INTEGRAL MATERIAL AND ENERGY FLOW MANAGEMENT IN MANUFACTURING METAL MECHANIC SECTOR

D 5.1

Set of commonly agreed technical, economic, social, and ecological assessment criteria

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MEMAN stands for "Integral Material and Energy flow MANagement in MANufacturing metal mechanic sector".
This project has received funding from the European Union's Horizon 2020 Programme under grant agreement no. 636926.

TABLE OF CONTENTS

1. DOCUMENT HISTORY 1
2. EXECUTIVE SUMMARY 2
3. GLOSSARY 3
4. INTRODUCTION 5
4.1 Objectives of Deliverable 5
4.2 Scope of the Deliverable and context with other project tasks 5
5. THEORETICAL BACKGROUND AND REQUIREMENTS 7
5.1 What is a KPI – a definition 7
5.2 Criteria and good practices for defining KPIs 8
5.3 Key requirements of KPIs to address different value chain stages 12
5.4 Sustainable Business Process Management as a model for KPI integration 14
6. EXISTING KPI FOR SUSTAINABLE SUPPLY CHAINS 16
6.1 KPIs in Supply Chain Management 16
6.2 KPIs used in CSR Reporting 17
7. KPI definition meeting the MEMAN requirements 20
7.1 Approach for a consistent set of MEMAN KPIs 20
7.2 Summary: KPIs for the assessment of MEMAN targets 24
8. CONCLUSIONS 27
9. REFERENCES 28

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Table of Figures:

Fig. 1: Relation of process level an management / business administration levels to be analysed 12
Fig. 2: Sustainable Business Process Management approach (BPM) by Meyer and Teuteberg 14
Fig. 3: BPM approach of MEMAN 15
Fig. 4: Interaction of KPI on company level and supply chain level 20
Fig. 5: Indicators generated by MEMAN toolbox 26

Table of Tables:

Table 1: Glossary 4
Table 2: Consistent set of indicators 6
Table 3: Desirable Characteristics of Key Performance Indicators 8
Table 4: Grouping taken from D2.4/2.5 13
Table 5: Environmental indicators of the GRI Reporting Standard relevant to MEMAN 19
Table 6: Indicators and parameters at different integration levels / different value chain stages 21
Table 7 : Definition of the boundary and levels for the monitoring system 22

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2. EXECUTIVE SUMMARY

This Deliverable report describes and summarises the specific requirements on generating Key Performance Indicators for sustainable industrial value chains, analyses in more details the state-of-art in this field constituted on the one hand by sustainable supply chain management approaches and by Corporate Social Responsibility Reporting practice on the other hand, and provides some theoretical considerations beyond these current approaches.

In order to describe, analyse and optimise industrial value chains thoroughly, KPIs must be distinguished on several hierarchical levels (at least business, product, and process level) and along the entire value chain. Further, algorithms need to be derived that describe the relation of these KPIs, both vertically over the hierarchy levels and horizontally along the value chain.

While present supply chain management approaches do not provide appropriate tools for such integration, the MEMAN toolbox already allows deriving appropriate algorithms integrating the process level and product level KPIs along the entire value chain. This approach will allow for the first time to identify critical process parameters which can be of both technical and non-technical nature and which have high impact on the entire value chain performance through the creation resp. the avoidance of interface disturbances.

Moreover, product level KPIs could be defined in detail to measure the achievement of the MEMAN targets as defined in the MEMAN DoA.

A challenge for further tasks remains to derive algorithms to link the KPIs at product level with those at business level.

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3. GLOSSARY

NAME	**DEFINITION**
Resource performance	Measurable results related to resource efficiency, resource use and resource consumption. Resources may include : - Energy - Raw materials - …
Resource Performance Indicator (RePI)	Quantitative value or measure of resource performance, as defined by the organisation
***Product system**:*	All the steps necessary to manufacture a product or delivery of a service. Source: EN 16247-3:2014 *Note: For MEMAN, processes will be separated in several categories:* • *Manufacturing processes: directly involved in the product transformation or transportation. The set of manufacturing processes to produce a case product is the* ***value chain*** • *utilities process : linked with the production of the utilities required in manufacturing processes (e.g. air compressor, cooling)* • *Technical building services: heating, cooling, hot water, lighting…*
Manufacturing process:	Set of machines and equipment to produce the case product
Utility:	Energy carrier necessary for the process and auxiliary. It can be Steam, hot water, compressed air, etc. Source: EN 16247-3:2014
Utility process:	Set of utility equipment and distribution Source: EN 16247-3:2014

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Building:	Construction as a whole, including its envelope and all technical building systems, for which energy may be used to condition the indoor climate, to provide domestic hot water and illumination and other services related to the use of the building and the activities performed within the building Source: EN 16247-2:2014
Flow:	Input to or output from a unit process or product system, Source: ISO 14040:2006 *Note: energy, emission, effluents, consumable… (for*
System boundary :	Set of criteria specifying which unit processes are part of a product system Source ISO 14040:2006
Unit process :	Smallest element (manufacturing process, utility process or technical building service) considered in the life cycle inventory analysis for which input and output data are quantified Source ISO 14040:2006
KPI	Key Performance Indicator ***See inside document***
KPI tree	Key Performance Indicator Tree ***See inside document***

Table 1: Glossary

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4. INTRODUCTION

4.1 Objectives of Deliverable

In the context of the objectives and tasks of work package WP5 which are

- for Task 5.1
  - to assess with an interdisciplinary approach the scenarios for value chain optimisation and re-engineering developed in WP4 in terms of their ecological, economic and social impacts;
  - to achieve interdisciplinary consensus among the consortium members on the most promising three scenarios to chosen for real life implementation under WP8 of a demonstrator in each of the 3 product value chains analysed;
- for Task 5.2
  - to perform the final assessment of the results of each of the three demonstrators implemented in WP8 in terms of their ecological, economic and social performance against rigorous baseline values;
- for Task 5.3
  - to develop 3 coherent detailed business cases for each of the solutions for value chain optimization demonstrated in WP8;

this present Deliverable D5.1 will set the scene by defining *a set of commonly agreed technical, economic, social, and ecological assessment criteria of value chain optimisation for resource efficiency and sustainability*. This task proved not to be trivial but instead required theory building beyond the originally planned scope of the Deliverable, as will be described here below.

This will provide the basis for the two further Deliverables completing Task 5.1

D5.2 Detailed ranking list of the set of optimisation scenarios developed in WP4;

D5.3 Selection of 3 scenarios for implementation;

which will be due in M21.

Inherent in the definition of the D5.1 assessment criteria – another, more commonly used term today is Key Performance Indicators or KPI – will be the more detailed definition of the KPIs to be used to measure the overall achievements and impacts of the MEMAN project as foreseen in the MEMAN DoA.

4.2 Scope of the Deliverable and context with other project tasks

Deliverable D5.1 relates in particular to the previous Deliverables D1.3 and D2.5. The key issue analysed in D1.3 had been the overall complexity of the themes addressed by MEMAN, and in particular the complex interrelation of issues such as

- the technical management and optimisation at process, factory and value chain levels;
- the requirements of Sustainable Business Process Management and Sustainable Supply Chain Management, for both of which have been developed own bodies of knowledge that need to be linked;

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- the growing requirements of Corporate Social Responsibility reporting which have substantially increased since D1.3 submission by the issuing of the so called CSR Directive of the EC.

Reliable indicators are critical to all of the above management approaches and tools. Yet there is so far no consistent set of indicators satisfying all the different information requirements, or even a consistent approach to integrate or link the different sets of indicators in use. For MEMAN, which especially requires such integrated approach in view of the complex objectives to be achieved, this situation poses a significant problem.

MEMAN implementation and exploitation will finally require a consistent set of indicators for different functions and at different levels of integration as shown in the following table:

Levels / Functionalities	Individual process (shop floor)	Factory / company	Value chain
Control and optimisation function	X	X	X
Reporting function	--	Internal External	Internal External

Table 2: Consistent set of indicators

Consistency means in this context in particular a transparent, logical relationship of the different types of indicators, preferably in the form of mathematical functions.

