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REGULATORY ASPECTS RELATED TO THE USE OF NANOTECHNOLOGY IN RENEWABLE ENERGY TECHNOLOGY

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Regulatory Aspects Related to the Use of Nanotechnology in Renewable Energy Technology

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Sandra CASSOTTA[*]

1. Potentials and Challenges on the Use of Nanotechnologies applied to the Environment

The strong need to improve innovation is an instinctive desire for all current industrial societies. Enterprises headed by business leaders are constantly committed to creating new products or improve their characteristics. One revolutionary way to improve this production is by using nanotechnologies as a key technological innovation and as a *unique* source of global industrial development.

Nanoscience and nanotechnologies (N&N) are new methods of Research & Development (R&D) which aim to dominate, manipulate and change the fundamental structure of materials at atomic, molecular and macromolecular scale, which is an ultra-fine scale, or a "nanoscale", or more specifically, the precision manufacture of mechanical parts with finished and tolerances in the nanometric range.[1] Etymologically, "nano" is a Greek world which means "dwarf". This means that nanotechnologies all have in common the production and use of materials illimitably small which applies across multiple sectors, from physics, chemistry, cosmetics, biology, food, medicines, renewable energy products and "energy storage".

In particular, when linked to the environment, nanotechnologies present numerous beneficial aspects but also challenges.

The new positive perspectives on the use of nanotechnologies applied to the environment is given by the often cleaner and safer characteristics compared to the older technologies as they may offer ways of remedying environmental harm directly through being a cleaner and less polluted production, and being more sustainable. The potential benefits of the use of nanotechnologies for the environment pushed the European Union (EU) to have focused so much on the role of nanoscience as a cornerstone of the Lisbon Strategy, provided as a strategy for economic reforms to develop Europe into a knowledge-based industrial society declaring its goals of making the EU the most competitive and dynamic economy in the world by 2010.

Nanotechnologies when used in Renewable Energy Technology (RET) offer a resource of saving through improvements in efficiency for renewable energy resources, energy production and storage such as solar cells, thermoelectric devices, fuel cells and other energy storage such as rechargeable batteries and supercapacitors or hydrogen storage. This means that when applied in the sectorial

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[1] The term "nanotechnology" was introduced by Taniguchi in 1974 to describe the precision manufacture of materials with nanometre tolerances. Nanotechnology mainly consists of the process of separation, consolidation, and deformation of materials by one atom or one molecule.

example of solar energy, nanotechnology is used in numerous domains such as solar power, wind, fusion reactors, fuel cells, batteries, storage transportation, or new electrical grids. The most positive aspect in the use of nanotechnologies in the RET consists of lowering the costs of production, especially, if the photovoltaic sector is taken as example in the production of photovoltaic panels (PVs), and at the same time, it improves considerably the efficiency of the product in its capacity of "source of storage".

PV panels represent a renewable resource of energy by enabling to direct conversion of solar radiation into current electricity, and in that process, N&N can be used to catalyze the product performance, especially in their capacity for energy storage. The issue of energy storage has also been emphasized amongst the United Nation Millennium Development Goals[2] in relevance to production and conversion, agricultural productivity enhancement, water treatment, and remediation.[3] From a legal and political perspective, solar energy in RET, is mainly focusing on an incentivize mechanism for PV in which photons are channelled into batteries or general energy grids. The energy production and storage at most efficient low-costs of the PV solar cells[4] are expected to be highly efficient and cheap. Numerous studies have been focusing on the different design aspects and performance characteristics of the PV cells produced with N&N, with the common goal of producing PV modules to compete with traditional energy sources.

Another strong potential in the use of nanotechnologies in RET is that it can improve the situation in developing countries, especially in relation to the new generation of solar cells, hydrogen fuel cells and novel hydrogen storage systems that could deliver clean energy to countries still reliant on traditional, non renewable contaminating fuels. In that sense, nanotechnologies could aid developing countries in avoiding recurrent shortages and price fluctuations that come with dependence on fossil fuels, and to enhance the agricultural benefits for these countries.[5] In developing countries, nanotechnologies can also increase soil fertility and crop production and also help to eliminate malnutrition through improving the water system.[6]

Parallel to all the positive perspectives on the scientific development brought by nanotechnologies, the main concern regarding the risks that nanotechnologies could have, is the negative impact on the environment, health and safety (EHS) which emerges mainly as there is very little scientific literature on the environmental toxicity or exposure to allow the undertaking of assessment of potential environmental and human health risks associated with environmental exposure to nanomaterials. However, even if the dangers *per se* are difficult to understand, what scares is the existence of a certain amount of studies into toxicity both for human health and environment[7] even

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[2] See Millennium Development Goals in http://www.un.org/millennium Goals.

[3] Faunce, T., "*Governing Nanotechnology for Solar Fuels: Towards a Jurisprudence of Global Artificial Photosynthesis*", 2011, RELP, pp. 160-164.

[4] The "cells" in the PVs, also called "solar paints", are the elementary materials for the construction of PV modules. Such types of cells are the so-called "Grethe cells" invented by the famous Swiss engineer to build PVs with the use of *titanium.* The patent of this kind of cells is very old and will soon expire. Another kind of cells made with nanomaterials are the so-called "fullerenes" and the "nano-tubes" which are another way to "treat" and experimenting with "nanoscale" technology.

[5] See the Report of the Organisation for Economic Cooperation and Development (OECD) "*Opportunities and Risks of Nanotechnologies*", Allianz.

[6] The water system in developing countries can be improved because of the existence of selective membranes which can filter contaminants or even salt from water (processes better known as "desalinisation"), as nano-membranes can remove pollutants from industrial effluents and contribute in such a way to the maintenance of industrial sustainability

[7] Bystrzejewska-Piotrowska, G., Golimowski, J., Urban L. P., "*Nanoparticles: Their Potential Toxicity, Waste and Environmental Management",* 2009, 29,Waste Management, Elsevier, pp. 2587-2595; Randerson, J., "*Carbon Nanotubes may be Hazardous to Health as Asbestos*", The Guardian; "*Carbon Nanotubes as Bas as Bad as Asbestos,*

though the impact of nanotechnologies on health and safety is also equally poorly understood as the likelihood of nanoparticles bringing a new dimension is not known.

Generally, the most alarming scientific aspect regarding the use of N&N in the manufacture of an "x product" is due to the *ratio* between surface/volume. This *ratio* is much higher in the small sided particles of the nanoproducts compared to in the "non-nanoproducts" or compared to the larger particles contained in a non-nanoproduct. This means that, given the fact that the time of propagation of the nano-particles contained in a product manufactured with N&N is much quicker than the time of propagation for larger particles of a non-nano product,[8] the time and effect of propagation into the environment or into the human body of the nano-products will be catalysed and intensified much more, especially if the nanoproducts are left, laying as "waste" on the ground or transported everywhere once their life as a product ceases and they become "waste". For such a reason, even though it is not certain what the impact of the nano-particles and products will be in the atmosphere or in the human body it is absolutely necessary and should therefore be mandatory to recycle, everywhere, the waste products containing nano-particles. Foresight of possible risks depends on a consideration of the life-cycle of the material being produced. This involves the necessity to understand the products, and the production processes of the materials used in manufacture, and the interactions between products and individuals or the environment during its manufacture and life, and the methods used in its disposal.

Due to these scientific reasons, it is a challenge, especially from a legal point of view, that nanoparticles bring a new dimension to the sphere of environmental liability, to personal injury and property damage losses, as well as or posing third party liability and product-recall risks. Also, over the next years, consumers will be exposed more and more to the manufacture of nanoparticles, and labelling requirements, as well as eco-design requirements and innovative market designs for products containing nanoparticles which do not yet exist.[9]

The problem of how to manage the risk will be more and more evident especially from an insurance perspective as possible risk scenarios from nanoparticles will make it difficult to attribute environmental liability as a consequence of this new generation of "nano-environmental and health damages".

