The research leading to these results has received funding from the European Community's 7th Frame work Programme under grant agreement nº 228802

METHODOLOGY FOR ASSESSING NANO ENHANCED NEW PRODUCTS

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SUMMARY

This report is a project deliverable D 2.1 ”Methodology for assessing nano enhanced new products” of the SUNPAP project.

The purpose of this report is to define a suitable methodology to be used when carrying out the sustainability assessment during the SUNPAP project. In addition, this report communicates not only to other Modules within SUNPAP project about tasks and logic but also to the general public being interested in developing suitable methodologies for assessing sustainability in the complex field of nanotechnology.

The first chapter of the report presents a short introduction to the theme. The second chapter describes the theoretical background of sustainability thinking, and means of measuring it. The third chapter outlines the methodology to be used during the project and the final chapter describes tasks and timetable more in detail.

The author of this report is Pöyry Forest Industry Consulting (Pöyry). For this report, Pöyry has followed the plan outlined in the SUNPAP DoW and made an extensive literature review on how sustainability assessments have been carried out in other similar projects. Pöyry knowledge and competence from earlier studies have served as good aid in carrying out the work. Moreover, the report has been reviewed and complemented by other partners in the project (KCL / VTT, CTP, PTS, SSCCP).

1 INTRODUCTION

This report is a project deliverable D2.1 *"Methodology for assessing nano enhanced new products"* of the SUNPAP project.

Objective of this report is to define the methodology to be applied in the work of WP2. This work package concerns sustainability assessments of nano-enhanced new products. The methodology is developed so that it fulfils the main objectives of WP2 that are;

1. Define the framework and indicators for assessing sustainability of nanotechnology applications in paper industry.

2. Guide and support the focus of the project to a sustainable direction.

3. Demonstrate sustainability aspects (environmental, social, and economic) of the developed processes and value added paper products.

As the sustainability assessment in WP2 is an iterative process, like the whole project, the methodology described in this report is not final, but it develops during the project.

A lot discussion around nanotechnology and sustainability assessment can currently be found in international media. This discussion concentrates on processing, emission and potential impacts of new products as well as on defining feasible methodologies for evaluating sustainability effects /1, 2, 3, 4/. This is a fact which makes the work created in this work-package even more important. As nanotechnology is still a pretty young field of research not all impact of the technology are easy to foresee and measure. An adequate methodology relying on the best available knowledge is the ultimate task of the SUNPAP project.

Figure 1 summarises key words and topics extracted from discussion around nanotechnology and sustainability using various sources (NGOs, companies, r&d institutes, blogs, authorities etc.). The figure summarises the discussion using text mining; the most relevant topics have been extracted and appear in the figure. The size of a word depicts the importance of the topic, and the distance between words describes how strongly the topics are linked to each other.

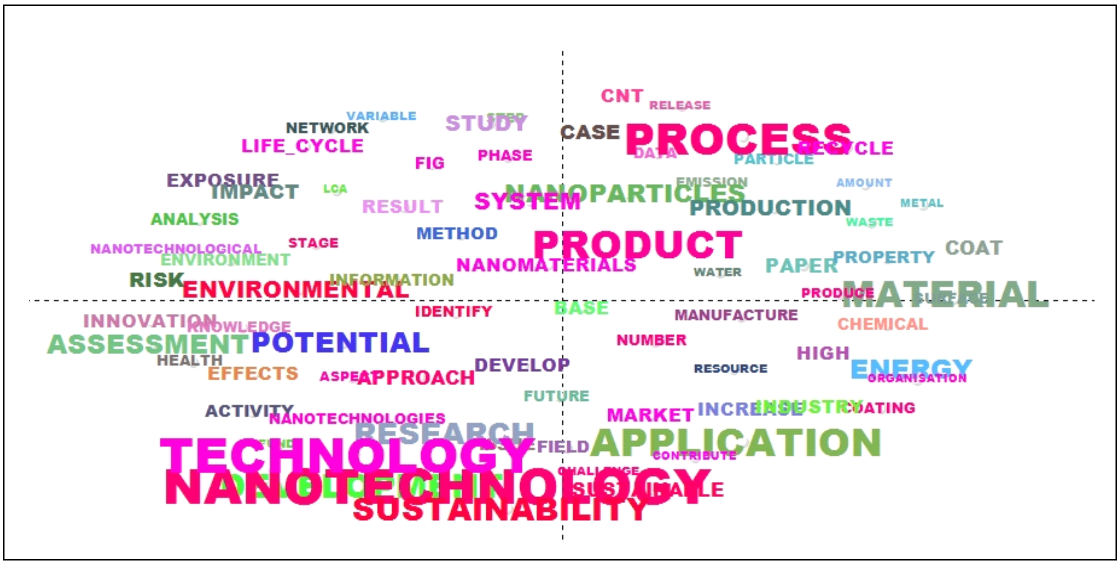

Figure 1. Nanotechnology and Sustainability Discussion, November 2009.

2 THEORETICAL BACKGROUND

2.1 DEFINITION OF SUSTAINABLE DEVELOPMENT

The concept of sustainable development emerged from the concern about the effects of development on the environment. Its origin is often traced back to the United Nations Conference on the Human Environment in 1972 and the concept was further developed in the 1987 Brundtland report. The concept became common knowledge after the United Nations Conference on Environment and Development (UNCED), also called the Rio Summit, in 1992.

