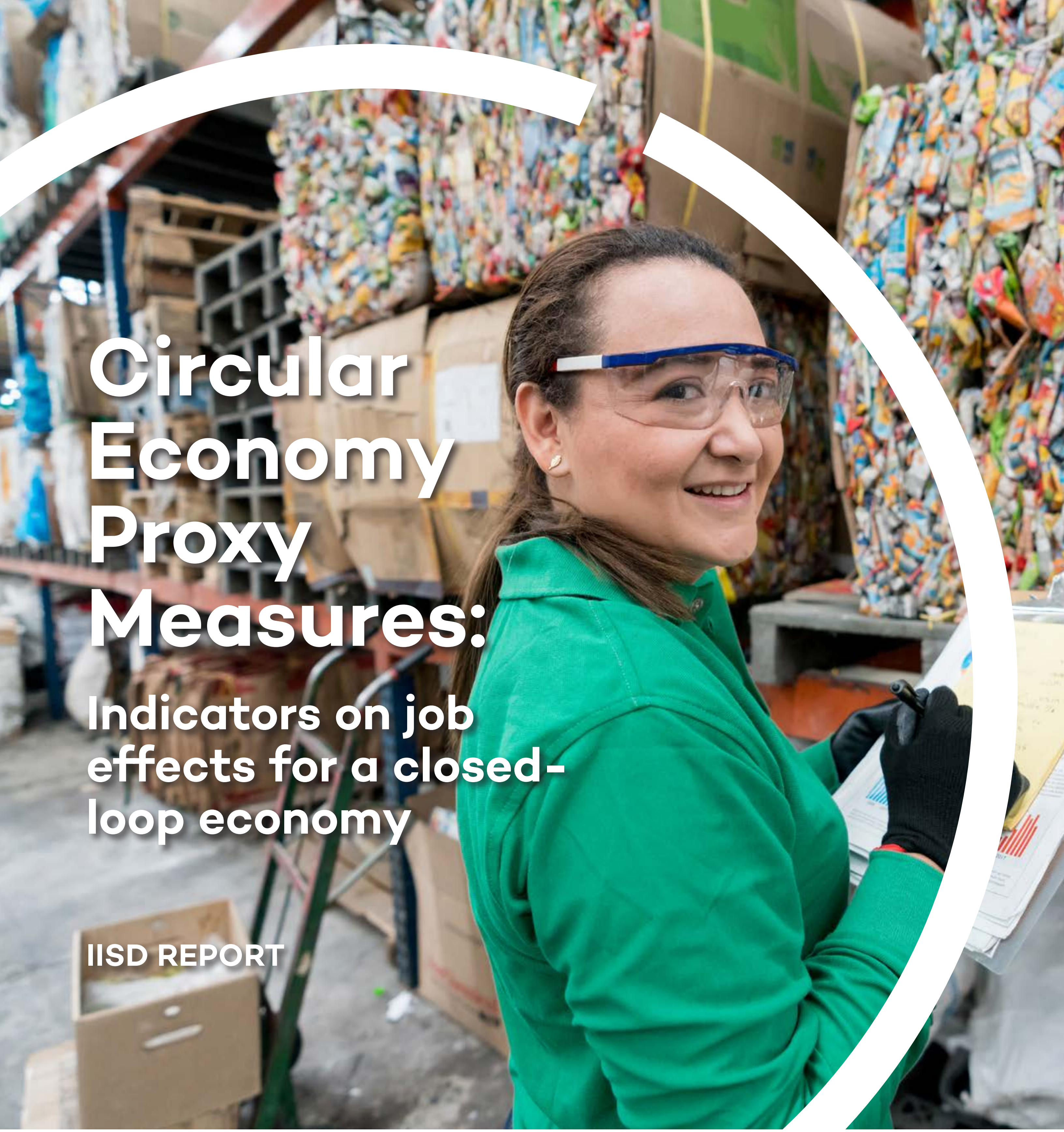

Circular Economy Proxy Measures:

Indicators on job effects for a closed-loop economy

IISD REPORT

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SITRA

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Circular Economy Proxy Measures:
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November 2020

Written by Daniella Echeverría, Joachim Roth, Mostafa Mostafa and Philip Gass.

Executive Summary

This study looks at six proxy measures to obtain a greater understanding of job growth potential in a circular economy. The six proxy measures were chosen based on their sectoral constitution in material and energy efficiency, recovery, repair and recycling. Each of these was examined in terms of their potential job impacts based on tracking where they have been implemented as well as research studies on their potential. Findings of the study include:

- **Material efficiency** has a positive job creation capacity due to three main factors: (1) the profitability of more efficient technologies (innovation); (2) changes in labour productivity; and (3) the foreign value added (meaning the value added of imported inputs that are used to produce products or services designed for export).
- **Waste recycling and reuse** is closely related to material efficiency. In Europe alone, direct jobs could increase by up to 322,000 and an additional 115 million tonnes of recycled material could be created if a 70 per cent target for recycling was successfully reached. These benefits would trickle down to 160,900 indirect jobs and 80,400 induced jobs.
- **Industrial ecology** is the concept of creating industrial networks to reduce waste significantly. There is a gap in studies that outline job creation potential within industrial ecology. Nonetheless, due to its micro-level thinking between related industries, it enables a positive contribution to economic benefits under a closed-loop approach.
- **Energy efficiency** is not only one of the most cost-effective ways to save energy and reduce emissions, it is also considered labour-intensive and conducive to a high rate of job creation, particularly in manufacturing, engineering and construction. In Europe, ambitious energy-efficiency programs could see an estimated potential increase of 0.7 million to 4.2 million new jobs by 2030.
- **Renewable energy** is on the rise globally, providing not only access to reliable, localized energy supply, but also employing many people around the world. Regarding direct job creation, renewable energy technologies have higher labour intensity than fossil fuels, particularly during the construction and installation phases. Comparing the different technologies, the average renewable energy potential is 0.65 jobs/GWh, moving upward to 0.80 jobs/GWh when energy efficiency is added to the mix. These two are far above the estimated average of 0.15 jobs/GWh for fossil fuel technologies.
- **Green procurement** enables a circular economy; although the job effects are less easily quantifiable than for other proxy measures, it can support local job creation while providing decent working conditions. Most of the literature reviewed focused on ways governments are able to utilize green procurement to shift goods and service providers' business models toward a circular economy via government purchasing power.

The six proxy measures to a circular economy present insights into the job trends and job growth potential under a closed-loop approach. All six measures present positive net benefits in job creation (direct and indirect) and induced economic impacts. As a whole, jobs linked to these proxy measures are more labour-intensive than fossil-fuel-related jobs and are able to decouple economic activity from greenhouse emissions.

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Acronyms and Abbreviations

BRICS	Brazil, Russia, India, China and South Africa
EIP	eco-industrial park
EU	European Union
EUEI	European Union Energy Initiative
GHG	greenhouse gas
GDP	gross domestic product
GVA	gross value added
IE	industrial ecology
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
OECD	Organisation for Economic Co-operation and Development
PV	photovoltaic
UKERC	United Kingdom Energy Research Centre

1.0 Introduction

The circular economy is broadly conceptualized as a closed-loop economic model that includes zero-waste and cleaner growth targets (Jensen-Cormier, Smith, & Vaughan, 2018). From this baseline description, the definition of a what a circular economy is varies between countries, organizations and companies. However, some common elements are applied to most definitions, including: material and resource efficiency (e.g., waste reduction via material reuse, repairing and recycling) and broader material efficiency (via different levels and types of recovery within industrial processes) to turn material into long-lasting products as well as useful goods and services (Jensen-Cormier et al., 2018; Witjesa & Lozano, 2016).

By moving away from a linear economic approach—take, make, waste—to a closed-loop approach, a circular economy opens a new space within productivity and wages through opportunities in "innovation, competitiveness, productivity, wage stabilization and industrial strategy" under an environmental and climate lens (Jensen-Cormier et al., 2018). Moreover, a circular economy has a higher rate of labour-intensive jobs compared to a linear economy and uses far fewer resources to boost economic activity (WRAP, 2015). A circular economy seeks to decouple economic activity from greenhouse gas (GHG) emissions in both production and consumption of goods and services (International Labour Organization, 2018) and seeks to stimulate job creation within its goal to boost economic activity by minimizing waste.

Based on a 2014 assessment, the World Economic Forum (2014) estimates that the circular economy has the potential to contribute USD 1 trillion globally, with significant job creation by 2025 and with the largest benefits found in Europe.[1] In Europe, McKinsey & Company (Hannon, Magnin-Mallez, & Vanthournout, 2016) estimated that, by 2030, the region can benefit from an increase of 3 per cent in resource productivity and obtain general cost savings of up to EUR 600 billion annually with an additional EUR 1.2 trillion in other benefits. Based on the induced economic gains and productivity increases, a circular economy will have positive employment effects (Hannon et al., 2016), but more research is needed to fully understand the number of direct and indirect jobs that can be created, alongside their induced economic impacts.

