Renewable energy employment effects in the EU and the Member States

Methodology Report

Marc Marsidi
Ton van Dril
Francesco Dalla Longa
Ayla Uslu
Luuk Beurskens

December 2017

EurObserv'ER

Acknowledgement

In this report ECN documents the methodology applied for estimating renewables-induced employment and turnover for all European Union member states. The approach has been discussed with multiple researchers outside ECN, which confirmed and at the same time improved the method. For their input and the discussions, the authors would like to thank the European Commission (Henrik Dam, Bogdan Atanasiu, Aliki Georgakaki, Pablo Ruiz-Castello, Johan Carlsson and Veronika Czako), Statistics Netherlands (Krista Keller), Observ'ER (Frédéric Tuillé), RENAC (Roman Buss), Fraunhofer ISI (Barbara Breitschopf). This work was carried out in the framework of the EurObserv'ER project, funded by the European Union (contract number ENER/C2/2016-487/SI2.742173).

In April 2018, ECN and TNO (the Netherlands Organisation for applied scientific research) cluster their strengths. The new organisation will be under the colours of TNO. This project is registered under ECN at project number 5.4753 (TNO project number 060.33772). Contact address for the socio-economic assessment of energy-related employment and turnover in the EurObserv'ER project: employment@tno.nl.

This project is funded
by the European Union under
contract n° ENER/C2/2016-487/SI2.742173

Disclaimer European Commission

Disclaimer ECN

Picture cover page by ABS Safety

Abstract

This working document presents the methodology, designed by ECN, to quantify the employment effects (direct and direct), and impact on turnover, of renewable energy sources (RES) deployment for each individual European Union Member State. Additionally the method also quantifies the (direct) employment effects in the conventional energy sectors regarding operational and maintenance activities (O&M) and fuel supply .

To compare the socio-economic impact of RES deployment between EU Member States, the methodology uses a uniform approach to convert expenditures on investments (CAPEX), maintenance and exploitation (OPEX) of RES capacity, into full-time equivalent employment (FTEs). The methodology takes into account the effects of production and trading of equipment and biomass feedstock, and also considers the differences in characteristics of economic sectors (e.g. labour costs) between Member States.

This document addresses various stakeholders such as research institutes, policy makers, renewables associations and country representatives, and is meant as input for discussions on the used parameters and methodology.

This document represents the methodology version of December 2017. The methodology will be continuously improved. All data in this report are preliminary and subject to future changes.

Contents

1

Introduction

1.1 Background

The EurObserv'ER project aims to provide technical support to the European Commission in the monitoring of the deployment of Renewable Energy Sources (RES) in the 28 EU Member States. The employment and turnover, created through renewable energy development and deployment, in the EU, are two important indicators in monitoring the socio-economic impacts of RES and the communication of these indicators towards relevant stakeholders.

There has been a number of sources presenting employment data related to RES deployment (e.g. ADEME (2016), BMVIT (2016) , BMWi (2016), Ortega, et al. (2015), PWEA (2016), ECN (2016a), IRENA(2017), Thornley et al. (2008), Cameron et al. (2015)) that focus on specific Member States, or specific technologies, and mostly present gross employment effects (i.e. excluding the impact of RES deployment on jobs in the conventional sectors)[1]. Often, it is difficult to compare the outcome of these studies because of the use of different methodological approaches and system boundaries.

This EurObserv'ER project uses input-output (I/O) tables to determine the employment effects of RES deployment[2]. The strengths of the project are:

- The use of a common methodology in calculating the effect of RES deployment on employment and revenues, so that a comparison between Member States can be made;
- The use of Eurostat data to take trading effects of equipment and biomass feedstock into account;
- Results of the effect on employment and revenues are on economic sector level, providing insights in which economic sector benefits the most.

1.2 Objectives

ECN, one of the partners of the EurOberv'ER consortium, was given the task to develop a robust methodology that determines the employment effects of RES deployment in the EU Member States(MS). Only forms of renewable energy production are taken into account; employment related to energy efficiency measures are outside the scope of this work. The methodology aims to provide a transparent link between the employment effects of existing and newly added RES capacity.

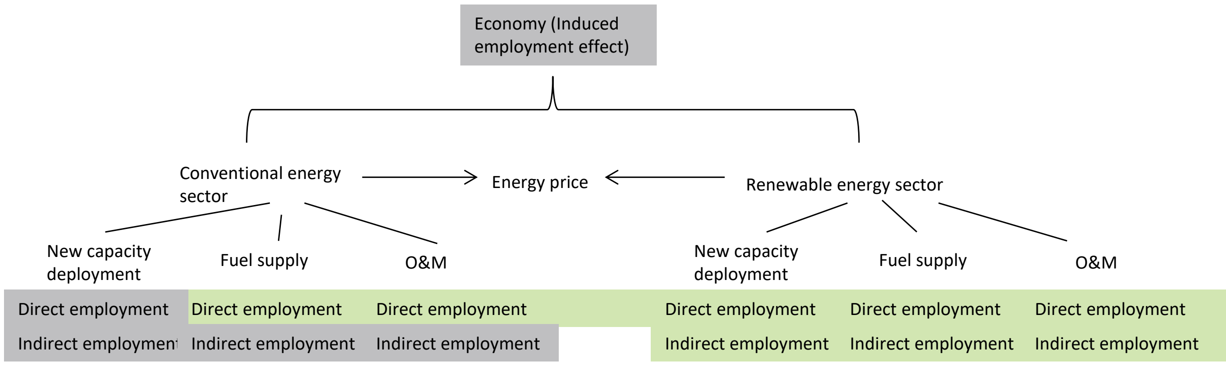
[1] Although there do exist some studies on net employment, such as Fraunhofer et al. (2014)

[2] For a comparison between I/O and other employment effect methodologies (e.g. macro-modelling), please refer to Breitschopf et al. (2014).

The gross employment effect is defined as the direct and indirect employment related to the yearly investments in newly added RES capacity, O&M and exploitation of RES capacity and, in the case of biomass technologies, the production of biomass feedstock. Direct employment includes manufacturing of equipment, construction, consulting and engineering, financial services, O&M and biomass supply. The indirect employment refers to employment from secondary activities, such as transport and warehousing.

The methodology includes analysing the impact of RES deployment on direct employment in the conventional energy sector. More specifically, direct employment in the conventional energy sector refers here to the total employment related to operational, maintenance and fuel supply activities in the conventional energy sector. The impact on indirect conventional sector jobs is not taken into account. Jobs affected by any further changes in the economy, like changes in income or in energy prices induced by increased shares of RES, are also not included in the analysis[3]. Figure 1 provides an overview of socio-economic effects in the RES and conventional energy sectors covered by the methodology.

Figure 1: Overview of employment effects covered (green) and not covered (grey) by the methodology



1.3 Report outline

The methodology encompasses all cost aspects of RES deployment:

- Investments in newly installed capacity (CAPEX);
- Operation and maintenance cost (O&M);
- Biomass feedstock cost.

The methodology is explained in chapter 2. Section 2.2 introduces how installed capacity is translated into investment costs (CAPEX) and section 2.3 introduces how O&M costs (OPEX) are calculated. Costs related to biomass feedstocks are detailed in section 2.4.

Equipment and materials, O&M and biomass feedstock form revenue streams for that are, partly, translated into employment - hence the description of the chosen methodology as ‘follow-the-money’ approach. The steps taken to translate these revenue streams into gross employment figures (measured in full time equivalents - FTEs) is presented in section 2.5. Section 2.6 focuses on the potential impact of RES deployment on jobs in conventional fossil fuel-based energy sectors (non-renewable power, heat and transport fuels production). The final section of the methodology chapter describes the system boundaries and discusses the limitations of the methodology.

[3] Induced effects can be analysed by macro-economic modelling.

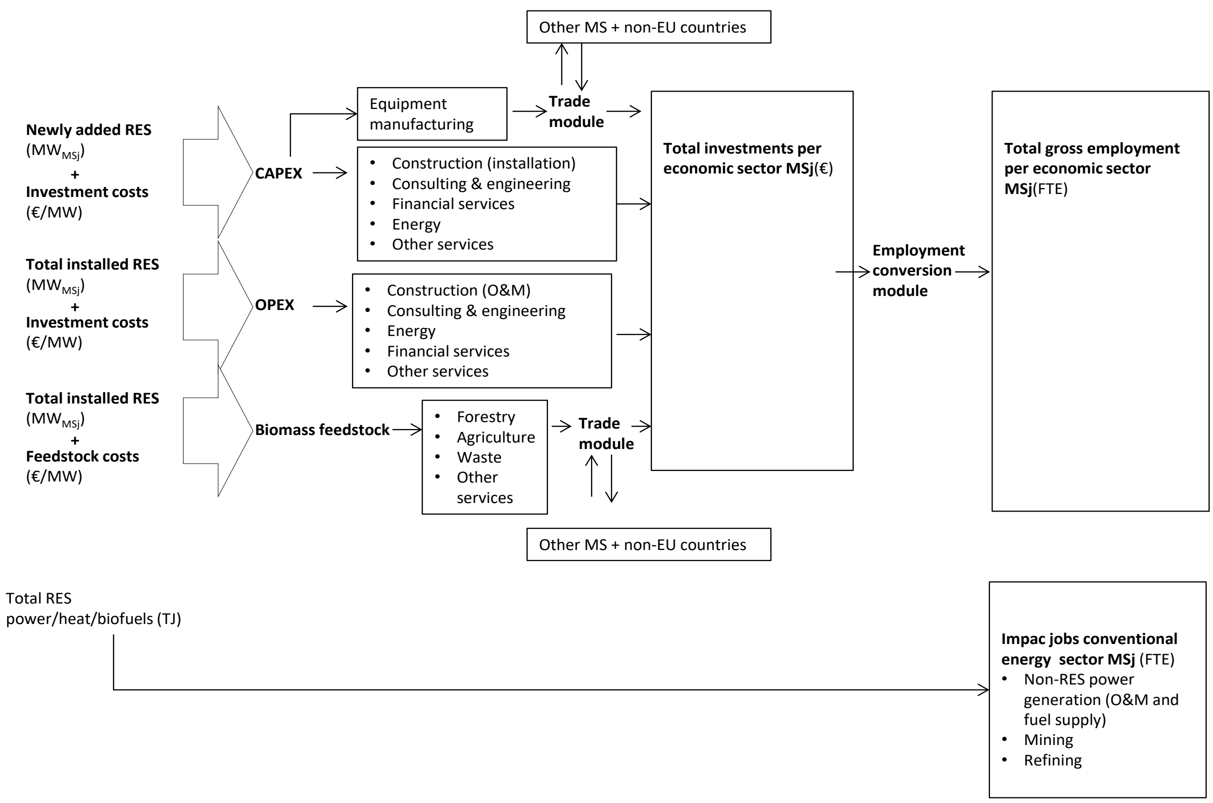
Note: All of the data presented in this report were taken from the model version of December 2017. When available, data for 2016 was used. When this was not, yet, available, the data for the year closest to 2016 was used.

2

Methodology

The methodology to calculate the gross employment effect of renewable energy technology deployment, uses the so-called ‘follow-the-money’ approach. The employment effect is determined by following the revenue streams, generated from investments and exploitation of RES deployment, that flow to different economic sectors, and subsequently calculate the amount of employees that are compensated using, a certain share of, these revenues. The result is a transparent link between the revenue streams related to the RES deployment and the related workers or full-time equivalent employment (FTEs), per economic sector, for an individual Member State *j* (MSj) (see Figure 2).

Figure 2: Overview methodology employment effect of RES for MSj



This chapter elaborates on the methodology, explaining the following steps:

1. Calculate the total investment expenditures per MS per technology (chapter 2.2);
    a. Translate MS specific data for annually installed capacity[4] into annual RES investment expenditures, using technology specific investment cost (€/MW) from case studies;
    b. Split the annual RES investment cost into costs for installation, manufacturing of RES equipment (CAPEX) and services;
2. Calculate the total operational cost;
    a. Calculate the total installed capacity;
    b. Calculate the exploitation and maintenance cost (OPEX) (chapter 2.3);
    c. Calculate, in the case of biomass conversion technologies, the cost for biomass supply (chapter 2.4);
3. Calculate the associated gross FTEs (chapter 2.5);
    a. Allocate the costs for CAPEX, OPEX and biomass feedstock to economic sectors;
    b. Translate the cost per economic sector into FTEs (gross employment);
4. Calculate the associated potential impact on (direct) FTEs in the conventional energy sector (chapter 2.6);

2.1 Used data

Installed and added capacity

The basis for the model is the amount of capacity RES installed in each Member State for the years *y* and *y-1*. For this, data provided by EurObserv'ER is used. See Table 9 in the annex for an example of the data. When required, additional data is used from, among others, Eurostat. Note that added capacity resulting from stock turnover is not taken into account, with the exception of biomass stoves and small pellet boilers.

When needed, the data was altered or replaced:

- For biofuels production, the EurObserv'ER data focuses on biofuels consumption, whereas the ECN methodology requires production capacity of biofuels. Therefore, biofuels production data from Eurostat was used to estimate the biofuels production capacity per MS.

- The provided EurObserv'ER data on solid biomass did not provide sufficient detailed data for the model. Eurostat data regarding industry and residential solid biomass for energy use, was used to calculate the total installed capacity of industrial boilers, and household pellet boilers and biomass stoves. Because the use of biomass for both biomass stoves and boilers (also called furnaces) are part of the Eurostat category residential solid biomass usage, data from the project *"Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)"* by Fraunhofer et al. (2016) was used to determine the ratio per MS between biomass stoves and boilers capacity. Also, yearly differences in degree days were taken into account, to take into account changes in solid biomass use for residential heating due to weather related effects.

Allocation of expenditures to economic sectors

The allocation of CAPEX and OPEX expenditures to economic sectors is based on case studies and other literature sources (see Table 1). The production and trade per Member State of specific equipment components for each RES, is included in the methodology. See for more details chapter 2.2.

[4] Annual installed capacity is determined based on the difference in installed capacity of *y* and *y-1*. Decommissioning of capacity is not taken into account (with the exception of biomass stoves and small pellet boilers, for which yearly decommissioning of equipment of 5% was used).

The annual expenditures on biomass feedstock for the biomass technologies are calculated based on the cost for feedstock (€/MWh) taken from the CAPRI model[5]. In the case of multiple feedstock input, the average cost of the input options is taken. The annual feedstock expenditures are allocated to economic sectors (*forestry, agriculture, waste*). The feedstock production and trade among MS, is included in the model. See for more details chapter 2.4.

The allocation of CAPEX, OPEX and biomass feedstock to the economic sectors is presented in Table 1.

