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Dans Journal of Innovation Economics & Management 2012/2 (n°10), pages 107 à 122
Éditions De Boeck Supérieur

DOI 10.3917/jie.010.0107

Article disponible en ligne à l'adresse
OPEN INNOVATION AND JOINT PATENT APPLICATIONS: THE CASE OF GREENHOUSE GAS CAPTURE AND STORAGE TECHNOLOGIES

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The comparatively recent interest in green technologies stems from the recognition that human activities are having destabilizing effects on the environment (polluted water resources, increased waste, scarcer natural resources, climate change, reduced biodiversity, deforestation, etc.). Climate change appears to be one of the most emblematic of these anthropic effects, (IPCC reports) and so much so that it has become a major concern for all scientists. Climate change and global warming in particular are closely associated with the quantity of greenhouse gases¹ in the atmosphere. Back in June 1992, the Rio Framework Convention on Climate Change recalled the necessity to stabilize the concentration of greenhouse gases in the atmosphere “at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner”. The question that then arises is what are the means to be implemented to achieve this objective.

While changes in behaviour are unavoidable, they will need to be accompanied by rapid major technology change (Lorenzi, Villemeur, 2009) so as to open up the way to making human activities sustainably consistent

¹ The gases that contribute to the greenhouse effect are those that absorb infra-red radiation. The most important ones are water vapour, carbon dioxide, methane, nitrogen oxides, ozone, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.
with the necessity to protect the environment (Andersen et al., 1997; Andersen, 2005; Depret, Hamdouch, 2008). As Aghion et al. (2009) recall “it will not be possible to keep the cost of reducing greenhouse gases at a reasonable level without involving a range of technologies going far beyond what is currently available”. These new technologies are often characterized as green technologies. They may be ranked into two main categories (OMC and PNUE 2009) according to whether they are for cure (adaptation technologies) or for prevention (transformation technologies). A substantial proportion of these green technologies relates more specifically to energy issues (energy efficiency, use of renewable energy sources, greenhouse gas sinks). The capture and geological storage of CO2 (Carbon Capture and Storage Technologies – CCS) is one potential technological solution to remove carbon from the world ecosystem, given the changing weight of fossil fuels in the world economy (IAE, 2008). In this paper we look specifically at this technological domain “[which involves] capturing the CO2 emitted by large industrial units (gas- or coal-fired power plants, incinerators, heating systems, etc.) and then injecting it into geological structures so that it can be stored there over very long periods” (Ha-Duong, Chaabane, 2010). It is thought that CCS technologies might be available options as early as 2015 (Lecourtier, 2010) or 2020 (Chevallier, 2009). The still experimental character of such technologies leaves room for controversy as to whether they will be effective or economically viable: “we already know that about 20% or scarcely more (Bataille, Birraux, 2006, p. 346) of total CO2 will actually be recovered, and only capture by fixed installations, and even then installations of a certain size, will meet the economic criterion” (Finon, Damian, 2010). These, then, are complex and untried technological projects, which, if they are to make it to the market, will require the organization of both functional and epistemological convergence processes. This will involve going beyond a sequential, closed, internal model of innovation and adopting a more open one instead.

Relying on the argument made by Chesbrough (2006) that firms’ interest in an open innovation model may vary with the technological and industrial context, the aim of this paper is to question the innovation process implemented in the domain of green technologies and more specifically to question whether or not there are open innovation behaviours (Chesbrough, 2003 and 2006) with respect to CCS technologies. The aim is to contribute to a sector-based analysis (Pavitt, 1984) of open innovation in line with

2. CCS relates to solution of geological storage, although other forms of storage are theoretically possible such as oceanic storage or storage by biological sequestration (in the biomass).
3. For which it seems difficult to contemplate any reduction because of the energy needs of emerging countries and difficulties in modifying consumer behaviour.
recommendations by West et al. taking account of there being a specific interaction between the organizational processes of producing innovation and the nature of the technological change produced: “However, neither the practice of nor research on Open Innovation are limited to the level of the firm. Innovations are created by individuals or groups of individuals, usually within organizations, so the subfirm level of analysis is particularly salient in understanding the sources of innovation [...]. And at the same time firms are embedded in networks, industries, and sectors; thus, to understand a firm’s business model […] it is essential to consider these levels of analysis” (West, Vanhaverbeke, Chesbrough, 2006, p. 287).