According to this categorisation, the MEMAN KPIs to assess DoA achievements are mainly value chain reporting indicators. Indicators required for WP9, for instance, will be factory/company reporting indicators; while indicators required for WP7 will be company control & optimisation indicators.

This approach and the according requirements for integration will be further elaborated below.

Comparison with originally intended approach

It was intended to evaluate parameters like CO_2 emissions, production costs, production quality, energy and materials consumption data, labour resources, safety at work, flexible production, etc. In order to select those scenarios which do not only provide a good life cycle balance but are also well feasible in technical, economic and social terms, the assessment criteria and their ranking needs to be discussed and agreed with all members of the value chain. **This approach will be kept.**

It will yet be amended as far as presently possible according to the above requirements. Due to the complexity of the task of deriving mathematical functions to describe the relations of different indicators, only development tasks for the further project work could be specified which will need to be completed in subsequent tasks.

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5. THEORETICAL BACKGROUND AND REQUIREMENTS

5.1 What is a KPI – a definition

A general definition of an indicator is that it **provides information or a set of information that contribute to the appreciation of a situation by a decision maker**.

A specific definition of a Key Performance Indicator (KPI) is that it is **a measure or group of measures steered on a critical aspect of the overall performance of an organisation**.

The combination of both aspects is the important current challenge in description the performance as well as effectivity of a company or a process. This is often differentiated in generations that develop a static description of a company performance towards more clarity between relevant and specific models and relationships (e.g. /1/):

Generation 1:

> Using a balance of financial and non-financial performance measures, long- and short-term horizons, and external as well as internal perspectives.

Generation 2:

> Using balanced scorecard design to understand the business model through value propositions and the causal relationships between objectives

Generation 3:

> Testing the business model by securing greater clarity between the assumed non-financial drivers of performance and cash flow.

In the context of that development, KPIs were found to meet a number of requirements and criteria to be used for comparison of performances and developments (Table 2).

These recommendations are suitable for all types of functions and specific needs: for manager, management control, quality service or project tracking. In all cases, it is not enough to stick to definitions. This is only a necessary step to build useful dashboards.

Indicator Criteria	Requirement
Direct	The indicator should measure as directly as possible what it is intended to measure. For example, if the result being measured is an increase in youth employment, then the best indicator is the number and percent of youths finding employment. The number and percent of youth that receive job or life skills training does not directly measure the result of interest. Nonetheless, sometimes we do not have direct measures, or we are constrained by time, resources, or technical capacity from getting direct indicators. In these cases, proxy indicators have to suffice.
Specific	Indicators need to be defined so that everyone understands them in the same way. Instructions on how to operationalize (put into practice) the indicator and definitions of all key terms should be explicit and clear.
Useful	Indicators need to help the project understand what it is measuring. The indicators should provide information that helps the project understand and improve its operations and results.

1 The Chartered Institute of Management Accountants: Effective Performance Management with the Balanced Scorecard - Technical Report, United Kingdom, 2005

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Practical	Costs and time involved in data collection and analysis are important considerations. Although difficult to estimate, the cost to collect indicators should not exceed their usefulness.
Culturally Appropriate	Indicators must be relevant to the cultural context. What makes sense or is appropriate in one culture may not be in another. Make sure that the indicators are reviewed and approved by persons familiar with the cultural context.
Adequate	There is no "correct" number of indicators. The number selected depends on the underlying result being measured and the resources and technical capacity of the project and it's implementing partners. The project needs to balance its need for information with the resource, time, and technical demands of data collection, management, analysis, reporting, and usage.

Table 3: Desirable Characteristics of Key Performance Indicators

5.2 Criteria and good practices for defining KPIs

Main criteria for choosing KPIs are

- Relevance (significant if > x% of the total, to be modified, in line with the site's strategy ...)
- Concrete and practical : KPI must be targeted for meaningful use (each KPI with a person and objectives / action-oriented)
- Measurable and incorporated (not falsifiable, known results at the right frequency to be able to act ...)
- Segmentation (aggregated measures and in different sectors to compare / benchmark : improve the worst, building upon the best ...)

In addition to these main criteria, the following three mechanisms underlying the generation of performance as well as the good practices discussed further below should be considered in the definition of KPIs:

1. HUMAN FACTORS

   Whatever the quality of a system or general framework operation, the actors greatly impact on the performance both collectively and individually.

   Collective behaviour:

   - The players' strategies as system control mode
   - Submitted to the inconsistencies of the system, the actors 'make do', hence: compromises and arrangements can generate malfunctions
   - For actors, their behaviour, far from being the problem, is the solution.
   - Inconsistencies
   - System Malfunctions "costs of regulation“: The cost of regulation takes the form of various malfunctions.
   - Their forced resolution can create even more costly malfunctions
   - Consistency of systemic resistance to change system
   - Visible inconsistencies in the system, we hide the great consistency
   - By changing an element is triggered the reaction of the whole system
   - Instead of stigmatizing or want to change collective behaviour:
     - Understand rational logic and the underlying conditions that lead reasonable players to seemingly irrational behaviour.
     - Changing the underlying conditions.

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Individual practices:

- Distinguish two complementary levels: Macros / Micros
  - The levels Macros define the system: theoretical framework of the company
  - The levels Micros make the actual operation. More diffuse and multifaceted that levels macros, they fall under the individual practices
- Revealing the stake levels Micros
- The range of performance between comparable entities is a goal for assessing media
- Potentials for Performance Improvement (PfP) of the levels Micros.
- Often unexpected, rarely measured, the PfP are still under-exploited
- The calculation of PfP is based on the differences between entities within the same framework exploitation requires no investment or structural change
- The PfP finely identify specific priority levels for each actor
- Combine industrialization (Macro) and human factor (Micro).
  - Though let the cursor between the two levels, or the level of industrialisation.
  - The human factor is a key factor to adapt to individual customers, to local circumstances, to cases outsized to hazards.

2. TRANSVERSALITY

No entity can fully control its performance. Each indicator is the result of the contribution of different processes and internal and external stakeholders.
The performance crosses all boundaries. The framework defines the theoretical operation.

- Extend the concept of control of its performance to the more unifying and more empowering, contribution to company performance
- Unlike dashboards, KPI are without borders: contributions interactions between process indicators and cross all boundaries
  - those between organizational units to reflect the process ;
  - those between process to take account of their interactions;
  - those of the company: to control the impact of customers and external partners.
- The concept of contribution is particularly useful for :
  - control processes, channels, matrix organizations;
  - optimize multichannel customer relations ;
  - develop the appraisal and remuneration system ;
  - better use of the synergies and identifying new sources of value.

3. INTERDEPENDENCE BETWEEN INDICATORS

Sometimes, indicators are linked between themselves. So, we have to be careful about interdependence between KPIs.

- Inside a sea of data and disparate tools, managers are periodically in search of relevant indicators: good KPI
- Extend the concept of relevant indicators with that of their organization
- The search for relevant indicators could be a false problem and a real trap
- They are all relevant. What is not always true, it is the use made of them
- Behind the relevant indicators, what is sought is the meaning of them
- To make sense, beyond the indicators their interactions must be understood.
- Obsessed by the indicators we are blind to their interactions.
- More than the intrinsic quality of each indicator, that helps it to take in account for their interactions is organization.
- Optimizing the value generation process over time and not to maximize short-term criteria.

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Good practices in the definition of KPIs and KPI-Tree KPIT

1. Consider the performance in a global perspective and not fragmented

   One of the major sources of adverse effects is related to the plot logic of traditional management.
   Indicators should identify all aspects of performance in the widest possible perspective of competitiveness, productivity, quality, safety, innovation, resources, skills, practices, human development, well-being at work etc.

2. Consider the performance as integrated and not fragmented

   Even when they are built from a global perspective, dashboards compartmentalize indicators into categories, which do not promote understanding of interdependence.
   Thus, we often separate indicators in four areas: Financial, Customer, Process, HR. Sometimes we separate them by purposes: decision indicators, action, monitoring...
   Contrary to partition, the **Key Performance Indicators Tree** integrates and organizes the indicators in order to account for the generation of performance. Thus, a global criterion will be refined into a product of very varied nature of indicators of quality, productivity, customer relations (sink rate, rate of equipment ...), transfer rate in a flow, significant autonomy actors...