Table 1: Allocation of cost to economic sectors

	The construction sector	Equipment manufacturing	Consulting and engineering services	Financial services	Energy sector[6]	Agriculture	Forestry	Waste	Other
CAPEX	X	X	x	x	x				X
OPEX	X		x		x				x
Biomass feedstock						x	x	x	x

Sector specific labour share

The expenditures for CAPEX, OPEX and biomass feedstock are converted into FTEs, based on the specific labour cost share[7] and labour cost per FTE, for each economic sector, in each Member State. The labour cost share takes into account the self-employment factor[8] and intra-sectoral spending. The impact of the spendings of a sector on intermediate goods and services (spill-over effects that lead to indirect jobs), is also accounted for. To calculate these parameters, input-output tables from Eurostat are used[9]. See for more details chapter 2.5.

The potential RES impact on direct O&M and fuel supply employment in the conventional energy sectors, is calculated based on the labour shares per energy category (FTE/MWh) of the conventional energy sectors. These shares were calculated using industry statistics from Eurostat[10]. See for more details chapter 2.6.

All expenditures in the sectors *construction, consulting & engineering, energy, financial services and waste* are assumed to create employment locally; executed by local companies. Expenditures related to equipment and biomass feedstock production can, however, lead to employment generation in other countries.

Trade effects

For expenditures on equipment and biomass supply, trade effects are taken into account. This is necessary, as these products can be imported and exported by and to other Member States, or even by and to non-EU countries.

[5] For more information, see JRC (2015b), or Britz et al. (2014)

[6] Sector that produces and sells energy, such as electricity and gas, to final users

[7] % of total revenues that is used for compensation of employees

[8] A self-employed person is someone who works for a company but is not (officially) registered and does not receive payment. An example are unpaid family workers.

[9] Eurostat table [naio_10_cp1610]

[10] Eurostat table [sbs_na_ind_r2]

A trading module was developed to accurately determine the actual allocation of RES investments and its subsequent translation into employment effects[11]. The trading module uses Eurostat production and trade data for equipment (Prodcom) [12] and biomass feedstock.

2.2 Capital Expenditures (CAPEX)

The annual investments expenditures, for added RES capacity, are calculated using investment costs per RES technology, provided by JRC (2014)[13] (see Table 10). For the following technologies, the investment costs are obtained from ECN databases: biogas production for heat, MSW heat, geothermal heat, and fluidised boilers.

The investment costs from JRC are not MS specific. Therefore, an MS specific correction is used (see 2.5.1). The calculated total investment cost for each RES technology, are allocated to the following economic sectors: *Equipment manufacturing, Construction, Consulting & Engineering, Financial Services, Energy*.

The allocation is, when available, based on the breakdown of cost provided by JRC (2014). This breakdown is converted into the economic sectors defined by ECN, using a conversion matrix[14] (see Table 2). The matrix is developed based on expert judgement. For the technologies[15] that are not described in the ETRI report, expert judgments are used. The allocation percentages will be evaluated on a yearly basis. For the full breakdown matrix of CAPEX to economic sectors, see Table 11.

Table 2: Conversion matrix ETRI breakdown into Eurostat sectors breakdown[16]

	The construction sector	Equipment manufacturing	Consulting and engineering services	Financial services	Energy sector
CAPEX allocation to >>					
Civil and structural cost	95%	5%	0	0	0%
Mechanical equipment supply and installation cost	25%	75%	0	0	0%
Electrical and I&C supply and installation	25%	75%	0	0	0%
Project indirect cost	50%	0	5%	5%	0%
Owner's cost	10%	0	60%	20%	10%

2.2.1 Equipment break-down

To model the trade flows of equipment expenditures more accurately, the main equipment parts of each technology are considered. These are divided into technology specific equipment (e.g. wind turbines and

[11] Examples of such equipment or feedstock are PV panels (over 60% of installed capacity imported from non-EU countries) and wood pellets (over 33% of consumed pellets imported from non-EU countries)

[12] Eurostat table [DS-066341].

[13] For the year 2013, expressed in € 2015

[14] The matrix has been reviewed by different stakeholders (JRC, CBS).

[15] Small biomass heating appliances and biofuel production plants.

[16] Note that for wind (onshore and offshore) a modified conversion matrix is used, based on feedback from JRC. See Table 7 and Table 8.

towers specifically for wind energy) and cross-cutting equipment (e.g. pipes and electric cables used by all technologies). The equipment break-down is based on expert estimates and literature sources (see Table 3 and Table 12).

Table 3: RES equipment breakdown

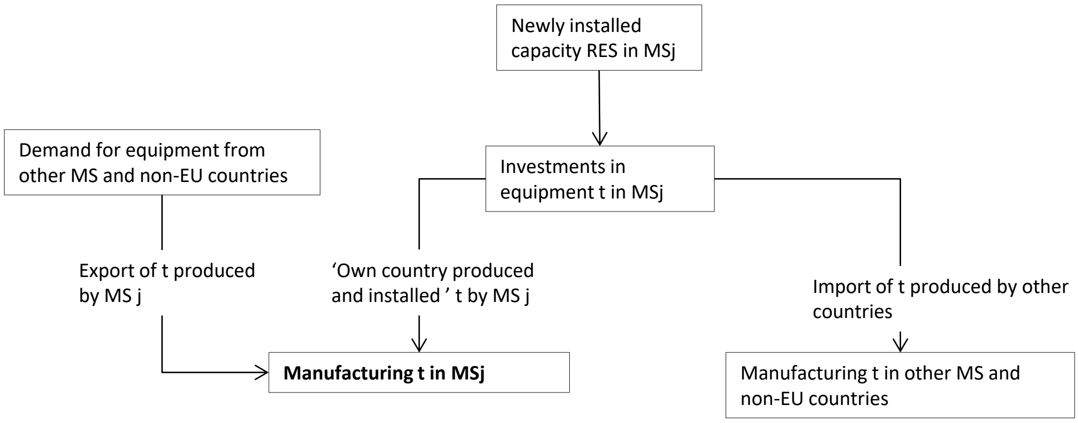
RES technology	RES equipment breakdown	Sources
Wind	Wind turbines, tower, offshore wind foundations, electrical equipment, civil construction materials	Ademe (2016) and review JRC
PV	PV panel systems, Inverters > 7.5 kVa, inverters < 7.5 kVa, electrical equipment	BMVIT (2016)
CSP	Concentrated solar power systems, electrical equipment, metal equipment, civil construction materials	IRENA (2012a)
Biomass (residential)	Biomass stoves and boilers, electrical equipment, metal equipment	Internal database
Heatpumps	Heat pumps, electrical equipment, metal equipment, civil construction materials	http://www.greenmatch.co.uk/heat-pump/ground-source-heat-pump/ground-source-heat-pump-prices
Solar heating	Heat exchangers, metal equipment	Internal database
Geothermal	Turbines, engines, generators (geothermal), electrical equipment, metal equipment, civil construction materials	Geo-elec (2013)
Hydro	Turbines, engines, generators (hydro), electrical equipment, metal equipment, civil construction materials	Irena (2012b)
Wave and tidal	Turbines, engines, generators, metal equipment	Review by JRC
Biomass (industry)	Turbines, engines, generators (biomass/MSW), biomass boilers, electrical equipment, metal equipment, civil construction materials	Internal database Carbon Trust fact sheets

2.2.2 Equipment trading module

Expenditures related to equipment are assumed to be subject to trading activities between the MS. The equipment trade module uses a set of matrixes to simulate the trading of RES equipment. The following steps (see also Figure 3) are used to determine which part of the investments in RES equipment is allocated to the MS in which it is deployed, and which part of the investment is allocated, via trading, to other EU countries, or non-EU countries:

- Determine the part of the added equipment that is produced locally (within the MS);
- In the case of insufficient own production, determine the part of the remaining equipment that has to be imported, and that will be provided by non-EU countries and by other EU MS;
- In the case of excess production of capacity, in other words more equipment is produced than needed for own use, determine the amount of equipment that is exported to other MS and non-EU countries.

Figure 3: Equipment trading module (arrows represent money flows)



Prodcom[17] data from Eurostat is used for the value (in €) of production (P), import (I), and export (E), of technology *t* in MS *j* to calculate the trading coefficients:

$INV_{MSj,t} = P_{MSj,t} + I_{MSj,t} - E_{MSj,t}$

$RatioOwn_{MSj,t} = P_{MSj,t} / INV_{MSj,t}$, -> if $RatioOwn_{MSj,t} > 100\%$, then we take 100%[18]

$INV_{EU,t} = \sum [INV_{MS,t}]$

$P_{EU,t} = \sum [P_{MS,t}]$

$RatioImport_{EU,t} = (I_{EU,t} - E_{EU,t})/INV_{EU,t}$

$RatioExport_{EU,t} = (P_{EU,t}/INV_{EU,t})-1$

$Sigma_{MSj,t} = (P_{MSj,t} - INV_{MSj,t}) / \Sigma[P_{MS,t} - INV_{MS,t}]$

Where:

$INV_{MSj,t}$ = total investments of installed *t* in EU Member State *MSj*

$P_{MSj,t}$ = production of t in MSj

$I_{MSj,t}$ = import of t by MS j

$E_{MSj,t}$ = export of t by MS j

$RatioOwn_{MSj,t}$ = ratio of installed t by MSj that is produced in MSj

$INV_{EU,t}$ = Total investments of installed t in EU

$P_{EU,t}$ = production of t in EU

$E_{EU,t}$ = export of t from EU to non-EU countries

$I_{EU,t}$ = total import of t by EU from non-EU countries

$RatioImport_{EU,t}$ = ratio of total European investment in t that is imported (net) from non-EU countries

$RatioExport_{EU,t}$ = total European production of t that is exported (net) to non-EU countries, expressed as ratio of total European investment in t.

$Sigma_{MSj,t}$ = ratio of export of t by MS j compared to the total export of all MS

[17] http://ec.europa.eu/eurostat/web/prodcom

[18] When Eurostat provides a ':' for production value (PRODVAL), and the export value is twice as large as the import data, we take 100% for $RatioOwn_{MSj,t}$,

Eurostat PRODCOM Production and related Trade data

Eurostat provides PRODCOM statistics on production of manufactured goods together with related external trade data on MS level and also on EU28 level (databse name DS-066341). The latter can be used to determine the amount of trade between Europe and non-EU countries. The PRODCOM data is obtained by the National Statistical Institutes of each MS.

Using PRODCOM data to determine the amount of purchased equipment by a MS, so-called apparent consumption (P+I-E), can result in ‘odd’ results, such as negative figures. This is a known phenomenon, discussed in among others Europroms (2008). Also, country data is sometimes missing, for example due to confidentiality issues. However, as Ortega et al. (2015) notes, the Eurostat data is also the most comprehensive data set available regarding production and trade values for RES equipment.

An overview of the PRODCOM codes regarding equipment that are used can be found in Table 13.

For the following RES there are no Eurostat data available. Alternative literature sources are used to provide estimations for these RES.

- CSP – concentrated solar power systems: No literature on production of equipment available (expert judgement used);
- Solar thermal installations (solar boilers): Eurobserver (2017)
- Wind – offshore wind foundations: JRC (2016);
- Geothermal – Turbines, generator: JRC (2015b);
- Tidal & wave – Turbines: No literature on production of equipment available (expert judgement used).

Table 4 provides an example of the trade coefficients for PV panel production, based on Eurostat data. Figures are in euros and represent, when available, the year 2015. Columns PRDOVAL, IMPVAL and EXPVAL, are extracted from Eurostat (DS-066341). Other cells are calculations. SigmaMSj,t is the ratio for exported products of MSj to the sum of exported products of all MS. App consumption is the amount (euros) of consumption in MSj. RatioImportEU is the amount of import (net) from non-EU countries, expressed as % of the total consumption in the EU. RatioExportEU is the amount of export (net) to non-EU countries, expressed as % of the total consumption in the EU.

Table 4: Example of Eurostat data for PV panels (Prodcom code 26112240).

DECL/INDICATORS	PRODVAL	IMPVAL	EXPVAL	App consumption[19]	$Sigma_{MSJ,t}$
France	127,314,374	512,659,460	259,358,890	380,614,944	0.0%
Netherlands	82,000,000	1,652,430,690	1,214,658,830	519,771,860	0.0%
Germany	961,686,374	1,614,914,000	1,817,489,630	759,110,744	95.0%
Italy	370,950,000	310,466,460	295,521,890	385,894,570	0.0%
United Kingdom	78,386,421	1,723,069,180	78,449,430	1,723,006,171	0.0%
Ireland	:	16,416,430	4,868,110		0.0%
Denmark	13,429,016	130,210,780	18,583,590	125,056,206	0.0%
Greece	:	9,056,040	2,397,970		0.0%
Portugal		36,744,680	15,680,330		0.0%
Spain	12,669,051	73,950,580	38,260,120	48,359,511	0.0%

[19] Apparent consumption = production t + import t – export t. In other words, the apparent consumption of an RES technology, equals the total amount of consumption of that technology (installed capacity).

Belgium	:	245,844,660	202,318,920		0.0%
Luxemburg		36,085,690	32,161,890		0.0%
Iceland		:	:		0.0%
Norway		:	:		0.0%
Sweden	:	55,637,600	25,512,820		0.0%
Finland		10,685,240	4,094,080		0.0%
Austria	62,061,100	147,145,050	101,753,420	107,452,730	0.0%
Malta		10,004,630	60,290		0.0%
Estonia	1,735,688	5,733,260	1,222,670	6,246,278	0.0%
Latvia		1,127,290	923,850		0.0%
Lituania	14,652,847	7,832,540	16,019,610	6,465,777	3.8%
Poland	26,600,607	530,441,920	331,617,390	225,425,137	0.0%
Czech Republic	:	108,807,400	143,695,400		0.0%
Slovakia	:	24,749,820	18,802,760		0.0%
Hungary	1,631,858	60,060,300	13,525,900	48,166,258	0.0%
Romania	:	40,857,630	2,182,160		0.0%
Bulgaria	1,533,899	4,623,260	2,099,450	4,057,709	0.0%
Slovenia	:	33,955,320	51,060,550		0.0%
Croatia	22,632,593	20,380,650	22,896,760	20,116,483	1.2%
EU25TOTALS	:	:	:		
EU27TOTALS	1,721,385,939	4,716,658,220	1,309,954,870	5,128,089,289	
Cyprus		4,879,210	272,600		

	Trade ratios
RatioImportEU,t	66.43%
RatioExportEU,t	0%

Using the coefficients derived from the Eurostat data, we can now, in combination with the figures for newly added capacity and its related investments in equipment, calculate the trading of RES equipment in each MS. To determine how much of the investment cost should be allocated to each MS, first it is determined if the EU is a net importing ($I_{EU,t} - E_{EU,t} > 0$) or net exporting ($I_{EU,t} - E_{EU,t} < 0$) country of technology t. Depending on the outcome, the following steps are taken:

EU as net importer

The module sums up the investments for technology capacity for each MS that cannot be met by its own production capacity, and also subtracts the investment expenditures that flow to non-EU countries (note that these investments flows to non-EU countries, do not results in jobs on the European market). The resulting sum, the remaining European investments in equipment, is divided among the EU Member States, based on their relative share (%) of export of the technology.

$$EUmarket_t = \Sigma\, [INV_{MS,t} * (1- Own_{MS,t})] - RatioImport_{EU,t}*INV_{EU,t}$$

$$INV\_own_{MSj,t} = INV_{MSj,t} * Own_{MSj,t}$$

$$INV\_sigma_{MSj,t} = Sigma_{MSj,t} * EUmarket_{i,t}$$

Where:

$EUmarket_t$ = the European total investments in t that is not met by $INV\_own_{MS,t}$ for each country minus the net EU import of t from non-EU countries.