The Brundtland report defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. This approach is often criticised for its pro-growth approach: To alleviate poverty, a significant increase in economic output is needed – yet, at the same time, such increase is commonly accompanied with environmental degradation.

Another definition, by the World Conservation Union, states that sustainable development means “improving the quality of human life while living within the carrying capacity of supporting ecosystems” /5/. This definition does not implicitly stress satisfaction of material needs, but speaks about quality of life.

Other definitions include those of economist Herman Daly, who considered environment as a form of capital, and of Amartya Sen, who suggest that the purpose of any development is to improve people’s lives by expanding their choices, freedom and dignity.

2.2 PRINCIPLES OF SUSTAINABLE DEVELOPMENT

Despite of varying definitions for sustainability - there is still no political or scientific agreement on one definition of sustainable development - some basic elements are commonly stressed: /6/

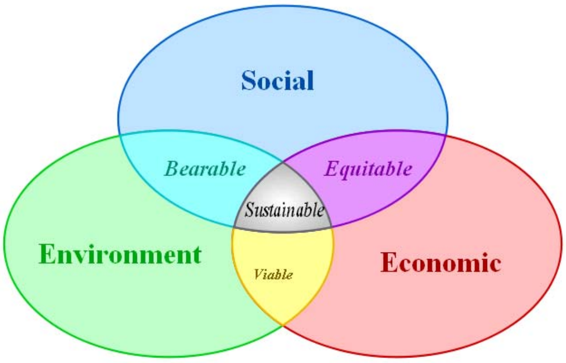

Figure 2. Three pillars of sustainable development /7/

- "Three pillars of sustainable development" refer to the idea that not only economic, but also environmental and social impacts of developmental decisions should be taken into account. This is presented in the Figure . Often also a fourth aspect, the institutional dimension (or cultural by some authors) is added.
- Intergenerational and intragenerational equity: The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.
- Public participation at all levels of decision-making
- The (environmental) policy integration principle: In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.
- The precautionary principle: Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
- The polluter pays principle: National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment.
- Cooperation in eradicating poverty as an indispensable requirement for sustainable development
- Striving for peace

Gender empowerment

2.3 EVALUATION OF SUSTAINABILITY

The Bellagio principles were developed as a response for a call set by the Bruntland Commission to find a suitable methodology to measure and assess progress of sustainable development /8, 9/. The Bellagio principles can be understood as evaluation standards specific to sustainable development evaluations.

1. GUIDING VISION AND GOALS Assessment of progress toward sustainable development should: • be guided by a clear vision of sustainable development and goals that define that vision
2. HOLISTIC PERSPECTIVE Assessment of progress toward sustainable development should: • include review of the whole system as well as its parts • consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts • consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms
3. ESSENTIAL ELEMENTS Assessment of progress toward sustainable development should: • consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate • consider the ecological conditions on which life depends • consider economic development and other, non-market activities that contribute to human/social well-being
4. ADEQUATE SCOPE Assessment of progress toward sustainable development should: • adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short term decision-making • define the space of study large enough to include not only local but also long distance impacts on people and ecosystems • build on historic and current conditions to anticipate future conditions - where we want to go, where we could go
5. PRACTICAL FOCUS Assessment of progress toward sustainable development should be based on: • an explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria • a limited number of key issues for analysis

• a limited number of indicators or indicator combinations to provide a clearer signal of progress • standardizing measurement wherever possible to permit comparison • comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate
6. OPENNESS Assessment of progress toward sustainable development should: • make the methods and data that are used accessible to all • make explicit all judgments, assumptions, and uncertainties in data and interpretations
7. EFFECTIVE COMMUNICATION Assessment of progress toward sustainable development should: • be designed to address the needs of the audience and set of users • draw from indicators and other tools that are stimulating and serve to engage decision-makers • aim, from the outset, for simplicity in structure and use of clear and plain language
8. BROAD PARTICIPATION Assessment of progress toward sustainable development should: • obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values • ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action
9. ONGOING ASSESSMENT Assessment of progress toward sustainable development should: • develop a capacity for repeated measurement to determine trends • be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently • adjust goals, frameworks, and indicators as new insights are gained • promote development of collective learning and feedback to decision-making
10. INSTITUTIONAL CAPACITY Continuity of assessing progress toward sustainable development should be assured by: • clearly assigning responsibility and providing ongoing support in the decision-making process

These standards are weighted and interpreted inconsistently, depending on e.g. the geographical location. Even if different organisations in different locations state that they follow the standards, the sustainability challenges, requirements, focus and priorisation may vary a lot.

2.4 INDICATORS FOR SUSTAINABLE DEVELOPMENT

In order to put the general concept of sustainability into action, various lists of sustainable development indicators (SDIs) have been created to assess sustainability of projects, programmes and policies at local, national and international levels. The SDIs collectively define key aspects of sustainability in specific contexts.

