Extrapolating resource efficient business models across Europe

The purpose of this document is to set out the methodology for monitoring and evaluating the quantitative performance of the REBus project.

Project code: RBM600
Research date: 2016
ISBN: N/a
Date: 9th November 2016

With the contribution of the LIFE financial instrument of the European Community

WRAP's vision is a world in which resources are used sustainably.

Our mission is to accelerate the move to a sustainable resource-efficient economy through re-inventing how we design, produce and sell products; re-thinking how we use and consume products; and re-defining what is possible through re-use and recycling.

Find out more at www.wrap.org.uk

Document reference (please use this reference when citing WRAP's work):
[WRAP, Year, Town, Title of Report, Prepared by xx]

Written by: Keith James, Peter Mitchell and Dorothea Mueller
With grateful acknowledgement of the contribution of Anne Owen, University of Leeds
[Double click to insert image]

Front cover photography: [Add description or title of image.]

Contents

Glossary

Financial Benefit (£ / €)	Financial benefit target will be based on increased turnover on a project-by-project basis. Net profit before tax will also be captured for the REBM companies.
FTE	Full Time Equivalent
GHG emissions (tonnes CO_2 eq)	Greenhouse gas emissions savings are used as a proxy for the environmental benefits from actions taken by projects, converted to a CO_2 equivalent saving, using data published to agreed standards on specific products.
Gross Value Added	Gross Value Added measures the contribution to the economy of each individual producer, industry or sector in the geographical area of interest (e.g. country).
Procurer	The organisation or individual acquiring products or services through a Resource Efficient Business Model
Provider of REBM	The organisation offering products or services through a Resource Efficient Business Model
REBM	Resource Efficient Business Model
Refurbishment	Any repair or restoration activity, including checking and cleaning.
Reuse	*Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived (i.e. dealing with waste prevention); (Waste Framework Directive 2008)*
RME	Raw Material Equivalent
SME	Small and Medium-sized Enterprises are defined in the EU recommendation 2003/361. The main factors determining whether an enterprise is an SME are staff headcount and either turnover or balance sheet total.

Executive Summary

The REBus (Resource Efficient BUSiness Models) project aims to make a significant contribution towards two of the targets highlighted in the EU's study on "Assessment of resource efficiency indicators and targets" (BIOIS 2013) (1) a 30% reduction in domestic material use by 2020, and; (2) a 20% reduction in greenhouse gas emissions by 2020. This report outlines how large scale adoption of the sort of business models which have been piloted throughout the course of the REBus project could deliver substantial economic and environmental benefits across Europe. An indicative quantification of scenarios illustrating the potential impacts on Gross Value Added (GVA) and raw material use are outlined in projections to 2030 for Europe as a whole, and for each of the EU28 member states.

Large scale adoption of Resource Efficient Business Models (REBMs) would be of itself a major industrial transformation, but while past industrial transitions have focused on capital investment, technology and labour productivity as drivers of growth they have tended to increase economic efficiency through reducing labour input (per unit of GVA) with little or no recognition of materials usage and/or resource constraints or the role of resource productivity. Adoption of REBMs involves using more labour and fewer resources (greater resource productivity) to increase the efficiency of prodcution and broader economic activity. As identified in WRAP (2015a), adoption of REBMs has the potential to create jobs (and net jobs) through lowering structural mismatch in labour markets – a factor that has played a role in sustaining high unemployment in some regions in Europe.

In this study the methodology developed in WRAP(2015a) has been developed to identify and quantify the potential economic and environmental impacts of greater adoption of REBMs in terms of GVA, job creation, raw material demand and greenhouse gas emissions. It derives metrics based on data from the REBus pilot companies, Eurostat and the UKMRIO database. The indicative scenarios quantified suggest an expansion in REBMs could offer the potential to create 1.2 million to 3 million jobs in Europe, reduce equilibrium unemployment by around 250,000 to 520,000, generate €114 billion to €324 billion in additional GVA, reduce raw material demand (excluding fossil fuels and energy carriers) by 70Mt to 184Mt, and reduce greenhouse gas emissions by 80Mt CO_2eq to 154Mt CO_2eq.

1. Introduction

Together with substantial environmental benefits REBMs offer substantial potential to create economic benefits through increasing the amount of value added by economic activity in Europe. Whereas past transformational industrial changes have largely focussed on investment in capital, technology and growth in labour productivity with little or no regard for resource use or resource constraints, REBMs provide an opportunity to use labour and resources more efficiently to drive increases in overall efficiency in economic activity, and increase the amount of economic value created across European economies.

This paper builds on the previous WRAP studies by considering the net impact on GVA, raw materials use and greenhouse gas emissions of widespread adoption of Resource Efficient Business Models piloted through REBus. The rest of the paper is structured as follows. First, there is a review of economic arguments around generation of GVA and the demand for materials. It then assesses the extent to which REBMs are already established (through a mapping of available data) and then reports indicative quantitiative results from scenario analysis of the potential impacts on GVA and resource use in Europe from large sale take up of REBMs to 2030. Next the paper considers the potential of resource productivity as a means of measuring economic performance and discusses how these measures could encourage a range of improvements and highlight possible areas of intervention to improve resource efficiency. The final section draws some conclusions.

2. Economic Arguments

2.1 Developments In European Labour Markets

Since the financial crisis in 2008 there has been a great deal of attention to the impact on employment and unemployment across Europe. WRAP (2015a) identified that a substantial degree of spare capacity exits in Europe's labour markets as evidenced by the level of unemployment and inactivity. In addition, the study observed that unemployment is distributed unevenly both across (and within) countries, with low to mid skill occupations more likely to experience higher unemployment compared to high skilled occupations. An analysis of the trend changes in occupational structure across countries is suggestive of a polarisation in the structure of employment: an increase in the share of employment in jobs at the top end and the bottom end of the labour market, but with a decline in jobs in the middle segment of labour market.

WRAP/GA (2015b) explores the impact of increasing resource efficiency on jobs and the labour market for the UK economy and provides a comprehensive discussion of economic issues relating to job creation and unemployment from the perspective of the UK. From the perspective of mainstream economic theory, the natural rate of unemployment or NAIRU ("Non Accelerating Inflation Rate of Unemployment) is the lowest level of unemployment which can be sustained in any economy over a long period of time. This is effectively a supply side labour market constraint. As a consequence the only way a growing sector can permanently create net jobs (rather than displace existing jobs) is if macroeconomic policies or other structural mechansims can work together to lower the NAIRU.

As part of their consideration of the potential role of a circular economy, WRAP (2015a) and WRAP/GA (2015b) identify the extent to which adoption of REBMs can reduce mismatch and thereby the NAIRU, allowing lasting improvements in labour market to be made across Europe. The definition of the circular economy used, as involving "keeping products and resources in use for as long as possible through recovery, reuse, repair, remanufacturing and recycling" is well aligned with the scope of REBus. WRAP/GA (2015b) also concludes that reuse and open loop recycling activities are likely to be the least geographically concentrated, requiring activity at both a local and regional level across countries. REBMs involving remanufacturing activity are likely to be relatively more concentrated and located near existing OEM manufacturing facilities. For both open/closed loop recycling and reuse activities there is a strong potential to offer some lower skilled jobs, with remanufacturing and recycling activities requiring a greater proportion of mid-level skilled jobs.

2.2 Gross Value Added (GVA)

National Income accounts typically show that consumer demand has the largest share of total demand or Gross Domestic Product (GDP). What this metric doesn't articulate is the extent to which consumer demand (and GDP) is driven through repeated consumer purchases of low-quality, short-lived products or higher quality longer-lasting goods. Over time, through such high frequency purchases consumers, could spend more replacing low-quality goods than they would have if they had bought higher-quality more durable goods in the first place. GDP would grow but inefficiently because of the higher level of waste. Similarly, regarding their final demand, the purchasing behavior of the corporate sector and the public sector could be wasteful and inefficient. And this also spills into inefficiencies in purchases of intermediate goods (raw materials and components etc) made by businesses. Using GVA data in combination with data on materials can show how roll-out of REBMs might address the challenge of growing economically without increasing waste and inefficiency.