$INV\_own_{MS,t}$ = investment in t by MSj, that is produced in MSj

$INV\_sigma_{MSj,t}$ = production of t by MSj that is exported to other MS

EU as net exporter

The module determines the EU-wide surplus production of the technology (in other words, the net export to non-EU countries) and divides this among the MS, again based on their relative export of the technology.

$EUmarket_t = \Sigma [INV_{MS,t} * (1- Own_{MS,t})]$

$INV\_own_{MSj,t} = INV_{MSj,t} * Own_{MSj,t}$

$INV\_sigma_{MSj,t} = Sigma_{MSj,t} * EUmarket_{e,t}$

$INV\_alpha_{MSj,t} = RatioExport_{EU,t} * Sigma_{MSj,t} * INV_{EU,t}$

Where:

$EUmarket_{e,t}$ = the European total investments in t that is not met by $INV\_own_{MS,t}$ for each country
$INV\_own_{MSj,t}$ = investment in t by MSj, that is produced in MSj
$INV\_sigma_{MSj,t}$ = production of t by MSj that is exported to other MS
$INV\_alpha_{MSj,t}$ = production of t by MSj that is exported to non-EU countries
$RatioExport_{EU,t}$ = ratio of total European investment in t that is exported to non-EU countries.
$INV_{EU,t}$ = Total investments of installed t in EU

2.3 Operational Expenditures (OPEX)

2.3.1 O&M cost

The installed capacity of renewable energy technologies is operated and exploited, and requires yearly maintenance to increase its lifetime. These expenditures (OPEX) are calculated using JRC (2014) O&M figures for fixed (FOM) and variable O&M (VOM) costs. The FOM are provided by ETRI as a percentage of the CAPEX. The VOM is provided as €/kWh and is calculated for each RES, using a technology specific capacity factor to determine the yearly produced energy (see Table 16). Both FOM and VOM are calculated based on the total installed capacity of each technology per MS.

In the ETRI report, personnel cost are excluded from the O&M cost, which need to be included as input for the model. ECN assumes that the personnel cost, as mentioned by ETRI in JRC (2014), is assumed to refer to operational cost. The JRC figures are modified to also include operational (labour) cost. The 'missing' personnel part is estimated based on the OPEX breakdown from literature sources (see Table 14).

Using the technology specific O&M data of Table 15, the annual cost for operation and maintenance activities are determined per technology, for the total capacity (newly added capacity plus already existing stock). As the used investment costs from JRC are not MS specific, we use a factor to correct for this (see 2.5.1).

2.3.2 Cost breakdown

The cost for operation and maintenance are allocated to the economic sectors 'Construction, Energy, Consulting & Engineering and Financial services' (see Table 17). The allocation ratio to each economic sector is, when possible, based on the cost breakdown examples of OPEX from case studies. When there are no case studies available, the breakdown is either based on expert opinion or on the ratio of a similar technology.

All O&M activities are assumed to be fulfilled by local companies and therefore expenditures in O&M contribute fully to local creation of employment.

2.4 Biomass feedstock cost

The total feedstock cost per technology is calculated using the feedstock cost (€/MWh)[20], extracted from the model *CAPRI*[21], and the average capacity factor of the technology (see Table 16). An average of the feedstock cost is applied[22] in the case of multiple feedstock inputs (see Table 18).

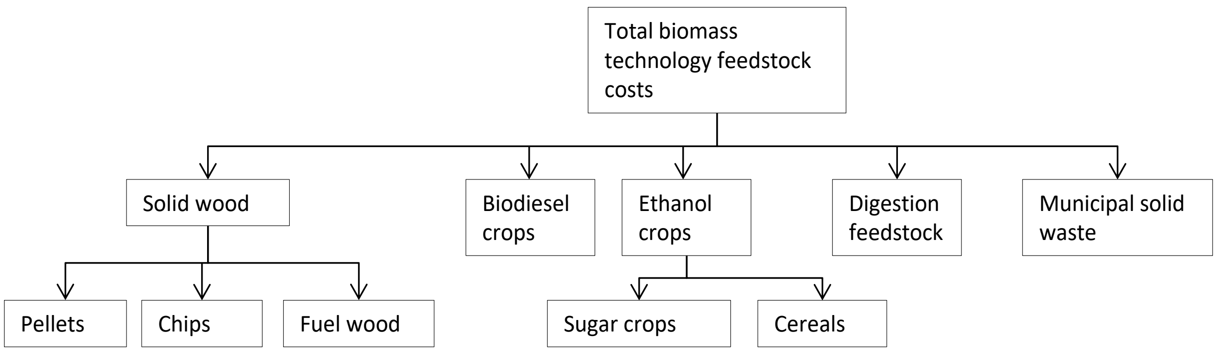
The following steps are used to allocate the calculated yearly cost for biomass feedstock for MSj, to the sectors '*Agriculture, Forestry and Waste'*:

- Allocate calculated feedstock cost per technology to biomass feedstock type;
- Use biomass trade module to determine total production of biomass feedstock in MSj, taking into account own consumption and trade;
- Allocate calculated cost per feedstock to the economic sectors *(forestry, agriculture and waste)*.

2.4.1 Biomass feedstock cost breakdown

The total biomass feedstock cost for each RES is split up into specific biomass types (see Figure 4).

Figure 4: Biomass feedstock cost breakdown into feedstock types



A standard categorisation of feedstock for solid wood, that is applicable to all MS, is not possible as the feedstock input varies per MS. Therefore, for each MS different feedstock ratios (based on Eurostat data[23]) are determined to proportionally allocate the feedstock cost to each biomass type (see Table 19). For wood fuel usage, we assume that in certain countries there is a significant amount of wood fuel acquired via the informal market or harvested by households in nearby woods. This part of the wood fuel usage does not generate revenues and therefore does not lead to (official) employment. To take this into account, we assume for the following countries that only 20% of the wood fuel is bought on the official market: Bulgaria, Czech Republic, Estonia, Greece, Spain, Croatia, Italy, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovenia, Slovakia.

[20] Note that we focus on feedstock and not biofuel such as bio-diesel and bio-ethanol. Biofuel that is imported from non-EU countries does not contribute to European employment, and biofuel that is produced in Europe is covered by the CAPEX, OPEX and feedstock in biofuel technologies in the model.

[21] For more information, see JRC (2015b), or Britz et al. (2014)

[22] A simplified method is used in which the average is taken from the feedstock with the highest cost and the feedstock with the lowest cost

[23] See Eurostat table: *Roundwood, fuelwood and other basic products [for_basic]*

The use of digestion feedstock can also vary (straw, manure, other waste streams), but there is no data available to determine the exact composition per MS. As the trading in digestion feedstock is limited, the module allocates all digestion feedstock cost to the agriculture sector.

The feedstock specific cost are allocated to economic sectors (see Table 5), based on expert opinion.

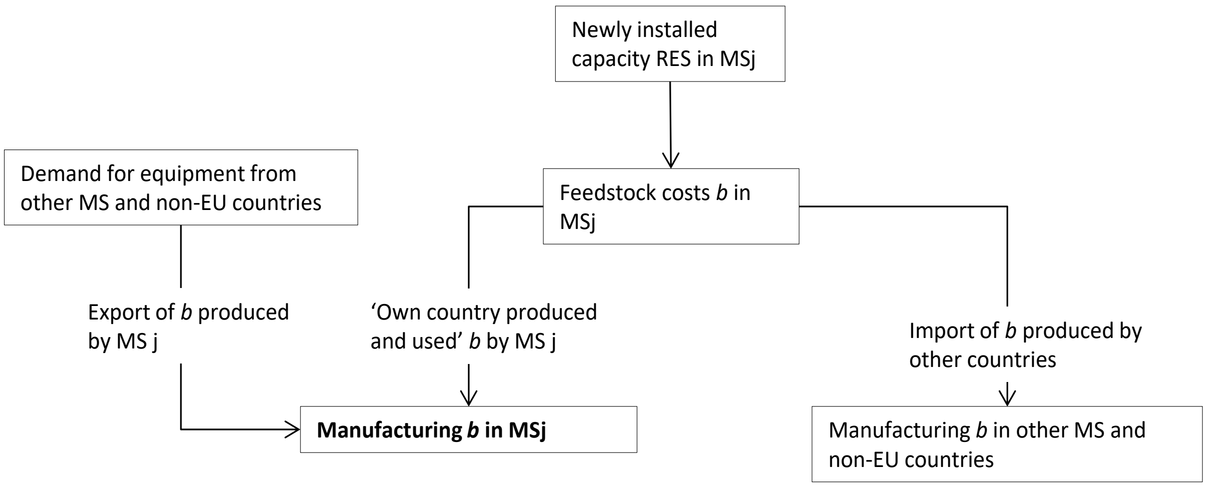
Table 5: Allocation feedstock cost to economic sectors (binary)

Fuel	Agriculture	Forestry	Waste
Pellets	0	1	0
Wood chips	0	1	0
Fuel wood (incl charcoal)	0	1	0
Straw & Manure	1	0	0
Oil-bearing crops	1	0	0
Sugar crops	1	0	0
Cereals	1	0	0
Municipal Solid Waste	0	0	1

2.4.2 Biomass feedstock trading module

Similar to the manufacturing of equipment (see chapter 2.2.2), the trading effect of biomass feedstock has to be accounted for. The trading effect is accounted for, based on the revenues of each Member State for feedstock consumption and trading (including trading with non-EU countries). As the feedstock costs are allocated to a specific biomass category, the trading effects of each biomass category can be determined for each Member State, using the same approach as for equipment cost (see chapter 2.2.2).

Figure 5: Biomass feedstock trading module (arrows represent money flow)



The Eurostat database provides data on production and related trade of solid biomass (pellets, chips, fuelwood), municipal solid waste (MSW), straw, and biofuels (oil crops, sugar crops) (see Table 6 for an example for wood pellets). As it is assumed that the trading of digestion feedstock is very limited, the trade ratio for digestion feedstock is set to 0.

Table 6: Example of Eurostat data for pellet production (denoted 'Wood pellets' in Eurostat).

DECL/INDICATORS	PRODVAL	IMPVAL	EXPVAL	App consumption	SigmaMSJ
Belgium	0	657	98	559	0.0%
Bulgaria	97	20	155	0	3.0%
Czech Republic	671	299	701	269	9.1%
Denmark	92	2146	166	2,072	0.0%
Germany	2078	419	683	1,815	5.9%
Estonia	769	62	641	190	13.1%
Ireland	32	0	0	32	0.0%
Greece	0	22	1	21	0.0%
Spain	350	37	40	348	0.1%
France	1050	171	124	1,097	0.0%
Croatia	193	4	161	35	3.6%
Italy	450	1936	11	2,375	0.0%
Cyprus	0	1	0	1	0.0%
Latvia	1280	88	1290	77	27.2%
Lithuania	250	72	298	24	5.1%
Luxembourg	:	:	:		0.0%
Hungary	3	8	13	0	0.1%
Malta	0	0	0	0	0.0%
Netherlands	279	449	442	286	0.0%
Austria	948	344	485	807	3.2%
Poland	700	52	183	570	2.9%
Portugal	1034	37	723	348	15.5%
Romania	550	3	413	140	9.3%
Slovenia	100	158	110	148	0.0%
Slovakia	100	19	98	21	1.8%
Finland	324	46	56	314	0.2%
Sweden	1577	522	253	1,846	0.0%
United Kingdom	354	4757	98	5,013	0.0%

	Trade ratios
RatioImportEU	33.21%
RatioExportEU	0%

Figures are in euros and refer to 2015. Columns PRDOVAL, IMPVAL and EXPVAL, are extracted from Eurostat. Other cells are calculations. SigmaMSj is the ratio for exported products of MSj of sum of exported products of all MS. App consumption is the amount (euros) of consumption in MSj. RatioImportEU is the % of total consumption in the EU, imported (net) from non-EU countries. RatioExportEU is amount of export (net) to non-EU countries, expressed as % of the total consumption in the EU.

2.5 Conversion of monetary values to employment

Using the CAPEX, OPEX and Biomass Feedstock modules, the total cost for all activities related to both newly placed and existing stock of RES is accounted for and allocated to their respective economic sectors. These costs are translated into FTEs, using the average labour costs (euro/FTE) for each economic sector in each Member State.

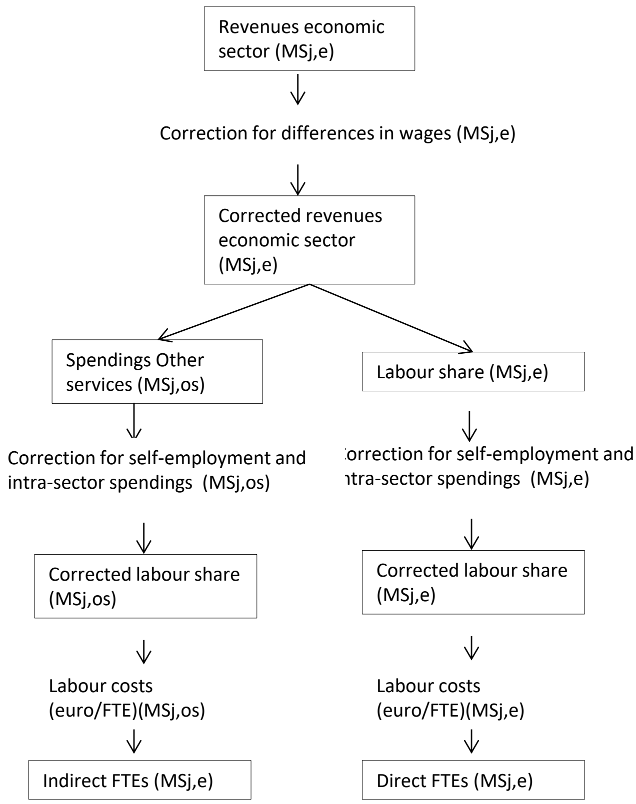
The calculated cost is, however, based on the assumption that the costs for CAPEX, OPEX and feedstock per capacity or feedstock, is the same for each MS. This is not correct, since countries with lower labour costs will have lower costs for several components of the total expenditures[24]. Therefore, the total investment costs per MW capacity or GJ feedstock will also be lower. The calculated expenditures per economic sector therefore need to be corrected for the differences in wage level between the MS.

