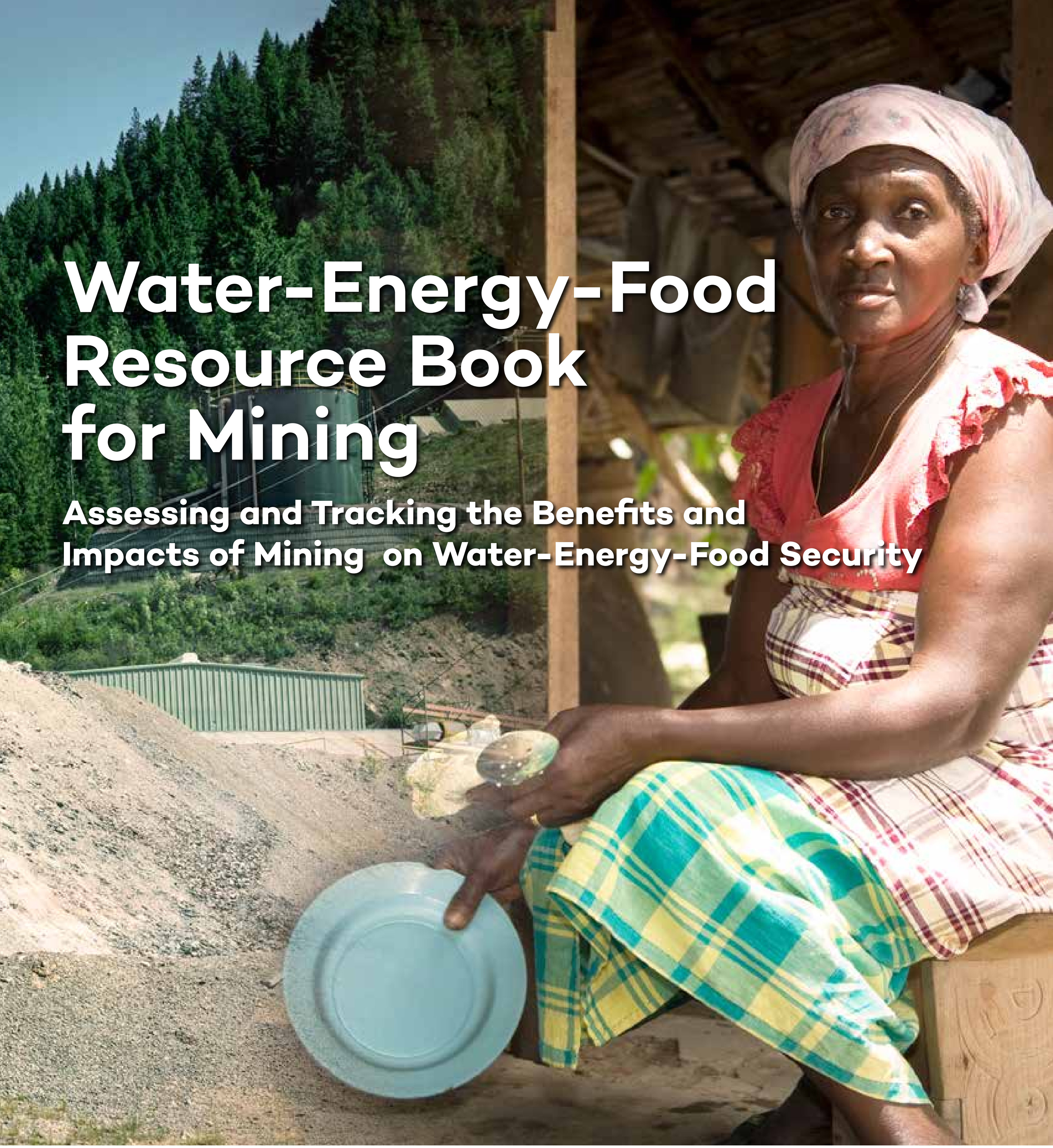

Water-Energy-Food Resource Book for Mining

Assessing and Tracking the Benefits and Impacts of Mining on Water-Energy-Food Security

IISD
International Institute for Sustainable Development

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September 2015

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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
DPSIR	Drivers-Pressures-States-Impacts-Responses
EITI	Extractive Industry Transparency Initiative
FRM	Framework for Responsible Mining
GMI	Global Mining Initiative
GRI	Global Reporting Initiative
ICMM	International Council on Mining and Metals
IGF	Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development
IRMA	Initiative for Responsible Mining Assurance
MAC	Mining Association of Canada
MCA	Minerals Council of Australia
MCEP	Mining Certification Evaluation Project
MMSD	Mining, Minerals and Sustainable Development
MPF	Mining Policy Framework
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PDAC	Prospectors and Developers Association of Canada
WEF	Water-Energy-Food
WEFsat	Water-Energy-Food security analysis tool for mining

1. INTRODUCTION

The increase in demand for minerals and metals by 2030 will drive mining developments to new frontiers in the coming decades. Demand for metals is expected to grow 250 per cent between 2005 and 2030, according to Organisation for Economic Co-operation and Development (OECD) estimates (Clay, 2004), while other forecasts predict that global ore extraction will increase 37 per cent by 2020, from 8 billion tonnes to 11 billion tonnes a year (Ellen MacArthur Foundation, 2012). Demand for mineral resources like steel, copper and aluminum is expected to increase 90 per cent, 60 per cent and 50 per cent, respectively, between 2010 and 2030 (Lee, Preston, Kooroshy, Bailey, & Lahn, 2012). However, with the exhaustion of easily accessible ore deposits, the mining industry is venturing into increasingly perilous terrain. The depletion of high-quality ores represents a particular challenge, as the exploitation of lower-grade ore deposits may entail significantly larger environmental costs. Moreover, many of the remaining reserves slated for exploration or exploitation are located in under-developed, vulnerable regions of the world—which suffer from a lack of infrastructure and where an unstable political climate often prevails, intensifying the risks of geopolitical events and local conflicts.

With the growing importance of the mining sector as the major economic driver in many countries, there is increasing interest in better understanding the contributions of mining to the overall environmental and social conditions of affected regions. The Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF), consisting of 49 member countries, has most prominently put forward a call to governments around the world to gradually implement socioeconomic and environmental safeguards, as specified within the IGF Mining Policy Framework (IGF, 2013). In particular, negative impacts on the quality and quantity of water, biodiversity and ecosystems are to be mitigated through adequate technologies and processes throughout the mining cycle, as required and enforced by governmental authorities. The socioeconomic benefits of mining can be ensured by promoting community and occupational health, optimizing local and national employment and business development.

While progress has been made in integrating sustainable development into mining contexts, there is still considerable need to better understand the impacts and benefits of mining operations on communities. Water-energy-food (WEF) security has been recently introduced as a novel concept to account for community well-being and help operationalize sustainable development in a practical and actionable manner (Hoff, 2011). The WEF security concept gained prominence amidst the food crises of 2008 and 2011, and ongoing energy and water shortages in countries around the world. It is increasingly recognized that current and intensifying resource pressures can, by way of a deterioration in water, energy and food production and consumption systems, hamper human and economic development, create social and geopolitical tensions, and cause further environmental degradation (World Economic Forum, 2011; European Report on Development, 2012).

1.1. OBJECTIVES OF THE RESOURCE BOOK

This Resource Book aims to provide a comprehensive source of information for assessing and tracking the benefits and impacts of mining on community and regional-level WEF

security. It draws on a comprehensive review of current practice and, building on IISD's 2013 water-energy-food assessment framework, introduces the new WEFsat-Mining, a Microsoft Excel-based workbook designed to guide mine operators, community organizations and policy-makers through an assessment of: (i) the current availability and accessibility of key WEF sources and their supporting infrastructure (built and natural) and supporting institutions and policies; and (ii) the potential benefits and impacts of mining operations during both full operations and closure; (iii) the actions needed to realize the potential benefits of mining and mitigate impacts; and (iv) the indicators necessary to monitor and report on progress toward WEF security.

The specific objective of this Resource Book are to:

1. Provide a thorough overview of existing frameworks and indicators for assessing and monitoring the sustainable development and WEF security impacts of mining operations as put forth in the literature and non-governmental organizations (NGOs) such as the International Council on Mining and Metals (ICMM) Sustainable Development Framework and the Intergovernmental Forum on Mining, Metals and Sustainable Development's (IGF) Mining Policy Framework (MPF);

2. Outline specific linkages between mining operations and WEF security at the community level and provide guidance on specific policies, actions and indicators to effectively monitor WEF security linkages in the mining context

3. Introduce a practical tool for assessing community–mine linkages in the context of WEF security, and in particular, for identifying actions to realize the benefits and mitigate the impacts of mining on WEF security at the community and regional levels.

1.2. USING THE RESOURCE BOOK

In this resource book you will find:

Section 1 – Introduction

Section 2 – Understanding WEF Security in the Mining Context. Presents a summary of our WEF security framework along with a suggested WEF security assessment process, and illustrative examples of the potential benefits and impacts of mining on WEF security.

Section 3 – A Review of Sustainability Indicator Frameworks for the Mining Industry. Reviews indicator frameworks on mining's contribution to sustainability issues along with the approaches currently being used for corporate reporting and country reporting.

Section 4 – A Review of Frameworks and Indicators for WEF Security. Reviews indicators for integrated WEF security and indicators for its individual components: water security, energy security and food security.

Section 5 – Introduction to WEFsat-Mining. Provides guidance on assessing WEF security status, assessing the influence of mining, and identifying actions and indicators.

Section 6 – Engagement Practices For Investing in a WEF-Secure Future. Underlines the importance of engagement practices and a structured approach to co-creating a regional investment and risk-management strategy for WEF security.

Annex A – Compilation of example WEF Security Indicators. Example indicators are organized by WEF availability, accessibility, supporting infrastructure and supporting policies.

In reading this resource book you will gain the necessary contextual and conceptual information for participating in assessments that apply WEFsat-Mining. For guidance on how to facilitate a participatory assessment using the tool, see the separate WEFsat-Mining Tool User Guidance Manual.

This resource book contains a comprehensive review of indicators for tracking WEF security in a mining context, and can be used by mine operators, community organizations and policy-makers to gain initial insight into the creation of a monitoring system for understanding the influence of mining operations on community or regional WEF security.

2. UNDERSTANDING WATER, ENERGY AND FOOD SECURITY IN THE MINING CONTEXT

Water-energy-food (WEF) security is a concept that accounts for the interlinkages between water, energy and food systems. In order to understand how mining affects these three interlinked systems, it is necessary to define the principle constituents that form the basis of WEF security. These are: (i) Availability of WEF sources; (ii) Access to WEF sources; and the existence, efficiency and effectiveness of: (iii) Supporting infrastructure; and (iv) Supporting institutions and policies. This section presents a comprehensive conceptual WEF security framework and provides a window to how mining interfaces with this framework. It concludes with two illustrative case studies centering on the high-level impacts of mining in Peru and Mali, which show both positive and negative WEF outcomes. By using this framework, policy-makers and mine operators should be better able to maximize their contribution to WEF security throughout the life cycle of mining projects.

The World Economic Forum has consistently ranked water, energy and food security issues among the top global risks facing governments and businesses around the world, along with other risks including terrorism, cyber-attacks and fiscal crises (for examples, see World Economic Forum, 2015). Making matters even more complex is the realization that water, energy and food security issues are inherently comingled, with the availability of water resources playing a central role (see Figure 1; also Hoff, 2011). In this context, the following is noted: "While water is a renewable resource, and globally there is enough water to feed a growing, and more wealthy population, demand temporarily or permanently outstrips availability in more and more regions of the world, most prominently in the bursting of regional 'water bubbles'" (Hoff, 2011, p. 16).

> "*A rapidly rising global population and growing prosperity are putting unsustainable pressures on resources. Demand for water, food and energy is expected to rise by 30-50% in the next two decades, while economic disparities incentivize short-term responses in production and consumption that undermine long-term sustainability. Shortages could cause social and political instability, geopolitical conflict and irreparable environmental damage.* ***Any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences.***"
>
> *(World Economic Forum, 2011, p. 7 emphasis added)*

2.1. A FRAMEWORK FOR UNDERSTANDING WATER, ENERGY AND FOOD SECURITY

Motivated by a need for a practical planning and decision-support process for landscape investment and risk management, IISD in 2013 developed an analysis framework for WEF security. The IISD framework was informed by a comprehensive literature review. It enables a place-based analysis of four main components: access, availability, supporting resources, and supporting policies, and each in the context of a region's water, energy and food supply (Bizikova et al., 2013).

