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INNOVATION REVIEW: Closed, Open, Collaborative, Disruptive, Inclusive, Nested… and soon Reverse How about the Metrics: Dream and Reality

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ABSTRACT: Innovation, a subject of massive interest:

- is multiple and subject to overlapping descriptors: Closed, Open, Collaborative, Disruptive, Inclusive, Nested… and soon Reverse.
- "Innovation is not the idea but what you do with it."
- "is the future of innovation in essence predictable?"
- "is a stronger-than-logic Creative Path based on Curiosity and Confidence."
- necessitates strong implementation discipline and clarity and has to be competitively unpredictable.
- does include the bricolage model and approach associated with trial and error, learning on the job; the question of serendipity and the role of chance.
- requires to realize that "all the best people do not work for you".
- is probably best handled by small autonomous teams, as small as 5, probably not bigger than 80, possibly 15 on average in large corporations.
- cannot be "cloned"; Innovation cultures are hardly transferable.
- "R&D spending or R&D intensity as indicators of innovation may result in either overestimates or underestimates".
- most results suggest that "raw patent data is an imperfect proxy for innovation."
- patent exploration constitutes a wealth of innovation potential, as simple as image analysis to combinatorial therefrom.
- moving towards fundamental co-creation with intense purposeful networking.
- and the advent of Big Data: "Word is worth a million images".
- … not without a business model.

Can it be measured? When and How?

Most of the above comments on innovation are introduced in this fifth chapter on Innovation, hosted by IJIAS; some are illustrated with case studies addressing disruptiveness, academia relationship, publication co-occurrence, spending, metrics, etc.
More than 80 reviews and detailed third party documented viewpoints have been cited and used to address the various subject matters; these are considerable wells of information which the readers may use for a more in depth study of one or the other particular topic.

KEYWORDS: Innovation – closed, open, collaborative, disruptive, inclusive, nested -, Big Data, visualization, visual analytics, ideation, trend analysis, neural networks, collaborative, Collaboratory™, adjacent technology analysis, ATA©, IP strategy, semantic analysis, image analysis, artificial intelligence, reverse engineering, confidence, curiosity, combinatorial, clarity, biotechnology, energy, hydrogen, HIV, AIDS, PV, photovoltaic, pharmaceutical.

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This assessment is intended to educate and raise awareness of some of the complex issues that surround the intellectual property in the field of knowledge extraction from the about 80 million patent documents available, and to assist in the development of practical skills for dealing with inventions. It does not seek to provide legal, managerial or technical advice on intellectual property related law as such. For any guidance, legal or any other, seek advice from the appropriate professionals; this study can by no mean substitute for expert legal, technical and managerial advice.
The opinions expressed by the writers in this article do not necessarily represent the viewpoints of the companies the author are employed by.

INTRODUCTION

INNOVATION

Can be closed as per the older consolidated corporate research and development practice; “but all the best people do not work for you”. This was the first chapter of our series on innovation hosted by the IJIAS [1] (Rebouillat, 2013).

Can be open or based on Collaboratory™ as long as Intellectual Property (IP) is well integrated; “Is IP central to innovation or is innovation central to IP?”. Then can ideation be engendered by artificial means? Those questions were raised in the second chapter of our series on innovation hosted by the IJIAS [2] (Rebouillat & Lapray-D, 2014).

Can be disruptive and “a stronger-than-logic Creative Path based on Curiosity and Confidence”. In the context of bio-inspiration some examples were discussed in the third chapter of our series on innovation hosted by the IJIAS [3] (Rebouillat & Lapray-M, 2014).

Can be inclusive with the advent of bigger data. “An image is worth a thousand words” and a “word is worth a million images”, as per the adage used in the fourth chapter of our series on innovation hosted by the IJIAS [4] (Lapray-D & Rebouillat, 2014).

Can it be Nested? Reverse or Trickle-up? Is academia playing a new role? Can the developing world be first before spreading it to the industrialized world? Are Combinative skills and Clarity additional dimensions of the equation? Can it be measured? How and When? These questions are part of the current fifth chapter of our series on innovation hosted by the IJIAS (Lapray-M & Rebouillat).

As per Figure 1 and 2, the initial “equation” $4C^{2©}$, then $4C^2\ 2C^©$ [1-4], and, now $4C^2\ 2Cx2C^©$ wherein Combinative skills and Clarity are bringing a multiplying dimension to the starting formula; therewith a multiplying synergism versus the usual additive synergism. The multiplying factor is the heart of the DNA of most disruptive innovators; Clarity being part of their questioning ability and reformulating art.

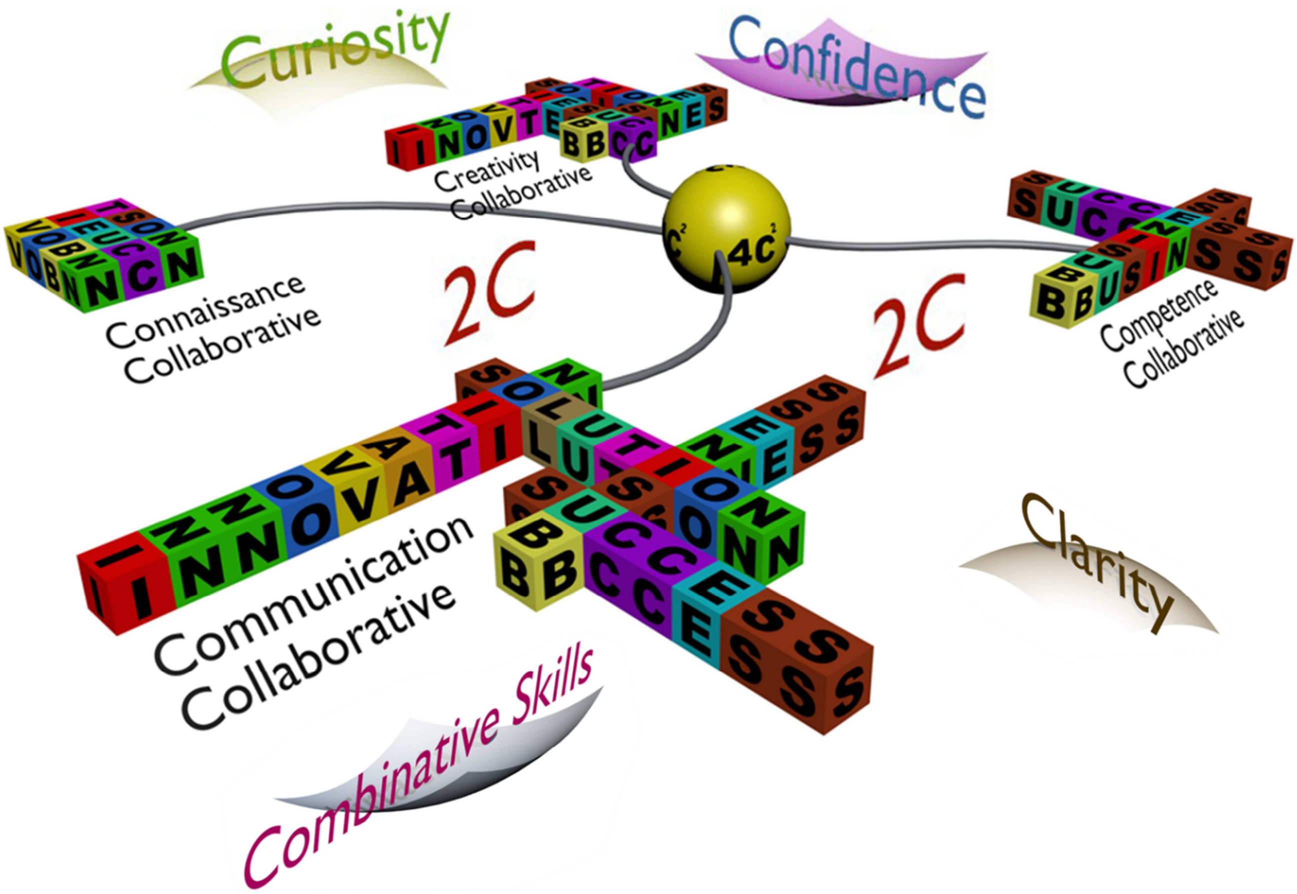

Figure 1 The Multiplying Dimensions of the Innovator, at large technical, science and business, now amount to $4C^2$ 2Cx2C© [1]–[4](Rebouillat, 2013; Rebouillat & Lapray-D, 2014; Rebouillat & Lapray-M, 2014; Lapray-D & Rebouillat, 2014).

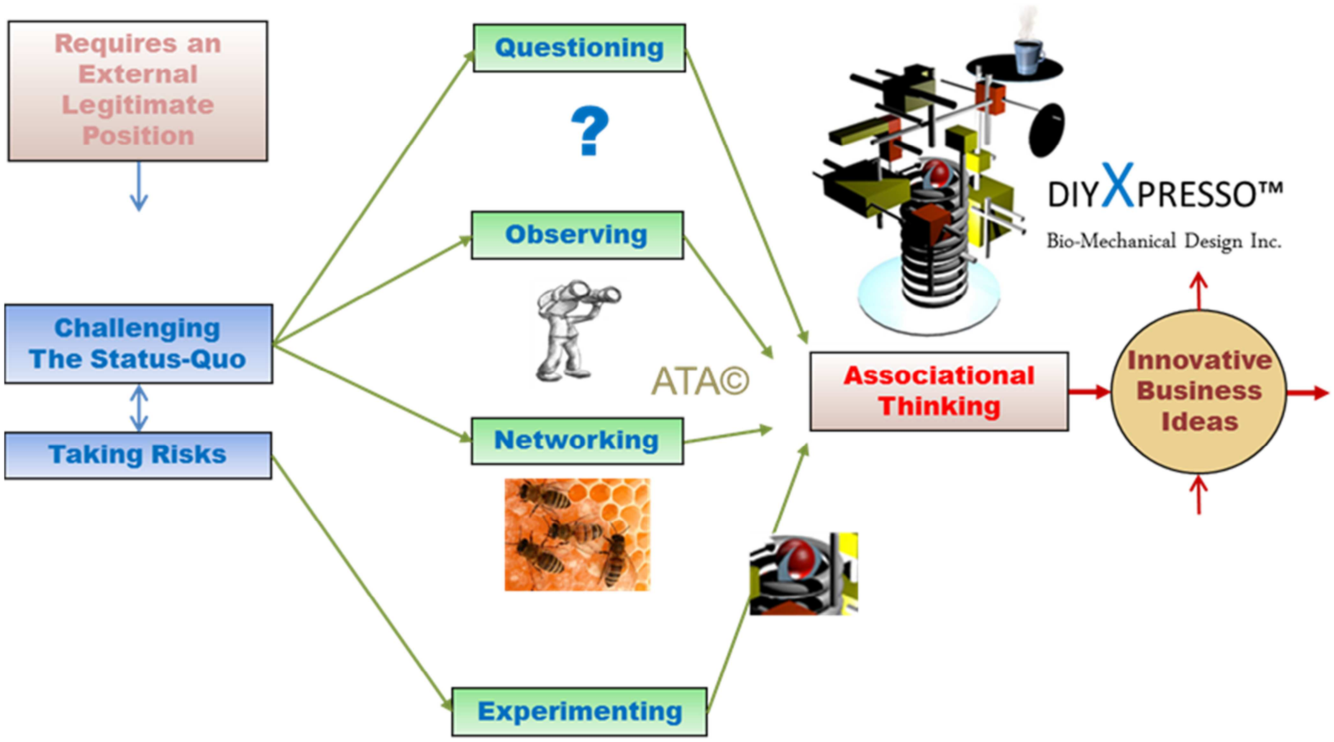

Figure 2 The stereotypical disruptive innovator profile. Combinative Skills in the "Big data" context are getting bigger than human conceptual Imagination [1]-[4] (Rebouillat, 2013; Rebouillat & Lapray-D, 2014; Rebouillat & Lapray-M, 2014; Lapray-D & Rebouillat, 2014).

Innovation majorly draws from Combinative/Associational skills in a boundary-less manner…

Figure 3 self explains the associational ability which grows with each individuals and multiply itself as Curiosity and Confidence unfold within organizations of various sizes.