Also, the impact of spill over effects needs to be included, as each economic sector has costs that result in revenues in other sectors (logistics, administration) and therefore additional employment.

The module that converts these cost (including spill over effects) into employment (FTE) figures, is described in this chapter (see Figure 6). The module consists of four parts:

- A MS and technology specific correction factor to adjust the revenues per MS (to account of differences in wage levels);
- Determining the labour share of the total revenues per MS and sector;
- Determining the spendings on other services;
- Correct the labour share and other services share, by taking into account self-employment and intra-sector spendings;
- Use the wages per MS per sector to calculate the direct and indirect FTEs

Figure 6: FTE calculation



Labour cost related corrections are not applied to RES equipment and biomass feedstock[25], as these products are considered to be tradeable and should therefore have a similar cost in each Member State, despite the differences in labour costs.

[24] For example, the expenditure for construction labour in Bulgaria are significantly lower than that of Germany, and will, even when taking into account for differences in worker efficiency, result in lower overall project costs.

2.5.1 Member State specific cost correction factor

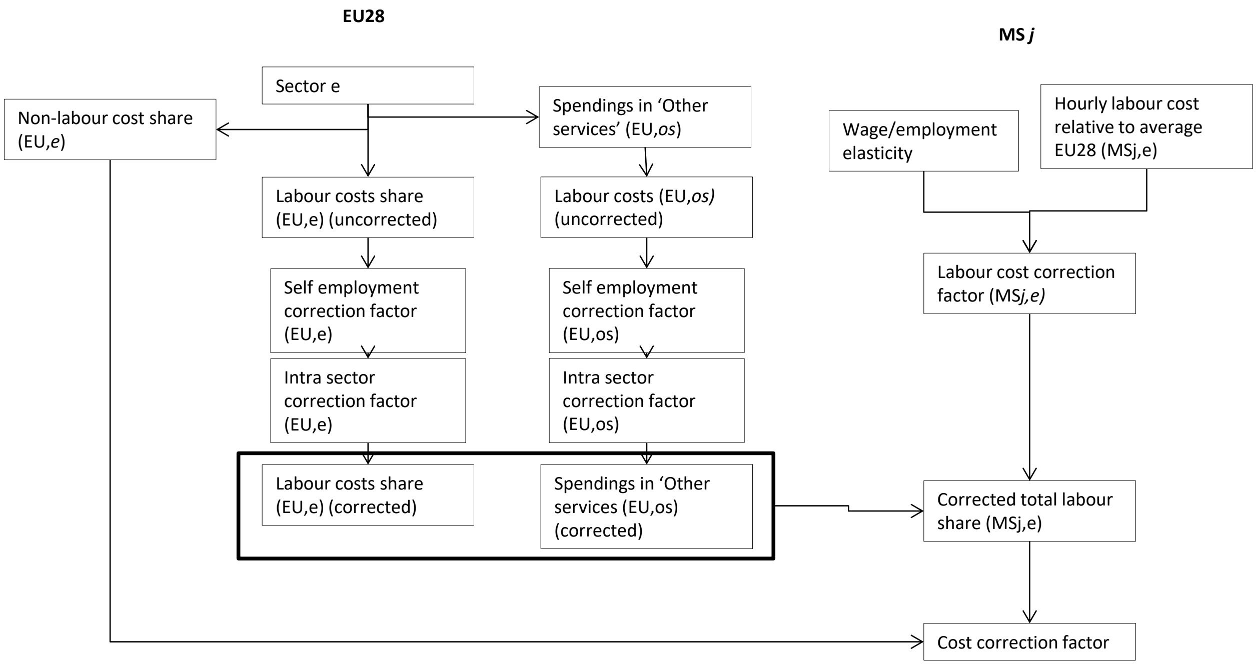
The cost for the economic sectors that are derived from the ETRI CAPEX (euro/MW) and OPEX (% of CAPEX or euro/kWh) conversion factors, are not MS specific and are assumed to represent the cost for 'EU28'. Using these factors for each MS alike is incorrect, since differences in labour cost between MS influence the total investment cost.

As the cost represent the cost for 'EU28', a correction factor is used, which is based on the relative labour costs per FTE difference of MSj compared to the European average, combined with an elasticity factor[26]. The equipment manufacturing and biomass feedstock cost are exempted from this correction, since they are considered to be freely traded to such a degree, that market effects should make their cost equal among MS regardless of any differences in labour cost.

Labour cost correction factor

In order to obtain the cost correction factor for MS j,e, the module uses the corrected labour cost of the economic sector and related spendings in other sectors, on EU28 level, and a MS specific labour cost correction factor.

Figure 7: Overview conversion of 'EU28 cost' to 'MSj cost'



The factor is calculated by using the wage/employment elasticity and the relative hourly labour cost of MS j, using -0.4 for the elasticity of the labour costs (based on expert opinion). The correction factor only applies to labour related costs.

$LCcorrect_{,MSJ,e} = Wagefactor_{MSJ,e} * (Elasticitylabour\ costs * (Wagefactor_{MSJ,e} - 1) + 1)$

$Wagefactor_{MSJ,e} = Labour\ costs_{MSj,e} / Labour\ costs_{EU,e}$

Where:

$LCcorrect_{,MSJ,e}$ = Labour cost correction factor to convert related EU28 labour cost to MS j for sector e

[25] Note, this applies to activities related to the sector 'agriculture' but not to 'forestry'. Reason for this is the high amount of fuel wood use, which is traded less and therefore can vary significantly in price per MS.

[26] This factor accounts for the effect that in countries with lower labour costs, the productivity per worker can also be lower.

$Wagefactor_{MSJ,e}$ = Labour cost correction factor for labour costs in MS j in sector e relative to EU 28
$Labour\ costs_{MSj,e}$ = hourly labour cost MSj in sector e
$Labour\ costs_{EU,e}$ = hourly labour cost EU in sector e
Elasticitylabour costs = elasticity of labour costs

The non-labour related cost of the economic sector e are:
$Non\text{-}LCshare_{EU,e} = 1 - Lcshare_{EU,e} - LCOSshare_{EU,e}$

Where:
$Non\text{-}LCshare_{EU,e}$ = Non-labour related cost share of total revenues of economic sector *e* in EU28
$LCshare\_correct_{,EU,e}$ = Share of direct labour cost of total revenues of economic sector *e* in EU28
$LCOSshare_{EUS,e}$ = Other services share of total revenus of economic sector *e* in EU28

The share of non-labour in the 'other sector' is then:
$Non\text{-}LCOSshare_{EU,OS} = OSshare_{EU,,e} * (1 - LCshare_{EU,OS})$

Where:
$Non\text{-}LCOSshare_{EU,OS}$ = Non-labour cost related share of total revenues in EU in *other sector*
$OSshare_{EU,e}$ = Other sector related spendings of *other sector* in EU
$LCshare_{,EU,OS}$ = Share of direct labour cost of total revenues of economic sector *OS* in EU

MS specific cost correction factor
The MS specific cost correction factor is calculated using equation:

$CC_{MSJ,e} = (LCcorrect_{,MSJ,e} * (LCshare_{EU,e} + LCOSshare_{EU,e}) + Non\text{-}LCshare_{EU,e} + Non\text{-}LCOSshare_{EU,OS}$

Where:
$CC_{MSJ,e}$ = MS specific cost correction factor
$LCcorrect_{,MSJ,e}$ = Labour cost correction factor to convert related EU28 labour cost to MS j for sector e
$LCshare_{EU,e}$ = Share of direct labour cost of total revenues of economic sector *e* in EU
$LCshare_{,EU,OS}$ = Share of direct labour cost of total revenues of economic sector *OS* in EU
$Non\text{-}LCshare_{EU,e}$ = Non-labour related cost share of total revenues of economic sector *e* in EU
$Non\text{-}LCOSshare_{MSj,OS}$ = Non-labour cost related share of total revenues in MSj in sector *other sector*

For an overview of the MS specific cost correction factors see Table 23.

2.5.2 Corrected labour share per economic sector

The national input-output tables available at Eurostat are used to convert the cost per economic sector into labour related cost. This in order to determine the labour share of total revenues per economic sector and per MS. The labour share (%) is calculated by:

$LCshare_{,MSj,e} = CE_{MSj,e}/Output_{MSj,e}$

Where:
$LCshare_{,MSj,e}$ = labour cost share of total revenues for economic sector *e* in MS j
$CE_{MSj,e}$ = Compensation of employees in economic sector *e* in MS j
$Output_{MSj,e}$ = Output in economic sector *e* in MS j

In each sector, part of the cost are formed by purchasing services or products from other companies that are part of the same economic sector. This results in 'double-counting' of revenues and creates an incorrect labour share. The double counting is corrected by subtraction of the cost incurred by intra sector spending (see Table 20). The intrasector spending correction factor is calculated by:

$Intracorrect_{,MSj,e} = 1/(1- \sum[Intraspend_{,MSj,e}]/ Output_{MSj,e})$

Where:
$Intracorrect_{,MSj,e}$ = Intra sector spendings factor in sector e in MS j
$Intraspend_{,MSj,e}$ = Purchases made by sector *e* in sectors that also belong to sector *e*
$Output_{MSj,e}$ = Output in economic sector *e* in MS j

In each sector there is also an ‘invisible’ workforce in the statistics, as a result of ‘self-employment’, such as friends or family members that perform labour but are not registered as official employees.This self-employment share can be found in the Eurostat database. The self-employment correction factors (see Table 24) can be calculated using:
$Selfshare\_correct_{,MSj,e} = 1 + Selfshare_{,MSj,e} / (1- Selfshare_{,MSj,e})$

Where:
$Selfshare\_correct_{,MSj,e}$ = Self-employment correction factor of economic sector *e* in MS *j*
$Selfshare_{,MSj,e}$ = self-employment share of economic sector *e* in MS *j*

The corrected direct labour cost in % of output is then:
$LCshare\_correct_{,MSj,e} = LCshare_{,MSj,e} * Intracorrect_{,MSj,e} * Selfcorrect_{,MSj,e}$

Where:
$LCshare\_correct_{,MSj,e}$ = Corrected share of direct labour cost of total revenues of economic sector *e* in MS *j*

See Table 26 for an overview of the corrected share of direct labour cost.

2.5.3 Other services

To model spill-over effects, for example the hiring of transport services or administrative services by a construction company building a biomass power plant, a spending in other sectors share is calculated for each MS and each sector (see also Table 22).

The spill-over effects basically form an extra sector that will be called ‘other sectors’. For an overview of the Eurostat sectors that fall under ‘other sector’ see Table 21.
The coefficient for the other sector is calculated as follows:

$OSshare_{MSj,e} = \sum OSspend_{MSj,e}/Output_{MSj,e}$
$\sum OSspend_{MSj,e}$ = Sum of spendings by economic sector *e* in *other sector* in MS j
$Output_{MSj,e}$ = Output in economic sector *e* in MS j

Where:
$OSshare_{MSj,e}$ = Other sector related spendings of sector *e* in MS *j*
See Table 22 for an overview of the spendings in other services.

2.5.4 Labour cost per FTE

The labour cost per FTE are calculated based on the hourly labour cost per sector per MS, and average hours worked per sector per MS.

$\text{Labour costsFTE}_{MSJ,e} = \text{Labour costs}_{MSj,e} * \text{HoursFTE}_{MSJ,e}$

Where:

$\text{Labour costsFTE}_{MSJ,e}$ = labour costs for one employed person working full-time for a year in MS *j* in sector *i*

$\text{Labour costs}_{MSj,e}$ = hourly labour cost MS *j* in sector *e*

$\text{HoursFTE}_{MSJ,e}$ = average hours worked in sector *e* in MS *j*

For labour costs in year *y* we then take an average for the labour costs over the years *y-4* to *y-1.*

The labour cost for each economic sector are available from Eurostat (see Table 25).

2.5.5 FTEs per sector

Using the factors as described above, the labour cost in MS *j* for sector *e* are calculated, as well as the labour cost in the *other spending* part (spillover) related to sector *e.*

The total FTEs for sector e can be calculated using equation:

$\text{FTEtotal}_{MSJ,e} = \text{LC}_{MSJ,e} / \text{Labour costsFTE}_{MSJ,e}$

Where:

$\text{FTEtotal}_{MSJ,e}$ = total FTEs in MS *j* in sector *e*

$\text{LC}_{MSJ,e}$ = total labour cost in MS *j* in sector *e*

$\text{Labour costsFTE}_{MSJ,e}$ = labour costs for one employed person working full-time for a year in MS *j* in sector *i*

2.6 Potential impact on non-RES sectors

Renewable energy production and consumption can directly substitute activities based on fossil fuels. Hence the employment for these fossil fuel based activities in the EU Member States may be affected.

We calculate the potential impact on employment[27] in the fossil fuel sectors, as a result to uptake of renewables, in the following categories:

1. Power generation;
2. Mining;
3. Oil for power generation;
4. Refinery;
5. Heat production;
6. Crude oil and natural gas extraction and supply.

[27] Source: Eurostat data Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2], Supply, transformation and consumption of electricity - annual data [nrg_105a], Supply, transformation and consumption of gas - annual data [nrg_103a], Supply, transformation and consumption of oil - annual data [nrg_102a], Supply, transformation and consumption of solid fuels - annual data [nrg_101a]

For each category an employment factor for total production is determined (FTE/MWh_{total}). These factors are subsequently multiplied with the amount of produced renewable energy (power, heat and biofuels). This serves as an indicator for the impact of RES deployment per MS.

The methodology to determine the factors and the impact on the analysed O&M employment for each sector, are discussed in the sections below. An overview of the determined factors is presented in Table 27.

2.6.1 Power generation

Power generation by RES is assumed to replace conventional generation to the full extent of its production. The substitution is likely to occur due to RES policy support and market mechanisms. The renewable power generation will not only lead to less energy produced by conventional power plants, but also closure or less construction of plants. In this study, only the effects on operation and maintenance (O&M) and fuel production are considered; the reduced construction activities of new conventional plants are not considered. The effect on O&M is assumed to be proportional with the reduced/avoided production[28].

