POLITECNICO DI MILANO

Closed loop supply chain: drivers and barriers analysis

Case study: Solar sector

Author: Giorgio Azzarone

Supervisor: Prof. Thomas E. Johnsen

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Abstract

The following thesis will describe the concept of Closed-loop supply chain and it will focus on the analysis of the opportunities and barriers to its adoption.. This work concentrates concentrating on a specific case study: the solar sector, focusing the attention is was on a particular community . The case study made the chance to go more deeply on what are the issues related to this change in a specific sector. This type of approach made the research more valid since it will be based on a real case study combining literature knowledge with empirical data and opinions by experts about the argument, making real examples, connecting also primary literature research with actual results. Considering that interview were gathered on a specific sector, the specific validity of the results was influenced by that. Furthermore, almost every result that came in, was from a Italian respondent, because geographically, the results in this research were limited to Italian market.

Sommario

In base a fattori ambientali, giuridici, sociali, ed economici , reverse logistics e problematiche legate alla Closed-loop supply chain (CLSC) hanno attirato l'attenzione sia tra il mondo accademico e gli operatori. Questa dedizione è evidente dal gran numero di pubblicazioni su giornali scientifici che sono state pubblicati .
CLSC è stata definita come "la progettazione, il controllo e il funzionamento di un sistema di massimizzare la value creation per l'intero ciclo di vita di un prodotto con recupero del valore di diverse modalità e rendimenti nel corso del tempo".
In aggiunta a ciò, negli ultimi anni, le aziende sono in costante desiderio a migliorare la progettazione delle loro catene di approvvigionamento, a causa della crescita del mercato accelerata, forte concorrenza e deterrenza economica dei mercati globali attuali. Nonostante questo, dilemmi economici ambientali tecnologiche sociali per quanto riguarda argomento CLSC sono diversi. Ad esempio, gli investimenti in risorse tecniche e operative sono necessari per creare CLSCs. Inoltre, i governi, vista la crescente quantità di rifiuti, stanno costringendo a questo cambiamento, cercando di impostare il percorso per l'adozione in futuro di un settore più sostenibile. Per esempio, il nuovo RAEE (Rifiuti di apparecchiature elettriche ed elettroniche, 2012) direttiva europea, ha

dichiarato che le aziende dovranno gestire correttamente gli end-of-life products (EOL) per lo smaltimento appropriato o per il recupero. Le aziende per questo motivo, stanno esaminando flusso inverso della catena di fornitura per differenziarsi e sfruttare le potenzialità del prodotto restituito, di recuperare quanto più valore possibile, e costantemente rivalutare la catena di fornitura con maggiore efficienza e precisione di funzionamento processi operativi.

Al giorno d'oggi, recuperando valore economico per EOL prodotti sta diventando di grande importanza. È in espansione un grande business intorno a questi problemi, che coinvolge anche i nuovi sistemi volti a estendere la catena di approvvigionamento e, potenzialmente, chiudendola in alcuni casi. Infatti, la prospettiva sta cambiando e filiera non è più il flusso di prodotti in avanti, ma anche nel senso opposto.

Il seguente lavoro ha avuto lo scopo di descrivere ciò che sono oggi le forze e le barriere all'adozione di una filiera a ciclo chiuso. Gli obiettivi di questa ricerca sono stati prendere spunto dallo stato attuale di un settore specifico, il fotovoltaico, per estrapolare in linea più generale i fattori ambientali che potranno portare allo sviluppo di un CLSC. Questo lavoro si fonda principalmente su interviste ai responsabili delle aziende ed esperti . Dal momento che gli attori coinvolti per raggiungere questo tipo di obiettivo sono stati diversi, la tesi incentrata su uno specifico caso di studio, il settore solare. Considerando che i dato sono stati raccolti su un settore specifico, la validità specifica degli ultimi è stata influenzata da questo. Geograficamente, i risultati di questa ricerca sono stati limitati a un paese, l'Italia. La ricerca futura dovrebbe cercare di allargare l'area geografica per ottenere maggiore efficacia, date le diverse influenze culturali per ogni paese.

Per quanto riguarda le interviste, la gente è stato chiesto di parlare di tematiche quali il riciclo e la loro percezione sul tema. Questo è veramente difficile da controllare. Percezione e realtà a volte sono molto diverse.

Dopo aver eseguito queste ricerche, è apparso chiaro che in termini di impegno generale, il concetto di CLSC è ancora interessante da studiare e approfondire, ma al giorno d'oggi la maggior contributo su questo tema è ancora fatta dalle università. Il motivo principale a è il fatto che le aziende percepiscono l' EoL come problema da risolvere e non un'opportunità di business da perseguire. Il progresso tecnologico non è ancora sufficiente a garantire un riciclo efficiente e i produttori sono ancora molto incerti su modificare le loro logistica e processi operativi. Quei manager che avranno una piena comprensione delle implicazioni strategiche delle loro decisioni saranno quelli che hanno le migliori possibilità di successo.

Al giorno d'oggi CLSC è ancora un modello ideale.

Le aziende hanno bisogno di positive networks per raggiungere questo obiettivo e governi hanno aiutato in questa direzione nel recente passato (vedi Raee e European directive 12/2015). Un ulteriore contributo sarà effettuata clienti finali e degli utenti, che dovranno essere sempre più coinvolti nelle attività di recupero. Approcci intenzionali hanno fallito in passato. L'attività del governo italiano è stata finora essenziale per segnare la strada verso il cambiamento. Diffusione di best practices, regolamentazione, e value creation sono essenziali, altrimenti gli studi e i congressi sulla sostenibilità avranno soltanto il valore di un esercizio filosofico fine a sé stesso.

CHAPTER 1: INTRODUCTION AND PROBLEM FORMULATION

1.1 Introduction

Based on environmental, legal, social, and economic factors, reverse logistics and closed-loop supply chain issues attracted attention among both academia and practitioners. This dedication is evident by the vast number of publications in scientific journals which have been published.

CLSCs have been defined as “the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time”. (Guide , 2009)

In addition to that, in recent years, companies are constantly aiming at improving the design of their supply chains, because of the accelerated market growth, fierce competition and economic deterrence of current global markets.

Despite this environmental, technological, social, economic dilemmas regarding CLSC topic are several. For example, investments in technical and operational resources are required to create CLSCs. Its economic viability is still uncertain since it is affected by not only the by uncertainty in yield, which takes into account the conversion rates of recycled components to ‘‘like-new’’ products, but also by the ambiguity surrounding customer demand, whose uncertainty is a known problem. (Georgiadis, Tsiakis, Longinidis, Sofioglou, 2011)

Furthermore, governments, since the increasing amount of wastes, are forcing to this change, trying to set the path for the adoption in future of a more sustainable industry. For instance, the new WEEE (Waste of electrical and electronic equipment, 2012) European directive stated that the companies will have to manage properly End of Life (Eol) products for an appropriate disposal or for recovery. Companies for this reason, are looking into incorporating the reverse flow of the supply chain to differentiate themselves and exploit the potential of the returned product, to recover as much value as possible, constantly re-evaluating the supply chain with more efficiency and accuracy of operational operational processes. (Gorskova, Ortega, 2012)

Nowadays , recovering economic value for EoL products is gaining importance. A big business around these issues is expanding, involving also new systems aimed at extend the supply chain and potentially closing it in some cases. In fact, the perspective is changing and supply chain is no longer the flow of products in forward direction, but also in the reverse one.

The following chapter will focus on the discussion of the CLSC topic, starting with a brief discussion of the current situation regarding this topic. Afterward the thesis purpose will be showed along with its delimitations.

1.2 Problem Formulation

Closed-loop supply chains (CLSC) focus on taking back products from customers and recovering added value by reusing the entire product, and/or some of its modules, components, and parts. Apparently, CLSC have enormous economic potential. Referring to the concept of sustainability, a closed-loop recycling system, is the best way to achieve this goal. However, as aspect always to consider and analyse is its implementation (Bayer, Bergmann, 2016).

However, little research has been conducted on how such closed-loop systems can be implemented, operated and enhanced in the long term. There is a lack of analysis of business opportunities, incentives and economic factors that go beyond environmental aspects. Studies about the technical operations of the processes are prevalent but not connected with critical success factors and the initiative such as enhancements and incentives for a sustainable industry. When planning and operating a supply chain, not only the technical part has to be considered but also how to achieve efficiency and effectiveness of the supply chain, the regulatory setting, value proposition, profitability and supply chain design (Tummala, Phillips, Johnson, 2006).

Organisations recognise the opportunities that exist to recover returned product value, yet there is little attention paid to developing a systematic way to do this due to the lack of knowledge about the reverse supply chain and its processes (Stock, Mulki, 2009).

Some companies therefore do not utilise their returned products and processes efficiently thus losing the value and the potential to reduce costs and increase profits. (7) Andel (1997) states: *'[. . .]* by ignoring the efficient return and refurbishment or disposal of products, many companies miss out a significant return on investment.'

The driving forces for CLSC implementation are several, like the rapid diminishment of raw material sources, decreasing space in landfills and increasing level of pollution. Some of the drivers associated with these forces are governmental regulation which more and more often require that the manufacturer take back the end-of-life products and customer perspective on environmental issues.

1.3 Purpose

The purpose of this thesis is to investigate how product returns are managed by the industrial system, giving an insight on what are the

- Motivations and barriers for the potential of recovery options in the future.
- The current state of the industry (focusing on a specific case study), with particular focus regarding information flow regarding recycling activities and opportunities
- Environmental, social, technological factors leading to the development of an extended environmental supply chain.

This thesis is developed in order to gain more empirical information about what are the motivation surrounding CLSC implementation. This work relies on interviews to companies' managers and technical experts. The focus will be on a case study on the Photovoltaic sector, in order to understand more deeply what are the join forces related to this change. A particular focus will be made on the opportunities of recycling and re-processing for the sector of interest, the solar. People working in different companies will be interviewed. A general opinion on the topic from these professionals will be relevant to draw conclusions.

1.4 Delimitations

- Due to geographical and time constraints the study is limited to few companies, therefore, in order to have a more complete idea of the closed-loop strategy opportunities in the solar energy technologies, further companies' analysis is needed.
- The analysis on solar energy is focused on the Italian market, with companies coming mainly from Italy, so our considerations can't be generalized to the whole industry.
- The research will focus on the network and not to a specific firm or plant, for this reason the results will not have a precise target.
- The data will be analysed in an qualitative way with few quantitative hints, caused by the restricted amount of opinion gathered by the companies.

CHAPTER 2 : TOWARDS CLOSED LOOP SUPPLY CHAIN

2.1 Introduction

The following chapter will give an insight of the evolution of CLSC's concept, starting from past researches which will set the path to the description of the different supply chain schemes developed over the years, giving also a brief explanation of Eol management and the European directives related to it. Literature review is important because along the years the number of publications surrounding recovering activities increased systematically. The contents of the researches followed the evolution of the perspective that changed along the years. First the focus of the researches was mainly on sustainable and green economy issues. Afterwards reverse logistics concept was built up and it set the way to the definition of CLSC and its following detailed studies. Since different studies and approaches and schemes about supply chains and recovery issue were developed in the past, it's important to have a focus on the evolution of them, and then explain the peculiarities of this research

After that there will be a focus of the different factors/drivers influencing companies decisions regarding CLSC's. Different nomenclature were given to each factor along the years, an explanation of those will be made. In conclusion of this chapter, the type of drivers chosen particularly for this thesis will be described, listed, to be examined in depth in a later part of the work, together with the results gathered by this study.

2.2 Literature review

This research tries to clarify several aspect around the evolution of the CLSC concept, starting from a brief systematic analysis of the contents of the previous researches. Then we will focus on Supply management, it will be explained what traditional and extended supply chain are , and finally what CLSC entails and its characteristics.

2.2.1 Previous researches towards CLSC

Between 1998 and 2004 the maximum number of papers published regarding reverse logistics per year was five. Between 2005 and 2009 this number increased to 13. As of the year 2010 publications significantly rose. Until the 2014, 77 articles were published making up. This reflects the increasing interest in topics of value creation in Reverse Supply Chains and Closed Loop Supply Chain over years. (Govindan,Soleimani,Kannan, 2014).

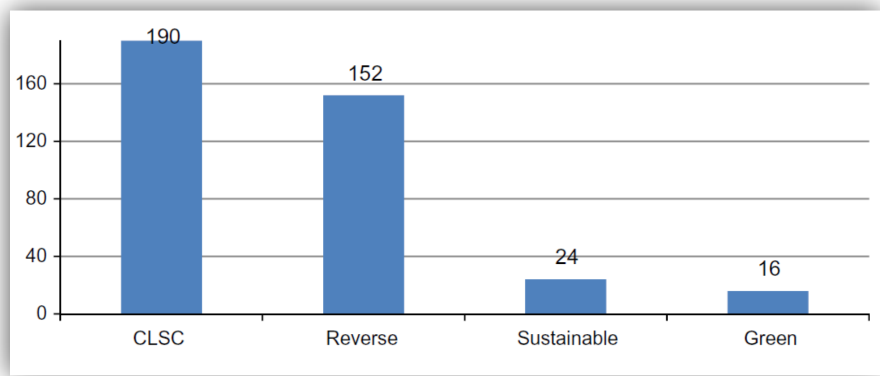
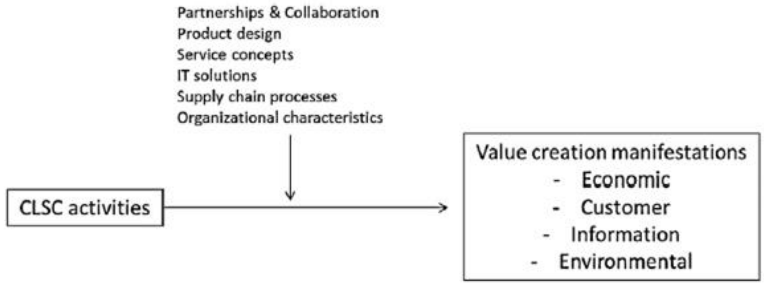


Fig. 1. The main fields of study of CSLC

Source : Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future, 2014, Govindan , Soleimani , Devika Kannan

Given the fact that only few studies were published before 2000, these results confirm that value creation in CLSCs is a 21st century concept (Govindan,Soleimani,Kannan, 2014). This can be linked to parallel developments in supply chain literature. Value creation topics such as the value chain or value co-creation gain increasing interest in the supply chain literature of the last decade. Recently, we have seen a large amount of researches on CLSCs, as a consequence of the growing importance of the study.



The number of publications across 2007 and 2013 is around 55 per year,

Fig. 2 Value creation in CLSC

SOURCE: Understanding value creation in closed loop supply chains , 2015, Schenkel,Caniëls, Krikke, van der Laanc pg 9

382 in total. The general categorizations of different studies are analyzed and a portion of each is illustrated in Fig.2 showing the percentage of various categorization portions from all papers. As we notice 190 out of 382 were focused on Closed-loop supply chain topic. The most of these papers focused on the CLSC concept describing different supply networks how actors should behave in terms of organizational policies in order to achieve this goal. On the other hand another focus was made through the analysis of the essential value creation drivers for the implementation of a CLSC, as summarized in the graph above.

2.2.2 Supply chain management

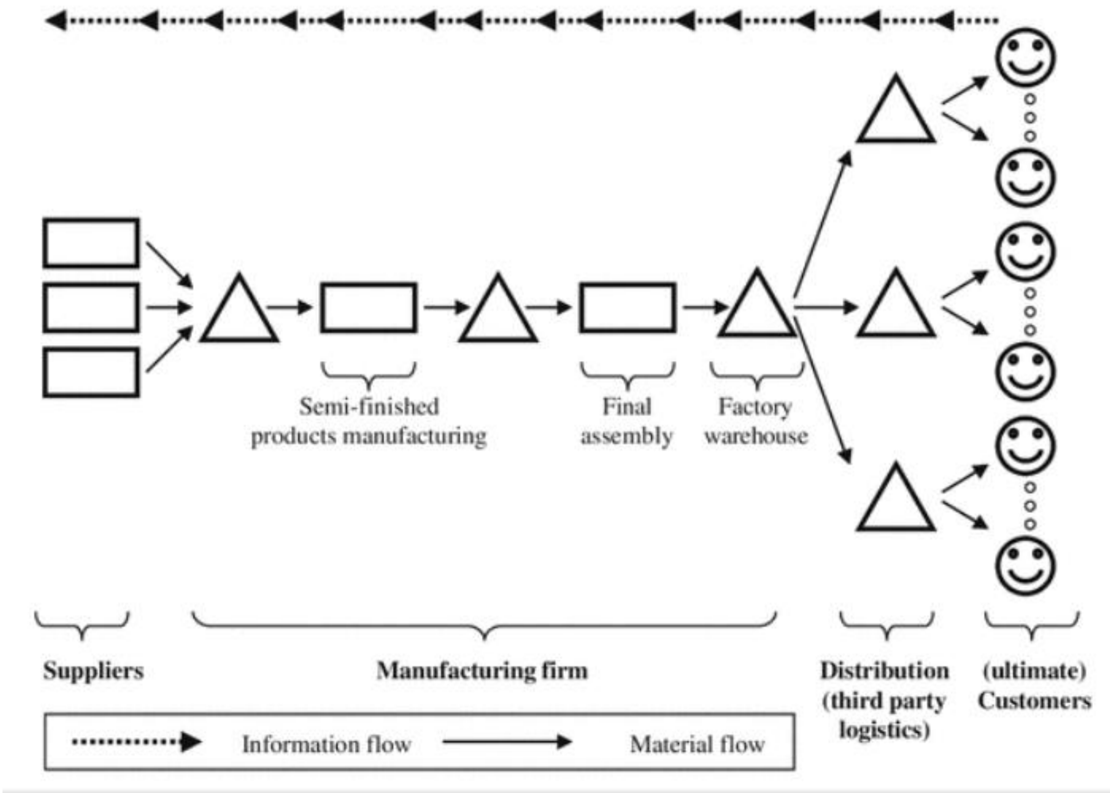


Fig.3 Supply chain example

Source: Stadtler, 2014, *Supply chain management: an overview,* Springer Texts in Business and Economics pp 3-28

Before focusing on Closed loop supply chain concept, it's better to define briefly what does it mean Supply chain management (SCM). The origin of supply chain management are related to Forrester, 1958, which stated that "Management is on the verge of a major breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower, and capital equipment. The way these five flow systems interlock to amplify one another and to cause change and fluctuation will form the basis for anticipating the effects of decisions, policies, organizational forms, and investment choices."

SCM focus on analysis is the supply chain, which represents a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form in the form of products and services in the hands of the ultimate customer. In fact, the supply chain management, is driven by the market not by the suppliers and also the work chain can be easily replaced by network since it can involve a high number of actors with different flows (fig. 3) (Cristopher, 2005).

Aitken (2007) for this reason define the supply chain as " network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users".

Mentzer et al., 2001, included two different flows and separate information concepts stating that SCM is a "set of entities (organizations and individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"

In the past most organizations have only paid attention to what was happening within their "four walls". Few businesses understood, much less managed , the entire chain of activities that ultimately delivered products to the final customer. The result was disjointed and often ineffective supply chains. (Handfield, 2011)

The thing is that the SCM purpose is not only to better manage products focusing only on one company perspective but the supply chain is analyzed and managed in order to achieve the best outcome for the whole system (Cooper, Ellram, 1993)

Supply chain management, then, is the active management of supply chain activities to maximize customer value and achieve a sustainable competitive advantage. It represents a conscious effort by the supply chain firms to develop and run supply chains in the most effective & efficient ways possible. Supply chain activities cover everything from product development, sourcing, production, and logistics, as well as the information systems needed to coordinate these activities.

Along the years the supply chains were considered with different perspectives, starting from the concept of traditional supply chain, ending with the adoption of a new nomenclature, which implies not only differences in operation in management processes, but also focus on the path made by the products/materials within the supply chain network.

1.2.3 Forward supply chain

A supply chain considering its traditional form (forward supply chain), is a combination of processes to fulfil customers’ requests. It includes all possible individuals or companies like suppliers, manufacturers, transporters, warehouses, retailers, and

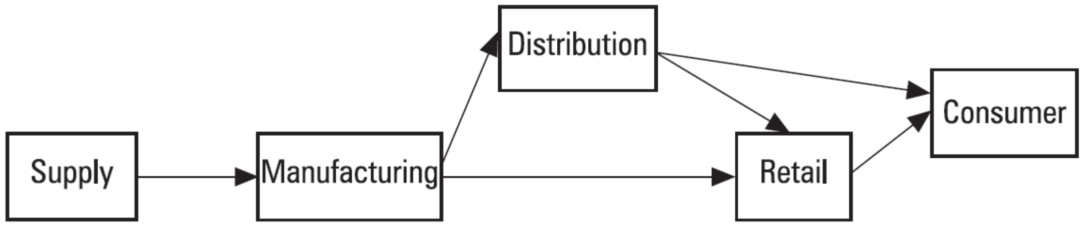


Fig.4 Description of a forward supply chain Source: Beamon,1999

integrated manufacturing process wherein raw materials are converted into final products, then delivered to customers. Under this definition, the supply chain includes only those activities associated with manufacturing, from raw material acquisition to final product delivery. It is characterised by a supply chain in which there is no flow back from the customer, a set of firms that pass materials forward raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain. (La Londe , Masters, 1994)

Design, modeling, and analysis of the traditional supply chain was focused on optimizing the procurement of raw materials from suppliers and the distribution of products to customers. The complexity of a traditional supply chain is defined by a number of echelons or cost centres, where an echelon is a place for holding inventory. Usually each echelon is characterised by a perceived demand for products, a production (value-adding) process, information on current performance, disturbances (e.g. breakdowns, delays), decision points where the information is brought together, transmission lags for all activities and decision rules based on all company procedures, for example, changing stock levels, placing new orders, production requirements (McKinnon , Cullinane, Whiteing, 2010).

(Beamon,1999) identified the issues considered within this scope of analysis:

- Production/distribution scheduling: manufacturing and/or distribution schedule.

- Inventory levels: determining the amount and location of every raw material, subassembly, and final assembly storage.

- Number of stages (echelons): determining the number of stages (or echelons) that

will comprise the supply chain. This involves either increasing or decreasing the chain's level of vertical integration by combining (or eliminating) stages or separating (or adding) stages, respectively.

- Distribution center (DC): determining which DC(s) will serve which customer(s).

- Plant determining which plant(s) will manufacture which product(s).

- Buyer supplier relationships: determining and developing critical aspects of the buyer-supplier relationship.

-Product differentiation step specification: determining the step within the process of product manufacturing at which the product should be differentiated (or specialized).

-Number of product types held in inventory: determining the number of different product types

Reverse logistics is much more difficult to forecast, because it starts from customers, Moreover, different products could have very different returns rates, depending on the quality and on a series of factors dues to the customers, which makes forecasting the return more complicate then forecasting the demand.

