

# Developing targets for global resource use

## Targets for freshwater use

### Final version

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Vienna University of Economics and Business (WU)  
March 2015, Vienna

IntRESS Working Paper 2.4

Further information on the Research Project:

<http://www.intress.info>

**Project for:** German Federal Environment Agency (UBA)

**Funded by:** German Federal Ministry for the Environment, Nature Conservation  
and Nuclear Safety

**Research ID (FKZ):** 3712 93 101

**Project duration:** October 2012 to January 2016



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## Abstract

The resource water plays a crucial role for a sustainable living and survival of our societies on the planet. Although a renewable resource, the availability of water is limited. Within as well as outside the EU water withdrawal in many regions exceeds – at least temporarily – the amounts of available water resources. Furthermore, water availability fluctuates throughout the year due to climatic variations. This leads to a reduced water flow in rivers, lowering groundwater levels as well as polluted water bodies.

This working paper focuses on the development of targets for sustainable global water use. It describes the different aspects which have to be born in mind when deriving targets for water use, as they are of high relevance and specific for the resource water. These aspects cover, among others, the different types of water (blue, green, and grey), the different types of water flows (abstraction vs. consumption), and the necessary spatial, temporal and sectoral differentiation. Available data and methods can so far only partially consider these aspects. However, the more difficult the quantification of water use and consumption, the more complicated the design of specific thresholds and targets will be.

The present paper discusses existing approaches for water use targets such as the Water Exploitation Index of the European Environment Agency, the Water Stress Index or the approach taken by Rockström et al. in their study on “Planetary Boundaries” and describes the strengths and weaknesses of these approaches. Building on these insights we suggest following a multi-level-track – from the watershed to the global level and from the production perspective to the consumption perspective – incorporating all relevant aspects such as using relative targets, for direct and indirect water appropriation, as well as focussing on annual values of water consumption, but including where possible monthly analyses and information on water abstraction.

## Contents

Abbreviations	2
1 Introduction	3
Background regarding the IntRESS project	3
The importance of the resource “water”	3
2 General considerations for the development of water use targets	7
Critical flows	7
Water abstraction vs. water consumption	7
Blue vs. green water	8
Spatial, temporal and sectoral differentiation	8
Direct vs. indirect water use	9
Scale dependency of water indicators	9
Productivity & technology	9
Access to water – water as human right	10
3 Existing suggestions for thresholds	11
Rockström’s Planetary Boundaries	11
WFN’s 4-pillar-approach for wise water governance	12
EEA’s Water Exploitation Index (WEI & WEI+)	12
Water Stress Index	14
Minimum rights to water	15
Water in the post-2015 development agenda	16
4 Suggestion for a comprehensive target setting approach	17
The potential of existing approaches	17
Principles for threshold development	19
Suggesting a comprehensive and consistent approach	21
5 Conclusions	22

## Abbreviations

EEA	European Environment Agency
GHG	Greenhouse gases
NAMEA	National Accounting Matrix including Environmental Accounts
SNA	System of National Accounts
UN	United Nations
UN SEEA-W	United Nations System of Environmental-Economic Accounting for Water
UNCCD	United Nations Convention to Combat Desertification
UNICEF	United Nations International Children's Emergency Fund
WEI	Water Exploitation Index
WHO	World Health Organisation
WSI	Water Stress Index
WWAP	World Water Assessment Programme

## 1 Introduction

### Background regarding the IntRESS project

The IntRESS project initiated by the German Federal Environment Agency (UBA) and funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety develops new insights, options and recommendations for international sustainable resource use policies through engaging the scientific community and relevant stakeholders. This should further strengthen the profile of resource efficiency and sustainable resource use issues on the European and international policy agenda.

The project develops and discusses science-based suggestions for international targets on sustainable resource use and focuses on the following key questions:

- How can internationally accepted, qualitative and quantitative targets for sustainable resource in the categories raw materials, water, and land use in the year 2050 be derived?
- How can scientific insights on planetary boundaries and social and economic concerns best be taken into account in such targets?
- What types of indicators could be most suitable to measure progress towards them?

Our analysis (see also the results of work package 1 of the IntRESS project) shows that very few studies so far have been published in the scientific literature that present procedures for deriving targets for sustainable resource use.

In IntRESS working paper 2.1, „Perspectives and Assumptions for setting resource targets“ and working paper 2.2, “Towards a scientific framework for resource targets revisited”, a general framework was developed to be applied to all resource categories concerned for the derivation of resource targets in the IntRESS project, i.e. for materials, water and land. The framework builds on Rockström’s concept of “planetary boundaries” (Rockström et al., 2009) while suggesting further differentiations of the boundaries which are considered of special importance for the derivation of resource targets.

These differentiations look at geographical specificities that should be considered, at different time scales and qualitative differentiations as well as at the question whether resource targets should be formulated with regard to direct use of the resource or also with regard to a consumption (i.e. rucksack or footprint) perspective.

### The importance of the resource “water”

Increasing resource efficiency as a means to achieve an overall decoupling of resource use from economic growth and higher well-being has reached the highest levels of European as well as global economic-environmental policy agendas. For example, the European Commission’s “Roadmap to a resource-efficient Europe” (European Commission, 2011) not only calls for a

measurement of resource use and an increase in resource efficiency, but also identifies the need for target setting as a means to evaluate progress towards the overarching policy goals.

However, as mentioned before, so far only in the case of greenhouse gas emissions a clear threshold of a maximum of 2°C temperature increase per year has been identified and translated into a maximum “allowance” of GHG emissions on the country level. The other three resource categories as specified in the Roadmap, i.e. materials, land and water, so far still lack such thresholds, as research is not yet as advanced and environmental thresholds and related limits for sustainable resource use have not been identified yet. Hence, there is a significant discrepancy between demand for thresholds to be met by humanity as a whole as well as by an individual country on the one hand and the already available thresholds and related policy targets on the other hand.

