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RESOURCE INNOVATION

NEW IDEAS FOR MANAGING SCARCE RESOURCES AND ENERGY

Report of a Science|Business symposium

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The fifth in a series of high-level academic policy debates on energy and resource innovation, this symposium produced key ideas and recommendations on how to manage scarce resources and energy in Europe.

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INTRODUCTION

Economic growth over the past century has been fuelled by rising consumption of finite resources. That practice is unsustainable, and resource innovation has become a crucial policy goal for governments around the world. The central challenge is to figure out how to generate growth with less – not more – natural resources. Countries that innovate to reduce energy, raw materials and water use will become more competitive, cut dependence on imports and help mitigate climate change by reducing greenhouse gas emissions.

The European Union aims to be a global leader in resource innovation. Creating a resource-efficient Europe is one of seven flagship initiatives in the €80 billion Horizon 2020 research and innovation programme for 2014-2020. "We cannot go on producing and consuming in the same way," says Janez Potocnik, European Commissioner for the Environment. And while many EU countries have long championed resource efficiency, there is plenty of scope for improvement. Japan is fifty per cent more productive than the EU in its use of materials in the economy, according to the European Commission.

A symposium organised by Science|Business on 28 September drew 35 experts on resource efficiency and innovation to debate challenging questions: What new technologies and innovations can help deliver large-scale gains in resource efficiency? How can European policymakers accelerate breakthroughs by creating market conditions that reward innovators? What are the right incentives and business models?

In its Roadmap for a Resource Efficient Europe, the European Commission notes that if the world continues using resources at the current rate, by 2050 we will need "the equivalent of more than two planets to sustain us." Europeans consume an average of 16 tonnes of materials per person per year, of which 6 tonnes ends up as waste, including 3 tonnes of landfill. At the same time, European households throw away on average 180kg of food waste a year, half of which is still edible.

To develop smart policies that address sustainable management of materials and reduce wasteful consumption, governments need to understand material flows involving many stakeholders, and they need a better understanding of why consumers behave the way they do. "There is a lot we don't understand about the way consumers make decisions… why do consumers throw away €500 in edible food every year?" asked Alan Seatter, deputy director-general, DG Environment at the European Commission.

In theory, market forces should solve the problem. As resources become increasingly scarce, prices should rise and both companies and consumers should have an incentive to cut their consumption. And many technologies already exist to reap big efficiency gains. But in practice, the rational choices that individuals and companies make in their own self-interest end up depleting the overall resources available – a concept known as "the tragedy of the commons".

This report seeks to support the European Commission at it lays the groundwork for its Horizon 2020 research and innovation programme and works to shape future policies on resource innovation. Overall two central messages emerged from the symposium debate: Europe needs to take a holistic approach to resource innovation that fully accounts for the interrelationships between energy, minerals, land and water. And it needs to focus on scale – innovations, sectors and materials that will make a major difference to resource efficiency and deliver large-scale gains.

"Any solution that we can think of influences not just water but also energy demand and land use."

Julian Allwood, reader in engineering and leader of the Low Carbon Materials Processing Group at the University of Cambridge

A HOLISTIC APPROACH TO ECO-INNOVATION

Image: David Eyton, Group Head of Technology, BP; Pirjo-Liisa Koskimäki, Adviser, Renewables, Research and Innovation, Energy Efficiency, DG Energy, European Commission; and Alexander M. Bradshaw, Scientific Member, Max-Planck-Institut für Plasmaphysik

Society's consumption of energy, water and raw materials is interlinked. Extracting and processing raw materials, for example, often involves the use of large volumes of water and considerable energy. To ensure policies don't backfire, governments striving to encourage resource efficiency and innovation should take a systems approach that accounts for knock-on effects on other resources.

A lifecycle approach to materials management – both over time and through supply chains – reveals hidden environmental costs. A recent report by the Organisation for Economic Cooperation and Development (Sustainable Materials Management – Making Better Use of Resources) notes that producing one tonne of copper emits seven tons of CO_2 and uses 70 tonnes of water. Another finding: food has a larger environmental footprint than the carton it comes in, so wasting some milk bought in one big container is worse for the environment than buying smaller containers adding up to the same quantity and not wasting any.