1.2.4 Extended supply chain

The evolution of manufacturing enterprises and to fully integrated management led to the extension of the concept in extended supply chain, which is based on the recognition that the environmental effects of the organization environmental impacts of goods and

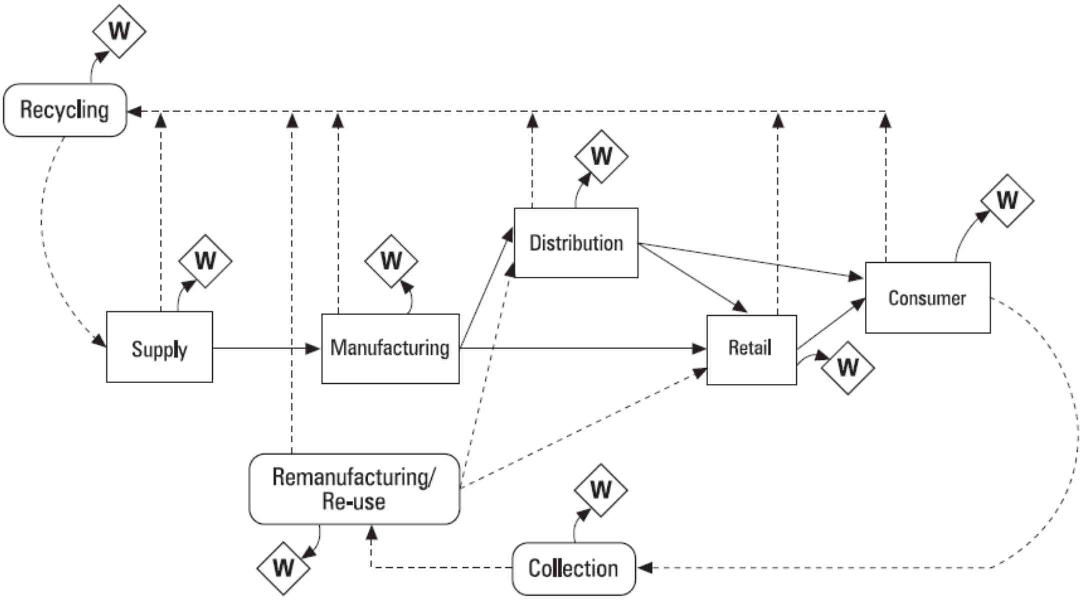


Fig.5a Extended supply chain Source: Beamon(1999)

processes from the extraction of raw materials, to the use of goods produced, to the final disposal of those goods (Beamon, 1999). The fully integrated, extended supply chain contains all of the elements of the traditional supply chain but extends the one way chain to construct a semi-closed loop that includes product and packaging recycling, re-use, and/or remanufacturing operations. Focusing on extended supply chain includes an understanding of the complicating characteristics of remanufacturing and reverse logistics, and the differences with traditional operations management activities (Guide, 2000); the characterization of common activities in reverse supply chains (Guide , Van Wassenhove 2001); and the identification of different types of products returns with their specific impact on the reverse supply chain (Thierry, Salomon, van Nunen, Van Wassenhove, 1995).

Reverse logistics

In the nineties, a formal definition of reverse logistics was diffused by the council of Logistics management, underlining the reverse logistics (Brito, Dekker, 2004).The term often used to refer to the role of logistics is recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal (Brito, Dekker, 2004).

Kopicki in his book “Reuse and recycling: reverse logistics opportunities”, 1993, gives the definition of reverse logistics based upon the direction of flow as “Reverse Logistics is a broad term referring to the logistics management and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution...which causes goods and information to flow in the opposite direction of normal logistics activities.”

Pohlen, Farris (1992) define Reverse Logistics as “the movement of goods from a consumer towards a producer in a channel of distribution.”

Hazen, Cegielski, Hanna, 2011 stated that reverse logistics contain the product components, materials and its packaging from customers.

Since the concept of reverse logistics came out it was described in several ways, it is important to mention that reverse logistics is “not necessarily a symmetric picture of forward distribution”. (Tibben-Lembke, Rogers, 2002). The differences are several and they involve several operational and logistics issues. Here there is a summary of the differences between the two direction of the flows:

Forward	Reverse
Forecasting relatively straightforward	Forecasting more difficult
One to many transportation	Many to one transportation
Product quality uniform	Product quality not uniform
Product packaging uniform	Product packaging often damaged
Destination/routing clear	Destination/routing unclear
Standardized channel	Exception driven
Disposition options clear	Disposition not clear
Pricing relatively uniform	Pricing dependent on many factors
Importance of speed recognized	Speed often not considered a priority
Forward distribution costs closely monitored by accounting systems	Reverse costs less directly visible
Inventory management consistent	Inventory management not consistent
Product lifecycle manageable	Product lifecycle issues more complex
Negotiation between parties straightforward	Negotiation complicated by additional considerations
Marketing methods well-known	Marketing complicated by several factors
Real-time information readily available to track product	Visibility of process less transparent

Fig 5b Differences between forward flows and reverse flows Source: Rogers, Tibben-Lembke, , 2002

1. Difficult to forecast

As the reverse flow initiate from the customers, it is almost completely uncertain. However, a general trend can be observed, that is, reverse logistics flow tends to follow trends in forward flows, with some lag. Sales and promotions, for example, will be followed by a wave of returned product.

This means that the information about the demand, the seasonal picks, the promotions and the sales is a strategic element to be shared, from the marketing departments, with the forward and the reverse logistics in order to plan in advance the resources needed at any time.

Anyway, different products could have very different returns rates, depending on the quality and on a series of factors dues to the customers, which makes forecasting the return more complicate then forecasting the demand.

2. Many to one transportation

The typical trade off of the transportation is combining forward and backward transportation, because it might lead to significant savings by one side, but some difficulties have to be overcome and some constrains put to the supply chain.

Difficulties are some physics ones: if a single truck has to be used to let new products and to keep returned ones from the retail stores, at any stop the previously charged returns may be offloaded in order to allow the new product to be offloaded as well.

Furthermore, the return centers should be located near to the distribution centers in order to save on the distance made by the trucks.

3. Product and packaging quality

Collecting returned products is complicated by the packaging, which is often not complete, damaged or opened, making handling it more complicate. A incomplete package rises the risk of damages for the product and often makes difficult the identification of the product in the reverse channel. Standard for packaging in the reverse flow are needed.

4. Destination/routing not clear

Due to the great range of possible destination of each returned item, determining where a particular one will be shipped may need a significant amount of time. Determining destination needs to be more automatic and rapid, through tests and clear dispositions.

5. Disposition options not clear

The secondary market is often marked by the rules and the restrictions imposed by the vendors, that make more difficult to identify the destination of the items.

6. Pricing not uniform

The range of prices that an item in the reverse flow is sold for is great because of the fact that not all product in the reverse flow is first quality. Life-cycle issues play also an important role: it may be difficult to discern, ahead of time, when a product has reached the point where it will or will not be attractive to a particular broker / buyer.

7. Different importance of speed

As the return process is not controlled, its rate is independent from the enterprise and the possible customers of returned products can not complain about it. Time passed in return center may be a significant factor in reducing a product's value.

8. Differences in nature and visibility of costs

Transport costs are higher then in forward logistics, because of the less-structured transport flow. Handling costs are much higher cause of the not uniform package and the variety of the products. Difficulties in the identification of returns makes the cost of the reverse flow to be higher. There are less dangers related to theft and shrinkage.

9. Inventory management not consistent

In reverse logistics, arrival of products tends to be very random and the price at which the product will be sold is also unknown, that make the hypothesis for traditional inventory management inconsistent. The highest managers often ask to sell quickly the returned items before the end of the quarter, in order to decrease inventory values for reporting purpose, even if this does not bring to optimisation of the value recaptured. New indexes should be created in an ecological and environmental framework, because it is not consistent to treat the reverse logistics as a traditional branch of the enterprise.

10. Product life-cycle issues more complex

The life-cycle length determines the attractiveness of a products and influences the value that is possible to recapture. A series of strategic informations are needed from the market in order to determine whether an item is still attractive or not.

11. Negotiation less straightforward

Negotiation is made more complicated than with new product because the quality of the product is not uniform, because of the buyer's special requests and because of the vendor's concerns about the secondary market.

There are special rules concerning the value of the items, that is, basing on the broker's wishes of treat great quantity of product, having large quantity of attractive items increases their value. Anyway, this is only true to an extent.

12. Marketing difficulties

Marketing difficulties rise from vendor's concerns and from the necessity of the price to be significantly lower than the price of new product. Furthermore, a retailer cannot assure to customers a consistent supply of products, due to the variety of the returns.

13. Visibility of entire process lower

Because reverse logistics is generally a lower priority for firms, the Information System resources necessary to increase its efficiency and effectiveness generally are not available.

The focus of product return programs has traditionally been on cost minimization. In many industries, learning to manage the reverse flow is of prime importance, because the large volume of product returned represents a significant cost. In addition to the cost of producing and transporting the product, the firm may face significant costs in disposing of the product (Rogers, Tibben-Lembke, 2001). Product return programs need to be organized in a very good way so that low cost of the product can be achieved. 10

Actually, repair, refurbishment, remanufacturing and remarketing, cannibalization and recycling of raw materials are all examples of recovery options that can represent an attractive business opportunity, sustainable development, and a way of achieving competitive advantage (De Koster, De Brito,Van de Vendel, 2002)
Several regulations have been introduced by the European Union in order to foster this activities, in particular the Directive on Waste Electronic and Electrical Equipment (WEEE), which imposes to recycle end of life products to companies operating in the electric and electronic sector. This regulation can be implemented also thanks to collective schemes, which provide an efficient and effective system for the collection and recycling of wastes. They adhere to principles of environmentally sound

management, provide collection opportunities and do not place an extra financial burden on local governments.

Fig.5c Reverse supply chain processes Source: Prahinski , Kocabasoglu, 2006,

1.2.5 Closed-loop supply chain

Closed-loop supply chain (CLSC) is a supply chain network that "include the returns processes and the manufacturer has the intent of capturing additional value and further integrating all supplychain activities" (Guide, 2003).The major difference between CLSC and traditional forward supply chains is for a forward supply chain the customer is at the end of the processes, and for a there is value to be recovered from the customer or end-user (Guide,Van Wassenhove 2003). A CLSC as extended supply chain is composed by forward and reverse supply chain, it comprehends the series of activities required to retrieve a used product from a customer and either dispose or reuse it. CLSC as a difference, identifies a direction, a scope. CLSC concept start from the assumption *"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs*." (Brundtland, 1987).

The report put forward that economic development should be possible without harming the environment and depleting natural resources. The definition itself is rather informal and does not provide one with sufficient handles to measure sustainability, let alone to define transitions towards sustainable operations. A popular way of understanding the concept of sustainability is to look at it from three perspectives: people (social impact), planet (environmental impact) and profit (economic impact). Sustainability has now been broken down into three dimensions that need to be measured separately. Still it is unclear what combination of scores would define 'sustainability'.

Managing CLSC include managing the design, control and operation of a system in order to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time (Guide, Van Wassenhove, 2009). The importance of this definition is the explicit business point of view instead of other factors like legal, social responsibilities, or even operational and technical details.

CLSCs strive to coordinate forward and reverse operations in such a way that economic and/or ecological value is maximized. Besides the traditional forward processes, such as sourcing, manufacturing and distribution, CLSC include 5 key activities (Guide, Van Wassenhove 2001):

- acquisition / collection
- reverse logistics
- inspection and disposition
- reprocessing (remanufacturing / repair / recycle)
- remarketing

As the definition implies, a CLSC must evolve over time to take advantage of different product return types and volumes as well as changing market conditions. Consequently, the design, operation, and control of a CLSC are not static, one-time process decisions. Rather, the CLSC is an ever-evolving set of processes and related performance measurements. Generally, implementing a CLSC involves multiple decisions at the operational, tactical, and strategic levels. In addition, to make a business case for closing the loop, managers must focus on the value creation as opposed to mere cost avoidance. (Abbey, Guide, 2012)

CLSC configurations can be very different since they strictly depends on the characteristics of the product and the circumstances in which the product is to be collected. If the environmental impact is in the usage phase, then it makes sense to design for environmental efficiency and safety in the usage phase. Product recovery options very much depend on the economic lifespan. Sometimes it is better to recycle and replace the product with one that is environmentally more efficient and sometimes remanufacturing is the better option. Logistics could be an environmental bottleneck; the positive environmental impact of product recovery by far could outweighs the negative impacts of more logistics activities (Quariguasi, 2016)

As showed in the figure below, there are mainly 4 activities that enable the implementation of a Closed-Loop Supply Chain:

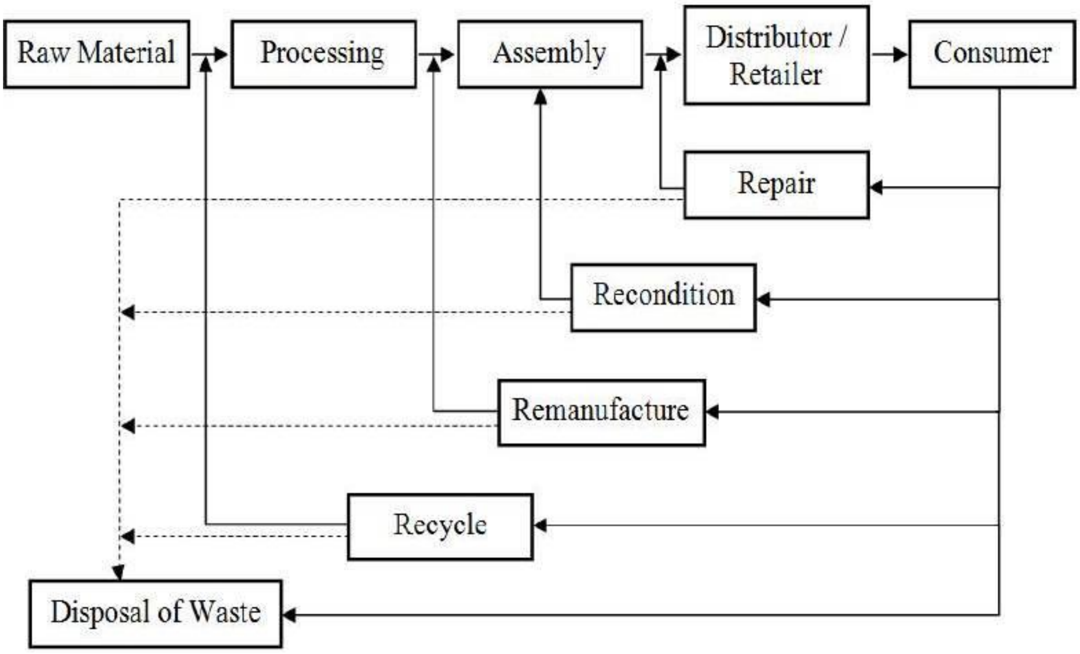


Fig. 6 Source: Industrial Eco-Efficency, Andrea Trianni, 2015

- **Repair:** it’s the most logical approach for closing the loop, consisting of fixing specific faults in order to extend the life cycle of the product.

- **Recondition**: it consists in the rebuilding or replace of som e major components, in order to bringing them again to a working condition

- **Remanufacture**: parts of the product are dismantled, cleaned and remanufactured to an “as new” specification. The process continues with the reassembly and final distribution.

- **Recycle**: “the series of activities by which discarded materials are collected, sorted, processed, and used in the production of new products”.

Recycling can offer several benefits, both from an environmental point of view and by increasing the supply security of materials. (Hagelüken, Lee-Shin , Carpentier, Heron 2013)

1.2.7 CLSC value

According to literature (Koppius , Özdemir-Akyıldırım, van der Laan., 2014), the advantages of resorting to a CLSC are different, and we can distinguish 4 categories of value:

- **Sourcing value:** it refers to all types of direct cost reductions and savings that can arise from CLSC practices (lower material costs, fewer manufacturing costs, fewer energy costs).

Through reprocessing strategies, product returns can be sold in secondary markets thus generating additional revenues for the firm or they can be used internally and reduce supply costs.

- **Environmental value**: reduced raw materials and natural resources consumption, waste reduction, less emissions from manufacturing.

Several waste management regulations have been introduced in the last decades, above all, the aforementioned WEEE. CLSC can enable manufacturers to take a proactive stance and ensure easy compliance with such regulations.

- **Customer value**: it refers to increased customer loyalty and better customer satisfaction, since an effective recollection system translates into a better service offered to customers. Higher sales deriving from eco-behaviour valuation from the customers

- **Informational value**: it refers to valuable data on customers, supply or on production, which can be acquired more easily through adopting CLSC practices.

However, there are several challenges and barriers that make its implementation difficult. Nowadays, the research on CLSC is focused on technical and operational issues, that need to be overcome in order to make reverse supply chain feasible for companies. However, even if remanufacturing is technically feasible, first of all it is necessary that the potential value recovery exceeds the costs of recovery operations. Then, to make it economically attractive, companies need sufficient quantities of used products, of the right quality and price and at the right time. Reconditioning and remanufacturing processes tend to be less predictable than traditional products, so making smart decision early in the chain is fundamental in order to make CLSC viable. Another important issue is the large number of actors in forward and reverse supply chains, that need to be extremely integrated in order to make the system as much effective as possible, since there is the need of designing the products at the beginning of the supply chain, by thinking already to the final steps of recycling.

Finally, in order to sell a recycled product, there is need to determine if there is demand for it or whether a new market must be created.

1.2.8 End of life management

Along with the CLSC concept is important to explain the concept of End-of-Life management. A product reach its end-of-life once it becomes dysfunctional for the owner/user, becoming what some classify as waste for the particular need the user has, according to Morselli et al., 2006. However, when a product no longer satisfies the initial user's need, this does not necessarily mean that it is in poor operational condition or has become obsolete. On the contrary, this could be an opportunity for its life to be extended by either being used for the same purposes by other users whose needs can be satisfied with this equipment, or by reusing the equipment or its parts and components, in which case it is necessary to dismantle the equipment to recover its parts. It is also possible to extend the use of the material contained within it through part, component or material recovery and recycling, better known as the end-of-life management.. Decisions related to managing the EoL are a consequence of recent directives, especially the WEEE.

1.2.8.1 Waste Electrical & Electronic Equipment (WEEE)

Waste of electrical and electronic equipment (WEEE) is one the fastest growing waste streams in the EU, with some 9 million tons generated in 2005, and expected to grow to more than 12 million tons by 2020.

Fig.8 WEEE directive

Source: ec.europa.eu/environment/waste/weee/index_en.htm

WEEE is a complex mixture of materials and components that because of their hazardous content, and if not properly managed, can cause major environmental and health problems.

In addition to that, the production of modern electronics requires the use of scarce and expensive resources (e.g. around 10% of total gold worldwide is used for their production). To improve the environmental management of WEEE and to contribute to a circular economy and enhance resource efficiency the improvement of collection, treatment and recycling of electronics at the end of their life is essential.

To address these problems two pieces of legislation have been put in place:

- The Directive on waste electrical and electronic equipment (WEEE Directive)
- The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive)

The first WEEE Directive (Directive 2002/96/EC) entered into force in February 2003. The Directive provided for the creation of collection schemes where consumers return their WEEE free of charge. These schemes aim to increase the recycling of WEEE and/or re-use.

In December 2008, the European Commission proposed to revise the Directive in order to tackle the fast increasing waste stream.

The new WEEE Directive 2012/19/EU entered into force on 13 August 2012 and became effective on 14 February 2014.

EU legislation restricting the use of hazardous substances in electrical and electronic equipment (RoHS Directive 2002/95/EC) entered into force in February 2003. The legislation requires heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives. In December 2008, the European Commission proposed to revise the Directive. The RoHS recast Directive 2011/65/EU became effective on 3 January 2013 (ec.europa.eu)

1.2.8.2 European commission

"Our planet and our economy cannot survive if we continue with the 'take, make, use and throw away' approach. We need to retain precious resources and fully exploit all the economic value within them. The circular economy is about reducing waste and protecting the environment, but it is also about a profound transformation of the way our entire economy works. By rethinking the way we produce, work and buy we can generate new opportunities and create new jobs. With today's package, we are delivering the comprehensive framework that will truly

enable this change to happen. It sets a credible and ambitious path for better waste management in Europe with supportive actions that cover the full product cycle. This mix of smart regulation and incentives at EU level will help businesses and consumers, as well as national and local authorities, to drive this transformation."

Vice-President Frans **Timmermans, responsible for sustainable development**

Another step forward in the adoption of a new perspective by the market world in general has been made also by the European commission adopted an ambitious step “to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs”. As the Commission said “The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy. The plans will extract the maximum value and use from all raw materials, products and waste, fostering energy savings and reducing Green House Gas emissions. The proposals cover the full lifecycle: from production and consumption to waste management and the market for secondary raw materials. This transition will be supported financially by ESIF funding, €650 million from Horizon 2020 (the EU funding programme for research and innovation), €5.5 billion from structural funds for waste management, and investments in the circular economy at national level.”

The actions adopted will include:

- **€650 million funds** under Horizon 2020 and **€5.5 billion** under the structural funds;
- Development of **quality standards for secondary raw materials** to increase the confidence of operators in the single market;
- Measures in the **Ecodesign working plan for 2015-2017** to promote reparability, durability and recyclability of products, in addition to energy efficiency;
- A **strategy on plastics in the circular economy**, addressing issues of recyclability, biodegradability, the presence of hazardous substances in plastics, and the Sustainable Development Goals **target for significantly reducing marine litter**;

- A series of **actions on water reuse** including a legislative proposal on minimum requirements for the reuse of wastewater.

1.3 Drivers classification for Closed Loop supply chain

The changing business market surrounding led to the classification of diffusion of different drivers to analyze the supply chains and the challenging issues for the development of CLSC.
Companies objectives like economic, corporate or marketing affect implementation of reverse logistics practices. In practice, the presence or absence of the factors are considered drivers or barriers to reverse logistics.

Several drivers were classified in the past, here there are the macro drivers that had been identified in the past by De Brito and Dekker identified in 2004, named as:
- Economic
- Legislation
- Corporate citizenship

1.3.1 Economics

The direct economic benefits include use of input materials, adding value with recovery and reduction of costs (De Brito, 2004). For instance, economic value can be gained from collecting metal scrap and offering it to steel companies as scrap metal which can be merged with virgin materials for further use. This could lead to production cost reduction for steel companies. Furthermore, closing the loop in supply chains implies cost such as production, distribution, material purchasing and after-sales service.

Indirect economic returns can be made by marketing and strategy underlining re-use commitment. For instance, companies may be encouraged in recovery activities for strategic reasons in order to preempt future legislation and even prevent it. Furthermore, recovery can also help in a ‘green-image’ building for companies in order to differentiate them from their competitors . ‘Green products’ offer new market opportunities for companies as customers become more aware of the environmental concerns (Fleischmann, Inderfurth ,Van Wassenhove ,1997).

1.3.2 Legislation

Then governmental legislation forced producers to take care of their End of Life (EOL) products. For instance, the Waste Electrical and Electronic Equipment (WEEE) directive (directive 2002/96/EC) became European law in 2003, which contains mandatory requirements on collection, recycling, and recovery for all types of electrical goods, with a minimum rate of 4 kilograms per head of population per annum (Georgiadis & Besiou, 2010). Since 13 August 2012, the recast WEEE (Waste Electrical and Electronic Equipment) Directive 2012/19/EU provides a legislative framework for extended producer responsibility of Photovoltaic modules at European scale. As from 14 February 2014, the collection, transport and treatment (recycling) of photovoltaic panels is regulated in every single European Union (EU) country(19). Originally launched in 2003, the Waste Electrical and Electronic Equipment Directive (WEEE) regulates the treatment of electrical and electronic waste at the end of their life cycle. The directive has been amended twice (“recasted”) in 2008 and 2012, resulting into an enlarged scope to include many new additional products. Photovoltaic (PV) (sector objective of the study) panels were introduced in the latest revision of 2012.

1.3.3 Corporate citizenship

Corporate citizenship involves the social responsibility of businesses and the extent to which they meet legal, ethical and economic responsibilities, as established by shareholders. It is receiving growing attention in the media, academia and the corporate world (20) (Pedersen, Andersen, 2006). Moreover, various stakeholders, including consumers, shareholders, Non-Governmental Organisations (NGOs), public authorities, trade unions, and international organisations, are showing an increasing interest in environmental and social issues related to international business . The goal is to produce higher standards of living and quality of life for the communities that surround them and still maintain profitability for stakeholders. The demand for socially responsible corporations continues to grow, encouraging investors, consumers and employees to use their individual power to negatively affect companies that do not share their values. Despite this, Bowen, Cousins, Lamming ,Faruk (2001) stated '*despite many multinational corporations' efforts to implement social and environmental issues in their supply chains, a gap exists between the desirability of supply chain sustainability in theory and the implementation of sustainability in supply chains in practice'.* Many years have passed after that speech.