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says Study", Indo-Asian News Service, May 2008, in "Nanotechnology Law Report published by Porter Wright; Porter, S., "*Alert over the march of the "grey goo in nanotechnology Frankenfoods*", 2008, Daily Mail.

[8] The speed at which nano-particles contained in nanoproducts propagate into the environment is due to the considerably larger *ratio* of surface/volume of nano-particles compared to the *ratio* of surface/volume of "non nanoparticles". This means that the time of propagation of nano-particles into the environment is faster as the surface area of this product is larger. In other worlds, the more an object (or a product) is smaller in size, the more the relationship between surface/volume increases.

[9] The incorporation of labelling needs into regulations is an important aspect of consumer policy and acceptance of nanotechnologies as the identification of material through the labelling is used as an instrument of risk management as it aims at informing consumers about the presence of nanoparticles in the products which make the consumer informed and free to choose to buy, or not, the product. The only exception to the existence of labelling needs is in the cosmetic sector. See for that aspect Van Calster, G., Bowman M. D., and D'Silva J., *"Protecting consumers or failing them? The Regulation of Nanotechnologies in the EU"*, European Journal of Consumer Law, 2011, page 108; and also the Commission Staff Document accompanying the Proposal for a Directive of the European Parliament and of the Council establishing a framework for setting of eco-design requirements for energy related products, COM (2008)399final, SEC (2008)2116, and finally, the "Position Paper of the European Photovoltaic Industry association (EPIA) "Toward Energy Future in Europe: Recommendation from the PV Industry", Brussels, 4 March 2011.

Consequently, an important challenge is to establish, in individual cases, a causal relationship between the actions of a company and the resulting injury or damage, and also to establish the causality link between the author of the damage and the event as it will be very likely that nanoparticles will not be so much a single cause or central origin of an illness or an environmental damage but more a contribution to a general health or environmental condition.

This will make the regulation of the nano-damage in a traditional environmental liability regime and compensation very challenging as a causal relationship must be established between the author of the damage and the event. At EU level, in the legal framework, such a causal relationship must be proved.

Reasoning from a "cycle-life perspective", the most challenging aspect in the use of nanotechnologies in the RET sector and its repercussions on the environmental and health concerns, is the waste aspect of the product, and an example could be the PVs and the wind mills once they become waste. What happens when the products arrive at their ending-life-phase after 25 years? Do they pollute? And in that case, do we have an end-life regulation which renders the producer liable?

The impact of the use of nanotechnologies in RET products when they become waste are mostly unknown, and yet there are high risks that they will pollute the environment. Hence, a link between nanotechnologies and waste must be established, especially as a means to assign environmental liability on the producer. From a life-cycle perspective, the linkage between environmental liability, nanotechnology and waste has to be contextualized in the light of the current multilevel regulatory panorama which is traced below, as only a holistic view can unveil the components which are adequate to create a more responsible and effective law regulating energy products containing nanotechnologies, such as the PVs.

2. State of the Art on Regulation of Nanotechnology at EU level, in the US Model and the Level of Standardisation

Nano-materials can be regulated by different types of environmental *media*[10] laws. Businessmen and manufactures are liable for the safety of the products containing nano-materials that they put into the market. This section evaluates the current legislation available for regulating nanoscale materials in relation to the use of RET. The section also takes into account the existing barriers and potentials that may exist when using laws addressing the potential risk posed by nanoscale materials. State of the art of regulations on nanotechnology in respect to hard-law and soft-law, such as voluntary measures, technical norms and international cooperation, are necessary in order to understand as whether there is the need for amendment or adjustment when nanotechnology is applied to the environment with the view of creating more responsible laws. In the medium to long term period, it is expected that most revolutionary applications of nanotechnology in RET will become reality.

Such challenging practices will have more and more relevance in the future, which is why it is important to give adequate attention to tackling them in the most efficient way and with the most effective regulations.

[10] The different *media* in environmental law language means: water, ground, habitat, and animal species.

The need to design adequate legislations in order to place nanoproducts in a "safe way" into the market it is a source of a hot debate at institutional level between the different carriers of interest, both of official and non-official actors (such as group of interests composed by stakeholders, associations, NGOs etc.). Different factors are characterizing this hot debate: the huge variety of nanomaterials and applications, the unique behavior and characterization of the materials at nanoscale, the absence of data for the characterization and typology of nanomaterials; and finally the multidisciplinarity and difficulty to develop risk analysis.

On the face of these focal difficulties, the EU, the US and the International Law of Standardisation involving the different carrier of interests, have started to determine, on the basis of existing regulations, whether the laws or regulations could be applied to the hot focal factors characterizing the difficulties in designing effective and safety laws for nano products.

EU Level

Currently, the EU is focusing on the so-called Engineer Nanomaterials (ENMs) which are products produced voluntarily in their free shape (free engineer nanomaterials) due to the effects that they can produce on EHS. Currently, there are a consistent number of hard regulations which could be interconnected with N&N and which are susceptible to being applicable. Several agencies and technical committees are involved in their regulation[11] especially in improving the instruments of support of regulations (technical norms, guidelines, codes of conduct, etc.) with the common objective of improving their effectiveness and implementation.

The waste Directive 2008/98/EC[12] instruct Member States to apply a "waste hierarchy" in the prevention and management of legislations and policies and set forth system legislation and permits. This directive is potentially able of covering interesting aspects of the nano-liability problems that could arise in the life-cycle approach. It contains specific provisions related to hazardous waste which is defined as "any waste which displays one or more hazardous properties listed in Annex III". Such hazardous properties include harmful and mutagenic substances. The linkage between Directive 2008/98/EC and its possible application to nanotechnologies has also been considered by the EU Commission.[13] However, even though the Commission advances the possible application of the directive on wastes containing nano-materials there are no structures and enterprises which know how or can treat "nano-wastes". For example, it is not know how the incinerators could manage and handle the nano-wastes. Wastes containing nano-materials could spread into the environment with damaging substances and what scares is that it is not known what the behavior of these nano-particels will be and there is a lot of uncertainty as to the risk and the typology of damage.[14]

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[11] See the Commission document"Regulatory Aspects of Nanotechnologies", COM (2008)366final.

[12] Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on waste and repealing certain Directives, OJ L 312.

[13] See the Commission document "Regulatory aspects of the nanotechnologies", COM (2008)366final.

[14] The typology of environmental damage, in case of nano-product is still remaining a huge *enigma.* Hence, it is precisely because of this enigmatic aspect that precautionary measures as to the waste containing nano-particles, should be taken in order to avoid that future generation pay just because of the superficial and immature behaviour of not taking into account the enigmatic aspect of the environmental risks justified by the lack of scientific data which the use of N&N could entail to human being, animal species and the environment.

Regulations on chemical substances, especially the "Registration, Evaluation, Authorization and Restriction of Chemicals" (REACH),[15] regulating the use and trade of chemical substances, has been widely considered in relation to the use of N&N. However, different aspects, in the application of this regulation still remain open. The REACH regime turned out to be ineffective from an environmental point of view, when applied to N&N.[16]

Even though REACH is potentially providing guiding principle for how should Europe face nano-regulations, especially for the relevance of the Precautionary principle, some aspects are not adequate in the regulation of nanomaterials such as for example the use of the levels of threshold based on the volume of substance produced and the existence of exemptions of some categories of materials in the current REACH regime.

The non-inclusions of such categories of material entail the exemption of the same materials in nano shape. It is worth noticing that according to the REACH regime, the burden of proof demonstrating that a given chemical substance is not damaging and has to be considered as "safe" before to be introduced into the market, is on the producer. However, no precise indications are given as to the life-cycle of chemicals products.

