

n°20 • april 2010

## **METHODOLOGY ANNEX – VERSION 1, APRIL 2010**

### **GETTING CARBON VALUE OUT OF THE FORESTRY AND WOOD SECTOR IN ANNEX I COUNTRIES: THE FRENCH EXAMPLE**

**Mariana Deheza and Valentin Bellassen**

---

The current document presents the computations and results of the carbon sequestration of every project complementing what was presented in Annex 1. of the Report.

The computations presented are intended to illustrate the study rather than to give precise project accounting. The results rely on many approximations and assumptions, and should therefore be taken with caution.

## CALCULATIONS PERFORMED FOR EACH PROJECT

This Annex describes the procedure followed to calculate the carbon sequestration of each project. The assumptions, extrapolations and approximations employed determine that these results must be considered with prudence. Therefore, they should be considered mainly as rough estimates rather than as precise results.

The conversion coefficients used in our calculations are:

1 m<sup>3</sup> of harvested wood = 1 metric ton of CO<sub>2</sub>

1 Dry metric Ton (DMT) = 0.5 metric tons of carbon

1 metric ton of carbon = 3.667 metric tons of CO<sub>2</sub>

Unless indicated otherwise, all the calculations and hypotheses have been performed and defined by CDC Climat Research.

### Example 1) Hardwood sawlog afforestation project

#### A. General project information

Species: Hybrid walnut (*sp. juglans nigla*)<sup>1</sup>

Location: Region of Provence-Alpes-Cote-d'Azur (PACA)

Project Size: 10 ha

Initial stocking density: 200 trees/ha – *low density*

Forest management: Thinned in years 25, 40 and 55. Clear cut in year 80.

#### B. Methodology used for the calculation of the carbon sequestration of the afforestation project

##### Forest stocks

The carbon sequestration data of the project during the certification period are taken from the accounting prepared by Reverchon (2006) for this project. These data are based on growth models (Becquey 1997) and on methodologies validated by the UNFCCC for afforestation projects. The parameters used by Reverchon include, among other things, the infradensity of the wood ( $D=0.55^2$ ) and the rate of carbon in the dry ligneous matter ( $Tc=0,5^3$ ).

The carbon sequestration of the project in its forestry compartment is illustrated in Figure 1.

**Intended use of the harvest:** On the basis of the data provided by Reverchon on the levels of harvesting during each forestry management operation, we have defined several hypotheses concerning the use of the harvested material. The conversion from m<sup>3</sup>/ha to DMT/ha is done by using the density<sup>4</sup> of the species at 15% moisture content = 0.670 DMT/m<sup>3</sup>. These estimates allow us to see the other effects of extending carbon sequestration in wood products and the reduction of emissions from other sources than use wood in energy generation or construction.

<sup>1</sup> **Other eligible species:** wild cherry, walnut, alder, sycamore, service tree, field maple, mulberry, linden, pear. These species have been selected on account of their adaptability to the terrain and the climate in the region.

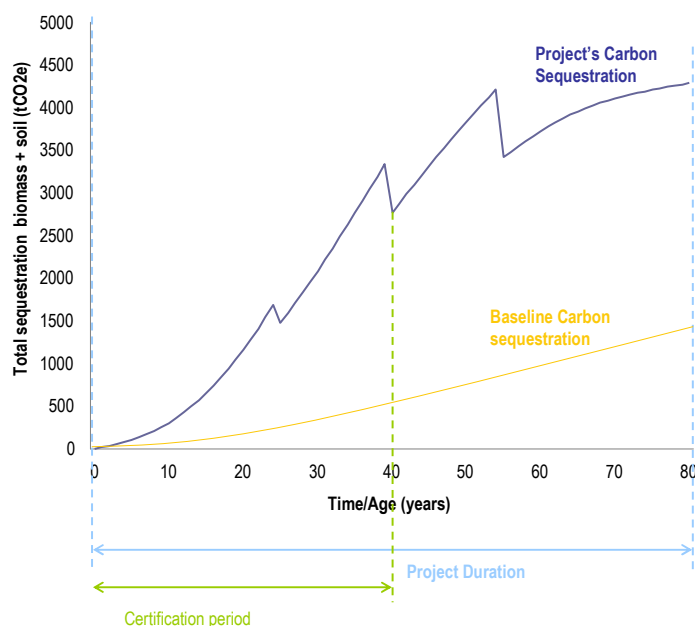
<sup>2</sup> Dupouey et al. (1999)

<sup>3</sup> GIEC

<sup>4</sup> <http://www.worldagroforestry.org/sea/Products/AFDbases/WD/asps/DisplayDetail.asp?SpecID=1877>

**Figure 1 – Carbon sequestration by the even-age high forest planting**

(Example: 10 ha of walnut trees – *Juglans sp.*)



Source: CDC Climat Research from Reverchon (2006)

**Table 1– Projet 1: The harvest and its uses**

Forestry operation	Age (years)	Harvest (m3/ha)	Conversion DMT/ha (15% hum)	Uses (%)			Aspects valued
				EW	SW	PW	
Thinning 1	25	27.7	18.5	100%	0%	0%	ES
Thinning 2	40	57.4	38.5	90%	10%	0%	HWP, ES, MS
Thinning 3	55	71.5	47.9	80%	20%	0%	HWP, ES, MS
Clear cutting	80	272.9	182.8	50%	50%	0%	HWP, ES, MS

EW: Energy Wood, SW: Sawlogs, PW: Pulpwood

ES: Energy Substitution, HWP: Inventory of Wood Products, MS: Material Substitution

### Harvested wood products (HWP)

We use the CCX methodology for the calculation of the extended storage of carbon in wood products. This methodology grants one carbon credit for each metric ton of CO<sub>2</sub> contained in the wood products (in use or buried in a landfill) and not re-emitted into the atmosphere 100 years after the harvest. It is based on data released by the US Department of Energy, each type of wood has its carbon conversion factor, depending on the product category it is destined to (sawlogs, pulpwood). The CCX coefficients are available for the US at the regional level, as an approximation, we calculate the average value of the extended storage of carbon in the wood products, depending on the two usage categories: sawlog and pulpwood.

	Sawlog	Pulpwood
Hardwood	0.276	0.241
Softwood	0.350	0.203

Source: CCX Offset Project Protocol - Forestry Carbon Sequestration<sup>5</sup>

<sup>5</sup> [http://www.chicagoclimatex.com/docs/offsets/CCX\\_Forestry\\_Sequestration\\_Protocol\\_Final.pdf](http://www.chicagoclimatex.com/docs/offsets/CCX_Forestry_Sequestration_Protocol_Final.pdf) (page 54)

The assumptions of intended use of the harvest were presented in Table 1 and they lead to the results in Table 2 for the stocks in the wood products.

**Table 2 – Projet 1: Extended Sequestration in wood products**

Forestry operation	Age (years)	Harvest (DMT/ha)	Harvest intended for wood products (DMT)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
				SW	PW	
Thinning 1	25	18.5	0.0	0.00	0.00	0
Thinning 2	40	38.5	38.5	5.30	0.00	19
Thinning 3	55	47.9	95.8	13.20	0.00	48
Clear cutting	80	182.8	914.0	125.90	0.00	462

EW: Energy Wood, SW: Sawlogs, PW: Pulpwood

### Energy substitution (ES)

The calculations use the average value by default of the following energy content: one metric ton of dry material (DMT) in the wood produces 2.93 kWh or 10.56 GJ (Sources: CITEPA, 2007. OMINEA). The average of the CO<sub>2</sub> emission factors per GJ of energy generated from coal, home heating oil and natural gas used by CITEPA (in accordance with GIEC recommendations), i.e. 0.8 tCO<sub>2</sub> prevented per DMT of wood used.

