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Developing a generic approach for FTTH solutions using LCA methodology

Methodological guide

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Report prepared for:

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We remind you that this study is only based on facts, circumstances and assumptions which have been submitted to us and which are specified in the report. Should these facts, circumstances or assumptions be different, our conclusions might be different.

Moreover, the results of the study should be considered in the aggregate with regard to the assumptions made and not taken individually. For all matters of interpretation, the original paper copy of our report takes precedence over any other version.

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Goals and applications of the study

The mission of the FTTH (Fibre To The Home) Council Europe SUDEFIB Committee is to educate, promote and accelerate FTTH and the resulting quality of life enhancements. This education encompasses sustainable development concerns. The FTTH Council Europe would like to develop a standard approach for FTTH solutions using LCA methodology. The goal is to assess three selected scenarios using the Life Cycle Assessment (LCA) methodology: urban dense dwelling (e.g. towers), urban wide dwelling (e.g. houses), and rural dwelling.

The FTTH Council Europe key objectives are the following:

- Evaluate environmental impacts of the deployment of FTTH technology depending on the three cases of dwelling, together with the environmental benefits associated with the fact that people will work at home or receive home-based medical assistance. A simplified LCA approach is used here.
- Qualify the resulting quality of life enhancements (the societal aspect) from the point of view of sustainable development.

According to ISO 14040, the environmental assessment is based on consistent and relevant data quality requirements.

Scope of the study and boundaries of the systems

1 Description of the FFTH scenarios

The local main access point is the starting point of what is included in the system. The system includes the Fibre network (Fibres + nodes) from the starting point up to the door of the user. The studied system doesn't consider the backbone (i.e. what is set before the local main access point) and the upstream of the backbone.

The system integrates the environmental impacts associated to the life of the fibre networks (Fibres + nodes) from their construction (including the fibres set up depending on the local duct situation) up to their maintenance, over the estimated life span of the fibre network. The end of life of the Fibre network is modelled as “leave the network in place” (i.e. basically). Cables and boxes ends of life are modelled.

We cover three case Studies for Fibre network, one for each type of dwelling.

- dense urban dwelling (e.g. towers)
- disperse urban dwelling (e.g. houses)
- rural dwelling

The Fibre network topology is assessed through the amount and nature of Fibres used, the number and nature of nodes (boxes), and the energy consumption at the Network use phase for each of the Case Studies.

The social changes associated to the deployment of FTTH network are represented by teleworking, three telemedicine cases and home-based medical assistance.
We consider in this study that the savings associated to these changes are equivalent for each scenario.

Of course the set up of the network is at the origin of environmental impacts.

The final results of the LCA presents an aggregation of both aspects (set up of the network and environmental savings) in order to evaluate if the set up of Fibres brings an overall environmental benefit.

2 Functional unit

The **functional unit** for the FTTH Network deployment LCA is as follows has been determined during the study and is as follows:

Allow a European citizen to use FTTH technologies during one year

The reference flow is the FTTH network user in Europe.

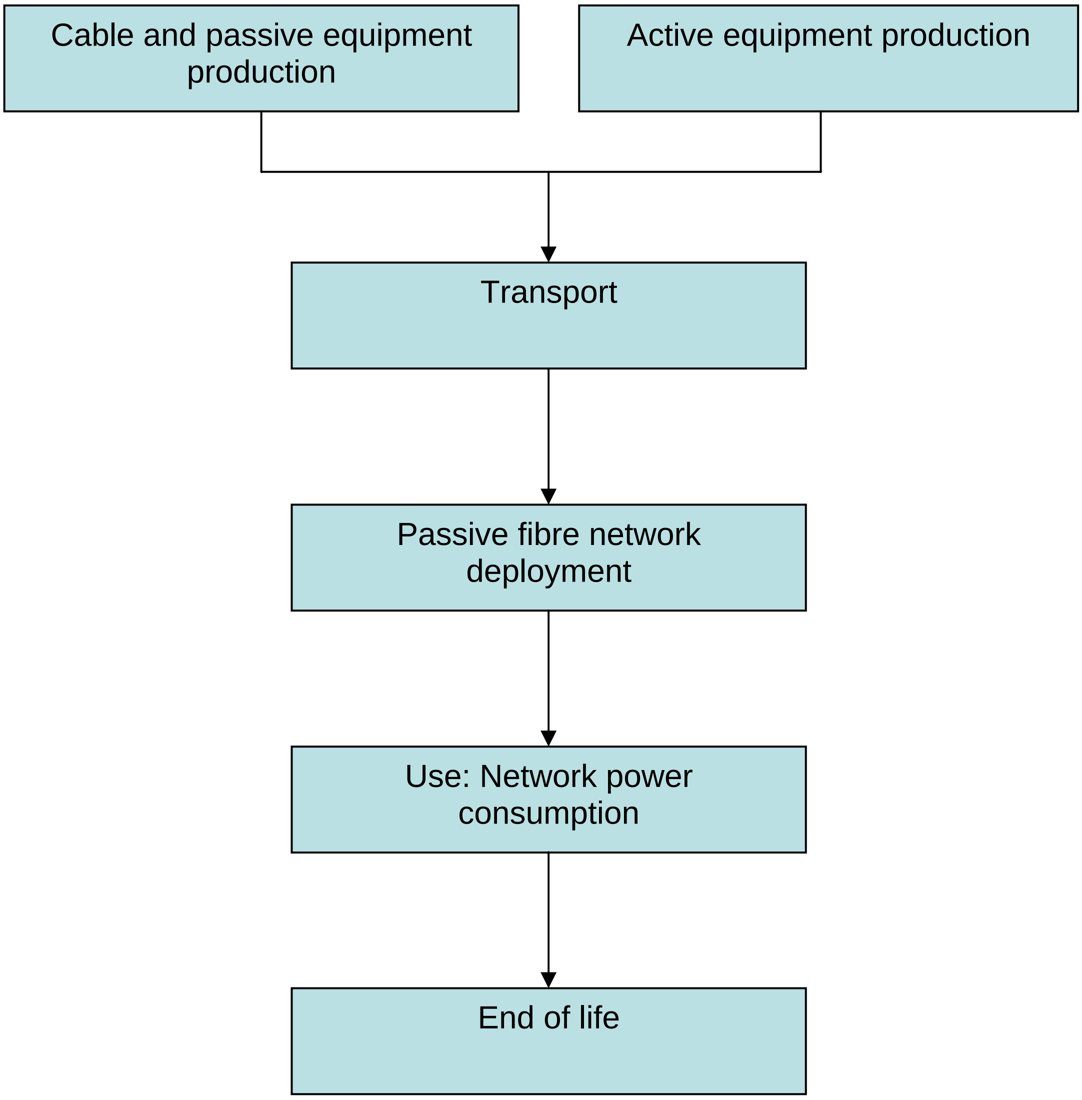
Nevertheless, in the following results, we choose the **number of years as a result** in order to evaluate the depreciation of the network deployment, compared with the total savings due to usage of this network.

Future LCA performed should determined the number of years of life of the different equipments (should be from 30 to 50 years for passive equipments and 5 to 10 years for active equipments).

In this study, the maintenance of the network and replacement of equipments have not been evaluated.

3 System and Life Cycle phases studied

This study is "**a cradle to grave**" screening LCA study: it covers the production steps, from the raw materials "in earth" (*the cradle*) to the FTTH Network end of life (*the grave)*.



System boundaries description

Ecobilan has modelled the FTTH network impacts and associated services savings using a life-cycle approach with its proprietary LCA software tool TEAM™.

