The awareness on environmental protection issues as reflected through the inventions

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ABSTRACT
The present study aimed to get the insight into specific environmental issues associated with key enabling technologies and to identify the environmental protection related niche areas of the highest potential for growth to which the future technology transfer activities should focus on. Analyses of environmental related inventions in terms of absolute numbers and their shares within the technology fields of electronics, materials, biotechnology and power sources were based on the annual data for the last decade. The shares of environmentally oriented inventions at the fields of electronics, materials, biotechnology and fusion power over the last decade remained as low as 1%, 5%, 9% and 2%, respectively, indicating low market demand for environmental applications. On the contrary the shares of inventions related to green power sources increased from 54% to 60% over the last decade, most probably due to intragovernmental actions on reduction of carbon dioxide emissions that took place over the last decades. Similar actions should be implemented promptly in order to support the innovativeness and technology transfer related to management of electronic and material waste in the following decades.

Keywords
Technology transfer, environmental protection, key enabling technologies, electronic waste, recycling, recovery, metals, rare earths, batteries, fossil fuel, fusion, nuclear, green power generation.

1. INTRODUCTION
Key Enabling Technologies (KETs) – a group of six technologies: micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies – increase industrial innovation to address societal challenges and creating advanced and sustainable economies [1]. In addition to having the highest potential for growth at the global markets the KETs have several applications related to the environmental protection, but there are also certain environmental issues associated with KETs at various fields.

Information technology is important for the growth of any country, but with the sudden development of new TV sets, smartphones, computers and their relatively short lifespan, the accumulation of waste electronics is increasing. Waste electrical and electronic equipment contains toxic substances that may leach into the ground and emissions that may escape into the air when disposed. Direct environmental impacts are the release of acids, toxic substances and heavy metals and carcinogenic chemicals [2].

In developed countries, formal sectors for e-waste management are being established, which take care of manual disassembly followed by semi-automated separation of various materials from which further attempts are made to recover metals using "state of the art" methods in smelters and refineries. In underdeveloped countries, equipment disassembly and separation of materials is manual, and the recovery of metals is made by heating, burning, and acid leaching of e-waste scrap in small workshops causing additional damage to environment [2].

Many batteries still contain heavy metals such as mercury, lead, cadmium, and nickel, which can contaminate the environment and pose a potential threat to human health. Batteries represent a complete waste of a potential and cheap raw material, when improperly disposed. In addition, battery recycling is not feasible from economic point of view. However, nanotechnologies could provide more economical battery recycling in the future [3].

Nanotechnologies are also used in radioactive waste clean-up in water, direct seawater desalination and disinfection by using nanochannels and nanopores, oil and water separation, detection of pollutants, carbon dioxide fixation, artificial photosynthesis, photocatalytic degradation of organic pollutants in waste waters, superhydrophobic and intelligent construction materials etc. [3].

In biotechnology, biological treatment plants are well known for removal of organic impurities in solid, liquid and gaseous form and removal of heavy metals from waste materials. An important application of environmental biotechnology are also biosensors enabling biomonitoring, including monitoring of biodegradability, toxicity, mutagenicity, concentration of hazardous substances, and monitoring of concentration and pathogenicity of microorganisms in wastes and in the environment [4].

Photonics have enormous potential of reducing the greenhouse and non-greenhouse gas emissions by reducing the electricity consumption from traditional energy sources [5]. Photonics have already significantly contributed to climate protection by applications such as energy saving light bulbs and LED lighting, photovoltaics and communication via fibre optic networks. Other environment protection related applications of photonics are at the moment in the beginning of their growth trajectory and include early detection of forest fires, laser-supported metal recycling and optical communication in 5G mobile networks [5].

In best case scenario, the introduction of automation will have a positive impact on the environment: greenhouse and non-greenhouse gas emissions will be reduced as well as the use of natural resources. However, automation will lead to increased electricity consumption, so the impact of increased automation on the environment depends primarily on how society will cope with the replacement of "dirty" energy sources. In worst case scenario, automation at the expense of increased electricity consumption would lead to increased greenhouse and toxic gas emissions and increased consumption of natural resources, increased consumption of rare materials for building electronic equipment and increased electronic waste [6].