GVA is one way of measuring the economic contribution (or incremental value added) to the economy of individual producers, industries or sectors in a country or region. At a country level it is used in the estimation of Gross Domestic Product (GDP). National accounting conventions define the link between GVA and GDP as GVA + taxes on products - subsidies on products = GDP (ONS). For the purposes of assessing REBMs, GVA and GDP can be considered broadly equivalent, as the business model of itself doesn't alter taxes nor subsidies on products or on production. GVA can be used to assess the impact on productivity as a result of a transition to an alternative busienss model such as a REBM. If large scale roll-out of REBMs are able to create more GVA in an economy than the business models they replace, then a country is more productive, and the gains from that enhanced productivity feed into higher living standards as measured by wages and profits.

2.3 Raw Materials And Greenhouse Gas Emissions

In this paper, 'materials' and 'resources' are used interchangably to mean biomass, metal ores, nonp-metallic minerals and ore excluding fossil fuels. The reason that fossil fuels are excluded from the analysis is because use of fossil fuels in power generation is part of the background system in a country (e.g. provision of electricity) and not directly associated with a change in business models. Unless otherwise stated, material weights are expressed in Raw Material Equivalents, whereby the mass of products is converted into the corresponding mass of raw materials required to make that product. For example, one tonne of aluminium is transformed into the equivalent of bauxite, which had to be extracted and processed in order to make that aluminium.

To quantify the change in raw material demand associated with potential changes in GVA of a sector two data sources are used. The first is the data collected through the pilots undertaken through the REBus project. These pilot phases amount to real world testing of new business models, and where successful, lead to roll-out of the models on a larger scale. The trial phase is designed to test the assumptions, research and data that developed the business model and feedback real world learnings so that the business case can be refined and approved for rollout.

The data reported by REBus pilots is presented in table 1. The tonnage figures are dominated by construction projects which were able to reduce their material demand. For non-construction activities the ratio of financial benefit to resources avoided was far higher than anticipated at the project conception. Note that not every pilot project reported data for all indicators, and therefore the ratios from teh table should not be taken as indicative of "average" impact of REBMs.

Table 1.1 Annualised Results from REBus Pilot projects reporting data

	Target	REBus achievement	% achieved
Number of pilot REBMs launched		26	
Tonnes of resources avoided (product weight) p.a.	5,000	62,619	1252%
Tonnes of GHG avoided p.a. (CO_2e)	20,000	1953	10%
Financial benefit p.a. (€)	12,000,000	5,621,623	47%

The second source of data derives from calculating the GVA associated with recycling, repair, rental/leasing and remanufacturing of materials/products and subsequently calculating the overall supply chain material impact (in terms of the tonnes of materials and greenhouse gas emissions) associated with those goods. Two metrics follow from dividing the tonnes of material and the tonnes on CO2(eq) by the GVA in monetary units: (i) a measure of the material intensity of these products, and (ii) a measure of the greenhouse gas intensity. In order to calculate the GVA and complete supply chain impact of products we use input-output analysis. In this study this is based on a multiregional input-output model (MRIO) database which incorporates information about the primary material extraction by 123 industries both in the UK and abroad. Annex 1 gives information about the MRIO database and the input-output methodology.

3. Baseline Mapping of REBM Activities

To get an idea of the current contribution of REBMs across Europe a proxy indicator of GVA and resource use is constructed using official data from Eurostat split by detailed business activity classifications (NACE Rev. 2). The mapping is outlined in Table 2 which also describes the REBM activities that are in scope for this paper.

In terms of the mapping for the indicator, re-use GVA is proxied by employment in retail of second hand goods, GVA in repair activities by repair of machinery and equipment and repair of electrical and electronic and household products, closed & open loop recycling activity is proxied by GVA in the wholesale of waste and scrap sectors and the waste and recycling sector, and servitisation is proxied by GVA in the rental/leasing sectors.

While this approach clearly has its limitations, for example it is not really possible to separately identify remanufacturing or servitisation with any confidence, it is an approach which uses the best available information and is useful in that, given a lack of alternatives, it is an attempt to quantify the current level of adoption of REBMs.

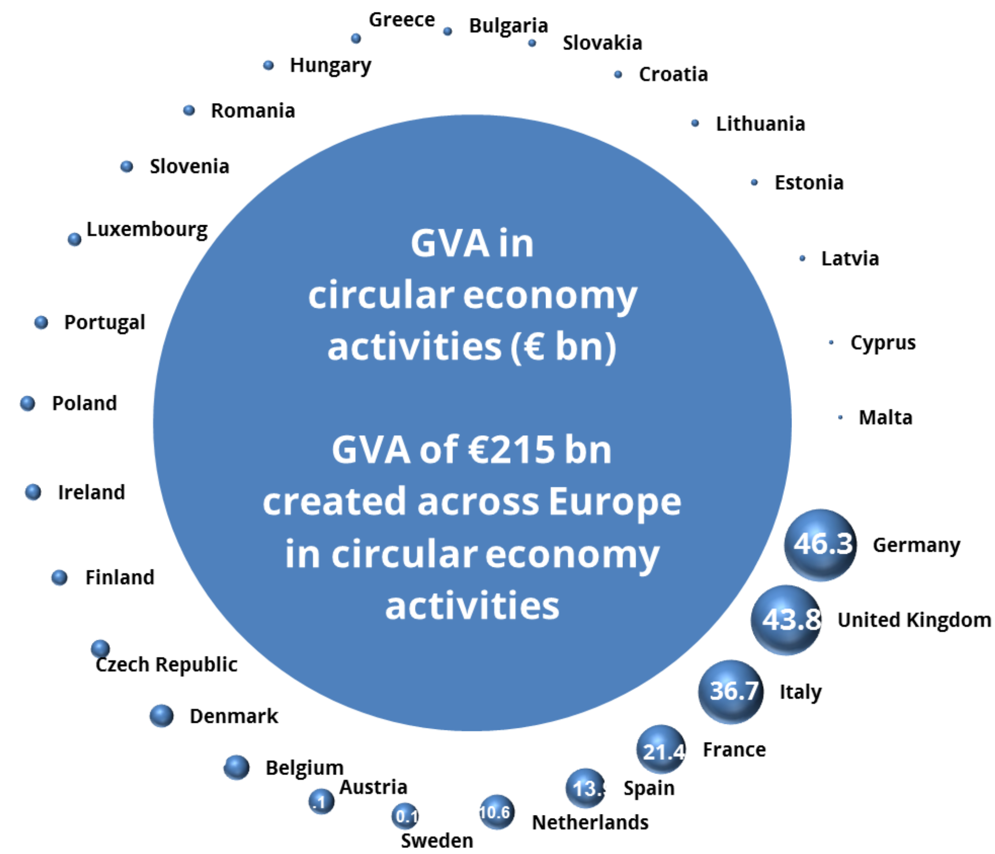
Table 2.1 Mapping REBMs to official sector classifications

Resource Efficient Business Model	Sector proxies in official data
Closed and open loop recycling – processes that create new products from waste without changing the inherent properties of the material. For example recovering PET from bottles for use in other PET applications. Open loop recycling – also referred to as downcycling, is where recovered materials are used to create products with lower value, for example use of glass containers an aggregate. Several procurement pilots link to recycled content.	Wholesale of waste & scrap Waste & recycling
Repair - where products need repair or reconditioning before going back into use.	Repair of machinery & equipment Repair of electronics & household goods
Reuse - examples included are electrical & electronic goods and textiles. These products are worth more than the raw materials they are made up from. A re-used iPhone retains around 48% of its original value compared to just 0.24% of its original value as recyclate.	In-store retail of second hand goods
Servitisation – examples are systems and business models that make more effective use of assets including include leasing of products and provision of products as services thereby deferring consumption of new assets. Many examples are B2B (business to business) such as Xerox and Ricoh leasing photocopiers and printers, Interface's carpet business or Philips 'pay per Lux' but there are B2C (business to consumer) and C2C (customer to customer) examples such as Airbnb or Streetcar.	Renting & leasing activities
Remanufacturing entails rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts Remanufacturing preserves most value. Take-back and return schemes are one route to remanufacturing	Remanufacturing is not a sector in itself; it sits within manufacturing.

Sources: WRAP/GA (2015a), REBUS Monitoring and Evaluation Methodology

The results of applying this approach is summarised in Figure 3.1 which reports proxy indicators of GVA in current REBM activities aggregated for the EU28 countries. In total, GVA by repair, waste and recycling, rental and leasing activities is estimated to be around €215 billion across Europe. Over a third (42%) is from rental and leasing activities, with repair accounting for a further 35%.