We remind that the maintenance of the network and equipments has not been evaluated in the following assumptions and results.

4 Methodology

4.1 An overview of our approach

In this section, we describe the approach we have adopted in providing the consultancy support required. We recognise that this is a project with various stakeholders, members of the FTTH Council, and have defined a structured and pragmatic approach, incorporating good business practice designed specifically to meet the requirements.

A critical success factor was the establishment of a close partnering between the participating companies and us. This ensures a shared project vision and objectives and facilitates the development of ownership of the Project and use of the results.

The following members of the SUDEFIB group have contributed to the project:

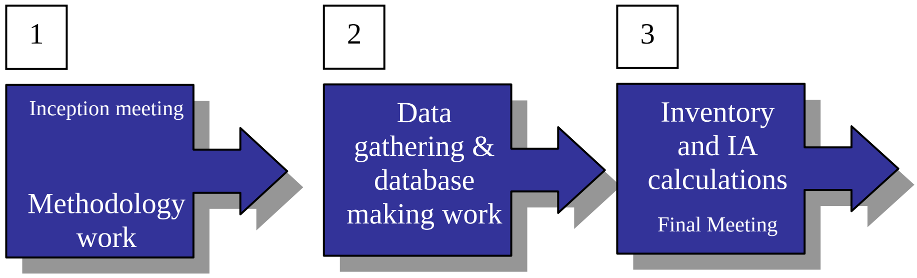
- Jacques Jaillet – Acome
- Maurice Sanciaume – Agilent Technologies
- Edgar Van Essen – Alcatel Lucent
- Wolfgang Fischer – Cisco
- Agnès Huet – Comptoir des Signaux
- Galit Wellner – ECI
- Bernard Dugerdil – Freescale
- Eric Lavillonnière – Mitsubishi Electric
- Sophie Pautonnier – Mitsubishi Electric
- Christian Ollivry – Motorola

4.2 Our methodology

We have followed the methodology defined by the ISO 14040 series of standards, to ensure a robust and defensible approach.

The objectives were to:

- focus the data gathering,
- ensure that sensible conclusions can be drawn from the data,
- present the data in a user way adapted to their purpose,
- ensure a good know-how transfer to FTTH Council members.



5 Main assumptions and data sources

5.1 Optical Fibre life cycle

Data sources and modelling assumptions have been mainly provided by the FTTH Council SUDEFIB (Sustainable Development Fibre) Committee.

Data are based on European averages.

Three scenarios have been considered for the calculation: urban dense, urban wide and rural areas.

5.1.1 Production of cables

Data related to the cable production has been delivered by Acome through a questionnaire.

Details of raw materials and assumptions are given hereafter. Detailed data are confidential.

Outdoor cable

Two types of outdoor cable have been taken into account: 50% of LTA and 50% of LCU.

- The 72 optical fibres LTA cable is mainly made of HDPE (polyethylene) and Polysester.
- The 72 optical fibres CCU cable is mainly made of HDPE (polyethylene), PVC and glass fibre

Aerial cable

The aerial cable is an outdoor cable consolidated with FRP (Polyester Resin) and additional polyethylene.

Indoor cable

The 24 optical fibres H-Pace cable is mainly made of LSOH which has been considered as polypropylene.

Home cable

The monomode Optical Fibre is mainly made of Photopolymerisable material (Acrylic Resin) and Silica which has been considered as Glass Fibre.

Distances of cables (Source FTTH meeting)

	Urban Dense	Urban Wide	Rural
Total distance of home cable (in m)	25	25	25
Total distance of indoor cable in the FTTH network (in m)	60	60	60
Total distance of indoor cable in the FTTH network (in m) per user	5	60	60
Total distance of outdoor cable in the FTTH network (in m)	500	3000	10000
Total distance of outdoor cable in the FTTH network (in m) per user	13.9	83.3	277.8

For indoor cable in urban dense area, the penetration rate is 50% considering 24 users.

For outdoor cable, the penetration rate is 50% considering 72 users.

5.1.2 Production of active equipments

Active equipments considered in this study are:

- ONT (Optical Network Terminaison)
- OLT (Optical Line Terminal)
- Network Nodes

Details of data and calculations are in the following:

- The weight of one ONT is 780 g (Source: CREDO). ONT is supposed to be a 50/50 mix of Steel and HDPE.
- Dimensions of OLT rack have been delivered by the FTTH council (Source: Cisco). OLT rack is supposed to be a 50/50 mix of Steel and HDPE.
- One OLT is made of 2 OLT racks in PON configuration and 4 OLT racks in Point to Point configuration (Source: FTTH council).
- Network Nodes correspond to the different nodes of the network: the different splitters and the distribution boxes.
    - The estimated weight for one splitter is 500 g and is supposed to be made of HDPE.
    - The estimated weight for one box is 3 kg and is supposed to be made of HDPE.

5.1.3 Production of raw materials

Bibliographical data has been used to the modelling of the production of raw materials (Appendix).

5.1.4 Repartition by FTTH user

We consider that 1 OLT deserves 4000 users (Source: CREDO).

There is 1 ONT per user.

For the Network Nodes:

- As an assumption, we take into account 32 splitters per 1000 home passed. This with a penetration rate of 50%, this leads to 64 splitters for 1000 FTTH users.
- We consider that 1 distribution box is used per 24 home passed (average value) (Source: CREDO).

5.1.5 Transport of raw materials

We consider that a truck covers an average distance of 1000 km and there are 144 km of cable per truck (Source: Acome).

5.1.6 Optical Fibre deployment

- **Micro-trench deployment**

Concerning the ready-mixed concrete and the road bitumen production, the maximalist hypotheses have been selected (Source: CREDO)

Trench depth: 0.5 m

Trench width: 0.13 m

In rural area, we consider that only 50% of these deployments use bitumen.

The duct cables are made of Polyethylene (HDPE) (Source: CREDO):

External diameter: 8 mm

Internal diameter: 5mm

Blowing machines are supposed to be fuel driven. The consumptions of these machines have been taken into account (Source: Internet website of operators)

Features concerning civil works engine consumption (Diesel Oil) have been provided by the FTTH council. We consider 100 l/h of working and an average distance per day of 500 m.

Four steps in this application have been taken into account (Source: CREDO):

- Preparatory studies (detection);

- Trenching;

- Cable installation;

- Ready-mixed concrete.

Three types of vehicles have been taken into account:

- Trenching vehicle is similar to heavy duty truck;

- Cable installation vehicle is similar to truck;
- Ready-mixed concrete vehicle is similar to engineering work vehicle.

Recovered matter can be represented by non-treated limestone (Source: Analysis of the efficiency of geogrids to prevent a local collapse of a road, Celine Bourdeau and Daniel Billaux, Itasca Consultants S.A.S.)

- **Traditional civil works deployment**

Civil engineering holes are supposed to be 1 meter wide.

Concerning the road bitumen production, in rural area, we consider that only 50% of these deployments use bitumen.

Features concerning Diesel Oil consumption for civil works engine are of 75 l / 250 m3 (Source: civil works company).

The duct cables are made of High Density Polyethylene (Source: CREDO).

- **Poles deployment**

We consider that one pole is set up every 40 m (Source: FTTH Council).

50% of poles are considered to be made of galvanized steel and 50% of poles are considered to be made of wood.

Data concerning steel and wood poles come from the internet website of a pole producer.

- **Existing deployment**

Average distance between 2 manholes has been provided by FTTH Council.