In addition to the growing need for recycling, recovery and regeneration due to lack of natural resources there is also a growing need associated with the electric power generation [7]. In particular, the source of electricity will determine the extent of damage that power generation will cause to the environment. Primary energy sources such as crude oils, coal and natural gas exhibit the highest amounts of greenhouse and toxic gases and should be reduced on behalf of the increased use of nuclear [8] and presumably fusion [9], hydro power and especially green power sources such as geothermal, wind, solar and bio energy [7].

Environmental protection related inventions will benefit the society and benefiting the society should be the main and only morally acceptable focus of public as well as private entities.

In this study, we examined the emergence of patent documents related to environmental protection at the fields of electronics, materials, biotechnology and power sources. We hypothesized: (i) that environmental applications should account for about half of all innovations now days; (ii) that the share environmental applications had grown sharply over the past decade.

The aim of this study was to search for the guidelines for future technology transfer based on the occurrence of environmental related inventions at the mentioned main fields of technologies and identifying the environmental protection related niche areas of the highest potential for growth to which the future technology transfer activities should focus on.

2. METHODOLOGY

The results of this study are based on comparison of the occurrence of patent documents between the general key enabling technology (KET) areas and its sub-areas related to environmental protection applications (e.g. area of "electronics" compared to its subarea "electronic waste") within the priority period from 2008 until 2018. Since the content of patent applications is normally confidential for the first 18 months after the priority date, the priority period 2008-2018 is quite well reflecting the known prior art of the last decade (June/July 2010 to June/July 2020). This paper was written in August 2020.

Keywords denoting different areas and subareas within KETs were selected based on the known literature considering the widest possible coverage of technology fields: The keyword (*electronic*) was selected to cover electronics, micro- and nano-electronics; the keyword (*material*) was selected to cover materials and advanced materials as well as micro- and nano- materials and consequently a certain range of nanotechnologies; the keyword (*bio*) was used to cover biotechnology.

Various combinations of keywords referring to metals, rare earths and batteries were selected rather than those referring to advanced production and photonics. According to the literature the natural resources such as metals and rare earth elements and magnets are often a limiting factor of advanced production, electronics and photonics sectors. For the purpose of this study batteries were classified among the materials although in reality the field of batteries is rather interdisciplinary representing the intersection between electronics, materials, chemistry, advanced production, photonics and energy conservation.

Fusion as the potential new power source and traditional power sources such as nuclear and fossil fuel were compared to green power sources such as hydro, wind, solar, geothermal and bioenergy.

The analyses was performed using PatBase [10] in August 2020. The exact keywords and combinations with basic Boolean operators and symbols are listed under the PatBase queries in Table 1. The PatBase search was set to search within titles, abstracts and claims (TAC) which are usually available in English language after publication by majority of national patent offices. Priority date (PRD) field was set to search within a certain year. In Table 1 the PRD was set to year 2018 for all the queries and the results were further analysed by PatBase analyticsv2 providing the numbers of filed, granted and published patent families, top five assignees and top five jurisdictions. Ten separate searches for data on the number of patent families without further analysis with PatBase Analytics v2 were performed for each of the priority years from 2008 to 2018 and graphically presented on Figure 1 and Figure 2. The calculations in Table 2 are based on the same dataset as Figures 1 and 2. Tables and Figures were prepared by Microsoft Excell software. Whenever average values were calculated the corresponding standard deviations are presented next to the average values (e.g. average value ± standard deviation).

There were 651.578 patent families for the query "TAC=(*material* and PRD=2018:2018)". PatBase analyticsv2 is capable of analysing up to 250.000 patent families at once. In order to maintain the comparability of results and for the reasons described in the previous paragraphs of this section, only the areas of metals, rare earths and batteries and their corresponding environmental protection related subareas were included into the analysis.

3. RESULTS

The patent families (Table 1 and 2, Figures 1 and 2) having priority filing dates in 2018 were published in summer 2020 and therefore represent the latest known prior art in the time this paper was written. Approximately half of the patent families filed in 2018 were granted by at least one jurisdiction and each of them was published by approximately five different jurisdictions. The term "invention(s)" will be used in the following text referring to the filed, granted and published patent families at the fields of Electronics, Materials / Chemistry, Biotechnology and Power Sources.