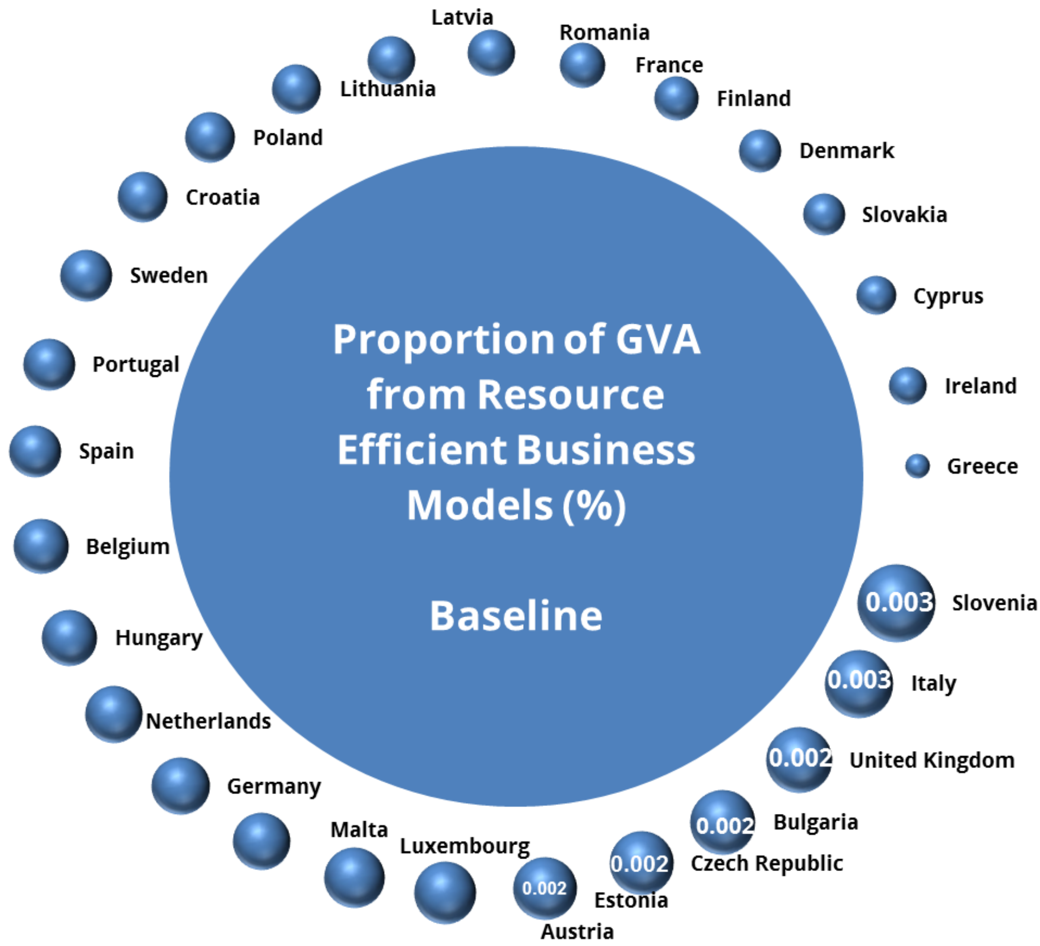
Figure 3.1 Estimates of current GVA by REBM activities across Europe



Source: WRAP calculations
(GVA is estimated as GVA per job x number of jobs)

Figure 3.2 shows the the level of GVA from REBM activities by country. There is a positive correlation between the level of GVA from REBMs and the overall level of GVA within an economy (with a *r* value of 0.95 and *p* value of $1.2*10^{-15}$), suggesting that larger economies have, inter alia, a larger contribution from REBMs. However, there is no relationship between the size of the economy and the percentage contribution from REBMs (*r* value of 0.1 and *p* value of 0.61). Figure 3 shows the relative contribution of Resource Efficient Business Models to national GVA. Although the percentages are small, there is an order of magnitude difference between the country for which GVA accounts for the highest and lowest proportions. This measure is of interest as it shows that there is no clear distinction between northern, southern, eastern or western Europe, and suggests that variables other than the size of the economy can affect the take-up of REBMs in different countries. There is therefore potential for growth regardless of the size of an overall economy. However, there may be country-specific circumstances which could limit the size of the market for REBMs. For example, a key requirement for a successful REBM is that there is a customer base willing to use the business model. If there is differing willingess to engage in REBMs amonst customer groups (businesses or consumers) this would affect the size of the market. Further research would be required at a country level to identify whether or not this is the case.

Figure 3.2 The relative contribution of REBM activities to national GVA by country



Source: WRAP calculations

4. Scenario Analysis

The three indicative scenarios from WRAP (2015a) are applied in this analysis for Europe. For the indicative quantification of these scenarios in this paper the EU28 countries are divided into three groups based on IEEP et al (2011) in order to recognise the heterogeneity across countries in terms of their economic structures, waste management systems and current progress in resource efficiency and recycling. These are shown in table 3. The key assumptions in the scenarios are summarised in Table 4.1.

Table 4.1 Country grouping for the purpose of quantifying the scenario analysis

Group	Economic characteristics	Waste characteristics	Member states
Yellow	Predominantly very fast evolving, currently with low GDP per capita (up until the recent economic crisis)	Characterised by a negative decoupling of waste, with predominantly a poorly established waste treatment and recycling capacity	Bulgaria, Croatia*, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia
Turquoise	Moderate GDP per capita and fast to very fast growing economies (up until the recent economic crisis)	Characterised by an emerging waste treatment and recycling capacity which is still not fully developed	Cyprus, Czech Republic, Greece, Malta, Portugal, Slovenia
Lavender	High GDP per capita, predominantly moderate growth (up until the recent financial crisis)	Evolving towards decoupling for municipal waste, and usually with a developed waste treatment and some recycling heritage	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, UK

Source: IEEP et al (2011), *for this analysis Croatia is allocated to the 'Yellow' category

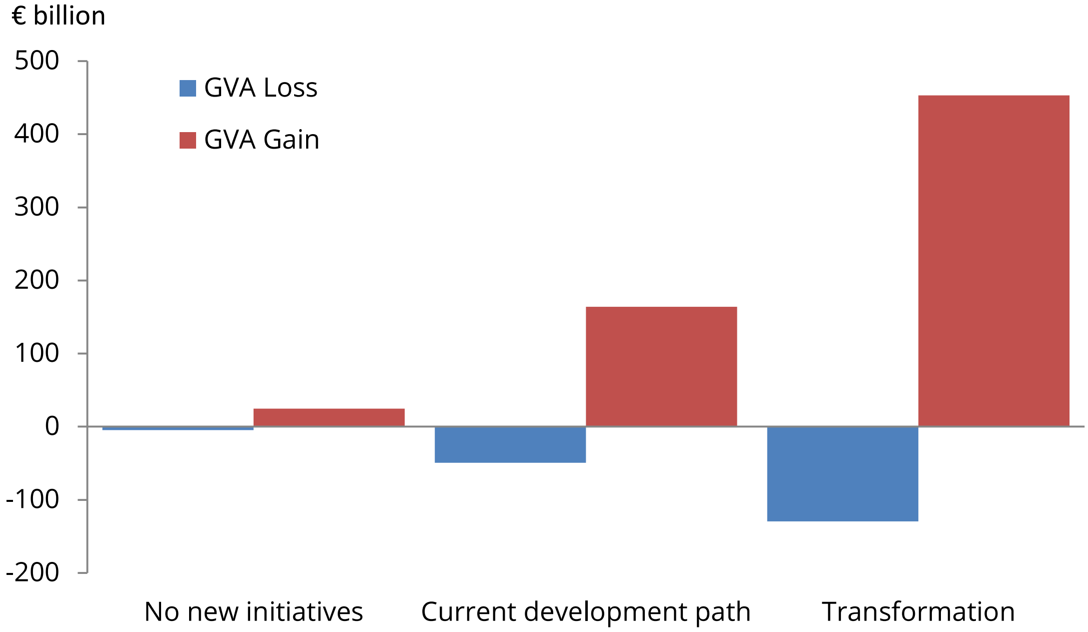
Table 4.1 Key parameters in the scenario analysis to 2030

Scenario parameters	Scenario 1	Scenario 2	Scenario 3
% change from baseline	No new initiatives	Current development	Transformation
Recycling rate (all waste streams) - EU	9	21	34
Yellow	10	20	32
Turquoise	12	33	47
Lavender	9	26	37
Remanufacturing rate - EU	No progress	Moderate	Substantial
Yellow	0	0	50
Turquoise	0	15	50
Lavender	0	20	50
Repair and Reuse - EU	Modest	Moderate	Moderate
Yellow	5	10	10
Turquoise	2	10	10
Lavender	10	15	15
Servitisation - EU	Limited	Modest growth	Substantial growth
Yellow	5	10	100
Turquoise	5	20	100
Lavender	5	30	100

As with the previous reports on jobs (WRAP 2015 a and b), the scenarios consider that growth of Resource Efficient Business Models would lead to a reduction in other activity. The calculation of changes in Gross Value Added, raw material demand and greenhouse gas emissions also take this into account.