To this end, section 2 proposes a set of arguments devised to justify the existence of a context amenable to open innovation given the characteristics of the technologies under study. In other words, the purpose is to show from work on green technologies that green technologies have a number of characteristics that seem to make them good candidates for the open innovation process. Starting from these theoretical postulates, we enquire in section 3 into the markers of the open innovation process and in particular into patents. Section 4 sets out our method of identifying patents in the domain of CCS. Finally in section 5 we propose to verify empirically whether or not there is open innovation in CCS technologies by using a specific marker, namely the joint patent application (or co-applications).

**ARE GREEN TECHNOLOGIES AMENABLE TO OPEN INNOVATION?**

The open innovation model was popularized by the work of Chesbrough in the 2000s. It postulates that an innovative firm is necessarily connected up with resources outside of it, the connection being made in any of several ways (acquisition, R&D contract, licensing, joint ventures, etc.). This concept is an extension of earlier work (Von Hippel, 1986; Kline, Rosenberg, 1986) emphasizing the reductive character of a purely internal and closed innovation process contributing to the ‘Not Invented Here’ syndrome. For Chesbrough (2003) open innovation “is a paradigm that assumes that firms can and should use external and internal ideas and internal and external paths to market… Open innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model”. Open innovation appears to be an increasingly widespread practice in firms, which relies on the organized opening up of the firm’s boundaries to innovation systems (Belussi et al., 2010) so as to optimize the innovative capacities of actors (Sachwald, 2008). Among the critical points frequently evoked in connection
with Chesbrough’s open innovation model, we might cite the haziness of the notion of openness (Dahlander, Gann, 2010) or the emphasis on a more transactional than creative conception of innovation (Ayerbe, Chanal, 2011). Moreover, in empirical terms, the focus on case studies that often involve large firms raises the question about whether the model can be generalized.

That being so, the purpose of this section is to enquire into the potential openness of the innovation process with CCS technologies, in other words, to gauge whether these technologies fit a profile that might promote the use of open innovation. Emerging work on green technology seems to be moving along these lines. Empirical work by Horbach (2008) shows, for example, that cooperative behaviour is found more commonly in German manufacturing firms producing green innovation than in traditional innovative firms. Similarly De Marchi (2010) claims that green innovators employ networks more than markets and hierarchies as governance structures to develop such innovations and to successfully commercialize them.

Several arguments are generally made in the literature to justify the relevance of open innovation. “Companies’ innovation strategies combine characteristics of both innovation models and the degree of openness depends on factors such as the importance of the technology, the firm’s business strategy, the industry’s characteristics, etc. Companies traditionally seek to retain their core capabilities and decide what to outsource or with whom to collaborate on innovation on that basis” (OECD, 2008, p. 37). Among these arguments, the actual characteristics of the technology or the industry in question are key factors of the context that may make open innovation relevant. The OECD (2008) reports significant differences among industries with respect to open innovation: “Industries such as chemicals, pharmaceuticals and information and communication technology (ICT) typically show high levels of open innovation”. Gassmann (2006) also highlights structural factors that may favour open innovation in an industry: globalization, technological intensity, interdisciplinarity and technological complexity, knowledge leveraging. We propose to review these different elements for CCS to evaluate whether or not they are amenable to the development of open innovation practices.