The resource water plays a crucial role for a sustainable living and survival of our societies on the planet. On Earth there are about 55,000 km<sup>3</sup> of freshwater available (AQUASTAT, 2014). Annual precipitation makes up for about a third in this total (Mauser and Wiegandt, 2007). Out of the total available renewable freshwater resources the upper threshold of accessible blue water is estimated at around 12,500–15,000 km<sup>3</sup> (Earthscan, 2007). In addition, although a renewable resource, the availability of water is limited throughout the year due to changing levels of water use and climatic variations. For instance, within as well as outside the EU water withdrawal exceeds in many regions – at least temporarily – the amounts of available water resources (EEA, 2010a). This leads to a reduced water flow in rivers, lowering groundwater levels as well as polluted water bodies.

The Water Framework Directive (European Parliament and Council, 2000) emphasizes that effective water management strategies cannot be carried out only on national and administrative levels, but have to be designed for the watershed level. However, the issue of water use (as environmental issues in general), as well as the impacts of water use within a watershed, have an additional dimension which has to be born in mind when discussing thresholds for a sustainable water use: the global context and interrelations between global economic, environmental and social developments respectively.

This interrelation is of special relevance as local water scarcities are often closely linked to global supply chains and the structure and dynamics of the global economy. The production of almost all goods and services is dependent on water in one or the other way – water is needed for plant growth, irrigation, as process or cooling water, to produce energy, etc. With every product we consume we indirectly also consume the water which was required up-stream in the production process. Allan created the term “virtual water” for this type of invisible water flow from the producer to the consumer (Allan, 1993). The sum of all water required to produce the goods and services consumed by a person, a region or a country is called “water footprint” (Chapagain and Hoekstra, 2004). The water footprint receives growing attention, as the geographical locations of water withdrawal for agricultural and industrial production versus of the consumption of products produced with that water are increasingly separated.

Moreover, in many water scarce regions water is used for the production of goods foreseen for the export industries. Hence, the final consumer also holds a responsibility for water shortages and their impacts in faraway areas. It is hence as important as difficult to come up with international, even global water policy strategies, which are able to cope with these complexities.

Another important topic in the context of water use and thresholds for water use is the aspect of water quality and setting limits for water pollution. A large number of policy strategies have already been developed to tackle this qualitative aspect of water use, for example, it is the main policy priority of the European Water Framework Directive (Commission, 2000). In this report, however, we will focus on the quantitative aspects of water use thresholds and potential targets, trying to stimulate a debate in an area, which has been less in the focus compared to the issue of water pollution.

The development of resource targets, especially at a global level, is often constrained to “quantities” of resource use, expressed e.g. in tonnes, hectares or cubic meters. This focused perspective often tends to disregard existing limitations in the access to or availability of different kinds of resources to local people. Internationally recommended minimum standards for basic human, social and economic development needs are often not achieved, in particular in developing countries. Also in the discussion about the identification of targets for water use so far only the necessity to reduce water use has been taken into account. This is understandable, as in general water resources tend to be overused, with negative impacts for societies and the environment. In this context, however, it must not be forgotten that the right to water is a basic human right. Therefore, when discussing water use limits, also the access to minimum quantities of water of decent quality has to be born in mind. This is even more relevant, as with decreasing water availability, competition for water between different users increases. Hence, water used for one purpose – e.g. industrial production – is not available any longer for other uses such as supplying drinking water. Consequently, while analysing existing approaches for water use thresholds in the present report we will also investigate to what extent approaches to target setting also include minimum quantities and thus relate to the social dimension.

Given the state of the art with regard to indicators of water appropriation and, consequently, of related thresholds and targets for sustainable water use, the aim of this thematic report is to illustrate the status quo of discussions as well as to come up with a set of principles which should be followed when designing water use thresholds and related policy targets. The identification of concrete thresholds should then happen as consecutive step.

The remainder of this working paper is structured as follows. Chapter 2 presents general considerations for the development of water targets, while Chapter 3 discusses the most prominent existing approaches towards establishing sustainable water use thresholds. In chapter 4 of this paper we suggest an approach towards setting targets for sustainable water use which was discussed and further elaborated by the participants of the international expert workshop which took place on 16th of December 2014 in Berlin.

Box 1: Definition of key terms (alphabetical order)

**Blue water:** Fresh surface and groundwater - water in freshwater lakes, rivers and aquifers.

**Green water:** Precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation.

**Grey water:** Volume of freshwater required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards.

**Fossil groundwater:** Deep aquifers with a very low rate of renewal (less than 1% per year) so considered to be non-renewable or "fossil".

**Thresholds for sustainable water use:** Thresholds determine the volume of water appropriation which is ecologically sustainable, in the sense that the ecosystem's capacity to renew the resource water is not limited and the minimum amount of necessary available water resources is guaranteed.

**Targets for sustainable water use:** A target ensures that water use/consumption is below the identified threshold.

**Water abstraction:** Volume of freshwater withdrawal from surface or groundwater: in accounting terms, the amount of water abstracted from a water body for economic activities is called "water use", while the difference between abstraction and returns – often termed "consumptive use" is called "water consumption".

**Water accounting:** A systematic method of organizing and presenting information relating to the physical volumes and flows of water in the environment as well as the economic values of water through cost-benefit analysis.

**Water consumption:** Volume of freshwater used and then evaporated or incorporated into a product.

**Water appropriation:** In this report, we use this term to when subsuming water use and consumption.

**Watershed/catchment/river basin:** The area of land drained by a river and its tributaries (the term is synonymous with drainage basin).

## 2 General considerations for the development of water use targets

For the identification of thresholds for water use in general, but specifically for developing targets for sustainable water use on the global level various aspects have to be considered, which are of high relevance for the indicators in use as well as for the identified thresholds. These aspects will be discussed in the following.

Available data and methods can so far only partially consider the aspects discussed in this section. This circumstance deserves special attention as for the identification of meaningful water use targets a reliable data basis is needed. Reliable data on water appropriation are scarce and difficult to compare, because time-scales often differ, the data were collected for different levels of geographic detail, and projections of future water use differ with regard to the proxy data used (population, share of population living in cities, etc.). In this context, the following aspects are of high relevance to harmonise data and enable establishing comprehensive and consistent water accounts as well as develop solid thresholds and policy targets.