**Table 3 – Projet 1: Energy substitution**

Forestry operation	Age (years)	Harvest (DMT/ha)	Harvest intended for energy(DMT)	Energy substitution	
				Energy produced (KWh)	Avoided emissions (tCO <sub>2</sub> )
Thinning 1	25	18.5	185.0	542.1	148
Thinning 2	40	38.5	346.5	1015.2	277
Thinning 3	55	47.9	383.2	1122.8	307
Clear cutting	80	182.8	914.0	2678.0	731

### Materials substitution (MS)

This calculation is based on the hypothesis that the entire volume of wood harvested in the project is transformed into beams, and that these wooden beams replace aluminum beams. The substitution coefficient used is that of the ENSTIB for a beam with a span of 7.5 m, a permanent load of 75 kg/m and an operating load of 300 kg/m, and volume per beam of 0.35 m<sup>3</sup>, i.e. 321 metric tons of CO<sub>2</sub> emissions avoided per beam.

On the basis of the number of beams of this size produced per metric ton of dry wood material, we get the material substitution effect:

**Tableau 4 – Projet 1: Material substitution**

Forestry operation	Age	SW (m3)	Material substitution	
			Beams	Avoided Emissions (tCO <sub>2</sub> ) <i>hyp. aluminum</i>
Thinning 1	25	0.00	0.00	0
Thinning 2	40	38.46	109.90	35
Thinning 3	55	95.78	273.67	88
Clear cutting	80	914.08	2611.66	838

SW: Sawlogs

### C. Carbon sequestration balance - 10 ha hardwood sawlog afforestation project

	ForestStocks	Stocks in Harvested Wood products	Total Stocks	Substitution	Total
Baseline (after 25 years)	0.05 ktCO <sub>2</sub>	0	0.05 ktCO <sub>2</sub>	0	0.05 ktCO <sub>2</sub>
Baseline (after 80 years)	0.3 ktCO <sub>2</sub>	0	0.3 ktCO <sub>2</sub>	0	0.3 ktCO <sub>2</sub>
Project (after 25 years)	1.18 ktCO <sub>2</sub>	0	1.18 ktCO <sub>2</sub>	0.14 ktCO <sub>2</sub> (ES)	1.33 ktCO <sub>2</sub>
Project (after 79 years)	3.77 ktCO <sub>2</sub> e	0.07 ktCO <sub>2</sub>	3.84 ktCO <sub>2</sub>	0.73 ktCO <sub>2</sub> (ES) + 0.12 ktCO <sub>2</sub> (MS)	4.70 ktCO <sub>2</sub>
Project (after 80 years – harvest)	0 ktCO <sub>2</sub>	0.53 ktCO <sub>2</sub>	0.53 ktCO <sub>2</sub>	1.47 ktCO <sub>2</sub> (ES) + 0.96 ktCO <sub>2</sub> (MS)	2.95 ktCO <sub>2</sub>

### Example 2) Afforestation industrial project for energy production

#### A. General project information

Species: Willow (*sp.Salix*)

Location: Aquitaine region

Project Size: 1 000 ha

Forest management regime: Project designed for 30 years with clear cutting every 3 years and natural reforestation until the project reaches maturity. 300 hectares are planted in years 1, 2 and 3 and the remaining 100 hectares in year 4 and then following the same pattern until the project ends.

#### B. Methodology used for the calculation of the project's carbon sequestration

##### Forest stocks

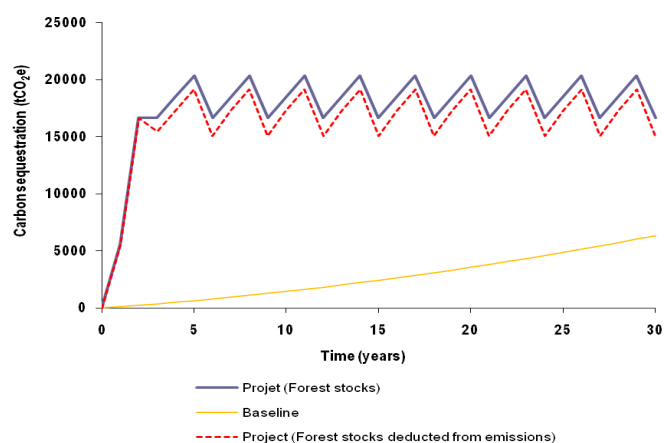
The accounting of the carbon sequestration was based on methodologies approved by UNFCCC for afforestation projects.

The parameters used in our calculations include the density of the wood ( $D = 0.45 \text{ DMT/m}^3$ ), the biomass expansion factor ( $\text{BEF} = 1.4$ ) and the rate of carbon in the dry ligneous matter ( $\text{Tc} = 0.5 \text{ tC/DMT}$ )<sup>6</sup>. The annual increase in the biomass is estimated at  $\text{inc} = 16 \text{ m}^3/\text{ha}/\text{year}$ .

Ultimately, the resulting carbon sequestration of the project in its forest compartment is illustrated in Figure 2.

<sup>6</sup> IPCC National Inventory Good Practice Guidelines, 2006

**Figure 2– Carbon sequestration by the energy afforestation project**



Source: CDC Climat Research

Intended use of the harvest: We determine the annual levels of harvest from the forest management regime. The conversions from tCO<sub>2</sub> to DMT were done using the following factors: density = 1.30 tons of green wood (TGW)/m<sup>3</sup> and moisture content = 0.45 DMT/TGW. The entire harvest is destined for the production of wood energy.

**Table 5– Project 2: The harvest and its uses**

Years	Forestry operation	Harvested by clear cutting (ktCO <sub>2</sub> )	Conversion kDMT (total)	Uses (%)			Aspects to be valued
				EW	SW	PW	
3, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, 23, 25, 26, 28, 29, 31	Clear cutting	16.6	194.6	100%	0%	0%	SE
6, 9, 12, 15, 18, 21, 24, 27, 30	Clear cutting	22.2	116.7	100%	0%	0%	SE

EW: Energy Wood, SW: Sawlogs, PW: Pulpwood  
ES: Energy Substitution

### Stocks in harvested in wood products (HWP)

Cannot be valued.

### Energy substitution (ES)

Calculation performed using the same methodology used in the previous project:

**Table 6 – Project 2: Energy substitution**

Year	Forestry operation	Harvest (kDMT)	Total harvest used for energy (kDMT)	Energy substitution	
				Energy produced (MWh)	Avoided Emissions (ktCO <sub>2</sub> )
3,4,5,7,8,10,11,13,14,16, 17, 19,20,22,23,25,26,28,19,31	Clear cutting	194.6	194.6	570	156
6,9,12,15,18,21,24, 27, 30	Clear cutting	116.8	116.8	342	93

### Material substitution (MS)

Cannot be valued.

### Carbon emissions (CE)

Carbon emissions have been estimated in the basis of the calculations performed by Liberloo et al. for a TTCR project after 3 years and correspond to 15% of the emissions avoided thanks to the use of wood for energy production.

