PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

PRACTITIONER'S GUIDE

TO STRATEGIC GREEN INDUSTRIAL POLICY

SUPPLEMENT

UNEP

International Labour Organization

UNDP
Empowered lives. Resilient nations.

UNIDO

unitar
United Nations Institute for Training and Research

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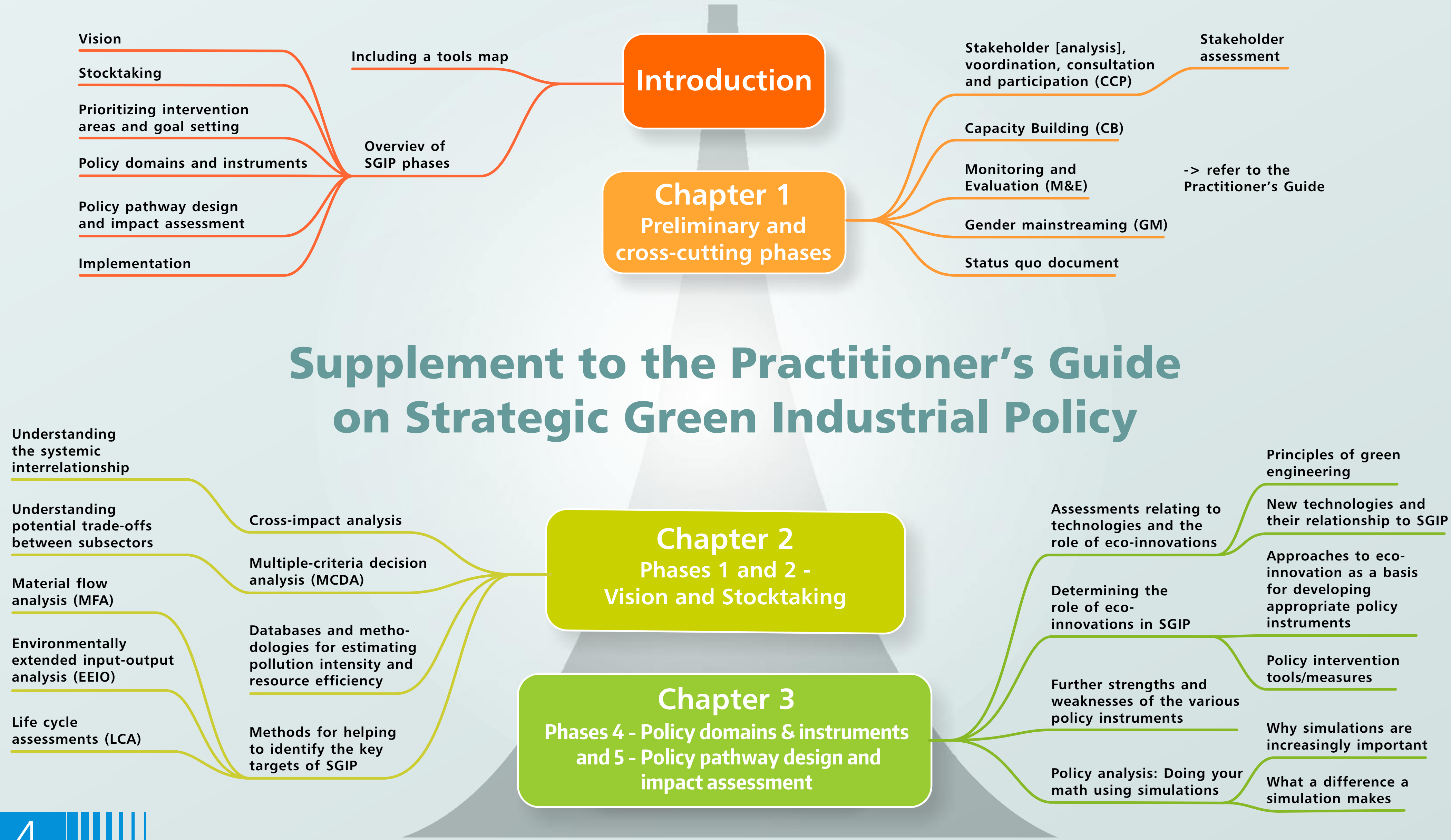
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ABBREVIATIONS

DE	domestic material extraction
DMC	domestic material consumption
DMI	domestic material input
DMO	direct material output
DPO	domestic processed output
EEIO	environmentally (or ecologically) extended input-output (analysis)
EE-MRIO	environmentally (or ecologically) extended MRIO
FU	functional unit (as in LCA)
GDP	gross domestic product
ICT	information and communications technology
IPPS	Industrial Pollution Projection System
ISIC	International Standard Industrial Classification
kt	kiloton
LCA	life cycle assessment
MCDA	multiple-criteria decision analysis
MFA	material flow analysis
MRIO	multi-regional input-output (analyses)
MVA	manufacturing value added
n.e.c.	not elsewhere classified
PTB	physical trade balance
PV	photovoltaics
R&D	research and development
SGIP	Strategic Green Industrial Policy
SMART	specific, measurable, achievable, reliable, timebound (required qualities for indicators)
SME	small and medium-sized enterprise
SSA	Sub-Saharan Africa
TMC	total material consumption
TMI	total material input
TMO	total material output
TMR	total material requirement
UN	United Nations
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar

INTRODUCTION

This is a Supplement to UNIDO's Practitioner's Guide to Strategic Green Industrial Policy (SGIP). While the Practitioner's Guide organizes the presentation of SGIP concepts and approaches along phases of a policy cycle and provides general information on the development of SGIP, the Supplement provides more detail on several tools and categories of assessment that are useful for developing SGIP.

These tools and categories are not mutually exclusive and can be used during the same SGIP development process. They all provide different angles on, levels of focus and entry points to the complex issues associated with the development and agreement of a SGIP. They are rooted in different disciplines and therefore complement each other in several ways.

When working with this Supplement, please remember the following points:

- The Supplement complements the Practitioner's Guide and functions like an extended annex and is not conceived as a stand-alone document. It is useful to consult the Practitioner's Guide before reading the Supplement.
- Many of the sections of the Supplement relate to chapters of the Practitioner's Guide. This relationship is usually directly referred to in the title of the section.
- Mindmaps are selectively used to provide a better overview of a specific section.
- The Practitioner's Guide and the Supplement each have their own lists of abbreviations and references. Especially when using the electronic version, make sure you look for them in the right document. Only the Practitioner's Guide contains a short glossary.

While every care has been taken to review them during the elaboration of the Practitioner's Guide and the Supplement, the mentioning of specific sources of data (e.g. IPPS) or products (e.g. softwares) does not imply endorsement by UNIDO. Moreover, given the current shift in paradigms, new sources of information and new tools are likely to be developed. Users of the Practitioner's Guide and this Supplement are advised to keep abreast of these developments.

M2 What tools can we use to shape SGIP?

Tools Map

What are important tools of empirical analysis and research for developing SGIP?

- Material flow analysis (MFA)
  - National
  - Regional
  - Sector
- Environmentally extended input-output analyses (EEIO)
  - National
  - Regional
  - Cross-border
- Life cycle analyses (LCA)
  - Subsector
  - Enterprise

How can we better understand the systemic links between manufacturing and the green economy?

- Cross-impact analysis

How can we better sort out "green" and "brown" when drafting SGIP?

- Multiple-criteria decision analysis (MCDA)

What are the indicators that we can use to set targets for SGIP?

- Increase resource productivity
  - Energy
  - Water
  - Material
- Decoupling
- Reduce and eliminate pollution

How can we determine pollution intensity and resource productivity?

- Benchmark
- Cross-check international databases

How do we adapt current policies to the requirements of SGIP?

- Review the table on policy intervention tools and measures for suggestions

If SGIP is based on thinking in systems, can we still use our logframe from linear planning?

- You can fill in your current logframes on the basis of the path you have selected as a result of a cross-impact analysis, or possibly even based on simulations that you have run.
- In the assumptions column you may wish to highlight that the impact will be attained not only on the basis of the direct effects, but also as a result of feedback loops (indirect effects).
- You can also change to other methods of planning. Sometimes balanced scorecards may be more practical. Yet there is no requirement for changing to different planning methods.

How do we assess technological options for greening domestic industry?

- Identify the drivers of eco-innovation in your country
  - Policy
  - Demand
  - Supply
  - Technology
- Apply and enforce green engineering principles

OVERVIEW

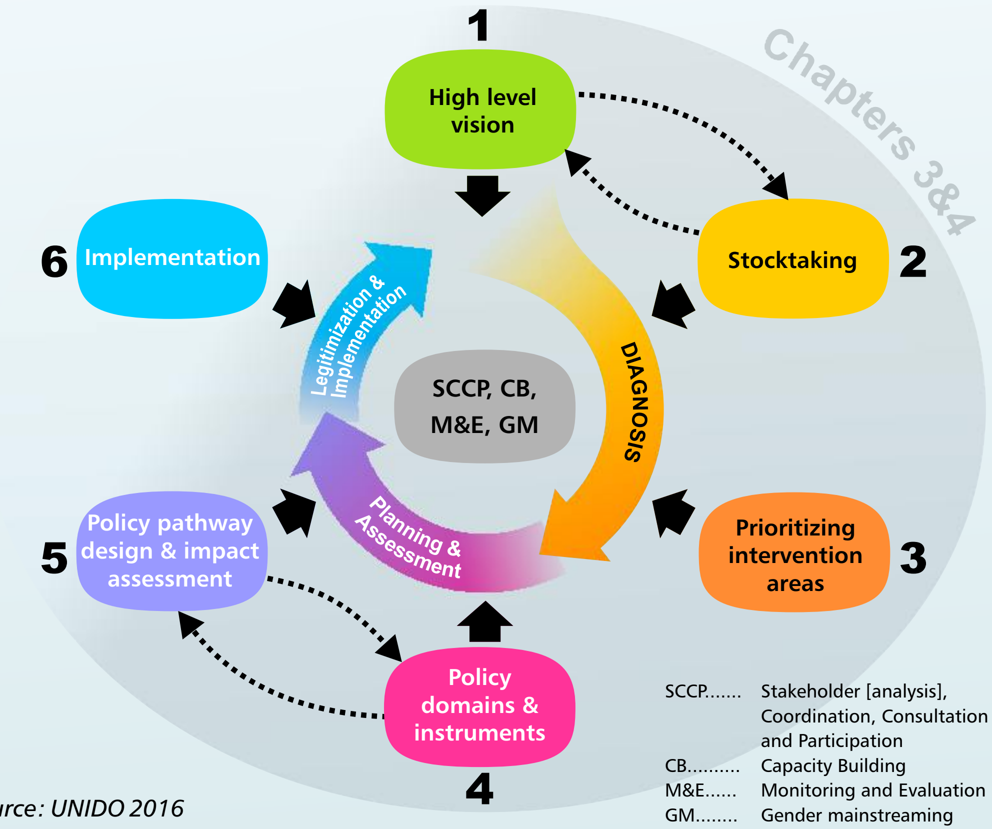
SO

SGIP Practitioner's Guide structure

Chapters 1 and 2 of the Practitioner's Guide on Strategic Green Industrial Policy (SGIP) served as a general introduction to the topic, with Chapter 3 providing an overview of the elements of the SGIP policy cycle. Chapter 4 of the Guide also followed this structure, although it delved into more detail than that provided in Chapter 3. This Supplement to the Guide now attempts to follow the same structure as the policy cycle, however, the major focus is on Phase 2 (Stocktaking), as well as Phases 4 and 5 (Policy domains & instruments, policy pathway design & impact assessment).

We hope that the Practitioner's Guide and its Supplement have successfully added to your understanding of how to develop your country's own SGIP.

Overview of the SGIP policy phases F1



Source: UNIDO 2016

SCCP....... Stakeholder [analysis], Coordination, Consultation and Participation
CB.......... Capacity Building
M&E...... Monitoring and Evaluation
GM........ Gender mainstreaming

S1 PRELIMINARY & CROSS-CUTTING PHASES

Stakeholder assessment

The Practitioner's Guide detailed how to undertake stakeholder analysis and coordinate the consultation process. The table below complements this work by highlighting how stakeholders can be assessed for their suitability for participating in the SGIP process.