Conceptual frameworks for SDIs help focus and clarify what to measure, what to expect from measurement and what kind of indicators to use. The main differences among frameworks are the way in which they conceptualise the main dimensions of SD, the inter-linkages between these dimensions, the way they group the issues to be measured, and the concepts by which they justify the selection and aggregation of indicators. /10/

Some of the more commonly used frameworks are:

- pressure-state-response (PSR) and its variations, limited mostly to the environmental pillar;
- human well-being/ecosystem well-being;
- issue- or theme-based frameworks; and
- capital-accounting based frameworks, centred on the economic and environmental pillar of SD. /10/

2.5 RECENT TRENDS IN THE DEVELOPMENT OF SUSTAINABILITY INDICATORS

Continuing interest in the development of aggregate indices (e.g. footprints, the Human Development Index /11/, the Environmental Sustainability Index /12/) to characterise progress towards SD or at least some of the dimensions of SD, and to mimic/supplement indicators for economic development such as gross domestic product (GDP);

- Interest in core sets of ‘headline indicators’ (e.g. the Millennium Development Goal Indicators) representing short core sets of indicators closely linked to political decision-making. The idea is to track progress (or lack of it) towards selected policy goals with robust core sets of indicators.
- Emergence of goal-oriented indicators, enabling their use in tracking performance and helping linking them to policy priorities;
- Measurement of sustainability by capital (e.g. green accounting systems); and
- Making better use of indicators in performance measurement of organisations (e.g. balanced scorecard).

2.6 EVALUATION CONCEPTS USED IN SUSTAINABILITY ASSESSMENT

Sustainability assessment can have different objects depending on the case. It may aim e.g. to compare different options, to understand the impacts of an option or to compare an option to the reference values.

For environmental impacts there are methodologies for the assessment, of which one well-known is Life Cycle Assessment (LCA). It is a system for collating and evaluating information on the environmental performance of an activity across its full life cycle, from "cradle to grave".

A LCA includes four phases, that are illustrated in the Figure 3:

1. Definition of the goals and scope of the LCA.

2. Inventory analysis, consisting of gathering data concerning the resources used, energy use, emissions, wastes and products resulting from each activity in the production chain.

3. Life cycle impact assessment, in which the results are evaluated to assess the magnitude of the potential environmental impacts of a product system.

4. Interpretation of results and identification of components that have the most significant environmental impacts.

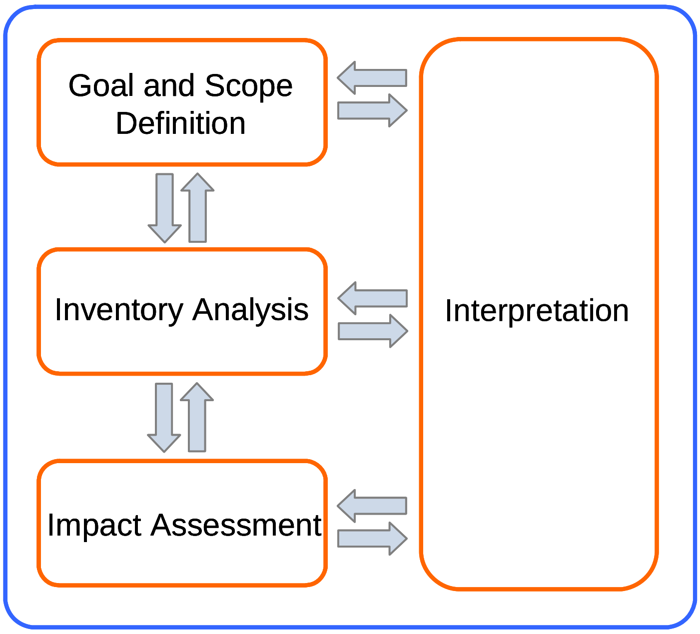

Figure 3. Phases of Life Cycle Assessment.

The life cycle impact assessment phase includes analysis of the indicator results, e.g. sensitivity and uncertainty analysis. Sensitivity analysis is systematic procedure for estimating the effects of the choices made regarding methods and data on the outcome of the study. Uncertainty analysis is procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability.

An additional optional phase of LCA is critical review. It may facilitate understanding and enhance the credibility of LCA. It is decided not to perform a critical review in this project.

The ISO 14 040 standards promote LCA as a technique for assessing the effects of a product throughout its entire life cycle.

Direct applications are for example:

- Product development and improvement
- Public policy making
- Marketing

For simultaneous assessment of three dimensions of sustainability no exact methods exist. For instance cost-benefit, cost-efficiency and multicriteria analyses can be applied for the assessment, but they all require inclusion of opinions. Whether the indicators are quantitative or qualitative, their importance needs to be weighted. As the measuring sustainable development is a participatory process, all the relevant stakeholders should be involved in the weighting.

The process of developing indicators also involves assessing the acceptability of the indicator values (e.g. “good” or “bad”). When the collected indicator data is analysed, sensitivity analysis should be performed to find out whether the change in one indicator changes the assessment results more drastically than the change in the other indicators. Special attention should be paid to those indicators to which the result is sensitive to. By sensitivity analysis it is also possible to identify a threshold value for an indicator; the point the assessment result turns from negative to positive or vice versa.

2.7 DEVELOPMENT OF SUSTAINABILITY TOOLS IN RECENT EU RESEARCH PROJECTS

Sustainability tools have been developed in the EU research projects from various points of view, the recent projects are listed here.