## C. Carbon sequestration balance for the afforestation industrial project for energy production

	Forest stocks ( ktCO <sub>2</sub> e)	Stocks in Harvested Wood products (ktCO <sub>2</sub> e)	Total stocks ( ktCO <sub>2</sub> e)	Substitution ( ktCO <sub>2</sub> e)	Carbon emissions ( ktCO <sub>2</sub> e)	Total ( ktCO <sub>2</sub> e)
Baseline (after 25 years)	4.9	0	4.9	0	0	4.9
Baseline (after 30 years)	6.6	0	6.6	0	0	6.6
Project (after 4 years)	18.5	0	18.5	15.6 (ES)	- 2.3	31.7
Project (after 25 years)	18.5	0	18.5	197.2 (ES)	- 29.6	186.1
Project (after 30 years)	16.6	0	16.6	241.3 (ES)	- 36.2	221.8

### Example 3) Conversion of chestnut coppice to an uneven-aged high forest stand

#### A. General project information

Species: Chestnut (*sp. Castanea sativa Mill.*)

Location: Rhône-Alpes region

Project Size: 800 ha

Forest management regime: Conversion from short-rotation coppice system (20 years) with a density of approximately 1000 trees/ha to an uneven aged high forest stand. During a transition phase, two thinnings are carried out at a three-year interval (to obtain a density of 100 to 300 trees/ha). The stand is then maintained as an uneven-aged forest by thinning every 7 years.

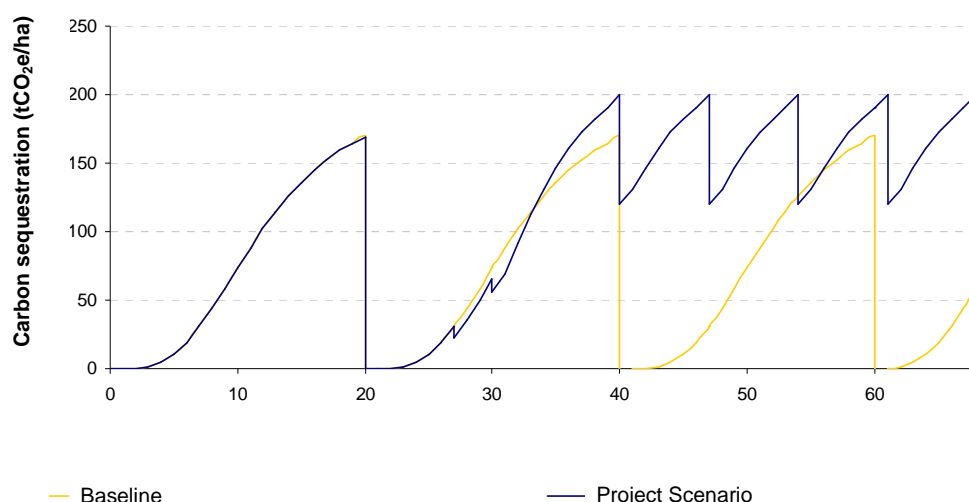
#### B. Methodology used for the calculation of the carbon sequestration achieved by the project

##### Forest stocks

The accounting of the carbon sequestration achieved by the project and its baseline was conducted on the basis of an extrapolation of the Bédéneau growth model (1993) for a chestnut coppice forest by applying the average values of carbon sequestration for a hardwood species in a coppice forest and in a high forest stand reported by the CARBOFOR project (2004)

Ultimately, the carbon sequestration of the project in its forest compartment is presented in Figure 3.

Figure 3– Carbon sequestration by the project of a coppice to an uneven-aged high forest stand



Source: CDC Climat Research

Intended use of the harvest:: The annually harvest volume for the two scenarios were determined from the described mode of forest management, after conversion of tCO<sub>2</sub> into DMT (density of the species in question at 15% moisture content = 0.5 DMT/m<sup>3</sup>)<sup>7</sup>. For the baseline, the applied usage assumptions were taken from Guyon (1998) for the harvesting of a chestnut coppice forest: 40% to chips, 50% for floor panels and 10% for industrial cabinetmaking, i.e. 100% pulpwood. For the project scenario, we assume that the distribution is identical to the final cutting of the afforestation project for sawlogs (50% sawlogs and 50% pulpwood)..

Table 7– Project 3: The harvest and its uses

Baseline

Forestry operation	Age (yrs.)	Harvest (m <sup>3</sup> /ha)	Conversion DMT/ha (15% moist.)	Uses (%)			Aspects valued
				EW	SW	PW	
Clear cut 1	20	169.5	84.7	0%	0%	100%	SPB
Clear cut 2	40	169.5	84.7	0%	0%	100%	SPB
Clear cut 3	60	169.5	84.7	0%	0%	100%	SPB

EW: Energy Wood, SW: Sawlogs, PW: Pulpwood

ES: Energy Substitution, HWP: Inventory of Wood Products, MS: Material Substitution

Project scenario

Forestry operation	Age	Harvest (m <sup>3</sup> /ha)	Conversion DMT/ha (15% moist.)	Uses (%)			Aspects valued
				EW	SW	PW	
Clear cut 1	20	169.5	84.7	0%	0%	100%	SPB,SM
Thinning conversion	27	8.6	4.3	0%	50%	50%	SPB,SM
Thinning conversion	30	9.3	4.7	0%	50%	50%	SPB,SM
Thinning uneven-aged forest - 1	40	79.5	39.8	0%	50%	50%	SPB,SM
Thinning uneven-aged forest - 2	47	79.5	39.8	0%	50%	50%	SPB,SM
Thinning uneven-aged forest - 3	54	79.5	39.8	0%	50%	50%	SPB,SM
Thinning uneven-aged forest - 4	61	79.5	39.8	0%	50%	50%	SPB, SM

EW: Energy Wood, SW: Sawlogs, PW: Pulpwood

ES: Energy Substitution, HWP: Inventory of Wood Products, MS: Material Substitution

<sup>7</sup><http://www.worldagroforestry.org/Sea/Products/AFDbases/wd/asps/DisplayDetail.asp?SpecID=679>



## Stocks in harvested wood products (HWP)

We use the CCX methodology to calculate the extended carbon storage in wood products, as described above for the first project.

**Table 8 – Project 3: Extended Sequestration in wood products**

### Baseline

Forestry operation	Age	Harvest (DMT/ha)	Harvest intended for SPB (DMT)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
				SW	PW	
Clear cut 1	20	84.7	67784.5	0.0	8180.7	30023
Clear cut 2	40	84.7	67784.5	0.0	8180.7	30023
Clear cut 3	60	84.7	67784.5	0.0	8180.7	30023

SW: Sawlogs, PW: Pulpwood

### Project scenario

Forestry operation (diameter)	Age	Harvest (DMT/ha)	Harvest intended for SPB (DMT)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
				SW	PW	
Clear cut 1	20	84.7	67784.5	0.0	8180.7	30023
Thinning for conversion	27	4.3	3443.2	237.2	207.8	1633
Thinning for conversion	30	4.7	3736.8	257.4	225.5	1772
Thinning uneven-aged forest - 1	40	39.8	31815.9	2191.3	1919.9	15088
Thinning uneven-aged forest - 2	47	39.8	31815.9	2191.3	1919.9	15088
Thinning uneven-aged forest - 3	54	39.8	31815.9	2191.3	1919.9	15088
Thinning uneven-aged forest - 4	61	39.8	31815.9	2191.3	1919.9	15088

SW: Sawlogs, PW: Pulpwood

## Energy substitution (ES)

Cannot be valued.

