Circular Jobs in Finland

Modelling employment impacts resulting from circular economy interventions

IISD TECHNICAL REPORT

International Institute for Sustainable Development

Andrea M. Bassi
Georg Pallaske

November 2020

Published by the International Institute for Sustainable Development

International Institute for Sustainable Development

The International Institute for Sustainable Development (IISD) is an independent think tank championing sustainable solutions to 21st–century problems. Our mission is to promote human development and environmental sustainability. We do this through research, analysis and knowledge products that support sound policymaking. Our big-picture view allows us to address the root causes of some of the greatest challenges facing our planet today: ecological destruction, social exclusion, unfair laws and economic rules, a changing climate. IISD's staff of over 120 people, plus over 50 associates and 100 consultants, come from across the globe and from many disciplines. Our work affects lives in nearly 100 countries. Part scientist, part strategist—IISD delivers the knowledge to act.

IISD is registered as a charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Province of Manitoba and project funding from numerous governments inside and outside Canada, United Nations agencies, foundations, the private sector and individuals.

Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

The Finnish Innovation Fund Sitra

The Finnish Innovation Fund Sitra is a future fund that collaborates with partners from different sectors to research, trial and implement bold new ideas that shape the future. Our aim is a Finland that succeeds as a pioneer in sustainable well-being. Sitra was founded in 1967 as a gift from Parliament to the 50-year old Finland. We are an independent public foundation operating directly under the supervision of the Finnish Parliament.

At Sitra, we work with partners to lead the way in the transition to a fair and competitive carbon-neutral circular economy – a new kind of society in which our everyday lives and well-being are no longer based on excessive consumption and fossil fuel use.

Sitra has received recognition for its national and international work on sustainability and circular economy.

Head Office

Itämerenkatu 11-13
PO Box 160
00181 Helsinki
Finland R3B 0T4

Tel: +358 294 618 991
Website: wwww.sitra.fi/en
Twitter: @SitraFund

Circular Jobs in Finland: Modelling employment impacts resulting from circular economy interventions

IISD Technical Report

November 2020

Written by Andrea M. Bassi and Georg Pallaske

Table of Contents

1.0 Overview of Sectors and Scenario Assumptions

The circular economy (CE) assessment explores the outcomes of implementing CE interventions for selected products and sectors in Finland. The areas analyzed include consumer electronics and appliances, textiles, food, mining and scrap metals, forestry and paper production, and buildings.

A dynamic simulation model based on System Dynamics (SD) (Sterman, 2000) was developed and calibrated to the Finnish context for each of these areas. A stand-alone model was created for each of these categories: (i) consumer electronics and appliances, (ii) textiles, (iii) food, (iv) mining and scrap metals, (v) forestry and paper production, and (vi) buildings. The modelling process included the following steps: identification of research questions (i.e., estimation of the job implications of CE transition); identification of a dynamics hypothesis via the creation of a system map, data collection, and formal model creation; structural and behavioural model validation; simulation of alternative scenarios; and interpretation of results.

1.1 Model Description

Given the breadth of the CE definition, which considers dynamics related to consumption, production, and materials management (Ellen MacArthur Foundation, 2015), we have developed models for (a) products and (b) sectors. Our work has focused on the following areas, which have been selected in consultation with the Finnish Innovation Fund Sitra to capture both policy relevance (with policy discussion primarily targeting products) and the diversity of products and sectors in Finland:

- Products: electronics, food, and textile products (e.g., apparel)
- Sectors: mining, forestry, and buildings (construction and retrofits)

While acknowledging that this is a limited number of areas to assess and considering existing data gaps at the product level, the goal was to cover diverse products and sectors to provide a coherent and unbiased assessment of the employment implications of a CE transition.

The SD models created are built using a few key features of the SD methodology, presented below.

First, the model is built using stocks and flows, explicitly representing accumulation over time. This allows the consideration of physical units for several types of indicators. For instance, product consumption is measured in "product units," materials use and management are measured in "tonnes," and employment is measured in "number of jobs, full-time equivalent."

Second, the use of stocks and flows captures the cascading effect of decisions across the value chain. For instance, a reduction in product ownership reduces production, materials used and waste, and materials management activities.

Third, the interaction of stocks and flows in the model leads to the creation of feedback loops. For instance, increased recycling and reuse of materials reduces the use of virgin materials in the manufacturing process, thereby reducing the total amount of materials in the system (across consumption, production, and materials management).

As a result, this model is different from others that have been used for the assessment of CE interventions and dynamics:

a) The SD models are parametrized and customized to Finland, based on national statistics. The models created are stand-alone product or sectoral models (and hence these product and sector models are not a subset of a larger macroeconomic or input-output [I–O] model). The geographical boundary is Finland, although import and export are considered as aggregate flows (i.e., the models are not multi-country and do not track specific import and export flows from or to a specific country).

b) In relation to specific models, the following differences are found:

   i. The SD models differ from computable general equilibrium (CGE) models because (1) the equations are not solved via optimization, (2) general equilibrium is not assumed—instead, these models can be defined as partial equilibrium, where prices do not determine the amount of products consumed or produced. By targeting products and physical production, the main drivers are per capita use of products and population (for products) or desired production based on domestic consumption and trade (for sectors, e.g., forestry). As a result, the economics of production does not change the mix of capital and labour or where production takes place. Employment is estimated using multipliers applied to the physical stocks and flows of products and materials (e.g., jobs per tonne of materials recycled every year).

   ii. The SD models differ from macroeconometric models in two ways. First, emphasis is on causality rather than correlation, and the model is solved using differential equations rather than based on historical data. Second, the approach is bottom up and process oriented, rather than top down and macroeconomic. In essence, the SD models focus on material flows rather than on economic performance.

   iii. The SD models differ from I–O models because the emphasis is on single sectors and products rather than the interaction of sectors or the interaction of material flows across sectors based on product consumption and production. The value chain is captured by representing consumption, production, and materials management rather than aggregate material flows by sector. On the other hand, similar to what is found in I-O models that track material flows or employment, the SD models use biophysical data as inputs (e.g., for materials use, energy, and water) and apply multipliers for the estimation of emissions.

Considering the method for solving equations indicated above, the SD model created for this study runs differential equations without optimizing flows. The model starts simulating in the year 2000 to create "what if" scenarios that end in 2040. Historical data are used to perform structural and behavioural validation up to 2018, and intervention options for CE are introduced from 2020. Time is therefore semi-continuous in these SD models—the time step is 1/16th of the year and results are presented with annual time steps.

Concerning the content and structure of the model, our approach to modelling the CE considers dynamics of (i) consumption, (ii) production, and (iii) materials management. Consumption indicates the amount of products owned by consumers (e.g., number of mobile phones) or the amount of materials consumed in the economy (e.g., wood), depending on whether a product or a sector is analyzed. The model considers the lifetime of products, which determines the manufacturing needs (e.g., a short product lifetime requires more volume of production than a longer product lifetime), also taking into account the import and export dynamics of Finland. Production represents the manufacturing process, where the amount of materials (e.g., considering the material intensity of products for a product-related assessment or raw materials required at the sectoral level for a sector-focused assessment) are estimated. Energy and water requirements are considered in addition to material requirements. Material management includes both the material outflows (or waste) generated in the production process and the materials embedded in products that are discarded after the end of their lifetime. It then tracks their flows, following different paths (e.g., recovery and reuse, as opposed to landfilling and incineration).

As indicated above, the CE models explicitly represent stocks and flows of products and materials for consumption (stock of products), production (stock of materials used in the production process, as well as flows of waste generated and flows of products created) and materials management (flow of waste managed—e.g., recycled and reused or disposed of, and stock of waste landfilled). These are used to estimate production inputs (e.g., water and energy) and outcomes (e.g., waste production). Employment is then estimated for consumption, production, and several materials management activities over time, from 2000 to 2040.

Figure 1 presents a subsystem diagram of the model and highlights (from left to right) that the models are primarily driven by demand, which determines consumption and production. Demand is influenced by population growth for electronics, food, textile products and buildings. Demand for mining and forestry is assumed to be constant in the future due to uncertainty about future trends. In the case of forestry, the assumption of constant production is aligned with the trend of the past 5 years. Consumption tracks products in use and discard, leading to the possibility to collect, recycle, reuse, refurbish products. Production instead determines material and resource use and waste. This leads to the possibility to reduce resource intensity and minimize waste generation, and increase waste reuse to curb landfilling and incineration. As a result, the models track recycling and reuse for products and materials, and account for their impact on reducing product demand (e.g., if products are repaired or lifetime extended) and material use (e.g., if materials are recycled and reused).

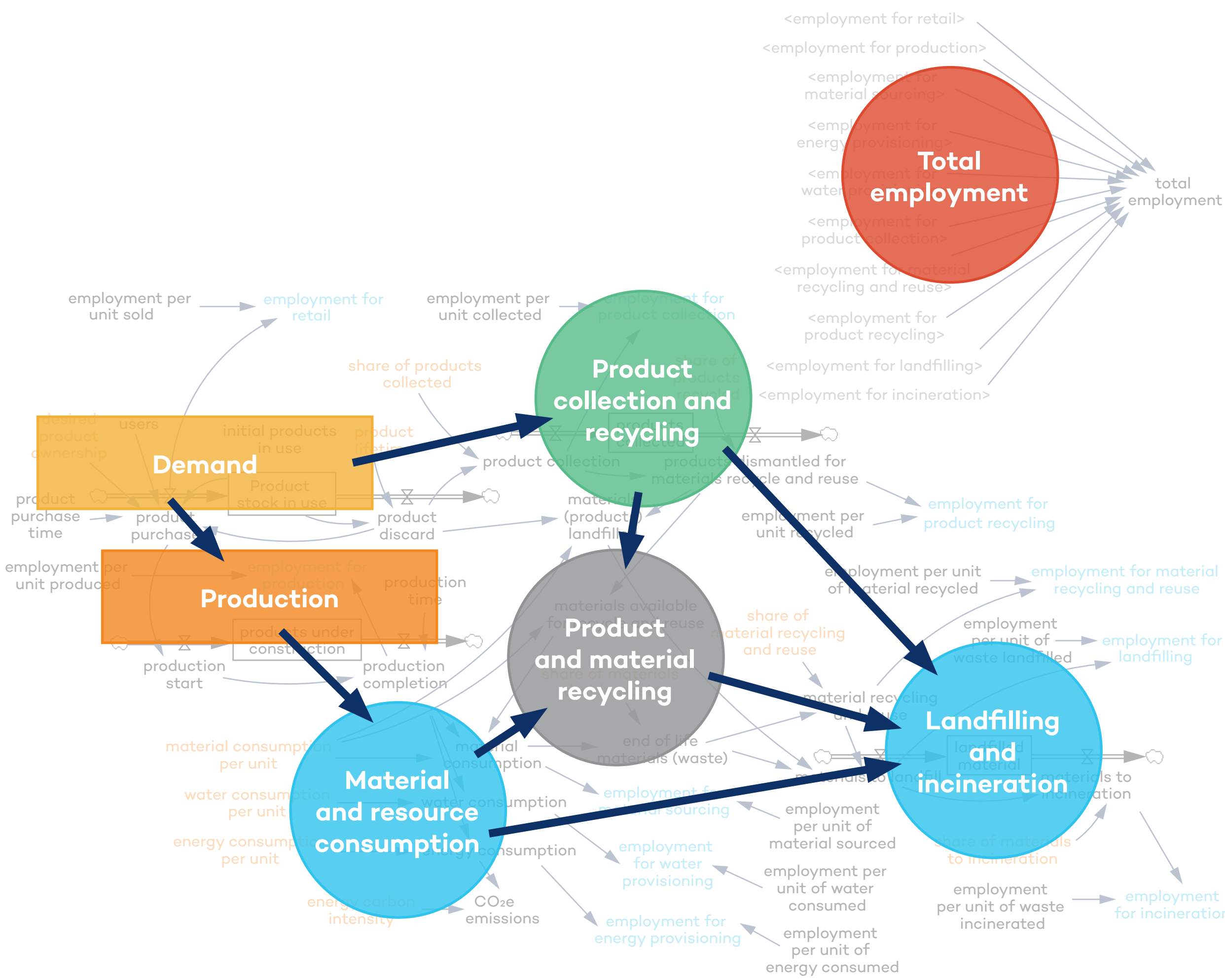

Figure 1. Subsystem diagram of the CE model.

Given the breadth of the definition, we have developed models for (a) products and (b) sectors. Our work has focused on the following areas:

- Products: electronics, food, textile products (e.g., apparel).
- Sectors: mining, forestry, buildings (construction and retrofits).

The CE models are designed to capture the employment impacts of circular economy interventions across (i) consumption, (ii) production and (iii) materials management (summarized in the diagram in the red circle). In order to estimate these employment impacts, we quantify the following employment categories (see Figure 2, pink variables):

- Products: retail, production (direct employment), product collection, product sorting, product recycling
- Materials: production (indirect employment for material sourcing, water and energy provisioning), material reuse, landfilling, incineration.

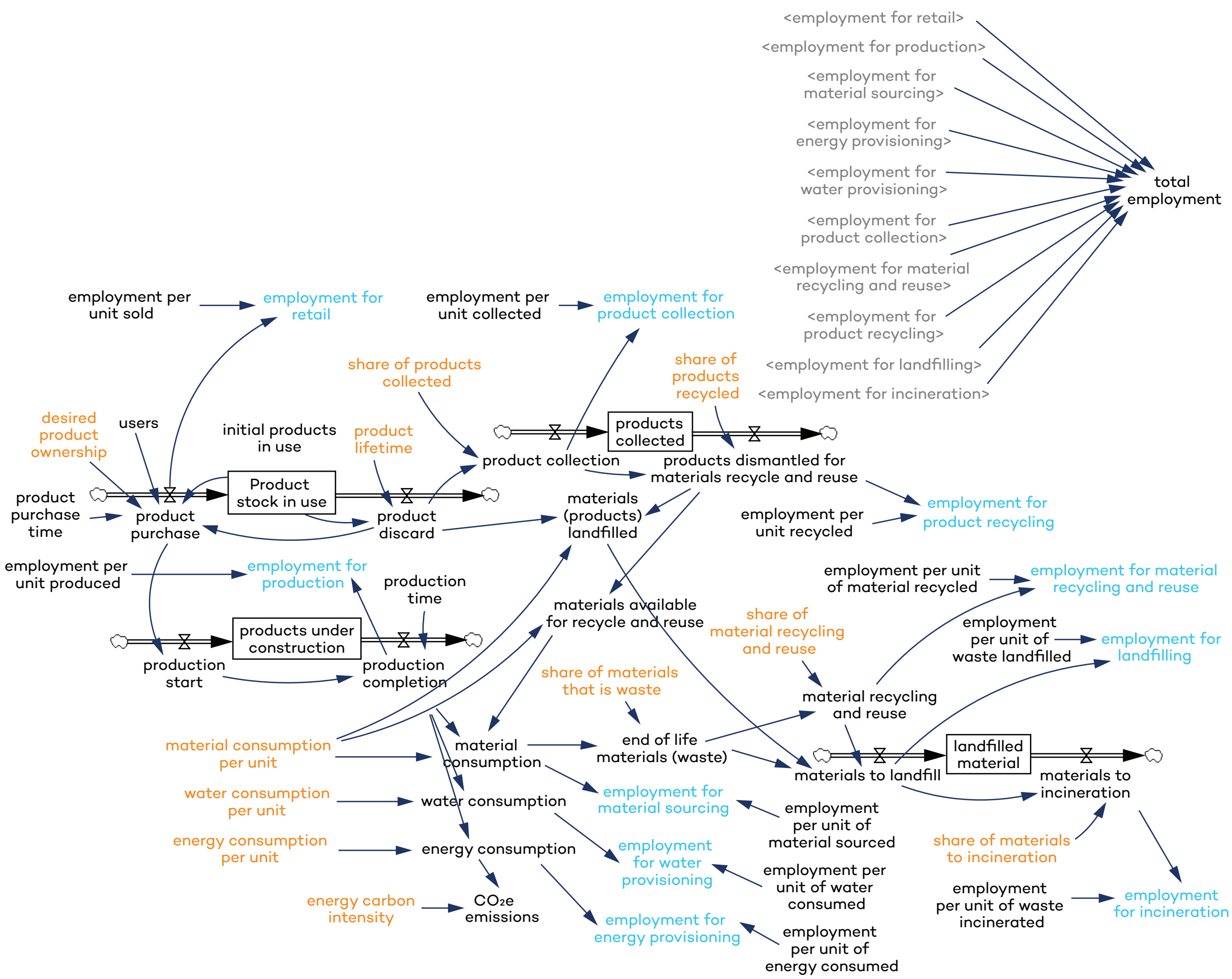

Figure 2. Model diagram, with CE interventions presented in orange and employment variables in blue

Black variables are either exogenous inputs (in bold letters) or variables endogenously calculated, with a distinction between stocks (boxed variables), flows (the variables affecting flows), and auxiliary variables (all other variables connected with blue arrows). Blue arrows represent causality, which is to say, if variables a and b are connected to variable c, a and b will be arguments in the equation of c (e.g., c = a + b).

