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Study 1305-01

The evolution of photovoltaic waste in Europe

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Contents

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Objective of the study

Over the past ten years, photovoltaic installations have grown at an unprecedented rate, exceeding all predictions. To date, this growth has predominantly taken place in Europe, and the aim of this study is to focus on an ever-increasingly important issue: Europe's waste collection and disposal capacities. This growth is supported by new European[1] and national legislation compelling manufacturers to comply with waste collection and disposal obligations. Therefore, the assessment of waste volumes is a key issue in attaining these goals.

This study aims to provide more specific information regarding the evolution of photovoltaic waste in the main European markets. The study focuses on seven European countries: Belgium, France, Germany, Italy, Spain, Slovakia and the United Kingdom. These countries account for more than 90% of total photovoltaic installations in Europe according to EPIA[2], and ultimately, of waste volumes. Although these seven countries have benefitted from political incentives favouring a rapid development of renewable energies, they do not constitute a homogenous group. This study aims to identify the main obstacles in recycling photovoltaic waste and to analyse the current proposed solutions.

[1] DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment(WEEE)

[2] European Photovoltaic Industry Association

Methodology used in the study

Based on CERES' experience, certain hypotheses have been made in order to ascertain the forecasts presented in this study.

- Average life span of a photovoltaic panel: 17 years
- Breakage rate during installation: 2%
- Production scrap rate: 1-2%
- Conversion of MW to tonnes: 1T = 0.01 MW

I – Photovoltaic waste volumes are beginning to appear in significant quantities

At the end of 2012, the global installed photovoltaic capacity was slightly greater than 102 GW, with 31.1 GW accounting for new installations, approximately a third of the cumulative capacity. In 2012, like in 2011, Europe was in the lead with the majority of new installed capacities on its territory, respectively 55% and 74% of cumulative installed capacity. In Europe, Germany accounted for the market with the highest absolute growth in 2012 with 7.6 GW of new installations, followed by Italy with 3.4 GW.

With such an abundant market, the estimation of photovoltaic waste volumes is becoming a crucial issue. A "fixed" waste volume already exists composed of used modules as well as broken and scrap panels. To this "fixed" volume, one must add a waste volume that will be more or less "variable" depending on the political climate towards photovoltaic energy, whose impact on the installation of new panels can potentially be very important.

(i) End of life of the first installed modules

Today, photovoltaic panels are guaranteed up to 25 years, with a tendency for the guarantee period to be progressively lengthened. However, the CERES' experience shows a life span of 17 years. Many users choose to replace their installations before the theoretical end of life span in order to benefit from much higher yields, due to the new technological improvements found in newer modules.

Based on an average life span of 17 years, in 2013, we would need to start collecting photovoltaic waste products from 1996. For the seven European countries studied, this represents between 20 tonnes for the United Kingdom and up to 300 tonnes for Germany (see Table 1).

Since the early 2000's, Europe is the world leader in terms of installed capacity, hence the very significant volumes of photovoltaic waste. Based on the installed capacities and an average life span of 17 years, the volume of photovoltaic waste will exceed 5,500,000 tonnes in 2026 and more than 1 million tonnes of photovoltaic waste will need to be collected in 2027 and over 2 million tonnes in 2028.

Table 1: Annual tonnage of photovoltaic waste

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Belgium	0	0	0	0	0	0	0	0	0	0	0	200	200	2300	8100	51900	41700	77550
France	30	50	150	170	150	150	220	260	330	390	490	700	1090	3130	10450	15550	71910	152200
Germany	100	200	300	700	500	900	4400	11000	11000	13900	67000	95100	84300	127100	195000	379400	740600	750000
Italy	200	170	20	70	100	80	50	100	200	400	470	680	1250	7020	33810	72300	232100	928000
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14800	31410
Spain	100	0	0	0	0	100	0	200	300	500	1200	2500	9900	55700	275800	6000	39200	35490
United Kingdom	0	10	0	20	10	40	80	80	140	180	230	270	340	380	440	350	4380	94422
Rest of EU	0	0	100	0	0	100	0	0	200	1300	1000	100	100	100	600	700	5880	6980
Total Europe	**710**	**690**	**891**	**1353**	**1363**	**2079**	**5564**	**12849**	**13525**	**19706**	**71820**	**100810**	**98266**	**198679**	**538730**	**579795**	**1331150**	**2153912**

Sources: IEA Photovoltaic Power Systems Programme, EPIA, EurObserver and national sources.