The EU Environmental liability regime set up with Directive 2004/35/EC[17] based on strict and *culpa* liability regime imposes *inter alia* a strict liability regime for operators carrying out hazardous activities.[18] On the basis of strict liability, the operator would be considered liable even without the necessity that the victim proves that he/she/it at fault or *culpa*. The operator will therefore be considered liable for preventing and restoring any damage caused by its activities caused to land, waster, protected species and natural habitat if it is possible to proof the causality link between the author of the damage and the event. The directive provide also from some exemption from liability to cause pollution for the operator. This means that in certain cases, the liable parties causing environmental damage are not liable and shall not pay in two cases. The first is referred to by the directive as to the "permit defense" means that the same operator can enjoy permission to avoid liability and defend its self from the accusation of having committed the damage if the damage was a consequence of an authorized activity.[19] The second derogation is called "state-of-the-art".[20] This case would be when an operator is not liable when the environmental damage was caused by a product for which it was not proven at the time of the manifestation of damage, to have damaging effects. This derogation is related to "an emission or activity or any manner of using a product in the course of an activity which the operator demonstrate was not considered likely to cause environmental damage according to the state of scientific and technical knowledge". Given that there is uncertainty on the risk of pollution and damaging effects that the nano-products could have on biodiversity, in case of manifestation of the damage, it is evident that enterprises will have a certain facility to avoid liability by using the argumentation that it was not know, at the time of production that nano-materials could have had toxically effects. The directive does not cover traditional damages such as personal injury, economic loss or property damage, for such damages Member State's regime apply.

[15] See Commission document 2008.

[16] See Van Calster, G., "*Regulating Nanotechnology in the European Union*", 2006, European Environmental Law Review", page 240.

[17] Directive 2004/35, OJ 2004 L 143/56.

[18] In Directive 2004/35/EC, the hazardous activities include manufacture, use, storage, processing, filling, release into the environment and onsite transport of those substances which are classified as dangerous substances which are classified as dangerous substances under the EU's chemical legislation, referred to above.

[19] See Art. 8.4 letter a) of Directive 2004/35/EC.

[20] See Art. 8.4 letter b) of Directive 2004/35/EC.

However, this Directive is not totally "ready" to be applied in case of nano-damages as there is total absence in its provisions of specific provisions for nanotechnology even though this piece of legislation has been considered in the debate on the regulatory aspects of nano-materials in a working paper of the EU Commission.[21] In that sense, the insertion of provisions for nanotechnology would be very important to improve the regulatory force of the sphere of environmental liability as a consequence of the use of nano-materials in renewable energy products.

With regards to the EU products liability laws, it is worth mentioning the "Product Liability Directive"[22] according to which manufactures of nano-materials or using nanotechnologies may be liable for an injury caused to consumers.[23] Article 3, paragraph 1, defines "producers" as being "the manufactures of a finished product, the producer of any raw material or the manufacturer of a component part or any person who by putting the name, trademark or other distinguish feature on the product presents himself as its producer." The directive states that the producer will be liable "for a defective product." The liability is strict, and to establish liability, the claimants have to establish what the specific defect of the product is, and that this defect caused their particularly injury. However, since the directive is a minimum harmonization directive, the regimes leaves much room for manoevre to Member States and a large number of focal points of the liability regime, such a causation, remoteness of the damage, standard of proof, assessment of the damage are left to the discretion to Member States.[24]

The directive is weak to cover damage or loss as a result of nanotechnology based products and processes also because nano-action has suggested that products liability claims are not the only the most likely for the nano-material industry but there are also other type of liability such as negligence, derivate liability and also the issue of nano-labelling as mentioned previously, which play an important role in the consumer perception and acceptance of nanotechnologies. In addition, the regime of this directive sets out defenses for claims made against the producer of a product under its Art. 7, according to which, the producer is not liable when the defection that caused the damage did not exists at the time the product was put into circulation. In particular, letter (e) of the same article sets out the "development risks defense" according to which the state of scientific and technical knowledge at the time the product was put into circulation was not sufficient to allow the defect to be discovered. However, the precise scope of this directive remain vague, especially when applied to nano-products, in particular because the scientific basis to understand all the proprieties and risks of nano-materials is not sufficient and available as there is a need to impose to Member States test methods and risk analysis.

Also the Council Directive 2008/1/EC[25] concerning Integrated Pollution Prevention Air Control should be considered as regulatory tool in relation to nano-materials. This directive is better known as the "IE (IPPC) Directive of Industrial Emissions" and it is a harmonisation measure based on the EU power to approximate national laws and establish internal market.

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[21] See the Commission Staff Working Document from the Commission to the EU Parliament, the Council and the European Economic and Social Committee on "Regulatory aspects of Nanomaterials" COM (2008 366final) pp. 35-37
[22] Directive 85/374, OJ, L 210
[23] Ware, A., Kelly B., "*Nanotechnology and the European Product Liability Directive"*, RAJ Pharma, April 2009
[24] Van Calster, V., "*Protecting Consumers or Fails Them*"? *The regulation of nanotechnologies in the EU*", European Journal of Consumer Law, 2011, page 107
[25] Council Directive 2008/1/EC of 15 January 2008 concerning integrated pollution prevention and control, OJ L 24.29.1.2008

The IE (IPPC) directive's *rationale* consists in explaining that there is also a responsibility for producers, and in general for the economical actors which should bear the whole responsibility of the products that they place on the market. The operator should therefore provide information on the environmental impact of its products. The concept of the IE (IPPC) directive is based on the principle that products must be designed, manufactured and used in a way that minimizes injury to respect health and environment damages throughout their life-cycle[26] and this is precisely the potential that should be considered and used in future nano-regulations applied to renewable energy products.

With regards to the implementation of the IE (IPPC) Directive as a "regulatory tool", more attention should be paid as to the assessment of the releases of materials from the IE (IPPC) installations and the role of the competent authorities to apply monitors and enforce compliance with emission limits value relating to nano-material which is currently non-existent.

The crucial link between nanotechnologies and the waste producer liability is contemplated in the Directive 2008/98/EC, as previously exposed. In the context of this important relationship existing between nanotechnology, waste producer liability and Directive 2008/98/EC, the concept of Extended Producer Liability" (hereinafter referred as the "EPL") incumbent on the producer, plays a crucial role in this life-cycle approach and therefore reveals to have highly strong promising potential for the design of nanoregulations.

The OECD defined, for the first time the concept of EPL as an environmental trend where there is a producer responsibility both material and financial as to the product which is extended also into the post-consumption phase of the life-cycle of the product.[27] The principle of EPL is twofold: on one hand, it places the burden of liability of the waste management on the producer's shoulders rather than on the competent authorities as is the case in the IE (IPPC) regime (see previous paragraph), on the other hand the idea of offering incentives to producers in order that they consider the environment in symbiosis to the products produced in an environmentally friendly manner. Hence, the important "marketing environmental philosophy" behind this concept is to "unify" environment and marketing products in a sole entity and not to consider them two sides of the same coin but rather as a sole entity.

In the waste sector, this type of EPL was incorporated and is therefore encapsulated in the regulations of collection and recycling of electrical and electronic equipment with the Directive on the Promotion of the Collection and Recycling of Electronic Equipment better known as the "Waste Electronic Equipment Directive" with the abbreviation "WEEE Directive"[28] which will be the object of analysis further on in this section, as it is potentially able to cover aspects of the nano-liability problems in a life-cycle approach even though problems exist in the adaptability of this legislation to the nano-products.

[26] Cassotta S., "*Environmental Damage and Liability Problems in a Multilevel Context: the Case of the Environmental Liability Directive*", in press, Kluwer Law International

[27] See the "Product Take-Back in International", OECD Extended Producer Responsibility (EPR) Project, in www.eiatrack.org.