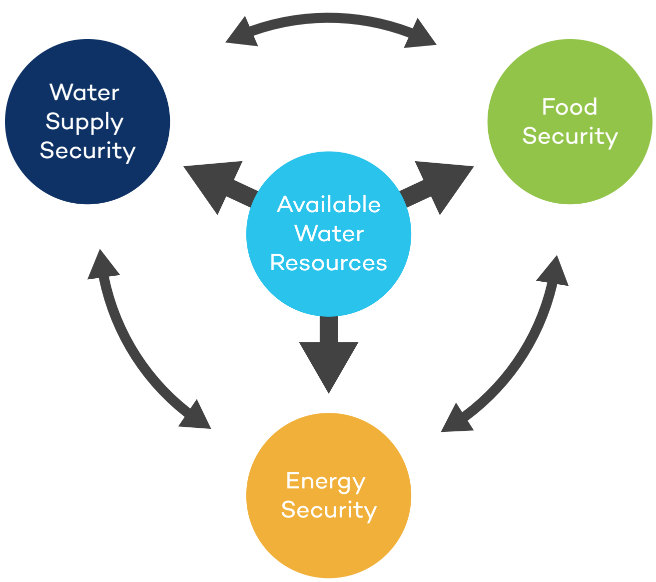


Figure 1. *Availability of Water Resources - A Central Role in the Water-Energy-Food Security Nexus. Source: Hoff (2011)*

The framework begins with an analysis of how water, energy and food are made **available** to households and communities. This requires consideration of five aspects, including: (a) sources and production (i.e., surface and groundwater, sources of energy and food production); (b) treatment of water, conversion of energy, and processing of food; (c) storage of water, energy and food supplies; (d) modes of distribution of water, energy and food supplies; and (e) markets for water, energy and food.

Central to the analysis framework is an understanding of how households (and communities of households) gain **access** to water, energy and food. Is it mostly through their own purchasing power (i.e., earned income), as is typically the case in higher-income households and countries? Or is access gained through a combination of purchasing power (income, remittances from family members in other countries, credit), aid, self-production, and barter, as is often the situation in lower-income households and countries?

It is then necessary to understand the types of **supporting infrastructure** relied on to ensure the access and availability of water, energy and food. Supporting infrastructure has two types: (a) built infrastructure, including communication, transportation and waste/sanitation systems; and (b) natural infrastructure, including the ecosystem goods and services associated with erosion control, storm protection, water purification, biological control, air quality maintenance and pollination.

The final component of the analysis framework requires identification of institutions and policies that support the natural and built infrastructure needed to ensure access and availability of water, food and energy sources in a community and region. This component is further broken down into two categories, namely: (a) supporting institutions, including utility boards, user associations and resource co-ops, education and training, safety oversight, law enforcement and security; (b) supporting policies and plans relating to resource use, climate change adaptation, disaster recovery and risk management, and R&D and innovation.

FRAMEWORK FOR ASSESSING WATER, ENERGY AND FOOD SECURITY	
SECURITY CATEGORY	**SECURITY COMPONENTS TO BE ASSESSED FOR WATER, ENERGY AND FOOD SOURCES**
Availability	**Uses** **Processing** **Storage** **Distribution** **Markets**
Access	**Purchasing Power** (livelihood income, remittances, credit) **Aid** (direct provision, safety nets, subsidies) **Self-production** (water wells, off-grid power, individual/community gardens) **Barter**
Supporting Infrastructure	**Built Infrastructure** (transportation, communication, waste removal) **Natural Infrastructure** (ecosystem services such as: erosion control, storm protection, water purification, biological control, air quality maintenance, pollination)
Supporting Institutions and Policies	**Institutions** (utility boards, user associations and resource co-ops, education and training, safety oversight, law enforcement and security) **Policies & Plans** (resource use, climate change adaptation, disaster recovery, risk management, research, development [R&D], and innovation)

Table 1. *IISD's Water-Energy-Food Security Analysis Framework.*
Source: Bizikova et al. (2013)

2.2. ASSESSING WATER, ENERGY AND FOOD SECURITY IN THE MINING CONTEXT

Population growth and economic prosperity are increasing the demand for minerals and other natural resources in unprecedented ways, posing the risk that intense pressures on the natural system could put WEF security for a nation's population at risk. At the same time, however, mining developments also present significant opportunities to improve WEF security in a community or region. IISD's WEF security analysis framework can be applied to help identify the potential benefits and impacts that a proposed or existing mining operation has on WEF security.

Figure 2 presents the engagement and assessment process that can be applied in specific mining-related contexts to highlight key issues and direct attention and investment to improve WEF security using a Microsoft Excel-based WEFsat-Mining. The first stage assesses the current status of each of the framework components for the community (or aggregation of communities) in question. The second stage in applying the framework includes identifying all of the possible benefits and impacts that each of the mining components (e.g., mine operations, ore processing, general operations) might have on each of the WEF security components. This necessitates the identification of all the individual mining components comprising the proposed or

existing mining development during operation and closure phases.

After gaining an understanding of the potential mining benefits and impacts on each of the WEF security components, the next stage of the assessment includes identifying specific actions that are necessary to help realize the potential benefits associated with mining's influence, or mitigate the potential impacts.

Two additional elements are integral to all stages of the above assessments. The first is engagement with relevant stakeholders. Addressing the assessment questions is only possible through iterative deliberation with persons who are involved in implementing mining operations and are impacted by them. Second, the ability to monitor and track changes in WEF security is critically important for ongoing adaptive management and continuous improvement in maintaining and improving WEF security. Therefore, this framework and its supporting WEFsat-Mining is designed to assist stakeholders in identifying practical indicators for measuring and tracking progress toward WEF security in relation to the availability and accessibility of key water-energy-food sources, the potential benefits and impacts of mining operations, and the specific actions necessary to leverage benefits and mitigate impacts.

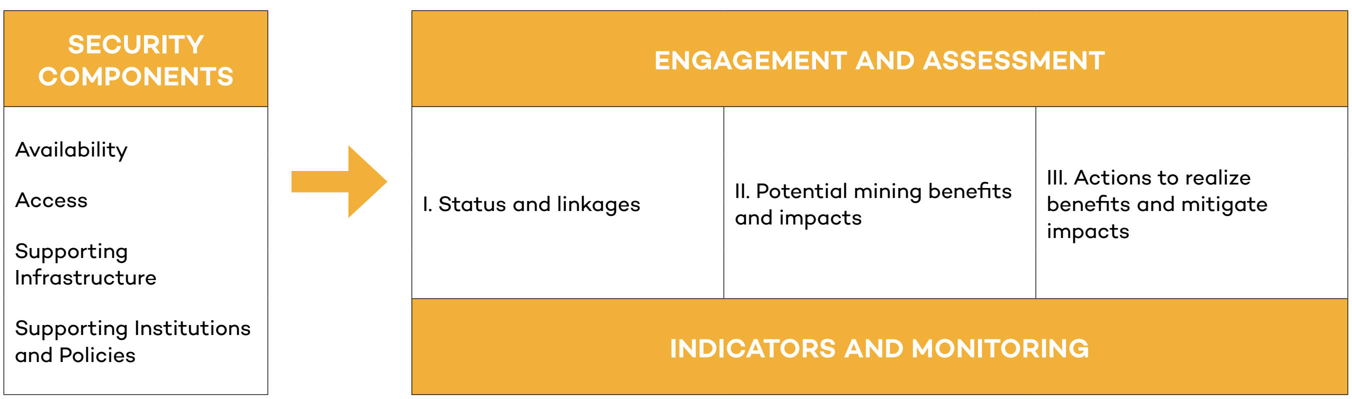


Figure 2. *IISD's WEF Security Analysis Framework Applied to the Assessment of Potential Mining Benefits and Impacts*

2.3. ILLUSTRATIVE BENEFITS AND IMPACTS OF MINING ON WATER, ENERGY AND FOOD SECURITY

Large-scale mining operations represent a significant development activity for any region, with myriad benefits and impacts on existing economic, social and environmental conditions.

During its life cycle, a mining project consists of several integrated facilities and activities. These activities are spread out across different stages of the mining project (see Table 2). The influence of mining on WEF security therefore changes across these different stages.

- **Exploration:** The purpose of the exploration phase is to find new sources of metal or useful minerals (Prospectors and Developers Association of Canada [PDAC], 2006). It consists of identifying large areas containing ore deposits that could be developed as a resource. PDAC, an association for the Canadian mineral exploration industry, has a tool called e3Plus, which aims to ensure a high level of social, environmental and health and safety performance during exploration activities. These include protecting culturally important sites, minimizing waste pollution and conserving biodiversity. The first contact with communities is made during this phase, and it is important to start off the mining project with sufficient engagement. Although it may not be necessary to undertake environmental baseline studies at this stage, many companies choose to assess cultural areas and the environment to inform their operations.

- **Development:** In the development phase, the purpose is to learn about the potential value of the deposit, and determine if it can be profitably mined all while benefiting the region as well as the company (PDAC, 2006). Many of the sustainability issues faced are similar to those in the exploration phase, except they may become more important as development progresses. Sufficient baseline studies and assessments are required in order to obtain mining permits. The company must also begin to negotiate agreements with communities. New sustainability impacts will occur in association with the construction of facilities on site, with issues such as noise, land development and pollution which can disturb wildlife.

- **Operations:** A mine enters the operation phase when earth and/or rock is being excavated from the ground and the processing plant produces a saleable product (PDAC, 2006). When rock is excavated, it is sent to the processing plant to separate the waste rock from the ore. Waste storage facilities such as tailings ponds retain the large amount of waste created in this process. The sustainability impacts occurring at this stage are very important. Waste, including heavy metals and chemicals, can contaminate water sources. There is also the potential for many benefits accruing to the community due to employment, salaries, local procurement and training.

- **Closure:** The closure phase consists of ensuring the orderly, safe and environmentally sound conversion of the mine to a closed state (PDAC, 2006). Following commercial resource extraction, decommissioning and rehabilitation activities are needed to remove or mitigate environmental and human health hazards, re-vegetate, and restore the environment so that the area, when abandoned, does not represent continuing risks (World Bank, 2010b). Because the rules for closure and reclamation vary across countries, many companies follow the World Bank and International Finance Corporation guidance in order to be able to access project financing from these organizations. However, companies such as Rio Tinto, BHP Billiton and Kinross Gold have also developed internal standards that require that specific procedures be followed. For example, BHP Billiton's internal closure standard is mandatory for all projects and has specific requirements for closure plan development and formal reviews.

Table 3 provides examples of potential benefits and impacts of mining on regional and local WEF security. These are elaborated in the sections that follow.

EXPLORATION	DEVELOPMENT	OPERATION	CLOSURE
7-10 YEARS	**5-10 YEARS**	**5-30 YEARS**	**2-10 YEARS**
Maximizing contributions to sustainable development throughout the project life cycle			
Prospecting: Mineral deposits are identified through basic surveying, sampling, drilling, and mapping of minerals. **Mining claim staking:** A mining claim is staked, giving the prospector an exclusive right to explore the area. Assessment reports submitted to government body. **Detailed exploration:** Geophysical and geochemical surveys, and diamond drilling is undertaken to explore deeper underground. **Sampling and drilling:** A costly drill program consists in bringing up cored rock (drilled core) from 100 metres underground, and analyzing these in the lab. **Environmental baseline work:** Cultural areas, soil, vegetation, wildlife and water analysis is undertaken. **Preliminary deposit evaluation:** All information is reviewed to determine feasibility of a mine.	**Detailed drilling:** Drill core samples are used to determine exact shape and size of deposit. **Bulk sampling:** Large samples enable metallurgical characteristics to be determined. **Environmental baseline studies:** The state of the environment is determined. **Feasibility studies:** Compilation and review of reports on the legal, geological, economic, engineering, and site data. **Closure and reclamation plan:** Details how the site will be cleaned and restored following mine operations. **Permitting:** Environmental assessments are required to obtain permits for further work. **Negotiation of agreements:** Agreements between the community and mining company are negotiated. **Construction:** Facilities such as a processing plant and related infrastructure are developed.	**Hiring:** Permanent employees and contractors are hired. Some companies will have agreements (e.g., IBAs) to work with and hire local candidates and aboriginals. **Training:** All new employees receive training so that they understand operations and how to stay safe. Other trainings such as cross-cultural issues, trades, literacy and life skills may also be offered. **Commissioning:** Facilities, processes and equipment are tested to see if they perform well before going into full production. **Production:** Waste rock is mined away to recover the ore. Once retrieved, ore is sent to the processing plant for processing. When market conditions are favourable, production is increased. **Mine expansion:** Expansions occur by enlarging the mine, opening more mine areas, buying more equipment, hiring more people, upgrading the processing plant, and doing more exploration work.	**Shut-down:** Employees are progressively laid off, but a small labour force is kept to shut down equipment. A formal review of the mine closure plan is carried out and any needed changes are submitted to the government regulators for approval. Various stakeholders are notified as to the shutting-down of operations. **Decommissioning:** Small crews take apart the mining and processing facilities and equipment. **Reclamation:** Disturbed land is restored as closely as possible to its original condition. **Post-closure:** Environmental activities continue in order to fully reclaim the affected land and monitor the success of reclamation activities.

Table 2. *Activities and Facilities Over the Full Life Cycle of the Mine*
Source: Adapted from PDAC (2006)

2.3.1. AVAILABILITY OF WATER, ENERGY AND FOOD

For a given mining project there exist a range of potential benefits and impacts related to both the quantity and quality of water, energy and food sources.

Sources of water, energy and food. Water withdrawals from surface water and groundwater sources for mining processes can reduce water availability in water-scarce areas. And the release of chemicals, heavy metals, and excessive sediment into the environment and its mobilization into water streams and groundwater can affect the appropriateness of water sources for human or economic use.

