BenchValue – Benchmarking the Sustainability Performances of Value Chains

BenchValue Indicators

Patrick Huber, BOKU
Bernhard Wolfslehner, BOKU
Tomas Ekvall, IVL
Diana Tuomasjukka, EFI
Tommi Suominen, EFI
Estelle Vial, FCBA
Jamie Goggins, UL

Vienna, 31.5.2018

Dissemination Level	
Public	x
Restricted to a group specified by the consortium	
Confidential, only for members of the consortium (including SumForest committee)	

Prepared under FP7 ERA-NET Sumforest Call 2016 "Sustainable forests for the society of the future" accepted project "BenchValue"

Project acronym: **BenchValue**

Project full title: **Benchmarking the Sustainability Performances of Value Chains**

Start of the project: 1 December 2016 / 1 January 2017

End of project: 30 November 2019

Project coordinator: European Forest Institute (EFI)

Project website: http://benchvalue.efi.int

Deliverable title: Integrated indicator framework for sustainability assessment of construction value chains

Deliverable number: 3.1

Nature of the deliverable: Report

Work package responsible: WP3

Partner responsible: BOKU

Other partners involved: EFI, FCBA, IVL

Due date of deliverable: 31.05.2018

Actual submission date: 29.06.2018

Deliverable status: final (for NCP review)

Version	Status	Date	Authors
1.0	Draft	December 2017	see title page
2.0	Draft	May 2018	see title page
3.0	Final	June 2018	see title page

Content

Figures

Tables

Preface

European Forest Institute (EFI) coordinating a research project - Benchmarking the Sustainability Performances of Value Chains - BenchValue. The project is funded under the framework of transnational ERA-NET network by the national funding bodies (Austria, Finland, France, Ireland, Lithuania and Sweden). The project aims to provide objective analysis between the sustainability performances of forest biomass-based vs. fossil/mineral-based value chains.

BenchValue describes value chains in a process-based approach aimed at decision making by assessing environmental, social and economic impacts of alternative chains using ToSIA (Tool for Sustainability Impact assessment). BenchValue focuses on the market place and develops generic indicators covering economic and socio-environmental aspects to be used in a benchmarking method that compares forest biomass-based materials against others.

This publication is a part of the BenchValue project and summarizes the findings of the work on indicators conducted during the first half of BenchValue in the context of work package (WP) 3. It integrates the outcomes of a suite of participatory processes aimed to develop an indicator framework for comparative assessments of construction value chains and strongly builds upon the perspectives of different stakeholders and experts who are actively engaged in the construction sector in Europe.

To set the stage for benchmarking of competing value chains, a generic reference value chain in the construction sector (typical house construction), which later on will be adjusted to suit country-specific situations (e.g. in the case studies), is used. The reference chain is meant to fulfill multiple functions: i) defining the system boundaries for the sustainability assessment (SA), ii) identifying and specifying occurring material flows, processes and products, iii) depicting options for a proper indicator set that can be linked to mapped processes and iv) delineating efforts for data collection to calculate indicator values for sustainability impacts.

This report identifies a set of core indicators that will be applied for the benchmarking extension of ToSIA, covering all three dimensions of sustainability: i) social, ii) economic and iii) ecological. Existing indicators available from various frameworks (i.e. LCA, ToSIA, LEVELs) serve as the baseline to integrate the most recent state of the art in sustainability science with an "indicator wish list" elaborated during a stakeholder workshop on sustainability indicators in frame of the WoodRise Congress in Bordeaux (France), the 1st World Congress on mid-rise and high-rise wood buildings, on September 14th, 2017 (see D 2.1 "Open Space workshop on sustainability indicators for buildings").

The generic reference chain for typical house construction shall provide the framework to identify a proper suite of indicators that can be applied to assess sustainability dimensions of construction value chains. Thus this report starts from the reference chain discussion to set the system boundaries for the sustainability assessment and by that decide upon data collection needs. Furthermore it serves the identification as well as the application of “black boxes” (i.e. data or datasets available from the literature or LCA databases, as well as recent or ongoing projects like the FORMIT project for certain raw materials and/or products that can be used for individual indicators and thus serve as an entry point for the sustainability assessment).

The feasibility and operationability of adding benchmark indicators and calculation routines to compare with fossil or mineral-based value chains will be explored further in WP 3 by applying, and if required developing, a suite of ecological, economic and social aspects key indicators for construction value chains. This process is ongoing and continues in the second half of BenchValue as part of the method development efforts, in relation to stakeholder demands and needs arising within the case studies. The indicator cohort will be tested against current standards before implementation in ToSIA. This requires the definition of processes along the value chain with linked indicators, and a common material flow denominator. Partially covered in this Deliverable, these tasks represent work in progress and are to be continued in WP 3 over the second half of BenchValue. The method development will be concluded in the Deliverable 3.2 “Benchmarking report on the method, synthesis of results and policy analysis”, at the end of the project.

The sole responsibility for the content of this report lies with the authors.

1 Introduction

1.1 Value chains and their application in ToSIA

In order to identify positive and negative effects of scenario changes (e.g. policies, technologies, materials) on the sustainable development of a sector or across sectors , we follow the Sustainability Impact Assessment (SIA) approach of the FP6 project ‘’EFORWOOD’’, which has been particularly designed to analyse sustainability dimensions of forestry-wood chains (FWC) in Europe (Paivinen et al 2012). For this approach, four elements are essential (cf. Lindner et al 2010):

1 processes are activities within value chains by which raw materials are converted into services and products. In a process, raw materials are changing their appearance, value and/or moving to another location, which is to be applied for the various stages defined;
2 products are mass-based inputs and outputs of processes and build the linkage among processes in the chain topology
3 material flow describes the amount of material that passes through the FWC and describes dispersing flows by means of input and output product shares at process level. Further, conversion factors are used to transform data at different units to a harmonised wood material flow;
4 indicator values are calculated by multiplying the input material flow for a process in the chain with a relative indicator value occurring at a specific process. This is done for all individual processes and all indicators used in the assessment procedure.

The Tool for Sustainability Impact Assessment (ToSIA) analyses environmental, economic and social impacts of changes in value chains and provides the opportunity to identify impacts of different scenarios in comparison to the current status quo (i.e. baseline). Value chains are defined as „the full range of activities which are required to bring a product or service from conception, through different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use“ (Kaplinsky and Morris 2002).