A way to understand the potential of job creation in a circular economy is through proxy measures[2] that closely support a closed-loop economy. Six proxy measures have been selected for assessment to understand their impacts on job creation or loss in a circular economy and, more broadly, on economic growth. The six proxy measures identified listed below represent actions common in a circular economy:

- **Material efficiency**
- **Waste recycling and reuse**
- **Industrial ecology**
- **Energy efficiency**
- **Renewable energy**
- **Green procurement**

The main region of focus in this study is Europe (however with some studies derived from United States and Canada), relying on literature that studies current job trends as well as those modelling job growth potential in the measures mentioned above. To this end, by understanding the potential job impacts from these proxy measures, a better idea is formulated on how a circular economy can contribute to both direct and indirect jobs, as well as its induced economic impacts.

[1] Large benefits are considered to be gained from Europe due to the high concentration of material importation in the region as well as its material-intensive sectors (e.g., the automotive industry) (World Economic Forum, 2014).

[2] Proxy measure means the use of indirect measures of a desired outcome that is strongly correlated to that outcome. In other words, these six measures are strongly correlated to a closed-loop economy, providing a pathway to a circular economy.

1.1 Direct Employment Impacts and Indirect Effects

It is important to note a few limitations that exist in the literature when identifying trends and modelling job growth potential. As noted by the European Union Energy Initiative, direct employment can be straightforwardly calculated, as direct jobs are those that produced the goods and services; however, indirect jobs are more difficult to determine because the "isolation and causality between a project or programme, and the resulting job impacts, are not explicit" (European Union Energy Initiative [EUEI], n.d., p. 3). In some cases, indirect job holders may not categorize or identify themselves in a particular sector. Indirect jobs also take more time to be established and observed. Induced economic impacts are also relevant in job creation but are one more step removed from direct employment and related core economic activities in a specified sector. Induced economic effects are related more to GDP per capita, changes in product or service prices (e.g., consumer tariffs on energy).

Data availability is also an influencing factor. Metrics on job creation often rely on input–output calculations based on national consensus and sectoral labour market data in the economy, which are very useful in determining direct, indirect and induced employment impacts; this data is at times readily available and other times less so. An alternate way of calculating job creation is by using parameters under specific types of technologies, for example, units of generation capacity installed, average electricity generated or project lifetime for the case of renewable energy. This is known as the employment-factor approach, which calculates full-time employment jobs per unit of product or service and can be calculated on aggregate data in the various stages of a project—manufacturing, construction and installation (EUEI, n.d.). However, this approach excludes indirect jobs and induced employment impacts.

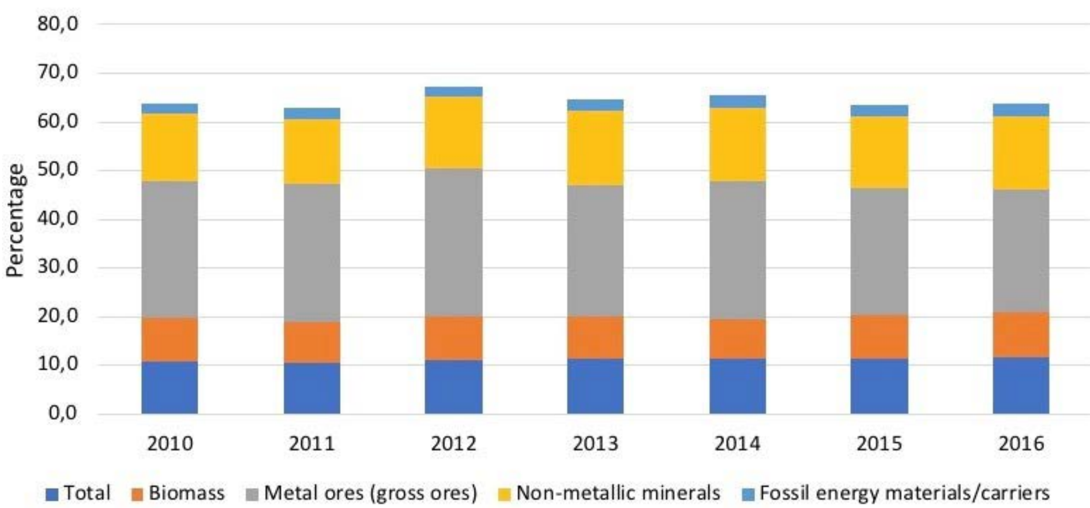
Due to inconsistency in accessibility to data and studies derived from this data, this paper relied on literature that presented both a percentage of jobs created based on labour market data as well as an employment-factor approach. With this in mind, the following sections provide findings on the literature review on the six proxy measures to identify trends, challenges and opportunities in circular economy and job creation. Annex 1 provides a summary of the gross and net jobs found within the literature review within the six different proxy measures.

2.0 Material Efficiency

With our material extraction rate increasing throughout the world by 60 per cent since 1980 (OECD, 2015), it is increasingly clear that our current development path is unsustainable. In 2015, in the space of one year, the world extracted 84 billion tonnes of materials (UN Environment, 2017). Much of this extraction is driven by the increasing demand for metal ores and construction minerals, which are used in construction, high-tech electronics and transportation. A way to reduce these extraction rates is through material efficiency.

Material efficiency is a circular economy concept that seeks to reduce the rate of material extraction while increasing reuse and recycling. It encompasses a wide range of sectors (construction, waste, energy, raw materials, minerals) and overlaps with other circular economy proxy measures, including energy efficiency and industrial ecology. It involves developing a range of sustainable practices such as using natural materials sparingly, managing resource side streams more effectively, reducing waste and increasing recycling methods (Ruuska & Häkkinen, 2014).

Figure 1. Circular material use rate by material type in the European Union (EU)



Source: Eurostat, 2018.

Figure 1 shows that circular material use rates vary significantly between different materials. Metal ores have the highest percentage of circular use whereas biomass and fossil energy materials have the lowest. The figure also reveals that these rates evolved very little between 2010 and 2016. As noted by the Organisation for Economic Co-operation and Development (OECD, 2019), although the high circular material use rate of metal ores is encouraging, it is key to improve those of biomass and non-metallic minerals, which will witness an exponential growth in their extraction rates with biomass increasing by 85 per cent and non-metallic minerals increasing by 132 per cent by 2060 (OECD, 2019).

The most noticeable challenge is the destruction of jobs linked to the reduction of raw material extraction in developing countries. Although material extraction is decoupled from GDP per capita in OECD countries, it is highly correlated with economic growth in non-OECD countries and Brazil, Russia, India, China and South Africa (BRICS) (OECD, 2013). This is explainable, as up to 25 per cent of material inputs from the OECD are imported from non-OECD countries compared to 5 per cent from the BRICS countries (OECD, 2013). A study by UN Environment (2017) on the potential economic implications of resource efficiency reveals that 40 per cent of the proceeds generated from material efficiency in developed countries will need to be reinvested to fund social programs and just transition policies in regions at risk, such as Russia, Mexico, Brazil, South Africa and West Asia. This is understandable, as the majority of low-income countries depend on resource rents for at least 10 per cent of their GDP (Wellesley et al., 2019). In contrast, in developed countries and particularly in Europe where imports represent 30 per cent of material inputs, there is a clear net job creation potential to be gained by increasing material efficiency (OECD, 2013). Material efficiency can reduce the reliance on foreign imports, strengthen domestic manufacturing (while creating greener jobs) and create additional jobs and value added through the opening of new economic sectors such as recycling and green building. Material efficiency also allows investors and companies to reduce costs and increase savings, which can create both indirect and induced jobs.

A global and coordinated approach to a circular economy would also be more beneficial to developing and developed countries. Using the OECD ENV-Linkages computable general equilibrium model, Chateau and Mavroeidi (2020) show that, if only OECD countries were to implement circular economy fiscal policies, global net job creation would be three times lower and material use seven times higher than if a global concerted approach were taken. If only OECD countries were to act, material use would increase the most in resource-intensive non-OECD countries. The latter would suffer employment losses due to lower imports of primary raw materials in OECD countries and the shift toward secondary materials and recycling.

2.1 Direct Employment Impacts

To better understand the direct link between jobs and material efficiency, it is important to know how global value chains function for individual materials and which segments can create the most jobs. Cooper, Skelton, Owen and Densley-Tingley (2016) illustrate how material efficiency creates more jobs than it destroys in the United Kingdom by using a multi-regional input–output model to estimate the job-creating potential of car sharing and the reuse of steel for construction. Their study reveals that car sharing will not reduce employment in the United Kingdom because the domestic automotive industry is already in decline, with 100,000 jobs displaced via automation over the last decade (Cooper et al., 2016). Car demand in the United Kingdom is also mostly met through imports. This means that car sharing will have a small job-displacing effect. On the contrary, car sharing is likely to be a net employment contributor by increasing household savings and creating indirect and induced jobs in other economic sectors.