(ii) Installation breakage rate and production scrap rates

During the installation of photovoltaic panels, a breakage rate of 2% has been recorded. Based on annual installation volumes, we estimate that a volume of 26,623 tonnes of photovoltaic waste was generated in 2012 and 43,078 tonnes in 2011 exclusively from installation breakages and production scraps.

Table 2: Annual tonnage of breakage rates based on installed capacities

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Belgium	0	0	0	0	0	0	0	0	0	0	0	0	4	4	46	162	1038	834	1992	1198
France	0,6	0,6	1	3	3,4	3	3	4,4	5,2	6,6	7,8	9,8	14	21,8	62,6	209	311	1438,2	3512	2158
Germany	4	2	4	6	14	10	18	88	220	220	278	1340	1902	1686	2542	3900	7588	14812	14970	15208
Italy	7,2	4	3,4	0,4	1,4	2	1,6	1	2	4	8	9,4	13,6	25	140,4	676,2	1446	4642	18908	6876
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	296	642	30
Spain	0	2	0	0	0	0	2	0	4	6	10	24	50	198	1114	5516	120	784	944	710
United Kingdom	0,2	0	0,2	0	0,4	0,2	0,8	1,6	1,6	2,8	3,6	4,6	5,4	6,8	7,6	8,8	7	87,6	1626	1850

Sources: IEA Photovoltaic Power Systems Programme, EPIA, EurObserver and national sources.

In 2012, 28,030 tonnes of photovoltaic waste were produced from breakages during installation in the seven countries studied. This figure increases with the growing number of installed panels.

With regard to the production scraps, this rate varies between 1% and 2% depending on the manufacturers. In 2012, European manufacturers accounted for approximately 23% of the global photovoltaic panel production market, which is equivalent to between 6,000 and 12,000 tonnes of waste. The waste volumes are primarily based in Germany, since more than half (57%) of European photovoltaic panel manufacturers are German companies accounting for 18.34% of the market.

Table 3: Main European photovoltaic panel manufacturers

Manufacturer	Country	Market share (%)*
Solar World	Germany	4,00
Schott Solar	Germany	3,32
Bosch	Germany	2,80
Solon	Germany	2,00
Aleo	Germany	1,56
Conergy	Germany	1,40
Siliken	Spain	1,30
Isofoton	Spain	0,92
Solar-fabrik	Germany	0,84
Scheuten	Netherlands	0,80
Tenesol	France	0,68
Heckert Solar	Germany	0,68
Sunset Solar	Germany	0,60
Schuco	Germany	0,60
Fire Energy	Spain	0,40
Photowatt	France	0,32
Alfasolar	Germany	0,30
Systaic	Germany	0,24
Issol	Belgium	0,20
Sillia	France	0,20
Auversun	France	0,12

