Extended abstract for the EU-SPRI 2021 conference – Track 17

An empirical investigation of intellectual property for sustainability and its relevance to IPR policy

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Intellectual property (IP) is a well-established global policy instrument for innovation and diffusion of novel technologies based on established legal systems, but also a strategic instrument for IP owners to manage relationships and collaborative innovation processes. The role of IP for sustainability however is not well understood. To drive sustainability transitions on a global scale for a carbon-neutral future, we need sustainable and green innovations. The development and diffusion of green innovations however involve complex and intertwined intellectual property (IP) related issues. The IP models relevant to facilitate green innovations are not adequately recognized and addressed. Further, lack of evidence-based insights hinders structured policy discussions.

In this paper, we aim to explore: which IP models exist of relevance to sustainability and the conditions under which certain IP models are preferred over others? We investigate the IP usage by a set of award-winning green innovators and discuss its managerial and policy relevance.

The body of literature discussing the role of IP for sustainability is limited. From the policy perspective, environment-focused laws and regulations dominate the ‘top-down’ initiatives for sustainability with little or no emphasis on knowledge and IP related barriers and solutions. Eco-design regulation by the European Commission (EC) for instance outlines the requirements for energy efficiency, functional requirements, off mode, standby and networked standby modes, material efficiency, and information availability, but no guidance on the IP perspective (Eco-design Directive, European Commission, 2019). From the strategic and managerial perspectives of IP literature, companies strategically use their IP to bring structural changes in the industry and the economy (Pisano & Teece, 2007; Lesser, 1998; Gambardella & McGahan, 2010). Strategically, an innovator developing green innovations may choose to keep their invention protected (e.g., secret or using patents (Holgersson and Wallin, 2017; Hannah, 2005) or share it with only selected strategic partners (e.g., via exclusive or non-exclusive licensing (Kim and Vonortas, 2006; Bogers et al., 2012; Winston, 2006) or share it for free to anyone (e.g., publishing or open source (Ziegler et al., 2014; Baker and Mezzetti, 2005). Accordingly, an IP model can be typologized as closed, semi-open or fully-open IP model based on the degree of openness in its IP ownership, access, and commercial usage rights (Vimalnath et al., 2020). In order to explore the IP models relevant for sustainability, we apply this IP model typology as a guiding framework across the innovation stages namely research and development, market entry (commercialization), and diffusion following the approach by Stefan & Bengtsson (2017).

As our research methodology, we apply an exploratory research design using qualitative data following a general inductive approach (Thomas, 2003) to study the finalists and winners of the European Inventor Award (EIA). EIA is a highly prestigious international prize, awarded annually by the European Patent Office since 2006 for invention that made significant economic, social or environmental contributions. As of September 2019, the EPO lists a total of 201 EIA award entries including finalists and award winners for the period from 2006 to 2019. Among all 210 awardees, we identified and classified 52 entries as green innovators for further analysis. We analyse how these innovators have used IP, particularly patents for their highly successful technological innovations with environmental impact. To maintain consistency in the analysis and in line with the purpose of our study to understand IP models for green inventions, we use the award-winning inventions as the unit of analysis. Amongst these are technologies, that have enabled massive energy savings in industrial applications, much more efficient wastewater treatment and purification systems, and large-scale plastic recycling, to name a few. The details provided by the EIA also included interview transcripts from the inventors themselves making the data credible and trustworthy. We follow the content analysis approach by Hsieh & Shannon (2005) and iteratively generated the coding structure based on literature as well as case description (Rourke & Anderson, 2004). A total of three experts coded the data and cross-verified (Jain & Ogden, 1999). After three rounds of revisions, the final set of coding frame included 11 different parent codes grouped under five categories.