T1 Form for assessing SGIP stakeholders

++	+	-	--	Criteria
				Systemic-biocybernetic influencing abilities
				Stakeholder is able to influence the existing overall development paradigms or the function of the industry system in support of greening.
				Stakeholder (understands the importance of and) contributes to self-organization and subsidiarity in the industry system.
				Stakeholder is able to influence rules, regulations, incentives, and constraints relevant for greening, and to contribute to their acceptance, enforcement and accountability.
				Stakeholder is able to influence the information structure in the system by adding, restoring or distributing missing information to those system nodes that will establish feedback loops conducive to greening.
				Stakeholder is able to reduce the gains around reinforcing feedback loops that counteract SGIP, e.g. phasing out of counterproductive incentive schemes, introducing the polluter pays principle.
				Stakeholder is able to restore or strengthen important balancing feedback loops that contribute to sustainable development, e.g. enforce environmental zoning.
				Stakeholder is able to influence delays that lead to oscillations in the industry system and bring it into step with actual rates of changes in stocks and prevent overshoots and collapse.
				Stakeholder is able to influence the design of stock and flow structures for the future, or to contribute to maximizing the efficient usage of existing infrastructures.
				Stakeholder is able to influence the size of buffers that contribute to stabilizing the system.
				Stakeholder is able to contribute to applying biocybernetic principles in the green-industry system.
				Organizational, motivational
				Stakeholder acts on a results-oriented basis and periodically reviews the achievement of results.
				Stakeholder is open to new ideas and adjusts their organization to new challenges.
				Stakeholder sticks to agreements and meets their provisions on a timely basis.
				Stakeholder actively informs partners of activities, exchanges information and responds swiftly.
				Stakeholder actively informs others of intentions, aims and expectations, and shows understanding for others.
				Stakeholder draws attention to tensions early on, and is willing to address them constructively, openly and quickly.

For initial assessment of partners for implementing (aspects of) SGIP. Drawing, partially, on GTZ, 2009, p. 66.

PHASES 1 & 2: VISION & STOCKTAKING S2

Tools of SGIP Analysis

This section provides more detail on some of the tools that are available to support the development of SGIP, with relatively more information provided on cross-impact analysis, as it is a method that has not been widely published and discussed. For the other tools, there is sufficient literature available, both technical and practical, that can be more easily accessed.

Cross-impact analysis for understanding the systemic interrelationships S2.1

The last century has seen the evolution of general systems theory which has helped us better understand the interconnectedness of many of our current problems. Discussions relating to planetary boundaries, for example, have, in part, been inspired by the limits-to-growth discussions, which were an outcome of the science of systems dynamics, a field which is increasingly penetrating many of our current technical discussions. Even economics, deeply rooted in the science of mechanics, is beginning to be influenced by the recognition of complexity as a factor that may make a difference.

For industrial policy practitioners, these new scientific developments provide many interesting options for crafting green industrial policies. Complex problems, such as the greening of industry, require complex solutions. "Systems thinkers" are able to explain and develop approaches for dealing with complexity. They also help us break out of our tendency to think and act in silos.

However, models, which are at the heart of any cognitive process, are more difficult to explain and share as their complexity increases. This poses a practical challenge to policy practitioners:

- How can complex models be built on a routine basis to assist with decision making?
- How can the complexity of an issue be presented to decision makers in a sufficiently accurate and intelligible way?
- How can the solution proposed be explained to people who have not been involved in the analysis itself (the model building process)?

The methods presented below can be used to address these very practical issues.

Background

A cross-impact matrix is a very useful tool that can be used to gain an understanding of the basic features of any system. It has been, and still can be, implemented on paper and pinboards as it was during the 1980s and 1990s when computers were not as widely used as they are today. They were labeled "paper computers" by Frederic Vester, one of the leading figures to advance the tool in Germany. To date, it remains one of the few approaches for dealing with complexity that can be implemented by the practitioner in the field without having to draw on external expertise (see Northrop, 2011, pp. 371-376). For some recent applications see, inter alia, Chan and Huang, 2004, and Huang and others, 2009, or PAGE, 2015b.

Cross-impact analysis is a basic building block for developing strategic green industrial policies (SGIP). By using cross-impact analysis, we are taking a significant and pragmatic step towards holistic analysis, a fundamental requirement for understanding and working with systems, and for organizing the transition of manufacturing industries into the green economy.

Strategic green industrial policy is related to many different factors. This is both a reflection of our increasing knowledge about the complexity of modern societies and their production systems, as much as it is a result of increasing complexity resulting from the advancement of globalization; continuing population growth; the proliferation of new technologies; the exponential growth of information available; and climate change. Our ability to cope with this multitude of continuously changing factors is limited. We need new tools for dealing with dynamic complexity.

We can no longer develop industrial policy without considering its wider implications. Instead of attempting to develop industry from our specific manufacturing based point of view, we need to develop joint, interconnected solutions that are equipped to deal with the complexity that our societies are facing.

Cross-impact analysis is a tool which allows us to better understand how different interconnected elements of a system influence each other. Its objective is to determine the roles the different elements play in the overall system. This information is important because it allows us to sketch interventions which draw upon the self-organizational features of the system in order to induce desired changes. We will also obtain a more general overview of the potential system dynamics.

Cross-impact analysis is one of the first tools that can be used when seeking to understand a system. Moreover, cross-impact analysis is highly transparent, a key advantage which many elaborate systems models do not share because their algorithms often are not revealed, or because they are too difficult to discuss with a wider range of stakeholders. Arguably, a cross-impact analysis could be drawn into the sand with a stick.

1

A cross-impact analysis includes the following steps:

Specify or identify the purpose of the system

A system is a set of factors that produces a characteristic set of behaviours. This set of characteristic behaviours is referred to as the purpose or function of the system.

The purposes of industrial systems could, for example, consist of reducing the amount of imports of manufactured goods in order to achieve a more favourable balance of trade or increasing MVA and local content, so as to more significantly raise per capita income. Greened purposes of industry systems could, for example, consist of decoupling material consumption or energy use from the growth of MVA.

It is easy to see that greening requires stretch. It may be an extension of purposes previously defined, or a completely new purpose. The systems to be analyzed for developing SGIPs are therefore wider, or at least pay much closer attention to the relationships of the industry system with the environment it is embedded in.

Identify the elements of the system

Once the purpose is identified, it is possible to specify the system's boundaries and to identify the different elements (or factors) it is made up of. Elements of a green industry system could, for example, consist of more detailed and specific descriptions of production factors, space, infrastructure, planning, regulation, watersheds, recycling systems, etc.

Ensure that the cross-impact analysis refers to a viable system

When describing the structure of a system, there is always a temptation to keep things simple, to sum everything up into key points and to leave out what seems not to be immediately relevant to the questions that we are confronted with. This approach is not adequate if we wish to address real-life issues of dynamic complexity, and questions where economic, social, political, ecological, cultural, geographic and technological elements are interconnected and influence the way a system behaves.

Vester (2012, pp. 211-218) has distilled a set of criteria against which to assess whether the set of elements that have been identified to describe a specific system, correspond to the characteristics of a viable system (i.e. a living, real thing). If the elements identified cover all of these characteristics in one way or another, the likelihood is high that a viable system is being described and that no essential part has been overlooked or ignored. If all characteristics have not been addressed, then the description is likely to be incomplete and needs to be supplemented or amended accordingly.

Describe the relationships between the elements of the system

Once the elements of the system have been identified, we need to describe the relationships between these elements. In practice, we usually draw a diagram of influences where arrows represent the relationships between the different elements.

The structure contained in the diagram of influences can also be transferred to a matrix. This matrix, called cross-impact matrix, or matrix of influence, is similar to an input-output table in that it displays each element of the system once in both rows and columns.

T2 Cross-impact matrix

effect of on	1	2	3	4	5	active sum (AS)	ratio*)
1							
2							
3							
4							
5							
passive sum (PS)							
product **)							

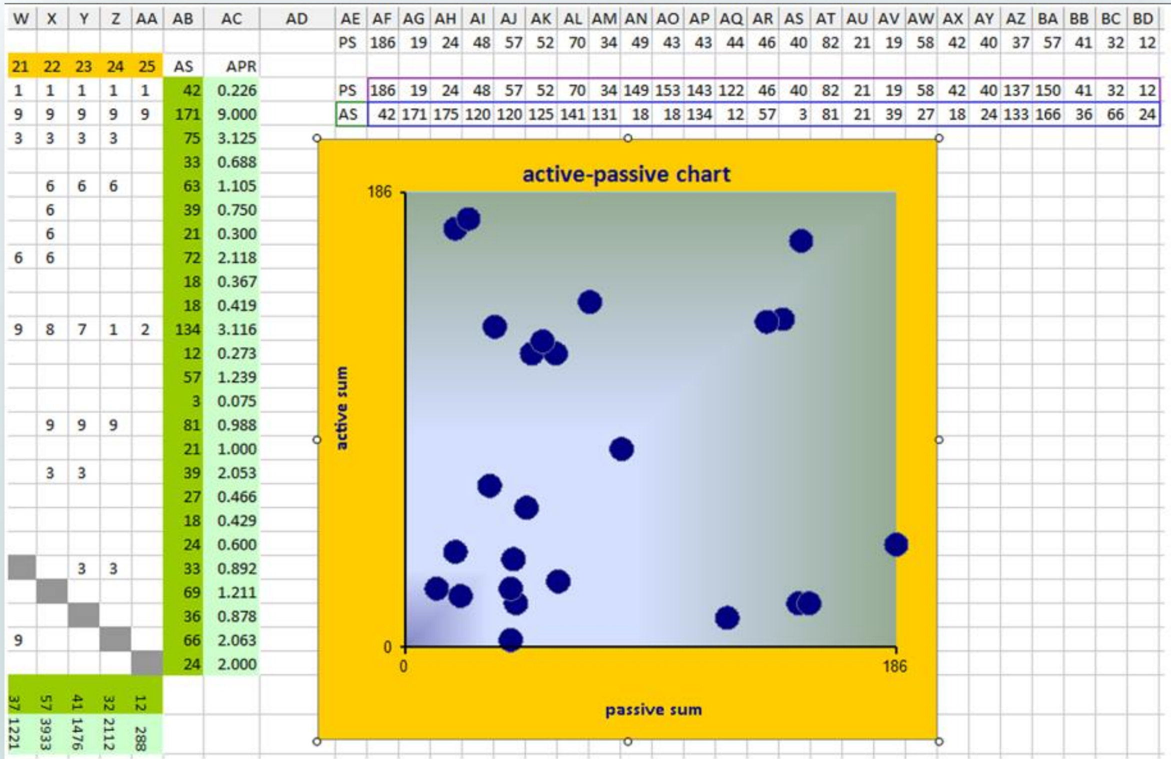
One key output of the cross-impact analysis is an active-passive chart. This chart displays the coordinates of the total value of influences received from other elements (passive sum) and the total value of influences exerted on other elements (active sum), for each element of the system. The active-passive chart is divided into four quadrants to classify elements according to their specific characteristics.

The active-passive chart informs us of the basic patterns of influence in the system. Active, passive, critical, buffer and neutral elements are distinguished. Understanding their role helps us to design appropriate interventions.

A cross-impact analysis is a basic building block for developing strategic green industry strategies that embody systemic fit. By implementing it, we can take a significant and pragmatic step towards holistic analysis – a fundamental requirement for understanding and working with systems.

We are able to prioritize areas of intervention based on the active-passive charts generated from the cross-impact analysis. This is a core element of any policy-design process.

Active-passive charts for understanding the relationships in a system F2



Observation: Active-passive chart produced using common spreadsheet software. There are also specialized softwares that facilitate cross-impact analysis, which can be used for group modeling, and even for simulations.

S2.2 Multiple-criteria decision analysis (MCDA) for understanding potential trade-offs between subsectors

Multiple-criteria decision analysis (MCDA) is a tool which helps to develop solutions for problems where optimal ones (i.e. when one single criterion can be used to describe the benefit or value of a policy decision) cannot easily be developed. Greening industry is a case in point as the industry needs to be both economically viable and/or competitive, while at the same time responsive to the constraints imposed by the ecosystem in which it is embedded. SGIP may also include further criteria that, for example, reflect national strategic interests and a political mandate relating to stakeholder interests.

Given that MCDA is often used in policymaking processes, there is far more material available on this approach than for cross-impact analysis. Moreover, many policymakers will have witnessed or actively participated in decisions prepared on the basis of MCDA.This section will therefore provide a brief overview of one of the few explicit MCDA approaches in relation to green industry policy formulation. Policymakers are invited to follow the approach highlighted or develop their own criteria, based on the specific context of their countries and the industries concerned.

Policymakers will need to ensure that any proposed algorithms of the method truly reflect their priorities (given that some experts may feel tempted to mathematically optimize the presumed preference of the policymakers they cater to) and that apples and pears are not unduly mixed in the process. Often, policymakers will find it more useful to decide on a policy where the different criteria are expressly rated and juxtaposed or listed for alternative policies instead of deciding on the basis of a summary value assigned by an algorithm. This will usually enhance the transparency of the decision-making and facilitate the communication of any decisions made.

UNIDO (2015a) proposes a framework that uses MCDA for assessing manufacturing subsectors with regard to their sustainability. The methodology combines different tools and uses a screening procedure in order to select the types of subsectors that policymakers should develop (perhaps because there are reasons to assume that they will be sustainable and have limited social and environmental impacts) and those they should not look to support. This three-step assessment framework seeks to integrate economic, social and economic aspects, while taking into consideration country-specific contexts and local realities.