There are many other ways material efficiency can contribute to employment. Sartorius (2015) shows through an input–output model that, in Germany, material efficiency increases net employment through the combination of three factors: (1) the profitability of more efficient technologies (innovation); (2) changes in labour productivity; and (3) the import of foreign value added. The first factor reduces the costs for producers and in turn increases overall aggregate demand and contributes to indirect and induced jobs. According to some estimates, private investors could save up to USD 2.9 trillion dollars a year by adopting more efficient technology, which would improve resource productivity for land, water, steel and primary energy in the range of 13–29 per cent (Dobbs et al., 2011). This scenario could in turn lead to the creation of 9 million to 25 million jobs worldwide (UN Environment, 2017). Second, material efficiency creates new economic sectors, such as the recycling of used materials in manufacturing. In turn, although these new economic sectors exhibit lower labour productivity as they produce overall less output, they are also more labour-intensive. Yet, these new jobs may initially be less decent than former manufacturing ones and, in the long run, as new recycling sectors develop, labour productivity and wages for green jobs are likely to increase, potentially offsetting some of the initial job creation (Sartorius, 2015). Third, analysis has shown that recycling and collection of scrap and the reduction of waste from non-ferrous metals provides Germany an opportunity to substitute some of its foreign raw material imports with domestic production, thus increasing its net employment (Sartorius, 2015).

In addition to these direct and indirect social benefits, induced jobs can be created. For example, reducing air pollution also reduces negative social and environmental externalities. In turn, this decreases the number of premature deaths per year and reduces the health costs for any given country (Flachenecker, Bleischwitz, & Rentschler, 2016). The induced benefits are clear in terms of improved labour productivity and economic growth.

In the United Kingdom, Morgan and Mitchell (2015) argue that material efficiency initiatives will increase overall employment but that the magnitude of this increase depends on how ambitious circular economy initiatives are. The authors develop a quantitative study with data from the United Kingdom's office for national statistics and use proxy measures for material efficiency such as reuse, closed-loop recycling, open-loop recycling, biorefining, repair and remanufacturing, and servitization. They develop three scenarios, from least to most ambitious, to estimate net job creation in different sectors, with scenario one as the least ambitious (see Table 1). Overall, the benefits of an ambitious material efficiency scenario are clear: the potential to create half a million gross jobs and to offset the reduction in skilled employment by 18 per cent (Morgan & Mitchell, 2015). Table 1 presents their findings in terms of net job creation.

Table 1. Job creation potential of material efficiency initiatives in the United Kingdom under three scenarios

	Scenario One: No New Initiatives	Scenario Two: Current Development Rate	Scenario Three: Transformation
Gross job growth	31,000	205,000	517,000
Net job creation	10,000	54,000	102,000
Unemployment rate fall	0.02%	0.15%	0.28%
% offset of predicted decline in skilled employment over the next decade	1.3%	6.8%	17.7%

Note: Job figures are rounded to the nearest 1,000

Source: Morgan & Mitchell, 2015.

This study also noted that resource efficiency is not only a net job creator, it also happens to be the most labour-intensive in British regions that have the highest unemployment rates, such as London, the northwest and the northeast. Conversely, in the southwest and southeast, where unemployment tends to be lower, material efficiency would lead to fewer jobs. This finding is significant because it reveals, at least in the United Kingdom, that circular economy initiatives are not only unlikely to crowd out jobs but are likely to absorb a certain amount of the population that is unemployed. Interestingly, this absorption of the labour force is possible because the new jobs created roughly match with the skillset of those that are unemployed (Morgan & Mitchell, 2015). The highest net job creation is in elementary sectors such as waste and recycling, which requires a lower skillset and which could absorb the highest share of unemployed people. The types of jobs created would also vary significantly, with mid-waged occupations to be found in repair, rental and leasing or transport, distribution and storage for bio-refinery activities, and higher wages located in marketing, development and testing (Morgan & Mitchell, 2015).

Many other studies, both at the European Union level and within Germany, revealed the positive net benefits of improved material efficiency, despite some job losses within the global value chain. By doubling its material efficiency by 2030, Germany could increase its GDP by 14 per cent and its net employment by 1.9 per cent (Sartorius, 2015). Using an input–output model, and assuming a 25 per cent material efficiency increase by 2030, Wijkman and Skånberg (2015) show that material efficiency could create more than 50,000 jobs in Finland and Sweden and up to half a million in France. Their study also reveals that unemployment could be cut by a third to a half in Sweden and the Netherlands and by a third in Finland and France, and that, on average, the trade surplus of these countries could increase by 1.5 per cent (Wijkman & Skånberg, 2015). The caveat is that, as developing countries establish more circular economies themselves, the benefits are likely to level off in EU countries (Wijkman & Skånberg, 2015).

At the global level, a study by Chateau and Mavroeidi (2020) using the OECD ENV-Linkages computable general equilibrium model shows that, from 2018 to 2040, the shift to a material fiscal reform scenario compared to a baseline (business-as-usual) scenario would lead to the reallocation of 18 million jobs and the total net creation of 1.3 million jobs. According to the authors, the material fiscal reform scenario is the most ambitious circular economy scenario: it includes a tax on primary materials (comprised between USD 5 and USD 50/tonne based on country-level existing extraction tax rates), a subsidy to recycling goods and a production subsidy to secondary metals.

2.2 Indirect Employment and Induced Economy Impact

Meyer (2011) shows through an EU-wide study that improved material efficiency with a total material requirement increasing by only 2.5 per cent (E3ME macroeconometric model) or 11 per cent (GINFORS global industry forecasting system model) from 2010 to 2030 could increase GDP between 2 and 3.3 per cent while creating 2.6 million jobs. So, although in the short run material efficiency represents an important initial investment, it is in the long run very profitable and can even lead to virtuous cycles of growth with the benefits spilling over into other economic sectors as well. A study from the European Commission on the benefits of resource-efficient policies highlights this point: most industries have important initial investment costs, with material efficiency really becoming profitable after 2–5 years (European Commission, 2014). In this study, the European Commission examined 21 cases of companies that implemented material efficiency measures, such as Ecocem, the Goodyear Tire and Rubber Company or AGC Glass Europe, to study the socioeconomic benefits of such measures. The European Commission showed that, while all companies witnessed net job creation, it was more or less significant, ranging from 1.3 per cent for some larger companies (such as Braskem) to 8.4 per cent for smaller ones (such as Ecocem) (European Commission, 2014). Ecocem saved 1.6 tonnes of clay, shale and limestone per tonne of product by developing low-carbon cement and sustained 300 indirect jobs while creating seven new direct ones; Braskem reduced its waste per tonne of product by 14.6 per cent in 2012 compared to 2011 by building a green ethylene plant that created 100 direct jobs. Gypsum Recycling International created 1 job for every 4,000 tonnes of gypsum while saving up to EUR 2.5 million per year by recycling gypsum from landfill to raw material (European Commission, 2014). Yet it is complicated to pin down exactly which factors are responsible for this net job creation, with many exogenous factors possibly interfering, including the financial state of a particular company, the state of the economy or whether the firm is a new player in the material efficiency market or not.

3.0 Waste Recycling and Reuse

Reducing material intensity, improving resource efficiency in production and consumption, and more effectively reducing, reusing and recycling waste within the economy are manifested in principles of the circular economy. The three main waste streams that have significant job growth potential for recycling activities based on a report by the Global Alliance for Incinerator Alternatives (2015) are organics, reusable products, and construction and demolition waste. Of these waste streams, organic and construction materials make up the largest components and, accordingly, generate opportunities in job creation and employment. Moreover, recycling provides more jobs than disposal activities per tonne of material (Global Alliance for Incinerator Alternatives, 2015).

Closing the material loop of production and consumption and using resources as efficiently as possible will inevitably affect both the number of people employed in the recycling and reuse sectors and their skill sets (Cambridge Econometrics, Trinomics, & ICF, 2018).[3] Repair activities not only account for nearly half of all people employed in jobs related to the circular economy, as they are labour-intensive, they also keep more jobs in local economies. Thousands of social enterprises across Europe constantly provide training and employment opportunities for disadvantaged workers in the repair sector (RREUSE, 2015). To this end, this section focuses on the share of waste that is recycled and returned into the economic cycle to continue creating value and to create waste valorization.

3.1 Direct Employment Impacts

Increasing the sustainability and efficiency of materials can generate innovation and new economic activity within the waste management value chain. As economies move toward a closed-loop approach, waste reduction becomes an economic activity that supports growth and green job generation (OECD, 2012). To understand the potential job growth areas, the following sections present information on employment in waste, recycling and remanufacturing.

3.1.1 Waste and Recycling

In Europe, information found on employment in recycling is limited because Eurostat employment data were not structured with a focus on recycling up until 2007. Additionally, data on some relevant activities (e.g., collection of recyclables) were aggregated with other activities. Hence, comparing data gathered up to 2007 with data from 2008 onwards is challenging. Despite these shortcomings, a steady increase in recycling-related activities in Europe is visible between 2000 and 2007 with an increase of 45 per cent, from 422 to 611 jobs per million inhabitants (European Environment Agency, 2011).

In a study conducted by RREUSE (2015), it is estimated that for "10,000 tons of waste products and materials, one job can be created if incinerated, six jobs if landfilled, 36 jobs if recycled, and up to 296 if refurbished and reused" (p. 1). However, further growth in the reuse sector requires concrete waste management policies, legislation, collection services and a stronger focus on achieving higher reuse targets (RREUSE, 2015, p. 1).