Our findings show that among the different IP models, certain models are preferred over others and their benefits vary across the green innovation process phases. Five categories of IP models namely closed protective IP model (no sharing), exclusive licensing model (semi-open type), non-exclusive licensing model (semi-open type), collaboration and partnership model (semi-open type), and other strategic mix of IP assets, emerge as relevant for green innovations. Those who adopt closed IP model, view patenting as a tool for exclusivity & protection, knowledge source, and attract investment. Actors lacking in-house commercialization expertise such as universities / research institutions adopt exclusive licensing (semi-open IP model) as their commercialization and market entry strategy. Non-exclusive licensing, another type of semi-open IP model, accelerate commercialization, internationalization and diffusion, and revenue generation from green innovations. Innovators prefer collaborative and partnership model during development, testing, scale-up, and commercialization stages to access complementary expertise, and for supply chain management. Out of the five categories, green innovators in our sample predominantly adopt the three semi-open IP models. Evidence thus show IP (patent) is an important tool for green innovation and can effectively facilitate and accelerate sustainability transition if shared (e.g., licensed). Our findings reinforce the criticality of ‘striking the right balance between sharing and protection’ (Henkel, 2006) for green innovation, rather than blind imitation of open approach similar to open source in Information & Communication Technology (ICT) sector. Further, evidence show successful green innovators benefiting from adopting and combining different IP models with different degrees of openness at different stages of their innovation process viz., technology development, commercialization/ market entry and diffusion.

Based on our findings, we propose IP as an effective strategic instrument for IP owners to meet sustainability goals when they implement right IP models. IP policy level discussion thus should move beyond incentivizing innovations through exclusivity towards facilitating IP sharing and collaborative approach to IP for sustainability. A very few IP related policy initiatives exist to this front. For instance, the ‘right to repair’ directive planned by the European Union which requires manufacturers to disclose their proprietary information which would otherwise have remained a trade secret/ not accessible to the customers to enable customers to repair the products themselves (European Commission, 2019) and the UK’s fast track patent examination route to green/sustainability focused inventions aimed at encouraging green innovators and innovations. But these initiatives do not strongly advocate the role of IP sharing mechanisms such as the licensing mechanisms for sustainability. Policy orientation towards 'IP sharing' and 'shared value' perspectives of sustainability is needed for inculcating the sharing mindset among firms innovating green technologies and to enable system-wide sustainability transition.

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The “valley of death” in the EU renewable energy sector: an investigation of possible policy solutions

Introduction

This paper is prepared under the framework of the EU’s Global Leadership in Renewables project, funded by DG Energy of the European Commission (EC). It aims to investigate the factors hampering the innovation potential of the renewable energy industry in the European Union. It contributes to the competitiveness of the EU renewable energy industry by bridging the funding gaps between research and development (R&D) and commercialisation of renewable energy (RE) technologies. This paper uses a mix of desk research and a case-study approach based on a small number of in-depth interviews with relevant stakeholders. It identifies and assesses the policy solutions to leverage and improve the synergies of EU funds for demonstration and deployment of RE technologies, and to mitigate risks associated with innovative pilot and pre-commercial RE projects.

The paper is structured as follows: First, we describe from the theoretical standpoint the paradox of the ‘valley of death’ in the innovation policy literature; Secondly, we briefly describe the magnitude of the phenomenon in the RE industry; thirdly we describe the RE industry in the EU and its innovation potential; Fourthly, we describe the methodology of the case-study research applied and the proposed policy solutions; The final Section provides concluding remarks.

Theoretical background

The valley of death

Technological change plays a relevant role in the transition towards more sustainable economic systems. In Europe the EC has put research and innovation (R&I) policy at the heart of its long-term development agenda and schemes such as Horizon 2020, the largest competitive R&D programme in the world, together with its previous iterations, have funded a significant volume of scientific discoveries at the forefront of research and technological development. Yet, while the economics of science tell us that research funding is in general good for innovation, the R&I evaluation community is constantly challenged in trying to measure and explain the effects of public programmes, whose effects may not be expected until some time in the future or may not materialise at all (Arnold, 2012).