The CE models capture:

1. Supply chain employment, including both (1a) upstream production employment, such as logging jobs in the forestry sector or farming jobs in the agriculture sector, (1b) retail employment (applicable to electronics, textiles and food), and (1c) manufacturing employment.
2. Recycling employment, such as for collecting, sorting, recycling, reusing products and materials.
3. Waste management employment, including landfilling and incineration of products and materials.

Our job estimation goes beyond the definition of "sector" that can be found in statistical classifications (e.g., Nomenclature of Economic Activities of the European Union [NACE], International Standard Industrial Classification of All Economic Activities [ISIC], and the Finnish Standard Industrial Classification [TOL]) to include downstream activities stemming from production and materials use in a given sector or for a given product.

Employment multipliers are used for each employment category estimated, based on product and material flows (units or tonnes per year), not on the economic value of production. These multipliers were calculated from data collected from various sources (see Figure 3 for a simplified graphical illustration and Annex 1 for more details). A limited number of employment multipliers is based on time series and change over time, primarily for manufacturing jobs, while others are constant. Examples of the former include employment for food production and processing, for sawn wood processed, and for textile production. These are areas for which sectoral data are available both on employment and production. Statistics Finland served as the primary source for both employment and consumption and production data, and gaps were filled with international data sources. Concerning future simulations, labor intensity for different waste management activities (measured as jobs per ton of materials managed) is assumed to remain constant for ease of comparison of results with current years, and due to lack of information for determining the extent to which labor intensity could change in the future.

Aside from employment data, the following data inputs were required to customize, parametrize and calibrate the CE models:

- Product: ownership (total number of products owned by Finnish consumers, e.g., for electronics), material intensity, percent of products collected, recycled after use.
- Production (sector): resource intensity (e.g., materials, water, energy, carbon), percent of materials labelled as "waste," reaching landfill and incinerated.

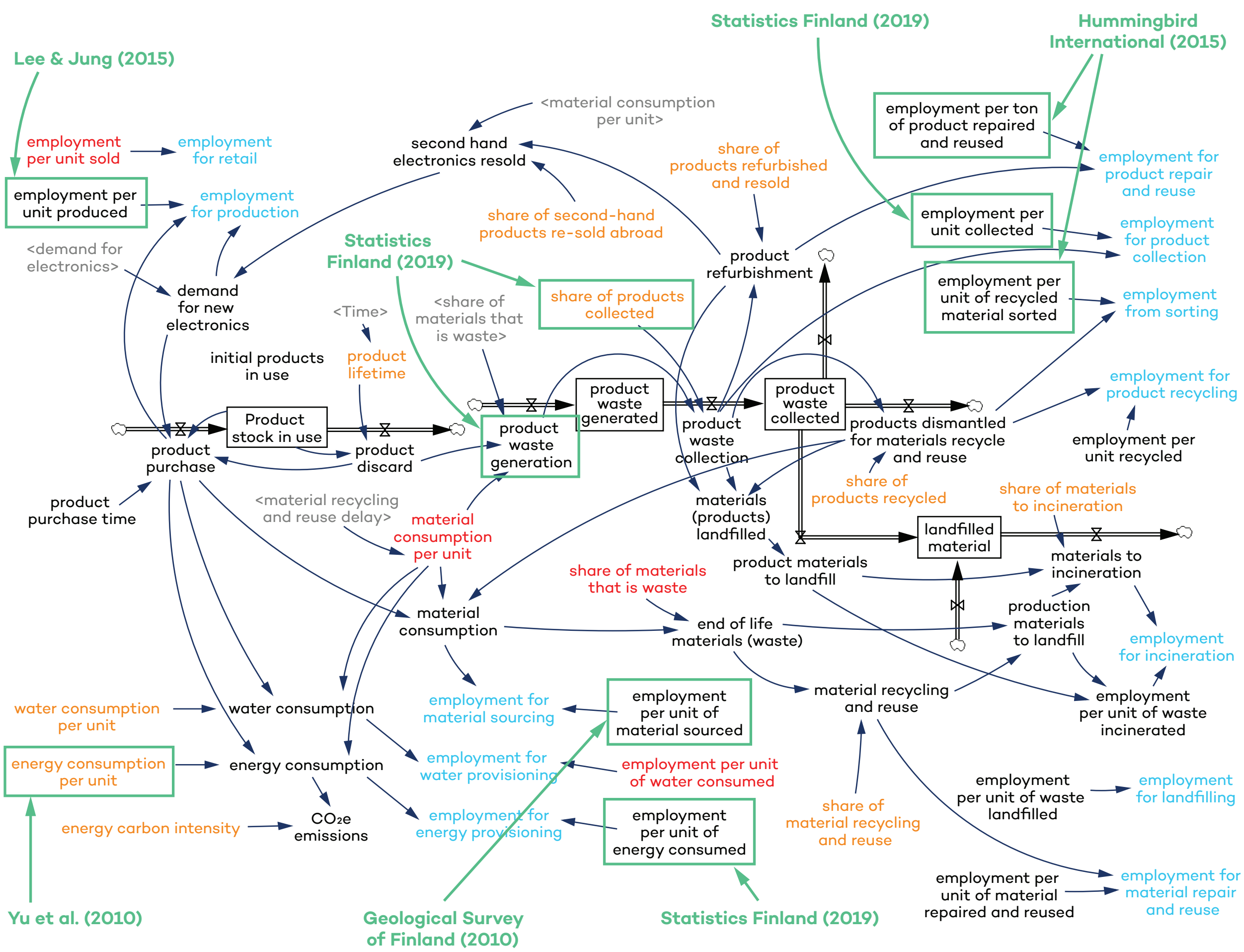

Figure 3. Simplified graphical representation of the data sources used for the parametrization of the electronics model.

All the data used and corresponding sources are listed in Annex 1. As indicated earlier, time series, when available, were used to parametrize and calibrate the models. Single data points were used only for parametrization.

Every simulation model is built for a purpose and has limitations. The models developed for this study are no exception. The main limitations are related to the static nature of the models, which include feedback relations only with respect to material flows. There are no economic feedback loops within the products and sectors analyzed (e.g., through prices, which could lead to higher or lower consumption, as well as to changes in labour intensity in the future as a result of the implementation of CE policies and investments). Further, there are no intersectoral or international dynamics represented in the models. Intersectoral dynamics refer to the impacts that changes in ownership and production processes, and hence material use, in one sector can have on other sectors that either provide or receive production outputs. This analysis is found in multisectoral I–O models. International dynamics refer to the impact that CE interventions can have on trade. On the one hand, a reduction in consumption could lead to reduced local production and/or imports. On the other hand, reduced production for domestic consumption can free up production capacity and resources for export. Of interest, and also not considered in the analysis, is the impact that the implementation of CE interventions can have on the Finnish economy.

Further limitations pertain to data availability. An important part of the modelling exercise performed was data collection from various sources and data consistency checks. This process highlights that data on labour intensity for materials management are largely missing at the national level and for several products and sectors. While this is not a structural limitation of the model, it is nevertheless a limitation when considering the uncertainty embedded in the forecasts generated.

Future steps for model development could be planned to address the limitations mentioned above and to expand the list of sectors and products analyzed. The latter would enable better exploration of the dynamics triggered by CE interventions in more diverse manufacturing sectors. The former includes the assessment of potential linkages of the models developed, both with multi-dimensional I–O models and with macro models, such as CGEs. This joint use of models, which could be realized in a first step with soft coupling and possibly at a later stage via hard coupling, would capture intersectoral and macro dynamics at both the national and international levels.

1.2 Circular Economy Interventions—Scenario Assumptions

Specific intervention options for each sector were identified and tested with the models. These interventions focus on (i) consumption (e.g., extending the lifetime of products), (ii) production (e.g., for waste prevention, reducing the amount of waste generated in the production process) or (iii) materials management (e.g., increased recovery of end of lifetime materials, via refurbish, repair, reuse).

A business-as-usual (BAU) scenario and two CE scenarios (CE1 and CE2) are simulated for all sectors. The BAU scenario assumes a continuation of current practices without an improvement in waste prevention or material recovery. The CE scenarios have moderate (CE1) and higher (CE2) ambition.

Table 1 presents the scenario assumptions used by product/sector and scenario.

Table 1. Scenario assumptions for the CE models

Sector	Intervention	Assumption 2019	Assumption 2030	Scenario
Electronics	Increased lifetime Increased share refurbished and resold Increased recycling fraction	5 years lifetime 0% 42.34%	5 years lifetime 0% refurbished 42.35% recycled	BAU
			6.25 years lifetime 10% refurbished 52.35% recycled	CE1
			7.5 years lifetime 20% refurbished 62.35% recycled	CE2
Textile	Increased lifetime Increased reuse fraction	2 years lifetime 52.8% of the amount collected is reused and resold	2 years lifetime 52.8% reused	BAU
			2.5 years lifetime 62.8% reused	CE1
			3 years lifetime 72.8% reused	CE2
Food	Reduced share of food wasted	18.57%	18.57% wasted	BAU
			13.57% wasted	CE1
			8.57% wasted	CE2
Mining	Increased share scrap metal collected	46.35%	46.35% collected	BAU
			61.35% collected	CE1
			76.35% collected	CE2
Forestry	Share of paper recycled Share of wood waste reused	62.5% of paper and paperboard recycled 30% of wood waste reused	62.5% paper rec. 30% wood reused	BAU
			72.5% paper rec. 40% wood reused	CE1
			82.5% paper rec. 50% wood reused	CE2
Buildings	Share of sustainable buildings Lifetime of buildings	10% 60 years	10% efficient 60 years lifetime	BAU
			20% efficient 80 years lifetime	CE1
			30% efficient 80 years lifetime	CE2

2.0 Results

2.1 Overview

The employment impacts resulting from the implementation of CE interventions are summarized in Table 2 and Figure 4. The table and figure present percent changes in the CE scenarios compared to the BAU case, for selected years.

Overall, positive employment impacts are forecast for the consumer electronics and forestry sectors, mainly emerging from the high labour intensity of collection, recycling and refurbishing activities. Buildings show net employment creation in the short term, and declines in the medium and longer terms. Negative employment impacts are forecast for all other sectors, largely due to the high contribution of upstream activities to total employment, in the form of primary production of materials (e.g., food, metal ores, textiles), and a reduction of retail jobs resulting from a higher lifetime of products.

A consideration has to be made regarding the boundaries of the analysis and whether upstream employment should be accounted for. This is because upstream employment is impacted by domestic consumption and trade, while the CE interventions considered reflect only interventions implemented, or new trends emerging at the national level. In this respect, it is important to highlight where the forecasts of employment creation and losses for the CE scenario may represent an over- or underestimation of real impacts, especially concerning upstream employment (see Table 2). Specifically, for the electronics and textile sectors, upstream employment losses may be an overestimate, given the importance of import and export for the sector. On the other hand, downstream job creation would be domestic. For food, if a CE strategy aims as sourcing zero-km food products and reducing waste, the forecast employment impacts are likely to be aligned with real developments. The same applies to buildings, for which construction, retrofit and maintenance jobs are likely to be mostly domestic. For mining and forestry, which are the most exposed to exports, the employment impacts forecasted may be an underestimate of the consequences of adopting CE strategies in Finland and by trade partners. Along the same line, adding prices to the models and related economic dynamics within and across sectors could lead to a reduction of the employment share in production as a result of CE interventions, resulting in job creation smaller than presented below. A similar trend may emerge due to the improved mechanization and automatization of materials management, resulting in reduced reliance on labour. These examples highlight that the forecasts presented could change considerably when making different assumptions about future trends and when using different models or different model formulations.

The results of sectoral forecasts can be summarized as follows:

- In the electronics sector, employment from increased refurbishing and recycling outweighs the loss of jobs in domestic electronics production, and results in positive net employment impacts.
- In the textile sector, the increase of product lifetime (i) reduces textile waste and (ii) purchases, leading to lower employment for production, retail and end-of-life materials management. While increased refurbishment and reselling of collected textiles contributes to maintaining jobs in second-hand retail, other end-of-life materials management jobs are lost due to the reduction in textile waste. Since a high share of jobs in the Finnish textile sector stem from the production (and retail) of textiles, the reduction in consumption leads to a net reduction in jobs.
- In the food sector, the reduction of food waste leads to (i) lower demand for food products, reducing upstream employment, and (ii) reduced food waste, which reduces end-of-life materials

management employment. Due to the significant contribution of upstream employment in the sector, net job losses are forecast. On the other hand, employment from energy recovery is not estimated.

- In the mining sector, the increased recovery of scrap metals leads to higher recycling rates and employment creation. On the other hand, this slightly reduces the demand for primary metals from Finnish producers, but does not result in a net decline of employment.
- In the forestry sector, the increased recycling of paper and the recycling of wood products yields job creation potential due to the comparatively higher labour intensity of activities related to product and material recovery. Further, since the net contribution of logging is relatively small compared to the employment from processing and end-of-life materials management, CE interventions in the forestry sector are forecast to result in net positive job impacts.
- In the buildings sector, the increase in sustainable buildings yields a net increase in employment. This is due to the higher labour intensity of sustainable buildings and retrofits.

Table 2. Summary of results CE interventions by sector and scenario, % relative to BAU

Sector	Scenario	2019		2025		2030		2035		2040	
		Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream
Electronics	CE1	0.0%	0.0%	10.3%	13.8%	18.0%	24.1%	17.4%	23.2%	17.4%	23.2%
	CE2	0.0%	0.0%	18.7%	25.0%	30.5%	40.7%	28.9%	38.6%	28.9%	38.6%
Textile	CE1	0.0%	0.0%	-8.8%	-5.8%	-15.7%	-10.9%	-15.6%	-11.1%	-15.7%	-10.9%
	CE2	0.0%	0.0%	-15.8%	-10.6%	-26.1%	-18.2%	-26.1%	-18.2%	-26.3%	-17.6%
Food	CE1	0.0%	0.0%	-1.8%	-2.4%	-3.5%	-4.9%	-3.6%	-5.0%	-3.6%	-5.0%
	CE2	0.0%	0.0%	-3.5%	-4.8%	-7.1%	-9.8%	-7.1%	-9.9%	-7.1%	-9.9%
Mining	CE1	0.0%	0.0%	0.3%	0.8%	0.5%	1.5%	0.5%	1.5%	0.5%	1.5%
	CE2	0.0%	0.0%	0.6%	1.6%	1.0%	3.1%	1.0%	3.0%	1.0%	3.0%
Forestry	CE1	0.0%	0.0%	0.3%	0.4%	0.6%	0.7%	0.6%	0.7%	0.6%	0.8%
	CE2	0.0%	0.0%	0.6%	0.7%	1.2%	1.4%	1.2%	1.5%	1.2%	1.5%

Sector	Scenario	2019		2025		2030		2035		2040	
		Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream
Buildings	CE1	0.0%	N/A	1.5%	N/A	1.5%	N/A	1.7%	N/A	1.8%	N/A
	CE2	0.0%	N/A	5.9%	N/A	5.9%	N/A	6.2%	N/A	6.3%	N/A

** As explained later in the report in more detail for each product and sector analyzed, upstream activities often dominate employment creation in many sectors. For example, food production accounts for the vast majority of jobs in the food value chain. In this case, it is difficult to assess and appreciate the changes that CE strategies will generate for employment in the sector, given the small number of jobs found in downstream activities. As a result, this table and the following section provide information on the relative change in employment when including or excluding upstream activities.*

It should also be noted that upstream activities include production (either for domestic consumption or export) that takes place in Finland. It is assumed that CE interventions can influence domestic demand and production but do not affect trade dynamics.