## Materials substitution (MS)

Under the assumption that the entire sawlog harvest is allocated to beam fabrication, the material substitution effect (aluminum) is calculated as for the sawlog afforestation project. The substitution effect of pulpwood is considered negligible, therefore zero for the baseline scenario.

**Table 9 – Project 3: Material substitution**

Project scenario

Forestry operation (diameter)	Age	SW (m3)	Material substitution	
			Beams	Avoided emissions (tCO <sub>2</sub> ) <i>hyp.</i> <i>Aluminum</i>
CR 1	20	0.0	0.0	0.0
Thinning f/conversion	27	3443.2	9837.8	3217
Thinning f/conversion	30	3736.8	10676.5	3491
Thinning -1	40	31815.9	90902.7	29725
Thinning -2	47	31815.9	90902.7	29725
Thinning -3	54	31815.9	90902.7	29725
Thinning -4	61	31815.9	90902.7	29725

SW: Sawlogs

**C. Carbon Balance sheet - Project of converting a coppice into a high forest stand**

	Forest Stocks	Stocks in Harvested Wood products	Total Stocks	Substitution	Total
Baseline (after 25 years)	81.5 ktCO <sub>2</sub>	30.1 ktCO <sub>2</sub>	111.6 ktCO <sub>2</sub>	0 ktCO <sub>2</sub> (MS)	111.6 ktCO <sub>2</sub>
Baseline (after 30 years)	122.04 ktCO <sub>2</sub>	60.04 ktCO <sub>2</sub>	182.08 ktCO <sub>2</sub>	0 ktCO <sub>2</sub> (MS)	182.1 ktCO <sub>2</sub>
Project (after 25 years)	146.0 ktCO <sub>2</sub>	33.4 ktCO <sub>2</sub>	213 ktCO <sub>2</sub>	66.1 ktCO <sub>2</sub> (MS)	279.1 ktCO <sub>2</sub>
Project (after 30 years)	128.4 ktCO <sub>2</sub>	78.7 ktCO <sub>2</sub>	207.1 ktCO <sub>2</sub>	95.9 ktCO <sub>2</sub> (MS)	303 ktCO <sub>2</sub>

## Example 4) Densification project for energy production

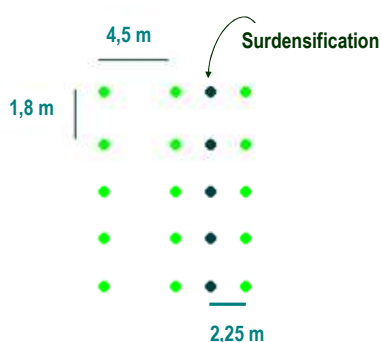
### A. General project information

Species: Maritime pine (*sp. Pinus pinaster*)

Location: Aquitaine Region

Project Size: 1 000 ha

Forest management regime: Overstocking of a plantation of maritime pine according to the plan presented below.



- **Management regime - Baseline**

Density of 1250 trees/ha (spacing 4.5 m)  
25% of the trees are cut at 15 years, then cut every 5 years, until 50 years, when the remaining 200 trees/ha are cut.

**Cycle:**

Thinning 1 (Year 15) = 25% trees

Thinning 2-5 (Years 20, 25, 30, 35) = 25%

Thinning 6-7 (Years 40, 45) = 15%

Clear cutting (Year 50) = 15%

- **Management regime - Project scenario**

Addition of one new line of pines between two rows, making it possible to increase from 1250 trees/ha to 2500

This row is cut at the end of 8 years for wood energy.

The management regime of the remaining rows is unchanged.

### B. Methodology used for the calculation of the carbon sequestration of the project

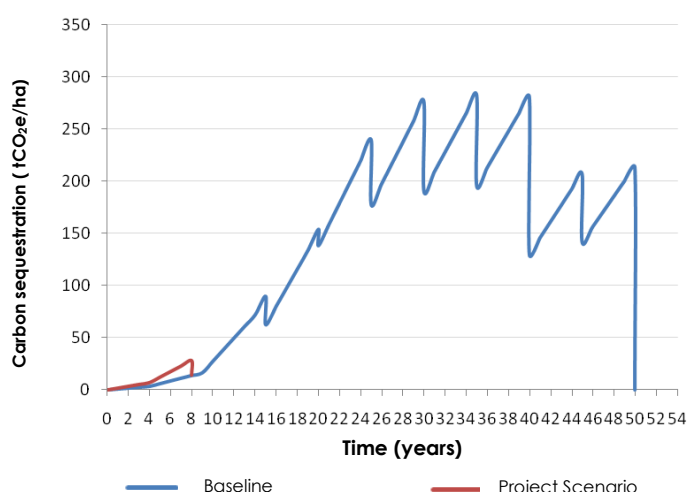
#### Forest stocks

The accounting for the carbon sequestration in the forest compartment is based on the annual increase of the biomass of the maritime pine, taken from the EFISCEN database.

Age (years)	0-5	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50
Increase m <sup>3</sup> /ha/year	0.87	2.61	11.09	17.77	20.32	19.88	18.56	17.28	15.51	14.52	13.05

The carbon sequestration in the forest compartment of the project is illustrated in Figure 4.

Figure 4 – Carbon sequestration by the overstocking project



Source: CDC Climat Research

**Intended use of the harvest:** The levels of harvesting for the two scenarios were determined according to the mode of forest management, and then converted from tCO<sub>2</sub> to DMT (average density of the species at 15% moisture = 0.6 DMT/m<sup>3</sup>)<sup>8</sup>. The destined uses of the harvest, for the baseline and the project scenario are described in the tables below. For the project scenario, the additional harvest is intended solely for energy purposes.

Table 10– Project 4: The harvest and its uses

**Baseline**

Forestry operation	Age (years)	Harvest (m <sup>3</sup> /ha)	Conversion DMT/ha (15% moist.)	Uses (%)			Aspects valued
				EW	SW	PW	
Thinning 1	15	20.8	12.5	0%	0%	100%	SPB
Thinning 2	20	46.1	27.6	0%	10%	90%	SPB
Thinning 3	25	59.2	35.5	0%	20%	80%	SPB
Thinning 4	30	63.5	38.1	0%	20%	80%	SPB
Thinning 5	35	65.3	39.1	0%	30%	70%	SPB,SM
Thinning 6	40	38.3	22.9	0%	30%	70%	SPB,SM
Thinning 7	45	41.7	25.0	0%	40%	60%	SPB,SM
Clear cut	50	287.8	172.5	0%	50%	50%	SPB,SM

BE: Wood energy, BO: Sawlogs, BI: Pulpwood

SE: Energy substitution, SPB: Inventory in wood products, SM: Material substitution

**Project scenario**

Forestry operation	Age (years)	Harvest (m <sup>3</sup> /ha)	Conversion DMT/ha (15% hum)	Uses (%)			Aspects valued
				EW	SW	PW	
Clear cut Overstocking	8	13.9	8.3	100%	0%	0%	SE

BE: Wood energy, BO: Sawlogs, BI: Pulpwood

SE: Energy substitution, SPB: Inventory in wood products, SM: Materials substitution

<sup>8</sup><http://www.worldagroforestry.org/sea/Products/AFDbases/WD/asps/DisplayDetail.asp?SpecID=2682>

## Stocks in harvested wood products (HWP)

The extended storage of carbon in wood products is estimated by applying the CCX methodology which was described for the first project. This is performed only for the baseline, because the project's harvest is to be used for energy generation only.

