D4.2 - Draft LCA report

Advanced Sensing Technologies for Paper Production (ASTEPP)

CIP Eco-innovation
Pilot and market replication projects

Call 2013

Call Identifier: CIP-EIP-Eco-Innovation-2013

Contract ECO/13/630333

Customer	**OMISS**
Address	**OMISS** **OMISS** **OMISS** **France**

Client:	**S.A. GIUSEPPE CRISTINI S.p.A.**
Re:	ASTEPP sensors application Life Cycle Assessment
Description:	Estimate of environmental loads while creating a paper product using innovative ASTEPP technology and comparing results with current production processes.
Issued by:	NEMOTEC SRL – Via Variante Aurelia 173 – Sarzana (SP)
Doc. code:	LCA_07_16

History of Revisions

Rev.	Object	Date
00	Issue	19 02 2016
-	-	-
-	-	-

CONTENTS

1. Introduction

The paper production phase is a high energy-consuming process; to transform the raw material, pulp and water into the semi-finished paper product, huge amounts of water and thermal, electrical and mechanical energy are required.

The ASTEPP sensors, offered by Cristini on the European market, allow some of the main operating parameters of paper machines to be monitored, thereby allowing the client companies to distinguish their production process according to the acquired parameters.

Thanks to the monitoring and evaluation of these data, the production process itself can be made efficient by setting the machines correctly. In fact, substantial energy and water savings can be obtained (heat, electricity, water).

This saving of energy flows as highlighted in the analysis of this document, obviously also affects the environmental emissions of the production process itself in a positive way.

Starting with the analysis of the data acquired by OMISS during a series of tests carried out on OMISS paper mill, this document indicates the assessment of the improvements on the environmental impacts that occur in the production process of corrugated board, if properly monitored and set using the data read by the Cristini ASTEPP sensors.

In particular, as required in the "Project information sheet" guide, issued by Eco Innovation, this document analyses aspects related to:

- ✓ "Reduction on Green House effect Gas emissions (GHG)";
- ✓ "Water usage reduction";
- ✓ "Reduction of energy consumption".

2. Reference documentation

Below are the documents, applicable standards and guidelines that have been used as references when executing this analysis.

Document code	**Name**	**Issued by**
UNI EN ISO 14040	Environmental management - Life cycle assessment - Principles and reference framework	UNI
UNI EN ISO 14044	Environmental management - Life cycle assessment - Requirements and guidelines	UNI
V2011-06-LCA	The Italian LCA network: Prospects and developments of the life cycle assessment in Italy	ENEA
1521453	Rapport de verification des declarations d'emissions des gaz a effet	APAVE
27/01/2016	Astepp OMISS project	OMISS
	Plant water consumption (data validated by DREAL)	OMISS
	Electricité 2014 usage : Industrie base – consummation	ADEME

3. Acronyms

Following are the acronyms that may be found in this document.

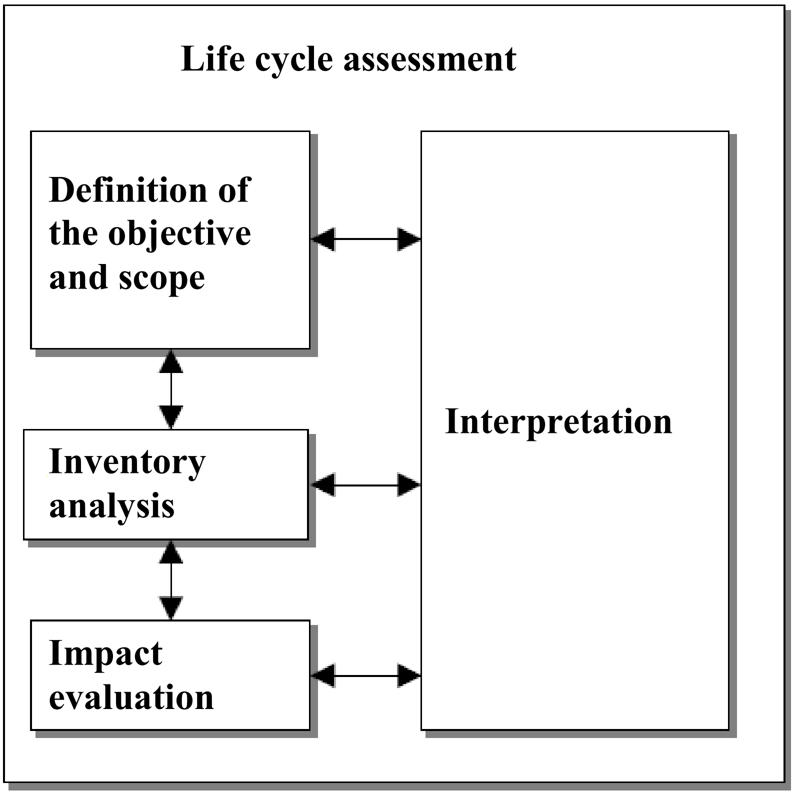
CML	Centrum Milekunde Leiden University
ENEL	Italian national authority for electricity
GHG	Reduction on Green House effect Gas emissions
GJ	GigaJoule
GWP	Global Warming Potential
KWh	kilowatt hour
L	Litre
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LCI	Life Cycle Inventory
m^3	Cubic metres
Min	Minute
t	Ton