In this respect, a relevant challenge for innovation policy that is receiving growing attention is the paradox of the so-called *valley of death* (VoD)*. The VoD refers: “to the situation in which a technology […] fails to reach the market because of an inability to advance from the technology's demonstration phase through the commercialization phase. The valley of death occurs when the developer of a particular technology has successfully demonstrated the efficacy of the technology but is unable to obtain financing for the scaleup and manufacturing process. At this point, the government considers the technology too "applied" to continue to provide funding, since the government's role is to fund more basic research, yet the private sector does not want to invest capital because the technology has not yet been implemented” (Frank et al. 1996:61).* Therefore, innovative projects are not deployed because they lack the necessary funding to become commercially viable (Heller and Peterson, 2016).

The EU is trying hard to turn the current health and economic crisis related to the COVID-19 pandemic, into an opportunity to promote and accelerate the green transition. the European Green Deal investment plan aims to mobilise at least €1 trillion of investments over the course of 10 years, turning the EU into the first climate-neutral continent by 2050. This will require significant investment from both the public and the private sector. Clearly, innovation activity in key European industries such as the renewable energy (RE) sector, which is one of the most technology-intensive industries in the EU, will play a key part in the supporting the achievement of the EU's ambitious targets.

The innovation potential in the European RE sector is extremely high. Technological advancements in some manufacturing industries such as solar photovoltaic (PV) are already improving our quality of life, bringing down the cost of energy and helping countries in meeting the ambitious goals set by sustainability policies. Yet, the full potential of the RE sector, is very far from being achieved and while Europe is the world leader in several RE manufacturing industries (e.g., hydropower) (see ETIPWind, 2020; Hewicker, 2015), it is challenged by other countries that are rapidly catching up.

While the EU RE industry develops first-class equipment to exploit many different sources such as ocean energy, wind and geothermal, a lot of innovative RE technologies fail to reach the market or take long time to be deployed because of high costs of demonstration and installations in early-stage commercialisation. The valley of death in the innovation process cripples research efforts and affects negatively the EU economy and its green transition. Yet, as observed in more mature sectors such as solar photovoltaics (PV), effective diffusion of technologies can have several positive effects, rapidly promoting incremental innovation activity, bringing down the cost of equipment, and ultimately the energy cost for citizens. Most importantly, the diffusion of RE technologies can have remarkable effects in several value chains, granting economic development and high-skilled jobs.

The valley of death in the RE industry

In the RE sector, many innovative technologies do not reach commercialisation or the market deployment needed to achieve the necessary economies of scale, despite the growing energy needs of EU countries and the scientific efforts put in developing technological breakthroughs. This is the case, for example, of sustainable energy technology first-of-a-kind (FOAK) projects, which face tremendous challenges in raising sufficient funding to achieve financial close, complete construction, become fully operational, and thereby prove to the market the efficient operational performance of the innovations (European Commission, 2016). The scale of finance required for such projects has hitherto failed to be fully recognised by policymakers.

The underlying drivers behind this VoD issue vary across RE technologies, but they share some common points. First, there is a lack of funding for development at high technology readiness levels (TRLs) i.e. technologies that are close to commercialisation, or those funding instruments exist but it is difficult to sequence different funding opportunities going from low to high TRLs. Second, many RE solutions are characterised by high capital requirements and technology risks, while risk insurance and guarantee services for new RE technologies are not available or charged at high premia. Ocean energy, geothermal energy, floating solar, the second generation of bioenergy and offshore wind are typical examples of cutting-edge technologies that face difficulties in upscaling the solutions to the EU market.

Methodology: A case study approach

In order to investigate possible policy solutions to address the VoD in the RE sector, we conducted in-depth interviews with eight relevant European stakeholders. The eight interviews were viewed as distinct cases, following multiple case-study approaches and logic (Yin, 1994).