Figure 4 shows the changes in GVA associated with the three scenarios, and figure 5 shows further detail on the GVA impact by REBM.

Figure 4.1 Potential GVA impacts from expanding Resource Efficient Business Models to 2030 across Europe



The first scenario assumes that there are no new initiatives undertaken, but some further advancement in REBM activities suggests an increase in GVA of €20 billion across Europe and a reduction in material demand of 7 million tonnes through extending product lifetimes, with an additional 20 million tonnes of material diverted through reuse, repair and recycling (shown in Figure 6) and a reduction in greenhouse gas emissions of 21 million tonnes CO_2eq (figure 7). .

The second scenario considered envisages a continuation of current trends in the adoption of REBMs and indicates that there is a potential to add over €114 billion and reduce material demand by over 63 million tonnes, with an additional 77 million tonnes of material diverted and greenhouse gas emission reductions of 82 million tonnes CO_2eq. Figure 8 shows the geographical distribution of GVA in this scenario, Annex 2 provides further details on a country by country basis.

In the third scenario which assumes that there is a much more extensive adoption of REBMs there could potentially be around €324 billion GVA created by 2030, a reduction in material demand of 184 million tonnes, an additional 172 million tonnes of material diverted and a reduction in emissions of 154 million tonnes CO_2eq. The distribution of GVA in this scenario is shown in figure 9.

Figure 4.1 shows that although GVA displacement (reduction in manufacturing) is highest in the transformative scenario, the gains are also greatest in this scenario and more than offset any losses. Figure 4.2 provides further insight suggesting that of the business models assessed, remanufacturing of products has the greatest potential to increase GVA. Servitisation (rental / leasing) also appears to offer significant potential increases in GVA.

Figure 4.2 Potential GVA gains by activity to 2030 across Europe (€GVA Billion)

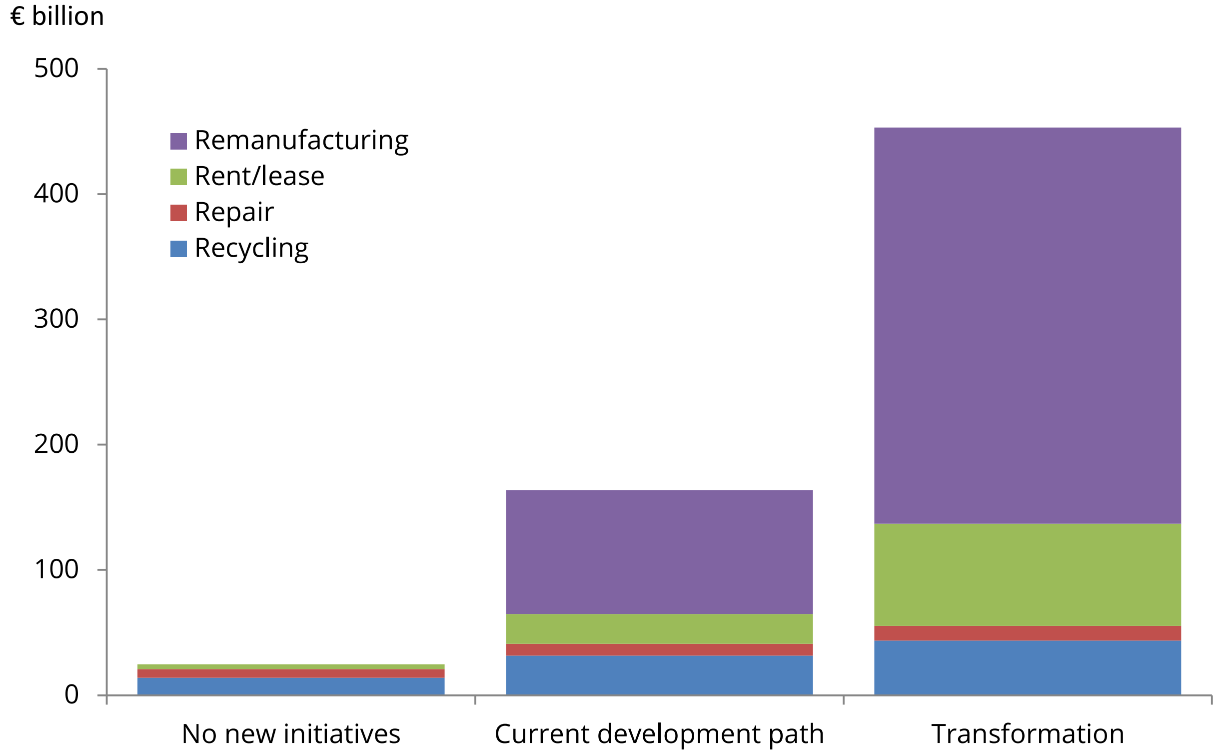


Figure 4.3 Materials diverted and use avoided in Europe, 2030 (Million Tonnes)

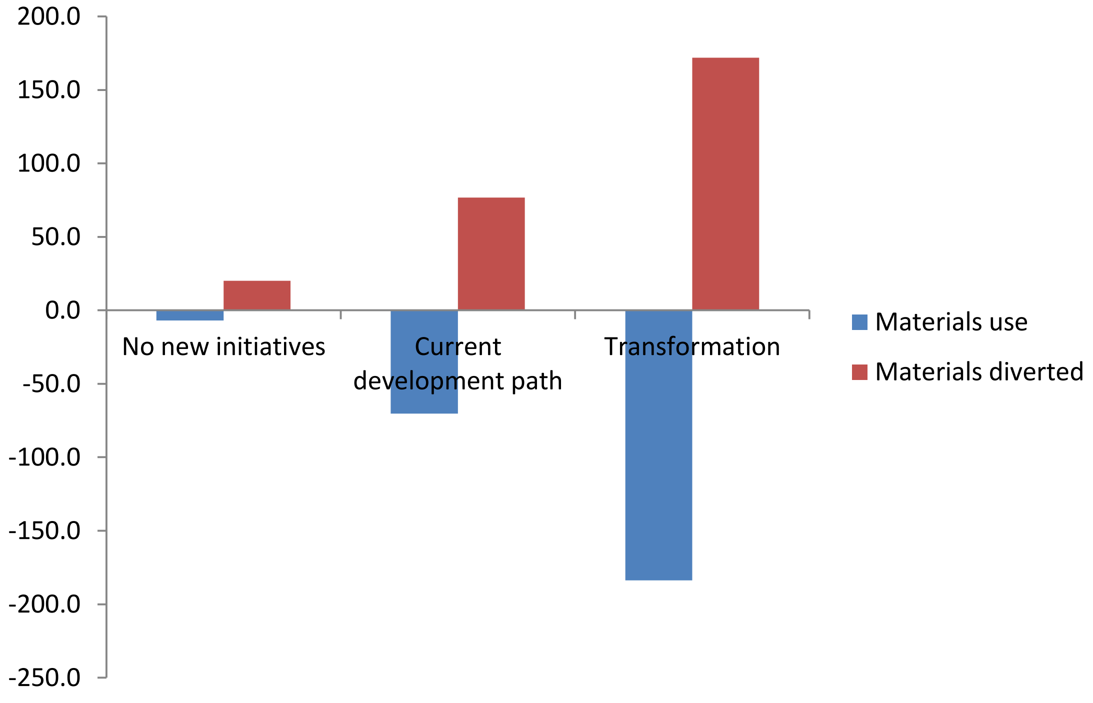


Figure 4.3 and 4.4 are intuitive in that greater adoption of resource efficiency leads to greater reductions in material use and associated greenhouse gas emissions. An important consideration here is the potential for a rebound effect; the idea that introduction of an efficiency may lead to a reduction in cost and therefore an increase in consumption, reducing environmental benefits.