"Any solution that we can think of influences not just water but also energy demand and land use," said Julian Allwood, reader in engineering and leader of the Low Carbon Materials Processing Group at the University of Cambridge. "The critical materials issue is not one of scarcity, it is one of energy," he added, highlighting how the International Space Station uses energy to recycle and purify the same water over and over again.

To better understand the nexus of land, water, materials and energy, BP is funding an interdisciplinary research programme involving 13 universities called the Energy Sustainability Challenge. Under the programme, the University of Cambridge has developed a tool to visualise how changes in the water system can impact the energy system and the land system, or vice versa. The tool, called "Foreseer", has been used to track, for example, how a reduction in the groundwater extraction in California would impact the energy and land systems there.

The symposium discussion highlighted how a holistic approach needs to consider the full cost of consuming resources, including disposal of waste, the role of taxation, and trade flows that capture the interaction of the European market for resources with the rest of the world. And even with this vital information in hand, policy decisions will not always be obvious. Social, environmental and economic objectives can conflict with one another and those conflicts need to be addressed at the highest level.

Measuring the real cost of resources

Economic theory would suggest that the best way to improve resource efficiency is to price resources in a way that fully reflects their life-cycle costs in both economic and environmental terms. But in most sectors consumers typically pay just a fraction of the resource life-cycle cost. That practice provokes waste and inefficiency.

Solving the problem is not easy. For starters, there are a variety of approaches to analysing the life cycle of a product or material and European policymakers face conflicting views on how to measure sustainability. "There are 300 different methods of measuring sustainability, noted DG Environment deputy director Seatter. "What kind of solution is that in a single market?"

Experts recommend the introduction of standardised methodologies for analysing product life cycles. Such methodologies should take into account that reserves of raw materials can be dynamic. Research by the University of Augsburg has demonstrated how economics, greater geological understanding and new technologies can increase reserves to meet demand, while recycling and substitution create additional options. Material flow analysis, as recommended in the OECD

Manual on Measuring Material Flows and Resource Productivity and carried out by e.g. the Wuppertal Institute, the Sustainable Europe Research Institute and others could become such a standardised methodology.

The role of taxation

Symposium participants debated the value of a major shift from taxation of labour towards environmental and resource taxation, as envisioned by the European Commission's Roadmap to a Resource Efficient Europe. The theory behind such a shift is that rising prices for materials will drive both consumers and companies to become more resource efficient.

David Victor, professor of international relations and director, laboratory on international law and regulation at the University of California, San Diego, questioned the wisdom of governments trying to steer markets. "What is our model for that?" he asked the symposium. Victor suggested that such a policy could prompt the European economy to stagnate as Japan's did, while potentially leading to a "disaster" for governments' tax revenues as companies migrate out of Europe. He also contended that regulation can often do more harm than good in this context: "Regulation can create rigidity against substitution… regulation becomes a barrier to switching… Japan has become very efficient within a suite of materials, but has been very bad at shifting into a new trajectory."

Asked in what circumstances governments should intervene, Victor said: "One of the things we have learned is that the role of the government is particularly important for technologies where there are tremendous risks in being first… the risk that the original mover can't recover the benefits," as in the case of carbon capture and storage (CCS) technologies.

Raimund Bleischwitz, co-director for material flows and resource management at the Wuppertal Institute and visiting professor at the College of Europe, contended that rising material prices do not necessarily impair economic growth. "According to modelling results, a 10 per cent reduction in material inputs can go along with a growth rate that is

"We need instruments that will work in the short term."

John Barrett, professor of sustainability research at the University of Leeds

slightly higher than business as usual… Construction materials are being taxed in many European countries and are probably a good complement to carbon taxation that exists." Bleischwitz also suggested feed-in tariffs (guaranteed prices) could also be used to encourage market development of eco-innovations in some markets. "You can recover 90 per cent of phosphorus from waste-water streams, but those facilities are not economically feasible yet," he said.

