Increasing Resource Productivity:

Rationale, Potential and Economic Implications

Based on the Report from the International Resource Panel to the G7

Annual Lecture of the Faculty of Geotechnical Sciences and Environmental Management of the Cyprus University of Technology

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Sources used for this presentation

Various publications from UNEP's International Resource Panel

Chatham House: Lee, B., Preston, F., Kooroshy, J., Bailey, R. and Lahn, G. 2012 *Resources Futures*, December, Chatham House, London

McKinsey Global Institute 2011 *Resource Revolution: Meeting the World's energy, materials, food and water needs*, http://www.mckinsey.com/features/resource_revolution

POLFREE: Policy Options for a Resource Efficient Economy, EU FP7 research project, http://www.polfree.eu/publications

International Resource Panel

The international resource panel was created in 2007 as a science-policy interface in response to economic growth, and resulting escalating use of natural resources and deteriorating environment and climate change.

Its Secretariat is provided by the United Nations Environment Programme (UNEP)

12 Assessments published 2007-2014

1. Assessing Biofuels (2009)
2. Priority Products and Materials (2010)
3. Decoupling Natural Resource Use and Env. Impacts from Eco. Growth (2011)
4. Metal Stocks in Society (2011)
5. Recycling Rates of Metals (2011)
6. Measuring Water Use in a Green Economy (2012)
7. Metal Recycling: Opportunities, Limits, Infrastructure (2013)
8. Environmental Risks and Challenges of Anthropogenic Metal Flows and Cycles (2013)
9. City-Level Decoupling and the Governance of Infrastructure Transitions (2013)
10. Assessing Global Land Use: Balancing Consumption with Sustainable Supply (2014)
11. Building Natural Capital: How REDD+ Can Support a Green Economy (2014)
12. Decoupling Technologies, Opportunities and Policy Options (2014)

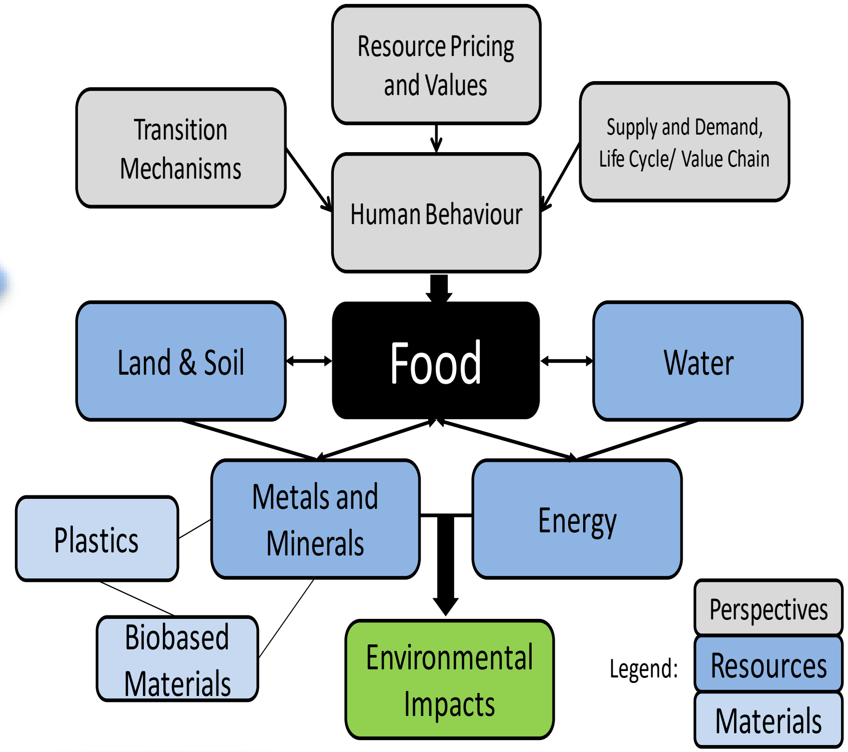
Ongoing work and upcoming reports

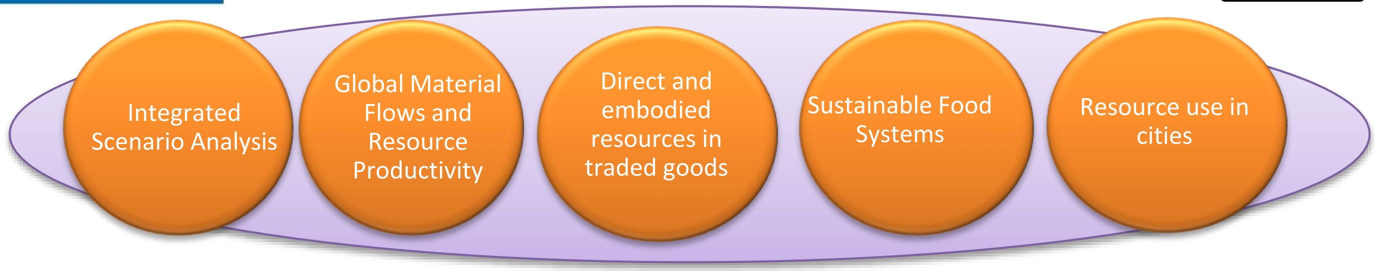
1. Water
2. Land and Soils II
3. Food Systems
4. GHG technologies I and II (supply and demand)
5. Global Material Flows
6. Integrated Scenarios
7. Cities II
8. Marine Resources
9. Circular Economy, Innovation & Remanufacturing
10. Land Restoration, Ecosystem Resilience
11. Rapid Assessment on SDGs
12. Governance of Resources and Poverty Reduction
13. Rapid Assessment on Resource Efficiency Potentials /Prospects

From individual resources to systems thinking

INDIVIDUAL RESOURCES

SYSTEMS THINKING





Rationale for increasing resource efficiency

- Assure the availability of resources for the future, in a context of growth of the human population and global economy
- Volatility of resource and commodity prices
- National resource security in the context of increasing competition for resources that may become geopolitically scarce
- Environmental impacts of resource extraction and use, including greenhouse gas emissions and other pollution, the depletion of renewable resource stocks, and land degradation and the loss of biodiversity.
- Considerable opportunities for resource efficiency to be increased with negative net costs, i.e. with overall economic benefits. (NB depends on the prices of the resources concerned and the ease with which resource efficiency can be increased by policy)

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The imperative of increasing resource efficiency

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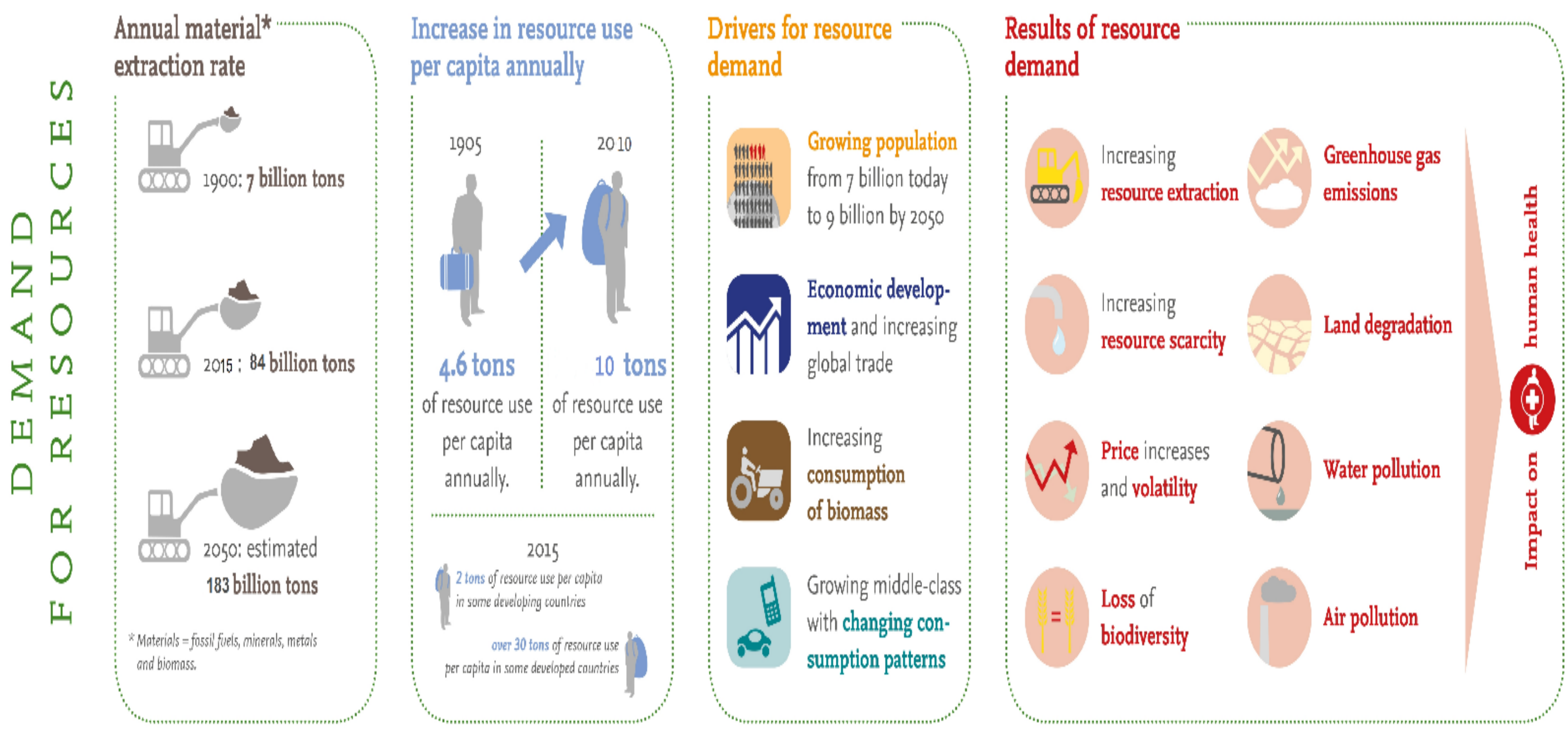
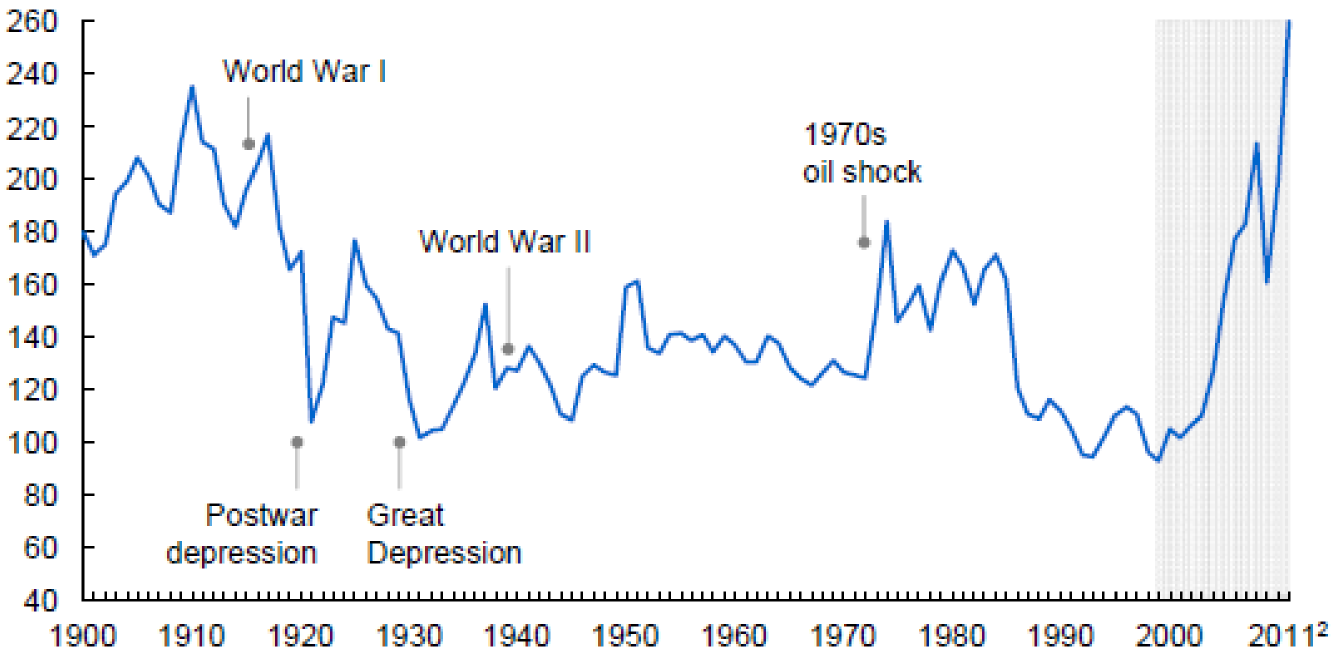