An OECD report prepared for the G7 environment ministers discusses employment implications of green growth on the European waste collection, treatment and recycling sector. In 2017 it was estimated that the sector employed around 3.5 million people. More than half of the jobs are found in the recycling industry of the EU, around 1.8 million jobs (OECD, 2017). However, employment is projected to continue to grow. In an analysis by Friends of the Earth (2010), it was estimated that, by achieving a 70 per cent recycling target, 322,000 direct, 160, 900 indirect and 80,400 induced new jobs could be created. The 2008 Waste Framework Directive defined a target of

[3] Nevertheless, the literature points to jobs in the repair sector being in decline as a result of increasing obstacles and costs to reuse and repair.

50 per cent of municipal waste to be recycled by 2020 in individual countries. At the moment, 14 countries are at risk of missing that target (Hogg, Elliot, Burgess, & Vergunst, 2018).

3.1.2 Remanufacturing

Lundmark, Sundin and Björkman (2009) highlight the importance of the remanufacturing industry in recycling and reuse, where, through its industrial processes, used products can be restored to an "as new" condition. In the *Remanufacturing Market Study* conducted by the European Remanufacturing Network (2015), it was estimated that the European remanufacturing industry in 2014 employed 192,000 people, with aerospace and automotive remanufacturing being the prominent sectors accounting for nearly 60 per cent. According to the European Commission's (2015) *Annual Analyses of the EU Air Transport Market 2013*, the European maintenance, repair and overhaul sector has considerable potential for growth. It is expected to grow at an annual average rate of 2.9 per cent until 2024.[4]

3.2 Indirect Employment and Induced Economic Impacts

In the previously cited Friends of the Earth (2010) report, it is noted that the contribution of the recycling sector and its supply chain over the last decade and tracked the growth of employment in this sector as recycling rates and tonnages have increased. Reaching a 70 per cent recycling target could add up to 322,000 direct jobs across the EU27. In order to reach this target, an additional 115 million tonnes of glass, paper, plastic, ferrous and non-ferrous metals, wood, textiles and biowaste have to be recycled. An induced impact to the wider economy could add 160,900 indirect jobs and 80,400 induced jobs to the job market. This adds up to 563,000 net new jobs. Yet the impact that exporting a higher rate of recyclate might have on processing and manufacturing opportunities in Europe remains unclear (Friends of the Earth, 2010).

At a country level, the United Kingdom showed that 29,400 new direct jobs could be added to the recycling sector by 2025 by increasing the national recycling target from 50 per cent to 70 per cent. Taking into account the indirect and induced jobs in the wider economy, up to 51,400 total jobs could be created. This would include 42,300 jobs in England, 4,700 jobs in Scotland, 2,600 jobs in Wales and 1,800 jobs in Northern Ireland (Friends of the Earth, 2010).

Flanders, the Flemish region of Belgium, with approximately 6 million inhabitants, managed to quadruple turnover in reuse shops with social benefits between 2001 and 2012. This shows great indications for growth and a win–win–win for people, business and the environment in the waste sector as a whole. Looking at the job increase in this sector, Dubois and Christis (2014) estimated that an added value of EUR 2.3 billion (1.3 per cent growth of Flemish GDP) or approximately 27,000 jobs can be generated in Flanders by 2020 through well-implemented circular economy policies. Flemish reuse centres employ approximately 5,000 people and collect around 64,000 tonnes of material annually, of which half is reused. Such policy moves have established Flanders as the vanguard of waste management in Europe. Further discussions focus on increasing the current rate of 5 kg reused material per capita to 7 kg by 2022 (RREUSE, 2015). In another example, an analysis by the Netherlands Organization for Applied Scientific Research shows that, under the projected increase in reuse, collection and recycling of products and waste, a 1.2 per cent increase in GDP and the creation of 54,000 (0.6 per cent of overall employment) new jobs is possible (Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013).

In summary, through sound investments and policy interventions, the overall trend in the last decades has shown that regarding the world's waste streams as valuable resources offers the potential to create a range of jobs, to reduce material intensity and to improve resource efficiency in production.

[4] The industry does face challenges, particularly within the collection phase. There is a lack of control regarding quantity, quality and timing of the returned products. Notwithstanding, with the emergence of a circular economy in which end-of-life products are reused, remanufactured and recycled, large industries have the opportunity to create more goods from recycled material (Lundmark et al., 2009), which can drive improvements in efficiencies to address current control issues through technology and application of best practices.

4.0 Industrial Ecology

Industrial ecology first developed in the 1970s, with some scholars viewing it as the precursor to the concept of circular economy (Bruel, Kronenberg, Troussier & Guillaume, 2018). The idea of industrial ecology is to have industrial networks that mimic natural ecosystems (Deutz & Gibbs, 2008). Firms can compete or cooperate with each other, working in symbiosis while displaying diverse features reminiscent of the diversity of living species. Many natural and industrial features are linked in that way, with inter-firm competition seen as the equivalent of natural selection, for example (Deutz & Gibbs, 2008). One of the key tenets of industrial ecology is that waste no longer exists, per se, but rather is replaced by the notion of residual. This means that one firm's input simply becomes another firm's output (Deutz & Gibbs, 2008). Industrial ecology therefore adopts a macro and systemic view of the circular economy where eco-efficiency must be implemented not simply at the individual firm level but within industrial clusters. At its core, industrial ecology regroups several practices such as joint firm purchasing and shared infrastructure, and increases inter-firm economic exchanges and sustainable supply chain management (Veleva et al., 2015).

Eco-industrial parks (EIPs) are one of the most significant forms of industrial clustering, where industries operating in different branches collaborate with each other to increase their material and economic efficiency (Veleva et al., 2015). These exchanges lead to long-term gains for the surrounding community with an increase in net employment and a higher quality environment. The Danish town of Kalundborg is cited as one of the earliest manifestations of industrial symbiosis and clustering in the industrial ecology literature. In Kalundborg, several firms entered into a symbiotic relationship over the space of 25 years by exchanging materials between each other with, for example, the transfer of fly ash from the local power station to the town cement plant or excess heating generated from the power station used for district heating (Veleva et al., 2015). The chief aim of industrial ecology and EIPs is to improve the competitiveness of local industries, to create quality jobs and good working conditions, and to reduce waste and pollution (Gibbs & Deutz, 2005). Industrial ecology creates green jobs in niche sectors through the build-up of these inter- and intra-firm synergies that open up new economic avenues. Waste firms, for example, are particularly active in industrial ecology and, through environmental regulations, are able to create new departments to address end-of-life material processing and to support the increased inter-exchanges between different firms (Paquin, Busch, & Tilleman, 2015)

4.1 Direct Employment Impacts

Through regression analysis using 313 industrial symbiosis cases across the United Kingdom, Paquin et al. (2013) were able to show which factors influenced the most job creation or destruction and which types of jobs were being created in the process. Their analysis revealed that having a specialized waste firm partner with other industrial groups increases the likelihood of creating eco-jobs by 12 per cent (Paquin et al., 2015). Interestingly, their data also shows that the correlation between increased inter-firm exchanges and job creation is low and that, if a firm has many sites within a particular country (in this example, the United Kingdom), the likelihood of job creation decreases significantly. The study concludes by saying that industrial ecology exchanges involving large quantities of materials increase the amount of savings and sales that firms can make (Paquin et al., 2015). Although the authors do not quantify the corresponding net job creation, it is likely that this has a positive effect on both indirect and induced jobs.

Table 2. Eco-efficiency and eco-development outcomes from industrial symbiosis exchanges in the United Kingdom

	Eco-efficiency outcomes: CO_2e reductions *and*:				Eco-development outcomes: CO_2e reductions *and*:			
	(1) Increased sales (eco-sales)		(2) Increased cost savings (eco-savings)		(3) Increased employment (eco-jobs)		(4) Business development (eco-business)	
Landfill diverted[a]	0.095***	(0.028)	0.082*	(0.025)	0.148***	(0.044)	0.218***	(0.066)
Waste firm	0.011	(0.302)	−0.666**	(0.319)	0.780*	(0.393)	1.317***	(0.392)
Industry grouping	0.066	(0.290)	0.136	(0.299)	0.444	(0.367)	0.003	(0.452)
Exchanges completed	0.171**	(0.053)	0.266***	(0.062)	0.073	(0.067)	0.037	(0.088)
Turnover[a]	0.005	(0.026)	0.065**	(0.026)	0.048	(0.043)	0.008	(0.050)
No of sites	−0.062	(0.072)	−0.071	(0.065)	−0.273*	(0.135)	−0.078	(0.130)
Material types								
Confidential	−0.281	(0.449)	0.877†	(0.453)	0.688	(0.567)	−0.532	(0.958)
Effluent	0.006	(0.356)	0.684*	(0.313)	0.202	(0.580)	0.185	(0.569)
Expertise	−0.201	(0.460)	0.002	(0.388)	1.336*	(0.548)	0.478	(0.666)
Food waste	0.613*	(0.276)	0.310	(0.265)	0.346	(0.485)	−0.257	(0.595)
Infrastructure	0.936*	(0.472)	0.457	(0.451)	1.328*	(0.629)	1.969••	(0.645)
Plastic	0.407	(0.304)	0.391	(0.281)	0.901†	(0.486)	0.474	(0.635)
Rubber	0.254	(0.433)	−0.042	(0.432)	0.615	(0.595)	0.063	(0.676)
Textiles	0.256	(0.482)	0.331	(0.430)	0.907	(0.690)	1.101	(0.739)
Wood	0.801*	(0.332)	1.336***	(0.331)	0.250	(0.600)	1.902*	(0.517)
x^2	38.76***		74.31***		33.74***		46.53***	
Log likelihood	−148.2		−172.6		−65.31		−48.38	

n=313; Standard errors in parentheses

***p<0.001, **p<0.01, *p<0.05, †p<0.10.

[a] indicates logged variable.