One of the most significant potential mining impacts on water resources is acid mine drainage (AMD). Mining projects extract ore containing sulphides, which require appropriate processes to prevent, minimize and control acid drainage. These projects require an early evaluation of the acid-generating potential of these materials, the development of effective strategies to minimize the oxidization of sulphides, and, where the acid drainage is unavoidable, the use of long-term control and treatment technologies (Murphy, Taylor, & Leake, n.d.). The Rio Tinto mining company has developed an environmental standard to minimize acid drainage and related risks through a hazard-screening protocol and a risk-review protocol. The hazard-screening protocol aims to assess all hazards created by the release of sulphide oxidation products, and ranks these hazards based on the chemical and physical setting of each site. The risk-review protocol covers 11 key performance areas (e.g., waste and rock characterization, materials management) for managing acid drainage and focuses on how mining operations are to manage these hazards according to good management practices.

In relation to energy, the construction of infrastructure to meet the electricity demands of mining operations can lead to increased energy supply for communities in the vicinity of the mine. At the same time, the increase in demand for electricity from mine operations can put a strain on the existing electricity supply, making it less reliable.

In the context of land and food resources, mining often competes with agriculture and other land uses related to food production: mining can also change soil composition and regimes due to mine

Box 1. Site-Level Water Management Plans

The development of a site-level water management plan that is informed by stewardship priorities at the catchment level is one of the first steps in managing water sustainably, according to ICMM (2012). These plans should aim to promote water-use efficiency by minimizing water use, and reusing and recycling it where possible. Companies should also strive to maintain long-term water balance throughout the project life cycle. Furthermore, the quality of discharged water should be monitored and controlled to minimize environmental impacts (ICMM, 2014). For example, Anglo American, a United Kingdom-based mining company, has a corporate water strategy that is guided by the four following concerns: water efficiency, water security, water risk and liability and stakeholder engagement (ICMM, 2012). In implementing the strategy, it developed water standards that specifically address these concerns across the life cycle of projects. Anglo American often develops site-level water action plans (WAPs) that take local catchment priorities into account, and operationalize these aspirations in the context of specific local needs.

tailings and other waste generated. In addition, chemical and/or heavy metal constituents of concern from mine waste facilities can potentially enter flora and fauna and animals, rendering these unsafe for human consumption.

Uses of water, energy and food. Mining introduces an additional competing use for water, energy and food in the region. This can potentially put a strain on already over-allocated resources in a region.

Markets for water, energy and food. With new mining development there is the potential for increased demand for water and water infrastructure, which can put upward pressure on the household cost of water services. Electricity costs could also potentially either increase or decrease due to regional mining operations. Food prices can potentially increase or decrease depending on the mine's influence on local population and volume of food purchases during operation and after closure.

2.3.2. ACCESS TO WATER, ENERGY AND FOOD

Occupational communities derive important financial benefits from their employment in mining and affiliated industries. Such benefits can substantially contribute to the reduction of poverty, and thus alleviate hunger, malnutrition and disease.

Purchasing power: Although mining rarely contributes to more than 1.5 percent of total national employment (ICMM, 2012), the jobs that mining projects create are usually well paid relative to national income levels (ICMM, 2014). Mining jobs often have health, pension and other benefits. In addition, for every mining company employee, there are typically two to four employees elsewhere in the economy that derive significant employment and income from mining activities. For example, a mining project operated by Vale in Brazil's Para State spent an average annual amount of USD700 million on local procurement from businesses such as manufacturing suppliers and other agencies between 2004 and 2008 (ICMM, 2012c). Thus, supplier development projects from local businesses can multiply the financial benefits that mining projects can have on communities. Local contractors can be hired for indirect activities such as constructing roads, building houses and the various businesses needed to serve the needs of occupational communities such as food and clothing.

Community aid and investments: Although employment and income are the primary financial benefits of mining, compensation payments for land and other impacts can be significant. Community development trust funds can also be important. For example, in Lao PDR, two mines, MMG Sepon and PBM Phu Kham Copper-Gold Operation, respectively contribute USD500,000 and USD300,000 annually to a community development trust fund that is spent in accordance with development priorities (ICMM, 2011). In addition, between 2003 and 2011, MMG Sepon distributed nearly USD3 million on community development programs (ICMM, 2011).

Self-production of water, energy and food. The establishment of a mine can potentially lower the local water table and affect the productivity of household and community water wells. The clearing of forests for mining can reduce local wood fuel sources, and land acquired for mining could potentially result in a reduction in locally grown food.

Bartering. For households that rely on local trade for their water, energy and food resources, there is the potential for disruption of bartering relations depending on how divisive the mining operation is among the local population.

2.3.3 SUPPORTING INFRASTRUCTURE – BUILT AND NATURAL

There are different types of built and natural infrastructure that support WEF security, such as communication, transportation, sanitation and landscape (such as wetlands and drainage) systems. These can be influenced both positively and negatively by mining development.

Infrastructure investments and services provided either primarily for the needs of the mine or for public benefit through commercial or in-kind arrangements can provide a significant boost for local communities. These infrastructure investments can help fill an important void in underserved communities, and can be critical to human development outcomes such as the reduction of poverty and overall well-being.

Built infrastructure: Mining projects often require significant investments in basic infrastructure such as roads, bridges, sewage, water supply and electricity, which can also benefit local communities. Recent studies have estimated that 60 per cent to 80 per cent of the costs of mining projects are due to infrastructure (World Economic Forum, 2014). But they also engage in developing infrastructure provided primarily for public benefit such as schools and hospitals. For example, AngloGold Ashanti's mine project in Obuasi, Ghana, has built 10 schools and one hospital in the municipality (ICMM, 2007a). The hospital built by AngloGold Ashanti is the biggest and best equipped in the municipality.

Natural infrastructure: With new mining development there exists a range of potential impacts on natural infrastructure that supports sources of water, energy and food. For example, the loss of vegetation could increase soil erosion and decrease water quality locally and regionally. The potential loss of wetlands could result in a decrease in the natural water treatment potential of the landscape, resulting in negative impacts on local and regional drinking water resources. The potential loss of local vegetation due to the mine footprint, and/or contaminants from mine waste can impact the mortality of pollinating insects. And in coastal areas, the potential loss of coastal zone vegetation (i.e., mangroves) could lead to increased weather-related risks to water, energy and food infrastructure.

Box 2. Biodiversity Strategies

Several mining companies now implement strategies to achieve a net positive impact on biodiversity through a mitigation hierarchy that first seeks to avoid impact where possible, minimize the impacts that are unavoidable, rehabilitate affected areas, and, finally, offset residual impacts. Many companies also abide by their commitments to avoid mining in "No Go" areas, which are places where any harm to biodiversity would be disallowed (e.g., UNESCO World Heritage sites). For example, in 2004 Rio Tinto made a public commitment to biodiversity conservation and the goal of achieving a "net positive impact" on biodiversity (ICMM, 2010a). In achieving this objective, the company works with formal partners (e.g., Birdlife International, Fauna & Flora International) and internal biodiversity planning experts to develop guidance materials for use by its operations sites. A biodiversity assessment protocol is used for assessing the biodiversity value of Rio Tinto's land and surrounding area to prioritize action. Where biodiversity value is assessed as being "high" or "very high," a Biodiversity Action Plan that elaborates on specific restoration offset and avoidance measures is required. The company is also looking into having its claims of "net positive impact" independently verified in the future.

2.3.4. SUPPORTING INSTITUTIONS AND POLICIES

There exists a host of institutions (e.g., government agencies, community networks) and public policies that play a role in supporting WEF security in any given region, and as is the case with supporting infrastructure, there can be both benefits and impacts on these due to mining development.

Supporting institutions. With mine development and operation, there will be an increased demand for tradespersons—this could put a temporary strain on local and regional education institutions as they strive to meet the new demand. With any new type of significant development, there will be an increased need for monitoring and enforcement of water and land-use regulations, and this can stretch already understaffed public agencies. And from the perspective of law enforcement and security institutions, the additional water, energy and food infrastructure that comes online as a result of a new mining operation may become targets for terrorist activity, requiring additional security services.

Supporting policies and plans. With mining development, existing water and land allocation policies may need to be revised to account for new demand following the introduction of mining. This can create tensions in already resource-scarce regions.

The potential impact of mining on regional and local ecosystems could increase community vulnerability to climate change in relation to the availability of water, food and energy. From a benefits perspective, corporate investment in local initiatives can improve the adaptive capacity of households and economic sectors in the region to deal with stresses such as climate change and market price volatility.

Mine extraction facilities (open pits, underground shafts) and mine waste facilities (waste rock piles and tailings dams) will be vulnerable to disaster in earthquake- and flood-prone regions, and therefore will require updates to local disaster recovery and risk-management plans and services.

There is also the potential for mine-related investment to result in an increase in research and development opportunities for water, energy and food technologies regionally, as well as the potential for new products and services to be introduced locally.

Box 3. Education Benefits from Mining Operations

The education and training practices of mining companies can be significant. Employee training programs typically range from technical mining skills and health and safety to more administrative and management skills focused. Some of this training may be targeted to the specific professional needs of employees such as project management training for high-level managers and woodworking for carpenters and other technical staff, or it can be more generic and accessible, such as language training for any employee. Community development projects can also contribute to human capital. For example, in Ghana, AngloGold Ashanti has funded various rural livelihood initiatives consisting of edible snail cultivation for domestic and export markets, guinea pig breeding for domestic and West African markets, and aquaculture production (ICMM, 2007a). These projects enable local communities to gain new skills that allow them to exploit market opportunities.

WEF SECURITY COMPONENT		POTENTIAL MINING BENEFITS AND IMPACTS ON...		
		WATER SECURITY	ENERGY SECURITY	FOOD SECURITY
AVAILABILITY	**Sources**	**Quantity:** Water withdrawals from surface and groundwater sources for mining processes can reduce water availability in water-scarce areas. **Quality:** The release of chemicals and heavy metals into the environment and their mobilization into water streams can affect the appropriateness of water sources for human or economic use.	**Quantity:** The construction of energy infrastructure to meet the energy demands of mining operations can lead to increased energy supply for communities. **Quality:** The increase in demand for electricity from mine operations can put a strain on the existing supply, making it less reliable.	**Quantity:** The destruction of aquatic habitats due to siltation and sedimentation can reduce fish stocks. Mining activities can supplant croplands, reducing locally grown food. **Quality:** Chemical and/or heavy metal residues along the food chain in fauna and flora can render these unsafe for human consumption.
	Uses	Mining introduces an additional competing use for water, energy and food in the region.		
	Processing	Drinking water treatment facilities may need to be expanded to meet additional demand of mine employees as well as runoff from the mine site.	Increased demand on electricity conversion stations.	Potentially increased demand on regional food processing plants.
	Storage	Introduced storage facilities (e.g. reservoirs) may increase or decrease water availability during dry seasons.	NA	Potential competition for warehouse storage facilities.
	Distribution	Potential for new water distribution infrastructure with mining development and operation.	New electricity distribution lines that are built to service the mine can lead to increased access to remote communities.	Mine construction and operation can compete with regional/local food transportation services.
	Markets	Increased demand for water and water infrastructure can put upward pressure on the household cost of water services.	Energy costs could potentially either increase or decrease due to regional mining operations.	Potential for food prices to increase or decrease depending on mining population influx and transportation infrastructure improvements.
ACCESS	**Purchasing Power** (livelihood income, remittances, credit)	An increase in income from mining-related jobs can lead to an improvement in people's ability to purchase water, energy and/or food. The loss of mining employment upon closure makes local population vulnerable with respect to future purchasing power.		
	Aid (direct provision, safety nets, subsidies)	Potential for corporate mining financial support to local food aid systems. Tax revenue from mining operation can potentially lead to increased government-sponsored food aid.		
	Self-Production (household and communal water sources, off-grid power, individual and communal gardens)	The establishment of a mine can reduce the physical accessibility of local water sources for surrounding communities due to threats of violence or other security concerns that may affect the mobility of people.	Clearing of forests for mining can reduce local wood fuel sources.	Land used for mining can result in loss of communal gardens.