*Manufacturer data 2011

(iii) Evolution of waste volumes until 2018

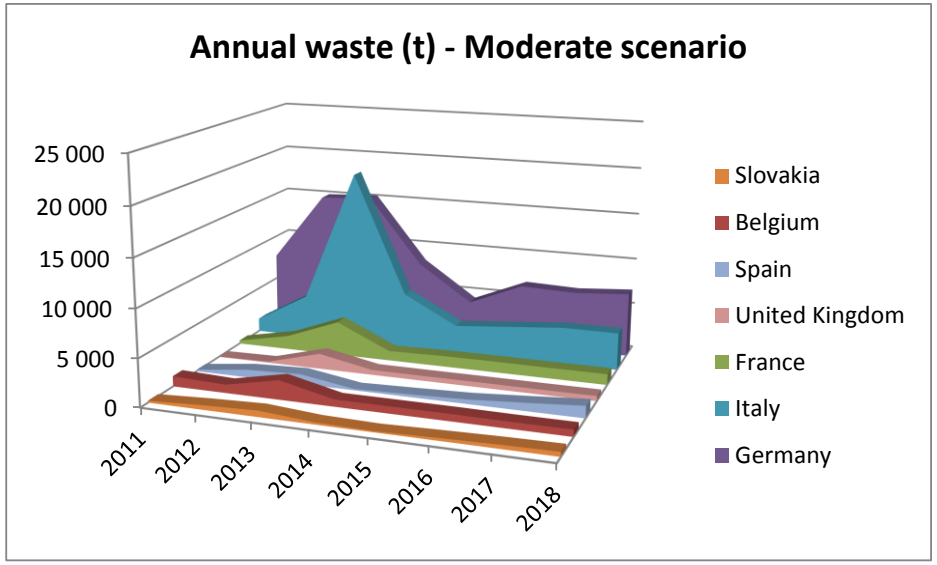
In Europe, energy produced by photovoltaic sources covers on average 2.6% of the demand. This percentage increases to 5.6% during peak demand. Since 2011, photovoltaic has been the primary source of electricity in terms of new installed capacities, however, several factors may

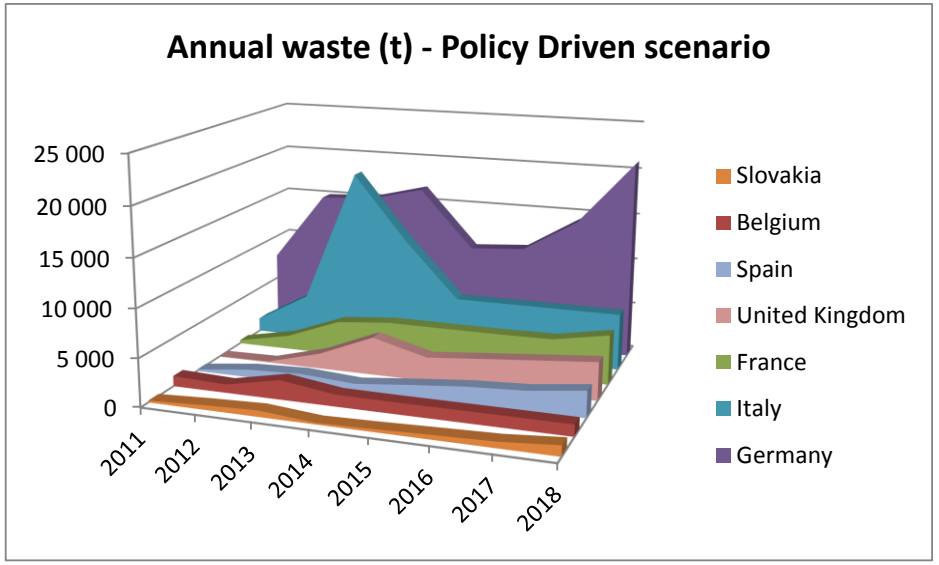
influence the further development of photovoltaics, in particular the political climate. In May 2012, EPIA published a report with forecasts on installed capacities in Europe until 2016. Depending on the political commitment by European governments, two scenarios can be envisaged:

- a moderate projection implying less support to the existing incentive mechanisms or even a decrease of such schemes, and

- a policy driven projection implying continued support for existing schemes and the introduction of new ones, clear political will to consider photovoltaics as a new energy source over the coming years and the disappearance of unnecessary administrative burdens as well as simplified processes relating to grid connections.