4. Brief Introduction of the LCA analysis

The Life Cycle Assessment is a technique of analysis, whose objective is to estimate the environmental loads of products and services through the evaluation of the life cycle of components or particular phases of use and application. The LCA technique in fact is recognised as one of the "official" methods for the environmental impact assessments. It was created and designed to provide scientific and quantitative information, thereby increasing awareness of the company with respect to the entire life cycle and the use of its devices. The LCA evaluates all the resources and the inputs required to "feed" the system being analysed, from an environmental aspect, and all the output flows from the system itself, that is to say the emissions in air, water and soil, etc. The applications and uses of a Life Cycle Assessment are very varied and can range from the entire life cycle of a product to a single process.
The data on the elementary flows of energy/resources, cover the extraction of raw materials to the disposal/recycling/final recovery of the product being studied.
This study refers to the principles and guidelines of an LCA, applying them to the specific field of analysis, as described in the following chapters.

The LCA analysis consists of 4 basic steps:

1. definition of the objective;
2. inventory analysis;
3. impact assessment (LICIA);
4. final interpretation of the results.

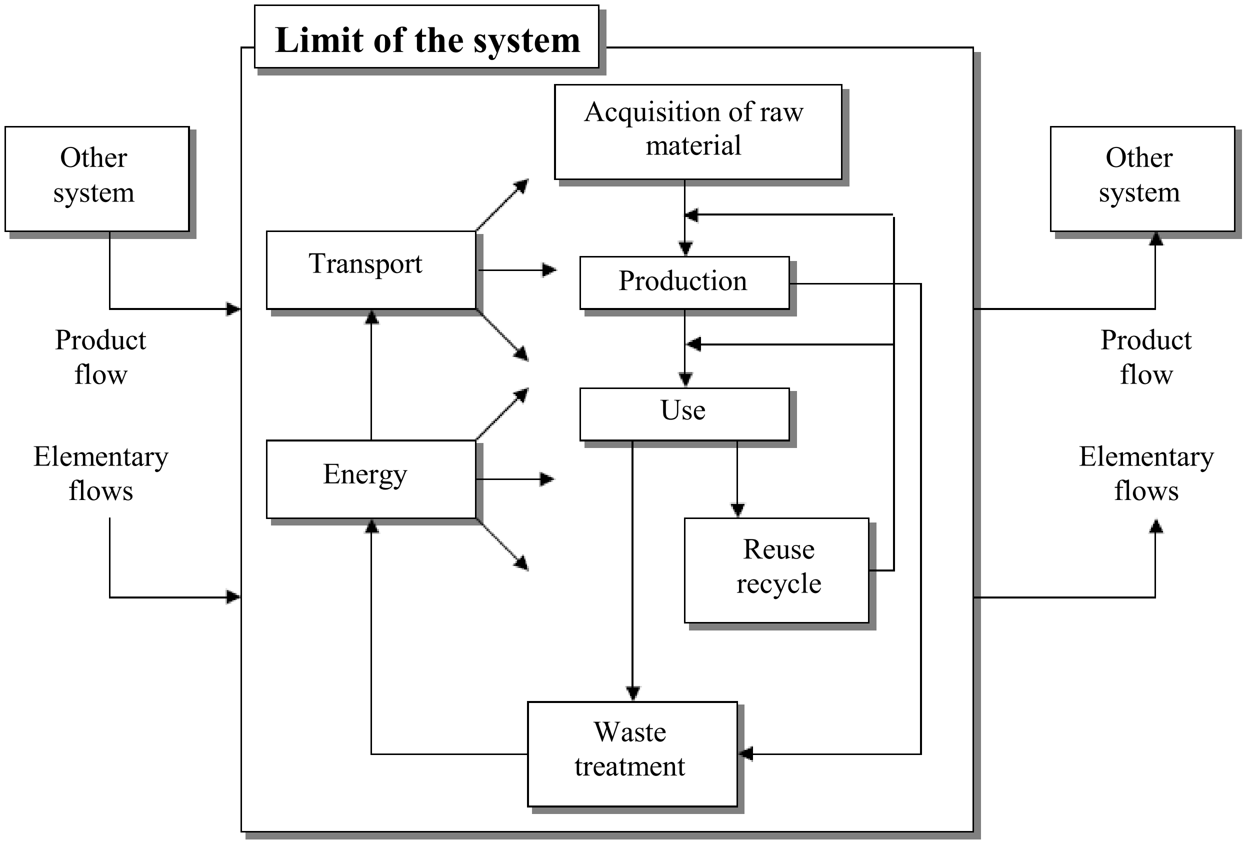


4.1. Definition of the objective

This is the first step of the LCA and requires the purposes of the study to be defined together with those of the functional unit, the system limits, recruitment, etc.
The following steps are carried out in this phase:

- Define the reasons and objectives of the analysis;
- Define the intended application;
- Define the limits of the system being studied;
- Define what can be considered as functional units and/or reference flows.

The choice of function and corresponding functional unit is significant on the entire study and the results obtained. The functions refer to the characteristic performance of the product, whereas the functional unit must quantify this performance, relating all the incoming and outgoing flows of material and energy. For example, in the study of a paper mill, the function is the production of paper and the functional unit is represented by a certain amount of paper produced (for example, a ton).