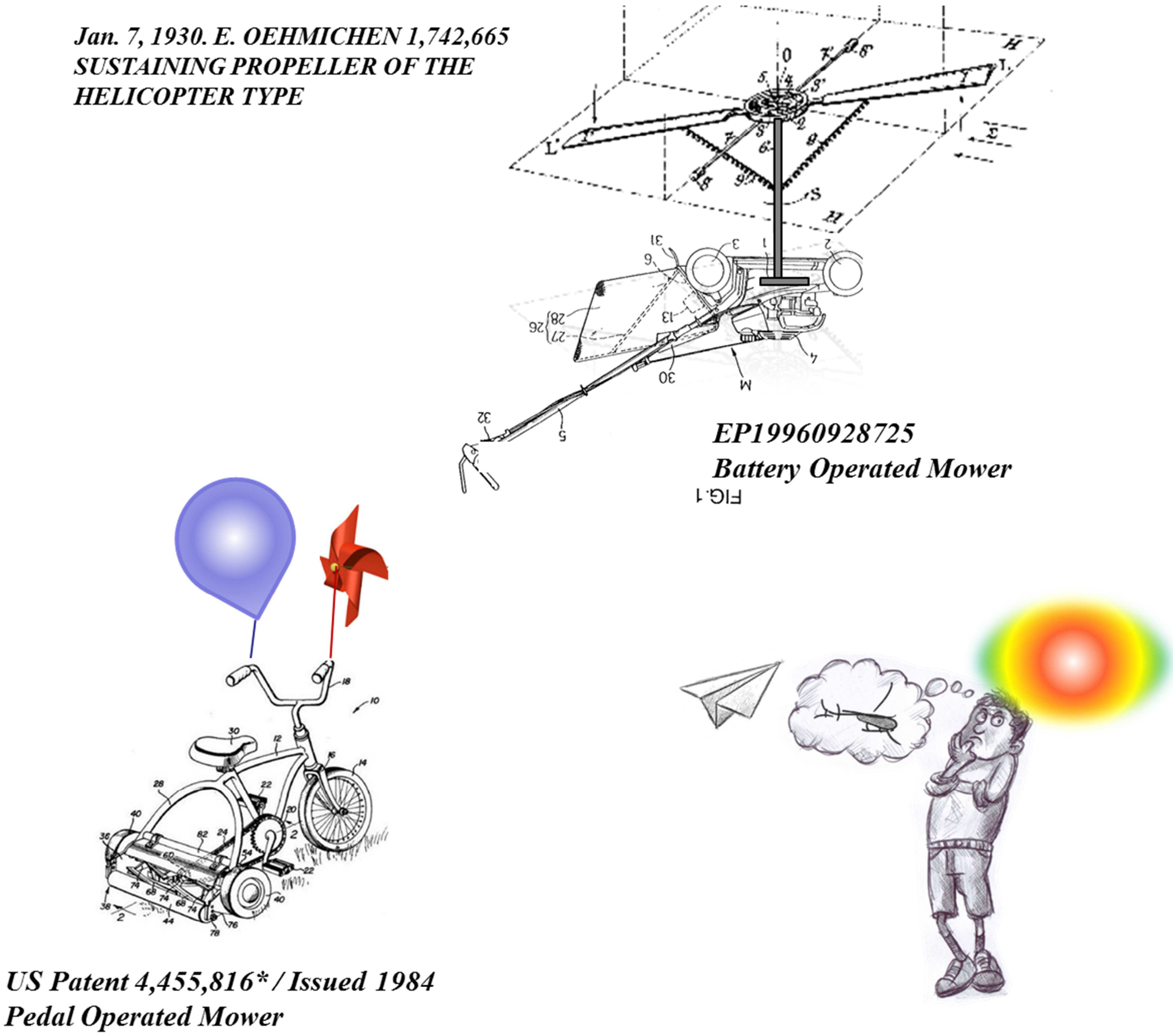

Figure 3 Boundary-less Innovation is Inclusive;
"Innovation is not the idea, but what you do with it". The Imaginary "Helico Air Mower" by Rebouillat (1998 ©)

Can Innovation be measured is certainly a long lasting question. Many attempts have been probed throughout years; such as in an industrial/business context [5] (Kaplan, 2006),

- "Annual R&D budget as a percentage of annual sales
- Number of patents filed in the past year
- Total R&D headcount or budget as a percentage of sales
- Number of active projects
- Number of ideas submitted by employees
- Percentage of sales from products introduced in the past X year(s)"

have all been used.

Generating a "family of metrics" for ensuring a balanced portfolio of measurements/metrics, counting both "input metrics" and "output metrics" to ensure the best management of resource allocation and capability development, as well as and above all the return on investment for all "societal" components, is essential to surround some aspect of metric necessity.

Innovation does require a process discipline such as illustrated on Figure 4; the latter provides opportunities to implement harmonized metrics at each and every Input and Output phases. These are sometime missing in the checking list of some business development processes. As pointed out on Figure 4 none of these metrics have the same weight and foundation therefore rendering the metric global equation more complex; as well more powerful pending on how analytics are developed and interpreted.

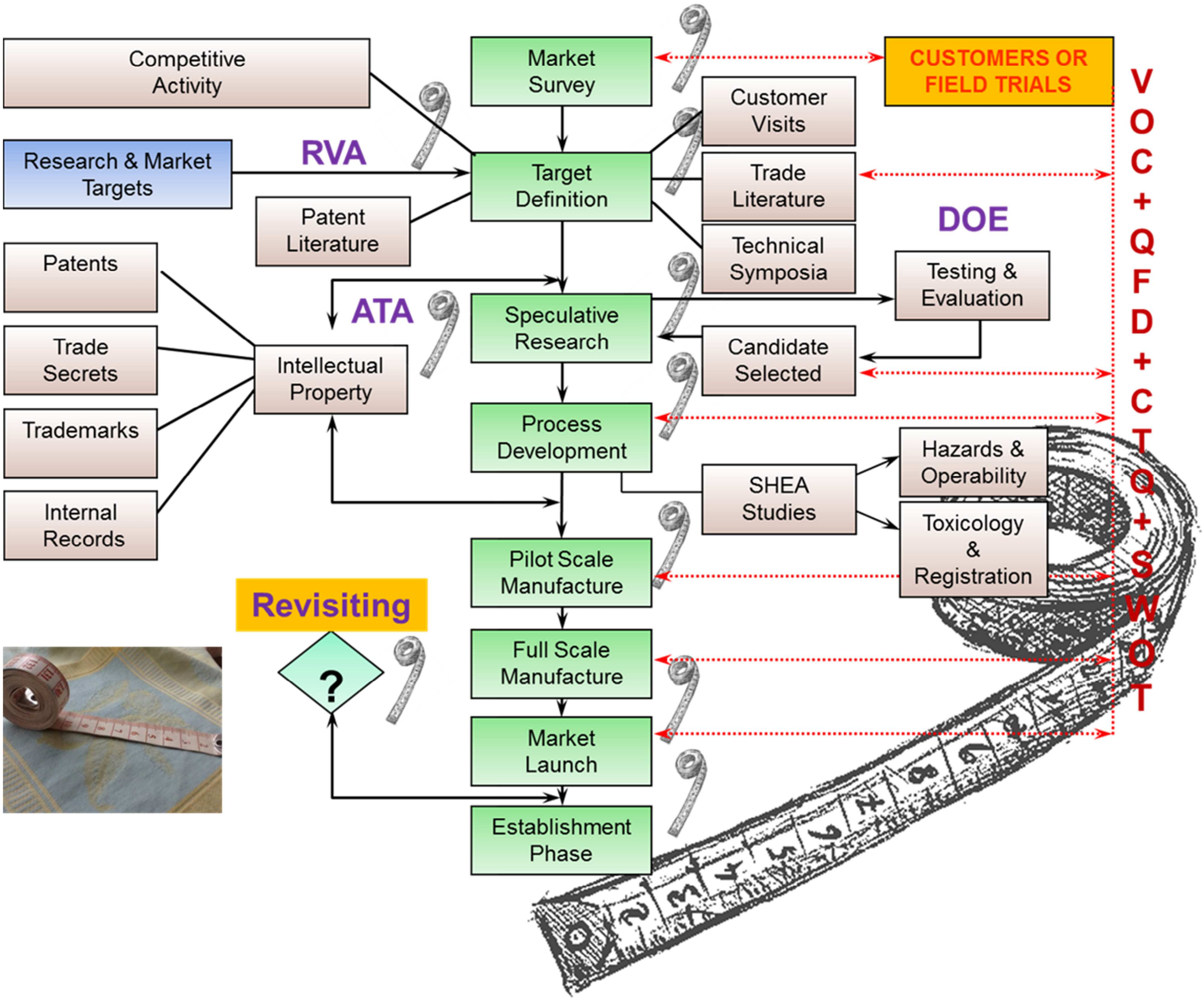

Figure 4 The opportunity to develop a harmonized portfolio of Metrics. The Z-Process, above, combines multiple business and technology management processes [1]–[4] (Rebouillat, 2013; Rebouillat & Lapray-D, 2014; Rebouillat & Lapray-M, 2014; Lapray-D & Rebouillat, 2014).

The analysis of innovation and nested preferential moves in chess game strategy demonstrated that the probability of a new innovation path to occur, decreases a per a power law of the frequency that the corresponding situations has occurred before. Similarly decision making can be likely influenced and its dynamic may become a hindering factor to innovation in general.

The above supports the necessity to promote innovator and implementer team composition across organizations.

As a practical set of examples let's refer to "The Innovator's DNA" [6] (Dyer, Gregersen, & Christensen, 2009):

- A reasonably opinion based ranking of the first 25 innovative companies, performed in 2005, ranked Apple and Google at level 1 and 2. And renowned German and Japanese car manufacturers in position 4, 13 and 14.
- With the assistance of the HOLT approach, which includes current market value and future potential market values (developed and practiced by a division of a Swiss bank), the classification was redone keeping the same 25 players. Then Amazon appears as #1, Apple #2, Google #3. And, the car companies mentioned previously appear at the bottom of the list?
- Finally the authors chose to rerun the classification from scratch using the HOLT approach. Saleforce.com ranked #1 (the cloud disruptive approach), Intuitive Surgical #2 (surgical robots) and Amazon ranked #3. Although using the same number of companies of same class and size selection, this time no car companies are appearing in the ranking of the authors.

Innovation metric is certainly a predicting art, which has to account for current and future innovations and return promises therewith. Value for the customer and return for the company are defining innovation in the business context and likewise in a societal context with measurable wellbeing and progress.

Many attempts have been made to link IP activity and innovation rating, given the current state of the art of the work "Bigger data analysis in the field of IP" [2] (Rebouillat & Lapray-D, 2014), we would reserve our opinion to a later coming paper.

"As imperfect as data on patents and R&D are as surrogates for innovation, both are nevertheless widely used because it is so hard to measure innovation directly and there seem to be no better alternatives"[7], [8] (Cotis, 2006; Dutta, 2012).

OPEN INNOVATION

"*The Open Innovation paradigm treats R&D as an open system. Open Innovation suggests that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well. This approach places external ideas and external paths to market on the same level of importance as that reserved for internal ideas and paths to market in the earlier era*" [9] (Chesbrough et al., 2006). This new model represents the opposite of "closed innovation model" where research and development of new products were entirely conducted within the company. This can lead to the production of innovative solutions that may, or may not be commercialized, depending on the current company's strategy. To illustrate the above, Henry Chesbrough uses the example of Xerox Palo Alto Research Center where many successful products have been developed but were not a subject of interest to management to take it to the market. Employees who have worked on these technologies set up start-up companies and some of them, such as 3Com and Adobe, became extremely successful. It is apparent that research results developed within the companies can easily cross its borders, therefore the closed innovation paradigm is not the most secured and sustainable. In other words, it shows that knowledge can travel, with increased mobility of skilled workers and academics, and develop in variety of settings that are alternative, external options for unused technologies (such as research facilities, start-ups, and academia). In an open innovation model companies can license-out the technology if they do not desire to use it, or license-in technology from other firms. In addition, companies can decide to leverage their research and find the best solutions by starting a partnership with academia or other industrial partners, or creating external joint laboratories. All of the pathways present with a very productive outsourcing potential. Another possibility is to collaborate with start-ups or acquire them. Some firms have formed internal venture groups to facilitate their own innovation process. The use of those options aims to capture more value for the companies. In other words, one may think about open innovation as a way for a company to stop working in isolation and being incorporated into an ecosystem where many ideas can merge and have additive value (Figure 5). Laursen and Salter tested the effectiveness of the open innovation based on the sample of 2707 UK manufacturing firms that answered questions about their innovation process [10] (Laursen & Salter, 2006). As suggested previously by Chesbrough [11] (Chesbrough, 2003) companies that use the external sources of knowledge have higher level of innovative performance [10] (Laursen & Salter, 2006). Nevertheless, it needs to remain to be closely managed so that the cost of knowledge search is not higher than possible gain; additionally IP aspects need attention too [10] (Laursen & Salter, 2006).

In the next paragraphs we will investigate if and how the open innovation model can be an engine for disruptive innovation? In addition, we aim to look at what is the current situation and models of cooperation between business and academia.