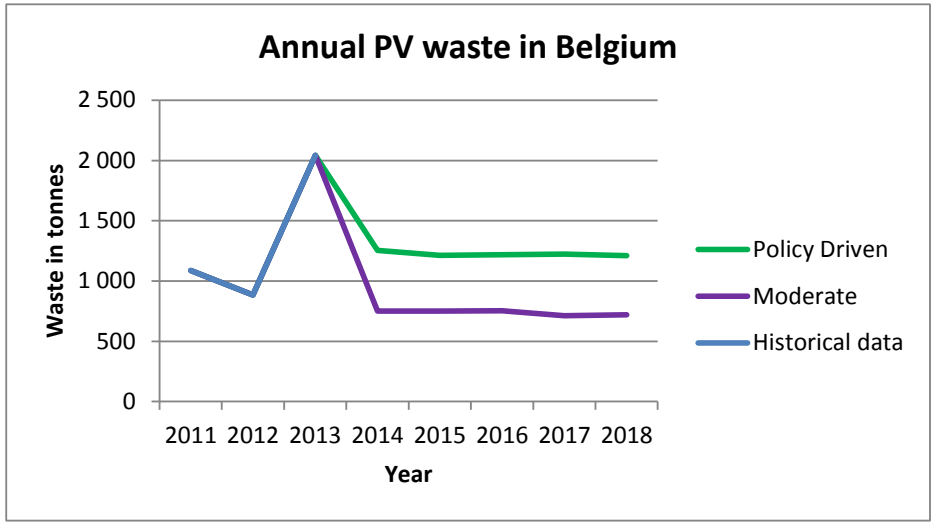
Based on the figures announced by EPIA regarding installed capacities, it is possible to estimate the volume of photovoltaic waste, taking into account the parameters mentioned in the methodology.