The product system is defined as an elementary set of process units that are interlinked by flows of material, energy and waste.
Under ideal conditions, the product system should be configured for the incoming and outgoing elementary flows (when materials and energy enter and leave the defined system without any prior transformation made by man).
The limits of the product system determine the process units to be included in the study and are determined by the assumptions used, the constraints due to the sources of the data and the scope of the analysis.



The system in turn is divided into process units, which are also interconnected by intermediate flows of material and energy and flows of waste to be treated. The product system can also be connected to another product system by flows of products and with the environment by elementary flows.

4.2. Inventory analysis

Data collection, their measurement and processing helps quantify inputs and outputs of each process unit. The most important categories in which data should be classified are:

- input of energy, raw materials, secondary support material, etc.;
- products;
- emissions in air, water, soil and other environmental aspects.

The data must have suitable quality requirements to support the LCA study. They are obviously inventory data that give accuracy and objectivity to the analysis. The following requirements should be considered during the data collection and sampling:

- temporal coverage, that is the age of the data and the duration of their collection;
- geographical coverage, that is the area where data will be collected;
- technological coverage, that is the technology to be applied in the data collection.

4.3. Evaluation of the impacts

The evaluation of the impacts in an LCA study is the phase in which the relevance of the environmental impacts is evaluated, associating inventory data with specific impacts and deepening the study. The level of detail, the impacts that are to be evaluated and the methods used, depend on the objective and the scope.
The evaluation generally consists of three steps:

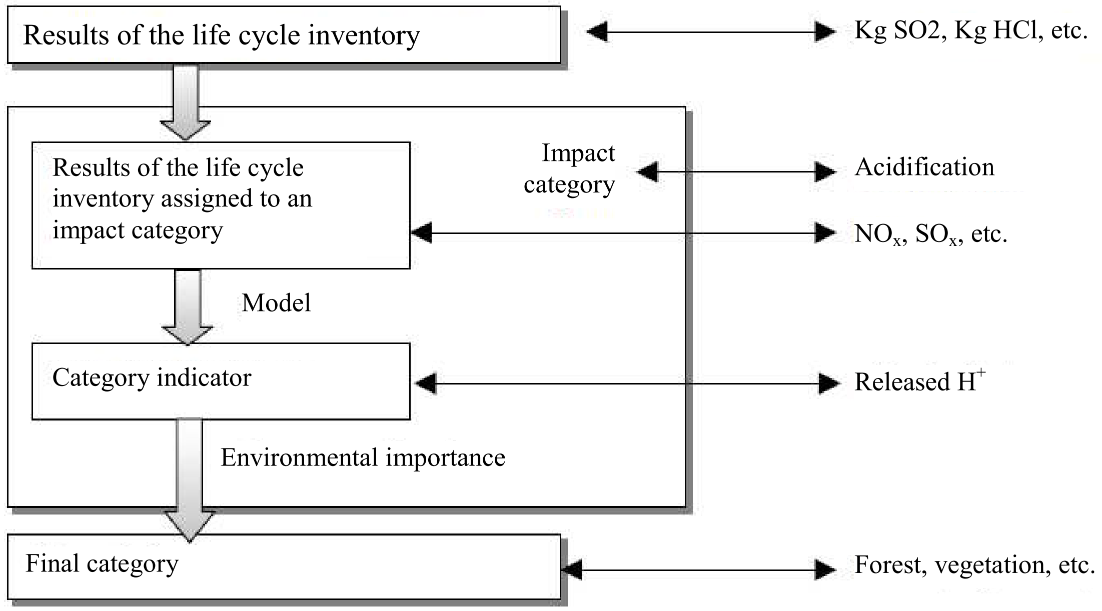
- classification, in which the inventory data are attributed to the individual impact categories;
- characterisation, in which the data within each category are weighed;
- normalisation, in which the impact categories are weighed.

It is important to consider that the evaluation is influenced by a certain amount of subjectivity in the choice of impact categories as well as, but especially, in the characterisation and weighting.

Classification is the phase in which the inventory data of the life cycle are distributed in the various impact categories. Each input and output can be included in one or more impact category and the choice depends on the objective of the study.

During characterisation, the environmental impact of the data obtained during the inventory phase is analysed and quantified, and aggregated in the impact categories with the classification. The result of the calculations is a numerical indicator, called a category indicator. The usefulness of the results of the indicators depends on the accuracy, validity and characteristics of the characterisation factors and models. The indicator results are calculated by using characterisation factors to convert the results of the inventory, assigned to the impact categories, in common units.

The results of the indicators are normalised by attributing a weight to the various data within the same impact category, in order to highlight the relevance of each result of the indicator, relative to a given reference flow.
In practice, the procedure transforms the result of the indicator by dividing it by a selected reference value.



Results of the life cycle inventory
Kg SO2, Kg HCl, etc.
Results of the life cycle inventory assigned to an impact category
Impact category
Acidification
NOx, SOx, etc.
Model
Category indicator
Released H+
Environmental importance
Final category
Forest, vegetation, etc.

4.4. Conclusions

The interpretation of the life cycle is the final phase of the LCA, which summarises and discusses the results of the inventory phase and assessment of the impacts. The aim is to draw conclusions and recommendations in order to make decisions in accordance with the objective and the scope of the study.
Significant aspects can be:

- the inventory parameters such as energy use, emissions, waste, etc.;
- the indicators of the impact categories such as use of resources, potential increase in temperature (GPW), etc.;
- the essential contributions so that the life cycle stages provide the results of the inventory or impact evaluation, either as an individual process unit or process groups, in terms of energy production and transport.

There are a variety of specific approaches, methods and tools to identify the environmental aspects and to determine their meaning.

5. ASTEPP sensors

5.1. Definition of the objective - ASTEPP Sensors

In this analysis, starting with the data obtained by OMISS, the evaluation of possible improvements has been carried out in terms of environmental impact and the ASTEPP sensors could lead to the paper production process. The improvements that can be obtained by monitoring the production process by means of the sensors being analysed have been evaluated and by optimising the operating parameters of the production line of a paper mill.
In particular, it's possible to obtain an energy saving with a runnability improvement. During paper production, there are paper breaks due to a bad parameters setting (i.e. humidity, speed, cylinders temperature etc) that lead to a loss of energy and resources.

Considering that Cristini ASTEPP sensors do not alter the quality of the final product or the chemical-physical characteristics of the product itself and the waste products of the production line in any way, and do not either alter the paper production process (limited to allowing for the optimisation of some operating parameters, which are normally "set" according to the operator's decisions and therefore, are totally subjective).

It is important to note that the analysis presented here is not intended to quantify all the individual contributions during the life of the "paper" product in terms of impacts on the environment, but in fact, only possible improvements are highlighted, which the ASTEPP sensors allow, limited to their operation and application, as detailed in the following chapters .