3. Consider the performance as dynamic and not static

   Traditional logic management considers the performance of statically (like a picture off) sought to enter by KPIs and indicators.
   Performance or results recorded (at a time or in a given period) result from complex interactions between indicators, themselves affected by different processes and internal and external stakeholders. More or less direct, the effects of these interactions can occur as quickly over several years.
   Beyond the individual quality indicators, interest KPIT is their tree organization reflecting the generation of performance.
   Pictorially, indicators are KPIT, what the strings are the strings of a tennis racket. In both cases, it is their organization that gives meaning and effectiveness to the elements.

4. Define indicators without Borders

   Traditional dashboards define indicators for a particular organizational unit. We often hear: "I want the indicators that I master" or "as indicators that I can act."
   Beyond dashboards, we need a transverse coherence framework to take into account the interdependencies between indicators processes between and among actors.
   To this end, we must expand the traditional logic of "control of its performance" with that of "contribution to business performance." This notion of contribution leads to defining transversal indicators versus any border:

   - those between organizational units: to drive the process
   - those between process to take account of their interactions
   - those of the company: to reflect the impact of external actors and steer the contribution of external partners

5. Define indicators as factual, not prescriptive

   The standards, often arbitrary (which is not to say irrational), are always a vis-à-vis the screen reality. They are of course essential in some areas would do to reduce risks. Beyond the risks, they may have other legitimate purposes. But in piloting the standards are misused. In this area, they can be advantageously replaced by non-normative references.
   In order to have the most neutral possible indicators and less arbitrary, KPIT uses only factual, not prescriptive.

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6. Use natural indicators, as opposed to synthetic indicators

   Except, KPIT indicators are "natural" only using evidence.
   In very rare cases, we may use synthetic indicators combining several concrete indicators which are assigned more or less arbitrary weight.
   But these indicators should remain an exception.
   Moreover, in the organization tree, synthetic indicators should always be curled by natural indicators.

7. Define the most neutral possible indicators

   Often the choice of performance indicators is based on the purpose, priorities of senior management or strategy.
   It is not only legitimate, but desirable, that adapts the tools to the purposes and strategic priorities of the company. But that does not stop, on the contrary, to have a transverse steering coherent framework, to put in perspective and contributions to federate multiple objectives or strategies to business performance.
   For that part of consistency is the most unifying and as stable as possible (vis-à-vis any change, including the priorities and strategy), it must be built for the most neutral finality.
   That's why KPIT, before any other purpose is a generic purpose: to help a shared understanding of the generation of the company's performance and contribution of the various internal and external stakeholders.
   Any other purpose or priority a priori bias is the neutrality of the KPIT, even if it can help all purposes afterwards. It is even precisely because of his vis-à-vis neutrality of any contextual purpose that KPIT can both unite and all contribute. Thus, thanks to its independence strategy that can contribute to the development, simulation, validation and exhaustive and objective evaluation of the impact of the Strategy.

8. Have a rigorous approach for a robust interpretation of indicators

   The quality of decisions and their negative or positive effects are strongly influenced by the quality of the interpretation of the indicators. That interpretation is very inadequate. In most cases, we cannot even speak of interpretation: we tend to draw hasty conclusions stopping at the first explanation that comes to mind.
   Never forget that an indicator can be explained by numerous assumptions. Have a minimum of rigor is essential: consider several explanatory hypotheses before committing as objectively as possible.
   The usual interpretations are even faultier, if we draw conclusions in the light of a single or a small number of indicators which represent only a very partial aspect of reality.

More detailed theoretical background is provided in the detailed studies performed on behalf of EC DG ENV "Assessment of resource efficiency indicators and targets" (2012)[2] and "Resource Efficiency Indicators Report" (2013)[3]. Even though these reports are addressing mainly KPIs for macro-economic reporting to achieve Europe's overall sustainability performance targets, the general principles for KPI generation are certainly applicable to MEMAN.

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2 BIO Intelligence Service, Institute for Social Ecology and Sustainable Europe Research Institute (2012) Assessment of resource efficiency indicators and targets. Final report prepared for the European Commission, DG Environment.
3 Science Communication Unit, University of the West of England, Bristol (2012). Science for Environment Policy In-depth Report: Resource Efficiency Indicators Report produced for the European Commission DG Environment, February 2013.

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5.3 Key requirements of KPIs to address different value chain stages

Summary of results elaborated in preceding Work packages

In D1.3 we had identified as one major result the need for an analysis of the organisational structures and information flows throughout the metal mechanic value chain, and in D2.5 we have elaborated a first estimation of the large resource savings potentials linked to the optimisation of the value chain organisation which, if not optimised, is the source of significant **'interface disturbances'**.

The basic issues of organisation structures and information flows to be addressed had been depicted in the following simplified graphic elaborated in D1.3.

Any changes in the technical (manufacturing) processes (in orange, blue) will require mutual communication and decision making along the value chain, involving various units inside the manufacturing company as well as units of upstream / downstream partners. Decisions will usually be based on economic issues which require an interaction at shop floor level as well as at management / business administration levels. This is indicated by the green arrows. Other situations, such as complaints of the customer will start at business administration level, indicated by the red arrows. Light blue arrows indicate direct problem solving at process (shop floor) level in case that cooperation is well established between partners of the chain.

The required organisational analysis will for instance concern organisation structure, main actors involved, decision making processes, economic and financial requirements such as present conditions of sharing costs and benefits along the value chain, financial instruments for investing in technological / organisational changes etc.

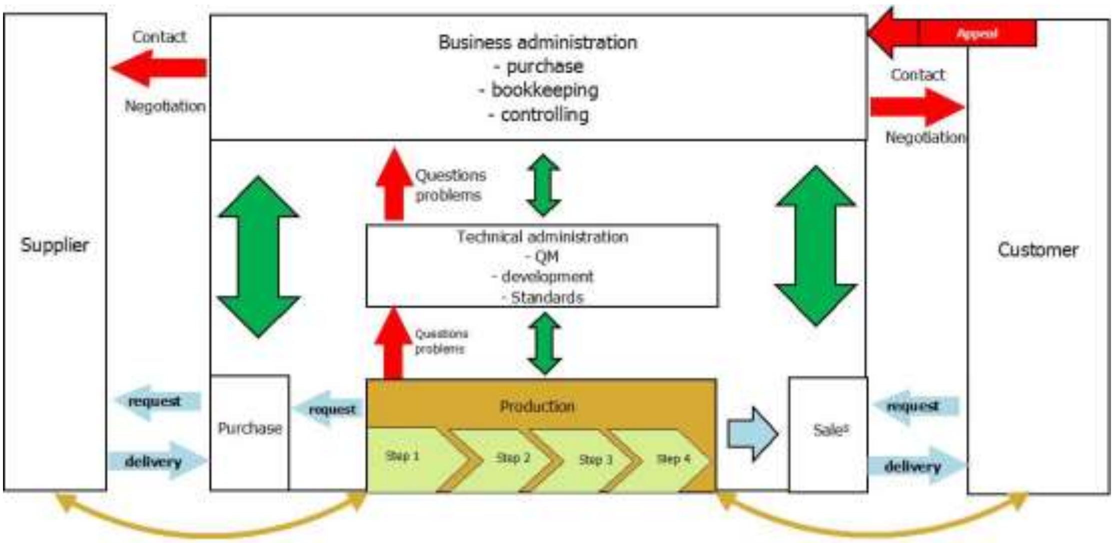

Fig. 1: Relation of process level and management / business administration levels to be analysed

The relevant failure modes were discussed in detail in Deliverable D2.2 and D2.5. Within the Deliverables a system was developed to work out the relevance of the different indicators and influencing factors. The various interfaces were allocated to the general use (Application category) and the type of influence was described. The following Table 4summarizes the procedure.

Especially, the disturbances at the interfaces and the assessment of the resulting impacts were elaborated. It came out that that the value chain efficiency is typically affected by various disturbances at interface level. These disturbances can be the result of technical issues as well as non-technical issues (e.g. operational problems, management decisions, organisational changes, business initiatives, etc.).