Source: Paquin et al., 2013.

Table 2 was built by the authors using data from the United Kingdom's National Industrial Symbiosis program from 2003 to 2007, where they created four categories of dependent variables (eco-sales, eco-savings, eco-jobs and eco-business). Increased employment refers both to jobs created and jobs at risk of being lost that are safeguarded with the industrial exchanges. Industry grouping is a binary variable that informs whether firms that work in industrial symbiosis are part of the same industry group. The regression results also reveal that environmental regulations do not have the same job- and value-creating effects, depending on the sector at hand. Indeed, eco-jobs are most likely to be created in the plastics, infrastructure and expertise industries.

4.2 Indirect Employment and Induced Economic Impacts

Although few studies quantify the job creation potential of industrial ecology in Europe, there are many other socioeconomic benefits to industrial symbiosis programs and industrial ecology. For example, Guatemala has used EIPs not only as a way to increase formal employment but also a means of attracting foreign direct investment. As a result, the country has promoted the development of 17 free economic zones that aim to create favourable local policy conditions for the development of low-carbon technologies. The plan has already been touted as a success, with the creation of 3,000 formal jobs (World Bank, 2016).

Despite the less easily quantifiable outcomes, industrial ecology has other medium-to-long-term positive impacts, including indirect employment creation through skill upgrading, technology transfer and demonstration effects that serve as best practice examples for other countries (United Nations Industrial Development Organization, 2016). Data and studies reviewed presented limitations in obtaining tangible information on job creation; however, due to the positive induced job impacts, such as increased material efficiency and inter- and intra-industrial synergies, industrial ecology supports a circular economy approach. Moreover, despite a lack of studies in net job creation, it is important to note that industrial ecology was the early forerunner to circular economy thinking at a micro level between related industries, and therefore an enabler to net economic benefits under a circular economy approach.

5.0 Energy Efficiency

Energy efficiency reduces the amount of energy required to deliver a product or service. At the same time, it also has positive impacts on economic performance and competitiveness, job growth, energy security and better health benefits from energy-efficiency measures. It plays a major role in limiting climate change, and it is one of the most economically viable options in reducing emission and energy use (Lebot & Yada, 2017). On job creation, in contrast to energy production, the energy-efficiency sector is considered labour-intensive and conducive to a high rate of job creation.

Given their focus on reducing the use of energy, energy-efficiency policies support the transition to a circular economy by reducing fossil fuel consumption and curbing GHG emissions. Further, they demonstrate the effective decoupling of economic activities from GHG emissions. Similar to waste recycling and reuse policies, energy-efficiency programs keep money in local economies, leading to direct and indirect job creation as well as to induced job impacts that often double the total number of jobs (European Climate Foundation, 2016). Due to its energy use focus, the majority of job creation is observed in manufacturing, engineering and construction labour markets.

5.1 Direct Employment Impacts

According to the report *A New Paradigm for the European Energy System*, in 2010, 1 million people worked in jobs dedicated to energy efficiency in the EU. This amounts to the same number of jobs in renewables in 2010 and more than the total number of jobs in the European nuclear industry (European Climate Foundation, 2016). Similarly, the International Energy Agency (IEA) reports that in 2017 there were over 2.25 million people employed in the United States in the energy-efficiency sector, double the number of jobs in all of the fossil fuel sectors combined (IEA, 2018). Moreover, the energy-efficiency sector was observed to be the fastest-growing job sector within the United States, with a net increase of 67,000 jobs between 2016 and 2017 (EFI & NASEO, 2018, cited in IEA, 2018).

In addition to understanding the potential in job creation in the energy-efficiency sector through observed trends, many studies have been conducted modelling on-the-job impact in the energy-efficiency sector in the short to long term. For example, a study conducted by Cambridge Econometrics (2015) assessed the employment and social impact of energy efficiency in the EU to 2030. In the study, the authors reported that energy-efficiency goods and services produced in 2010 amounted to approximately 0.9 million jobs. This figure increased to 2.4 million jobs when other activities that could potentially generate energy savings were included in the analysis (direct and indirect), equivalent to 1 per cent of total EU employment. Using these figures, the study applied two macroeconomic models, the GEM-E3 (computable general equilibrium) model and the E3ME (macroeconometric) model.[5] Under both models, projected increases are observed in EU employment, noting a shift in production from energy-intensive (i.e., fossil fuel) sectors to labour-intensive sectors (e.g., renewable energy). Under ambitious energy-efficiency programs, the models estimated a potential increase in EU employment of 0.7 million to 4.2 million by 2030 (Cambridge Econometrics, 2015).

In Canada, a study focused on the implementation of the national climate and low-carbon economy plan for the years 2017–2030. Based on macroeconomic modelling (Clean Energy Canada, 2018), the analysis reviewed anticipated energy-efficiency targets in existing and new residential and commercial buildings, appliances and equipment and large industry energy management. The modelling projected that, for CAD 356 billion in investments in energy-efficiency improvements and energy savings, Canada will obtain a net increase of 118,000 full-time-equivalent jobs, or over 1.6 million "person years" (or one full-time position for a period of one year) of

[5] One of the main differences between these two models is in the assumptions about resource use or optimizing behaviour. The GEM-E3 assumes optimal behaviour in efficient resource use from individuals and firms, while the E3ME bases its relationships on historical patterns, identifying unused resources and the potential to increase efficiency in resource use (Cambridge Econometrics, 2015).

employment spread evenly over the 14-year span. Under more ambitious investments of CAD 595 billion, this will translate to over 174,500 full-time jobs on average or over 2.4 million "person years" between 2017 to 2030 (Clean Energy Canada, 2018). Given the labour-intensive nature of energy efficiency, it is not surprising that the modelling results project that the majority of job creation will be within the construction, manufacturing and retail/wholesale trade sectors (Clean Energy Canada, 2018).

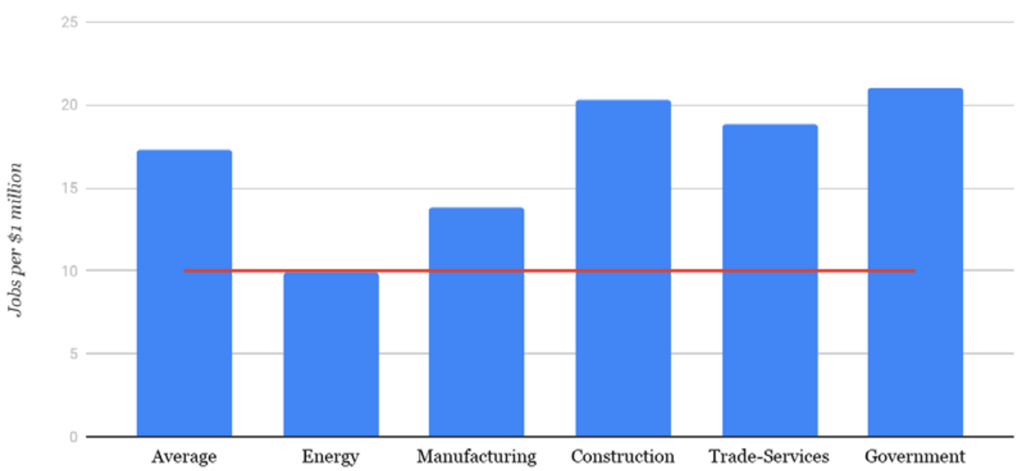
5.2 Indirect Employment and Induced Economic Impacts

Indirect job creation and induced employment effects are also observed through investments in energy efficiency. For example, between 2009 and 2013 in the EU an estimated EUR 6.5 billion was invested in the sector, with an observed 79,000 people indirectly employed and an estimated EUR 1 billion returned to the state via the value-added tax (European Commission, 2017a). Moreover, in the same time period, energy savings amounted to over 28,000 GWh.

A report prepared for The Climate Institute examined the causal relationship between energy efficiency and economic growth, and concluded that energy-efficiency improvements contributed positively to economic growth for the group of 28 OECD countries over the last three decades (Vivideconomics, 2013). Further statistical evidence demonstrates that energy efficiency positively contributes to economic growth. For example, Vivideconomics (2013) estimated that a 1 per cent increase in the level of energy efficiency is associated with a 0.10 per cent increase in the rate of economic growth in that year.