Table 1: Number of filed, granted and published inventions (patent families) and top five assignees and jurisdictions based on the specific PatBase queries denoting wide areas (white background) and environment protection related sub-areas (shadowed background) within the technology fields.*

Technology Fields	Areas and Sub-Areas	PatBase query	Patent families filed	Patent families granted	Patent families published	Top five assignees	Top five jurisdiction
Electronics	Electronics	TAC=(*electronic*) and PRD=2018:2018	174.737	88.457	577.376	Samsung Electronics Co. Ltd GuangDong Oppo Mobile Lenovo Group Ltd Qualcomm Inc Apple Inc.	China P. Rep. USPTO WIPO Japan EPO
	Electronic waste	TAC=(*electronic* AND *waste*) and PRD=2018:2018	2.332	1.170	12.229	Ford global technologies Alibaba Group holding Ltd. Beijing Qihoo Tech Co. Ltd Netease Hangzhou Networl Co. Ltd Univ. Shanghai 2ND Polytechnic	China P. Rep. WIPO USPTO EPO Japan
Materials	Metal	TAC=(*metal*) and PRD=2018:2018	218.502	108.249	757.025	Taiwan Semiconductor MFG Co. Ltd Samsung Electronics Co. Ltd Intel Corp; LG Chemical Ltd. BOE Technology Group Co. Ltd	China P. Rep. USPTO WIPO Japan EPO
	Metal recycling	TAC=(*metal* AND (recover* OR recycl*)) and PRD=2018:2018	9.587	4.285	54.242	Exxon Mobil Corp. Univ. Kunming Science and Tech Univ. Central South UOP LLC BASF SE	China P. Rep. WIPO USPTO EPO Japan
	Battery	TAC=(batter*) and PRD=2018:2018	145.739	82.062	331.599	LG Chemical Ningde Contem… Sonoef Hefei Tech Hefei Guoxuan Bosch Gmbh	China P. Rep. USPTO WIPO Japan South Korea
	Battery recycling	TAC=(batter* and (recycl* or regenerat*)) and PRD=2018:2018	2.484	1.087	9.221	Toshiba KK Bosch Gmbh Toyota Jidosha KK Honda Motor Co. Ltd Toyota Motor Corp.	China P. Rep., USPTO WIPO Japan EPO
	Rare Earths	TAC=(rare AND earth* AND (magnet* OR element*)) and PRD=2018:2018	2.971	985	13.769	TDK Corp. Nichia Corp Hitachi Metals China Petroleum Univ Jiangxi Scientific	China P. Rep. USPTO WIPO Japan EPO
	Rare Earths recovery	TAC=(rare AND earth* AND (magnet* OR element*) AND recover*) and PRD=2018:2018	164	60	1.223	Sabic Global Technologies BV Exxon Mobil Corp. Univ Jiangxi SCI and Technology Inner Mongolia Jarud Banner Luan Commissariat A Lenergie Atomique	China P. Rep. WIPO USPTO EPO Canada
Biotechnology	Biotechnology	TAC=(bio*) and PRD=2018:2018	99.862	37.244	497.744	IBM Samsung Electronics Co. Ltd Univ. California Univ. Jiangnan Univ. South China Tech.	China P. Rep. WIPO USPTO EPO Japan
	Bio waste treatment	TAC=(biotreat* OR Biodegrad* OR bioaugment* OR biosens* OR biomonitor*) and PRD=2018:2018	7.208	2.566	42.793	Univ. Jinan Univ. Tianjin Univ. California Univ. South China Tech. Univ. Zhejiang	China P. Rep. WIPO USPTO EPO South Korea
Power sources	Fossil Fuel	TAC=(power AND (crude* OR coal OR gas OR fossil)) and PRD=2018:2018	27.824	15.535	110.970	Tokyo Electron Ltd. Applied Materials Inc. Toyota Jidosha KK United Technologes Ltd. Huaneng Clean Energy RES Inst.	China P. Rep. USPTO WIPO EPO Japan
	Nuclear	TAC=(nuclear AND power) and PRD=2018:2018	3.214	1.739	11.245	China General Nuclear Power China General Nuclear Power ENG Cnnc Nuclear Power MAN Co. Ltd. Jiangsu Nuclear Power Corp. China Nuclear Power Design Co. Ltd.	China P. Rep. WIPO USPTO South Korea Japan
	Fusion	TAC=(fusion AND power) and PRD=2018:2018	1.512	708	17.226	State Grid Corp. China Hewlett Packard Development Co. Siemens AG Saint Gobain SA Corning Inc.	China P. Rep. WIPO USPTO EPO Japan
	Green	TAC=(power AND (hydro* OR wind OR solar OR geothermal OR bio*)) and PRD=2018:2018	48.465	27.245	167.115	State Grid Corp. China Beijing Hanergy Photovoltaic Invest Beijing Boyang Dingrong PV Tech Beijing Goldwind Science and Hanergy Mobile Energy Holding	China P. Rep. WIPO USPTO EPO Japan