### Critical flows

With regard to critical flows, two aspects have to be observed specifically for the water case. First, the minimum water inflow, i.e. the amount of water staying in an aquifer (surface water or groundwater body) after water abstraction and its availability for other “uses”, such as the maintenance of ecosystems. In most of the cases, these minimum flows, for instance water quantities below which negative impacts can be expected, are site-specific and are determined on a local level.

Second, the hydrological system as a whole needs to be comprehensively considered from a global point of view. An exaggerated intervention in this system through an overstraining use of the available water reserves increases the risk of depleting available water resources and causes major changes in terrestrial as well as aquatic ecosystems on regional as well as continental levels (Rockström et al., 2009). Setting thresholds for maximum sustainable water use in this context therefore is challenging and approaches are currently only under development (chapter 3.1).

### Water abstraction vs. water consumption

Water appropriation for societal activities can exert pressure on the environment in two different ways: First, the act of water abstraction is an intervention into the respective ecosystem, either because required critical minimum flows (see above) are not provided or because, in order to access the water resources, buildings have to be put in place which disturb or interrupt the flow or the general functioning of a river or groundwater body. In addition to this aspect, another important measure is water consumption (or “consumptive use”) which is calculated as abstraction minus backflow to the ecosystem. Water consumption quantifies the pressure exerted onto the whole ecosystem where

the water abstraction is taking place (see also EEA's description in the context of the WEI+ in the next chapter), as the consumed amounts are no longer available for the original ecosystem. The consumed water includes evaporation, transpiration as well as water incorporated into products (Gleick and Palaniappan, 2010). The EEA estimates that of the water abstracted for agriculture, urban uses, industry and energy production 80%, 20%, 20% and 5% respectively are actually consumed and not given back to the water body it was taken from (EEA, 2009).

### Blue vs. green water

Another important aspect to consider is which type of water is used for economic activities – “blue water” from surface water or groundwater bodies or “green water” (precipitation infiltrating into soil water which is taken up by plants). Due to different reasons the latter category only recently gained importance in economic-environmental analyses. Rockström et al. (2009) explain that impacts caused by changes in green water flows can be through land degradation and desertification (changes in soil moisture generation, or green water resource) or shifts in precipitation through changes in moisture feedback (large shifts in green water flow from land-use, mainly related to deforestation). They further explain that both aspects (soil moisture availability and green water consumption) are linked to land-use change and affect the stability of the freshwater system, as the balance between vapour flows and runoff is shifted leading to river depletion.

This comprehensive approach of accounting for blue as well as green water was adopted by Eurostat in the design of its new water accounting scheme as well as by the UN in the UN System of Environmental-Economic Accounting for Water (UN SEEA-W; United Nations, 2007, 2012).

### Spatial, temporal and sectoral differentiation

Water has spatial and temporal characteristics, which are usually not addressed in standard statistical accounts and go beyond the scope of the System of National Accounts (SNA) or National Accounting Matrix including Environmental Accounts (NAMEA) which account annual water flows on the national level. However, the availability and use of water can change according to different factors such as climatic conditions, or temperature. In addition, water availability varies from watershed to watershed. Depending on the available data, water accounts can be differentiated by various geographical levels; e.g. of administrative regions, river basins or accounting catchments at sub-national level. Also the Water Framework Directive (European Parliament and Council, 2000) acknowledged the watershed as the most adequate spatial unit for designing water management strategies (see above). Hence, when elaborating global indicators and related targets, it is of utmost relevance to build these on data with highest possible geographical detail.

Finally, water requirements vary significantly between different economic sectors. On the global level, agriculture is the largest water user; however, in Europe also the electricity sector plays a key role as a water user (EEA, 2010a). Hence, it is essential to provide a sectoral disaggregation of high level of detail to ensure that water appropriation is allocated to the responsible economic

activity. The more detailed data on water appropriation for economic activities are available the better goal-oriented policies can be designed to address so-called “hot spots” of water input in the economy.

### Direct vs. indirect water use

When identifying thresholds for global water use a link of water use per economic sector and watershed or country via international trade relations is needed. By that means, not only direct (localised) water use but also indirect uses via products, which have been produced elsewhere using the water resources at the production site and then exported to the final consumer country, can be accounted for.

This consumption perspective (in contrast to the production point of view) is essential, if the final consumer’s responsibility for impacts of water use shall be taken into consideration and transnational solutions for water management be elaborated.

As a recent study on water embodied in European consumption (Lutter et al., 2014) has illustrated, the EU-27 is a significant net-importer of embodied water. Of the total EU-27 blue water consumption of almost 380 billion m<sup>3</sup> in 2007, 50% (or 189 billion m<sup>3</sup>) were imported from other world regions as water embodied in internationally traded products. Major source regions of embodied water consumed in the EU-27 are Asia and Latin America.

### Scale dependency of water indicators

Another relevant aspect with regard to water availability, water use and related indicators is the scale dependency of indicators. Even within one watershed, availabilities and quantities of use might differ considerably between different sections of a river, as the example of the Nile illustrates, where in the Upper Nile, water availability is high, versus in the densely populated Lower Nile areas, water availability faces significantly higher demand. Hence, indicators in use and related thresholds have to be tested for their scale dependence and thresholds possibly defined for different geographical levels.

### Productivity & technology

Hoekstra (2011) argues that due to various reasons the development of a global threshold for water use is difficult. On the one hand, only a share of the total amount of precipitation reaching the ground surface is economically usable, as it falls irregularly with regard to time and space. Hence, there will always be places where rain flows into the sea without any human use. Only 30% of the rain is economically usable; however, it is not yet scientifically clarified which part of this share has to remain within the environmental system to allow sustaining all ecosystems functions and services.

On the other hand, a threshold for sustainable water use heavily depends on the available technology: productivity of water use can be determined either on the basis of available technology (which also differs geographically) or of potentially applicable technology – in both cases the applied technology would result in different amounts of water needed for economic activities.

In this context also water recycling or reuse comes into play. The more water used in production processes can be substituted by reused water, the less

freshwater sources have to be abstracted from renewable or non-renewable sources, reducing the pressure put on the environment.