An O&M power generation employment factor (pgef) for conventional generation is determined, specific per Member State, based on the formula below.

$$Pgef_{MSj} = eps_{MSj} \ / \ pg_{MSj}$$

Where:

$Pgef_{MSj}$ = O&M power generation employment factor in MSj
eps_{MSj} = Total employed in power generation in MSj
pg_{MSj} = Total annual power production in MSj

2.6.2 Mining

Fuel supply replacement effects are based on country specific gas, oil, nuclear and solid shares and member state specific efficiencies in power generation. Regarding to solids, only Member States with mining are affected and for oil products, only Member States with refineries. Coal and lignite trading effects are not incorporated[29], so displaced conventional solid fuel- fired generation in MSj affects only mining in MSj. A fuel supply employment factor is only used for solids mined in the country itself. Imported solids are assumed to come from outside the EU[30] and not affect employment in other Member States. The factor takes into account the share of power generation that uses solid fuel, the power generation efficiency, and a mining employment factor.

$$Mefpg_{MSj} = (sfpgs_{MS} / sbpge_{MS}) * mef_{MSj}$$
$$Mef_{MSj} = MFTEtot_{MSj} / PrimSol_{MSj}$$

Where:

[28] There are some effects that counterbalance each other like: intermittency may lead to less closures; older plants will employ more and will close down sooner; high marginal cost gas fired plants may close sooner; on the other hand these are more flexible and may be kept more often as intermittency backup.

[29] There is no impact on jobs when Ms with mining keep solids production stable and may export more, on the other hand there may be longer term programs to abandon mining, indirectly correlated to upcoming renewables or other policies.

[30] Gross solids consumption in the EU amounts to 11 EJ (Eurostat 2015), production (mining) is 6 EJ, net imports are 4,7 EJ. So coal substitution is likely to affect mining outside the EU.

$Mefpg_{MSj}$ = solid power generation mining employment factor in MSj
Mef_{MSj} = mining employment factor in MSj
$MFTEtot_{MSj}$ = total FTE in the mining sector in MSj
$PrimSol_{MSj}$ = primary production of solid fuels in MSj
sfpgs $_{MSj=}$ % of non-renewable solid fuel power generation in MSj
sbpge $_{MS=}$ Generation efficiency of solid fuel power plants in MSj

2.6.3 Oil for power generation

For replaced oil based fuel production, the replaced mineral oil production is assumed to have a proportional effect on refining capacity in the same Member State. Countries without refining capacity are assumed to import from the nearest country with refining capacity. No further oil trading effects are assumed, and no effect on EU oil extraction. The factor takes into account the share of oil used for power generation, the power generation efficiency and a refinery employment factor.

RefpgMSj = (ofpgsMSj/ obpgeMSj) * refMSj
refMSj = OFTEtotMSj / PrimPetMSj

Where:
$Refpg_{MSj}$ = Oil power generation refinery employment factor in MSj
$Ofpgs_{MSj}$ = oil for power generation share in MSj
obpge $_{MSj}$ = oil based power generation efficiency in MSj
ref_{MSj} = refinery employment factor in MSj
$OFTEtot_{MSj}$ = total FTE in the oil refineries sector in MSj
$PrimPet_{MSj}$ = primary production of petroleum products in MSj

2.6.4 Refinery

Biofuels production will also replace mineral oil products on a TJ basis. This replacement is assumed to take place for refineries in the country where the biofuel is produced. No trade effects are assumed. The refinery employment factor is used (ref_{MSj}).

ref_{MSj} = $OFTEtot_{MSj}$ / $PrimPet_{MSj}$

Where:
ref_{MSj} = refinery employment factor *in MSj*
$OFTEtot_{MSj}$ = total FTE in the oil refineries sector in MSj
$PrimPet_{MSj}$ = primary production of petroleum products in MSj

2.6.5 Heat production

Replaced fossil heat production by renewables is more complicated to assess. The replaced heat may be produced with combustion of solids, oil, gas, or may come from a district heating system or power generation unit[31]. The heat may be produced for residential or commercial sectors, or for industrial processes. Thus, the replaced capacity and fuel and the affected economic activity are diverse. The chosen approach is to assume all fossil fuels in end use are proportionally replaced by renewable heat on energy

[31] As far as e.g wood stoves are replaced by pellet boilers or heatpumps, these effects are covered in the calculation on renewables

content basis. For derived heat, the fossil fuel input for heat only district heating capacity is added. Replaced biomass is assumed to be already captured by the data on renewables capacity and production. Fossil based heat is substituted on a heat output basis (TJ), no further differences in conversion efficiency are considered since they are very case specific. The factors for coal, oil and gas for heat generation share are cfhgs , ofhgs ,and gfhgs, respectively.

$Hpef_{MSJ} = (mef_{MSJ} * cfhgs_{MSJ}) + (ref_{MSJ} * ofhgs_{MSJ}) + (gfhgs_{MSj} * geef_{MSj})$

Where:
$Hpef_{MSJ}$ = heat production employment factor in MSj
$cfhgs_{MS}$ =coal for heat generation share in MSj
mef_{MSj} = Mining employment factor in MSj
$ofhgs_{MSj}$ = oil for heat generation share in MSj
ref_{MSj} = refinery employment factor in MSj
$gfhgs_{MSj}$ = gas for heat generation share in MSj
$geef_{MSj}$ = gas extraction employment factor in MSj

2.6.6 Crude oil and natural gas extraction and supply

Imports are dominant in crude oil and natural gas supply in Europe. Substitution by renewables is assumed to therefore affect only imports, and therefore has no net effect on EU employment.

The employment affected with reduced use of natural gas is assumed to be negligible. It is not likely that installations for natural gas extraction, conversion and transports are taken out of operation due to the uptake of renewables. O&M staffing of the existing installations is not likely to be affected by reduced gas demand.

2.7 Model limitations/Discussions

- More detailed data of RES installed capacity could create more accurate estimates of RES related employment. Currently, installed capacity data is relatively aggregated for, among others, solid biomass, PV and heat pumps. A differentiation, for example between residential and commercial appliances, would improve the results;
- Differentiation between solid biomass fuel use for residential appliances and industrial boilers is currently based on Eurostat data. It is, however, not clear how accurate this data is. Because the Eurostat data provides information on energy consumption and not on installed capacity, the installed capacity of wood stoves and boilers has to be estimated using a capacity factor. For residential use of biomass, the impact of the weather also has to be taken into account using heating degrees days. This results in a certain degree of uncertainty regarding the estimated installed MW of residential and industrial biomass technologies;
- The amount of fuel wood that is purchased via the informal market, or that is acquired by household owners by cutting wood in local forests, cannot be determined precisely;
- Data on production and trade of equipment has proven difficult to acquire. Often data is available for something similar to the equipment in question, but encompasses more than just that type of equipment. Data for tower production for wind energy, for example, is now based on Prodcom 25112200, but these are described in Eurostat as 'Iron or steel towers and lattice masts', and could very well encompass other types of towers than wind turbines. Or, the tower could be part of Prodcom 28112400 - *Generating sets, wind-powered*;
- For some countries, e.g. Ireland and Belgium, there is often no manufacturing data available for most of the technologies;
- Data on feedstock production for biofuels is currently based on Eurostat data for the production of feedstock in each Member State that *can* be used as biofuels feedstock, but can also be used for other sectors, such as the food industry. Furthermore, there is no data on the production and trade of waste oils, which are more and more used for biodiesel production. More accurate data on the actual production of crops and waste oils for specifically biofuels application would greatly enhance the accuracy of the biofuels employment results;
- Large swings in added capacity per year might lead to 'unrealistic' results between years (such as a very large sudden increase for installation and O&M jobs in the construction sector), because we have not modelled a time frame in the model (added capacity, and all accompanying investments, in our model take place 'overnight' in the year that they are added). For RES that can have large differences in added capacity per year, such as hydropower and MSW incineration, we have spread the revenues over the years *y-2, y-1* and *y*;
- For conventional energy, only the potential impact of RES on direct O&M and fuel supply employment is included;
- The revenues related to any economic sector, except for equipment, agriculture and forestry, is now fully allocated to the MS in which the activity takes place, but perhaps it should, partly, be allocated to the producing countries of equipment (for example export of maintenance or installation services of Danish wind turbine manufacturers for offshore wind);
- Decommissioning of capacity is (except for biomass stoves and small pellet boilers) not included in the model. The end result should therefore be considered as a conservative estimation, as investments in new equipment are actually higher.

3
References

ACE (2014): *Energy Farms – Anaerobic Digestion.*

ADEME (2016): *Marches et emplois lies a l'efficacite energetique et aux energies renouvelables: situation 2013-2014 et perspectives a court terme.*

BMVIT (2016): *Innovative Energietechnologien in Österreich Marktentwicklung 2015*.

BMWi (2016) Bruttobeschäftigung durch erneuerbare Energien in Deutschland und verringerte fossile.

Black and Veatch (2012): *Cost and performance data for power generation technologies.*

Breitschopf, B., Lehr, L. (2014): *How can we measure employment from renewable energy?*

Britz W. and P. Witzke (2014): Capri model documentation 2014.

Cameron, L. and van der Zwaan, B. (2015): *Employment factors for wind and solar energy technologies: A literature review.* Renewable and Sustainable Energy Reviews 45 (2015) 160-172.

ECN, PBL, CBS, RVO (2016a) Nationale Energieverkenning 2016

ECN (2016b) Conceptadvies basisbedragen SDE+ 2017 voor marktconsultatie

Eurobserver (2017) Solar thermal and concentrated solar power barometer

Europroms (2008): PRODCOM Data

Eurostat (2017) Roundwood, fuelwood and other basic products

Eurostat (2017) Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data

ESMAP (2012) Geothermal Handbook: Planning and Financing Power Generation

Fraunhofer, Ecofys, EEG, Rutter, Seureco (2014) Employment and growth effects of sustainable energies in the European Union

Fraunhofer, TU Wien, Observer, TEP, IREES (2016) Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)

Geo-elec (2013) Geothermal investment guide

Haas, M.J., McAloon, A.J., Yee, W. C. and T.A. Foglia (2006) A process model to estimate biodiesel production costs

Irena (2012a) Concentrating Solar power

Irena (2012b) Hydropower

Irena (2017) Renewable Energy Jobs Annual Review 2017

JRC (2014) ETRI 2014 Energy Technology Reference Indicator projections for 2010-2050

JRC (2015a) The JRC-EU-TIMES model - Bioenergy potentials for EU and neighbouring countries

JRC (2015b) geothermal status report

JRC (2016) Wind Energy Status Report

Obernberger, I and G. Thek (2008) Cost assessment of selected decentralised CHP applications based on biomass combustion and biomass gasification

Ortega, M., del Rio, P., Ruiz, P., Thiel, C. et al (2015) Employment effects of renewable electricity deployment. A novel methodology.

PWEA (2016) The State of Wind Energy in Poland in 2015

RAB (2010) Value breakdown for the offshore wind sector

Thornley, P., Rogers, J. and Huang, Y. 2008. Quantification of employment from biomass power plants. Renewable Energy 33 (2008) 1922-1927

4

Annexes

4.1 Annex: Adapted conversion tables for breakdown wind energy

Table 7: Conversion table for wind onshore (Source: Feedback JRC)

	The construction sector	Equipment manufacturing	Consulting and engineering services	Financial services	Energy sector
CAPEX allocation to >>					
Civil and structural costs	85%	5%	10%	0	0%
Mechanical equipment supply and installation costs	10%	90%	0	0	0%
Electrical and I&C supply and installation	25%	75%	0	0	0%
Project indirect costs	50%	0	5%	5%	0%
Owner's cost	10%	0	60%	20%	10%

Table 8: Conversion table for wind offshore (Source: Feedback JRC)

	The construction sector	Equipment manufacturing	Consulting and engineering services	Financial services	Energy sector
CAPEX allocation to >>					
Civil and structural costs	90%	5%	5%	0	0%
Mechanical equipment supply and installation costs	25%	70%	5%	0	0%
Electrical and I&C supply and installation	40%	55%	5%	0	0%
Project indirect costs	10%	0	25%	65%	0%

Owner's cost	10%	0	60%	20%	10%

4.2 Annex: Example input installed RES capacity

Table 9: Example used input installed RES capacity (in MW) Germany (Source: EurOberv'ER)

Technology	2014	2015	Added in 2015
Heat pump air source	1,582	1,702	120
Anaerobic digestion	5,074	5,394	320
Biodiesel	4,208	3,824	0
MSW (heat only)	406	466	61
Biogas (heat only)	103	136	33
Pellet boiler residential	203	212	10
Biomass CHP	1,066	1,017	0
Biomethane	145	163	18
Co-firing	716	644	0
CSP - no storage	2	2	0
Bio ethanol	746	724	0
Fluidised bed boiler	4,081	3,888	0
Geothermal flash	24	26	2
Geothermal heat installation	276	285	9
Heat pump ground source	1,573	1,651	79
Hydropower dam large	9,951	10,072	121
Hydropower dam small	1,283	1,327	44
MSW incineration	866	823	0
PV	38,234	39,786	1,552
Tidal	0	0	0
Solar thermal	12,591	13,038	447
Wave	0	0	0
Wind offshore	994	3,284	2,290
Wind onshore	38,199	41,386	3,187
Wood stove	55,982	58,609	2,627

4.3 Annex: CAPEX of RES technologies

Table 10: CAPEX(ref) of RES technologies (Source: ETRI (2014) and ECN database)

Technology	Parameter	Unit NEW	
Air source - commercial	CAPEX ref	EUR2015/kWth	1991
Ground source - commercial	CAPEX ref	EUR2015/kWth	3490
Air source - residential	CAPEX ref	EUR2015/kWth	799
Ground source - residential	CAPEX ref	EUR2015/kWth	1695
Water source - residential	CAPEX ref	EUR2015/kWth	1097
Biodiesel (1st generation)	CAPEX ref	EUR2015/kW	246
Biodiesel (2nd generation)	CAPEX ref	EUR2015/kW	4643
Biomethane (1st generation)	CAPEX ref	EUR2015/kW	1877
Biomethane (2nd generation)	CAPEX ref	EUR2015/kW	2308
Ethanol (2nd generation)	CAPEX ref	EUR2015/kW	3497
Anaerobic digestion	CAPEX ref	EUR2015/kWe	3700
MSW heat	CAPEX ref	EUR2015/kW	560
Biogas production for heat	CAPEX ref	EUR2015/kW	850
Mono digestion	CAPEX ref	EUR2015/kW	3051
Bioliquid CHP	CAPEX ref	EUR2015/kW	1110
Biomass boiler	CAPEX ref	EUR2015/kW	1080
Wood stove	CAPEX ref	EUR2015/kW	214
Biomass CHP	CAPEX ref	EUR2015/kWe	2828
Biomass IGCC	CAPEX ref	EUR2015/kWe	4548
Co-firing	CAPEX ref	EUR2015/kWe	491
Fluidized bed boiler	CAPEX ref	EUR2015/kWe	560
MSW incineration	CAPEX ref	EUR2015/kWe	5983
Geothermal deep	CAPEX ref	EUR2015/kWe	12006
Geothermal flash	CAPEX ref	EUR2015/kWe	5399
Geothermal heat installation	CAPEX ref	EUR2015/kWe	2393
Hydropower dam large	CAPEX ref	EUR2015/kW	2212
Hydropower dam medium	CAPEX ref	EUR2015/kW	3335
Hydropower dam small	CAPEX ref	EUR2015/kW	4446
Hydropower run-of-river	CAPEX ref	EUR2015/kW	5558
Tidal	CAPEX ref	EUR2015/kW	8947
Wave	CAPEX ref	EUR2015/kW	8183
PV commercial large - no tracking	CAPEX ref	EUR2015/kW	934
PV commercial large - tracking	CAPEX ref	EUR2015/kW	1357
PV commercial medium	CAPEX ref	EUR2015/kW	1048
PV residential	CAPEX ref	EUR2015/kW	1257
District heating	CAPEX ref	EUR2015/kW	536
Solar thermal	CAPEX ref	EUR2015/kW	1060
CSP - no storage	CAPEX ref	EUR2015/kW	5314