Table 3. Summary of results CE interventions by sector and scenario, absolute values

Sector	Scenario	2025		2030		2035		2040			
		Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream
Electronics	BAU	3,230	2,440	3,260	2,460	3,250	2,450	3,250	2,450	*Net change relative to BAU*	
	CE1	3,560	2,770	3,840	3,050	3,810	3,020	3,810	3,020	*560*	*570*
	CE2	3,830	3,040	4,250	3,460	4,180	3,390	4,180	3,390	*940*	*940*
Textiles	BAU	4,390	320	4,430	320	4,420	320	4,420	320	*Net change relative to BAU*	
	CE1	4,000	300	3,730	290	3,730	290	3,730	290	*-690*	*-40*
	CE2	3,690	280	3,270	260	3,260	260	3,260	270	*-1,160*	*-60*

Sector	Scenario	2025		2030		2035		2040			
		Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream	Including upstream	Excluding upstream
Food	BAU	67,370	7,470	68,020	7,540	68,020	7,540	68,020	7,540	*Net change relative to BAU*	
	CE1	66,180	7,290	65,610	7,170	65,600	7,170	65,600	7,170	*-2,410*	*-370*
	CE2	64,990	7,110	63,200	6,810	63,190	6,790	63,190	6,790	*-4,830*	*-750*
Mining	BAU	17,850	9,030	17,850	9,030	17,850	9,030	17,850	9,030	*Net change relative to BAU*	
	CE1	17,900	9,100	17,940	9,170	17,940	9,160	17,940	9,160	*90*	*140*
	CE2	17,950	9,170	18,030	9,300	18,020	9,300	18,020	9,300	*170*	*270*
Forestry	BAU	53,250	47,260	53,400	47,410	53,510	47,520	53,590	47,590	*Net change relative to BAU*	
	CE1	53,410	47,420	53,720	47,750	53,840	47,870	53,920	47,950	*330*	*360*
	CE2	53,560	47,590	54,040	48,100	54,160	48,220	54,250	48,310	*660*	*720*
Buildings	BAU	78,480	78,480	80,670	80,670	81,110	81,110	82,780	82,780	*Net change relative to BAU*	
	CE1	79,640	79,640	81,870	81,870	82,520	82,520	84,300	84,300	*1,520*	*1,520*
	CE2	83,140	83,140	85,440	85,440	86,170	86,170	88,020	88,020	*5,250*	*5,250*
Total	BAU	224,560	144,990	227,620	147,420	228,160	147,970	229,890	149,710	*Net change relative to BAU*	
	CE1	224,690	146,530	226,720	149,300	227,440	150,030	229,290	151,890	*-600*	*2,180*
	CE2	227,160	150,330	228,230	153,370	228,990	154,140	230,920	156,090	*1,030*	*6,380*

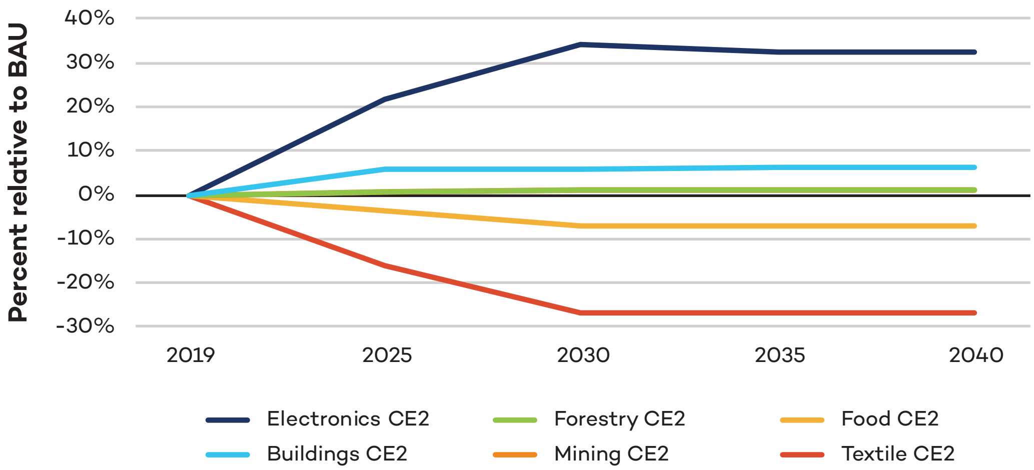

Figure 4. Net change in employment in the CE2 scenario compared to BAU

2.2 Electronics

In the BAU scenario, demand for electronic products, related production, and materials management provides 1,370 jobs in production and retail, 1,830 jobs in collection and recycling and 50 jobs from landfilling and waste incineration. As indicated earlier, our job estimation goes beyond the definition of "sector" that can be found in statistical classifications (e.g., NACE, ISIC, TOL) to include downstream activities stemming from production and materials use. As no structural changes are foreseen in the BAU scenario, the employment shares remain constant throughout the simulation. These are 42.1 per cent of sectoral employment from supply chain activities, 56.3 per cent from recycling and 1.7 per cent from landfilling and waste incineration. Figure 5 presents the change in the allocation of employment by activity.

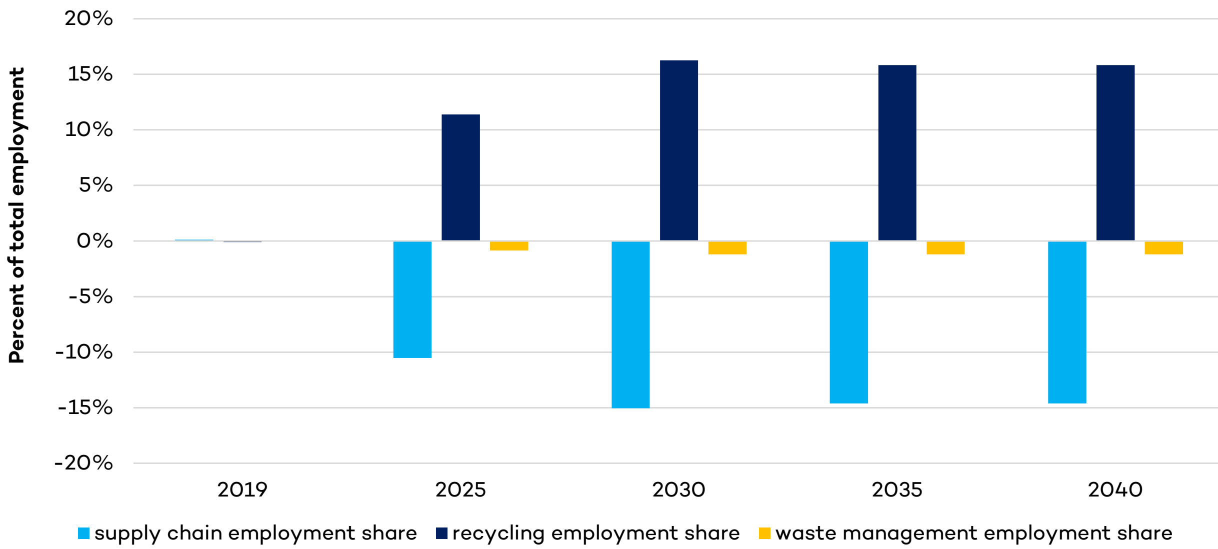

Figure 5. Employment shares in the electronics sector – CE1 vs. BAU scenario

In the CE scenario, the increase in recycling and refurbishment of a longer lifetime of electrical and electronic (E&E) products leads to an increase in sectoral employment compared to the BAU scenario. The simultaneous implementation of the three interventions is projected to generate around 580 additional jobs by 2040.

Employment for primary production, collection and recycling, and landfilling and incineration is displayed in Figure 6 (BAU) and Figure 7 (CE). The forecast net employment gain is due to E&E waste collection and sorting, recycling and refurbishment being more labour-intensive than primary production and retail activities. This implies that the impacts of extending the lifetime of E&E products, which causes the total purchasing rate to decrease as products become obsolete at a lower rate, does not fully offset the gain in employment from the other CE interventions mentioned above.

In the CE scenario, the consumer electronics sector provides 1,230 supply chain jobs, 2,540 recycling jobs and 30 jobs in landfilling and waste incineration. This is equivalent to a net gain of 39.2 per cent in recycling and refurbishing jobs, and a net reduction of 9.6 per cent in supply chain employment and 38.8 per cent in landfilling and incineration employment. The employment shares are illustrated in Figure 5 and for the BAU and CE scenarios.

In the CE scenario, the dominance of the recycling sector becomes more evident compared to the BAU scenario. While the increase in product lifetime reduces E&E waste generation, it also reduces the repurchase rate of obsolete goods and leads to a net job loss in production and retail employment for electronics. In summary, the CE results of the CE scenario indicate a net gain of 720 jobs in recycling and refurbishing and a net loss of 130 and 20 jobs in supply chain and landfilling and incineration employment respectively. Absolute employment estimates for supply chain, recycling and landfilling and incineration employment are presented in in Figure 6 (BAU) and Figure 7 (CE).

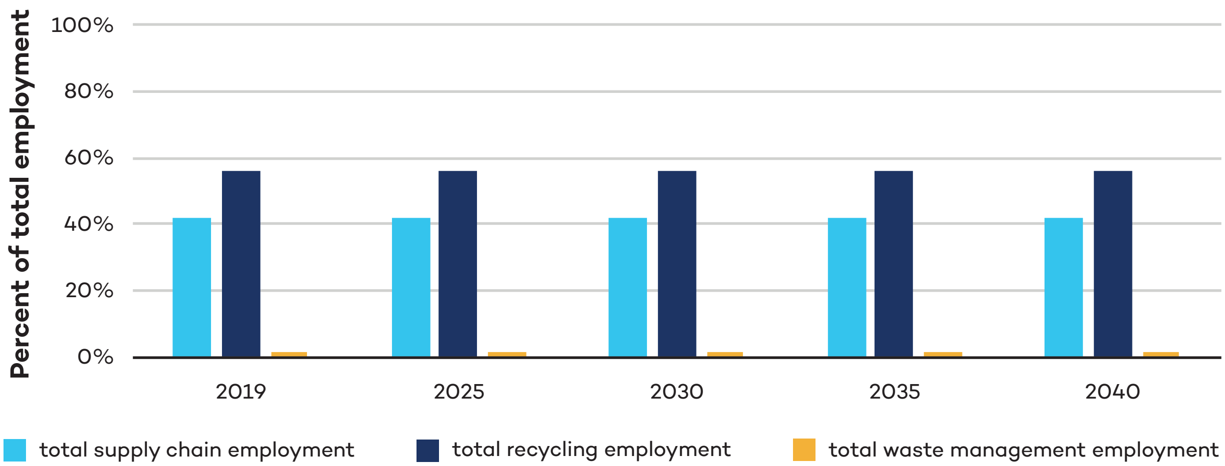

Figure 6. Employment in the electronics sector – BAU scenario

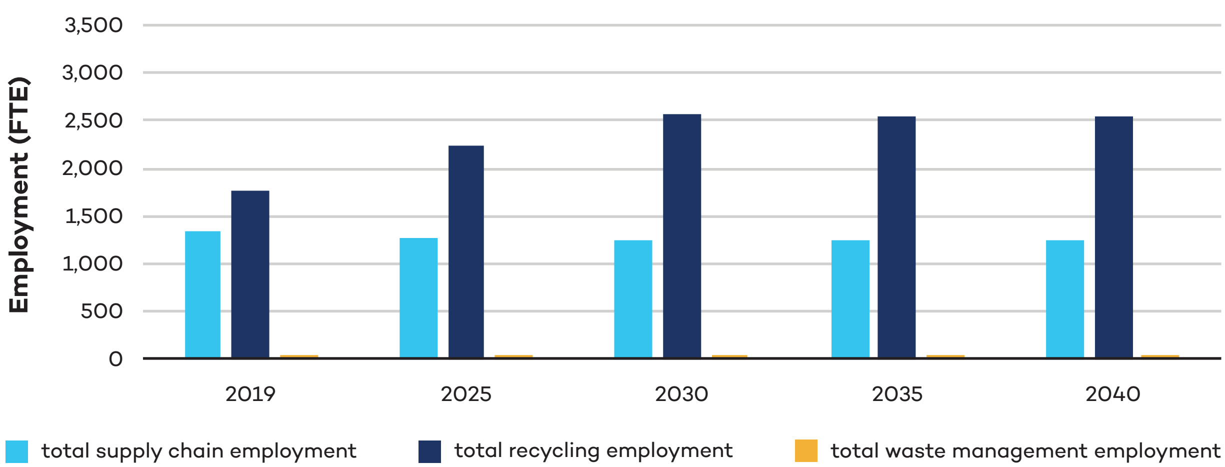

Figure 7. Employment in the electronics sector - CE scenario

2.2.1 Relevance of Upstream Activities

Upstream activities often dominate employment creation in many sectors. In this section we present an analysis where these jobs are not explicitly considered, so that the impacts of CE interventions on other types of employment—especially when the number of jobs in these categories are comparatively small— can be better appreciated.

In the case of E&E products, the production of consumer appliances constitutes approximately 42 per cent of total supply chain employment, while the other 58 per cent is provided by material extraction (i.e., upstream activity), energy and water provisioning, and retail jobs. Due to a high import share, the reduction in upstream employment in the electronics sector resulting from implementing CE policies could be less significant than what is forecast (i.e., some of the job reductions would occur in the countries that export to Finland). The results of the analysis for supply chain employment (when excluding upstream jobs), recycling employment and waste incineration employment are summarized in Table 4.

Table 4. Overview of employment in the electronics sector excluding upstream employment

	2018	2025	2030	2035	2040	
Total recycling employment						
CE2	1,730	2,590	3,080	3,020	3,020	↑↑
CE1	1,770	2,240	2,570	2,540	2,540	↑
BAU	1,790	1,810	1,830	1,830	1,830	
Total supply chain employment (excluding upstream)						
CE2	540	420	360	360	360	↓↓
CE1	550	480	440	440	440	↓
BAU	560	570	570	570	570	
Total waste management employment						
CE2	51.4	30.9	19.2	19.2	19.2	↓↓
CE1	52.1	40.9	33.2	32.9	32.9	↓
BAU	52.9	53.5	54.0	53.8	53.8	

2.2.2 Relevance of End-of-Life Materials Management

In terms of employment provided by end-of-life materials management, waste sorting activities provide the highest number of sectoral jobs in the BAU scenario. Further, it is assumed that there is no refurbishment of consumer electronics in the BAU scenario. In the BAU scenario, product-sorting activities provide around 800 jobs, product collection 280 jobs and the electronics sector accounts for approximately 50 jobs landfilling and incineration jobs.

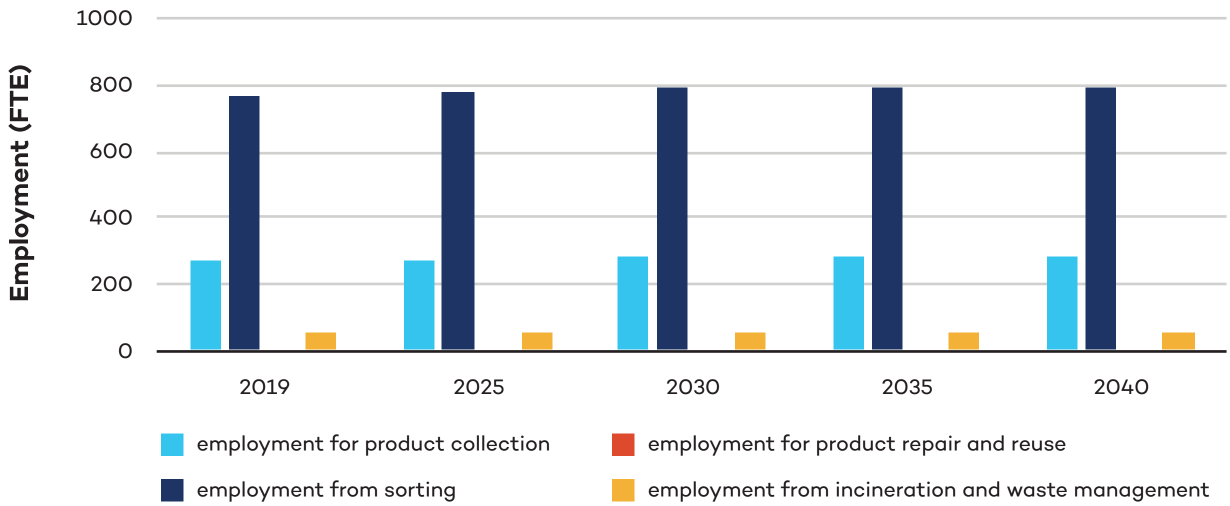

Figure 8. End-of-life materials management employment in the electronics sector – BAU scenario

In the CE scenario, 10 per cent of E&E products are assumed to be refurbished and resold in combination with a 10 per cent higher collection rate. As a result, the refurbishment of obsolete consumer electronics becomes the highest sectoral employment contributor. By 2040, the repair and reuse of products provides approximately 990 jobs, while a reduction in E&E waste from the increase in lifetime slightly reduces employment in waste sorting (780 jobs), waste collection (220 jobs) and landfilling and incineration (30 jobs).

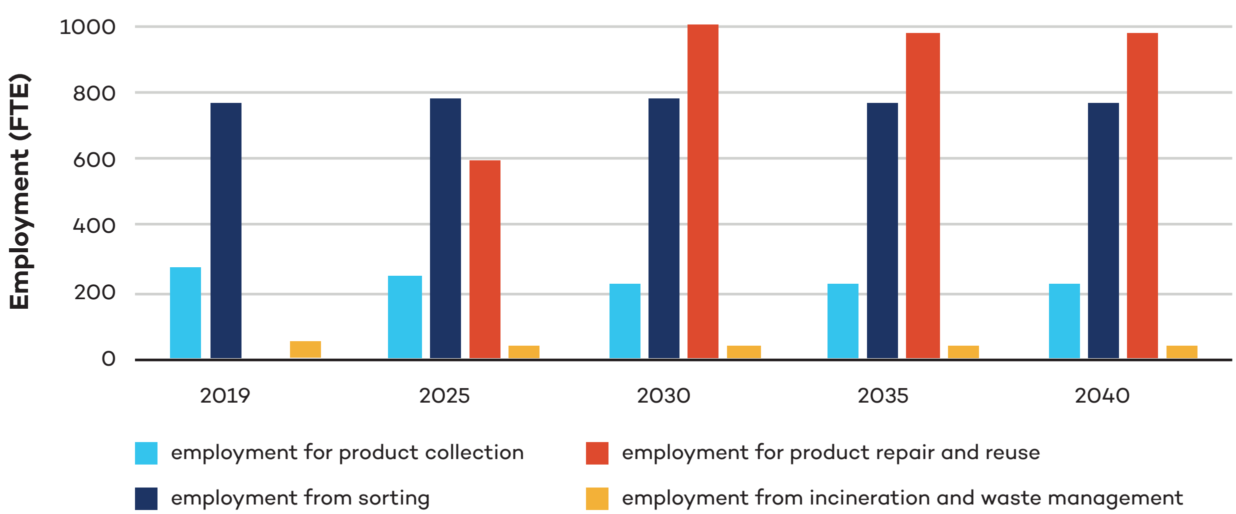

Figure 9. End-of-life materials management employment in the electronics sector – CE scenario

2.3 Textile

In the BAU scenario, the textile sector provides approximately 4,200 jobs in production and retail, 210 jobs in collection and recycling and 3 jobs from landfilling and waste incineration. Since no structural changes are forecast in the BAU scenario, the employment shares remain constant throughout the simulation. Supply chain employment contributes 95.1 per cent of sectoral employment, 4.8 per cent stem from recycling and 0.1 per cent from landfilling and waste incineration. The change in sectoral employment shares for the BAU scenario are presented in Figure 10.