**Table 11 – Project 4: Extended Sequestration in wood products**

### Baseline

Forestry operation	Age (years)	Harvest (DMT/ha)	Harvest intended for SPB (DMT)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e)
				SW	PW	SW
Thinning 1	15	12.5	12490	0.0	1655	6073
Thinning 2	20	27.6	27633	490	3295	13894
Thinning 3	25	35.5	35513	1261	3764	18442
Thinning 4	30	38.1	38095	1352	4038	19783
Thinning 5	35	39.1	39123	2083	3629	20963
Thinning 6	40	22.9	22940	1222	2128	12292
Thinning 7	45	25.0	25005	1775	1988	13811
Clear cut	50	172.5	172533	15312	11430	98146

BO: Sawlogs, BI: Pulpwood

### Project scenario

Cannot be valued.

## Energy substitution (ES)

**Table 12 – Project 4: Energy substitution**

Forestry operation	Age (years)	Harvest (DMT/ha)	Total harvest destined for energy (DMT)	Energy substitution	
				Energy generated (KWh)	Avoided emissions (tCO <sub>2</sub> )
Clear cut Overstocking	8	8.3	8332	24414	6666

## Materials substitution (MS)

As described for previous projects, the materials substitution effect is calculated only for sawlog wood, which we assume as adaptable for beam manufacturing from the fifth thinning, on the perspective of wood replacing aluminum beams.

**Table 13 – Material substitution**

Baseline

Forestry operation	Age (years)	BO (m3)	Materials substitution	
			Beams	Avoided emissions (tCO <sub>2</sub> ) <i>hyp. aluminum</i>
Thinning 1	15	0	0	0
Thinning 2	20	4609	0	0
Thinning 3	25	11848	0	0
Thinning 4	30	12709	0	0
Thinning 5	35	19578	55936	17956
Thinning 6	40	11480	32799	10528
Thinning 7	45	16684	47669	15302
Clear cut	50	143898	411136	131975

**BO: Sawlogs**

Project scenario

Cannot be valued.

**C. Carbon sequestration balance sheet - Overstocking project**

	Forest stocks	Wood products	Total inventory	Substitution	Total
Baseline (after 7 years)	13.9 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	13.9 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	13.9 ktCO <sub>2</sub>
Baseline (after 8 years)	13.9 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	13.9 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	13.9 ktCO <sub>2</sub>
Baseline (after 25 years)	177.7 ktCO <sub>2</sub>	38.4 ktCO <sub>2</sub>	216.1 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	216.1 ktCO <sub>2</sub>
Project (after 7 years)	27.8 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	27.8 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	27.8 ktCO <sub>2</sub>
Project (after 8 years)	13.9 ktCO <sub>2</sub>	0 ktCO <sub>2</sub>	13.9 ktCO <sub>2</sub>	6.7 ktCO <sub>2</sub> (ES)	20.6 ktCO <sub>2</sub>
Project (after 25 years)	177.7 ktCO <sub>2</sub>	38.4 ktCO <sub>2</sub>	216.1 ktCO <sub>2</sub>	6.7 ktCO <sub>2</sub> (ES)	222.7 ktCO <sub>2</sub>

**Example 5) Species change project**

**A. General project information**

Species: Maritime pine

Location: Aquitaine Region

Project Size: 100 ha

Forest management regime: Replacement with a more productive hybrid species.

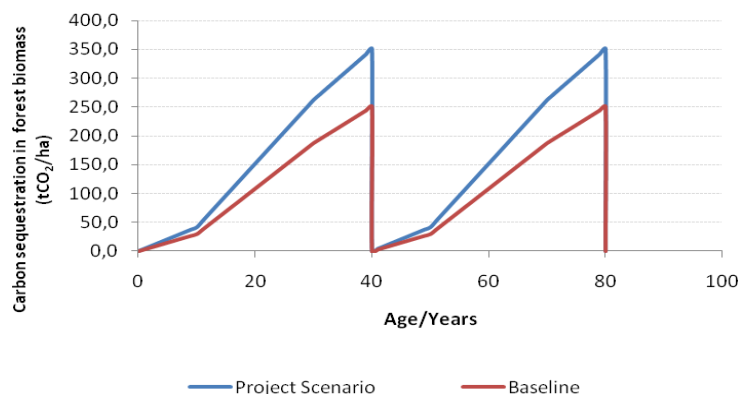
## B. Methodology used for the calculation of the carbon sequestration of the project

### Forest stocks

Carbon sequestration accounting for the project and the baseline was based on an extrapolation of the Zaehle (2006) data for biomass growth of softwood with the following wood production assumptions:

- Baseline: 250 m<sup>3</sup> wood/ha at the end of 40 years (clear cutting)
- Project scenario: 350 m<sup>3</sup> wood/ha at the end of 40 years (clear cutting) with a more productive species of pine

**Figure 5– Carbon sequestration in the forest compartment of the species replacement project**



Source: CDC Climat Research

**Table 14– Project 5: The harvest and its uses**

USES	Entire harvest	Aspects to value
Sawlogs	40%	SPB, SM
Pulpwood	50%	SPB
Wood energy	10%	SE

SE: Energy substitution, SPB: Inventory in wood products, SM: Materials substitution

### Stocks in harvested wood products (HWP)

Once again, the extended storage of carbon in the wood products is calculated by applying the CCX methodology.

**Table 15 – Project 5: Extended Sequestration in wood products**

Baseline

Species	Harvest at 40 years (m3)	Harvest intended for SPB (m3)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
			SW	PW	
Maritime pine	25 000	22 500	954.4	689.7	6 033

BO: Sawlogs, BI: Pulpwood

Project scenario

Species	Harvest at 40 years (m <sup>3</sup> )	Harvest intended for SPB (m <sup>3</sup> )	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
			SW	PW	
Pin maritime	35 000	31 500	1 336.1	965.6	8 447.3

BO: Sawlogs, BI: Pulpwood

**Energy substitution (ES)**

The conversion factors used for the maritime pine are a density of 0.9 TGW/m<sup>3</sup> and a moisture content = 0.61 DMT/TGW.

**Table 16 – Project 5: Energy substitution**

Baseline

Harvest in year 40 (m <sup>3</sup> )	Total harvest intended for energy (DMT)	Energy substitution	
		Energy produced (kWh)	Avoided emissions (ktCO <sub>2</sub> )
25 000	1 372.5	4021.4	1.1

Project scenario

Harvest in year 40 (m <sup>3</sup> )	Total harvest intended for energy (DMT)	Energy substitution	
		Energy produced (kWh)	Avoided emissions (ktCO <sub>2</sub> )
35 000	1921.5	5630	1.5

**Materials substitution (MS)**

As for the above projects, the materials substitution effect is calculated for sawlog wood only, once again under the assumption that sawlog harvested wood is used to replace aluminum beams.