Wind offshore	CAPEX ref	EUR2015/kW	3319
Wind onshore	CAPEX ref	EUR2015/kW	1393

4.4 Annex: Breakdown matrix CAPEX to economic sectors

Table 11: Breakdown matrix CAPEX to economic sectors

	The construction sector	Equipment manufacturing	Consulting and engineering services	Financial services	Energy sector
Wind onshore	23%	63%	7%	2%	1%
Wind offshore	32%	37%	14%	15%	1%
PV commercial medium	40%	42%	7%	3%	1%
PV commercial large - no tracking	40%	42%	7%	3%	1%
PV commercial large - tracking	40%	42%	7%	3%	1%
PV residential	28%	68%	1%	1%	0%
CSP - no storage	32%	50%	10%	4%	2%
Hydropower dam large	45%	29%	15%	5%	2%
Hydropower dam medium	45%	29%	15%	5%	2%
Hydropower dam small	45%	29%	15%	5%	2%
Hydropower run-of-river	45%	29%	15%	5%	2%
Geothermal flash	29%	44%	13%	5%	2%
Geothermal heat installation	36%	42%	8%	3%	1%
Geothermal deep	41%	28%	8%	4%	1%
Wave	32%	37%	14%	15%	1%
Tidal	32%	37%	14%	15%	1%
Biomass CHP	36%	54%	6%	2%	1%
Fluidized bed boiler	33%	46%	11%	4%	2%
Biomass IGCC	32%	40%	16%	6%	3%
Anaerobic digestion	38%	53%	4%	2%	1%
MSW incineration	37%	35%	12%	5%	2%
Co-firing	37%	35%	12%	5%	2%
Biomass boiler	33%	53%	4%	2%	1%
Wood stove	33%	53%	4%	2%	1%
Biogas small	38%	53%	4%	2%	1%
Mono digestion	38%	53%	4%	2%	1%
MSW heat	38%	53%	4%	2%	1%
Ethanol (1st generation)	33%	42%	13%	5%	2%
Ethanol (2nd generation)	33%	42%	13%	5%	2%
Biodiesel (1st generation)	33%	42%	13%	5%	2%
Biodiesel (2nd generation)	33%	42%	13%	5%	2%
Biomethane (1st generation)	33%	42%	13%	5%	2%
Biomethane (2nd generation)	33%	42%	13%	5%	2%
Bioliquid CHP	33%	53%	7%	3%	1%
Water source - residential	41%	50%	4%	2%	1%
Ground source - residential	41%	50%	4%	2%	1%
Air source - residential	31%	55%	6%	2%	1%
Ground source - commercial	41%	50%	4%	2%	1%

Air source - commercial	31%	55%	6%	2%	1%
Solar thermal	28%	68%	1%	1%	0%

4.5 Annex: Technology investment breakdown into equipment

Table 12: RES equipment breakdown

	Turbines, engines, generators (biomass, MSW)	Biomass boilers, processing, storage	Electrical equipment, cables	Metal equipment, pipes	Civil construction materials (concrete, steel etc.)
Biomass CHP	13%	41%	28%	18%	13%
Biomass IGCC	33%	30%	18%	19%	33%
Co-firing		47%	32%	21%	
Fluidized bed boiler		40%	41%	20%	
MSW incineration	13%	41%	28%	18%	
Anaerobic digestion	9%	33%	3%	22%	34%
Biogas production for heat		41%	3%	22%	34%
Mono digestion	9%	33%	3%	22%	34%
MSW heat		41%	3%	22%	34%
Ethanol (1st generation)		63%	7%	30%	
Ethanol (2nd generation)	28%	43%	4%	26%	
Biodiesel (1st generation)		63%	7%	30%	
Biodiesel (2nd generation)	28%	43%	4%	26%	
Biomethane (1st generation)		40%	41%	20%	
Biomethane (2nd generation)		40%	41%	20%	
Bioliquid CHP	9%	33%	3%	22%	34%

	Biomass stoves, combustion	Electrical equipment, cables	Metal equipment, pipes
Biomass boiler	58%	6%	35%
Wood stove	100%		

	Turbines, engines, generators (geothermal)	Elektrical equipment, cables	Metal equipment, pipes
Geothermal flash	52%	8%	40%
Geothermal deep	52%	8%	40%
Geothermal heat	52%	8%	40%

	Heatpumps	Electrical equipment, cables	Metal equipment, pipes	Civil construction materials (concrete, steel etc.)
Air source - commercial	35%	20%	35%	10%
Air source - residential	35%	20%	35%	10%
Ground source - commercial	35%	20%	35%	10%
Ground source - residential	35%	20%	35%	10%
Water source - residential	35%	20%	35%	10%

	Turbines, generators (hydro)	Electrical equipment, cables	Metal equipment, pipes	Civil construction materials (concrete, steel etc.)
Hydropower dam small	20%	23%	20%	37%
Hydropower dam large	20%	23%	20%	37%
Hydropower dam medium	20%	23%	20%	37%
Hydropower run-of-river	51%		49%	
Tidal	24%	14 %	38%	24%
Wave	24%	14%	38%	24%

	PV panel systems	Inverters>7.5 kVA	Inverters<7.5kVA	Electrical equipment, cables
PV commercial large - tracking	53%	8%	8%	31%
PV commercial large - no tracking	53%	8%	8%	31%
PV commercial medium	53%	8%	8%	31%
PV residential	53%	8%	8%	31%

	Concentrated solar power systems	Turbines, engines, generators (biomass, MSW)	Electrical equipment, cables	Metal equipment, pipes	Civil construction materials (concrete, steel etc.)
CSP - no storage	4%	11%	35%	24%	26%

	Heat systems, other (heatexchangers, solar, distribution)	Metal equipment, pipes
Solar thermal	78%	22%

	Wind turbines	Offshore wind foundations	Electrical equipment, cables	Civil construction materials (concrete, steel etc.)
Wind offshore	49%	24%	26%	1%
Wind onshore	82%	0%	10%	8%

4.6 Annex: Prodcom codes

Table 13: Prodcom codes used for the production and trade values of RES equipment (Source: Eurostat)

Equipment	Prodcom code
Wind turbines	28112400 - Generating sets, wind-powered
Tower	25112200 - Iron or steel towers and lattice masts
Offshore wind foundations	Not available
PV panel systems	26112240 - Photosensitive semiconductor devices; solar cells, photo-diodes, photo-transistors, etc.
Inverters>7.5 kVA	27115055 - Inverters having a power handling capacity >¿7,5 kVA
Inverters<7.5kVA	27115053 - Inverters having a power handling capacity <=¿7,5 kVA
Concentrated solar power systems	Not available
Biomass stoves, combustion	27521270 - Iron or steel solid fuel domestic appliances, including heaters, grates, fires and braziers (excluding cooking appliances and plate warmers)
Heatpumps	28251380 - Heat pumps other than air conditioning machines of HS 8415 28253070 - Parts of refrigerating or freezing equipment and heat pumps, n.e.s.
Heat systems, other (heatexchangers, solar, distribution)	Not available
Turbines, engines, generators (geothermal)	Not available
Turbines, generators (hydro)	28112200 - Hydraulic turbines and water wheels
Turbines, generators (tidal)	Not available
Turbines, generators (wave)	Not available
Turbines, engines, generators (biomass, MSW)	28112150 - Steam turbines for electricity generation
Biomass boilers, processing, storage	25301150 - Vapour generating boilers (including hybrid boilers) (excluding central heating hot water boilers capable of producing low pressure steam, watertube boilers)

Electrical equipment, cables	27121090 - Other apparatus for switching. electrical circuits >¿1¿000 V 27122330 - Electrical apparatus for protecting electrical circuits for a voltage <=¿1 kV and a current <=¿16 A (excluding fuses, automatic circuit breakers) 27122350 - Electrical apparatus for protecting electrical circuits for a voltage <=¿1 kV and for a current >¿16 A but <=¿125 A (excluding fuses, automatic circuit breakers) 27122370 - Electrical apparatus for protecting electrical circuits for a voltage <=¿1 kV and for a current >¿125 A (excluding fuses, automatic circuit breakers) 27123170 - Other bases for electric control, distribution of electricity, voltage <=¿1¿000 V 27124030 - Boards, panels, consoles, desks, cabinets and other bases for apparatus for electric control or the distribution of electricity (excluding those equipped with their apparatus) 27201100 - Primary cells and primary batteries 27201200 - Parts of primary cells and primary batteries (excluding battery carbons, for rechargeable batteries) 27202300 - Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators 27202400 - Parts of electric accumulators including separators 27311100 - Optical fibre cables made up of individually sheathed fibres whether or not assembled with electric conductors or fitted with connectors 27321100 - Winding wire for electrical purposes 27321200 - Insulated coaxial cables and other coaxial electric conductors for data and control purposes whether or not fitted with connectors 27321340 - Other electric conductors, for a voltage <=¿1¿000 V, fitted with connectors 27321380 - Other electric conductors, for a voltage <=¿1¿000 V, not fitted with connectors 27321400 - Insulated electric conductors for voltage >1¿000 V (excluding winding wire, coaxial cable and other coaxial electric conductors, ignition and other wiring sets used in vehicles, aircraft, ships) 27331100 - Electrical apparatus for switching electrical circuits for a voltage <=¿1 kV (including push-button and rotary switches) (excluding relays) 27331360 - Prefabricated elements for electrical circuits for a voltage <=¿1 kV 27331380 - Other apparatus for connections to or in electrical circuit, voltage <=¿1¿000 V 27331410 - Trunking, ducting and cable trays for electrical circuits, of plastics 27331430 - Insulating fittings of plastic, for electrical machines, appliances or equipment (excluding electrical insulators)
Metal equipment, pipes	22212155 - Rigid tubes, pipes and hoses of polymers of propylene 22212157 - Rigid tubes, pipes and hoses of polymers of vinyl chloride 24201400 - Tubes and pipes, of non-circular cross-section, seamless, and hollow profiles, seamless, of steel 24442630 - Copper tubes and pipes 24511220 - Ductile iron castings for transmission shafts, crankshafts, camshafts, cranks, bearing housings and plain shaft bearings (excluding for bearing housings incorporating ball or roller bearings) 24521030 - Steel castings for bearing housings and plain shaft bearings (excluding for bearing housings incorporating ball or roller bearings) 24531020 - Light metal castings for transmission shafts, crankshafts, camshafts,

	cranks, bearing housings and plain shaft bearings (excluding for bearing housings incorporating ball or roller bearings) 25291110 - Iron or steel reservoirs, tanks, vats and similar containers for gases, of a capacity >¿300 litres (excluding compressed or liquefied gas, fitted with mechanical or thermal equipment) 25291120 - Iron or steel reservoirs, tanks, vats and similar containers lined or heat-insulated, for liquids, of a capacity >¿300 litres (excluding fitted with mechanical or thermal equipment) 25501152 - Cold extrusion steel parts for transmission shafts, camshafts, crankshafts and cranks 25721460 - Other base metal mountings, fittings and similar articles (excluding for motor vehicles, buildings or furniture) 25736013 - Rock drilling or earth boring tools with working part of cermets 25941113 - Screws, turned from bars, rods, profiles, or wire, of a shank thickness <=¿6 mm 25941117 - Screws and bolts without heads in steel 26515150 - Barometers, not combined with other instruments (including barometric altimeters, sympiesometers) 26515175 - Electronic hydrometers, hygrometers and psychrometers 28121320 - Hydraulic pumps (piston) 28121350 - Hydraulic pumps (gear) 28121380 - Hydraulic pumps (vane)
Civil construction materials (concrete, steel etc.)	n/a

4.7 Annex: OPEX cost breakdown literature

Table 14: Literature used to determine OPEX allocation to economic sectors

Technology	Literature
Biomass CHP	Obernberger et al. (2008)
Co-firing	Assume same as Biomass CHP
Fluidized bed boiler	Assume same as Biomass CHP
Biomass boiler	Expert judgement
Wood stove	Expert judgement
MSW incineration (CHP	Assume same as Biomass CHP
MSW incineration (heat only)	Assume same as Biomass CHP
Anaerobic digestion (CHP)	ACE et al. (2014)
Anaerobic digestion (heat only)	Assume same as anaerobic digestion
Ethanol (1st generation)	Assume same as biodiesel 1st generation
Ethanol (2nd generation)	Assume same as biodiesel 1st generation
Biodiesel (1st generation)	Haas (2006)
Biodiesel (2nd generation)	Assume same as biodiesel 1st generation
Biomethane (1st generation)	Assume same as anaerobic digestion
Biomethane (2nd generation)	Assume same as anaerobic digestion
Geothermal flash (CHP)	ESMAP (2012)
Geothermal heat installation (heat only)	Assume same as geothermal flash
Air source heat pump	Expert judgement
Ground source heat pump	Expert judgement
Hydropower dam small	Based on Black and Veatch (2012)
Tidal	Assume same as wind offshore
Wave	Assume same as wind offshore
PV	Expert judgement
CSP - no storage	Assume same as geothermal flash
Solar thermal	Expert judgement
Wind offshore	RAB (2010)
Wind onshore	https://www.wind-energy-the-facts.org/operation-and-maintenance-costs-of-wind-generated-power.html

4.8 Annex: OPEX based on JRC and ECN

Table 15: OPEX based on JRC (2015b) and ECN (2016b)