The global dimension

For many raw materials, Europe is heavily dependent on other regions of the world, making it impossible for the EU to act in isolation to improve its resource efficiency. Moreover, the recycling of many European products, such as cars, takes place in Asia and other geographies with lower labour costs. With the market for raw materials "dramatically more global than it was 15 years ago", Victor called on the big innovators – the EU, Japan, US and China – to get around a table and coordinate international policy on resource innovation. "There will be many cases, where, if the EU thinks about this as an EU innovation policy, it is going to completely miss the story… rare-earths recycling is an example."

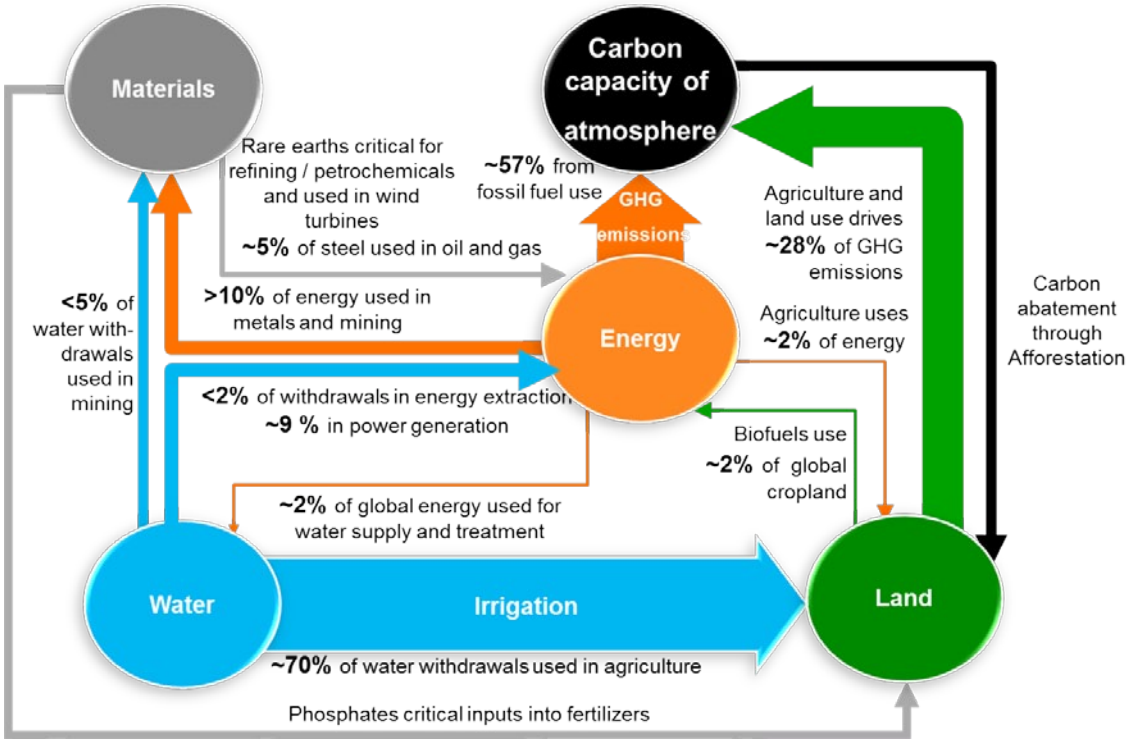
Some international cooperation on resource management is already under way. The EU and China, for example, are engaged in an ongoing dialogue around the recycling of raw materials and the EU is looking to work with the US on the recycling and collection of waste. Gwenole Cozigou, director, chemicals, metals, mechanical, electrical and construction industries, raw materials, DG Enterprise and Industry, European Commission, noted that the international waste market needs to be better regulated. He points out that non-ferrous metals, for example, are often being recycled in environmental conditions that would be prohibited in Europe. Although the Commission is not considering export restrictions on secondary raw materials, "We are looking at the possibility of a certification scheme for recycling facilities," he said. "We can do it on a voluntary basis or with legislation behind it."