Data concerning diesel oil consumption for excavation are of 75 l / 250m3. Assumption on hole features:

Length= 1m,

Depth= 2 m,

Width= 2 m.

Blowing machines are supposed to be fuel driven. The consumptions of these machines have been taken into account (Source: Internet website of an operator).

Protection boxes are supposed to be made of Polyester Resin (Source: CREDO).

We consider 160 protection boxes for 1000 FTTH users (Source: Andorra STA questionnaire).

5.1.7 Repartition of deployment technologies

The following repartition has been elaborated during FTTH Meetings.

	Urban dense	Urban wide	Rural
Percentage of **Existing** application for the FTTH deployment	60%	20%	12%
Percentage of **Poles** application for the FTTH deployment	0%	20%	40%
Percentage of **Facade** application for the FTTH deployment	0%	0%	0%
Percentage of **Traditional civil work** application for the FTTH deployment	20%	30%	24%
Percentage of **Microtrench** application for the FTTH deployment	20%	30%	24%

Rural area detailed calculations:

We consider 40% of Poles and 60% of underground networks, among them:

- Micro-trench (new): 40%;

- Traditional (new): 40%;

- Existing: 20%.

Exiting technologies are assumed to be blown technologies.

5.1.8 Use: active equipments power consumption

In the use phase, only electrical consumption has been considered. The calculations have been made for 1 entire year of FTTH utilisation.

Activity mode and sleeping mode have been distinguished.

Concerning ONT:

- 10 h of activity (12 W);

- 14h in sleeping mode (2 W).

Concerning OLT: 2W/user for Point to Point configuration and 0.6 W/User for PON during 24 hours/day.

Data about consumption have been provided by Credo and by FTTH council.

5.1.9 Optical Fibre end of life

The reference case for the end of life model is the CCU 72OF cable.
Demolition impacts are not taken into account (vehicules and energy used for demolition)

End of Life assumptions:
Polyethylene end of life is considered to be 50% incinerated and 50% lanfilled.
Glass fibre has been considered as silica and is 100% incinerated.

5.2 Environmental benefits of FTTH deployment

Teleworking, telemedicine and home assistance have been assessed.

Three cases have been considered for telemedicine: teledialysis, telemedical meetings and medical imaging transfer.

Transportation assumptions for all cases:

- Average of oil and diesel consumption: 6 liters / 100 km

- 50% of diesel cars in Europe

From the current trends (2010-2011 and beyond) in FTTH networks use, we have chosen the following assumptions:

Assumptions on Teleworking:

	Teleworking assumptions in Europe for 1 year	Sources
Population		
% of active population in Europe	50% of the total population	Eurostat
% of teleworkers in active population	**2.5% of european working population telework at least 1 full day per week**	"Rapport Morel" from INSEE
% of prospective teleworkers in active population	**10% of european working population telework 3 full days per week** (due to the fact that some Nordic countries have already 17%)	Assumptions chosen for the present study (Final report ECaTT 2000)
Number of working weeks per year	47	
European average Home-Work Distance Round trip (km)	**30 km**	Etude Manicore from INRETS/ INSEE
Floorspace reduction		
Number of m² / employee in an office building	10 m² / employee	Assumptions chosen for the present study
Energy consumption for heating system	532.3kWh/m²/year approx. 2000 MJ / m² / year	Etude Manicore from CEREN
Required Total primary Energy to produce 1 electric MJ	3 MJ	Bibliographical data of Electricity LCA

Assumptions on Telemedicine:

- **Imaging transfer**

	Imaging transfer assumptions	Sources
Number of km saved /inhabitants/year	0.031	Study case :GIP Picardie
We consider that 1 imaging transfer correspond to 1 road transfer avoided	100%	Assumptions chosen for the present study

Detailed calculations of the number of km saved / inhabitants / year:

Picardie Population	1 800 000
Average Weighted Distance between hospital (km)	81.5
Total Imaging Transfer / Year	677
Total km avoided	55 172
km avoided / inhabitants	0.031

- **Teledialysis**

	Teledialysis assumptions	Sources
% of population who could be concerned about teledialysis	0.022%	Study case : Teledialysis St Brieuc
Number of km saved /patient/week	300	Study case : Teledialysis St Brieuc

Detailed calculations:

The results of this study have shown that teledialysis patients between Lannion and St-Brieuc (France) save 100 km per consultation. And they have 3 consultations per week.

In France, 35,000 patients have dialysis, which represent 0.05 % of the French population.

And according to nephrologists, 40% of the population having dialysis could benefit from teledyalisis.

Extrapolation to the population considered:

We will consider that 0.022 % of the population taken into account could save 300 km/week, on a basis of 52 weeks/year.

- **Telemedical meetings**

	Telemedical meetings assumptions	Sources
Number of km saved /year/inhabitants	0.045 (i.e. 27510 km avoided per year for a population of 570000 inhabitants)	Study case : Teledialysis St Brieuc

Assumptions on home medical support:

	Home medical support assumptions	**Sources**
Number of km saved /trip	50	Assumptions chosen for the present study
Number of trip /week	0.25 (once per month)	Assumptions chosen for the present study
% of people of more than 75 years old in 2007	13%	Orange Health Division
% of the above population who need help	40%	Orange Health Division
Prospective % of the above population using innovative device	**50%**	Assumptions chosen for the present study
Prospective % of the above population using High Speed	**100%**	Assumption chosen for the present study

Assumptions on population concerned with home medical support in France (source: Orange Health Division):

8.4 millions of people more than 75 years old in 2007 (+2.5%/year). Among them:

- 10% in a old people's home;

- 40% need help, among them:

  - 55% daily;
  - 35% aftercare;
  - 10% innovative device of which 10% High Speed.

5.3 Production of energies and transport

Details of bibliographical data used for the production of energies and transport are in appendix.

6 Impact categories

Ecobilan selected a list of impact categories presented in this section.

The fourteen following impact categories are usually used by Ecobilan to perform life cycle impact assessment:

Indicator	Environment	Calculation method
Total Primary Energy	RESOURCE	Sum of feedstock + fuel energy = sum of non renewable + renewable energy
Feedstock Energy	RESOURCE	Sum of feedstock energy consumption
Fuel Energy	RESOURCE	Sum of fuel energy consumption
Non renewable Energy consumption	RESOURCE	Sum of non renewable energy consumption
Renewable Energy	RESOURCE	Sum of renewable energy consumption
Depletion of abiotic ressources: “Abiotic resources” are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. The characterisation factor of abiotic depletion potential (ADP) for each extraction of minerals and fossil fuels is expressed in kg antimony equivalents.	RESOURCE	CML2000[1]
Greenhouse gas effect: The "greenhouse effect" refers to the ability of some atmospheric gases to retain heat which is radiating from the earth, and the Global Warming Potential (GWP) is the impact category measuring this effect, based on different time span. The Intergovernmental Panel on Climate Change developed the characterisation method used by Ecobilan. The category indicator is in gram equivalent CO2. Ecobilan selected the direct impact at a span of 100 years	AIR	IPCC[2], 2001
Air acidification: The air acidification impact category represents an increase in the atmosphere of acid compounds such as nitrogen oxides and sulphur oxides. The characterisation factor of a substance is calculated on the basis of the number of H+ ions, which can be produced per mole. The air acidification indicator is the sum of the inventory flows, which contributes to the air acidification multiplied by their characterisation factors. ETH developed the characterisation method used by Ecobilan.	AIR	CML2000

[1] CML : University of Leiden (Netherlands).