Green technologies are generally presented as complex, systemic technologies (Andersen, 2008). This is the case for CCS technologies. Accordingly, it becomes illusory for one firm to hope to master the specialized technological knowledge in-house. It is therefore necessary to resort to complementary competences in the sense of Teece (1986) with the result that the complex and systemic character of producing innovation goes along with a high degree of cooperation among differentiated actors. This is particularly the case since for many firms the development of CCS technologies is peripheral to their core business. Now, we know that it is the activities
that are furthest from the firm’s core business, in other words the least strategic activities, that may be where they are most open to the outside world. However, the organizational form of such cooperation remains uncertain. For Chesbrough and Teece (1996), open innovation is more worthwhile in a context of autonomous innovation facilitating the sharing of codified information than in a context of systemic innovation where innovation implies the exchange of tacit knowledge among clearly separate partners.

The opening up of the innovation process is also justified by the intensity of pressure in terms of costs and time to market experienced by green technologies. For technologies capable of mitigating climate change, the pooling of resources but also the sharing of risks are a reasonable strategic responses for firms, allowing them to speed up the development process of these technologies and reduce the time to market.

The literature also mentions a third type of argument for facilitating open innovation, namely the exploratory character of research. Open innovation strategies and mechanisms can be varied depending on whether one is upline of or downline from the innovation process. Firms’ exploration and research activities are favourable to a global, open approach whereas their exploitation and development activities rely more on resources that are internal, local and close-to-hand (Sachwald, 2008). CCS technologies have clearly not yet achieved sufficient industrial maturity for them to be commercialized. Prospective work on the subject suggests that no industrial applications of this technology are expected before 2015 or 2020 (Lecourtier, 2010; Chevallier, 2009). It is clear that we are at the upstream end of the innovation line, at an exploratory stage. Accordingly, it can be assumed that with CCS there is frequent resort to outside competence and knowledge.

The nature of the innovation induced by CCS technologies is another key to interpreting open innovation practices. CCS technologies may be thought of as break-away innovation in that they require a change in user behaviour and they call into question firm’s assets (IEA, 2008 and 2009). Controlling the risks associated with this type of innovation involves sharing them with other actors. In the case in point, since we are upstream in the innovation process it is above all the technological and scientific risk that will be shared. In any event, we can expect to see close relations form between industrial actors and public-sector research.

All of these arguments suggest that CCS technologies are intrinsically amenable to the development of open innovation behaviour. These are complex, break-away technologies currently in the exploratory stage that is upstream in the innovation process and are being explored by organizations for which they are not the core business. This confers all its heuristic value on the domain of green technologies with respect to open innovation.
MEASURING OPEN INNOVATION: HOW RELEVANT IS PATENT INFORMATION?

As West et al. note “Advancing our knowledge about Open Innovation requires that researchers find new and more extensive data sources to illustrate and test different hypotheses derived from Open Innovation” (2006, p. 302). Thus beyond the most commonly mobilized case studies around the high-technology sectors (ICT, chemicals, pharmaceuticals, biotechnology), the analysis of open innovation practices mobilizes ever more data from R&D surveys (Sachwald, 2008), innovation surveys (De Marchi, 2010), and patents or licences (OECD, 2008). Given the diversity of forms of open innovation (Dahlander, Gann, 2010), various indicators may be used throughout the innovation chain (De Backer et al., 2008; Sachwald, 2008; OECD, 2008) to account for outside-in open innovation processes around technological cooperation and inside-out open innovation processes with data on the granting of licences and exploitation of patents.