The Commission has drawn up a list of critical raw materials, indicating the risk level of each, depending on whether they are available inside the EU and whether they are impacted by trade policies and political risks in other parts of the world. "We have a list of 14 that we considered particularly critical to the EU. It will be reviewed every three years," said Cozigou.

> For many raw materials, Europe is heavily dependent on other regions of the world.

Bleischwitz suggested going further still to create an international database capturing where specific materials are used. He suggested that multinational companies could report how much of each material they use "with some kind of certification for environmentally sensitive or conflict materials". There may also be a case for creating scenarios and technology road maps for main material markets such as the ones that the International Energy Agency has developed for energy.

Figure 1: Relationships among the natural resources relevant to energy



Source: McKinsey and Energy Sustainability Challenge (ESC) analysis

Image: Alan Seatter, Deputy Director General, Coordination of resource-efficiency policies & instruments, DG Environment, European Commission; David Eyton, Group Head of Technology, BP; and Pirjo-Liisa Koskimäki, Adviser, Renewables, Research and Innovation, Energy Efficiency, DG Energy, European Commission;

There are many areas of waste and inefficiency the EU could address, but it needs to identify and tackle a few things that really matter. In short, pay attention to the big things first.

Greater energy efficiency needs to be near the top of the list. Energy is a key input to food, water and materials systems, and two-thirds of industrial-materials energy use relates to steel, cement, paper plastics and aluminium. But our industrial system and infrastructure wastes energy. Julian Allwood et al compared the maximum energy that can be extracted from the fuels we use today with the actual energy delivered by devices, and estimate that the overall efficiency of global energy conversion is only 11 per cent. Global demand for energy could in theory be reduced by almost 90 per cent if all energy conversion devices were perfect, although of course practical limits constrain this overall potential.

The big opportunities for resource innovation discussed at the symposium included improving the energy efficiency of buildings and vehicles, reducing waste in industry, better management of fresh water and greater use of recycling.

Driving energy efficiency

Improving the efficiency of so-called passive systems, such as buildings and vehicles, can deliver large-scale gains, said Allwood. By redesigning passive systems, governments could effectively slash energy use by 75 per cent, he argued.

Given that energy usage is directly proportional to the mass of vehicles, policymakers should focus on encouraging the use of lighter cars through regulation, in addition to more efficient drive trains and other transport efficiency measures. The average vehicle in the UK, for example, achieves 35 miles per gallon, even though Volkswagen has developed several concept versions of a one-litre-engine car with a carbon-fibre body that achieves 235 miles per gallon, or 100 kilometres per litre. “Light weighting needs to be introduced with a very short timeframe. We need to overcome lobbying to make sure this happens,” stressed John Barrett, professor of sustainability research at the University of Leeds. “We need instruments that will work in the short term.”

However, even if auto makers seek to use lightweight materials and develop more environmentally friendly projects, policymakers may need to steer consumer behaviour by “foreclosing options” or at least introducing incentives to buy resource-efficient products. “We talk about light weighting of cars, and we improve day by day every process and material usage, but somehow the cars are getting heavier” in response to consumer demands for top safety standards and comfort, said Muriel Desaeger, senior principal technologist, Energy Research Group, Toyota Motor Europe.

Regulators could also mandate that buildings use far less steel, cement and other energy-intensive materials, offering major savings of energy and resources. Builders typically use twice as much material as is required by existing regulations, Allwood said, partly because this approach reduces their labour costs, exacerbating the consumption of resources.

To improve energy efficiency, the state of Hessen in Germany is renovating 3 per cent of public buildings a year. “The government and the public sector need to act as role models,” said Ralf Tegeler, head of unit, environment, energy, agriculture and consumer protection, Representation of the State of Hessen to the European Union.

Cutting industrial waste

Another major opportunity to cut resource consumption lies in reducing the volume of materials wasted by industry. A University of Cambridge study led by Allwood found that one-

quarter of the steel produced annually never makes it into a product. As labour is far more expensive than raw materials, the steel industry makes an intermediary product from which its customers can cut out the specific components they need. The residual scrap is recycled, but this requires a great deal of energy. New processes could potentially create less waste, according to the research.