The first step consists of analyzing the economic potential of a manufacturing subsector in terms of its export capacities, the domestic demand for its products and its interdependencies with other manufacturing subsectors in the country. A subsector will qualify for potential support if::

- it is classified a "champion" or "underachiever" in trade analysis;
- it has been classified as a "local champion" based on domestic demand and a production analysis;
- it is classified as a "high impact" subsector based on domestic interdependence analysis.

If a subsector "fails" the first step, i.e. if there are no positive economic impacts identified, then additional criteria may be applied to assess whether there is any reason for supporting the subsector concerned. For example, these criteria may relate to employment generation, building local knowledge, or an analysis of the effects related to social and environmental hot and cool spots. If the subsector concerned "fails" on these additional criteria, support is not an option for the policymaker, and it is dropped from the list of sectors that merit support ("forget").

Those subsectors which have passed the initial screening ("pass"), are then reviewed with regard to their proximity to national limits (constraints) in terms of environmental and social impacts. This will result in a broad classification of the subsectors according to the following categories.

Example of a classification grid for industrial subsectors in multiple-criteria decision analysis (MCDA)

T3

		Economic impact	
		positive	*negative*
Near ecosystem, environmental, or social constraints?	*yes*	**"growth with care"**	**"double trouble"**
	no	**"green growth"**	**"strong medicine"**

Source: Based on UNIDO, 2015a, p. 64, fig.21.

Following this initial classification, all of the considered subsectors should be investigated more specifically in terms of:

- value chains;
- hot, cool, and blank spots;
- required infrastructure, skills, and supply;
- subsector forecasts; and
- the results of stakeholder consultation (environmental and social).

Those subsectors which operate near constraints ("growth with care" and "double trouble"), will require more detailed hot spot investigation such as:

- detailed impacts;
- potential solutions (global);
- options for mitigation.

All subsectors, with the exception of those in the category of "green growth", are subjected to opportunity cost analysis.

The rationale behind this approach is that it is extremely important for governments to understand their competitive position in comparison to other countries when making decisions related to greening their manufacturing sectors. Moreover, it will help to ensure that policies for manufacturers are crafted in line with the country's current endowment structures and global market trends.

The degree of confidence that this analysis requires will depend to a large extent on the quality of the obtained information for the various aspects under consideration. In many lower-income countries, quantitative data may not be available beyond areas such as trade or GDP (economic impact) and energy (constraints). Therefore, qualitative assessments and a triangulation of expert opinions may be required to fill the gaps.

The methodology does not allow for an assessment of the systemic interrelationships that exist between manufacturing subsectors and the systems they are interacting with. Thus, it will not reveal any triggers that may accelerate the greening of the industrial system. However, it does provide a systematic approach for categorizing manufacturing subsectors according to greening criteria. However, this should not prevent policymakers from using MCDA for the purpose of developing SGIP. After all, data and information for developing new action fields is usually lacking.

Databases and methodologies for estimating pollution intensity and resource efficiency

S2.3

Pollutant Intensities

Most developing countries still have little or no data on industrial pollution. In response to this situation, the World Bank has assembled the Industrial Pollution Projection System (IPPS) to estimate a more comprehensive profile of pollutant intensities for the manufacturing sector and subsectors within it. The modelling system was developed in the 1990s based on environmental and economic data from approximately 200,000 facilities across the United States of America in the late 1980s, and subsequently applied in several developing countries (Indonesia, Mexico and Thailand). While dated, and no substitute for current data, it shows the relative pollutant intensity of manufacturing sectors. It is still the only international modelling system available. It can be applied to estimate air emissions, water effluents and solid waste loadings. A full description of the modelling system can be found in the Industrial Pollution Projection System (see World Bank, 1995).

The pollutant intensity coefficients for 14 pollutants can be multiplied by one of four measures of economic activity: total value of shipment in millions, total value of output in millions, value added in millions (all values in USD 1987) and total employment per 1,000 persons based on country-specific data in order to give pollutant loadings.

Pollutant loadings = pollutant intensity X economic activity

In addition to pollutant coefficients, the IPPS includes subsector average abatement cost (USD 1994) per ton for water and air pollutants. Hartman, Wheeler and Singh (1994) explain the basis of the approach for estimating the cost of air pollution abatement. However, there is no explanation for the cost of water pollution abatement.[1]

The table below shows the pollutant estimates and the cost of reductions for five pollutants in Senegal. This is based on the latest value-added data from 2010 (the last year for which data are available). The highest potentially polluting categories are: 21 per cent of total toxic loadings from petroleum; 75 per cent of total sulphur loadings from cement; 42 per cent of the total of organic water pollutants from the dairy industry; 75 per cent of total metal loadings from precious metals; and 81 per cent of total particulate matter from the cement industry.

[1] There are cost estimates for SO2, NO2, particulates, lead, volatile organic compounds, toxic air, air other, water conventional, water non-conventional, toxic metal water and toxic organic water.

T4 Potential pollutant loadings for Senegal

Senegal 2010

ISIC rev3/rev2		OUT%	#Establishment	Poll. in Tons	%POLL	Cost (USD1994/ton)	70% of pollutant	Total cost to reduce 70%poll
				TOX				
2320/3540	Petroleum	14.4%	1	71	21%	82	49	4 054
2520/3513	Plastic	3.9%	35	66	19%	1277	46	58 562
2412/3511	Fertilizers	7.3%	2	64	19%	22	45	1 013
2720/3720	Precious	2.7%	21	46	14%	2021	43	65 471
2421/3512	Pesticides	0.3%	2	14	4%	1352	10	13 239
TOT				**261**	**78%**		**183**	**142 340**
				SO2				
2694/3692	Cement	13.3%	9	2648	75%	14	1853	26 096
2320/3540	Petroleum	14.1%	1	277	8%	626	194	121 410
2696/3699	Stones	1.2%	7	244	7%	3778	171	646 217
2720/3720	Precious	2.7%	21	162	5%	151	114	17 161
1514/3115	Oils&fats	5.8%	3	85	2%	259	59	15 323
TOT				**3416**	**96%**		**2391**	**826 206**
				BOD				
1520/3112	Dairy	2.2%	14	28	42%	89	20	1 747
2720/3720	Precious	2.7%	21	12	19%	85	9	741
1542/3118	Sugar	3.1%	1	10	15%	6	7	43
1512/3114	Fish	5.2%	33	5	7%	153	3	496
2320/3540	Petroleum	14.1%	1	3	5%	18	2	43
TOT				**59**	**88%**		**41**	**3 069**
				METAL				
2720/3720	Precious	2.7%	21	30	75%	672	21	13 939
2412/3511	Fertilizers	7.3%	2	3	8%	672	2	1 500
2520/3513	Plastic	3.9%	35	2	4%	672	1	719
2713/3710	Cast.Iron, steel	0.2%	8	2	4%	487	1	512
2320/3540	Petroleum	14.1%	1	1	3%	17	1	14
TOT				**37**	**93%**		**26**	**16 684**
				PT				
2694/3692	Cement	13.3%	9	1281	81%	13	896	11 656
2696/3699	Stones	1.2%	7	118	7%	65	83	5 398
1514/4115	Oils&fats	5.8%	3	87	5%	53	61	3 220
2320/3540	Petroleum	14.1%	1	24	2%	65	17	1 107
1542/3118	Sugar	3.1%	1	21	1%	57	14	829
TOT				**1530**	**96%**		**1071**	**22 209**

Resource Use – Energy

The estimation of current and future resource use by the manufacturing sector requires specific data on energy consumption, materials consumption and water use. Fortunately, the International Energy Agency compiles country-specific data on energy consumption by the manufacturing sector for many developing countries.However, there are no comparable comprehensive data on water and material use by the manufacturing sector.

Energy balances published by the IEA (2013a, 2013b), report energy consumption in kilotons (kt) of oil equivalents for 30 OECD countries and 108 non-OECD countries. Data for OECD countries have been available since 1960 and for non-OECD countries since 1971. For these 108 countries, some report only manufacturing sector data, while others report both total manufacturing and subsector data[2]. Table 5 below shows the most recent data for energy consumption by the manufacturing subsector for Ghana.

Unfortunately, there is no universal modelling system similar to the IPPS available for estimating energy consumption for specific subsectors within the manufacturing sector. What is known is that some subsectors are significantly more energy-intensive than others. Recent UNIDO research (2010) classified manufacturing subsectors at the two-digit level of ISIC into three energy-intensive categories (see T5). Six manufacturing subsectors are classified globally as high energy-intensive; manufacture of textiles; paper and paper products; coke and refined petroleum products; chemical products; non-metallic products; and manufacture of basic metals.

[2] There is no data entry per se for manufacturing energy consumption. Rather nine subsectors should be summed up, which are different from ISIC divisions, to obtain a total for manufacturing. (The construction and energy industries should not be included in the manufacturing sector.)

Subsector energy intensities in Ghana

T5

Intensity of energy consumption	ISIC3	Description of activities
High energy-intensive	17	Manufacture of textiles
	21	Paper and paper products
	23	Coke and refined petroleum products
	24	Chemical products
	26	Non-metallic mineral products
	27	Manufacture of basic metals
Moderate energy-intensive	15	Food products and beverages
	18	Wearing apparel; dressing and dyeing
	19	Manufacture of leather products
	20	Wood and wood products
	22	Printing and publishing
	24	Rubber and plastic products
	28	Fabricated metal products
Low energy-intensive	16	Tobacco products
	29	Machinery and equipment n.e.c.
	30	Office, accounting and computing machinery
	31	Electrical machinery and apparatus n.e.c.
	32	Radio, TV and communications equipment
	33	Medical, precision and optical instruments
	34	Motor vehicles, trailers and semi-trailers
	35	Other transport equipment
	36	Furniture and other manufacturing n.e.c.
	37	Recycling

ISIC3 ... attributions to ISIC 3 categories
n.e.c. ... not elsewhere classified.

Source: UNIDO, 2010.

Resource Use – Water

Surprisingly little is known about industrial water use. While it is generally agreed that industrial water consumption is about 20 per cent of the world's freshwater withdrawals, the percentage varies between regions and countries. In the case of Africa, industrial water withdrawal is estimated to be about 5 per cent of total water withdrawal, with agriculture using 85 per cent and human settlements 10 per cent (UNESCO, 2014). Even this estimate is questionable as water withdrawals by small and medium size industry are often conflated with domestic consumption. Consequently, estimates of actual water withdrawal and consumption by industry are only approximations.

There is no water use database for the manufacturing sector equivalent to the energy consumption data maintained by the IEA. The only global database on industrial water use, AQUASTAT, is maintained by the Food and Agriculture Organization (FAO, 2015). FAO obtains water withdrawal values from ministries or other governmental agencies at country level, although some data gaps are filled using United Nations (UN) data. EUROSTAT and OECD are valuable sources of information for Europe, Australia, Japan, New Zealand and Northern America, and are also used to fill data gaps.

AQUASTAT data for industry are presented in five year intervals, starting with the period 1988-1992; the latest interval is 2008-2012. The data rich periods are 1996-2002 and 2003-2007. There are virtually no country-level industrial water data for most developing countries for the period 2008-2012.

Resource Use — Materials

Data on material extraction and consumption are to be found on the Sustainable Europe Research Institute (SERI) and Vienna University of Economics and Business database (www.materialflows.net). It is an online portal for material flow data, providing access to material flow data sets at the country level. The database comprises data for more than 200 economies for the time period from 1980 to 2011, with more than 300 different materials aggregated into 12 categories of material flows.

The country-level data on domestic material extraction and consumption are defined as follows

- **Domestic Material Extraction (DE)** is the amount of raw material (excluding water and air), in physical weight, extracted from the natural environment for export and domestic material consumption measures.
- **Domestic Material Consumption (DMC)** measures the total amount of materials used within an economic system and is defined as the quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. Hence, if DMC is greater than DE it implies a relative material intensity of imports of a country. If DMC is less than DE, the country extracts more materials than it consumes, enabling material exports. In Ghana, the latter is the case.

Domestic Material Consumption = Domestic Extraction + physical imports - physical exports

Data from www.materialflows.net, as an example, shows that DE in Ghana grew significantly from 1980 to 2010, with the greatest growth in industrial and construction minerals (see T.6). In 2010 the manufacturing sector accounted for 21 per cent of material consumption, compared to 41 per cent by agriculture and 23 per cent by the mining sector. These data show that industry was not the largest consumer, giving slightly lower results than the mining sector. The large (positive) difference between DE and DMC shows that a considerable share of material extraction in Ghana is exported as raw material.

Decoupling Analysis

One can estimate the extent to which relative or absolute decoupling of resource use from industrial output has occurred over a reasonably long time frame and compare the extent of decoupling with other countries in the region, a regional average, or a global estimate. The decoupling trends are characterized on two dimensions – relative and absolute. Relative decoupling is said to occur when the growth rate of the resource variable is positive, but less than the growth rate of MVA. Absolute decoupling is said to occur when the growth rate of resource use is zero or negative and the growth rate of MVA is positive. In this case, pressure on the environment from resource use is either stable or falling. From an environmental perspective, the more significant achievement is not relative, but absolute change in the resource use variable, since decoupling could occur, but yet may not be sufficient to keep pollutants within the limits of environmental standards.

