The European Forest-Based Industry: Bio-Responses to Address New Climate and Energy Challenges?

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Concurrently a carbon sink, a source of bio-materials and a renewable energy deposit, the forest-based industry has an important part to play in the face of two major challenges of our time: fighting climate change and identifying alternative energy solutions to fossil resources. Initiated under the French Presidency of the European Union, at the impetus of the Ministry of Agriculture and Fisheries, organised by Ecofor, with the cooperation of AgroParisTech-Engref, and entitled "*The European Forest-Based Industry: Bio-Responses to Address New Climate and Energy Issues?",* the international conference held by Ecofor last 6 and 7 November, brought together over 260 representatives of the forest-based industry, European governments, non-governmental organisation and universities to address this issue. Through some forty presentations, it brought out a clearer vision of the industry's potential in the face of this two-fold necessity, better identify the concrete and political barriers to achieving this potential and, lastly, to suggest avenues and tools so that public policies better take into account forest carbon. This article endeavours to summarise the scientific data, analysis and prospects presented at that event.

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1 – The forest and forest-based products: determining the best mechanisms for carbon capture, storage and efficiency

As the prime site of photosynthesis, the forest ecosystem has the ability to sequester atmospheric carbon and, subsequently, to store it. This property makes the forest-based industry a powerful driver for mitigating climate change. However, it does not serve only as a *carbon sink.* Once gathered, wood-based material constitutes an advantageous substitute for more energy-intensive materials and extends carbon storage throughout the duration of its products' life cycles. Wood-based energy can also stand in for non-renewable energies, to which it has always been a forerunner and from which it is on the verge of taking over.

1.1 Carbon sinks and climate change

Carbon emissions of anthropogenic origin (industry, transport, agriculture, deforestation), which are experiencing exponential growth, currently amount to 9 PgC.yr^{-1}, 29% of which is absorbed by terrestrial carbon sinks (or pools), the remainder being found in the atmosphere and the oceans (*Canadell et al., 2007, PNAS*)[1]. The said terrestrial sinks are made up primarily of forests: it has been calculated that the forests of the North alone sequester nearly 20% of the world's carbon emissions *(Philippe Ciais, Nancy2008)* [2]. In contrast, those of the South are currently acting as a net carbon source: it is estimated that deforestation and forest degradation in developing countries together account for 20% of anthropogenic carbon emissions. These few figures are enough to show the power of the carbon sequestering mechanism in forests, but also points up its vulnerability.

Carbon capture by forests is the result of a chain of biochemical phenomena, in which photosynthesis is but the first link. The average magnitude of the various phenomena involved is provided in Table 1, which deals with European forests (*Luyssaert et al., Nancy2008*). In the hours following absorption, trees release over half of their so-called "autotrophic" respiration. From the remaining amount, must be deducted so-called "heterotrophic" respiration, as it is not ascribable to the trees themselves, but to the insects and fungi that decompose the leaves and deadwood. Another part of the carbon also leaves the ecosystem once dissolved into the soil or as conveyed by forest fire. Lastly, the wood removed as part of industrial activity lowers the amount of carbon in the forest, all the while enabling continued storage in wood-based materials and lower carbon emissions than if other products or energies were used. Ultimately, 75 gm^{-2}yr^{-1} (or 0,75 tC/ha) of carbon remain actually sequestered in the forest environment.

[1] One petagram (Pg) is equal to one trillion grammes (or 10^{15}g) and, thereby to one billion tonnes or one megatonne (Gt); it is a recognised unit of measurement under the international unit system, unlike the megatonne. The symbol C denotes a carbon mass.
[2] The indication Nancy2008 indicates that the related statement is derived from a contribution at the International Conference held in Nancy, on 6-7 November 2008

Table 1: Order of magnitude of phenomena occurring in carbon sequestering in European forests, according to Luyssaert et al. (for guidance purposes, 100 $gCm^{-2}yr^{-1}$ =1 tC/ha/yr).