Nowadays, in 2016, do companies realized that Closed-loop supply chain commitment will stimulate, in addition to the sustainability effort and the enhanced green image, higher customer satisfaction and higher corporate profitability?

2.4 Value creation for CLSC

Currently, the focus on the analysis about the drivers, was carried on involving the concept of value creation for CLSC. Different drivers were identified in order to promote CLSC. According to the literature the current perspective in analysing the supply chain is looking at the reason why the companies should change on CLSC perspective.

Drivers for CLSC	**Manifestations**

Environmental value	Corporate image, Green processes , ethical corporate responsibility, green products
Economic value	Cost reduction, revenues generation, risk reduction
Technological value	Technology progress, R&D commitment for innovation
Information value	Improved product/process design, lifecycle information, collect expertise, learn from customer satisfaction and sales

Fig 9. (source: Caniëlsa, Krikkea, van der Laanc 2015)

More fragmenting the analysis range and focus on value creation nowadays is the most widespread way to promote the Closed loop supply chain interest. It happened that the old drivers that were explained before are included in the new drivers, justifying the step of changing the perspective and not the content of the overall analysis made in the past, whom contents are still valid and interesting.

For the reasons I explained before, the current study will focus on these drivers

The figure below shows the growing attention along the years by the literature on these drivers and the overall increase of the total amount of articles published in the last years. (Caniëls, Krikkea, van der Laanc, 2015) It also shows the emergence of attention for the different value types aforementioned.

CHAPTER 3: SOLAR SECTOR CASE STUDY

3.1 Introduction

Photovoltaic (PV) is growing at a rapid pace in the last decade. It achieved a considerable attention as one of the low carbon most promising renewable energy alternatives since it can support the overall electricity production in the world.

PV industry has been continuously growing at a rapid pace over the recent years. Regarding the market trend for photovoltaic the journal Repubblica reported “Italy first in the world for the use of photovoltaics. That's right: our country is the one where solar energy well covers 8% of its energy consumption. Followed in ranking countries like Greece with 7.4% and Germany with 7.1%. Witness the International Energy Agency report (IEA), an intergovernmental organization that OECD collects 29 of the most industrialized countries “…”. After Italy, Greece and Germany, countries that use more photovoltaics are Belgium and Japan (around 4%), followed by Bulgaria, the Czech Republic and Australia (around 3.5%). China is only 21th , with only 1% of its requirements covered by the sun. Worse the US, 25% place with less than 1%.” These data confirm our country strong position in clean energy.

The chapter below is aimed at giving an thorough description of the status of photovoltaic technology and market, the Eol management for photovoltaic panels, underlying the opportunities in terms of recycling and the “Closing the Loop” in opportunities.

3.2 Technology

The term "Photovoltaic system" or more generally "System PV" means a combination of elements which enable the Direct conversion of solar radiation into electricity. The Photovoltaic performance in general depends on the incident irradiation, ambient temperature and thermal characteristic of the PV technology. Silicon crystalline PV modules are widely used in the world. New PV technologies with cheaper manufacturing cost compared to traditional silicon crystalline based modules are available in the international market these days such as; amorphous silicon (a-Si), Cadmium Telluride (CdTe) and Copper Indium Selenium (CIS). In addition, new standards and testing schemes are developed to be comparable with the new or improved technologies. Along with photovoltaics, belong to the system also equipment for regulation, control and energy storage produced; wiring and support structures (Cucchiella , D'Adamo , Rosa, 2015)

Generally, the elements that together constitute a photovoltaic system can be divided in two main categories:

- **Photovoltaic modules;**

- **Components Technical or BOS (balance of system):** made up of cables, electrical panels, inverters, batteries accumulation, charge controllers, support structures and anchor.

The key part of the system is the **generator** that represents the photovoltaic field, consisting of a set of modules capable of convert the intercepted solar radiation into electrical energy, giving rise to a direct current.

A PV module is constituted in turn by a certain number of cells, typically connected in

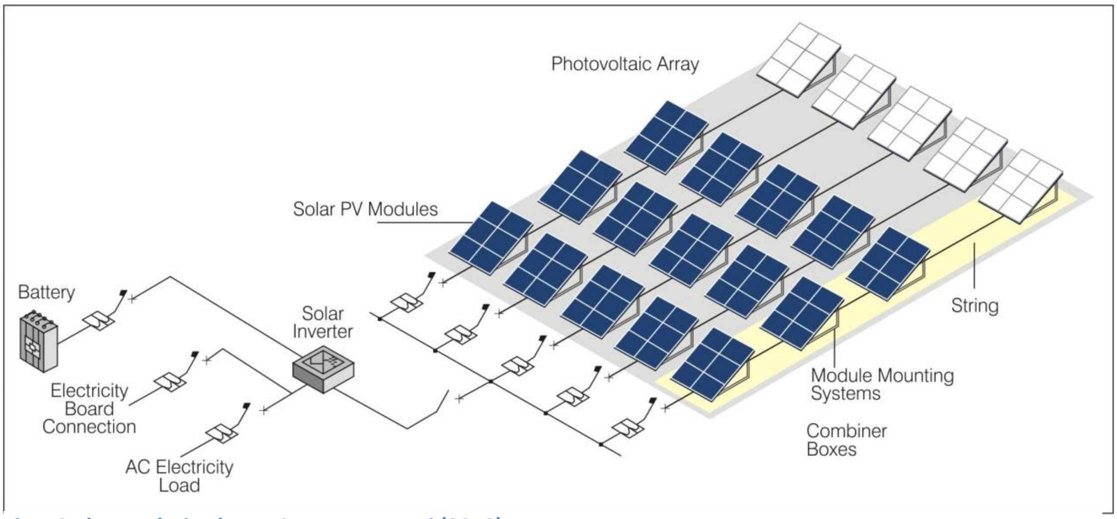


Fig. 10 Photovoltaic plant Source: Pompei (2010)

series, which are mostly made of semiconductor material: thanks to the particular properties of this type of materials you can convert light energy directly into electrical energy, that is, without the need of organs mechanical motion. So the photovoltaic cell constitutes the main device and essential for the conversion of solar radiation. (26) (Pompei, 2010)

The main constitutive elements of a Photovoltaic panel therefore are (27) (Blazev ,2011):

- Photovoltaic modules: constituted by

❖ **Front surface**:

It is mainly is a glass cover, and it must have a high transmission and low reflection capability for the concerned sun light wavelength. Low iron glass is commonly used because of its "low cost,

Fig,11 photovolatic panel

Source: dir.indiamart.com

strong, stable, highly transparent, and impermeable to water and gases and has good self-cleaning properties”

❖ **Encapsulant**:

It is used to provide a strong bond between the solar cells in the module, it should be stable at different operating temperatures and should be transparent with low thermal resistance. EVA (ethyl vinyl acetate) is commonly used with a very thin layer at the front and back surface of the assembled cells

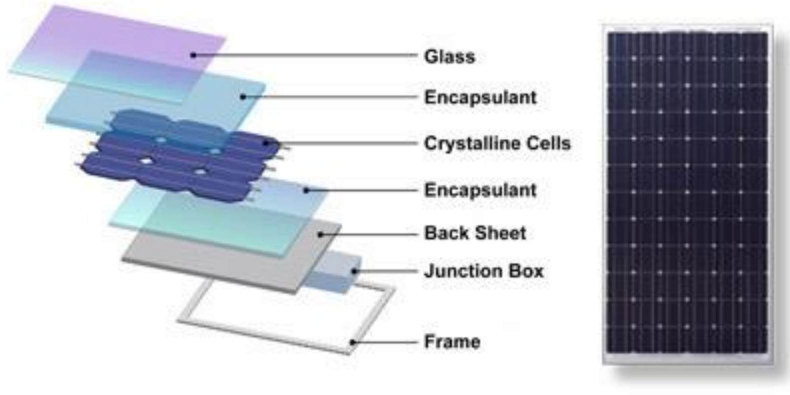


Fig. 12 Solar panel structure

Source: http://2011.solarteam.org/news/recycling-methods-for-used-photovoltaic-panels

❖ **PV cells**:

It is the part which is responsible for producing power. A photovoltaic cell is obtained from a "slice" of semiconductor material called “wafer” and it consists of the following elements:

- Semi-conductor material(usually silicon):base element, layer of about 0.25 mm;
- Electrical contacts (silver or aluminium) : represent a continue surface on the rear side and a grid on the upper one, they serve to convey the electrical current outside the cell;
- Anti reflective coating: thin layer of titanium oxide that minimizes the reflected radiation;
- Texturing: The surface is not flat, but shaped into tiny pyramids to increase the useful area and facilitate mutual reflections.

❖ **Back surface**: is the back sheet for the PV module, it can be made from Tedlar (thin polymer sheet) material or glass for building façade. It must have low thermal resistance.

3.2.1 Categories

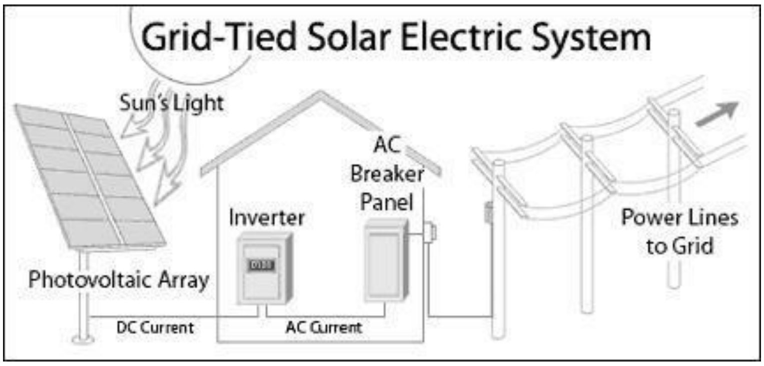


Fig. 13 Grid connected system.

Source: www.alternative-energy-tutorials.com

Photovoltaic systems are mainly grouped in two categories; **Stand-alone system** (also called off-grid) and **Grid Connected System** (also called on-grid). Stand-alone systems can be integrated with another energy source such as Wind energy or a diesel generator which is known as hybrid system. A stand-alone or off-grid system is not connected to the electrical grid. They can vary widely in size and its application are for instance for houses, home and garden devices wristwatches or calculators to remote buildings or spacecraft. If the load is to be supplied independently of solar insolation, the generated power is stored and buffered with a battery. (Pompei, 2010)

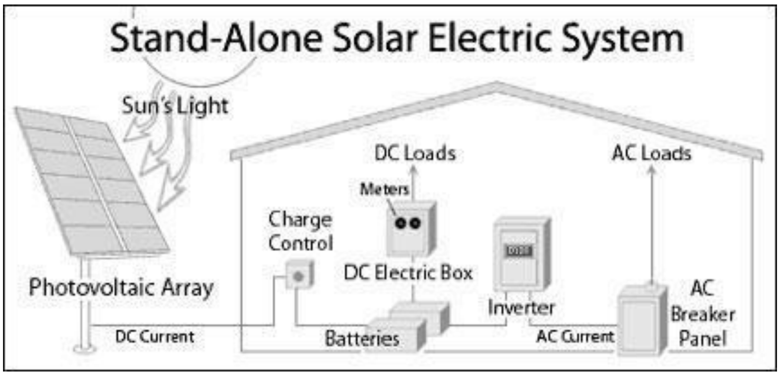


Fig. 14 Stand alone system

Source: www.alternative-energy-tutorials.com

The storage system is the main difference between stand-alone and on-grid categories. The produced electrical energy is stored in batteries in off-grid system while the public grid utility is the storage tank for the excessive produced energy from on-grid systems. On-grid systems are installed more often nowadays and some countries offer incentives to encourage people to invest in Photovoltaic and to reduce greenhouse gas emissions.

A PV plant can be made by various components. The focus is on the photovoltaic modules which are made of a plate of tempered glass, the EVA (a transparent sealer) a glass of Polyvinyfluoride (PVF) or Tedlar and by the Photovoltaic cells. The cells are the most important materials because they are the ones with the capability of capturing the sun's energy indeed the distinction among PV systems depends on the materials used in the cell (Chiesa,2015). There are three main competing technologies: crystalline silicon, thin film, amorphous silicon.

3.2.2 Crystalline Silicon (C-si)

Fig.15 Crystalline silicon

Source:http://www.123rf.com/photo_4378946_crystalline-silicon-on-a-white-background.html

Crystalline silicon is the dominant semiconducting material used in photovoltaic technology for the production of solar cells. These cells are assembled into solar panels as part of a photovoltaic system to generate solar power from sunlight. They can be of two different types, with different producing procedure . Monocrystalline is made by slicing wafers from a single crystal boule while polycrystalline is made by cutting a cast block of silicon first into bars and then into wafers. In order to function phosphorus must be spread over the silicon wafer, moreover to convey the current outside the cell electrical contacts are needed, they represent a continue surface on the rear side and a grid on the upper one and are made of silver or aluminium. The advantages of the technology are the high efficiency and the very reliable technology. The energetic efficiency of these cells goes from 12% to 16%. Today crystalline silicon has 78-80% of market share. (Chiesa, Manzolini, 2015)

3.2.3 Thin Film

This technology is a consequence of the attempt of reducing cost, the most common materials used are amorphous silicon, cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIS, CIGS). In the front a tin oxide layer forms the electrical contact while a metal layer forms the rear contact. These materials permit a minor thickness of wafers, from 150-200 microns to just 3 microns. The energetic efficiency of these cells goes from 8% to 12%. Today thin film covers 18-20% of market share. (Chiesa, Manzolini, 2015)

Fig. 16 Thin film

Source: http://topdiysolarpanels.com/3rd-generation-of-solar-panels-thin-film/

3.2.4 Amorphus silicon

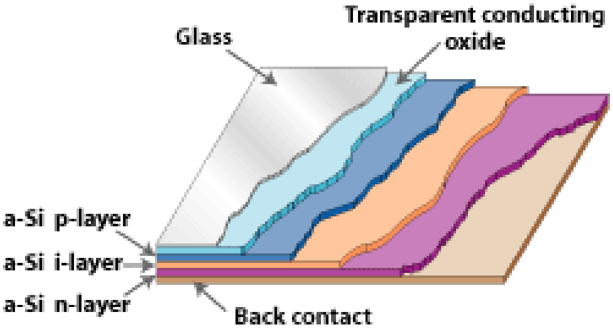


Fig. 17 A-si composition

Source: www.daviddarling.info

Two different processes can be defined in order to realize the deposition of the material:

- chemical vapour deposition

- plasma-enhanced chemical vapor deposition.

The cells based on this technology are characterized by an irregular structure which degrades with ageing. In the case of amorphous silicon, the energy gap increases from 1.2 eV to 1.8 eV, with consequent penalties on efficiency.

Although the expectations for an important development of the 80s, this technology represented just the 3% of world market in 2011.

Another important aspect is the low efficiency that can be reached: lab scale efficiencies: 12.5%, field efficiencies: 6 and 9% (,Manzolini , 2015).

3.2.5 Copper Indium Gallium (di)selenide- CIGS

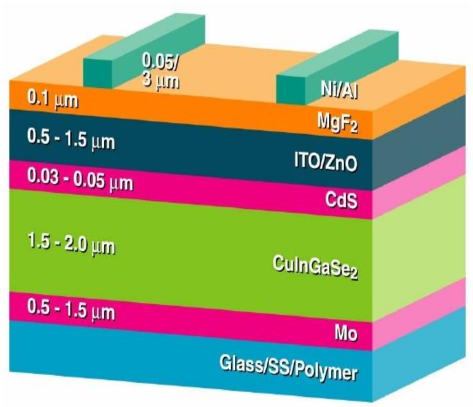


Fig.18 CGIS composition

Source: http://www.slideshare.net/

CGIS cell is manufactured by depositing a thin layer of copper, indium, gallium and selenide on glass or plastic backing, along with electrodes on the front and back to collect current.

Because the material has a high absorption coefficient and strongly absorbs sunlight, a much thinner film is required than of other semiconductor materials.

The grain boundaries form an inherent buffer layer, preventing surface recombination and allowing for films with grain sizes of less than 1 micrometer to be used in device fabrication.

Lab scale efficiencies: above 18%, field efficiencies: 12 and 14% (Manzolini , 2015).

3.2.6 Cadmium telluride – CdTe

Cadmium telluride PV is the only thin film technology with lower costs than conventional solar cells made of crystalline silicon in multi-kilowatt systems.

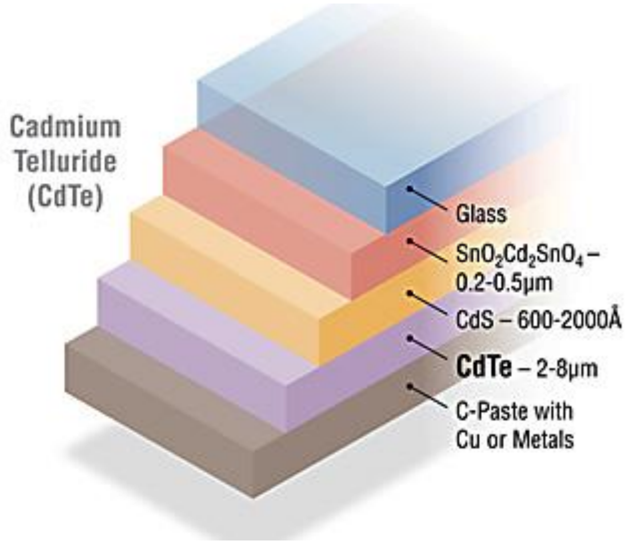


Fig. 19 Cadmium Telluride

Source: http://www.nrel.gov/continuum/spectrum/photovoltaics.html

On a lifecycle basis, CdTe PV has the smallest carbon footprint, lowest water use and shortest energy payback time of all solar technologies. CdTe's energy payback time of less than a year allows for faster carbon reductions without short-term energy deficits.

The main problem with this technology is related to the toxicity of cadmium, which is a strong environmental concern. This problem can be mitigated recycling CdTe modules at the end of their life time, which is, in any cases, a complex and delicate process. Therefore, there are still uncertainties on its use and the public opinion is sceptical towards this technology.

3.2.7 Electrochemical

In this case the component is on a liquid phase. They use a dye-sensitizer to absorb light and create electron hole pairs in a nanocrystalline titanium dioxide semiconductor. The electrical contact is made of a tin ox ide glass sheet and a rear carbon contact layer. The concentrated solar power (CSP) is a technology that concentrates the sun’s rays to heat a medium (liquid or gas) which is then used in a steam or gas turbine. There are four CSP designs currently in use: parabolic troughs, tower systems, parabolic dishes and linear troughs. (Chiesa, Manzolini,2015)

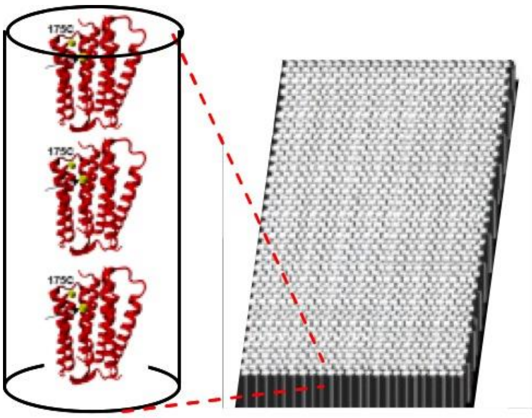


Fig.20 Cell with Electrochemical reaction

Source: https://www.icb.ucsb.edu

3.3 Overview of the market

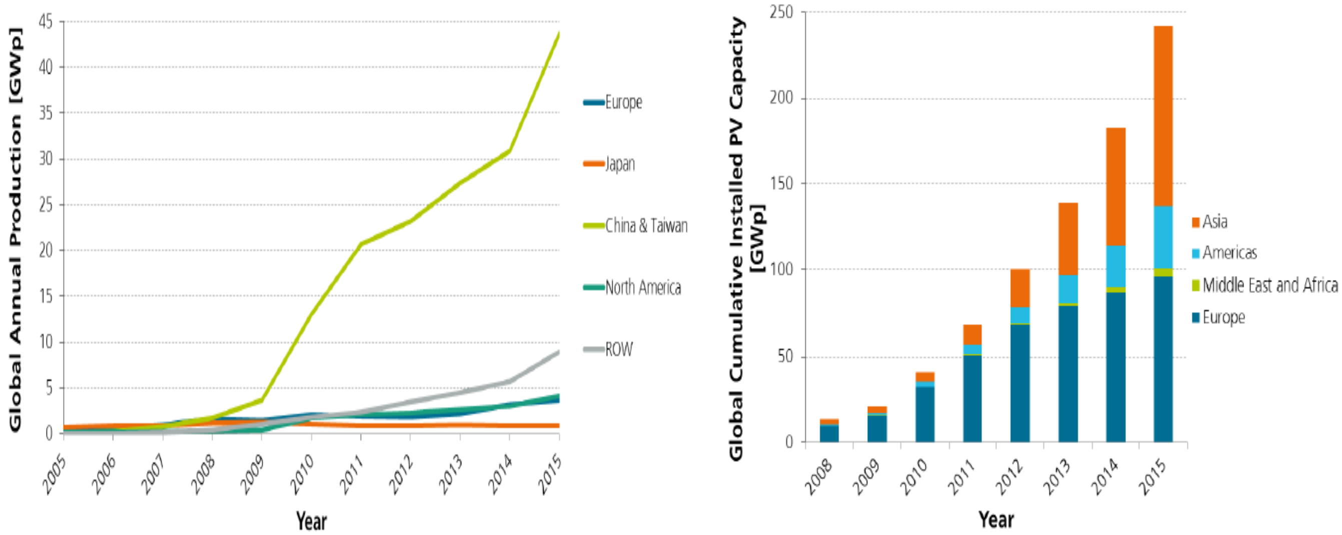


Fig. 21 Pv installation in the world along the years

Source: HIS. Gaph: PSEAG 2016

The Compound Annual Growth Rate (CAGR) of PV installations was 41 % between 2000 to 2015.

This growth is mainly due to the surprising development of the Chinese market. At the moment, indeed, China is definitely the most important player in the market, and it is able to influence it through its decisions (Renewable Energy World – China's Solar PV

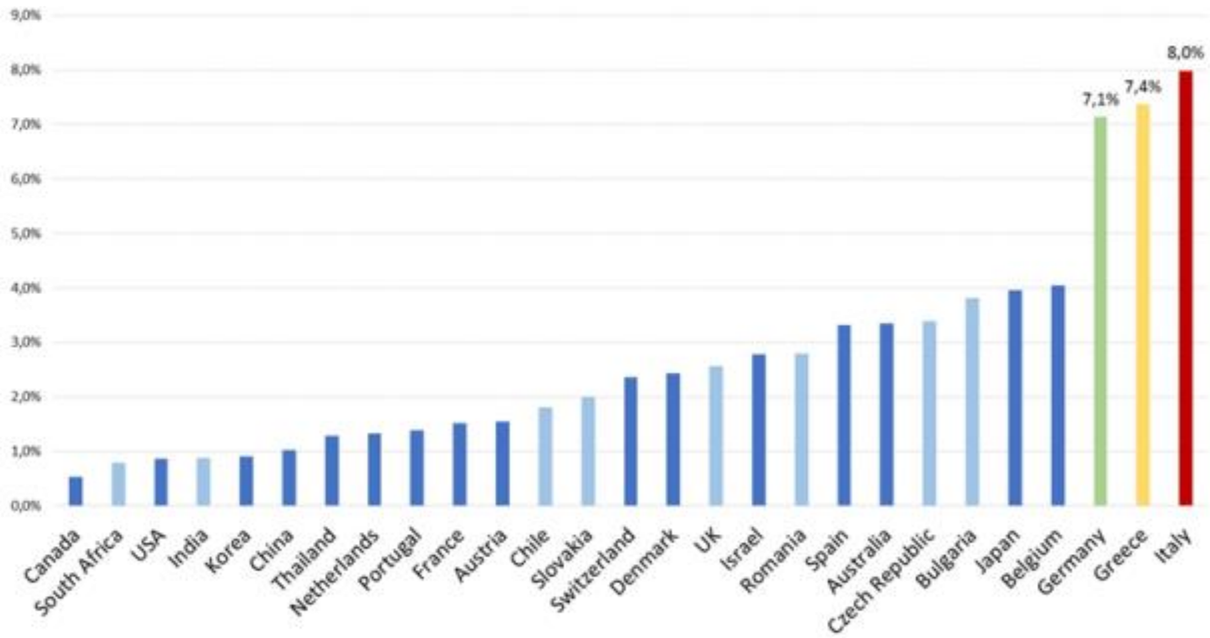


Fig. 22 Global Pv markets IEA PVPS

Sector Achieves Rapid Growth Amid Global Economic Downturn). Despite this, Italy, as explained in the graph below is the country where solar energy well covers 8% of its energy consumption. Followed in ranking countries like Greece with 7.4% and Germany with 7.1%. China, in terms of percentage, in this case, is only 21th. Unfortunately, in the last year Italian government imposed retroactive cuts on incentives for renewable content. Due to these weaker financial incentives PV additions " slowed dramatically in the last year, but global demand remains strong "said Josefin Berg, senior analyst of solar demand for IHS Technology. However he continued: "The supply chain continues to benefit from a period of relatively stable pricing, and there could be a new wave of capacity expansions."