Domestic material extraction and consumption (Ghana) T6

Domestic Material Extraction (in kt)	1980	2010	%Variation
Biomass	28 400	109 200	284%
Fossil Fuels	0	220	--
Industrial and Construction Minerals	4 120	35 880	771%
Ores	10 470	80 130	665%
Total	**43 000**	**225 430**	**424%**
Domestic Material Consumption (in kt)		**2010**	**%Of Total**
Agriculture		71 184	48%
Manufacturing		25 211	17%
Mining		51 905	35%
	1980	**2010**	**%Variation**
Total	**30 300**	**148 300**	**389%**

Source: www.materialflows.net.

For the most part, decoupling in current analyses is estimated only for energy use because there are sufficient energy use consumption data. For example, energy decoupling is calculated for several countries in Africa. The decoupling analysis reveals relative decoupling occurred at the global level but less so at the sub-Saharan Africa (SSA) regional level from 1990 to 2010. The SSA region has, however, seen relative decoupling in more recent years (2005 to 2010). Absolute decoupling has not yet occurred at the global or SSA regional levels.

According to the IEA data in T7, relative decoupling only occurred in four of the eight countries surveyed for the longer time frame (1990 to 2010), but in seven of the eight countries over the shorter time frame (2005 to 2010). Relative decoupling in seven of the eight countries was less than the global change (-0.21) from 1990 to 2010 and in five of the eight countries was less than the SSA change (-0.02).

T7 Results of decoupling analysis (different countries of sub-Saharan Africa)

Group	Relative Decoupling Indicator		Absolute Decoupling Indicator	
	1990-2010	2005-2010	1990-2010	2006-2010
World	-0.21	0.02	0.36	0.14
SSA	-0.02	-0.11	0.77	0.13
Cameroon	0.23	0.52	0.74	0.59
Ethiopia	0.30	-0.13	1.55	0.37
Ghana	1.81	-0.06	1.98	0.06
Kenya	0.13	-0.01	0.83	0.23
Mozambique	-0.64	-0.01	0.81	0.15
Nigeria	-0.25	-0.27	0.64	0.09
Tanzania	-0.07	-0.07	1.72	0.41
Zambia	-0.09	-0.07	0.46	0.05

Source: IEA 2013a, 2013b; UNIDO, 2015b.

Methods for helping to identify the key targets of SGIP[3]

Material flow analysis (MFA)

S2.4

MFA is a method to measure and quantify flows of material inputs and outputs. It is the key tool for recording the material inputs and outputs of an economy or certain economic sectors, on an annual basis. At the macro level, economy-wide material flow accounts look at, for example, the throughput of the aggregate mass of materials measured by DMC. Material flow indicators can be applied at other levels, or in specific areas of interest, ranging from primary materials, products, or enterprises to economic (sub) sectors.

DMC calculates the total quantity of materials used within an economy while excluding indirect flows. Therefore, DMC represents a close equivalent to aggregate income within the conventional system of national accounts. It is calculated by subtracting direct exports from DMI. Resource or material efficiency can be calculated when DMC is combined with data on economic performance.

Material flow-based indicators are aggregated measures of physical mass over time or per unit of service. Usually, these materials are expressed in tons per year or kilograms per unit of service.

Measurements of material stocks refer to materials in the Earth's crust (abiotic materials) and available ecosystem resources, such as timber, plants or animals (biotic materials). Materials stored in the economic system, i.e. the total stock of durable products, buildings and infrastructure, are also included.

1) How can MFA help policymakers?[4]

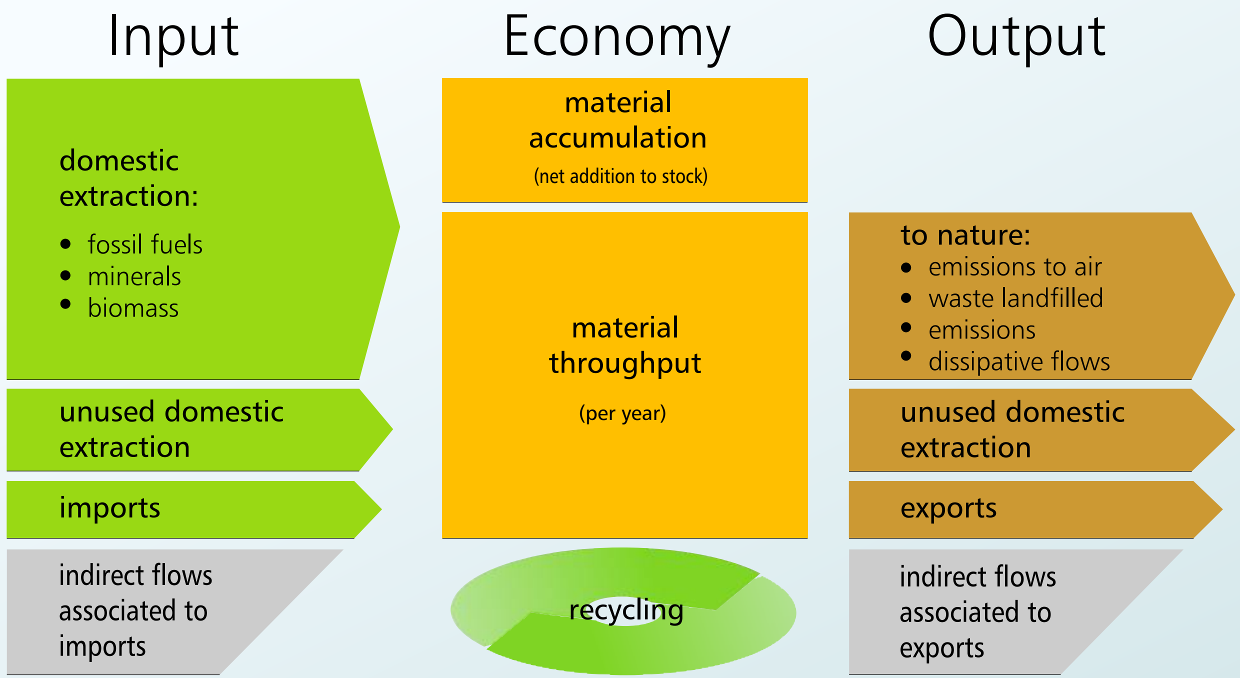
MFA can help policymakers to:

- Provide insights into the structures and changes over time of the material requirements of an industrial system or an economy;
- Derive a set of aggregated indicators for resource use, resource productivity and eco-efficiency by relating aggregated resource use indicators to GDP and other economic and social indicators;
- Derive a set of aggregated indicators for the material intensity of lifestyles by relating aggregated resource use indicators to population size and other demographic indicators; and
- Identify and manage potential supply risks and vulnerabilities of certain materials and resources.

2) What does an MFA require?

According to the law of conservation of mass, total inputs must, by definition, equal total outputs plus net accumulation of materials in the system, as, for example, in buildings. This material balance holds true at the global level, for a regional or national economy, or for any subsystem of the economy (such as the manufacturing industry). Therefore, the inputs and outputs of a defined system are the relevant flows required to compile a consistent MFA.

F3 Schematic of material flow analysis (MFA)



Observation: Economy-wide material balance scheme usually exclude air and water flows even if they usually represent the largest part of all material flows.

Source: EUROSTAT, (2001), p. 16, Figure 5.

Three different types of flows are being considered.

a. **Domestic extraction (DE)**

Complete data for DE can either be retrieved from national statistics or from the SERI global database (www.materialflows.net) which also provides data for unused extraction such as mining by-products etc.

b. **Imports**

c. **Exports**

Trade data in physical quantities can be retrieved either from national statistics or UNCOMTRADE.

3) How to build the indicators

Main input indicators

- Domestic material input (DMI) comprises all materials which have economic values and are directly used in production and consumption.

DMI = domestic extraction + imports

- Total material input (TMI) equals domestic material input plus unused domestic extraction.

TMI = DMI + DEunused

- Total material requirement (TMR) include, in addition to TMI, the indirect (used and unused) flows associated to the imports of an economy. TMR is thus the most comprehensive material input indicator.

Main output indicators

- Domestic processed output (DPO) compromises all outflows of used materials from domestic or foreign origin. DPO includes emissions to air and water, wastes deposited in landfills, and dissipative flows.
- Total material output (TMO) also includes, in addition to the direct material output (DMO), the unused domestic extraction.

Main consumption indicators

- Domestic material consumption (DMC) measures the total quantity of materials used within an economic system, excluding indirect flows. Thus DMC is the closest equivalent to aggregate income in the conventional system of national accounts.

DMC = DMI - exports

- Total material consumption (TMC) includes, in addition to DMC, the indirect flows associated to imports and exports.

TMC = TMR - exports +/- indirect flows

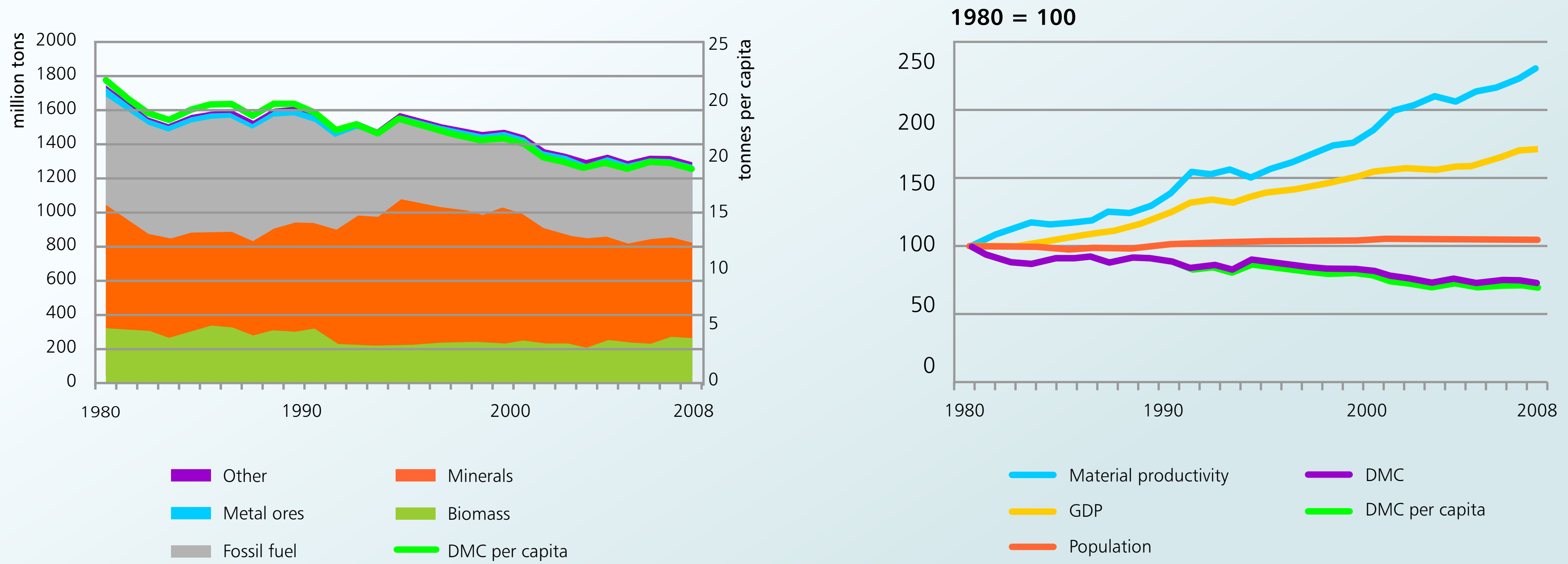
- Physical trade balance (PTB) shows whether resource imports from abroad exceed resource exports of an economic system, and to what extent the system relies on domestic resource extraction or on imports from abroad.

PTB = imports - exports

Resource efficiency indicators

In order to measure decoupling or the dematerialization of an economy or any other system, GDP is divided by one of indicators above, e.g. GDP/DMC, to provide an appropriate resource efficiency indicator.

F4 DMC and calculations of resource efficiency for Germany 1980-2008



Source: UBA (2013), p.12, fig. 7-8.

Generally, industry's overall impact during the process of greening is expected to decline. This points to strategies of double decoupling, hence it may be useful to review the ways in which decoupling is being achieved:

- The decoupling of <u>resource use from economic growth</u> by increasing resource productivity;
- The decoupling of <u>environmental impacts from resource use</u> by reducing resource specific impacts.

Environmentally extended input-output analysis (EEIO) S2.5

Input-output analysis is a basic tool for economists to analyze flows in the economy. To a certain extent, it represents the concept that comes closest to the notion of a circular economy as its original objective was to reveal the circulation that occurs within an economy. Input-output analysis establishes a direct relationship between total output and final demand, emphasizing the fact that the ultimate purpose of all productive activities is to satisfy final consumption.