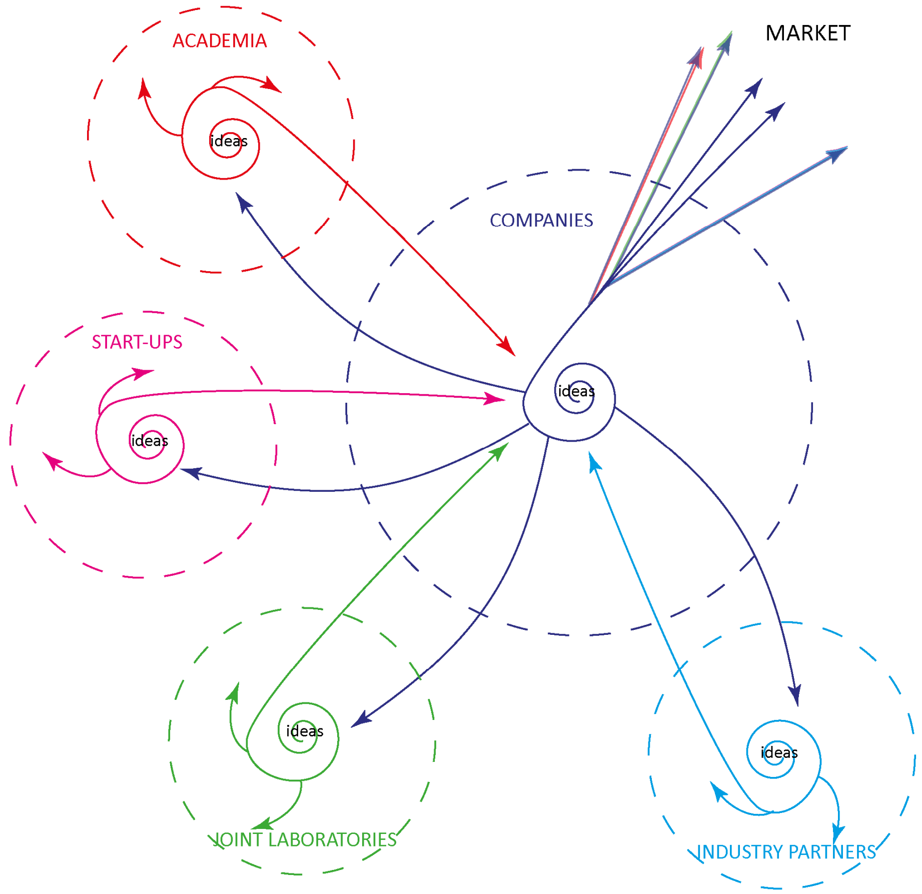

Figure 5 Knowledge circulation in an open system.

DISRUPTIVE, INCLUSIVE AND REVERSE INNOVATION OF A NEXT DECADE

Disruptive innovation is a term describing a situation when a new technology/service interrupts an existing market and value network and creates a new one. It is important to note that the term *disruptive technology* is not necessarily equivalent to *disruptive innovation*. The core idea is that a new solution has to have a potential to alter the entire market to become a true *disruptive innovation*. In other words, capacity to disrupt must be equal or exceeding its economic impact. There are multiple examples of novel technologies that completely transformed their respective markets and truly changed our culture. Several examples of disruptors are: e-mail, smartphones, digital photography etc. The theory of disruptive innovation has emerged as a result of analysis of disk drive industry. It has been chosen predominately because it faced several cycles when new technologies have emerged and have discontinued previous ones in a short time scale [12], [13] (Bower & Christensen, 1995; Christensen, 1997). Interestingly, this situation kept repeating, proving that it is not easy or obvious to catch and invest into a truly promising, novel technology. The authors of the analysis suggested that *disruptive innovation* is initially characterized as having low gross margins and target markets, and often simply don't match current customers' need. This presentation does not evoke an interest of management to invest on the negligible and therefore unattractive market. Instead their efforts are focused on satisfying clients' needs and financing improvement of a current technology. This creates a space, a niche market, for new and potentially disruptive competitors to emerge. As noted by some, this theory may just touch the surface of the complex situation and needs additional research of interrelated areas e.g. existence of more types/dimensions of technology change [14] (Danneels, 2004). An important aspect to consider when discussing disruptive innovation is its appearance as *inclusive innovation.* According to the Global Research Alliance *inclusive innovation* can be described as *"any innovation that leads to affordable access of quality goods and services creating livelihood opportunities for the excluded population, primarily at the base of the pyramid, and on a long term sustainable basis with a significant outreach"* [15] (Mashelkar).

To sum up, it is vital to be able to identify the technologies that have a true disruptive potential. There is no universal approach to complete this task. However, laying down some directives can help to identify appropriate candidates. McKinsey global institute identified four factors that describe technologies with substantial potential for disruptive economic impact [16] (The McKinsey Global Institute, 2013). According to the report these include: (1) "*a rapid rate of change in capabilities in terms of price/performance relative to substitutes and alternative approaches, or they (disruptive technologies) experience breakthroughs that drive accelerated rates of change or discontinuous capability improvements.*"; (2) "*(…) technology must have broad reach – touching companies and industries and affecting (or given rise to) a wide range of machines, products, or services.*"; (3) "*(…) technology must have the potential to create massive economic impact.*"; (4) "*technologies that matter have the potential to dramatically change the status quo. They can transform how people live and work, create new opportunities or shift surplus for businesses, and drive growth or change comparative advantage for nations*" [16] (The McKinsey Global Institute, 2013). The analysis of currently emerging technologies according to the above criteria resulted in the list of 12 potential candidates: (1) mobile internet; (2) automation of knowledge work; (3) the internet of things; (4) cloud technology; (5) advanced robotics; (6) autonomous and near- autonomous vehicles; (7) next-generation genomics; (8) energy storage; (9) 3D printing; (10) advanced materials; (11) advanced oil and gas exploration and recovery; (12) renewable energy [16] (The McKinsey Global Institute, 2013). Together these technologies have the potential of estimated economic impact ranging from $14 to $33 trillion per year in 2025 [16] (The McKinsey Global Institute, 2013). In a similar spirit one could try to identify next disruptive innovation by analyzing specific portfolio of several companies. A useful guidance is provided by the list of “50 Disruptive Companies in 2013” chosen by MIT Technology Review [17] (MIT Technology Review). According to the authors "*Each company on this list has done something over the past year that will strengthen its hold on a market, challenge the leaders of a market, or create a new market.*" The companies are divided in 5 broad categories: biomedicine, computing and communication, energy and materials, internet and digital media, transportation [17] (MIT Technology Review). Importantly, the scope of interest of chosen companies overlap with the list of 12 technologies mentioned before.

To bring a degree of predictability and a better control over the process of innovation Christensen compiled a few principles helpful in designing the process [18] (Anthony et al., 2006). One of them is identifying and expending to disruptive market outside of the core business. Christensen isolated three possible scenarios for such a situation. The first one is to propose to customers’ easy and simple solution to do an important job, in the situation when competitors are fragmented or are not responding to their need. It can start with identifying the novel application of existing product by customers, leading to uncover specific requirements and proposing a more suitable solution. Secondly, one may try to target customers at the low end of an existing market. Propose a product that is good enough to satisfy all the basic customers’ needs at low price, in a situation when competitors do not focus on this segment of the market. The third scenario proposes to remove the barriers to consumption and thus expand a market, in the situation when competitors judge the market as unattractive. As a next step one has to carefully analyze the history of a market in the context of disruptive innovation principles. It helps to create a list of questions to ask when evaluating new opportunity from multiple perspectives exceeding company’s core competences. This exercise helps to uncover the characteristics of the novel product and can lead to the generation of the desired idea [18] (Anthony et al., 2006).

However, the complicated ecosystem of nurturing innovative process is not easy to embrace and many companies still struggle to work out efficient tools to maintain it.

For the sake of completeness let’s mention the reverse innovation process which focuses initially on developing areas and move to more industrialized market zones once established and proven as efficiently meeting customer satisfaction and investor returns. Generally the key benefit is simplification, therewith disruption of an established market and a product complexities; and resource therewith.

MANAGING THE PROCESS OF INNOVATION

The process of innovation to remain effective must be supported by an appropriate business model. Chesbrough identifies six business models depending on how openly they are capable to innovate [19] (Chesbrough, 2007). Most of the companies fall into the first type of “undifferentiated firms” that sell goods or services that are no different from competitors. On the other side of the spectrum he finds fully open and adaptive companies that take advantage of all external resources and possibilities [19] (Chesbrough, 2007). In this scenario “*some companies use corporate venture capital to explore alternative business models in small start-ups. Others create spin-offs and joint ventures to commercialize technologies outside their own business model. And there are those that create internal incubators to cultivate promising ideas that aren't yet ready for high-volume commercialization*”[19] (Chesbrough, 2007). The external incubation could be associated with the nested innovation introduced by Rebouillat earlier on. It is consequently of importance to rethink organizational processes that govern a company, and as Chesbrough points out “*(…) the potential rewards are compelling: lower cost for innovation, faster times to market, and the chance to share risks with others. These enhancements can unlock new sources of organic growth and revitalize your company*” [19] (Chesbrough, 2007). Few companies may serve as rather remarkable examples of embracing open innovation business model, such as Philips or Cisco Systems, Inc. [20] (Cisco Internet of Things Innovation Grand Challenge, Philips Research).

The McKinsey Quarterly survey (September 2007) questioned 1458 executives, equally representing all levels of responsibility, on their approach to innovation [22] (McKinsey Quarterly, 2007). Not surprisingly, 70% indicated innovation as one of the most important factors that drive growth [22] (McKinsey Quarterly, 2007). In the subsequent edition of an online survey (July 2010; 2,240 executives) percentage of executives that share this view rose to 84 [23] (McKinsey Quarterly, 2010). On the contrary to that declaration, only 24% of the top managers in 2007 (722 of responders) control the budget set for the purpose of innovation and only 22% control performance metrics [22] (McKinsey Quarterly, 2007). Lack of governance was perceived as an obstacle, and 47% of the top managers would like to improve the process of innovation by assembling it as a core part of their agenda [22] (McKinsey Quarterly, 2007). In 2010, the main difficulties to effective innovation have not changed, 42% managers still think that more formalize and organized processes of innovation along with integrating it into company strategic planning is a necessity [23] (McKinsey Quarterly, 2010). In the same time 39% of responders say that their organization has general innovation priorities but they are not formalized [23] (McKinsey Quarterly, 2010). This set of data points out the clear direction to be taken by management and shows the need to develop more organized way to manage the process of innovation (Figure 6). At the same time it is not a practice solely based on trial and error and should have defined construction [18], [24](Anthony et al., 2006; Stage-Gate®). This has been illustrated earlier on with Rebouillat's Z-Process of figure 4, which provides clear steps and the need for tailored metrics all along that process.

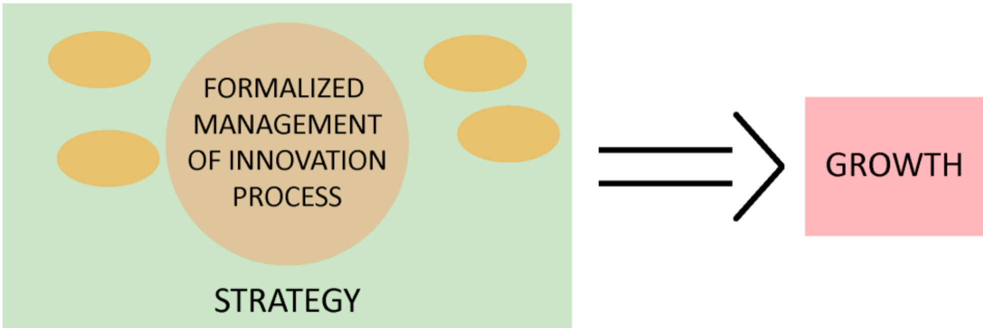

Figure 6 Management of innovation process as a key component of strategy ensuring stable company growth [22], [23] (McKinsey Quarterly, 2007, 2010).

Importantly, for the topic of this review executives also indicated the means that are currently used to develop new ideas or commercialize a new business [22] (McKinsey Quarterly, 2007). The primary source is an in-house product-development team, as indicated by 56% of top managers. Interestingly, partnerships with academia and research centers were mentioned as a second one (34%). The remaining includes: centralized innovation initiative teams (25%), centralized innovation group (20%), R&D center (17%), outsourced R&D center (14%), corporate venture capital fund (7%), other (15%) [22] (McKinsey Quarterly, 2007). It becomes clear that the majority of efforts remain centralized, as evident in figure 7. In 2010, 30% of responders assessed that their organization is extremely/very effective at using partnership and open innovation as a tactic to drive innovation, 39% rate it as somehow effective, 10% as not at all effective and 19% said they don't use it [23] (McKinsey Quarterly, 2010). Executives, pointed out centralized innovation initiatives and traditional R&D as more effective tactic used by their organization than open innovation (centralized innovation initiatives, 33% very/extremely effective and 42% - somehow effective; R&D, 31% very/extremely effective and 42% as somehow effective) [23] (McKinsey Quarterly, 2010).

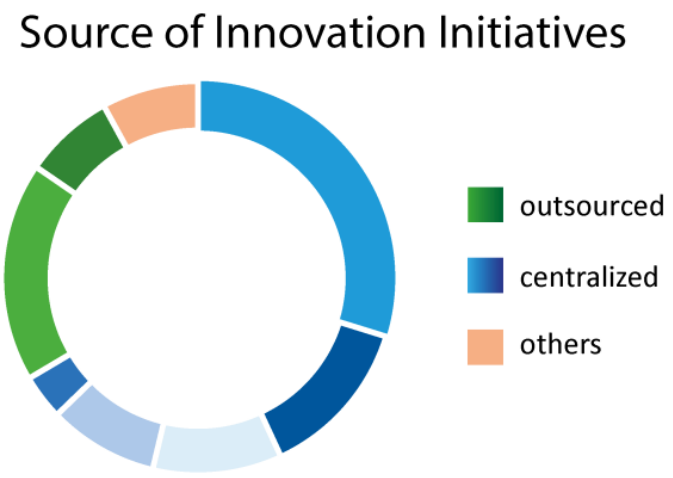

Figure 7 The use of internal vs external sources for innovation development. n=722 responders, multiple answers [22] (McKinsey Quarterly, 2007).