Phenomena	Absorptions (+)	Emissions (-)	Balance
Photosynthesis	+1 110 $gCm^{-2}yr^{-1}$		+1 110 $gCm^{-2}yr^{-1}$
Autotrophic respiration		- 590 $gCm^{-2}yr^{-1}$	+520 $gCm^{-2}yr^{-1}$
Heterotrophic respiration		- 370 $gCm^{-2}yr^{-1}$	+150 $gCm^{-2}yr^{-1}$
Dissolved organic carbon		- 10 $gCm^{-2}yr^{-1}$	+140 $gCm^{-2}yr^{-1}$
Forest fires		- 5 $gCm^{-2}yr^{-1}$	+135 $gCm^{-2}yr^{-1}$
Harvesting		- 60 $gCm^{-2}yr^{-1}$	**+75 $gCm^{-2}yr^{-1}$**

As average orders of magnitude, these figures provide broad guidance. For instance, they indicate that one hectare of forest, including the forest bed and soil, forms a carbon store anywhere between 150 and 350 tonnes. The actual quantities, though, vary significantly from forest to forest. It is deemed that the carbon balance in an ecosystem depends on four major factors (*St André et al. Nancy2008, Cirad*): genetics (the species of trees involved), soil fertility, climate and the forest management method. These four influences are obviously inter-related. A Portuguese study on eucalyptus populations in the district of Setubal, Portugal showed that the species offered carbon sequestering capacity twice as great as that of oaks *under the relevant observation conditions,* specifically a Mediterranean climate and acid brown soil (*Pita et al., Nancy2008)*

The effects of forest management on the overall carbon cycle, meanwhile, are difficult to analyse in that they go far beyond forest-based sequestering alone, and trigger a series of impacts in the forest-based industry, competing sectors and the economy as a whole. Several recent research programmes have endeavoured to compare various forestry strategies with respect to the carbon cycle. In Switzerland, a study has compared the research findings, based on modelling, regarding four different management scenarios (from "minimal" management to increased harvesting), The comparison dealt primarily carbon sequestering and wood harvested (*Thürig and Kaufmann, Nancy2008*). The simulation makes the distinction between Alpine and plain forests and extends until 2090. The influence of forest management on the carbon sink turns out far more noticeable in plain forests. The minimal forest management scenario generates a carbon sink over the time horizon considered, but leaves the forest too exposed to risks and cancels out the benefits of substituting wood for other materials or energies. The 33% increased harvest scenario yields better forecasts in terms of energy substitution, but its implications, in particular on biodiversity, make it also unattractive. The study concludes that the 50% harvest reduction and standing-stock conservation scenarios both combine a high long-term growth and a large carbon well, all the while limiting risks and preserving biodiversity.

Generally speaking, pure conservation of a standing tree population will ultimately lead to stabilisation of the amount of biomass, with high carbon storage, but also carbon sink regression or saturation (*Freiburger et al., 2008)*. In contrast, an intensive scenario would stimulate photosynthesis but lower the amount of carbon stored in the soil. If, furthermore, this is done solely for energy purposes, no benefit can be derived from the wood material. Between the two extremes, the ideal solution depends on each forest, its location and the intended uses, including in terms of water, soil, landscape and biodiversity conversation.

On this last point, a forward-looking study carried out by the European Forest Institute (EFI) showed that the institution of specific regulations, with a quota of 5% of protected forest surfaces, had no negative impact on the industry's overall economic balance, provided a responsible increase in the use of non-protected forests (*Lindner, Nancy2008).*

The carbon balance of forests depends in large part on the biotic, abiotic and human risks weighing upon them and may, for the vast majority, be triggered by climate change and an increase in the greenhouse effect. For instance, storms cause unusually large amounts of wood to be abandoned in the forests and they decompose there, releasing their carbon; drought has depressive effects on forest productivity; insects and pathogens are responsible for sometimes disastrous damage in forest populations, as is the case in Canada, with a borer, *dendroctonus*, fostered by climate warming; tropospheric ozone should also benefit from warming and increasing human activity, and thereby act on the climate in two ways: first, by directly contributing to the greenhouse effect, and secondly by attacking vegetation, and thus the forest, the carbon sink of which would then be destroyed.