The most important function of input-output analysis is to reveal the linkages that exist between different sectors of the economy. Policymakers can devise strategies to influence these flows, and they may also use the outcomes to assess the potential effects that industrial policies can have on the flows between different sectors.

The regional application of input-output analysis is flexible as regions of any size can be analyzed using them. This is why it has been an important tool for regional planners. Input-output models can refer to a single-region or entire countries. They can also combine various regions, as in multi-regional or multi-country models (see Giljum and others, 2013).

Input-output analysis can also be applied to sectors and subsectors, i.e. it records the inputs and outputs for the manufacturing sector, or the production of, for example, clothing. However, its real strength lies in providing a more comprehensive picture of the forward and backward linkages that exist between various economic subsectors.

Input-output analysis usually depicts economic flows. However, it can also be used to display other types of flows, such as material flows. Typically, it is better to maintain the same unit within the same table, but a combination of different units (value and mass) is possible as long as they are clearly labelled and do not confuse the user. For example, they may reflect resource use and emissions.

If ecological or environmental relationships are of interest (as they are for shaping SGIP), the traditional framework of input-output analysis needs to be extended to environmental and/or ecological factors. The first attempts to integrate ecological issues date back to the 1970s. While gathering data for the analysis can be an issue, and may require the policymaker to commission additional supportive research, the method itself is well established.

The basic framework for such extensions is described in the following figure (F5) where the upper left-hand quadrant represents the traditional subsector by subsector (commodity-by-industry) table. This quadrant can be extended by adding ecosystem flows both to the input and output sides, and, ideally, by ecosystem flows that do not enter the economic system in question (lower right-hand quadrant). Such analyses are called ecologically extended input-output analyses (EEIO). They are becoming increasingly popular for providing assessments of environmental aspects at the sectoral level (see Giljum and Lutter, 2014).

F5 Structure of environmentally or ecologically extended input-output (EEIO) tables

	→ to economic (sub-)sectors	→ to ecosystems
from economic (sub-)sectors → • agriculture: a1, a2, a3... • manufacturing: m1, m2, m3... • services: s1, s2, s3...	flows from economic sectors → to economic sectors	flows from economic (sub)sectors → to ecosystems
from ecosystems → • materials → • water → • air → ...	flows from ecosystems → to economic sectors	flows within and among ecosystems

Observation:
Traditional input-output tables encompass the area enclosed by the bold blue frame. These tables are extended to the ecosystems by adding the area enclosed by the double-line frame. Flows within ecosystems need not form part of the tables, but the flows between the ecosystems and the economy need to be included.

Multi-regional input-output analyses (MRIO) is a framework of analysis that is increasingly used to assess the interrelationships between different regions, e.g. national and international linkages across sectors. By ecologically extending such analyses, they become EE-MRIO (environmentally or ecologically extended MRIO). For practical examples, see Murray and Lenzen, eds., 2013.

How to implement the EEIO

Depending on the national data situation, the basic commodity-by-industry framework (based on "make" and "use" tables) or the common static Leontief model (based on symmetric input-output tables) can be used to integrate environmental data. It is best to implement an input-output analysis jointly with the national statistics authority.

The basic commodity-by-industry framework allows for additional rows of environmental inputs (in the case below, direct material input). F6 presents the structure of this model.

Make-use framework, extended with ecological inputs

F6

	commodities	industries	final demand	total output	ecological commodities
commodities		use matrix U	final demand matrix Y	vector of commodity gross outputs q	R
industries	make matrix V			vector of industry total outputs g	
value added		value added	GNP		
total inputs	q’	g’			
ecological commodities		T			

Source: Adapted from Miller and Blair, 1995, p. 253.

This framework allows for the flow of environmental commodities from the environment into the economy and of waste products from the economy back to the environment. Besides the output flows of solid waste, it provides a framework for a comprehensive assessment of the indicators related to production and consumption activities. In addition, it can be extended with additional environmental data, such as land use on the input side, waste water and CO2, or other emissions into the atmosphere.

On the basis of these extended input-output tables, it is possible to calculate weighted multipliers that account for direct and indirect requirements, or effects per unit of production in each economic sector and for the components of final demand (household consumption, public sector consumption, exports, and investment). These multipliers can be interpreted as intensities with regard to resource, emissions and labour intensities of the production of services and commodities. An extended input-output analysis was applied for a green industry case study on Peru within the framework of the Partnership for Action on Green Economy (PAGE 2015a).

S2.6 Life cycle assessments (LCA)

Another tool, besides MFA and EEIO, is Life Cycle Assessments (LCA) which evaluates the environmental aspects of a single product, a product group, or a service system throughout all stages of its life cycle. This method is a bottom-up approach (Giljum and others, 2013) and quantifies all physical exchanges with the environment, including both inputs (materials, water, land use and energy) and outputs (waste and emissions to air, water and soil). These exchanges are further assessed in relation to specific environmental impact potentials such as climate change, eutrophication, or contamination (see European Commission, 2012).

LCAs can be seen as an instrument for supporting decision making in policy fields in terms of highlighting and specifying the environmental impacts. In order to achieve a life-cycle economy, reliable data on the LCA performance is required. The calculation methodology of LCA was standardized by the ISO norms 14040/14044.

How to implement LCAs

In order to understand the various potential environmental impacts a specific good or service may have during its life cycle, it is practical to use the LCA methodology to investigate such impacts. ISO14040 defines four major steps that should be considered for a LCA.

When beginning, it is useful to sketch a flow chart which displays all the process steps and their interactions. Each process could have several inputs and outputs. What exactly "all processes" entails depends on the system boundaries specified. System boundaries are relevant at different scales: geographic boundaries (local, regional, national, global); temporal boundaries (e.g. 2012-2032); and boundaries for input flows (for example, using the "5 per cent rule" – taking into account all input flows that have a weight of more than 5 per cent).

Goal and scope definition

- What is the intended usage (e.g. assessment of a certain product policy, decision support, etc.)?
- What is the target group to be addressed (e.g. manufacturers, consumers, other stakeholders)?
- What is the reason for undertaking the LCA (e.g. gaining a more detailed understanding of environmental impacts; the growing importance of the usage of a particular kind of material)?

Very important: Define the functional unit (FU) as a core element of the LCA. Every environmental impact refers to the FU which is considered to be the reference value. The FU for a window could, for example, be "1 square metre window including the frame over an expected lifespan of 20 years." The FU for a pencil could be "1 kilometre of line drawn."

The quantities of the materials used are stated in the reference flow (e.g. for a window: X kg of glass, X kg of wood, plastic, or aluminum for the frame). The choice of the FU will have a critical influence on the results of the LCA.

1) Inventory analysis:

The main output of the inventory analysis should be a list of all the relevant inputs and outputs of the product system being investigated. Procedure: Sketch the process flow chart, collect the data of all inputs and emissions for all processes (possible sources: ecoinvent, GEMIS, own measurements, scientific publications, expert knowledge, or estimates) and create a system model (e.g. using open LCA, common spreadsheet, or other suitable software). In this context, the allocation of the environmental impacts for joint products should be treated as the result of one process (e.g., a power plant produces both electricity and heat) and indicated by physical properties (mass or energy content) or economic values.

2) Impact Assessment:

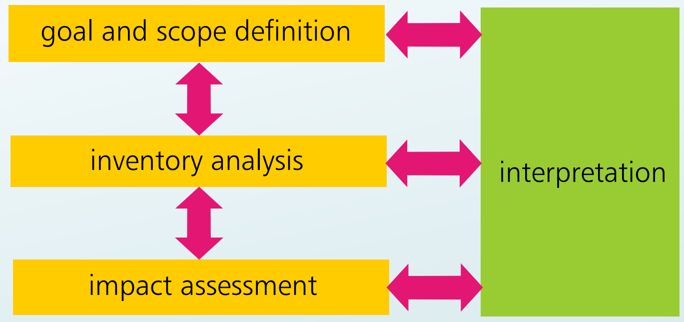
Convert the list created above into environmental impacts. Firstly, select proper impact categories (global warming, acidification, terrestrial toxicity, ozone depletion, cumulative energy demand, land use, etc.). Then classify, i.e. assign the results of the inventory analysis (emissions, resource consumption) to the impact categories. Finally, convert the results from the inventory analysis into potential environmental impacts using conversion factors (e.g. for environmental impacts of different construction materials). The last step is called "characterization".

3) Interpretation:

This is an iterative process of quality control which includes the evaluation of the methodology, the used data sets, and the results concerning integrity, sensitivity, and consistency.

Steps of Life Cycle Assessment

F7



Source: ISO14040ff.

Besides LCA, which is focused on product development, all the traditional tools of environmental management remain relevant at the subsector and plant levels. It is important to continue to encourage the use of energy audits, clean production assessments and environmental management accounting to improve the performance of the respective targets.

S3 PHASES 4 & 5: POLICY DOMAINS & INSTRUMENTS, POLICY PATHWAY DESIGN & IMPACT ASSESSMENT

Tools of SGIP Analysis

S3.1 Assessments relating to technologies and the role of eco-innovations

Technology is a key element for greening the manufacturing industry, and manufacturing is a key sector for developing technologies that allow us to move towards greener economies. One of the starkest challenges facing manufacturers over the coming decades is the need to escape the technological lock-ins of previous decades and to develop technologies that are able to fulfil the requirements of a SGIP, or the green economy more generally. The challenge for policymakers is to create an environment, and the necessary support, that enables manufacturers to "change winning teams" (from those that were competitive in the old economy to those that will succeed in the new green economy).

To make this feasible, the green economy needs to be more competitive than the old economy. Moreover, the sunk cost argument from economics will need to play a much larger role in the decision-making process, both for governments and manufacturers. It is wrong to invest in unsustainable technologies merely because substantial investments were made in previous years or over several decades.

Given the strong interrelationships between manufacturing and technological development, policymakers need to actively encourage the development of green technologies or technologies that will help with greening the economy. The mechanisms for doing this will vary significantly according to the current technology being used, the size and growth rates of the markets for the manufactured products from domestic firms, and the country's R&D potential.

As a minimum, they should typically be based on regular meetings of panels of domestic technology experts, both from industry and science, that are able to estimate future trends and/or agree on new possible technological paths.

In order to meet the requirements of a SGIP, such panels will need to occasionally break with standard industrial classifications and leave their manufacturing sector silos so as to assess opportunities that may arise from cross-sectoral collaboration and cross-fertilization. Jointly assessing technological trends and identifying technological opportunities that should be seized (e.g. by reviewing the plethora of patents that are currently unused and which have essentially only been registered to block the development of rival technological solutions, or by agreeing to collaborate in specific fields of pre-competitive research) will be an important basis for developing SGIP. These assessments will help to provide the guidance the manufacturing industry needs in order to develop marketable technological solutions.

The intermediate goals required for achieving the transition to a green economy are (see Hinterberger, Femia and Luks, 1999):

- cleaner material input
- more efficient production
- more services from current production
- increased sufficiency

A drastic reduction in overall environmental impacts can also be achieved by identifying or creating synergies between relatively smaller advances in each of these elements, for example, by:

- an increase in the life cycle, or the end-of-life of products
- a substitution of high-impact materials with those of low-impacts
- an increase in productivity as a result of less resource demand
- a more frequent and shared service intensity of products (e.g. leasing or sharing schemes)

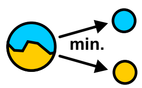
The key principles of the technologies we need for the green economy have been developed over the last few decades and are described below in B1. Policymakers involved in developing SGIPs need to ensure that these principles are increasingly applied in their country's manufacturing industry and, in particular, remove any disincentives or obstacles to their application.

B1 Principles of green engineering

Designers need to strive to ensure that all material and energy inputs are as inherently non-hazardous as possible.

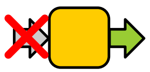
It is better to prevent waste formation than to treat it after it has formed.

Separation and purification operations should be designed to minimize energy consumption and materials use.

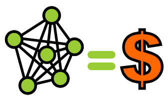


Products, processes and systems should be designed to maximize mass, energy, space and time efficiency.

Products, processes and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.



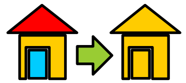
Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse or beneficial disposition.



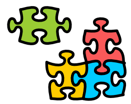
Targeted durability, not immortality, should be a design goal.

Design for unnecessary capacity or capability (e.g. "one size fits all") should be considered a design flaw.

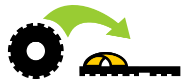
Material diversity in multi-component products should be minimized so as to promote disassembly and value retention.



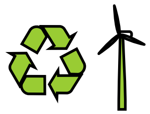
Design of products, processes and systems must include integration and interconnectivity with the available energy and material flows.



Products, processes and systems should be designed for performance in a commercial "afterlife".



Material and energy inputs should be renewable rather than depleting.