	ETRI (2014) (Adapted figures)	ETRI (2014)
	% CAPEX	€2013/MWh
Technology	**FOM**	**VOM**
Wind onshore	3.6%	0.00
Wind offshore	4.4%	0.00
PV commercial medium	3.3%	0.00
PV commercial large - no tracking	2.3%	0.00
PV commercial large - tracking	2.0%	0.00
PV residential	2.0%	0.00
CSP - no storage	5.3%	0.08
Hydropower dam large	1.4%	0.03
Hydropower dam medium	2.0%	0.05
Hydropower dam small	2.0%	0.05
Hydropower run-of-river	2.0%	0.05
Geothermal flash	2.2%	0.00
Geothermal heat installation	3.3%	0.00
Geothermal deep	2.8%	0.00
Wave	4.8%	0.00
Tidal	4.5%	0.00
Biomass CHP	8.0%	0.70
Fluidized bed boiler	6.4%	0.70
Biomass IGCC	4.2%	0.08
Anaerobic digestion	5.1%	0.03
MSW incineration	4.3%	0.07
Co-firing	7.4%	0.00
Biomass boiler	0.0%	0.00
Wood stove	0.0%	0.00
Biogas production for heat	5.1%	3.1%
Mono digestion	5.1%	3.1%
MSW heat	4.3%	6.9%
Ethanol (1st generation)	4.5%	0.00
Ethanol (2nd generation)	4.5%	0.00
Biodiesel (1st generation)	4.5%	0.00
Biodiesel (2nd generation)	4.5%	0.00
Biomethane (1st generation)	4.5%	0.00
Biomethane (2nd generation)	4.5%	0.00
Bioliquid CHP	Not used	Not used

Water source - residential	4.0%	0.00
Ground source - residential	2.7%	0.00
Air source - residential	2.7%	0.00
Ground source - commercial	2.7%	0.00
Air source - commercial	2.7%	0.00
Solar thermal	1.5%	0.03

4.9 Annex: Capacity factors

Table 16: Technology specific capacity factors (based on JRC (2014) and internal calculations made by ECN)

Technology	Capacity factor (%)
Air source - commercial	20
Ground source - commercial	26
Air source - residential	20
Ground source - residential	26
Water source - residential	26
Biodiesel (1st generation)	96
Biodiesel (2nd generation)	95
Biomethane (1st generation)	96
Biomethane (2nd generation)	91
Ethanol (1st generation)	80
Ethanol (2nd generation)	80
Anaerobic digestion	70
MSW heat	80
Biogas production for heat	80
Mono digestion	91
Bioliquid CHP	80
Biomass boiler	15
Wood stove	15
Biomass CHP	70
Biomass IGCC	70
Co-firing	85
Fluidized bed boiler	80
MSW incineration	80
Geothermal deep	95
Geothermal flash	95
Geothermal heat installation	80
Hydropower dam large	35
Hydropower dam medium	40
Hydropower dam small	37
Hydropower run-of-river	37
Tidal	35
Wave	21
PV commercial large - no tracking	13
PV commercial large - tracking	18
PV commercial medium	13
PV residential	12
District heating	11
Solar thermal	6
CSP - no storage	37
Wind offshore	36
Wind onshore	25

4.10 Annex: OPEX breakdown to economic sectors

Table 17: OPEX breakdown to economic sectors

	The construction sector	Energy sector	Engineering/ services	Financial services (insurance etc.)	Source
Biomass CHP	28%	62%		10%	Obernberger et al. (2008)
Biomass IGCC	24%	67%		9%	Obernberger et al. (2008)
Co-firing	28%	62%		10%	Assume same as Biomass CHP
Fluidized bed boiler	28%	62%		10%	Assume same as Biomass CHP
Biomass boiler	100%				Assumption
Wood stove	100%				Assumption
MSW incineration	28%	62%		10%	Assume same as Biomass CHP
Anaerobic digestion	30%	19%	12%	40%	ACE et al. (2014)
Biogas production for heat	30%	19%	12%	40%	Assume same as anaerobic digestion
Mono digestion	30%	19%	12%	40%	Assume same as anaerobic digestion
MSW heat	30%	19%	12%	40%	Assume same as anaerobic digestion
Ethanol (1st generation)	36%	58%		6%	Assume same as biodiesel 1st generation
Ethanol (2nd generation)	36%	58%		6%	Assume same as biodiesel 1st generation
Biodiesel (1st generation)	36%	58%		6%	Haas (2006)
Biodiesel (2nd generation)	36%	58%		6%	Assume same as biodiesel 1st generation
Biomethane (1st generation)	30%	19%	12%	40%	Assume same as anaerobic digestion
Biomethane (2nd generation)	30%	19%	12%	40%	Assume same as anaerobic digestion
Bioliquid CHP	100%				Assumption
Geothermal flash	64%	36%			Based on ESMAP (2012)
Geothermal deep	64%	36%			Assume same as geothermal flash
Geothermal heat installation	64%	36%			Assume same as geothermal flash
Air source - commercial	75%	25%			Assumption

Air source - residential	100%				Assumption
Ground source - commercial	75%	25%			Assumption
Ground source - residential	100%				Assumption
Water source - residential	100%				Assumption
Hydropower dam small	74%	26%			Based on Black and Veatch (2012)
Hydropower dam large	74%	26%			Assume same as dam small
Hydropower dam medium	74%	26%			Assume same as dam small
Hydropower run-of-river	74%	26%			Assume same as dam small
Tidal	75%	25%			Assume same as Wind Offshore
Wave	75%	25%			Assume same as Wind Offshore
PV commercial large - tracking	75%	25%			Assumption
PV commercial large - no tracking	75%	25%			Assumption
PV commercial medium	75%	25%			Assumption
PV residential	100%				Assumption
CSP - no storage	32%	32%		37%	Assumption
Water heaters	100%				Assumption
District heating					
Wind offshore	69%	15%		16%	Source: RAB (2010)
Wind onshore	32%	32%		37%	https://www.wind-energy-the-facts.org/operation-and-maintenance-costs-of-wind-generated-power.html

4.11 Annex: Biomass feedstock cost

Table 18: Feedstock cost (Source: CAPRI)

Technlogy	Parameter	EUR2015/MWh
Biodiesel (1st generation)	Fuel cost ref	81
Biodiesel (2nd generation)	Fuel cost ref	30
Biomethane (1st generation)	Fuel cost ref	17
Biomethane (2nd generation)	Fuel cost ref	20
Ethanol (2nd generation)	Fuel cost ref	19
Anaerobic digestion	Fuel cost ref	18
MSW heat	Fuel cost ref	20
Biogas production for heat	Fuel cost ref	19
Mono digestion	Fuel cost ref	21
Bioliquid CHP	Fuel cost ref	81
Biomass boiler	Fuel cost ref	19
Wood stove	Fuel cost ref	16
Biomass CHP	Fuel cost ref	27
Biomass IGCC	Fuel cost ref	42
Co-firing	Fuel cost ref	21
Fluidized bed boiler	Fuel cost ref	26
MSW incineration	Fuel cost ref	7

4.12 Annex: Biomass feedstock type allocation

Table 19: Biomass feedstock type allocation per MS (Source: based on Eurostat)

	Solid wood			Digestion feedstock	Oil crops	Ethanol crops		Municipal solid waste
%	**Pellets**	**Chips**	**Fuel wood (incl charcoal)**	**Straw & Manure**	**Oil-bearing crops**	**Sugar crops**	**Cereals**	**MSW**
Belgium	26%	17%	57%	100%	100%	63%	37%	100%
Bulgaria	0%	0%	100%	100%	100%	1%	99%	100%
Czech Republic	13%	13%	75%	100%	100%	32%	68%	100%
Denmark	54%	6%	40%	100%	100%	19%	81%	100%
Germany	12%	28%	60%	100%	100%	40%	60%	100%
Estonia	8%	23%	69%	100%	100%	0%	100%	100%
Ireland	7%	56%	37%	100%	100%	4%	96%	100%
Greece	2%	1%	97%	100%	100%	12%	88%	100%
Spain	8%	22%	70%	100%	100%	15%	85%	100%
France	5%	11%	84%	100%	100%	41%	59%	100%
Croatia	3%	2%	95%	100%	100%	35%	65%	100%
Italy	27%	28%	45%	100%	100%	17%	83%	100%
Cyprus	20%	9%	71%	100%	100%	2%	98%	100%
Latvia	5%	36%	58%	100%	100%	0%	100%	100%
Lithuania	1%	27%	72%	100%	100%	30%	70%	100%
Luxembourg	0%	96%	4%	100%	100%	0%	100%	100%
Hungary	0%	4%	96%	100%	100%	7%	93%	100%
Malta	43%	1%	56%	100%	100%	43%	57%	100%
Netherlands	89%	10%	2%	100%	100%	61%	39%	100%
Austria	11%	26%	63%	100%	100%	42%	58%	100%
Poland	9%	31%	60%	100%	100%	31%	69%	100%
Portugal	19%	56%	26%	100%	100%	14%	86%	100%
Romania	3%	0%	96%	100%	100%	10%	90%	100%
Slovenia	12%	4%	84%	100%	100%	1%	99%	100%
Slovakia	5%	53%	42%	100%	100%	25%	75%	100%
Finland	3%	42%	55%	100%	100%	17%	83%	100%
Sweden	16%	42%	42%	100%	100%	33%	67%	100%
United Kingdom	68%	15%	18%	100%	100%	29%	71%	100%

4.13 Annex: economic sector-input intra sector

Table 20: Economic sector - Input intra sector spending

Economic sector	Intra sector input
Agriculture	Products of agriculture, hunting and related services
Forestry	Products of forestry, logging and related services
Equipment	Fabricated metal products, except machinery and equipment Computer, electronic and optical products Electrical equipment Machinery and equipment n.e.c.
Construction	Fabricated metal products, except machinery and equipment Computer, electronic and optical products Electrical equipment Machinery and equipment n.e.c. Constructions and construction works
Energy	Electricity, gas, steam and air conditioning
Financial	Financial services, except insurance and pension funding Insurance, reinsurance and pension funding services, except compulsory social security Services auxiliary to financial services and insurance services
Engineering, R&D, management	Legal and accounting services; services of head offices; management consultancy services Architectural and engineering services; technical testing and analysis services Scientific research and development services
Other	Wholesale and retail trade and repair services of motor vehicles and motorcycles Wholesale trade services, except of motor vehicles and motorcycles Retail trade services, except of motor vehicles and motorcycles Land transport services and transport services via pipelines Water transport services Air transport services Warehousing and support services for transportation Postal and courier services Accommodation and food services Publishing services Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services Telecommunications services Computer programming, consultancy and related services; Information services Financial services, except insurance and pension funding Insurance, reinsurance and pension funding services, except compulsory social security Services auxiliary to financial services and insurance services

	Real estate services excluding imputed rents Imputed rents of owner-occupied dwellings Legal and accounting services; services of head offices; management consultancy services Architectural and engineering services; technical testing and analysis services Scientific research and development services Advertising and market research services Other professional, scientific and technical services and veterinary services Rental and leasing services Employment services Travel agency, tour operator and other reservation services and related services Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services
Waste	Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other waste management services

4.14 Annex Other sector description

Table 21: Eurostat sectors falling under 'Other sector'

Wholesale and retail trade and repair of motor vehicles and motorcycles	Accommodation and food service activities
Wholesale trade, except of motor vehicles and motorcycles	Telecommunications
Land transport and transport via pipelines	Computer programming, consultancy, and information service activities
Water transport	Other professional, scientific and technical activities; veterinary activities
Warehousing and support activities for transportation	Rental and leasing activities
Postal and courier activities	Employment activities
Security and investigation, service and landscape, office administrative and support activities	

4.15 Annex Spending share in other sector

Table 22: Spending share sector *e* in *other services* ($OSshare_{MSJ,e}$) (source: Eurostat input-output tables)

	Agriculture	Forestry	Equipment	Construction	Energy	Financial	Engineering, R&D, management	Waste
Belgium	0.23	0.23	0.25	0.27	0.12	0.31	0.25	0.30
Bulgaria	0.21	0.17	0.21	0.33	0.11	0.07	0.24	0.22
Czech Republic	0.17	0.18	0.00	0.32	0.09	0.00	0.00	0.25
Denmark	0.23	0.23	0.22	0.34	0.04	0.15	0.29	0.37
Germany	0.19	0.09	0.18	0.19	0.10	0.37	0.18	0.28
Estonia	0.13	0.35	0.00	0.25	0.08	0.00	0.00	0.42
Ireland	0.00	0.00	0.00	0.30	0.05	0.00	0.00	0.24
Greece	0.16	0.09	0.23	0.23	0.08	0.16	0.26	0.16
Spain	0.11	0.10	0.20	0.24	0.14	0.16	0.21	0.21
France	0.14	0.22	0.24	0.25	0.09	0.30	0.29	0.25
Croatia	0.13	0.07	0.26	0.37	0.14	0.24	0.13	0.16
Italy	0.09	0.13	0.27	0.29	0.31	0.18	0.16	0.48
Cyprus	0.13	0.03	0.23	0.20	0.18	0.41	0.15	0.26
Latvia	0.09	0.18	0.12	0.22	0.04	0.21	0.16	0.18
Lithuania	0.19	0.11	0.00	0.11	0.04	0.00	0.00	0.21
Luxembourg	0.09	0.04	0.00	0.37	0.05	0.32	0.00	0.23
Hungary	0.12	0.21	0.21	0.25	0.17	0.22	0.18	0.24
Malta	0.07	0.00	0.00	0.21	0.00	0.82	0.00	0.00
Netherlands	0.15	0.19	0.45	0.25	0.08	0.21	0.27	0.27
Austria	0.12	0.05	0.21	0.21	0.11	0.29	0.24	0.22
Poland	0.15	0.15	0.22	0.19	0.11	0.20	0.18	0.16
Portugal	0.14	0.12	0.21	0.19	0.10	0.20	0.30	0.24
Romania	0.18	0.31	0.20	0.20	0.15	0.13	0.20	0.39
Slovenia	0.16	0.10	0.20	0.24	0.12	0.17	0.17	0.32
Slovakia	0.13	0.05	0.28	0.14	0.10	0.16	0.14	0.17
Finland	0.23	0.08	0.00	0.22	0.08	0.00	0.00	0.23
Sweden	0.20	0.05	0.00	0.28	0.07	0.00	0.26	0.42
United Kingdom	0.14	0.18	0.12	0.20	0.04	0.39	0.21	0.31