ToSIA follows value chain thinking as a framework to set the system boundaries for studies of individual cases that may range from local to international assessments and from detailed „real“

company applications to more generic, aggregated ones. The main elements of a value chain in ToSIA cover:

- Processes
- Products
- Modules

According to the European Forest Institute these elements are defined in the following way (cf. Suominen et al 2013):

Process: The smallest and most important element of a value chain is a Process. Transformation of energy and materials takes place in a process. In a process (wood) material will change its appearance and/or move to another location. Every process requires inputs and produces outputs. Inputs for each process in a chain are supplied by outputs of previous processes. Processes include e.g. planting trees, stand treatments, harvesting, transport, sawing, pulping, papermaking, printing, packaging, recycling, and energy production - or when needed subsets thereof.

Products: Products are the Carbon mass-based inputs and outputs of processes. The functional purpose of products is to link together processes to form chain structures. Products are expressed in mass units and for each product the conversion factor, for converting it to different units (e.g. tons of C, m3, ha) needs to be stated. Processes can also receive input products from outside of the FWC system boundaries (e.g. imported materials or non-wood material used in furniture manufacturing).

Modules: Modules are organisational entities at the sub-chain level. Modules combine processes together in logical groups. Modules present the highest hierarchical level of a value chain.

Common characteristics across all value chains regardless of the raw material are the need for:

- Base units: e.g. tons (dry) for all materials
  - Timber: tons of Carbon (t of C)
  - Steel: tons of iron (t of Fe) or tons (t)
  - Cement: according to the cement used in m3 (correlated to tons of limestone and clay)
- Modules:

  Following the Lifecycle Assessment of a Building (EN 15978:2011)[1] the value chain topology of ToSIA is adopted to integrate the LCA Modules accordingly (see Figure 1).

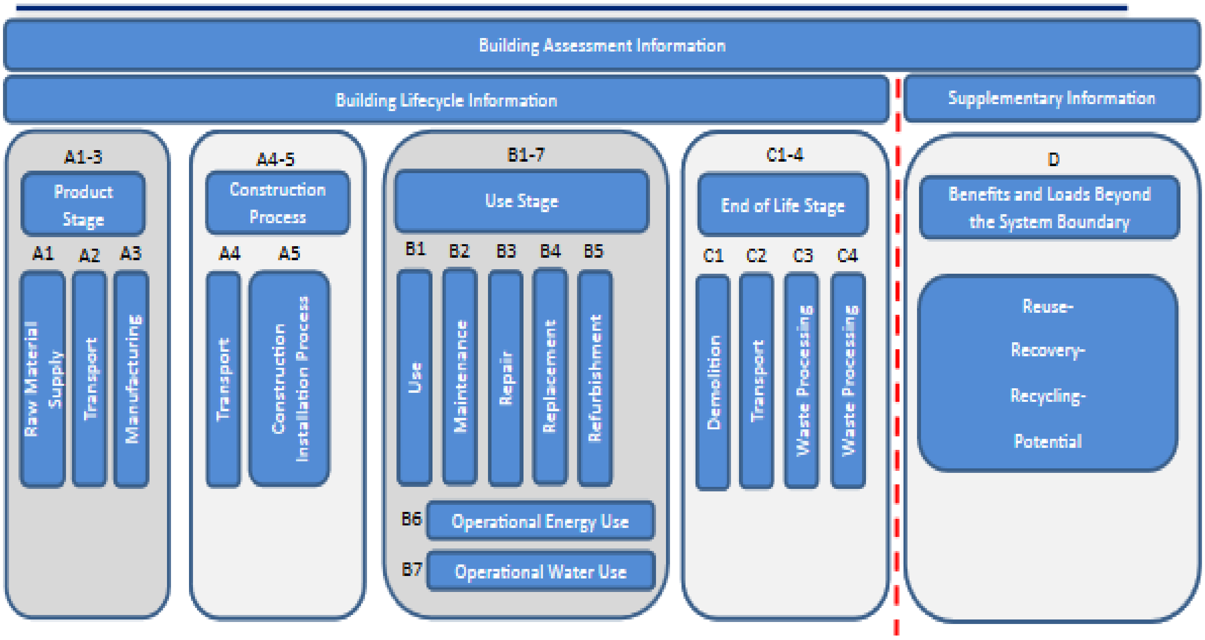

Figure 1: Life Cycle Modules A to D across the different stages A1 to C4 from product stage to end of life stage (EN 15978:2011)

For the Sustainability Assessment within BenchValue, stages A1 to C4 will be particularly relevant and integrated in the benchmarking extension of ToSIA.

1.2 Indicator frameworks and their application

Indicators are the tools of choice for measuring, monitoring and assessing progress towards sustainable development. Most recent developments include the formulation of the 17 Sustainable Development Goals (SDGs) that include 169 targets and a total of 230 indicators (UN

2015). Indicator frameworks help to focus and clarify what and how to measure, what to expect from the measurement and what kinds of indicators to use. Such frameworks include an array of different approaches, like: i) Driving force-state-response frameworks, ii) issue- or theme-based frameworks, iii) capital frameworks, iv) accounting frameworks, or v) aggregated indicators among others (UN 2007). In light of European bioeconomy developments, Wolfslehner et al (2016) recently recapped the state of the art of indicator application in Europe and particularly addressed the role of forest indicators in this regard. Following a former study (European Forest Institute 2013) five major applications of indicator use in Europe were identified:

- Reference framework for dialogue, communication, and streamlining the forestry debate.
- Tool for monitoring and reporting on the progress towards sustainable forest management, and improving quality and comparability of forest information among European countries.
- Reference framework for the development and adaptation of national policy instruments and/or forest-related policies.
- Assessment tool for measuring progress towards sustainable forest management and identifying emerging issues.
- Information tool for creating links to other sectors and global initiatives.