An important distinction between REBMs and efficiency gains in a conventional business model is that REBMs operate in such a way that the productivity of resource use is increased, rather than production costs per unit being reduced. Furthermore, the selling points of REBMs include removing a customer's pain through business model rather than product-based innovation, not necessarily cost-reduction (Baines and Lightfoot 2013). The potential for rebound effects should therefore not be discounted, but should be considered distinct in nature from that associated with conventional efficiency gains.

Figure 4.4 Greenhouse Gas Emissions Reductions from a Global Perspective, 2030 (Million Tonnes CO_2eq)

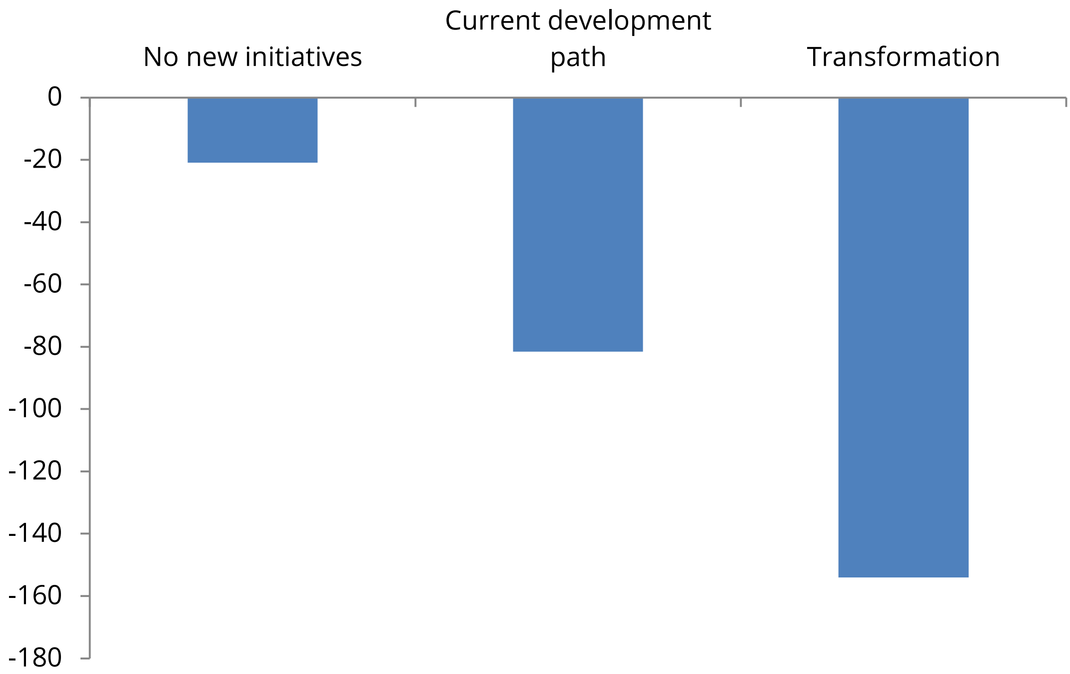
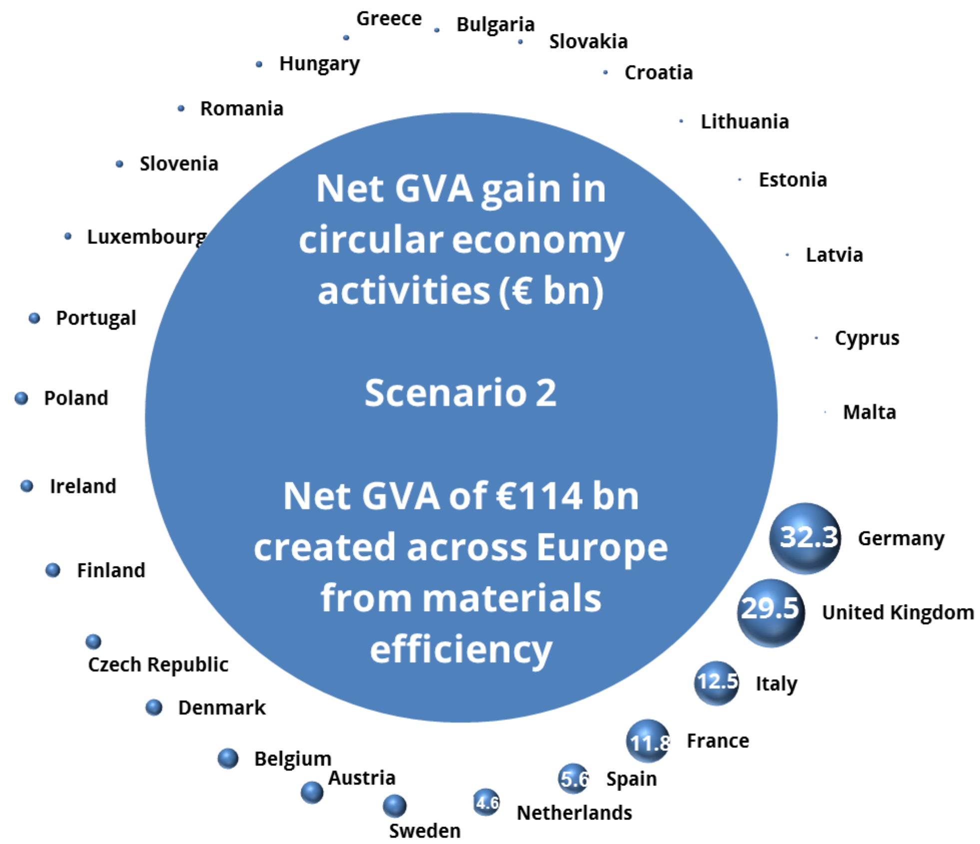
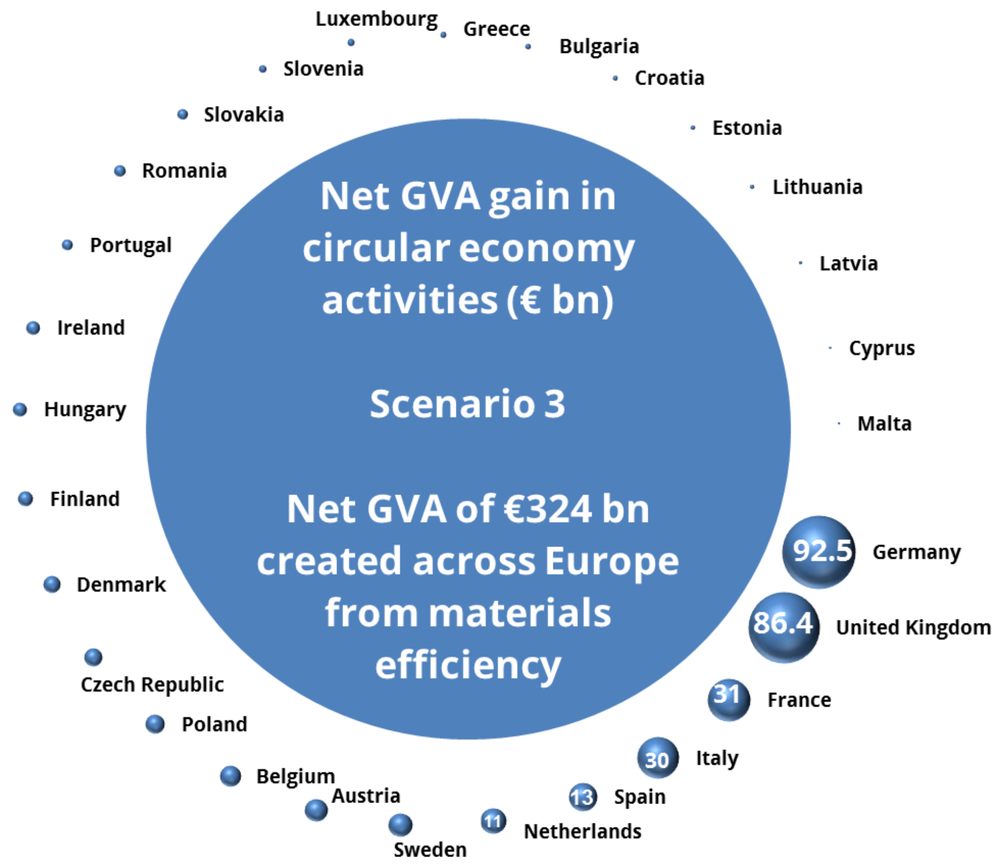


Figure 4.5 Potential increase in GVA from expanding Resource Efficient Business Models to 2030 across Europe



Source: WRAP calculations

Figure 4.6 Potential increase in GVA from transformative scenario Resource Efficient Business Models to 2030 across Europe



Source: WRAP calculations

Figures 4.5 and 4.6 show that the potential gains from REBMs under the current development path and transformative scenario are distributed across European economies. Opportunities exist in in all economies to increase GVA . France, Poland, and Hungary have notable growth opportunities compared to the current contrinbution of REBM activities within their economies .