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The disturbances will affect the co-workers in production and administration as well as the machining level. The former one is e.g. the knowledge of workers, their availability due to holidays or lack of personnel. The latter one are e.g. failures in plants by e.g. errors in hardware control units or lack of working materials (different to availability of production material).

These disturbances are likely to modify the specification in a negative way that could not be foreseen (in terms of timing or quality requirements for instance) by the original expected requirements This results in major deviations that have not been intended for the defined processes in the value chain. Hence, each disturbance entails a failure mode and affects the normal operation mode of the value. Such disturbances can be classified in 3 main categories towards the produced impact downstream at the interfaces in the value chain. These categories of disturbances are:

i. timing of value chain operations,
ii. process functionality, and
iii. combined issues.

Application category	1. management process 2. manufacturing process 3. support process 4. raw material supply 5. other
Affecting value chain interfaces	1. affects only one process / site; 2. affects the next production site of the value chain 3. affects several processes / sites
Expected impact on	1. energy 2. raw material 3. environment 4. recycling 5. work safety 6. production time 7. other
Disturbance factors	1. Production time per year 2. Number of workers per machine 3. Quality rate 4. Processing time

Table 4: Grouping taken from D2.4/2.5

The disturbances / failure modes are generic features for the three considered clusters. For each disturbance / failure mode, the interface(s) affected is (are) listed, the resulting impact is provided, with its estimated duration, as well as the associated traceability.

The knowledge and expertise available in the value chain is also an important variable when it comes to resource efficient manufacturing. In general, especially the knowledge level in the critical field of material science and metallurgy is declining. Due to limited interest of students in many European countries for material sciences, educational institutions have diminished the attention that is given to this field of expertise. Experts on materials and corrosion are aging and leaving the sector. Consequently, many decision makers are not able to predict problems with the products and the production processes because of a lack of knowledge on material properties, process parameters, etc. It is important for the European metal mechanical sector to address this issue.

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5.4 Sustainable Business Process Management as a model for KPI integration

According to the analysis in D1.3, "the term business process management (BPM) means a structured approach to analyse and continually improve fundamental activities such as manufacturing, marketing, communications and other major elements of a company's operations. In the context of corporate sustainability management …, the concepts of BPM offer perspectives of systematic control and improvements of the operational process in terms of carbon emissions."

Key researchers in the BPM field try to unite the existing sustainability management approaches by defining the interaction of the different levels of the business activities in more detail. One exemplary approach relevant to the MEMAN requirement of integrating the different levels and objectives of business activity is presented by Meyer and Teuteberg /4/.

The following figure describes the model presented. It takes into account the following levels:

1. Sustainable indicators
2. Corporate strategy for sustainable Business Process Management (BPM)
3. Organisational structure
4. Process model
5. Stakeholder influence
6. Information technology architecture

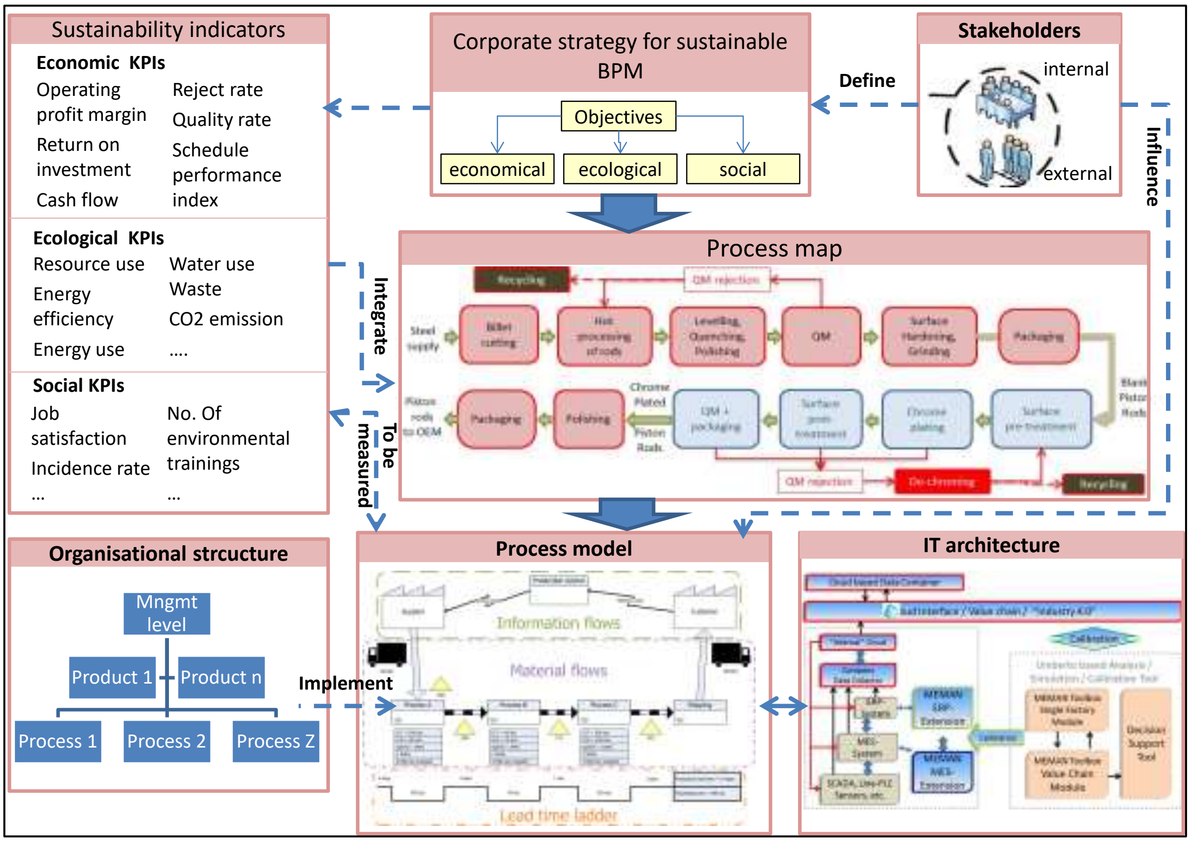

Fig. 2: Sustainable Business Process Management approach (BPM) by Meyer and Teuteberg. (with elements of the MEMAN toolbox integrated)

4. Jens Meyer, Frank Teuteberg, in: Multikonferenz Wirtschaftsinformatik 2012, Tagungsband der MKWI 2012, Hrsg.: Dirk Christian Mattfeld; Susanne Robra-Bissantz)

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The analysis shows that this approach reflects well the interaction of the supply chains discussed in MEMAN. The following figure associates the levels of the BPM approach to MEMAN work packages.

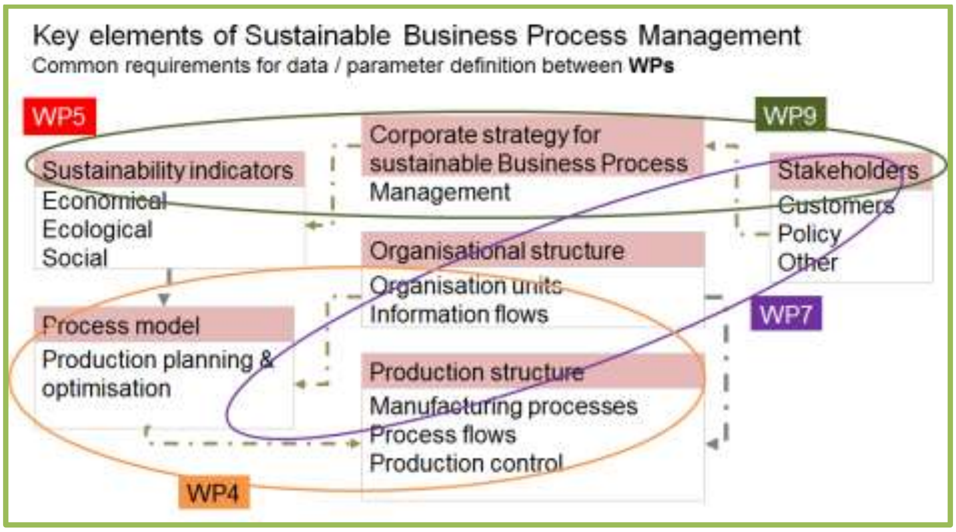

Fig. 3: BPM approach of MEMAN

The figure indicates that this approach could well structure the overarching interrelation between the different objectives pursued in these work packages and the different types of KPIs required to measure the achievement of these objectives:

- WP4: Process / production level optimisation across value chains
- WP7: Business model optimisation, integrating process level optimisation with company level (economic) objectives and customer benefits
- WP5: Proof of company / value chain level resource efficiency optimisation
- WP9: Company / value chain level reporting and benchmarking of energy efficiency optimisation

From the figure the required sustainability indicators can be differentiated:

1. **Ecological dimension:**
   Goal: Selection of **global KPIs** of the different value chains possible;
   Necessary:
   - Adjustment of KPIs on company level and global KPIs
   - Adjustment of parameters of the production of companies
   - Adjustment of possibilities of the companies to realize the KPIs
2. **Social dimension**
   Goal: Selection of global KPI of the different value chains are mainly based on **companies KPIs**
3. **Economic dimension**
   Goal: Selection of KPI of the different value chains are mainly based on **companies KPIs**
4. **Organisational dimension**
   Goal: Selection of KPI of the different **value chain KPI** commonly describing
   Commonly business models used
   Necessary
   - Simulating tools to describe the quantitative influence.
   - Parameters comparable with technical data
5. **Technological dimension**
   Goal: Process/Machine indicators – **Process KPI -** to describe the manufacturing process
   Data available from D2.4 / D2.5
   Necessary:
   - Simulation Tools available
   - Selection and assessment of simulated data

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6. EXISTING KPI FOR SUSTAINABLE SUPPLY CHAINS

6.1 KPIs in Supply Chain Management

In D1.3 we had already analysed the so called **Supply Chain Operations Reference** (SCOR) model which is considered to be "… the most promising model for strategic decision-making and the most rigorous for supply chain performance evaluation" (compare Deliverable D1.3). Therefore, the relevance of the metrics approach used by SCOR has been further analysed concerning its applicability for MEMAN.

There are over 250 SCOR metrics that are organized in a hierarchical (and codified) structure from organization level 1 to process level 2 to diagnostic level 3. The metrics are categorized in five performance attributes: reliability, responsiveness, agility, costs and asset management efficiency. The first three attributes are considered customer-focused; the latter two are internally focused.

Performance Attribute	Definition
Reliability	The ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process. Typical metrics for the reliability attribute include: On-time, the right quantity, the right quality.
Responsiveness	The speed at which tasks are performed. The speed at which a supply chain provides products to the customer. Examples include cycle-time metrics.
Agility	The ability to respond to external influences, the ability to respond to marketplace changes to gain or maintain competitive advantage. SCOR Agility metrics include Flexibility and Adaptability.
Costs	The cost of operating the supply chain processes. This includes labour costs, material costs, management and transportation costs. A typical cost metric is Cost of Goods Sold.
Asset Management Efficiency (Assets)	The ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs. outsourcing. Metrics include: Inventory days of supply and capacity utilization.

Table: The SCOR Attributes

While the SCOR performance attributes as such are not directly relevant to MEMAN, the hierarchical structure of the metrics could provide insights and could eventually be adaptable to MEMAN. This hierarchy is depicted in the above graphic (Source: APICS www.apics.org). But further analysis revealed that the present state of development of the model does yet not provide a consistent metric beyond level 2. From level 3 downwards, required metrics are too much company specific to provide a standardised approach.

To include Sustainability measurement into the Supply Chain Management, the GreenSCOR model developed by the Supply Chain Council provides a generic framework for measuring the total carbon footprint and environmental footprint in a supply chain. The model is based on the SCOR model and proposed five additional performance metrics to include the environmental concerns in supply chains. The five proposed environmental metrics are

1. carbon emissions in tons of carbon dioxide equivalent,
2. air pollutant emissions,
3. liquid waste generated,
4. solid waste generated, and
5. percentage of solid waste that is recycled.

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The total environmental footprint of a supply chain member is the sum of the air pollutant emissions, liquid water generated, and solid waste that is generated and not recycled**.**

A major drawback of the GreenSCOR is that supply chain performance is determined just by summing up the performances of each supply chain member. This is not sufficient compared to the MEMAN approach.

6.2 KPIs used in CSR Reporting

Also the relevance for MEMAN of Corporate Social Responsibility Reporting initiatives and the KPIs used in this context had already been discussed in Deliverable D1.3. The European CSR Directive published in December 2015 has further enforced the importance of this approach and the various sets of KPIs such as GRI and EFFAS in use for CSR reporting.

The European CSR Directive

By 6 December 2016, EU member states must comply with the Directive 2014/95/EU on disclosure of non-financial and diversity information by certain large undertakings and groups. This new directive for disclosing non-financial information transposes the provisions into national legislation.

The Directive specifies how large companies should disclose social and environmental information in their annual reports. The new provisions will be applicable to market-listed incorporations over 500 employees or other undertakings which are of significant public relevance because of the nature of their business, their size or their corporate status. It is expected that the Directive will raise the number of companies performing CSR reports from today about 2,500 to over 7,000. **This will include more or less all relevant OEMs and end users of the metal mechanical value chain.**

The information that should be reported includes policies, main risks and outcomes related to environmental matters including in particular Reducing CO2-emissions and carbon footprint, social and employee aspects, respect for human rights, anti-corruption and bribery issues, and diversity on their board of directors. The reports will **include the performance of the relevant supply chains** of the reporting companies, and will give shareholders and other stakeholders a comprehensive overview of how the company is performing.

Although small and medium sized companies are in principal exempt from the Directive, relevant commentators expect that reporting duties will be passed on to the SME suppliers by the OEMs in their value chains, since the OEMs have to include their supply chains in their reporting.

For their reporting, companies will be encouraged to use **standardized, recognized frameworks, such as the Global Reporting Initiative (GRI**), the UN Global Compact, ISO 26000 or ILO Tripartite Declaration. In particular the GRI has played a central role during the development of the directive and is the basis for many other standard approaches.

GRI Sustainability Reporting Guidelines provide up-to-date guidance for effective sustainability reporting. Environmental indicators of the GRI Reporting Standard relevant to MEMAN include in particular the set shown in the table on the next page.

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Category	Indicator no.	Definition	Details
Materials	G4-EN1	Materials used by weight or volume	a. total weight or volume of materials that are used to produce and package the organization's primary products and services during the reporting period, by: Ÿ Non-renewable materials used Ÿ Renewable materials used
	G4-EN2	Percentage of recycled input materials used to manufacture the organization's primary products and services.	
Energy	G4-EN3	Energy consumption within the organization	a. total fuel consumption from non-renewable sources in joules or multiples, including fuel types used. b. total fuel consumption from renewable fuel sources in joules or multiples, including fuel types used. c. total: • Electricity consumption • Heating consumption • Cooling consumption • Steam consumption d. total: • Electricity sold • Heating sold • Cooling sold • Steam sold e. total energy consumption.
	G4-EN5	Energy intensity	a. energy intensity ratio. b. organization-specific metric (the ratio denominator) chosen to calculate the ratio. c. types of energy included in the intensity ratio: fuel, electricity, heating, cooling, steam, or all.
	G4-EN6	Reduction of energy consumption	
	G4-EN7	Reductions in energy requirements of products and services	
Water	G4-EN8	Total water withdrawal by source	a. total volume of water withdrawn from the following sources · Surface water, including water from wetlands, rivers, lakes, and oceans · Ground water · Rainwater collected directly and stored by the organization · Waste water from another organization · Municipal water supplies or other water utilities
GHG Emission	G4-EN15	Direct greenhouse gas (ghg) emissions	a. gross direct (Scope 1) GHG emissions in metric tons of CO 2 equivalent, independent of any GHG trades, such as purchases, sales, or transfers of offsets or allowances. b. gases included in the calculation (whether CO2, CH4, N2O, HFCs, PFCs, SF6, NF3, or all).
	G4-EN18	Greenhouse gas (ghg) emissions intensity	
	G4-EN19	Reduction of greenhouse gas (ghg) emissions	amount of GHG emissions reductions achieved as a direct result of initiatives to reduce emissions, in metric tons of CO 2 equivalent