[2] IPCC : International Panel on Climate Change.

Depletion of the stratospheric ozone The ozone layer is present in the stratosphere and acts as a filter absorbing harmful short wave ultraviolet light whilst allowing longer wavelengths to pass through. This "hole" over the Antarctic is created due to the unique chemistry present over the Poles. Most chlorine and bromine (from CFCs and other sources) in the atmosphere is bound in reservoir compounds which render them inert and unable to affect ozone. However, in the presence of the PSCs, complex reactions occur which release active chlorine and bromine from the reservoir compounds.	AIR	CML2000
Photochemical oxidant formation: Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level, where they react with sunlight to produce photochemical smog. One of the components of smog is ozone, which is not emitted directly, but rather produced through the interactions of volatile organic compounds (VOCs) and oxides of nitrogen (NOx). The photochemical oxidant formation index is expressed in g. eq. ethylene.	AIR	CML2000
Water eutrophication: Eutrophication is defined as the enrichment in nutritive elements of waters when referring to human intervention. Oxygen depletion is the possible consequence of such enrichment. The characterisation method used by Ecobilan is based on the method developed by the Centre of Environmental Science (CML), Leiden University, taking into account only the water compartment. It is based on the capacity of a substance to contribute to algae profusion. This contribution is translated into oxygen depletion taking into account the quantity of oxygen consumed when algae decompose. Characterisation factors are given in gram equivalent phosphate.	WATER	CML2000
Toxicity (3 impacts): It is important to consider the potential impact of the FTTH deployment on **human life**, **aquatic life** and **terrestrial life**. However, the toxicity indices that are generated may not necessarily be reported as part of the impact results, but may be tested to compare the results of existing methods. The USES method, used by CML to derive a LCA characterisation method, is considered as an improvement over previous methods. All emissions may participate through all compartments (air to water etc.). Eco-toxicity impacts should be handled with care (see below).	WATER HUMAN	CML2000

7 Comparison of Inventory and Environmental Impact Assessment

7.1 Results and Contribution Analysis

7.1.1 Synthesis of total results

The full inventory and impact assessment results are presented in the following table. These results take into account all the above-mentioned assumptions.

The 3 scenarios have been aggregated. These results are for a deployment scenario made of 60% in urban dense areas, 30% in urban wide areas and 10% in rural areas.

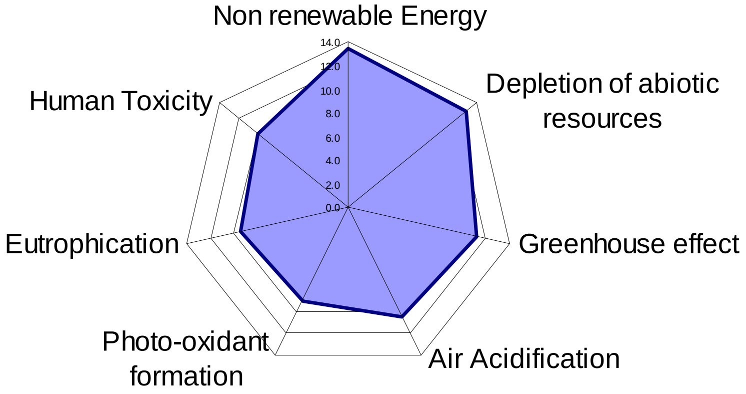
The number of years represents the depreciation of the FTTH network. The impact of FTTH Network deployment takes into account the following stages: production of passive and active equipments, transportation, deployment and end of life. The environment savings are computed as the difference between the benefits drown from the use of the FTTH network and the enrgy required to power the network Environmental savings are represented by one study case of teleworking, home assistance and the three telemedicine.

On the last column, years represent the depreciation of FTTH network. The numbers of years are obtained dividing FTTH network impact by Total savings.

Comparative results	units	FTTH network impact / user	Total savings / user / year	Depreciation of FTTH network (in years)
Resources				
E Total Primary Energy	MJ	14685.78	775.59	18.9
E Feedstock Energy	MJ	8123.21	-0.03	-240737.4
E Fuel Energy	MJ	6567.37	777.14	8.5
E Non Renewable Energy	MJ	10233.10	760.23	13.5
E Renewable Energy	MJ	4452.11	15.36	289.9
CML2000-Depletion of abiotic resources	kg eq. Sb	4.37	0.34	13.0
Air impact				
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2	581248.93	51876.19	11.2
CML2000-Air Acidification	g eq. SO2	2700.21	262.55	10.3
CML2000-Depletion of the strastosphic ozone	g eq.CFC-11	0.15	0.02	9.6
CML2000-Photo-oxidant formation	g eq.ethylene	86.73	9.77	8.9
Water impact				
CML2000-Eutrophication	g eq.PO43-	382.00	40.48	9.4
Toxicity				
CML2000-Aquatic Toxicity	g eq.1,4-DCB	6410.04	549.42	11.7
CML2000-Human Toxicity	g eq.1,4-DCB	42141.80	4278.76	9.8
CML2000-Terrestrial Toxicity	g eq.1,4-DCB	1103.77	64.06	17.2

We can summarize these results on a radar graph which only shows the 7 main representative impacts.

Depreciation of FFTH network (in years)



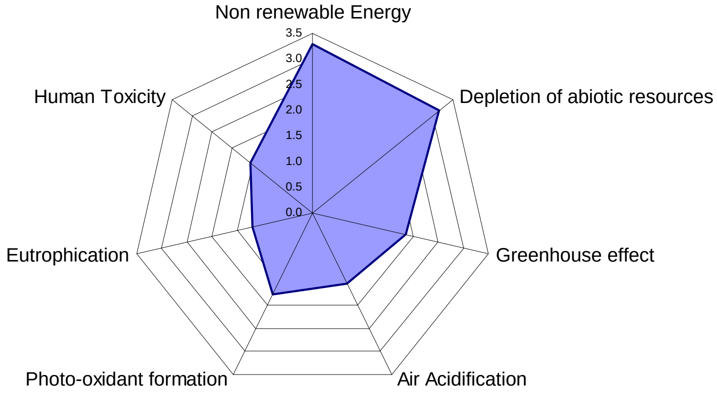
** For a deployment scenario made of 60% in urban dense areas, 30% in urban wide areas and 10% in rural areas*

As a main quantitative finding, the environmental impact of the deployment of a typical FTTH network will be positive in less than 15 years considering only the three selected services (Teleworking, telemedicine and home medical support).

7.1.2 Total results by geographical areas

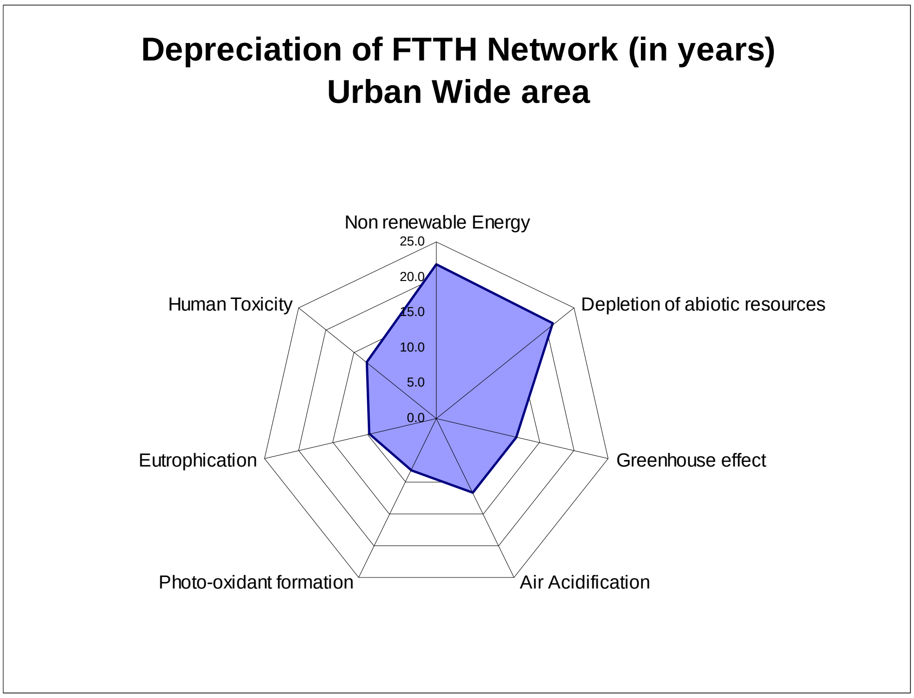
The following graph represents the depreciation of FTTH Network in urban dense area.