Trends in global resource prices: upward trend this century to 2010

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

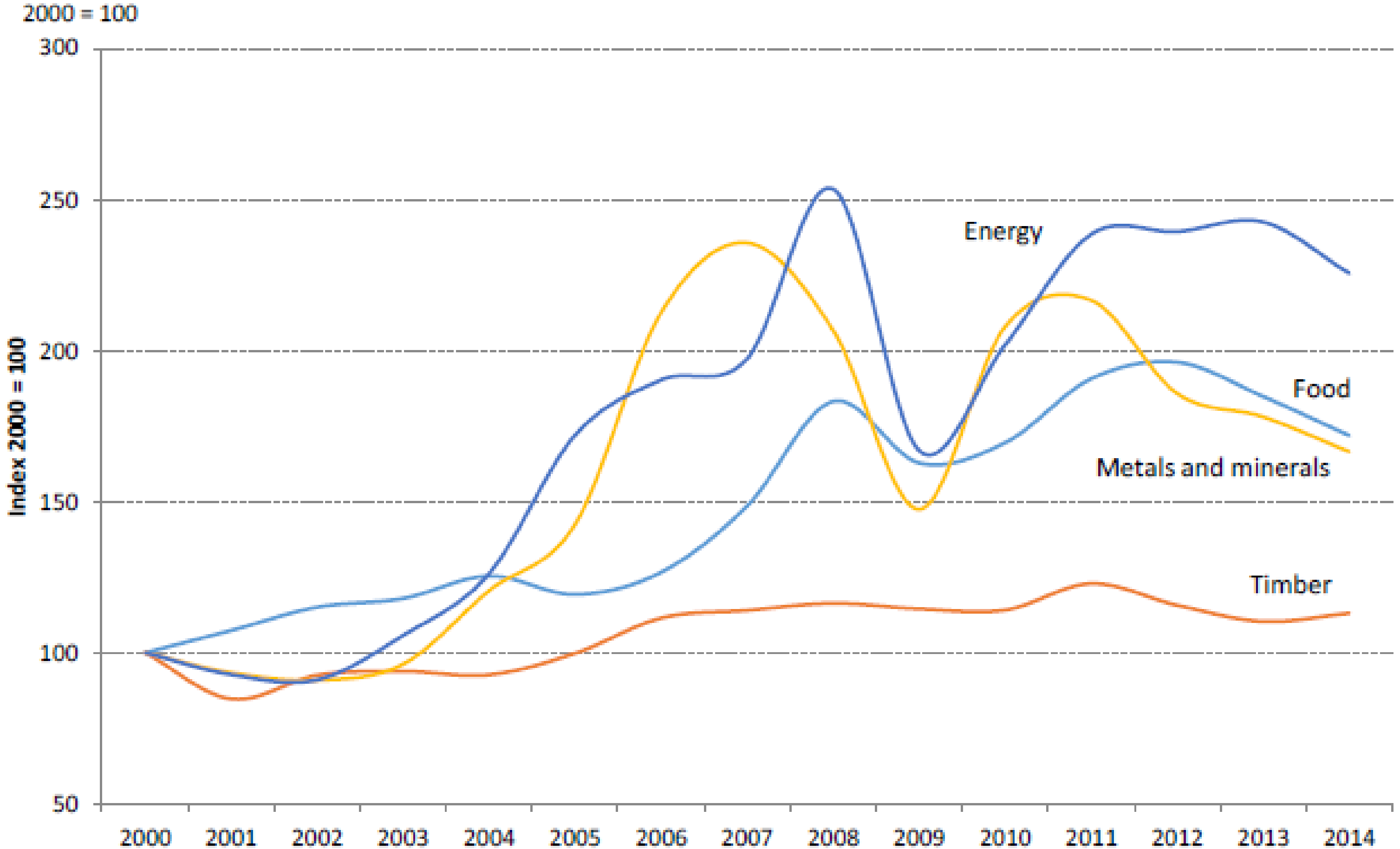
MGI Commodity Price Index (years 1999–2001 = 100)[1]



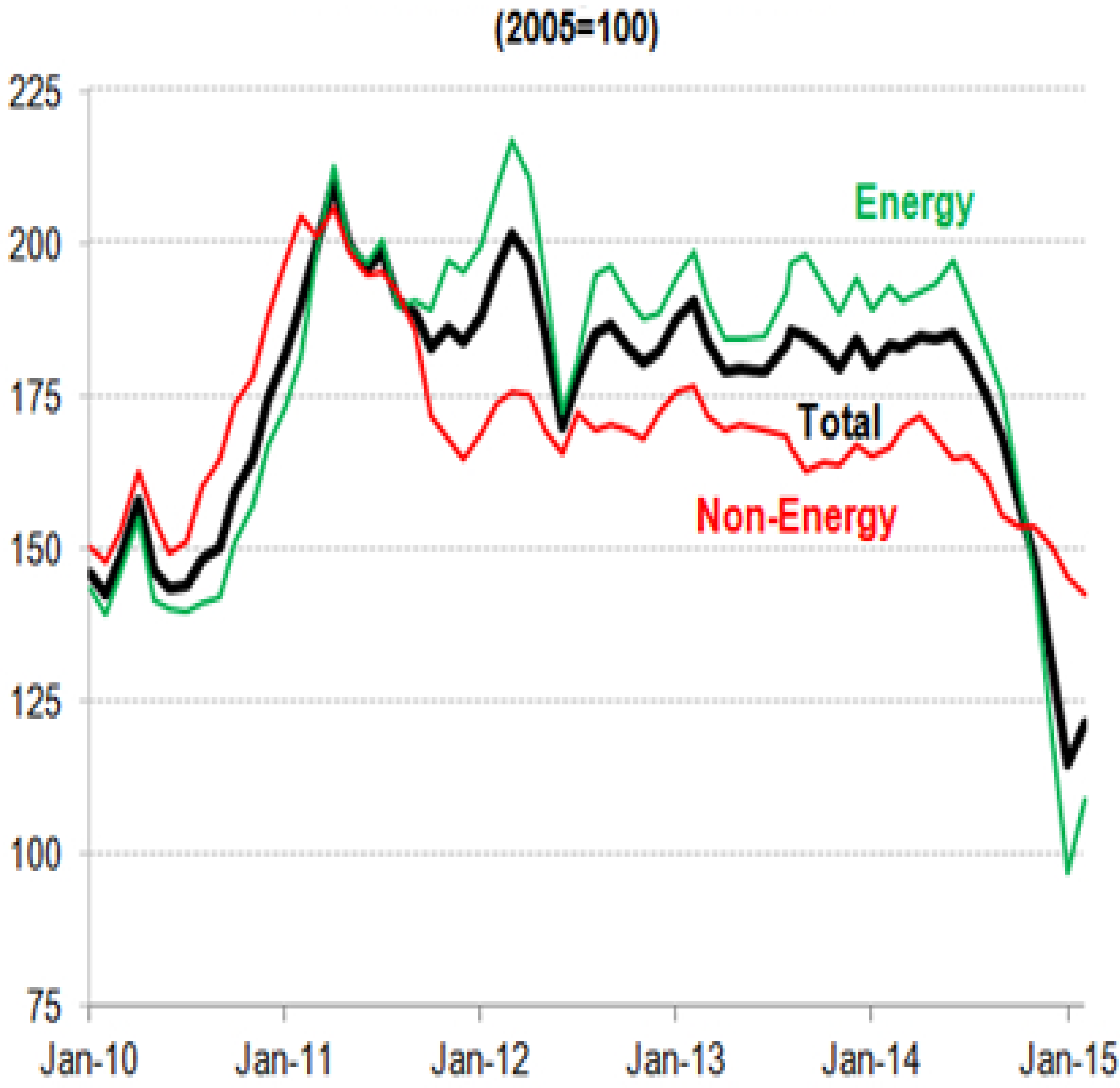
1 See the methodology appendix for details of the MGI Commodity Price Index.
2 2011 prices are based on average of the first eight months of 2011.
SOURCE: Grilli and Yang; Stephan Pfaffenzeller; World Bank; International Monetary Fund (IMF); Organisation for Economic Co-operation and Development (OECD);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

Source: McKinsey

Trends in global resource prices: volatility the norm



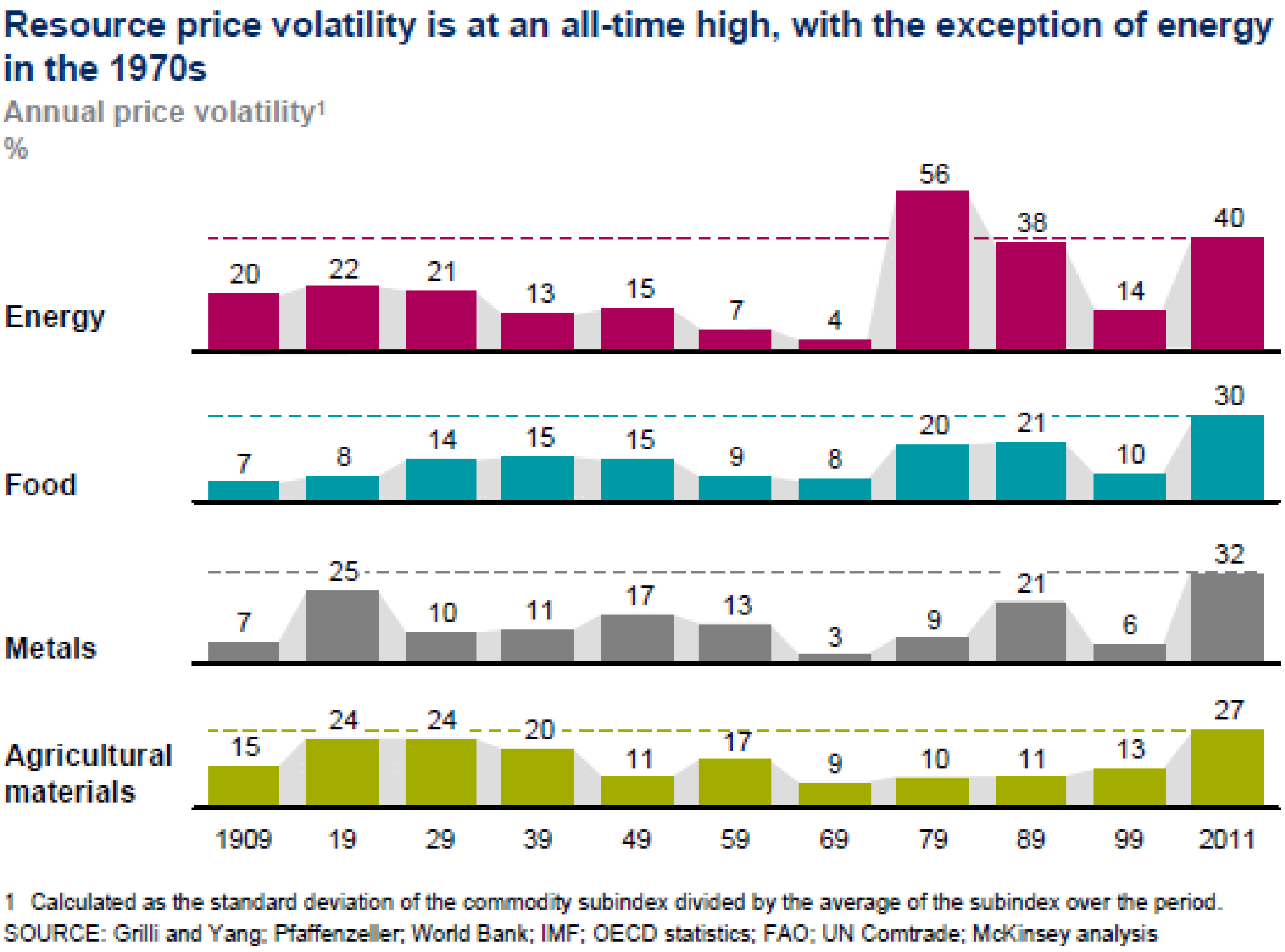
Source: IRP



IMF COMMODITY PRICE INDICES, 2010-2015

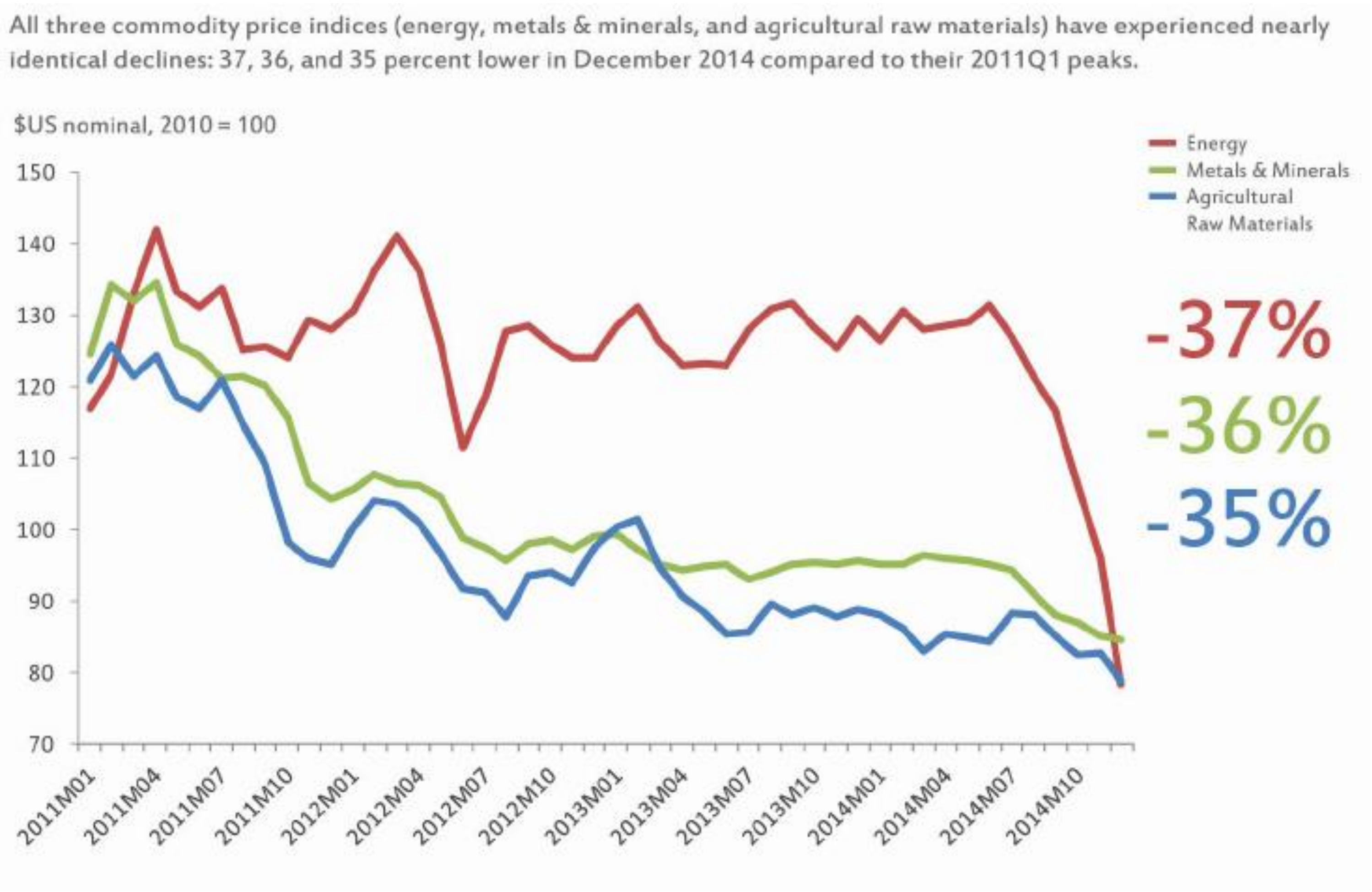
Source: IMF (2016), https://www.imf.org/external/np/res/commod/index.aspx