The pharmaceutical industry is clearly among the most innovation demanding ones and with years of experience should perfect the process of managing discoveries and bringing them to market. However, this assumption does not reflect the reality. In 2013, U.S. Food and Drug Administration's Center for Drug Evaluation and Research (FDA's CDER) approved 27 new medicines, known as new molecular entities (NMEs). This amount is below what is required for sustainable development of pharmaceutical business [25] (U.S. Food and Drug Administration, 2013). Companies themselves define that they need 2-3 NMEs per year to fulfill their growth objectives, and none of them ever reached that level [26] (Munos, 2009). Among the approved drugs (2013), 33% (9 out of 27) where shown to be innovative and have a novel mechanism of action (classified as First-in-Class NMEs). Despite ever growing investment in R&D process, the average number of accepted NMEs remains constant at the level of 26 per year from 2004 to 2012 [25] (U.S. Food and Drug Administration, 2013). Even more remarkably, this trend is stable since 1950, excluding the 90s and the peak of 1996, when 51 drugs were approved [26] (Munos, 2009). This anomaly is attributed to the change in administrative process of approval itself, which caused faster processing a backload of applications. This trend is pointing to the disappointing conclusion that any changes introduced to the process of drug discoveries did not translated into bigger output of successful drug commercialization, figure 8 [26] (Munos, 2009). Data provided by the Pharmaceutical Research and Manufacturers of America (PhRMA) can shed some light on the scale of R&D of drug development [27] (PhRMA, 2014). Average cost of successful NMEs launching, including failures, reached $1.2 billion in 2000s as compared to $800 million in 1990s and $320 million in 1980s [27] (PhRMA, 2014). In that process the numbers bluntly point out that more and more substances do not reach or pass subsequent clinical trials that translate to higher cost. Some of that can be reduced by more rigorous fundamental and pre-clinical research of new molecular entity that subsequently have higher chances of success and launch [28] (Paul et al., 2010). Only 2 out of 10 marketed drugs have revenues that match the investment cost. In the same time the total spending of PhRMA members on R&D has been growing at an average rate of 12% since 1970s to reached a total of $5.1 billion in 2013 (that equals around 20% of sales) [27] (PhRMA, 2014). In turn, this increases the prices of branded or patented products as compared to generics. An example can be 17-fold difference in price between branded and generic formulation of HIV/AIDS medicine, lamivudine. In 2001 GlaxoSmithKline US price was $3271 per patient per year as compared to Indian generic producer Cipla's price of $190. Another drug, viramune (nevirapine), was sold as branded product for $3,508 while the Cipla generic price was $340 (Khor).

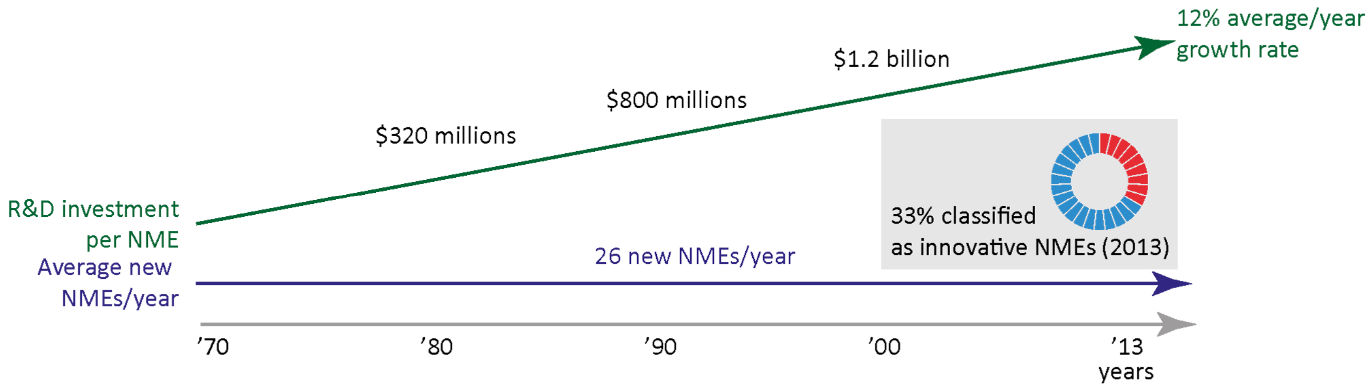

Figure 8 Increasing R&D funds for drug development vs number of novel formulations on the market

The challenges ahead of the pharmaceutical business fall in the following categories: (1) upcoming patent expirations of several high revenue generating drugs and lack of suitable replacement at hand; (2) demand from health care providers to provide evidence that treatment has a cost advantage over competitors’ product; (3) increase in the amount of safety evaluation demanded by regulatory entities; (4) not sufficient number of promising drug candidates [28], [30] (Kaitin, 2010; Paul et al., 2010). Combination of all of the above push pharma business to cut costs e.g. by merging and acquiring other partners (latest examples are Pfizer-Wyeth, Merck-Schering-Plough, Roche-Genentech). However, many agree that simply reducing R&D cost will not fill in for the draining pipeline of therapeutics [28] (Paul et al., 2010). Another strategy to counteract the above situation is to move away from the model when company own and manage the entire R&D process. Instead, they move towards a network model of innovation, sometimes referred to as a fully integrated pharmaceutical network [30] (Kaitin, 2010). In that situation, to enhance the output of the process of drug development the pre-discovery and pre-clinical research is outsourced to parties with appropriate competencies, namely academia and small pharmaceutical companies [30] (Kaitin, 2010). Others propose the “quick win, fast fail” drug development paradigm where emphasis is put on discovery process itself and establishment of solid proof of concept before proceeding to a next phase [28] (Paul et al., 2010). In that model (executed and named by Eli Lilly’s as “Chorus model”) the aim is to increase the probability of success in later phase and thus reduce associated costs and risks [28] (Paul et al., 2010).

It seems that it is more reasonable that every effort should be directed towards effective management of fundamental research carried out by both external and internal parties, figure 9.

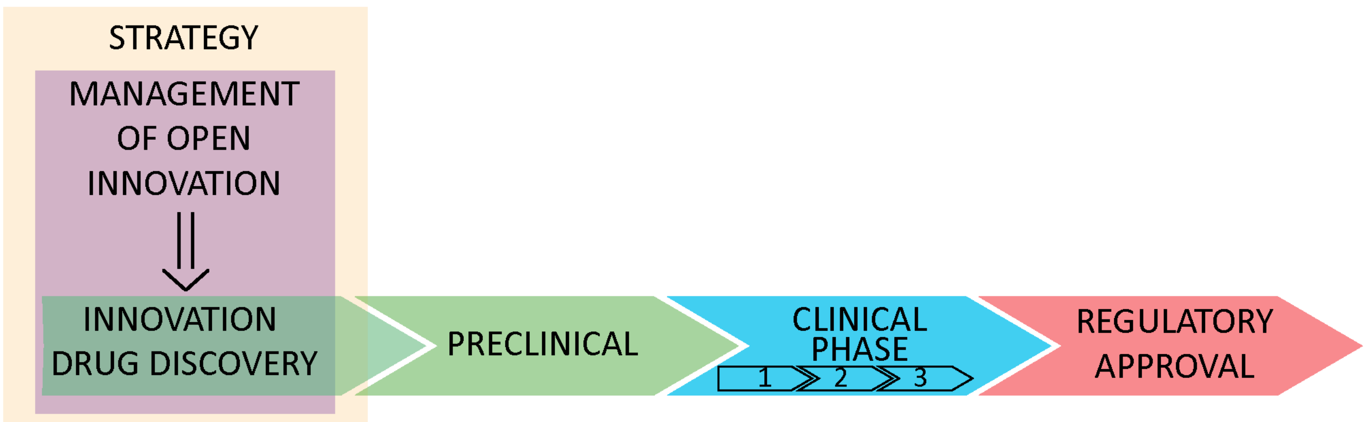

Figure 9 Management of innovation in drug development process as a key component of strategy ensuring stable company growth.

INNOVATION METRICS

Innovation is a form of business investment and in principle should be measured. Still, the process that is based on creativity, discovery and learning by definition doesn't have well defined end point, is ambiguous by nature and bear high risk. In other words, many aspects of innovation are intangible and as such are difficult to evaluate. It doesn't necessarily mean those are not prone to measurement, but require careful choice of methods and tolerance to their approximation rather than definitive values [31], [32] (BearingPoint, 2011; Morris, 2011).

The solid concept of return on investment (ROI) is a basic and useful way of evaluating many types of projects. The key in applying ROI depends on the stage of the project. ROI could be successfully used in the case of innovation-driven projects of short term or at advance stage when we have an idea of the target market and related business processes. In that case we are aware of the existing situation and can relate to it in our predictions. If the ROI measurement should be applied at very early stages of projects, especially when we have no idea about possible market, we are forced to guess based only on our biased assumptions. This process may well kill any project before it has proven its value [31] (Morris, 2011).

Another way of somehow quantitatively and retrospectively measure innovation performance, as well as its categorization as disruptive or incremental, is the use of patent database. The most accepted and advised way is to compare the number of patent citations issued for use in the same industry [33]–[35] (Albert et al., 1991; Carpenter et al., 1981; Katila, 2000). This is a measure of a quality of innovation as the amount of a patent's citations resemblance its value and impact in the field. Provided that we choose the correct time period of the analysis (e.g. amount of years after the patent was granted), such analysis can distinguish companies that focus on incremental vs disruptive solutions [33]–[35] (Albert et al., 1991; Carpenter et al., 1981; Katila, 2000).

The above measures are of retrospective approach and as such are not helpful to assess the ongoing projects. Due to the uncertainty of the innovation processes it seems that a mixture of quantitative and qualitative metrics could create a reasonable evaluation approach. All of them could be categorized as external, internal and people metrics that are extremely interconnected and will allow you to gain a more holistic view of the impact of innovation on your organization [31] (Morris, 2011). External metrics measure, for example, the output of innovation as new sales and customers, brand recognition and image, as well as growing network of external partners. Their aim is to assess the brand recognition and impact on the open innovation ecosystem. Internal metrics, for example, look on valuation of innovation portfolio as compared to prior years, increase in a number of new projects (incremental and non-incremental) in pipeline, percentage of revenues attributed to innovation within existing portfolio or growing investment opportunities available for senior management to consider. Their aim is to look at various parameters that describe growth and revenue. People metrics evaluate the level of participation in innovation process such as the quality of efforts of people involved in the project or the completion time. Langdon Morris proposes the metrics in the form of 92 questions being a mixture of quantitative/qualitative and external/internal/people measures [31] (Morris, 2011). It would be difficult to answer all proposed questions, therefore one need to make a choice adequate to the situation and time point of the innovation driven project.

FUNDAMENTAL RESEARCH AS A KEY TO DISRUPTIVE INNOVATION

There are many examples where the strong academic research was a key to produce a blockbuster drug, meaning that its annual revenue is over $1 billion. Many believe, that only better understanding of the underlying causes of human diseases and uncovering its complexity can lead as to produce effective therapeutic solutions [28] (Paul et al., 2010). An example can be a drug, currently market by Pfizer under the name Lyrica. It is a pregabalin developed by Dr. Richard Silverman, a professor of chemistry at Northwestern University (USA), that is approved as a treatment for fibromyalgia and epilepsy (Northwestern University). History of the development process of 21 drugs of high therapeutic value (introduced 1965 – 1992) shows that almost 80% of enabling discoveries were carried out by research sponsored by public money, as opposed to synthesis of the compound that was founded mostly by private sector [37] (Cockburn & Henderson, 1997). This clearly indicates that academia mission and capabilities are not in compliance to drug discovery process but their contribution to development is crucial. It leads to a new type of partnership where interdisciplinary teams work in collaboration with pharma-based scientists and managers.

Innovative Medicines Initiative (IMI) is an example of public-private partnership with a mission to support the process of discovery and development of novel drugs. It has been an undertaking by EU and the European Federation of Pharmaceutical Industries and Associations (EFPIA), with a €2 billion budget. The projects funded by IMI have a goal of boosting collaborative ecosystem for pharmaceutical R&D. As a result, in all of the 47 initiatives (June 2014) participants are the mixture of small-and medium-sized enterprises, patients' organizations and hospitals, universities, research societies, regulatory agencies and others [38] (Innovative Medicines Initiative).

Nevertheless, some universities are experiencing decreased funding of fundamental drug research, thus they attempt to develop support systems for their researchers themselves. An example comes from increased efforts of academic institutions to self-fund early drug development research with the goal of bringing it to the market [39] (Hayden, 2014). Harvard and Oxford Universities recently raised money to support drug discoveries and subsequent commercialization. It brings the money to public institutions, gives a certain degree of freedom for researchers in deciding how to conduct experiments and may nurture, at least partially, the pipeline of new drugs [39] (Hayden, 2014).

The innovative idea in any domain can come anytime from fundamental research. Association of University Technology Managers yearly presents a report on how academic research and technology transfer have changed our way of life, a so-called Better World Project. Every report presents success stories and real impact of technology that benefit the general public in variety of domains such as novel food sources, health improvement, replenishing water supplies, and many more [40] (Association of University Technology Managers). Despite many success stories the key question remains: do universities and business sufficiently nourish their cooperation in order to boost the innovation process?