### Access to water – water as human right

There are a number of factors influencing the access to and availability of water for the subsistence of local people. For example, the distance to the water source plays an essential role. The longer the distance to the next water source the lower the probability that the basic needs for water are met. In 2000, “halving the proportion of the population without sustainable access to safe drinking water and basic sanitation” until 2015 was defined as one sub-target of the Millennium Development Goal No. 7, which refers to “ensuring environmental sustainability”<sup>1</sup>. However, in 2010 about 884 million people were estimated to lack access to safe drinking water and about 2.6 billion people did not have access to improved sanitation (WHO and UNICEF, 2010). Only in the European Region about 120 million people do not have access to safe drinking water (WWAP, 2012). UNCCD (2014) forecasts the same number of people living in areas with periodic water scarcity and about 200 millions of environmental refugees by 2050.

Since September 2010 the human right to safe and clean drinking water and sanitation with the adoption of resolution A HRC/24/L.31 by the UN Human Rights Council is legally binding. The UN General Assembly recognized this fundamental right (A RES/64/292) already in July 2010.

Environmental thresholds and targets for sustainable resource use have so far only been discussed in the context of the overexploitation of natural resources. When discussing such thresholds it has to be born in mind that the minimum rights to sustain livelihoods must not be constraint by any means.

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<sup>1</sup> <http://www.un.org/millenniumgoals/environ.shtml>

## 3 Existing suggestions for thresholds

### Rockström's Planetary Boundaries

The category freshwater use is one of nine categories discussed in Rockström's et al. "Planetary Boundaries" (Rockström et al., 2009; Steffen et al., 2015). The authors argue that when discussing thresholds for water the aim has to be (1) the provision of sufficient green water to ensure sufficient moisture feedback for the production of precipitation, (2) that terrestrial ecosystem functions are enabled (e.g. carbon sequestration, food production, biodiversity, etc.) and (3) to ensure the availability of blue water for aquatic ecosystems.

Rockström et al. suggest focusing on blue water consumption when discussing benchmarks for global freshwater use and quantify the maximum level of human blue water consumption at ~4,000 km<sup>3</sup> per year. According to the authors, the risk of depleting blue and green water resources and causing major changes in terrestrial and aquatic ecosystems on regional and continental level is increased substantially when water use is beyond this level.

The authors determine this maximum value building on estimates of deFraiture et al. (2001) quantifying the utilisable blue water resource at 12,500-15,000 km<sup>3</sup> per year and assessing that physical water scarcity is reached when consumption of water exceeds 60% of the utilisable resource. Hence Rockström et al. deduce that water consumption of ~6,000 km<sup>3</sup> per year are a threshold above which physical water scarcity is reached on the global level. They further derive that 4,000-6,000 km<sup>3</sup> per year of blue water consumption constitutes a threshold that should not be passed and suggest to set a boundary at the lower proposed uncertainty range, i.e., at 4,000 km<sup>3</sup> per year.<sup>2</sup>

The authors specify that, while the current level of global blue water consumption still leaves some space for an increase (of around ~35%), it has to be stated that the global picture can differ significantly from specific local conditions. Moreover, it can be assumed that especially through an increase in demand for food and electricity also the demand for water will increase dramatically in the future (Rockström et al., 2009).

As stated earlier, for the definition of the planetary boundary with regard to water appropriation Rockström et al. (2009) refer to estimates of the upper limit of accessible blue water resources e.g. by deFraiture et al. (2001) as well as of the overall amount of annual water use. For the latter, deFraiture et al. use the PODIUM model (IWMI, 2000) to estimate these amounts. The model is based on assumptions about daily per-capita calorie intake and the composition of diets as well as food production based on expected yields and cultivated area under both irrigated and rain-fed conditions. The model further converts the projected national food production into equivalent water demand making allowances for water use efficiency and recycling. Finally, domestic and

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<sup>2</sup> In general, the terminology in Rockström's study is not 100% coherent, as consumptive use and withdrawal is mixed.

industrial water use is based on income and income growth projections of sectors and nations.

The identified boundary is communicated rather as an expert judgment than following a specific line of argumentation. In the original text the authors refer to the supplementary information – where limited information can be found. Also, the planetary boundary approach focuses on earth systems functioning. Hence, an important question is the scale of threshold applicability, i.e. ideally identified thresholds are applicable on different levels and link to the global level equally as to the regional or watershed level.

### WFN's 4-pillar-approach for wise water governance

In their paper in Science, Hoekstra and Wiedmann (2014) identify four pillars for wise global resource management. The four key areas of management are identified as (1) sustainability with regard to staying below sustainable thresholds, (2) reducing resource efficiency as a crucial means for reducing resource throughput, (3) considering fair sharing of limited natural resources, and (4) considering security issues by limiting national dependency on resources the supply of which is difficult to control or influence.

The Water Footprint Network (WFN) translated these four pillars into requirements for wise water governance and specific measures (Hogeboom and Hoekstra, 2014): (1) Sustainability of water use should be ensured by identifying usage caps for different countries (or watersheds). (2) Increasing efficiency in water use could be achieved by determining efficiency benchmarks which to thrive for. (3) Equity issues should be dealt with via establishing minimum subsistence water consumption levels. And (4) security could be increased by declaring certain self-sufficiency levels which would ensure that a specific share of the national water demand is covered by domestic sources.

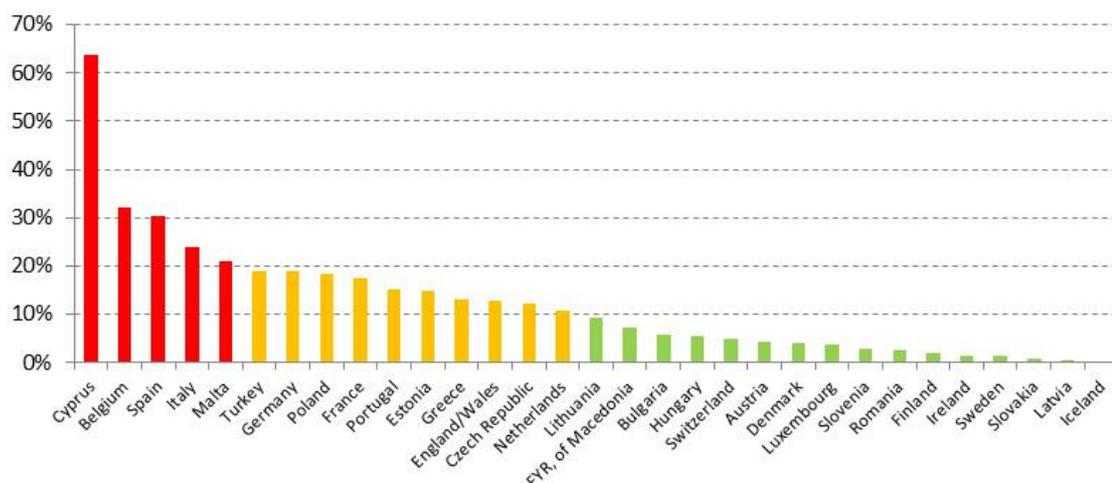
### EEA's Water Exploitation Index (WEI & WEI+)