In order to quantify these improvements in terms of environmental impacts, it has been decided to analyse the process and to characterise the impacts through the typical CML model of the LCA analyses. In fact, the CML methodology provides results according to known impact categories measured in equivalent substance units.

5.1.1. Functional unit

This work considers the industrial production of paper used for production of corrugated board. The production of paper is defined as a function of the industrial system, whereas the functional unit is represented by a certain amount of paper produced, specifically a ton.

The composition and the main characteristics that define the paper relative to the functional unit in question are described below (a ton of corrugated board producted).

Characteristics	Values
Mixture	100% waste paper
Weight	80-120 g/m^2
Humidity	7,5%

Table 5.1 Features of the functional unit

5.1.2. Limits of the system

The process of production of the corrugated board within a paper mill is performed by the manufacturing lines, commonly called continuous lines, which manage the step of complete realization, from the entrance of the pulp in the plant up to the exit of the finished product from the pope. Cristini ASTEPP sensors monitor a sub-step of the production process within the continuous line.

The limits of the system referred to in the study include a sub-step of the production system of the corrugated board . In particular, the productive sub-system is analysed from when the mixture of water and pulp, previously prepared and refined, is sprayed on the sheet, to the output phase of the finished product (pope roller area).

The analysis therefore, is gate to gate type and only considers that which remains within the gates of the company and the identified system, excluding the upstream and downstream stages of the process and the procurement and distribution of the product.

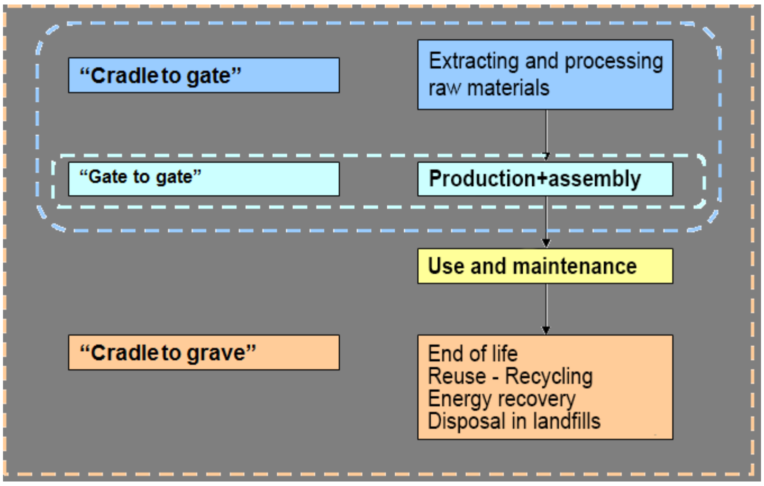


Figure 1 Settings of the limits of the system

Energy/raw material/emission flows, relating to the auxiliary systems of the process in question are included in the product system, with reference to the data published by OMISS and APAVE for the years 2014-2015 and relevant to the aspects on the "Reduction on Green House effect Gas emissions (GHG)", "Reduction of water usage" and "Reduction of energy consumption".

The limits of the system do not include:

- Production pulp, additives and fuels ancillary to the process;
- Production of packaging and transport;
- Use;
- Recycling/disposal of paper, of waste and of any residue in the production process of the continuous line;
- All the activities upstream and downstream of the process being examined.