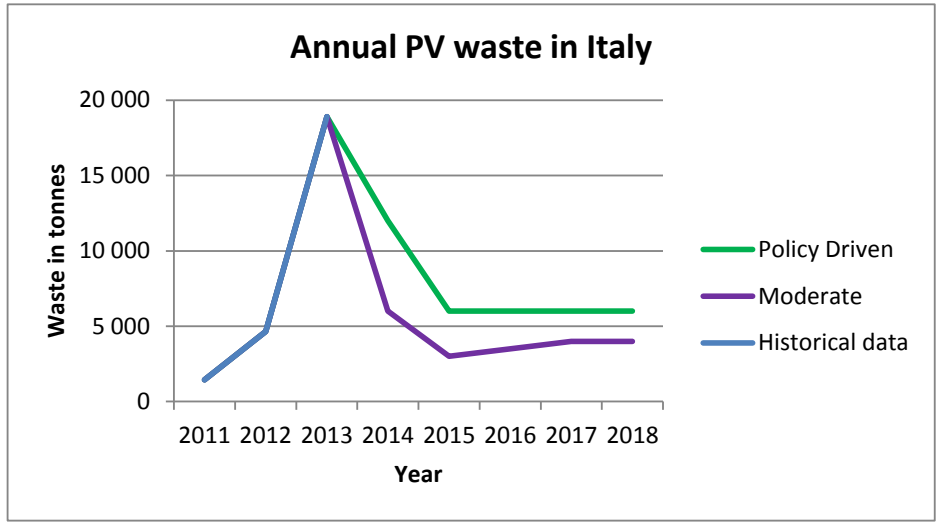




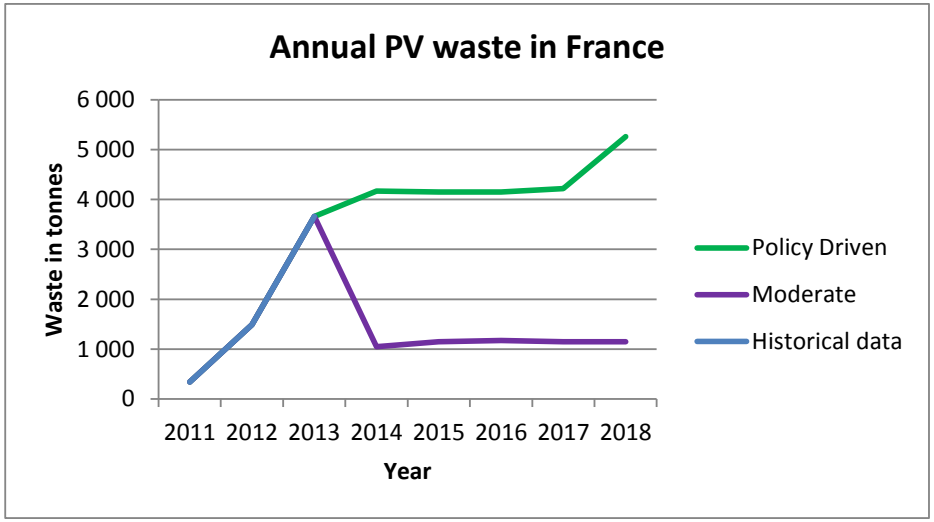
According to the moderate scenario, 15,049 tonnes of waste will be produced in the seven countries analysed, out of which Germany accounts for 46% (6,900 tonnes) in 2018 compared to 41,359 tonnes with the policy driven scenario, where Germany accounts for 51% (21,000 tonnes).

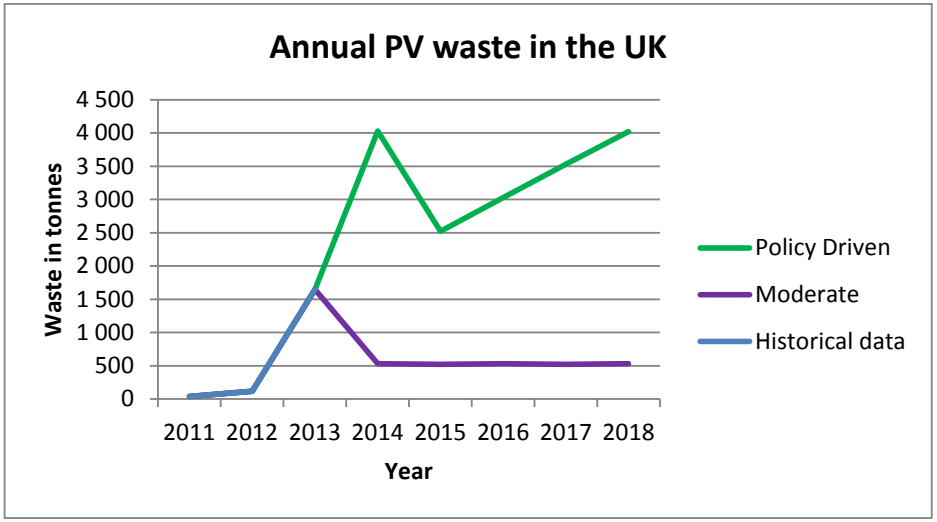
Of the seven selected countries, it can be noted that regardless of the scenario retained, the forecasts show that for Belgium and Italy, a peak in annual production of photovoltaic waste will occur in 2013 (1,602 tonnes for Belgium and 18,560 tonnes for Italy). The huge installation policies of the last few years have slowed down, and the breakage and failure volumes of modules during the early years are significantly higher than the historical waste which represents a very small portion of the volumes collected.