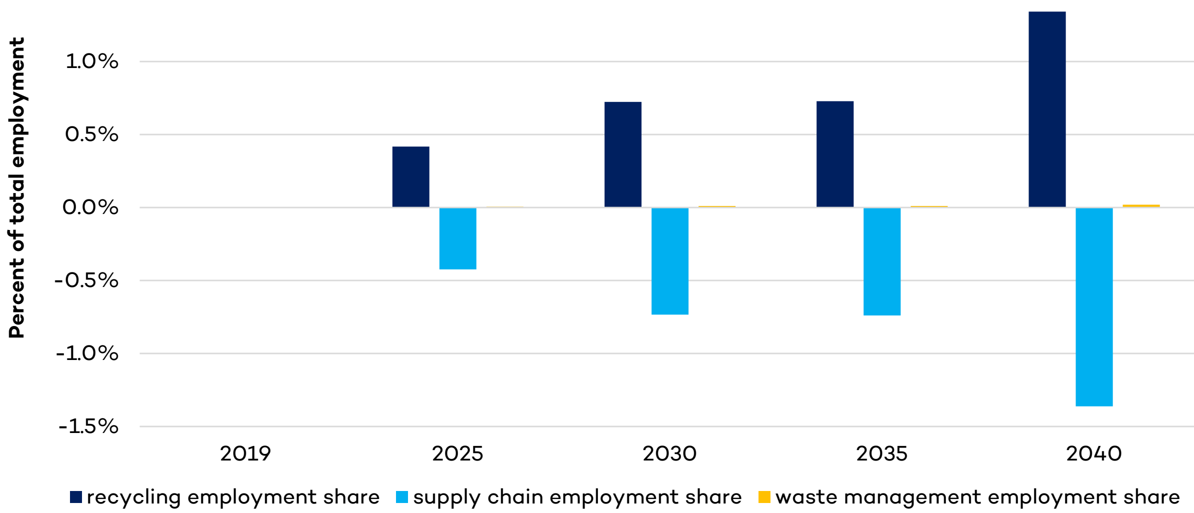

Figure 10. Employment shares in the textile sector – CE vs BAU scenario

Despite the increase in product refurbishment and reuse (and related employment creation), the assumed increase in product lifetime and resulting reduction in consumption and production, lead to a net job decline for the textile sector.

CE interventions reduce employment in production and retail (because of the extended lifetime and reuse of textile products), recycling and refurbishing (because of the reduced number of products owned and consumed), and landfilling and incineration (because of the reduced amount of waste created) by 16.0 per cent, 8.9 per cent and 9.3 per cent respectively compared to the BAU scenario.

By 2040, the CE scenario is projected to provide 3,730 jobs; 3,530 jobs in production and retail, 190 jobs in recycling and refurbishment and 3 jobs in landfilling and incineration. This indicates that the above-mentioned shares of jobs lost correspond to a net job loss of approximately 670 supply chain jobs, 20 recycling jobs and 0.3 landfilling and incineration jobs. Sectoral employment in the BAU and CE scenario for selected years is displayed in Figure 11 and Figure 12 respectively.

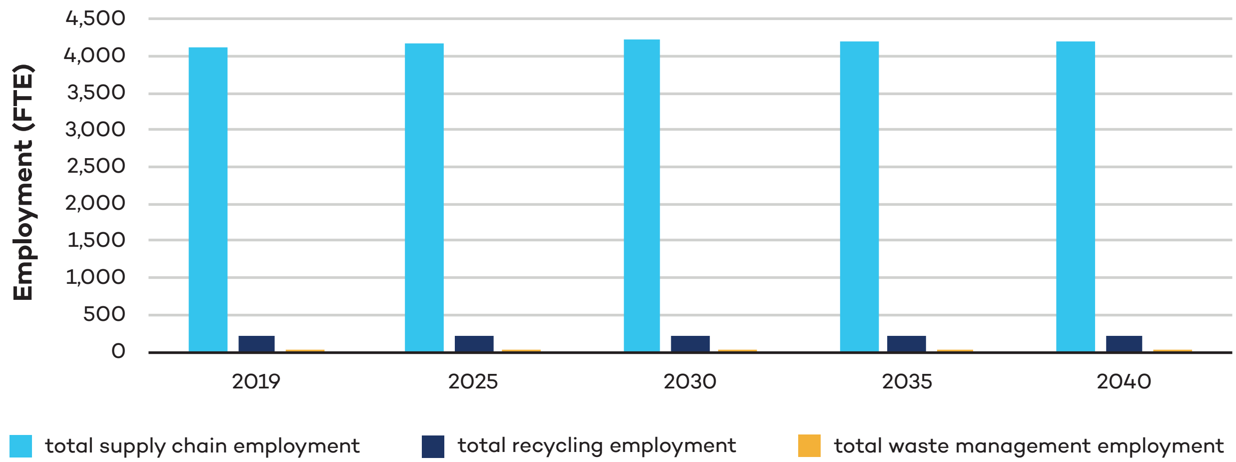

Figure 11. Employment in the textile sector – BAU scenario

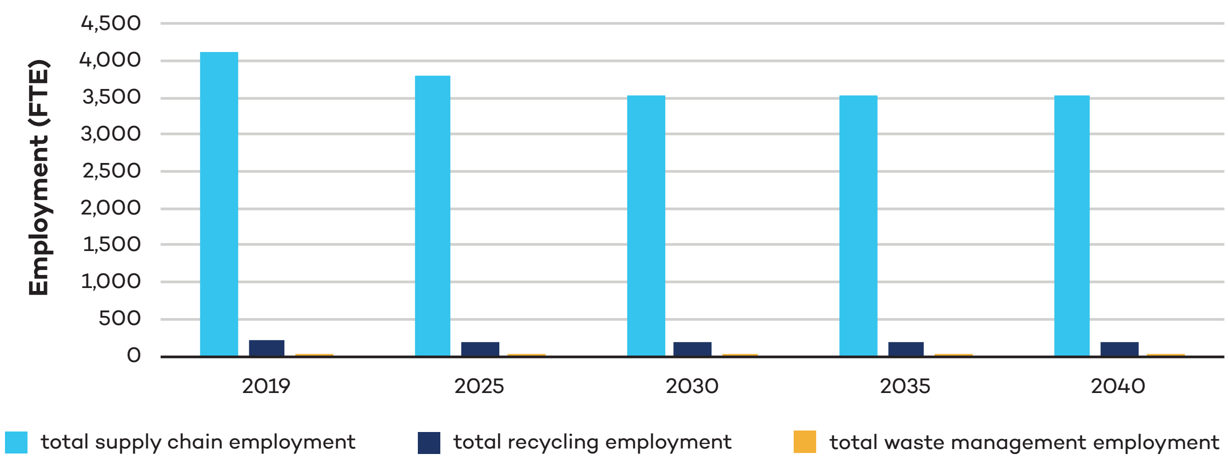

Figure 12. Employment in the textile sector – CE scenario

2.3.1 Relevance of Upstream Activities

Upstream activities often dominate employment creation in many sectors. In this section we present an analysis where these jobs are not explicitly considered, so that the impacts of CE interventions on other types of employment—especially when the number of jobs in these categories are comparatively small—can be better appreciated.

Upstream employment for the textile sector constitutes 95.1 per cent of the total supply chain employment. The other 4.9 per cent is provided by end-of-life materials management (4.8 per cent recycling and refurbishing, and 0.1 per cent landfilling and incineration). Due to a relatively high textile import share, the reduction in upstream employment in the textile sector resulting from implementing CE policies could be less significant than what is forecast. In fact, we forecast a net reduction of approximately 850 jobs in textile production and retail, which would include imported products as well.

The results for supply chain employment (excluding upstream jobs), recycling employment and waste incineration employment are summarized in Table 5.

Table 5. Overview of employment in the textile sector excluding upstream employment

	2018	2025	2030	2035	2040	
Total recycling employment						
CE2	210	190	180	180	180	↓↓
CE1	210	200	190	190	190	↓
BAU	210	210	210	210	210	
Total supply chain employment (excluding upstream)						
CE2	100	90	80	80	80	↓↓
CE1	100	100	90	90	90	↓
BAU	100	110	110	110	110	
Total waste management employment						
CE2	3.1	2.9	2.7	2.7	2.7	↓↓
CE1	3.1	3.0	2.9	2.9	2.9	↓
BAU	3.1	3.1	3.2	3.2	3.2	

2.3.2 Relevance of End-of-Life Materials Management

Figure 13 and Figure 14 provide an overview of the end-of-life materials management employment in the BAU and CE scenario respectively. In the BAU scenario, end-of-life materials management employment increases by approximately 10 jobs (or 2.9 per cent) to 210 jobs by 2040. In the CE scenario, total end-of-life materials management declines by 8.9 per cent by 2040, which is equivalent to a net reduction of around 20 jobs. In the CE scenario, employment from product collection, recycling and refurbishing and landfilling and incineration declines by 15 per cent (10 jobs), 40 per cent (10 jobs) and 9.3 per cent (0 jobs) respectively, while employment from product reuse and repair increases by 1.2 per cent (1 job).

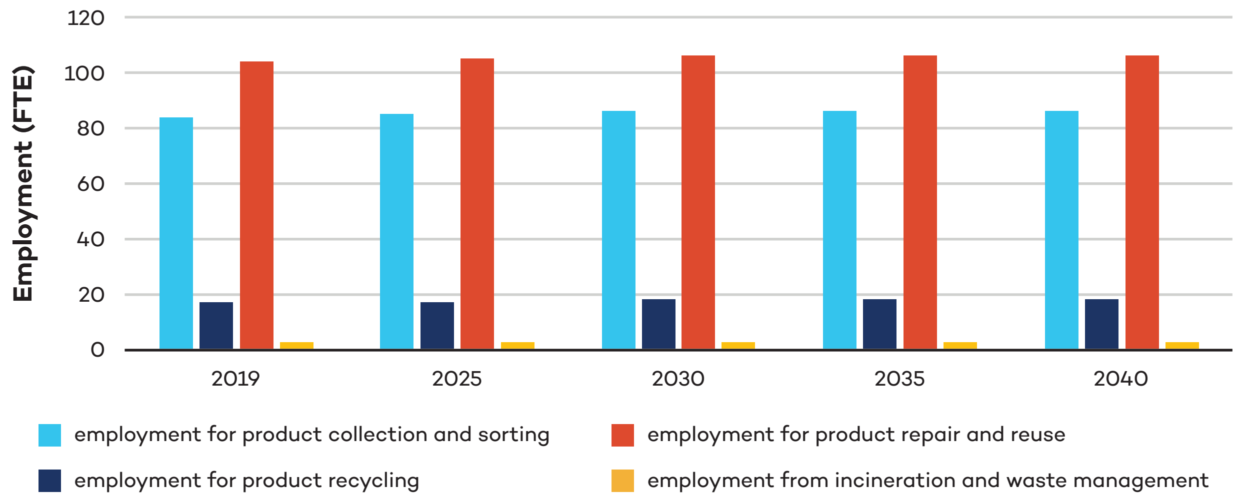

Figure 13. End-of-life materials management employment in the textile sector – BAU scenario

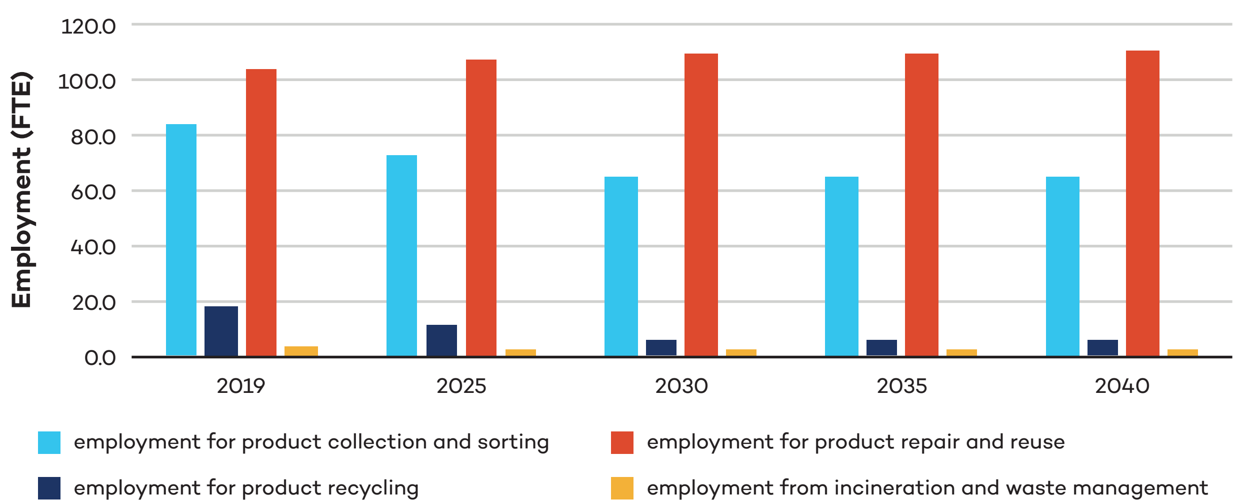

Figure 14. End-of-life materials management employment in the textile sector – CE scenario

2.4 Food

In the BAU scenario, the food sector provides approximately 67,410 jobs in production, 260 jobs in collection and recycling, and 350 jobs from landfilling and waste incineration. An overview of total employment in the BAU scenario by category in the food sector is provided in Figure 16.

Since no structural changes are forecast in the BAU scenario, the employment shares remain constant throughout the simulation. Supply chain employment contributes 99.1 per cent of sectoral employment, 0.4 per cent stem from recycling and 0.5 per cent from landfilling and waste incineration. The change in composition of sectoral employment shares for the BAU scenario is presented in Figure 15.

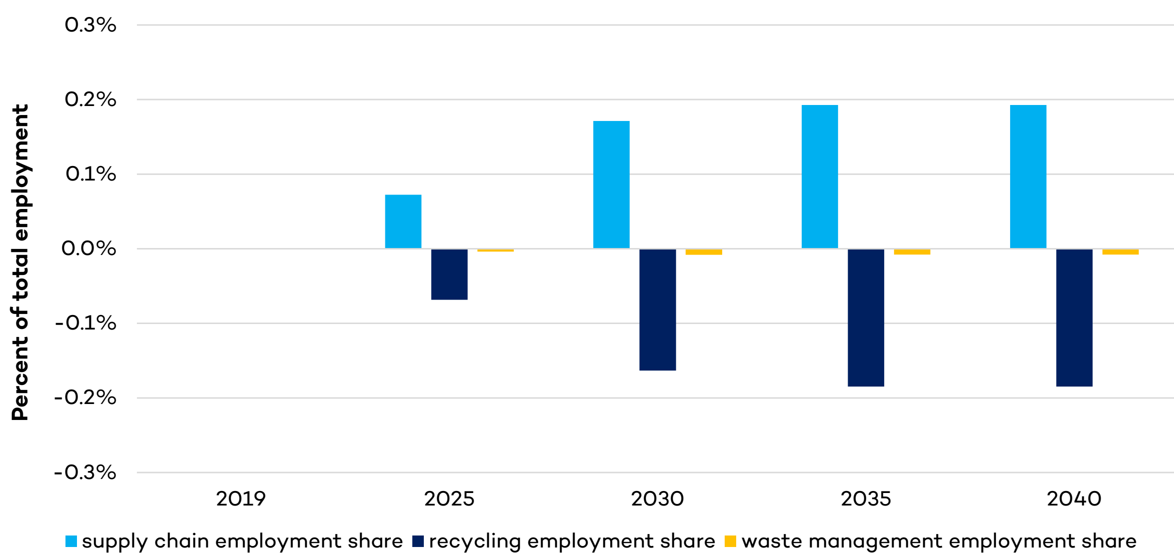

Figure 15. Employment shares in the food sector – CE1 vs BAU scenario

The implementation of CE interventions for reducing food waste is projected to reduce total sectoral employment compared to the BAU scenario.

The reduction in food waste resulting from CE interventions leads to a reduction both in waste streams and food purchase and hence reduces both end-of-life materials management and primary production and retail. By 2040, total employment in the food sector is reduced by 2,410 jobs (-3.6 per cent), which translates into the loss of 2,330 supply chain jobs, 70 recycling, and 10 landfilling and incineration jobs. The development of employment in the CE scenario is displayed in Figure 17. Relative to the BAU scenario, supply chain employment decreases by 3.5 per cent (due to lower purchases and production), recycling and refurbishing employment by 26.2 per cent (due to lower waste generation) and landfilling an incineration employment by 4.3 per cent (due to lower waste disposal). By 2040, supply chain employment contributes 99.2 per cent, recycling and refurbishing employment 0.3 per cent, and landfilling and incineration employment 0.5 per cent.