For the built environment several indicator frameworks have been developed and are applied, often in context of a rating system for environmental assessment of sustainable buildings. Castellano et al (2016) provide a review of contemporary rating systems, including Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Built Environment Efficiency (CASBEE), or Building Environmental Assessment Method (BEAM plus) among others. Since the building (respectively construction) industry is considered to be one of the largest exploiters of natural resources and has regularly been in the centre of criticism regarding energy use, waste production, greenhouse gas emissions and impacts on the landscape sustainable construction has recently gained momentum in construction research (e.g. Al-Nassar et al 2016, Kibert 2012, Kashap et al 2003). One of the latest assessment systems which is expected to become binding for public procurement is the EU's Level(s) framework (European Commission 2017) and national interpretation such as for Finland "Low Carbon buildings" (Kuittinen et al 2017) or for Austria "klimaaktiv", the national climate programme that integrates standards for sustainable buildings (BMNT 2018). Similar initiatives and respective standards exist in France, Ireland and Lithuania.

2 Reference chain for typical house construction

ToSIA operates on the level of value chains to analyze sustainability effects, no matter if these chains represent complete or only partially mapped systems. To come to grips with the system boundaries of a generic reference chain for typical house construction in Europe, this chapter pinpoints the various elements that are required to describe the value chain, i.e. the system of analysis for the benchmarking of wood value chains against fossil or mineral based value chains.

2.1 Chain topology

The structure of the reference value chain shall visualize the complexity of the system that will be analyzed with the BenchValue benchmarking method in the final phase of the project. The main elements of a chain topology in ToSIA, as outlined above (see chapter 1.1), are: i) processes, ii) products, and iii) modules. They are used to provide a brief overview of the entire value chain system and link the Life Cycle Assessment modules (A1-D) that are highlighted in Figure 1 in a simplified manner (Figure 2).

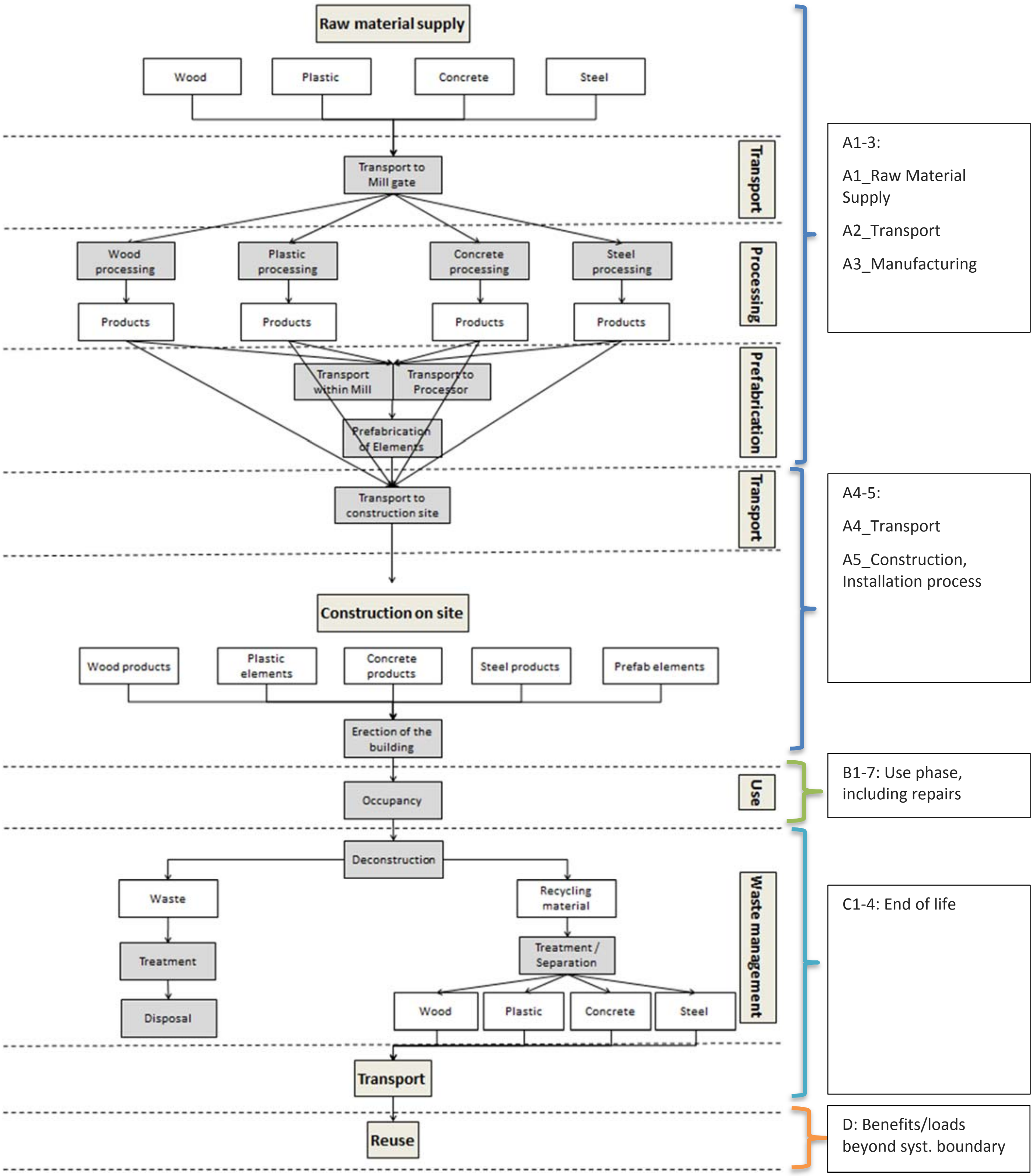

Figure 2: Simplified topology of a typical house construction value chain (processes= grey boxes; products = white boxes; modules= light brown, bold letters, separated via dashed lines)

Life Cycle thinking seeks to identify possible improvements to goods and services or products by lowering their environmental impacts and reducing the use of resources across all life cycle (EC 2010). Life Cycle Assessment (LCA) thus starts from cradle, i.e. raw material supply, and ends either at gate, grave or cradle according to the underlying sustainability design paradigm. Within ToSIA the lifecycle concept is implemented cradle to cradle, i.e. raw material supply to reuse, and can flexibly adjust to the modelling of recycling material flows. The value chain approach in Figure 2 shows the main processes and products per (LCA) module that need to be modelled in detail for the Sustainability Assessment. At current state they are summarized at macro level and serve as a reference structure for the generic value chains that are set up per raw material (i.e. wood, cement, steel) in the further work of WP 3. To illustrate the level of detail required, a brief example for steel is used in the following.