Similar to the EU, energy-efficiency measures have also increased job creation in the United States. For example, a study by Bell (2014) noted that the impact of investments in energy efficiency goes beyond environmental benefits and energy use savings. The study outlines that there is considerable focus on what can be done to improve the energy efficiency of existing buildings. For example, in addition to replacing light bulbs and building electronics, fitting doors with self-closing mechanisms to minimize the time that they are open and ensuring that windows and doors are fitted with appropriate draft excluders are other ways in which energy efficiency can be improved. Figure 2 shows that the U.S. construction sector supports approximately 20.3 jobs per USD 1 million investment. This sector is more labour-intensive than the average economy per USD 1 million invested. Based on Figure 2, the U.S. economy creates 17.3 jobs per USD 1 million invested; shifting this initial investment into the construction industry creates three more jobs per USD 1 million, totalling 20.3 jobs/USD 1 million investment (Bell, 2014).

Figure 2. Jobs per USD million of revenue by key sectors of the U.S. economy



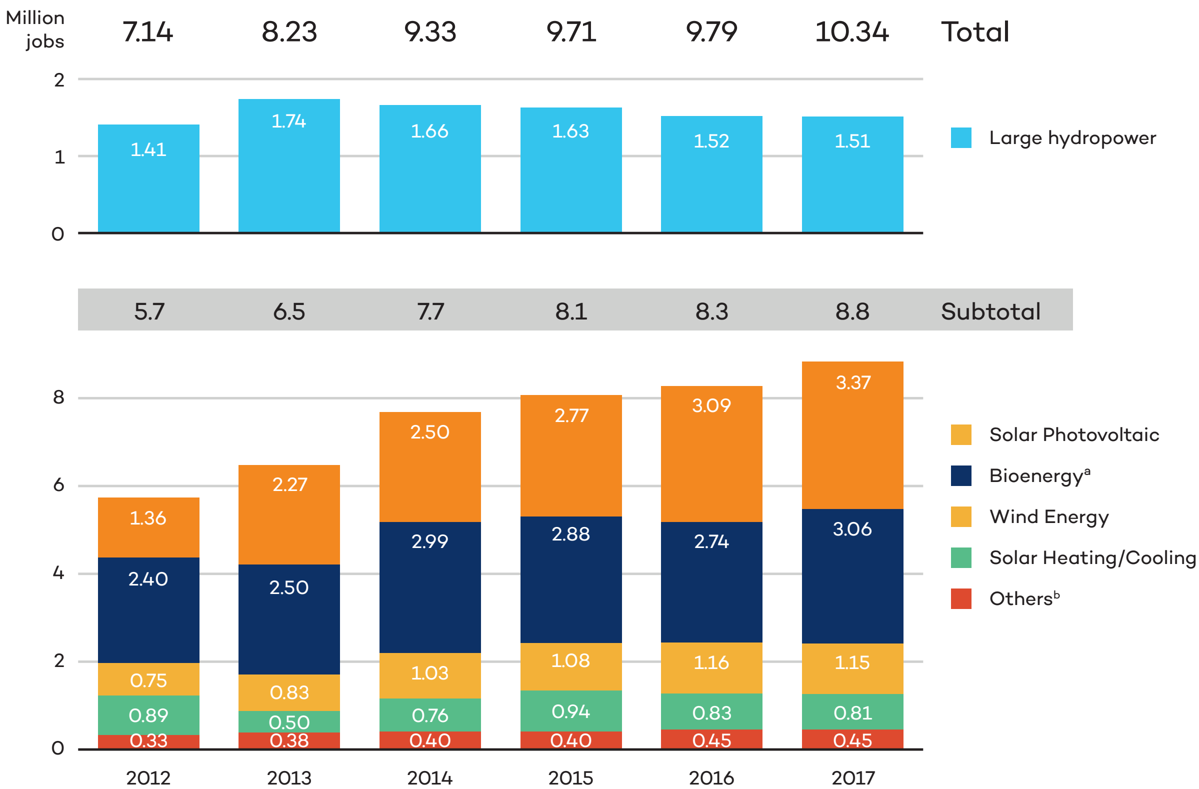
Source: MIG, 2011; ACEEE, 2011, as cited in American Council for an Energy-Efficient Economy, n.d.

To sum up, investments in energy efficiency can lead to new job creation in construction, manufacturing, research and other industries. In addition, different studies demonstrate that energy-efficiency measures show promising trends not only for reducing energy bills but also for reducing emissions and pollution. Based on their positive socioeconomic and environmental benefits, many countries around the world are implementing energy-efficiency measures across all sectors, successfully decoupling economic activity from (supply and demand) energy use and the release of GHG emissions. A survey of central bank officials, finance ministry officials, and other economic experts from G20 countries identified building efficiency spending for renovations and retrofits—including improved insulation, heating and domestic energy storage systems—as one of five COVID-19 recovery stimulus policies that are perceived to deliver large economic multipliers, can be implemented reasonably quickly and help shift the emissions trajectory toward net zero (Hepburn et al, 2020).

6.0 Renewable Energy

Renewable energy generation has positive enabling effects on economic growth and contributes to energy resiliency and grid decentralization, limiting technical failures during extreme weather events and the disruption of goods and services production (Armeanu, Vintila, & Gherghina, 2017). Moreover, there is job creation in developing, setting up and operating renewable energy systems (Armeanu et al., 2017). Based on the International Renewable Energy Agency's (IRENA) *Renewable Energy and Jobs: Annual Review 2018*, over the past few years there has been an observed upward trend in direct and indirect jobs in renewable energy: 2017 witnessed a 5.3 per cent growth in the sector from the year previous, employing an estimated 10.3 million people worldwide.[6] The leading industries in job creation were solar photovoltaic (PV) and bioenergy industries (IRENA, 2018). Figure 3 provides a summary of the global trends in employment in renewable energy by technology between 2012 and 2017.

Figure 3. Global renewable energy employment by technology, 2012–2017



Source: Adapted from IRENA, 2018.

Note: The numbers shown in this Figure reflect those reported in past editions of the Annual Review

a Includes liquid biofuels, solid biomass and biogas

b Other technologies include geothermal energy, hydropower (small), concentrated solar power (CSP), heat pumps (ground-based), municipal and industrial waste, and ocean energy

Since 2012 renewable energy technologies have matured and improved continuously, and as technological advancements in the sector continue to grow, so do the economies of scale surrounding them, positively supporting

[6] Of the 10.3 million jobs, 43 per cent of these are located in China, followed by Brazil, the United States, India, Germany and Japan, all leading producers in renewable energy technologies.

indirect employment and induced economic impacts.[7] To understand employment potential in renewable energy, the sections below provide insights on the four major types of renewable energy: biomass, hydroelectricity, solar PV and wind.

6.1 Direct Employment Impacts

Renewable energy technologies have higher labour intensity than fossil fuels, particularly during construction and installation phases. This results in higher job creation during the construction, installation and manufacturing phases in the value chain over the operation and maintenance periods of these systems (EUEI, n.d.). This translates to higher-paying jobs in the renewable energy field compared to fossil fuels, as well as job creation for low-skilled workers. Based on a study conducted by the United Kingdom Energy Research Centre (UKERC, 2014), non-fossil-fuel technologies (including renewal energy and carbon capture and storage) have a higher rate of job creation per energy unit than coal and natural gas. In their study, UKERC note that, due to the labour-intensiveness in renewable energy (and energy efficiency), in the short term, building new generation capacity creates more jobs than investing in an equivalent level of fossil fuel energy generation. Further on investments, the European Union Energy Initiative notes that renewable energy creates 16.7 jobs per every USD 1 million invested, contrary to 5.3 jobs per every USD 1 million invested in fossil fuels (EUEI, n.d.). However, not all renewable energy sources have the same potential in job creation.

6.1.1 Biomass

A study conducted by Armeanu et al. (2017) on EU28 countries tracking economic growth between 2003 and 2014[8] observed that biomass is one of the fastest-growing renewable energies and contributors to job creation, particularly in rural areas. Rural economies experience positive job creation under bioenergy operations (including solid fuels, biogas, municipal waste, biogasoline and biodiesel). Bioenergy production in rural areas directly decreases dependency on energy from outside the area, reducing financial and ecological costs related to transporting fossil fuels. Moreover, it reduces the amount of biomass in landfills, spurring job creation in converting waste into energy sources, as well as increasing the demand for agricultural and forestry wastes in the local area (Armeanu et al., 2017). Based on IRENA's latest renewable energy report, Europe's solid biomass and wind power industries are the industries with the highest job creation in renewable energy, with an estimated 389,000 and 344,000 jobs created, respectively (IRENA, 2018).

6.1.2 Hydropower

Hydropower generation also supports positive economic growth. In their study, Armeanu et al. (2017) found that, following bioenergy, hydropower demonstrates the second most positive impacts on economic growth when compared to geothermal, solar and wind. The positive correlation between hydropower and economic growth is due to the fact that hydropower is the least expensive to produce and because it is more trustworthy and efficient than the other three sources, which either require tectonic activity or are intermittent. On the other hand, solar and wind are less prone to extensive breakdowns and power shutdowns for an entire area (Armeanu et al., 2017). However, compared to the other renewable energy sectors, on a global scale, hydropower is declining due to depreciating investments in China and Brazil, which, together with India, account for 52 per cent of the total direct employment for hydropower in the world (IRENA, 2018).