**Table 17 – Project 5: Material substitution**

Baseline

Harvest in year 40 BO (m <sup>3</sup> )	Total harvest destined for beams m <sup>3</sup> (70% BO)	Materials substitution	
		Beams	Avoided emissions (ktCO <sub>2</sub> ) <i>hyp. aluminum</i>
10 000	7 000	20 000	6.4



Project scenario

Additional harvest BO (m3)	Total harvest destined for beams m3 (70% BO)	Materials substitution	
		Beams	Avoided emissions (ktCO <sub>2</sub> ) <i>hyp. aluminum</i>
14 000	9 800	28 000	9

**C. Carbon sequestration balance sheet - Harvest increase project**

	Forest stocks (KtCO <sub>2</sub> )	Wood products (KtCO <sub>2</sub> )	Total inventory (KtCO <sub>2</sub> )	Substitution (KtCO <sub>2</sub> )	Total (KtCO <sub>2</sub> )
Baseline (after 25 years )	14.7	0	14.7	0	14.7
Baseline (after 39 years )	24.4	0	24.4	0	24.4
Baseline (after 40 years )	0	6	6	1.1 (SE) + 6.4 (SM)	13.5
Project (after 25 years )	20.7	0	20.7	0	20.7
Project (after 39 years )	34.1	0	34.1	0	34.1
Project (after 40 years)	0	8.4	8.4	1.5 (SE) + 9 (SM)	18.9

**Example 6) Reallocation of timber usages project**

**D. General project information**

Location: Aquitaine Region

Annual harvest: 8.828 Mm<sup>3</sup>/year (Source: Agreste - Annual Forest Exploitation Survey 2007)

Intended use of the harvest: Constant harvested volumes but an increase in the share allocated to construction uses (from 7.5% to 20%) is proposed, with a decrease in the "paper, kraft paper and packaging" item.

## E. Methodology used for the calculation of the project carbon sequestration

### Forest stocks

Constant, at approximately 256 MtCO<sub>2</sub>e<sup>9</sup>.

**Table 18– Project 6: The harvest and its uses**

Uses	SR %	SR Category	SP %	SP Category
Mortality	1.0%	Not used	1.0%	Not used
Losses	10.5%	(11.5%)	10.5%	(11.5%)
Structural woodwork (*)	0.8%	Sawlogs (10%)	20.0%	Sawlogs (22.5%)
Prefabricated wood structures (*)	0.2%			
Doors and windows (*)	0.5%			
Lumber (*)	6.0%			
Other lumber, including formwork	1.0%			
Furniture and fittings from sawlogs	1.5%			
Wooden pallets and packaging	9.0%	Pulpwood (71.5%)	9.0%	Pulpwood (59%)
Composite floors and fittings	7.0%			
Other uses, including carbonization	0.5%			
Decorative and landscaping chips	7.0%			
Chips not counted	6.0%			
Furniture and fittings from panels	10.0%			
Paper, kraft paper and packaging	24.0%			
Industrial papers	8.0%			
Chips for energy use	7.0%	Wood energy (7%)	7.0%	Wood energy (7%)

SR: Baseline SP: Project scenario

(\*) Wood for construction uses

Source: Malfait et al. (2008)

### Stocks in harvested wood products (HWP)

The utilization of the CCX coefficients is based on the hypothesis that the proportion of hardwood/softwood in the region's total harvest (90% softwood) remains identical throughout the different use categories.

**Table 19 – Project 6: Extended Sequestration in wood products**

Baseline

Type of species	Annual harvest (Mm3)	Harvest intended for SPB (Mm3)	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
			SW	PW	
Hardwoods	0.8400	0.6846	6,311	39,534	168
Softwoods	7.9880	6.5102	76,297	315,397	1,438
<b>Total</b>	<b>8.8280</b>	<b>7.1948</b>	<b>82,608</b>	<b>354,931</b>	<b>1,606</b>

O: Sawlogs, BI: Pulpwood

<sup>9</sup> Standing wood inventory in Industrial Forests in the Aquitaine Region (Source: Mémento FCBA 2008)

Project scenario

Type of species	Annual harvest (Mm <sup>3</sup> )	Harvest intended for SPB (Mm <sup>3</sup> )	Stocks in harvested wood products (tC) (after 100 years)		Stocks in harvested wood products (tCO <sub>2</sub> e) (after 100 years)
			SW	PW	
Hardwoods	0.8400	0.6846	12,740	33,900	171
Softwoods	7.9880	6.5102	154,024	270,460	1,557
<b>Total</b>	<b>8.8280</b>	<b>7.1948</b>	<b>166,764</b>	<b>304,360</b>	<b>1,729</b>

Sawlogs, BI: Pulpwood

### Energy substitution (ES)

The emissions reductions related to the energy substitution cannot be valued because the share of the harvest intended for energy use remains constant. By using the density and the moisture content of the maritime pine for the entire harvest as a proxy we determine 0.3 MtCO<sub>2</sub>e to the energy substitution effect per year for both the baseline and project scenario.

### Materials substitution (MS)

Materials substitution effect is calculated only for sawlog wood harvest under the assumption that it replaces aluminum beams.

**Table 20 – Project 6: Material substitution**

Scenario	BO for beams (m <sup>3</sup> )	Materials substitution	
		Beams	Avoided emissions (ktCO <sub>2</sub> ) <i>hyp. aluminum</i>
Harvest - Baseline	441.4	1,261,143	405
Harvest - project	993.2	2,837,571	911

BO: Sawlogs

## F. Carbon sequestration balance of the reallocation of timber usages project–

	Forest stocks (MtCO <sub>2</sub> )	Wood products (MtCO <sub>2</sub> )	Total Inventory (MtCO <sub>2</sub> )	Substitution (MtCO <sub>2</sub> )	Total (MtCO <sub>2</sub> )
Baseline (after 20 years)	256	32.09	288.1	6 (ES) + 8.1 (MS)	330.1
Project (after 20 years)	256	34.58	290.6	6 (ES) + 18.2 (MS)	302.2

**Example 7) Harvest increase project**

**A. General project information**

- Species: Softwood stands
- Location: Lorraine Region
- Forest management regime: Increase the harvest of softwood trees in the region

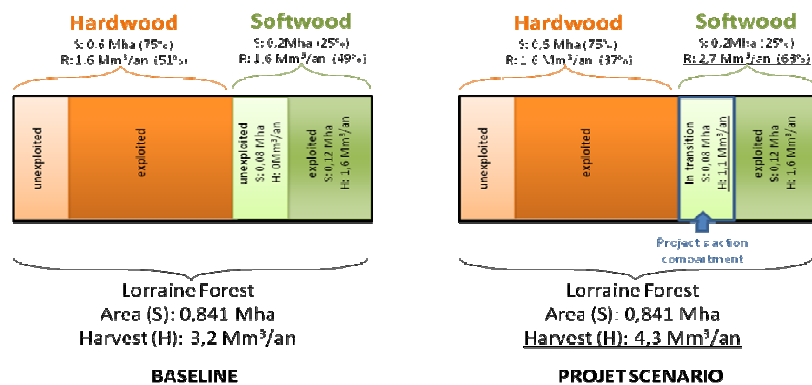
**B. Methodology used for the calculation of the carbon sequestration of the project**

**Forest stocks**

The carbon sequestration of the project and of the baseline is based on the following hypotheses:

- Baseline:
- Forest Inventory in the Lorraine Region = 166 Mm<sup>3</sup> (Source: Mémento FCBA 2009)
- h  
g  
project scenario:
- Harvest: 3.2 Mm<sup>3</sup>/an
  - Harvesting objective in 2030 (after 20 years): 4.3 Mm<sup>3</sup>/year (+1.1 Mm<sup>3</sup>/year)
  - According to data presented by Zaehle (2006) for mature softwood (inventory of 441.5 m<sup>3</sup>/ha for 100-year stands) and on the assumption of an average annual increase of 13 m<sup>3</sup>/ha/year, we estimate the number of additional hectares that must be exploited to meet the harvesting objective, the associated reduction in the forest inventory and the harvest volumes of the clear cuts during the transition phase.