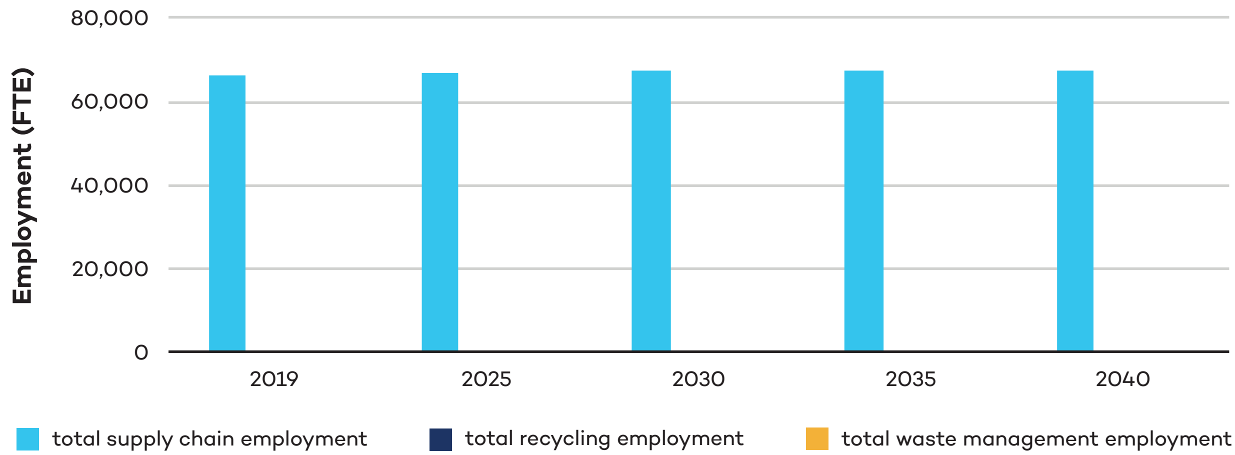

Figure 16. Employment in the food sector – BAU scenario

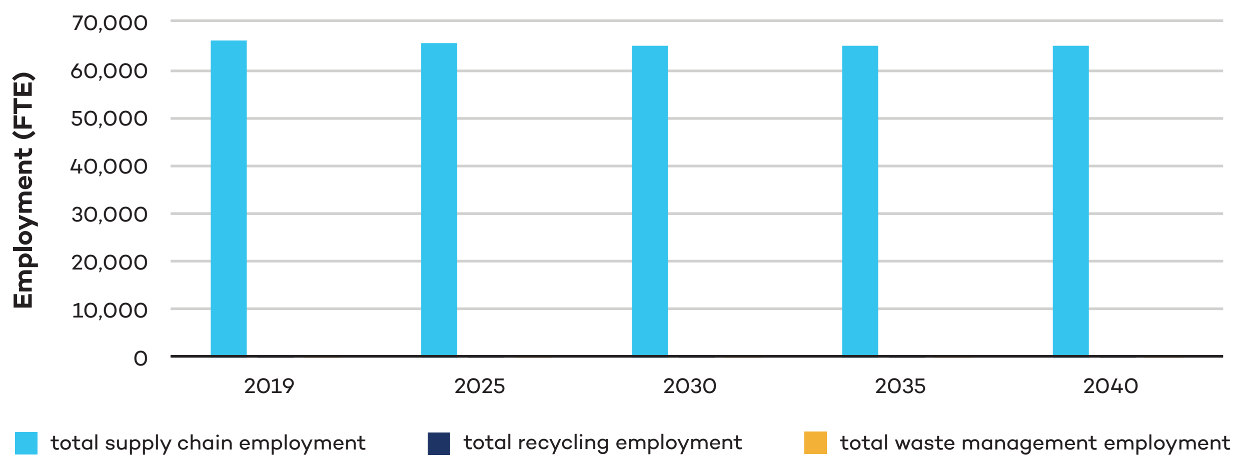

Figure 17. Employment in the food sector – CE scenario

2.4.1 Relevance of Upstream Activities

Upstream activities often dominate employment creation in many sectors. In this section we present an analysis where these jobs are not explicitly considered, so that the impacts of CE interventions on other types of employment, especially when the number of jobs in these categories are comparatively small, can be better appreciated.

Farming employment makes up more than 99 per cent of estimated food sector employment,[1] which indicates that observed changes in employment from processing and end-of-life materials management appear to be more significant in this sector than others. The development of sectoral jobs excluding farming employment are illustrated in Table 6.

[1] Upstream employment in the food sector only considers jobs in primary production (farming), and does not consider retail jobs. If retail jobs were included, the share of upstream employment would be higher than indicated above.

Table 6. **Overview of employment in the food sector excluding upstream (farming) employment**

	2018	2025	2030	2035	2040	
Total recycling employment						
CE2	250	200	140	120	120	↓↓
CE1	250	230	200	190	190	↓
BAU	250	250	260	260	260	
Total supply chain employment (excluding upstream)						
CE2	6,790	6,580	6,353	6,350	6,350	↓↓
CE1	6,790	6,730	6,640	6,640	6,645	↓
BAU	6,790	6,870	6,940	6,940	6,940	
Total waste management employment						
CE2	340	330	320	320	320	↓↓
CE1	340	340	330	330	330	↓
BAU	339	343	347	347	347	

2.4.2 Relevance of End-of-Life Materials Management

Employment from end-of-life materials management in the food sector for the BAU and CE scenario is illustrated in Figures 18 and 22. The results do not consider employment from energy recovery, for which data were not available.

In the BAU scenario, food waste contributes to 50 jobs in product collection, 110 jobs in waste sorting, 90 jobs in recycling, and 350 jobs in landfilling and incineration employment.[2]

The reduction in food waste leads to a net reduction of 80 jobs in end-of-life materials management, of which 10 jobs are lost in product collection, 30 jobs in waste sorting, 20 jobs in material recycling, and 10 jobs in landfilling and incineration. This is equivalent to reductions of 24.6 per cent in employment in collection, sorting and recycling of food waste and a 4.3 per cent reduction in landfilling and incineration employment.

[2] The employment related to the landfilling and incineration of food waste may appear to be very high. This is because the model assumes that the efficiency of food production and processing is at 87 per cent, and that 15 per cent of production residues (and so 15 per cent of 13 per cent of the total inputs to production) from farming and food processing are waste that is directly sent to landfill. The amount of waste from primary production sent to landfill is therefore on average 700,000 tons per year between 2030 and 2040, which leads to a high employment value from landfilling and waste incineration. If this waste were handled in a different way, e.g., within the sector, employment from landfilling and incineration would be lower than forecast.

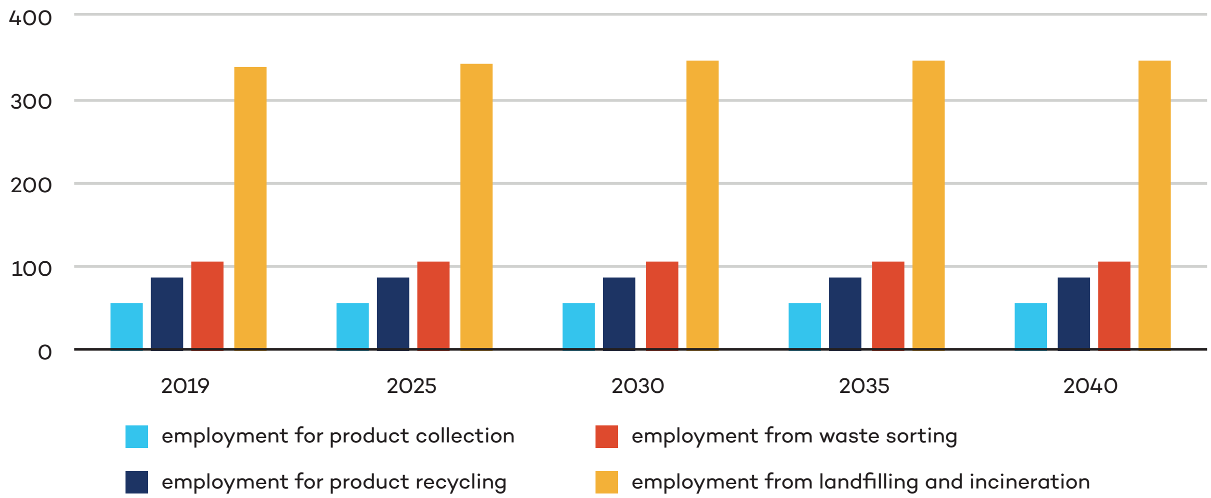

Figure 18. End-of-life materials management employment in the food sector – BAU scenario

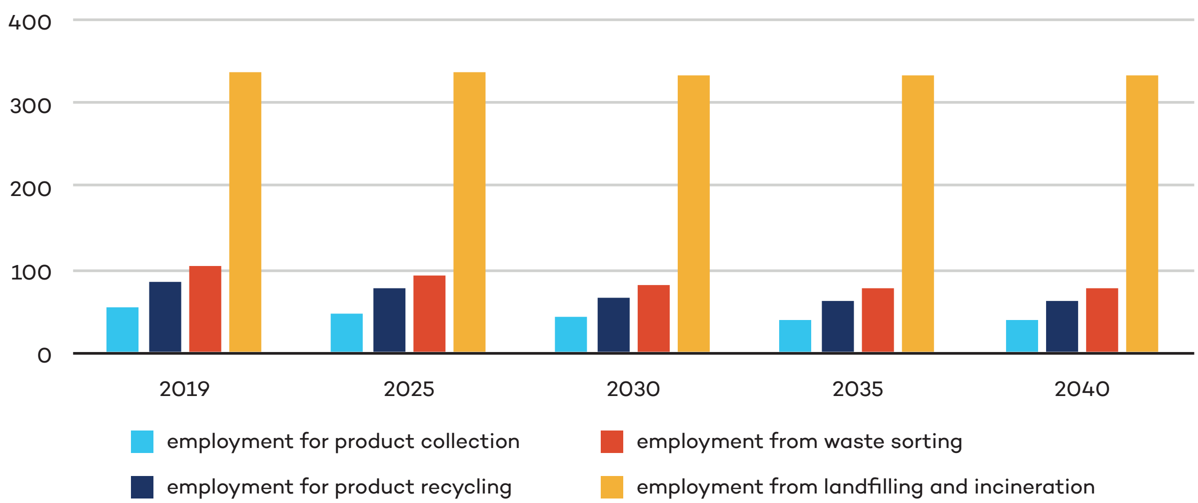

Figure 19. End-of-life materials management employment in the food sector – CE scenario

2.5 Mining

In the BAU scenario, the mining sector provides approximately 17,360 jobs in production, 480 jobs in collection and recycling, and virtually no employment for landfilling and waste incineration (due to high recycling rates and onsite waste management). An overview of total employment in the BAU scenario by category in the mining sector is provided in Figure 21.

Since no structural changes are forecast in the BAU scenario, the employment shares remain constant throughout the simulation. Supply chain employment contributes 97.3 per cent of sectoral employment, 2.7 per cent stems from recycling and 0 per cent from landfilling and waste incineration. The change in composition of sectoral employment shares for the BAU scenario are presented in Figure 20.

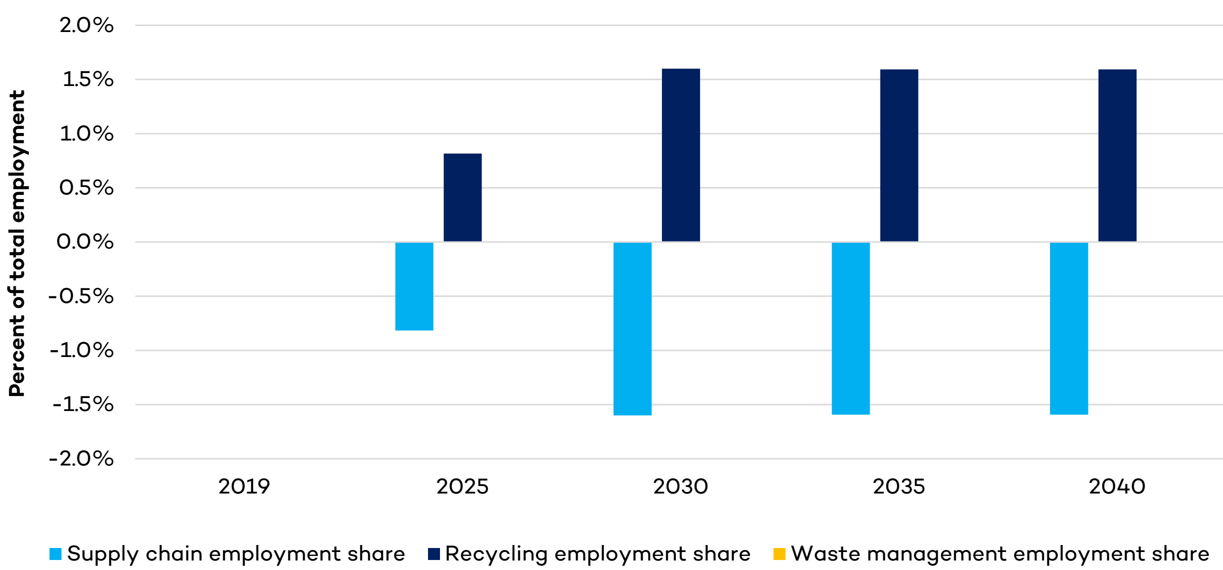

Figure 20. Employment shares in the mining sector – CE1 vs BAU scenario

The implementation of CE interventions increases the amount of metal scrap collected, which leads to reductions in total sectoral employment compared to the BAU scenario.

The increased reuse of metals reduces upstream employment by 60 jobs, while generating 150 additional jobs in recycling and refurbishing. This indicates that implementing CE interventions targeting scrap metal collection and reuse leads to a net gain of 90 jobs in sectoral employment by 2040. Absolute sectoral employment in the CE scenario is displayed in Figure 22.

CE interventions shift 0.84 per cent of sectoral jobs from supply chain jobs to recovery and reuse jobs. The share of supply chain employment declines from 97.3 per cent to 96.46 per cent, while the share of recycling and refurbishing employment increases from 2.7 per cent to 3.54 per cent.

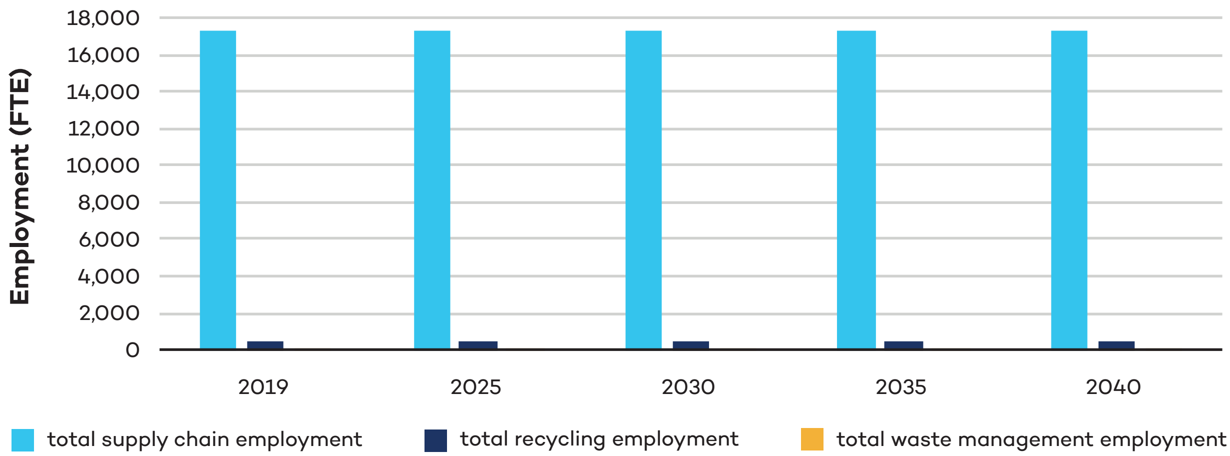

Figure 21. Employment in the mining sector – BAU scenario

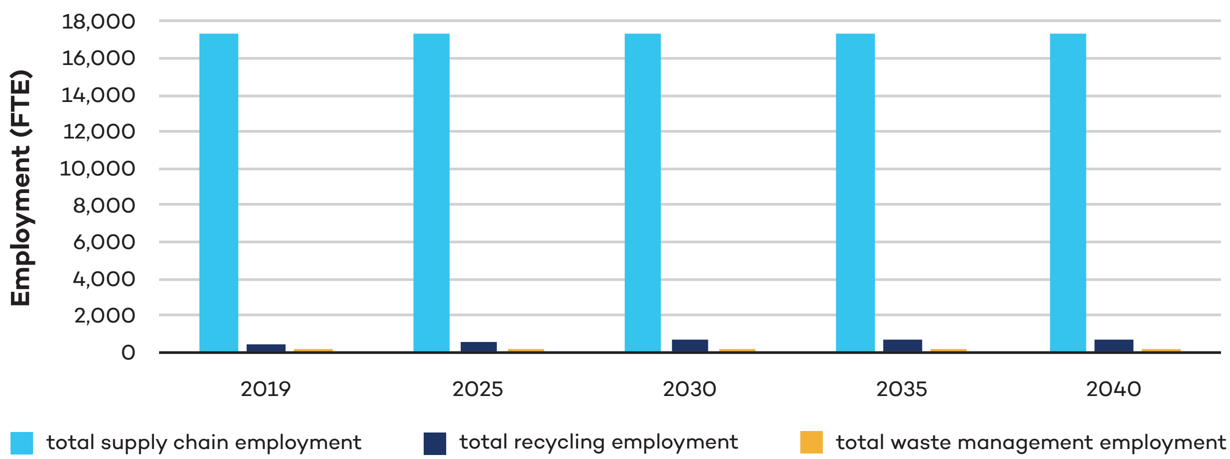

Figure 22. Employment in the mining sector – CE scenario

2.5.1 Relevance of Upstream Activities

Upstream activities often dominate employment creation in many sectors. In this section we present an analysis where these jobs are not explicitly considered, so that the impacts of CE interventions on other types of employment, especially when the number of jobs in these categories are comparatively small, can be better appreciated.