In-depth interviews were conducted with two representatives of the EC, two associations representing the geothermal energy industry, one association representing the ocean energy industry, one association representing the wind power industry, one association representing research centres in renewable energy and one hydropower and offshore energy project developer.

Each stakeholder was presented the very same structure of interview, the main obstacles to be addressed by an EU policy intervention, the general and specific objectives of such intervention, the different policy solutions that could be considered and a succinct assessment of their expected impacts, including impacts on the competitiveness of the EU RE industry.

Findings: the underlying drivers of the VoD

Overall, two main drivers are contributing to hindering new RE technologies from reaching commercialisation or the market deployment needed to achieve the necessary economies of scale.

Driver 1: Bridging the funding gap.

While there is legitimate concern that public R&D might 'crowd out' corporate investments (IEA, 2020), evidence shows that the productivity of corporate research is increasingly dependent on ideas arising from publicly funded R&D. Therefore, public R&D funding in the energy sector may 'crowd in' private sector spending along the whole technology development process, not the contrary (e.g., the solar PV sector and Li-On batteries). In the EU RE sector, **innovative RE concepts face a funding gap between R&D and market commercialisation**, explained by either i) the lack of funding for development at high technology readiness levels (TRLs) (i.e. technologies that are close to commercialisation), or ii) difficulties in sequencing different funding opportunities going from low to high TRLs.

First, the **limited public support to address the aforementioned valley of death issues** undermines the impact of the large amount of public investments in the previous research stages (with low TRLs) such as basic research, where typically the involvement of public research organisations is larger. It has been noted that despite EU leadership in RE innovation, public research, development and innovation (R&D&I) expenditure in the energy sector in the EU is stagnating (European Commission, 2020a) and other countries such as China, Japan and the US are catching up in terms of innovation rates and moving ahead in terms of public R&D&I expenditure (European Commission, 2020b). When it comes to the number of patent filings, the EU has been bypassed by China and Korea in recent years. In particular, China has shown an remarkable increase in innovative activities. In 2008, China and the EU each represented about one fifth (20-26 %) of the global number of patent family filings. In 2016, two thirds (66 %) of the filings came from Chinese applicants, while the EU's shares went down from 20% to 8 % between 2008-2016 (Prognos & COWI, forthcoming).

Stakeholders consulted in the in-depth interviews raised their concerns that innovative RE technologies currently faced challenges in accessing cheap loan for large demonstration projects. So far, the European Investment Bank (EIB) has been risk-adverse and reluctant to fund risky projects. Commercial banks, in turn, charged very high interest rate (approximately 10%) for new RE technology projects. Several stakeholders participated in the in-depth interviews also pointed to the EU's lack of clear vision and commitment on future development for specific RE sectors (e.g. targets for specific RE technologies in the coming 10-20 years). In turn, the rate of private investment is also low: only a small share of business revenue is currently being spent on research & innovation (R&I) in those sectors that most need large-scale adoption of low-carbon technologies. The conditions in which EU companies are attractive to third party investors have not materialised (SolarPower Europe, 2019). A competitive RE industry can only exist if it attracts private capital as well as public financing. This investment is essential both for technological breakthroughs and incremental innovation.

Second, while increasing R&D funding is seen by many stakeholders as a necessary step to promote innovation in the RE sector, some call for a more efficient and effective generation of synergies between different sources of public funding such as Horizon 2020 and the European Structural and Investment Funds (ESIF) (JIIP, 2017), even if the networking promoted by Horizon has been found to be beneficial also at later stages of technology development (Vantoch-Wood and Connor, 2013). More should be done to create concrete linkages between programmes in order to ensure real coherence and complementarity (European Parliament, 2019).

Driver 2: Reward risk providing incentives.