Engineers have been a major driving force in the development and success of manufacturing industries. As we move towards the green economy, engineers, naturally, will need to follow green principles in all spheres of their work in order to contribute to building a greener future. Government policymakers should be aware of the principles listed below, so that government regulations may respect them, and promote and support their application in manufacturing enterprises.

Source: Anastas and Zimmermann, as cited in Graedel and Allenby (2009), p 106, Table 8.2. Symbols by UNIDO.

New technologies and their relationship to SGIP

As the use of new technologies does not automatically lead to a sustainable economy or society, a critical assessment and evaluation of technological innovations is required. For example, elements such as: potential rebound effects; any ineffectiveness; negative externalities of any new technology use; the interconnection of certain technologies among many sectors and its acceptability to potential users, need to be considered. Sustainable or innovative technologies and eco-innovations can contribute to a systemic change and transitions in various ways. In combination, these innovations can lead to system-wide impacts, specifically by improving or creating intermediate and new structures, processes or systems.

Technologies: Fostering bottom-up and local development

B2

Some of the most promising current technologies are related to renewable energy, and those that could be termed "bottom-up". These are eco-innovations by design, from eco-design to structural designs that change organizational patterns, which trigger multiple changes along a single value chain and on to much larger systems.

3D printing

The main advantages of 3D printing are:

- It is increasingly affordable;
- It enables a decentralized and almost self-sufficient production; and
- It allows the situational and temporal production of spare parts.

Moreover, it allows for products to be customized and for the production of fewer units compared to traditional manufacturing. As a result, it reduces pressure on the entrepreneur to sell more units to gain profits and lowers the entry barriers for new businesses.

Innovations and ICT support

Innovations and the spread of ICT support the development, deployment and maintenance of various sharing schemes and platforms, the exchange of (sustainable) knowledge, or the metering of energy use and other resources on demand. For example:

- Car-sharing or micro-community-transport systems may be maintained and managed with the help of apps;
- Sharing platforms may address a broader audience or number of users;
- Appliances, tools, and instruments may be shared; and
- Transformative knowledge or knowledge about sustainable activities can be disseminated.

B3 Small technological innovations can reduce the negative environmental impact

Not everything new is innovative, and not everything innovative is eco-innovativeT

The massive technological progress in electronics and ICT has led to an unnecessary and disproportionate replacement of products (in order to remain "up to date") such as notebooks and smartphones. These are multi-component products not easily disassembled for value retention.

More resource-efficient engines for automobiles are a favourable development. Unfortunately, this type of efficiency is frequently limited to only a very minor and special test scope (implemented under ideal conditions). Outside of this testing range, some engines have actually become less resource-efficient than those of older vehicles.

As long as manufacturers are not held responsible for any harmful environmental impacts caused by the extraction of the resources needed, or for the ecological feasibility of disposal of their products, they are likely to continue on a "business as usual" course. It is in this area where policymakers can make a substantial difference – by developing green policies that are uniformly applicable to all manufacturers

Substitutions – using more efficient materials of sufficient quality

The substitution of certain materials can have large multiple effects on the life cycle and resource-intensity of manufacturing products or construction. For example, when:

- using recycled synthetic materials, e.g. for vehicle interiors
- applying hybrid materials for buildings, e.g. mixes of wood, concrete and bricks
- using renewable materials, e.g. bamboo instead of aluminium for carriages

Industrial and business symbioses

Advances in Photovoltaic (PV) technology, specifically in terms of efficiency, affordability, simplicity of application and reduced demand on infrastructure, have made this form of electricity generation one of the most promising at a global level. The implementation of PV does not harm the environment during use (only during production in terms of raw materials), and it can be applied in even the most rural and least developed areas.

Furthermore, businesses will not only save resources and energy costs, but also contribute to social goods both at the local level (offering free services) and at the global level (reducing emissions). For example, an Austrian consulting company offers a business strategy for regional SMEs called "Green Business Solutions" which helped to establish the world's first free charging station route based on PV. The business concept included the installation of PV power plants on the roofs of buildings (subject to the condition that they would offer a free charging point for e-mobility vehicles). It meant that businesses received both electricity and earnings through feeding surplus power into the public power grid, and at the same time contributed to regional development, sustainability, and a reduction in emissions

(See http://greensolutions.gfb-prodinger.com/solution/solution-r.php .)

Waste management, recycling and circular economy

Similarly, there are many opportunities for developing symbioses and resource cycles between businesses and waste management, whereby the waste of one business becomes a valuable resource for another.

Systemic change towards sustainability may be achieved through a cascade of decoupling processes. Multiple changes can occur simultaneously at several stages through a combination of eco-innovations in production-consumption chains or within an organization, system or culture, leading to positive impacts on the environment (see EIO, 2013a). In addition, behavioural changes, lifestyles and politics can play a key role in upscaling these changes and limiting rebound effects.

Since systemic eco-innovations aim to develop fundamental and lasting system-wide changes at both the societal level (e.g. societal values and attitudes) and the technical level (e.g. infrastructure, technology, tools, production processes), it can increase sustainable competitiveness and economic development by advancing radical eco-innovations and creating new markets (see EIO, 2013b). Policymakers need to determine, in conjunction with different stakeholders and taking into account specific national contexts, the combinations of technologies and other factors that need to be prioritized.

The massive changes required will invariably create opportunities even in the technological periphery, which traditionally absorbs technology from the core only after it becomes obsolete there. Lower wage levels, for example, may facilitate a combination of manufactured products with personalized service, and thereby the shift towards markets that fulfil functions and not only deal in manufactures. It is even conceivable that formal sector manufacturers may seek to ally themselves more deeply with local informal sectors, particularly where there is a huge amount of practical experience in the use of recycled products.

This guide is not the place to discuss the diverse and very specific technological development options that exist for green manufacturing systems. Many interesting technological paths that could be pursued have already been identified. There are reference publications which have systematically listed biological designs which may be drawn on for the development of sustainable products and processes (see Nachtigall, 2005). There are many tips and practical examples that may both inform and inspire policymakers and technology experts that can, inter alia, be found in the classic "Factor X" publications (by Weizsäcker and others 2006) and which may lead to tremendous increases in resource productivity.

Determining the role of eco-innovations in SGIP

S3.2

By developing a coherent vision and a long-term commitment, governments and their agencies can achieve and boost support from society and raise confidence levels, especially among enterprises and investors. On the other hand, government inaction may lead to the inefficient growth of traditional sectors at the expense of new and promising initiatives. Path dependencies often lead to countries neglecting forward-looking visions. In order to develop and implement green industrial strategies, governments will have to (re)assume a leading role in (re)directing green innovations and the required technological changes (see Mazzucato, 2013).

The following table (T8) outlines the results of a panel-based study into the future of eco-innovation markets by 2030, from a European perspective. This also includes analysis of the roles and potentials of different stakeholders (government, buyers/consumers, producers, technology developers), outlining the vast opportunities which may arise with a shift to a green economy. It should be stressed that these opportunities are not limited to European economies. They concern all other countries in the world, even if the specifics may vary between them. Policymakers need to assess which specific factors are driving eco-innovations in their countries in order to determine the best methods for fostering their development for the benefit of greening industry.

T8 Approaches to eco-innovation as a basis for developing appropriate policy instruments

Approach	Policy driven	Demand driven	Supply driven	Technology driven
Main characteristics	Strives to achieve resource efficiency targets by distributing information and supporting eco-innovation with integrated policy measures	Final consumers and investors demand evidence on compliance with eco-innovative practice; recyclability or reusability of final products is also important	Transformation of production processes and logic of operations towards eco-innovative; eco-innovativeness not necessarily visible to the final consumer	Technological breakthroughs open up new possibilities for various types of eco-innovations
	Focus on life cycle changes and systemic changes in infrastructures (creating new markets); cross-sectorial cooperation between government and other stakeholders	Focus on eco-innovativeness of products including services	Focus on production methods and new product development that supports new logic (including product-service systems)	Perspective changes in the in scientific community and technological development towards more holistic approaches; open source type innovations important; implementation by businesses
	Part of a trend to implement systemic innovations in all areas of society	Attention given to life cycle sustainability of products and services	Attention given to life cycle sustainability of products and production processes	
Associated social values	Trust in governmental and supra-governmental guidance	Sustainability	Free markets and market-based solutions	Science and technology optimism
Key actors or stakeholders driving change	Governmental bodies, local administration, supranational bodies	Public sector (green procurement), NGOs, media, consumers	Businesses, mainly manufacturers of environmental technology and in material-intensive areas	Universities and research institutions; ICT, biotechnology, and nanotechnology businesses
Role of technologies	Key innovations are not technological in nature; eco-innovations combine technological knowledge with values; of crucial importance for "disrupting" existing technological lock-in and a change of paths	Important for feasibility and viability	Crucial	Crucial
Major type of innovation	Institutional, organizational, systemic	Social, service	Technological, product, business model	Technological, product

Approach	Policy driven	Demand driven	Supply driven	Technology driven
Challenges	Organizational resistance to change; lack of cooperation between agencies	Many businesses are slow to react to changes in values held by consumers	Financial benefits more difficult to detect than costs	(Shortfalls in) funding
	Vested interests; populism			Silo-thinking obstructs interdisciplinary approaches
Important factors for implementing and/or accelerating change	Changes in legislation, institutions, and physical and administrative infrastructures	Changes in buyer/consumer values towards sustainability	Partnerships between businesses benefit from use of a common resource	Investments in interdisciplinary research
	Taxation according to the use of material inputs (with respective tax revenues invested in supporting eco-innovation)	Better mechanisms for buyers/consumers to access information on the sustainability of products and services	Strong monitoring and information systems that increase efficiency of eco-innovation in manufacturing	Increased collection and use of data and information on all stages of product and service value chains
	Eco-innovation policies (e.g. by closer integration of industrial, technology, resource management, and environmental policies)	Better consumer response systems (allowing consumers to reveal their opinion on products and services in real time)	New business models that take into account resource efficiency, sustainability, and long-term profits	Further development of environmental technologies
	Open and flexible structures for information flows; international cooperation and technology transfer		Open and flexible structures for information flows	Open and flexible structures for information flows
	Pilot projects			Pilot projects (promoting benefits of new technologies)
	Generally accepted and implemented accounting framework for well-being and sustainability (replacing GDP)			System detecting life cycle material impacts of production processes and consumption patterns
	Identifying and dismantling lock-ins that obstruct eco-innovations			Development and promotion of ubiquitous technologies
	Changes in the formal structures of institutions			Development of biotechnology and nanotechnology
Subsectors or businesses most affected	Urban planning, ICT, waste management, subsectors with strong public ownership and/or control (e.g. natural monopolies)	All subsectors or businesses with direct final consumer interface and all virtual services and products (trade, logistics, ICT)	All material and energy intensive subsectors (i.e. mining, construction, forestry, agriculture, waste management) and energy production; strong indirect impact on equipment manufacturing	Biotechnology, energy production, technology, transportation, construction, ICT

Approach	Policy driven	Demand driven	Supply driven	Technology driven
Important drivers	Silo thinking considered ineffective and costly; systemic thinking increasingly becomes the guiding principle in governance	Values favouring sustainability (reinforced by increasing degradation of ecosystems)	Scarcity of materials and energy	Increased funding for interdisciplinary research that combines many different fields (e.g. ICT, machinery, chemistry, biology, social sciences)
	Political will to address sustainability challenges jointly with other policy measures (e.g. job creation, well-being)	Increasing demand for de-materialized goods (virtual goods, services, etc.)	Revenues expected from increased resource efficiency	Increased technology convergence encouraging systemic thinking and eco-innovation
	Inability of the market process to provide sustainable solutions (market failures)	Health aspects of human impact on ecosystems (consumer concern)	Eco-innovations also improve efficiency in the short term	
			Increased technology convergence encouraging systemic thinking	
Examples of eco-innovations	Eco-cities	Eco-innovative services and lifestyle eco-innovations	Processes/products solving problems they cause (e.g. mining with clean water and energy as by-products; water treatment plants producing fertilizer)	Products minimizing inputs required for production and delivery (e.g. 3D-printing)
	Promotion of tele-work	Virtual products and services	Renewable local energy solutions for large buildings (e.g. geothermal energy in warehouses)	Production, distribution and storage solutions for different renewable energies (e.g. smart energy grids)
	Virtual (electronic) governance	Collaborative consumption	Eeco-innovative business parks/industrial symbiosis	Sensors
	More efficient waste management systems (based on the cradle-to-cradle principle)	Transportation sharing schemes	Industrial value chain management	New and more environmentally compatible materials (e.g. replacing metals)
		Urban farming		IT solutions for eco-innovative procedures
				New materials with better ecological qualities (e.g. self-cleaning fabrics)

Based on Eco-Innovation Observatory (EIO) (2011), pp. 35-40, Table 3. Slightly modified. Eco-innovations are defined as "... the introduction of any new or significantly improved product (good or service), process, organizational changes or marketing solutions that reduce the use of natural resources (including materials, energy, water and land) and decrease the release of harmful substances across the life-cycle" (EIO, 2012).