EFORWOOD, Sustainability Impact Assessment of the Forestry-Wood Chain (funded under the EU “Global change and ecosystems“ research activity of FP6, www.eforwood.com)

ECOTARGET, New and innovative processes for radical changes of the European pulp and paper industry (under FP6, http://www.ecotarget.com/)

Methods and Tools for Integrated Sustainability Assessment: Improving the toolkit for conducting Integrated Sustainability Assessments (funded by FP6, www.matisse-project.net)

Sustainability A-test: Inventory of tools for assessing sustainability of policies (funded by FP6)

Evaluating socio-economic development: Handbook on evaluating socio-economic development, particularly EU structural funds (http://ec.europa.eu/regional_policy/sources/docgener/evaluation/evalsed/guide/index_en.htm)

Local Authorities’ Self-Assessment of Local Agenda 21: Questionnaires for sustainability assessment of local development projects (funded by DG Research, www.localevaluation21.org)

Sort-IT, Recovered Paper SORTing with Innovative Technologies (under FP7, http://www.sortit.eu/)

3 SUSTAINABILITY ASSESSMENT IN SUNPAP PROJECT

Nanotechnology is a fairly young field of research. The research activities have, however, speeded up radically during the last ten years and more information about nanotechnology opportunities are obtained continuously. The position of new technologies, materials and nano-enhanced products being researched regarding safety towards the environment and human health is, however, not yet very well established nor widely researched. Actually it is not yet thoroughly known what parts of the ecosystem nanotechnology might impact harmfully.

The European Union stresses the importance of incorporating research of environmental and health aspects tightly into research projects in its communication: “Towards a European Strategy for Nanotechnology” /13/:

“Scientific investigation and assessment of possible health or environmental risks associated with nanotechnology need to accompany the R&D and technological progress. Some dedicated studies are underway to assess the potential risks, which are also examined within FP6 IPs and NEs projects in the field of nanotechnology. In particular, nanoparticles might behave in unexpected ways due to their small size. They may present special challenges, for example, in terms of production, disposal, handling, storage and transport. R&D is needed to determine the relevant parameters and prepare for regulation, where necessary, taking into account the full chain of actors, from researchers, workers to consumers. This R&D also needs to take into account the impacts of nanotechnologies throughout the whole of their life cycle, for example, by using Life-Cycle Assessment Tools.”

In this communication LCA is acknowledged as a way of evaluating the possible effects nanotechnology based products might have on the environment. LCA will also serve as one of the cornerstones in evaluation of environmental impacts during the SUNPAP project. Fundamental research on health aspects will be conducted as part of the project. Results from these studies will be incorporated into the sustainability assessment in order to respond the targets set by the Europeans Commission to identify real and perceived safety concerns at the earliest possible stage. Knowledge about the impact of nanotechnology enhanced products on the environment is extended through eco-toxicity studies related to end-of-life phase of products. Results from the health and toxicity research enables improving knowledge of risks related to human health, environment, consumers and workers at all stages of the life-cycle of the technology/process/products.

As earlier defined the target of the SUNPAP project is not only to address the LCA but to make a complete sustainability assessment, with the aim to also understand the social and socioeconomic impacts of the new products and processes. In this part both qualitative and quantitative methods will be applied to model cases corresponding to reality in the best possible ways.

Hence, the methodology to be applied during this project is two folded: one consisting of LCA and the other part of social and economic analysis based partly qualitative and quantitative data.

On its top level this sustainability assessments consists of the following phases:

PHASE		CHAPTER
Screening Phase	Definition of research focus	3.1
	Definition of cases and scope	3.2
	Selection of sustainability indicators	3.3
	Data collection	3.4
	Theoretical screening phase analysis	3.5
Final Sustainability Assessment	Definition of cases and scope	3.6
	Selection of sustainability indicators	3.7
	Data collection	3.8
	Analysis based on pilot data	3.9
	Integration of the results	

3.1 DEFINITION OF RESEARCH FOCUS; THE STARTING POINT

As outlined in SUNPAP Description of Work (DoW), the focus of this research project is Nano Fibrillar Nanocellulose (NFC). The target is to develop nanocellulose based processes to provide radical product performance improvements, new efficient manufacturing methods and introduction of new added value functionalities. NFC could potentially be used in a wide range of different applications. Here, the aim; however is to develop new products for the papermaking value chain.

The target is defined as follows:

- High performance products and environmentally friendly NFC enabled production processes, demonstrated for graphical papers and packaging boards
- Functional products and innovative processes enabled by NFC with active functionalities, demonstrated for papers and packaging materials
- High added value fibre based products with highly specific properties made only possible by NFC, demonstrated for fibre based filters and other selected innovative materials

The need and content of NFC will most certainly vary a lot between the different applications. Some of the NFC will be applied in the matrix of different products whereas some in coatings. In addition, the NFC will be functionalised i.e. given new properties enabling production of products with completely new features.

The different uses of NFC studied during the project will all be taken iteratively into account during the sustainability assessment. This means that sustainability assessment will develop and target its focus in-line with the project. Initially, a wide range of applications are selected for study. Research and tests with these will be conducted primarily on lab scale. An initial sustainability screening will be conducted for a set of these applications. The most promising applications will be selected for further study and pilot demonstrations. For the pilot cases comprehensive sustainability assessments will be conducted. It is assumed that the final sustainability evaluation will be conducted for maximum 5 products.

The ultimate sustainability goal of this project is to create new fibre-based and recyclable paper and packaging products which will reduce landfill waste and minimise the use of petroleum-based chemicals. Moreover the target is to provide radical product performance improvements, new efficient manufacturing methods and the introduction of new added value functionalities.