Upstream jobs in the mining sector are a critical contributor to sectoral employment, with 97.3 per cent of total sectoral jobs. Due to a high import share of metals for processing, the impact of CE interventions could be less severe than forecast. The development of sectoral jobs excluding mineral extraction employment is presented in Table 7.

Table 7. Overview of employment in the mining sector excluding upstream employment

	2018	2025	2030	2035	2040	
Total recycling employment						
CE2	480	630	770	770	770	↑↑
CE1	480	560	630	630	630	↑
BAU	480	480	480	480	480	
Total supply chain employment (excluding upstream)						
CE2	8,540	8,540	8,530	8,520	8,520	↓
CE1	8,540	8,540	8,540	8,530	8,530	↓
BAU	8,540	8,540	8,540	8,540	8,540	
Total waste management employment						
CE2	0.1	0.1	0.2	0.2	0.2	↑
CE1	0.1	0.1	0.1	0.1	0.1	=
BAU	0.1	0.1	0.1	0.1	0.1	

2.5.2 Relevance of End-of-Life Materials Management

End-of-life materials management employment rates for the BAU and CE scenarios are displayed in Figure 23 and Figure 24 respectively. Waste recycling (which includes reprocessing) is the highest contributor of end-of-life materials management jobs.

In the BAU scenario, waste recycling contributes 360 jobs, while waste collection and waste sorting contribute 70 and 50 jobs respectively.

In the CE scenario, the increase in scrap metal leads to a 30.7 per cent increase in end-of-life materials management employment across all categories and generates around 150 additional jobs compared to the BAU scenario.

In the CE scenario, employment from recycling and refurbishing provides 470 jobs, waste collection 100 jobs and waste sorting 10 jobs, which is an increase of 110, 20 and 10 jobs respectively compared to the BAU scenario. Due to its very small contribution, employment from landfilling and incineration is not displayed.

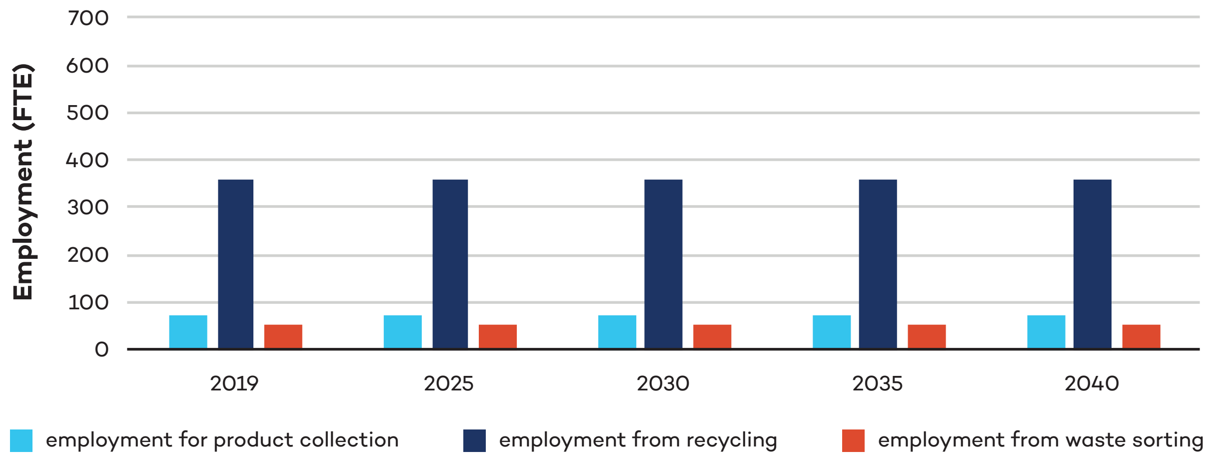

Figure 23. End-of-life materials management employment in the mining sector – BAU scenario

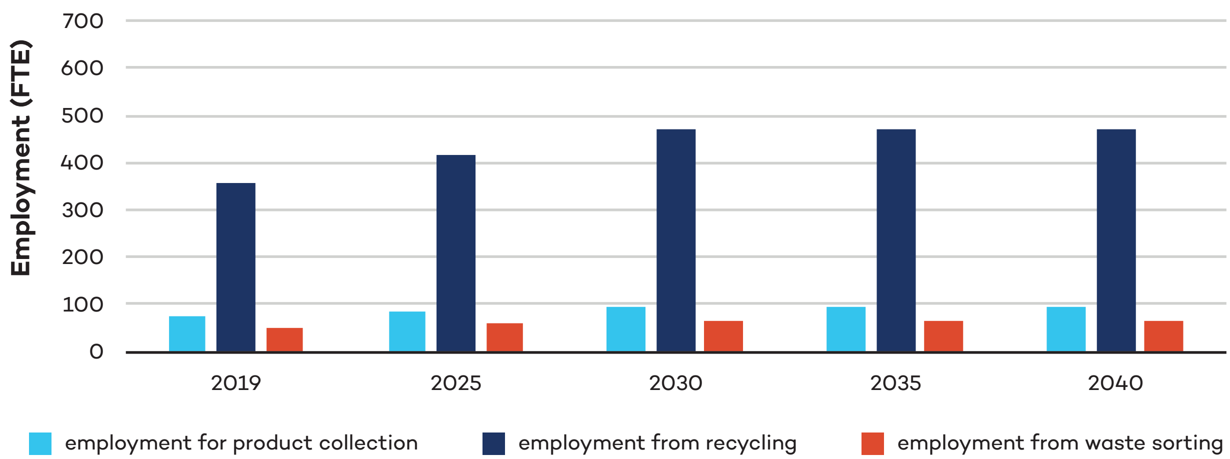

Figure 24. End-of-life materials management employment in the mining sector – CE scenario

2.6 Forestry

In the BAU scenario, the forestry sector provides approximately 48,030 jobs in logging and processing, 4,180 jobs in recycling and refurbishing, and 1,380 jobs from landfilling and waste incineration.[3]

Since no structural changes are foreseen in the BAU scenario, the employment shares remain constant throughout the simulation. Supply chain employment contributes 89.6 per cent of sectoral employment, 7.8 per cent stem from recycling and 2.6 per cent from landfilling and waste incineration. Sectoral employment shares for the BAU scenario are presented in Figure 25.

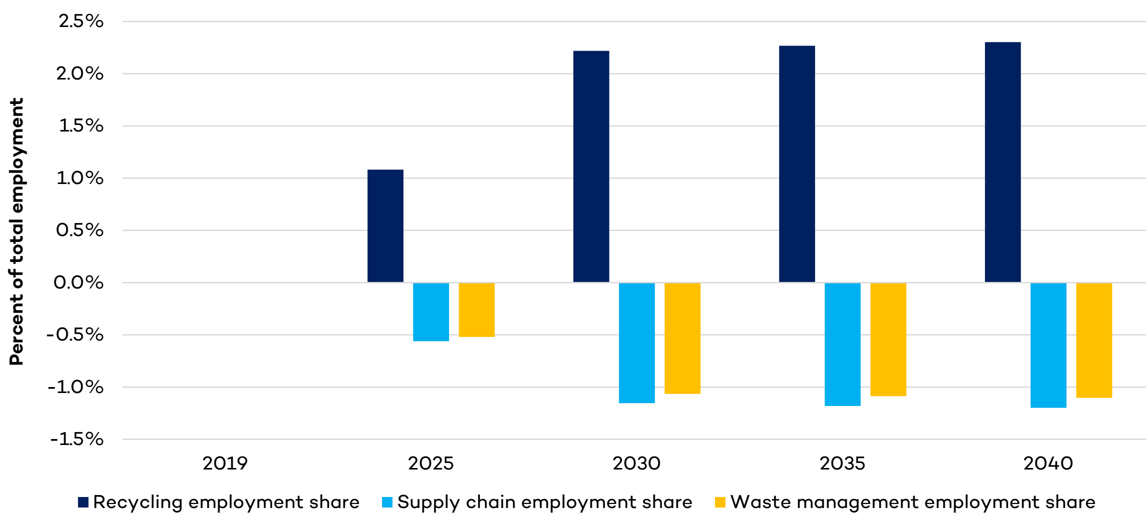

Figure 25. Employment shares in the forestry sector – CE1 vs BAU scenario

The implementation of CE interventions leads to a net increase in sectoral jobs due to the high labour intensity of recycling and refurbishing activities. The results of the CE scenario indicate a net increase of 330 jobs, which is a 0.6 per cent increase compared to the BAU scenario.

This increase in employment is driven by recycling and refurbishing activities, which generate 650 additional jobs by 2040. The increased reuse and refurbishment of wood products reduces the demand for wood and the total amount of wood product waste at the same time. This reduces annual logging employment on average by 30 jobs and lead to a reduction of 290 jobs in landfilling and incineration employment.

[3] The lifetime of wood products is assumed to be 15 years. However, since sawn wood might also be used in construction, its lifetime could be three to four times longer, which would reduce the wood waste stream and related employment. Further, information on total wood recycled and refurbished could not be obtained, and a 30 per cent recycling rate was assumed for the BAU scenario. The residual wood is sent to landfill, and 80 per cent of this amount is assumed to be incinerated. This results in a high employment value, due to the comparatively high employment multiplier for waste incineration obtained from Finnish statistics.

In addition, it is assumed that 1 per cent of materials extracted (from logging) end up in the landfill (as direct discard from production), which is equivalent to 1.5 million tons of per year on average. This is 10 times the amount of materials that forecasted to be sent to landfill from collected wood products (based on the assumptions described above, 15 years of lifetime, 30 per cent recycling rate). If this assumption were to be changed and landfill reduced, due to on-site management of wood waste for instance, the amount of employment from landfilling and incineration would greatly decline.

In the CE scenario, the forestry sector provides 48,000 jobs in production and processing, 4,830 jobs in recycling and refurbishment, and 1,090 jobs in landfilling and incineration, as illustrated in Figure 27. The structural composition of employment in the forestry sector, displayed in , indicates that 89.6 per cent of jobs stem from supply chain employment, 7.8 per cent from recycling and refurbishment, and 2.6 per cent from landfilling and incineration. The CE scenario leads to an increase of 15.6 per cent jobs in recycling and refurbishing and a decrease of 0.1 per cent jobs in supply chain, and 21 per cent in landfilling and waste incineration employment.[4]

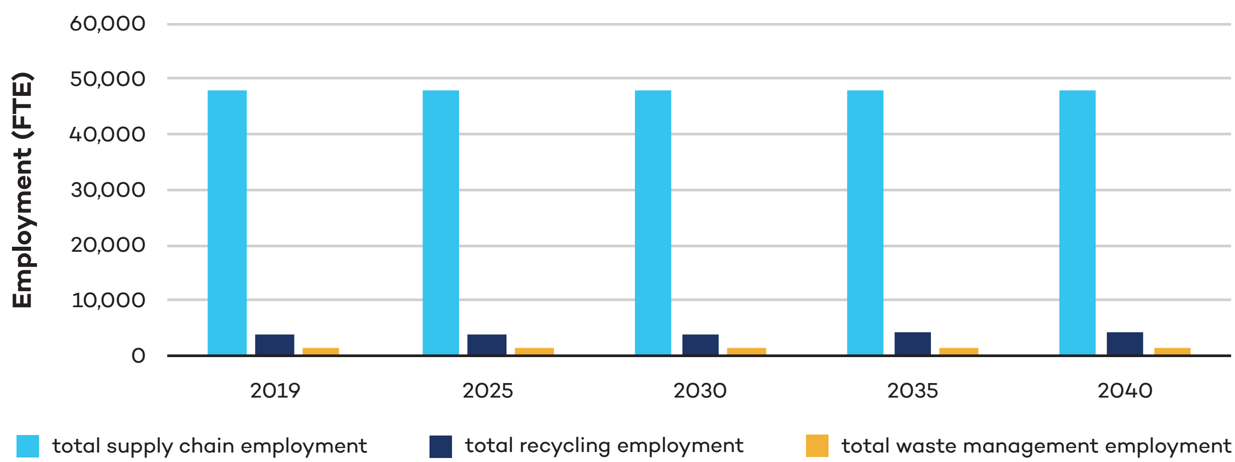

Figure 26. Employment in the forestry sector – BAU scenario

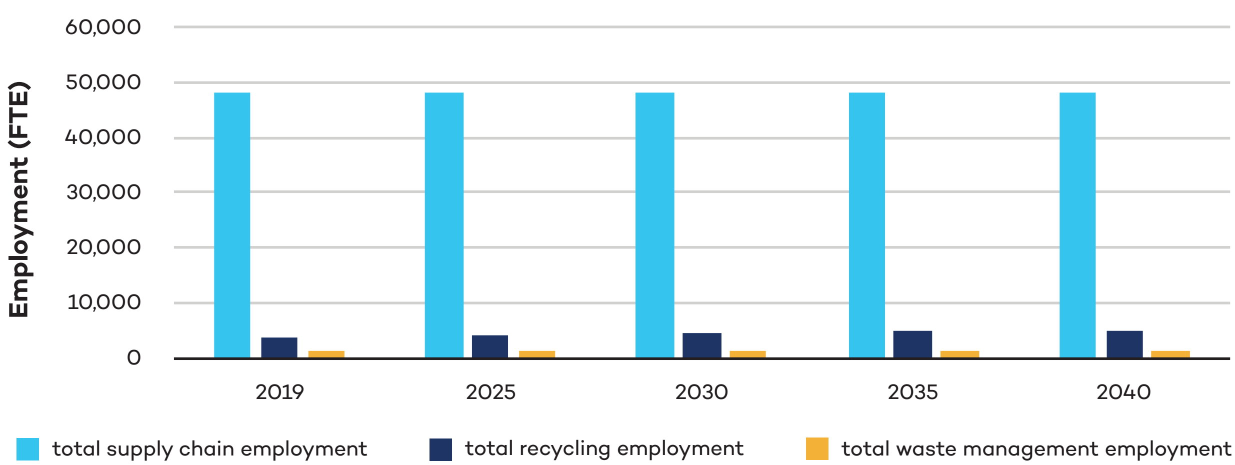

Figure 27. Employment in the forestry sector – CE scenario

[4] As indicated in Footnote 2, a high share of domestic wood waste is assumed to be sent to landfill, which leads to a high employment number for this activity in the BAU case, and hence to a strong reduction in jobs in the CE scenario.

2.6.1 Relevance of Upstream Activities

Upstream activities often dominate employment creation in many sectors. In this section we present an analysis where these jobs are not explicitly considered, so that the impacts of CE interventions on other types of employment, especially when the number of jobs in these categories are comparatively small, can be better appreciated.

In the forestry sector, logging jobs are considered upstream employment. Compared to the total employment provided by processing (sawn goods and pulp and paper) and end-of-life materials management, logging jobs contribute approximately 11.3 per cent to total sectoral employment.

The analysis considers that recovered paper reduces total material inputs in the production process, which reduces the demand for wood in the CE scenarios and consequently reduces the employment from logging.[5] Nevertheless, the logging industry is an important job contributor and drives the export of Finland's wood and pulp and paper products, and hence the changes in employment forecast are likely to overestimate the actual impacts. The development of sectoral jobs excluding logging employment are presented in Table 8.

Table 8. Overview of employment in the forestry sector excluding upstream (logging) employment

	2018	2025	2030	2035	2040	
Total recycling employment						
CE2	3,680	4,500	5,270	5,390	5,480	↑↑
CE1	3,680	4,200	4,650	4,750	4,830	↑
BAU	3,680	3,900	4,020	4,110	4,180	
Total supply chain employment (excluding upstream)						
CE2	42,030	42,030	42,030	42,030	42,030	=
CE1	42,030	42,030	42,030	42,030	42,030	=
BAU	42,030	42,030	42,030	42,030	42,030	
Total waste management employment						
CE2	1,290	1,060	800	800	800	↓↓
CE1	1,290	1,200	1,070	1,090	1,100	↓
BAU	1,290	1,330	1,350	1,370	1,380	

[5] Note that seasonal variations in logging employment are not considered in this assessment. The analysis assumes an average annual employment in the logging sector based on data obtained from Forestry Statistics and Luke.