UNIVERSITIES TO BUSINESS COOPERATION

As clearly exampled in previous chapters there are two environments where innovation takes place that are research facilities set in business or public environment. It is of interest to examine if and how researchers and managers interact with each other.

Research and education is the core of university values and activities. Would it be possible to add entrepreneur activities to its portfolio by intensifying the collaboration with the industry? One can name several factors that can address why universities may and should strengthen their relation with industry. Among many reasons we can point out few such as (1) overlapping research goals, particularly similar content of fundamental research, (2) necessity to gain novel source of funding, (3) development of technologies that have the opportunity to be transformed into technological solutions and thus fulfill (4) the obligation to governmental policies to gain economic return on publicly funded projects [41] (Bercovitz & Feldmann, 2006). On the other side, we have innovation-lead businesses that by engaging with universities can benefit from (1) access to new ideas and (2) specialized pool of consultancy. In addition, they directly (3) transfer knowledge and technology by organizing internships and allowing graduate work to be carried within a company and finally recruiting graduates. Therefore, it is in their best interest to boost their relationship with academia. The academic and business are very different worlds in terms of environments they operate in, building foundation, mission etc. However, their converging interests are influencing a change of perspective for both entities and results in measurable action towards tightening collaborative work (Figure 10).

At the moment, research institutions hold some degree of interactions with industry. However, the level of this collaboration is far from being satisfactory. The biggest study on European university-business cooperation (included 6 280 responses among academics from all members and candidates of the European Union) found that the third of universities have no or very low interactions with business [42] (Science-to-Business Marketing Research Centre, 2011). Details of statistics for every country can be found on-line [42] (Science-to-Business Marketing Research Centre). One can measure the interactions in two ways looking at tangible outcomes (such as number of patents, licenses, spin-offs) and intangible (such as development of academic staff). Many studies point out those individual viewpoints, is crucial to create and maintain university-business collaboration hence making it a very important factor to monitor [41], [42] (Bercovitz & Feldmann, 2006; Science-to-Business Marketing Research Centre, 2011). Researchers of Science-to-Business Marketing Research Centre divided the interactions between universities and business into 8 categories containing both types of outcome: (1) collaboration in R&D, (2) mobility of academics, (3) mobility of students, (4) commercialization of R&D results, (5) curriculum development and delivery, (6) lifelong learning, (7) entrepreneurship, and (8) governance, defined as interaction of management level during decision making [42] (Science-to-Business Marketing Research Centre, 2011). The survey data shows that academics do not recognize the benefits of university-business cooperation neither as a drive for their research neither in terms of career development. Importantly, the study showed a strong correlation between academics perspective and level of engagement in such collaboration. The lack of funding was pointed out as the main barrier to pursue university-business cooperation. In addition, sufficient founding was not named as a main motivation to start collaboration. Instead, a mutual research interest and trust was the highest rated driver. Therefore, solely removing the obstacle of sufficient funding will not stimulate the growth of university and business collaboration. It is necessary to simultaneously change academics attitude towards the novel collaboration type by developing the awareness of possible personal benefits and supporting interactions with industry [42] (Science-to-Business Marketing Research Centre, 2011). Despite this rather negative message of the above study, there are multiple cases of collaborative, mutually beneficial research projects undertaken by companies and universities. Such activities by example will influence both entities. One of the most active academic institutions is Massachusetts Institute of Technology (MIT) that claims to interact with 700 companies [44] (Massachusetts Institute of Technology- Collaboration with Industry). National Science Foundation ranks MIT the first in industry-sponsored research, which totaled $128 million in 2013 subsidizing to 19% of its research funding [44] (Massachusetts Institute of Technology-Collaboration with Industry). On the other hand MIT strongly promotes entrepreneurship activities among students at all levels. The Martin Trust Center for MIT provides variety of courses to teach and promote effective entrepreneurs [45] (Martin Trust Center for MIT Entrepreneurship). The common type of research collaboration between industry and academia are (1) contract or joint research, between two or more partners, (2) creation of cooperative laboratories and (3) endowments for research or professional chairs. A dual industry-academia collaborative research center may be a special source of inspiration. An example of a newly formed partnership is The Karolinska Institute - AstraZeneca Joint Research Program in Translational Science, established in 2012 for an initial period of 5 years. AstraZeneca declared to provide $4.5 million per year in funding to support Karolinska scientists at the Centre [46] (AstraZeneca and Karolinska Institute to create new Translational Sciences Centre). Overall, in 2013 biotechnology/pharmaceutical industry partnered in 301 deals (decrease by 20% from 2012) and the most active companies were AstraZeneca (14 agreements), Johnson&Johnson (11 agreements), Pfizer and GlaxoSmithKline (both 9 agreements) [47]. The above examples of success stories are contrasting to data showing that overall venture-capital funding in many domains of academic activities (media, life science, software, industrial/energy, IT services) has remain flat in the past 10 years [39] (Hayden, 2014).

Therefore, there is a need to boost existing and create new forms of interaction between academia and business, starting with a change in university and business culture that will allow formation of novel initiatives.

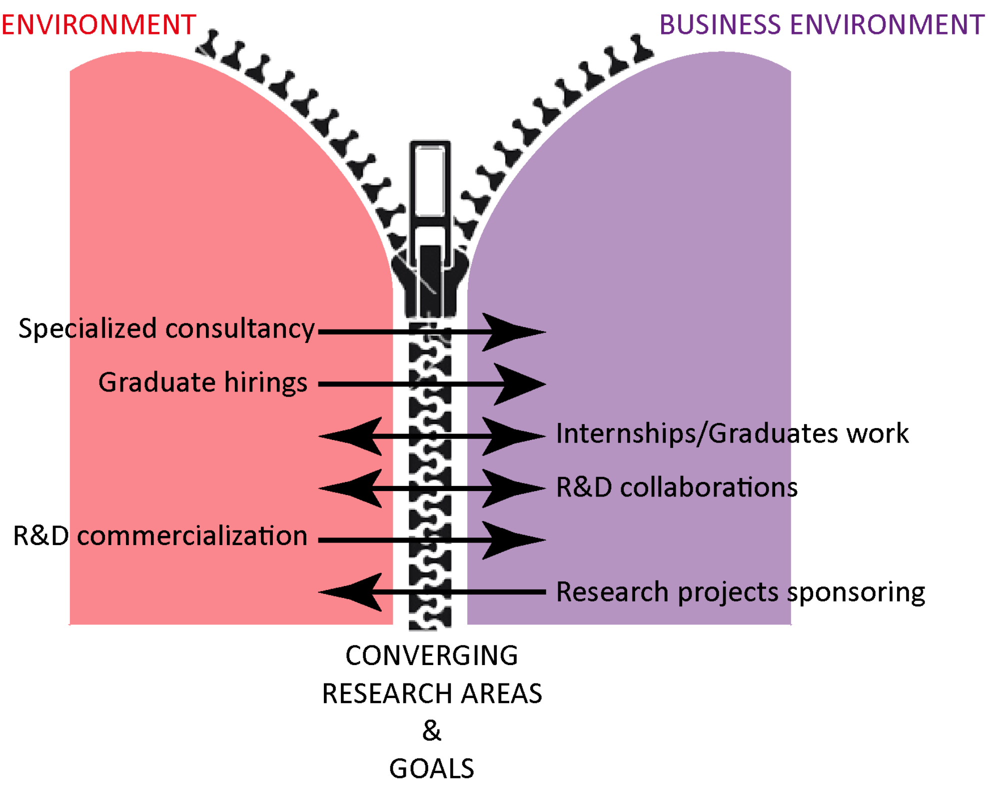

Figure 10 Converging interests of business and university cooperation

UNIVERSITY SUPPORT OF INNOVATION

In the past years many universities established Technology Transfer Organizations/Offices (TTOs). Their emergence is linked to the USA Bayh-Dole Act of 1980 that permits a university, small business, or non-profit institution to assign inventions they made using federal funding. Its role is to enable the process of translating the results of academic research into commercial products or making it more accessible for further development into new products or services [48] (Haour & Miéville, 2011). The main activities cluster around managing all forms of IP, that include overlooking the process of patent application, licensing and selling IP, and spinning off companies based on patents generated by universities [48] (Haour & Miéville, 2011). As a result, according to The Economist "*since 1980, American universities have witnessed a tenfold increase in the patents they generate, spun off more than 2,200 firms to exploit research done in their labs, created 260,000 jobs in the process, and now contribute $40 billion annually to the American economy*" [49] (Innovation's Golden Goose, 2002). The performance of TTOs receives mixed evaluations from academics that use their services, some think they were the key players in the process of establishing and licensing IP and others claim that their needs were misunderstood and it led to disruption of any further collaboration [50] (Wadman, 2008). The speculation is that it mostly depends on the number and quality of the staff working at TTOs. Most of offices have teams of 6 or fewer employees which by virtue of its size may lack expertize in all domains of technology and science represented in their university, and more experienced staff may choose to develop their career in industry [50] (Wadman, 2008). Despite the fact that few TTOs secured multimillion deals *via* the royalties paid for their inventions in most of the cases they generate only 1-5% of their respective academic institution research budget [50] (Wadman, 2008). Although the main aim of TTOs is not to make money but rather to stimulate economy by translating publicly funded research into technology, they often struggle to maintain unlicensed patents [51] (Ledford, 2013). The rationale for universities to engage in such a seemingly not beneficial activity lays in their core values and mission. According to the analysis of Haour and Miéville it's a way to disseminate the knowledge, prove its relevance to public, and reward the curiosity-driven researchers [48] (Haour & Miéville, 2011). The benefits of academic technology transfer can be grouped into several categories, following McDevitt et al, these are: revenue generation for universities, increased funding opportunities for research projects, promoting a culture of entrepreneurship, add to student exposure to translational research, benefits the society and enhance local development of economy [52] (Mcdevitt et al., 2014).

Another way to capture university innovation is a creation of spin out company based on IP generated with the help of TTO. It is a very challenging and long process starting with the phase of "incubation" when research project is transformed into venture. It consists of two critical steps: validation of proof of concept and creating a business plan [48] (Haour & Miéville, 2011). The next step is to rise funding for your business. Depending on the stage of the project these may include: bootstrapping, debt financing, grants, friends and family, "Angel Investors", factoring or venture capitalists. The big companies often choose to partner with a start-up or invest in it. There are countless examples of start-up companies that look very promising. Examples can be taken from a list created by editors of Nature Biotechnology who identified "*ten best-funded start-ups that are pursuing groundbreaking science*" [53] (Bouchie et al., 2014). Again, there are many success stories of start-ups that have further developed; some examples include NovImmune (spin-off from Geneva University), Genentech, Inc. (spin-off from University of California), Crucell N.V. (spin-off from Leiden University), Lycos, Inc. (spin-off from Carnegie Mellon University), Plastic Logic Ltd (spin-off from University of Cambridge), and many more [54], [55] (Association of University Technology Managers, 2007; The TOP 100 Swiss start-ups of 2013).

The big companies' links with universities are visible, however it is safe and reasonable to assume that the discrepancy between investments into internal R&D compared to university based research is large.

THE INNOVATION-BOOSTING ECOSYSTEM OF THE TRIPLE HELIX

Since the disruptive technology has a power to shape the global economy and ultimately society it is most important that it is accompanied by appropriate action from policy and law makers. This includes both creating environment that can help people to prosper and be protected at the same time. There are many questions that are still under consideration and require attention such as use and labeling of genetically modified organisms [56] (Frewer et al., 2013), use of gene therapy [57] (Kirkpatrick et al., 2013) or protecting our privacy [58] (Protect Your Privacy Online), to name just a few. More importantly, the recognition of the potential of disruptive technology should be accompanied by creating appropriate environment to nourish its development. It can be achieved if institutional triad of university-industry-government work together to enhance each-other performance. This model is often referred as "The Triple Helix" [59] (Etzkowitz, 2003). "*The Triple Helix thesis postulates that the interaction in university-industry-government is the key to improving the conditions for innovation in a knowledge-based society. Industry operates in the Triple Helix as the locus of production; government as the* *source of contractual relations that guarantee stable interactions and exchange; the university as a source of a new knowledge and technology, the generative principle of knowledge-based economies*" [59] (Etzkowitz, 2003). Several conditions have to be fulfilled for the triple helix to fulfil its objectives. Every of the parties have to embrace additional functions, as well as to influence each other's by exchanging the ideas and knowledge. It mostly takes place on the regional level where university, government and industry recognize the specific needs and engage into the activity aiming to, for example, enhance local economy, provide tailored student training or create a translational research center. In addition, these interaction need to have some degree of formal organization, e.g. in a form of a network groups, incubators, science parks, figure 11 [59] (Etzkowitz, 2003). Switzerland is an example case of a country that invests heavily in R&D and fosters innovation-boosting environment, that in turn translates into the generation of highest number of patents (per million of citizens) in the world, attracts business and creates vivid economy [60], [61] (Swiss–American Chamber of Commerce and The Boston Consulting Group, 2008, 2012).