Depreciation of FTTH Network (in years)
Urban Dense area



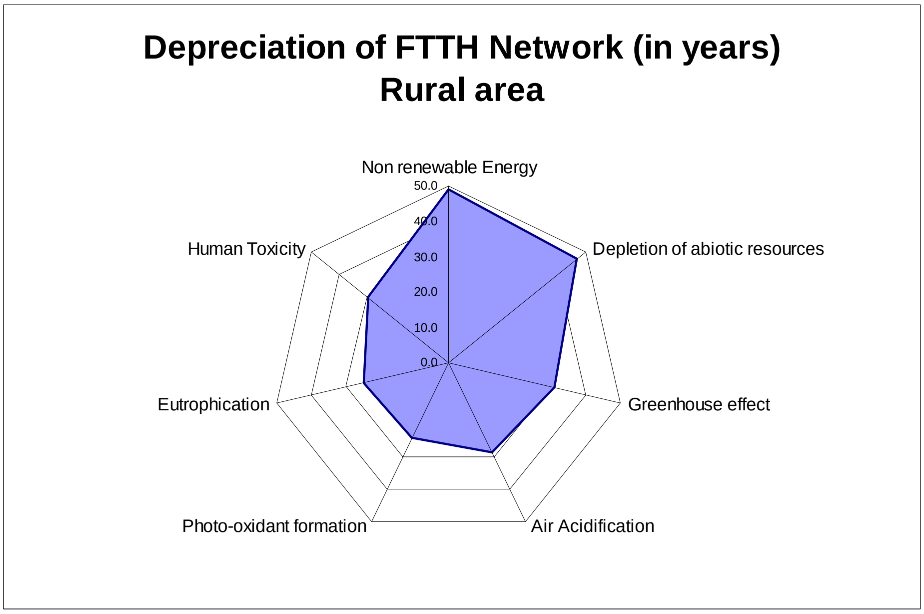
As a main finding, we can see that the deployment of a typical FTTH network will be positive in less than 3.5 years in urban dense area.

The next graph represents the depreciation of FTTH Network in urban wide area.



As a main finding, we can see that the deployment of a typical FTTH network will be positive in less than 25 years in urban wide area.

Finally, the following graph represents the depreciation of FTTH Network in rural area.



As a main finding, we can see that the deployment of a typical FTTH network will be positive in less than 50 years in rural area.

Taking into account the above assumptions, the total savings related to the 3 services are the same in the 3 areas.

The high differences on depreciation between these 3 areas are due to the fact that FTTH network impacts are different in these areas. The key parameter which impacts the deployment of a network is the length of duct per home-passed.

As a reminder, the total distance of outdoor cable in the FTTH network (in m) per user is around 30 m in urban dense area, 100 m in urban wide area and 300 m in rural area.

7.1.3 Detailed results of FTTH network impact per user (excluding use)

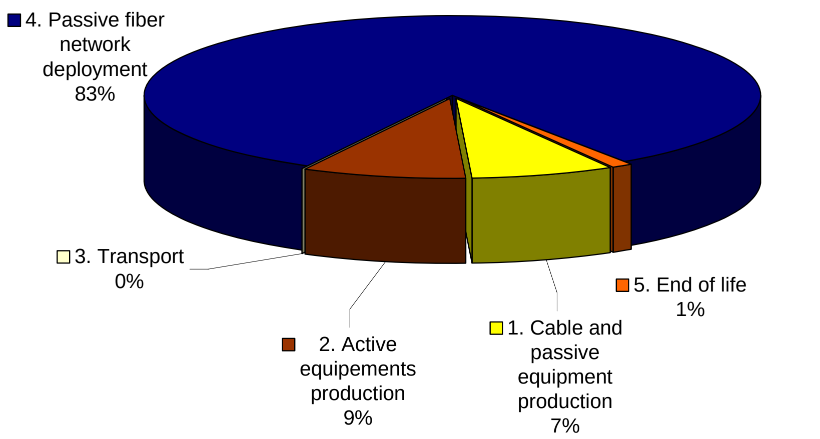
Contribution of different FTTH network life cycle phases

The full life cycle of FTTH network is described on the following table. It has been shared in 6 phases. This table allows understanding the most impacting phases of the full life cycle.

Comparative results	units	FTTH network impact / user	1. Cable and passive equipment production	2. Active equipements production	3. Transport	4. Passive fiber network deployment	5. End of life
Resources							
E Total Primary Energy	MJ	14685.78	1071.66	738.41	11.51	12859.40	4.81
E Feedstock Energy	MJ	8123.21	297.64	216.29	0.00	7609.23	0.06
E Fuel Energy	MJ	6567.37	776.81	522.04	11.51	5252.34	4.67
E Non Renewable Energy	MJ	10233.10	1037.47	729.03	11.50	8450.48	4.62
E Renewable Energy	MJ	4452.11	34.19	9.38	0.01	4408.34	0.19
CML2000-Depletion of abiotic resources	kg eq. Sb	4.37	0.41	0.30	0.01	3.66	0.00
Air impact							
IPCC-Greenhouse effect (direct, 100 years)	G eq. CO2	581248.93	42965.95	50036.78	921.27	480624.94	6700.01
CML2000-Air Acidification	G eq. SO2	2700.21	341.04	80.91	5.55	2270.58	2.13
CML2000-Depletion of the strastosphic ozone	G eq.CFC-11	0.15	0.01	0.00	0.00	0.15	0.00
CML2000-Photo-oxidant formation	G eq.ethylene	86.73	5.00	15.97	0.10	65.47	0.19
Water impact							
CML2000-Eutrophication	G eq.PO43-	382.00	16.43	7.59	1.33	355.84	0.81
Toxicity							
CML2000-Aquatic Toxicity	G eq.1,4-DCB	6410.04	364.00	503.52	18.16	5144.70	379.66
CML2000-Human Toxicity	G eq.1,4-DCB	42141.80	6716.48	270.79	84.98	34883.65	185.89
CML2000-Terrestrial Toxicity	G eq.1,4-DCB	1103.77	175.35	182.67	0.98	588.49	156.28

The deployment phase is predominant and represents, for each impact, approximately 80% of the total impact of FTTH network.

The next graph focuses on the impact of greenhouse gas emissions during the life cycle. It allows understanding better the relative contribution of each phase.



As shown, passive fibre network deployment represents 83% of the total impact. In particular, the key impacting parameter over the carbon emissions is the length of new ducts (meters) per home passed.