Trends in global resource prices: volatility at an all time high



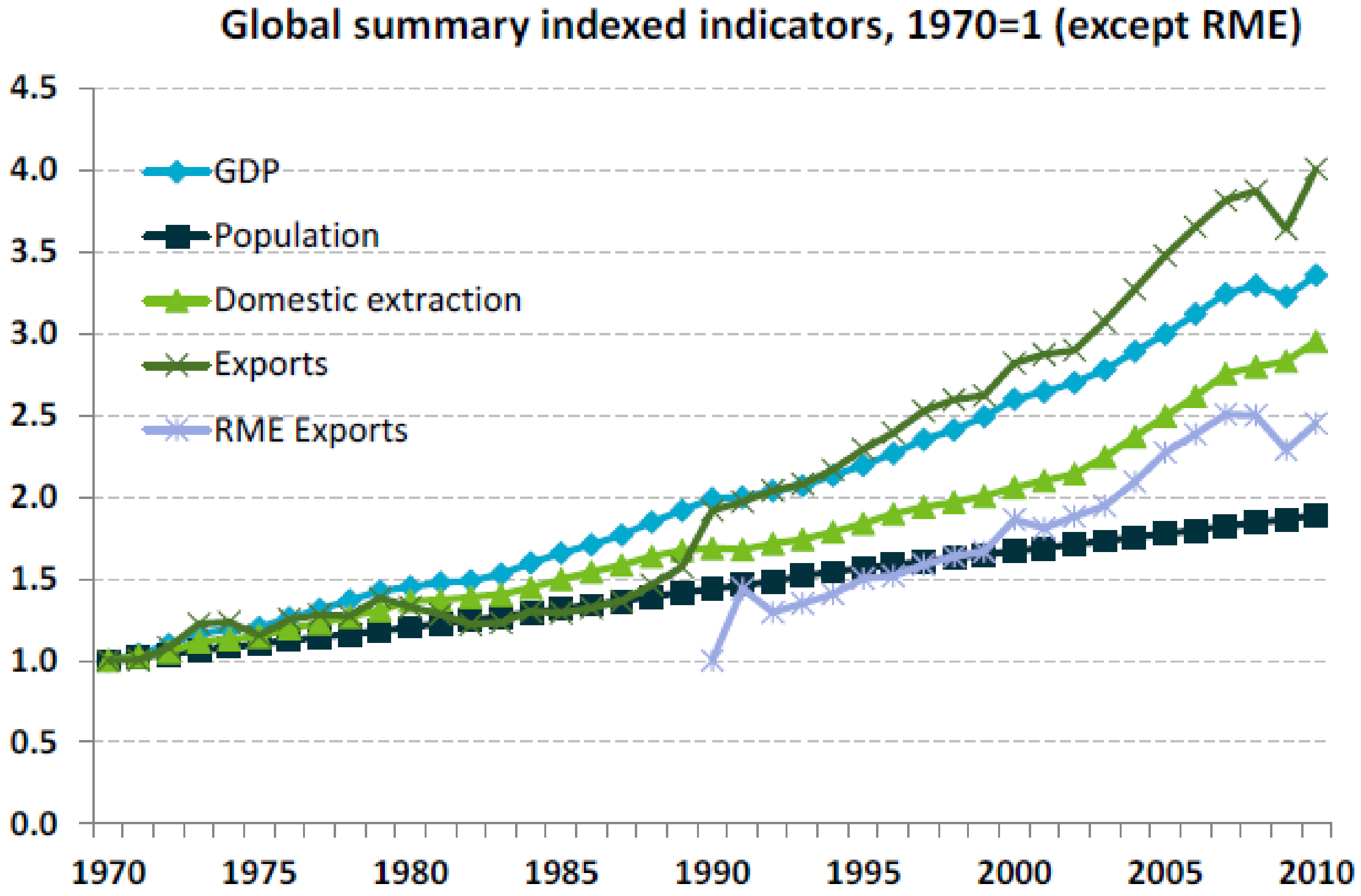
Source: McKinsey

Trends in global resource prices: what goes up can come down



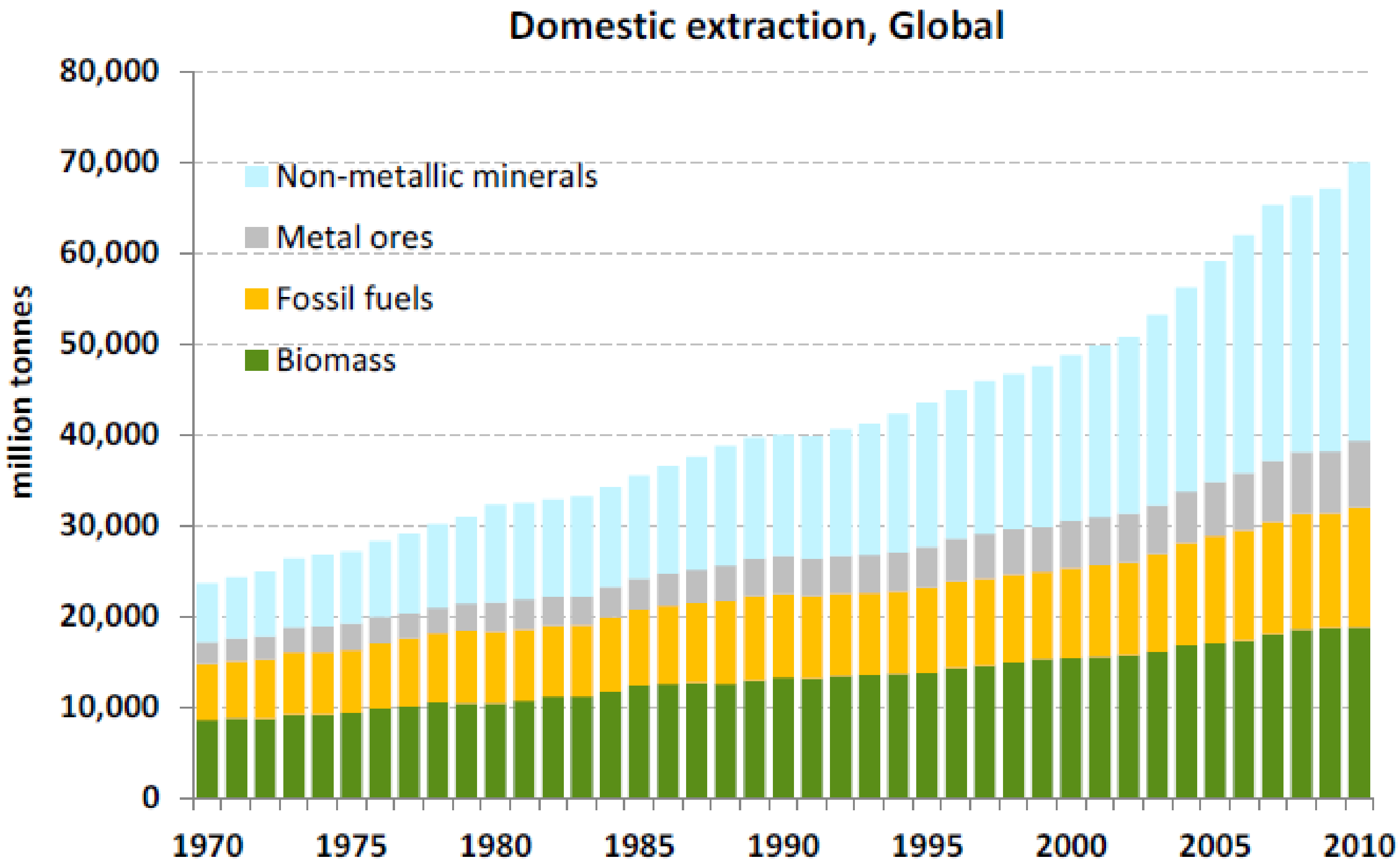
Source: Commodity Markets Outlook, Jan. 2015

Trends in global resource quantities: a growth story (1)



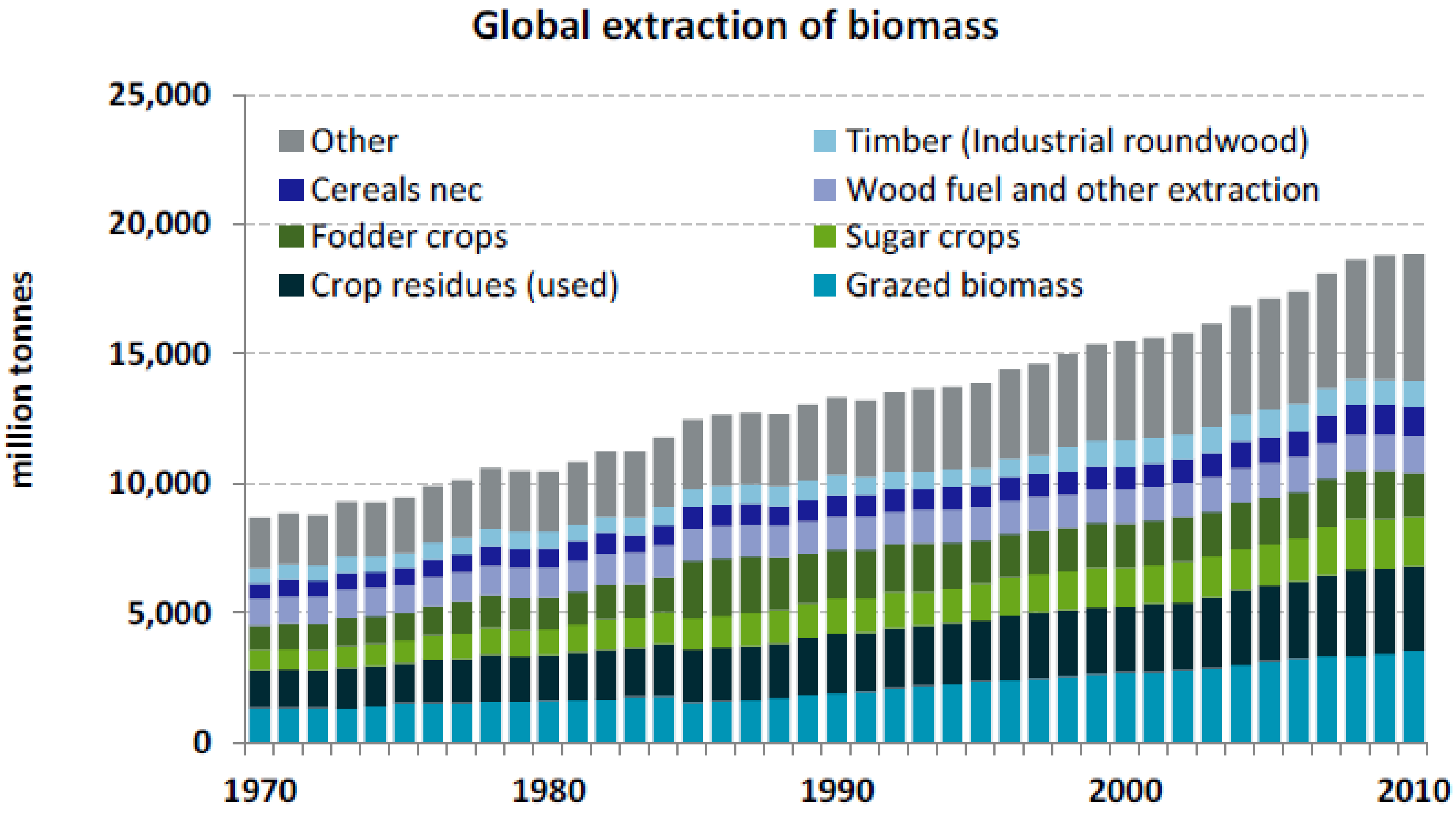
Source: IRP

Trends in global resource quantities: a growth story (2)