Since many years the European Environment Agency (EEA) publishes the so-called Water Exploitation Index (WEI). This index analyses to what extent European countries find themselves in situations of water abundance or scarcity. The WEI is calculated as the annual total water abstraction (= blue water use) as a percentage of available long-term freshwater resources. Hence the WEI indicates to what extent in the single countries the current level of water use exerts pressure on the available water resources.

The EEA applies the following thresholds to evaluate water stress: values below 10% show no stress, 10-20% signifies low stress, and 20-40% indicates heavily stressed countries. These thresholds have to be understood as average values. Hence, countries with a WEI of >20% are likely to face heavy water stress in periods of low water levels – although specific watersheds might not be affected. The thresholds build on two different original sources: a report by Alcamo et al. (Alcamo et al., 2000) and a report from the United Nations (Nations, 1997).

The following Figure 1 provides an overview over the WEI of European countries based on the latest available data for the WEI from the EEA (EEA, 2010b).

Figure 1: Water Exploitation Index (WEI) of European countries



Source: based on EEA (2010b)

Figure 1 illustrates that five European countries are already today in the area of significant water stress: Cyprus (with a WEI of 64%), followed by Belgium, Spain, Italy and Malta. 10 other countries show WEI levels of low stress. In 16 other investigated European countries, WEI values are below 10%, indicating that no water stress can be observed on the national level.

In recent years the WEI has been revised and extended by the Expert Group on Water Scarcity & Droughts to the so-called WEI+, which aims at better capturing the balance between renewable water resources and water consumption, in order to assess the prevailing water stress conditions in a river basin. Using data on water consumption instead of water use, the proposed WEI+ incorporates returns from water uses and effective management, tackling as well issues of temporal and spatial scaling. While the spatial scale is suggested to be the watershed level, it is recognized that the monthly index level best represents seasonal shortages that may not be revealed in the annual scale (Faergemann, 2012). Hence, the WEI+ responds better to the requirements of the Water Framework Directive which calls for the watershed and monthly level for setting up monitoring and management measures (European Parliament and Council, 2000).

While the WEI+ has the potential of improving the analysis of water stress and is currently tested on the watershed level, the expert group was planning to validate the data from the Eurostat water accounts project as well as the results of comparing the data with the current WEI thresholds with a view to updating them for use of the WEI+ (Faergemann, 2012). So far, no information has been published on the current status of development – neither of the WEI+ itself nor of related thresholds.

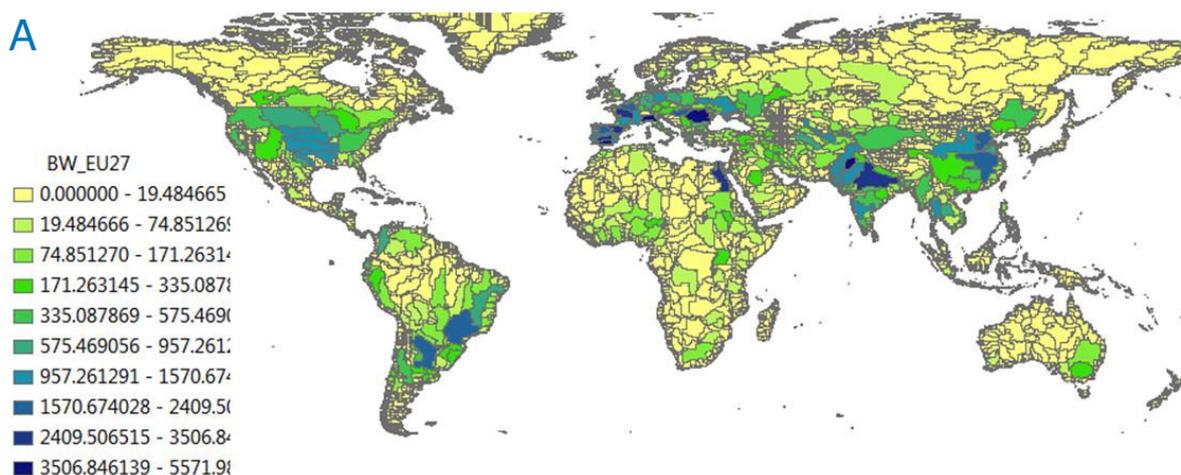
## Water Stress Index

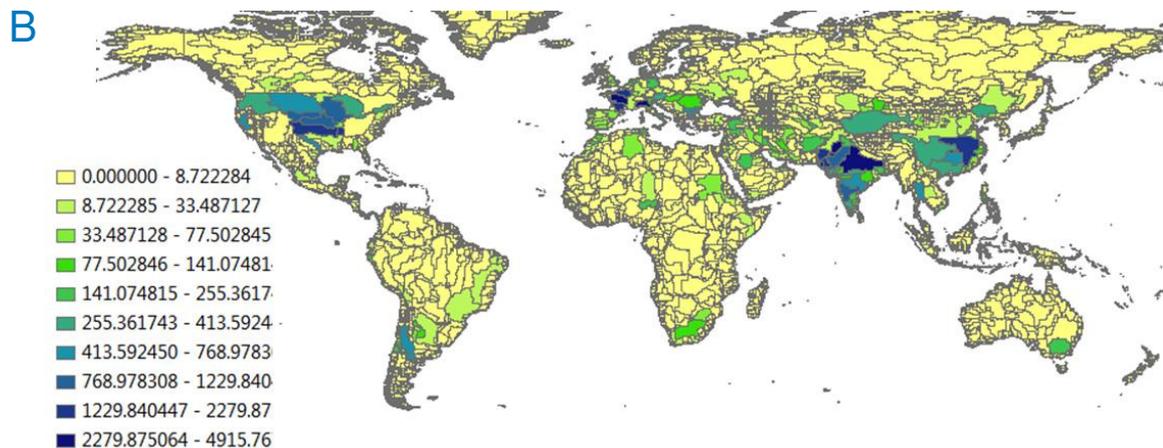
Also the Water Stress Index (WSI) as developed by Pfister et al. (2009) is based on the definition of water stress as the ratio of total annual freshwater withdrawals to hydrological availability and applies the same thresholds as defined for the WEI, with moderate and severe water stress occurring above a threshold of 20% and 40%, respectively.