Example for steel production (modelling of processes)

Key raw materials needed in steelmaking include iron ore, coal, limestone and recycled steel. The two main steel production routes and their related inputs are (Figure 3):

1. The integrated steelmaking route, based on the blast furnace (BF) and basic oxygen furnace (BOF), which uses raw materials including iron ore, coal, limestone and recycled steel. On average, this route uses 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of recycled steel to produce 1,000 kg of crude steel.
2. The electric arc furnace (EAF) route uses primarily recycled steels and direct reduced iron (DRI) or hot metal and electricity. On average, the recycled steel-EAF route uses 880 kg of

recycled steel combined with varying amounts of other sources (DRI, hot metal, and granulated iron), 16 kg of coal and 64 kg of limestone, to produce 1,000 kg of crude steel.

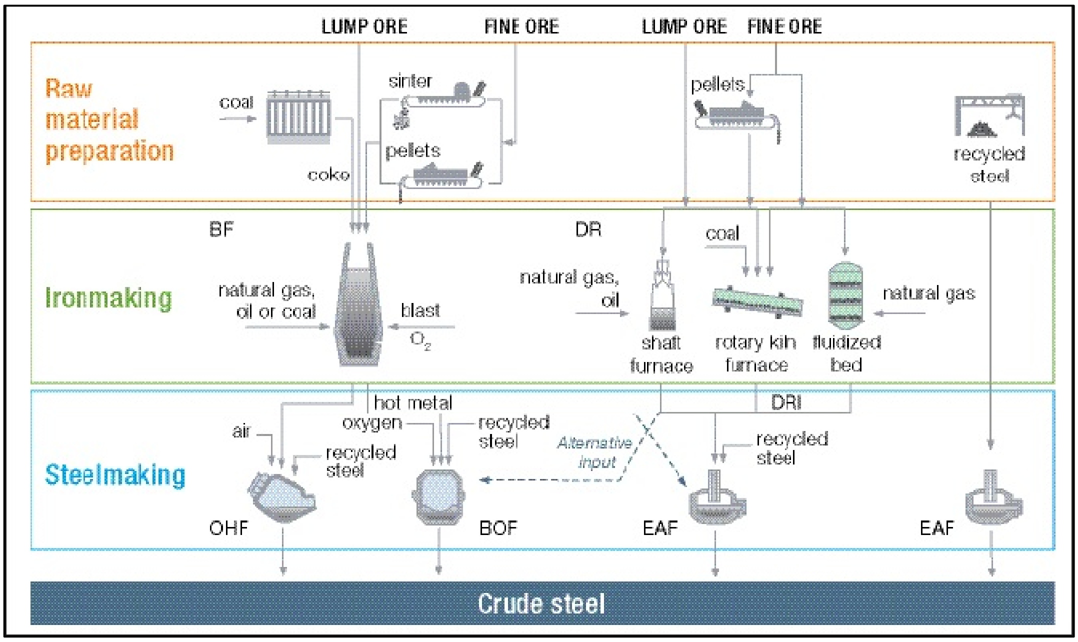

Figure 3: Steel production routes (World Steel 2018)

Steel is an alloy consisting mostly of iron and less than 2% carbon. Iron ore is, therefore, essential for the production of steel, which in turn is essential in maintaining a strong industrial base. 98% of mined iron ore is used to make steel. Average iron content for high-grade ores is 60% to 65%, after taking into account other naturally-occurring impurities. Iron ore is mined in about 50 countries with the key producing countries being Brazil, Australia, China, India, the US and Russia. As iron occurs only as iron oxides in the earth's crust, the ores must be converted, or 'reduced', using carbon. The primary source of this carbon is coking coal. Coal is a key raw material in steel production primarily used as a solid fuel to produce electricity and heat through combustion. Coke, made by carburising coal (i.e. heating in the absence of oxygen at high temperatures), is the primary reducing agent of iron ore. Coke reduces iron ore to molten iron saturated with carbon, called hot metal (World Steel 2018).

To translate the various steps required to produce crude steel and model that type of value chain in ToSIA, each process has to be covered in detail.

2.2 Processes and products

Every single process along the value chain (from cradle to cradle) has to be precisely defined, inter alia to secure transparency and safeguard potential future repetition or adaptation of the assessment. Processes are the most important elements for sustainability assessments within ToSIA (see chapter 1.1). Products are the mass-based inputs and outputs of processes and link processes to form chain structures. Products are expressed in mass units and for each product the conversion factor, for converting it to different units (e.g. tons of C, m3, ha) has to be known. Processes can also receive input products from outside of the system boundaries (e.g. non-wood material used in manufacturing, recycled steel for the production). Table 1 pinpoints examples for processes, their definitions and underlying assumptions.

Table 1: Examples for process descriptions required for the modelling of BenchValue generic chains in ToSIA

Process ID	Module	Name	Assumptions
1	A1-3	raw material supply wood	Wood supply at forest road from a typical forest management regime (including: regeneration of stand, planting of seedlings, reduction of stems, maintenance of natural regeneration, pre-commercial thinning operations, harvesting and forwarding)
2	A1-3	raw material supply plastic	
3	A1-3	raw material supply concrete	
4	A1-3	raw material supply steel	
5	A4	transport to mill gate	e.g. wood transport covers roundwood transport by a 44 t truck, transport distance 150 km
6	…	…	…
7	…	…	…

In relation to the example on steel production above (see section 2.1), process ID 4 (Table 1) "*raw material supply steel*" would thus summarize the entire supply chain activities that have to be taken into consideration when modelling the steel production route (i.e. blast furnace and basic oxygen furnace or electric arc furnace). In either routes the processes start with the extraction of the raw materials required (i.e. iron ore, coal and limestone). Iron ore is usually mined by exploding rocks that are transported to the plants by heavy trucks or conveyors for further processing. However, Table 1 shows only examples on individual processes (or clustered processes respectively) to raise awareness on the complexity of the value chain model - the full list of processes has to be determined in the further work of WP regarding method development and will be extensive for individual materials (World Steel 2012).