3.2 SCREENING PHASE: DEFINITION OF CASES AND SCOPE

The SUNPAP project is an industry driven project with the aims of piloting and commercialising the most feasible products within as short time frame as possible. The aim of the screening phase is to give all products a “chance” and later drop off unsuccessful cases. I.e. during the screening phase a large set of potential products included. The screening phase starts with two key phases: definition of value chains and related reference cases and scoping and definition of system boundaries.

To enable screening, the potential applications and their value chains have to be defined. This is done in collaboration with other WPs. Life cycle thinking is applied in the work of WP2, so the value chains of the reference cases are followed from the raw material acquisition to end-of-life treatment. The main focus in this project is on the production processes of the new products, but in the sustainability assessment the whole value chains of the products are taken into account.

3.3 SCREENING PHASE: SELECTION OF SUSTAINABILITY INDICATORS

Various sets of sustainable development indicators (SDIs) exist, and they are created for sustainability assessments of different levels, from individual projects to international policies. To create an extensive and balanced set of indicators for SUNPAP project, Bellaggio principles are followed. These principles are considered as evaluation standards for sustainability assessments, and are presented in the chapter 2.3 .

Based on the principles, the most essential requirements for sustainable development indicator selection process of this project are

- clear vision of sustainable development and goals that define the vision
- definition of scope that includes the system holistically enough
- balanced selection of indicator set that considers all the dimensions of sustainability
- an explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria
- a limited number of key issues for analysis
- design to address the needs of the audience and set of users

The goal that defines the vision of sustainable development in this project is that development of new products and their industrial-scale production should be environmentally sound, economically feasible, have no negative health effects and create welfare on EU level. More detailed goals are reducing landfill waste, minimise the use of petroleum-based chemicals, reduce the energy requirements, and improvement of material efficiency. The scope of the indicators is from an individual to EU level. The Figure 4. describes the levels that are analysed in the sustainability assessment.

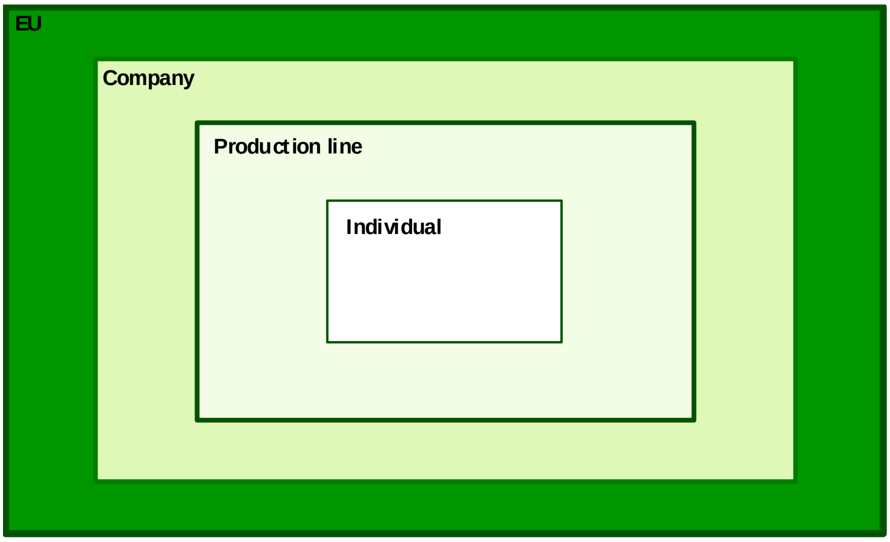

Figure 4. Levels analysed in the sustainability assessment in the SUNPAP project.

To obtain an extensive set of indicators several existing indicator sets are gone through. These are e.g.

- Impact Assessment Guidelines for the European Commission
- Sustainable Development Indicators for the European Union (SDI-Eurostat)
- Indicators of Sustainable Development of the Commission on Sustainable Development of the United Nations (CSD)

EFORWOOD was a four-years (November 2005-October 2009) integrated project, funded under the EU "Global change and ecosystems" research activity of the Sixth Framework Programme. In the project, EFORWOOD indicator set was developed. The set aims at consistency with other sustainability indicator frameworks in Europe and globally, and it includes indicators relevant for the forest sector. Thus, special attention was paid to this indicator set while mapping the potential indicators.

According to Bellaggio principles there must be a limited number of key issues for the analysis. Hence, the list of indicators to be collected is made compact. To create a balanced set of indicators the following indicators selection criteria is used:

- How well indicator links to the goals of the assessment
- Is the indicator relevant for the studied area
- Is there data available / possible to estimate for the indicator
- Is there information from other WPs that could be utilised in the assessment

Additionally, the following general interpretations of basic requirements for indicators/ sets of indicators are taken into account:

- easiness to measure
- validity and reproducibility
- availability and reliability of data sources
- relevance
- unambiguousness

- easiness to understand (practicality)
- guiding of decisions at a proper level
- manageable in number
- results of a participatory process

The list of indicators can be adjusted as the project work proceeds and more information on the studied products exist. As the process of selecting indicators follows the principles of openness and participation, the initial list is distributed to the project participants who deliver data for the sustainability assessment in the course of the project. The list is adjusted according the comments received, and it can also be adjusted later during the iterative project. The initial list of indicators is presented in the following. The more detailed list is presented in the annex.