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Waste	G4-EN23	Total weight of waste by type and disposal method	a. total weight of hazardous and non-hazardous waste, by the following disposal methods: • Reuse • Recycling • Composting • Recovery, including energy recovery • Incineration (mass burn) • Deep well injection • Landfill • On-site storage • Other (to be specified by the organization) b. waste disposal method: • Disposed of directly by the organization or otherwise directly confirmed • Information provided by the waste disposal contractor • Organizational defaults of the waste disposal contractor

Table 5: Environmental indicators of the GRI Reporting Standard relevant to MEMAN

To some extent, this makes the task to define KPIs related to sustainability reporting for SMEs in the metal mechanical value chain – and hence for MEMAN – easier since this reduces the problem to the selection of the 'right' set of KPIs. On the other hand, since various reporting formats will be in use by the different OEM customers of the SMEs, the **reporting capabilities have to be flexible enough to meet different reporting requirements of different customers which will pose a significant problem to small companies**.

Two other drawbacks are also remaining compared to the MEMAN approach:

The first is that the monitoring of the sustainability performance of the supply chain will be based of the sum of individual performances of supply chain members, and not an overall optimisation as proposed by MEMAN.

The second is that there is a significant lack of clarity and transparency how the global KPIs used for CSR reporting can be consistently generated from concrete, measurable manufacturing process parameters.

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7. KPI definition meeting the MEMAN requirements

According to the analysis performed in the previous chapters, a major problem remained to develop a model to integrate the relevant manufacturing and business process parameters at process / product level, firm level and value chain level all along the value chain into one consistent set of KPIs.

7.1 Approach for a consistent set of MEMAN KPIs

The key criteria which will differentiate such set of MEMAN KPIs are to what extent the value chain as a whole is actually addressed by the KPIs, and not only as a sum of the single value chain members. Hence, the following questions have to be answered:

- **To what extent can a specific (net) impact be attributed to an intervention at value chain level**?
  Developmental impacts are typically caused by multiple factors, which may or may not be necessary or sufficient for those impacts to occur.
- **Does the intervention at value chain level make a real difference?**
  This question considers the necessity and sufficiency of an intervention to result in the observed impact.
- **What effect of the intervention at the value chain does make a difference?**
  The amount of existing knowledge about an intervention will influence how to best answer this question.
- **Will the intervention at the value chain work elsewhere?**
  This last question emphasizes the importance of analysing and strengthening the external validity of the evaluation findings.

Moreover, MEMAN is aspiring to fill the gap that is persistent in all existing KPI systems including also the well-established SCOR supply chain metrics (compare above), that there is no consistent relation linking process level, measurable parameters (e.g. levels 3-5 in the SCOR model) to business level KPIs (e.g. SCOR levels 1-2). Ideally, such link between different metrics levels could be described by mathematical function "$KPI_x = f(KPP_{1...n})$", with KPP = key process parameters used to generate the KPIs on the next level above. This approach will be required both for single company KPIs as well as for value chain level KPIs as is depicted in the following graphic.

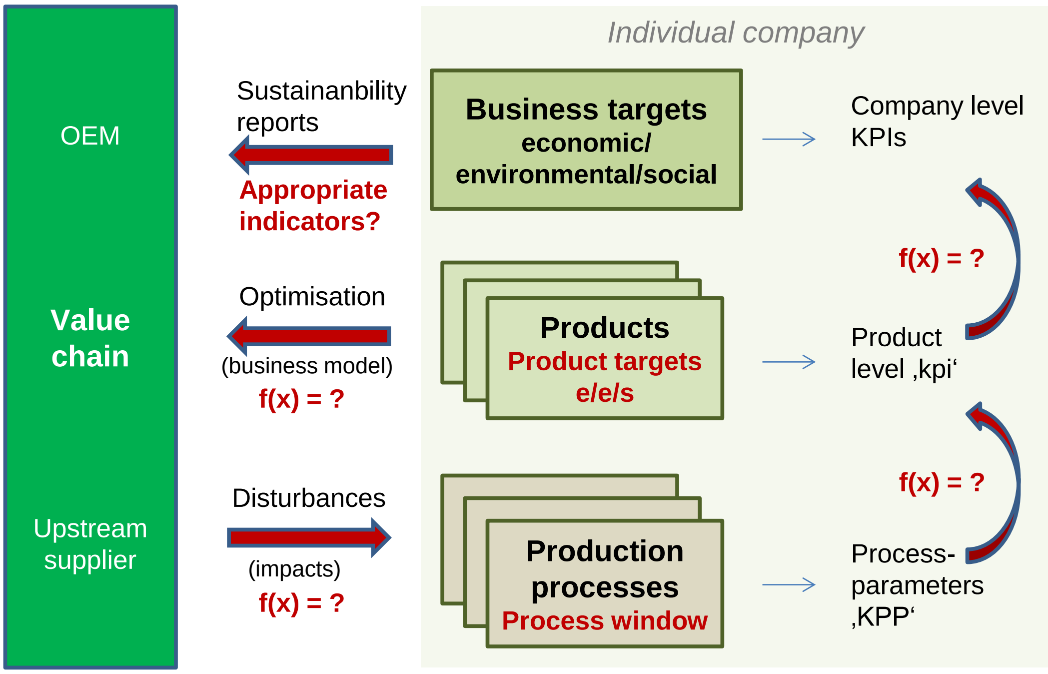

Fig.: Interrelations of KPIs at company level and supply chain level

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A consistent set of 'KPIs' meeting these requirements will comprise several types of indicators and parameters addressing different business levels and different value chain stages. An overview is provided in the following table.

<table>
<tr><th rowspan="2"></th><th colspan="2">Key Process Parameters (KPP)</th><th colspan="2">Key Performance Indicators (KPI)</th></tr>
<tr><th>Value Chain</th><th>Single company</th><th>Single Company</th><th>Value Chain</th></tr>
<tr><td rowspan="2">Definition</td><td rowspan="2">Critical parameters affecting many key value chain processes and consequently the overall performance of the value chain
- Measurable (e.g. material quality indicators such as defining the microstructure of a steel grade)
- Qualitative (e.g. 'quality of communications' in the value chain)</td><td rowspan="2">Process parameters at single company which are
(a) critically affecting the firm's manufacturing performance, and
(b) being substantially influenced by Value Chain interface disturbance factors.</td><td>Product level
- Production cost per product;
- Energy use per product;
- Material use per product;
- CO2 footprint per product;
- Production time per product;
- …</td><td>- Life cycle cost per product;
- CO2 footprint per product;
- energy use per product;
- Material use per product
- …
(measured cradle-to-gate or over product life cycle)</td></tr>
<tr><td>Business level
- Turnover per year;
- Profit;
- Energy intensity;
- Material intensity;
- …</td><td>- Not applicable -</td></tr>
<tr><td>Objective</td><td>Medium-to-long-term optimisation of value chain performance through <u>reduction</u> of disturbance factors</td><td>Short-term optimisation of single firm performance through <u>reaction</u> on disturbance factors and re-balancing of firm performance (e.g. by keeping the KPP in an optimal process window)</td><td>Internal use: control of business objectives / business plans
External use: Reporting on business standards</td><td>Internal use: control of Value Chain objectives (customer satisfaction)
External use: Reporting on Value Chain standards (stakeholder satisfaction)</td></tr>
<tr><td>Selection of indicators</td><td>• CO_2-Emission
• Energy consumption
• Share of renewable energy
• Amount of waste
• Amount of resources (Material, energy)
• Employment rate
• Education</td><td>• Sales forecasts
• Inventory
• Procurement and suppliers
• Warehousing
• Transportation
• Reverse logistics

(One company)</td><td>Parameters controlling the production process
(One process out of various in one company)</td><td>The resource consumption can be measured or estimated at the value chain level
(Various companies)</td></tr>
</table>