2.3 Material flow

According to Tuomasjukka (2017), ToSIA tracks material flows along the entire value chain, starting from the initialization process and includes imports, exports as well as losses as defined by the user. Material flows are captured in organic carbon content (i.e. tons of carbon) for wood value chains, both within the material (e.g. wood) and in area (e.g. hectares), as well as in the product unit itself (e.g. m3 or tons). Within Bench Value, and in regard to the comparative sustainability assessment of different materials, the material flow has to be initiated using the same base unit for all investigated materials (i.e. wood, cement, steel).

- Base unit for all three materials
  - timber, steel, cement: tons (dry)
- Base unit for individual material according to individual value chain modelling
  - Timber: tons of Carbon (t of C)
  - Steel: tons of iron (t of Fe) or tons (t)
  - Cement: according to the type of cement under investigation in tons (t) or m^3

Mass in tons of Carbon is used as the information carrier for value chains in ToSIA. Tons of Carbon is used in internal calculations in ToSIA to ensure that all information is comparable, and consistent. To link the material flow with ToSIA calculation routines, various conversion factors are in use to convert, e.g. a certain amount of material into CO^2 equivalents – an essential step for the quantification of sustainability effects.

3 Quantification: Indicators

In order to quantify impacts on the sustainability dimensions of value chains with ToSIA indicators are used. An indicator shows something or points to something and can thus be defined as: "A parameter, or a value derived from parameters, which points to / provides information about / describes the state of a phenomenon / environment / area with a significance extending beyond that directly associated with a parameter value (OECD 1992)." As outlined in chapter 1.2, various indicator frameworks for the built environment exist and are applied in context of environmental assessments of sustainable buildings. As ToSIA originally has been designed for the analysis of wood value chains (or Forestry-Wood-Chains, cf. Green et al 2015), to integrate several life cycle aspects for different raw materials for the benchmarking approach within BenchValue, a limited indicator cohort shall secure the validity, reliability and robustness of the method expansion. WP 3 made use of existing indicator sets (see below 3.1) and stakeholder perceptions (see below 3.2) as regards the relevance of indicators needed to holistically assess the sustainability of buildings in Europe.

3.1 Indicators from other frameworks

This chapter describes diverse indicator sets used for sustainability assessments and focuses on indicators relevant for the built environment. A couple of standards and norms at European level have been developed in the past to support such assessments:

- EN 13187 Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method. CEN/TC 89 Thermal performance of buildings and building components, 1998.
- prEN 15603 standard. Energy performance of buildings – Overarching standard EPBD. CEN/TC 371 Energy Performance of Buildings, 2013.
- EN 15643-1 Sustainability of construction works. Sustainability assessment of buildings – Part 1: General framework. CEN/TC 350 – Sustainability of construction works, 2012.
- EN 15643-4 Sustainability of construction works. Assessment of buildings – Part 4: Framework for the assessment of economic performance. CEN/TC 350 – Sustainability of construction works, 2012.
- EN 15804 Kestävä rakentaminen. Rakennustuotteiden ympäristöselosteet. Laadinnan yleissäännöt. CEN/TC 350 - Sustainability of construction works, 2014.
- EN 15978 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method. CEN/TC 350 – Sustainability of construction works, 2012.
- EN 16485 Round and sawn timber. Environmental Product Declarations. Product category rules for wood and wood-based products for use in construction. CEN/TC 175 Round and sawn timber, 2014.
- EN 16627 Sustainability of construction works. Assessment of economic performance of buildings. Calculation methods. CEN/TC 350 Sustainability of construction works, 2015.
- EN 16757 Sustainability of construction works. Environmental product declarations. Product Category Rules for concrete and concrete elements. CEN/TC 229 Precast concrete products, 2017.
- EN ISO 14001 Ympäristöjärjestelmät. Vaatimukset ja niiden soveltamisohjeita. CEN/SS S26 – Environmental management, 2015.
- EN ISO 14024 Environmental labels and declarations. Type I environmental labelling. Principles and procedures. CEN/SS S26 Environmental management, 2000.
- EC. Green Public Procurement Criteria for Office Building Design, Construction and Management – Procurement practice guidance document. Joint Research Centre, 2016. online: http://ec.europa.eu/environment/gpp/pdf/Guidance_Buildings final.pdf. JRC102383.

This list is not exhaustive but serves as a reference for assessment methodologies, valuation systems and indicator availability. For the benchmarking extension of ToSIA, as developed within BenchValue, the minimum portfolio of indicators used is based on the current state of the art in

Sustainability Science (e.g. Kates at al 2001, Sala et al 2013) and relates to the following frameworks in particular (see below 3.1.1 – 3.1.2).

3.1.1 LCA

Life Cycle Assessment (LCA) quantifies and assesses the emissions, resources consumed, and pressures on health and the environment attributed to different products over their entire life cycle (EC 2012). LCA takes inventory data and converts it to indicators for each impact category, which typically include:

- Global warming potential (GWP100)
- Ozone depletion potential (ODP)
- Photochemical ozone creation potential (POCP)
- Acidification potential (AP)
- Eutrophication potential (EP)
- Non-renewable primary energy (PE-NR)
- Total primary energy demand (PE)
- Share of renewable primary energy (%PE-R)

Although LCAs rarely include all of these, they may include the following impact categories in addition (EU 2013):

- Ecotoxicity for aquatic fresh water
- Human Toxicity - cancer effects
- Human Toxicity - non-cancer effects
- Particulate Matter/Respiratory Inorganics
- Ionising Radiation - human health effects
- Resource Depletion - water
- Resource Depletion - mineral, fossil
- Land Transformation

3.1.2 LEVELs

In 2015 the European Commission initiated a study to develop an EU framework of core indicators for the environmental performance of buildings (LEVELs) and identified six macro-objectives that establish the strategic focus and scope for the framework of indicators. These priorities are: i) greenhouse gas emissions throughout the buildings life cycle, ii) resource efficient and circular material life cycles, iii) efficient use of water resources, iv) healthy and comfortable spaces, v) adaptation and resilience to climate change, and vi) life cycle cost and value (EU 2017). Following the macro-objectives and building upon stakeholder consultation a suite of indicators was identified, with the following ones suggested as core indicators within the framework (Dodd et al 2016):

- Operational energy consumption
    - Total primary energy consumption
    - Final energy consumption
- Operational and embodied Global Warming Potential
- Service life of bill materials
- Construction and demolition waste
- Mains drinking water consumption
- Airborne pollutant levels
    - Quantitative airborne pollutant levels
    - Qualitative airborne pollutant levels
- Indoor air class (ventilation, CO2 and relative humidity)
- Occupant thermal comfort
- Additional energy required
- Life Cycle cost
    - Utility costs
    - Acquisition and maintenance costs
- Value and risk factors

Level(s) yet represents a voluntary reporting framework to improve the sustainability of buildings and provides a common EU approach to the environmental performance in the built environment.