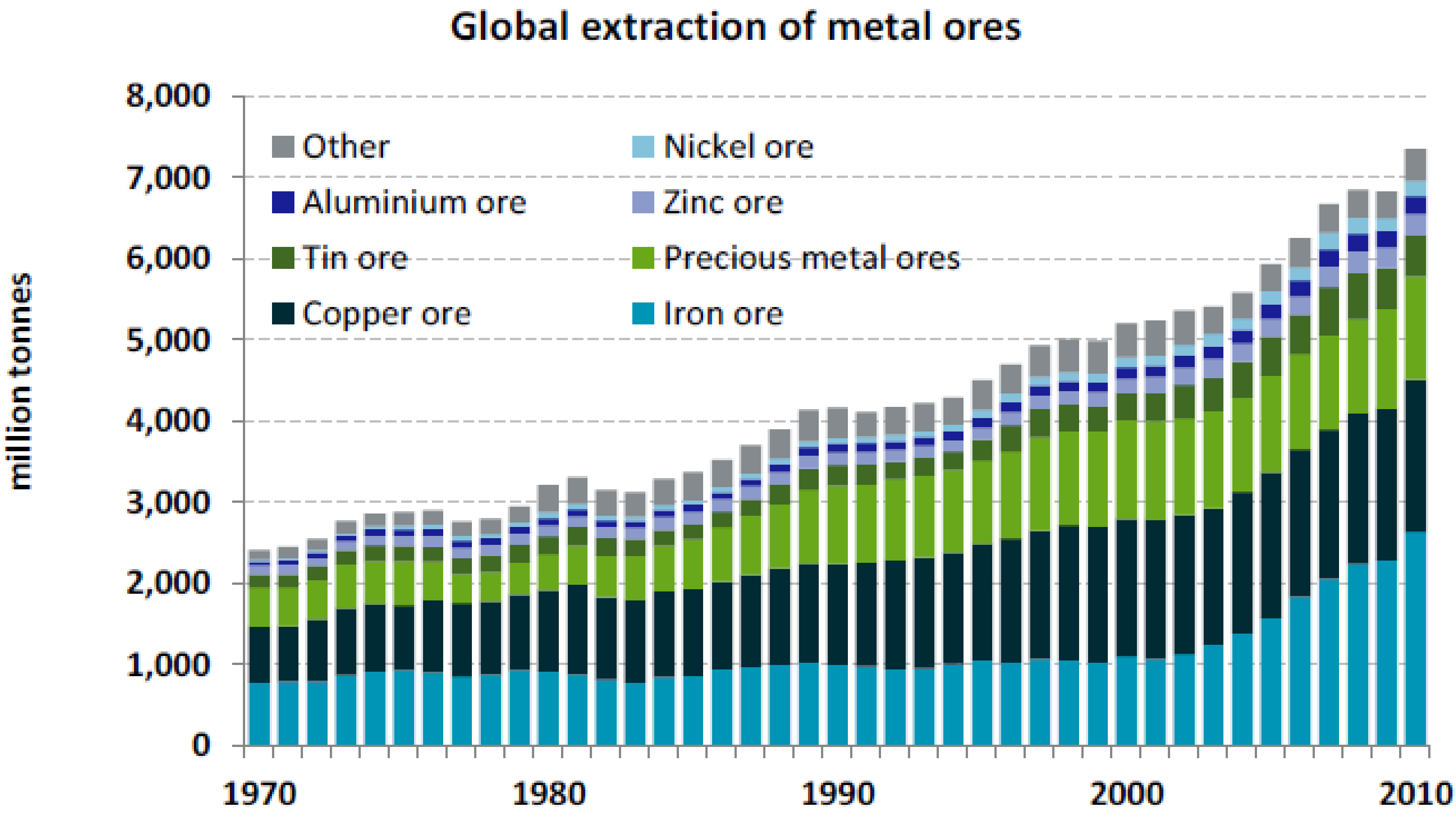
Source: IRP

Trends in global resource quantities: a growth story (3)



Source: IRP

Trends in global resource quantities: a growth story (4)



Source: IRP

Prospects for resource supply (1)

Type of resource	Fraction of global resource extraction	Basis for planetary limits	Potential limit	Reference
Fossil fuels	20%	Absolute scarcity CO_2 emission targets	EU greenhouse gas (GHG) targets (20-20-20 or30% reduction by 2020) Scientific targets (>80% reduction by 2050)	IPCC (2007), EC (2008, 2010), Meinshausen et al. (2009).
Biomass	30%	Maximum human appropriation of net primary production of biomass (HANPP)	Currently, 30%-35% of available biomass is extracted by humans. Target may be stabilization or minor growth	Vitusek et al. (1986), Haberl et al. (2007).
Metal ores and industrial minerals	10%	Absolute scarcity (varies by metal). Most metal ores need high levels of energy to be transformed, implying a 'linkage' to CO_2 emission targets and energy constraints	Focus on 14 critical raw materials identified in the Raw Materials Initiative. Changes in energy and mobility infrastructure (solar cells, batteries) determine future criticality	EC (2010). For linkages with energy use, see Graedel and Van der Voet (2010).

Source: POLFREE

Prospects for resource supply (2)

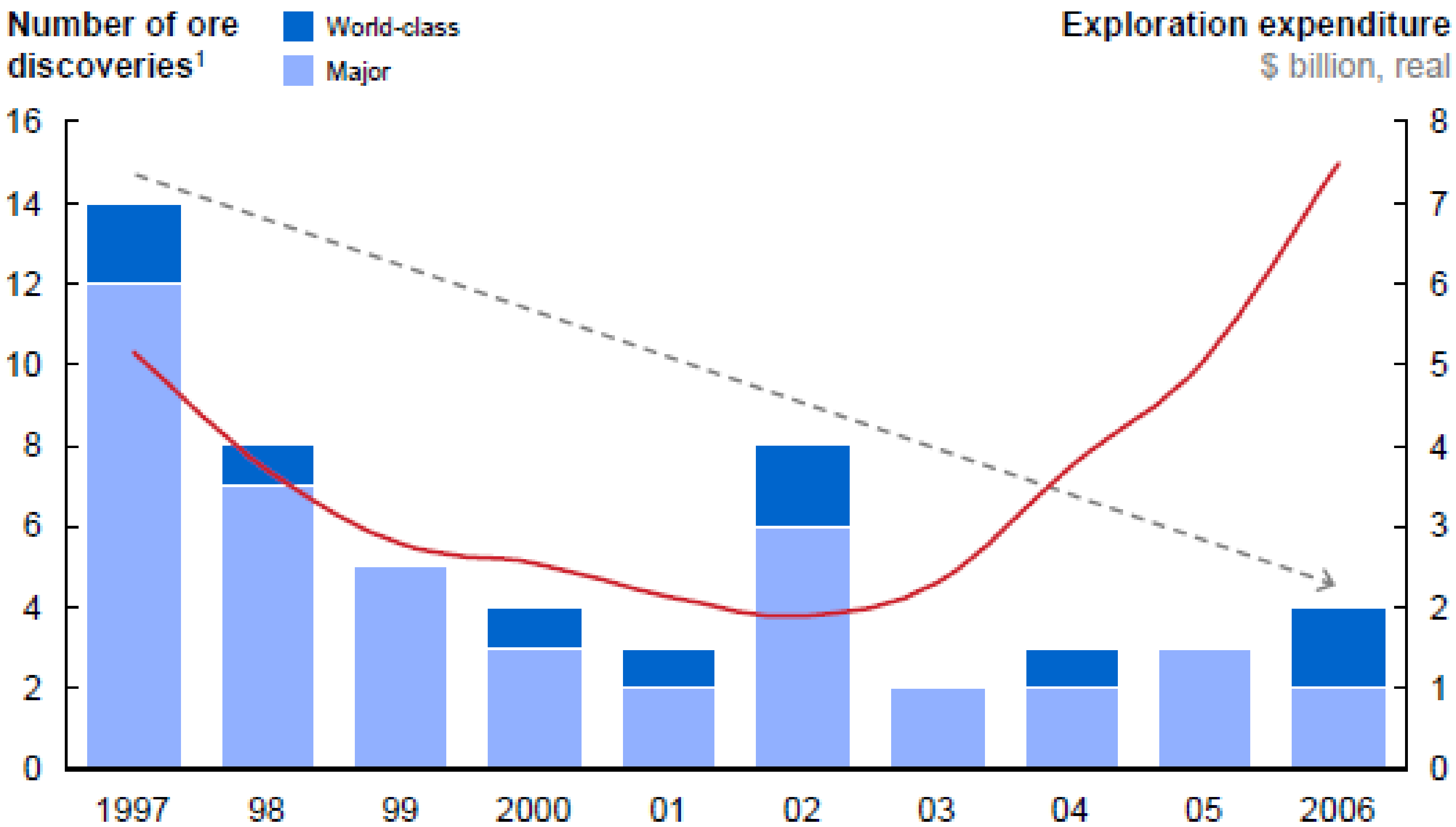
Type of resource	Fraction of global resource extraction	Basis for planetary limits	Potential limit	Reference
Construction minerals	40%	Absolute scarcity seems irrelevant, except in densely populated areas where space for sand, clay and gravel mining is limited.	Implicit targets for construction minerals that need high levels of energy in their production (e.g., cement, ceramics) and linkages to land use targets (e.g. soil sealing)	For linkages: e.g. Hanle et al. (2006). http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf
Land	p.m. (not expressed as mass)	Available bioproductive land, with reservations for nature areas (e.g., rainforests)	Conflicting information about remaining areas that can be converted to agricultural use	Erb et al. (2009), OECD/FAO (2009), Nature (2010a and b), WWF (2010). EC 'Soil sealing guidelines' (2012)
Water	p.m. (usually not included in Material Flow Analysis)	Renewable supply (varies by region); agriculture is dominant user	A global 'water gap' of 30% expected in 2030,	Hoekstra and Chapagain (2007), Water resources group/ McKinsey (2009).

Source: POLFREE

Prospects for resource supply (3)

- With very few exceptions, metals and minerals are not geologically scarce
- However, getting them out of the ground, and to the right place at the right time in the right quantity can:
  - Be expensive
  - Be geographically challenging and geo-politically uncertain
  - Require substantial investment and infrastructure
  - Involve long lead times