Although regulation may well be required to persuade manufacturing and construction industries to change their processes, technology could offer new solutions. "Techniques developed in the textile industry to make the maximum use of the material could be applied," Allwood said. "We could live well with half of the steel we are using now… We could make products lighter, keep products for longer and reduce the yield losses."

Improving water management

Europe also needs to address water waste and improve the overall management of water as a resource. EU water systems lose 6 to 40 per cent of volume in transit. Over the past 30 years, droughts across the EU have dramatically increased in number and intensity, affecting 11 per cent of the population and costing the continent €100 billion, according to the Commission. By 2030, 45 per cent of the EU will suffer from stressed water supplies.

To help national governments put a more accurate value on water, the Commission is looking to create a database tracking how the water in individual river basins across Europe is used. "The way the climate is changing over the Alps has major consequences in terms of water flow," Seatter said. "For many river basins, we don't even know the quantitative flows and who is using them."

There may also be a case for more consistent pricing of water across Europe to generate the investments needed to ensure that the supply of water keeps up with demand. "We have over 40 per cent leakage in parts of Europe, but only 6-7 per cent in Denmark," Seatter noted. "We do not have a proper value on water services… That is only going to happen by introducing charges." In surveys of European citizens run by the Commission, 80 per cent of respondents have said they support some form of water pricing but half of this group also said there would need to be a support mechanism for people unable to pay.

Transforming waste to raw materials

One way for Europe to boost resource efficiency would be to recycle far more waste than it does today, managing it as a resource. "Recycling can cover more than half of our raw-material needs," said Cozigou at DG Enterprise and Industry. Besides reducing the need to source primary raw materials, recycling also cuts energy usage. Recycling aluminium, for example, takes just 5 per cent of the energy it takes to produce aluminium from scratch from bauxite.

To encourage more recycling, Europe could develop technical criteria for waste, such as copper and aluminium, to certify that a specific stock is good enough to be used as a secondary raw material. Europe also needs more inspectors checking the quality of waste. One way to facilitate recycling is to encourage consumers and companies to rent, rather than buy, products and equipment. Several participants in the symposium noted that a widespread shift to renting would greatly increase recycling as end-of-life equipment is returned to the manufacturer. Some companies now provide their products as a service. Rolls-Royce, for example, leases its engines to customers who pay according to how much time their aircraft spend in the air.

European Commissioner for Environment Potocnik recently called for a Europe-wide ban on landfills to galvanize innovative solutions and waste recycling. "Taxing landfill is soft policy," says Potocnik. "If we would introduce a ban on landfilling, we then create a very clear case for investing in recycling… That will move the industry exactly in the right direction."

David G. Victor, Professor; Director, Laboratory on International Law and Regulation, University of California, San Diego