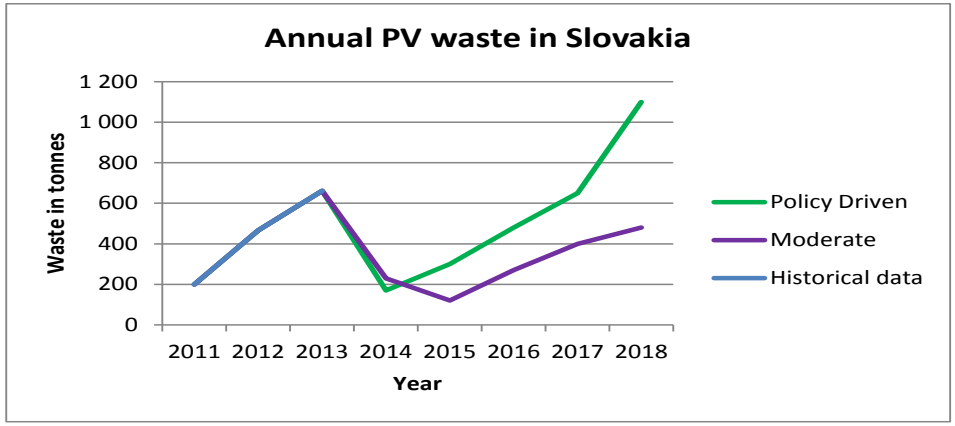
In France and the United Kingdom, energy policies will have a significant impact on installations, and consequently on the photovoltaic waste volumes between 2013 and 2018. The moderate scenario generates 1,150 tonnes of photovoltaic waste in France and 530 tonnes for the United Kingdom in 2018 compared to 5,260 tonnes in France and 4,020 tonnes in the United Kingdom with the policy driven scenario. Regulatory support would therefore result in an increase of waste volumes by 357% in France and 658% in the United Kingdom.

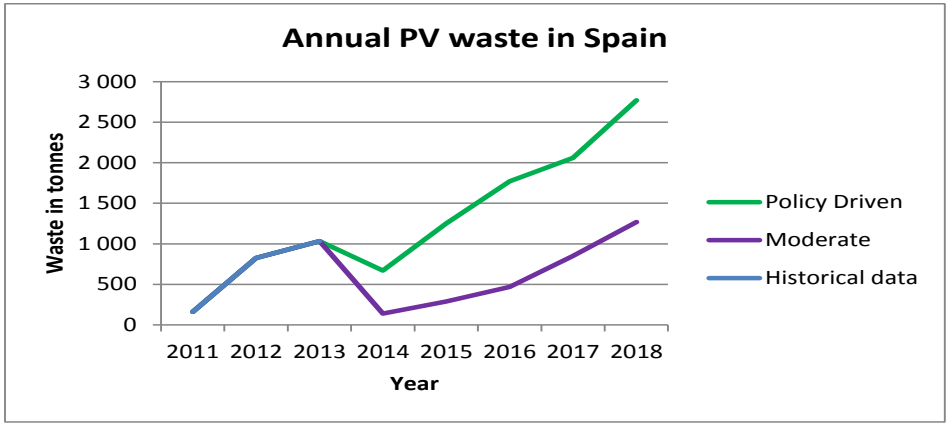


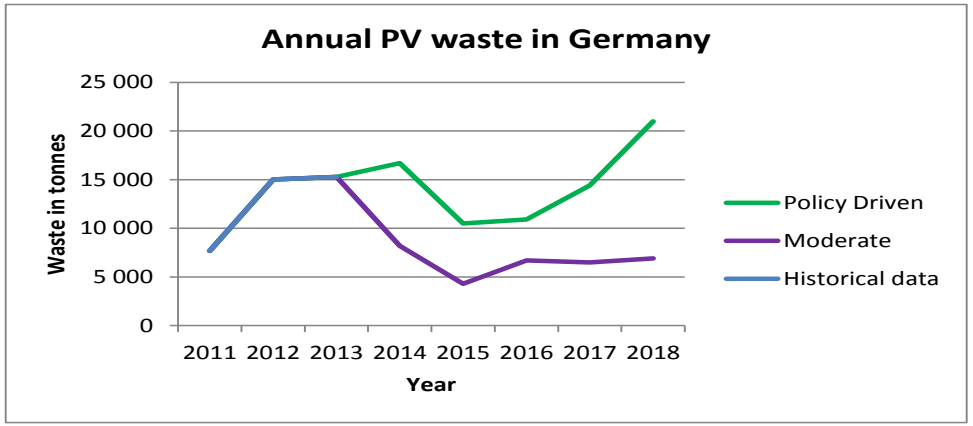


For Slovakia, Spain and Germany, the trends do not vary depending on the scenarios. The trend starts with a slight dip before increasing. For Slovakia, this decrease corresponds to a significant reduction in prices which is just below € 0.20 / kWH according to EPIA. In Spain, this decrease can be explained by the establishment of a moratorium on the development of new capacity generation, which has resulted in the cessation of all support mechanisms for photovoltaics. With regards to Germany, this decrease can be linked to the decision to drastically cut feed-in-tariffs.