(©Fraunhofer ISE: Photovoltaics Report, updated: 6 June 2016).

3.4 Photovoltaic supply chain

As explained before, the solar panels are the core component of a solar photovoltaic system or station. The solar modules are manufactured by solar module suppliers, with complex manufacturing process of polysilicon purification, ingot molding, wafer slicing, cells manufacturing and panel/module producing. **The solar modules together with batteries, controllers, inverters and trackers are then assembled** to solar photovoltaic systems by photovoltaic assemblers. Finally, those solar photovoltaic systems (include the Building Integrated PV station, the grid connected PV system, etc.) are sold and installed for the customers in the market. (Zheng, Prince, 2015)

Photovoltaic supply chain is quite different from the other consumer or industrial goods supply chains:

• A PV system generates power from the solar energy and reduces the consumption of fossil fuel, which contributes to the energy conservation and Green House Gas (GHG) emission reduction.

• PV supply chains are both capital and technology intensive with very high entry barrier.

• The solar energy market size is still very small and the market pricing based on the production costs is difficult and hard to compete with existing utility providers. Thus, the purchasing decision of end users relies on the promotional pricing supported by the government subsidy policies.

• The construction and operation of a PV supply chain are not possible without the government's appropriate industry and facilitation policies.

In a PV supply chain, there are major and minor players. (29) (Bingqing, Zheng , Prince, 2015)

Major players include PV assembler, solar modules suppliers and strategic consumers. Minor players are common component suppliers. Neglecting those minor components suppliers, PV industry supply chain can be described as a supply chain system in Fig, composed by solar module suppliers, photovoltaic assemblers, strategic consumers, and companies which take care of End-of Life products. The next paragraph will explain what are the main activities and the main technologies involve in the potential recycling process of a solar panel

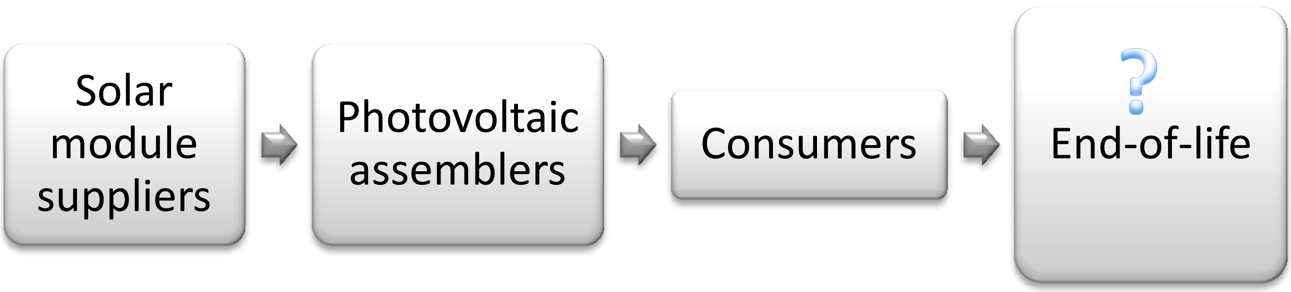


Fig. 23 Photovoltaic supply chain

3.5 End-of-life management for photovoltaic panels

Solar photovoltaic (PV) deployment strongly increased from 2000s on . Global solar installations are expected to surpass 64 GW this year, breaking 2015 record and bringing total installed solar capacity to an expected cumulative total of over 310 GW by the end of the year.

Last year, solar passed the 1% threshold for percentage of energy produced globally, and we can expect it to continue to increase, especially considering the fast development of the photovoltaic capacity of India, China and other developing counties.

Considering the long lifecycles of these technologies, many solar products have not yet reached their End-of-Life, in fact, panels installed in the early 1990s are still performing with performances not too far from those registered at the installation. Therefore, taking into account the dramatic growth of the industry, annual PV waste will be about 100,000 tons in 2017 .

For this reason, as global PV market increased so did the volume of decommissioned PV panels.

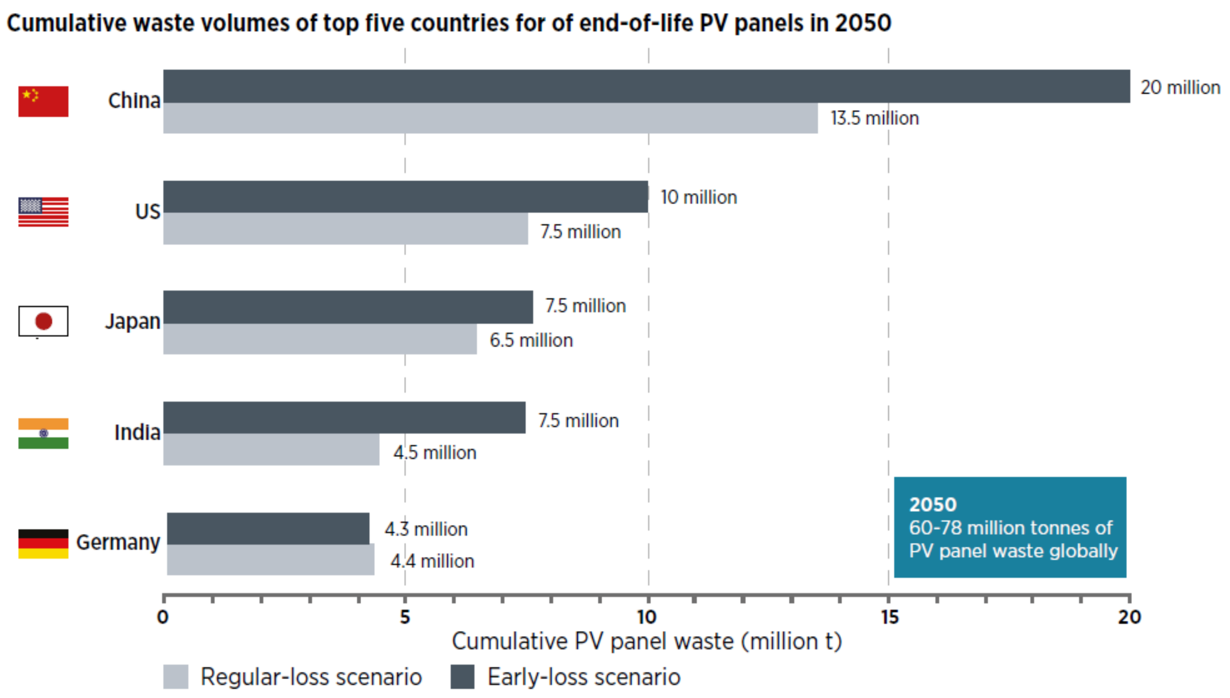


Fig. 24 Cumulate waste volumes of top five countries for end-of-life PV panels in 2050 Source: Mckinsey report

3.5.1 The importance of End-of-Life management

Growing PV panel waste presents a new environmental challenge, but also opportunities to create value and pursue new economic returns. End-of-life management could become a significant component of the PV value chain. The recovered material injected back into the economy can serve for the production of new PV panels or be sold into global commodity markets, thus increasing the security of future raw material supply. Sectors like PV recycling is important in the world's transition to a sustainable, economically viable and increasingly renewables based energy future in a time in which a great amount of panel waste is expected.

Considering the production of a solar panel, there are two main moments in which the collection and recycling of waste is needed: first of all, for the scraps during the manufacturing, then for the EoL management.

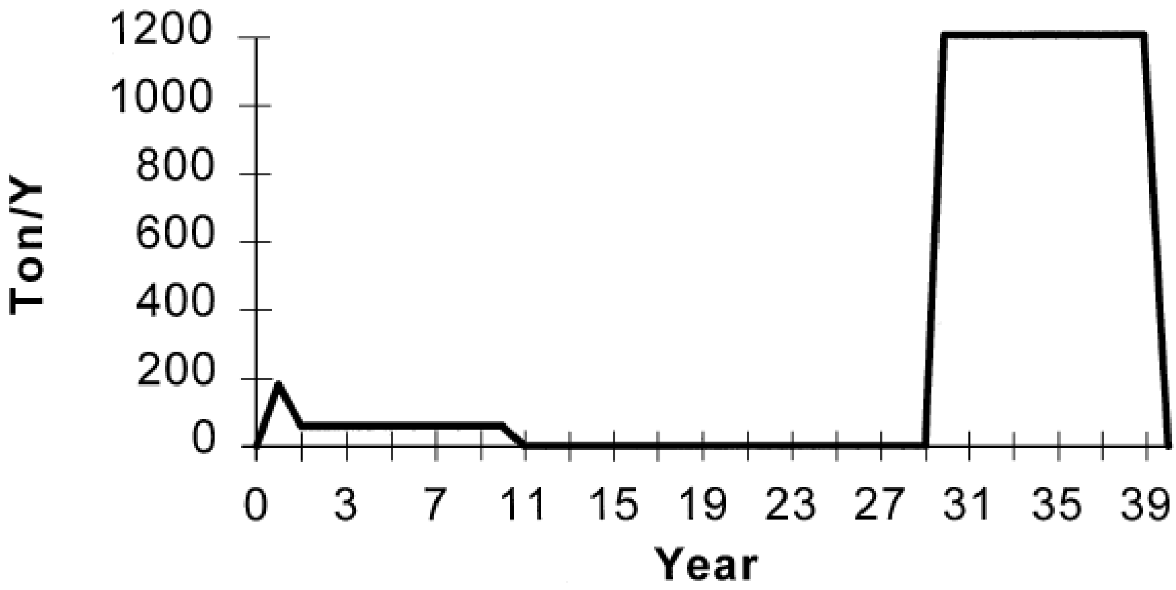


Fig. 25 Quantity of PV scrap and used modules from a 10 MW/y manufacturing facility.

Source: End-of-life management and recycling of PV modules:. Fthenakis, Weadock

Fabricating the panels requires the use of chemicals and huge quantities of water and electricity, the production of which emits greenhouse gases. It also creates waste. These problems could affect solar ability to fight climate change and reduce environmental pollution.

Simply landfilling EoL solar panels is clearly not a suitable solution. In fact, in addition to occupy valuable landfill space, many PV panels contain heavy metals, such as cadmium and lead. These substances can potentially be released into the environment contaminating the soil, water and/or air. Some solar panels also include some rare and critical elements, (e.g. gallium and indium). Not recovering these materials from the disposal panels because they are abandoned in the soil is not the way to proceed if the objective is to ensure the supply of these substances in the future (McNeill, 2016).

3.5.2 Recycling: the process

Most of the components of a solar module can be reused. Thanks to technological innovations that occurred in recent years, up to 95% of some semiconductor materials or glass, as well as vast amounts of ferrous and non-ferrous metals used in photovoltaic modules can be recovered. Some private companies and non-profit organizations, such as PV CYCLE, the European Union, are engaged in the collection and recycling of the modules at the end of the life cycle. As a general activity recycling is complex to perform, since it involves a complex matrix of operational and material-specific systems, which usually include collection, drop-off and buy-back centres, commercial recycling centres, and material recovery facilities. (Fthenakis, Weadock, 2004).

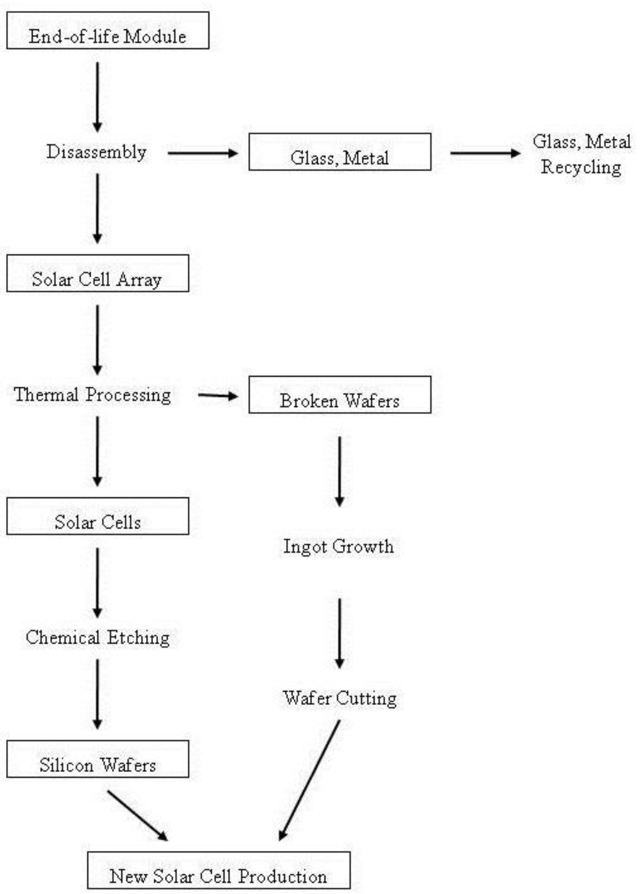


Fig. 26 Recycling process

Source: Recycling Methods for Used Photovoltaic Panels: N. Weadock, 2011

Recycling of solar panels is even more complicated, because of the long-time intervals between installing and processing modules, the low concentration of valuable materials in the final product, and their geographical dispersion, PV market is in fact characterized by dispersed installations, such as off-grid power systems for industrial sites, and stand-alone residential applications, so the collection phase is a crucial process and an important challenge for a well-functioning recycling system.

Also from a material point of view, solar panel recycling is not an easy task, because they are composed of multiple and extremely different materials, such as:

- **Glass** (comprising the front cover of most PV panels)
- **Aluminium** (frame)
- **Synthetic materials used to encapsulate and seal in the silicon cells**: e.g. ethylene-vinyl acetate (EVA), polyvinyl butylar (PVB) and/or polyvinyl fluoride)
- **Silicon** (solar cells)
- **Metals such as lead, copper, gallium and cadmium (metallisation connections and thin film semiconductors)**

	c-Si (crystalline silicon cells)	**a-Si (amorphous silicon cells)**	**CIS (copper indium diselenide cells)**	**CdTe (cadmium telluride cells)**
%				
Glass	74	90	85	95
Aluminium	10	10	12	< 0,01
Silicon	Approx. 3	< 0,1		
Polymers	Approx. 6,5	10	6	3,5
Zinc	0,12	< 0,1	0,12	0,01
Lead	<0,1	< 0,1	< 0,1	< 0,01
Copper (cables)	0,6		0,85	1,0

Indium		0,02	
Selenium		0,03	
Tellurium			0,07
Cadmium			0,07
Silver	< 0,006		< 0,01

Fig. 27; composition of c-Si and thin film modules (corresponding to the respective technology)

Source: Recycling of solar modules – potential and requirements of a future material flow/ PV CYCLE study, 2007

Low critical mass of critical metals in PV modules and scrap does not generate any significant recycling value, so at the moment the interesting materials are glass and aluminium, which have a certain value to smelter operators (Fthenakis, Weadock, 2004).

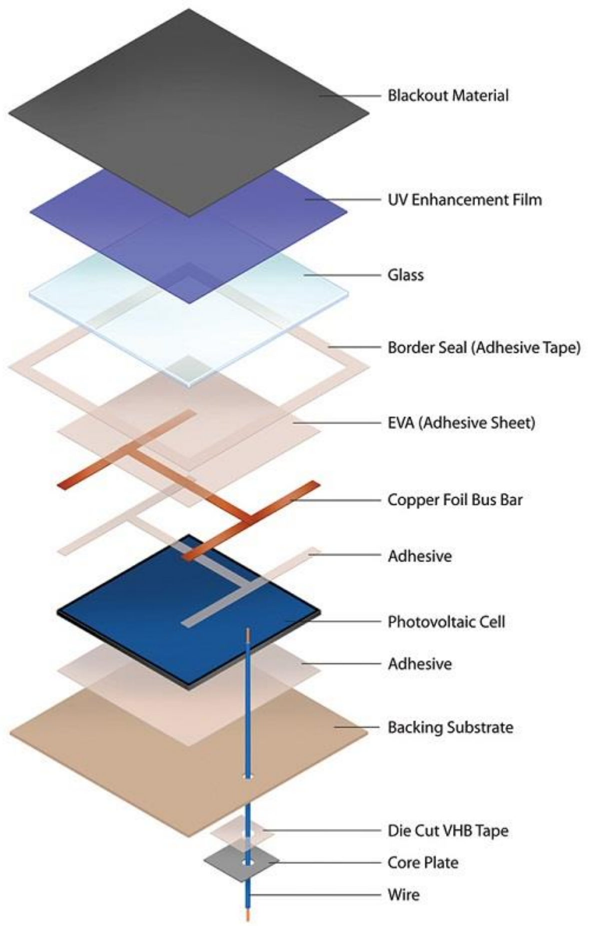


Fig.28 Explosion of PV panel

Source: www.sinovoltaics.com

From a standard module of 21 kg can recover about 15 kg of glass, 2.8 kg of plastic, 2 kg of aluminum, 1 kg of silicon powder and 0.14 kg of copper.

More than 100 million PV modules installed in Italy and the bulk of the modules will start recycling market within a few years, since the lifetime of a PV system is 20-25 years. With the new technologies recently introduced is, however, already advantageous to replace the old modules with those of last generation that guarantee greater efficiency.

At the beginning of the nineties the users of photovoltaic modules required for the producers of recycling solutions because at that time the amount of waste for disposal was very limited, the efforts of producers was focused on traditional recycling methods. An example of the technical limitations of the time it is offered by the draft Pilkington Solar International that during the nineties failed because it could not ensure adequate purity of the fractions of recovered materials. Other producers began to point the more specific recycling processes that did not prove interesting from an economic point of view; other companies have proved reluctant to engage in highly specialized technologies.

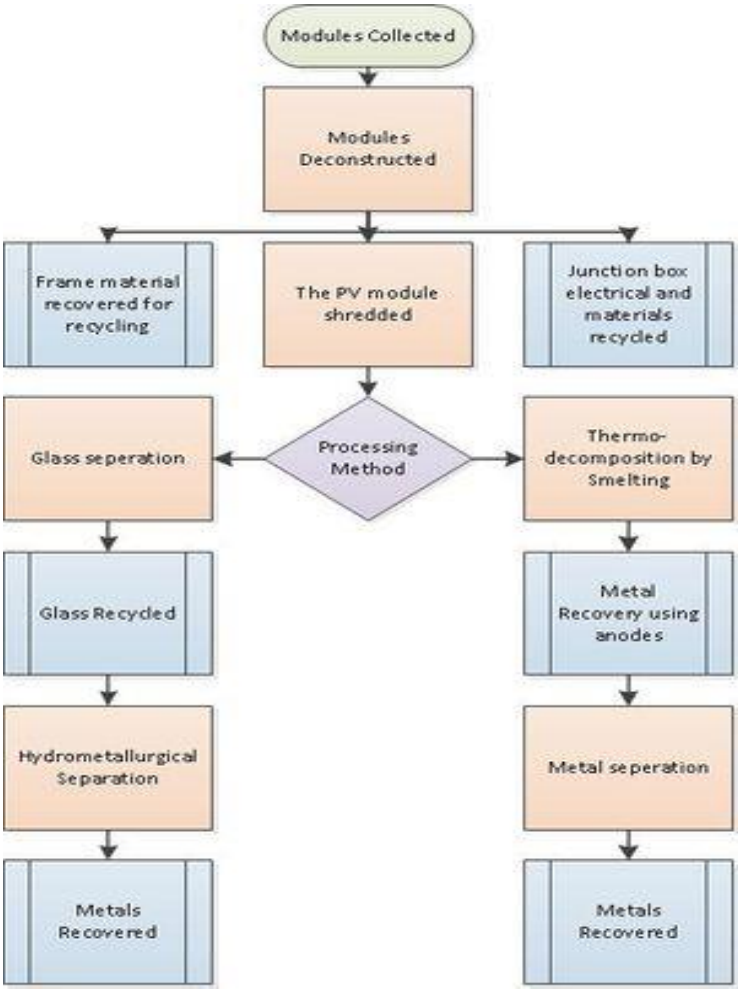


Fig.29 Process map for recycling

Source: www.appropedia.org

Currently, the End-of-Life modules are treated as industrial waste according to the WEEE directive, **in the majority of the cases, glass and metal components are recycled, but not the cells**. It's becoming more and more insistent the will to act in this regard, to solve this criticality. Some disposed wafers are intact, and recycling methods have been developed by various research groups to try refurbish old solar cells into new cells with comparable efficiencies (Weadock, 2011).

The same general recycling process is used by various companies: first, modules are broken down by removing the metal frames and glass plate, leaving the solar cell stuck between an ethylene vinyl acetate (EVA) resin and back film.

A life-cycle analysis of Deutsche Solar AG was conducted by Müller's research group to determine **environmental effects of the recycling process** of new modules versus ones created using recycled solar cells, concluding that the recycling process reduces the environmental burden of processing new silicon as well as the burden associated with disposing of the PV modules through more conventional means.

	Module with new wafers	Module with recycled wafers	Unit
Wafer production	306	0	kWh
Recycling process	0	92	kWh
Cell processing	49	49	kWh
Module assembly	45	45	kWh
Total	400	186	kWh
Energy generation	120	120	kWh/year
EPBT	3.3	1.6	Years

Fig.30 Environmental effects of the recycling process in a module

Source: Müller's research group

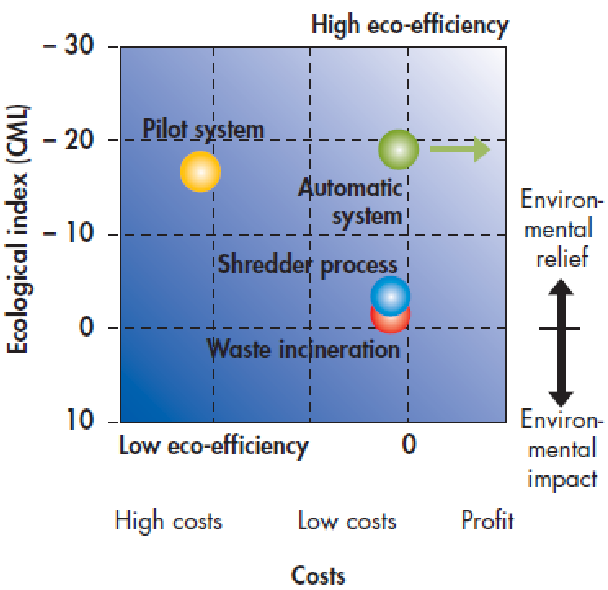


Fig.31 Efficiency of recycling methods Source: BINE Informationsdienst – Recycling photovoltaics modules

To complete the analysis of the recycling methods it should not be forgotten to consider also the environmental impact of the activities.

The ecological efficiency of different recycling processes varies greatly. With shredders and incineration, the recycling rate for Al, Cu and glass is low, the end products are low-quality and cost reduction is unrealistic.