Replenishing reserves of materials is increasingly difficult and expensive

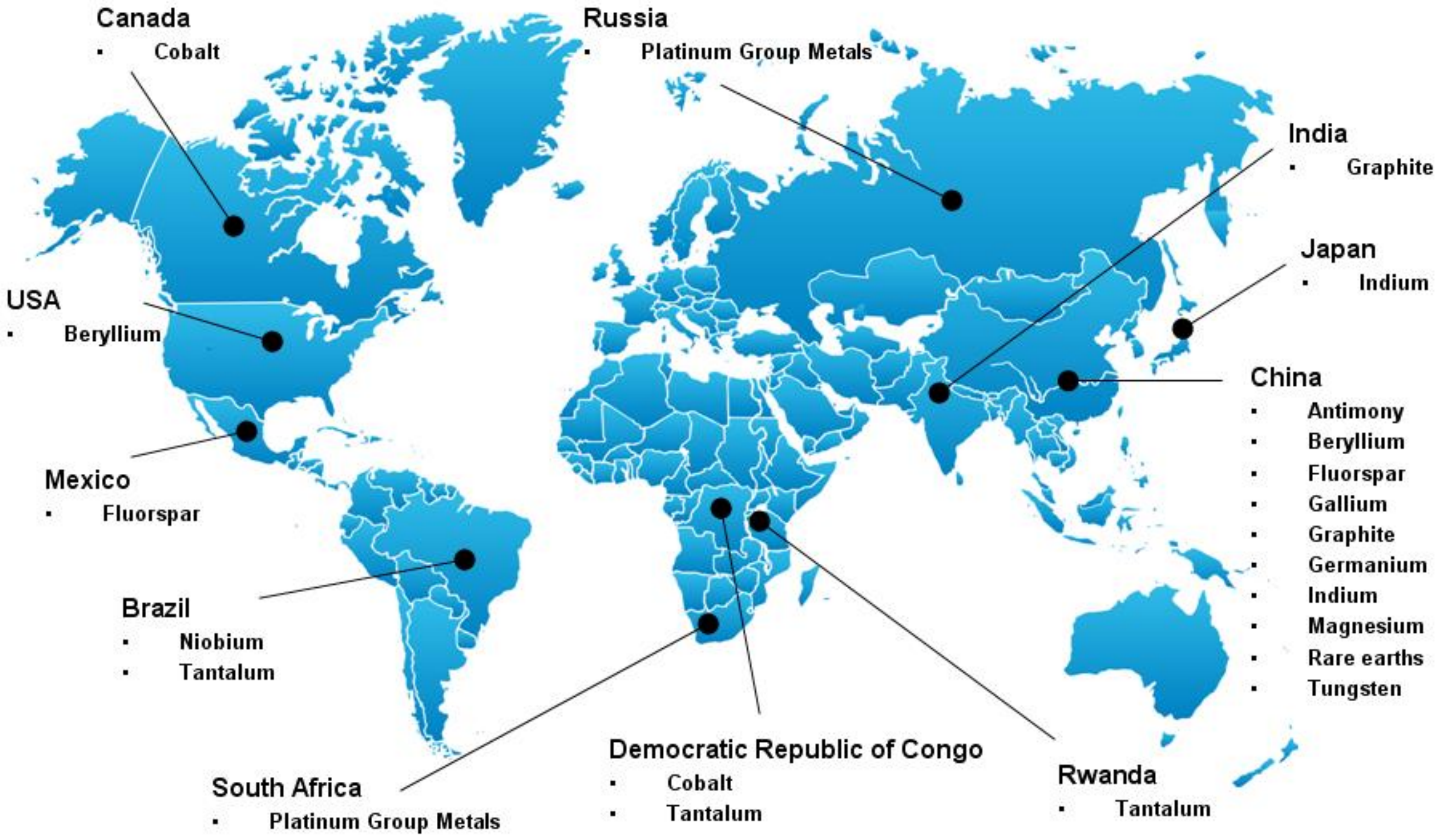


1 All metal and mining materials; latest data available to 2006.

SOURCE: BHP Billiton; USGS; MEG Minerals 2009

Source: McKinsey

Production concentration of critical raw mineral materials



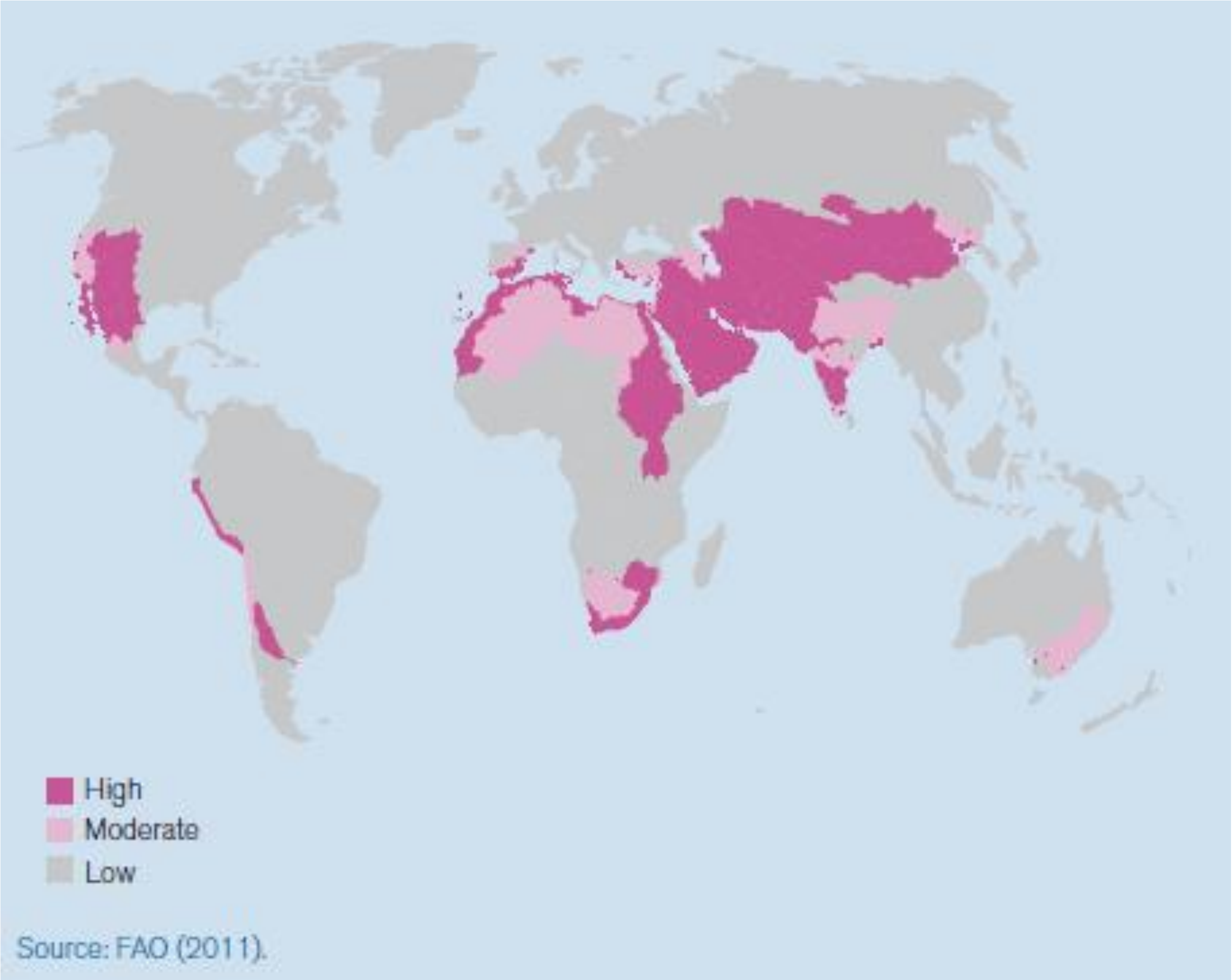
Source: http://europa.eu/rapid/press-release_MEMO-10-263_en.htm

Prospects for resource supply (4)

- Renewable resources are quite different
- Many such resources are in effect being ‘mined’ (i.e. renewable stocks are not being replaced): e.g. tropical forests, fish
- Soils are subject to widespread degradation and even desertification
- Water is largely untradable over long distances and many countries are subject to water stress, exacerbated by climate change

Prospects for water supply

Global distribution of physical water scarcity



Source: Chatham House

Prospects for resource demand (1)

1. Population will increase by at least 2 billion by 2050.
2. Up to three billion more middle-class consumers, with greatly increased per capita resource use, will emerge in the next 20 years.
3. Finding new sources of supply, and extracting them, is becoming increasingly challenging and expensive.
4. Resources have increasingly close links. The correlation between resource prices is now higher than at any point over the past century, and a number of factors are expected to drive a further increase.
5. The impact of strongly rising demand for resources on the environment could restrict supply. Increased soil erosion, the excessive extraction of groundwater reserves, ocean acidification, declining fish stocks, deforestation, the unpredictable effects of climate change, and other environmental concerns are creating increasing constraints on the production of resources and broader economic activity.
6. Growing concern about inequality might also require action. A large share of the global population still lacks access to basic needs such as energy, food, and water.

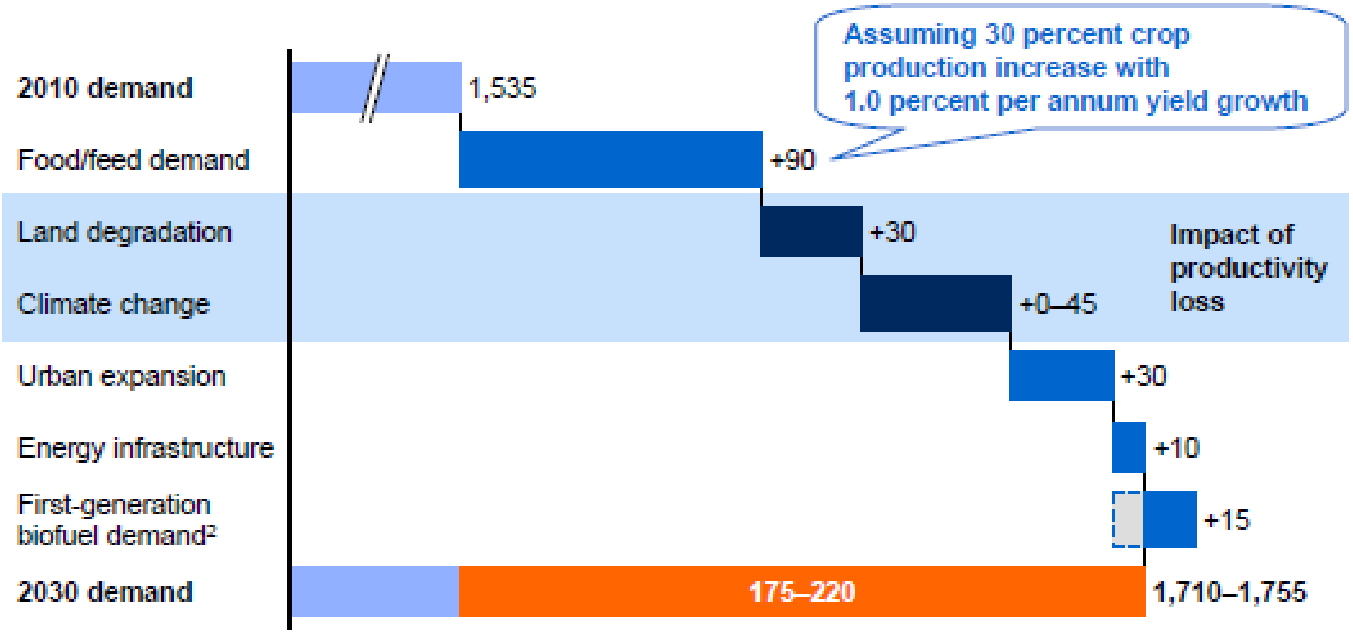
Source: McKinsey

Prospects for resource demand (2)

To meet 2030 food, feed, and fuel demand would require 175 million to 220 million hectares of additional cropland

Base-case cropland demand[1] by 2030

Million hectares



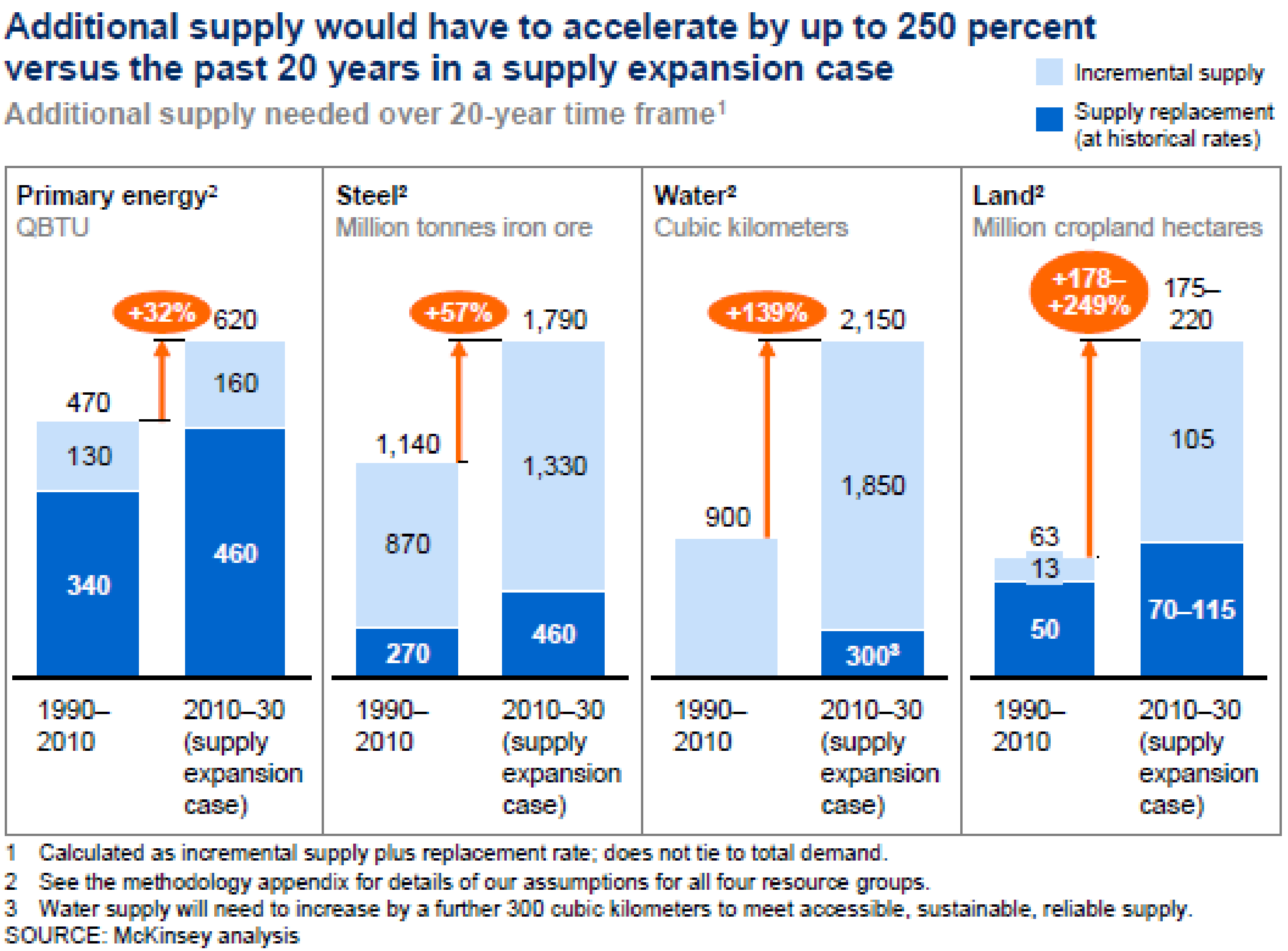
1 Defined as "arable land and permanent crops" by the FAO.

2 As 30–80 percent of biomass input for biofuel production is fed back to livestock feed, the cropland required to produce feed crops would be reduced by about ten million hectares.

SOURCE: International Institute for Applied Systems Analysis (IIASA); FAO; International Food Policy Research Institute; Intergovernmental Panel on Climate Change; Global Land Degradation Assessment; World Bank; McKinsey analysis

Source: McKinsey

Prospects for resource demand (3)



Source: McKinsey

Putting supply and demand together

Potential shortages of materials and the possible economic impact determined our focus on steel

- Minimal concern
- Some concern
- Major cause for concern

	Potential for shortage				Impact of shortage			
Criteria	Reserves (based on USGS)	Short-term shortages	Geographic concen-tration risk	Recycla-bility	Global market size[1]	Lack of substitutes	Contribu-tion to production process	Resource linkages with energy/ food
Unit	Number of years (2010 production)	Historical price volatility 2004–09; standard deviation/mean %	Low/ medium/ high risk	Recycling rate, United States %	2010, $ billion	Low/ medium/ high risk	Low/ medium/ high risk	Low/ medium/ high risk
Iron ore	75	30	Low	61	206	High	High	High
Coking coal	<50	34	Medium	Low	151	Medium	High	High
Copper	39	30	Medium	32	144	Medium	High	Medium
Gold	20	40	Low	High	104	Medium	Low	Low
Bauxite/Al[2]	133	18	High	48	72	Medium	High	Medium
Zinc	21	45	Low	30	28	Low	High	Low
Nickel	49	42	Low	43	29	Low	High	Low
Silver	23	29	Low	Medium	14	Low	Medium	Low
Platinum GM[3]	174	24	Medium	High	14	High	Medium	Low
Lead	20	30	Low	77	20	Medium	High	Low
Tin	20	24	Medium	34	7	Low	High	Low
Rare earth	846	42	High	Medium	11[4]	High	High	High
Phosphate	406	62	High	Low	21	High	High	High
Potash	283	68	Medium	Low	18	High	High	High