Table 3. *Example WEF Security Benefits and Impacts from Mining*

ACCESS	**Barter**	Potential for disruption of bartering relations dependent on how divisive the mining operation among the local population.
SUPPORTING INFRASTRUCTURE	**Built**	
	Transportation	A new mining development can be the catalyst for improvements in local and regional transportation networks. Mine construction and operations can also compete for scarce local and regional transport vehicles, potentially disrupting food and water distribution and/or prices.
	Communication	A new mining development can be the catalyst for improvements in local and regional communication networks. Mine construction and operations can also compete for scarce local and regional bandwidth, potentially disrupting existing communication services and prices.
	Sanitation and waste	A new mining development can be the catalyst for improvements in local sanitation and waste management services. Mine construction and operations can also exacerbate existing environmental pressures associated with household and industrial sanitation and waste facilities and services.
	Natural	
	Ecosystem goods and services other than water, fuel and food sources: erosion control, water purification, biological control, pollination, storm protection, air quality	• Loss of vegetation could increase soil erosion and decrease water quality locally and regionally. • Potential loss of wetlands can result in a decrease in the natural water treatment potential of the landscape, resulting in negative impacts on local and regional drinking water resources. • Potential loss of local vegetation due to mine footprint, and/or contaminants from mine waste can impact the mortality of pollinating bees. • Potential loss of coastal zone vegetation (i.e., mangroves) can lead to increased vulnerability and risk of water and energy infrastructure and loss of agriculture land. • Change in river and stream quality and quantity can result in loss of aquatic species and delivery of sediments to floodplains and wetlands during high flows.
SUPPORTING INSTITUTIONS AND POLICIES	**Institutions**	
	Utility boards	No significant impact or benefit likely as a result of mine operations and closure.
	User associations and co-ops	No significant impact or benefit likely as a result of mine operations and closure.
	Education and training	Increased demand for tradespersons could put strain on local and regional education institutions.
	Safety oversight	Increased monitoring and enforcement needs for water and land use regulations.
	Law enforcement and security	The additional water, energy and food infrastructure that comes on line as a result of a new mining operation may become targets for vandalism, requiring additional security services.
	Policies and Plans	
	Resource use and allocation	Existing water and land allocation policies may need to be revised with the introduction of mining.
	Climate change adaptation	Impact of mining on regional and local ecosystem goods and services could increase community vulnerability to climate change. Corporate investment in local initiatives can improve the adaptive capacity of households and economic sectors in the region.
	Disaster recovery and risk management	Mine extraction facilities (open pits, underground shafts) and mine waste facilities (waste rock piles and tailings dams) introduce new potential for disasters in earthquake and flood prone regions.
	R&D and innovation	Mining investment can increase research and development opportunities for water, energy and food technologies regionally, as well as the potential for new products and services to be introduced.

Table 3. *Example WEF Security Benefits and Impacts from Mining*

2.4. CASE STUDY: PERU'S WATER ISSUES AND MINING'S CONTRIBUTION

Peru is one of the most water-scarce countries in South America (United Nations Environment Programme [UNEP], n.d.), with most of the population living west of the Andes, where less than 2 per cent of water resources are found (Global Water Partnership, 2013). Peru is also one the most important destinations for mining companies, as one of the world's leading producers of silver, bismuth, copper, lead, gold and tin. The Peruvian mining sector uses about 5 per cent of Peru's water, or about 2 per cent of its total water withdrawals. In comparison, agriculture accounts for 80 per cent of Peru's total water withdrawals (Algeria, 2006). Domestic use accounts for about 12 per cent, but one quarter of Peruvians do not have access to water supply services (Algeria, 2006).

Competition from the mining sector over water resources is an area that has attracted public protests due to the fear that mining operations may deplete water resources. Water contamination is also an issue, especially for remote communities that rely on this water. Gold mining is a particularly water-intensive activity. A hydrological study completed in 1992 prior to the opening of the Yannacocha Gold Mine (the world's largest gold mine, it is located near Cajamarca, in the north of Peru) found that this operation alone would require 1,000 cubic metres of water per day, and estimates have projected that the operation has used 125 million cubic metres of water between 1993 and 2004 (Lubovich, 2007). This amount is compared to Peru's 2.5 billion cubic metres in annual domestic water use (Algeria, 2006). However, water pollution is the issue that has received the highest amount of scrutiny from local communities over concern for contamination from substances such as cyanide and arsenic. These communities are typically poor and depend heavily on subsistence aquaculture, relying on rivers for drinking water, irrigation and for livestock. A study has found that the Chuppala River has twice the amount of arsenic than allowed by Peruvian law (Salazar, 2007).

Many companies have taken upon themselves to improve the water security of communities in Peru. For example, Doe Run, which is a lead producer based in the United States, spent 2.4 times more than required by their initial agreement with the Peruvian government for environmental improvement by, in part, building three sewage treatment plants to treat the wastewater from thousands of households in addition to its own wastewater (Lubovich, 2007). Freeport-McMoRan Copper & Gold, which operates a mine in the Arequipa Province in the south of Peru, engaged with municipalities and communities in the surrounding area of their concession and as a result identified the need for clean water as the area's most important need (ICMM, 2012). The province is fast growing and there is limited availability of water due to the arid environment (ICMM, 2012). However, the watershed that supplies most of the drinking water needs of the population had become contaminated due to household and industry discharge of untreated water into the river. The company built a potable water plant and a wastewater treatment plant. The costs of building these two plants were shared equally by the company and the municipalities. None of the water generated by the potable water treatment plant were to be used for the mine's operation, while the wastewater treatment plant would ensure that environmental and human health impacts of dumping untreated water would be reduced, and would ensure a clean supply of water for the region's agricultural sector, thus improving regional water and food security.

SUSTAINABILITY IMPACTS	SYSTEM CHANGES	SECURITY OF WEF SUPPLIES
Effluents to Water Acid mine drainage Overburden, tailings and other mine waste Hazardous material use and spills	Increased presence of toxins in water Reduced flora/fauna density and diversity Reduced fish stocks Ocean health worsening	Decreased household and economic water consumption Reduced staple crop yields Decreased water for food production Undernourishment
Water treatment infrastructure investment	Improved water quality and flora/ fauna (opposite above	Improved water and food security (opposite above)

Figure 3. *Causality Chains – Peru Case Study*

2.5. CASE STUDY: MALI'S SOCIAL AND ECONOMIC ISSUES AND MINING'S CONTRIBUTION

Mali is one of the poorest countries in the world, with a ranking of 176 out of 187 countries on the UNDP's Human Development Index (UNDP, 2014). An estimated 78 per cent of the population lives on less than USD2 a day (World Bank, 2010). Economic activities have traditionally been limited to the areas irrigated by the Niger River, with some 80 per cent of the population deriving their living from farming or fishing (CIA, 2014). However, in the last 20 years, with the advent of large-scale mining, mineral production has become an increasingly important activity.

In particular, Mali is now Africa's third-largest gold producer (after South Africa and Ghana), and gold accounts for over half of all of the country's exports, while gold mining accounts for approximately 20 per cent of government revenues (Drakenberg, 2010). As a result, mining has been recognized as a prominent driving force in the country's poverty-reduction strategy (Republic of Mali, 2006). It is estimated that approximately 13,000 people are formally employed by the sector, representing 15 per cent of the country's total formal employment (Drakenberg, 2010). However, with an estimated average yearly salary of CFCF 2.32 million (USD3,477), incomes are extraordinary in the eyes of ordinary Malian citizens, as they are nearly four times the country's GDP per capita (Jul-Larsen, Kassibo, Lange, & Samset, 2006). Moreover, approximately 90 per cent of those employed by the mining sector are Malians (Jul-Larsen, Kassibo, Lange, & Samset, 2006). Nearly all of those employed are men.

Surveys among the mining workforce in Mali has found that these people were able to save money and make investments (Jul-Larsen, Kassibo, Lange, & Samset, 2006). Almost half of the workers (46 per cent) had invested in land and/or a house. About one in five (18 per cent) bought a car, while more than half (54 per cent) bought a motorcycle. In addition, one in four (23 per cent) bought cattle, with the majority of these (68 per cent) reporting that the purchase of cattle is a form of saving. Finally, about one third (32 per cent) acquired a savings account at a bank. The vast majority of workers sent money to members of their family (92 per cent), and more than half of them (55 per cent) sent money on a monthly basis for "the purpose of consumption, either of basic commodities such as food and clothing, or major family events such as weddings and funerals." It is estimated that about four people depend on the wages of each mine worker in Mali (Jul-Larsen, Kassibo, Lange, & Samset, 2006). For these people, financial benefits result in their being able to more easily afford water, energy and food.

SUSTAINABILITY IMPACTS	SYSTEM CHANGES	SECURITY OF WEF SUPPLIES
Employment Salary and benefits Government revenue	Decreased unemployment rate Net savings improved Debt ratio improved Investments in productive assets	Greater disposable income, savings and investments enhance the ability of these people to afford water, energy and food.

Figure 4. *Causality Chains – Mali Case Study*

3. A REVIEW OF SUSTAINABILITY FRAMEWORKS AND INDICATORS FOR THE MINING INDUSTRY

Understanding and measuring the sustainability impacts of mining provides important insight into the ultimate influence of mining on WEF security. The specific linkages between these sustainability impacts, however, are not universal and depend upon the specific context of the mining project and communities, including whether communities are sufficiently resilient and the extent to which they rely on the natural environment for food and subsistence. This chapter presents an overview of the broader sustainability benefits and impacts of mining operations and relevant indicators for assessing and tracking changes over time. It concludes by summarizing the approach of leading countries in measuring and monitoring the sustainability impacts of the mining sector.

The sustainability impacts of mining are the principle levers by which the components of WEF security are affected (Table 5). Water use and pollution are some of the most serious environmental impacts of the industry, and occur from three factors: sedimentation, acid drainage, and metal deposition. This deposition occur as a result of the release of particulate matter from mining operations first into the atmosphere and secondly into the soil and water bodies. These factors are a direct result of the amount of waste produced by mining operations which, in the case of gold and silver, includes more than 99 per cent of the ore extracted (Da Rosa & Lyon, 1997). The use of chemicals in processing, such as cyanide and arsenic, can also be an important contributor. Water security is inadvertently affected as a result of its environmental release, and food security is a corollary concern because water is at the foundation of all animal and vegetal life. Other significant environmental impacts include greenhouse gas emissions and biodiversity loss.

The direct social and economic effects of mines are related to resettlements and land rights, health and safety, and employment (Table 5). Whereas the environmental impacts of mines are typically negative, the social and economic effects are mixed. Mining can provide income and employment, and thereby improve the ability of households to afford and secure water, energy and food needs. However, where employment leads to health and disability issues, it can reduce this ability in the future. The displacement of communities can deprive households of their usual water, energy and food sources.

SUSTAINABILITY IMPACTS OF MINING PRODUCTION SELECTED FROM THE GLOBAL REPORTING INITIATIVE:	WATER	ENERGY	FOOD	REASONING
Strength of relationship between mining's sustainability impacts and WEF: ● Strong linkage; O Weak linkage				
ENVIRONMENT				
Total water use	●	O	●	Access to water for agriculture and other uses may be diminished.
Land in indigenous territory	●		●	Access to critical resources may be limited.
Major impacts on biodiversity in terrestrial, freshwater and marine environments	●		●	Some populations may rely on surrounding fauna/flora for subsistence, incomes and livelihoods.
Greenhouse gas emissions	●	●	●	On a global scale, GHGs are contributors to climate change, which affects WEF production systems through drought, excess moisture, for example.
NOx, SOx and other significant air emissions	●		●	NOx and SOx emissions causing acid rain, which affects the quality and quantity of water and food sources.
Different types waste and their destination	●		●	Quality of water and food, through food chain effects, can be affected by mine waste.
Significant discharges to water	●		●	Quality of water and food, through food chain effects, can be affected by liquid effluents.
Significant spills of chemicals, oils, and fuels	●	O	●	Quality of water and food, through food chain effects, can be affected by significant spills.
Incidents of and fines for non-compliance with international frameworks and applicable regulations related to environmental issues.	●	O	●	Generalized effect on quality, quantity and access due to wide-ranging relevance of measures.
Increased sediment release to surface water bodies	●	O	●	Quality of water in terms of sedimentation can reduce potential for drinking water, reduce the quantity of food sources (e.g., piscivorous fish), and can impact hydroelectrical infrastructure.
SOCIAL				
Health and Safety				
Standard injury, lost day, absentee rates and number of work-related fatalities.	●	●	●	Access to WEF may be reduced due to decreased ability for self-production, lost income, and employability/productivity.
Number of new cases of occupational disease by type	●	●	●	Access to WEF may be reduced due to decreased ability for self-production, lost income, and employability/productivity.
Training and Education				
Average hours of training per year per employee by category of employee	O	O	O	Access to WEF may be improved due to increased ability for self-production, increased income, and employability/productivity.

Table 4. *Overview of the Linkages Between Select Mining Sustainability Impacts and WEF Security*

Community				
Policies/procedures/programs to manage impacts on communities in areas affected by activities.	●	●	●	Generalized effect on quality, quantity and access due to wide-ranging relevance of measures.
Local economic contribution and development impact of particular significance and interest to stakeholders.	○	●	●	Financial access to WEF may be improved due to increased purchasing power.
Programs that address artisanal and small-scale mining within company areas of operation.	●	●	●	Generalized effect on quality, quantity and access due to wide-ranging relevance of measures.
Resettlement				
Resettlement activities	●	●	●	Access to WEF may be decreased due to foregone ability to access traditional livelihood and income resources.
Land Rights				
Process for identifying local communities' land and customary rights and grievance mechanisms used to resolve any disputes.	●	●	●	Access to WEF may be safeguarded by protecting land rights due to maintained ability to access traditional livelihood and income resources.
ECONOMIC				
Employment				
Breakdown of workforce by status (employee/non-employee), and by employment contract (indefinite or permanent/fixed term or temporary).	○	●	●	Employment enhances financial access to WEF.
Net employment creation and average turnover.	○	●	●	Employment enhances financial access to WEF.
Percentage of employees represented by independent trade union organizations or other bona fide employee representatives OR percentage of employees covered by collective bargaining agreements.	○	●	●	Equitable salary and working conditions can help ensure continued financial and physical access to WEF by promoting a decent income and safeguarding the health of workers.
Policy and procedures involving information, consultation & negotiation with employees over changes in the organization's operations e.g., restructuring.	○	○	○	Equitable salary and working conditions can help ensure continued financial and physical access to WEF by promoting a decent income and safeguarding the health of workers.