The moderate scenario produces 480 tonnes of photovoltaic waste in Slovakia, 1,270 tonnes in Spain and 6,900 tonnes in Germany compared to the policy driven projection which sees Slovakia produce 1,100 tonnes of waste, 2,770 tonnes in Spain and 21,000 tonnes in Germany. Favourable energy policies would result in an increase of waste in Slovakia of 129%, 57% in Spain and 204% in Germany.







Given these figures, it is clear that waste management will play a key role for the photovoltaic actors and that a clear regulatory framework is necessary in order to ensure the collection and recycling of photovoltaic waste.

II – The revision of the waste electrical and electronic equipment directive is a challenge and an opportunity

On 14 February 2014, the extended producer liability will be applicable to photovoltaic modules. This legal requirement, which aims to internalise costs related to recycling end of life products, accelerates waste management from this industry.

(i) Collection obligations

The revised version of the Waste Electrical and Electronic Equipment Directive (WEEE) was published on 24 July 2012 in the Official Journal of the European Union (Directive 2012/19/EU), following a co-decision procedure between the European Commission, the European Parliament and the Council.

For the first time, photovoltaic modules are included in the scope of the directive. The modules already represent a significant volume of the total marketed electrical and electronic equipment.

Thus, in France according to various statements, a total of 1.66 million tonnes of electrical and electronic equipment was placed on the French market in 2011. In this same year, 120,000 tonnes of photovoltaic modules were installed in France.

The current regulation defines a collection target of 45% of the average of products entering the market over the last three years. However, for a product with an average life span greater than 15 years on a market such as ours, these collection obligations cannot be attained and justify derogation objectives for photovoltaic modules. This option is clearly set out in the directive, specifically mentioning the problem with

photovoltaic modules. However, as the directive is currently being transposed in Europe, no clear definition of this derogation has yet emerged.

The WEEE also provides for a systematic selective treatment of some components and hazardous substances contained in electrical and electronic equipment (EEE), and achieving re-using and recycling goals as well as recovery objectives. Various manufacturers contacted during this study indicated that re-using so-called end of life modules appeared to be technically complicated as a re-certification of modules would be necessary and economically non-viable due to the costs of sorting the modules and the low yields that could be offered.

(ii) Positive value waste

Some waste recyclers already believe that end of life photovoltaic crystalline modules can generate a positive commercial value. The money gained from selling the raw materials extracted from photovoltaic modules, especially the older generation modules, currently covers recycling costs. As this type of module accounts for more than 90% of modules installed, this recovery provides a real opportunity for the photovoltaic industry. It will not be a source of additional income but it will enable collection costs to be partially subsidised, thus reducing the eco-contribution, which is paid by the end user. This will maintain the competitiveness of modules, meaning that grid parity[3] will be achieved earlier, which is the prerequisite for the success of solar energy as a widespread energy source.

[3] When the photovoltaic production costs are equal to the purchasing price of conventional electricity, which is ever increasing, grid parity will have been attained

Table 4: Current technologies

Technology	Crystalline silicon	Thin film
Type	Mono-crystalline silicon (c-Si)	Amorphous silicon (a-Si)
	Poly-silicium (pc-Si/mc-Si)	Cadmium telluride (CdTe)
		Copper, indium, gallium et selenium (CIGS)

Source: EPIA

III – Structuring of collection and recycling

The first collection and recycling solutions have been developed by the photovoltaic industry. With the increasing waste volumes needed to be recycled, new players are entering the arena.

(i) Existing waste collection agencies

Today there are currently two continental waste collection agencies operating in Europe for the photovoltaic industry, PV Cycle and CERES. National agencies are also available with eco-organisations operating in certain countries like Italy for example.