A number of key risks and barriers can threaten investment in RE projects and thus prevent rapid uptake of desirable technologies, such as the exploration risk in the geothermal industry or prototypical/technology risks in tidal and wave technologies. Unlike mature RE technologies e.g. solar PV and onshore wind (Egli 2020; Angelopoulos et al., 2017), risk insurance and guarantee services for RE projects relying on new technologies are not available or charged at high premia to investors, especially in Member States with unstable regulatory environments. Typically, these instruments allow investors to transfer part of the risk (e.g., natural hazards or technical failure) to a third party that is better able to bear it.

Due to the lack of risk insurance and guarantee services for innovative RE projects, there are less incentives to innovate in new RE technologies - investments are attracted by less risky sectors. Small-scale RE projects are often not considered by commercial financiers because of less favourable risk/return ratios. In the offshore wind energy sector, delays or damage during fabrication, transport, installation, testing and commissioning can affect the revenue profile of a project; consequently, the construction stage of a wind farm is the key area of concern for investors (UNEP, 2004).

Reimagining the biofoundry in the new regional bio-economy: Framework and policy for accessible and responsible translational research

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Extended Abstract

Key words: Biofoundy, science and technology policy, bio-engineering, translational research, responsible innovation, regional development

1. Background

The past several decades have seen a number of publicly supported interventions aimed at facilitating technology-based regional economic development. These often take the form of university-led science parks, incubator facilities and a variety of centres for technology transfer, among others (see Phan et al., 2005 & Ng et al., 2019). Such interventions, often involving public-private partnering, seek to support research translation and commercial spillovers by creating and leveraging knowledge agglomeration and resource sharing. These interventions also reflect the emerging technologies of their time: early science parks were established to generate spin-offs in micro-electronics and communications technologies, whereas more recent years have seen the proliferation of incubators and accelerators focused on software-based start-ups. In other words, as technology has changed, so too has the portfolio of interventions and the innovation and economic models these interventions embody.

The recent convergence of synthetic biology with advanced automation and increasing computational power has positioned the field of engineering biology as a main transitional driver to what is viewed as a new bioeconomy (McKinsey, 2020). This emerging field holds much promise for addressing multiple societal challenges, from climate change, sustainable biofuels, and secure food sources to global health (new vaccines and therapies) and biomanufacturing. At the same time, economic and innovation development in this domain faces three key challenges:

(1) *Translation*: engineering biology transitions require longer time horizons than, say, for software development, along with pilot and scaled-up production facilities. Engineering biology is a "deep tech" (BCG, 2019) that is characterised by needs for extensive applied development, substantial capital investment, and a lengthy time to market. The number of organisations, companies, and regions that currently have the capacity and resources for translation of engineering biology solutions to societal challenges is limited.
(2) *Responsibility*: while engineering biology holds much promise, it is a technology that also raises societal, environmental, and regulatory challenges (Kemp et al., 2020). As with other emerging technologies, for potential adverse impacts to be anticipated and avoided, it is vital that research and innovation is carried out in a responsible and inclusive way.
(3) *Sustainability:* it is often assumed that new engineering biology applications will be more sustainable than incumbent applications that use petrochemicals and other

conventional approaches, but this is not necessarily the case. Customisation to address specific feedstock, energy, industrial, and consumer characteristics at regional levels could help to ensure sustainability optimization.

Addressing these challenges and realising engineering biology's potential (and avoiding its possible adverse effects) requires new types of public interventions.

2. Relevance

We are beginning to see the emergence of the biofoundry: 'an integrated molecular biology facility that includes robotic liquid-handling equipment, high-throughput analytical equipment, and the software, personnel, and data management systems . . . that help to build and strengthen a Design-Build-Test-Learn (DBTL) approach to biological engineering' (Holowko et al. 2020). Biofoundries are generally specialised in their area of research (Jessop-Fabre, 2019) and can be described as either commercial or non-commercial. The former are usually established and run as profit driven entities, while the latter are established with public funding, are typically non-profit, and are usually associated with universities, although this is not always the case. Both types of biofoundry aim to significantly improve translational speed, but non-commercial foundries often aim, as part of their mandate, to either facilitate research that has potential societal benefit and/or which contributes to the development of their own regional bioeconomy (e.g. start-ups).

