – Advanced Information Models for knowledge creation and learning
- RP3.4 – ICT support to worker-process interaction and collaborative competence development
- RP3.5 – Next generation of recommendation systems for European workforce
- RP3.6 – Tools for worker behaviour tracking, monitoring, and analysis
- RP3.7 – Plug & Play interfaces for factory workers in dynamic work environments
- RP3.8 – Linked organisational knowledge for connected enterprises

Beyond the Shop Floor
A Manufacturing 2.0 Enterprise



Collaborative Supply Networks

- RP4.1 – Cloud-based Manufacturing Business Web for Supply Network Collaboration
- RP4.2 – End-of-Life (EoL) applications in a network of remanufacturing stakeholders
- RP4.3 – Mobile store and applications for an agile and open supply network
- RP4.4 – Connected objects for assets and enterprises in the supply networks
- RP4.5 – Complex Event Processing (CEP) for state detection and analytics in supply networks
- RP4.6 – Collaborative Demand and Supply Planning, Traceability, and Execution
- RP4.7 – Digital Rights Management (DRM) of products and code in supply networks
- RP4.8 – Multi-Enterprise Role-Based Access Control (mRBAC) in Manufacturing 2.0 enterprises



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- Prof. Marco Garetti, Politecnico di Milano
- ActionPlanT, http://www.actionplant-project.eu/