However, the WSI advances this concept to calculate a water stress index (WSI), ranging from 0 to 1. A WSI of 0.5 equals a ratio between withdrawal and available resources of 0.4 (40%). In the analysis of the WSI the authors take a step further and “translate” the information on water scarcity (expressed by the WSI) into damage assessment according to the framework of the Eco-indicator-99 assessment methodology (Goedkoop and Spriensma, 2001), identifying three areas of protection: human health, ecosystem quality, and available water resources (Pfister et al., 2009).

The following figure, taken from a recently published report on EU-27 water consumption and its global impacts (Lutter et al., 2014), has two components. In the upper part (A) the blue water consumption of the EU-27 is traced back to the origin of water abstraction in all watersheds worldwide, with darker colours indicating a higher level of abstraction than lighter colours. The lower part of the figure (B) multiplies the levels of water abstraction induced by European consumption with the water stress index calculated for each watershed to come up with an indicator of water stress for each watershed.

Figure 2: (A) Distribution of blue water consumption and (B) the water stress induced by EU27 consumption, by watershed





Source: Lutter et al. (2014)

Part A of the figure illustrates that consumption in the EU-27 directly and indirectly (via international trade) induces abstraction of water in watersheds all around the globe. Major areas of blue water abstraction outside the EU-27 are some watersheds in Asia, in particular in Northern India and Eastern China, in Latin America, in particular Southern Brazil and Northern Argentina as well as the Mid-West areas in the US.

After the multiplication with the water stress index, some regions keep their high importance (Northern India, Eastern China), while others even gain in importance (US regions), indicating that in these watersheds EU consumption significantly contributes to increasing water stress. In water-rich regions, such as Latin America, high levels of blue water abstraction do not translate into water stress to a significant extent.

Thresholds with focus on access to water

### Minimum rights to water

The daily per capita requirement of water for basic domestic consumptive purposes was quantified by the WHO and UNICEF with 20 litres per day (WHO and UNICEF, 2010). In 2003, UN World Water Assessment Programme defined 4.7 litres per capita per day as the requirement of drinking water for an active and healthy life (WWAP, 2003). In parallel, in the UN Millennium Development Goals target 7.C aims at halving, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation which was achieved already in 2010; however, according to the UN, in 2011, 768 million people still remained without access to an improved source of drinking water.

### Water in the post-2015 development agenda

In its final Report on the Post-2015 Development Agenda the UN High-Level Panel of Eminent Persons concluded that “the agreed vision and recommended priorities for the shape of the post-2015 development agenda cannot be communicated effectively without offering an example of how goals might be framed” (UN High Level Panel, 2013). The suggested Goal No. 6 is called “Achieve Universal Access to Water and Sanitation” and is divided into four sub-goals: (a) Provide universal access to safe drinking water [...], (b) End open defecation and ensure universal access to sanitation at school and work [...], (c) Bring freshwater withdrawals in line with supply and increase water efficiency in agriculture by x%, industry by y% and urban areas by z%, and (d) Recycle or treat all municipal and industrial wastewater prior to discharge.

There is hence a strong focus not only on minimum access to water but also on water efficiency and the wise use of available water resources. The designed thresholds for sustainable water use should therefore be in line with this goal, in order to ensure the maximum use of synergies.

## 4 Suggestion for a comprehensive target setting approach

### The potential of existing approaches

The development of comprehensive indicators to measure water use by human beings is ranking high on the policy agenda – in Europe in the context of the strategy of scarcity and droughts (European Commission, 2012b) and the Blueprint to Safeguard Europe's Water Resources (European Commission, 2012a) as well as globally (United Nations, 2012). The elaboration of thresholds and derived targets in the course of the IntRESS project builds on these ongoing initiatives and aims at harmonising them into one consistent and comprehensive suggestion.

In the context of defining thresholds for sustainable water use, it is essential to ensure that system boundaries are correctly set and to clearly define, which aspects actually shall be measured. Therefore, a common understanding and terminology of the conceptual framework is needed. The UN System of Environmental and Economic Accounts / SEEA (United Nations, 2012) was proposed by experts participating in the IntRESS water workshop to serve as a conceptual framework for the IntRESS work on water targets. However, during the expert workshop it was also critically remarked that SEEA would put too little emphasis on the issue of water stocks.

It was further recommended that (a) the focus should be set on questions and target approaches that can be addressed with existing knowledge, as some data are just not available yet; and (b) that thresholds should be designed in a way that the consequences of surpassing a thresholds are emphasized. Hence, it is crucial to specify which type of future is desirable, in order to avoid negative consequences.

In the following we analyse to what extent different approaches could be aligned and how such a consistent and integrated approach for deriving targets should be designed.

As stated earlier, for the definition of the planetary boundary with regard to water use Rockström et al. (2009) refer to estimates of the upper limit of accessible blue water resources e.g. by deFraiture et al. (2001) as well as of the overall amount of annual water use. However, this boundary is communicated rather as an expert judgment than following a specific line of argumentation, which would allow for pinpointing the specific consequences of surpassing the threshold. Further, Rockström's boundary is formulated for the global level. However, as explained earlier, in the context of water use and consumption it is essential to establish water management strategies – including thresholds and derived targets for water use and consumption – for the watershed level. The simplest approach would be to use the ratio between Rockström's boundary volume and the assumed available accessible water resources, which is ~30% (4,000/12,500), equally for each specific watershed world-wide. Data on available accessible water resources on the watershed level are available or

can be estimated with the help of models (e.g. Alcamo et al., 2003). This would provide a first indication of a target to reach for.