Warming also changes the very workings of forest ecosystems, in depth, in particular in cooler areas. This is why there is concern about the consequences of warming on the frozen soils of the Great North. Similar impacts are expected in the mountainous regions. In an experiment carried out over a four-year period in Austria (*Jandl, Nancy2008*), the soil temperature at a mountain forest site was artificially increased by 4°C, as a result of which, a 40% increase in CO_2 emissions was observed in the soil, and a 50% increase in N_2O, which has 310 times more warming potential than CO_2, but is fortunately present in much smaller quantities.

Lastly, it should be noted that, while the forest does have indirect action on the climate, by sequestering carbon in the atmosphere, it also acts directly, by reflecting, to a greater or lesser extent depending on its albedo, the solar energy beamed upon it. Whereas a snowy surface has high albedo, which limits warming, a high-altitude conifer forest has lower albedo than does a snowy field or lawn, and this lowers its value as a carbon sink.

At the global level, the system remains extremely complex. Eleven working groups from the International Panel on Climate Change (IPCC) have focused on coupling, hour-by-hour, the climate and the carbon cycle. The aim was to determine the overall impact of climate change on the CO_2 cycle and estimate the risk of the system's going out of control. Each group came to different conclusions, proving the significant uncertainties around these forecasts. However, it can be concluded that there exists a clear difference between the forecasts regarding the temperate zone and those of tropical countries: most of the models show that the sink will tend to grow in the North and shrink in the South, even though the magnitude and speed of the total change will depend in large part on the model used (*Ciais et al., Nancy2008*).

All in all, what can be concluded from the results elaborated upon above is the extremely multi-factorial nature of the phenomena governing the forest carbon cycle. The impact of climate change on the natural equilibriums has given rise to a highly-complex dynamic system. The ability of scientific models to understand and foresee such changes will condition the implementation of appropriate policies in order to mitigate climate change. Some of the major scientific challenges for the years to come will be to improve these models and gradually incorporate available knowledge into them, while also bringing out new knowledge and the major scientific challenges for the years to come.

1.2 Wood-based material: carbon storage and the substitution effect

The IPCC's Fourth Assessment Report (2007) points out the need to increase or maintain carbon storage all the while producing or gathering wood for construction purposes. In a broader and more integrated outlook toward climate change mitigation, there is nothing contradictory between the two recommendations: the wood gathered makes it possible, as was shown above, to prevent the forest carbon sink from becoming saturated, while wood-based products (materials, fibres or energy) carry on the virtuous circle, by improving the carbon balance.

Wood-based material impacts the carbon cycle via two distinct mechanisms. It makes it possible to extend wood's carbon storage effect, delaying emissions into the atmosphere throughout the life cycle of the products under consideration, including possible recycling. Moreover, it offers the opportunity to substitute wood, in the fields of construction, packaging, furniture, etc. for materials such as steel, glass or plastic, which have greater warming potential.

A number of studies and research projects have yielded data that can be used to approach these mechanisms. One of them (*Pajot et al., Nancy2008*), for instance, focused on carbon storage in wood-based products from the Gascony moors, in south-western France. This is a thick of maritime pines, which yielded 50 million tonnes of carbon from standing trees in 2008, distinctive for its intensive forestry which removes up to 12 to 14 m^3 of wood per hectare and per year on the most favourable sites. Assuming a total life cycle for construction wood from 15 to 40 years, the study estimates that, 35 years after harvest, 35% of the carbon remains stored in construction wood products (13% in construction and 22% in other uses), 40% is lost and 25% is used as energy. Specially-tailored policies can optimise this potential. For instance, a strong-willed policy to redistribute logs for long-term use in construction, based on 2008 harvesting levels, would make it possible to store, 35 years after harvest, not 35% but 55% of carbon, making for additional storage of 300 000 tonnes of carbon per year of harvest.