Table 6: Indicators and parameters at different integration levels / different value chain stages

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The combination of the results of D2.3 (Table 3) with Table 6 then will lead to a differentiation of the importance of the indicators describing the situation of the supply chain:

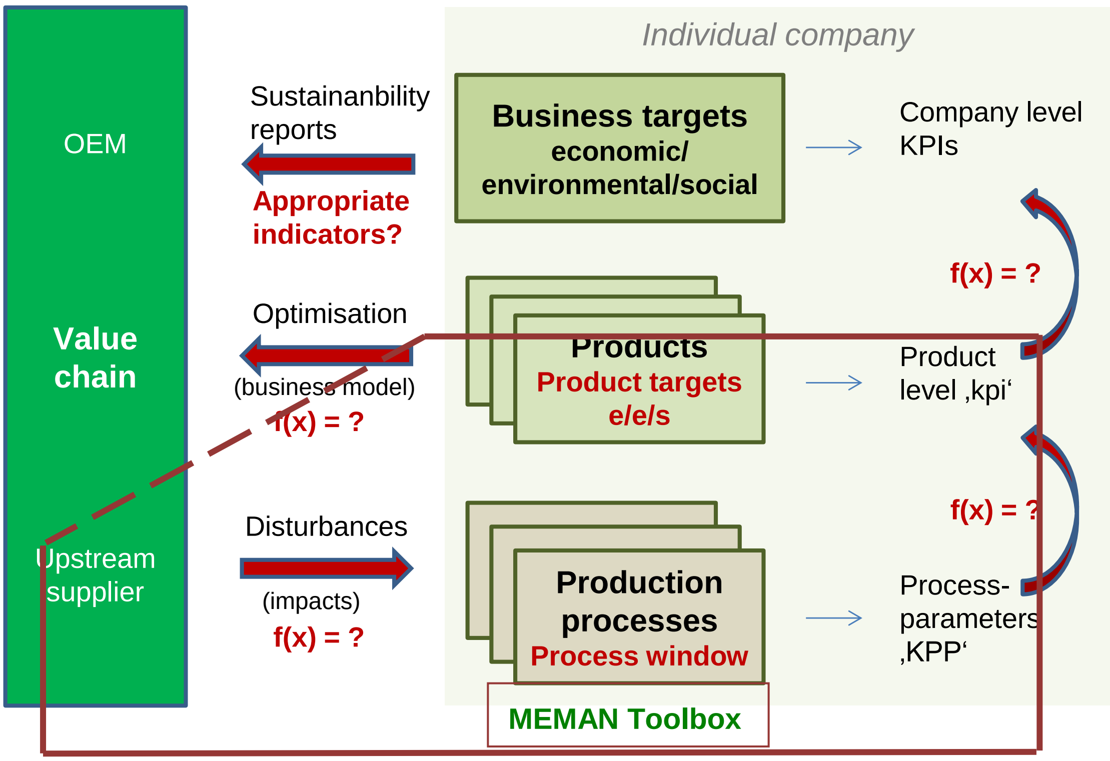
Level	Description	Type	Requirements for indicators /KPI
1	Unit process	Single manufacturing process	It is necessary to monitor a machine or equipment to follow its consumptions
2	Process chain	Combined Technological manufacturing processes	Group of process dedicated for the part studied and can be measured as a whole.
3	Factory	Overall processes at factory level, including management processes	The accuracy of the measurement is not mandatory, and it can be measure at the site level.
4	Value chain	Interface processes between different stages (companies) in the value chain	The resource consumption can be measured or estimated at the value chain level

Table 7 : Definition of the boundary and levels for the monitoring system

Defining the relations between KPPs / KPIs

The key issue is still (compare graphic above), how the functional relation between the various parameters and indicators can be defined.

The present Umberto / Anylogic based MEMAN toolbox developed in WP3 already solves the problem to describe mathematically the relation of KPPs / KPIs in the value chain **at the process and product levels** (graphic below).



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The **functionality for optimization of the value chain** can only be partly covered by the Umberto / Anylogic based MEMAN toolbox developed in WP3, i.e. as far as it is linked to the **technological process optimization**. The **business administration component of such optimization** needs to be addressed by according business model (WP7) resp. business case (WP5) development.

This optimization of technological and administrative processes along the entire value chain of course has a more mid-term perspective, as highlighted in the above table.

For **immediate reaction on disturbances coming from the value chain**, each company in the value chain also needs an appropriate, simple tool that takes into account the overall functional relations.

As a first approach to such tool, the so-called KPI Monitor had been introduced in D3.4. The basic idea behind the Key Performance Indicator (KPI) Monitor is to assess and comprehensibly visualize the **performance of the value chain at factory level**. The goal is to express operational or strategic goals by defining target values for selected KPI. With this KPI Monitor one single company can be very well described in economic, ecological and social dimensions.

For instance, this can be cost targets for cost units of the company, ecological impacts caused by the manufacturing of a product or the yearly turnover per employee. In the context of MEMAN, KPIs can be used to answer specific questions such as:

- Which processes are the bottlenecks of the process chain?
- Do some resources have free capacities while others are fully utilized?
- How much material is used per part produced?
- How relevant are the losses caused by quality problems?
- Which share of energy is used value adding and non-value adding?
- How high are the production costs per part?

Yet, this approach cannot yet take into account the various influence factors coming from the value chain. Hence, the following impacts need also effectively to be addressed by an according tool:

1. Impact of socio-economic factors on **resource efficiency performance** of the value chain (e.g. unplanned changes in lot size leading to reduced capacity utilisation)
   a. Impact of social factors on performances on the various levels.
   b. Impact of the requirements of customers on the performances
   c. Impact of the information about the product quality within the value chain, e.g. in choosing the substrate material
2. Impact of socio-economic factors on **business models** for value chain optimisation **and their implementation** (e.g. key stakeholders to be involved in implementation decisions)
3. Impact of the factors on the various levels described above.

Therefore, a **further objective** is **to derive target process windows** for the most critical process parameters (KPP) which allow **to rebalance quickly the manufacturing processes** towards achieving the target KPIs whenever a value chain influence occurs that is disturbing optimal manufacturing performance. For this further analytical work will be required in the real life implementation so that the algorithm describing the relation between KPPs and target KPIs can be derived.

Dashboard for immediate rebalancing of value chain performance

Finally, this approach will lead to a 'dashboard' for short-term optimisation or re-balancing of the value chain performance at factory level. The dashboard shall be linked with the advanced MES system (integrated ERP-process control system) so that the relevant process

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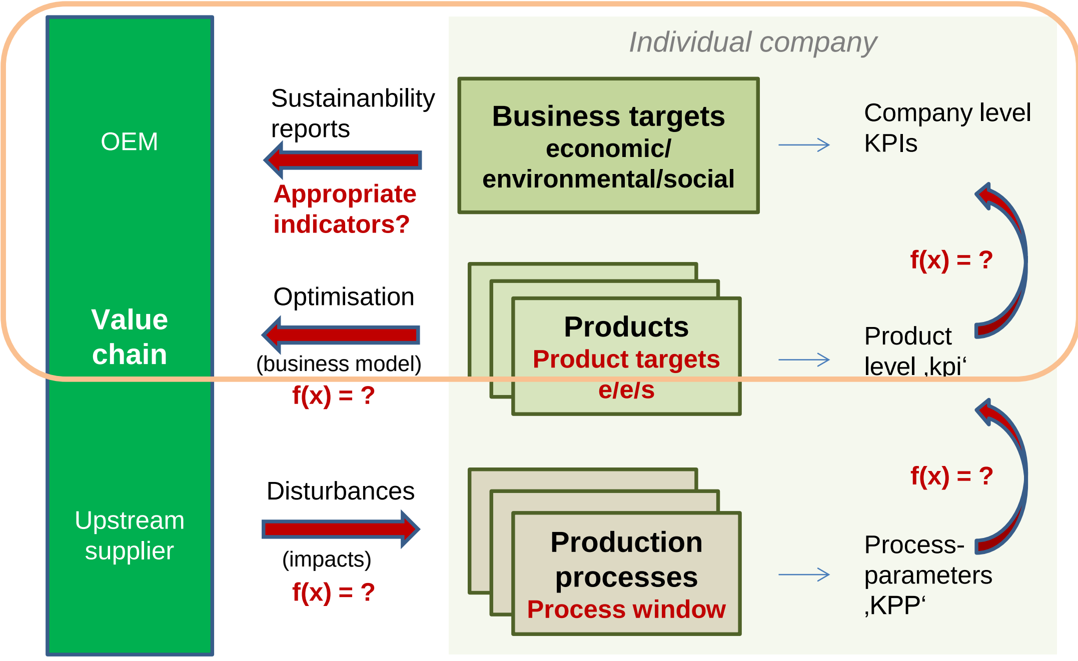
data will be automatically generated and the process rebalancing can be implemented in real-time.