[28] Directive 2003/108/EC on the European Parliament and of the Council of 8 December 2003 amending Directive 2003/96/EC on waste electrical and electronic equipment (WEEE).

The principle of EPL finds its corollary in Directive 2008/98/EC especially with its Art. 8 because unveiling the existence of a new type of liability different, if it is compared to the product liability, to the producer liability and to the type of liability set up in the framework of the Environmental Liability Directive, because this type of liability for which the EPL is a carrier, recognizes the existence of obligations on the producer in the whole "life-cycle" of the products. Hence, the liability of the producers is not only as to the costs and elimination of wastes but also on the "choice" that the producer makes at source from the very first moment when faced with choosing the materials for the products even "before" that the product is produced. The producer is therefore responsible for the substances that are to be incorporated into the product which can have a negative impact at the end-of the life-cycle or in the recycling phase, and will therefore be obliged to pay for the environmental damage that this choice at source will determine.[29]

The WEEE directive, like the End of Life Vehicles Directive[30], contains a general duty for Member States to encourage eco-design[31], and the producer's responsibility attached to the separate collection. Article 5, paragraph 1 of this directive specifies that Member States are responsible for ensuring that the WEEE is collected separately from other waste streams. As regarding the WEEE from private households, however, there is an additional duty to ensure that such waste may be returned at least free of charge.[32] The WEEE directive contains a novelty which could be defined as "very consumer friendly" for collecting WEEE which is the obligation according to which the distributor is required to take-back[33] at least free of charge the old appliance whenever a new similar appliance is sold.[34] In addition, Article 7 requires Member States ensuring that producers and importers of electrical and electronic equipment set up a system that will guarantee minimum levels of reuse, recycling and recovery of WEEE, and the costs of collection and treatment of WEEE are to be borne by importers and producers of the appliances and they may choose that individually or collectively. Also, the directive contains a distinction between private households and other users that allows for some of these costs to be borne (by non-house holders). But this distinction is unclear in the directive and this same uncertainty may also risk being reflected in the case of nano-waste, as will be shown further on in the next section treating the PV case.

However, the WEEE directive is not completely suitable for nano-products and would need serious adjustments if applied to nano-products since it is not possible to compare the effects of nanoparticles of nanoproducts contained into electronic equipments with the larger particles of normal "non nano-products" contained in the same electronic equipments. The WEEE directive permits the use of larger particles and certain hazardous substances in a product provided that 65% of the product using these substances can be recyclable and the remaining 35% lost into the environments.

However, this is not going to work in cases of recycling of nano-products because: 1) the percentages of hazardous substances propagated into the environment cannot be comparable with those of the nano-products as nano-particles will propagate with considerably higher speed into the

[29] See for that point Verdure, C., « *Nanotechnologies et déchets : de la dissonance à l'unisson ?* » Lacier, 2010, Chapter 4, page 257

[30] Directive on the End of Life Vehicle 2000/53/ED, OJ 2000 L 269/34, as amended by Decision 2005/673, OJ 2005 L 254/69

[31] Art. 4 of the WEEE directive

[32] Art. 5, paragraph 2, letter a) of the WEEE directive

[33] The "tack-back obligation" is stated in Art. 5, paragraph 2, letter b) of the WEEE directive

[34] See Jans, J. "*European Environmental Law*", 3rd edition, 2007, European Law Publishing Test, page 436

environment due to their higher surface/volume *ratio* and it is therefore not possible to compare the 35% of larger non nano products with the 35% of smaller nano-products; 2) the calculation of percentages in term of the quantity which is permitted to be recycled and the "how much can be lost into the environment" has to be reviewed or calculated in a different way. This is because the polluting effect of the impact into the environment of the percentages of dispersions is not known and "to treat or not to treat" the two products "nano and non nano" in the same way in term of recycling is not fair, not certain and not equitable, and this, not only from a legal point of view, but also from an ethical point of view, as will be explained in a more concrete manner in the PV case in section 3.

The EU producer utilizing N&N is concerned with the EPL principle existing in the available current EU products liability laws, as has been explained in the previous paragraphs of this section. This EPL principle has similarly been implemented for the WEEE, as observed previously. This is because, not always but often, it is in the WEEE where dangerous substances are used and it is often in these electronic particles that nano-materials "are used" not only alone, but also in combination with other hazardous substances which apart from being "hazardous" *per se* can become even more hazardous if they are reduced to "nanoscale", such as in the case of *cadmium tellure (Cdte)*, a hazardous substance. This substance is very often reduced at nanoscale in order to catalyze the characteristics of certain products and increase business and selling. One of the most prominent directives in the WEEE is the ROHS directive in force since July 2006.[35]

The RHOS directive is on the restriction of the use of certain hazardous substances in electrical and electronic equipment. The ROHS directive is based on Art. 114 of the TFEU (previous Art. 95 EC) and contains mainly product-related rules according to which from 1 July 2006, Member States accept that new electrical and electronic equipment put on the market does not contains lead, mercury, cadmium hexavalent, chromium, polybrominated biphensyls (PBB) or polybroninated diphesyl ethers (PBDE) in quantities exceeding maximum concentration values.[36] This basic rule is however subject to exceptions for products and applications listed in its Annex.[37] Hence, compliance with the ROHS directive requires manufacturers to ensure that they do not use material components that contain the restricted above mentioned substances. This directive contains the actual producer responsibility scheme of the EPL as it is therefore interconnected and interacting with the WEEE directive and should be considered, to a certain extent, in conjunction with its provisions when applied to nano-products.

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[35] Directive 2006/692, OJ, 2006 L 238/50 amending directive 2002/95/EC (ROHS)

[36] Art. 4(1) of the ROHS directive

[37] In that sense, there has been a Commission decision for amending the Annex of this Directive for the purpose of adapting to technical progress. See the Commission Decision of 12 October 2006 amending, for the purposes of adapting to technical progress, the Annex to Directive 2002/95/EC of the European Parliament and of the Council as regards the exemptions for application of hexavalent chromium, O.J, 14.10.2006 L283/50

US Model

In the US, nano-materials are regulated through one of the most important legislative tools of the Environmental Protection Agency (EPA) which is one of the federal watchdog agencies challenged by nanotechnology. Within the EPA's jurisdiction, nanotechnology cross several core environmental statutes such as the Toxic Substances Control Act (TSCA); the Clean Air Act (CAA); the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Clean Water Act (CWA).[38]

Whilst in Europe, as has been explained in the previous section, REACH provides that it is the producer who has the burden to prove that a given chemical substance is "safe" before such a substance is introduced into the market, in the US, it is the responsibility of the legislators and regulators of the EPA, especially with TSCA, that have to proof that a given chemical substance is not dangerous before forbidding or restricting its use or removing it from the market.[39]

TSCA gives the EPA the authority to prohibit or limit or remove the manufacture of chemicals based on risk assessment and the power to control existing chemical substances with risk or potential risk to the environment. TSCA is mainly designed for chemicals substances or mixed of chemical substances and act as a *lex generalis*, with provisions that can cover specific type of products by *lex specialis* such as cosmetics, pesticides, medical products.[40] However, regulation can appear unsuitable when it comes to regulate nanomaterials because of chemical regulation assumes a direct relationship between volume of material and exposure whilst in the nano-products materials and toxicity is presumed to be related to surface area rather than the weight or volume.[41] Also, scientific evidence ignores the behavior of nanomaterials and the risk profile of these materials is different compared to chemical and it is very difficult to make predictions. This "unpredictability" is a problem even if TSCA defined chemical substances by reference to its "particular molecular identity" and that nanomaterials such as carbon in bulk form and at nanoscale (carbon nanotubes or carbon fullerenes) have the same molecular structure of chemical nanomaterials because the risk is unpredictable, unmanageable and unknown.[42]

The CAA has the authority to entitle EPA in setting National Ambiental Quality Standards (NAQS) for pollutants which have been assessed by the EPA to pollute the environment and human health. Even though under the CAA, the EPA has the power to regulate nanoparticles air emissions, this kind of application present problems because of the fundamental differences between nanomaterial composed by small particles and non nano-materials composed by larger particles.