The process by which sustainability translates into WEF security benefits and impacts can be conceptualized as a three-step process (Figure 5).

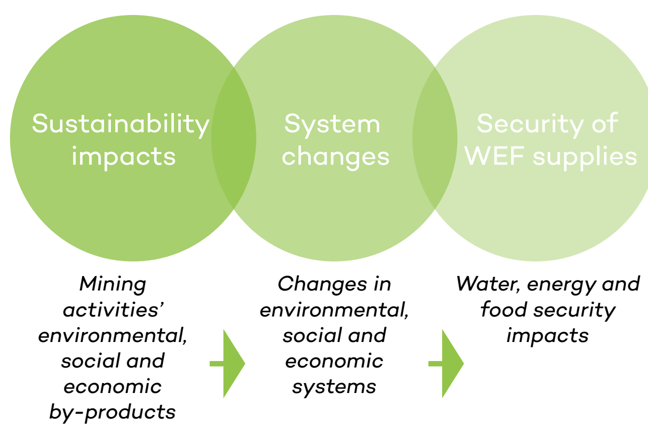


Figure 5. *Sustainability Impacts and WEF Security*

3.1. SUSTAINABILITY BENEFITS AND IMPACTS OF MINING

While the economic benefits of mining are important, especially in developing countries, the process of exploration for and exploitation of mineral deposits is directly associated with undesirable by-products that can cause harm to environmental and social systems. Such by-products include the overburden and tailings that are produced when extracting and processing ore. The water effluent from these waste facilities can be managed with state-of-the art technologies, such as the mitigation of cyanide, arsenic and other chemical effluents into the environment. Social by-products can also be managed with appropriate policies that promote occupational health and safety, community consultations, training and education, and so on. Economic benefits are often the most easily measurable by-products of mining, and include employment, salaries and government revenues.

These immediate effects typically form the core of existing indicator and reporting systems of mining companies, and relate to the direct by-products of activities required to explore and exploit mineral deposits. Often these effects depend on the kind and level of environmental technologies, and social and economic practices involved in these activities. Mining also undertakes significant spending on goods and services from local businesses, and infrastructure investments.

ENVIRONMENTAL	SOCIAL	ECONOMIC
Hazardous material use and spills	Occupational health and safety	Employment
Acid mine drainage	Labour/management relations (incl. collective bargaining)	Salary and benefits
Effluents to water	Training and education	Government revenue
Water withdrawal	Child labour	Procurement and suppliers
Overburden, tailings and other mine waste	Forced labour	Local, gender and indigenous participation
Emissions to air	Resettlement	Infrastructure investment
Biodiversity disturbance	Artisanal and small-scale mining	Ownership
Energy production and use	Indigenous land, culture and human rights	
Mercury and cyanide use and management	Human rights training	
Closure and rehabilitation	Community compensation, development and impact management	
Land-use change	Community engagement	
Land disturbance	Security issues	
Noise and other nuisance	Corruption and public policy	

Table 5. *Possible Headline Indicator Categories for Monitoring Sustainability Impacts of Mining*
Source: Synthesis based on IISD's review of indicator frameworks at the company level.

3.2. SYSTEM CHANGES AND SECURITY OF WEF SUPPLIES

Environmental systems potentially change due to mining activities, resulting in poorer air quality, greater deforestation, higher levels of toxicity, reduced flora and fauna density, and so on. A decline in the state of the environment leads to a deterioration in the levels of adequate quantity and acceptable quality water, energy and food. Water and food are typically the most negatively affected by adverse environmental impacts, as the contamination of water due to mining activities not only affects water quality but also indirectly affects flora and fauna that consume contaminated water and may die as a result or bio-accumulate toxins to levels that are unsafe for human or animal consumption. If communities and industries rely on the natural environment for their water and food needs, then they can be negatively affected due to these effects. Taking natural capital or ecosystem goods and services values into account, overall economic values might be positive or negative.

Economic and traditional market systems tend to benefit from mining through a reduced unemployment rate, greater macroeconomic performance and household savings. Access to water, energy and food is improved through mining's economic benefits, which will improve the purchasing power of individual beneficiaries. Social systems tend to be negatively affected, although effects are mixed—for example, education rates and labour productivity can be improved, while the prevalence of occupational diseases and community conflicts can increase. A deterioration in the social system will lead to a

ENVIRONMENTAL	SOCIAL	ECONOMIC
Air quality	Occupational diseases	Macroeconomic performance
Land use and status	Community conflicts	Foreign investment
Proportion of land that is forested	Workplace accidents	Trade
Proportion of forest damaged by defoliation	Labour productivity	Net gain or loss in environmental goods and services values
Presence of toxins in water	Education rate	Unemployment rate
Flora/fauna density and diversity	Land rights	Net savings
Threat status of species	Compliance with International Labour Organization standards	Debt ratio
Critical biome		Share of women/indigenous in employment
Biochemical oxygen demand (BOD) in water bodies		
Fish stocks		
GHG emissions		
Ocean health		
Water resource use		
Fragmentation of habitat		
Generation of hazardous waste		

Table 6. *Possible Headline Indicator Categories for Monitoring System Changes*
Source: Synthesis based on IISD's review of indicator frameworks at the company level.

reduction in access to water, energy and food by, for example, a loss in the ability to self-produce as a result of occupational disease, or inappropriate resettlement and infringement/loss of land rights which prevent physical access to subsistence resources.

As a result of mining-related changes in environmental, social and economic systems, WEF security may be positively or negatively affected as illustrated in the example causality chains in Table 7.

CAUSALITY CHAIN EXAMPLE	SUSTAINABILITY IMPACTS	SYSTEM CHANGES	SECURITY OF WEF SUPPLIES
	MINING ACTIVITIES' ENVIRONMENTAL, SOCIAL AND ECONOMIC BY-PRODUCTS	CHANGES IN ENVIRONMENTAL, SOCIAL AND ECONOMIC SYSTEMS	WATER, ENERGY AND FOOD SECURITY IMPACTS
1	Acid mine drainage	Higher presence of toxins in water	Water may be unsafe for human consumption, and/or use for crops and fish if it exceeds limits specified in applicable standards.
2	Poor occupational health and safety	Increased prevalence of occupational diseases	Reduced ability to generate income and afford or self-produce goods.
3	Emissions to air	Decreased air quality and acid rain	Decline in agricultural productivity and a deterioration in terrestrial and aquatic ecosystem can lead to decreased availability of food and water.
4	Employment	Reduced unemployment rate	Ability to afford goods is improved.

Table 7. *Example Causality Chains for Sustainability Impacts and WEF Security*

3.3. THE ORIGINS OF MINING SUSTAINABILITY PRACTICES AND REPORTING FRAMEWORKS

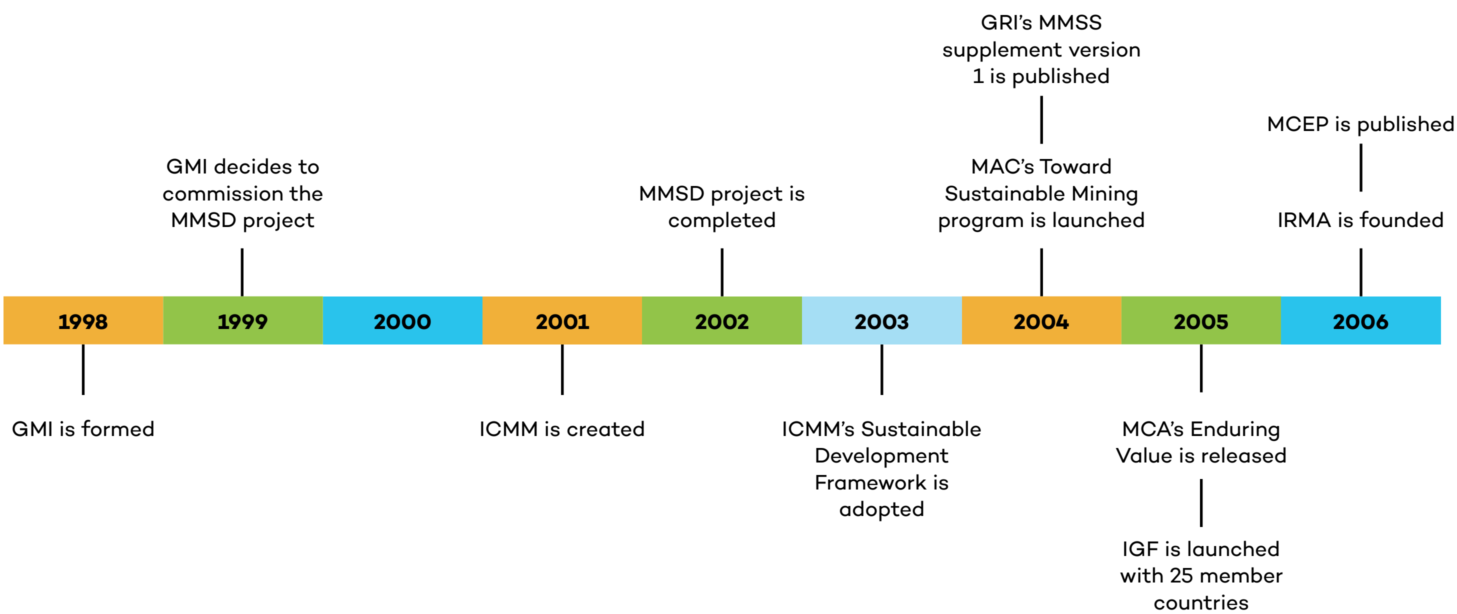
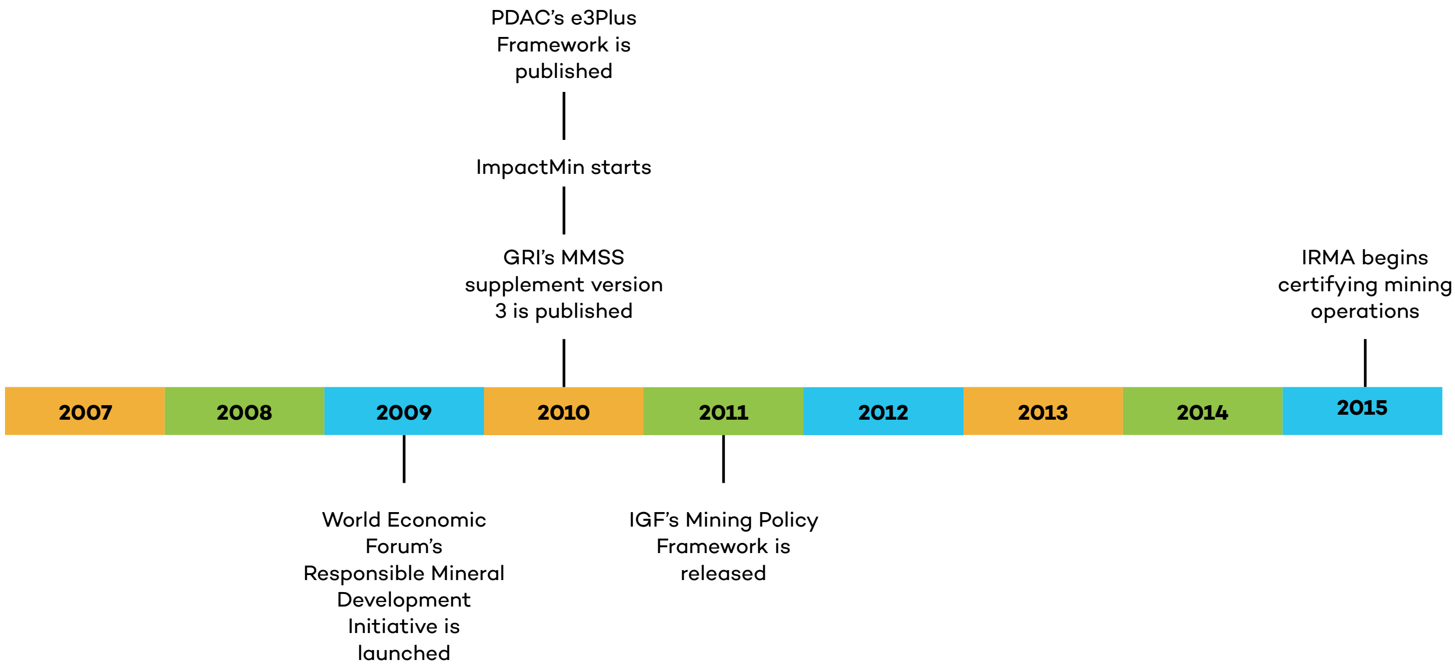


Figure 6. *Timeline of Initiatives: Mining Sustainable Development Events*
Source: IISD


PDAC's e3Plus Framework is published
ImpactMin starts
GRI's MMSS supplement version 3 is published
IRMA begins certifying mining operations
2007
2008
2009
2010
2011
2012
2013
2014
2015
World Economic Forum's Responsible Mineral Development Initiative is launched
IGF's Mining Policy Framework is released

Over the last 15 years, an alternative movement has emerged. It pivots away from addressing the sustainability impacts of mining using an adversarial and advocacy-based approach—instead, it increasingly revolves around a shared agenda. A series of initiatives formed the basis for a shared strategy and collective action around mining's contribution to sustainable development for both policy-makers and mining companies.