<u>Environmental indicators (KCL/VTT defines)</u>

- Energy use
- Raw material use
    - from renewable sources
    - from non-renewable sources
    - petroleum-based products

- Water use
- Carbon footprint / GHG emissions
- Air emissions (to be defined in more detail, e.g. SOx, NOx, particles)
- Water emissions (to be defined in more detail, e.g. N, P and COD)

In the final sustainability assessment phase the following indicators are collected to the end-of-life phase of products (possibly including sludge):

- Recyclability, compostability and ecotoxicity (together with WP3)

Social indicators

- Employment
    - male/female
    - age classes
    - educational categories
- Wages and salares
    - male/female
    - type of employment
- Quality of work

In the final sustainability assessment phase the following topics are commented on the general level:

- Exposure to substances that have health effects along the life cycle of the product (together with Module 4)
- Acceptance

– Effect on rural development

Economic indicators

- Production costs
  - raw material costs
  - energy costs
  - labour costs
  - transports
  - investment costs / capital charges
- Gross value added

In the final sustainability assessment phase the following topics are commented on the general level:

Investment (gross fixed capital formation)

3.4 SCREENING PHASE: DATA COLLECTION

The data of the screening phase is theoretical data. The data will be collected mainly from the literature, and other available sources are utilised additionally. The reference unit of the collected data is the functional unit (kg or ton) of the product in question.

3.5 SCREENING PHASE: THEORETICAL ANALYSIS

The analysis of the screening phase is based on theoretical data. A sensitivity analysis will be included into the study to be able to point out critical sources for uncertainty within the analysis. The analysis will be conducted on the value chains defined in the definition phase. The outcome of this part is a map illustrating the sustainability of the evaluated cases.

The applications having promising technical, economical and sustainability performance will be selected for further study i.e. demonstrations.

3.6 FINAL SUSTAINABILITY ASSESSMENT: DEFINITION OF CASES AND SCOPE

The most promising applications are selected to further study and demonstration in the project. This is done in collaboration with many WPs. The value chains of these selected applications must be defined to enable the sustainability assessment.

All relevant life cycle stages must be included to the study. The environmental assessment is performed by the means of Life Cycle Assessment (LCA), and in that case the standardised (ISO 14040 and ISO 14044) methodology must be followed as literally as possible. For uniformity, the scoping for social and economic sustainability analysis is defined to be rather similar with the scoping for environmental sustainability analysis, even though not all phases are analysed quantitatively in social and economic cases.

To model value chains they are divided in blocks meaning that each phase of the chain can be managed separately. The division is extremely dependent on the studied products, but general main blocks can be applied to each case.

3.7 FINAL SUSTAINABILITY ASSESSMENT: SELECTION OF SUSTAINABILITY INDICATORS

The indicator list defined in the screening phase is updated based on the principles presented in the chapter 3.3 .

3.8 FINAL SUSTAINABILITY ASSESSMENT: DATA COLLECTION

The data will be collected from all Modules in the SUNPAP project. The Figure 5 illustrates detailed data flow during the sustainability assessment. Here, WP1 Market needs will provide input data on markets and, technologies and deliverables on other economic parameters. WP3 Recyclability and biodegradability will provide information on how the piloted products behave in recycling operations as well as in biodegradability. WP4, Production will feed information about processes and technologies first to WP1 where these will be modeled to processes and then adopted by WP2. WP5 will deliver data on the functionalisation of NFC. Here, important parameters on materials being applied and concentrations etc. are important to include into the sustainability assessment. WP6 NFC Applications will deliver information about further processing of NCF into commercial products. Here, specific product designs are modeled which will serve as the definitions on the final cases. WP8 Demonstrations will be the information source for the pilot trials. Finally, Module 4 will deliver information about potential health risks related to the production and use of the produced NFC products. Data collected from pilot processes will be complemented by data gathered during the earlier stages in the study.