As to substitution, the potential of wood-based products is on par with that of other materials, based on life cycle analyses, in particular those carried out for the German construction market (*Welling et al., Nancy2008*). In Germany, 7% of inner partitions are equipped with a wood framework structure, with insulation and plaster panels (Type A), 21% are equipped with a metallic structure with insulation and plaster panels (Type B), 72% are concrete blocks (Type C). For a partition 5 metres long and 2.5 metres high, the total warming potential for all three solutions amounts respectively to 1 500, 2 500 and 4 000 MJ[3]. Increasing the contribution of the wood framework partition market from 7% to 30%, without changing the relative contribution of the other two solutions, the annual savings would exceed 300 000 tonnes of CO_2 equivalent. Taking another example, if the share of wood flooring were increased from 21% to 25% of total floor coverings, the amount of carbon saved annually would be equal to the annual emissions of 300 000 automobiles. Other analyses carried out at the European level (*Robert, Nancy2008*, *from Werner et al., 2006*) focused on the extent of net savings in kilograms of CO_2 per kilogramme of wood substituted for another material. The comparison between wood and steel yields a ratio of 2.2 for a pillar and 1.9 for furniture. The data available show that the potential for mitigation due to substitution is clearly higher than that of the carbon storage effect of wood-based products, which remains entirely significant.

For public policy to effectively take into account these sources of potential requires exact and reliable data on the future of wood products, in terms of use and life cycle. Such data can be found in a number of European countries from as early as now, or provided a reasonable data consolidation effort. In France, the FCBA set out on this process in 2006, at the request of the Ministry of Agriculture and Fisheries. Five main outlets were identified for wood: construction, furniture, packaging, energy and paper products. The inventory focused on products in use and refuse products. The method used was based on IPCC recommendations. The data required comes from many sources: statistics from Ministries, specialised agencies, trade federations and expert opinion (for instance on the average product life cycle). One of the many findings had to do with the total carbon stored in wood-based products in France, which is 55% composed of construction wood, half of which is made up of reconstituted wood panels. This emphasises the importance of glues and wood preservation products, most of which still come from chemical compounds. Today, there exist environmentally-friendly and competitive products that can be used to limit environmental impact: adhesives from plant tannins, lignin or soy powder; mechanical friction welding processes, without any chemical additives; and thermal preservation processes, already used at the industrial level in certain countries (including France and Germany).

In closing this survey of wood-based material, it is important to make the connection with the issue of forest management. The two aspects have been studied in detail, through simulations of different management scenarios, on a sessile oak forest (*Robert, Nancy2008*). The study used a growth simulation model, taking into account the plantation density, site fertility and diameter of the forest chosen, in combination with an algorithm for calculating storage effects per hectare and annual

[3] MJ désigne le Mégajoule, soit un million de joules

substitution by hectare, with a breakdown by type of product (in particular, logs, firewood, paper and cardboard, furniture, barrels and construction). The study obviously confirmed a large reduction in forestry diameter (70 to 35 cm), which brings about a decrease in forest carbon storage. However, this effect is limited when the forestry diameter reduction is lower (70 to 50 cm), particularly when the soil is fertile. The increase in density of the forest population, meanwhile, leads to an increase on carbon savings by type of storage and by type of substitution. The effect of management on substitution potential is moderate, however, as long as there is average to high tree density and forest diameter.

1.3 Wood-based energy: an alternative with a future

In March 2007, the European Union dealt itself the target of lowering its greenhouse gas emissions by 20% by 2020, as compared to 1990, and at the same time, increase renewable energies to 20% of total energy consumption. The adoption of the Climate Energy Package in December 2008 made these objectives binding and extended them to the Union, with specific targets per country. Achieving these far-reaching objectives implies steady and coordinated development of all of its renewable energy sources. Out of these sources, wood-based energy offers significant advantages. It already accounts for 54% of renewable primary energy production in the EU and 6.3% of its total primary energy production (*Eurostat)*. Out of the 485 million cubic metres of logs used each year in the Europe of 27 (*Eurostat)*, it is estimated that 378 (or 78%) end up going to power generation, either directly, or through the recycling of industrial residual waste or derivative products *(Sipila et al, Nancy2008*); as a result, the forest-based sector is already equipped, in this field, with a tightly-knit, integrated and competitive infrastructure.