3.1.3 ToSIA

In ToSIA, indicator values per material flow are taken from a database client, where the set of indicators are introduced (based on existing case studies and indicators that have been used for recent SIA studies). In ToSIA, the calculated process indicator values are determined based on the material flow through the process and the indicator values per material flow from the database. Calculated module and FWC indicator values are then determined by aggregating the calculated process indicator values along the chain taking into account the system boundaries selected by the user. In the following Table (2) a brief, but not at all complete, list of indicators available in the database client is shown.

Table 2: Indicator list per sustainability pillar available in ToSIA (exzerpt from ToSIA database client)

Economic	Social	Environmental
Gross value added	Employment	Energy generation and use
Production cost	Wages and salaries	Greenhouse gas emissions and carbon stock
Trade Balance	Occupational safety and health	Transport
Resource use, incl. recycled material	Education and training	Water Use
Forest sector enterprise structure	Corporate social responsibility	Forest Resources
Investment and research & development	Quality of employment	Soil condition
Total Production	Provision of public forest services	Water and Air Pollution
Productivity	Cultural heritage & Sense of Place	Forest biodiversity
Innovation	Traditional Knowledge and Stories	Generation of waste

First try-out of adding LCA perspectives into ToSIA by defining separate indicators for direct and indirect energy use and Greenhouse gas emission, as well as an Emission Saving Criteria calculating the sum of direct plus indirect emissions for a renewable value chain and comparing it against a fixed Fossil Fuel Comparator (FFC) to express Emission savings of renewable versus fossil value chains was described in detail in Tuomasjukka et al (2017).

3.2 Indicators from stakeholders

The stakeholder workshop on sustainability indicators for buildings (see D 2.1) revealed the following most important topics to be considered in sustainability assessments of buildings (Ekvall et al 2017):

- Local impacts, e.g. local added value and its distribution among local actors, optimized resource use
- Waste management, e.g. LCA indicators, share of prefabrication, types of waste
- Health and well-being, e.g. exposure time and rate, air quality, comfort
- Resource depletion, e.g. land use effects, use of renewable resources, species diversity
- Adaptability, e.g. reuse of building and its components, flexibility of buildings, risk and climate change adaptability

- Beauty and Biophilia, e.g. to what extent the building fits into the natural and cultural context at the site
- Employment, e.g. direct and indirect employment effects
- Climate impacts, e.g. all greenhouse gases

4 Indicator cohort for the benchmarking extension of ToSIA

Taking stock of an array of indicators available, in this chapter we identify and describe the core set of indicators that will be used throughout Bench Value to further develop and test the benchmarking extension of ToSIA. It is designed to be applied at the macro-level (i.e. European), but shall provide a flexible and adoptable framework for the application at the case study level (e.g. BenchValue case studies). The indicator list integrates findings from the review of existing frameworks and their objectives as well as potential limitations regarding data availability and data quality. For the generic chain the list of indicators thus does not reflect a full and comprehensive set of indicators that could be relevant for sustainability assessment of the built environment (according to existing frameworks or stakeholders´ perception respectively – see chapter 3), instead it aims to depict an indicator cohort that is applicable for implementation during the BenchValue project (i.e. data availability and quality secured; allocation across processes feasible). The indicators are listed per sustainability pillar and described in detail regarding their definitions and the underlying rationale (see below, chapter 4.1 – 4.3).

4.1 Ecological

Table 3: Minimum set of ecological Indicators used for the sustainability assessment of construction chains in BenchValue

Indicator	Definition	Rationale
Greenhouse gas emissions	Greenhouse gas emissions in kg CO2 equivalents	Climate impacts are among the most relevant aspects and addressed by all referred frameworks (see LCA/ToSIA/LEVELs); to compare GWP
Carbon stock	Carbon stored in wood/steel/cement/plastic products in kg C	Related to climate impacts; to address mitigation potentials, might be related to service life?
Energy use	Energy used in MJ	can be split in primary and total energy use; fossil/renewable (if feasible); to disentangle energy intensity across raw materials, resource depletion,...

4.2 Economic

Table 4: Minimum set of economic Indicators used for the sustainability assessment of construction chains in BenchValue

Indicator	Definition	Rationale
Production cost	average production cost per process including cost for raw materials, labour, energy and other productive and non-productive costs	Addressing life cycle costs; identifying cost efficiency
Gross value added	GVA (at factor cost) = GVA at basic prices (only prices of inputs and outputs used to produce the specified outputs of this very process) â€“ taxes on production (i.e. this very process) + subsidies on production (of this very process)	Measures the difference between value for the output and intermediate consumption at basic Prices;to mirror economic benefits
Trade balance	Value of net trade in raw materials and products derived from raw materials	can be split in primary and total energy use; fossil/renewable (if feasible); to disentangle energy intensity across raw materials, resource depletion,...

4.3 Social

Table 5: Minimum set of social Indicators used for the sustainability assessment of construction chains in BenchValue

Indicator	Definition	Rationale
Employment	Number of persons employed in total for this process	Reflects the amount of working hours; addresses job opportunities; indication of labour intensity
Wages and salaries	Average wages and salaries per employee relative to country average in €	Measures the difference between value for the output and intermediate consumption at basic Prices;to mirror economic benefits
Occupational safety and health	Absolut number of (non-fatal / fatal) occupational accidents per 1000 employees per reporting unit	can be split in primary and total energy use; fossil/renewable (if feasible); to disentangle energy intensity across raw materials, resource depletion,...