The RCRA provide EPA with the authority to regulate solid waste and generation, transportation, management, treatment, storage and disposal of hazardous waste. However, nanoscale materials are covered by RCRA if they are solid waste and subject to more stringent regulation if they are also

[38] Ningel M., Cameron S., Mitchell E. M., "*Nanoscale – Issues and Perspectives for the Nano Century*", 2007, Wilely

[39] Ningel M., Cameron S., Mitchell E. M., "*Nanoscale – Issues and Perspectives for the Nano Century*", 2007, Wilely, page 224-225

[40] Van Calster, G., "*Regulating Nanotechnology in the European Union*", 2006, European Environmental Law Review, page 239

[41] Van Calster, G. "*Regulating Nanotechnology in the European Union*", 2006, European Environmental Law Review, page 240

[42] Ningel, M., Cameron S., Mitchell E. M., "*Nanoscale – Issues and Perspectives for the Nano Century*". 2007, Wilely, page 224

hazardous wastes.[43] The definition of hazardous waste of the RCRA is subject to four characteristics: ignitability, corrosivity, reactivity, or toxicity. The problem is that first, nanomaterials wastes will likely not be qualified under these characteristics or met this description and will then not be covered by these regulations because of their atypical, unpredictable, unknown characteristics.

The CERCLA (or "Superfund") is a law which gains recognition for having created the Superfund, providing the US government with the possibility to clean-up abandoned and uncontrolled hazardous waste sites. CERCLA provide EPA with the authority to address releases or threatened released of hazardous substances and nanomaterials that CERCLA's broad criteria would qualify. The law is broader as it deals with hazardous substances releases and not just hazardous waste disposal.[44] The law is concerned with the decontamination of the sites subject to environmental risk and charges the liable parties with the reimbursement of the clean-up costs by creating a public fund (the so-called "Superfund").

CERCLA present a problem when regulating nanomaterials because it assumes that larger quantitative of hazardous material pose a real risk which is not applicable in the case of nanomaterials as such materials can have huge toxic effects even at very low volume surface.

However, if the EPA classify nanomaterials as "hazardous in the future", CERCLA would apply retroactively. Moreover, CERCLA would be effectively applicable to nanomaterials because this law was originally designed to handle with "adverse and undetected activities" and allocating liability for such kind of activities and for the past actions.[45]

Finally, the CWA offers a very broad regulation on pollution which makes nanomaterials discharge into navigable waste very likely to be subject to this regulation. Nanomaterials could therefore fall within this ambitious goal but EPA would need to determine that particular nanoscale materials are pollutants.[46]

Also in the US Model regulating nanomaterials and nano-products, as in the EU, the lack of a specific method of measurement and characterization of nanomaterials and nano-products, together with the absence of risk analysis as to the extent of exposure associated with the use of nanomaterials, is one of the main focal factors of "uncertainty" from a regulatory point of view. However the US Model in regulating nanomaterials and nano-products is presenting potential which can be used as a source of inspiration to improve the EU regulatory approach in regulating nanomaterials.

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[43] Hodge, G., Maynard D. A., "*International Handbook on Regulating Nanotechnologies*", 2010, Edward Elgar, page 346

[44] www.epa-gov/Superfun/action, CERCLA, paragraphes 102, 42, USCAS S 9602

[45] Ningel, M., Cameron S., Mitchell E. M., "*Nanoscale – Issues and Perspectives for the Nano Century*". 2007, Wilely, page 230.

[46] Hodge, G., Maynard D. A., "*International Handbook on Regulating Nanotechnologies*", 2010, Edward Elgar, page 346.

Level of Standardisation

EU Level

Since there are several difficulties for the EU secondary and primary legislation in solving problems related to certain requirements that have to be fulfilled before placing a product containing nanomaterial into the market, some technical norms, called “standards” or “technical standards” have become relevant in their capacity to establish quality systems based on risk assessment, and safety and quality requirements.

In other words, standards are of vital importance for businessmen man because they ensure the quality and safety of products. The standards are technical specifications, reports, and guidelines published by Standard Development Organizations (SDOs).

At EU level, it is the European Committee for Electro Technical Standardisation (CENELEC) and the European Telecommunication Standard Institute (ETSI). Relevant non-official actors are invited to take part in their meetings when they work on indicating the best practices for manufacturers and regulators. The objective of these standards is to provide for methods in a way that safety and risk assessment can be carried out, for example, in the difficult task consisting of “how to define a nanoproduct”, how to measure a nano-particle, or what are the important parameters of nanoparticles (surface volume or size).

An important committee is the CEN/TC 352 which has important tasks such as developing standards for classification, terminology and nomenclature, risk assessment and toxicity tests. Whether such standards, if introduced at EU level, will be in the form of guidelines or binding requirements, is uncertain.[47]

International Level of Standardisation

At international level, the technical norms regulating nanotechnologies and nanomaterials are not so numerous. Several International Organisations (I.Os) of standardisation have dealt with initiatives regulating N&N. For example, the OECD provides for specific activities to improve harmonization, security and coordination. The activities of these I.Os of standardisation are therefore crucial as there is a need for technical norms able to describe, specify and measure nanomaterials. Another important institution at international level for the development of technical definitions for nanomaterials is the International Standard Organisation (ISO) which set up a technical committee (TC), the ISO TC 299: Nanotechnologies in connection with the correspondent TC of the IECTC 113 – Nanotechnology for Electrical and Electronic Products and Systems. The activities of more than thirty-three countries are currently using the above mentioned committee as a benchmark. Amongst the national entities more active in the sector, it is worth noticing the BSI/NT1 of the UK, the SAC/TC 279 of China, and the American National Standard Institution (ANSI-NSP) of the US.

[47] Van Calster, G., “*Protecting consumers or failing them? The regulation of nanotechnologies in the EU”,* Journal of European Consumer Law Review, 2011, page 105.

There are also several official collaborative agreements set-up with other ISO Technical Committees, the activities of which are strictly interconnected with the N&N such as ISO TC 201 (surface and chemical analysis), ISO TC 202 (microbeam analysis) and ISO TC 94 (personal safety, protective clothing and equipments, and ISO TC 213 (biological evaluation of medical devices). There are also some active SDOs, such as the American Society for Testing Materials the "ASTM" (TC ASTM 56) and IEEE (International Electrical and Electronic Engineers). The activity of ISO TC 229 has been organised in four working groups active on focal points to be improved for the development of N&N under ISO 2007.[48] Other I.Os cooperates with ISO and the OECD on issues related on nanotechnologies, such as the World Health Organisation (WHO), and the United Nation Development Programmer (UNDP). In 2009, a database has been activated by the OECD on all the activities and research projects at world level on aspects of EHS related to nanotechnologies and very recently, a current state of the art on the development of the activities on the EHS of manufacture of nanomaterials has been drawn up.[49]

3. Towards the Creation of More Responsible and Effective Regulations: An Example of the Photovoltaic Sector

Solar photovoltaic electricity production is, as previously argued, the most obvious niche-sector where N&N is contributing to R&D and to promoting RET. Also in other renewable energy sectors of production, such as the wind energy sector, nanomaterials are used as a technique of production and as a means of promoting RET.[50]

Solar energy is regarded as a green technology but what happens to PVs once they have reached the end of their life-cycle?