The manual separation, in conditions of low throughput achieves a satisfactory recycling rate in an energy-efficient and cost-efficient manner.

CHAPTER 4: THE ITALIAN PHOTOVOLTAIC INDUSTRY

4.1 Introduction

The next chapter will focus on Italian solar sectior, giving an insight of the plants installed nowadays and describing also the supply chain is made, not forgetting to mention how Eol life management is pursued in Italy

4.2 Photovoltaic in Italy

On 31 December 2015 photovoltaic systems installed in Italy were 688,398, which corresponds to a power amounted to 18,892 MW. Smaller plants (not exceeding 20 kW) up over 90% of total systems installed in Italy and represent 18% of the national total output. The average size of the plants installed in Italy at the end of 2015 amounted to 27.4. Only in year 2015, just over 40,000 systems were installed, almost all of lower power to 200 kW, with a total installed capacity of 298 MW. Compared to 2014, the plant began operating in the year dropped by about 23% and reduced by 30% also the installed power; the difference is mainly explained by the entry into operation during 2014 of the last plant in Conto Energia. (Gestore dei Servizi energetici,2015)

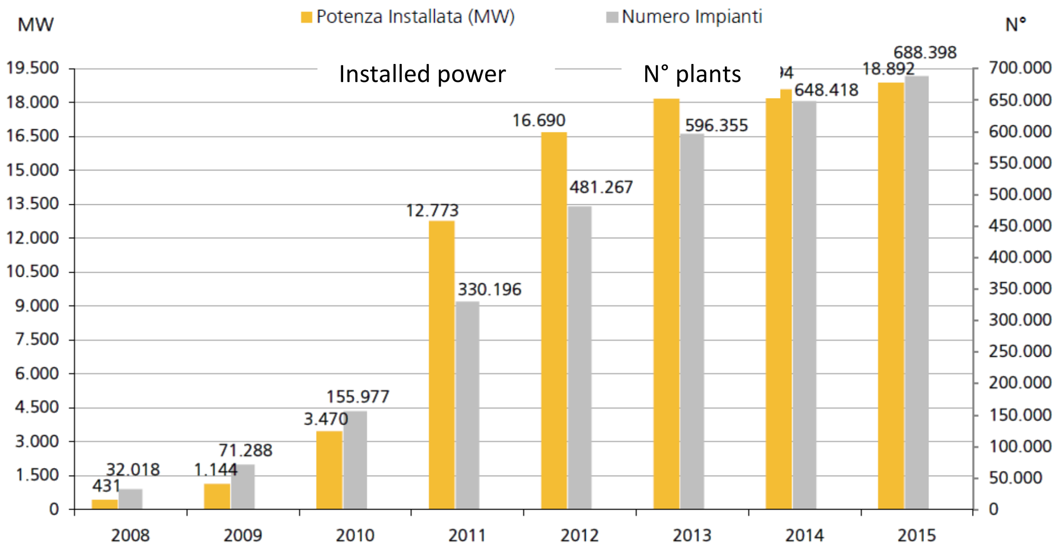


Fig. 32 Italian installed power

Source : rapport statistic fotovoltaico GSE

The graph shows the evolution of the time series of the number and the installed capacity of photovoltaic plants in Italy. In 2015 the number of Photovoltaic reached around 689000 units. From 2013, the year of termination of the Energy Bill, the growth took place according to a slower pace.

The plants came into operation during 2015 (mostly installations are in households) service have an average power (7.1 kW) significantly lower than that of previous years, bringing the national average size of PV systems by little more than 27 kW.

In Italy different photovoltaic panels are diffused. The chart shows the distribution of photovoltaic panels by type of panel, for each region.

In all regions prevail in the polycrystalline silicon panels, followed by monocrystalline panels, while the thin film and the other types of panels are used in still modest amount.

At the national level 73% of the installed capacity is made of polycrystalline silicon, monocrystalline silicon 21% and 6% in thin film or in different materials.

New types of thin-film panels are used in measuring the highest percentage in Sicily, where they represent 12% of installed capacity. Valle d'Aosta and Trentino Alto Adige are the regions with the highest proportion of monocrystalline panels (respectively 37% and 35% of the total). (Gestore servizi energetici, 2015)

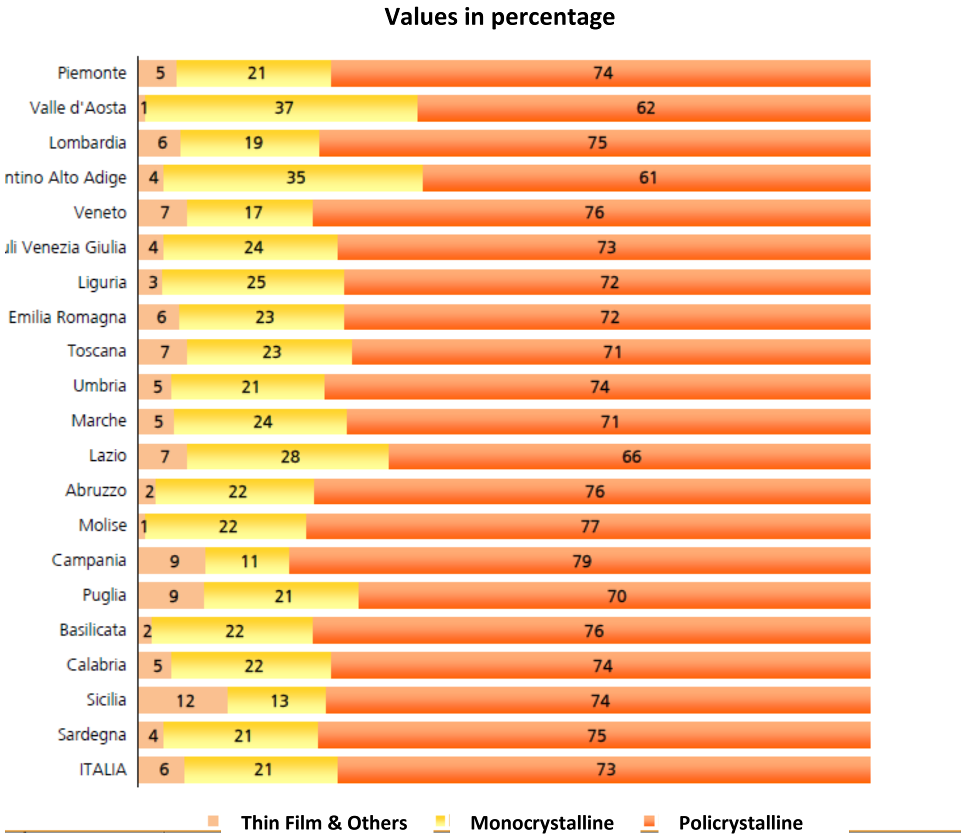


Fig. 33 Different technologies in different regions according to their proportion

Source: rapporto statistico fotovoltaico 2015 GSE

According to the different technologies, the number of PV plants in Italy is continuously growing. As a consequence the number of potential wastes is growing rapidly.

	2014	2015	2016	…	2028	2029
Scraps	0,60	0,60	0,60		0,60	0,60
EoL	0,15	0,13	0,02		25,36	54,23
Total	0,75	0,73	0,62		25,96	54,83
	2030	**2031**	**2032**	**2033**	**2034**	**2035**

Scraps	0,60	0,60	0,60	0,60	0,60	0.60
EoL	174,45	709,05	261,00	108,00	30,00	30,00
Total	175,95	709,65	261,60	108,60	30,60	30,60

Fig. 34 Projections about the amount of waste PV modules to treat (data in kiloton). Source: (Cucchiella ,D'Adamo , Rosa , 2015)

4.3 Panel wastes in Italy

Italy is gaining a good position in Photovoltaic recycling. Considering the recycled materials linked to PV sector, PV Cycle quantified the amount of treated wastes from 2010 to 2014 (1st quarter) in 9225 ton , about the 0.11% of all European WEEEs. In 2014 Italy became " the first major PV market to implement the EU recast WEEE Directive (2012/19/EU), to ensure the correct treatment of waste of electrical and electronic

equipment. Based on the notion of 'Extended Producer Responsibility'. The legislative decree n°49/2014 defines 'Producers' as comprising all companies or individuals located in Italy and manufacturing and selling, reselling under their own trademark or importing PV modules." Following this directive, producers must place a symbol on their modules to inform their customers of disposing the discarded PV modules separately from other waste. They also must inform end-customers about how the collection is organized and treatment facilities about the potential use of dangerous substances in order to facilitate the recycling. Making a data analysis about the Italian installed power since 1992 onward. In this case volumes of PV panels to treat from 2010 up to 2035 were estimated, as you can see on the table below.

Comparing data about potentially PV wastes generated and currently treated, there is an evident distinction in values during the 2010–2013 period (1449 ton treated, out of 26 kilotons potentially generated).

The total amount of waste PV modules to treat from 2014 up to 2035 results to be about 1.4 million tons, with a peak (89%) concentrated within the 2030–2033 period. It exists ,hence ,a reduced propensity to recycle ,typical of new products considered within the WEEE list . However, this effect is not determined by a scarce awareness toward environmental issues ,but it is due to a lack in regulations and an additional uncertainty on PV panels, recycling profitability, caused by the available reduced volumes to treat and the low amount of recoverable key materials (Cucchiella ,D'Adamo , Rosa , 2015)

4.4 End-of-life management in Italy: General outlook

In Italy the End-of-Life management of electronic products is different depending on the case. A photovoltaic panel is in effect a WEEE (Rejection of Electrical and Electronic Equipment), and its disposal is regulated by Legislative Decree no. 49/2014 (in particular Art. 40). Basically a photovoltaic is treated as a television or any electronic device. The Photovoltaic disposal operations are free for household: the panels can be delivered at one of the collection centers like the eco-center in your community which are authorized to collect the devices.

For what concerns professionals PV WEEE, however, the rules are different and you have to turn to qualified professionals by law, i.e. "individual and collective systems for WEEE management, which are called “Consorzi”.

GSE has a central role, because the Decree provides that it is the GSE to define the operational modalities for the management of photovoltaic waste stimulated through the Conto Energia.

The legislation specifies what is meant specifically for "waste management":

• The withdrawal of the photovoltaic panel from the site of use (except of course the disassembly operations from the roof);

• Logistics to transfer WEEE photovoltaics from the site of use to the treatment plant (considering also any additional costs due to storage);

• Proper treatment of WEEE;

• Recovery and environmentally compatible disposal of waste produced by the photovoltaic panels

(Gestore servizi energetici, 2015)

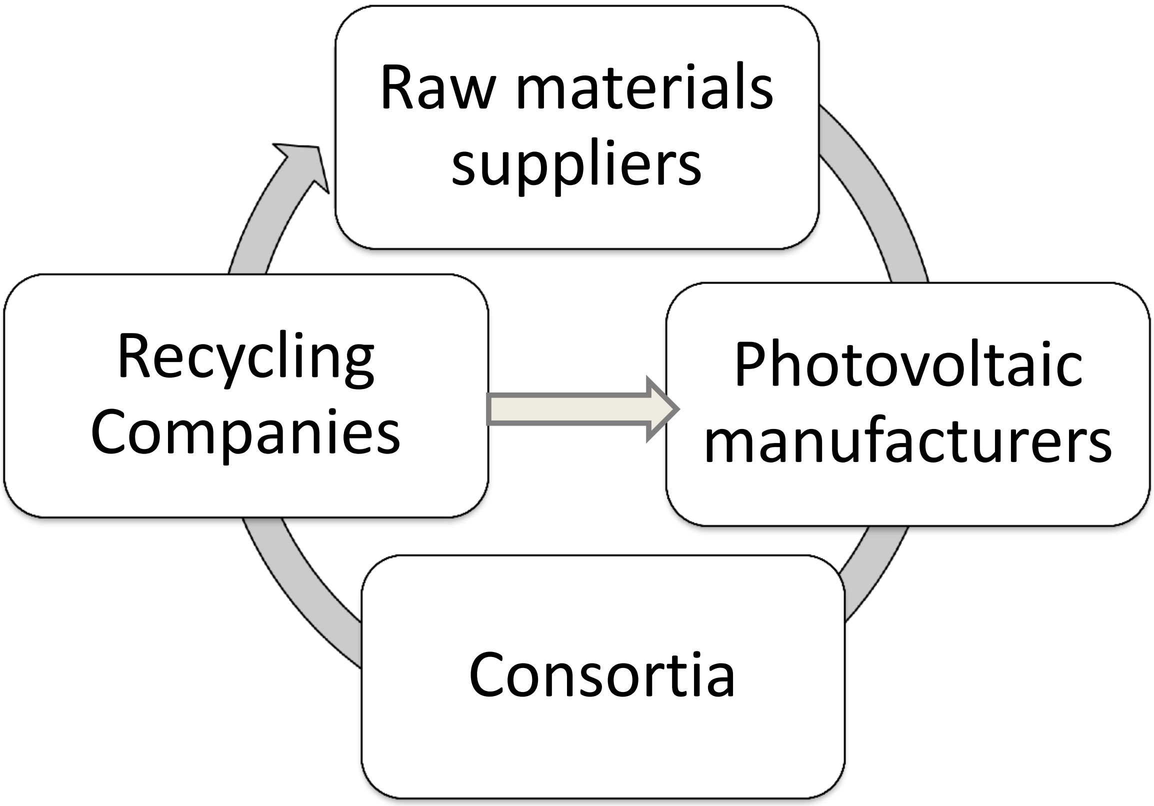


Fig. 35 Photovoltaic supply chain

CHAPTER 5: METHODOLOGY

5.1 Research approach

This work is based on real case studies on companies operating in the photovoltaic sector in Italy. Therefore, the focus of attention is on this particular community. This type of approach will make the research more valid since it will be based on a real case study combining literature knowledge with empirical data and opinions by experts about the argument. A case study enables to focus on a specific example, connecting primary literature research with actual results. Our work intends to understand the materials usage faced by manufacturing companies and the recycling strategies adopted. The research was based on the collection of primary sources by the companies and of secondary data from the literature and from the material disclosed by the companies (company reports, companies' websites). The following chapter describes te methology used starting from the description of data collection and analysis, interview questions and companies interviewed.

5.2 Sampling method

Considering Italy as a market of reference, it was designed to be the subject of the study. The sector of analysis is the Solar energy one with particular attention to the structure of its supply chain, which is fragmented, the research is conducted analysing actors who play complementary roles along the PV supply chain. In this way we were able to receive a multiple stakeholder perspective of the problem of interest.

Regarding the choice of the interviewees, I tried to contact people from:

–Supply chain management.

–Research and development.

–Technical office.

–Purchasing department.

–Business development.

The interviews where organized by contacting employees, managers or delegate in companies through emails, Linkedin profile, website, or through call centres of manufacturing companies.

5.3 Data collection method

Since the objective was to collect empirical data directly from the industry, the analysis was based on a case study approach. The choice was to carry out interviews and data gathering from the companies' websites. The companies interviewed were 14. The interviews were semi structured, based on a developed questionnaire that we developed. However, according to the evolution of the interview, certain issues were faced in asking specific question and neglect some aspects that the interviewees were not able to develop in depth.

Considering the exploratory nature of the research, collected qualitative open-ended data were gathered.

The information and data collected through the interviews were further supplemented and integrated with secondary data coming from companies' websites and reports.

The analysis of the solar sector started with the recognition of the entity involved in the production process , selling process and eventually the organisms aimed the management and the potential disposal or recycling of the End-of-Life products. The chart below describes what companies and entities were involved and interviewed in the following study

Company	Sector	SC Position	Size	Description	Person interviewed	Secondary Data

ECOEM riciclo e gestione dei raee	Consortium	EoL management	-	ECOEM deals with the withdrawal of all electrical and electronic equipment including batteries, at the municipal and private waste collection centers and in the distribution	**General director**	Website: www.ecoem.it
Sunerg SOLAR ENERGY	Solar	Photovoltaic panels producer	M	Italian company specialized in the manufacturing of traditional silicon PV panels	**Technical office employee**	Website: www.sunergsolar.com
avproject Advanced Vision Project	Solar	Photovoltaic panels producer	S	AV PROJECT produce photovoltaic models with high quality, mono and poly cells, modules are made of high-quality products	**Technical office employee**	Website: www.avproject.it
Enecom	Solar	Photovoltaic panels producer	Micro	Enecom Italia produces solar panels with modules using a different support material, plastic. The features makes our the first flexible crystalline modules appeared on the market in Italy and worldwide.	**Technical office employee**	Website: www.enecomitalia.com
DAY4 ENERGY	Solar	Photovoltaic assembler	S	Day4europe sell and in part we produce photovoltaic cells.	**Business development manager**	Website: www.d4europe.com

	Solar	Photovoltaic panels producer	Medium	Ferrania produces and sell PV modules operate on international markets, but Italy covers most of our sales.	**Key Account Manager**	Website: www.ferraniasolis.com
	Electronics	Electronics producers	M	Company which manufactures battery charging systems, welding technology and solar electronics (inverters).	**General manager**	Websites: www.fronius.com/cps/rde/xchg/fronius_italia
	Solar	Photovoltaic producer	M	Lux is the first Italian manufacturer of multicrystalline wafers for photovoltaic applications.	**Chairman**	Website: http://luxsrl.it/2014/index.php/it/
	Consortium	EoL management	-	Consortium that to guarantees the End-of-life treatment of the products.	**R&D responsible**	Website: www.cobat.it
	Consortium	Eol management	-	Consortium that to guarantees the End-of-life treatment of the products	**Head of Public Affairs and Communications**	Website: www.pvcycle.org

	Solar	Photovoltaic producers	Micro	Our company is engaged in production and marketing of photovoltaic modules made in Italy and made in Asia with principal focus in Europe.	**Export manager**	Website: www.exesolar.com
	Consortium	EoL management	-	Remedia is a leading Italian Consortia for the eco-sustainable management of technological waste or Waste Electrical and Electronic Equipment (photovoltaic included) batteries and accumulators (PA) at the end of life	**Secretary**	Website: www.consorzioremedia.it
	Recycling	Recycling and disposal	M	Our company is aimed at the disposal and the potential recycling of wastes	**Logistics**	Website: www.carisservizi.com

European Recycling Platform	Recycling	Eol and recycling	-	European Recycling Platform (ERP) is the only pan-European collective system currently present in Italy. European leader in the management of household and professional WEEE, waste batteries and accumulators, of the PV panels and packaging	**Technical regulation manager**	Websites: www.erp-recycling.it

Fig. 36 Companies list (Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain)

	N° employees	Turnover	Total balance sheet
Micro	10	Y<= 2 (mln)	Z<2
Small	10<x<49	2<Y<10 (mln)	2< Z<10
Medium	50<x<249	10<Y<50 (mln)	10<Z<43
Large	x>249	Y>= 50 (mln)	Z>43

Size: L=Large; **M**=Medium; **S**=Small; **Micro**=Micro

The evaluation of the size of the company was made based on the following scheme:

For all four types of enterprise worth the autonomy requirement, as described in the Ministerial Decree of 18 April 2005.

Reference scheme

The list of the companies according to their role in the supply chain in presented below. As already said, in order to have a multi stakeholder perspective it has been chosen to try to cover all the stages of the supply chain, not considering the raw material suppliers, since the objective of this work is to analyse the opportunities of recycle products for second purposes or in case re-insert the raw materials in the production process.

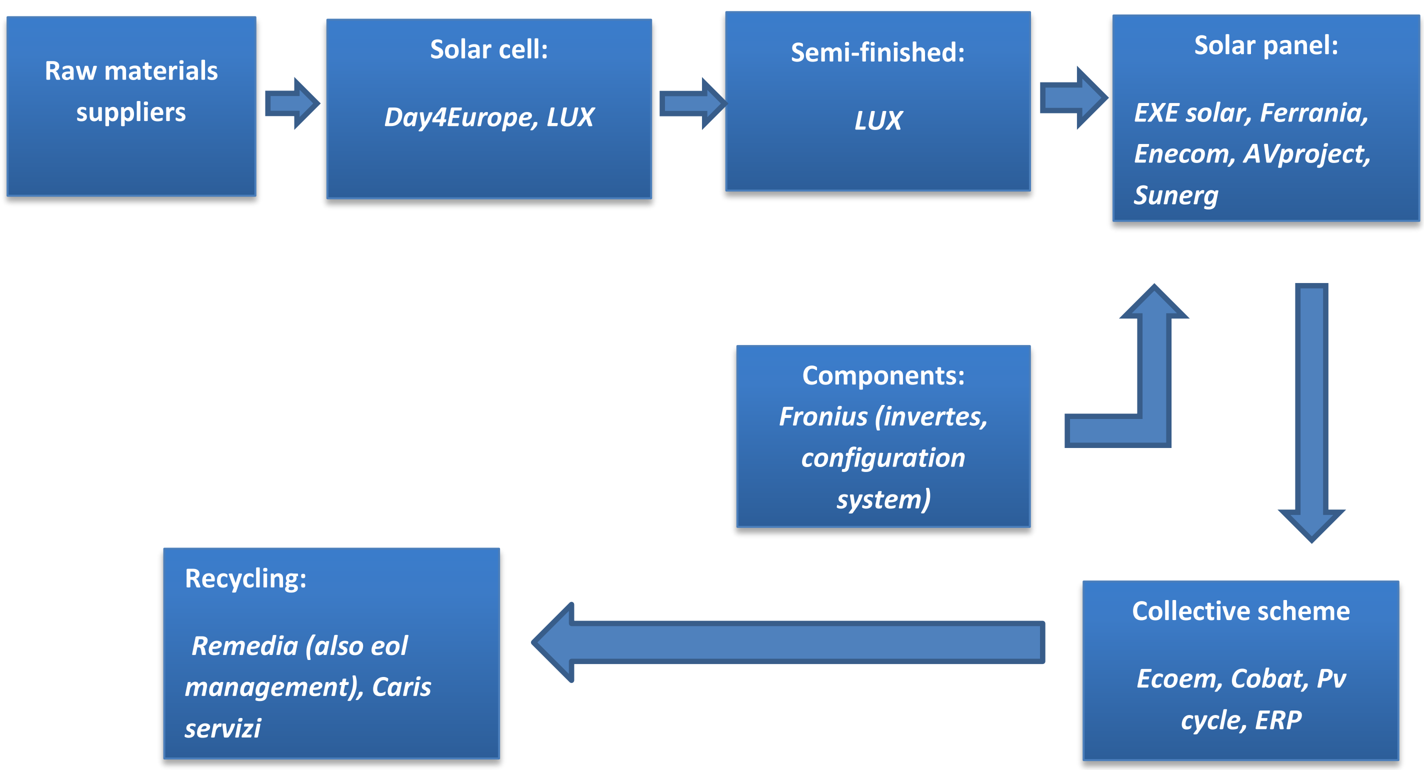


Fig. 37 Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

5.4 Data analysis method:

As already said, this research approach was mainly qualitative and exploratory "The goal of qualitative research is the development of concepts which help us to understand social phenomena in natural (rather than experimental) settings, giving due emphasis to themeanings, experiences, and views of all the participants" (Pope, Mays, 1995).

As a result, the analysis will be qualitative; nonetheless, there will be few quantitative evaluations .

In developing the work, we also referred to the following table, which highlights the main differences between qualitative and quantitative analyses:

	Qualitative	Quantitative
Purpose	To describe a situation, gain insight to particular practice.	To measure magnitude how widespread is a practice
Format	No pre-determined response categories	Pre-determined response categories, std measures
Data	In depth exploratory data from a small sample	Wide breath of data from large statistically representative sampling
Analysis	Draws of patterns from	Test hypotheses, uses data

	concepts and insights	to support conclusion.
Results	Illustrative explanation and individual responses	Numerical aggregation in summaries, response are clustered
Sampling	Theoretical	Statistical

Fig. 38 Differences between analyses

Source: Qualitative Data Analysis: Nigatu (MPH), 2009

The main purpose of this research is to explain 'how' and 'why' materials disposals are faced by companies and analysing the closed-loop supply chain opportunities in the sector of interest.