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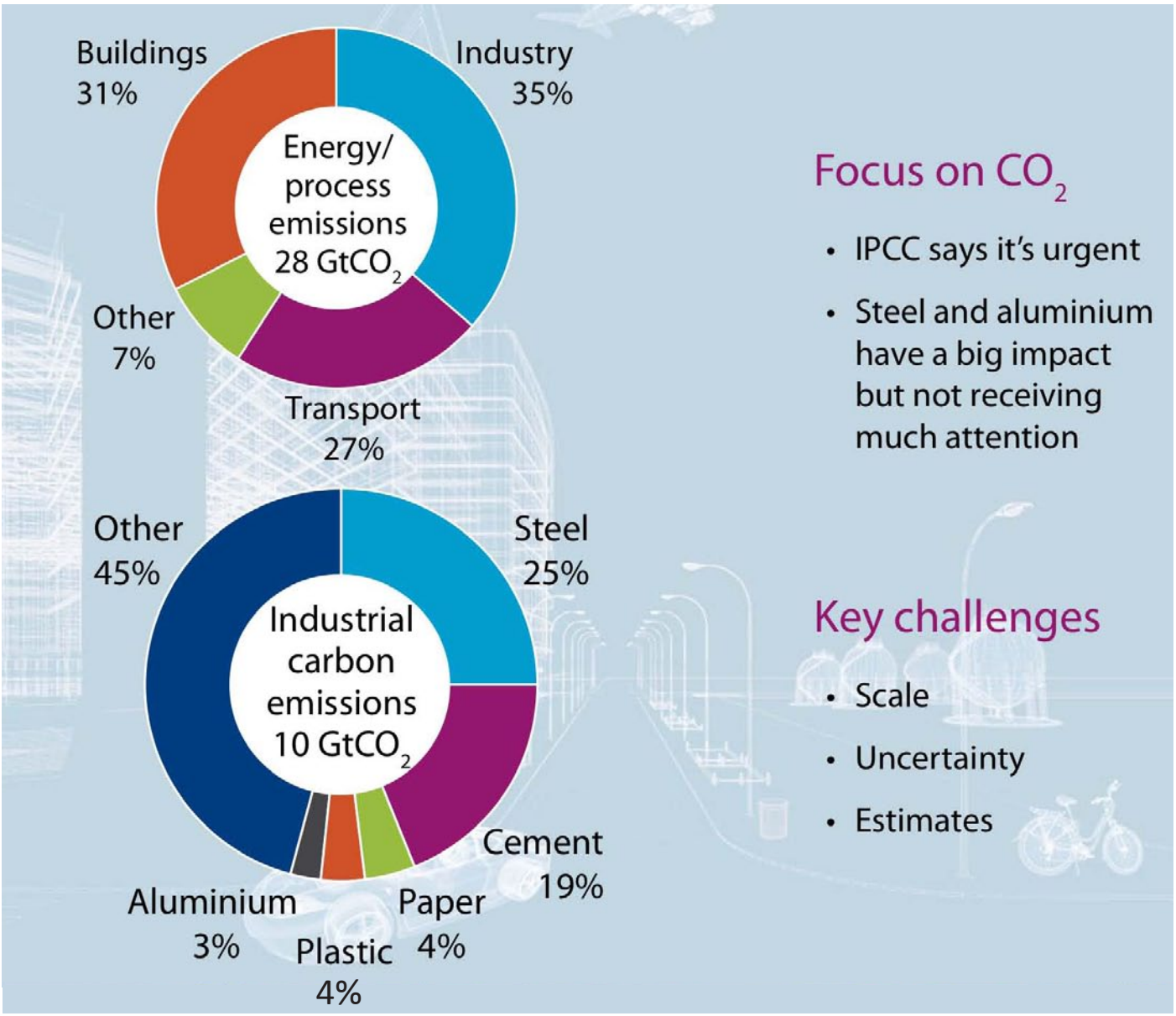
John Barrett, Professor of Sustainability Research, University of Leeds

Raimund Bleischwitz, Co-Director, Research Group "Material Flows and Resource Management", Wuppertal Institute for Climate, Environment and Energy

Figure 2: Steel and aluminium and climate change



Source: Sustainable Materials – With Both Eyes Open: Future Buildings, Vehicles, Products and Equipment – Made Efficiently and Made with Less New Material, Julian M. Allwood, Jonathan M. Cullen. UIT Cambridge LTD (2012)

RESOURCE INNOVATION – POLICY RECOMMENDATIONS

TAKE A HOLISTIC APPROACH

- Use global research and systems analysis to identify the biggest opportunities and market failures.
- Tackle key market failures such as the pricing of carbon and water, the fragmentation of construction supply chains, and designs that inhibit recycling.
- Introduce a single, consistent method of measuring the sustainability of specific sources of materials, taking into account the impact of economics, advances in geological understanding and new technologies.
- Conduct more research into seemingly irrational consumer behaviour to understand why, for example, many throw away edible food.

LARGE-SCALE OPPORTUNITIES

- Price fresh water in a consistent way that truly reflects its value and scarcity, driving investment to reduce leakage.
- Introduce greater incentives to improve energy efficiency and hence reduce greenhouse gas emissions.
- Introduce greater incentives to develop and buy lightweight vehicles and renovate buildings.
- Encourage recycling by ensuring consumers and companies pays the real cost of landfill.
- Introduce incentives to rent rather than buy products, making it easier to recycle raw materials.