In that respect, it is important to make sure that certain hazardous substances used in the PVs construction such a *Cdte* do not find their way into the PV products and that they are properly collected and recycled and incinerated when no longer used. This is a *unique* opportunity for EU enterprises, business leaders and corporate governance to innovate in a sustainable growth manner, and have access to valuable raw materials, as the EU seeks to maintain its leadership role in becoming a resource-efficient economy which minimizes the products environmental and health effects throughout their life-cycle.

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[48] J – WG1: terminology and nomenclature; J-WG2: measurement and characterization; J-WG3: health, safety, and environmental aspects of nanomaterials and J-WG4: Material specification.

[49] See the recent document "*Current Development/Activities on the Safety of Manufactured Nanomaterials*" OECD, ENV/JM/Nano (2011)122, No. 29.

[50] For the use of nanoproducts and processes in the wind energy sector, especially in relation to wind turbines, see WJok, R., "*Tribology and Corrosion Aspects of Wind Turbines*", National Centre for Tribology at Southampton, School of Engineering Sciences, University of Southampton; IInca, A., "*Analysis and Mitigation of Icing Effects on Wind Turbines*" Wind Energy Research Laboratory, Université du Quebec à Rimouski, Canada; page 188; Vinciguerra J., "*Creating Anti-Icing Surfaces*" in www. ge.geglobalresearch.com; Mubarok, F., Armanda S., Johnesen R., Espallargas N.,"*Novel Coating System for Rotating Parts in Offshore Wind Turbines*", Department of Engineering Design and Materials-NTNU, Norwegian University of Science and Technology (NTNU)

In that sense, there is a need to create a more sustainable and effective regulation. This is certainly not an easy task. In particular, it is not trivial to remark that it is necessary "to think differently" by considering the dichotomy between "renewable energies" and "non-renewable energies", as the value and importance given to one or the other is dependent upon the ways of thinking about and understanding this dichotomy. Hence, very often it is a political issue and not an economic one.

At the EU level, the application of the EPL in the PV sector could be "better integrated" by Member States which can adopt more responsible and effective laws which take into consideration in the product-conception, the waste production of PVs[51] and the use of nanotechnologies in the waste and recycling phase. The EPL regime can be well integrated with the (IE) IPPC policy product, which is a public policy the aim of which is to be more part of the group of the products which have to be conceived in a cycle-life approach. The EPL is also a prolongment of the Integrated Product Policy. According to the state of the art of the current regulations on nanotechnologies, it is possible to apply the existing regulations on regulatory issues related to RET products, such as PVs containing nanomaterials or treated at a nanoscale. However, there are no enterprises that manage the "PV waste" in the different sectors, such as industry waste, recycling, incineration, etc.

In addition, an important question arising in the PV case is the understanding of whether the PV containing nanomaterials, once arriving at the end of their life, are considered as a "normal waste" or as "dangerous waste". Also, another issue is to distinguish between public waste (PV for public use) and "private waste" (the waste of a private use of the PV installed at home). This distinction could have an important impact on the way they should be incinerated, for example.

In that sense, it is important to enquire as to whether enterprises in the PV sector are recycling or incinerating PV models, and how the recycling and treatment of the PVs containing *Cdte* are being done and if these enterprises are proceeding by doing this in a normal way, or if they have to follow different routes. This is the aim of this section which attaches a certain importance to these aspects since the use of PVs with nanomaterials in the RET influences the waste production and consumption. Another important question considered here, is how is it possible to create effective regulations in the PV sector which can also be harmonized, and whether the current legal framework in the PV sector is taking into account the risk and management uncertainties which are crucial for the life-cycle ending products.

At EU level, the issue of regulation of the PVs using nanomaterials is extremely controversial, politicised and enigmatic. On one hand, sustainable growth through innovative nano-techniques used in PV cells will be able to create new paradigms more sustainable and highly efficient at lower costs and at the same time "spare" the use of natural resources. On the other hand, the challenge of this positive aspect in the use of nanomaterials in PVs need the set-up of a more responsible market of the "PV product" which can only be achieved by creating effective and responsible laws.

In order to fully grasp why the issue of regulation is in the PV using nanomaterials and nano-processes is so enigmatically controversial, it is important to understand where and how is N&N used in the PVs. Thus, after having taken "science" as a starting point, and explain the challenges in regulating PVs, this section will suggests as to how this situation of uncertainty in regulating the PV using N&N could be resolved.

[51] The waste production of PV should also include an "eco-conception" of the product

In particular, attention is drawn to which legal solution may be designed *ad hoc* taking as a source of inspiration elements selected out of the possibilities existing in the current state of the art of the regulations of nanotechnologies.[52]

Nanotechnologies and nanomaterials in PVs are used in the nanostructured alternatives films which are currently on the market. They use an active layer of a micron thickness deposited on a cheap substrate such glass. Within this method of production, which uses nanomaterials in a very limited manner, are distinguished three ways to "use" nanomaterials in three types of photovoltaic panels.[53]

The first type of PVs, are called "1st generation PVs" and use nanotechnologies and nanomaterials by utilizing *amorphous silicon* and represent approximately almost 80% - 85% of the current market of PV production, whilst *circa* 6% of this same market, uses *crystalline silicum (c-si)* which is much more expensive compared to the *amorphous silicum*. Again, in this production, nanomaterial is very limited or almost nonexistent.

Another, second, available alternative, which has also entered into the market representing a 15% of its share, is called the "2nd generation of PVs", and is using nanomaterials and *Cdte* which is considerably cheaper compared to *silicum.* As has been previously remarked, *Cdte* is a metal that is reduced at nanoscale and which is high risk for the environment. The market opportunities for using *Cdte* technology may be diminished because of health and environmental concerns.

A third way of producing PVs, is defined as the "3rd generation of PVs" also called Concentrator Photovoltaics (CPVs) which represents an emerging technology. The CPVs utilise lenses to focus sunlight onto the solar cells. CPVs can be based on *silicum* or *III-V compounds*, generally *gallium arsenide* or *GaA*, which are extremely toxic for the environment and human health.

From all that proceeds, it is obvious that PVs can be produced with or without nanomaterials and processes, and that there is a certain market share where some producers have voluntarily chosen to manufacture their products by using nanomaterials in some accessories and components of the PV cells.

In other words, there are many ways to construct and manufacture PV products and it is the producers who have the responsibility for that original important choice which they make at source. The choice consists, obviously, of between using or not using nanomaterials and nanotechnologies.

The market share which chooses, voluntarily, to use nanomaterials, will continue to use them more and more, as there are strong expectations in the future for using these materials in the PV sector, especially in their electronic proprieties and components, and batteries.[54] The use of nanomaterials in the electronic accessories of the PVs confers onto the product *unique* electronic properties which are expected to permit a much more efficient absorption of light in order to create super-highly efficient cells. One way in which is to make these cells highly efficient is to utilise "nano-ink" in order to make them even more efficient.[55]

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[52] See the previous section.

[53] Interview with Prof. Girolamo di Francia, Italian Agency for New Technologies, Energy and Environment (ENEA), Italy, and expert for the EU Commission.

[54] Interview with Prof. Ferdinando Briones, Director of the Institute of Microelecronic, Madrid, Member of the Consejo Superior de Inventigaciones Cientificas and inventor of the epitaxial cells in the PV

[55] See Zervos H., and Kahn B., "*Printed and Thin Film Photovoltaics and Batteries*", 2008, IDTTechEx Ltd

The consequences of this method of production will be dangerous and highly risky especially when the product becomes waste. At the EU level, the issue is very controversial because it is not understood and there is great uncertainty as to the way in which the PV cycle-life works. Initially, the EU forbade the use of *Cdte* in the PVs due to the risks for the environment and health concerns.