Given this choice, our qualitative research investigated:

–General knowledge and understanding of the given issue among the interviewees.

–People's experiences with the themes of our analysis.

–Market, social processes and contextual factors that can influence how the issue is addressed.

Qualitative data analysis, usually includes an interpretative phase based on researchers' impressions in which the objective is to examine the meaningful content of the data collected, explaining their core sense, making generalizations providing answers to our research questions.

In data analysis a **deductive approach** is combined a**,** i.e group the data looking for similarities and differences and an **inductive approach** , developed to interpret the data and then search for causal relationships.

We tried to identify recurrent themes, notice respondent clusters, build sequence of events and develop some interpretation hypothesis.

(Nigatu , 2009).

The last objective is to concentrate all of the information and knowledge acquired regarding key themes that can shed light on our research questions, therefore proceeding with decoding the material collected. Thanks to this activity it has been possible to perform a data reduction and their interpretation. The following step is to go through the different codes and group them together to represent “common, salient and significant themes”.

As stated in the methodology section, the analysis was made developing qualitative and quantitative data from interviews, and secondary data from website and report.

Qualitative analysis includes impressions of the interviewer and it is influenced by them. For this reason it has been decided to develop the analysis of the results and findings through a systematic approach and, in order to give more validity, report observations and conclusions are put in a structured and transparent form.

(Save the Children; Monitoring, Evaluation, Accountability and Learning (MEAL) – Cap6: Methods of data collection and analysis)

Therefore, the general approach, was to develop a framework of analysis aimed to guide in the discussion part in order to look for those elements linked to objectives and interests of the study.

This way to proceed is consistent with policy and programmatic research with specific interests determined before starting the analysis was focused mainly on those elements which answer to the research questions (Pope et al ,2000).

Simultaneously, the so called thematic network analysis was followed (Attride-Stirling, 2001), which allowed to make emerge new impressions and intuitions that can partially reformulate the framework of the analysis, for example in case of unexpected events.

(Save the Children; Monitoring, Evaluation, Accountability and Learning (MEAL) – Cap6: Methods of data collection and analysis).

Below the framework as it was developed.

5.5 Target and interview questions

Target	Information about the company in order to understand the role along the supply chain and the raw material processed by the company
Questions	a. Give me a brief description of your company, general operations of the company, its business model, the production systems? b. Which materials do you use mostly in the production? c. What is the most important in terms of performance?

After this brief explanation of their business of the product, questions will go deeper on the on concept of recycling, re-use, re-manufacturing explaining in case the meaning of Closed loop supply chain concept

Target	Understand recycling opportunities, the actors involved and their opinion about recycling, re-use

Questions	d. What happen at the End-of-life of the products, do you take back the product personally? e. What is aimed at re-processing the raw materials? f. What kind of materials can be re-cycled? g. What kind of material can you re-use? h. Does your firm have information about the lifecycle of the product? i. Is it recycling worth it for some materials? Tell me your opinion.

	Explaining the CLSC concept, and report their opinion about it
Questions	j. Do you know what does it mean CLSC? k. Do you think, given the situation nowadays, it is a promising idea? l. What are the limits you perceive on that? m. What are your future expectations on CLSC's?

Fig.39 Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

Data are based on interviews to company professionals.

It has been decided to structure the data analysis paragraph in different sections according to the research questions (as they are indicated in the tables above) that we wanted address:

- **Questions a-c**

- Qualitative analysis of the interviews. Evaluation of what is the company activity, what type of business model they have, if they are involved only in assembling the product, or if they produce it as well. Moreover they explained the characteristics of their product. This preliminary part is very important because it is aimed at identify the potential level of involvement on CLSC topic. These companies were analysed from the point of view of their operations and their supply chain, considering both the information received through the interviews and those we found in the secondary data.

- **Questions d-i**

- Qualitative analysis of the interviews, coding the materials, generation of aggregate results. In this part strategies aimed at closing the loop are considered**:** specific questions about the level of involvement in re-cycling, re-manufacturing, re-use strategies. In this part the way materials are recovered are highlighted. The different role of the person interviewed made the level and thoroughness of the answer very different. Anyway it allowed to understand what kind of roles are more interested and proactive towards this kind of change.

Question j-m

- The main purpose, at this stage of analysis, was to evaluate the opportunity of closing the loop of the supply chain of manufacturers' products. The objective step in our work was to enlarge the scope of the analysis, considering the opportunities to adopt a Closed-Loop Supply Chain for the entire sector. The attempt to evaluate the factors affecting the development of closed-loop supply chain in the solar industry. This part of the interview was aimed to understand the opinion of each actor for the CLSC's, asking specific questions on what are its limits, the production and organizational hurdle you have to overcome and finally the potential opportunities. Also in this case, the answer are strictly related to the role played by the interlocutor.

- The first two conditions which that have to be satisfied in order to be able to close the loop in the supply chain are for sure :

• **Technological progress**: The reverse logistic activities like collection, recovery and especially reuse have to be technically and operatively feasible, in the sense that there must be no technological limitations in all those activities that lead to the reuse of components and/or materials in the supply chain.

• **Economic returns** : The value recovered with all the activities of the reverse logistic chain has to be higher than the costs associated to those activities. In other words, there must be a market for the reverse logistic flow.

This two fundamental conditions were then further broken down into sub-conditions, according to the outline below:

TECHNOLOGICAL PROGRESS

- Technological and operational processes must be suitable in order to implement the reverse logistic activities.
- The system has to be able to recycle materials and in case re-process them

ECONOMIC RETURNS

- There must be the profitable conditions for the implementation of the closed-loop supply chain market.
- A Closed-loop supply chain strategy has to be more economically convenient than using virgin materials

After this different CLSC's enhancing factors were identified according to different issues:

ENVIRONMENT

- There must be environmental value creation in order to enable the success of the CLSC.
- There must be environmental regulation to achieve and maintain CLSC.

INFORMATION VALUE

- Information collection on recycling opportunities improves value creation
- Spread information about customer behaviour, product lifecycle (LCA assessment) in order to recognize opportunities

These factors are important elements that have an impact on the possibility to close the loop and, depending on whether or not they are respected in the sectors of interest, they can at the same time represent a barrier or a driver for the implementation of a Closed-Loop Supply chain strategy.

CHAPTER 6: FINDINGS

6.1 Introduction

The purpose of the previous chapter was made to have a brief description of the Photovoltaic sector, how it is structured, production technology, recycling technology and the market trends . PV sector has been taken as a reference to analyze its CLSC's opportunities. A focus on Italy, the reference market of the study, was made. The companies taken into account in this work are all Italians or, at least, operating and having a branch in Italy. Also the information gathering was made on this purpose: the supply chain network analysis for every kind of sector needs to concentrate on a particular market, cause this makes it more valid in terms of results obtained. Data gathering from companies all over the world would make my research less practical, cause every different country has its different Supply Chain Network and structure, and a most of the time of my research would have been made understanding the similarities and differences of different countries, losing the main direction of my research.

The research is aimed at understanding the main forces towards the change to a network which exploit more and more the value of every different product, byproduct, or waste, creating a frame in which a waste foster the process of re-manufacturing, re-use, recycling. Moreover, the objective of my research was to having precise response on specific questions on the Supply Chain Network, looking at the actors and understand what are the join forces exploiting the change to the widespread concept of Circular Economy, or better to say in this case Closed Loop Supply Chain. As my researches deduces, these two concept are quite overlapping in the literature view, but while the concept of Circular Economy is more interested on defining a general mission, Closed Loop supply chain strategy was more interested on finding a specific solution for specific sectors. Many concept surrounded recycling, re-using and re-manufacturing. Someone focused on environmental perspective, calling Industrial Ecology the analysis of the materials and flows with the attempt of Closing the Loop, comparing the industries with the natural eco-system. This perspective anyway, besides being focused on environmental perspective, it is praiseworthy but strictly philosophical: there's few analysis and comment on that on how the industries actor should behave and what are the main reason, apart from sustainability, triggering the change.

After a comprehensive review of the CLSC's literature, my research was made from primary information from companies (some interviews to companies can be found at bottom of the study) and secondary information from website, reports and catalogues, analyzing its actual opportunities and drivers. A particular focus will be made on the opportunities of recycling and re-manufacturing for the sector of interest.

Since in the past different drivers were involved regarding the CLSC's concept (legislation, corporate citizenship, economic), in this paper I wanted to identify a different aspects, considering **economic and environmental** aspects are essentials for the objective of the study, I could not neglect them. In addition to that I decided instead to consider also the aspect related to the **value of informations** because if collected, they can serve as a feedback to improve processes and product design that can in turn increase customer, environmental and economic value creation. Last but not at least **technology** aspect was considered, with the objective to understand the importance of technology progress about this topic, and its contribution on value creation regarding CLSC's issues. Summing up, to have a more comprehensive view of the situation, different perspectives will be considered in the analysis CLSC's drivers using as a reference the PV sector:

- Economic
- Environmental
- Information
- Technology

A particular attention will be paid on the last two aspects which in previous literature were not so deeply analyzed.

6.2 Preliminary analysis

On the preliminary part the scope of the analysis was to summing up and distinguish and divide the results considering the following issues : technology, economic, environment, information.

Company	TECHNOLOGY	ECONOMIC	ENVIRONMENTAL	INFORMATION
ECOEM	-Technological innovation related to lifecycle. -Nowadays high level of recycling rate	-The recycling is crucial not to be dependent on manufacturers like (China, USA, Russia, etc.) - Profitability regarding the opportunities of making them suitable for a second life	- Secondary raw materials (steel, iron, copper, gold, lead, aluminum, etc.) represent materials that have a high recycling value. They are equivalent to virgin materials. - Making them suitable for a second life	-Knowledge of the Network -Choice of the partners after several qualitative assessments. -Knowledge of the categories in which it operates, but the categories contain several hundred products, therefore the information about it are very extensive.(lack of information about the overall set of products) .
COBAT	-High recycling rate for some materials	- Overall cost related to the improper disposal has to be considered -Positive networks are essential, if the recovery activity exists only to reduce the environmental impact, it is not enough.	-Change perspective towards a more sustainable economy	-No knowledge of the big picture
PV CYCLE	-High recycling rate but not for re-use or re-manufacturing			

ERP	-Innovation is challenging from an economic point of view -Efficient and profitable recycling	-We use procedures to demonstrate environmental excellence and economic sustainability - Efficient and profitable recycling -Achieve an optimization logistics as well as environmental. - recycling processes in certain cases have positive economic value	-Green economy, allows industry to feed themselves while reducing reliance on virgin materials. -The first goal of the recycling industry must be to protect the environment	-Eco-design can facilitate recycling, a traceability producers and products, an incentive to reuse and thus prolonging the life of the products, a widespread and simple -Create a certified recycling chain and oriented to the green economy. All the actors are key to achieving the objectives set at EU and national level. - The creation of a "culture of recycling" is important -The virtuous circle of rejection starts from the hands of the first holder of the latter, namely the citizen.
SUNERG	- When you recycle the end of life panels, the cell is not recycled, and it is a problem difficult to solve -Only aluminum, glass and a bit of silicon can be recycled	-Aluminum is the material you can better recycle		
AV PROJECT	- R&D has to really understand what it is and it is not possible from a technical point of view and then, if we reach this stage,	-There is a very big business around recycling nowadays, several companies do a lot of profit around it. - Recycling is feasible only for		

	we can go forward with actions in the rest of the supply chain.	material present in large quantity, like glass and aluminum, where the recycling technology are very efficient. -The only issue regarding my company is finding new ways to re-use every material in order to reduce drastically production cost. In certain case recycling is cheaper than buying or reprocess again.	
ENECOM	-thanks to the material used, a large part of the panel can be recycled. - different quality of a recycled product, performance. -customer expectations -customer satisfaction		-no trust in a recycled material -It's a matter of customer expectations -future are biodegradable materials.
FERRANIA	-More than 80% of the PV modules is recyclable (silicon, glass, aluminum) - Technological limitations: PV technology is not yet fully mature the whole supply chain (including		-The eco-sustainability is intrinsic in photovoltaic technology - There will be more and more chances in future.

	recycling) -New existing technologies for the recycling of modules and materials used in PV modules.			
EXE SOLAR	-Technology, which now thinks only to disposal and not for recycling, because the icon corresponds to recycling processes more , and more jobs you have, more cost you have, and become less competitive			
DAY FOR EUROPE	- The most important component is the cell is nearly irrecoverable at the End-of-Life. Anyway it's not a problem we are facing today but maybe in the next years. Lifetime of our products is about 15-20 years so it is not a big deal			.
LUX	-Regarding recovery in general, on the one hand we have glass that is recovered, aluminum also. the results of using recycled material in production will	-We don't now the cost of disposal. It is too much uncertain this. There are too many variables, also for example for what concerns the feasibility of it in Italy. -Send recycled		-It depends on the step in which you take back the discarded material. Once you have assembled the panels, it's very difficult. This is particularly true because nowadays quantities are really scarce, so nothing about it has developed yet

	never reach the level of pure materials. Silicon does not return in the photovoltaic sector (reasons of price and lower efficiency).	products to third world countries is a smarter strategy than closed-loop, because I think the cost of recovery will be higher than the actual value.		
FRONIUS			-The panels end of life is not happening yet, but actually they live for very long. I think that PV systems will not be dismantled then because they can still produce energy without further costs, so their life is still long. There is a law, which thinking at the 20-years incentives, has introduced some recycling objectives (preparation of sites and of plans) but the panels will last more than the years of the incentive, so there is not the necessity to recycle panels that are still functioning.	
REMEDIA	-E-Waste Lab promoted by Remedia aims to maximize the value of recycling. A first phase of analysis of the scenario and the economic and environmental opportunities, follows a complementary	-Remedia is partner of Premanus project funded program under the Seventh European Framework Programme. Premanus project started with the goal of building a "business decision" model to help companies evaluate the economic and		

	pilot projects which aim to identify and realize economic feasibility studies for the collection, transportation, recycling and recovery of precious metals from electronic waste, with a focus on innovation and organizational process.	environmental impacts related to the opportunity to carry out activities of "re-manufacturing" (repair and reconditioning of used products) of a product or component, or start to disposal / recycling.		
CARIS SERVIZI				Basically the actors involved don't care about Closing the Loop. They have incentives for the disposal so they behave like this. However, in general they don't care because for them, apart from the governmental regulations, it is not a big deal.

Fig.40 Summary of the interview (the overall interviews are attached in the bottom of the paper) Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

6.3 Focus on specific drivers

The second part of the study will focus on specific issues that I explained before. The aim of this part is to identify potential drivers and barriers picked up by the different interviews. The following part will focus on two concepts, first the recycling opportunities, secondly the re-manufacturing opportunities for solar sector.

6.3.1 Technology

Before proceeding to the following aspects it's important to underline the fact that certain opinion shared by the person interviewed have been affected by the perspective the person interviewed had. First of all the majority of the people was influenced by the role they had in the company.

On the table below are summarized the data related to the recycling opportunities following the technology perspective.

TECHNOLOGY	
Drivers	**Barriers**
High recycling rate (around 90% for panels)	Cells (the most important part of the panel, is still not well recycled)
Efficient recycling(aluminum, glass and plastic)	PV technology is not yet fully mature in the whole supply chain
Large extent in R&D investments	Recycling is apparently more expensive than disposal
Long termism	The quantity of silicon present in the cells and its low price don't justify so much investments in recovering it
Recovery of precious and rare metals from electronic waste is important looking at the future with the current technologies (gallium, indium)	Short termism
	Different quality of some recycled material (purity of recycled silicon is not enough)

Fig.41 technology drivers and barriers, Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

6.3.1.1 Discussion on technologic view

It was noticed that the short termism was very common, especially regarding the top management perspective, who described the recycling issues as a problem we will face in the future and not nowadays (50% of top managers). On the other hand the 80% of the other people interviewed (technical office, R&D, logistics responsibles) identified recycling and potential usage of recycled product a concept to invest and to work on it. While the top management is more aligned on the results of certain activities, other employees which were more involved in technical and managing activity identified this objective and promising, at least for recycling, with less expectation for re-manufacturing. In fact the 93 % of the people interviewed considered the recycling as a very promising activity, while 100% of the people says that in most of the case re-process is an unfeasible activity nowadays. They suggested to use that recycled materials in third world countries or for urban applications (traffic signals, road signs) (LUX). The main issue related to re-process opportunities are the different performances of secondary raw materials with the virgin ones (plastic, silicon)(ENECOM, DAY4EUROPE) , with some exceptions, the aluminum and in certain cases glass. In terms of investments the extent of the effort is high, especially by the recycling companies and consortia. Investments until now are focused on optimizing collection, transportation and recycling activities. R&D support on PV end-of-life activities can improve technological performance and lead higher value from the recycling output (REMEDIA). R&D and optimization of recycling processes will realize the full potential of material recovery, especially considering that, as extracted by the interviews, by the previous and current panel designs do not include recycling among the objectives.

6.3.2 Economic

On the table below different drivers and drivers were identified following the economic perspective

ECONOMIC	
Drivers	**Barriers**
Profitability regarding the opportunities of making materials suitable for a second life	There's not a overall positive network yet
Recycling processes in certain cases have positive economic value	Computational difficulties in identify actual profitable opportunities for producers
Several companies do a lot of profit around EoL management	More focus on disposal than recycling
Subsiding (IV V Conto energia, WEEE directive	The cost of recovery will be higher than the new value
Overall costs related also to the improper disposal have to be considered	
It's important not to be dependent on manufacturers like China, Russia, USA	

Fig.42 Economic barriers and drivers, Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

6.3.2.1 Discussion of economic point of view

The main issue identified by companies was the difficulty in identifying real opportunities for producers. Economic results are essential to push towards the progresses regarding CLSC topic. Government support on these virtuous processes is a successful, measure, if there is a legislation that support these activities. "The thing is that in an market economy in which everything moves thanks to the money, if a firm complying with certain obligations, as a consequence it wastes money, these becomes only a philosofic exercise which end with itself" (COBAT) . It is important that a circular economy is supported with a long range strategy, not imposing choices to the production machine, but determining the conditions towards this change, making this activity profitable for companies. All the people interviewed identified as re-processing secondary raw materials as unfeasible nowadays. Anyway, since the driving forces are strong because the necessity of not being dependent by foreign manufacturers (ECOEM) and the consideration also of the economic cost related to disposal, brought companies on investing on finding the way to reach economic profitability on recycling. This is a good point to consider because if the level of the investments on this issue increase, the total results expected are going to be higher, forcing the change in this direction. The 30% of the interviewed considered CLSC target a promising but the it's important to find positive networks. The main problem is that with the current technologies, for some components cost of recycling is higher than the recovered value. Legislation set the path to achieve that, through WEEE directive, subsiding disposal and potential recycling activities. This initiatives by European union together with Italian government, created the good premises at least for the creation of secondary supply chain, made by secondary raw materials. The purpose is stimulating investments and innovative financing PV end-of-life management can overcome barriers and make certain the support of all the stakeholders.

6.3.3 Environmental

On the table below different drivers and drivers were identified following the environmental perspective

ENVIRONMENTAL	
Drivers	**Barriers**
Changing perspective towards a more sustainable economy	The panels end of life is not happening yet.
Green economy permit industry to produce	Producers basically don't care really about recycling,

with less usage of virgin materials.	they care about incentives related to proper disposal
Protecting the environment should be one goal for the companies	
The eco-sustainability is intrinsic in photovoltaic technology	

Fig. 43 Environmental drivers and barriers. Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

6.3.3.1 Discussion on environmental point of view

Regarding environmental perspective 100% of the people interviewed defined the protection of the environment as one of the target to pursue. In fact, recycling can lead to the supply chain sustainability in the long-term by enhancing at the same time the recovery of energy and materials in PV modules and the CO_2 emissions. Promoting green image is one of the most common marketing activities nowadays but looking at the response of the interview the actual contribution made by companies regarding this issue is more related to the processing phase, especially material use reduction, than in the disposal or recycling one. As explained in the previous sections, the 30% of the people interviewed identified the disposal as non-relevant issue nowadays since the panels EoL is going to be reached in 10-15 years. By the interviews an important concept has been noticed, i.e the green perspective is not enough to promote recycling activity or sustainability in general. Institutional development is essential to promote Eol practices because a system approach can enhance the integration of different entities, like suppliers, producers and customers. Intentional approaches on recycling for producers are impractical and failed in the past. The path was set by WEEE European directive and IV&V Conto Energia in Italy, which force producers and consumers to take their own responsibility . Indeed, Extended-producer-responsibility schemes are the ones that had the most successful outcome so far.

6.3.4 Information

On the table below different drivers and drivers were identified following the information perspective.

INFORMATION	
Drivers	**Barriers**
Eco-design	Lack of knowledge of the big picture also in the local environment (producers)
Consortia has a central role on spreading information	No feedback about recycling processes (lack of information regarding opportunities)
More attention on lifecycle (consortia)	Fragmented supply chain, few coordination
Culture of recycling	
More expertise (consortia)	

Fig. 44 Information drivers and barriers. Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

6.3.4.1 Discussion on information value

Information value gained power in the last year through the adoption of the WEEE European Directive which force producers to" reporting responsibility an and information responsibility" (Weckend,2015):

Reporting responsibility: Producers are obliged to report monthly or annually on panels sold, taken back (through individual or collective compliance schemes) and forwarded for treatment. Within this reporting scheme, producers equally need to present the results from the waste treatment of products (tonnes treated, tonnes recovered, tonnes recycled, tonnes disposed by fraction e.g. glass, mixed plastic waste, metals).

Information responsibility: Producers are accountable for labelling panels in compliance with the WEEE Directive. They must inform buyers that the panels have to be disposed of in dedicated collection facilities and should not be mixed with general waste, and that takeback and recycling are free. They are also responsible for informing the buyer of their PV panel end-of-life procedures. Specific collection schemes might go beyond legal requirements, with the producer offering pick-up at the doorstep, for example. Lastly, producers are required to give information to waste treatment companies on how to handle PV panels during collection, storage, dismantling and treatment. This information contains specifics on hazardous material content and potential occupational risks. In the case of PV panels, this includes information on electrocution risks when handling panels exposed to light. (Weckend,2015)

The value of information regarding recycling is a concept recently developed and deepened. Current studies focus on the value of spreading information regarding lifecycle of products and an innovative design, specifically eco-design. In this case the value of information was enhanced by the presence of consortia along the supply chain. Consortia are the entities that nowadays support the progress with higher effort, in terms of competences and expertise involved and in terms of investments. Interview suggested again that, as explained before, the voluntarily approach by producers in terms of recycling and recovery , fails. Consortia play the intermediary role between producers and recycling companies, helping and supporting the system in incorporate Eol Management among the overall objectives. Thanks to the current regulation more information are diffused nowadays.

6.4 Conceptual implications

The previous analysis was aimed at stand out what are the main barriers and drivers for the adoption of CLSC in a specific supply chain. It was decided to focus on a specific supply chain, focusing on the network and not to the specific plant or firm. These method permit the access to general in information a not so specific to the precise actors involved. Despite this the results make this work able to have a general view of the network giving more access to information regarding the general decision making of the actors, and regarding the overall supply chain strategy. Different drivers were involved and divided for each area of interest. First of all it is important to underline what are the conceptual implications of the work made so far. The issues that were described before are strictly related each other and the success of the CLSC is a consequence of an improvement of all those. Considering them separately in the beginning was important not to lose the focus on what were the macro concept to deepen. Regarding a general view it is important to consider that CLSC is not a target that will be realized only through enhancing the concern for only one of those aspects (environmental, technological, information, environment). Economic profitability could represent the most important, but it is only a consequence of what have been done before, in terms of investments in R&D for instance, or after specific government guideline.