The European paper industry provides an example of integrated use of wood-based energy. Usually found near the resources themselves (making for easier logistics), its production units now rely on wood for 52% of their energy supply (*CEPI 2007)*. Its potential additional energy production has been estimated at the European level, based on opportunities for replacing wood-powered boilers with new-generation technologies, thereby enabling electricity-heat cogeneration, or even the production of ethanol (multi-product plant) (*Sipilä, Nancy2008*). The study estimated that this could occur for 60 boilers in Europe by 2020, for a total investment of EUR 4.5 to 5 billion, thereby doubling their total output. The additional needs generated by the new facilities could be fully-covered by the use of wood residues available in the wood-based industry, part of which is not currently put to use. The economic forecasts depend, however, on how the price of fossil fuels, wood and tonne of CO_2 develops.

In Austria, where wood accounts for 9% of the nation's power generation, the government has committed to increasing this to 13%, by 2020. A research programme (*Schmidt, Nancy2008*) has focused on modelling potential power generation from wood across the country. It aims to optimise bio-energy plant sites, depending on how energy demand, the geographic breakdown of domestic resources and imports develop, comparing two technologies: cogeneration (joint production of electricity and heat, from wood fuels) and integrated multi-product plant (ethanol, biogas, electricity and heat from wood fermentation). The study considers several possible scenarios with differing raw material price trends (ancillary carpentry products) and tonne of CO_2, from 0 to 250 euros. Conducted across Austria, it provides several interesting conclusions with a global perspective. For instance, outlets for wood-based power generation depend in very large part on the price of ancillary products, demand from industrials and the price of CO_2. For instance, a 20% increase in the price ancillary products would, where Austria is concerned, divide cogeneration power generation by a factor of three. Combined with a 25% increase in demand from the paper industry, it would lead to a sharp fall in energy production potential. Under the current conditions, cogeneration appears less costly than does multi-product technology, although the latter offers greater carbon savings and higher overall yield.

In this age of new technologies, with far higher yields than those of traditional processes, available data confirm the irrefutable potential of Europe's forest-based industry in the production of bio-energy. In a highly-competitive business environment, the development of this potential could, furthermore, benefit from the related innovative production techniques with high added value. One example lies in the prospects offered in the field of nanocellulose, which can be used to produce lightweight paper with very good mechanical properties, or for instance, a compound derived of spruce, which has anti-oxidant benefits and could be used to treat certain types of hormonal cancer[4].

It is important that these new avenues not overshadow the factors that might limit the development of wood-based energy in Europe. The uncertainty around fossil resource price trends has a direct impact on how suitable the model is economically. The question of how available resource are and how they will be allocated (material or energy) is also central with a view toward sustainable management.

As this first section, dedicated to detailing the benefits of the forest-based industry from the standpoint of carbon, comes to a close, we would like to emphasise the concept of the *trickle-down* forest economy, as portrayed in the development and application of a model for Switzerland (*Werner, Nancy2008*). The strategy consists of managing the forest on a sustainable basis in order to consistently sequester as much carbon as possible, harvest wood continually, supply wood-based material outlets as a priority, recycle products as much as possible and produce end of life cycle energy. This consequently mobilises, one after the other and in a long-term perspective, all of the benefits of the forest-based industry from the viewpoint of the carbon cycle. First of all, the carbon sink and carbon storage prior to harvest, wood-based energy then combine substitution and storage extension until they are recycled into renewable energy, which emits only carbon *previously absorbed* by the forest. This system does not mean that logs cannot be used as a source of energy, but suggests that they be reserved for small timber from thinning harvests and tree tops. Re-use of ancillary products from construction wood, saw mills and the paper industry for energy purposes contributes to this virtuous cycle.

[4] Hydroxymatairesinol (HMR)

2 – From science to decision-making: which public policies will best enable efficient forest carbon use?