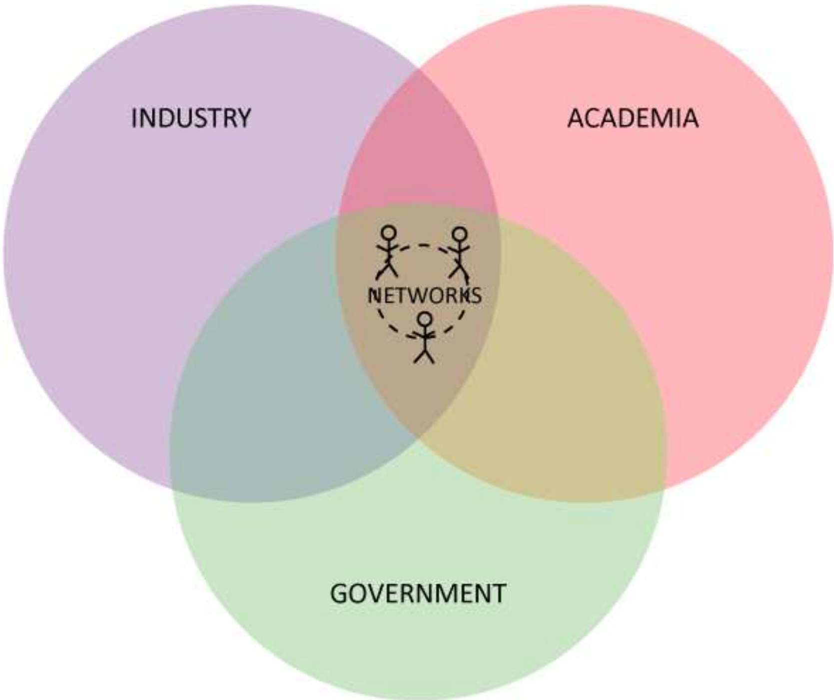

Figure 11 The innovation-boosting ecosystem of the Triple Helix

The need and the value of the knowledge transfer and its socio-economical potential has been recognized by policy makers. An example of a pro-active action taken by EU is research and innovation program named Horizon 2020 that is €80 billion of funding available over 7 years (2014 to 2020) devoted to fund research and capitalize them to the market (Horizon 2020). Another example is The Eurostars Programme sponsorising R&D carried out by small and medium enterprises [62] (The Eurostars Programme). Another example is the Swiss Commission for Technology and Innovation (CTI). This is an innovation promotion agency that supports knowledge and technology transfer by funding scientific innovations R&D projects with strong market potential and the development of start-up companies [63] (Commission for Technology and Innovation).

CASE STUDIES

The world is in need of innovation to overcome challenges in every domain of life including sustainable development, clean water, energy, etc. [64] (The Millennium Project - 15 Global Challenges). Below we present a brief description of the pathway and state of research including innovative ideas in the three cases of hydrogen energy, solar photovoltaic system and HIV treatments.

HYDROGEN ENERGY- FUEL CELLS AND BATTERIES

Hydrogen (H) is the lightest element on the periodic table yet it is the most abundant substance in the universe. On the Earth it does not occur in a pure form, but is naturally included in other substances: water and hydrocarbons, and each of them can be used to extract pure hydrogen. There are several methods of hydrogen production broadly divided into thermochemical (that uses biomass or fossil fuel) or electrolytic (from water with the use of power generated by sunlight, wind or nuclear sources). In nature some algae and bacteria produce hydrogen as a by-product of water splitting (electrolysis). Currently, the process of steam reforming, that produces hydrogen from fossil fuels remains the most cost efficient technology for commercial use. It is important to note that this process requires energy and produce CO_2. For that reason, many efforts are directed towards researching and developing economical and efficient production of hydrogen from renewable energy resources [65] (www.hydrogen.energy.gov/production.html). Hydrogen appears as a perfect energy carrier as its conversion to power is environmental friendly and does not generate any pollution. Therefore, it has been proposed to be a basis for the whole system of energy delivery called 'hydrogen economy'. Similar to any fuel, the production must be followed by its packing (by compression or liquefaction), transport (fitted vehicles or pipelines), storage and transfer. As a consequence developing and operating hydrogen economy can be very energy consuming and some suggest that it could require more energy than today's energy consumption [66] (Bossel & Eliasson). However, the efforts to overcome these obstacles are still ongoing with the short term goals "*(…) to advance hydrogen technologies to the point that industry can make commercialization decisions on hydrogen fuel cells vehicles and fuel infrastructure by 2015 so these technologies can begin to penetrate consumer markets by 2020*" [67] (DOE Hydrogen Program, 2005). A fuel cell can convert the chemical energy from hydrogen to produce electricity, heat and water. It sustains chemical reaction and produces electric power for as long as hydrogen (fuel) is supplied, therefore, they are not considered as batteries. Hydrogen fuel cells (or an energy conversion device) are a promising technology possible to use for any energy need. They could be used as stationary fuel cells (e.g. backup power; e.g. www.ballard.com) or power any type of portable devices that uses batteries (e.g. cell phones) [68] (Spare et al., 2011). Many focus on its role in transportation as a replacement for the petroleum currently used in cars and trucks. One example comes from UK's H_2Mobility project that aims to a commercial use of hydrogen fuel cell electric vehicles [69] (UK H2Mobility). Most of car manufactures have already presented prototype models of fuel cell vehicles (all types). The first cars for commercial sale are planned to be available in 2015 [70] (Green Car Congress).

On the other hand, one could also consider the use of previously mentioned hydrogen batteries, which work with the same principle. Examples of use of the nickel hydrogen battery come from NASA. The batteries were first used 1977 aboard the U.S. Navy's Navigation technology satellite-2 (NTS-2). Later on the Hubble Space Telescope was powered by nickel hydrogen batteries (during its night) for over 19 years (NASA). Other missions that have used these batteries include Mercury, Gemini, Apollo, Lunar Rover, and the International Space Station. The major supplier and producer of various types of nickel hydrogen battery is reported to be EaglePicher Technologies LLC [72] (EaglePicher Technologies).

We extracted the number of references quoting hydrogen energy using the Google Scholar search tool (Figure 12). To examine the trends in publication rates referring to the subject of hydrogen energy we used key words "hydrogen energy" (up to June 2014 it showed a total of 2710K results) and "hydrogen fuel" (total of 1590K results) and "hydrogen batteries" (total of 229K results). Both show progressive increases in the interest of the topic.

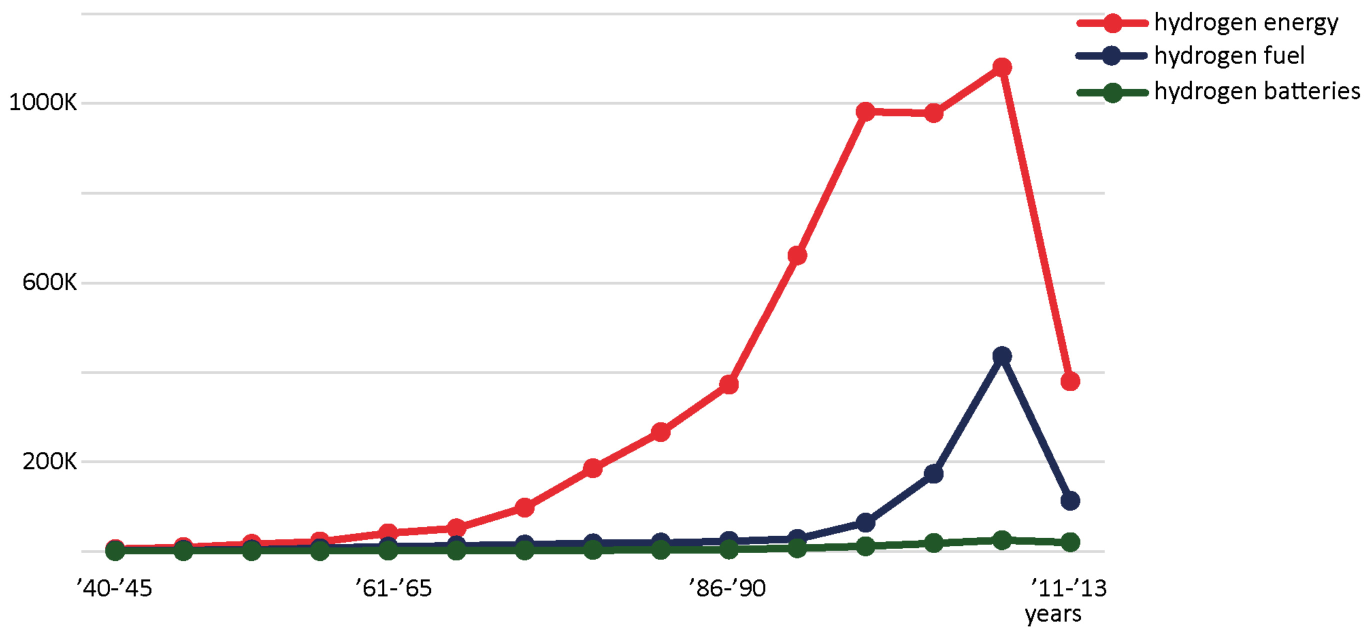

Figure 12 Trends in publication rates referring to hydrogen energy, fuel and batteries.

Using the information gathered in the above section, a search of the most pertinent about 6000 patents, published in the last 20 years, was performed using a semantic analysis with traditional patent search engines. The trend in the patent rate is provided on Figure 13.

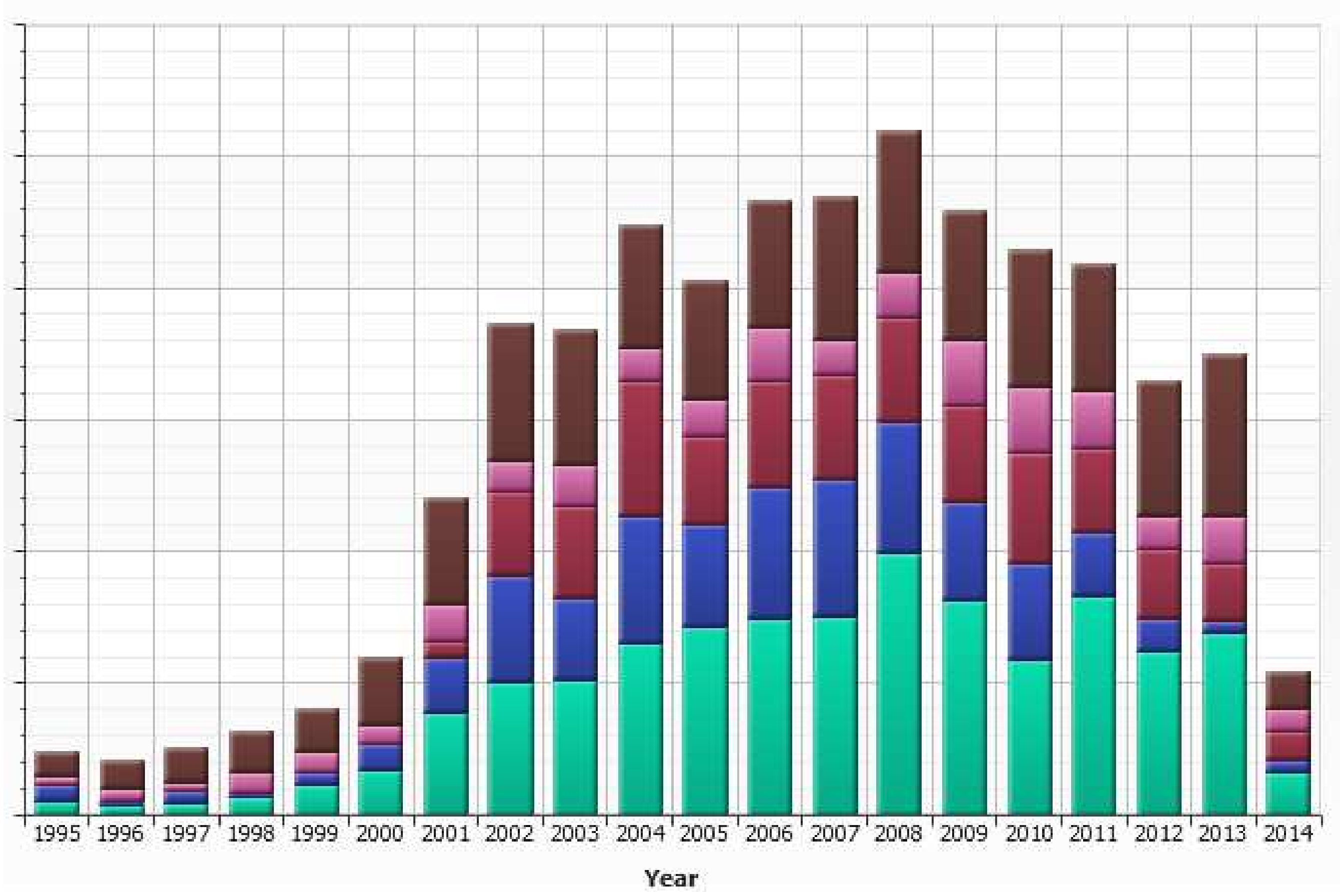

Figure 13 The number of patents per year, in the field of Hydrogen Energy, as per semantic analysis of corresponding section (6156 patents total, peak at 520 patents).