Link with top level KPIs

One final challenge still remains, which is to describe the functional relation between product and company level KPIs.

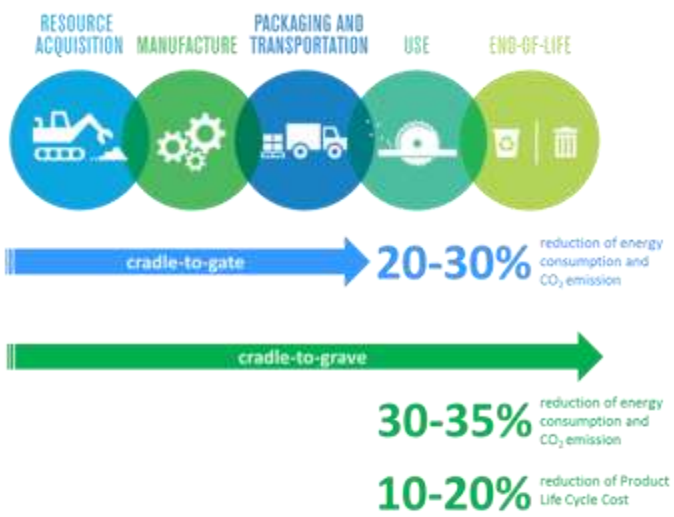


Typically, this is only done in an ex post analysis over the year, which could be sufficient for instance for CSR reporting in relation to one particular value chain. Still, this can be challenging if for instance the overall energy consumption of a factory is to be attributed to a multitude of individual products in different value chains.

This issue becomes yet really difficult and also highly critical if the KPIs to be generated should be the basis to compare or benchmark whole companies as is the objective of MEMAN WP9. Whether a principle approach for this can be derived, or whether a comparison will only make sense in view of the performance within a specific value chain remains still to be seen.

7.2 Summary: KPIs for the assessment of MEMAN targets

For the final assessment of key MEMAN impact targets which are defined in the opposite graphic, a more practical approach can be chosen since the assessment will take place at the individual product level in each of the three value chains concerned.



For this, the KPI Monitor of the MEMAN Toolbox can provide

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already a broad set of relevant indicators which are exhibited in the table below.

System Level	Scope	KPI	Unit	Reference	Reduction Target (acc. to DOA)	Impleme nted	Comment
Single Factory	Production Stage (Gate to Gate)	Processing Time	s/pc	Product		x	Time product remains in processes
		Cycle Time	s/pc	Process		x	Output rate of process step
		Energy Intensity	kWh/pc	Product		x	Sum of direct energy demands to produce product
		Material Efficiency	kg/kg	Process		x	Share of used material which remains part of the product
		Quality Rate	%	Process		x	Share of good parts
		Utilisation Rate	%	Machine		x	Share of available time, in which machine is producing
		Costs	€/pc	Product			Costs caused directly in the stage of production
	Life Cycle (Cradle to Grave)	Cumulated Energy Demand (CED)	kWh/pc	Product			Embodied energy of the product (includes indirect energy demands)
		Ecological Impact	kg CO_2 eq./pc	Product		x	Ecological impact due to manufacturing & disposal of product (includes material pre chains); use phase is not considered
		Costs	€/pc	Product		x	Costs caused over the products life cycle

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System Level	Scope	KPI	Unit	Reference	Reduction Target (acc. to DOA)	Imple-mented	Comment
Value Chain	Production Stage (Gate to Gate)	Processing Time	s/pc	Product		x	Time product remains in processes
		Energy Intensity	**kWh/pc**	**Product**	**20 - 30 %**	**x**	Sum of direct energy demands to produce product
		Material Efficiency	kg/kg	Product		x	Share of used material which remains part of the product
		Quality Rate	%	Process		x	Share of good parts
		Costs	€/pc	Product			Costs caused directly in the stage of production
	Life Cycle (Cradle to Grave)	**Cumulated Energy Demand (CED)**	**kWh/pc**	**Product**	**30 - 35 %**		Embodied energy of the product (includes indirect energy demands)
		Ecological Impact	**kg CO_2 eq./pc**	**Product**	**30 - 35 %**	**x**	Ecological impact due to manufacturing & disposal of product (includes material pre chains); use phase is not considered
		Costs	**€/pc**	**Product**	**10 - 20 %**	**x**	Costs caused over the products life cycle

Fig. 4: Indicators generated by MEMAN toolbox

In order to measure the achievement of MEMAN targets as defined in the DoA, primarily the four KPIs at value chain level printed in bold green in the above table will be used. These are:

- The energy intensity of the production of one piece in kWh / piece
- The Cumulated Energy Demand (CED) (including indirect energy demands) of one piece
- The CO2 footprint of the production of one piece in kg CO2 eq. / piece
- The production costs of one piece in EUR / piece.

In the energy consumption and CO2 emission calculation, all according effects from increasing the material efficiency will also be included.

Nevertheless, it will be useful to compare in addition the material efficiency improvements, as well as quality rates and processing times achieved. As can be seen from the SCOR and CSR indicator tables, such data are typically measured and compared separately.

The KPI Monitor will thus allow a most comprehensive assessment of the MEMAN achievements. The according baseline scenarios against which the comparison will be made are developed and reported in WP4.

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8. CONCLUSIONS

As a result of the research performed on present indicator systems and sustainable supply chain management approaches, it can be stated the MEMAN approach to describe, analyse and optimise industrial value chains is significantly going beyond the limitations of current approaches.

In order to be able to describe, analyse and optimise industrial value chains thoroughly, it is required to **distinguish relevant KPIs on several hierarchical levels and along the entire value chain**. A simplified and practical approach is to differentiate KPIs at three hierarchical levels:

- At business level;
- At product level, and
- At manufacturing process level.

For value chain analysis and description, KPIs at these three levels need to be defined for each member of the value chain. Hence, a KPI matrix will be generated to describe the value chain.

Next, algorithms need to derived that describe the relation of these KPIs, both horizontally and vertically in the matrix.

The algorithms for the horizontal relation will describe the performance of the overall value chain at the different hierarchical levels. It is important to note, that this simple addition of the individual KPIs along the value chain does not sufficiently take account of the complex interrelation of supply chain activities, not even at the business level. Current sustainable supply chain tools nevertheless are only able to add business level KPIs of value chain members to generate a supply chain KPI.

Algorithms describing the vertical relation allow to generate KPIs of a higher hierarchical level from those of the lower levels. Again in present supply chain tools, this is only possible to a limited extend.

The MEMAN toolbox already allows to derive appropriate algorithms integrating process level and product level KPIs along the entire value chain. Based on this, product level KPIs could be defined in detail to measure the achievement of the MEMAN targets as defined in the DoA. Besides those KPIs that address the target figures of the DoA, a number of further KPIs describing specific performance targets can be used. Most important, **this approach will allow for the first time to identify critical process parameters that have high impact on the entire value chain**. One example which still needs to be verified could be quality parameters of the base material of a product (e.g. the crystallographic microstructure of steel). But also non-technical parameters (‘disturbance’ or influence factors at value chain interfaces) can have significant impacts that can be described and measured by according KPIs.

A **remaining challenge** for further tasks will be to derive **algorithms to link the KPIs at product level and business leve**l. This will be addressed in subsequent tasks of WP5 as well as in other work packages (WP7, WP8, and WP9).

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