In their proposal for a research agenda on open innovation West et al. query the use of patent data for monitoring this phenomenon: “Given that Open Innovation defines innovation as both technical invention and a business model, how can this be captured using patent data?” (West et al., 2006, p. 302). Patents are one of the keys to the green revolution not just with respect to the means of appropriation/diffusion of green technologies (Hall, Helmers, 2010) but also because patents are led to play a new role in the partnership innovation process in that they contribute to structuring processes of collective knowledge creation (Cohendet et al., 2009). Patents are now the subject of strategic thinking by firms (Corbel, 2007) extending well beyond their initial role of protection and defence and providing the vehicle for an offensive strategy (Pénin, 2010). The approach in terms of open innovation highlights this more strategic vision of intellectual property rights (the aim is to manage the firm’s patent portfolio as well as can be) and makes intellectual property an asset with market value that can be traded. In this context, the issue of managing intellectual property rights is frequently associated with open innovation (Ayerbe, Chanal, 2011) in so far as the opening of the firm’s borders and the collective production of innovation raise the contentious issue of the appropriation of the rights relating to collectively created innovations.

However, a number of patents are of little economic value or even appear to be dormant patents (Gambardella, 2005). Not all patents issued are equally valuable (Hall et al., 2005) nor do they have the same business potential (Shane, 2001); and again not all patents lead to innovations, while a non-negligible proportion of innovative activity is not perceptible via patents. It is important to bear in mind these limits inherent in the use...
of patent data when identifying open innovation practices since such identification is necessarily incomplete.

The question that arises, then, is to determine how to identify open innovation behaviour from patents? Patent data bases may be mobilized in several ways to cast light on open innovation (Blanchard, 2006; Sternizke et al., 2008): they can be approached by joint invention, by citation, by joint applications. We propose to review these three types of indicator here. Patents systematically feature the name of the inventors who contributed to producing the invention. Where several inventors are involved we shall speak of co-invention. The co-invention indicator reflects the collective character of the invention. Even so it does not systematically reflect its open character since most co-inventors belong to the same firm. It is also suggested that patent citations could be used as an approach to open innovation (West et al., 2006, p. 303). The fact is that any patent is supposed to cite the patents it relies on and whose limitations it surpasses; similarly any patent issued may in turn be cited. By analysing citations we can therefore weave a network of relations among inventions. However, it seems to us that the nature of this network is cognitive rather than the expression of any actual collaboration. Citations reveal above all connections among documents and not actual relations among whoever files the citing and cited patents.

A third indicator of open innovation may be constructed by using the records of a patent’s joint applicants or holders (or co-applications). These are signs of technological collaboration that is being continued through shared ownership of the invention. Co-application relates to the fact that several legally separate entities declare they share ownership of the invention described in the patent that is filed. This information about patent applicants/holders is contained in the patent’s bibliographic field and can be used to trace the occurrence of actual relations between the joint applicants of patents ahead of the innovation process, which leads us to speak more of open invention than open innovation. However, the identification of open invention practices through joint patent applications requires us to note the status of the co-applicants so as to remove situations where the co-applicants are the inventor and the firm employing him or her. In other words, a sine qua non condition for using joint applications as an indication of the openness of an organization to the outside world is to consider co-applications among legal entities only. Here we propose this indicator of co-application as a marker for open invention practices with respect to CCS technologies.

4. Patents may be filed either by legal entities or by natural persons (in which case we speak of an individual inventor). It is not rare to see joint applications involving solely natural persons (applications by co-inventors) or involving a legal entity and a natural person. These cases reflect situations where the inventor is also the owner of his/her invention.
IDENTIFYING GREEN PATENTS FROM THE EUROPEAN ‘CLEAN ENERGIES’ CLASSIFICATION

Investigation of the behaviour of open invention in technologies for mitigating climate change based on patents was thwarted until recently by it being impossible to identify patents in this technological domain as they were buried within the traditional classification. It will be recalled that since the Strasbourg Arrangements (March, 1971) all patents are systematically classified by a code listed in the International Patent Classification (IPC). The IPC developed by the World Intellectual Property Office (WIPO) describes the technological domains to which a patent belongs; it comprises 70,000 subdivisions and is arranged in a hierarchical branching structure with sections, subsections, classes, subclasses, groups and subgroups. As a supplement to the IPC the European Patent Office (EPO) has developed a European Classification system (ECLA) with 135,000 subdivisions. The ECLA codes are attributed to patent documents by EPO examiners so as to facilitate research into the state of the art. The European classification is continuously being revised and applied retrospectively.