4.16 Annex Member State specific conversion factor

Table 23: Conversion factor EU28 level to MS cost

	Agriculture	Forestry	Equipment manufacturing[32]	Construction	Energy	Financial services	Consulting and engineering services	Waste
Belgium	1.00	1.12	1.00	1.11	1.04	1.11	1.12	1.11
Bulgaria	1.00	0.77	1.00	0.57	0.86	0.60	0.48	0.62
Czech Republic	1.00	0.90	1.00	0.75	0.92	0.78	0.68	0.79
Denmark	1.00	0.91	1.00	1.12	1.03	1.09	1.12	1.09
Germany	1.00	1.14	1.00	1.04	1.03	1.04	1.05	1.13
Estonia	1.00	0.83	1.00	0.77	0.89	0.73	0.64	0.77
Ireland	1.00	0.80	1.00	1.06	1.04	1.01	1.02	1.04
Greece	1.00	0.85	1.00	0.85	0.97	0.87	0.71	1.11
Spain	1.00	0.87	1.00	0.98	1.03	0.98	0.86	0.95
France	1.00	1.12	1.00	1.09	1.04	1.06	1.10	1.08
Croatia	1.00	0.96	1.00	0.72	0.89	0.71	0.75	0.69
Italy	1.00	0.98	1.00	1.02	1.01	1.04	1.01	1.04
Cyprus	1.00	0.79	1.00	0.88	0.99	0.94	0.79	0.74
Latvia	1.00	0.80	1.00	0.65	0.87	0.70	0.57	0.74
Lithuania	1.00	1.06	1.00	0.65	0.86	0.68	0.55	0.73
Luxembourg	1.00	1.12	1.00	1.02	1.03	1.09	1.10	1.11
Hungary	1.00	0.82	1.00	0.67	0.90	0.73	0.63	0.67
Malta	1.00	1.00	1.00	0.75	0.91	0.76	0.63	0.67
Netherlands	1.00	1.12	1.00	1.11	1.03	1.08	1.08	1.14
Austria	1.00	1.13	1.00	1.07	1.03	1.04	1.04	1.17
Poland	1.00	0.91	1.00	0.68	0.89	0.69	0.60	0.73
Portugal	1.00	0.87	1.00	0.81	0.96	0.95	0.77	0.90
Romania	1.00	0.80	1.00	0.58	0.86	0.65	0.50	0.67
Slovenia	1.00	0.86	1.00	0.81	0.95	0.83	0.79	0.81
Slovakia	1.00	0.85	1.00	0.73	0.90	0.75	0.64	0.72
Finland	1.00	1.13	1.00	1.10	1.02	1.00	1.06	1.13
Sweden	1.00	1.10	1.00	1.12	1.04	1.10	1.13	1.03
United Kingdom	1.00	1.07	1.00	1.04	0.99	0.99	0.99	1.06

[32] Note that for the following RES technologies a MS specific conversion factor is used, as their prices for equipment are believed to be MS dependant: pellet boilers, wood heat pumps, solar thermal (boilers), fluidized boilers, geothermal flash, geothermal heat installation.

4.17 Annex: self-employment factors

Table 24: Self-employment factors (source: based on Eurostat)

	Agriculture	Forestry	Equipment	Construction	Energy	Financial	Engineering, R&D, management	Other	Waste
Belgium	0.66	0.10	0.06	0.28	0.02	0.10	0.37	0.13	0.00
Bulgaria	0.43	0.10	0.04	0.12	0.02	0.09	0.28	0.11	0.00
Czech Republic	0.21	0.10	0.07	0.39	0.04	0.27	0.40	0.17	0.04
Denmark	0.43	0.10	0.04	0.18	0.00	0.00	0.22	0.10	0.00
Germany	0.38	0.10	0.04	0.18	0.02	0.10	0.26	0.11	0.03
Estonia	0.19	0.10	0.04	0.15	0.00	0.00	0.27	0.11	0.00
Ireland	0.67	0.10	0.08	0.38	0.00	0.05	0.29	0.16	0.00
Greece	0.74	0.10	0.23	0.42	0.00	0.11	0.56	0.23	0.00
Spain	0.40	0.10	0.11	0.31	0.03	0.07	0.36	0.16	0.04
France	0.58	0.10	0.05	0.20	0.00	0.05	0.19	0.09	0.00
Croatia	0.67	0.10	0.06	0.19	0.00	0.00	0.28	0.10	0.00
Italy	0.40	0.10	0.11	0.38	0.05	0.17	0.58	0.22	0.06
Cyprus	0.40	0.10	0.18	0.23	0.00	0.08	0.23	0.19	0.00
Latvia	0.35	0.10	0.05	0.13	0.00	0.00	0.27	0.09	0.00
Lithuania	0.46	0.10	0.04	0.13	0.00	0.00	0.15	0.00	0.00
Luxembourg	0.56	0.10	0.00	0.06	0.00	0.03	0.20	0.00	0.00
Hungary	0.30	0.10	0.05	0.19	0.00	0.11	0.30	0.13	0.00
Malta	0.62	0.10	0.07	0.33	0.00	0.00	0.27	0.16	0.00
Netherlands	0.49	0.10	0.07	0.29	0.00	0.13	0.34	0.14	0.00
Austria	0.61	0.10	0.04	0.09	0.00	0.05	0.25	0.10	0.00
Poland	0.65	0.10	0.06	0.23	0.00	0.13	0.35	0.15	0.04
Portugal	0.67	0.10	0.09	0.23	0.00	0.08	0.35	0.13	0.00
Romania	0.50	0.10	0.02	0.25	0.00	0.00	0.16	0.00	0.00
Slovenia	0.36	0.10	0.06	0.21	0.00	0.05	0.27	0.12	0.00
Slovakia	0.17	0.10	0.08	0.41	0.09	0.27	0.47	0.14	0.00
Finland	0.60	0.10	0.06	0.23	0.00	0.00	0.21	0.11	0.00
Sweden	0.49	0.10	0.06	0.19	0.00	0.04	0.18	0.10	0.00
United Kingdom	0.47	0.10	0.07	0.40	0.05	0.06	0.23	0.16	0.04

4.18 Annex: labour costs

Table 25: Euro per FTE[33]

	Agriculture	Forestry	Equipment	Construction	Energy	Financial	Engineering, R&D, management	Waste	Other
Belgium	57,468	50,000	77,900	67,145	127,207	122,591	92,874	29,997	62,586
Bulgaria	5,160	4,460	5,895	6,067	14,851	12,352	11,282	2,911	8,024
Czech Republic	12,906	13,424	17,496	18,063	29,424	33,401	25,931	10,855	18,958
Denmark	37,267	63,040	67,941	65,143	86,466	100,496	78,175	34,432	63,282
Germany	23,035	38,874	62,325	45,751	80,831	82,912	66,096	39,253	41,901
Estonia	11,115	11,512	16,960	20,495	24,498	31,119	23,072	9,978	18,736
Ireland	37,801	37,859	55,486	46,576	94,236	77,815	63,534	28,920	43,482
Greece	10,007	10,941	29,105	22,302	51,469	47,574	23,991	36,500	27,343
Spain	9,597	10,364	41,454	38,750	89,352	71,439	43,585	21,467	31,554
France	27,891	44,130	62,384	54,168	94,835	92,623	80,248	32,899	52,684
Croatia	9,446	11,973	14,951	15,899	23,762	24,666	32,371	5,512	16,654
Italy	21,188	18,824	49,231	43,169	68,833	84,844	59,016	28,661	37,425
Cyprus	13,277	4,866	24,597	26,045	53,999	61,236	36,392	14,233	27,744
Latvia	7,667	7,964	11,154	11,490	17,346	25,872	16,266	8,274	13,299
Lithuania	7,736	24,097	10,881	11,270	14,900	21,876	15,722	7,684	12,572
Luxembourg	24,725	50,000	56,089	43,269	87,488	104,917	84,805	41,884	50,842
Hungary	8,636	7,630	13,839	11,175	26,038	27,381	20,630	4,489	14,951
Malta	8,107	19,034	14,676	17,102	23,262	24,892	24,458	5,512	16,315
Netherlands	39,285	50,000	55,222	59,711	85,380	100,400	67,051	41,884	40,468
Austria	22,367	37,817	59,239	53,508	84,594	87,560	64,496	58,647	45,282
Poland	8,224	12,759	13,690	14,693	24,193	24,329	20,967	7,619	15,481
Portugal	11,043	10,635	20,443	21,772	45,149	66,601	35,181	17,341	24,503
Romania	2,541	6,836	7,612	6,689	15,174	18,901	13,185	3,666	9,757
Slovenia	13,505	10,729	27,039	22,140	42,672	42,301	34,844	12,139	26,724
Slovakia	14,200	10,698	17,641	16,902	28,432	31,007	25,178	6,885	16,768
Finland	32,445	37,340	62,996	61,032	73,411	75,032	64,955	40,571	48,702
Sweden	15,778	55,080	72,051	69,542	87,466	103,129	80,885	27,589	59,519
United Kingdom	31,570	22,770	47,139	50,486	61,807	80,363	60,654	30,954	39,671

[33] Based on Eurostat data for hourly labour costs and yearly amount of worked hours (table lfsa_ewhun2).

4.19 Annex: Corrected labour cost shares

Table 26: Corrected labour cost shares ($LCshare\_correct_{MSj,e}$) (Source: based on Eurostat input-output tables)

	Agriculture	Forestry	Equipment manufacturing	Construction	Energy	Financial services	Consulting and engineering services	Waste	Other
Belgium	0.14	0.06	0.32	0.34	0.17	0.33	0.34	0.26	0.57
Bulgaria	0.13	0.22	0.19	0.14	0.14	0.25	0.41	0.19	0.34
Czech Republic	0.24	0.12	0.23	0.35	0.07	0.33	0.49	0.23	0.45
Denmark	0.20	0.37	0.37	0.40	0.10	0.39	0.59	0.15	0.50
Germany	0.21	0.30	0.38	0.41	0.15	0.40	0.61	0.23	0.52
Estonia	0.21	0.16	0.28	0.31	0.09	0.29	0.72	0.17	0.53
Ireland	0.38	0.24	0.21	0.67	0.17	0.29	0.41	0.21	0.60
Greece	0.35	0.52	0.33	0.33	0.14	0.45	0.67	0.30	0.38
Spain	0.17	0.32	0.30	0.45	0.09	0.43	0.67	0.24	0.52
France	0.30	0.33	0.35	0.41	0.17	0.35	0.53	0.30	0.56
Croatia	0.17	0.61	0.36	0.31	0.11	0.26	0.58	0.34	0.48
Italy	0.24	0.52	0.31	0.35	0.09	0.38	0.49	0.25	0.42
Cyprus	0.19	0.46	0.31	0.38	0.10	0.33	0.36	0.29	0.45
Latvia	0.18	0.21	0.23	0.27	0.13	0.36	0.47	0.20	0.36
Lithuania	0.25	0.32	0.30	0.43	0.10	0.32	0.47	0.26	0.36
Luxembourg	0.22	0.65	0.32	0.35	0.14	0.26	0.34	0.38	0.57
Hungary	0.17	0.47	0.23	0.29	0.14	0.38	0.57	0.25	0.45
Malta	0.40	0.52	0.31	0.30	0.09	0.08	0.49	0.25	0.42
Netherlands	0.21	0.37	0.24	0.47	0.12	0.36	0.72	0.28	0.53
Austria	0.16	0.16	0.29	0.36	0.18	0.44	0.54	0.24	0.46
Poland	0.23	0.43	0.22	0.23	0.14	0.31	0.31	0.24	0.28
Portugal	0.37	0.11	0.31	0.44	0.06	0.39	0.66	0.28	0.43
Romania	0.09	0.27	0.18	0.16	0.10	0.25	0.24	0.13	0.21
Slovenia	0.13	0.18	0.30	0.39	0.15	0.38	0.50	0.30	0.54
Slovakia	0.17	0.20	0.20	0.30	0.08	0.35	0.58	0.23	0.38
Finland	0.33	0.16	0.27	0.44	0.10	0.36	0.44	0.18	0.49
Sweden	0.46	0.18	0.25	0.38	0.11	0.32	0.44	0.16	0.49
United Kingdom	0.38	0.24	0.46	0.52	0.12	0.30	0.53	0.29	0.60

4.20 Annex: conversion factors impact O&M jobs conventional energy sector

Table 27: Conversion factors O&M jobs conventional energy sector (Source: based on Eurostat)

Factors for 2015	pgef [a]	sfpgs [b]	sbpge [c]	mef [d]	ofpgs [e]	obpge [f]	ref [g]	cfhgs [h]	ofhgs [i]
	FTE/GWh	% of GWh	GWh/TJ	FTE/PJ	% of GWh	GWh/TJ	FTE/PJ	% of TJ	% of TJ
GEO/INDIC_NRG			(2014 values)			(2014 values)	0		
European Union (28 countries)	0.16	38%	0.00	47.51	3%	0.00	6.93	14%	23%
Belgium	0.14	8%	0.11	0.00	1%	0.14	5.28	9%	34%
Bulgaria	0.32	63%	0.09	49.12	1%	0.00	7.26	13%	15%
Czech Republic	0.18	66%	0.09	26.53	0%	0.03	15.27	24%	7%
Denmark	0.15	77%	0.10	0.00	3%	0.05	0.00	3%	26%
Germany	0.14	67%	0.11	9.43	2%	0.22	6.55	13%	24%
Estonia	0.20	8%	0.00	19.90	106%	0.73	0.00	7%	28%
Ireland	0.12	38%	0.11	0.00	2%	0.11	0.00	12%	47%
Greece	0.17	67%	0.10	20.18	17%	0.11	3.84	5%	72%
Spain	0.07	31%	0.10	27.33	10%	0.09	5.72	6%	37%
France	0.13	3%	0.10	0.00	1%	0.08	3.80	9%	31%
Croatia	0.22	69%	0.11	0.00	7%	0.11	1.40	4%	36%
Italy	0.13	27%	0.11	0.00	8%	0.06	7.20	4%	19%
Cyprus	0.50	0%		0.00		0.11	0.00	1%	99%
Latvia	0.47	0%	0.00	0.00	0%		0.00	5%	24%
Lithuania	0.48	0%		0.00	12%	0.28	0.00	13%	11%
Luxembourg	0.20	0%		0.00	0%	0.00	0.00	5%	28%
Hungary	0.24	23%	0.09	1.90	0%	0.08	16.17	6%	14%
Malta	0.19	0%		0.00	106%	0.11	0.00	0%	100%
Netherlands	0.12	45%	0.12	0.00	2%	0.01	3.05	6%	20%
Austria	0.16	37%	0.11	0.00	6%	0.37	3.06	15%	22%
Poland	0.23	103%	0.10	41.95	2%	0.39	8.03	57%	12%
Portugal	0.11	57%	0.11	0.00	5%	0.11	2.83	0%	51%
Romania	0.48	52%	0.09	194.93	1%	0.03	17.78	9%	20%
Slovenia	0.24	45%	0.10	67.75	0%	0.10	0.00	6%	37%
Slovakia	0.23	17%	0.07	335.01	2%	0.04	13.61	26%	4%
Finland	0.09	24%	0.09	0.00	1%	0.09	5.38	27%	43%
Sweden	0.08	2%	0.05	0.00	1%	0.08	2.22	35%	39%
United Kingdom	0.13	32%	0.10	13.16	1%	0.07	10.86	9%	15%

ECN

Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 ZG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ecn.nl
www.ecn.nl