** PatBase queries were based on the keywords to be searched in titles, abstracts and claims (TAC) across the patents and patent applications having priority date in 2018 (PRD=2018:2018). Analyses were performed using PatBase in August 2020. Priority patent applications are published after 18 months from the priority date. The represented data therefore reflects the present known state of the art.*

There is a correlation between number of filed, granted and published patent families within the categories of Table 1. Average ratio of number of granted and filed patent families was 0,46 ± 0,08 and the average ratio of number of published and filed patent families was 5 ± 2. The results in the following Table 2 and Figures 1 and 2 are based on the filed patent family data.

The queries referring to technology field of Materials have jointly contributed the highest number of inventions filed in 2018 followed by the fields of Electronics, Biotechnology and

Power. The situation is different when comparing environmental protection subareas within the general technology fields. The highest number of environmental related inventions is the subarea Green followed by Metal recycling, Bio waste treatment, Battery recycling, Electronic Waste and Rare Earths recovery subareas representing the descending order of Power, Materials, Biotechnology and Electronics fields in terms of the number of inventions (Table 1). A similar order in the number of inventions by field has been observed over the past decade (Figures 1 and 2) with the exception in the field of Batteries and Biotechnology. In 2008 fewer Battery related priority patent applications were filed as compared to Biotechnology, but from 2015 onwards the field of Batteries exceeded the field of Biotechnology by the number of inventions due to presumed exponential growth ($R2 = 0,98$) of Battery related inventions (Figure 1). However, in general the number of inventions within all areas has been growing over the priority years 2008 – 2018 (Figures 1 and 2, Table 2). Moreover, the number of inventions in general areas of technology as well as the number environmental related inventions were growing proportionally resulting in similar proportions of environmental related inventions within the general areas in 2008 and 2018 (Table 2).

The proportion of environmental related inventions within the general fields of Electronics, Materials and Biotechnology was low, ranging from 1% up to 10%, throughout the whole priority filing period 2008-2018. The said proportions have slightly increased over time except the proportions of Bio waste treatment related inventions, which dropped from 10% to 7% from 2008 to 2018, respectively. On the contrary, the proportion of Green Power within the field of different Power sources was higher than 50% in 2008 and increased to 60% in 2018 (Table 2, Figure 2).

Top five assignees are presented for each of the areas listed in Table 1. Some of them are active in more than one area at the same time: Samsung Electronics in areas of Electronics, Metals and Biotechnology; LG Chemical in areas of Metals and Rare Earths; Exxon Mobil Corp. and Univ. Jiangxi Scientific in area of Rare Earths and Rare Earth recovery; Toyota Jidosha KK in area of Battery recycling and Fossil fuels; University of California in Biotechnology and Bio waste treatment and State Grid Corp. China in areas of Fusion and Green Power Sources. The top assignees listed under the general areas usually differ from the ones listed under the environmental protection related subareas (Table 1).

In general, based on the number of published inventions the top five jurisdictions were China, America, Europe and Japan appearing in descending order. South Korea is classified among top five jurisdictions in the areas of Batteries and Bio waste treatment and Nuclear Power sources displacing European, Japan and European jurisdictions from the top five jurisdictions at the said areas, respectively. Canada displaced Japan among the top five jurisdictions at the field of Rare Earths recovery.