The necessity of monitoring technological change in the domain of green energies has led patent offices to make substantial changes to the level of classification of patents. These changes correspond to the growing need for economic actors, both private and perhaps above all public, to identify green patents. This is a major public policy challenge: the traceability of green patents is becoming crucial for public-sector actors who need to include the climatic (or environmental) impact of technologies in their decision-making processes. The two most commonly used patent classifications (WIPO and EPO) were modified almost simultaneously but in different ways.

For the EPO a project involving the UNEP, EPO and ICTSD (2010) led to a new code being introduced in late 2010, Y02 Climate change mitigation technologies (cf. Appendix 1), listing technologies for Greenhouse gases – capture or storage/sequestration or disposal (Y02C) and technologies for Greenhouse gases – emissions reduction technologies related to energy generation,  

5. In March 2007, 29.5 million documents in the worldwide base had an ECLA classification.
6. At WIPO level, further to the drawing up of the list by the UN Framework Agreement on Climate Change, a committee of experts of the IPC Union came up with a green inventory based on the IPC for listing patents on environmentally friendly technologies. The methodology is a little different from the European approach. It is interesting to note a tropism leading to the European classification restricting green patents to technologies for affecting climate change and especially for reducing greenhouse gas emissions. This clearly reflects the line taken at European level that focuses environmental policy on climate change.
transmission or distribution (Y02E)\textsuperscript{7}. This code was then retrospectively attributed to patents meeting this definition. In this paper we use the European classification to identify patents on the capture and storage of greenhouse gases and especially CO\textsubscript{2} (code Y02C10).

APPLICATIONS AND JOINT APPLICATIONS FOR CCS TECHNOLOGY PATENTS.

CCS patent applications

In order to evaluate open invention behaviour with respect to Carbon Capture and Storage technologies, we compiled a data base of 1646 patent families\textsuperscript{8} (without geographical restrictions) pertaining to CCS technologies identified by the ECLA Y02C10 code\textsuperscript{9}. The unit of analysis here is the patent family and not the patent document, a patent family being made up of all of the documents (patents, extensions, etc.) with the same priority number. Thus each patent family relates to one invention and redundancy is avoided. The patent families studied are from the world data base and relate to patents with a priority number earlier than 31/12/2010. In this section we set out the characteristic features of this data base.

The earliest patents filed in the domain of CO\textsubscript{2} capture and storage date from 1955. These were a French patent jointly filed by Société pour l’équipement des industries chimiques and Pingris et Mollet Fontaine Réuni for one and an Air Liquid patent for the other. As Figure 1 shows, there was a very gradual rise in the number of patents filed in this technological domain until the mid 1970s. A first acceleration occurred from 1975 to 1995 and from the mid-1990s a sharp break saw exponential growth in patent families in this technological domain, surging from a little under 300 applications between 1990 and 1999 to more than 900 applications between 2000 and 2010\textsuperscript{10}.

This quantitative change reflects the worldwide dynamic of growth in patent registration. Guillec \textit{et al.} (2010) recall that between 1990 and 2007, the number of patents registered with the USPTO rose by 160\% and by 110\% for patents registered with the EPO. But the growth in the number of

\textsuperscript{7} It is interesting to note a tropism leading to the European classification restricting green patents to technologies for affecting climate change and especially for reducing greenhouse gas emissions. This clearly reflects the line taken at European level that focuses environmental policy on climate change.

\textsuperscript{8} Patent families have been extracted using Orbit software.

\textsuperscript{9} The ECLA code applies to the set of documents of the same family.