However, this restriction on the use of *Cdte*, at EU level, has been postponed until 2013 due to the strong pressure from the group of interests, the interests for some, was, and still is to continue producing PVs with *Cdte*. Another motive which makes the issue of regulation of PVs using *Cdte* at a nanoscale so controversial, is due to the fact that such a method of production is connected and entrenched with the regime of laws on recycling and use of hazardous substances in electronic equipment and toxic substances, since in the PVs, (as also in other RET products) it is always a matter of using nanomaterials in the "electronic parts" of the cells.[56] Hence, there is an undeniable and evident interconnection between PVs using nanotechnologies and the WEEE Directive[57], as well as with the ROHS directive, previously analysed.

The interactions of the issues of regulation of PVs with the WEEE directive and the ROHS directive appears to be extremely politicised because of the strong role of the non-official actors who exercise a certain power of influence in the law-making debate and shape the way regulation is enacted. There is also an evident heterogeneity amongst the group of interests representing the non-official actors who are lobbing the decision-makers on issues of regulation of the PV. Additionally, there is discordance as to the interests between Member States and the group of interests on how to shape regulation in the PV industry.

With regards to the interconnection between the issue of regulation of PV and the WEEE directive, on one hand, the European Photovoltaic Industry Association (EPIA) has voiced its opposition, at the EU Parliament, to regulate the disposal of PV under the WEEE directive.

On the other hand, Member States have disagreed with the EU Parliament's vote this year, to exempt PV from the scope of application of the WEEE directive. Amongst the supportive Member States' stance, the European Waste Management Association (EWMA) supported the inclusion of PV in the WEEE directive because it would simplify the compliance measurement procedure whilst providing legal certainty and incentive to invest in treatment facilities.

The EPIA and another association, PV Cycle, have objected to the conclusion of a study which calls for PV panels to come under the scope of application of the WEEE directive.[58] Arguments advocated by the EPIA and PV Cycle justifying their willingness to exclude the PV from the WEEE directive is the lack of coherence with the promotion of renewable energies fostered by the EU in the Lisbon Strategy and the disproportionate compliance costs due to the different transposition costs. Another association, "Glass for Europe", argued that the potential impact of the PV inclusion proposal into the WEEE directive has not been the object of sufficient due attention.

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[56] See Zervos H., and Kahn B., "*Printed and Thin Film Photovoltaics and Batteries*", 2008, IDTTechEx Ltd

[57] The "WEEE Directive" and its important relationship with the EPL has already been presented and explained in the previous section

[58] See PV Cycle: Input of the EU –Stakeholder Consultation WEEE, "*Summary of the EPIA/PV Cycle Statement*", in www.pvcycle.org.

According to the EPIA and PV Cycle, they will accept the inclusion of PV within the WEEE directive only if the sector's voluntary take-back scheme based on a single European fee is accepted as an implementing measure.[59]

In December 2010 PV Cycle submitted an "Environmental Agreement on the separate collection and recycling of PVs, proposing a voluntary collection and recycling scheme for the photovoltaic industry, whose validity was dependent on acceptance of the European Commission".[60] However, the Commission evaluated the agreement and did not acknowledge or recommend it due to a number of specific concerns including financial and target settings, and, therefore, the voluntary agreement proposed by PV Cycle has not been taken into consideration.[61]

PV Cycle has in addition, in 2010 conducted a take-back system in Germany with the objective of gradually expanding such a system overall into the EU. Under the WEEE directive, the fees paid vary according to Member States, in which the enterprise sells products. EPIA and PV Cycle also suggested that the proposed 65% target for collection set up by the WEEE directive, of all the WEEE by weight does not suit PVs because of the products long life-span which is typically 25 years, the target is set according to volumes of WEEE placed on the market in the previous three years. In the last two and a half years, the WEEE directive has been subject to several amendments. In that respect, the European Electronic Recyclers Association (EERA) has played a position role on WEEE amendments proposed by the EU Parliament and contributed several times to the review of the WEEE directive. Amongst the most salient amendments wanted by EERA, is the proposal that the collection rates should be based on 85% of the WEEE arising instead of the 65% of the volumes put into the market.[62]

However, the fact of increasing the rate from 65% to 85% and still allowing that still that 15% is "permitted" as a quantity of not being necessarily recycled, and therefore susceptible to being spreadable into the environment, is not morally and ethically acceptable since the percentages should be lifted not to 85% but rather to 100% in such a way that all waste should be collected and treated. This is because admitting that this 15% contains *Cdte* treated at nanoscale, and contains nanoparticles, even though the quantity in percentages is reduced to 15%, will make no difference at all, in the case of nano-waste, because this kind of waste will still have a much higher impact on the environment and health, with a much faster and intensive propagation compared to the same percentages of non-nano particles of "non nano-products." It is therefore not acceptable to "compare" this 15% of "permitted waste" under the WEEE directive when it is nano-waste, with the 15% of non nano-products.

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[59] See the Position Paper prepared by EPIA and PV Cycle "*Recast of WEEE directive*", Joint Position Paper of 20 November 2009, page 3, point 4, in the part "financial commitment of the members" where it is written: "At the last General Assembly meeting of PV Cycle in September, members agreed to the payment of a contribution fee of 0.24 Euros/Kg for the 2% of PV modules that were placed on the market in 2008. This contribution fee will enable the financing of PV Cycle's operations in 2010 and create the foundations of a reserve fund for the operation of PV Cycle over long term. This fund will assume the financial means to collect and recycle end-of-life modules in the future even if a producer would become insolvent and therefore cease to exist".

[60] EPIA and PV Cycle, "*Recast of the WEEE directive*", Joint Position Paper of EPIA and PV Cycle, Annex 1, PV Cycle current status and timeline for 2010 launch, page 3, in www.pvcycle.org.

[61] See the Report prepare by the Bio Intelligence Service, "European Commission DG Environment – A project under the Framework Contract ENV.G.4/FRA/2007/0067, "*Study on Photovoltaic Panels Supplementing the Impact Assessment for a Recast of the WEEE directive*", Final Report, 14 April 2011, page 14.

[62] See "*EERA Position on WEEE amendments proposed by the EU Parliament*" in www. recyclingportal.eu/article, 14 June 2010.

In addition, it is not easy to determine the WEEE volumes that also arise, because this is dependent on the municipalities' activities and retailers which often do not report WEEE volumes that they collect. Including PVs in the WEEE directive will reduce the potentially negative environmental impact of improper disposal and generate economic benefits for avoiding *Cdte* being spread into the environment, as specified in a study on PVs supplementing the impact assessment for a recast of the WEEE directive and in favor of the inclusion of PV in the WEEE directive.[63] In this study it is shown that mentionable quantities of recyclable panels will occur in around 2025 or 2030 and the total quantities of 9. 57 million tons are expected in 2050.

Hence, inclusion or not inclusion of PVs in the WEEE directive, and, changes in the percentages of the amount "permitted" in the "non-recyclable" figures, are not the only issues which should be considered in order to achieve good recycleing which is sustainable and effective in the case of nano-waste. The most ethical solution is to avoid any percentages of non-recycle material being permitted, which is to say 100% should be recyclable and nothing left to be spread into the environment.

Admitting that the solution of rendering 100% of PVs recyclable is not possible because it is not acceptable "politically", since it has been observed that the pressure of the groups of interest, the economic interests, the money invested and the promotional strategies launched, are strong, then the threshold of the percentages,[64] contained in the WEEE directive, should be recalculated, as already introduced in the previous section 2 of the present article. The percentages should be calculated in a different way in the case of nano-particles compared to non nano-particles because the environmental impact of nano-products is different due to its costing much more to extract nano-particles from the nano-waste, compared to the normal waste not containing nano-particles.