Source: McKinsey

Critical materials: the EU 14

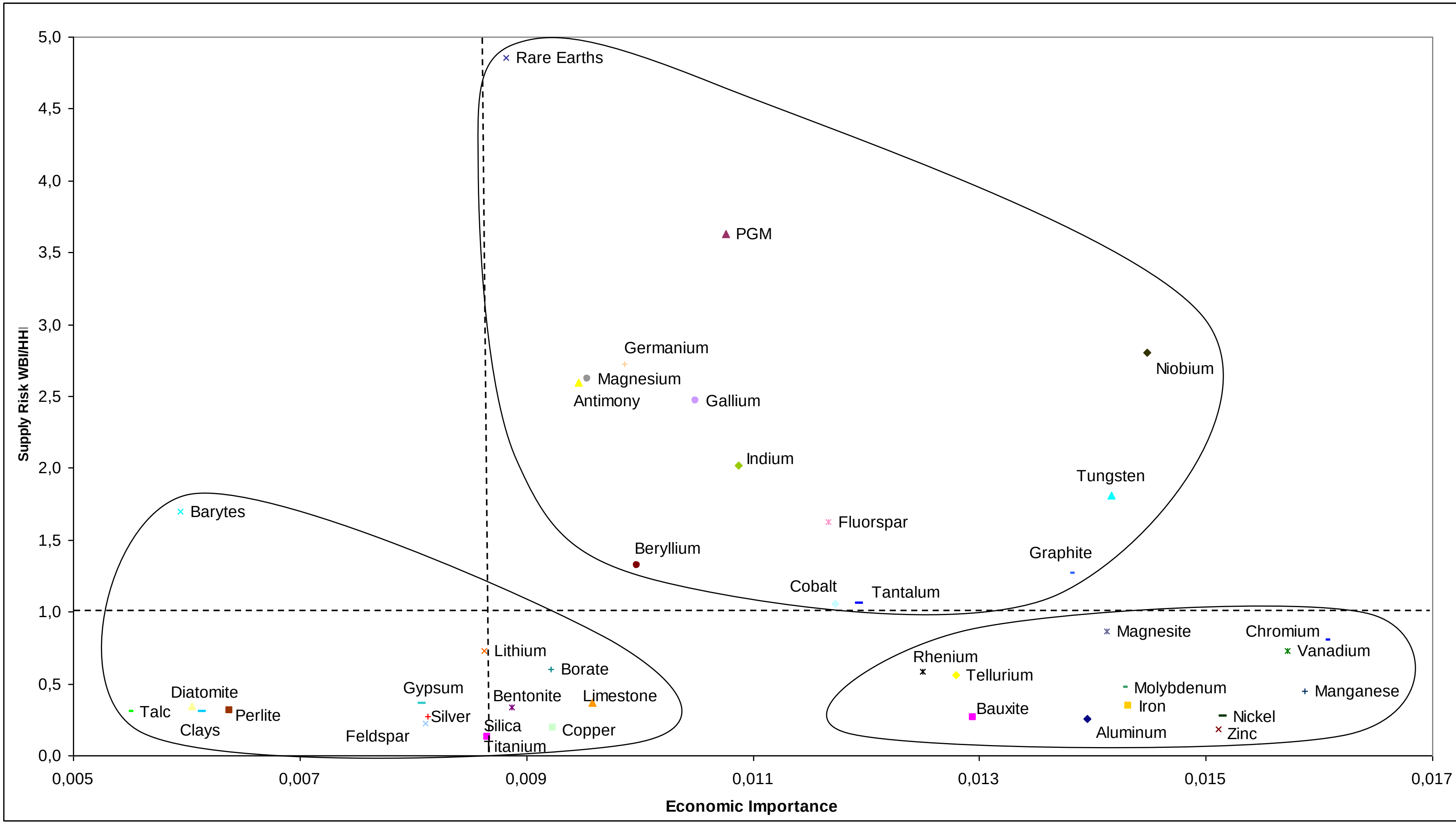
List of critical raw materials at EU level (in alphabetical order)

Antimony	Indium
Beryllium	Magnesium
Cobalt	Niobium
Fluorspar	PGMs (Platinum Group Metals)
Gallium	Rare earths
Germanium	Tantalum
Graphite	Tungsten

[1] The Platinum Group Metals (PGMs) regroups platinum, palladium, iridium, rhodium, ruthenium and osmium.
[2] Rare earths include yttrium, scandium, lanthanum and the so-called lanthanides (cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)

Source: http://europa.eu/rapid/press-release_MEMO-10-263_en.htm

Critical materials: criticality analysis



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The promise of double decoupling

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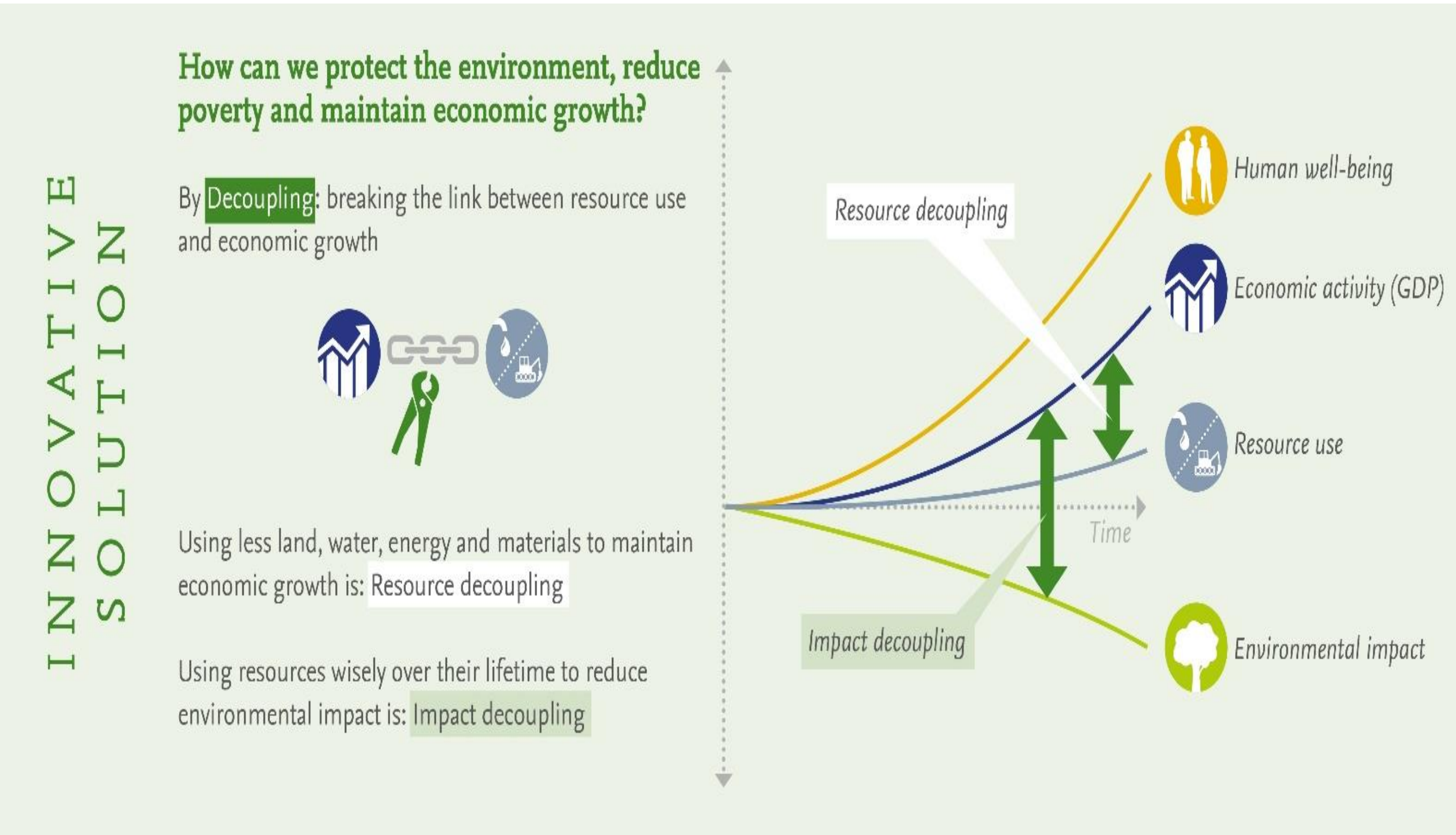

Key messages from the Summary for Policy Makers

http://www.unep.org/resourcepanel/KnowledgeResources/AssessmentAreasReports/Cross-CuttingPublications/tabid/133337/Default.aspx

Headline Message:

"With concerted action, there is significant potential for increasing resource efficiency, which will have numerous benefits for the economy and the environment"

By 2050 policies to improve resource efficiency and tackle climate change could

- **reduce global resource extraction** by up to **28%** globally.
- **cut global GHG emissions** by around **60%**,
- boost the value of **world economic activity** by **1%**

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1. *Key Message:*

"Substantial increases in resource efficiency are essential to meet the Sustainable Development Goals – enabling development while protecting the environment"

SDGs directly dependent on natural resources

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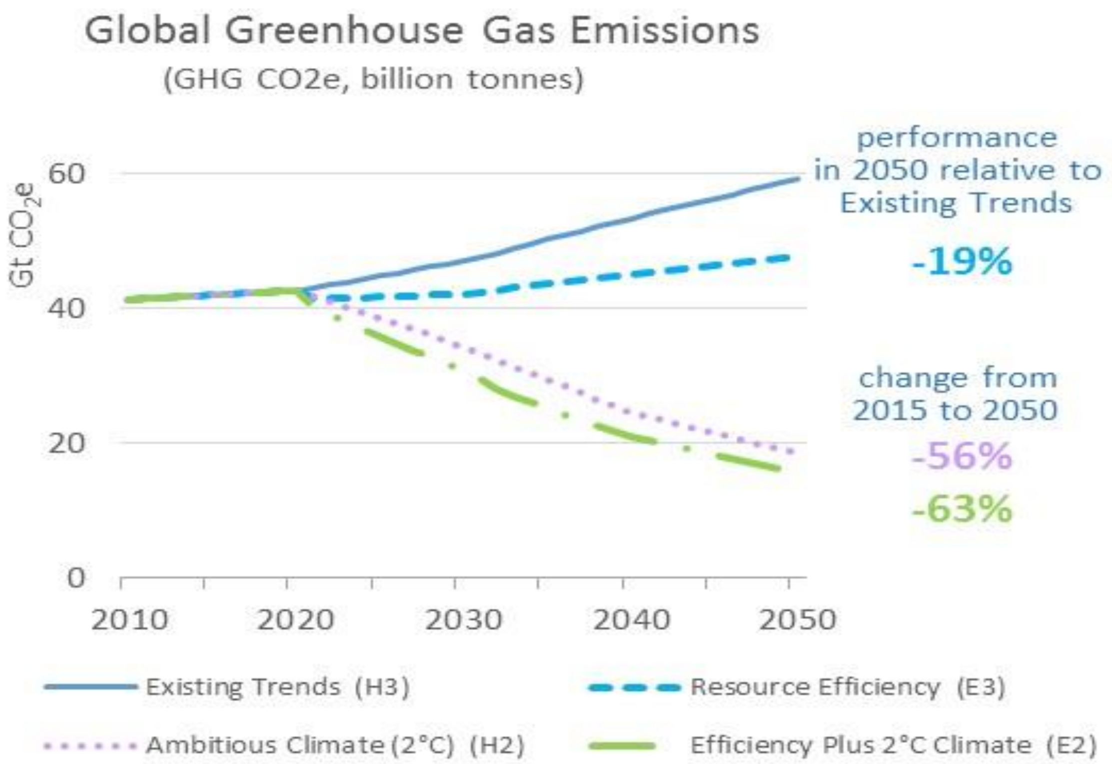
2. Key Message:

"Improving resource efficiency is indispensable for meeting climate change targets cost effectively"

Modelling by Hatfield-Dodds, S., CSIRO, Australia



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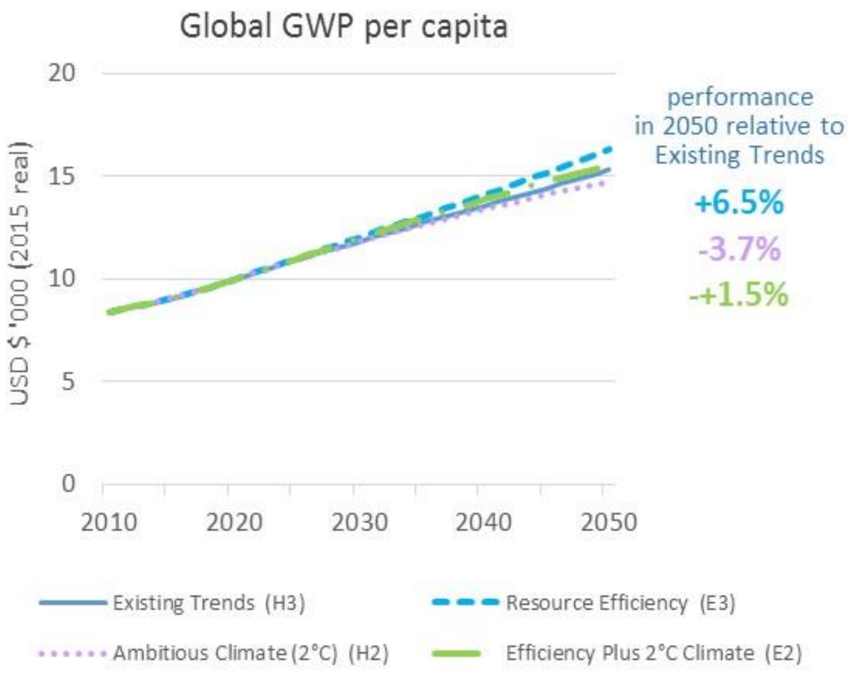
3. Key Message:

"Resource efficiency can contribute to economic growth and job creation"

Modelling results differ in size, but all of them show that increasing resource efficiency can lead to **higher economic growth and employment**, often even when environmental benefits are not accounted for