With the discussion above, we endeavoured to provide a detailed review, based on available scientific knowledge, of the potential of Europe's forest-based industry with regard to climate and energy issues, as well as the technical possibilities for making them reality. As the international community is mobilising with a view toward the new post-2012 climate regime, it is important to set this analysis within a political framework. This means working from a broad view of the existing objectives and tools to examine several avenues for development so that forest carbon is incorporated into public policy in a realistic, effective and sustainable manner.

2.1 Forest carbon sinks in international negotiations

Put forth for ratification in 1992 and put into effect in 1994, the United Nations Framework Convention on Climate Change (or "Climate" Convention) urges all parties, in its Article 4, to promote sustainable development and management of carbon sinks and reservoirs. The Kyoto Protocol, which came into effect in February 2005 after very complex negotiations and results from the aforementioned Convention, has been ratified as of today by 172 countries, with the noteworthy exception of the United States. For all of the countries in Appendix 1 of the Convention, it lists emissions-reduction targets (listed in Appendix B). The base year emissions levels (1990) are then used to determine the amount allocated to each party. For Appendix 1 countries, the role of forest sinks is currently taken into account through two articles: Article 3.3, which is binding, and Article 3.4, which is optional.

Article 3.3 is limited to afforestation, reafforestation and deforestation since 1990, the effects of which are measured over the first commitment period of the Kyoto Protocol, from 1 January 2008 to 31 December 2012, as follows: all greenhouse gas absorption due to afforestation and reafforestation having contributed to an extension of forest land since 1990 is accounted for in CO_2 equivalents; from that absorption, one deducts the emissions that occurred during the same period 2008-2012, due to deforestation carried out between 1990 and 2012 (this involves the radicular biomass, soil, forest bed, deadwood and, for the period from 2008 to 2012, air biomass). Where the balance is positive, the result is a carbon sink; otherwise, it is considered a source. The natural reafforestation of abandoned farmland, not resulting directly from human activity, is not taken into account.

Pursuant to Article 3.4, which is optional, countries can decide to take into account the effects of CO_2 storage in all or some of their land use sectors: forest, farmland, pastures, wetlands and residential zones. In practice, over half of the signing countries chose to do so in the forest sector. For the latter, and only the latter, account is taken for forests managed in CO_2 equivalent, between 1 January 2008 and 31 December 2012, the net increase in carbon storage due to direct human activity since 1990. The accounting system consists of deducting from the net change (absorptions – emissions) in carbon stored from 2008 to 2012, five times the net absorption from year 1990; however, the result is limited to a level negotiated on the basis of 15% of the declared carbon sink for Year 1990.

As to the States of the Europe of 15 (which formed the European Union when the Kyoto Protocol was ratified), the carbon sinks accounted for under Articles 3.3 and 3.4 of the Protocol, very largely dominated by the forest, make for annual absorption of 57.5 Mte CO_2, of less than 17% of the EU-15's reduction target for the current commitment period. By accurately valuing forest sinks, the current model offers the advantage of encouraging their protection and sustainable management. However, the choice of the sector provided for under Article 3.4, by allowing certain CO_2-emitting activities not to be taken into account, limits the environmental relevance of the land use sector.

Looking ahead to the negotiations underway for the post-2012 period, it would appear, in any event, that all possible developments in the regulations should be considered, so that the contributions from land use and, thus, the forest, can be better taken into account. A prior objective is to extend, in the member countries, the carbon inventory – in particular on farmland, wetlands and urban areas, where they are often very incomplete. To remain realistic and taking into account the current abilities of each country, the inventories must at least focus on the most important sources. They will also have to offer a good compromise between ease of implementation and actual physical layout. This is a major challenge in terms of credibility if the idea is to demand of emerging countries, in the future, a precise account of their deforestation and forest deterioration activities.