In 1999, out of concern for the adverse reputation of the mining industry within society, the chief executive officers of the nine largest mining companies, under the auspices of the Global Mining Initiative (GMI), decided to commission a global review of the ways in which the industry could optimize its contribution to sustainable development. The GMI then initiated the **Mining, Minerals and Sustainable Development (MMSD)** project, which had the following goals:

- To assess global mining and minerals use in terms of the transition to sustainable development—its track record in the past

ISSUES	PROGRESS 10 YEARS FOLLOWING COMPLETION OF MMSD
Local communities and mines	The past 10 years have helped to define what community good practices look like. Mining industry associations now provide binding policies and guidance on the community development concerns for their members. Industry paternalism has decreased and there is evidence that companies are taking concrete steps to ask communities what they want. In addition, Community Sustainable Development Plans are taking shape in the form of Impact Benefit Agreements and Community Development Agreements and are spreading into regulation. Moreover, progress has been made in the area of capacity building for both communities and companies, but it still remains a challenge. Communities now better understand their rights and place more demands on governments and companies to ensure benefits from mining activities. At the same time, mining companies are continuously engaged in maintaining their social license to operate throughout the life cycle of the mine.
Mining, minerals and the environment	Technical advances have been made on water and waste metals toxicity. In addition, the frequency of environmental disasters has markedly decreased. Water is currently seen amongst the top three sustainable development issues for the next 10 years, and a number of innovations are being developed to respond to this concern. Biodiversity is another area of leadership, with ICMM member companies agreeing not to explore or mine in World Heritage sites. Biodiversity-offset programs have also been developed to assist companies in creating a net positive contribution to biodiversity. While mine closure is still a challenge, exemplary approaches such as turning old mine sites into wind farms and jatropha plantations for green energy production have been developed.
An integrated approach to using minerals	Progress has been made with regards to addressing conflict minerals, and a movement toward supply chain traceability for mining products.
Access to information	A large number of reporting initiatives has emerged through initiatives such as the GRI's mining sector supplement, the ICMM's Sustainable Development Principles and the Extractive Industry Transparency Initiative (EITI). While these have helped shape best practices, there is still a lack of adequate accountability and verification systems for assessing the mining industry's performance and progress.
Sector governance – roles, responsibilities and instruments for change	The number of multistakeholder initiatives has grown tremendously since 2002, which has contributed to an increased understanding of sustainable development and an enhanced ability for cooperation among those with similar interests. Several voluntary codes and forms of guidance have emerged, but not all of them have public reporting and independent verification.

Table 8*. Progress Following the Decade Since the MMSD Project*
Source: Buxton (2012)

and its current contribution to and detraction from economic prosperity, human well-being, ecosystem health and accountable decision making.

- To identify if and how the services provided by the minerals system can be delivered in accordance with sustainable development in the future.
- To propose key elements of an action plan for improvement in the minerals system.
- To build a platform of analysis and engagement for ongoing cooperation and networking between all communities of interest.

Completed in 2002, MMSD created a shared idea of the appropriate and necessary roles for the major actors in mining and sustainable development on global and regional levels. Ten years after the completion of the MMSD, a number of issues had significantly progressed, as illustrated in Table 9.

Following the recommendations of the MMSD initiative, various bodies were formed, including the **International Council on Mining and Metals (ICMM)** and the **Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF).** The ICMM brings together 22 mining and metals companies as well as 32 national and regional mining associations to

Box 4. The IGF's Mining Policy Framework

The Mining Policy Framework is a compendium of best practices to guide governments as they address the full range of issues related to mining.

Legal and policy environment *- A mature modern legislative regime is one that provides clear lines of responsibility and accountability. Such a regime provides the foundation of good governance and contributes to sustainable development in all aspects of social and economic life.*

Financial benefit optimization *- Taxes and royalty revenues derived from exploration, mine development and production reflect the value to society of the resources mined. They are collected and put to work in support of the sustainable development of the nation.*

Socioeconomic benefit optimization *- The conversion of natural capital into human capital holds the greatest promise for sustainable outcomes from mining activities.*

Environmental management *- The management of the natural resource base within ecosystems is the continuous responsibility of any society seeking to become more sustainable.*

Post-mining transition *- A mining operation that is considered consistent with sustainable development is one where planning for closure exists throughout the entire operation of the mine.*

Artisanal and small-scale mining *- Artisanal and small-scale mining is a complex and diversified sector that ranges from informal individual miners seeking to make a subsistence livelihood, to small-scale formal commercial mining entities that can produce minerals in a responsible way respecting local laws.*

Source: IGF (2013)

drive forward the contribution of the sector to sustainable development, while the IGF brings together 48 countries into a global venue for sustained discussions among governments on practical issues related to its sustainable management and development. These organizations have continued MMSD's legacy in their ongoing contribution to the establishment of a global set of rules for sustainable development best practices in the mining and metals industry.

The IGF's main contribution has been its **Mining Policy Framework** which was tabled at the 19th session of the United Nations Commission on Sustainable Development (CSD19), held in May 2011. This document provides a "compendium of activities that [IGF member countries] identified as best practices for exercising good governance of the mining sector and promoting the generation and equitable sharing of benefits in a manner that will contribute to sustainable development" (IGF, 2013, p. 4). The progressive implementation of this framework by IGF member countries is to follow.

The ICMM's main contribution has been its Sustainable Development Framework, which all ICMM member mining companies are required to implement and report on. The Sustainable Development Framework is comprised of 10 principles related to sustainable development issues, such as human rights, health and safety, environmental performance, biodiversity conservation, land-use planning and socioeconomic development. The principles are:

1. Implement and maintain ethical business practices and sound systems of corporate governance.
2. Integrate sustainable development considerations within the corporate decision-making process.
3. Uphold fundamental human rights and respect cultures, customs and values in dealings with employees and others who are affected by our activities.
4. Implement risk-management strategies based on valid data and sound science.
5. Seek continual improvement of our health and safety performance.
6. Seek continual improvement of our environmental performance.
7. Contribute to conservation of biodiversity and integrated approaches to land-use planning.
8. Facilitate and encourage responsible product design, use, reuse, recycling and disposal of our products.
9. Contribute to the social, economic and institutional development of the communities in which we operate.
10. Implement effective and transparent engagement, communication and independently verified reporting arrangements with our stakeholders.

The **Global Reporting Initiative (GRI)**, which has been the leading reporting framework for companies across all industry sectors, has collaborated with the ICMM over a number of years and released a Mining and Metals Sector Supplement version 3 in March 2010, complementing the GRI guidelines by providing specific guidance for mining companies on reporting on aspects of sustainable development that are particularly relevant to the mining sector.[1]

A relatively more recent initiative, the **Initiative for Responsible Mining Assurance (IRMA),** which was founded in 2006 by a coalition of NGOs, affected communities, mining companies and trade unions, is developing standards for mining's contribution to environmental and social issues. The IRMA expects to begin certifying mine sites in 2015 with the goal of helping companies to

[1] For more information, please see https://www.globalreporting.org/resourcelibrary/G3-1-English-Mining-and-Metals-Sector-Supplement-Quick-Reference-Sheet.pdf

PRINCIPLES	GUIDELINES	STANDARDS
MORE INTERPRETIVE LESS GUIDANCE LITTLE COMPLIANCE	→	MORE PRESCRIPTIVE MORE GUIDANCE STRICTER COMPLIANCE
1. Centre for Science in Public Participation (CSP2) Framework for Responsible Mining 2. Azapagic's (2002) Mining and Sustainable Development Indicators	3. Global Reporting Initiative (GRI) Guidelines and Mining and Metals Sector Supplement 4. Prospectors and Developers Association of Canada (PDAC) e3Plus Framework*	5. Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining 6. Mining Association of Canada's (MAC) Towards Sustainable Mining 7. Mining Certification Evaluation Project (MCEP)
* is currently exploring options to certify operations (to become a standard)		

Table 9. *Existing Frameworks in which Indicator Systems Have Been Developed*
Source: Authors' research

adopt practices that are "consistent with healthy communities and environments, and leave positive long-term legacies."

Other organizations have focused on fostering transparency and good governance of the mining industry. These include: Natural Resource Governance Institute's Natural Resource Charter, and Extractive Industries Transparency Initiative (Natural Resource Governance Institute, 2014; EITI, 2015). In addition, large mining companies often adhere to a wider set of sustainability frameworks that are more sector-agnostic, such as the IFC Performance Standards, ISO 14001, ISO 18001, ISO 26000, OECD Guidelines for MNEs, World Bank Safeguard Policies and UN Global Compact.

While the ICMM, IGF, GRI and other transnational initiatives are mostly engaged at the global level, others operate at the regional and national levels. These include:

- Mining Association of Canada's Towards Sustainable Mining program, which helps Canadian mining companies to achieve sustainable mining practices by providing a set of tools, best practice guidance and reporting protocols to allow them to demonstrate performance to key stakeholders (MAC, n.d).
- The Prospectors and Developers Association of Canada's e3 Plus Framework for Responsible Exploration, which describes a set of best practices and tools for the improvement of mining companies' social, environmental, and health and safety performance. The e3 Plus Framework is currently exploring options to develop indicators, reporting frameworks and verification/certification systems to measure performance on these issues. (PDAC, n.d.).
- In Australia, the Mining Certification Evaluation Project (MCEP) has sought to evaluate the feasibility of independent third-party certification to assess the environmental and social performance of mining sites (WWF-Australia, 2010).

- Also in Australia, a sustainable development framework called Enduring Value has been developed by the Minerals Council of Australia (MCA) to provide implementation guidance for Australian mining companies' operationalization of ICMM principles (Minerals Coucil of Australia, 2005).
- In Europe, a project called ImpactMin that is co-financed by the European Union has aimed to develop new methods and a toolset for impact monitoring of mining operations using Earth Observations and in-situ data (ImpactMin, n.d.).

Mining sustainability practices and reporting frameworks are continually evolving. Initiatives such as the World Economic Forum's Responsible Mineral Development Initiative, World Business Council for Sustainable Development's Vision 2050, and Chatham House's Resource Futures have proposed various options for the sector's contribution to sustainable development into the decades ahead (WBCSD, 2010; Wolrd Economic Forum, 2013; Lee, et al., 2012).

3.4. REVIEW OF MINING AND SUSTAINABLE DEVELOPMENT INDICATORS

The MMSD project provided early guidance for mining companies' development of sustainability indicators. A report commission by MMSD reviewed the landscape of sustainability indicator development approaches at the time, suggesting a number of ways in which such approaches can meet the needs of a wide range of stakeholders (Figure 6) (Warhurst, 2002). The most appropriate methodological approach was seen as one that is sufficiently generic to be applicable to the different indicator models in use by diverse stakeholder groups, while being sufficiently tailored to the particular operating environment of the mining sector. The global-level drivers of indicator system development are suggested to encourage the uptake and development of indicator systems, while project-level drivers encourage mining companies to ensure that these indicators adequately describe tangible benefits to business, governments and communities (Warhurst, 2002). The report did not recommend a specific set of core indicators, but rather attempted to provide guidance for the content and coverage of future indicator systems. Its basic findings provided a backdrop for the development of the reporting component of the ICMM's Sustainable Development Framework, which was developed in 2003–2005 and released in 2005, and the GRI Mining and Metals Sector Supplement, which was developed in partnership with the ICMM starting in 2003, first piloted in 2005 and issued in finally issued in a version 3 format in 2010.

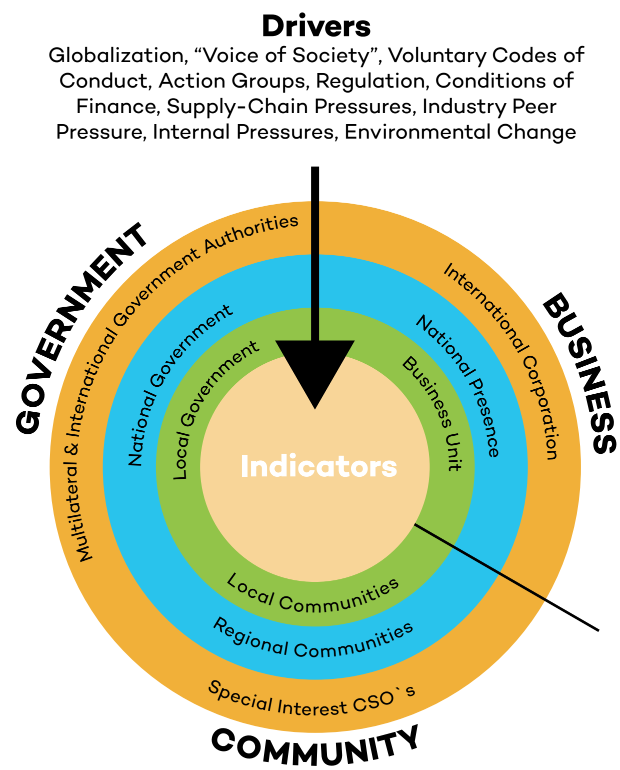


Figure 7. *Global-Level Drivers of Indicator System Development and Uptake Suggested by MMSD-Commissioned Report*
Source: Warhurst (2002)

Aiming to take stock of these and other early efforts to develop sustainability indicators, the Centre for Science in Public Participation and the World Resource Institute launched an independently led investigation that sought to draw on and learn from these initiatives and other academic and NGO sources (Miranda, Chambers, & Coumans, 2005). The primary goal of their review was to assess prior research on mining's contribution to sustainable development, identify best practices, and provide recommendations for retailers and other companies that are either directly engaged in mining or source mineral products in a responsible and sustainable manner.