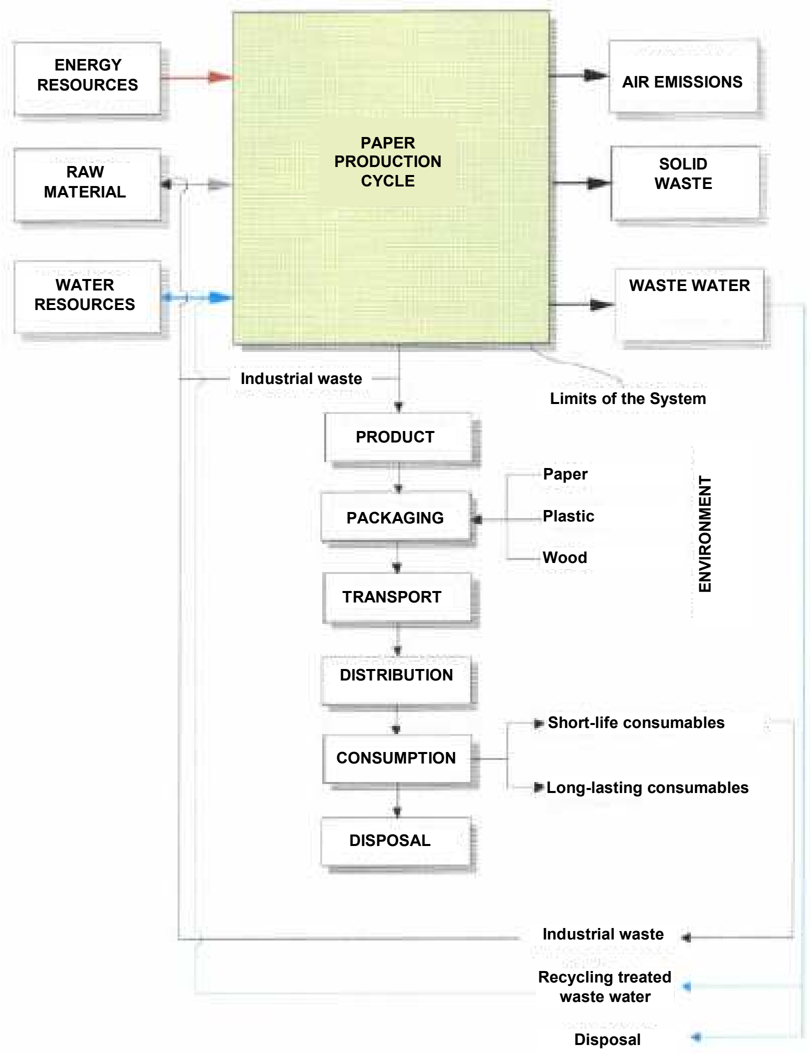


Figure 5-1 –Paper production system

5.2. Inventory analysis - ASTEPP Sensors

The data that are generally used in an LCA type of study can be divided into primary and secondary data.

The words "primary data" refer to all the data collected on site and which guarantee the best level of representativeness of the analysed system.
In this case, the primary data were taken directly on site by OMISS, at the plant in OMISS.

"Secondary data" refers to data that are used to complete the analogue model of the system and that are retrieved from databases or from studies that have been carried out previously and published.
Specifically, secondary data are published by APAVE in the RAPPORT DE VERIFICATION DES DECLARATIONS D'EMISSIONS DES GAZ A EFFER DE SERRE (GES) for the plant in OMISS and those related to the generation of electricity in French grid.

5.2.1. Input data

The flows of energy and materials within the product system have been reconstructed with reference to data published by OMISS on his plant for 2013-2014.
In particular, the data related to water, electricity and methane consumption are basic.

Primary data have time references from October 23rd to December 22nd 2015 and are divided in 2 period :
Period A is from October 23rd to November 19th ;
Period B is from November 19th to December 22nd .

	Period A	Period B
Time avaible	28 days (24/11/15-19/11/15)	28 days (25/11/15-25/12/15)
Paper production	30240 ton	30240 ton
Shutdown	7% of total time	5% of total time
Brakes	3% of total time	5% of total time
Time efficiency	90%	90%
Paper waste	5%	5%
Grade	70-135g/m^2	70-135g/m^2

Table 5.2 Average production

5.3. Evaluation of the impacts - ASTEPP sensors

5.3.1. Energy Flow

Inside the plant, during the normal production process, the continuous line consumes large amounts of electricity and thermal energy (high energy-consuming process). The thermal energy, resulting from the use of natural gas, biogas and biomass, is basically used to dry the paper, whereas the electricity, supports the various stages of the processing cycle.

5.3.1.1. Vapor

The vapor is produced by 4 natural gas boilers and 1 burner. The vapor is used to warm up the cylinders in the paper machineries and its flux isn't linearly related to the paper production flow.

During the paper breaks, infact, the vapor flux is regulated in a way to maintain warmed the cylinders (without overheatings) but the paper production is stopped.

In OMISS data, about 2014, are reported the vapor flux required by the paper production

Steam production 2014	**480989 t**	**100%**
Biomass boiler	199968 t	41,6%
Gas burners	281021 t	58,4%
Specific consumption	1,65 t	

Table 5.3 Vapor production

With APAVE data is easy to connect CO2 emitted from gas burners for vapor production

Gas burners	281021 t
CO2 from gas	40449 t
Specific CO2 from gas	139 Kg/t

Table 5.4 CO2 Production

5.3.1.2. Vapor saving

During a break the steams flow are adapted to prevent over-heating and cool down of the drying cylinders which could bring tail threading difficulties.