5. Realising Potential

As part of REBus a surey was undertaken in the UK and Netherlands on business attitudes to REBMs in 2014 and 2016. The survey asked whether companies considered themselves to operate specified REBMs, when they started, if they are considering such models and which sectors they operated in (e.g. construction).

The 2014 survey found that in the UK REBMs are most likely to be service models rather than a product (e.g. mobile phone contract, or a Netflix subscription service). 43% of businesses do not have systems that we consider to represent new business model innovation. In the Netherlands, more businesses reported extending product life beyond the market average e.g. through good quality design and design for repair of products. 64% of businesses do not have systems that we consider to represent new business model innovation.

The survey was carried out in 2016. It asked the same four questions as the 2014 survey, and also asked what internal and external barriers there were to adopting Resource Efficient Business

Models, and what benefits they anticipated. As in 2014, the survey found that 43% of UK businesses do not have systems that we consider to represent new business model innovation. However, the proportion of Dutch respondents who do not have systems we consider to represent REBMs increased from 63% to 75%. Service models are still the most likely resource efficient business model to be adopted in the UK, and extending product life is the most common REBM in the Netherlands. The survey suggest little change in the take-up of REBMs from 2014 to 2016.

In both countries for most REBMs, over half of companies adopting these did so over 2 years ago. However, for collection and resale of products the picture is more mixed, with less than 20% of respondents having adopted this model over 2 years ago in the UK, and 36% in the Netherlands. This should be viewed with caution due to a small sample size, but it is worth noting that this is the business model which appears to have the greatest opportunity for growth in the economic analysis.

For all business models, approximately 10% of business respondents are considering adopting the model over the coming 18 months. Cost savings was the most common benefit cited. This suggests that there is continued business intereste in REBMs.

Though 39% of UK respondents saw no internal barriers to adopting business models and 45% saw no external barriers, 40% of respondents did not think there were any benefits. The degree of overlap between these answers has been assessed to see what proportion of respondents saw neither barriers or benefits. 63% of those who see no benefit also see no internal barriers, rising to 77% for external barriers. Over 60% of respondents who say no barriers also saw no benefits.

This suggests that many businesses do not see a case for adopting REBMs. This hypothesis is further supported by the assessment of the internal barriers which are perceived, with the most significant internal barriers being a lack of perceived applicability and lack of familiarity with the models, and also that those with REBMs are more likely to identify internal and external barriers (i.e. they are more aware of barriers). The split across perceived external barriers across all groups was evenly split across regulatory, financial, market acceptance barriers and also a lack of economic "push" to move to such a model.

[link to REBUs tools and website, REBus recommendations and the need to remember the customer when developing a model]

6. Conclusions

This report builds on WRAP (2015 a and b) and the experience of the REBus pilots to suggest that alongside increased employment, REBMs offer the potential for increases in GVA in every EU Member State whilst also enabling a reduction in Greenhouse Gas Emissions and material demand. Remanufacting and servitization offer the greatest opportunities for growth. Whilst the current contribution of REBMs to the GVA of a nation is closely correlated with the overall GVA of an economy, the percentage contribution to an economy is affected by a wider range of variables, with growth opportunities across the EU. All scenarios ansiticpate growth in adoption of REBMs piloted through REBus, with the greatest gains in all indicators where additional activity is undertaken to develop and enable their adoption.

This additional activity is essential to encourage wider adoption of REBMs. The survey undertaked suggests that whilst 10% of businesses are considering adoption of REBMs in the next two years in the Netherlands and the UK, a significant proportion of businesses are not aware of either the benefits of adopting REBMs or the barriers to adopting these.

References

Baines, T.S., Lightfoot, H. (2013), *Made to Serve: Understanding What It Takes for a Manufacturer to Compete Through Servitization and Product-Service Systems*, Wiley, Hoboken, NJ.

BIOIS (2013) *Assessment of resource efficiency indicators and targets* European Commission https://ec.europa.eu/growth/tools-databases/eip-raw-materials/en/community/document/assessment-resource-efficiency-indicators-and-targets-final-report-%E2%80%93-executive

DEFRA (2011) The Further Benefits of Resource Efficiency http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=16943

European Commission (2013) Labour Market Developments in Europe 2013, European Economy 6, 2013, European Commission

European Parliament (2015) Draft report on resource efficiency: moving towards a circular economy European Parliament Committee on the Environment, Public Health and Food Safety, Brussels http://www.europarl.europa.eu/meetdocs/2014_2019/documents/envi/pr/1055/1055309/1055309en.pdf

Eurostat (2014) Material flow accounts - flows in raw material equivalents http://ec.europa.eu/eurostat/statistics-explained/index.php/Material_flow_accounts_-_flows_in_raw_material_equivalents

Eurostat (2015) Resource Productivity Statistics http://ec.europa.eu/eurostat/statistics-explained/index.php/Resource_productivity_statistics

IEEP et al (2010) "Supporting the Thematic Strategy on Waste Prevention and Recycling", IEEP, ECOLOGIC, ARCAADIS UMWELTBUNDESAMT, BIO INTELLIGENCE SERVICES & VITO http://ec.europa.eu/environment/waste/strategy.htm

WRAP/GA (2015a) Employment and the circular economy – job creation in a more resource efficient Britain, Julian Morgan (Green Alliance) and Peter Mitchell (WRAP) http://www.wrap.org.uk/content/employment-and-circular-economy

WRAP/GA (2015b) Opportunities to tackle Britain's labour market challenges through growth in the circular economy, Julian Morgan (Green Alliance) and Peter Mitchell (WRAP) http://www.wrap.org.uk/content/employment-and-circular-economy

WRAP (2015) Economic Growth Potential of More Circular Economies http://www.wrap.org.uk/content/economic-growth-potential-more-circular-economies

Annexes

Annex 1 The UKMRIO database

The University of Leeds (UoL) has constructed the UKMRIO database (Barrett et al. 2013) which is used to calculate consumption-based accounts (CBA). A CBA reallocates environmental impacts such as greenhouse gas (GHG) emissions, energy or material extraction from production to the point of consumption allowing the full supply chain impact of a product to be determined. UoL calculates the UK's officially reported CBA for CO_2 and all other GHGs (Defra 2014). Since the CBA is a National Statistic[1], the MRIO database is built using input-output (IO) data produced by the UK's Office of National Statistics (ONS). This data is supplemented with additional data on UK trade with other nations and how these other nations trade between themselves from the University of Sydney's Eora MRIO database (Lenzen et al. 2013).

Data from the Eora MRIO database (Lenzen et al. 2013) is used to disaggregate the UK's import and export data to further sectors from other world regions. Data from Eora is also used to show how foreign sectors trade with each other but first the data must be converted to Great Britain Pounds (GBP). The Eora MRIO database is mapped onto the UK's 106 sector aggregation. Eora has a heterogeneous data structure meaning that different countries' IO data have differing sectoral detail. Where a country has a greater level of sectoral detail than the UK, sectors are aggregated to the UK's 106 sectors. When a country has data at a lower level of detail, sectors must be disaggregated. In the absence of more appropriate data, total UK output is used to disaggregate the sectors. Once this step has been performed, the data can be further aggregated by region. Since Eora contains data from almost 200 countries, we are able to select the most appropriate regional grouping for the trade data. For this MRIO materials study, we construct four regions: the UK, the Rest of Europe, China and the Rest of the World.