The result of this study was the Framework for Responsible Mining, which "outlines environmental, human rights, and social issues associated with mining and mined products, and explores state-of-the-art social and environmental improvements" (Miranda, Chambers, & Coumans, 2005, p. xi).

Also in 2005, the International Mineral Processing Council convened with international experts in minerals sustainability in an event titled "Indicator of Sustainability for Mineral Extraction Industry: A Review" and participating authors and presenters represented government, academia and industry

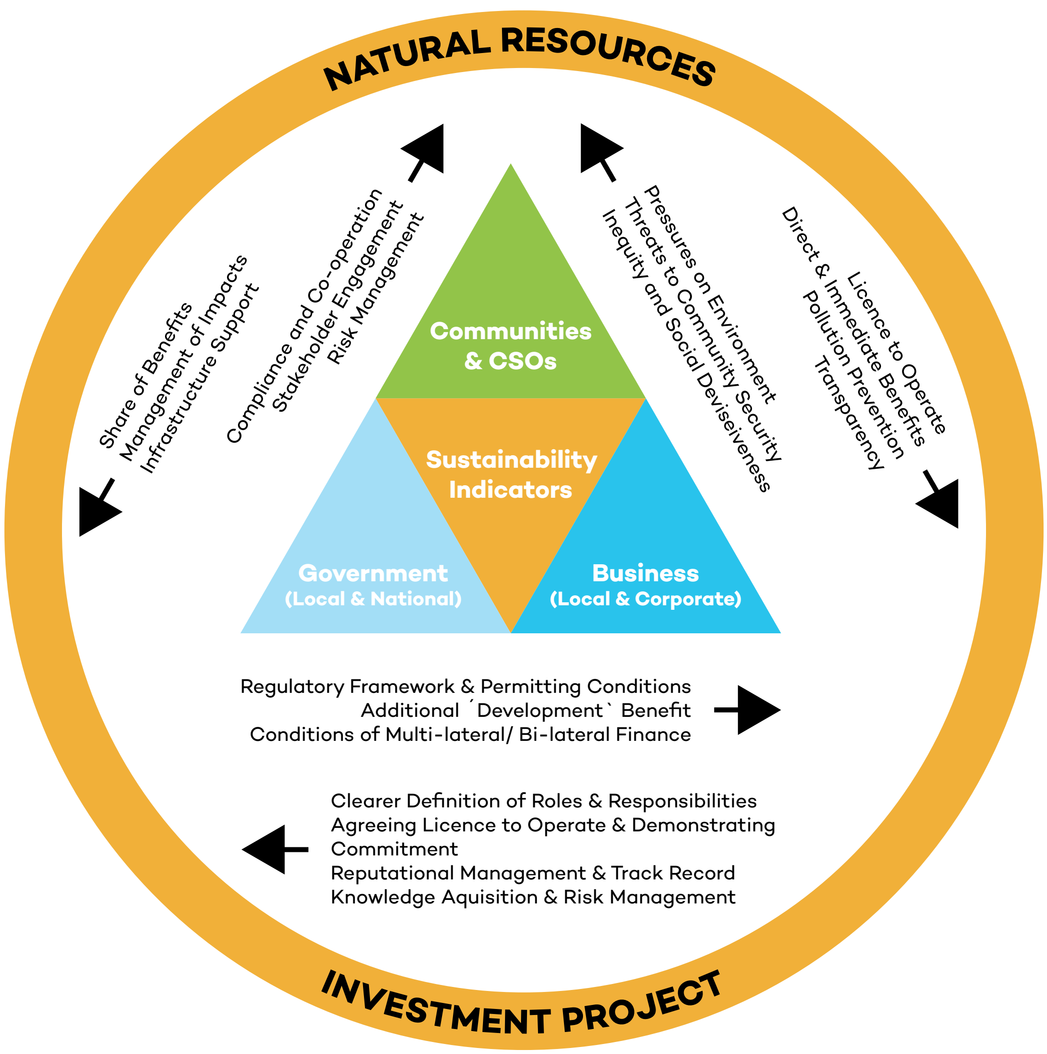


Figure 8. *Project-Level Drivers of Indicator System Development and Uptake Suggested by MMSD-Commissioned Report*
Source: Warhurst (2002)

from 13 countries and the European Union. The event provided a good overview of ongoing efforts to develop indicator systems for the mining sector in different regions of the world (Villas Boas, Shields, Solar, Anciaux, & Onal, 2005).

Our review has shown that current indicator systems vary widely in their breadth and depth of coverage across different environmental, social, and economic issues. Table 11 provides a general overview of these findings.

INDICATOR CATEGORIES WITHIN INDICATOR FRAMEWORKS:	GRI	AZAPA GIC	FRM	E3PLUS	MCEP	MAC	IRMA	COVERAGE
ENVIRONMENTAL								
Spills	x			x				2
Hazardous material use	x	x		x				3
Acid mine drainage	x	x	x			x	x	5
Effluents to water	x	x	x	x			x	5
Water withdrawal	x	x	x				x	4
Overburden, tailings and other mine waste	x	x	x	x	x	x	x	7
Emissions to air	x	x	x	x			x	5
Biodiversity disturbance	x	x	x	x	x	x	x	7
Energy production and use	x	x	x			x		4
Mercury and cyanide use			x				x	2
Closure and rehabilitation	x	x	x	x		x	x	6
Land use		x						1
Land disturbance				x				1
Noise and other nuisance		x	x				x	3
SOCIAL								
Occupational health and safety	x	x	x	x	x	x	x	7
Labour/management relations (incl. collective bargaining)	x	x	x	x	x		x	6
Training and education	x	x		x	x		x	5
Child labour	x	x		x	x		x	5
Forced labour	x	x	x	x	x		x	6
Resettlement	x	x	x	x	x		x	6
Artisanal and small-scale mining	x		x	x				3
Indigenous land, culture and human rights	x	x		x	x		x	5
Human rights training	x			x	x		x	4
Community compensation, development and impact management		x	x	x	x		x	5
Community engagement	x	x	x	x	x	x	x	7
Security issues			x	x			x	3
Corruption and public policy	x	x		x	x		x	5

Table 10. *Indicator Framework Coverage*

ECONOMIC								
Employment	x	x					x	3
Salary and benefits	x	x		x			x	4
Government revenue	x	x						2
Procurement and suppliers	x	x					x	3
Local, gender and indigenous participation	x	x	x	x			x	5
Infrastructure investment	x	x					x	3
Ownership		x						1

Table 10. *Indicator Framework Coverage*

A compilation of selected indicators is found in the following tables.

ENVIRONMENTAL ISSUES	INDICATOR CATEGORY DESCRIPTION	ENVIRONMENTAL INDICATOR EXAMPLES
Hazardous material use and spills	The types and volumes of hazardous materials used, and the methods in existence for the safe storage of these substances. The presence of safeguards to ensure the minimization of the occurrence and magnitude of spills, and the methods in existence to ensure that spills are managed appropriately when they occur to minimize harm on the environment and human health.	**GRI:** • Materials used by weight or volume. • Percentage of materials used that are recycled input materials **Azapagic:** • Breakdown by type and the total amount of chemicals used. • Percentage of waste chemicals (processed or unprocessed) used from both internal and external sources.
Acid mine drainage	Pre-mining and operational practices to appropriately document and mitigate acid mine drainage in accordance with best available practices and technologies	**FRM:** • Companies should conduct adequate pre-mining and operational mine sampling and analysis for acid-producing minerals, based on accepted practices and appropriately documented, site-specific professional judgment.
Effluents to water	The volume, quality and destination of liquid effluents	**GRI:** • Total water discharge by quality and destination. **Azapagic:** • Total volume of tailings and disposal methods. • Percentage of permitted sites causing downstream and/or underground water quality problems relative to the total number of permitted sites. • Describe measures put in place to prevent acid main drainage, if applicable. • Describe measures put in place to prevent tailings dam(s) failure. • Breakdown of substances discharged with liquid effluents.

Table 11. *Mine-Level Sustainable Development Indicators on Environmental Issues*

Water withdrawal	Total amount of water that is withdrawn and the amount of this water that is reused relative to the availability of water from each water source.	**GRI:** • Total water withdrawal by source. • Water sources significantly affected by withdrawal of water. • Percentage and total volume of water recycled and reused.
Overburden, tailings and other mine waste	Total amount and type of non-saleable material extracted, including overburden, relative to saleable material. The disposal of hazardous and non-hazardous solid waste. Construction of tailings impoundments and waste rock dumps in a way that minimizes environmental and human health threats.	**GRI:** • Breakdown of the amount of each saleable primary resource extracted. • Total waste extracted (non-saleable material, including the overburden). • Percentage of the amount of saleable products relative to the total amount of material extracted. • Percentage of each resource extracted relative to the total amount of the permitted reserves of that resource. **Azapagic:** • Total hazardous and non-hazardous solid waste and breakdown by type and description of disposal methods. • Percentage of permitted sites that have a problem of land contamination relative to the total number of permitted sites.
Emissions to air	Significant air emissions by type (e.g., GHGs, ozone-depleting substances, NOx, SO_2, particles, heavy metals, dioxins, silica).	**GRI:** • Total direct and indirect greenhouse gas emissions by weight. • Other relevant indirect greenhouse gas emissions by weight. • Initiatives to reduce greenhouse gas emissions and reductions achieved. • Emissions of ozone-depleting substances by weight. • NO, SO, and other significant air emissions by type and weight. **Azapagic:** • Equivalent number of fully grown trees that would be required for sequestration of the total CO_2 emissions. • The amount of CO_2 emissions that can (theoretically) be sequestered by the trees planted by the company. • Net emissions of CO_2 (total CO_2 emissions minus CO_2 emissions potentially sequestered by trees). • Emissions of ozone-depleting substances, breakdown by substance. • Emissions of particles. • Toxic emissions (including heavy metals, dioxins, crystalline silica and others), breakdown by substance.
Biodiversity disturbance	Location and size of land in or adjacent to areas of high biodiversity value, and the number of IUCN Red List species with habitats in areas affected by operations. The activities used to identify areas of high conservation	**GRI:** • Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas.

Table 11. *Mine-Level Sustainable Development Indicators on Environmental Issues*

Biodiversity disturbance (cont.)	value, habitat protection and rehabilitation.	• Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas. • Amount of land (owned or leased, and managed for production activities or extractive use) disturbed or rehabilitated. • Habitats protected or restored. • Strategies, current actions, and future plans for managing impacts on biodiversity. • The number and percentage of total sites identified as requiring biodiversity management plans according to stated criteria, and the number (percentage) of those sites with plans in place. • Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk. **Azapagic:** • Description of the activities for habitat protection or rehabilitation.
Energy production and use	Direct and indirect energy consumption by primary and secondary energy sources by type (fuels including natural gas, diesel, LPG, petrol and other fuels; hydroelectricity, wind), and total energy production.	**GRI:** • Direct energy consumption by primary energy source. • Indirect energy consumption by primary source. • Energy saved due to conservation and efficiency improvements. • Initiatives to provide energy-efficient or renewable energy based products and services, and reductions in energy requirements as a result of these initiatives. • Initiatives to reduce indirect energy consumption and reductions achieved. **Azapagic:** • Breakdown by type of the amount of the primary energy used (including natural gas, diesel, LPG, petrol and other fuels). • Breakdown by type of the amount of the secondary energy (electricity and heat) used and exported. • Energy from renewable sources used and exported. • Total primary and secondary energy used. • Percentage of renewable energy used relative to total energy consumption.
Mercury and cyanide use	The use and management of cyanide and mercury, including capture and disposal methods, compliance with international codes and conventions, and third-party certifications.	**FRM:** • Mine operators should adopt the Cyanide Management Code, and third-party certification should be utilized to ensure that companies implement safe cyanide management.
Closure and rehabilitation	The presence and scope of closure plans, and a fund for mine closure and rehabilitation, including the mitigation of post-closure environmental and social impacts.	**GRI:** • Number and percentage of operations with closure plans. **Azapagic:** • Number of quarries/mines closed. • Number of sites rehabilitated. • Total land area rehabilitated.