[7] However, IRENA (2018) highlights that, on a global scale, the one renewable energy sector that has experienced a 10 per cent decline in employment compared to 2016 is hydro (See Figure 3). This was in part due to the decrease in hydropower installation in China and Brazil, which together with India accounts for 52 per cent of the total direct employment.

[8] In their study, Armeanu et al. (2017) used GDP per capita as a proxy for sustainable economic growth, renewable energy measures and country-level controls.

6.1.3 Solar PV

Solar energy also has one of the fastest-growing market shares in renewable energies at a global scale, with an estimated 8.7 per cent increase in 2017, equivalent to 3.37 million jobs. In direct employment, primarily in manufacturing, the highest job concentrations are in China, India, United States and Japan. In Europe, Turkey and Germany are the hubs for solar energy manufacturing; however, only 3 per cent of the global solar PV jobs are concentrated in Europe (with 90 per cent concentrated in China) (IRENA, 2018). It is also interesting to note that, in Europe, solar PV employment is going down (8 per cent compared to 2016) due to limited domestic installation markets as well as lack of competitiveness among European module manufacturers (IRENA, 2018). China has this market cornered, closely followed by Japan. Nonetheless, despite its challenges, solar PV continues to provide socioeconomic benefits in Europe, both in terms of job creation and gross value added (GVA) (EY, 2018).

Based on the 2014 UKERC study, in Europe the majority of jobs created by solar PV are primarily in manufacturing, closely followed by installation and with less emphasis on operations and maintenance. That is to say, there are more short-term jobs on a particular product, as opposed to long-term jobs such as operations and maintenance jobs, which last over the lifetime of the plant. In their study, Cameron and van der Zwaan (n.d., cited in UKERC, 2014) estimated that, over the span of the three scenarios (minimum, median and maximum growth), there is job creation found in both short- and long-term jobs. Under a median-growth scenario, the highest numbers in job creation are found in manufacturing and installation, at 0.26 jobs/annual GWh and 0.20 jobs/annual GWh, respectively. Long-term jobs in operation and maintenance grow at half the rate, at 0.11 job/annual GWh. Overall, their models estimated a 0.57 job/annual GWh in the sector, under a median scenario (Cameron & van der Zwaan, n.d., cited in UKERC, 2014).

6.1.4 Wind Power

Over 76 per cent of employment in this sector worldwide is concentrated in five countries, with China accounting 44 per cent of total wind power jobs and Europe as a close competitor at 30 per cent of total jobs (with the highest concentration in Germany, United Kingdom and Denmark) (IRENA, 2018). In Europe, the wind sector had the highest number of jobs recorded for the region at 344,000 in 2016, demonstrating a 10 per cent increase from the previous year. However, wind sector jobs are considered less labour-intensive than solar. Based on a 2009 survey, in Europe the majority of direct jobs from the wind sector were found in manufacturing (37 per cent), closely followed by component manufacturers (22 per cent) and developers (16 per cent). Following the value chain, employment in the wind sector was found in the independent power producer/utility sector (9 per cent) and installation/repair/and operations and maintenance (11 per cent) (UKERC, 2014). However, job creation for the wind sector is inverse to solar PV, where there is higher growth in long-term jobs in the wind sector, compared to high-growth jobs in the manufacturing of solar PV. Based on Cameron and van der Zwaan's study, since it is less labour-intensive, the wind sector has lower job growth per annual GWh, where the total for the sector is projected at 0.18 jobs/annual GWh compared to solar PV's total 0.57 job/annual GWh (under the median growth scenario) (UKERC, 2014).

In their review of over 95 studies, UKERC (2014) conclude that the renewable energy sector has high job generation potential compared to conventional non-renewable energy sources. Compared across the different technologies, the average renewable energy potential is 0.65 jobs/GWh, moving upward to 0.80 jobs/GWh when energy efficiency is added to the mix. These two are far above the estimated average of 0.15 jobs/GWh found for fossil fuel technologies (UKERC, 2014). Table 3 illustrates the different short-term direct jobs during the construction period under various energy generation technologies, where solar PV presents the highest jobs per year per installed MWp, compared to (fossil fuel) gas, which presents less than 5 per cent of the potential of solar PV.

Table 3. Average short-term direct jobs during construction period

Technology	Average short-term employment factor (Job-years/installed MWp)
Gas	1.0
Lignite	1.5
Coal	4.3
Wind	4.5
Hydro	5.7
Biomass	6.4
Geothermal	6.8
Solar CSP	10.2
Landfill Gas	12.5
CCS	20.5
Solar PV	21.6

Source: UKERC, 2014.

6.2 Indirect Employment and Induced Economic Impacts

Renewable energy penetration in the energy generation mix has been growing over the past decade across the globe, improving in its technological advancements and expanding in its economies of scale. This leads to impacts on indirect jobs and impacts on the economy at large, such as GVA. In Europe, it is estimated that, by 2021, the solar PV sector alone will sustain 175,000 jobs and generate an estimated EUR 9,500 million in GVA (EY, 2018). At the country level, in Germany there is a positive correlation between manufacturing jobs in renewable energy technologies and local economies (such as farmers, land owners, local installers and maintenance crew), as well as induced impacts via tax revenues for municipalities and federal states (Ecofys, 2017). Following current trends, Germany is expected to see an estimated EUR 25 billion by 2030 (compared to EUR 18 billion in 2012) in value-added benefits from renewable energy (IÖW, 2013, cited in Ecofys, 2017).

In Germany, expected growth in the renewable energy sector will be seen primarily in jobs related to operations, maintenance and system operation. The renewable energy technologies that will see higher percentages in the long-term jobs (operations, maintenance, system operator) are wind and bioenergy (heat and electricity) (Ecofys, 2017). This supports UKERC's (2014) finding that these technologies are less labour-intensive than solar (PV, thermal) and geothermal, which presents greater opportunities in indirect jobs related to operations and maintenance employment during the lifespan of these systems.

In their study Armeanu et al. (2017) assessed the casual relationship between renewable energy consumption and economic growth via GDP per capita. In their findings the authors note that, with a 1 per cent increase in renewable energy in final energy consumption, there is a positive correlation of a 1.61 per cent increase in GDP per capita. This is due in part to the energy and financial savings obtained through fuel switching from costly non-renewable energy sources to low-cost renewable sources. Moreover, the labour-intensive nature of renewable sources for developing, installing and operating supports positive job creation trends for the sector (Armeanu et al., 2017). Lastly, the study concluded that, due to improved resiliency in renewable energy infrastructure, rural areas are able to have access to continuous energy supply to support their basic needs, such as illumination, communications and water.

Overall, the renewable energy sector supports transition to a circular economy, both in decoupling economic activity from GHG emissions and creating both direct and indirect jobs. However, not all renewable energy technologies are the same, and some offer higher employment potential in direct jobs in manufacturing and installation, such as solar PV, while others provide higher job growth potential in indirect jobs such as operations and maintenance of the systems (e.g., wind power sector). Notwithstanding this difference, as a whole, the renewable energy sector is more labour-intensive than the fossil fuel sector, and, with the advancement in technology and greater penetration in the various national and subnational jurisdictions, the renewable energy sector is highly competitive to non-renewables and positively contributes to a closed-loop approach to economic growth.

7.0 Green Procurement

Public procurement can be defined as the process by which national, subnational and local governments purchase works, goods or services from companies. Green public procurement takes this definition and applies an environmental lens, whereby governments seek products and services that reduce environmental impacts throughout the product's life cycle (e.g., through recycling and reuse) compared to those of a linear approach that have a single, limited use. Therefore, a green procurement process takes into consideration the long-term impacts of each purchase (European Commission, 2017b). Applying a circular public procurement approach then adds another filter onto green procurement, where the role of the government is to contribute to "closed energy and material loops within supply chains, whilst minimizing, and in the best case, avoiding negative environmental impacts and waste creation across their whole life-cycle" (European Commission, 2017a, p. 5). A strong proponent of a circular economy approach to procurement is the European Union under its its 2015 *EU Action Plan for Circular Economy*, which proposes action to keep resources in the economy, retain their value and contriute toward a "sustainable, low carbon, resource efficient and competative economy" (European Commission, 2017b, p. 5).

As one of the major clients for a diverse array of goods and services, governments have significant purchasing power. Through their demand for goods and services, governments are able to shift the construction of works, production of goods and delivery of services to include circular economy principles (reduce, repair, recycle). For example, an estimated 16 per cent of the European Union's GDP is spent under public procurement, and in some developing countries the share of GDP goes up to 25 per cent (European Commission, 2017c; International Training Centre, 2007). Therefore, with their purchasing power through green procurement, governments enable the reduction of emissions in their own operations, create a market for green products and jobs, and drive innovation and competitiveness in green products and services (International Training Centre, 2007).

Green public procurement can also have important local socioeconomic benefits. It can increase production standards, benefit small and medium enterprises through mandatory spending requirements, and create decent jobs that support the inclusion of minorities through training programs and education opportunities for employees (International Institute for Sustainable Development, 2015). Several countries in Latin America have already implemented such measures; for example, the Dominican Republic is allocating 20 per cent of its public spending for micro, small and medium-sized enterprises with Law 488-08. Similarly, through its Procurement Law 19.886 and Directive 17, Chile provides extra benefits to suppliers that actively employ people with disabilities, Indigenous groups, youth and women while offering decent working conditions (International Institute for Sustainable Development, 2015). These examples show that, when well designed, green procurement can be perfectly aligned with a just transition and decent work principles.