Deployments impacts comparison for deploying 1km of FTTH network

As a reminder network deployment phase is an aggregation of 4 types of deployment. The following table shows impacts comparison between these 4 deployments for 1 km of FTTH network.

Comparative results	units	Microtrench	Traditional civil work	Poles	Existing
Resources					
E Total Primary Energy	GJ	198.02	229.43	305.91	5.52
E Feedstock Energy	GJ	22.04	131.36	268.01	2.65
E Fuel Energy	GJ	176.22	98.00	37.90	2.87
E Non Renewable Energy	GJ	191.57	228.37	39.77	5.49
E Renewable Energy	GJ	6.42	1.05	266.14	0.04
CML2000-Depletion of abiotic resources	t eq. Sb	0.07	0.10	0.02	0.00
Air impact					
IPCC-Greenhouse effect (direct, 100 years)	kg eq. CO2	18 888.81	7 267.89	3 029.18	196.86
CML2000-Air Acidification	kg eq. SO2	73.35	51.40	6.62	1.32
CML2000-Depletion of the strastosphic ozone	kg eq.CFC-11	0.01	0.00	0.00	0.00
CML2000-Photo-oxidant formation	kg eq.ethylene	1.48	1.32	1.13	0.02
Water impact					
CML2000-Eutrophication	kg eq.PO43-	13.21	7.52	0.86	0.17
Toxicity					
CML2000-Aquatic Toxicity	kg eq.1,4-DCB	166.65	117.67	10.47	2.49
CML2000-Human Toxicity	kg eq.1,4-DCB	1 228.80	699.26	35.22	18.80
CML2000-Terrestrial Toxicity	kg eq.1,4-DCB	15.76	13.04	0.82	0.87

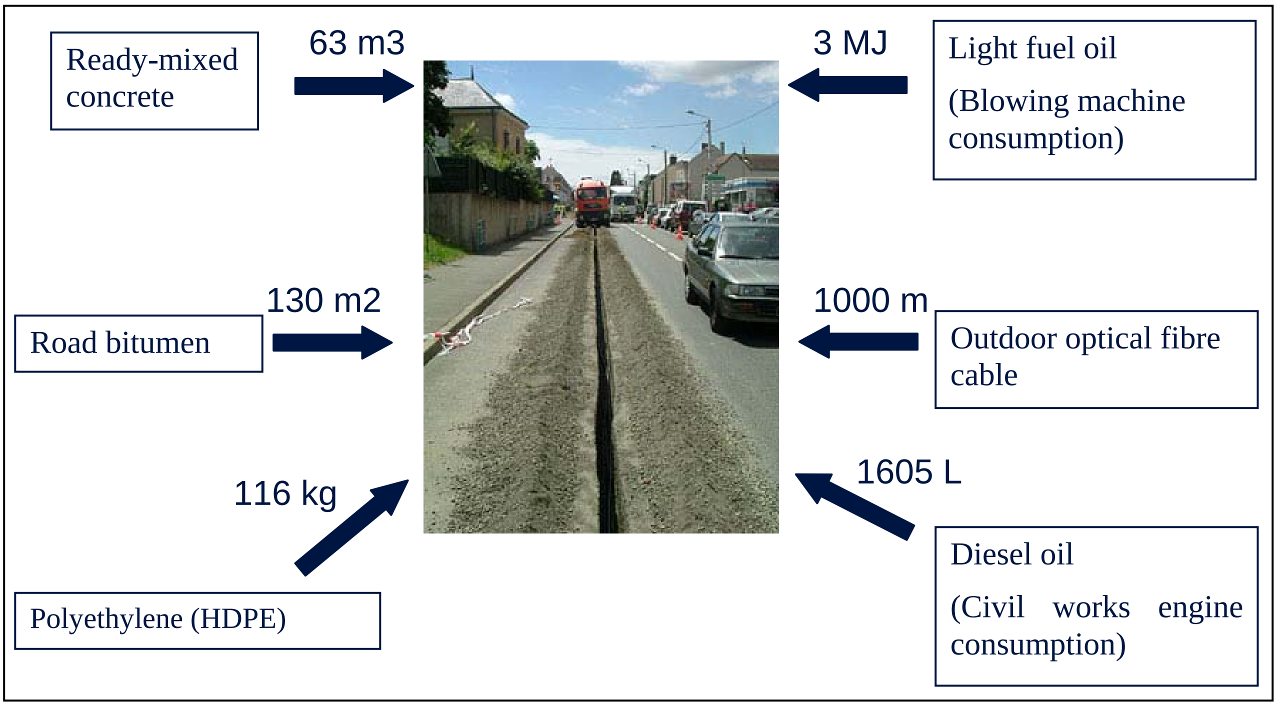
Regarding the Total Primary Energy impact, poles deployment has the biggest impact.

However, regarding the climate change impact, microtrench deployment is higher than poles and traditional civil works.

It is obvious that existing ducts deployment has a neglected impact compare to the other deployments.

Microtrench deployment detailed results

As an example, we have chosen to describe on the next picture the modelling of the deployment of 1 km of microtrench:



On the next table, we can see the relative contributions of the different inputs of Microtrench on the 7 main representative impacts.

Comparative results	units	4.1 Microtrench	Concrete production (m3)	High Density Polyethylene (HDPE) production	Road production and deployment (1m²)	Road Transport (Diesel Oil, litre)	Light Fuel Oil combustion	Electricity (European Union,2002) production
Resources								
E Total Primary Energy	MJ	3261.92	54%	4%	12%	29%	0%	0%
CML2000-Depletion of abiotic resources	kg eq. Sb	1.25	44%	4%	15%	36%	0%	0%
Air impact								
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2	300962.41	71%	1%	2%	26%	0%	0%
CML2000-Air Acidification	g eq. SO2	1181.60	54%	1%	6%	39%	0%	0%
CML2000-Photo-oxidant formation	g eq.ethylene	23.79	56%	3%	4%	36%	0%	0%
Water impact								
CML2000-Eutrophication	g eq.PO43-	210.58	44%	0%	2%	54%	0%	0%
Toxicity								
CML2000-Human Toxicity	g eq.1,4-DCB	19871.43	57%	0%	7%	36%	0%	0%

Taking into account only the climate change impact, we observe that the concrete production represent the main part of the total microtrench climate change impact.

The second contribution is the consumption of diesel oil used for civil work engine (26%).

7.1.4 Detailed results of use associated to FTTH network

The Total use for 1 year are presented in the following table. It represents the savings associated to the 3 services taken into account during 1 year minus the network power consumption for 1 year.

Comparative results	units	Total savings for 1 year	1 year savings associated to services	Network power consumption for 1 year
Resources				
E Total Primary Energy	MJ	775.59	1528.62	753.03
E Feedstock Energy	MJ	-0.03	-0.03	0.00
E Fuel Energy	MJ	777.14	1534.46	757.32
E Non Renewable Energy	MJ	760.23	1469.99	709.76
E Renewable Energy	MJ	15.36	58.62	43.26
CML2000-Depletion of abiotic resources	kg eq. Sb	0.34	0.61	0.27
Air impact				
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2	51876.19	87042.35	35166.16
CML2000-Air Acidification	g eq. SO2	262.55	494.61	232.06
CML2000-Depletion of the strastosphic ozone	g eq.CFC-11	0.02	0.02	0.00
CML2000-Photo-oxidant formation	g eq.ethylene	9.77	14.59	4.82
Water impact				
CML2000-Eutrophication	g eq.PO43-	40.48	49.35	8.87
Toxicity				
CML2000-Aquatic Toxicity	g eq.1,4-DCB	549.42	910.44	361.02
CML2000-Human Toxicity	g eq.1,4-DCB	4278.76	10691.17	6412.42
CML2000-Terrestrial Toxicity	g eq.1,4-DCB	64.06	181.99	117.94

The contributions of the different services above-mentioned in assumptions are described on the following table.