Image: Richard L. Hudson, CEO & Editor, Science|Business

CONCLUSIONS

Europe has vowed to lead in transforming the world's resource-intensive model to a sustainable one, driving innovation in everything from life-cycle measurement to sustainable business models. "We need to change what we finance and what we reward," says European Commissioner for the Environment, Janez Potočnik.

The guiding principle in that ambitious transition should be a systems-based approach to research and innovation in resource management. Our limited resources should be focused on programmes and policies that will generate large-scale gains.

Policymakers can influence the supply of, and demand for, resources in a myriad of ways, such as through regulation, feed-in tariffs, taxation, targeted research, international cooperation and, to some extent, by guiding market forces through communication campaigns and public-private partnerships. With so many causes and potential solutions, it is tempting for policymakers to tackle all the varied facets of the resources market at the same time. But they need to focus on the biggest opportunities – assessing the planet's resources as part of a complex and interlinked global system. Major changes in the way in which we use water, land, minerals or energy will have knock-on effects on the supply and availability of other resources.

As governments focus on resource innovation policy, top priorities should include addressing market failures, including the pricing of carbon and water, the fragmentation of construction supply chains, and designs which inhibit recycling. Landfill availability should be priced to encourage resource conservation or limited. Consumers, too, need incentives to adopt resource-efficient behaviour such as reducing waste and using less energy.

Above all, achieving major advances in resource efficiency requires leadership. The Commission's ambitious road map for building a more sustainable economy by 2020 demands a new approach to resource management. Research and innovation will be vital to the transformation. But governments can start reaping major gains by focusing on the big opportunities, moving quickly and making better use of existing technology to speed change.

"We need to change what we finance and what we reward."

Janez Potočnik,
European Commissioner
for the Environment

Image: Pirjo-Liisa Koskimäki, Adviser, Renewables, Research and Innovation, Energy Efficiency, DG Energy, European Commission

Image: Gwenole Cozigou, Director, Chemicals, metals, mechanical, electrical and construction industries; Raw materials, DG Enterprise and Industry, European Commission

ANNEX

Sustainable Materials – With Both Eyes Open: Future Buildings, Vehicles, Products and Equipment – Made Efficiently and Made with Less New Material, **Julian M. Allwood, Jonathan M. Cullen**. *UIT Cambridge LTD (2012)*

The Climate Threat We Can Beat, **David G. Victor, Charles F. Kennel and Veerabhadran Ramanathan**, *Foreign Affairs (2012)*

Global Warming Gridlock, **David G. Victor**, *Cambridge University Press (2011)*

The Global Resource Nexus, **Philip Andrews-Speed et al.**, *The Transatlantic Academy (2012)*

Towards a resource policy – unleashing productivity dynamics and balancing international distortions, **Raimund Bleischwitz**, *Mineral Economics – Raw Materials Report (2012)*

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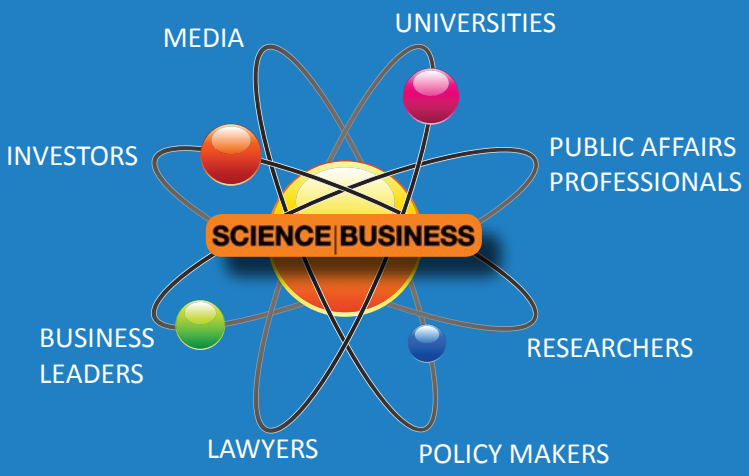

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