The WEI/WEI+ and the WSI apply a slightly different approach, however with a similar objective. For these indicators a threshold has been developed which defines different levels of water stress (see above). The threshold for water stress is defined at 20%, for severe water stress at 40% of water withdrawals (or consumption) in comparison with the available water resources. However, the further developed WEI+ focuses on water consumption only (withdrawals minus returns). Hence, while the amount of available resources remains the same, it accounts for significantly lower amounts of water appropriated by society. As a consequence, the shares are expected to decrease. Still, this approach focuses on water abstractions from surface or groundwater resources (blue water), but does not include water consumption by plants through evapotranspiration (green water). Evapotranspiration (and precipitation) are, however, included in the quantification of available water resources. In conclusion, while the 40% (and 20% respectively) threshold(s) seem to be a reasonable basis, it appears that there are still scientifically sound conventions to be elaborated regarding the calculation of available resources and water use. If these parameters are being changed, the validity of the thresholds of 40% and 20% respectively might need to be adjusted. As in the case of the 30% ratio deducted from Rockström's data, also the WEI/WEI+ or WSI thresholds can be applied to whatever geographical level, i.e. the local, watershed or national level. Also in the case of WEI/WEI+ and WSI it is rather a question of data availability with regard to water availability and appropriation which limits the level of detail of the calculations.

The following table provides an overview of selected countries and theoretical targets for sustainable water use derived from Rockström's approach versus the WEI/WEI+/WSI approach.

Table 1: Selected countries, available water resources and targets according to Rockström et al. and WEI/WEI+/WSI

	Total renewable water resources (10 <sup>9</sup> m <sup>3</sup> /yr)	Rockström et al.	WEI/WEI+/WSI		Abstraction
		Share: 32%	Moderate Stress (20%)	Severe Stress (40%)	Quantity/year
Austria	78	25	16	31	na
Brazil	8233	2635	1647	3293	75 / 2010
China	2840	909	568	1136	554 / 2005
Germany	154	49	31	62	32 / 2007
India	1911	612	382	764	761 / 2010
United States of America	3069	982	614	1228	487 / 2005

Source: (FAO, 2014)

Table 1 illustrates two important aspects with regard to the setup of (global) water targets. First, according to these first assumptions of thresholds a number of countries already is coming up or even surpassing the moderate stress level (China and Germany), others are even close to the severe stress level (India). Still, in this context it has to be born in mind that the reference level here is the national level. Hence, while some watersheds could face severe water stress, others could be perfectly fine.

The second aspect is the data availability issue. As can be seen availability especially of data on abstractions varies with regard to the year among countries. And Austria does not at all report water withdrawal data. These circumstances have to be taken into consideration when discussing thresholds of sustainable water use (see the next sub-chapter for more information on data issues).

Also for the 4-pillar approach by Hoekstra and Wiedmann (2014) and the elaboration by the WFN (Hogeboom and Hoekstra, 2014) specific suggestions exist:

- For the sustainability pillar, the WFN suggests establishing Water Footprint caps per basin, comparing the blue Water Footprint (WF) in a basin with the blue water availability.
- With regard to the efficiency targets, the WFN proposes to define WF benchmarks per product (group), orienting the value at the best 25% of the global production.
- Fair share targets should be identified as minimum subsistence water footprints for the per-capita level.
- With regard to security targets, no specific self-sufficiency rate was identified by the WFN; however, as explained above, the aim is to reduce the dependence on foreign water resource to a specified level.

These approaches for setting thresholds seem to point into the right direction. However, it shall be noted – as also commented throughout the IntRESS expert workshop on water targets – that, while the WF is a good tool for communication, the WF method (Hoekstra et al., 2011) is perhaps not the right "common concept" to be used for the identification of thresholds.

### Principles for threshold development

Similar to other resource categories such as carbon (emissions) or material use different types of thresholds and related targets can be defined and we suggest to establish a set of targets, which is able to reflect the complexity of the issue better than only one target. In order to develop the approach for deriving sustainable levels of water use further, we suggest the following set of principles to determine best-suited targets:

- **Blue water in focus:** While it is recognised that both types of water flows – blue and green water – are important to be accounted for, when identifying thresholds for sustainable water use, it is more appropriate to focus the specification of targets on blue water. The management of blue water is more tangible and easier to implement, as was also discussed in the course of the IntRESS expert workshop.
- **Watershed level:** Unlike other resource types (such as materials or land) the most relevant management level for water is not the country but the watershed level. Thresholds should be defined for this level (or ideally be adaptable for all watersheds following the same logic). Ideally, identified thresholds are specified even for the sub-watershed level.

- **Annual targets:** Water availability as well as pressures exerted by water use differ throughout the year. As a consequence, data on water appropriation should be collected and accounted on a monthly basis. However, regarding data availability as well as practicability of monitoring it is most appropriate to define targets for one specific year.
- **Relative values:** More than in the case of materials or carbon (but similar to land), and due to its renewability, the criticality of water use depends on the ratio between water appropriation and availability. We hence suggest establishing thresholds for this ratio instead of absolute values of water consumption. However, focus has to be set to ensure their universal applicability on different geographical levels.
- **Water consumption and water abstraction:** Water abstraction and consumption exert different kinds of pressures on the (aquatic) environment; water use is related to environmental flows in a specific watershed, while water consumption relates to the ecosystem as a whole. We suggest focussing on water consumption, but including water abstraction by means of a sub-threshold.
- **Direct AND indirect water:** Water scarcity and competition for available water resources are very localised phenomena. Hence, it makes sense to determine thresholds for direct water appropriation on the watershed level (see above). However, through the import of water-intensive products from abroad final consumption can have a considerable influence on local competition for water. Thresholds for indirect water appropriation, i.e. for the water footprint, could be designed for the national level and compare national water availability with a country's dependence on indirectly imported water resources.