The second major issue to be addressed is whether the inventories should be mandatory or optional. Considering the holes that exist in the inventories today and the uncertainties about data, the key challenge is to reduce the risks of underestimating or neglecting an important source. A less radical response would be to combine two concepts: "conditional accounting" and "key categories". Conditional accounting provides that a country shall only choose to include an activity in its accounts if the said activity can be assessed in a thorough and transparent manner, without omitting any component likely to be a source of carbon. For example, any accounting of forest carbon must include the emissions from the peat bogs which they contain. Alongside this, each country must identify, on the basis of reliable forecasts, land use categories that significantly contribute to their global emissions, key categories as listed in the IPCC report. The key categories will need to include all those where sources are growing.

Such recommendations, which do not require inventory-taking as a rule, would guarantee the model's environmental relevance. The prospect of enforcement after 2012 leaves the relevant countries the time to carry out the required analyses.

2.2 Wood-based products: determining the best-suited accounting system

Under the Kyoto Protocol's current rules, carbon emissions and absorptions from bioenergy production are considered neutral where the greenhouse effect is concerned. They offer the benefit of reducing the energies for which they stand in, the said savings being attributable to the energy sector.

This type of system is well-suited to wood-based energy, the use of which is encouraged as a result.

The same is not true of wood-based material, however. Currently, regulations are based on the IPCC's default assumption, which deems that carbon stored in trees is immediately released into the atmosphere upon harvest. However, as was shown in Point 1.2 of this article, wood-based material acts, quite to the contrary, as a substantial climate change mitigation factor, by extending carbon storage. As to the substitution effect, which is reflected as fossil energy savings, it is accounted for under the energy sector, without providing an effective incentive to use wood, as opposed to competing sources, which are more energy-intensive.

These shortcomings are attributable to the practical issues arising from the traceability of wood-based products throughout their life cycle, which are further heightened in an environment of international commercial exchange. Progress is being achieved in this respect however and certain countries – Australia, Canada and many European countries, for instance – already have extensive databases. Pursuant to the current "Climate" Convention, the time appears ripe for reconsidering the current system so that the role of wood-based material on carbon flows. Both understandable and common to all of the parties, achievable and compatible with the rules currently in effect in the land use sector, effectively accounting for all wood-based products would help balance out the various activities in the industry (forest protection and management, wood-based product manufacturing, bio-energy generation) and foster the trickle-down climate change mitigation model, along the entire industrial chain. Several accounting methods have been considered toward this end. Here, we will mention three of the most commonly-mentioned: *atmospheric flows, production and changes in storage levels.*

The most intuitive approach is the so-called atmospheric flow approach. It consists of accounting for carbon flows – absorption and emission – at each stage of the wood-based product production and transformation chain – in the country where they take place, when they take place. This attractive method, in theory, makes it possible to take into account all emissions. However, it requires full traceability for all wood-based products throughout the industrial chain, which commonly extends across several countries. Such monitoring appears impossible to achieve in the medium term. Moreover, the method is not consistent with the rules in effect in the rest of the land use sector.

The production-based method, meanwhile, consists of accounting for changes, *as regards the wood-producing country,* in carbon stored and emissions due to log production and end-use, including when they take place in another country. While it does allow changes in emissions levels to be quantitatively accounted for over time, this approach has a number of major flaws as regards the future of wood-based products. In particular, it does not foster the use of the trickle-down model, when changes often take place outside the country under which they have been listed.

In the "change in carbon stored" approach, interest is focused on the net change in carbon sinks resulting from the transformation and use of wood-based products, *in the country where consumption* *took place and regardless of the products' origin*. This method offers definite advantages. It is compatible with the operating principles of the land use sector, taking into account all changes in carbon storage levels due to the use of wood-based products. Emissions and absorptions are accounted for under the country where they take place, which is one of the conditions for sustainable and reasoned wood-based material at the domestic level, and for broader use of the trickle-down principle. The change in carbon stored model, too, is flawed, however: where wood is imported from a third-party country, it does not provide any means for ascertaining the sustainability of the forest management system used. As such, it leaves the door open to the use of wood from deforestation, in contradiction with the recommendations of the mechanism of reducing emissions due to deforestation and the deterioration of forests in tropical areas.