Comparative results	units	Services savings for 1 year	Telework savings (3days/week)	Imaging transfer savings	Teledialysis savings	Telestaff savings	Home-medical support savings
Resources							
E Total Primary Energy	MJ	1528.62	1483.45	0.07	7.58	0.10	37.41
E Feedstock Energy	MJ	-0.03	-0.03	0.00	0.00	0.00	0.00
E Fuel Energy	MJ	1534.46	1489.29	0.07	7.58	0.10	37.41
E Non Renewable Energy	MJ	1469.99	1424.85	0.07	7.58	0.10	37.39
E Renewable Energy	MJ	58.62	58.60	0.00	0.00	0.00	0.02
CML2000-Depletion of abiotic resources	kg eq. Sb	0.61	0.59	0.00	0.00	0.00	0.02
Air impact							
IPCC-Greenhouse effect (direct, 100 years)	g eq. CO2	87042.35	83553.67	5.23	585.83	7.70	2889.92
CML2000-Air Acidification	g eq. SO2	494.61	478.62	0.02	2.69	0.04	13.25
CML2000-Depletion of the strastosphic ozone	g eq.CFC-11	0.02	0.02	0.00	0.00	0.00	0.00
CML2000-Photo-oxidant formation	g eq.ethylene	14.59	13.88	0.00	0.12	0.00	0.59

Water impact							
CML2000-Eutrophication	g eq.PO43-	49.35	46.05	0.00	0.55	0.01	2.73
Toxicity							
CML2000-Aquatic Toxicity	g eq.1,4-DCB	910.44	873.14	0.06	6.26	0.08	30.90
CML2000-Human Toxicity	g eq.1,4-DCB	10691.17	10511.54	0.27	30.16	0.40	148.80
CML2000-Terrestrial Toxicity	g eq.1,4-DCB	181.99	179.98	0.00	0.34	0.00	1.67

It is obvious that Teleworking represent almost 100% of the total benefits but only 3 study cases of telemedicine have been taken into account and we can consider that FTTH network provides a lot of other telemedicine services.

7.1.5 Other benefits

Beyond its environmental-friendly aspects, FTTH solutions offer additional social and economical benefits.

Moreover, FTTH networks can contribute to other fields not assessed in the present study (see also DG JRC report "The future impact of ICTs on environmental sustainability"):

- Energy demand;
- Supply chain management;
- E-commerce (see also appendix IV);
- Tele-meetings;
- Dematerialised products and services;
- Intelligent Transport Systems;
- Facility management;
- Production progress management;
- Improve service and product utilisation.

8 Conclusion

As a main quantitative finding, the environmental impact of the deployment of a typical FTTH network will be positive within less than 15 years in average considering only the three selected services.

Further either existing or developing applications will emphasize these results.

Beyond their environmental-friendly aspects, FTTH solutions can offer considerable additional social and economical benefits.

If we admit the fact that we are in the middle of a new industrial era, FTTH solutions are a key sustainable utility driver in this context.

The sustainability of FTTH solutions will be clearly demonstrated when:

> Users' experience grows

> Bottlenecks such as network vertical and horizontal accesses are removed.

In the present study we consider an overall approach of FTTH alternative networks and associated services. In particular, we consider PON and Point to Point configurations using aggregated data.

For the first 15 years of a given network deployment, greenhouse gas emission savings per user are approximately 330 kg eq. CO_2 or the equivalent of the emissions caused by a car travelling 2,000 kilometres.

For the next 15 years the savings are 780 kg eq. CO_2 or the equivalent of a car travelling 4,600 kilometres. This is due to the fact that the network is depreciated and only part of the infrastructure needs to be renewed.

The study is based on global European inputs and environment. An ecodesign approach can be adopted on a network basis. The scope can be extended to other geographical contexts (US and Asia through local FTTH Councils) or to specific local deployments.

FTTH network solutions represent a responsible investment for:

- Operators
- Public bodies
- Shareholders
- Utilities

… and provide decisive leverage to policy makers.

Appendices

Appendix I: Bibliographical data used (Raw materials)

Appendix II: Bibliographical data used (Energy and transport)

Appendix III: Electricity model used

Appendix IV: Bibliographical elements on the environmental impact of E-commerce

Appendix I: Bibliographical data used (raw materials)

Name	Sources
_241I Silicone Rubber: Production	Confidential : SRI report160, June 1983
_261 Glass Drop (White): Production	BUWAL (Bundesamt für Umwelt, Wald und Landschaft) n°250 Bern, 1996 Page 102-103
_900 SILICA: Inscineration	WISARD module 2007
_BPE: Production (m3)	SNBPE 2007
_road 1 m2	Bitumen production: Eurobitume Mise en oeuvre: European civil works company
020I Wood (55% dry): Supply	Ecobilan data
141I Limestone ($CaCO_3$): Quarrying	Buwal 250 (Bundesamt für Umwelt, Wald und landschaft) Ökoinventare in Verpackungen Band II Bern, 1996 page: 463
142I Kaolin ($Al_2O_3.2SiO_2.2H_2O$): Mining	BUWAL 250 (office federal de l'environnement des forets et du paysage) Volume II: inventaires ecologiques relatifs aux emballages Berne, 1996 page 447
145I Perlite (SiO_2, ore): Mining	Data from one European site.
211 Cardboard (Recycled, Grey Board): Production	BUWAL (Bundesamt für Umwelt, Wald und Landschaft) n°250 Band II: Ökoinventare für Verpackungen Bern, 1996 Page 254-255.
241 Carbon Dioxide (CO_2): Production	Confidential data aggregated with upstream processes in order to preserve confidentiality
241 High Density Polyethylene (HDPE, Europe, 2005): Production	Ecoprofiles of the European plastics industry Polyolefins p19-25 I.Boustead PlasticsEurope, Brussels, March 2005 available on web site: http://www.PlasticsEurope.org
241 Hydrochloric Acid (HCl, 100%): Production	ELF ATOCHEM expertise, Mr. Lecouls' letter of 25 July 1997
241 Polypropylene (PP, Moulded by Injection): Production	Ecoprofiles of plastics and related intermediates I.Boustead APME, Brussels, 1999 available on web site: http://www.apme.org
241 Polyvinyl Chloride (PVC, Moulded by Injection): Production	Ecoprofiles of the European plastics industry PVC Conversion Processes Pages 34 to 41 I.Boustead APME, Brussels, October 2002 available on web site: http://www.apme.org
241 Sodium Hydroxide (NaOH, 100%): Production	Eco-profiles of the European plastics industry (APME) Polyvinyl Chloride I.Boustead Brussels, September 2002 Page: 50 à 55
241I Acrylic Resin: Production	BUWAL n°232 Comparative environmental evaluation of construction paints and varnishes Volume 2: data Bern , 1994 Page: 84-85
241I Argon (Ar): Production	Laboratorium für Energiesysteme ETH (Eidgenössische Technische Hochschule Zurich) Zurïch, 1996 Page 106
241I Boric Acid (H_3BO_3): Production	Confidential site data (1992)