Pan-European solutions have the advantage of offering a service across the whole of the EU and making it easier for manufacturers. This way, manufacturers deal with one agency ensuring compliance on all of their markets. These national solutions can be advantageous for small manufacturers operating in a single member state. However, the sheer force in numbers is particularly important and organisations collecting the largest volumes benefit from the scale effect making them much more competitive.

Collection mainly takes place via voluntary drop-off points setup by photovoltaic module installers and distributors. The volumes from the voluntary drop off points are then combined and taken to an approved recycling centre to be processed in accordance with existing national and European regulation.

(ii) Waste collection to date

The waste volumes collected are growing exponentially, mainly due to the strong increase in photovoltaic installations since 2000.

PV Cycle claims to have collected close to 3,700 tonnes in 2012. During this same period, CERES has collected 1,200 tonnes. This corresponds to an uptake of 10% of the potential photovoltaic waste volumes.

This low uptake rate, constantly increasing, is largely due to consumers being unaware of their rights. In addition, as there is no legal requirement to collect photovoltaic modules before 14 February 2014, some waste volumes are currently stored by third parties awaiting the emergence of recyclers capable of managing large volumes.

(iii) Waste processing solutions

At first, the recycling of end of life modules consisted of de-laminating the panel in order to recover the glass only. This costly solution was not environmentally acceptable as most of the cells and backsheets ended up incinerated or buried.

More advanced waste processing solutions have emerged in recent years and using these methods it is possible to recover the rare metals used in crystalline photovoltaic modules. Waste processing solutions also exist for thin film and Cadmium telluride (CdTe) modules but recycling these modules is not economically viable in itself, therefore resulting in a higher eco-contribution compared to the classic crystalline modules.

In addition, processing solutions depend on the technology used in the modules to be recycled. For this reason, specialised manufacturers are increasingly eager to recycle photovoltaic waste themselves.

Table 5: Identified recyclers

Recyclers	Technologies processed	Country
Calyxo	Thin film	Germany
First Solar	Thin film (CdTe only)	United States
Lôser Chemie	Thin film	Germany
Photocycle	Cristallins	France
Recupyl	Cristallins	France

Source: CERES

The principal difficulty encountered regarding the recycling of photovoltaic modules is financial. The recycling processes are costly and the waste volumes are still fairly low with regards to industrialising these processes. Today, the most advanced industrialists are able to recycle a module up to 90% of its weight. Technically, it is possible to increase this rate however, as the marginal cost of recycling increases, in practice it becomes counter-productive and may encourage 'lone ranger' attitudes in order to avoid this overhead.

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In conclusion, over the last two years Europe has experienced extremely strong growth in photovoltaic installations despite the economic crisis. This growth is set to continue in Europe but at a slower rate. Countries such as the United States, China and India will take the lead. It can be observed that regardless of the scenario retained, photovoltaic waste volumes are increasing exponentially. According to EPIA, the moderate scenario could generate a global market of 48GW and 84GW with the policy driven forecast.

Since 2007, the photovoltaic industry is organised to collect and recycle photovoltaic waste. In 2011, the WEEE Directive was reviewed to include photovoltaic modules in its scope, meaning that the extended producer liability is now applicable to this industry. New players are positioning themselves on this promising market. Collection solutions already benefit from a few years' experience whereas recyclers are only just emerging. Waste volumes collected leave space for a limited number of actors, in the medium term, able to reduce their average collection costs. This consolidation is principally driven by increasing waste volumes and decreasing collection costs.

On the other hand, recyclers tend to group themselves into competing central purchasing bodies. These groups include a glass manufacturer as well as companies specialised in the different technologies required to separate the various components in the modules to be recycled. Recycling crystalline modules produces a positive commercial value and it is plausible to imagine that the producer or holder of photovoltaic waste will be able to make a profit from this, albeit limited in the medium term.

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CERES

CERES is a pan-European organisation which collects and recycles used photovoltaic modules.

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