In OMISS plant there are 3 breaks possibilities : Pope break, Sizer break and pre-dryer break.

The time duration of each break is different, here below are reported average breaks duration:

	Duration pope [min]	Duration after sizer [min]	Duration pre-dryer [min]	Total time [min]
Pope Break	10	0	0	10
Sizer Break	10	10	0	20
Pre-dryer break	10	10	10	30

Table 5.5 Average break duration

So we can calculate the steam consumed during each break (tons)

	Steam per break [t]
Pope Break	9,4
Sizer Break	17,4
Pre-dryer break	19,6

Table 5.6 Average steam consumption during breaks

Comparing values of steam consumption between Period A and Period B, it's clear an energy saving in the first period due to a less break time.

The 2% less breaks brings -1,69% less total steam, otherwise -2,89% less gas burner steam.

With ASTEPP technology we are able to grow up the runnability of the process, and we can reach a gas burner vapor saving of 0,028 t of vapour for each ton of paper producted.

5.3.1.3. Electricity

The analysis of the data published by OMISS shows that overall, the electrical consumption is given by :

- an almost constant part for the process and auxiliaries;
- a variable part of 500 KWh in case of paper breakdown.

The electrical consumption in case of paper breakdown is variable because it depends to the kind of breakdown (in particular where the paper break is).

During the PERIOD B we find in OMISS data, an average specific consumption of about 500 KWh/ton.
During the PERIOD A the average specific consumption is less than PERIOD B, and is about 489 KWh/ton.
This difference of electrical consumption is due to a 2% less breakdown time during period A; therefore during a breakdown machines still run like during normal operation and a pulper, equipped with 2 x 250 KWh motors, is in function for all breakdown phase.

With ASTEPP sensors is possible to monitor all critical parameters and set the machines in due to avoid paper breakdowns.

5.3.1.4. Electricity saving

Like as done for the calculation of vapor saving, here we report the total electrical energy consumed during each break (calculated taking into account avarege time of breaks).

	Line Electricity [KWh]	Pulper electricity [KWh]
Pope Break	4167	83
Sizer Break	8333	167
Pre-dryer break	12500	250

Table 5.7 Average electricity consumption during breaks

5.3.2. Air emissions

The air emissions must be identified in order to evaluate the degree of reduction of the "Green House effect Gas emissions (GHG)" that ASTEPP system use has on the paper production process.
Part of the air emissions derive directly from the production process and partly from the use of electricity generated by non-renewable sources.
With reference to ADEME web site, we know the CO2 emission factor for FRANCE power production (incertitude 30%)

- France CO2 emission factor : 0,59 g/MWh

From which, in turn, one can derive the amount of CO_2 associated with each ton of paper produced (final reference unit of the analysis) considering only the energy acquired by the power grid

Reference period	$Kg(CO_2)/t$
A	28,38
B	29

Table 5.8 CO2 per Ton of corrugated board producted

These data, with reference to the electricity alone, which OMISS purchases from power grid to produce one ton of paper, have to be added to the equivalent CO_2 contributions produced directly by OMISS during its normal production cycle (due to the combustion of natural gas, in terms of the production of heat).

5.3.2.1. Impact category GPW100

As indicated in the reference documents, the Global Warming Potential is the impact category to be considered: Global warming potential calculated in 100 years (GPW100). GWP100 expresses the global warming caused by gas emission into the atmosphere. The index is based on a relative scale which compares each gas with the carbon dioxide, whose GWP is defined as value 1.

Therefore, correlating all the data reported in the previous paragraph is in CO_2, according to the above indexes, and summing the input contributions from electricity purchased by OMISS and its own input of the company production process will obtain the following total values (always correlated with the selected functional unit):

Reference Period	$Kg(CO_2)/t$
A	165
B	168

Table 5.9 Emissions in environment

5.3.3. Water flows

In order to assess the actual water savings that the system would have on the cycle it is important to understand the water flow in the paper mill process in question (see image below).