2.6.2 Relevance of End-of-Life Materials Management

Employment rates provided from end-of-life materials management in the BAU and CE scenario are displayed in Figure 28 and Figure 29 respectively. In the BAU scenario, end-of-life materials management in the forestry sector provides 5,200 jobs by 2040. The collection of products contributes 520 jobs, product sorting 1,140 jobs, recycling and refurbishment 2,160 jobs, and landfilling and incineration 1,380 jobs.

In the CE scenario, the increased recycling of paper and wood products generates 360 additional end-of-life materials management jobs by 2040, which is an increase of 7 per cent. While employment from product collection and sorting remains the same as in the BAU scenario with 520 and 1,140 jobs respectively, the number of jobs in product recycling and refurbishment increase by 650 from 2,160 to 2,820 jobs (30.2 per cent) while the number of jobs from landfilling and incineration declines by 290 jobs from 1,380 to 1,090 jobs (-21 per cent).

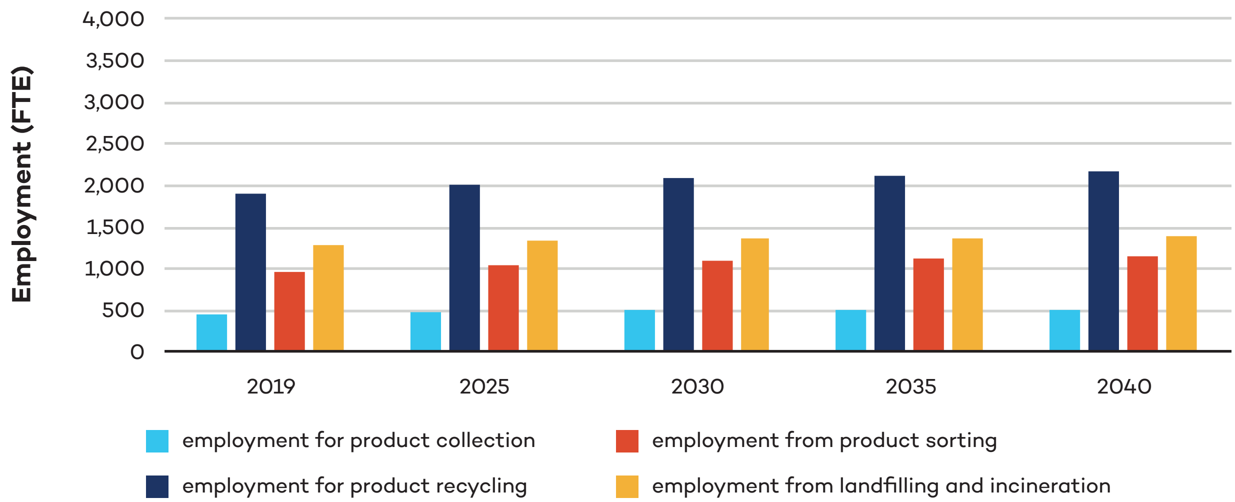

Figure 28. End-of-life materials management employment in the forestry sector – BAU scenario

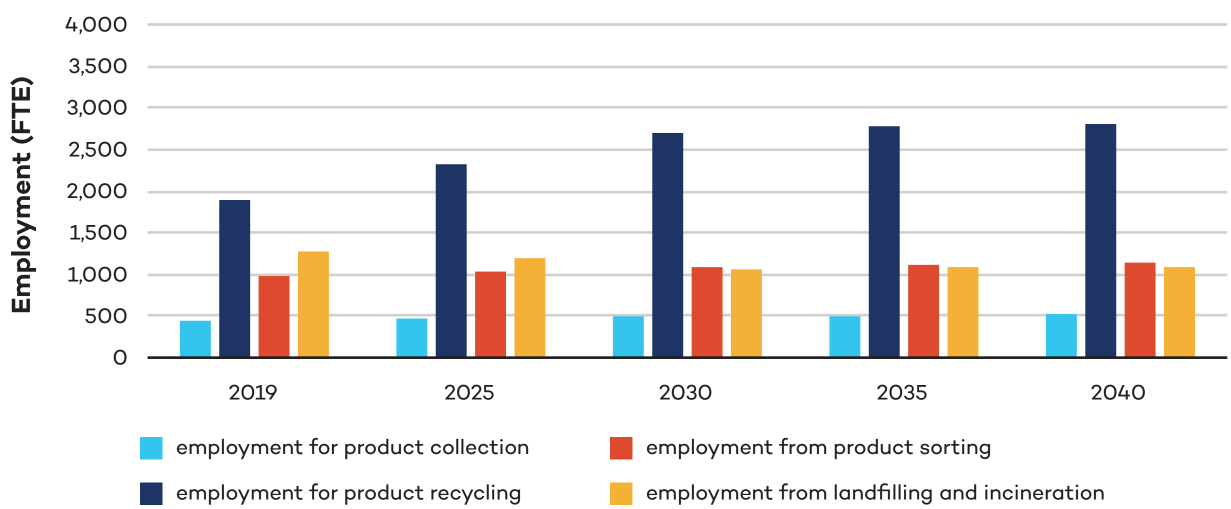

Figure 29. End-of-life materials management employment in the forestry sector – CE scenario

2.7 Buildings

In the BAU scenario, the buildings sector provides approximately 46,180 jobs in construction and building finishing, 36,200 jobs in demolishing, recycling and refurbishing, and 390 jobs in energy provisioning.

Since no structural changes are forecast in the BAU scenario, only minor changes are observed in the structural composition of employment in the buildings sector. The share of construction employment decreases by 2.7 per cent in the long run, while the maintenance share increases by the same amount. By 2040, the construction share of employment is 55.8 per cent, operations and maintenance share 43.7 per cent, and the share of energy provisioning is 0.5 per cent. The change in composition of employment in the buildings sector is presented in Figure 30, while total employment in the BAU scenario is illustrated in Figure 31.

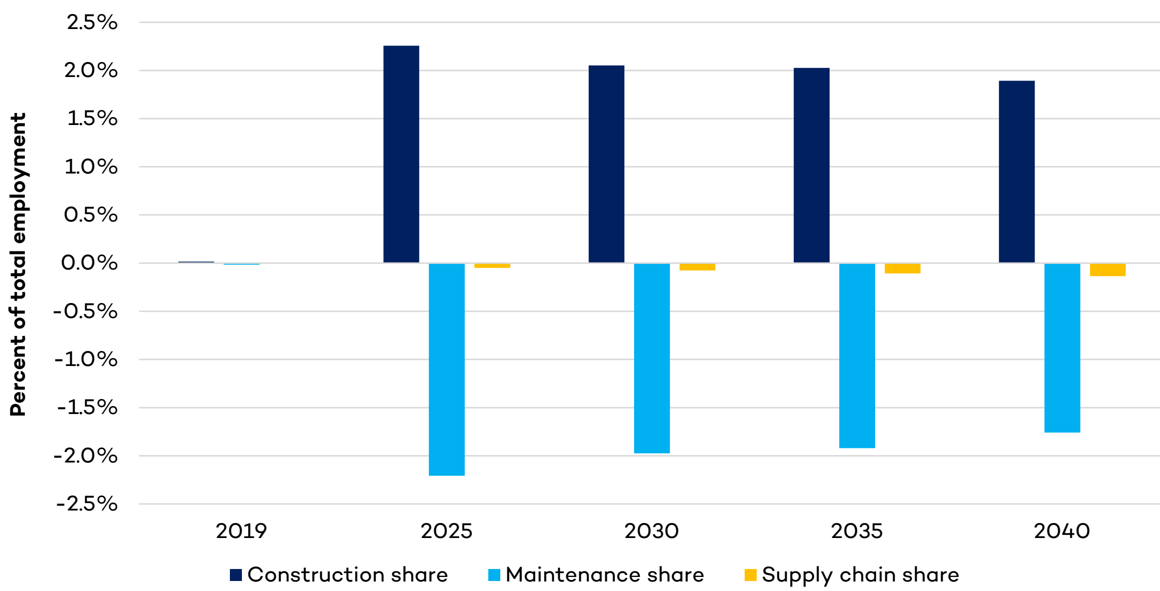

Figure 30. Employment shares in the buildings sector – CE2 vs BAU scenario

Two CE scenarios are simulated for the buildings sector. Both scenarios (CE1 + CE2) assume that the share of sustainable buildings increases by 20 per cent through new constructions between 2019 and 2040. However, CE2 assumes that 2.5 million square meters per year are retrofit in addition to new constructions, which increases the total share of efficient buildings by an additional 21.4% compared to CE1. The assessment further assumes that the lifespan of efficient buildings is 20 years longer than conventional buildings (and that retrofits extend the lifespan of an existing building by 20 years).

The construction share in sectoral employment increases in the short run compared to the BAU, for both CE scenarios. This increase is related to the implementation of the ambition to make the buildings stock more sustainable. By 2040, the average share of construction in total employment in the BAU scenario is 55.8 per cent, while the construction share in the CE1 (new constructions) and CE2 (new construction plus retrofits) scenarios is 56.2 per cent and 57.7 per cent respectively. This indicates that the ambition to increase the efficient buildings stock by means of new construction increases construction during the implementation period. Furthermore, additional retrofits would increase total construction related employment by an additional 1.5% and accelerate the transition towards a fully efficient buildings stock.

A reduction in construction employment from the increased average lifetime of the buildings stock, which could lead to lower re-construction rates in the long run, is not observed as the lifetime of new sustainable buildings (80 years) falls outside the time horizon of this analysis. Building sector employment figures for the retrofit and additional construction scenarios are displayed in Figure 32 and Figure 33.

By 2040, employment from maintenance is 1.0 and 2.1 per cent in the CE1 and CE2 scenario respectively, as efficient buildings are assumed to be 10 per cent more labour-intensive compared to conventional buildings. This per cent increase translates into 360 and 750 additional jobs in buildings maintenance for the CE1 and CE2 scenario respectively. However, as the buildings stock becomes more energy efficient through refurbishments or new sustainable construction, total energy provisioning employment is projected to decline by 30 jobs in the CE1 scenario and 90 jobs in the CE2 scenario in the long run. This reduction is equivalent to 8.5 and 23.7 per cent for CE1 and CE2 respectively compared to the BAU.

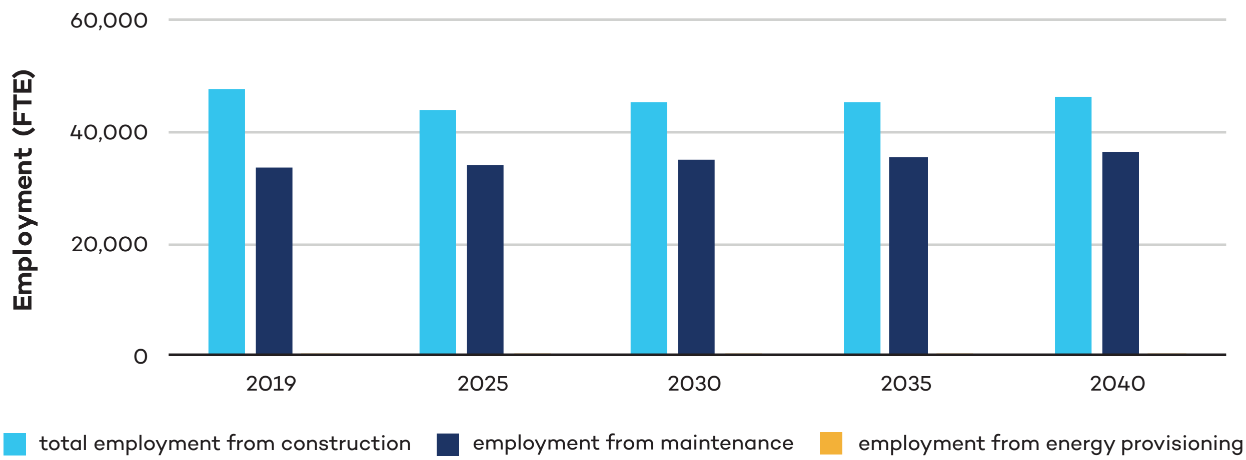

Figure 31. Employment in the buildings sector – BAU scenario

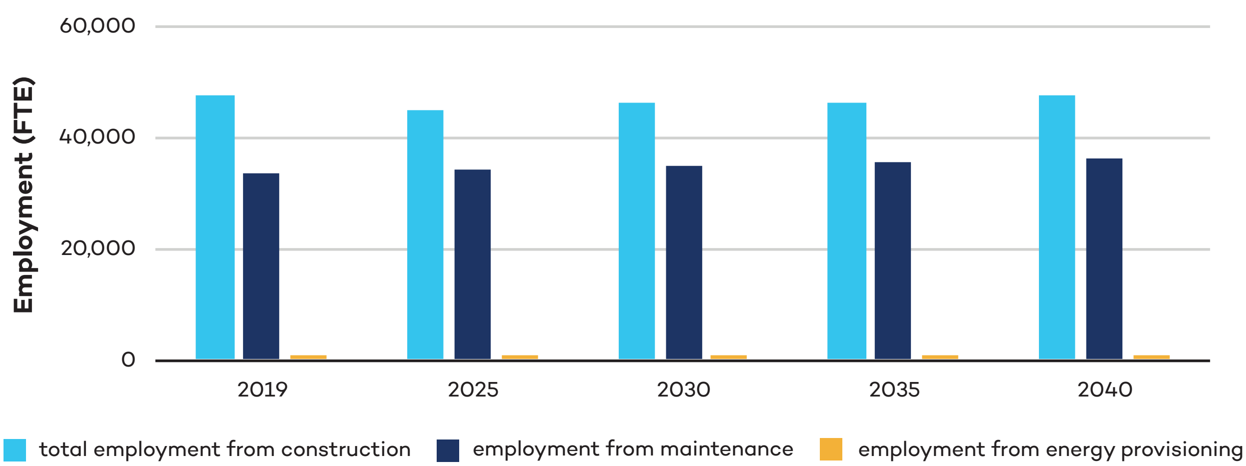

Figure 32. Figure 32. Employment in the buildings sector – Retrofit scenario

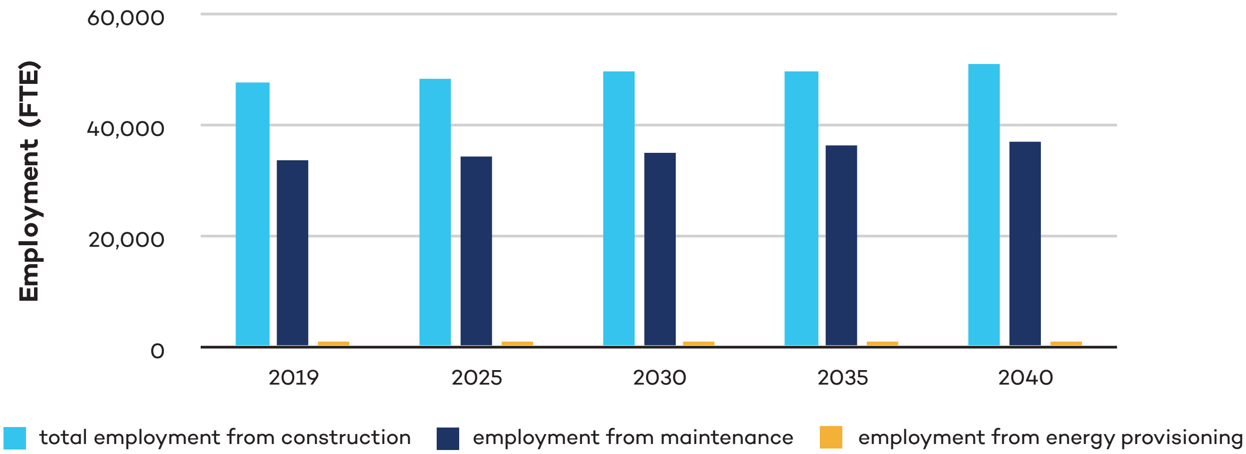

Figure 33. Employment in the buildings sector – New construction scenario

References

Briggs, D. (1994). *Forest products measurements and conversion factors: with special emphasis on the U.S. Pacific Northwest*. Institute of Forest Resources. Retrieved from http://www.ruraltech.org/projects/conversions/briggs_conversions/briggs_book.asp

European Parliament. (2017). *Employment in privatised utilities: A higher risk of precariousness?* Retrieved from http://www.europarl.europa.eu/RegData/etudes/STUD/2017/602061/IPOL_STU(2017)602061_EN.pdf

Eurostat. (2019). *Total water abstraction*. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php/Water_statistics#Water_as_a_resource

Finnish Forest Industries. (2019). *Forestry industry statistics*. Retrieved from https://www.forestindustries.fi/statistics/

Friends of the Earth. (n.d.). *Mind your step – The land and water footprints of everyday products*. Retrieved from https://friendsoftheearth.uk/sites/default/files/downloads/mind-your-step-report-76803.pdf

Geological Survey of Finland. (2010). *Finland's minerals strategy*. Retrieved from http://www.mineraalistrategia.fi/

Global Green Growth Institute (GGGI). (2018). *The economic, social, and environmental impacts of greening the industrial sector*. Retrieved from http://gggi.org/site/assets/uploads/2018/10/GGGI_Greening-the-Industrial-Sector-in-Cambodia_FULL-REPORT.pdf

Hummingbird International. (2015). *How ewaste recycling is creating a lot of jobs*. Retrieved from http://hummingbirdinternational.net/how-ewaste-recycling-creating-jobs/

Kauppila, P.M., Räisänen, M.L., & Myllyoja, S. (2011). *Best environmental practices in metal ore mining*. Finnish Environment Institute. Retrieved from https://www.researchgate.net/publication/284046091_Best_environmental_practices_in_metal_ore_mining/download

Lee, K. & Jung, M. (2015). Overseas factories, domestic employment, and technological hollowing out: A case study of Samsung's mobile phone business. *Review of World Economics*, *151*(3), 461–475.