The following table elaborates on the policy intervention tools/measures on page 51 of the Practitioner's Guide.

Measure/instruments

T9

Tax exemptions, FDI, Free or export processing zones Skills support	Many countries encourage FDI, expecting that there may be spillovers that contribute to industrial growth and/or industrialization. This may include a diffusion of skills in the labour force, of management practices in business, or through the subcontracting of local producers. Increased openness to FDI can positively affect the availability of technology, finance and skills. FDI can be encouraged through a variety of measures, ranging from tax exemptions to creating special infrastructures. The costs and benefits for a country encouraging FDI need to be calculated for each investment. This calculation must include environmental externalities if, and where they arise. In many cases, foreign investors will introduce new technologies that should be cleaner than the average used in the host country. However, in order to ensure that FDI is green, it is important to make this an explicit precondition for the granting of any FDI benefits, and to monitor whether there is actual compliance.
Export promotion policies	Green export promotion policies will encourage greening if there is a reciprocal demand for green products in target markets. These markets are usually located in high-income countries where consumers or producers have developed a stronger interest in green products and green supply chains. Measures to enter markets where green products are in demand may lead to the transfer of knowledge and know-how along the supply chain. The benefits will be manifold: improving export capabilities; increasing eco-efficiency; and reducing pollution, material flow, water consumption and emissions. Incentives for export may also affect product markets more generally, as exporting often requires producers to manufacture more competitive goods, and use more advanced production techniques and technologies than those used in production for the domestic market.
Taxes	Taxes can be used to stimulate and to discourage the behaviour of industrial enterprises. Taxes are relatively easy to administer with regard to manufacturing enterprises in most countries. They can be applied to different production factors (labour, capital, technology, location) and to manufacturing outputs (turnover, emissions, wastes, etc.). As taxes directly influence profit and loss accounts, they are powerful tools for incentivizing, with almost immediate effects. This is both an advantage and a risk. Over-dosage may cripple enterprises and create severe imbalances in competition (if not applied in an even manner). Care needs to be taken when taxes are used to stimulate structural changes from brown to green or to circular production, e.g. by way of tax exemptions or subsidies for developing green technology, or for green investments. It is important that these incentives remain time-bound. They should not lead to artificial economies which have no basis in the real world, in order to ensure that the industry's competitiveness is not harmed in the medium term. The infant-industry argument also holds for greening industry and developing the circular economy.
Access to working capital	Policies that aim to provide long-term finance to investors can be used to encourage green investments. This can either be by redefining the objectives for making this finance available, or by introducing cleaner production and green economy criteria for screening the applications for finance. For example, if there are credit lines available for specific industrial sectors the country is promoting, they may be greened by subjecting the investment to requirements such as ensuring that it contributes to a reduction in GHG emissions and a reduction in the use of water, etc.

Access to working capital	If a country has a policy to **encourage technological developments** by providing venture (equity) capital to high-potential investments, these policies may also be greened by explicitly refocusing on developing green technologies, or by giving preference to technologies that save energy and water, or which reduce material waste and pollution when selecting investment opportunities. If there are specific policies to **facilitate access to working capital**, as in countries that face shortages of foreign currency yet depend on critical imports, this leverage may also be used to incentivize the applicants to green their products and processes. To what extent this tool can be used for greening will depend on how constrained the enterprises are and how much working capital is being made available by the policy. **Microcredit** is usually not a tool of industrial policy because it is generally too small in terms of volume to allow for equipment purchases. If microcredit is made available in enterprise clusters where industries are located, microfinance institutions may be requested to include green screening criteria into their procedures as a means of reinforcing green industrial policy through clauses such as exclusion criteria e.g. "green requirement not met" for credit committee approval. Access to long-term finance could also be made subject to the condition that the enterprise meets specific green standards, such as ISO 14000. Policies that aim to provide long-term finance to investors can be used to encourage green investments. This can either be by redefining the objectives for making this finance available, or by introducing cleaner production and green economy criteria for screening the applications for finance. For example, if there are credit lines available for specific industrial sectors the country is promoting, they may be greened by subjecting the investment to requirements such as ensuring that it contributes to a reduction in GHG emissions and a reduction in the use of water, etc.
Land	**Zoning** Zoning is a key tool in separating potentially hazardous or disturbing activities of production from housing areas. The infrastructure provided in industrial zones should not only allow for efficient production, but also promote closed-loop and/or cleaner production, and, as a minimum, ensure proper emissions, waste and sewage treatment (environmental services for the collective abatement of pollutants). Zones are used for managing "industrial metabolism". It is important to ensure that zoning does not lead to an indirect shift of polluting activities to spaces outside of the zones: i.e. leading to a scenario where there are clean, well-managed, and successful enterprises inside the zones, with proper infrastructure under the eye of the government vs. polluting enterprises, possibly even suppliers along the same value chain, located outside the zones without proper infrastructure and monitoring. Unless the industrial activities organized in these zones involve high risks for adjacent populations (e.g. the chemical industry), they are ideally not placed in remote areas, but relatively close to urban areas. This can allow the labour force to easily commute to work and enable economic linkages to be created within the community where they are located.
Industrial clusters, cluster management	**Industrial clusters, cluster management** Industrial clusters, managed or emerging, can be important for developing circular economy patterns and green technologies. The requirements for developing circular economy patterns (industrial symbiosis) are: clearly defined input-output relations between different production processes; economic feasibility (ideally symmetrically distributed between participating firms); limited investment requirements; long-term vision; business continuity; and cluster organizational continuity. When it comes to developing green technologies, the usual benefits of agglomeration can be enhanced by cluster management. Clusters can be combined with zoning activities.

Resource pricing	Prices essentially reflect current scarcities as communicated through market mechanisms. Market prices do not necessarily reflect economic scarcities as they do not include externalities, and thus the needs of future generations are also not usually included because discount rates emphasize present values. Resource pricing policies often interfere with free market prices by subsidizing the costs of production inputs, primarily for energy and water. In some cases, the policies are ones of neglect, to the extent that they fail to set any price, which happens in the case of groundwater. Below market prices for these production inputs encourage their excessive use by manufacturing enterprises. Regulating prices is not an easy task, and needs to be kept to a level where the benefits of the market mechanism for efficiently allocating resources, do not disappear. After all, the resource efficiency obtained from optimum market allocation cannot be discarded. At the same time, the market mechanism can be destructive when it concerns inputs limited by nature's reproductive processes (e.g. overfishing, deforestation, the tragedy of the commons) or determined physical limits (water, planetary boundaries and GHG emissions). In some locations the pricing of specific goods, e.g. water or bread, is strongly influenced by tradition and culture. In these cases, it will be important to secure, as a first step, a consensus that there is a difference between the industrial use of resources (by enterprises) and consumptive use (by households).Therefore, the first task for resource pricing is to ensure that all externalities are reflected and that key resources remain available for future generations. This is likely to affect the profit and loss account of industrial enterprises that hitherto have not been subject to such policies. For example, if an industrial establishment draws its water from wells based on its own premises, it may become necessary to impose charges for the use of this resource so that externalities and the interest of future generations are properly reflected. In such a context, it will be important to accompany price changes with technological and managerial support measures that allow the enterprise to save water (closed loops), and not exclusively rely on drawing from the well. In this regard, cooperation with the water sector is recommended. A similar approach would apply to the pricing of energy inputs from sources that increase GHG emissions or which are non-renewable. In this case, it would be possible to establish different prices for energy from various sources, or allow for the remunerated feed-in of excess electricity generated from renewables by industrial enterprises (or even households) into local power grids. Cooperation with the energy sector is recommended, although not required. In general, higher resource prices that reflect full production costs and (if applicable) pollution damage, provide an incentive for adopting environmentally sound technologies, particularly cleaner technologies. They motivate plant managers to reduce total expenditure on resource inputs by using cleaner technologies that lower water and energy use per unit of output. For industries where other resource prices are an issue (e.g. fish processing, furniture), cooperation with other sectors (fishery, forestry) to improve and enforce regulations, will be important for reaching green solutions.
Skills	Industry requires some modification to the skills sets currently in demand. On the one hand, there are skills related to new technological developments that need to be delivered. On the other, the capability of labour to understand complete processes of production and their interrelationship with the environment, needs to be enhanced. Simple task-based training is viewed as insufficient to address issues related to greening. Moreover, skilled workforces will be an important source for generating ideas as to how to green the different manufacturing steps of the industrial processes they are involved in. Governments can help to articulate the skills that would be needed for a green economy.

Education policy	Education policy is an essential building block for an industrialized economy, and it will be the same for a green economy. Industry has a keen interest in ensuring that education policy raises awareness in relation to the importance of greening industry and the economy. This includes developing attitudes and behaviour compatible with greening, and disseminating basic knowledge and skills about the interrelationships between industry and the environment, as well as the circular economy concept. Industry stakeholders need to partner with education stakeholders to ensure that any new concepts are quickly integrated into present-day curricula.
Technology diffusion	If global targets for reducing GHG emissions and material flows are to be achieved, it will be important to speed up the diffusion of technologies and management patterns that enable a reduction in energy and material flows. Government facilitated or organized technology transfer usually needs to focus on the diffusion of the results of pre-competitive research to ensure that disincentives are not created for market-based technology developments. Governments should, however, also be aware of patents that have been registered for the specific purpose of blocking the development of rival technologies, which are not being used by the owner. Technology transfer is most important for small businesses that cannot afford the extensive investment in research and development that large enterprises can. In terms of the adoption of green technologies, it may also be important to find ways to engage with the informal crafts and industrial enterprises (some of which may employ hundreds of workers), even if they do not form part of the usual industry stakeholders.
New capital stock	New capital stock is often more resource efficient than the stock it replaces in terms of using less energy, water and raw material per unit of output. Increasing the efficiency of use of the capital stock (process optimization) often requires the use of cleaner technologies (CT). Therefore, policies that favour technological upgrading and innovation are important for greening. Innovation includes developing green(er) technologies, greener products and greener processes, and circular economy patterns. Existing incentives for innovation can be greened by setting minimum environmental standards which need to be met by the innovations.
Subsidies	Subsidies are usually administered from budget lines in favour of certain enterprises or industrial subsectors that are considered to be too important to be allowed to fail in a given political and economic setting. They may also be applied to help create new industries. Subsidies can be administered in a one-off fashion (e.g. in response to an unexpected situation) or in a regular, continuous form. They can be applied to both state-owned and private sector enterprises. Whether a specific subsidy and its level are economically or socially justified, should be ascertained on a case-by-case basis. They are usually neither warranted, nor welcome where a level playing field is the basis for achieving and maintaining industrial competitiveness. As with taxes, subsidies can be a very powerful tool and therefore should only be administered with great care. Making subsidies time-bound increases the incentive for enterprises to reach a sufficient level of competitiveness within a certain time frame. Existing subsidies may be greened by requiring beneficiaries to meet specific environmental standards. It should be noted that subsidies to firms that generate negative externalities should be phased out as they cause twofold damage to the economy. Any new subsidies should be made conditional upon meeting all environmental standards and the generation of positive environmental outcomes. Subsidies for the development of new technologies that promote the circular economy and which enhance the greening of industries should be justified on the basis of both material flow analyses and economic assessments. The infant-industry argument applies.

Further strengths and weaknesses of the various policy instruments

S3.3

Political and technical management capabilities are required for all of the above instruments, albeit to varying degrees. Corruption and clientelism-related issues pose difficulties for all of the available instruments. This is probably most pronounced in the case of subsidies, which can encourage lobbying and lead to windfall profits. The effective monitoring and enforcement of regulation can also be hampered, while voluntary instruments/ information disclosure are least affected. Some of the instruments require particularly high technical capabilities, such as cap and trade systems.

When pollution abatement is the aim of a green industrial policy, the number of polluters is crucial. When there are few polluters, regulation can be the most effective instrument because few polluters are relatively easy to monitor. On the other hand, few polluters can coordinate more easily and may be able to exert joint pressure on regulating entities. However, regulation may be the best option as markets often do not function effectively when the number of actors is too small. Information disclosure/voluntary instruments are a suitable complement, in particular, if polluters fear a loss of reputation, although on their own they may be too weak as policy instruments, e.g. for the control of hazardous substances.

When policymakers are faced with strong vested interests from industry, rent seeking is likely to become an issue. Taxes usually raise opposition from polluters, while freely allocated tradable permits tend to be their favoured option. Subsidies often trigger rent-seeking behaviour and need clear and transparent rules. Since there are few rents to be gained (or lost) from deposit-refund schemes and information/voluntary schemes, these may be suitable instruments when facing strong industry pressure.

High inflation rates complicate every policy that is based on changing the price of goods or services. These include taxes, deposit-refund schemes and subsidies. Cap and trade schemes, which regulate the amount rather than the price, remain unaffected – the price is determined by the market and will adapt to inflation. Similarly, regulation and information/voluntary instruments are unaffected.