European Forest Institute has contributed to and is responsible for the Data Collection Protocol (DCP), developed for ToSIA user guidance (cf. Tuomasjukka et al. 2012). For each of the above mentioned indicators, a precise description for data collection is available. An example for the economic indicator Gross value added shall illustrate the DCP definitions (Table 3).

Table 6: Description of data collection and calclulation routines – example of ToSIA indicator "Gross Value Added" (Tuomasjukka et al, 2012)

Full name of indicator (including subclasses):	***Gross value added (GVA) at factor cost and contribution to gross domestic product***
ToSIA definition	GVA (at factor cost) = GVA at basic prices (only prices of inputs and outputs used to produce the specified outputs of this very process) – taxes on production (i.e. this very process) + subsidies on production (of this very process)
Name of subclass	1.1 Gross value added (at factor cost) by [processes within each module]
Measurement units:	1.1 In € per reporting unit.
System Boundaries	Only prices of inputs and outputs used to produce the specified outputs of a given process are to be included, e.g. avoid including transportation if modeled independently in subsequent processes. This implicitly defines a system boundary.
Possible data source	Current situation (test chains): data collection by modules for each process. Future potential data providers: Eurostat, UN World bank, National Statistics Office. At process level: national organizations of foresters, industry, etc. at national level. In some cases, such organizations compile reliable statistics and estimates.
Calculation mode (incl. conversion factors)	GVA at factor cost = GVA at basic prices – taxes on production + subsidies on production Gross value added at factor cost can be derived from Gross Value Added at basic prices by subtracting indirect taxes and adding subsidies on producer's production. From the point of view of the producer, purchaser's prices for inputs and basic prices for outputs represent the prices actually paid and received. Gross value added is an unduplicated measure of output in which the values of the goods and services used as intermediate inputs are eliminated from the value of output. The production process itself can be described by a vector of the quantities of goods and services consumed or produced in which inputs carry a negative sign. By

	associating a price vector with this quantity vector, gross value added is obtained as the inner product of two vectors. Example: Let q = the N × 1 vector quantities consumed (negative sign) or produced p = the 1 × N vector of prices, Then, Gross Value Added (GVA) = pq (N × N) When p corresponds to basic prices – taxes on production + subsidies on production External effects (noise, GHG, waste, emissions to air) are not usually included in the GVA because they are not internalised by the companies. Externalities will be handled related to the relevant indicators in CBA separately. In addition, some externalities are covered in the environmental indicators.
Key definitions	**Gross Value Added (GVA):** is defined as the value of all newly generated goods and services less the value of all goods and services consumed as intermediate consumption. The depreciation of fixed assets is not taken into account. (Eurostat definition) See definitions below.

Calculation mode:

General rule:

Output at basic prices	(1)
- Intermediate consumption at purchasers' prices	(2)
= GVA at basic prices	(3) = (1) – (2)
- Other taxes on production	(4)
+ Other subsidies on production	(5)
= GVA at factor cost	(6) = (3) – (4) + (5)

Similar guidelines exist for all of the selected indicators in the BenchValue indicator cohort and provide the case studies with

5 Conclusions and further work

The buildings sector is one of the most resource consuming sectors in Europe, accounting for approximately half of all extracted materials, half of total energy consumption, one third of water consumption and one third of waste generation and thus has been in the centre of criticism regarding energy use, waste production, greenhouse gas emissions and impacts on the landscape in recent years (e.g. EU 2017, Al-Nassar et al 2016, Kibert 2012, Kashap et al 2003). In light of contemporary developments to foster a more integrated and sustainable European economy – in respect to circular and bioeconomy discourses – efforts to monitor sustainable development in the construction sector have gained momentum. Indicators are the tools of choice for measuring and assessing the progress towards sustainability. A plethora of indicators is available from various frameworks that have been developed and are often applied in context of a rating system for an environmental assessment of sustainable buildings (Castellano et al. 2016). However, there is no harmonized and integrated approach for sustainability assessment of construction value chains that follows life cycle thinking and bridges life cycle and impact assessment. Level(s) is the currently evolving European voluntary framework that aims to set the standard for a sustainability framework of the circular economy, and offers a tiered approach to life cycle assessment.

BenchValue aims to contribute to related developments as well as discourses and intends to foster the sustainability performance of the construction industry in Europe and brings together life cycle and sustainability assessment in a benchmarking methodology to assess the sustainability effects of construction value chains. Generic reference chains of typical house construction in Europe serve as a reference (see chapter 2). The indicator portfolio provides the tool to quantify these effects (see chapter 3). Sustainability assessments require various methodological decisions including the selection of as well as the adaptation of (new) indicators or the integration of indicator thresholds as a baseline for benchmarking.

Several of these shortcomings will be addressed and are to be further elaborated in the future work of the project BenchValue. This includes activities to improve (and detail) both the reference chains per material (i.e. wood, cement, steel) and the indicator portfolio for a comprehensive and contrasting assessment of construction value chains. This work is to be continued throughout the second half of the BenchValue project and will be further elaborated in WP 3.

References

Al-Nassar, F., Ruparathna, R., Chhipi-Shrestha, G., Haider, H., Hewage, K. and Sadiq, R. (2016). Sustainability assessment framework for low rise commercial buildings: life cycle impact index-based approach. Clean Techn Environ Policy (2016) 18: 2579-2590. DOI: 10.1007/s10098-016-1168-1

BMNT (2018). KLIMAAKTIV BASISKRITERIEN 2017. 2. Auflage, BMNT, Abteilung Energie und Wirtschaftspolitik. BUNDESMINISTERIUM FÜR NACHHALTIGKEIT UND TOURISMUS. Vienna, Austria.

Castellano, J., Ribera, A. and Ciurana, J. (2016). Integrated system approach to evaluate socia, environmental and economics impacts of buildings for users of housings. *Energy and Buildings* 123:106-118. http://dx.doi.org/10.1016/j.enbuild.2016.04.046.

Dodd, N., Cordella, M., Traverso, M. and Donatello, S. (2016). Towards an EU framework of core indicators for the environmental performance of buildings Proposals and discussion points to inform the 2nd Working Group meeting, Brussels,30thNovember 2016. JRC (Unit B5), European Commission.