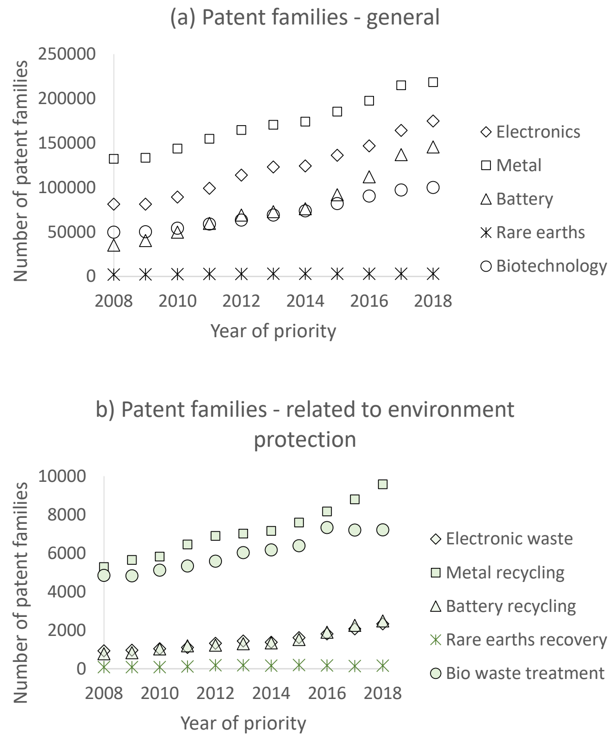

Figure 1: Number of inventions (patent families) with priority dates ranging from 2008 to 2018 referring to: (a) general areas of Electronics, Materials - including metal, rare earths and batteries - and Biotechnology; (b) environment protection related sub-areas of electronic waste, recycling or regeneration of materials - metal, rare earths and batteries - and bio waste treatment.*

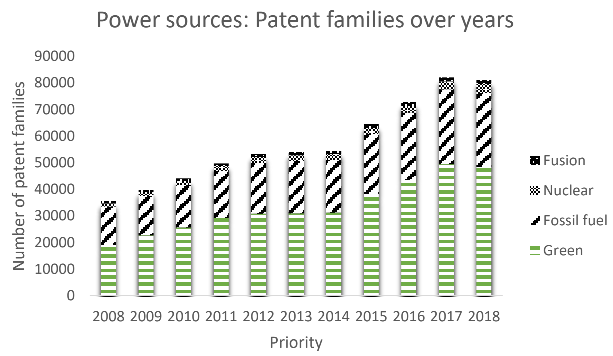

Figure 2: Number of inventions (patent families) with priority dates ranging from 2008 to 2018 referring to different power sources: fusion; nuclear; fossil fuel including crude oil, coal and gas; and green including hydro, wind, solar, geothermal and bioenergy sources.

**Analyses were performed in August 2020 using PatBase [10] and PatBase queries listed in Table 1.*

Table 2: Absolute numbers of general and environmental related inventions (patent families) filed in 2008, 2018 [Nr.] and the proportions [%] of environmental related inventions (patent families) filed in 2008 and 2018 and the 10-year average (Avrg) proportion with corresponding standard deviation (stdev).*

Environmental related subareas		General areas		Number and percentage of environmental related patent families in priority years													
				2008					2018					2008-2018			
				[Nr.]				[%]	[Nr.]				[%]	Avrg		Stdev	
Eletronic waste	:	Electronics	=	928	:	81266	=	1,1%	2332	:	174737	=	1,3%	1,2%	±	0,1%	
Metal recycling	:	Metal	=	5284	:	132352	=	4,0%	9587	:	218502	=	4,4%	4,1%	±	0,1%	
Battery recycling	:	Battery	=	776	:	35109	=	2,2%	2484	:	145739	=	1,7%	1,8%	±	0,2%	
Rare Earths recovery	:	Rare Earths	=	88	:	2123	=	4,1%	164	:	2971	=	5,5%	5,0%	±	1,0%	
Bio waste treatment	:	Biotechnology	=	4850	:	49774	=	9,7%	7208	:	99862	=	7,2%	8,6%	±	0,9%	
Green Power	:	Power	=	19023	:	35513	=	54%	48465	:	81015	=	60%	58%	±	2%	

*data on the number of patent families for individual filing years 2008-2018 are represented at the Figures 1 and 2. The PatBase queries referring to the keywords shown in Table 1 were combined with the priority dates (PRDs) ranging from 2008 to 2018 reflecting the known prior art from 2010 to 2020.