Without drawing inconsiderate conclusions one may notice a shape resemblance between the publication rate of Figure 12 and the patent rate on Figure 13, in the field of interest and for the coinciding period. A double or triple hump curve profile seems to allude to multigenerational continuous innovation.

SOLAR PHOTOVOLTAIC SYSTEM

Sunlight is one of the natural sources of renewable energy. We are constantly developing solar technologies enabling us to capture and convert it to electricity. One of the strategies is to use photovoltaic devices (PV). They use a solar energy to free electrons from materials called semiconductors and induce its flow in an electric circuit. The PV devices are called solar panels and are composed of a number of solar cells containing a photovoltaic material. Depending on its size they can be used to power any electrical devices of daily use like road signs, or sending electricity to the grid. Frequently they are used in off-grid industrial applications (e.g. in telecommunication) as an alternative to installing cable networks [73] (European Photovoltaic Industry Association, 2010). The drop in its cost made them a more competitive and thus popular solution. As a direct result 31.1GW of PV systems were installed around the world in 2012, and, was the dominant new source of electricity in Europe [74] (European Photovoltaic Industry Association, 2013). As such it covers 2.6%-5.2% of European electricity demand and affects the market and electrical system management. It has been prognosed that the global annual market could reach between 48-84GW in 2017, highly depending on policymakers' decisions [74] (European Photovoltaic Industry Association, 2013). The most popular technology, representing 90% of the market, uses crystalline silicon cells of one of three types (mono-, poly-, crystalline or ribbon sheets). Alternative technologies use thin layers of photosensitive materials (of 4 types: amorphous silicon, cadmium telluride, multi junction cells or cooper indium/gallium diselenide/disulphide) layer on glass, steel or plastic. Currently, commercially available technologies allow converting 12-17% of sunlight into electricity [73] (European Photovoltaic Industry Association, 2010). Therefore, novel developments aim to improve the solar cells efficiency by concentrating the sunlight ('concentrated photovoltaic', efficiency up to 35%). An example of novel technology comes from the start-up company, Semprius [75] (Bourzac, 2010) that has entered a list of 50 Disruptive Companies in 2013 chosen by MIT Technology Review [17] (MIT Technology Review). It is worth mentioning that a total of 4 companies focusing on photovoltaics system were included into the above list and 3 of them are start-ups (Alta Devices, BrightSource Energy, Dow Chemical, Semprius). Similarly, there are 3 companies focusing on solar panels technology that entered the list of 100 most innovative Swiss start-ups (ActLight, glass2energy, Cleantech) [55] (Top 100 - les meilleurs start-up suisses, 2013).

We extracted the number of references quoting solar panels using the Google Scholar search tool (Figure 14). To examine the trends in publication rates referring to the subject of solar energy we used key words "solar panels" (up to June 2014 it showed a total of 354K results) and "photovoltaics" (total of 143K results). Both show progressive increase in the interest of the topic.

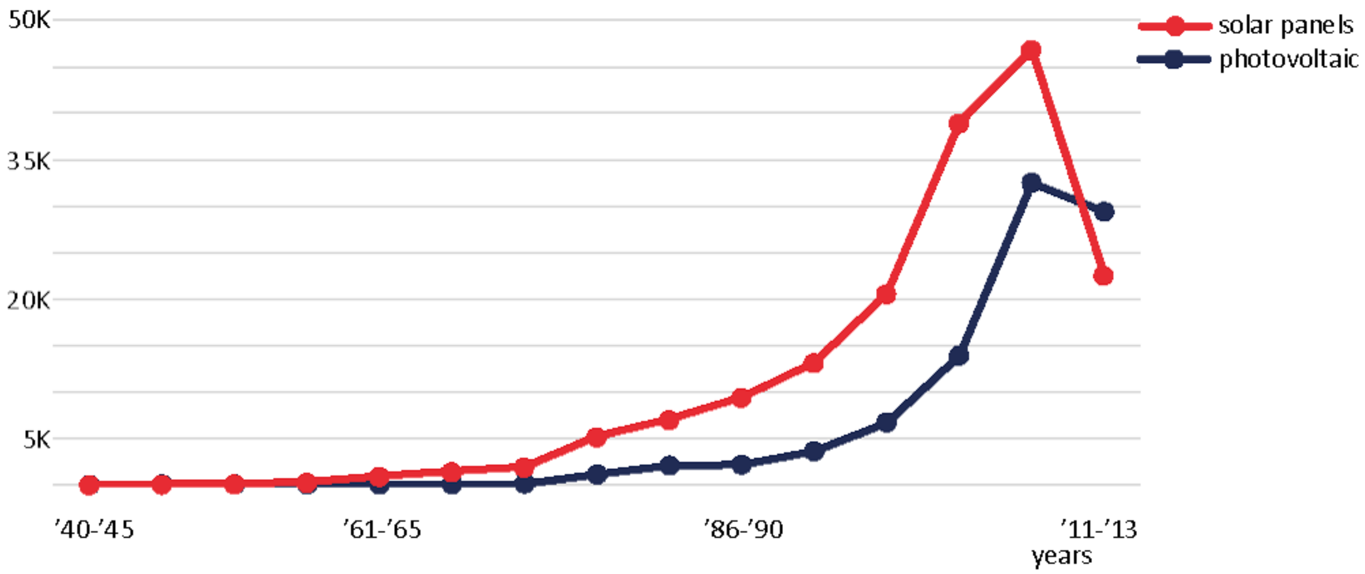

Figure 14 Trends in publication rates referring to solar panels and photovoltaic

Using the information gathered in the above section, a search of the most pertinent about 6000 patents, published in the last 20 years, was performed using a semantic analysis with traditional patent search engines. The trend in the patent rate is provided on Figure 15.

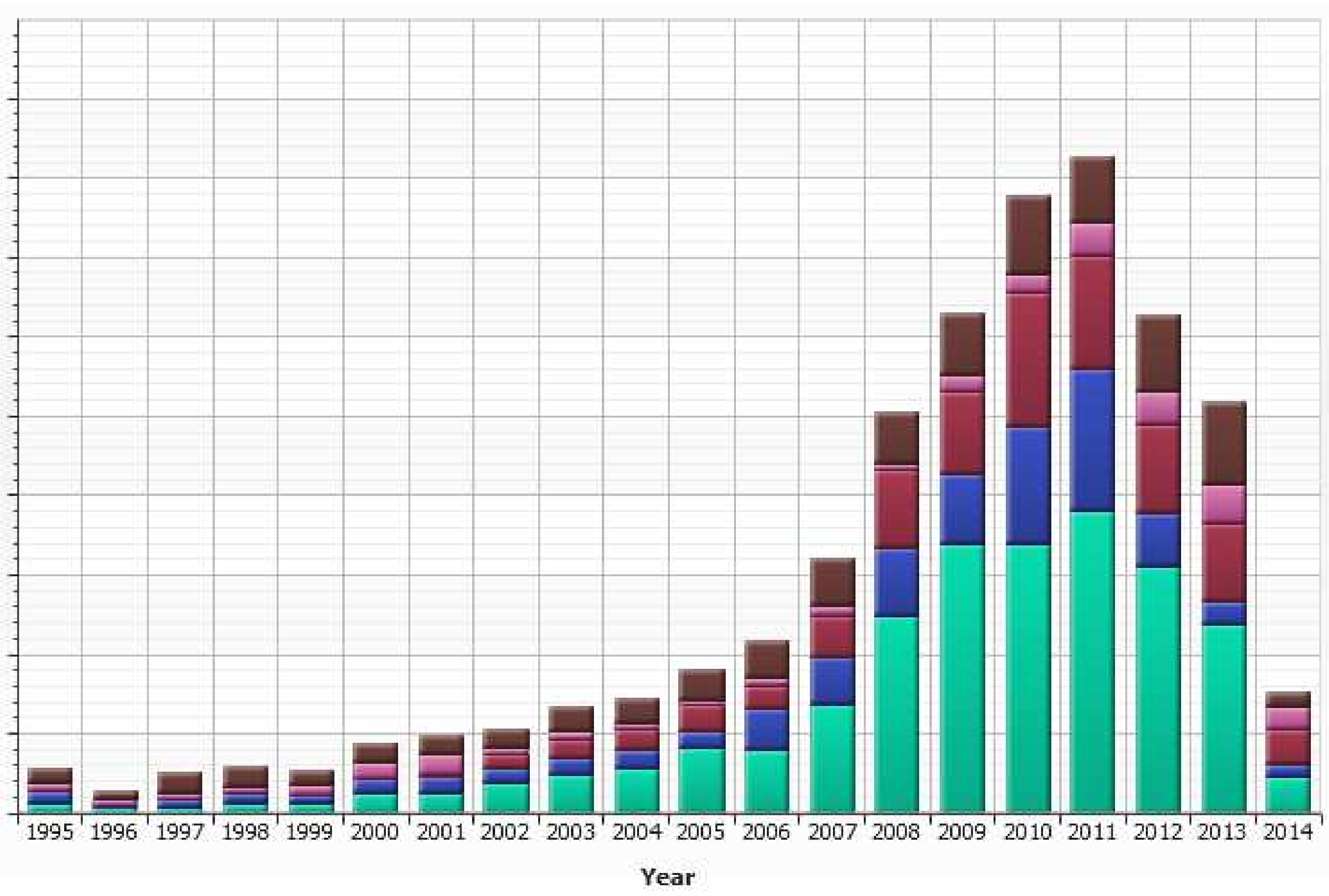

Figure 15 The number of patents per year, in the field of Solar Panels & Photovoltaic, as per semantic analysis of corresponding section (6240 patents total, peak at 830 patents).

Without drawing inconsiderate conclusions one may notice a shape resemblance between the publication rate of Figure 14 and the patent rate on Figure 15, in the field of interest and for the coinciding period. A double kinetic curve profile seems to allude to multigenerational innovation with a pretty exponential increase more recently.

HIV- CURRENT TREATMENTS

At the moment there is no treatment that can cure HIV. Since the discovery of the virus in 1983, there is about 30 drugs that have been developed to prevent the advance of HIV to AIDS and reduce the risk of virus transmission [76] (A Timeline of AIDS). The current treatment plan includes taking 3 types of drugs belonging to different groups of medication. The drugs can be called antiretrovirals and their aim is to prevent the virus replication and thus increase in the amount of HIV in the body. Depending on their specific action they can be separated into the following groups: (1) Nucleoside/Nucleotide Reverse Transcriptase Inhibitors, (2) Non-Nucleoside Reverse Transcriptase Inhibitors, (3) Protease Inhibitors, (4) Entry/Fusion Inhibitors, (5) Integrase Inhibitors. The full list of medicines approved for the treatment of HIV infection can be easily accessed in a number of web portals devoted to the HIV/AIDS [77] (FDA-Approved HIV Medicines). However, scientists agree that an HIV vaccine development would be the most effective tool to prohibit the spread of disease and help to stabilize the spread of virus in the blood from the site of infection (viremia). This is a pressing problem as according to WHO more than 40 ml people live with HIV [78] (World Health Organisation & Joint United Nations Programme on HIV/AIDS, 2005). There are several international initiatives that are raising money for research focusing on HIV vaccination [79] (International AIDS Vaccine Initiative). To raise the awareness of the challenge, every 18th of May is devoted to the discussion and bringing attention to the problem (World AIDS Vaccine Day). Due to the differences in the HIV structure, its action and disease progression as compared to other viruses, the classical development of vaccine is not effective at the moment. It seems that only a better understanding of the mechanisms governing the virus at fundamental level could lead to the development of efficient cures. There is a pressing need for worldwide collaboration to sufficiently understand the problem. The investment into vaccination development reached a total of US$ 8bn (2001-2011: average of US$ 824 ml) [80] (HIV Vaccines & Microbicides Resource Tracking Working Group, 2012). That allowed reaching few milestones, like findings of new antibodies that could decrease the risk of infection and efficacy trials scheduled for the coming years. There are several immunological approaches that have been tested in clinical studies, details can be found in [81] (Corey et al., 2011). It is essential to produce data on vaccine efficiency in clinical trials because of the differences of human and primate lentiviral infections and lack of appropriate animal models [81] (Corey et al., 2011). At the moment there are two vaccinations scheduled for large scale-efficacy trials starting in 2016 and many others at various points of development (ranging from applied research to phase I/II clinical trial) [82] (Koff, 2014).