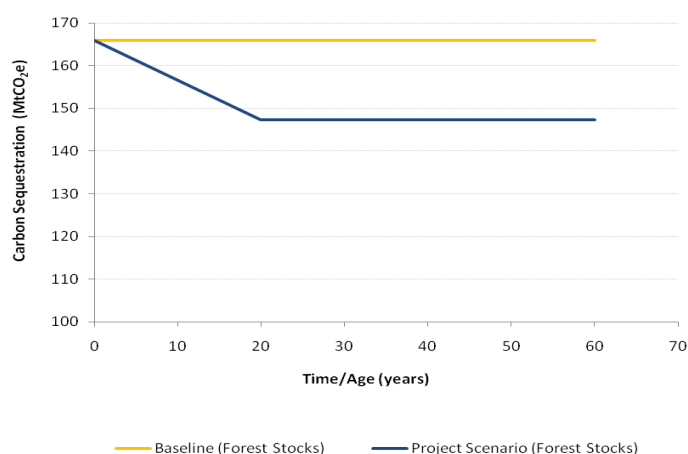
The following diagram illustrates the project diagram and shows the number of hectares mobilized and the harvest volumes during the transition phase:



Source: CDC Climat Research

As previously indicated, the mobilization of 0.08 Mha results in a reduction of the forest stocks up to 147 Mm<sup>3</sup>. We assume that it takes 20 years to the forest to return to a new equilibrium, as illustrated in Figure 6.

**Figure 6 – Carbon sequestration of the harvest increase project**



Source: CDC Climat Research

Intended use of the harvest: The intended use is determined by the results of the 2006 survey of the business sectors of the forestry and timber industry in the Lorraine Region<sup>10</sup>:

**Table 21– Project 7: The harvest and its uses**

USES	Total harvest	Hardwood	Softwood
Sawlog	54%	40%	69%
Pulpwood	37%	52%	22%
Energy Wood	8%	8%	9%

Source: 2006 Survey - Forestry Industry Sectors

### Stocks in harvested wood products (HWP)

We use the CCX methodology to calculate the extended storage of carbon in the wood products described for the first project. The calculation is made over a period of 20 years.

<sup>10</sup> [http://draaf.lorraine.agriculture.gouv.fr/fichiers/37\\_05\\_Infos\\_DRAF\\_10.pdf](http://draaf.lorraine.agriculture.gouv.fr/fichiers/37_05_Infos_DRAF_10.pdf)

**Table 22 – Project 7: Extended Sequestration in wood products**

Baseline

Type of species	Harvest intended for SPB (Mm <sup>3</sup> )	Stocks in harvested wood products (MtC) (after 100 years)		Stocks in harvested wood products (ktCO <sub>2</sub> e) (after 100 years)
		SW	PW	
Hardwoods	32.6	0.9736	1.1186	7,674
Softwoods	31.4	2.0734	0.3835	9,017
<b>Total</b>	<b>64.0</b>	<b>3,0470</b>	<b>1.5021</b>	<b>16,691</b>
			<b>at 25 years</b>	<b>21,705</b>

Project scenario

Type of species	Harvest intended for SPB (Mm <sup>3</sup> )	Stocks in harvested wood products (MtC) (after 100 years)		Stocks in harvested wood products (ktCO <sub>2</sub> e) (after 100 years)
		SW	PW	
Hardwoods	38.3	1.1409	1.3108	8,998
Softwoods	36.8	2.4298	0.4495	10,567
<b>Total</b>	<b>75.0</b>	<b>3.5707</b>	<b>1.7603</b>	<b>19,565</b>
			<b>cum. At 25 years</b>	<b>26,008</b>

**Energy substitution (ES)**

The conversion factors used are those for the maritime pine: a density of 0.9 TGW/m<sup>3</sup> and a moisture content of 0.61 DMT/TGW.

**Table 23 – Project 7: Energy substitution**

Baseline

Year	Harvest (Mm <sup>3</sup> )	Total harvest intended for energy (Mm <sup>3</sup> )	Total harvest intended for energy(MDMT)	Energy substitution	
				Energy produced (GWh)	Avoided Emissions (MtCO <sub>2</sub> )
0	3.20	0.27	0.15	0.44	0.12
20	64.00	5.44	2.99	8.75	2.39
40	64.00	5.44	2.99	8.75	2.39
				<b>cum. at 25 years</b>	<b>3.1</b>

Project scenario

Year	Harvest (Mm <sup>3</sup> )	Total harvest intended for energy (Mm <sup>3</sup> )	Total harvest intended for energy (M DMT)	Energy substitution	
				Energy produced (GWh)	Avoided emissions (MtCO <sub>2</sub> )
0	3.20	0.27	0.15	0.44	0.12
20	75.00	6.38	3.50	10.25	2.80
40	86.00	7.31	4.01	11.76	3.21
				<b>cum. at 25 years</b>	<b>3.8</b>

## Materials substitution (MS)

Under the hypothesis that 70% of the harvest of sawlogs is intended for the fabrication of beams, we have calculated the materials substitution effect (*aluminum*).

**Table 24 – Project 7: Material substitution**

### Baseline

Year	Harvest BO (Mm <sup>3</sup> )	Total harvest intended for beams Mm <sup>3</sup> (70% BO)	Materials substitution	
			Beams / Millions of beams	Avoided emissions (MtCO <sub>2</sub> ) <i>hyp. aluminum</i>
0	1.73	1.21	3.47	0.39
20	34.70	24.29	69.39	7.80
40	34.70	24.29	69.39	7.80
			<b>cum. At 25 years</b>	<b>10.1</b>

### Project scenario

Year	Harvest BO (Mm <sup>3</sup> )	Total harvest intended for beams Mm <sup>3</sup> (70% BO)	Materials substitution	
			Beams / Millions of beams	Avoided emissions (MtCO <sub>2</sub> ) <i>hyp. aluminum</i>
0	1.73	1.21	3.47	0.39
20	40.66	28.46	81.32	9.14
40	46.62	32.64	93.24	10.48
			<b>cum. At 25 years</b>	<b>12.1</b>

## C. Carbon sequestration balance - Harvest increase project

	Forest inventory MtCO <sub>2</sub>	Wood products MtCO <sub>2</sub>	Total Inventory MtCO <sub>2</sub>	Substitution MtCO <sub>2</sub>	Total MtCO <sub>2</sub>
Baseline (after 25 years)	166	21.7	187.7	3.1 (ES) + 10.1 (MS)	200.9
Project (after 25 years)	147	26.0	173	3.8 (ES) + 12.1 (MS)	189.3