241I Nitrogen (N2): Production	Swiss Federal Office of Environment, Forests and Landscape (FOEFL or BUWAL) Environmental Series No. 132 Bern, February 1991 page A59
241I Oxygen (O2): Production	Swiss Federal Office of Environment, Forests and Landscape (FOEFL or BUWAL) Environmental Series No. 132 Bern, February 1991 page A59
241I Polyester Resin: Production	Confidential data - SRI
241I Sodium Sulphate (Na2SO4): Production	BUWAL 250 (office federal de l'environnement des forets et du paysage) Volume II: inventaires ecologiques relatifs aux emballages page 458 Primary source: Sodium sulfates. Ullmann's Encyclopedia of Industrial Chemistry. A24, 1993:355-368
241S Polyester Resin: Production	Confidential data - SRI
241S Silica (SiO2): Production	Data from one European site.
261S Glass Fibre (Continous Wire Mast): Production	Confidentiel site data (1992)
266I Concrete: Production	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 3, Basismaterialieren Page 51 Primary source: T.Weibel, \' Vergleichende Umweltrelevanz des Einsatzes alternativer Kältemittel in Kompressions-Wärmepumpen und Kälteanlagen\' , Bundesamt für Energiewirtschaft, Bern 1996
271 Primary Steel: Production (IISI)	IISI study for European production 1996 data
900 Polyethylene (PE): Incineration	Buwal 250 (Bundesamt für Umwelt, Wald und Landschaft) Ökoinventare für Verpackung: Band II Bern, 1996 page 433 primary source: Doka G., Huber F., Labhardt A., Menard M., Zimmermann P., Ökoinventare von Entsorgungprozessen-Grundlagen zur Integration der Entsorgung in Ökobilanzen, ESU-Reihe 1/96; Institut für Energietecknik, Gruppe Energie-Stoffe-Umwelt, ETH Zürich, 1996.
900 Polyethylene (PE): Landfill	Buwal 250 (Bundesamt für Umwelt, Wald und Landschaft) Ökoinventare für Verpackung: Band II Bern, 1996 page 433 primary source: Doka G., Huber F., Labhardt A., Menard M., Zimmermann P., Ökoinventare von Entsorgungprozessen-Grundlagen zur Integration der Entsorgung in Ökobilanzen, ESU-Reihe 1/96; Institut für Energietecknik, Gruppe Energie-Stoffe-Umwelt, ETH Zürich, 1996.

Appendix II: Bibliographical data used (Energy and transport)

Name	Sources
Road Transport (Gasoline, litre)	1) Gasoline production Swiss Federal Office of Environment, Forests and Landscape (FOEFL or BUWAL) Environmental Series No. 132 Bern, February 1991, page A9 2) Gasoline combustion European Car Manufacturer
Diesel Oil: Engine Combustion	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 3, Anhang B: Transport und Bauprozesse Page 56 primary source: 1) Bundesamt für Umwelt , Wald und landschaft, \'Schadstoffemissionen und Treibstoffverbrauch von Baumaschinen\', Synthesebericht, Umwelt-Materialieren Nr 23 Luft, Bern 1994. 2) Bundesamt für Strassenbau , \'Infromation Schweizerische Nationalstrassen\', Bern 1992
Road Transport (Diesel Oil, litre)	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Anhang B: Strassengutertransport Page 22. Primary source: M.Maïbach, D.Peter, B.Seilen \'Okoinventar Transport; Grundlagen fûr den ôjologischen Vergleich von Transportsystem und fûr den Einbezug von Transportsystem in ökobilanzen\', SPP Umwelt, Modul 5, Infras Zurîch, 1995.
Diesel Oil: Engine Combustion	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 3, Anhang B: Transport und Bauprozesse Page 56 primary source: 1) Bundesamt für Umwelt , Wald und landschaft, \'Schadstoffemissionen und Treibstoffverbrauch von Baumaschinen\', Synthesebericht, Umwelt-Materialieren Nr 23 Luft, Bern 1994. 2) Bundesamt für Strassenbau , \'Infromation Schweizerische Nationalstrassen\', Bern 1992
Sea Transport (Freighter, kg.km)	Swiss Federal Office of Environment, Forests and Landscape (FOEFL or BUWAL) Environmental Series No. 32 Bern, February 1991. pages A16, A8 (precombustion) Adaptation covers CO2, methane, N2O emissions (Ecobilan Data).
Diesel Oil: Production	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 1, Erdol Page 173-174 Primary source: 1) Schmidt K.H, Romey I, \'Kohle, Erdöl, Erdgas; Chemie und Technik\', Würzburg 1981. 2) Concawe (Hrsg.), \'quality of aquous effluents from oil refineries in western europe\', Concawe report n°84/53, Brussels 1984 3) Concawe (Hrsg.), \'oil refineries waste survey -disposal methods, quantities and costs\', Concawe report n° 5/89, Brussels 1989. 4) Concawe (Hrsg), \'Performance of Oil Industry Pipeline in Western Europe Statistical Summary of Reported Spillages-1994\', Concawe report n° 4/95, Brussels 1995 5) <Raffoil 1991> Vertrauliche Informationen einer modernen, westeuropaischen Raffinerie, 1991.
Electricity (European Union, 2002): Production	1) For combustion of coal, lignite, heavy fuel oil, natural gas, process gas: Laboratorium für Energiesysteme ETH, Zurich, 1996 2) for breakdown efficiencies: Electricity Information 2004 IEA Statistics International Energy Agency
Heavy Fuel Oil: Combustion	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 1, Erdol Page 219-220
Natural Gas: Combustion	Laboratorium fur Energiesysteme ETH, Zurich, 1996 Teil 1, Erdgas Page 66-67

Appendix III: Assumptions on electricity production in the European Union

The electricity production grid for Europe is based on the International Energy Agency "Electricity information" report of 2004 and corresponds to 2002 data.

The data for Europe are representative of the average production in European Union, based on the gross electricity production of each of the 25 countries except for Cyprus, Estonia, Latvia, Lithuania and Malta.

Table 1 - Electricity grid for Europe in 2002

	UE (25) (2002)
Coal	30.75%
Process gas	
Fuel oil	5.87%
Natural gas	17.35%
Nuclear	31.80%
Geothermal	0.16%
Solar	0.01%
Renewable fuels	1.95%
Hydro	10.85%
Tide	0.02%
Wind	1.20%
Other	0.04%

Appendix IV: Bibliographical elements on E-commerce

Three studies (Gay et al. 2005, Matthews and Hendrickson 2001, Williams and Tagami 2003) suggest that there is no clear difference between the energy and CO_2 emissions associated with the sale of tangible goods via traditional and e-commerce methods:

Traditional sales consume less energy when:

- Population density is high: consumers live close to stores
- Consumer transport is minimal: mass transportation more often used to shop
- Distribution:
    - E-commerce would involve air transportation
    - Traditional distribution to retail store is very efficient (high load factor and energy efficient vehicles)
- Packaging: E-commerce would require heavy external and substantial internal packaging
- Retail inventory is low: the floor space dedicated to the storage and display of the products is low

E-commerce sales consume less energy when:

- Population density is low: consumers live far from stores
- Consumer transport is significant: the consumer drives the car to the store
- Distribution:
    - E-commerce would involve ground transportation only
    - Traditional distribution to retail store is inefficient (low load factor and standard vehicles)
- Packaging: E-commerce requires only light packaging (e.g. light corrugate or Tyvek bag)
- Retail inventory is high: significant floor space is dedicated to the storage

The high majority of E-commerce sales are of tangible goods.