Countries such as South Korea and Denmark have followed suit, with the former reporting 12,143 jobs created and both financial (KRW 54.5 billion) and emissions (3.1 million tonnes of carbon dioxide) savings through the 2005 Act on Encouragement of Purchase of Green Products (OECD, 2015). In Denmark, green procurement has also been actively promoted through the Partnership for Green Public Procurement, which was launched in 2006 as a means for Danish municipalities to collaborate with the Ministry of Environment and Food on such measures (Line, Iben, Bettina, & Estevan, 2015). Although still at quite a micro level, the job benefits are already visible, with companies such as Gamle Mursten (a brick recycling company) providing its services to many local businesses. The Danish Ministry of the Environment estimates that, if this company can recycle the 30 million bricks annually disposed of in Denmark for construction, it could create 400 new jobs while saving the equivalent heating cost of 3,000 homes annually (Danish Ministry of the Environment, 2013).

By supporting local job creation, green procurement also has positive spillover and multiplier effects with increased foreign direct investment due to a more stable domestic investment climate, economic diversification and increased demand for greener products (International Institute for Sustainable Development, 2015). Green procurement is therefore an enabler to a circular economy, and although the job effects are less easily quantifiable than for other proxy measures, it can support local job creation while providing decent working conditions. As such, most of the literature focuses on the ways that green procurement can shift business models to promote the circular economy via their purchasing power. Through their procurement processes, governments can pursue increased collaboration with suppliers to increase efforts to reduce raw material use and waste generation (Witjesa & Lozano, 2016). In turn, by responding to the requests of governments, contractors and service providers provide the services that meet this demand, supporting job creation.

8.0 Conclusion

This study looked at six proxy measures to obtain a greater understanding of job growth potential in a circular economy. The six proxy measures were chosen based on their sectoral constitution in material and energy efficiency, recovery, repair and recycling. Below are some of the main characteristics of each of the proxy measures in support of a circular economy and job creation.

- **Material efficiency** has a positive job creation capacity due to three main factors: (1) the profitability of more efficient technologies (innovation); (2) changes in labour productivity; and (3) the foreign value added. With these three factors, industries are able to save materials and create new economic sectors, such as the recycling of used material in manufacturing. Moreover, by introducing higher rates in material reuse, jurisdictions are able to decrease dependency from material imports. This is primarily the case for Europe, as it is a net importer of raw materials.
- **Waste recycling and reuse** is closely related to material efficiency. In Europe, waste recycling and reuse already have a dominant presence, but there is a room to grow. Growth can occur through an increase in resource productivity through innovation and new economic activities in waste collection, treatment and recycling. In Europe alone, direct jobs could increase by up to 322,000 and an additional 115 million tonnes of recycled material could be created if a 70 per cent target for recycling was successfully reached. These benefits would trickle down to 160,900 indirect jobs and 80,400 induced jobs.
- **Industrial ecology**, known to some as the precursor to the circular economy, is the concept of creating industrial networks to reduce waste significantly. Industrial ecology, however, is more of an enabler of the circular economy. The literature review identified a gap in studies that outline job creation potential within industrial ecology. Nonetheless, due to its micro-level thinking between related industries, it enables a positive contribution to economic benefits under a closed-loop approach.
- **Energy efficiency** is not only one of the most cost-effective ways to save energy and reduce emissions, it is also considered labour-intensive and conducive to a high rate of job creation, particularly in manufacturing, engineering and construction. Moreover, investments in energy-efficiency programs keep money in local economies, leading to direct and indirect job creation as well as to induced job impacts that often double the total number of jobs created. In Europe, ambitious energy-efficiency programs could see an estimated potential increase of 0.7 million to 4.2 million new jobs by 2030.
- **Renewable energy** is on the rise globally, providing not only access to reliable, localized energy supply, but also employing many people around the world. Regarding direct job creation, renewable energy technologies have higher labour intensity than fossil fuels, particularly during the construction and installation phases. Based on a study conducted by UKERC (2014), non-fossil-fuel technologies (including renewable energy and carbon capture and storage) have a higher rate of job creation per energy unit than coal and natural gas. Comparing the different technologies, the average renewable energy potential is 0.65 jobs/GWh, moving upward to 0.80 jobs/GWh when energy efficiency is added to the mix. These two are far above the estimated average of 0.15 jobs/GWh for fossil fuel technologies.
- **Green procurement** enables a circular economy; it does not create direct jobs but rather is an important contributor to indirect jobs and induced economic impacts. Most of the literature reviewed focused on ways governments are able to utilize green procurement to shift goods and service providers' business models toward a circular economy via government purchasing power. Through their procurement processes, governments collaborate with suppliers to reduce raw material use and waste generation. In turn, by responding to the requests of governments, contractors and service providers offer services that meet this demand, supporting job creation. In addition, green procurement is also an enabler of social benefits within local businesses. By benefiting small and medium-sized enterprises and vulnerable groups, green procurement leads to local job creation and is aligned with decent work principles.

The six proxy measures to a circular economy present insights into the job trends and job growth potential under a closed-loop approach. All six measures present positive net benefits in job creation (direct and indirect) and induced economic impacts. However, industrial ecology and green procurement work more as enablers than direct job creators. As a whole, jobs linked to these proxy measures are more labour-intensive than fossil-fuel-related jobs and are able to decouple economic activity from GHG emissions. Therefore, collectively and individually, these proxy measures present opportunities to transition to a closed-loop economic approach.

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Annex 1. Various Circular Economy Proxy Measures Adopted and Impacts on Jobs

Circular Economy Proxy Measures	Sector/Activity/ Scenario/Country	Net Jobs	Gross Jobs
Material Efficiency	Land, water, steel and primary energy		9 million–25 million gross jobs worldwide
	Managerial positions	0.04% of the UK labour force by 2030 under current rate of circular economy development	
	Associate professional and technical	0.04% of the UK labour force by 2030 under current rate of circular economy development	
	Administrative and secretarial	0.12% of the UK labour force by 2030 under current rate of circular economy development	
	Sales and customer services	0.24% of the UK labour force by 2030 under current rate of circular economy development	
	Skilled	0.28% of the UK labour force by 2030 under current rate of circular economy development	
	Operatives	0.74% of the UK labour force by 2030 under current rate of circular economy development	
	Elementary	0.61% of the UK labour force by 2030 under current rate of circular economy development	
	Transformational circular economy initiatives (UK)	102,000 net jobs	517,000 gross jobs
Waste Recycling and Reuse	70% recycling target across the EU27	322,000 direct, 160,900 indirect and 80,400 induced for a total of 563,000	
	70% recycling target across the UK	29,400 direct jobs by 2025 and up to 51,400 with indirect and induced jobs	

Circular Economy Proxy Measures	Sector/Activity/ Scenario/Country	Net Jobs	Gross Jobs
Energy Efficiency	Under ambitious scenario using GEM-E3 and E3ME	Increase in EU employment from 0.7 million to 4.2 million by 2030	
	CAD 356 billion in investments on energy-efficiency improvements and energy savings	Increase in full-time net equivalent jobs in Canada by 118,000	
	CAD 595 billion with most jobs in construction, manufacturing, retail/ wholesale trade	174,500 full-time net jobs in Canada	
	EU (2009–2013) with EUR 6.5 billion investment	79,000 indirect jobs	
	Energy	10 jobs/$1 million investment	
	Manufacturing	13.8 jobs/$1 million investment	
	Construction	20.3 jobs/$1 million investment	
	Trade services	18.8 jobs/$1 million investment	
	Government	21 jobs/$1 million investment	
Renewable Energy	On average	0.65 jobs/GWh	
	Solar PV	3.37 million jobs in 2017 worldwide (with most jobs located in manufacturing followed by installation and operations and maintenance). By 2021, the European solar PV sector alone will sustain 175,000 jobs.	
	Solar heating/cooling	0.81 million jobs in 2017 worldwide	
	Bioenergy	3.06 million jobs in 2017 worldwide; with 389,000 in Europe	
	Large hydropower	1.51 million jobs in 2017 worldwide	
	Wind energy	1.15 million jobs in 2017 worldwide; with 344,000 in Europe with 37 per cent of direct jobs in manufacturing (closely followed by component manufacturers [22 per cent] and developers [16 per cent])	
	Other sources than those listed above	0.45 million jobs in 2017 worldwide	
	All sources of energy	16.7 jobs every USD 1 million invested	
Green Procurement	South Korea	12, 143 jobs created since 2005 through the country's Act for Encouragement of Purchase of Green Products	

Note: Industrial ecology was excluded as it contributes only minimally to employment.

Source: Own elaboration with information from Bell, 2014; Brinkman, & Zornes, 2011; Cambridge Econometrics 2015; Clean Energy Canada, 2018; Dobbs, Oppenheim, Thompson, & Zornes, 2011; Friends of the Earth, 2010; IRENA, 2018; Morgan & Mitchell, 2015;Vivideconomics, 2013; UKERC, 2014.

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