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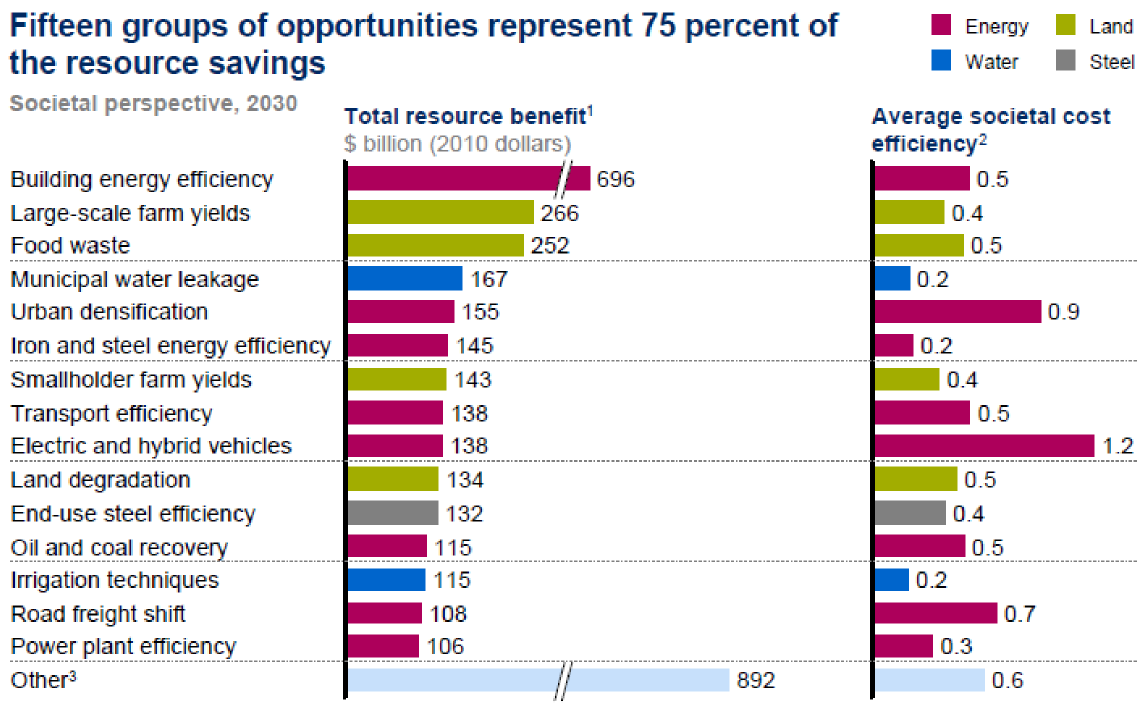
4. Key Message:

"There are substantial areas of opportunity for greater resource efficiency"

The top 15 categories of resource efficiency potential



1 Based on current prices for energy, steel, and food plus unsubsidized water prices and a shadow cost for carbon.
2 Annualized cost of implementation divided by annual total resource benefit.
3 Includes other opportunities such as feed efficiency, industrial water efficiency, air transport, municipal water, steel recycling, wastewater reuse, and other industrial energy efficiency.

SOURCE: McKinsey analysis

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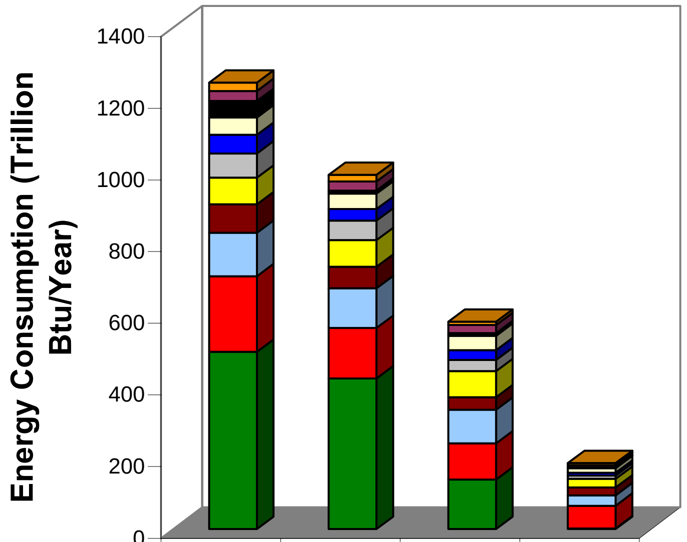
5. *Key Message:*

"Increased resource efficiency is practically attainable"

Energy consumption and saving potential by equipment type in US mining industry



	Current	Best Practice	Practical Minimum	Theoretical Minimum
Blasting	24	18	10	5
Dewatering	28	25	23	7
Separations	46	8	7	2
Electric Equipment	48	43	40	13
Crushing	52	32	27	8
Drilling	67	54	32	9
Ancillary Operations	75	75	72	24
Digging	79	60	35	22
Ventilation	122	111	94	29
Materials Handling-Diesel	211	141	101	63
Grinding	494	420	138	2

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Conclusions from the report: Realising the potential

- Markets will not achieve higher rates of resource efficiency by themselves
- There are significant barriers to the increases in resource efficiency which are required, but they can be removed
- Public policy and political will be needed and countries required to take concerted action
- EU's Circular Economy Package (CEP), and G7 Alliance on Resource Efficiency, are steps in the right direction, but
  - Should be scaled up and intensified
  - CEP Plan of Action needs to be made more specific, with targets and timescales

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Policy Briefs: policy lessons from the report

1. Imperative for Resource Efficiency
2. Integrated Modelling of Resource Efficiency and Climate Policy
3. Economics of Resource Efficiency
4. Aligning Resource Efficiency and Economic Efficiency
5. Coordinating Supply Chains
6. Resource-efficient Cities and Transport in Urban Areas
7. Resource efficient electricity systems
8. Resource-efficient food systems
9. Managing the transition, possible “losers” from resource efficiency
10. Transformation to a Sustainable World

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Source: AMEC, & BioIS. (2013). The opportunities to business of improving resource efficiency. Final Report to the European Commission. : AMEC Environment & Infrastructure and Bio Intelligence Service

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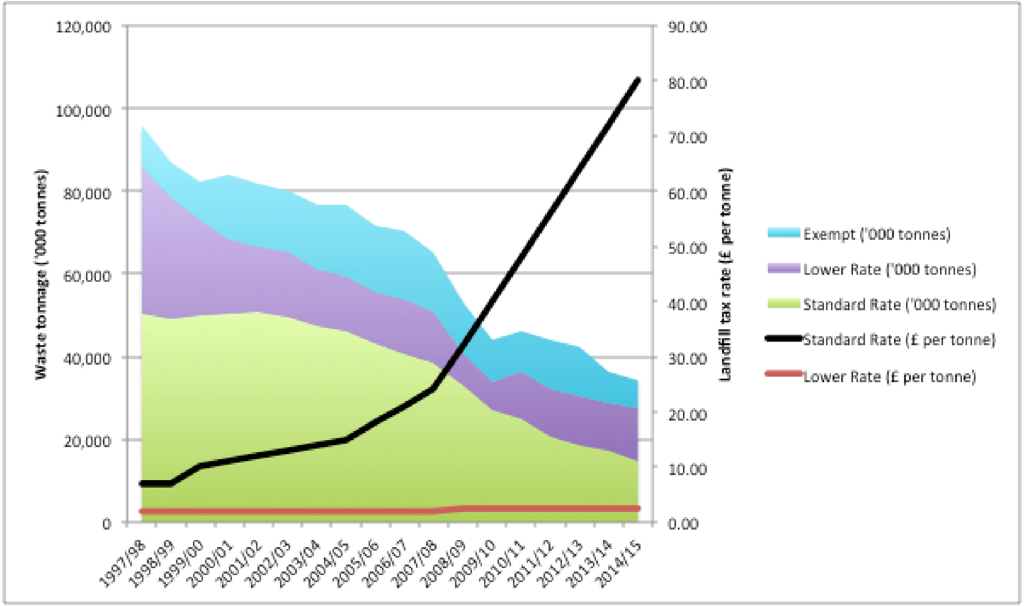
The disconnect between resource efficiency and economic efficiency: the resource-efficient option may be more expensive

Rebalance the cost of labour, and the costs of resources and pollution by:

- pricing externalities and using taxation to stimulate investment in resource-efficient alternatives
- using dynamic taxes to buffer price fluctuations, thereby reducing volatility and future uncertainty
- creating other incentives for actors to favour paying for labour to save materials, rather than for materials to save labour, such as reducing taxes on labour



UK: Waste tonnage sent to landfill, and landfill tax rates

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Urbanisation must become more resource-efficient, especially in respect of transport

- Five “Ds” are important in shaping energy use and transportation:
  - Density: Population density (people per square km) as well as activity density (people plus jobs per square km)
  - Diversity of uses, e.g. mixed residential – commercial
  - Distance to public transit (the closer the better)
  - Design to support multiple modes of travel, including pedestrian, bicycle, automobile and public transit
  - Access to Destinations, with focus on job locations
- Vauban, eco-city development in Germany:
  - All of the housing is designed to a high efficiency standard, with 100 buildings reaching Passivhaus standard, and many with solar cells installed, including 59 that are net exporters of electricity.
  - The area is designed to enable sustainable transport, with a tram line connecting to the centre of Freiburg, and all homes within easy walking distance of a tram stop.
  - The layout of the district has been designed to actively encourage walking and cycling and discourage car use, by reducing the number of streets through which cars can pass continuously through the neighbourhood, but a network of pedestrian and cycle paths permeates the neighbourhood with continuity

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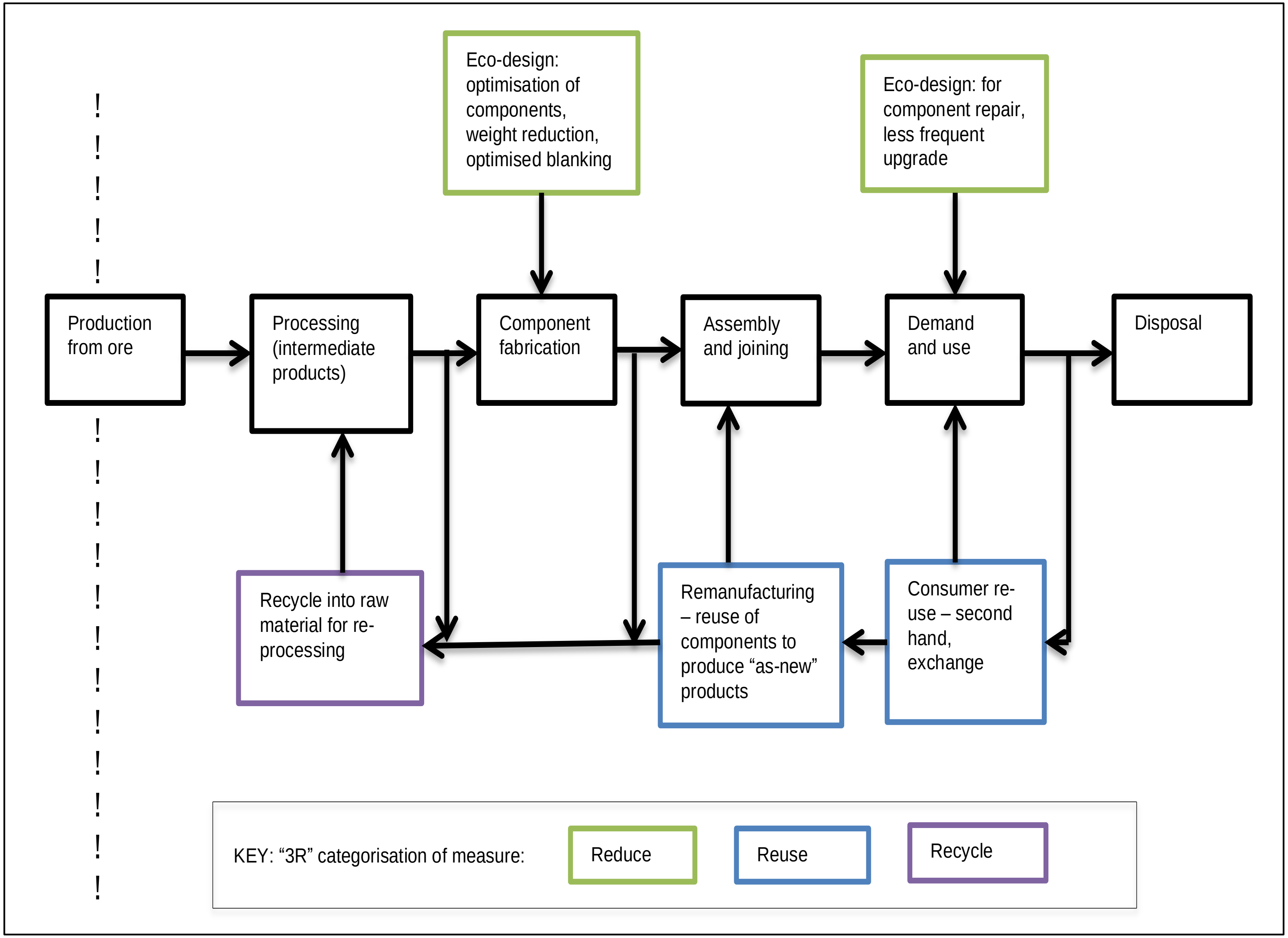
Co-ordination of logistics and supply chains: the 3Rs



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The growing practice of industrial symbiosis

Eco-Town programme in Japan

- 61 recycling facilities established across the 26 Eco-Towns.
- Nearly 2 million tonnes of waste recycled per year, in various industrial processes.
- Stimulated private sector activity – for every government subsidised plant, 1.5 built by private sector without subsidy, due to connections made by the programme.
- Carbon emissions also saved – for example reduced by 14% in Kawasaki Eco-Town.