C chemokine receptor type 5 (referred to as CCR5 or CD195) is a protein that serves as a receptor on the surface of white blood cells, among few on a T cell type. HIV virus uses CCR5 and/or CXCR4 as co-receptors to enter a host cell. Therefore, CCR5 receptor becomes an alternative target for treatment of HIV. CCR5 receptor antagonist have been designed PRO140 (Progenics), Vicriviroc (Phase III trials were cancelled in July 2010) (Schering Plough), Aplaviroc (GW-873140) (GlaxoSmithKline) and Maraviroc (UK-427857) (Pfizer). The threat in antagonising only one co-receptor is that it may push HIV virus to evolve to use another one. However, examination of viral resistance to AD101, molecular antagonist of CCR5, indicated that resistant viruses did not switch to another co-receptor (CXCR4) but persisted in using CCR5, either through binding to alternative domains of CCR5, or by binding to the receptor at a higher affinity [83] (Trkola et al., 2002). The issue of CCR5 becomes more interesting when scientists discovered that a genetic mutation (known as CCR5-delta 32) prevents the virus from entering the cells, and hence infection [84] (Marmor et al., 2001). The turning point in the HIV therapy directions happened in Berlin due to the two patients with HIV who have received different treatments, and are known as the Berlin patients. First patient, remaining anonymous, in 1998 during acute period of infection received combination therapy that included anti-cancer drug (hydroxyurea). Remarkably, after the therapy the virus was undetectable, however the exact cause and mechanism remains unknown. It is speculated that it may be due to the genetic background of the patient himself that helped him to control the infection. However, this case, even if it didn't provide any definitive answers stimulated HIV researchers to look towards eradication and early therapy studies. Second patient, Timothy Brown, had HIV and leukaemia. To treat the cancer he underwent chemotherapy and radiation followed by two bone marrow transplants to rebuild his immune system. As it turned out, the donor was a carrier of HIV-resistant mutation CCR5-delta 32. Remarkably, Brown survived leukemia and remains HIV-free [85] (Hütter et al., 2009). This incidental discovery of possible solution is not feasible for societies in need of thereof, but yet again, this case stimulated gene therapy line of research. In yet another case, two Boston patients suffered from lymphoma (not leukemia) and in parallel were carrier of HIV. Their treatment plan included a moderate round of cancer therapy and partial bone marrow transplant without receiving stem cells with the delta 32 mutation. They received anti-retrovirals drugs after anti-cancer therapy. Similar to Timothy Brown they remained HIV-free. However, the course of action was significantly different from Berlin patients, here the immune system was not fully compromised, and they continue to take anti-retrovirals. The leading physicians of the case hypothesised that the drugs were preventing the virus from spreading, while healthy new cells from the bone-marrow transplant eliminated the old and weakened HIV-infected cells. Unfortunately, despite the initial enthusiasm when patients remained virus free four years after bone-marrow transplants, the virus was again detected in December 2013 [86] (Hayden, 2013). The described medical discoveries will most likely not be converted to standard procedures as they carry huge risk per se and are very expensive. However, the discoveries that they are associated to stimulated new lines of research and allowed to form new testable hypothesis.

We extracted the number of references quoting HIV using the Google Scholar search tool (Figure 16). To examine the trends in publication rates referring to the subject of HIV treatment we used key words “HIV” (up to June 2014 it showed a total of 1740K results) and “AIDS” (total of 2260K results). Both show a progressive increase in the interest of the topic, reaching its highest point in 2008.

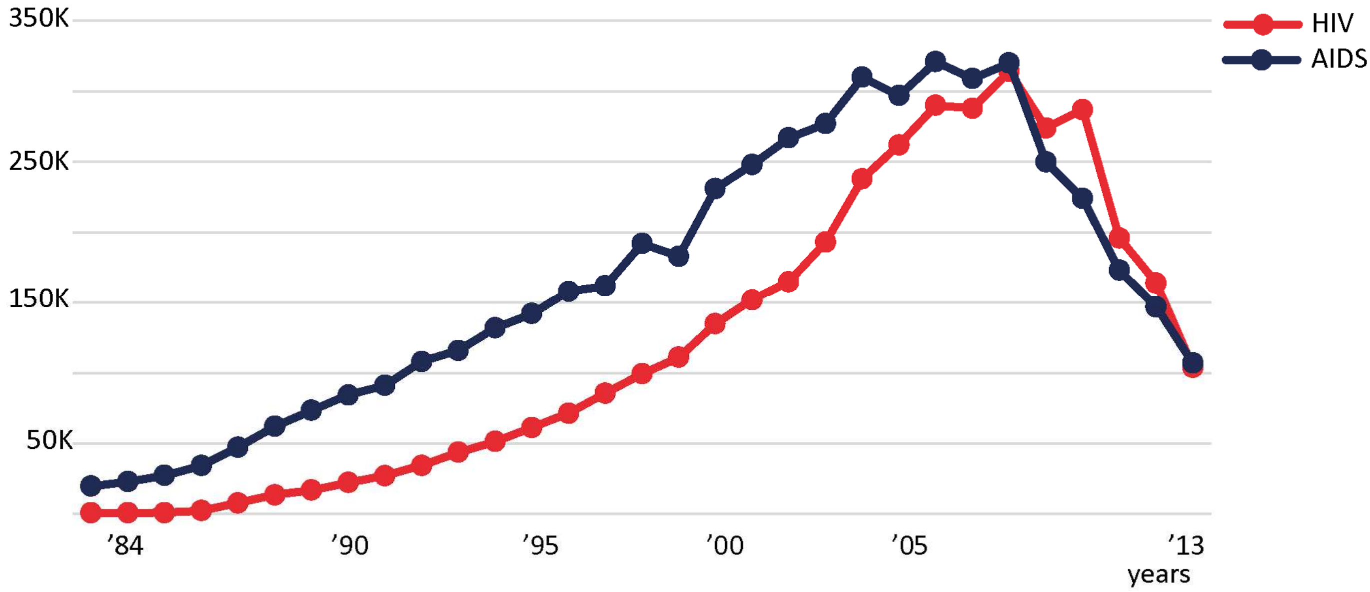

Figure 16 Trends in publication rates referring to HIV and AIDS.

Using the information gathered in the above section, a search of the most pertinent about 6000 patents, published in the last 20 years, was performed using a semantic analysis with traditional patent search engines. The trend in the patent rate is provided on Figure 17.

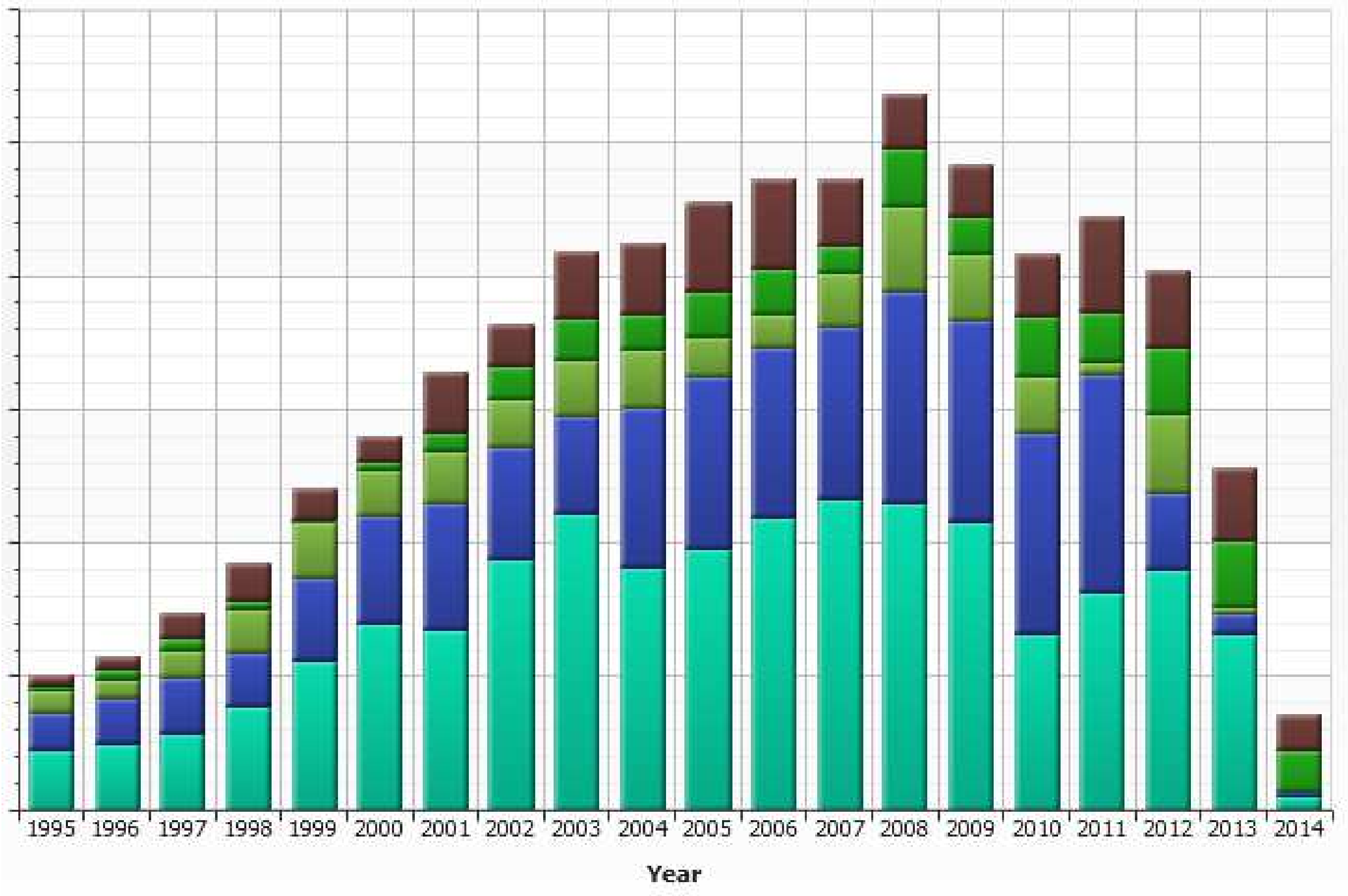

Figure 17 The number of patents per year, in the field of HIV & AIDS, as per semantic analysis of corresponding section (6951 patents total, peak at 540 patents).

Without drawing inconsiderate conclusions one may notice a shape resemblance between the publication rate of Figure 16 and the patent rate on Figure 17, in the field of interest and for the coinciding period. A more progressive curve profile seems to allude to a continuous innovation with a roughly linear initial growth profile of publications and patents.

DISRUPTIVE? TO WHAT EXTEND?

Roughly a million publications at curve peak for the Hydrogen Energy field versus 50 thousand for the Solar/PV area and 350 thousand for HIV/AIDS; this clearly states out the focus and interests vs. societal changes and remediation vs. industrial and directly predictable commercial potential. Co-current direct commercial interests and societal changes/remediation would yield maximum publications and patent productivity, therewith the highest likelihood of disruptive innovation to emerge.

A Forward-Citation measurement was conducted on the 1000 most relevant patents of the about 6000 patents selected initially for each of the three selected fields.

- ***When HIV/AIDS generates 4000 (patents) forward citations out of the most relevant 1000 selected patents, i.e. a ratio of 4/1,***
- ***Hydrogen Energy generates 8000 (patents) forward citations, ratio 8/1,***
- ***and Solar/PV generates 12000 (patents) forward citations, ratio 12/1.***

Theoretically one would attribute disruptiveness to the area which most influences the sector of interest, all things considered (product, breadth of applications, market, route to market, consumerism at large, societal benefits and wellness…). From an immediacy stand point, Solar/PV already under implementation for several years has a potential to revolutionize the energy use and consumption; likely at the condition that current solar conversion yield can be raised, "dreamily" in the range of 30% rather than current 10/15%.

A still long demanded disruptive innovation in the field of HIV/AIDS seems to be confirmed in its "relative infancy" **strictly** judging from the present work on the rate of publications, the patent rate shape over the last 20 years and the forward citation number per 1000 patents. Co-creative fundamentally disruptive approaches comprising multidisciplinary involvements, beyond the traditional pharmaceutical innovation format as described in the dedicated section, may provide more hope than currently envisioned; this from the **very limited data** used in the present work for illustrative purpose only.

CONCLUSION

From the above one may derive a few conclusions:

- Open & disruptive innovation is probably an inevitable challenge to maintain the pace of changes occurring in some technology areas. Creative confidence, Combinative skills and Clarity are to be reinstated in the broader creativity scheme which embraces a much larger range of functions than the ones generally anticipated.
- A matter of co-creativeness and Collaboratory™… When performed by enlarged teams comprising the engineer, scientist, IP strategist, business model expert, sales and marketing teams, accountant, executive and operating teams, the ATA©, adjacent technology analysis – *covered more extensively in previous reviews by Rebouillat et al.* – conducted with the depicted disruptive innovator mindset, is one way to further challenge the imperfect patent and publication exploration tools especially when dealing with open disruptive innovation.
- Semantic is, in the present study, shown as an improvement, still lacking motion and pictures and a better integration of visuals.
- Innovation and inventions can largely be transformed by visualization, images and motions in general; visual analytics being the next step. The patent language barriers can likely be reduced from new semantic analysis converting thousands of words in new pictures and thousands of pictures in new concepts; 3D animations and virtual comparisons with real situations, including patent images and schematics, hold great potential for fast and disruptive open innovation. This can be definitely stressed once more in this fifth chapter on innovation.
- In this "Bigger" Data context, developing analytics to learn from the on-going evolutionary development matters may reveal powerful, anticipatory and provide ad hoc reactiveness to redirect the efforts.

As illustrations, we described here three domains that are rapidly developing and are in the need of innovation to overcome challenges that societies face. In all of them, one sees a growing collective effort in working and developing the required technologies. It might be that, in those particular situations, disruptive innovation won't emerge suddenly but rather will be gradual, based on the continuous discussion between many parties. As such, the moment of its emergence will be more difficult to identify, however its effect on the market will be evident and almost predictable. If this is indeed a case, what about open, inclusive and reverse innovation embedded in supporting ecosystem as a key driver to progressive disruptive innovation?

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