4. DISCUSSION

The results indicate that the shares of environmental applications account for less than 10% of all innovations in the fields of electronics, materials and biotechnology now days and there was no sharp growth of the shares of environmental applications observed over the past decade in these fields (Table 2 and Figure 1), which is not consistent with any of our introductory hypotheses. On the other hand, in the field of power sources the environmental applications account for more than half of all inventions, while their share grew from 54% to 60% over the past decade, which is consistent with the hypotheses.

A possible explanation for extremely low share (approximately 1%) of inventions in the field of "electronic waste" within the wider field of "electronics" could be due to inappropriate methodological approach - choosing too secular keyword for the analysis (as explained latter this was not the case). Electronic waste is indeed a mix of different materials and its recycling is therefore closely linked to the recycling of various materials including metals, rare earths and batteries [2]. Interestingly, Samsung Electronics did not only appear among the top five assignees in the field of its core business (electronics), but also in the field of metals, which is not surprising, since Samsung is investing in the development of metals (e.g. semiconductors), which are an integral part of electronic devices they are producing [11].

However, the proportions of inventions related to recycling, recovery and regeneration of metals, rare earths and batteries were low as well, amounting approximately 4%, 5% and 2%, respectively. And the top five assignees in the general areas of electronics, metals, rare earths and batteries were mostly different to those associated to the subareas related to recycling, regeneration and recovery of these products.

With electrification of transport and growing demand for natural resources, the need for batteries and battery recycling is growing sharply, which explains the presumed exponential growth in terms of the number of inventions in this area. It is not surprising that representatives of automotive industry and/or auto parts suppliers Toyota, Honda and Bosch are among the top five assignees in the subarea of battery recycling. It seems that national programs need to become involved to support the recycling of products, otherwise these activities would not be economically feasible for large corporations. For example, Toshiba, Panasonic and Sharp funded an Electronic Manufacturers Recycling Management Company (MRM) in 2007 and Toshiba as the top assignee in the field of batteries is also a partner of the Rechargeable Battery Recycling Corporation (RBRC) under the national U.S. Call2RecycleTM program dedicated to recycling of batteries [12].

Surprisingly, two large IT corporations Samsung and IBM appeared in the general area of Biotechnology, most probably due to their activities in healthcare and life sciences, such as computational biology [13] and pharmaceuticals [14]. However, the Bio waste treatment subarea was dominated by universities. Universities of California and South China appeared among top five assignees in both, general Biotechnology area and Bio waste treatment subarea as well. In addition to the absence of large corporations at the subarea of “Bio waste treatment”, the average proportion of “Bio waste treatment” related inventions has decreased from 10% to 7% over the last decade.

Technology transfer in the field of environmental solutions is often unsuccessful because, as evidenced by the low proportions of environmental inventions in this study, market interest in environmental technologies is low. As a result, a negative feedback loop arises: (i) Environmental solutions are not a priority to companies, since they present financial loss rather than profit to them. For example, the introduction of recycling of products in parallel with the production would drastically affect the price of products and consequently the competitiveness; (ii) Public research organizations, which are supposed to be a driver of innovation and the well-being of society are trying desperately with the commercialization, but they sooner or later stop with patenting of environmental solutions due to the low probability that these technologies will be licensed out to companies. Therefore, it would be illusory to expect that the corporations mentioned in this study - in other words the largest producers of waste and pollution - will begin to change their attitude towards the environment on their own [15].

As mentioned in the introduction, photovoltaics and other photonic applications will contribute to reduced electricity consumption and consequently lower greenhouse gas emission [5]. On the other hand, advanced production will increase the consumption of electricity and presumably increase the greenhouse gas emission [6]. Switch to green power sources is therefore extremely important [7]. However, it is necessary to understand that the power generation from green sources is less reliable due to low capacity potential and dependency of momentary environmental parameters. Therefore, complete transition to green sources is most probably not possible and the need for reliable power sources, such as fossil fuels and nuclear power will remain [8].