Eco-Industrial Park programme in Korea

- Reduced material waste: 477,633 tonnes.
- Cost reductions: USD 97 million.
- Revenue generation: USD 92 million.

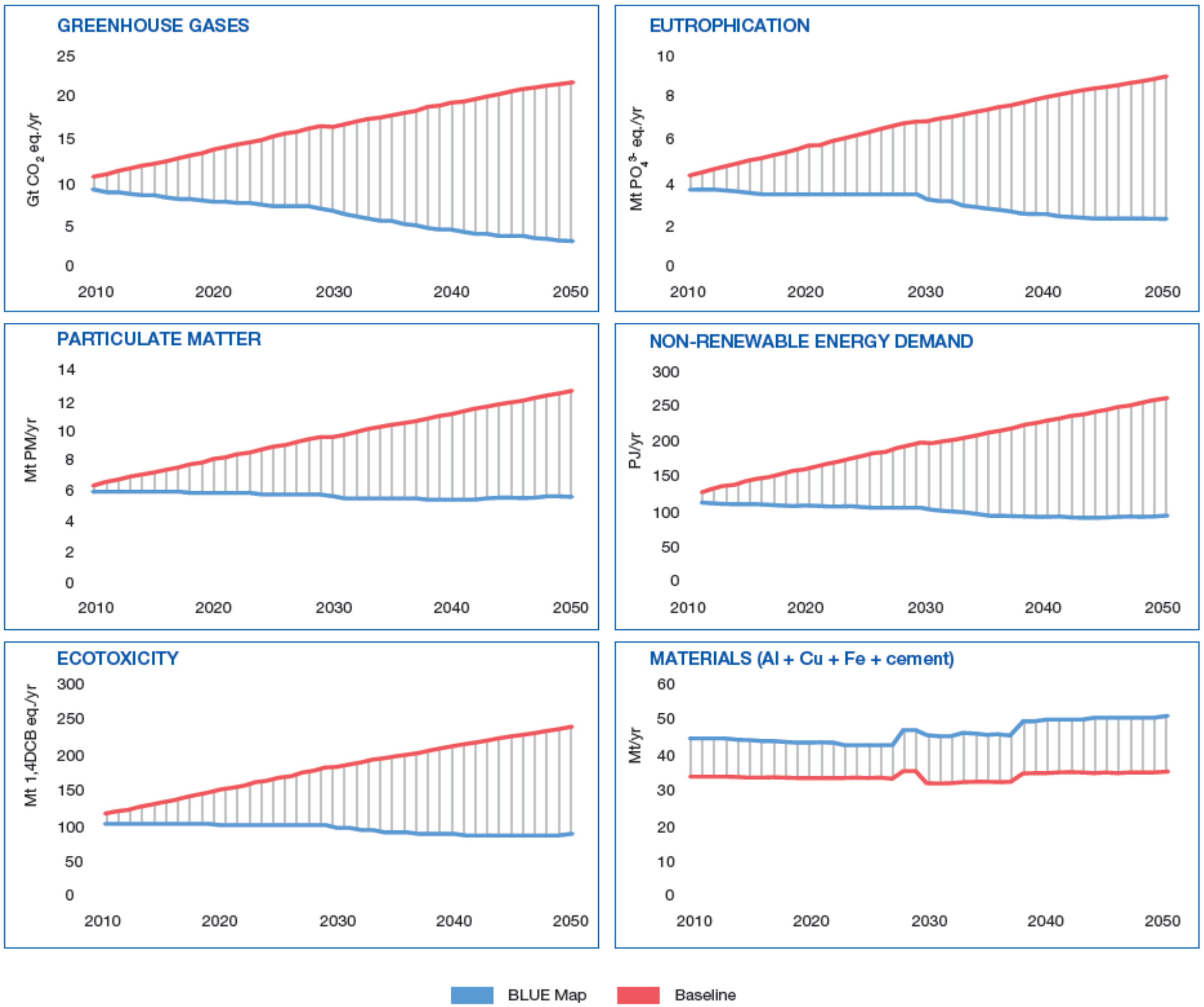
National Industrial Symbiosis Programme (NISP) in UK

- Received £28 million in public funding over 2005-10
- Diverted 7 mt materials from landfill, reduced CO_2 emissions by 6 mt, saved 9.7 mt virgin materials and 9.6 mt water, and reduced hazardous waste by 0.36 mt.
- Increased business sales by £176 million, reduced business costs by £156 million, leveraged £131 million in private investment, and saved or created a total of 8,700 jobs.
- This extra economic activity meant that the Treasury received in taxes more than three times its original £28 million investment

Regulations that militate against resource efficiency should be changed

- Rules set up to manage a linear material management chain may prevent material classified as waste from re-entering the supply chain.
- Regulations that govern materials, water and energy flows, while continuing to safeguard human health and the environment, should be revised to enable more circular resource flows.
- Definitions and provisions for waste management, recycling and removing counter-productive subsidies should be revisited.
- The Action Plan of the European Commission's Circular Economy Strategy seeks to:
  - Distinguish secondary raw materials them from wastes;
  - Set quality standards for such materials; and
  - Clarify extended producer responsibility (EPR) schemes for their management.
- EPR schemes, when effectively defined and implemented, can greatly increase the quantity of materials recovered for recycling: schemes in Sofia in Bulgaria increased the recycling or WEEE by over 150 percent over 4 years, while buy back campaigns in Romania have led to 80-90 percent recycling of WEEE, equivalent to 30 percent of waste sales in Romania

Increased resource efficiency will make a low-carbon electricity system preferable across the board



UNEP. (2015). Green Energy Choices: The benefits, risks, and trade-offs of low-carbon technologies for electricity production. E.G.Hertwich, T. Gibon, S. Suh, J. Aloisi de Larderel, A. Arvesen, P. Bayer, J. Bergesen, E. Bouman, G. Heath, C. Peña, P. Purohit, A. Ramirez. . Paris: International Resource Panel, United Nations Environment Programme

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Policy concepts for increasing resource productivity

- Circular economy (reduce, re-use, recycle)
- Waste hierarchy (prevention, re-use, recycling, recovery, disposal)
- Extended producer responsibility: producers have responsibility for end-of-life management; in the limit, retailers may not sell matter, but only the services it provides – the matter remains in their ownership and is their responsibility at end of life to manage in accordance with regulations
- Industrial symbiosis: producers collaborate to use each others' by-products
- Implementing these policies is politically challenging

Importance of a resource efficiency/productivity target

- Effective management requires measurement
- Targets give politicians a sense of purpose and industry a sense of direction
- Governments have targets for everything they care about
- European Resource Efficiency Platform (EREP) target: “The target should aim to secure at least a doubling of (the rate of increase of) resource productivity as compared with the pre-crisis trend. This would be equivalent to an increase (from 2014) of well over 30% by 2030.”
- Resource productivity measured as GDP/DMC (or RMC)

National and international targets for resource efficiency should be adopted and progress towards them monitored

- The SDGs
- Material flow indicators in the context of Japan's "Fundamental Plan for Establishing a Sound Material-Cycle Society"

Fiscal year		2020 (Target year)	2000	2013	2013 vs.2000
Resource productivity	10,000 yen/ton	46	25	38	+ 53%
Cyclical use rate	%	17	10	16	+ 6
Final disposal amount	Total (million tons)	17	56	16	- 71%
	Municipal waste (million tons)	-	12	5	- 62%
	Industrial waste (Million tons)	-	44	12	- 73%

International Resource Panel

Policy objectives and instruments for increasing resource productivity (1)

- Clear direction of future travel (recycling and efficiency targets)
- Extended producer responsibility (materials remain the property and responsibility of the producer)
- Product focus
  - Increase the time material products deliver their service before becoming wastes (product durability)
  - Reduce the quantity of materials required to deliver a particular service (light-weighting)
  - Increase the amount of information available about what materials are in products, and where (product passports)
  - Reduce the use of energy and materials required both to produce a product and in its use phase (eco-design, efficiency regulations)
  - Reduce the use of materials that are hazardous or difficult to recycle of dispose of (substitution)
  - Design products that are easier to recycle (eco-design)

Policy objectives and instruments for increasing resource productivity (2)

- Waste/resource management focus
  - Make it easier to recycle materials by differentiating between wastes and recyclables (definition of waste, by-products)
  - Increase the quality of collected recyclates (separate collections)
  - Create markets for recycled materials through product specifications and green public procurement (standards and regulation)
  - Ban the incineration of recyclables
  - Facilitate industrial clusters that exchange materials while they are still resources to prevent them from becoming wastes (industrial symbiosis)
- Consumer focus
  - Require separation of wastes (create recycling habits)
  - Provide facilities in buildings (make recycling easier)
  - Incentivise waste reduction and high-quality separation by consumers (e.g. variable waste charging, or Pay As You Throw)
  - Incentivise separation and collection systems that reduce the costs of recycling and re-use (e.g. deposit-refund schemes)

Resource Efficiency: RMC Study

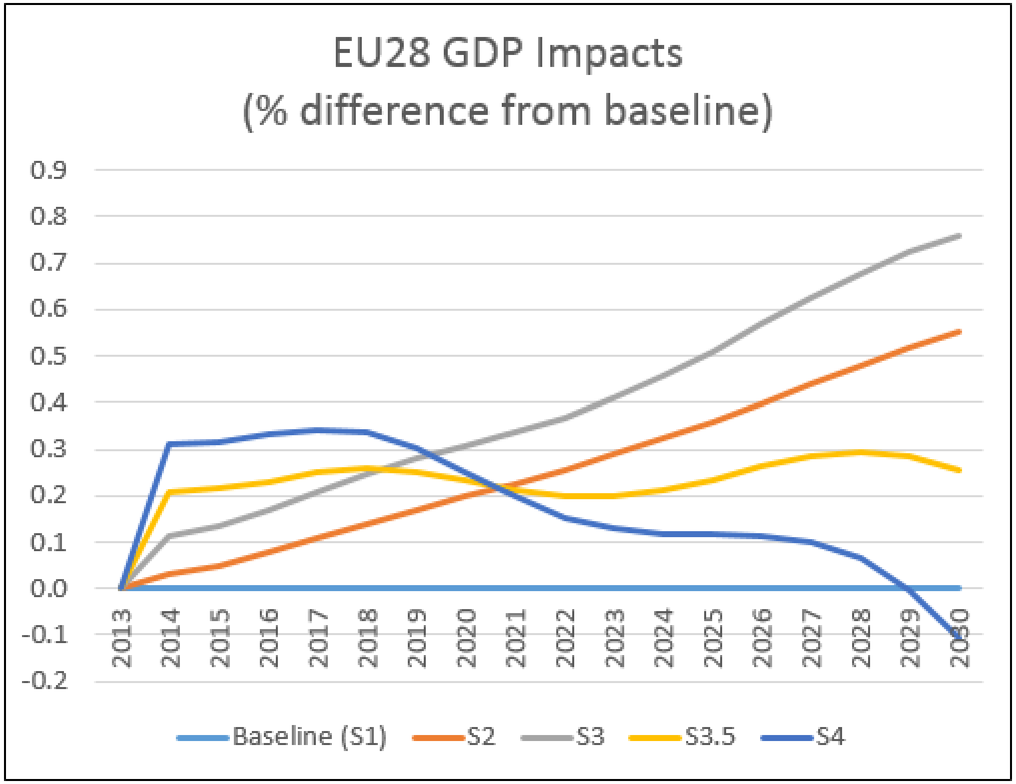
Study on Modelling of the Economic and Environmental Impacts of Changes in RMC
(DG Environment, European Commission, 2013)

"To assess the economic, social and environmental impacts of alternative policy packages to improve European resource productivity (RP), as measured by Raw Material Consumption (RMC) per unit of GDP"

Policy Assumptions

- The final policy mix includes:
  - 1/3 publicly funded investments in the capital stock to improve resource efficiency
  - 1/3 privately funded business measures (such as recycling systems)
  - 1/3 market-based instruments (MBI) (such as tax)
- RMC reductions in the scenarios come from the least cost (or highest benefit) options first and move on to more expensive ones as the resource productivity targets become more ambitious

Macroeconomic Impacts



Overall resource productivity improvement between 2014 and 2030

Scenario	Description	Approximate Improvement (2014-30)
S1	Baseline	14 %
S2	Modest and flexible improvement	15%
S3	Enhanced and flexible improvement	30%
S3.5	Further enhanced and flexible improvement	40%
S4	Ambitious and flexible improvement	50%

e3me

Summary of Findings

- Absolute decoupling of material consumption is possible
- Cutting down resource consumption helps boost EU28 GDP by
  - promoting resource and energy efficiency R&D investment
  - reducing EU dependency on raw material imports
  - boosting household income by using tax revenues to reduce other tax rates
- Two million additional jobs in the EU could be created in S3
  - from higher investment and reduction in labour costs
- Beyond RP improvement of 2%pa (S3) improvement options are becoming more expensive

Conclusions on increased resource productivity

- Negative cost opportunities for resource efficiency
- Innovation and investment: new technology, economic activity, exports
- Increased resource security (reduced vulnerability): food, water, energy, rare materials
- Environmental improvement: reduced GHG emissions, waste to landfill, extraction of virgin materials
- International credibility, and exports, as the global community gradually goes in the same direction
- None of these benefits can be achieved without government intervention to provide massively increased information through a new knowledge infrastructure, and incentives and regulation to guide innovation in the direction of greater resource productivity

Overall conclusions

- Volatile resource prices present an increasing threat in coming years to the smooth functioning of the global economy
- Scarcities or bottlenecks related to essential resources (e.g. food), especially shared resources (e.g. water), are potential flashpoints for social unrest and intra- or inter-state conflict
- Strategies to address such situations include:
  - Building domestic resilience, through indigenous resources or reserves
  - Collaborative governance and international diplomacy
  - Increasing resource efficiency/productivity

Thank you

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