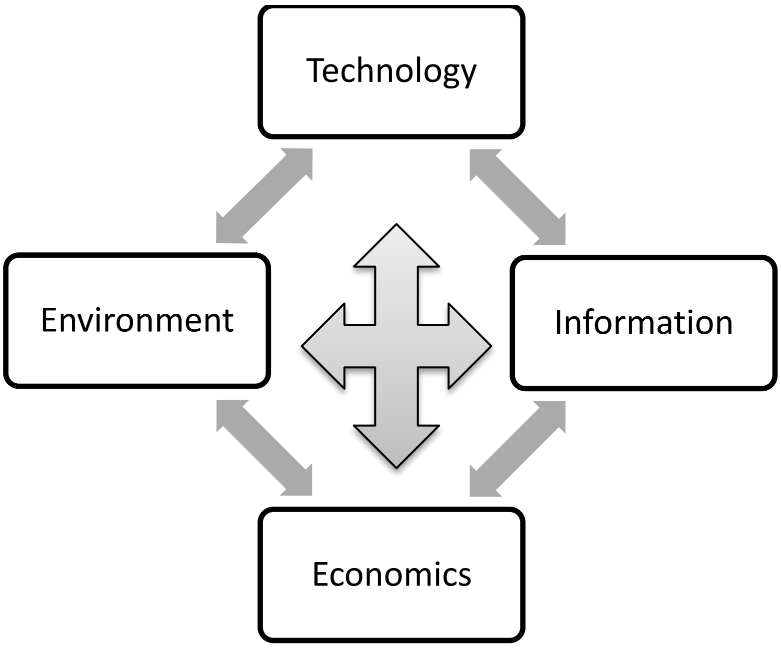


Fig.45 Intercorrelation between drivers. Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

Companies nowadays are struggling with sustainability but this problem is keeping the same characteristics over the latest years. The main concern is on implementing design choices with are as more sustainable as they can, in order to reduce the polluting materials composing the final products. Only on 2016 a great contribution has been done by legislation to change the supply chain structure promoting Eol activities in several sectors, for several product categories.

Undoubtedly, the environment concern is not enough. Economic profitable actions are needed. Economics suffer short term perspective and it is affected also by the technologic progress, which is influenced by the general commitment in terms if investments. In turn, the diffusion of recycling activities is influenced by the profitability on certain actions and by the level of the information widespread, and so on and so forth. The strict correlation among the different issues make the success of CLSC a process very elaborated and it involves different intentions, sometimes aligned , sometimes not.

For this reason End-of-life management policies has to be part of a broad range of instruments that support the overall change and overcome all the barriers at once, tailoring to specific national conditions, focus not anymore on a specific company but on adopting a system-level approach.

6.5 Managerial and stakeholder implications

The first concept that came up after the data gathering was the economic profitability of recycling activities: the producers in particular, underlined the necessity of improving the recycling technologies in order make it able to recycle materials for a proper re-use. Environment concerns were expressed by everyone, but the overall inclination was blaming the other stakeholder and the supply chain system in general for the current situation, with an apparent limitation of responsibility by the single individual. As a second problem for what concern the managers, they were influenced in particular by short termism in decision making, considering the Eol management not really a big deal, looking at the lifetime of the PV panels in this case.

It has been noticed for this reason that management orientation regarding CLSC was more reactive than proactive. This was a concept for sure of the short termism of the stakeholders. Let’s try to summarize this concept underlining the difference between a proactive and a reactive behavior.

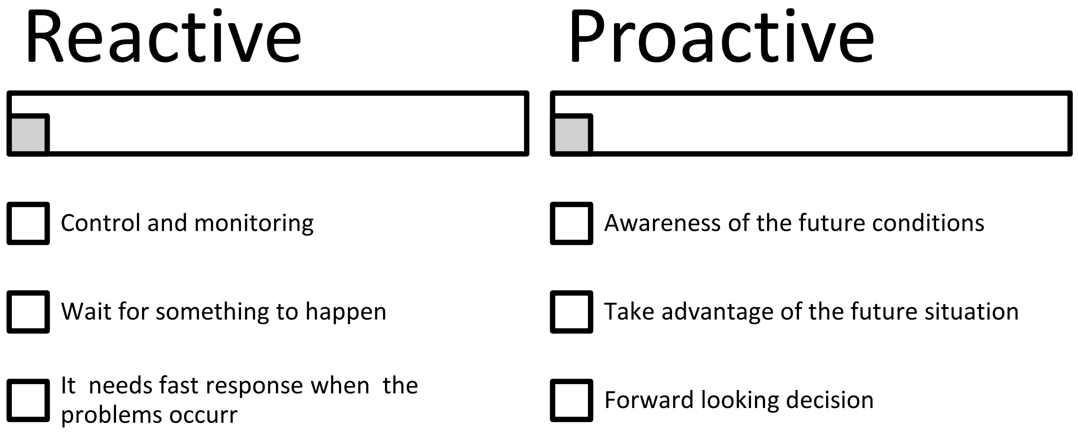


Fig.46 Reactive-Proactive. Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

Taking in consideration all the details explained before stakeholders in Solar industry should be aware that when Eol of solar panels will arrive, maybe the will not have time to react properly, without anticipating the situation that will incur in ten years.

Moreover, implementing a consistent solution in a fragmented supply chain is very difficult. Cooperation and communication among members is essential for the CLSC success. This can be done focusing on creating the right contract terms among the different actors. A CLSC approach requires involvement from both management and other stakeholders, therefore it implies an overall consensus and common intents. European directives on Circular Economy issue were very useful for the beginning of this process creating incentives and increasing the responsibility for every single partner, from the producer to the customer. This was a good stimulus to align the practices ensuring a better sustainable management system in the supply chain, giving also an economic incentive for the good practices.

Another issue that was noticed are the level of the information that was very scattered along the supply chain. Producers are still not informed enough on the recycling process and its opportunities. Information flow for example would help the redesign of products. For this reason information is essential to reach common targets and a proper system of communication through the different actors is extremely important to support innovation process. Secondly, in order to support the feasibility of recycling

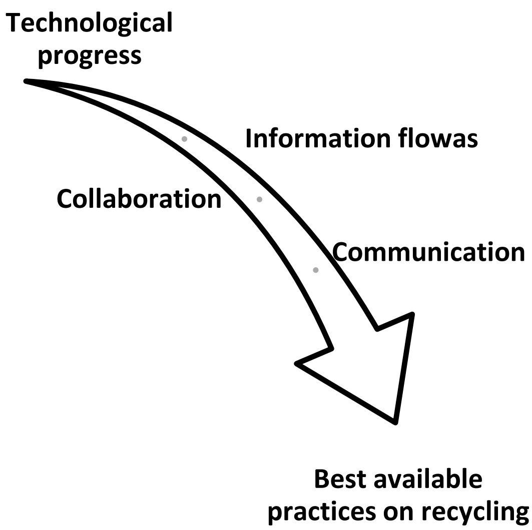


Fig.47 Azzarone,Johnsen, 2016, Analysis barriers and drivers Closed-loop supply chain

opportunities, technological progress is important and managerial attention should focus on this starting point.

It was noticed also that since the companies were forced to Eol management through different directives producers do not perceive economic advantages on doing that and since it is considered a problem, they look at the low cost option, often outsourcing the recycling activities. To designate another entity, It provides a quick and easy solution, but little opportunity for creating a better supply chain. On the other hand , participating in recycling activities, is an expensive strategy but it implies a more control on resources and potential opportunities. This strategy is a consequence of the perspective companies have regarding recycling activities, i.e unprofitable and even expensive. The thing is that this behavior make the companies losing the opportunity to gain an advantage over its competitors, creating a recycling process inside.

The advantage related to the recycling process is creating a new business. In fact, developing new markets for recovered products and materials seems to be very successful nowadays, therefore recycling companies are very concentrated on that because there is a promising business around it. Until now, the great attention made by the recycling market is on establishing more and more relationships with clients which use recovered products for different new and profitable purposes, so stretching the supply chain. The different quality of the recycled materials is the main reason related to those actions.

This is a good starting point, and technological progress and improved efficiency on recycling activities, is the only countermeasure to set the path to materials reprocessing in the same supply chain. After that the main problem will be revolutionize the logistics, operations and production activities.

6.6 Conclusions and reflections for future researches

The following work was made at describing what are nowadays the join forces and the barriers to the adoption of a closed loop supply chain. The objectives of this research were to describe the current state of the industry, investigating the environmental factors leading to the development of a CLSC. It was developed to gather more empirical information about the motivation surrounding CLSC implementation. This work relied on interviews to companies' managers and technical experts. The focus on a case study on the Photovoltaic sector made the chance to go more deeply on what are the join forces related to this change in a specific sector, since in general the actors involved to achieve this kind of target were several. Considering that interview were gathered on a specific sector, the specific validity of the results was influenced by that. Almost every result that came in, was from a Italian respondent, geographically, in fact the results in this research were limited to Italy. Future research should try to enlarge the geographical area to gain effectiveness . Every country has its own culture and values, and this make the CLCS target as an issue to so specifically, given the characteristics of a certain market and supply chain

Concerning the interviews , people were asked about CLSC characteristics and their perception. This is really difficult to control. Perhaps the people could have given their perception and not the reality. For future research, it could be useful to link quantitative research to qualitative research, in order to link perceptions to the facts.

In terms of general commitment, the concept of CLSC is still interesting to study and to deepen but nowadays the greater contribution on this issue is still made by universities. The main reason related to that is the fact that companies consider Eol management as problem to solve and not a business opportunity to pursue. Technology progress is still not sufficient to guarantee efficient recycling and producers are still very uncertain on modify their logistics and operational processes for the material take back. EoL product management is probably an issue that all chains will have to face in the short-term period. Those managers that will have a full understanding of the strategic implications of their decisions will be the ones that have the best chance of success.

Government set the path on this direction but nowadays CLSC is still an ideal model. With the right policies and enabling frameworks in place, the generation of new industries that recycle and re-purpose will drive considerable economic value creation. This will be an essential element in the world's transition to a sustainable energy future.

In reality systems will try to close the loop in part in order to obtain sufficient supply of end-of-life products and find sufficient market in which to sell the recycling products. Companies need a positive network to achieve this target and governments helped in this direction in the recent past.

Furthermore, an additional contribution will be made final customers and user, which will have to be more and more involved in the recycling activities. Intentional approaches failed in the past so a good activity is to force the change through governmental directives which will force the process of change. Positive network and spread information of recycling opportunities are essential, otherwise the studies, congresses and presumed investments will be just self-referential, losing the focus the actual situation and being only a philosophical exercise which will end in itself.

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Attachments:

Interviews

1) General director , **Consortium ECOEM info azzurro tech rosso env giallo economic verde**

What your consortium is mainly involved?

The ECOEM Consortium is the collective system recognized by the Ministry to operate in the management of WEEE, Batteries and Accumulators home and business in Italy. ECOEM joined the National Coordination Centre WEEE and Batteries and Accumulators.

What is the target of a photovoltaic panel at the end of life?

The photovoltaic modules now for April 2014 are considered WEEE in effect under the new European directive, Dlg. 49/2014, so the disposal and recovery process follows the same practice held for disposal (refrigerator, air conditioners, computers, etc.). The legislator has included modules in the grouping R4 (ie generalist electrical equipment not dangerous), so the form is intended for accredited facilities for the recycling of non-hazardous equipment specifically R4.

As for the photovoltaic panels in this case, but also other products in general, do you to pick up the panel at the end of life?

ECOEM deals with the withdrawal of all electrical and electronic equipment including batteries, at the municipal and private waste collection centers and in the distribution. In the specific case of the photovoltaic modules, today the collection is not very developed yet if you think that you collect less than 5% of the quantities placed on the market (WEEE hovering around 35-40%). ECOEM is accredited by the GSE (manager of energy services Spa) and as a Consortium certifies the end of life of the modules that have been entered and registered to the data base of the Consortium through a traceability system, so we handle both the logistics activities and the phase recovery and disposal, entrusting our national partners.

Which organization or company deals with the eventual recycling? No matter the name, I just want to know if your consortium also carries out this activity.

The Network acts as an intermediary accredited, the actual withdrawal and recycling is carried out by our partners chosen after several qualitative assessments, taking into account that we collaborate with about 40 treatment plants and as many logistics operators throughout the national territory.

Do you have special information about the life cycle of each product? (YES / NO I understand the discretion to communicate this type of information)

Obviously working in end of life of WEEE, the Consortium knows the categories in which it operates, but the categories contain several hundred products, therefore the information about it are very extensive. Specifically a photovoltaic module has a life cycle ranging from 10 to 15 years, some of great quality even reach 20 years, this is the reason why today did not even collect a lot because they sell in large quantities only from a few years and also those that are gathered are often considered WEEE just because replaced by more efficient forms or because they have been damaged by the weather, but they are often working. Technological innovation affects the life cycle of the product, making it outdated compared to the new modules.

Recycling is a valid economic level? What materials can live as it were "a second life" after being reprocessed? Some of these have a quality equivalent to virgin materials?

Absolutely, the green economy in Italy is among the sectors that have achieved the highest growth levels in recent years, also even in times of crisis the industry have absorbed the effects compared to other sectors most affected. Takes into account that the country we live in is not a producer of raw materials, so the recycling of the same is crucial to allow not been totally dependent on manufacturers like (China, USA, Russia, etc.). A WEEE is a product complex, formed by different components, in most cases the components are all recyclable up to 90%, also exist WEEE in which their structure consists of metals of great value for the market (100% recyclable) and for the environment, (steel, iron, copper, gold, lead, aluminum, etc.) represent materials that have a high recycling value, equivalent to virgin materials.

I have explained in the introduction, the concept of closed loop supply chain. Have you already heard it ?

Yes.

Thought to be a promising idea?

I think that philosophy to recover the maximum value from the entire life cycle of a product is very promising, given that we live in an era of excessive consumerism and lack of attention to the exploitation of the world reserves of raw materials. As pertaining to our activities in the reverse logistics of course they are in full harmony with the capacity of goods manufacturers to improve their products by making them more easily recyclable and suitable for a second life. In the same new WEEE Directive was replaced by the concept of "reconditioning", or the creation of a landfill site at collection centers where it is evaluated whether the WEEE and then waste may be used for a second use, before they are ultimately destined for disposal.

What are the major limitations (technological, legislative, economic) today to reach a goal of this type? What are your expectations with respect to the concept of circular economy or Closed loop supply chain?

The targets are very challenging though achievable, but in my opinion the greatest limits derive from a high bureaucracy that slows down and makes it difficult to implement these mechanisms, many manufacturers invest in research and development and possess the necessary know-how, the difference largely is made by the country in which it operates, whereas there were (for example Italy) where the legislative apparatus walking slowly than technological innovation, also the existence of many standards (sometimes at the protection of ' environment or consumer) dissuade investors to be able to implement efficient philosophies and sometimes to the overall improvement of industrial flows, logistics and recycling.

2)SUNERG tehnical office employee

I explain the purposes of my work, before entering in detail of these issues, could you please present your company? Tell me about the general operations of the company, its business model, the production systems.

Basically we produce photovoltaic panels. The materials that we are dealing with are few: photovoltaic cells, aluminium for the frames, Tedlar for the back sheet, EVA as encapsulating material, glass and some fixing seals, but there is not much other as far as concerns the productive cycle. The aluminium is purchased in Italy, we design the frames and there are companies that realize the aluminium extrusion.

The rest are common consumables: there is glass, with different providers: various types of borosilicate glasses, also with anti-reflective treatment. Here there are certifications problems, therefore we only buy glasses from certified producers. The ethylene vinyl acetate is an encapsulating material, there may be various suppliers but we try to change it as little as possible.

Speaking about the cells, there are a lot of different possible supply sources, depending on what is on the market and from the technology that are you looking for, almost all the suppliers come from the East, so China, Taiwan, Vietnam, Malaysia.

So you buy the cells and, thereafter, you assemble the module?

Exactly, we buy the cell and then we laminate the panel.

As far as concerns the cells, did you observe substantial price fluctuations?

Yes, there have been for sure, even if now I can't give you the exact numbers, anyhow the cells' price is very variable, for two main reasons.

The first one is a matter of availability on the market: depending on the market period you can find more or less availability according to the production volumes of other countries.

The second reason is linked to the fact that the production is almost completely Chinese and China is able to undertake a war price with the Western companies on the cells' price. They are able to set prices higher than those that they apply internally. This is because they produce with substantial national interventions, that is the reason why they are not recognized as a free market economy and on the cells are applied excise duties.

In any case, generally the price fluctuates a lot, according to the market and according to the cell type, it is quite unpredictable.

How does this variability affect your business activities?

Yes, no doubts, it is a criticality on which, however, you can do very little because, unfortunately, there are not cells produced in other parts of the world, because the European production is more expensive, and also because the cell production is an energy intensive process, therefore it has to be produced where the cost of electricity is low.

Furthermore, you have to consider the fact that in order to open a cell plant in Italy, you need 25 years just to obtain the permissions for the handling of acids, or for the closed water cycle management, in fact, you need a huge quantity of water for the cutting process, and this water has to be filtered and decontaminated or for other similar permissions.

Therefore, you can understand that it is a problem difficult to solve, also because when you recycle the end of life panels, the cell is not recycled. You can reuse the silicon, grind it again in order to use it in the ovens, but the cell itself is destroyed.

From the panel, at the end of its useful life, you can take the aluminium and grind the glass, these materials are well recycled, the rest is recycled to reuse a bit of silicon, but that's all.

Are recycling activities made by companies?

Yes, it is mandatory, there are companies which business is the disposal. You take part of a consortium, which deals with the disposal, specifically we are subscribed to PV CYCLE, so the panel at the end of its useful life is collected and disposed. There is a fee that you pay for every panel produced, and in the price that you obtain from your customer is already included a certain quota which represents the cost of disposal. The company which is in charge of the disposal obviously takes the money obtained through the recycled materials.

We know that the value of the fee can be related to some design choices, for example adopting solutions aimed to get simpler the disassembling. Is this also your case or it is fixed?

I don't know, because we do just one type of assembling, therefore I don't believe that we ever thought about this problem. I think that the disassembling would be simpler for a frameless panel glass-to-glass type, however this solution is realized with a very low production volume. In any cases, it is true that it is less expensive from a disposal point of view, but you have to consider that the recycling company does not have the aluminium frame anymore, which is the more profitable material because you can completely and easily recycle it and also because it is the heavier component with respect to the panel. Therefore, for these companies, it is convenient to have the aluminium, that is the material that you can better recycle. In the glass-to-glass panels you can better disassembly the panel, but there is also less material, the glass isn't completely recyclable, the aluminium, instead, yes.

Can we hope that in the future the components of the cell itself will able to be recycled more effectively?

The components are recycled, but when you disassemble the panel, the cell, even if it seems intact, is immersed in an encapsulating material, therefore to reach the cell, take it off and reuse it it's impossible for two reasons: first of all because, mechanically, it is impossible to do the work because it is merged into a solid gel, so you can't take it out. The second reason is related to the fact that when you go to recycle the panel you do also because the cells are no longer effective, because they are old, therefore, the best you can do is to pick the silicon, grind it again, and, only if you manage to reach adequate levels of purity, reuse it for the microchips production.

However, whereas the raw silicon is fairly cheap, there isn't a great interest in its reuse.

Typically, several electronic components, which are larger and without encapsulating material around them, are more easily reused.

You also have to take into account that a cell is 0.5 microns, so actually there isn't so much silicon, I think it's the 0.5% of the Panel.

3)AV project SRL technical office employee

I explain my project to them. Can you please describe your company?

AV PROJECT produce photovoltaic models with high quality, mono and poly cells, modules are made of high-quality products, guarantee of high performance by using cells with good efficiency. We monitor the production step-by-step. Laminated sheets undergo periodical screening tests verifying their minimal gel content, while the laminators temperature is constantly and strictly under monitoring. Afterwards end products are tested.

What is your behaviour regarding End-of-life products?

We take care personally of the disposal of the product if it is written below the contract, the main importance for us is the management of the module, but the most important issue is that every single material has to be re-worked and re-processed to be utilised again.

Who takes care of the re-process of the materials?

Consortium takes care of it for what concern materials like aluminium, glass and silicon. Anyway aluminium and glass are easier to recycle.

Why?

Because the problem regarding Silicon is that you cannot recycle a lot of material, when the cell is ready for disposal, in order to re-use a certain part of silicon you have to destroy the entire cell, since the silicon is incapsulated inside and you cannot recover the all its quantity. Moreover, when we operated in the PV industry, we tried to work with recycled silicon, but without obtaining results that were comparable with the use of the pure one. The more the material is pure the more the cell is efficient.

I don’t believe that we will see in the future the use in the PV sector of recycled silicon

So glass and aluminium are most re-cycled raw material, is it worthy for companies, I mean for your company and for the companies who recycle?

In economic terms it is, mainly regarding materials I mentioned before it is very common, there is a very big business around recycling nowadays, several companies do a lot of profit around it. Anyway I think that this is feasible only for the recycling of material present in large quantity, like glass and aluminium, where the recycling technology are very efficient.

Is there any difference between a recycled material and a new one?

Aluminum for example is one of the most recyclable materials. After the process, the quality of the product is the same as a the virgin one. You cannot make out the difference. It all depends from the recycling process and the recycling technology. If it is efficient, the material will be the same. Regarding Silicon, when we operated in the PV industry, we tried to work with recycled silicon, but without obtaining results that were comparable with the use of the pure one. The more the material is pure the more the cell is efficient.

I don't believe that we will see in the future the use in the PV sector of recycled silicon

You have incentives and government regulation on recycling, don't you?

Yes but currently, economic incentives are inadequate to move to voluntary recycling. However, I hope so, because in terms of environmental impact it is very important. I hope this may change in the future, maybe   thanks to new technologies developed , preventing pollution and reduce the emissions. Anyway this is more a social perspective, the only issue regarding my company is finding new ways to re-use every material in order to reduce drastically production cost. Because of course in certain case recycling is cheaper than buying or reprocess again.

What do you think is needed, in terms of actions from other actors in the supply chain and/or from governments, in order to enhance recycling and in a wider sense a Closed-Loop Supply Chain in the future?

At the moment I don't think it's necessary any intervention within the supply chain. What is needed is instead that the R&D really understands what it is and it is not possible from a technical point of view and then, if we reach this stage, we can go forward with actions in the rest of the supply chain.

I see the CLSC as a possibility in the future, the near future, but not now.

4) ENECOM Technical office

I explain the purposes of my work, before entering in detail of these issues, could you please present your company? Tell me about the general operations of the company, its business model, the production systems.

Enecom Italia produce solar panels with modules using a different support material, plastic. The features makes our the first flexible crystalline modules appeared on the market in Italy and worldwide. The absence of glass and frame making them ultra-light and ultra-thin. Their efficiency is almost three times greater than that of the flexible panels made of amorphous silicon and are made from fully recyclable plastic materials.

Who is aimed at the re-processing of the material?

When the product reach its end-of-life the company sells the panel to a constortium which takes care of its disposal and potentially of it's re-use

What kind of materials can be re-used?

Thanks to the material used, a large part of the panel can be recycled. The main material which can be re-used after the disposal is the plastic. After the small amount of copper we have In our product and silicon. However silicon suffer the problem of the composition of the product, since silicon is incapsulated in the cell, so it is not so easy to reach a good level of recycling.

So for what concern the silicon nowadays the recycling is not worth it?

Exactly, the thing is that with the technology we have nowadays it is not possible to make recycling of silicon feasible, perhaps the next years it will be easier.

Is there any difference between a recycled material and a new one?

Yes , the quality of a recycled product I mean, plastic for example is completely different. I would not use recycled plastic for new panels because this procedure may affect the quality and the performances of the product. Plastic is re-used mainly for other reasons, it is used in other industries, as for example trash cans, which don't suffer this issue. The main problem it is still the technology, a recycled product has less performance than a new-processed one. A potential customer never use a product with that characteristics.

What are your expectation regarding the CLSC concept?

As I said before, I don't think it will reach so much success, I wouldn't trust a product with recycled material. It's a matter of customer expectations. The future in my opinion is using materials which are biodegradable, in this way the process of disposal will be easier and with less pollution.