Negative effects of policies on the poor should be avoided and hence, should be a particular focus of policymakers. Vulnerable population groups should receive compensation.

Policies that raise the consumer price of goods or services upon which the poor depend (e.g. drinking water, fuel for cooking and heating) need particular attention. If firms are not subject to strong competition, the added cost of regulation and tradable permits are often passed on to the consumer. Depending on the relative share of household income spent on the goods or services concerned, the poor may be hit harder than the rich by such price increases. It should be noted in this context that compensation for the poor is generally preferable to maintaining prices below social cost (i.e. market prices plus environmental cost/regulation cost). This is because price signals are vital for triggering deeper changes in economic structures.

Similarly, taxes can also harm the poor. However, they can often be designed to avoid negative effects (e.g. through tax allowances) or even contribute to reducing poverty, depending on the taxed good and on the use of tax revenues.

Deposit-refund schemes can provide people living in poverty with modest income opportunities, while information and voluntary tools are unlikely to have strong distributive effects.

While poverty impacts affect vulnerable households, competitiveness is of concern to industry. Small and open economies are particularly vulnerable to losses of competitiveness in industries that face direct competition from external players in their own territory and which hold little market power (are "price takers"). In this case, taxes and regulation would require international coordination as a means to help level the playing field for all market actors. Alternatively, national industries would need compensation for, or exemption from, taxes.

Nevertheless, policymakers need to carefully verify claims made by industry of loss of competitiveness due to regulation or taxation. Competitiveness cannot be sustainable if it is based on environmental degradation, this therefore obliges the government to intervene. This argument, often made in conjunction with a risk of job losses, while frequently used, is not always valid.

Furthermore, stricter regulation or taxation can send signals to national industry to prepare for increasingly strict environmental requirements in export markets. Carbon border adjustments, environmental food standards, or the labelling of environmental product footprints in export markets are examples. Information disclosure requirements can be a starting point for later regulation.

When policy packages comprise several instruments, they need to be analyzed for unintended interactions, and, if necessary, harmonized. One example is the parallel operation of a feed-in tariff for renewable energies and a cap and trade system for carbon emissions. On the one hand, it can be argued that any lowering of carbon emissions induced by a feed-in tariff would lead to the availability of additional certificates, which, once sold, would generate corresponding emissions elsewhere. On the other hand, the political decision of where exactly to fix a cap for emissions may itself be partly influenced by anticipating trends of future renewables capacity. In essence, the parallel operation of feed-in tariffs and emissions trading schemes will crowd out most of the former's emission reduction benefits – although not the other benefits it creates, such as energy diversification, or gains in competitiveness and innovation. Similar (positive or negative) interactions may occur with other policy fields, such as trade, agricultural, or research policy. Cross-impact analysis can be a useful tool to assess interactions between different instruments and different policy fields.

Policy analysis: Doing your math using simulations S3.4

This part of the Supplement builds on the work outlined in Phases Four and Five which recommended that there be a form of impact assessment undertaken to assess the impact of any policy instrument or mix of policy instruments for SGIP.

There are a number of tools and methods that could be utilized to undertake this. We shall provide an outline on simulations below as a means to anticipate the potential impacts of policy interventions under consideration.

Simulations S3.5

Though modern simulation and gaming arguably originated in the public sector, policymakers and public sector decision makers, with the exception of a few specific fields, are not easily convinced that simulation and gaming is worth its time. This is particularly so when the savings made by the simulation exercises are not as apparent as with military exercises or as easily calculated, as in the case of costly technological investments.

Big industry has often relied on simulations. This is partially due to the requirements of designing and implementing complicated processes, e.g. in the aerospace industry which, beyond this, even makes available simulation tools as flight simulators for training purposes. But even some of the earliest applied work in systems dynamics which dealt with complexity were concerned with industry dynamics, notably at the level of the firm. They showed, inter alia, how inventory systems would fluctuate not only due to external inputs, but also due to their internal dynamics (cf. Forrester, 1961).

Such simulations are typically developed on a one-off basis for a specific purpose. They involve intensive research and modelling, and then are normally used for testing what is too costly to test in real life.

So should strategic green industrial policy design wait for simulations? After all, we do not have a lot of resources in the public sector, and, often enough, we do not have enough competencies to check whether the rather costly simulation models are adequate for our situation.

B4 Why simulations are increasingly important

*"Feedback generates system dynamics. ...Even if the system structure should be simple, the response of such systems can rarely be assessed reliably even by experienced analysts. We therefore have to rely on mathematical analysis (**not always possible**) and simulation (**always possible**) to produce information about system behavior."*

Bossel 2007a, p.9. (Emphasis added.)

There are several reasons why one may wish to consider using simulations to refine understanding of impacts before completing the design of policies following a cross-impact analysis.

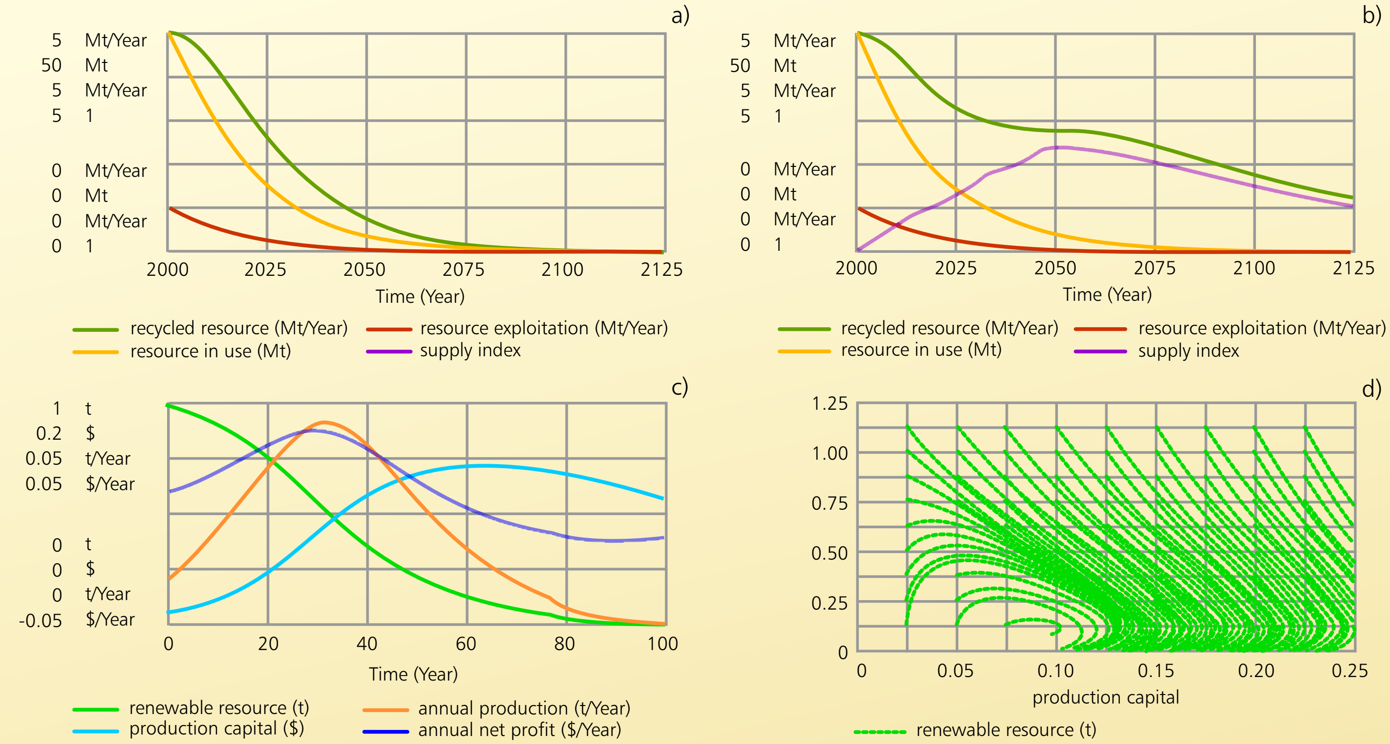
- Systems, even if their basic structures are understood from the cross-impact analysis, do occasionally lead to surprises. This is notable because they can behave differently, depending on the state the elements of the system are in. As the states of elements change, some elements may reach certain thresholds at which they change their behaviour.
- Cross-impact analysis, when implemented on paper only, is somewhat unwieldy for integrating time as a factor. As some influences of elements occur without delay and others involve delays, the behaviour of the system over time is not necessarily constant. When implementing the analysis with a computer, cross-impact analysis can also be used for simulations.
- Not all behaviour is linear and more easily modelled. Some cannot be modelled at all. Running sensitivity tests with different values helps to narrow down the options and select the "safer" or "more promising" strategies that can be pursued.
- Independent of path dependencies resulting from lock-ins, a priori there is not always a single best path that can and should be selected and pursued. Given the structure of a system, sometimes elements can be influenced in the desired way by selecting alternative paths, and working with alternative feedback loops. It is also possible to compare what happens with the system when alternative paths towards the same target are pursued.
- The envelope may be pushed by designing intervention measures (which work with and through the existing system structure) and testing them on the computer before applying them in the field. Such simulations are much cheaper than real-life experiments and quicker to implement. They also allow us to identify potentially harmful effects resulting from planned interventions.

In order to conduct simulations, it is possible to develop specific models using spreadsheets and programming, or by working with special software packages that have been developed for thinking in systems. In many cases, it may be sufficient to conduct sensitivity analysis on the elements and relationships that have emerged as contentious or critical so as to get a better feel for what is likely to occur. Some common spreadsheet programs, in the meantime, are accurate enough for statistical processes and even facilitate regression analyses.

The capacities and the prices of these systems analysis packages vary widely. It is recommended that policymakers seek to ensure that the package selected allows for running simulations. If one wishes to program something directly, the risk of errors and workloads associated with bugs should not be underestimated. Off-the-shelf software packages sold in the marketplace have usually been tested, are usually maintained (updated), and they save users significant amounts of time.

What a difference a simulation makes

B5



Simulation results from different quantitative systems analyses

(1) Resource extraction and recycling:

(a) Resource availability without recycling.

(b) Resource availability with increasing recycling.

Bossel (2007b): pp.178, 186.

(2) Tragedy of the commons:

(c) Overuse of renewable resource leading to collapse.

(d) Two possibilities of system behaviour **found by simulation**, an oscillatory approach to a low renewable resource level equilibrium point, or a complete erosion of the resource.

S4 CONCLUSION

SGIP is an emerging concept that involves a significant amount of input from a diversity of disciplines and stakeholders representing a wide spectrum of interests.

Greening will require multiple interventions to be developed and agreed upon by affected stakeholders.

The task is ambitious, but it is very necessary in the context of complex global challenges such as climate change.

Thus, we hope that the Practitioner's Guide and this Supplement have provided policymakers with a solid overview of the issues and the tools available in order to be able to develop their country's own SGIP.

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M3 CROSS IMPACT ANALYSIS

Overview of cross-impact analysis

Advantages of working with cross-impact analysis

- Embody systemic fit
- Dealing with dynamic complexity
- Complex problems need complex solutions (Law of requisite variety)
- Understand how different interconnected elements of a system influence each other
- Highly transparent
- Understanding the system's feedback loops
- Different paths to reach the same outcome (The notation of the critical path may disappear.)

Step 1

Specify or identify the purpose of the system

- System = set of factors, elements, or parts that are coherently organized and inter-connected in a pattern or structure that produces a characteristic set of behaviours.
- Systems exist at different levels and there may be sub-systems within systems.
- Purpose of the industrial system, or industrial development
- Shift to green, sustainable purposes

Step 2

Identify the elements of the system

- Specify the system's boundaries
- Sub-systems
- Examples of elements of a green industrial system
  - Minimize material diversity in multicomponent products
  - Multiple utilization of the same product
  - Recycling
  - Industrial symbiosis
  - Products and processes based on biological design
- Formulated as variables

Step 3

Ensure the cross-impact analysis refers to a viable system

- Viable systems are open to the outside world
- Viable system check

Step 4

Describe the relationships between the elements of the system

- Direction relationships
  - Direction
    - From A to B
    - From B to
  - Quality
    - Reinforcing
    - Balancing
  - Strength
    - Strong
    - Medium
    - Weak
  - Delay
    - Short
    - Medium
    - Long
  - Indirect influence between elements is a result of the direct influence exerted.
- Diagram of influences
- Matrix of influences

Step 5

Analyze the results

- Dissecting the active-passive map
- Elements
  - Active
  - Critical
  - Neutral
  - Buffer
  - Passive

SGIP

STRATEGIC GREEN INDUSTRIAL POLICY

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

The Partnership for Action on Green Economy (PAGE) is a joint programme between the United Nations Environment Programme (UNEP), International Labour Organization (ILO), the United Nations DevelopmentProgramme (UNDP), the United Nations Industrial Development Organization (UNIDO), and the United Nations Institute for Training and Research (UNITAR).

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