The costs of extraction of nano-particles in order to avoid environmental pollution are much higher and should be considered as "external costs". In other words, if the EU cannot succeed in recycling 100% of the PV products containing nano-particles, then the costs of recycling must be calculated in a different way otherwise the WEEE directive will not be suitable for renewable energy nano-products and will impede a sustainable production. This will create obstacles to the smooth functioning of the internal market because it will create a situation of distortion in the market due to the existence of different costs of recycling which would jeopardise the efforts made by the solar industry to reach competitiveness.

With regards to the interconnection between the PVs and the ROHS directive, at EU level, there has been an obvious shift in stance in the trend of the regulations on the use of nano-materials in the PV sector, as EU Parliament lifted the restriction on the use of *Cdte* in the PV sector and this, was mainly as a consequence of a political decision.[65]

The EU Parliament recently approved, with 640 votes in favour, 3 against and 12 abstentions, to exclude photovoltaic modules and RET in general, from the scope of the ROHS directive of 2003 on the "Restriction of the Use of certain Hazardous Substances in Electronic Equipment", which

[63] See the Report prepared by the Bio Intelligence Service, "European Commission DG Environment – A project under the Framework Contract ENV.G.4/FRA/2007/0067, "*Study on Photovoltaic Panels Supplementing the Impact Assessment for a Recast of the WEEE directive*", Final Report, 14 April 2011, pp. 1-86.
[64] The threshold of the percentages of the amount permitted of the "non recyclable" under the WEEE directive.
[65] See Press Release-Environment, 24 November 2010 – Plenary Session, "*Parliament Votes for Safer Electronic and electrical products*", in www.europa.eu/en; "*The Project Details*", Wuppertal Institut Für Klima, Umwelt, Energie GmbH, Energie GmbH, in www.wuppertal.org; and "ROHS Compliance in EU, WEEE/Reach legislation" in www.rohs.en.

limits the use of hazardous substances in all electrical applications and electronic devices. This means that for the first time, technologies for renewable energies are exempt from the ROHS directive. The current amendments to this environmental regulation which is ROHS, also retains the exemption provision for photovoltaic products.

The ROHS directive forbids the use of toxic substances. However, although *Cdte* is on the black list of the EU it is important to understand that its use in PVs must still remain the centre of attention in the recycling phase when the PV will become waste.

The amended text of the ROHS directive establishes that the PVs are out of its scope of application because they are installed and removed by qualified personnel and that "this is perfectly in line with the EU objectives" and with the EU plan on the promotion of RET through recycling with very high quality methods, with high levels of production and with very low environmental impact.

Considering that the average life of a PV panel is 20 to 25 years, and considering also that the risks of *Cdte* treated at a nano-scale are not known and are totally unpredictable, it is wondered as to whether the enterprises which are concerned with the recycling phase of the PVs using nanomaterials can guarantee that there will be no dispersion of toxic substances both into the air (in cases of incinerations) and into the water or ground when they will be obliged to dispose of the "old module of PVs", since there is a serious risk that the release of *Cdte,* into the atmosphere in cases of combustion or incineration of PV modules and in cases where there would not be recycling of the product, will pollute.

A possible solution to the above problem is offered by an American manufacturer, the "First Solar" producing thin-film PV modules. First Solar provides for a solution to the problem existing at EU level previously exposed, since the way this enterprise operates can be taken as an important source of inspiration for the EU enterprises in the production of the same product.

First Solar is a colossal enterprise in the production of PVs cells [66] and is producing PV with a massive quantity of *Cdte* at nanoscale. It is the only enterprise which is producing with such a massive quantity of *Cdte* and which chooses to produce with *Cdte* [67] instead of *crystalline silicon*[68]. At the same time, it is also the only enterprise which has decided to incorporate into the price of the product on sale the costs of recycling, and to also consider and include in such a way, in the price of production of the PVs, the possible costs of environmental pollution determined by the nano-products. First Solar supports services that include finance, construction, maintenance and end-of life panel recycling.[69]

[66] It is curious to note that First Solar is a "solar division" of the same enterprise responsible for the explosion of the platform "Deep Water Horizon". It is even more curious to note (without any malicious intent) that the very first primary use of photovoltaic usages utilizing nano applications, has been made mainly in electronic equipment and systems of petrol installations situated in the Mexican Gulf, and especially used as "substitute products" for toxic and huge battery products.

[67] PVs produces with *Cdte* are the 2nd generation of typology of PVs.

[68] PVs produced with *crystalline silicon* are the 1st generation of typology of PVs.

[69] See official overview of Krueg L., Vice-president of First Solar "*First Solar Module Collection and Recycling Programme"* explaining the whole cycle of production which is also taking into account the distinction of production for a private or public usage of the PV.

In that sense, imitating the pattern of First Solar in Europe, in the PV sector, would be positive for EU enterprises producing and importing PVs. Hence, it would be even more useful to make this with an EU eco-design requirement legally certified which would be able to furnish the evidence of 1) the existence of a certain respect of ethical aspects in the production,[70] 2) of an extended societal responsibility of the producers, and 3) the achievement of real objectives to produce in an innovative and sustainable manner. These three important factors would ensure energy products such as PVs, to elaborate and improve their environmental performances but also ensure the free movement in the EU market.

4. Conclusion

Business leaders are concerned about future liability issues emerging from the life-cycle of the PV products, especially with regards to the use of nanotechnology which is a carrier of potential and challenges, such as the environmental damage as a consequence of incorrect treatment or maintenance of end-of-life-cycle, and recycling. Following the inspiring American pattern of the "First Solar" solution, European producers, businessmen and corporate governance, should have a holistic environmental view of sustainability more projected into the future and on a long-term perspective rather than on a brief short term perspective. The pattern suggested by First Solar, could therefore represent a solution for PV production which makes use of nanotechnologies within Europe, since it also takes into account the risk in cases where the product is incinerated, both at the private and public sphere by giving a strong importance to the EPL.[71] The EPL requires companies to take responsibility for the impact of their products: from material used in manufacture to product recycling.

This principle exists at EU level but should be incorporated clearly into the EU regulations to be applied to nanotechnologies or nanomaterials, as the PV case demostrates. The reliance upon the EPL principle would help the producers avoid the temptation to escape liability as a consequence of the nano-environmental damage, and avoid the producers invoking the defences for claims made against the producer using N&N, as those contained in the EU product liability laws, such as Art. 7 of the Product Liability Directive, and even the derogation from liability of the "permit-defences" and the "state-of-the-art" contained in the Environmental Liability Directive 2004/35/EC.

Conjointly, the WEEE directive should be revised with regards to possible changes in the percentage of the amount permitted for the "non-recyclables" which are allowed, in case that reaching the solution of First Solar of recycling 100% of the waste in the PV would not be possible at the EU level because of political barriers.

Hence, since the PV sector is just an example of a renewable energy product, and the same is true for the use of dangerous metals such as the *Cdte*, and that it has been observed that there are plenty

[70] The existence of ethical aspects in the production *via* and EU eco-trade mark certified, is very important for the producers and consumers which would be able to understand that it certainly is not worth the risk to create damage to health and environment in future generations just because there are no data and scientific evidence on the toxicity of these products and most importantly because there are no responsible regulations for recycling, the absence of which would be justified by the absence of scientific data and evidence or uncertainty. There is a need to break this vicious circle.

[71] The concept of EPL (Extended Producer Liability) has already been presented and discussed in the previous sections, especially at the EU level or regulations, as an important solution to be used as a source of inspiration when facing the scientific peculiarity of nanomaterials.

of metals and substances that can be treated at nanoscale in the manufacture of RET products, time has come to elaborate a general legal framework. This is because it is not possible to put in peril and to risk environmental and health problems at the global level and for future generations, just because there is insufficient scientific proof or an absence of data on the toxic impact of nano-products used in PVs. Most importantly, it is not possible to jeopardize the environment and the health of human beings, just because there is an absence of regulation in PVs or other RET products, in their recycling phase.