EC (2010). Making sustainable consumption and production a reality. A guide for business and policy makers to Life Cycle Thinking and Assessment. European Commission, Joint Research Centre, Institute for Environment and Sustainability.

EC (2012). Life cycle indicators framework: development of life cycle based macro-level monitoring indicators for resources, products and waste for the EU-27. European Commission, Joint Research Centre, Institute for Environment and Sustainability.

EC (2017). Level(s): building sustainability performance. Sustainable buildings. Online: http://ec.europa.eu/environment/eussd/buildings.htm

Ekvall, T., Hult, Å. & Tuomasjukka D. (2017). Open Space workshop on sustainability indicators for buildings. Bench Value Deliverable 2.1

EN 15804:2012+A1:2013 Sustainability of construction works – Environmental product declarations – ore rules for the product category of construction products.

EN 15643-1:2010 Sustainability of construction works - Sustainability assessment of buildings - General framework.

EN 15643-2: 2011 Sustainability of construction works - Assessment of buildings -Framework for the assessment of environmental performance.

EN 15643-3: 2012 Sustainability of construction works - Assessment of buildings - Framework for the assessment of social performance.

EN 15643-4:2012 Sustainability of construction works. Assessment of buildings. Framework for the assessment of economic performance.

EN 16485:2014 Round and sawn timber – Environmental Product Declarations – Product category rules for wood- and wood-based products for use in construction.

EN 15978:2011 Sustainability of construction works — Assessment of environmental performance of buildings — Calculation method.

EN 16309:2014 Sustainability of construction works - Assessment of social performance of buildings - Methods.

EN 16627:2015 Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods.

EU (2013). Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. Official Journal of the European Union L 124/1.

EU (2017). Level(s). Building sustainability performance. #BuildCircular. Publications Office of the European Union, 2017. Available online: http://ec.europa.eu/environment/eussd/pdf/Level(s)_factsheet-EN-web.pdf [June 2018].

European Forest Institute (2013). Implementing Criteria and Indicators for Sustainable Forest Management in Europe. 132 p. ISBN: 978-952-5980-04-2.

Green, T., Werhahn-Mees, W. and Suominen, T. (2015). Handbook for ToSIA, Database Client, Assessment tools. Integrated ToSIA handbook. Deliverable D1.4.10: ToSIA functionality and use.European Forest Institute.

Kaplinsky, R., and Morris, M. (2002). *A Handbook for Value Chain Research.* Institute of Development Studies.

Kashyap, M., Khalfan, M. and Zainul-Abidin, N. (2003). A proposal for achieving sustainability in construction projects through concurrent engineering. The RICS Foundation, London

Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grubler, A., Huntley, B., Jager, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H.,Moore, B., O'Riordan, T. and, Svedin, U., (2001). Environment and development: sustainability science. Science 292:, 641–642.

Kibert, C.J. (2012). Sustainable Sustainable construction: green building design and delivery, 3rd edn. Wiley, Hoboken.

Kuittinen M, Roux S. (2017). Vihreä julkinen rakentaminen. Helsinki: Ministry of the Environment, Department of the Built Environment. Available from: http://urn.fi/URN:ISBN:978-952-11-4744-9 55

Lindner, M., Suominen, T., Palosuo, T., Garcia-Gonzalo, J., Verweij, P., Zudin, S. et al. (2010). ToSIA _ A tool for sustainability impact assessment of forest-wood-chains. Ecological Modelling, 221, 2197_2205.

OECD (1992). Project and Policy Appraisal: Integrating Economics and Environment (eds. Pearce D., Whittington D., Georgiou S., and James D.).

Päivinen, R., Lindner, M., Rosén, K. & Lexer, M. J. (2012). A concept for assessing sustainability impacts of forestry-wood chains. European Journal of Forest Research, 131, 7_19.

Sala, S., Farioli, F. and Zamagni, A. (2013). Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: Part 1. *International Journal of Life Cycle Assessment* 18(9):1653-1672.

Suominen, T., Tuomasjukka, D., and Lindner, M. (2013). ToSIA – leading the way to sustainability. Glossary. Online: http://tosia.efi.int/glossary.html [December 2017]

Tuomasjukka D, Athanassiadis D, Vis M. (2017). Threefold Sustainability Impact Assessment method comparison for renewable energy value chains. Int J For Eng. 28:116–122.

Tuomasjukka, D. (2017). ToSIA Handbook for TDC 1.0 and ToSIA 3.0. Version 17/2/2017. European Forest Institute.

UN (2007). Indicators of Sustainable Development: Guidelines and Methodologies. Third Edition. United Nations, New York.

UN (2015). Discussion paper on Principles of Using Quantification to Operationalize the SDGs and Criteria for Indicator Selection. EGM on the indicator framework. United Nations Statistics Division, New York.

Wolfslehner, B., Linser, S., Pülzl, H., Bastrup-Birk, A., Camia, A. and Marchetti, M. (2016). Forest bioeconomy – a new scope for sustainability indicators. From Science to Policy 4. European Forest Institute. ISBN: 978-952-5980-29-5.

World Steel (2012). The White Book of Steel. World Steel Association. ISBN 978-2-930069-67-8

World Steel (2018). FACT SHEET. Steel and raw materials. Available online: https://www.worldsteel.org/en/dam/jcr:16ad9bcd-dbf5-449f-b42c-b220952767bf/fact_raw+materials_2018.pdf [May 2018]

CONTACTS

Project Coordinator

Dr. Diana Tuomasjukka

European Forest Institute (EFI)

Bioeconomy programme

Yliopistokatu 6

80100 Joensuu

diana,tuomasjukka@efi.int

+358-10-773 4320

Contact information for this publication

MSc. Patrick Huber, BOKU, patrick.huber@boku.ac.at

Project partners:

Aleksandras Stulginskis University (Lithuania)

European Forest Institute (Finland)

European Forest Institute, regional office (France)

French Institute of Technology for forest based and furniture sectors (France)

Lithuanian Research Centre for Agriculture and Forestry (Lithuania)

National University of Ireland, Galway (Ireland)

Swedish Environmental Research Institute (Sweden)

University of Limerick (Ireland)

University of Limoges (France)

University of Natural Resources and Life Sciences (Austria)