The fresh water, drawn from wells/water supply is primarily used for the pump seals, for the production of steam, and for other services of various nature. While using the continuous machine, the water lost during the production process must be topped up, essentially for the following reasons

- evaporation while the paper is dried;
- residual moisture in the finished product;
- water not recoverable after the clarification treatments.

As the process water is removed from the paper, it is recovered and sent to the clarifier to then be used again in the mixture.

The paper mill data published by OMISS show that the water consumption in paper making in mainly used when machine is running producing or not producing paper.

The fresh water intake is mainly used for:

- Pump sealings
- Lubrication showers
- Cleaning showers
- Ring sealing for vacuum pumps
- Chemicals preparations
- Chemicals dilutions

A big part of these waters are going to the white water system and will be reused but a constant flow of fresh is needed and this constant entering flow is not depending of the quantity of paper produced.

When machine is running even during breaks a big part of the above mentioned flows are stable.

The only possibility not to use this fresh water is when the machine is down (during shutdown).

During a start-up preparation an extra water consumption is needed to fill up the white water loops and this volume should then stay stable if runnability of the paper machine is acceptable.
During run, all this entering water will have to be taken out and send to the effluent plant (same flow but not the same quality because this fresh water went to the white waters).
Often to avoid raw material losses, this out-going waters are clear filtrates (some solids, higher conductivity and COD loaded).
Water flows are obtained from plant (effluent flow meter 160FIC-700:me) and the data are validated by DREAL.

We compare the two periods designed:
Period A
Specific water consumption 6,85 m^3/ton
Paper producted 30240 ton
Water usage 207144 m^3

Period B
Specific water consumption 7 m^3/ton
Paper producted 30240 ton
Water usage 211680 m^3 during the 28 of running days.

The difference between the two period object of the analysis is due to a breaking time saving of the 2% in period A. With a correct set up of machineries is possible to obtain a water saving of 0,15 m^3 for each ton of paper producted.

Reference Perod	m^3/ton	**Water saving between A and B**
A (23/10/15-20/11/15)	6,85	2,14%
B (24/11/15-21/12/15)	7	

Table 5.10 Water consumption

In view of the above, it is important to note that the water saved due to optimisation of the process using the ASTEPP system , like in case A, is fresh water.

5.4. Conclusions - ASTEPP sensors

Following the analysis, the monitoring of the paper production process , guaranteed by the Cristiani S.p.A. sensors called ASTEPP , allows the operators to set better the operating parameters of the paper production lines , thereby reducing the paper breaks, and having an energy saving. It is evident that the operator, who operates without the support of the measurements and data provided by the ASTEPP sensors, has no guidelines and information about certain operating parameters of the production line. The company Cristini therefore, highlighted the impossibility of having a perfect setting of the machine and of the production process.

To date, the settings of the continuous machine, in particular those that modify these parameters, are set according to the sensibility and experience of the operator, according to sensation and knowledge. In fact, during the data collection and testing, the company Cristini could directly note how each operator set these values in a personal way and therefore, different from other operators.

In conclusion, the analysis showed that it is possible to use the production system by adjusting the operating parameters of the continuous line based on objective technical information provided by ASTEPP sensors and not on personal sensations or subjective parameters.

It is also important to emphasise that optimisation of the energy consumption of the continuous line using the ASTEPP sensors does not affect the quality and/or quantity of the final product in any way.

Below is a summary of the advantages in terms of potential energy savings and the environmental impact that Cristini ASTEPP sensors can achieve, with only a less 2% break time. In particular, as required in the "Project information sheet" guide, issued by Eco Innovation, this document highlighted aspects related to:

Reduction of energy consumption

The results obtained have shown a potential reduction of:

- electrical energy consumption of 11Kwh per ton of paper produced;
- vapor production of 0,028 t per ton of paper produced.

Reduction on Green House effect Gas emissions (GHG)

The analysis results have shown a potential reduction in the amount of CO_2 ,produced from fossil fuels, equivalent to 2,98 Kg per ton of paper produced (a reduction of fossil CO2 emission of 1,77%).
We have to remember the emissions from biogas and biomass burners are considered 0 like in the APAVE report.
Usually this kind of emissions are considered null, because the CO2 emitted during the combustion is equal to the CO2 consumed by the biomass during its life.

Water usage reduction

The analysis results have shown a reduction in the amount of water used equivalent to 150 l per ton of paper produced.
This value corresponds to a water saving of 2,14% for the paper production.