1.1 Input-output method

The Leontief input-output (IO) model is constructed from observed economic data and shows the interrelationships between industries that both produce goods (outputs) and consume goods (inputs) from other industries in the process of making their own product (Miller & Blair 2009; Bjerkholt & Kurz 2006). In a balanced IO table, inputs equal outputs.
Consider the transaction matrix, **Z** (Figure 0.1), reading across a row reveals which other industries a single industry sells to and reading down a column reveals who a single industry buys from in order to make its product output. A single element, $\mathbf{z_{ij}}$, within $\mathbf{Z}$ represents the contributions from the i[th] supplying sector to the j[th] producing sector in an economy.
Reading across the table, the total output ($\mathbf{x_i}$) of a particular sector can be expressed as:

$$\mathbf{x_i} = \mathbf{z_{i1}} + \mathbf{z_{i2}} + \cdots + \mathbf{z_{in}} + \mathbf{y_i} \quad (0.1)$$

where $\mathbf{y_i}$ is the final demand for that product produced by the particular sector. Essentially, the IO framework shows that the total output of a sector can be shown to be a product of its intermediate and final demand. Similarly if a column of the IO table is considered, the total input of a sector is shown to be a product of its intermediate demand and the value added in profits and wages.
If each element, $\mathbf{z_{ij}}$, along row i is divided by the output $\mathbf{x_j}$, associated with the corresponding column j it is found in, then each element in $\mathbf{Z}$ can be replaced with:

[1] *https://www.gov.uk/government/statistics/uks-carbon-footprint*

$$\mathbf{a_{ij}} = \frac{\mathbf{z_{ij}}}{\mathbf{x_j}} \tag{0.2}$$

forming a new matrix $\mathbf{A}$, known as the direct requirements matrix. Element $\mathbf{a_{ij}}$ is therefore the proportion of input as part of all the inputs in the production recipe of that product.

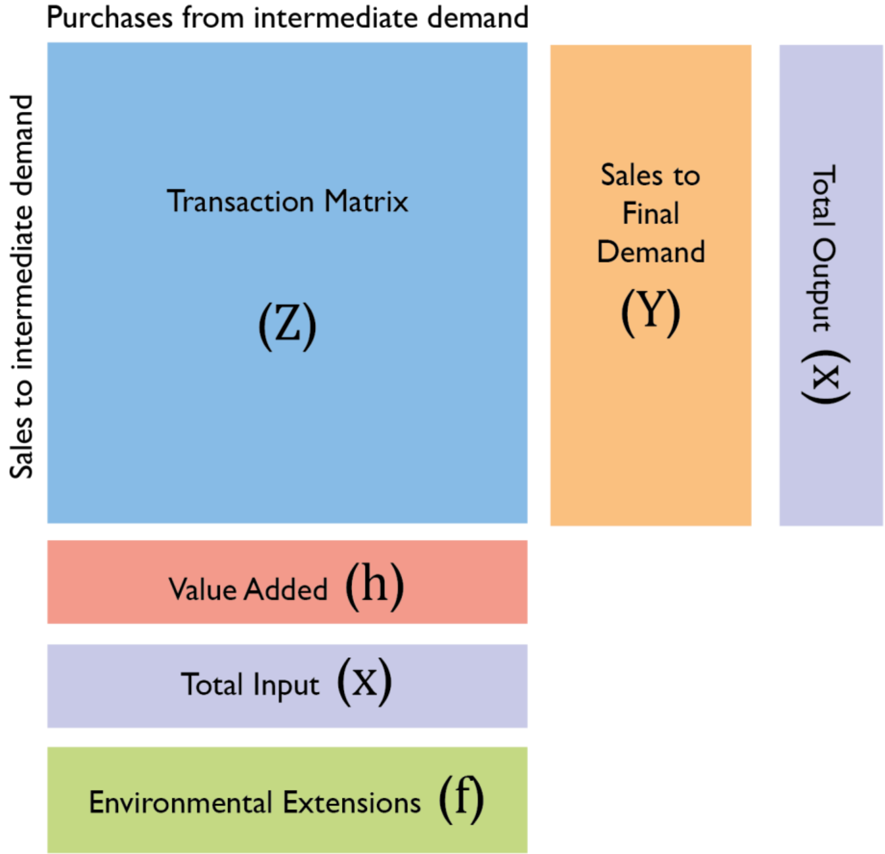


Figure 0.1: Basic structure of a Leontief Input-Output system

Each element in the row vector $\mathbf{h}$, (value added), becomes $\mathbf{h_j} = \frac{\mathbf{h_j}}{\mathbf{x_j}}$

This process normalises the column sums to unity. In other words, summing column j of $\mathbf{A}$ and $\mathbf{h}$ gives a result of one.

Substituting for (0.2) in (0.1) forms:

$$\mathbf{x_{i=}a_{i1}x_1 + a_{i2}x_2 + \cdots + a_{in}x_n + y_i} \tag{0.3}$$

Which, if written in matrix notation is $+\,\mathbf{y}$. Solving for $\mathbf{y}$ gives:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{0.4}$$

(0.4) is known as the Leontief equation and describes output $\mathbf{x}$ as a function of final demand $\mathbf{y}$. $\mathbf{I}$ is the identity matrix, and $\mathbf{A}$ is the technical coefficient matrix, which shows the inter-industry requirements. $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse (denoted hereafter as $\mathbf{L}$).

$$\mathbf{x} = \mathbf{Ly} \tag{0.5}$$

1.1.1 Environmentally extended input-output analysis

Consider, a row vector $\mathbf{f}$ of annual material extraction by each industrial sector

$$\mathbf{e} = \mathbf{f\hat{x}^{-1}} \tag{0.6}$$

is the coefficient vector representing material extraction per unit of output[2]. Multiplying both sides of (0.5) by $\mathbf{e}$ gives

$$\mathbf{ex} = \mathbf{eLy} \tag{0.7}$$

and simplifies to

$$\mathbf{Q} = \hat{\mathbf{e}}\mathbf{L}\hat{\mathbf{y}} \tag{0.8}$$

where $\mathbf{Q}$ is the material extraction in matrix form allowing the consumption-based material impact of products to be determined. $\mathbf{Q}$ is calculated by pre-multiplying $\mathbf{L}$ by emissions per unit of output and post-multiplying by final demand. Material extraction is reallocated from production sectors to the final consumption activities. Adding an exogenous environmental variable to an IO framework produces an environmentally extended input-output model (EEIOM). If we sum the columns of $\mathbf{Q}$ the material footprint of products is calculated.

1.1.2 Gross value added

Now consider, the row vector $\mathbf{h}$ of annual value added by each industrial sector.

$$\mathbf{S} = \hat{\mathbf{h}}\mathbf{L}\hat{\mathbf{y}} \tag{0.9}$$

where $\mathbf{S}$ is the GVA in matrix form. If we sum the columns of $\mathbf{S}$ the GVA of products is calculated.

2. References

Barrett, J. et al., 2013. Consumption-based GHG emission accounting: a UK case study. *Climate Policy*, 13(4), pp.451–470. Available at: http://www.tandfonline.com/doi/abs/10.1080/14693062.2013.788858 [Accessed February 28, 2014].

Bjerkholt, O. & Kurz, H.D., 2006. Introduction: the History of Input–Output Analysis, Leontief's Path and Alternative Tracks. *Economic Systems Research*, 18(4), pp.331–333. Available at: http://www.tandfonline.com/doi/abs/10.1080/09535310601020850 [Accessed March 31, 2014].

Defra, 2014. UK's Carbon Footprint. Available at: https://www.gov.uk/government/statistics/uks-carbon-footprint [Accessed December 5, 2014].

Lenzen, M. et al., 2013. Building Eora: a Global Multi-Region Input–Output Database At High Country and Sector Resolution. *Economic Systems Research*, 25(1), pp.20–49. Available at: http://www.tandfonline.com/doi/abs/10.1080/09535314.2013.769938 [Accessed October 8, 2013].

Miller, R.E. & Blair, P.D., 2009. *Input-output analysis: foundations and extensions*, Cambridge University Press.