\textsuperscript{10} The year 2010 is grouped with the 2000s, representing 10 or so patent families.
patent families also reflects the interest of business and knowledge producers for these green technologies under the influence of the 1992 Rio Convention on climate change and then of the 1997 Kyoto Protocol.

Figure 1 – Changes in the number of CCS patent family applications and co-applications worldwide

If one looks at the main countries of origin of applicants for CCS patent families (Figure 2), it can be seen that the United States followed by Japan, Germany and France lead the field. Notice that this distribution of applicants does not reflect the distribution of countries as can be observed from the share of public expenditure on R&D in CCS technologies (OCDE 2009).

Figure 2 – The main countries of origin of Y02C-10 patent family applicants
Analysis of the legal status of CCS patent family applicants (Figure 3) reveals a clear domination by firms: over the period nearly 80% of patents were filed by firms. However, from the mid 1990s, we observe a growing presence of academic applicants and applicants from the world of knowledge producers probably in connection with the technological orientations of public policies and with the changing requirements as to the value enhancement of academic activities.

Figure 3 – Changes in CCS patent applications worldwide involving at least one of the types of actor

Finally we observe quite a high concentration of applications since the largest 50 applicants hold more than 60% of patent families and the first 10 applicants have more than 32% of patent families. Among these we find essentially big multinational firms (Mitsubishi, Air Liquid, Exxon Mobil, Air Products and Chemicals, Kansai Electrical Power, Shell, Linde, Alstom, General Electric) but research organizations too (US Department of Energy, Institut Français du Pétrole).

Open invention behaviour in CCS technologies

We identify 273 patent families for which there are joint applications among legal entities, i.e. 18% of the 1540 patent families constituting the data

11. Some 32 patent families we jointly filed by the firm and the inventor. They were removed from our data base as they are not markers of Open Innovation.
base (the 105 families of individual inventors are excluded)\textsuperscript{12}. This percentage is markedly different from what is observed in other domains. If the 1980s is taken as the reference decade, Duguet (1994) claims that joint patent applications (all technological domains together) were made for 15\% of the patents involving a French firm and the trend towards making co-application followed the more general upward trend in the number of applications (with annual growth of 10.3\% for the 1980s). In the domain of CCS, the 1980s were marked by the more prominent presence of joint applicants who represented 28\% of applications (these are figures for the whole world) compared with a mean value of 18\% over the period 1950–2010. However, the 2000s saw a lag between the growing trend of patent applications and the proportion of them that were joint applications. In other words, while co-applications remain numerous and growing, their growth is slower than for patent applications, suggesting a slow-down in the propensity for open invention. The causes of this remain to be explained.

Not only does it seem to be confirmed, subject to closer comparative analysis of the behaviour of the different subpopulations, that CCS technologies are amenable to open invention practices, but in addition it is especially interesting to observe the change in the type of actors involved in the joint application process (Figure 4).

Figure 4 – Change in joint applications for CCS patents by co-applicant type

Figure 4 highlights the change in forms of open invention in CCS technologies. Globally, joint applications dominate with partnerships among firms since the mid 1970s. The firms in question are big firms for the most part: this result recurs elsewhere (OECD, 2008) that big firms use open innovation more than small organizations do.

\textsuperscript{12} With the exception of the 1950s, the weight of individual inventors remains comparatively stable: they represent on average 7\% of the patent families filed in the last two decades.
The 1990s saw the appearance of new forms of open invention with the more marked involvements of a ‘new’ actor, public research (conducted in universities or research institutes), which were involved in 30% of joint applications. Co-application by firms and universities (18.6% of joint applications) was not entirely new, but swelled from the mid 1990s, probably under the combined impetus of the growing interest of universities for the subject (confirmed by the upturn in public R&D spending in this area) and the policy for enhancing the value of public research by patent application. It is interesting to note that this behaviour is specific to this technological domain since usually open innovation practices develop among actors of the same kind: “While universities and public research institutes are generally considered an important source of knowledge for companies’ innovation activities, especially in more upstream research and exploration activities, they represent only a small share of innovation collaborations” (OECD, 2008). Moreover, co-applications involving several universities or institutes (11% of joint applications), a phenomenon that was non-existent before the 1990s, represented 7% of co-applications in the 1990s and 17% in the 2000s. So what we are seeing is an upheaval in research practices that combine both more frequent resort to patent application and more open invention processes among actors of various stripes.