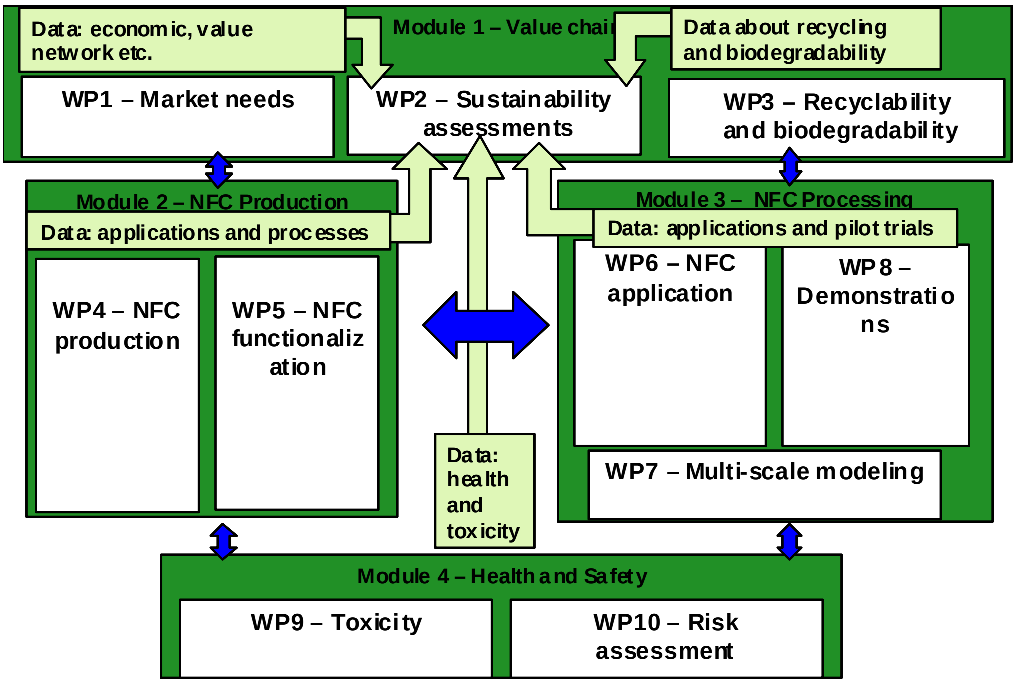

Figure 5. Data collection sources for sustainability assessments in the SUNPAP project.

3.9 FINAL SUSTAINABILITY ASSESEMENT: ANALYSIS BASED ON PILOT DATA

A complete sustainability assessment based on data gathered from pilot trials will be conducted to these cases.

3.9.1 Sustainability assessments of final products

The different key components, environmental, social, and economic assessments, included in the sustainability assessment are carried out separately. Finally they are combined as united sustainability performance profiles of each final product.

Environmental assessment is performed by means of Life Cycle Assessment (LCA) which is presented in the chapter 2.6.

Social and economic assessments are performed by combining quantitative and qualitative methods. The production process data is quantitative and the other parts of the value chain are qualitative when it is sufficient from the assessment point of view or when it is more feasible for an indicator. Some of the impacts are analysed on the individual level, some are expanded even to the EU level. Collaboration with WP1 is important in order to take into account how much production of each final product there could be in the EU area.

Finally, the assessments on three dimensions of sustainability are integrated. The result is a performance profile for each studied application. The integrated profile of results will be expressed by SWOT analysis to show strengths, weaknesses, opportunities and threats of each studied application. The importance of different indicators, dimensions of sustainability and impact levels is evaluated by expert opinions supported by sensitivity analysis. The studied products are basically so different that any values cannot be directly compared against each other.

3.9.2 Challenges and uncertainties during the sustainability assessment

Following factors are identified to decrease reliability of result obtained from the analysis.

- The value chains in the initial phase will be modeled based on theoretical data. As this is a research project dealing with development and adoption of radically new processes, gathering of data for these will be difficult. Some of the data has to be based on modeling.
- As research work is conducted on lab-scale/pilot-scale critical parameters (efficiencies, raw material utilizations, investment costs, operational and business models) can only be modeled from these. Real industrial scale production conditions will be difficult to determine.
- Evaluation of social and economical impacts for the new technologies, processes and products will as well be hard. E.g. pricing of new to the market products is extremely hard.
- Evaluation of impacts on health, safety and different ecosystems will be hard as some of the testing methodologies are still under development.

- As nanotechnology is a new scientific area of research not all areas to be evaluated considering health and safety aspects are enough well known. That is why it is probable to expect, even thought the methodologies applied during the project will rely on best available knowledge, that some on the ones used will later on turn out to be inferior as the field of science evolves.

4 TIMETABLE

A summary for carrying out sustainability assessment in SUNPAP is illustrated below. The vertical axis describes key elements in the project: *steps, value chains, tasks and deliverables* whereas the horizontal axis defines key phases in the project*: defining scope and case, screening phases, final sustainability assessment and writing reports.*

The Figure 6 illustrates the procedure applied during the project.