The above described specifications can already be covered by the indicators above – provided a few adaptations in some cases. The WEI and the WEI+, if calculated for the watershed level cover the first four bullets – and, when calculated in both variations, could provide a comprehensive picture of pressures exerted on the national level. It is clear though that thresholds have to be different for abstraction and consumption (or the calculations of the available resources calculated differently respectively), as quantities of water abstraction and water consumption differ significantly from each other. In addition to that an indicator covering the indirect water consumption of a country would have to be added to make sure this impact is covered as well. A footprint-type indicator – e.g. calculated with a multi-regional input-output model (MRIO), see Lutter et al. (2014) – would cover this aspect. In addition to the availability of thresholds/targets also the practicability of using 2-3 indicators might be a limiting factor for application.

To elaborate thresholds for sustainable water use it is essential to bear in mind the functioning and system boundaries of the complete hydrological system and its interrelationships with society and, more specifically, the economy. However, while the elaboration process hopefully results in the most meaningful indicators and thresholds, the availability of data to calculate the indicators and monitor compliance of the thresholds in many cases might hinder their implementation.

Box 2 provides an overview of the main data sources on the international level, which might serve as basis for such monitoring exercises.

Box 2: Data availability linked to threshold considerations

**Aquastat (UN FAO):** Best available international data set on water abstraction in the agricultural, industrial and the domestic sector, as well as on water availability; however, often outdated. Another disadvantage is the missing detailed industry data, as well as the absence of watershed and seasonal data;

**EUROSTAT/NSI:** For assessments on smaller scales, also regional (e.g. Eurostat) or national data should be consulted. Data coverage ranges from water abstraction by sector group to specific sectors by type of water source.

**UNESCO & WHO:** set up the “Joint Monitoring Programme” with good data coverage for domestic water use, e.g. sanitation;

**GEMS:** The Global Environmental Monitoring System provides a valuable water quality database;

**IGRAC:** The International Groundwater Resources Assessment Centre provides good groundwater data;

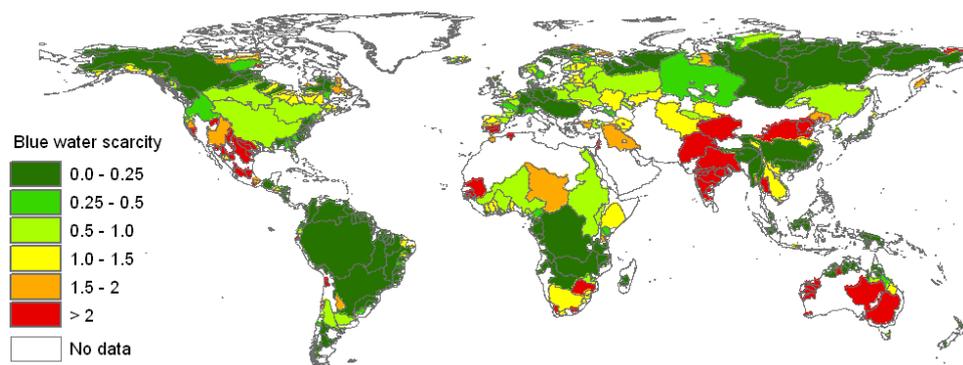
**IWA:** The International Water Association is the alliance of all national water associations and could potentially also be a valuable source.

### Suggesting a comprehensive and consistent approach

For the overall global level, in accordance with Rockström et al. as well as Alcamo, a total annual appropriation of ~10 trillion m<sup>3</sup> (20% of the total of ~55,000 km<sup>3</sup> of worldwide available renewable freshwater resources (AQUASTAT, 2014)) would mean staying on the safe side with low water stress on the global level. However, as illustrated in Figure 3, despite the fact that current global abstraction rates are still below this benchmark, in a large number of watersheds the threshold of 20% is (by far) surpassed. The regions with the most critical situations are located in Southern Asia (India, Pakistan), East Asia (some Chinese regions), in Australia, in some regions in the USA and Mexico as well as in some parts of Africa.

Conceptually, by transferring water users from watersheds facing stress to those without stress the map illustrated in Figure 3 could be transformed in a pure green colouration, meaning that no watershed is facing stress. Hence, from a production perspective, a shift from production activities in water stressed watersheds towards watersheds without stress has to be the aim.

Figure 3: Global water scarcity levels per watershed – low water scarcity (<100%), moderate water scarcity (100-150%), significant water scarcity (150-200%) and severe water scarcity (>200%)



Source: (Hoekstra et al., 2012)

From a consumption perspective, an option would be to compare – e.g. European – per-capita direct and indirect water appropriation values with the globally per capita available resources. Such a comparison would provide a first insight regarding Europe acting as a global water stressor. Still, the argument might be that a water-rich country or region is “allowed” to use above its fair global share, as long as no pressure is put on the domestic resources, neither on foreign watersheds where goods are produced which are produced in that country. Defining thresholds on the global level might hence not make too much sense. As a consequence, in a second step, the analysis could be made geographically more specific by pinpointing those watersheds where a specific region’s consumption indirectly induces water stress (see Figure 2B above).

The challenge is hence to specify thresholds on the watershed level but at the same time to include the responsibility factor. In other words, in case that in a specific watershed the threshold is surpassed an analysis would have to be carried out to see to what extent the stress produced in the watershed was induced by production for domestic or for foreign consumption. In the latter case, the final consumer country could then be obligated to provide a co-financing of local activities aimed at improving the situation or even to stop importing from the stressed areas.

## 5 Conclusions

The present paper discusses existing approaches for water use targets such as the Water Exploitation Index of the European Environment Agency, the Water Stress Index or the approach taken by Rockström et al. in their study on “Planetary Boundaries” and describes the strengths and weaknesses of these approaches. Building on these insights, we suggest following a multi-level-track – from the watershed to the global level and from the production perspective to the consumption perspective – incorporating all relevant aspects specific for the resource water: e.g. types of water appropriation, of water flows or temporal and

spatial variations. As always in the context of establishing targets for sustainable resource use, the challenge lies not only in identifying a sustainable level for the best suited indicator but also in the underlying data, as availability and quality vary significantly across countries and indicators. However, once a threshold or target is set, there is also more demand for improved data supply.

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