CONCLUSION

Finally, these preliminary exploratory results attest that it is worthwhile using patent data to explore open innovation behaviour dynamically and systematically. The results presented reveal an upturn in open invention practices in the domain of CO2 capture and storage technologies, which is consistent with our hypothesis that the organization of the innovation processes and technological systems evolve conjointly. In addition, we have been able to observe significant change in the forms that open invention takes. These forms break free from the firm alone to more systematically involve all of the actors of the triple helix and especially knowledge producers.

That being so, plainly this work opens up several directions for further research. First, we should examine more closely the dynamics of open invention in climate change mitigation technologies with respect to conventional innovation and study technologies other than CCS technologies for evidence of similar behaviour. It is on this condition alone that we will be able to validate the existence of sector-specific models of ‘green’ innovation.

13. We have not expanded on this but it noteworthy, too, to see banks among the applicant consortia. This arrangement concerns 28 patent families.
Next, examination of behaviours depending on the national origin of applicants should provide control of the effect of the national innovation system on innovation behaviour. Three factors seem important at this stage. First public aid for the development of green technologies varies by country and provides a greater or lesser incentive. Second public R&D spending is more or less sustained from one country to another and so provides different levels of technological opportunity. Third access to venture capital is also a vehicle for differentiating new innovation behaviours among the various national systems of innovation.

Finally it would be worth studying more closely whether or not firms adopt different innovation behaviours depending on whether they are developing traditional technologies or ‘green’ technologies.

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**Appendix 1 - ECLA Classification**

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<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>Y01</td>
<td>General tagging of new technological developments</td>
</tr>
<tr>
<td>Y02</td>
<td>Broad technical fields characterized by dimensional aspects</td>
</tr>
<tr>
<td>Y02C</td>
<td>Technologies or applications for mitigation or adaptation against climate change</td>
</tr>
<tr>
<td>Y02C10</td>
<td>Capture, storage, sequestration or disposal of greenhouse gases</td>
</tr>
<tr>
<td>Y02C10/02</td>
<td>CO₂ capture or storage</td>
</tr>
<tr>
<td>Y02C10/04</td>
<td>Capture by chemical separation</td>
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<tr>
<td>Y02C10/06</td>
<td>Capture by absorption</td>
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<tr>
<td>Y02C10/08</td>
<td>Capture by adsorption</td>
</tr>
<tr>
<td>Y02C10/10</td>
<td>Capture by membranes or diffusion</td>
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<tr>
<td>Y02C10/12</td>
<td>Capture by rectification and condensation</td>
</tr>
<tr>
<td>Y02C10/14</td>
<td>Subterranean or submarine CO₂ storage</td>
</tr>
<tr>
<td>Y02E</td>
<td>Reduction of greenhouse gaze emission, related to energy generation, transmission or distribution</td>
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<tr>
<td>Y02E10</td>
<td>Energy generation through renewable energy sources</td>
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<tr>
<td>Y02E20</td>
<td>Combustion technologies with mitigation potential</td>
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<tr>
<td>Y02E30</td>
<td>Energy generation of nuclear origin</td>
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<tr>
<td>Y02E40</td>
<td>Technologies for an efficient electrical power generation, transmission or distribution</td>
</tr>
<tr>
<td>Y02E50</td>
<td>Technologies for the production of fuel of non-fossil origin</td>
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<tr>
<td>Y02E60</td>
<td>Technologies with potential or indirect contribution to GHG emission mitigation</td>
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