[2] ^ *denotes matrix diagonalisation*

Annex 2 Detailed Scenario Results by Country

Scenario 1 No New Initiatives

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Austria	367	198	130	0	695	130	566	0.2	0.5	0.5
Belgium	408	150	137	0	695	134	561	0.2	0.6	0.6
Bulgaria	54	11	4	0	69	6	62	0.0	0.1	0.1
Croatia	42	10	5	0	57	7	50	0.0	0.1	0.1
Cyprus	16	1	2	0	18	1	17	0.0	0.0	0.0
Czech Republic	266	4	26	0	296	12	284	0.0	0.3	0.4
Denmark	159	95	60	0	314	72	242	0.1	0.2	0.2
Estonia	14	6	7	0	27	4	23	0.0	0.0	0.0
Finland	136	110	27	0	272	82	190	0.1	0.2	0.2
France	1,499	1,315	593	0	3,406	907	2,499	1.3	2.3	2.4
Germany	3,051	1,449	732	0	5,233	1,014	4,219	1.4	4.3	4.6
Greece	41	7	16	0	64	15	49	0.0	0.1	0.1
Hungary	86	28	30	0	145	32	114	0.0	0.1	0.1
Ireland	84	28	66	0	177	96	82	0.1	0.1	0.2
Italy	2,547	727	248	0	3,522	564	2,958	0.8	3.4	3.8
Latvia	18	5	3	0	27	4	22	0.0	0.0	0.0
Lithuania	28	7	6	0	41	6	35	0.0	0.0	0.0
Luxembourg	26	5	34	0	66	5	61	0.0	0.0	0.0

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Malta	3	0	2	0	5	0	4	0.0	0.0	0.0
Netherlands	937	331	227	0	1,495	290	1,205	0.4	1.3	1.4
Poland	377	142	54	0	573	96	476	0.1	0.5	0.6
Portugal	229	11	13	0	253	10	242	0.0	0.3	0.3
Romania	108	19	16	0	144	15	129	0.0	0.1	0.2
Slovakia	40	20	11	0	71	15	56	0.0	0.1	0.1
Slovenia	67	5	1	0	72	4	68	0.0	0.1	0.1
Spain	1,307	374	215	0	1,895	361	1,534	0.5	1.8	2.0
Sweden	394	143	85	0	622	127	495	0.2	0.5	0.6
United Kingdom	1,728	1,538	1,302	0	4,568	804	3,764	1.1	2.9	2.3
EU 28	14,028	6,738	4,053	0	24,819	4,814	20,005	7	20	21

Scenario 2 Current Development

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Austria	796	296	783	2,713	4,588	1,474	3,114	2.1	2.1	2.2
Belgium	883	225	825	1,974	3,907	1,212	2,695	1.7	2.0	2.1
Bulgaria	107	22	9	0	137	13	125	0.0	0.1	0.1
Croatia	83	21	10	0	114	14	100	0.0	0.1	0.1
Cyprus	29	3	3	6	42	6	36	0.0	0.0	0.0
Czech Republic	500	20	52	1,610	2,182	743	1,439	1.1	1.1	1.4
Denmark	344	143	361	1,814	2,662	972	1,690	1.4	1.1	1.3
Estonia	29	11	14	0	54	9	45	0.0	0.0	0.0
Finland	294	164	161	1,482	2,102	812	1,290	1.2	0.9	1.1
France	3,247	1,972	3,556	8,910	17,685	5,856	11,829	8.3	8.1	8.6
Germany	6,610	2,174	4,395	38,289	51,468	19,136	32,332	27.2	20.9	26.2
Greece	77	34	32	136	279	107	172	0.2	0.2	0.2
Hungary	173	57	61	0	290	63	227	0.1	0.2	0.3
Ireland	181	41	395	1,210	1,827	864	963	1.2	0.7	1.0
Italy	5,520	1,090	1,487	9,791	17,888	5,408	12,480	7.7	10.3	12.2
Latvia	36	11	7	0	54	9	45	0.0	0.0	0.1
Lithuania	56	15	11	0	81	12	70	0.0	0.1	0.1
Luxembourg	57	8	206	69	340	45	295	0.1	0.2	0.0
Malta	5	1	8	2	16	3	13	0.0	0.0	0.0

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Netherlands	2,029	497	1,360	2,506	6,393	1,824	4,568	2.6	3.8	4.0
Poland	753	285	108	0	1,145	193	953	0.3	1.0	1.1
Portugal	430	57	64	301	852	178	674	0.3	0.6	0.7
Romania	216	39	32	0	287	30	258	0.0	0.3	0.3
Slovakia	80	40	22	0	142	30	112	0.0	0.1	0.1
Slovenia	125	24	3	279	432	141	291	0.2	0.2	0.3
Spain	2,832	560	1,288	3,640	8,320	2,474	5,846	3.5	5.1	5.8
Sweden	853	214	513	3,577	5,157	1,885	3,272	3	2	3
United Kingdom	5,248	1,538	7,813	20,833	35,433	5,919	29,513	8	15	9
TOTAL	31,595	9,559	23,579	99,144	163,877	49,433	114,444	70	77	82

Scenario 3 Transformation

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Austria	1,027	296	2,610	8,163	12,096	3,619	8,477	5.1	4.5	4.0
Belgium	1,140	225	2,750	5,939	10,053	3,023	7,030	4.3	4.0	3.5
Bulgaria	188	22	88	419	716	187	529	0.3	0.4	0.4
Croatia	146	21	103	276	546	151	395	0.2	0.3	0.3
Cyprus	42	3	34	26	106	24	82	0.0	0.1	0.1
Czech Republic	725	20	520	6,575	7,839	2,617	5,222	3.7	2.9	3.4
Denmark	444	143	1,202	5,459	7,248	2,431	4,817	3.5	2.5	2.6
Estonia	51	11	135	265	462	132	331	0.2	0.2	0.1
Finland	380	164	538	4,459	5,540	1,952	3,588	2.8	1.9	2.2
France	4,191	1,972	11,853	26,807	44,823	13,818	31,004	19.6	17.0	14.7
Germany	8,532	2,174	14,650	115,202	140,558	48,026	92,532	68.3	48.4	53.5
Greece	112	34	321	556	1,023	419	604	0.6	0.4	0.5
Hungary	303	57	609	3,863	4,832	1,639	3,193	2.3	1.7	1.8
Ireland	234	41	1,316	3,639	5,230	2,290	2,941	3.3	1.7	2.2
Italy	7,124	1,090	4,958	29,458	42,631	12,979	29,652	18.5	19.0	20.5
Latvia	64	11	65	86	226	60	166	0.1	0.1	0.1
Lithuania	98	15	111	141	365	88	276	0.1	0.2	0.2
Luxembourg	74	8	686	207	975	117	858	0.2	0.4	0.0
Malta	8	1	82	9	100	21	79	0.0	0.0	0.0

Country	GVA gain (€ million)					GVA Potential Loss (€ million)	GVA Net Potential Gain (€ million)	Materials avoided (Million tonnes RME)	Materials diverted (Million tonnes RME)	Net reduction in GHG emissions (Million tonnes CO_2eq)
	Recycling	Repair	Rental/ Leasing	Re-manufacturing	Subtotal					
Netherlands	2,619	497	4,534	7,541	15,191	4,453	10,737	6.3	6.9	6.3
Poland	1,321	285	1,078	6,161	8,845	2,755	6,089	3.9	3.8	4.1
Portugal	624	57	642	1,231	2,553	620	1,933	0.9	1.3	1.2
Romania	379	39	325	1,990	2,733	823	1,910	1.2	1.1	1.2
Slovakia	140	40	225	2,099	2,503	868	1,636	1.2	0.8	1.0
Slovenia	182	24	25	1,141	1,372	462	910	0.7	0.6	0.7
Spain	3,655	560	4,293	10,952	19,460	6,028	13,432	8.6	9.1	9.4
Sweden	1,101	214	1,710	10,763	13,787	4,738	9,050	6.7	5.0	5.6
United Kingdom	8,739	3,844	26,044	62,683	101,310	14,954	86,356	21.3	37.7	14.6
TOTAL	43,642	11,865	81,507	316,109	453,123	129,294	323,829	184	172	154

www.rebus.eu.com

With the contribution of the LIFE financial instrument of the European Community