5)Day4 Europe srl   Business Development Manager

Tell me something about your company and your business model.

We sell and in part we produce photovoltaic cells.

Which materials do you use mostly in the production of your production ?

The basic component of a solar cell is pure silicon, other elements are aluminum and glass. In terms of weight i would say glass, aluminum and silicon.

Who is in charge of the disposal of the product at the End-of-Life?

We deliver the product to particular consortium that are aimed at disassemble the product and that proceed to the recycling in certain cases of some materials or to the disposal. The most important component is the engine, the cell is almost irrecoverable at the End-of-Life. Anyway it's not a problem we are facing today but maybe in the next years. Lifetime of our products is about 15-20 years so it is not a big deal.

What are the limits as regards the re-use of recycled materials? (Technology, product quality ....)
What are your expectations for the future regarding the possibility of reprocessing products and materials previously used already?

I have no idea, actually.

6) **FERRANIA SOLIS S.r.l**. *Key Account Manager e Formazione*

What does your company in particular, what is your business model and how markets operate?

We produce and sell PV modules operate on international markets, but Italy covers most of our sales.

What materials are used mainly in the production of your products? (Copper, aluminum, glass, plastic, silicon?)

Tempered glass, encapsulant (EVA), cells in mono and polycrystalline silicon, aluminum frames.

Which of these has greater importance in terms of performance of the final product?
Cells in mono and polycrystalline silicon.

Who is commissioned disposal of the product at the end of life?
COBAT Consortium.

There is the possibility of recycling some component?
More than 80% of the PV modules is recyclable (silicon, glass, aluminum)

Are there regulations regarding the recycling of material with regard to your industry?
Obviously. At European level it is DIRECTIVE 2012/19 / EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) and the respective national laws conform to it (in Italy worth the Decree. 49 of 14 March 2014).

My thesis project is inherent in the possibility to re-use recycled materials in the production of a new finished product, think is possible nowadays?
it'salready so for certain components, for example for silicon used in the PV cells (production waste are collected and returned for recycling right).

What are the limits as regards the re-use of recycled materials? (Technology, product quality ....)

Until now we have technological limitations: PV technology is not yet fully mature the whole supply chain (including recycling).
Someone is starting to develop and refine only recently technologies for the recycling of modules and materials used in PV modules.

What are your expectations for the future regarding the possibility of reprocessing products and materials previously used already?

The eco-sustainability is intrinsic in photovoltaic technology: there is no doubt that there is the possibility and is already in this way for certain components (for example, as mentioned, for the silicon used in the PV cells) and there will be more and more in future.

7) LUX chairman(interview made for another projects, some useful question were extracted)

I explain my work

Are you involved in recycling? Can you tell us something about the recycling of silicon?

It depends on the step in which you take back the discarded material. Once you have assembled the panels, it’s very difficult. This is particularly true because nowadays quantities are really scarce, so nothing about it has developed yet. If you consider the sandwich made with EVA, you can’t do anything for recovering, except for a thermic process to recover plastic. Instead, it is not a big issue from the cell to come back to the silicon, this is already done (but especially for silver, not now for silicon, because it is more convenient, with actual prices of silicon, to buy it on the market).

For what concerns recovery in general, on the one hand we have glass that is recovered, aluminium also. It remains only the sandwich, which can be recycled thanks to thermic processes, but in this way we produce pollution. Right now there are only research projects about that, also because the results of using recycled material in production will never reach the level of pure materials. Silicon does not return in the photovoltaic sector (reasons of price and lower efficiency).

So in your opinion the recycling and recovery sector will not develop more in the future?

Fur sure at least within 10 years, when we will start to have more returned products, it will become interesting. But what will the costs be? Now we can't tell what they will be. It is too much uncertain this. There are too many variables, also for example for what concerns the feasibility of it in Italy. I know that in Germany they have developed some plants, but they were just tests.

And for what concerns stability of volumes in the future?

Plants made in the last years (photovoltaic is a young industry, more or less 5 years) that returned back, are disassembled and sent to tertiary countries that accept also panels with efficiency not higher in our markets. It is like this also for automobiles, for example. They are sold at lower price to these countries.
I think this is a smarter strategy than closed-loop, because I think the cost of recovery will be higher than the actual value.

8) FRONIUS (interview made for another projects, some useful question were extracted)

General manager

Is it possible to recycle Lithium?

I don't know this. I can say that now the price of lithium is low for a matter of demand/offer, but I expect a raising issue in the future years. Lithium is in the same situation of Oil, if we consider the number of years of availability.

Has Fronius some plans in order to prevent these issues?

Our plan is to find alternative materials to Lithium, but it is not easy to find them. For now, we are considering substitution of lithium, not recycle.

Why?

You should know that we are buying components using lithium and not extracting or manipulating it. Very few companies extract lithium and it is also very complex and dangerous to be managed, so you must have the correct knowledge to not create damage to people and environment.
Producers of lithium come mainly from Japan and China.

What is your opinion about the recycling and in particular of closing the loop for PV panels?

I see a false problem. The panels end of life is not happening yet, but actually they live for very long. Some have thought the problem would arise when the incentive schemes had finished, but I think that PV systems will not be dismantled then because they can still produce energy without further costs, so their life is still long. There is a law, which thinking at the 20-years incentives, has introduced some recycling objectives (preparation of sites and of plans) but the panels will last more than the years of the incentive, so there is not the necessity to recycle panels that are still functioning.

9) Cobat consortium R&D

Describe your business, general operations of the company, its business model, the production systems?

We are a consortia who respond to a very precise regulation frame, related to the concept of responsibility of the producer, following this directive producers and sellers have to guarantee the End-of-life treatment of the products. We are one of the biggest Italian systems to whom the companies turn to obtain the incentives contained in the IV Conto Energia, which was extremely linked to the collection of the End-of-Life products.
We have collected few modules so far, because we are far from the obsolescence of the modules so the most of them comes from the disposal of old plants. We do not have a treatment line, firms do that, so we do not have the technical detail regarding the recycling activities .

The destination is to a third party ?

Yes. The destination is a company which take care of recycle or in case the disposal.

What are the raw material you re-use the most?

Most of the recover is the glass because silicon is minimal. The FV module has an aluminum frame and it is recovered with the electronic parts .

Do you have problem in recovery material? Is it worthy for you?

No problems in terms of managed quantities, the "power" is enough to guarantee more than that we actually do. You have to consider also that there is a parallel activity, made by other operators which, with the proper permissions, they work on supply chains in where our consortia has no control. Our consortia does not have a thorough picture in general terms, we tipically have a partial picture of the situation. You have to consider also that a lot of wastes travel out of our territory, in this case not determining a valorization of the national one. Often, foreign companies buy these secondary raw materials

What actions are needed to achieve CLSC's?

Government support on these virtuous processes is a successfull measure, if there is a regulamentation that support these activities. The thing is that in an market economy in which everything moves thanks to the money, if a firm complying with certains obligations, it wastes money, these becomes only a philosofic exercise which end with itself. It is important that a circular economy is supported with a long range strategy, not imposing choices to the production machine, but determining the conditions towards this change, making this activity profitable for companies.

How do you think we can achieve this?

It is important to find positive networks and that the regulamentation creates the proper links: recovery with certain performance and recovery because a system exist able to receive raw materials. If the recovery activity exists only to reduce the environmental impact, it is not enough. Very often we limit ourselves in selling material without looking the costs related not to recovery them properly and ineffective disposal. We need a regulamentation which makes an effort to create an effective network. There are a series of directives, for example the European directive on December which is a landmark because it tried to diffuse this mechanism. European directive followed schemes which in the past were promoted by environmental associations or universities to promote the change towards a more sustainable economy this make me keep hoping. Anyway, this is only a starting point, the way towards CLSC is still long and difficult.

Why?

Because, we are still in a utopistic phase with no real evidence, so until now it is difficult to orient because everyone share opinions.

10) PV CYCLE Consortium, Head of Public Affairs and Communications

Explanation of the project. Can you explain us the operations of your company?

I'm the public affairs manager. We are an industry association with the mission of taking back PV modules. Before it was on a voluntary basis, because PV industry knew that it was producing a green product and it wanted to make sure that also at its end of life this product was treated properly, with a sustainable disposal. Today it is not anymore on a voluntary basis, because of the directive for waste of electrical and electronic equipment introduced by the European Union (WEEE), and now that also applies to PV modules. Since 2014 companies working in the PV industry in the EU have to comply with this law and a lot of them do that by joining PV Cycle.

We take back PV modules, for that we have also several collection points. And we also have what we call an on-site pick up service, that is that we come to your location to pick up large quantities of PV modules. We work on different channels for taking back PV modules, and then we take them to our recycling partners, that are in Italy, Germany, Spain, etc. But they come from different industries, so some are battery recyclers, some electronic equipment recyclers, and so on. So from very types of recycling industries. Every kind of PV technology can be recycled in PV cycle.

What is the destination of recycled products?

Our recycling partners deal with the selling of materials.

They can sell to PV industries but normally sell to other industries, that can be several types of industries. This is because aluminium and copper that we can recover for example can be used in any kind of copper and aluminium product.

The glass that we recover from PV modules can't be used for them anymore, because PV modules require a very pure glass. This is because you want sun to go through glass, so recycled glass cannot be used anymore for PV modules. It normally goes to glass packaging, glass insulation, these kind of products.

So you (your partners) can recycle every component of PV modules or there are some critical materials?

At PV Cycle we have an average recycling rate between 90-97%. It depends from the PV technology, so for silicon based technologies, so all technologies that use silicon as a semiconductor, we have a recycling rate of 90%, for modules that use a different semiconductor, such as cadmium telluride, our average recycling rate is 97%. It's a huge recycling rate and it means that a very little rate has to be disposed because there's no possibility of recovery. I will send you our briefing book on recycling, so you can have an overview of all the materials.

So, apart from glass, for all the other products you have no problem of reaching a high quality level, or there are some other materials that give you problems from this point of view?

No, as I said to you glass goes to glass packaging or insulation, but other materials such as aluminium and copper, they are very easy to recover, we obtain basically the same material that can be reused in every kind of product. We can recover plastic, for example and also in this case there are many uses of it. There are some semiconductors that can be recovered up to 95%, such as cadmium telluride, that can be used also in other kind of products. We can recover also silicon, silicon dioxide, but can't be used for the production of other PV modules but for other products. This is because for the cell you need a very high level of silicon. This is not really because of the quality of recycling, but because for modules you need a really high level of purity of silicon. Also silicon that you find on the market needs to have a very high level of purity in order to be used for PV modules.

Can you tell what are in your opinion the barriers for recycling and for CLSC? For example, there is a trade off between the long life cycle of these products and their recycling?

From the technical point of view there are really few limitations and challenges, since PV module is not very different from other flat products, since the principle is the same. What is challenging is that nowadays we have relatively few PV modules coming back as waste, because of its long life cycle, but we expect that within the next 5-7 years in Germany, Spain, which are very mature markets, we will have higher quantities of modules coming back as waste. In other countries like Italy, France, UK, that are younger PV markets, to have higher quantities of waste we will have to wait at least 10-12 years.

Today we have treated more or less 14000 tons of modules, but those were mainly derived from installation or transportation damages, weather damages, so not modules that reached the end of their technical life.

Do you think is needed some action from other actors, such as governments for example, or more integration between the company in the value chain, in order to help the development of the CLSC?

I don’t think that from the legal point of view we need a lot of change. What we see in our company is that we spend a huge amount of hours to educate PV companies and PV owners on the correct disposal, so it is more about collection than recycling. So in our opinion the challenge is more in the take back than in the recycling.

If I can say something about legislation, maybe they can spend more time on inspections and education in order to make sure that everybody in the value chain knows the correct way to dispose modules. We do a lot to educate people, but the collective phase is really challenging.

From the technical point of view there are not big challenges, of course there is always room for improvement, in fact we are involved in several R&D projects.

As I said, the main challenge is in the take back, for example also the end customer has to know how to dispose correctly the modules. It is the same principle of mobile phones or televisions, once you own them, you are responsible for their proper disposal.

There is something else you want to add that could be useful to our research?

I will send you some materials about the products we can recover and our monthly status report (briefing book) and our monthly status report to say what we collect and in which country.

11) Exe solar export manager (EMAIL INTERVIEW)

What does your company in particular, what is your business model and how markets operate?

Our company is engaged in production and marketing of photovoltaic modules made in Italy and made in Asia with principal focus in Europe.

What materials are used mainly in the production of your products? (Copper, aluminum, glass, plastic, silicon?)

In the production of the modules we can list the following materials:

-celle poly silicon or monocrystalline

- Glass
- EVA - Ethylene Vinyl Acetate
- Tedlar (bottom cover)
- Aluminium frame
- Connection box

Which of these has greater importance in terms of performance of the final product?

Surely the poly silicon or monocrystalline cells, however, the set is also very important.

Who is commissioned disposal of the product at the end of life? To your knowledge, there are regulations regarding the recycling of material with regard to your industry?

COBAT - The modules are considered WEEE (Refusal of equipment Electrical and Elettornica) and to the purchase in Italy the customer already pays the contribution WEEE, a disposal fee. All it regulated by Legislative Decree 49/2014, that on February 2 was amended by Law 221 of 28 December 2015 (entered into force on environmental Connected amending art. 40 of Legislative Decree no. 49/2014), bringing the contribution of WEEE to the current € 4,50 / module (independent of the module power) - find more information about COBAT - National Collection and recycling Consortium

There is the possibility of recycling some component? My thesis project is inherent in the possibility to re-use recycled materials in the production of a new finished product, think is possible nowadays?

Yes, of course, the silicon does not lose its properties of absorption of solar radiation, and then the cells can be recycled and reused (Only for panels Thin films not, because they have little silicon, however, we do not work with these panels).
They also recycle the glass and the aluminum.

What are the limits as regards the re-use of recycled materials? (Technology, product quality ....)

I would say the technology, which now thinks only to disposal and not for recycling, because the icon corresponds to recycling processes more and more jobs you have, the cost, and become less competitive ... I honestly do not know here to look into.

What are your expectations for the future regarding the possibility of reprocessing products and materials previously used already?

I think the possibilities are there, everything will depend also on those costs which must decline and incentives that need to increase ...

12) REMEDIA Segreteria Soci (E-MAIL INTERVIEW)

What does your company in particular, what is your business model and how markets operate?

Remedia is a leading Italian Consortia for the eco-sustainable management of technological waste or Waste Electrical and Electronic Equipment (ndr photovoltaic included) batteries and accumulators (PA) at the end of life.
The Consortia is the environmental commitment of the more than 1000 member companies - need to comply with legal obligations related to WEEE batteries and accumulators, who produce or import small and large appliances, IT and telecommunications, air conditioning equipment, toys, medical devices, monitoring and control equipment, musical instruments, portable batteries, industrial batteries and vehicles, lead-acid batteries and photovoltaics. For all categories of products covered by the Decree WEEE from both the domestic circuit), Remedia guarantees services transport and treatment according to an operational excellence model based on integrated quality and environment of the Consortium .

What happen at the End-of-life of the products ? Photovoltaics in particular?

Remedia, with an operational excellence model , operates efficiently and safely all types of Technological Waste (WEEE, Batteries / accumulators exhausted and Photovoltaics at end of life).

What about the recycling technology?

They are being numerous research and development projects to locate the best recycling technology of the most commonly used photovoltaic panels that with crystalline modules (policrystalline or monocrystalline) and thin film. For crystalline silicon panels are traces the process of the modules flat-screen whereas for the non-silicon modules establishment of different phases, still being studied.

The silicon of the panel in a short recycling process: removal of the aluminum frame and the connection box, shredding, flow of processing (similar to the recycling of flat screens)

What's your opinion regarding CLSC? What are the future opportunities?

Just by recycling, derive a significant chance for the recovery of essential minerals without deteriorating beyond repair ecosystems.

E-Waste Lab promoted by Remedia aims to maximize the value of recycling of WEEE and direct investments of the elements of the sector towards greater efficiency and integration along the supply chain itself. A first phase of analysis of the scenario and the economic and environmental opportunities, follows a complementary pilot projects which aim to identify and realize economic feasibility studies for the collection, transportation, recycling and recovery of precious metals from electronic waste, with a focus on innovation and organizational process.

Remedia is partner of Premanus project funded program under the Seventh European Framework Programme. Premanus project started with the goal of building a "business decision" model to help companies evaluate the economic and environmental impacts related to the opportunity to carry out activities of "re-manufacturing" (repair and reconditioning of used products) of a product or component, or start to disposal / recycling.
The goal of Premanus is to develop an architecture "IT Service Oriented" that welcomes information related to the product and the service for the recovery process in the end of life.

13) **Caris servizi logistics responsible**

Give me a brief description of your company, general operations of the company, its business model, the production systems?

Our company is aimed at the disposal and the potential recycling of wastes

Which materials do you use mostly in the production? What is the most important in terms of performance?

Cardboard, paper, glass, aluminium. It depends on the characteristics of the product we collect.

What happen at the End-of-life of the products, do you take back the product personally?

It depends on the type of contract, sometimes we collect the waste personally, sometimes not.

Who is aimed at re-processing the raw materials? What kind of materials can be re-cycled? What kind of material can you re-use?

Actually I don't know, I am not concerned about it, you should ask to someone else because my task does not include these type of problems

Does your firm have information about the lifecycle of the product?

I don't know.

Is it recycling worth it for some materials? Tell me your opinion.

Yes, for sure. Our company works on this issue and this activity for us is profitable.

Do you know what does it mean CLSC?

No I don't know
(I explain it to her)

Do you think, given the situation nowadays, it is a promising idea? What are the limits you perceive on that?

I think it's not because basically the actors involved don't care about it. They have incentives for the disposal so they behave like this. However, in general they don't care because for them, apart from the governmental regulations, it is not a big deal.

What are your future expectations on CLSC's?

I pretty sure it is not going to be successful, too many actors involved with different perspectives, target and different level of profitability. Legislation is enough, also because without it companies would put their wastes in the neighbourhood without any problem.

14 ERP Italy Andrea Bizzi, Technical Regulation Manager of

What you are mainly engaged in your consortium?

European Recycling Platform (ERP) is the only pan-European collective system currently present in Italy. European leader in the management of household and professional WEEE, waste batteries and accumulators, of the PV panels and packaging.
Established in 2002, it provides associated Manufacturers recycling solutions and compliance high quality services at competitive prices, with benefits that are reflected also on consumers and the environment. The ERP commitment to providing the best solutions to its partners translates into actions aimed at affirming the European culture of recycling, using the experience and expertise gained at the international level.
ERP Italy is the Italian subsidiary of ERP: founded in 2006, it has initiated the withdrawal of WEEE in 2008. It is one of the main collective schemes in Italy and manages compliance and withdrawal activities for all types of WEEE, waste batteries and accumulators and photovoltaic panels to over 500 customers.
The ERP Italian mission is to develop efficient recycling services and high quality for the benefit of member producers, consumers and, basically, the environment and society. The network and the experience gained ensure compliance with the manufacturers and importers, allowing them to focus on core business activities.

What is the destination of a photovoltaic panel at the end of life?

The photovoltaic modules are divided into domestic / occupational and historic / future depending on the power of the system on which you have installed and the date of placing on the market.
The photovoltaic modules installed in plants with a rated power up to 10 kW are considered domestic, and as such, at the end of life and regardless of the date of placing on the market, can be conferred from your local drop-off, or your distributor in case of purchase of new photovoltaic modules, for an equivalent number.
For domestic photovoltaic modules placed on the market after February 2, 2016, you can directly apply to the Producer of the same.
All PV modules installed on systems with greater than 10kW power rating are considered professional and their management at the end of life, with regard to the modules installed as from 12 April 2014, is submitted to the manufacturer of such forms. In the case of professional photovoltaic modules placed on the market before 12 April 2014, the management is delegated to the Manufacturer of the new forms provided, in case of replacement, and the holder in the other cases.

As for the photovoltaic panels in this case, but also other products in general, mind you to pick up the panel at the end of life?

Yes , on behalf of the member producers, ERP Italy intervenes both at communal collection centers or directly from photovoltaic systems that need to be recycled.
ERP Italy deals with all stages on the withdrawal, transport and recycling / disposal, through a network of logistics providers and treatment can cover the entire national territory and selected according to strict quality standards. It is part of the service we offer to the customer.

Which organization or company deals with the eventual recycling? No matter the name, I just want to know if your consortium also carries out this activity.

ERP Italy deals with the recycling of photovoltaic modules giving to partner treatment plants, selected and certified on the basis of strict protocols and procedures to demonstrate environmental excellence and economic sustainability.
The chain of Italian ERP was implemented taking into account the environmental

performance of the treatment plants, the efficiency of recycling processes and trying to minimize the distance to be taken to give WEEE treatment plants selected in order to achieve an optimization logistics as well as environmental.

Do you have special information about the life cycle of each product?

Web portal ERP Italy, the http://www.erp-recycling.it/come-riciclare/cosa/ section details the recycling processes of the various groupings WEEE, batteries and other materials, with an indication of materials that can be recovered from each grouping.
This particular section, it immediately makes the idea of which path to take any grouping at the moment when you start the recycling process.

Recycling is a valid economic level? What materials can live as it were "a second life" after the re-processing? Some of these have a quality equivalent to virgin materials?

The recycling industry, with particular focus on WEEE, is definitely important business and economic activity in Italy that has developed strongly in recent years.
However, it should not make the mistake of thinking of WEEE as just a gold mine, source of easy money and safe.
The first goal of the recycling industry must be to protect the environment, treating WEEE with technologically advanced processes and definitely challenging from an economic point of view. Compared to the concept of environmental education ERP it is always concentrated in the creation of a "culture of recycling" because it firmly believes that the virtuous circle of rejection starts from the hands of the first holder of the latter, namely the citizen.
That's why the EU has implemented the "principle of extended responsibility of the Producer": Manufacturers must take responsibility for the end of life of the products they put on the market, both from a financial point of view and operationally.
Clarified this concept, there is no doubt that the WEEE recycling processes help realize materials, especially certain metals, which can be fed back into the production cycle, resulting in some cases a positive economic value; This, in effect, is what he asks us the "green economy" to allow industry to feed themselves while reducing reliance on virgin materials.

In the introduction I explained the concept of closed loop supply chain. He had already heard?

Absolutely, in the WEEE world is a well-established concept that comes in all stages: from eco-design of new EEE (with a view already geared to facilitate future recycling), a traceability producers and products, an incentive to reuse and thus prolonging the life of the products, a widespread and simple WEEE collection system for the consumer, to a certified recycling chain and oriented to the green economy. All the actors are key to achieving the objectives set at EU and national level.

Do you think it is a 'promising idea?

Certainly, to achieve the objectives that the EU has set itself.

What are the major limitations (technological, legislative, economic) to achieve a goal of this type?

There are various aspects to consider. The first is definitely a technological limit: the design of eco-friendly AEE may entail additional costs for companies, so it is important to make a "cost-effective" design of this type, for example by providing a reduction in the contribution to the management of WEEE to those manufacturers that invest in eco-friendly products. From a legislative point of view it is important that the rules are few, clear and precise: it must be a simplification, for example, the administrative burden on the part of the distributors of EEE, to encourage them to fulfill their obligations to take into account 1 1 and 1 with 0. Finally, one cannot overlook the economic aspect: the environmental performance demands require technological and financial commitment that only producers can ensure systems. It 'easy to treat a poorly WEEE solely to obtain exploitable components. The task of environmental operators is rather to provide new raw materials and the second industry without compromising in terms of environmental protection and sustainable management of recycling processes used.

10. What are your expectations with respect to the concept of circular economy or Closed loop supply chain?

ERP is strongly committed on this issue. He has submitted its comments and suggestions on the subject of Green economy at Community and national level, in relation to the various legislative proposals on the table. ERP believes the Green Economy as the only sustainable economy over the long term, but it requires clear and transparent rules to ensure fair competition and does not discriminate between the various stakeholders involved and the various member states, defining the responsibilities and obligations of each person involved.