In some respects, biofoundries *could* bring about greater openness to science by offering automation and computational capabilities to users previously made available to only the largest of research-intensive companies. Recently, however, questions have been raised concerning the sustainability of non-commercial biofoundries, pointing to a gap between significant facility capabilities and more limited user needs, to their often niche focus, which limits the number and type of user and concurrently a lack of long-term funding (see Hillson et al., 2019).

3. Paper aims and research questions

While addressing the issue of sustainability for existing non-commercial biofoundries is warranted, *we argue that there is also room and opportunity to reimagine the biofoundry as a public facility that is more accessible, less niche-oriented and with research more aligned with societal needs, and which prioritises and supports 'translational' research and collaboration that contributes to the transition toward distinct regional bio-economies*. In other words, a biofoundry that better fulfils its societal promise and public missions.

As defined above, the aim of this paper is to put forward the contours of a newly conceptualised 'public' bio-foundry. In doing so, this paper seeks to answer the following interrelated questions:

(1) What are the main functions of a public biofoundry as defined above?

(2) How might these functions be best realised in terms of user access and needs, facility capabilities and design, education and outreach, and sustainable funding streams?

(3) In what ways can national and regional policy best support and sustain public biofounderies as defined above?

In answering these questions, we aim to advance the concept of the public biofoundry and enhancing its role in public science education and outreach, as well as university research and training, while expanding and refocusing its mission on responsible translational research. In doing so, we hope to revitalise the debate around participatory science and the development of important emerging technologies; repositioning the biofoundry as a catalyst for regional development; and offering policy recommendations for realising a more accessible and sustainable biofoundry.

4. Research framework and methodology

To answer these research questions, we (1) build a theoretical framework for conceptualising the public biofoundry, this based on notions in the literature of responsible research and innovation (RRI) and participatory science, particularly ideas of anticipation and inclusiveness toward societally beneficial research (Stilgoe et al., 2013). This is coupled with theory regarding the location dynamics of innovation and the challenges of both research translation and regional capacity building (see Mattes, 2012 & Balland et al., 2015). With a framework in place, we then (2) apply it to indicative cases, based on a mix of existing non-commercial biofoundries, virtual bio-engineering building platforms, and participatory science facilities. With these cases, we employ a coding system to identify the main functions, attributes and weaknesses of these facilities, deriving examples of our framework in practice. This case study work will be carried out via desktop and document research. Finally, we (3) present the more formal contours of our reimagined public biofoundry and (4) offer subsequent policy recommendations.

5. Expected results & contribution

From our research, the paper suggests the following four functions as necessary for an accessible and sustainable public biofoundry:

1. *Provide research access to a wide range of users*, from the scientific community (university and industry), entrepreneurs, and the public, with an emphasis on those ‘communities’ which are locally placed in proximity to the biofoundry;
2. *Facilitating translational research,* i.e. supporting the application and commercialisation of research;
3. *Aligning research, education, and outreach activities with societal needs,* i.e. aimed at improving livelihoods, creating meaningful employment, addressing global challenges;
4. *Facilitating the regional bioeconomy transition*: activities derive from and support local/regional communities of practice, including local/regional universities, entrepreneurial activity and small firms.

Numerous challenges exist toward integrating these functions into a practical and sustainable business model. For example, tensions may exist between expanding user access and supporting translational research. Such tension may be averted, however, when research activities are oriented toward addressing societal needs. A biofoundry, configured as such, should contribute to the regional bioeconomy transition by offering engineering biology the capabilities and resources to overcome the translational gap, to responsibly meet societal needs, and to do so through customised and ultimately more sustainable solutions. For this, policy recommendations are offered.

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