Fusion power will be able to replace environmentally harmful energy production with fossil fuels in the future, if successful [9], but decades will pass by then. This is also evident from the number of inventions related to fossil and nuclear power sources, wherein a number of inventions related to less environmentally friendly fossil fuel was approximately nine times higher as compared to cleaner nuclear and fusion power sources. However, the major concept of the vast majority of fossil fuel inventions was related to carbon dioxide according to PatBase Analyticsv2 [10], indicating that research and development in this area is mainly concerned with optimizing fuel use towards lower carbon dioxide emissions, which is admirable.

Even more favorable trends were observed in the field of green power at which the share of inventions was high and has grown from about 54% to 60% in the last decade. These data are encouraging in terms of reducing the global warming, environmental pollution and health hazard originating from "dirty" power sources, which gives optimistic forecast for the future.

A kind of "push" obviously exists at the energetics sector that forces states, governments and consequently all kinds of private and public entities including the players of innovation ecosystem to deal with environmental issues. This might be not only due to a lack of natural resources, but also due to clear rules at international and intergovernmental level, which oblige countries to respect the environment globally. The 1997 Kyoto Protocol, which has been in force since 2005 and replaced by the Paris Agreement in 2015 [16] seems to play a key role encouraging innovation towards the use of green energy sources by reducing the carbon dioxide emission [7].

Despite the fact that some countries do not respect the Kyoto Protocol and later Paris Agreement, it still is a good practice as it has - by insisting on solving climate problems at the international and intergovernmental level - created markets for green power sources around the world. Even China for example, which has often been declared a non-Kyoto country, is active producer of the equipment related to exploitation of green power sources – most probably due to the existence of global market as well as due to its own awareness on the environmental issues in the last decades [17]. Environmental issues associated with the "dirty" power sources are decades old and have been consequently addressed more in detail by the relevant authorities as compared to newer environmental threats (e.g. electronic waste, batteries, rare earths, metals etc.).

The establishment of the UN E-Waste Coalition and the introduction of the Platform for Accelerating the Circular Economy (PACE) [18] will hopefully lead to at least as effective international protocols in the field of electronics and waste material recycling as were established in the field of power sources. Measures that would encourage companies to protect the environment should therefore apply to all companies and all countries in order to maintain healthy competition between them. Once such a global pressure will be established, new markets will appear committing the private and public entities to become innovative also at the field of environment protection.

Technology transfer within the innovation ecosystem is a part of the solution, but unfortunately it works well in case of clear demand for breakthrough technologies at the market. In the field of alternative energy sources, intergovernmental agreements have emerged over the decades, creating such a demand for technologies enabling the exploitation of alternative power sources. This can be observed by the high number and shares of inventions in the field of green power sources.

However, the need in the market has yet to be created for technologies dealing with recycling of waste electronics and waste materials. And it is illusory to expect that this demand will arise on its own without adequate political support to put pressure on manufacturers globally. The task of the innovation ecosystem stakeholders is therefore to properly present these problems to the interested public, through which the pressure to the policy makers will be exerted. In fact, it would be great, if the solution in the field of electronic waste and waste materials management would be even more efficient and implemented faster than in few decades.

5. CONCLUSIONS

Although the number of inventions has generally increased over the past decade, the share of environmentally oriented inventions has not changed at the fields of electronics, materials and biotechnology, and has remained on average as low as 1%, 5% and 9%, respectively.

Large corporations leading at the areas of electronics, materials and biotechnology are not as innovative and active at the subareas related to the recycling of their own products, therefore they should refocus and invest into the environmental protection. In order to do so, legal basis, programs and incentives for non-profit recycling at national, international and global levels are beneficial.

On the contrary, the situation is more optimistic in the field of electric power generation, wherein the share of inventions related to green power sources grew from 54% to 60% in the last decade suggesting that technology transfer works well in case of clear demand at the market. In the field of alternative energy sources, intergovernmental agreements have emerged over the decades, creating such a demand for technologies related to exploitation of green power sources.

The players of innovation ecosystem should therefore convince and support the interested public to exert the pressure to the policy makers in order to create a market demand for the technologies dealing with recycling of wastes, especially electronic and material waste through establishment of intergovernmental agreements on the global scale.

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