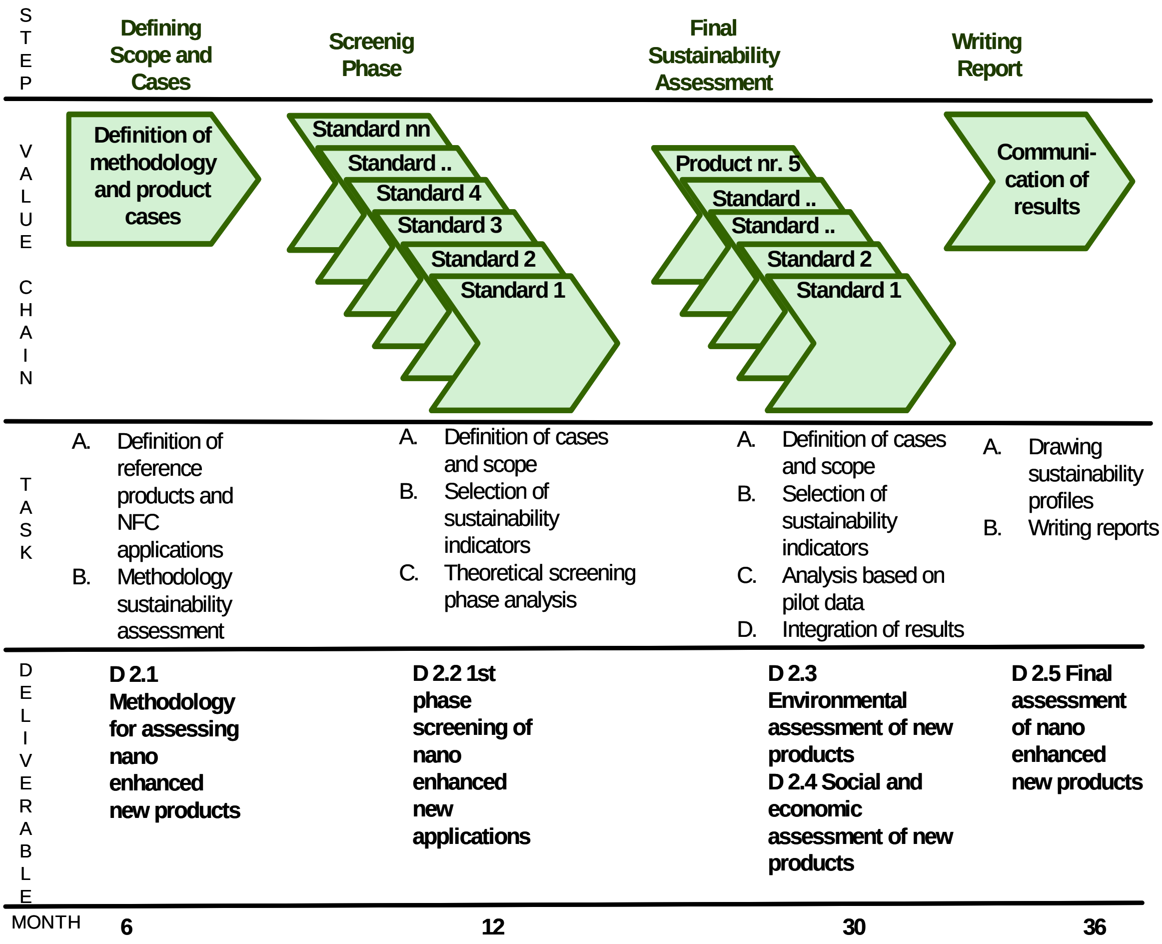

Figure 6. Process to be applied during the SUNPAP project.

The different elements of the project are described more in detail in following sections whereas detailed descriptions of the key phases can be found in chapters 3.1 to 3.9.

4.1 STEPS

The steps outline the names of the different phases in the analysis procedure. Four main phases are defined:

1. Defining cases, which refers to the work which is carried outside the sustainability assessment (together with other partners in the projects and definition of the methodology to be used in the analysis). After that the exact scope is defined.

2. Screening phase, which describes the theoretical or the initial analysis carried out during the sustainability assessment,

3. Final sustainability assessment outline the analysis conducted by using state of the art pilot data obtained during the project,

4. Writing reports, defined reports to be delivered according to the DoW.

4.2 VALUE CHAINS

Selection of relevant value chains is one of the crucial tasks in the work. This part is lifted up as a distinct phase in the process scheme to illustrate its importance during the project. The project starts by defining a larger number of value chains which will be modelled using theoretical data, followed by scaling down to a number of chains which are piloted during the SUNPAP project. Selection and modelling of value chains will be done in close co-operation with WP1 and other specialists in the projects.

4.3 TASKS

Describe the actual work to be conducted at different phases of the work. At different phases of the project various types of working methods will be applied. Close cooperation with other Modules and WPs is of utmost importance through out the whole project especially, in selection of products, modelling of value chains, and delivery of data.

4.4 DELIVERABLES

Deliverables describe reports and output which will be conducted in accordance to the SUNPAP DOW.

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APPENDICES

Appendix 1. Tentative indicator lists

Theme	Environmental indicators (to be selected and defined by KCL/VTT)	
Energy efficiency	**Name**	Energy use
	Sub-indicators	-from renewables -from non-renewables
	Description	
	Unit	
Resource efficiency	**Name**	Resource / raw material use
	Sub-indicators	-renewable sources -non-renewable sources -petroleum-based products
	Description	Raw materials, chemicals etc. used in the process
	Unit	
Resource efficiency	**Name**	Water use
	Sub-indicators	
	Description	
	Unit	
Emissions	**Name**	Carbon footprint / Greenhouse gas emissions
	Sub-indicators	-CO_2 -N_2O -CH_4
	Description	
	Unit	
Emissions	**Name**	Air emissions
	Sub-indicators	SO_x, NO_x, particles, ?
	Description	
	Unit	
Emissions	**Name**	Water emissions
	Sub-indicators	N, P, COD, ?
	Description	
	Unit	
for end-of-life phase	**Name**	Recyclability, compostability and ecotoxicity
	Sub-indicators	
	Description	Information from WP3
	Unit	
	Name	
	Sub-indicators	
	Description	
	Unit	

Theme	Social indicators	
Effects on employment	**Name**	Employment
	Sub-indicators	-male / female -age classes -educational categories
	Description	Number of persons employed
	Unit	
Labour wellbeing	**Name**	Wages and salaries
	Sub-indicators	-male / female -type of employment
	Description	
	Unit	
Labour wellbeing	**Name**	Quality of work
	Sub-indicators	
	Description	
	Unit	
Product safety / health effects	**Name**	Exposure to detrimental substances
	Sub-indicators	Exposure to substances, that have health effects, along the life cycle of the product
	Description	Information from Module 4
	Unit	qualitative
Public acceptance	**Name**	Acceptance
	Sub-indicators	
	Description	
	Unit	qualitative
Regional development	**Name**	Effect on rural development
	Sub-indicators	
	Description	
	Unit	qualitative
	Name	
	Sub-indicators	Production costs
	Description	-labour -transports -investment costs / capital charges
	Unit	