Ministry of Economic Affairs and Employment. (2018). *Sector report 1/2018 – Mining sector*. Retrieved from http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160584/SectorReports_1_2018_MiningSector.pdf

Natural Resources Institute Finland (Luke). (2019). *Labour force and forestry machines in harvesting of industrial roundwood*. Retrieved from http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__04%20Metsa__02%20Rakenne%20ja%20tuotanto__06%20Teollisuuspuun%20hakkuut%20ja%20tyovoima/03_Tyovoima_ja_kalusto_kk.px/?rxid=478bafea-954b-4a4a-8b8e-bba4595c6849

Nordic Council of Ministers. (2014). *Towards a Nordic textile strategy*. Retrieved from https://www.diva-portal.org/smash/get/diva2:720964/FULLTEXT01.pdf

Oliveira, L. (2017). *Water consumption in pulp mills* [LinkedIn post]. Retrieved from https://www.linkedin.com/pulse/water-consumption-pulp-mills-luciano-oliveira/

Statistics Finland. (2016). *Waste statistics 2016*. Retrieved from https://www.stat.fi/til/jate/2016/13/jate_2016_13_2018-01-15_en.pdf

Statistics Finland. (2018). *Waste statistics 2008–2016*.

Statistics Finland. (2019a). *Building and dwelling production*.

Statistics Finland. (2019b). *Employment persons by occupation group*.

Statistics Finland. (2019c). *Energy Supply and consumption*. Retrieved from https://www.stat.fi/til/ehk/index_en.html

Statistics Finland. (2019d). *(Archive) Waste treatment by type of waste, year and treatment 2004–2013*.

Tellus Institute. (2011). *More jobs, less pollution: Growing the recycling economy in the U.S.* Retrieved from https://www.tellus.org/pub/More%20Jobs,%20Less%20Pollution%20-%20Growing%20the%20Recycling%20Economy%20in%20the%20US.pdf

Ürge-Vorsatz, D., Wójcik-Gront, E., Tirado Herrero, S., Labzina, E., & Foley, P. (2012). *Employment impacts of a large-scale deep building energy retrofit programme in Poland*. Budapest: The Center for Climate Change and Sustainable Energy Policy (3CSEP). Retrieved from https://publications.ceu.edu/sites/default/files/publications/final-reportempl-impacts-of-large-scale-deep-bldg-retrofit-prg-in-poland_0.pdf

WRAP (2017). *Valuing our clothes: The cost of UK fashion*. Retrieved from http://www.wrap.org.uk/sites/files/wrap/valuing-our-clothes-the-cost-of-uk-fashion_WRAP.pdf

Yu, J., Williams, E., & Ju, M. (2010). Analysis of material and energy consumption of mobile phones in China. *Energy Policy, 38*(8), 4135–4141.

Annex 1. Data sources

	Unit	Value	Source
Mining			
EMPLOYMENT			
Resources			
Employment per unit of material sourced	Person / ton	7.55095E-05	Geological Survey of Finland (2010)
Employment per unit of water consumed	Person / litre	1.91E-06	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / terajoule (TJ)	0.001157	Statistics Finland (2019b)
Supply chain			
Employment per unit processed	Person / ton	0.002206864	Geological Survey of Finland (2010)
Employment per unit collected	Person / ton	0.000141057	Statistics Finland (2019b)
Employment per unit recycled	Person / ton	0.002206864	Geological Survey of Finland (2010)
Employment per unit of waste landfilled	Person / ton	0.000435	Statistics Finland (2019b)
Employment per unit of waste incinerated	Person / ton	0.0001	Tellus Institute (2011)
MATERIAL USE			
Material consumption per unit	Ton ore / ton extracted	2.4421	Ministry of Economic Affairs and Employment (2018)
Water consumption per ton extracted	Litre / ton	2,500	Water consumption at copper mines in Arizona
Energy consumption per unit	TJ / ton	0.000227	Kauppila et al. (2011)
Share of products collected	%	46%	Statistics Finland (2016)
Share of products recycled	%	99%	Statistics Finland (2019d)
Share of material recycling and reuse	%	99%	Statistics Finland (2019d)

	Unit	Value	Source
Share of materials that is waste	%	1%	Statistics Finland (2019d)
Ore Extraction Ratio	%	48.3%	Time series, average value

Electronics

EMPLOYMENT PARAMETERS			
Resources			
Employment per ton of material extracted	Person / ton	0.001660	Geological Survey of Finland (2010)
Employment per unit of water consumed	Person / litre	1.91E-06	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / TJ	0.001157	Statistics Finland (2019c)
Supply chain			
Employment electronics production	Person / ton	0.000129	Lee & Jung (2015)
Employment electronics retail	Person / ton	0.00033	Assumption, calculated based on phone retails, and adjusted down to match retail only related to electronics
Employment per ton of waste processed (macro)	Person / ton	0.000451	Statistics Finland (2019c)
Employment per unit collected	Person / ton	0.000141	Statistics Finland (2019c)
Employment per unit sorted	Person / ton	0.000309	Statistics Finland (2019c)
Employment per unit sorted	Person / ton	0.030	Hummingbird International (2015)
Employment per unit sorted used	Person / ton	0.003	Assumption
Employment per unit repaired and reused	Person / ton	0.2	Hummingbird International (2015)
Employment per unit recycled	Person / ton	0.0150	Hummingbird International (2015)
Employment per unit of waste landfilled	Person / ton	0.007	Tellus Institute (2011); Hummingbird International (2015)
Employment per unit of waste incinerated	Person / ton	0.00087	Statistics Finland (2019d) (with the value divided by two in order to distinguish between waste incineration and wastewater management)

	Unit	Value	Source
Employment per unit of recycled material sorted	Person / ton	0.03	Hummingbird International (2015)
MATERIAL USE			
Material consumption per phone	kg / phone	0.0714286	Assuming 70 kg of materials across all electronics.
Water consumption per ton of electronics	litre / ton	12760000	Friends of the Earth (n.d.)
Energy consumption per unit	TJ / ton	0.187264	Yu et al. (2010)
Share of products collected	%	100%	Statistics Finland (2018)
Share of products recycled	%	99.9%	Statistics Finland (2018)
Share of material recycling and reuse	%	43.2%	Statistics Finland (2018)
Share of materials that is waste	%	56.8%	Calculation // Assumption based on recycling and reuse share
Share of materials landfilled	%	0.1%	Calculation // Assumption based on recycling share
		Average	**2000**
Time series recycling rate e&e waste	%	34.2%	

Food

EMPLOYMENT PARAMETERS			
Resources			
Employment per ton of food sourced	Person / ton	0.027436	Statistics Finland (2019b)
Employment per unit of food processed	Person / ton	0.002113	Statistics Finland (2019b)
Employment per unit of water consumed	Person / litre	1.91E-06	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / ton	0.001157	Statistics Finland (2019c)
Supply chain			
Employment per ton of waste processed (macro)	Person / ton	0.000451	Statistics Finland (2019b)

	Unit	Value	Source
Employment per unit collected	Person / ton	0.000141	Statistics Finland (2019b)
Employment per unit sorted	Person / ton	0.000309	Statistics Finland (2019b)
Employment per unit of waste landfilled	Person / ton	0.0001	Tellus Institute (2011)
Employment per unit of waste incinerated	Person / ton	0.000435	Statistics Finland (2019b)
Employment per unit of waste recycled	Person / ton	0.000251	Sorting employment per ton is 0.000309 according to data obtained from Statistics Finland (2019b) (Average employment per ton of municipal waste - value for the years 2010–2016). The Tellus institute (2011) indicates processing employment for food scraps of 0.00056, therefore we assume an additional employment of 0.000251 person per ton for the recycling of food waste here.
MATERIAL USE			
Material consumption per unit	Ton / ton	1.15	Assumption
Water consumption per ton produced	Ltr / ton	14700	Global Green Growth Institute (2018)
Energy consumption per unit	TJ / ton	0.0072	Global Green Growth Institute (2018)
Share of products recycled	%	91.2%	Statistics Finland (2019d)
Share of materials that is waste	%	1.2%	Statistics Finland (2019d)
Share of materials to energy recovery	%	7.6%	Statistics Finland (2019d)

Textiles

EMPLOYMENT PARAMETERS			
Resources			
Employment per ton of textile	Person / ton	0.243675	Nordic Council of Ministers (2014)
			Statistics Finland (2019b)

	Unit	Value	Source
Employment per unit of water consumed	Person / Ltr	1.91E-06	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / TJ	0.001157	Statistics Finland (2019c)
Supply chain			
Employment per unit produced	Person / ton	0.243675	Nordic Council of Ministers (2014)
			Statistics Finland (2019b)
Employment per unit resold	Person / ton	0.007650	Nordic Council of Ministers (2014)
Employment per unit collected & sorted	Person / ton	0.003279	Nordic Council of Ministers (2014)
Employment per unit of waste landfilled	Person / ton	0.000435	Statistics Finland (2019b)
Employment per unit of waste incinerated	Person / ton	0.0001	Tellus Institute (2011)
MATERIAL USE			
Material consumption per ton of textile	Ton garment / Ton textile	1.115	Global Green Growth Institute (2018)
Water consumption per ton of textile	Ltr / Ton	150000	Global Green Growth Institute (2018)
Energy consumption per ton of textile	TJ / Ton	0.0357	Global Green Growth Institute (2018)
Material demand per capita	Ton / Person / Year	0.016316	WRAP (2017)
Share of products collected	%	34.2%	Nordic Council of Ministers (2014)
Share of products recycled	%	34.0%	Nordic Council of Ministers (2014)
Share of material recycling and reuse	%	52.8%	Nordic Council of Ministers (2014)
Share of materials that is waste	%	13.2%	Nordic Council of Ministers (2014)
Buildings			
EMPLOYMENT PARAMETERS			
Resources			
Employment per unit of material sourced	Person / ton	7.55095E-05	Geological Survey of Finland (2010)

	Unit	Value	Source
Employment per unit of water consumed	Person / Ltr	1.91E-06	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / TJ	0.001157	Statistics Finland (2019c)
Supply chain			
Employment per m^2 (planning)	Person / m^2	0.000679	Statistics Finland (2019a, 2019b)
Employment per m^2 (construction)	Person / m^2	0.002146	Statistics Finland (2019a, 2019b)
Employment per m^2 (o&m)	Person / m^2	0.000147	Statistics Finland (2019a, 2019b)
Employment per m^2 (retrofit)	Person / m^2	0.001360	Ürge-Vorsatz et al. (2012)
Employment per unit of waste landfilled	Person / ton	0.0001	Tellus Institute (2011)
Employment per unit of waste incinerated	Person / ton	0.0001	Tellus Institute (2011)

Forestry

EMPLOYMENT PARAMETERS			
Resources			
Employment per unit of material sourced	Person / ton	0.000089	Natural Resources Institute Finland (Luke) (2019)
Employment per unit of water consumed	Person / Ltr	1.66E-03	Eurostat (2019); European Parliament (2017)
Employment per unit of energy consumed	Person / TJ	0.001157	Statistics Finland (2019c)
Supply chain			
Employment per ton of wood extracted	Person / ton	0.000089	Natural Resources Institute Finland (Luke) (2019)
Employment per unit processed			
Employment per ton pulp and paper	Person / ton	0.001441	Finnish Forest Industries (2019)
Employment per m^3 of sawn wood and board	Person / m^3	0.001139	Natural Resources Institute Finland (Luke) (2019)

	Unit	Value	Source
Employment per unit collected	Person / ton	0.000141	Statistics Finland (2019b)
Employment per unit repaired and reused	Person / ton	0.0028	Tellus Institute (2011)
Employment per unit recycled	Person / ton	0.00056	Tellus Institute (2011)
Employment per unit of waste landfilled	Person / ton	0.000434974	Statistics Finland (2019b)
MATERIAL USE			
Material consumption sawn wood	m^3/ ton of sawn wood	1.053	Assumption based on calibration to total wood use
Energy consumption per unit	TJ / ton	0.001435886	Finnish Forest Industries (2019)
Wood use per ton of pulp	m^3/ ton	4.76	Briggs (1994)
Water use per ton or pulp	m^3/ ton	30	Oliveira (2017)
Share of paper and paperboard recycled	%	63%	Finnish Forest Industries (2019)
Share of products recycled	%	30%	Assumption
Share of material recycling and reuse	%	10%	Assumption
Share of materials that is waste	%	1%	Assumption

Annex 2. Sensitivity Analysis

Several assumptions are used in the Circular Economy (CE) models, as well as several data sets from Finland or abroad, that require further investigation and validation. Our research makes use of secondary data only, and reliable information on the employment impacts resulting from CE interventions is largely missing in the literature.

For this reason, we indicate that model results should not be interpreted as predictions. Instead, we generate forecasts that are intended to inform decision making, providing insights on the sense of the direction and rough magnitude of the employment impacts expected. The goal is to support the use of a systemic approach to policy-making, where both the potential for job creation and concerns about job losses are considered.

In the process of creating and validating the CE models, several alternative simulations have been created, including sensitivity analysis, to test the sensitivity of model outputs to changes in model inputs. Since most dynamics in employment are directly proportional to changes in material flow (i.e., because of the use of employment multipliers per tonne of material flow), most tests revolved around the extent to which the potential job gains forecasted in the main scenarios could be turned into net job losses.

The example of electronics is provided below. One thousand simulations were created, with varying assumptions for labour intensity and with the possibility to see a potential increase in labour intensity of up to 1% per year or a decline of up to 1% per year. Random uniform distribution was used. The most relevant results emerge for the latter, where, with the improvement of labour efficiency (i.e., a reduction in labour intensity) in the CE scenario, it is possible that the potential job gain generated by investments in a CE would be cancelled by 2040 when compared to the business-as-usual (BAU) scenario. This means that by 2040 the total number of jobs in the sector would be the same as in the BAU scenario. Further considerations have to be made in relation to whether the same improvement in labour productivity would also take place in the BAU scenario (hence indicating net job creation in the CE case as well, regardless) or only in the CE scenario and primarily due to improvements in materials management practices and in infrastructure and equipment. The graphs presented in Figure 34 show, on the left side, the confidence intervals (or the probability of obtaining certain outcomes). Results indicate that, with the range of inputs used and with the probability distribution employed, there is a 75% probability (yellow and green areas) of obtaining net job creation by 2040. The graph on the right side presents the results of all simulations tested, from which confidence intervals (presented on the left) are computed.

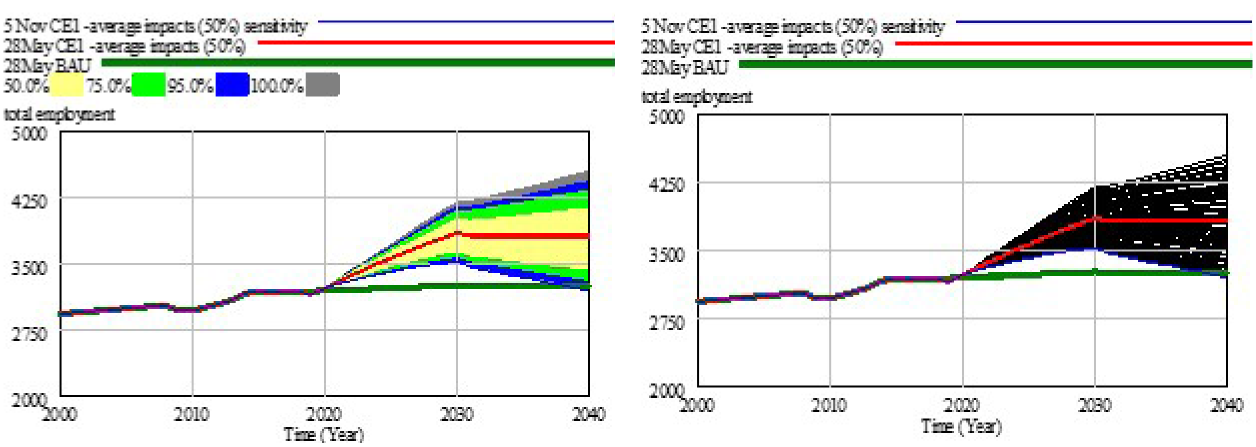

Figure A1. Results of sensitivity analysis for the electronics sector

Published by the International Institute for Sustainable Development.

Head Office

111 Lombard Avenue, Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

IISD

iisd.org