Several studies have suggested that this inadequacy be overcome by limiting accounting to the percentage of wood produced and used at the national level. For instance, a country that imports 60% of its construction wood could not benefit from any more than 40% of the wood-based products it manufactures. In order to keep from resorting to non-sustainable forest management, the accounting requirement could also be limited to countries having chosen forest management under Article 3.4 of the Kyoto Protocol. This method, which could be referred to as the "change in quantities of local products" still needs to be fine-tuned – in particular as regards inspections on wood imports. It does, however, appear a well-suited accounting option, applicable in the short term, and, moreover, provides strong incentive to use forest-based products on a trickle-down basis and find substitutes for energy-intensive materials, the sources of which are accounted for under the relevant country.

2.3 Toward sustainable use of natural resources

In the current European Union of 27, land use inventories carried out under the Climate Convention, though still incomplete, particularly where source activities are concerned, show clear trends on carbon flows. Farmland generally acts as a moderate carbon source (around 50 $TgeCO2.yr^{1}$), pastures are even, and the forest-based sector is a sink amounting to around 500 TgeCO2 annually[5]. Overall, the land use sector acts as a net sink, largely dominated by the forest sector. The sink would equal, in absolute terms, 9% of European greenhouse gas emissions (*European Commission)* – a figure that needs to be put into perspective, however, considering that variations occur annually and that the inventories today are still incomplete.

These data, like other available data, confirm that forests – at least in the Northern Hemisphere, are one of the main sources of leverage today for mitigating climate change, offsetting the farming activities that, in contrast, contribute to the change. However, taking the issue in its entirety, political decisions will not achieve any results from the climate standpoint unless they make it possible to address, at the same time, an issue just as important: the issue of food security. Our planet is now

[5] One teragramme is equal to one million grammes (10^{12}g), which is equal to one million tonnes (Mt) ; eCO2 means carbon dioxide equivalent.

home to six to seven billion inhabitants. This figure will probably rise to nine billion in 2050. To keep pace, it is estimated that global food production will need to increase by as much by 2050, either through an increase in farmland (implying deforestation), or by improving yield levels. In Sub-Saharan Africa, the first option caused the destruction of five million hectares of forest per year, from 1975 to 2000. In France, the latter enabled grain production to improve its efficiency four-fold, between 1950 and 2000.

In the face of such a complex challenge, an Integrated Planetary Environment Assessment model *(A. Riedacker, Nancy2008)* has been issued, suggesting an all-encompassing approach to land use and merchandise and energy flows, from solar energy and mining resources to end-products and services. Pointing up the shortcomings of current life-cycle analysis tools, which fail to take into account the concepts of land efficiency and change in land use, it advocates sustained effort toward sustainable improvement of farm yields, in particular in the South, as a necessary passage toward forest development, highly-desirable with a view toward climate change mitigation.

Within the problem of land use as a whole, the new issues in energy provide Europe's forest-based industry with a significant arbitration factor: unlike agro-fuels, the production of wood-based energy does not imply the reallocation of farmland at the expense of food products. This is an essential point which, when combined with the high yields from new wood energy conversion processes and the contribution of the trickle-down wood use model, makes second-generation wood-based biofuels, a sustainable alternative to plant-based biofuels – colza, corn, beet, cane sugar, palm, etc. – which, furthermore frees up farmland for crop farming.

Emerging carbon capture and storage technologies (*Lohmander, Nancy2008*), designed to trap and bury a portion of carbon waste from industrial sites, could provide an additional argument in favour of developing the forest-based industry, in an energy-production outlook. All the while neutralising the carbon effect of fossil energies, the use of bio-energy also becomes a net carbon sink.

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As the next major deadlines approach, the crucial decisions required for the future of our planet will become clearer. Choices on land use and the development of the forest-based industry will have to make it possible for the said industry to fully and sustainably play its part in the face of new climate and energy issues. To do so, they will have to take full advantage of the production potential in the forestry industry, all the while making it possible, through well-balanced policies, to safeguard the cultural heritage it represents, respect locally-specific issues, take advantage of the full potential of the tourist industry and protect biodiversity.

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Bibliographic References

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