## REFERENCES

- Arrouays, D., J. Balesdent, J.C. Germon, P.A. Jayet, J.F. Soussana et P. Stengel (eds). (2002). Contribution à la lutte contre l'effet de serre. Stocker du carbone dans les sols agricoles de France? Expertise scientifique collective. Synthèse du rapport. INRA (France), 32 pp.
- Bilek, E. M., Becker, P., McAbee, T. 2009. CVal: A Spreadsheet Tool to Evaluate the Direct Benefits and Costs of Carbon Sequestration Contracts for Managed Forests. FPL-GTR-180. U.S. Forest Service, Forest Products Laboratory, Madison, WI. 30 p.
- CarbonFix, 2008, CarbonFix Standard - Version 2.0 Criteria. CarbonFix, Staufen – Germany
- Chenost C., September 2007, Vers une gestion intégrée des forêts et des produits bois pour la lutte contre le changement climatique, Thèse Professionnelle, Institut Supérieur International de Gestion de l'Environnement
- Chicago Climate Exchange, 2006, Rulebook: CCX Exchange Offsets and Exchange Early Action Credits
- Climate, Community, and Biodiversity Standard, 2008, 2nd Edition
- Pearce D., Turner K., 1990, Economics of Natural Resources and the Environment, The John Hopkins University Press.
- De Cara S., Thomas, A., Projections d'émissions/absorptions de gaz à effet de serre dans les secteurs forêt et agriculture aux horizons 2010 et 2020, Rapport final pour le Ministère de l'Agriculture et de la Pêche. Thiverval-Grignon: UMR Economie publique, 2008. 202 p.
- FCBA, July 2008, Comptabilisation du carbone dans les produits bois en France, en vue d'un rapportage volontaire dans l'inventaire national 2006 des émissions et absorptions de gaz à effet de serre, réalisé au titre du Protocole de Kyoto
- Galik C., Baker J., Grinnell, J., Transaction costs and forest management carbon offset potential, Duke University, 2008, 15 p.
- Galik, C., Mobley, M., Richter, D., forthcoming. A virtual "field test" of forest management carbon offset protocols: the influence of accounting. Mitigation and Adaptation Strategies for Global Change. 2008
- Galik, C. S., Richter, D. deB., Mobley, M. L., Olander, L. P., Murray, B. C. 2008. A Critical Comparison and Virtual "Field Test" of Forest Management Carbon Offset Protocols. Climate Change Policy Partnership, Durham, NC. 45 p.
- Gardette Y-M., Locatelli B., Mai 2007, Les marchés du carbone forestier, ONF International, Cirad
- GIEC, 2006, <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html>, IPCC AFOLU Guidelines
- Guigon P., Bellassen V., Ambrosi P., Voluntary Carbon Markets: What the Standards Say..., CDC Climat Research
- Goodale, C. L., Apps, M. L., Birdsey, R. A., Field, C. B., Heath, L. S., Houghton, R. A., Jenkins, J. C., Kohlmaier, G. H., Kurz, W., Liu, S., Nabuurs, G., Nilson, S., and Shvidenko, A. Z. (2002). Forest carbon sinks in the Northern hemisphere. Ecological Applications 12, 891-899.
- Guyon, J.P. (1998), Références Forêt 2<sup>e</sup> Edition, Editions Synthèse Agricole, 296 p.
- Hamilton K., Sjardin M., Marcello T., Shapiro A. (2009), Fortifying the Foundation: State of the Voluntary Carbon Markets 2009, Ecosystem Marketplace & New Carbon Finance
- Hamilton K., Chokkalingam U., Bendana M., (2010), State of the Forest Carbon Markets 2009: Taking Root & Branching Out, Ecosystem Marketplace
- Janssens, I. A., Freibauer, A., Ciais, P., Smith, P., Nabuurs, G., Folberth, G., Schlamadinger, B., Hutjes, R. W. A., Ceulemans, R., Schulze, E. D., Valentini, R., and Dolman, A. J. (2003). Europe's terrestrial biosphere absorbs 7 to 12% of European anthropogenic CO<sub>2</sub> emissions. Science 300, 1538-1542.



*Climate Report No. 20 - Getting carbon value out of the Forestry and Wood sector in Annex I countries:  
The French Example (Methodology)*

- Kägi, Schmidtke. A qui va l'argent? Qu'est-ce que les propriétaires de forêts des pays développés attendent du protocole de Kyoto, Document préparé pour la FAO.
- Leguet B., Merckx V. (2005), « Puits de Carbone » domestique: quel intérêt pour la France ?, Mission Climat (CDC), ONF
- Leseur A., 20 February (2007), Promotion de la séquestration biologique du carbone par l'agriculture et la forêt en France, Caisse des Dépôts et Consignations Mission Climat et Société des Agriculteurs de France
- Luysaert et al. (2007), The CO<sub>2</sub>-balance of boreal, temperate and tropical forests derived from a global database, *Global Change Biology*, 13(12), 2509-2537.
- Malfait J. J., Pajot G., Séquestration des flux de carbone forestier: Mise en place d'un projet d'additionnalité des usages du bois dans la construction, Université de Bordeaux GREThA UMR CNRS 5113 & Macaulay Institute, Aberdeen, UK Cahiers du GREThA no. 2008-16
- Malfait J. J., Pajot G., Séquestration des flux de carbone forestier: rotations des peuplements, prise en compte des produits bois et optimisation des stocks de carbone, Université de Bordeaux GREThA UMR CNRS 5113 & Macaulay Institute, Aberdeen, UK Cahiers du GREThA no. 2008-19
- Maris C., 2008, L'accès aux marchés du carbone pour les propriétaires forestiers français: Sortir de Kyoto ?, CRPF d'Aquitaine, Mémoire de fin d'étude pour l'ENITA Bordeaux
- Martin A., Nollen G., (2009), Financial and economic analysis of forestry carbon trading
- MEEDDAT (2008), Réaliser un projet MDP ou MOC de réduction des émissions de gaz à effet de serre: Quelles opportunités, comment passer à l'action.
- Merger E., Williams A., (2008), Comparison of Carbon Offset Standards for Climate Forestation Projects participating in the Voluntary Carbon Market, University of Canterbury, Christchurch, New Zealand
- Merger E., (2008), Forestry Carbon Standards 2008
- New Carbon Finance, 15 September 2008, Voluntary Carbon Index
- Office National des Forêts, printemps 2008, Forêt, bois énergie, bois matériau et carbone, RDV techniques no. 20
- Pearson, T., Brown, S., Andrasko, K. (2008). Comparison of registry methodologies for reporting carbon benefits for afforestation projects in the United States. *Environmental Science and Policy* 11(6): 490 p. 504.
- Puech J. (2009), Mise en valeur de la forêt française et développement de la filière bois, Paris : Ministère de l'Agriculture
- UNFCCC, 1997, Protocole de Kyoto
- Reverchon, F., 2006 Fixation de carbone par des plantations forestières provençales et application à la lutte contre l'effet de serre en région PACA, Mémoire de fin d'études, FIF, ENGREF.
- Taverna, R., Hofer, P., Werner, F., Kaufmann, E., Thürig, E., (2007): The CO<sub>2</sub> effects of the Swiss forestry and timber industry. Scenarios of future potential for climate-change mitigation. *Environmental studies* no. 0739. Federal Office for the Environment, Bern, 102 pp.
- Trumper, K., Bertzky, M., Dickson, B., van der Heijden, G., Jenkins, M., Manning, P. (2009), The Natural Fix? The role of ecosystems in climate mitigation. A UNEP rapid response assessment, United Nations Environment Programme, UNEP-WCMC, Cambridge, UK
- U.S. Department of Energy, 2006, Forestry Appendix
- Voluntary Carbon Standard, 2009, Guidance for Agriculture Forestry and Other Land Use Projects
- Werner F., Taverna R., Hofer P., Richter K., October 2005, Carbon pool and substitution effects of an increased use of wood in buildings in Switzerland: first estimates, Environment and Development, Zurich
- WWF, Kollmuss A., Zink H., Polycarp C., March 2008, Making Sense of the Voluntary Carbon Market: A Comparison of Carbon Offset Standards, Stockholm Environment Institute