Table 11. *Mine-Level Sustainable Development Indicators on Environmental Issues*

Closure and rehabilitation (cont.)		• Percentage of the land area rehabilitated relative to the total land area occupied by the closed mines/quarries, awaiting rehabilitation. • Number of awards for rehabilitation and a summary, if applicable. • Number of sites officially designated for biological, recreational or other interest as a result of rehabilitation. • Net number of trees planted (after thinning and after subtracting any trees removed for the extraction activities).
Land use	Total area of permitted developments and newly open for extraction activities.	**Azapagic:** • Total area of permitted developments (quarries/mines and production facilities). • Total land area newly opened for extraction activities (including area for overburden storage and tailings). • Percentage of newly opened land area relative to total permitted developments.
Land disturbance	Land management methods to prevent and control soil erosion, vegetation clearing, sedimentation, wetland impacts and other issues.	**e3Plus:** • Methods of erosion control. • Clearing of vegetation. • Soil conservation. • Managing drainagee and runoff. • Methods to control sediment.
Noise and other nuisance	The implementation of maximum noise level requirements, and the management of other nuances such as road dirt and dust and visual impact.	**Azapagic:** • Total number of external complaints related to noise, road dirt and dust, visual impact and other nuisance.

SOCIAL ISSUES	INDICATOR CATEGORY DESCRIPTION	SOCIAL INDICATOR EXAMPLES
Occupational health and safety	The presence and quality of health and safety policies and practices, including education and training. The prevalence of occupational accidents and diseases, and their fatality and human health impacts. Programs to for HIV/AIDS prevention and protection.	**GRI:** • Percentage of total workforce represented in formal joint management–worker health and safety committees that help monitor and advise on occupational health and safety programs. • Rates of injury, occupational diseases, lost days, and absenteeism, and number of work-related fatalities by region. • Education, training, counselling, prevention, and risk-control programs in place to assist workforce members, their families, or community members regarding serious diseases. • Health and safety topics covered in formal agreements with trade unions. **Azapagic:** • Percentage of hours of training regarding health and safety relative to the total number of hours worked. • Number of fatalities at work. • Lost-time accidents relative to the total hours worked.

Table 12. *Mine-Level Sustainable Development Indicators on Social Issues*

Occupational health and safety (cont.)		• Percentage of total absence-hours on health and safety grounds relative to the total hours worked. • Number of compensated occupational diseases.
Labour/ management relations (incl. collective bargaining)	The presence of collective bargaining agreements, worker organizations, freedom of association, formal complaint mechanisms, and appropriate policies on consultations and negotiations with employees. Frequency and duration of strikes and lockouts, and response to these by the management.	**GRI:** • Percentage of employees covered by collective bargaining agreements. • Minimum notice period(s) regarding operational changes, including whether it is specified in collective agreements. • Number of strikes and lockouts exceeding one week's duration, by country. **Azapagic:** • Ranking of the company as an employer in internal surveys. • Policy and procedures involving consultation and negotiation with employees over changes in the company (e.g., restructuring, redundancies etc.).
Training and education	The existence, quality and accessibility of training, skills management, lifelong learning programs and financially supported education to enhance the skillset of employees and improve the employability of these after career ending. The use and adequacy of performance and career development reviews.	**GRI:** • Average hours of training per year per employee by employee category. • Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career endings. • Percentage of employees receiving regular performance and career development reviews. **Azapagic:** • Percentage of hours of training (excl. health and safety) relative to the total hours worked (e.g., management, production, technical, administrative, cultural etc.). • Number of employees that are financially sponsored by the company for further education. • Summary of programs to support the continued employability of employees and to manage career endings.
Child labour	The existence of processes to identify operations that are at risk for incidents of child labour, and processes to identify non-compliance with ILO Convention 182.	**GRI:** • Operations identified as having significant risk for incidents of child labour, and measures taken to contribute to the elimination of child labour. **Azapagic:** • Specify any verified incidences of non-compliance with child labour national and international laws.
Forced labour	The existence of processes to identify operations that are at risk for incidents of forced labour, and processes to identify non-compliance with ILO Convention 29.	**GRI:** • Operations identified as having significant risk for incidents of forced or compulsory labour, and measures to contribute to the elimination of forced or compulsory labour. **Azapagic:** • Summary of the policy to prevent forced and compulsory labour as specified in ILO Convention No. 29, Article 2.

Table 12. *Mine-Level Sustainable Development Indicators on Social Issues*

Resettlement	Whether resettlement has taken place. If resettlement occurred, the number households affected, how livelihoods have been affected in the process, and whether appropriate compensation has been made to affected households.	**GRI:** • Sites where resettlements took place, the number of households resettled in each, and how their livelihoods were affected in the process. **Azapagic:** • Number of proposed developments that require resettlement of communities, with a description, if applicable.
Artisanal and small-scale mining (ASM)	The presence of artisanal and small-scale mining at or adjacent to the mining site, and actions taken to address associated risks. Efforts made to engage ASM workers and their communities to help them obtain legal status to be integrated within the formal sector, gain access to markets, and work in a more environmentally and socially sustainable fashion.	**GRI:** • Number (and percentage) or company operating sites where ASM takes place on, or adjacent to, the site; the associated risks and the actions taken to manage and mitigate these risks.
Indigenous land, culture and human rights	Whether operations take place in or adjacent to indigenous people's territories, formal policies that address the rights of these communities, and whether formal agreements have been reached with these communities. The occurrence of incidences where violations of indigenous rights have been committed and actions taken.	**GRI:** • Total number of operations taking place in or adjacent to Indigenous Peoples' territories, and number and percentage of operations or sites where there are formal agreements with Indigenous Peoples' communities. • Total number of incidents of violations involving rights of indigenous people and actions taken. **Azapagic:** • Number of proposed developments that require resettlement of communities, with a description, if applicable.
Human rights training	Training of employees, security forces and suppliers on human rights issues.	**GRI:** • Total hours of employee training on policies and procedures concerning aspects of human rights that are relevant to operations, including the percentage of employees trained. • Security practices. • Percentage of security personnel trained in the organization's policies or procedures concerning aspects of human rights that are relevant to operations.
Community compensation, development and impact management	The redistribution of revenues to communities in terms of compensation, community infrastructure and other community projects. The use of binding contracts that are enforceable through the national court system to secure these agreements.	**Azapagic:** • Summary of the policy for protection of land rights and for land compensation. • Summary a Community Sustainable Development Plan to manage impacts on communities in areas affected by its activities during the mine operation and post-closure. • Specify any community projects in which the company has been involved. • Total number of health and safety complaints from local communities, with a summary, if applicable.

Table 12. *Mine-Level Sustainable Development Indicators on Social Issues*

Community compensation, development and impact management (cont.)		• Percentage of revenues that are redistributed to local communities from the relevant areas of operation, relative to the net sales. • Investments into community projects (e.g. schools, hospitals, infrastructure) as percentage of net sales.
Community engagement	The approaches by which stakeholders are identified and engaged to help inform decision making with regards to the key topics of concerns in affected communities.	**GRI:** • Nature, scope, and effectiveness of any programs and practices that assess and manage the impacts of operations on communities, including entering, operating, and exiting. • Number and description of significant disputes relating to land use, customary rights of local communities and Indigenous Peoples. • The extent to which grievance mechanisms were used to resolve disputes relating to land use, customary rights of local communities and Indigenous Peoples, and the outcomes. **Azapagic:** • Summary of the policy for liaison with local communities. • Summary of the policy on stakeholder involvement, including the mechanisms by which stakeholders can participated in decision making on the issues that concern them.
Security issues	Methods by which management ensures that the use of security personnel respects human rights and promotes an environment that is conducive to conflict prevention and resolution.	**FRM:** • Companies should conduct an independent peace and conflict impact assessment to assess the risk of provoking or exacerbating violent conflict through their operations. Companies should avoid investing in areas where the risk of violent conflict is high (e.g., in areas of civil war or armed conflict).
Corruption and public policy	Policies, procedures and employee training to minimize the risk of bribery and corruption. Engagement in politics and policy via political contributions and lobbying.	**GRI:** • Percentage and total number of business units analyzed for risks related to corruption. • Percentage of employees trained in organization's anti-corruption policies and procedures. • Actions taken in response to incidents of corruption. • Public policy positions and participation in public policy development and lobbying. • Total value of financial and in-kind contributions to political parties, politicians, and related institutions by country. **Azapagic:** • Summary of the policy on addressing bribery and corruption that meets (and goes beyond) the requirements of the OECD Convention on Combating Bribery. • Summary of the policy for managing political contributions and lobbying.

Table 12. *Mine-Level Sustainable Development Indicators on Social Issues*

ECONOMIC ISSUES	INDICATOR CATEGORY DESCRIPTION	ECONOMIC INDICATOR EXAMPLES
Employment	Total workforce employment and type of employment (e.g., contractor, staff, consultant, full-time, part-time). Representation of workforce across age groups, gender and region.	**GRI:** • Total workforce by employment type, employment contract, and region. • Total number and rate of employee turnover by age group, gender, and region. • Benefits provided to full-time employees that are not provided to temporary or part-time employees, by major operations. **Azapagic:** • Net employment creation expressed as percentage contribution to employment in a region or country. • Employee turnover expressed as percentage of employees leaving company relative to the total number of new employee.
Salary and benefits	Total payroll costs and benefits, including health, pension, other benefits and redundancy packages). The range of ratios of standard entry-level wage compared to local minimum wage.	**GRI:** • Direct economic value generated and distributed, including revenues, operating costs, employee compensation, donations and other community investments, retained earnings, and payments to capital providers and governments. • Coverage of the organization's defined benefit plan obligations. **Azapagic:** • Health, pension and other benefits and redundancy packages provided to employees as percentage of total employment costs. • Ratio of lowest wage to national legal minimum, breakdown by country.
Government revenue	Amount of money paid to the government in the form of taxes and royalties.	**GRI:** • Direct economic value generated and distributed, including revenues, operating costs, employee compensation, donations and other community investments, retained earnings, and payments to capital providers and governments. • Significant financial assistance received from government. **Azapagic:** • Breakdown by country of the total sum of all types of taxes and royalties paid. • Fines paid for non-compliance (economic, environmental and social). • Amount of money paid to political parties and institutions whose prime function is to fund political parties or their candidates.
Procurement and suppliers	Spending on locally based suppliers, and the percentage of contracts that are paid in accordance with agreed terms.	**GRI:** • Policy, practices, and proportion of spending on locally based suppliers at significant locations of operation. **Azapagic:** • Percentage of contracts that are paid in accordance with agreed terms, with an explanation, if appropriate. • Percentage of local suppliers, relative to the total number of suppliers.

Table 13. *Mine-Level Sustainable Development Indicators on Economic Issues*

Local, gender and indigenous participation	Composition of work force and governance bodies per category according to gender, minority group membership, locality, indigenous and other indicators of diversity across all ranks of organization (senior level, middle management, entry-level).	**GRI:** • Composition of governance bodies and breakdown of employees per category according to gender, age group, minority group membership, and other indicators of diversity. • Ratio of basic salary of men to women by employee category. • Total number of incidents of discrimination and actions taken. • Procedures for local hiring and proportion of senior management hired from the local community at locations of significant operation. **Azapagic:** • Percentage of women employed relative to the total number of employees. • Percentage of women in senior executive and senior and middle management ranks. • Percentage of ethnic minorities employed relative to the total number of employees, with an explanation of how representative that is of the regional or national population makeup. • Percentage of ethnic minorities in senior executive and senior and middle management ranks. • Summary of the equal opportunity policy. • Percentage of sites with "fly-in, fly-out" operations relative to the total number of sites. • Percentage of employees sourced from local communities relative to the total number of employees.
Infrastructure investment	The development of infrastructure and services for public benefit provided through in-kind, commercial or pro bono engagement (e.g., schools, hospitals, community infrastructure, energy infrastructure).	**GRI:** • Development and impact of infrastructure investments and services provided primarily for public benefit through commercial, in-kind, or pro bono engagement. • Understanding and describing significant indirect economic impacts, including the extent of impacts. **Azapagic:** • Percentage of revenues that are redistributed to local communities from the relevant areas of operation, relative to the net sales. • Investments into community projects (e.g., schools, hospitals, infrastructure) as percentage of net sales.
Ownership	The ownership of shares among employees.	**Azapagic:** • Percentage of employees that are shareholders in the company.

Table 13. *Mine-Level Sustainable Development Indicators on Economic Issues*

3.5. CORPORATE REPORTING

The Global Reporting Initiative's (GRI's) Sustainability Reporting Guidelines and Mining and Minerals Sector Supplement are the central reporting frameworks for mining companies. With over 2,000 companies using the framework across a range of sectors, it is the leading and most widely accepted sustainability reporting and indicator system globally. Members of the ICMM, which represent 22 of the largest mining companies in the world, are required to report against the ICMM Sustainable Development Framework Principles in accordance with these GRI frameworks. Furthermore, national mining organizations such as the Minerals Council of Australia require that applicable companies commit to issuing public reports that may be self-selected from the GRI frameworks (KPMG, GRI & UNEP, n.d.). Governments may also encourage the uptake of GRI—for example, Canada's Corporate Social Responsibility (CSR) Strategy for the International Extractive Sector promotes the GRI guidelines to enhance transparency and encourage market-based rewards for sustainability performance. In 2012, 165 companies in the mining and metals sector reported against the GRI globally, representing a 50 per cent increase between 2009 and 2012. In addition, 48 per cent of these companies obtained external assurance for their sustainability reports in 2012.

Finally, there are a number of reasons for the growth in the uptake of sustainability reporting across sectors and in the mining sector in particular. In the context of the mining sector, a wide range of stakeholders, including investors, local communities, employees and host country governments are particularly interested in the environmental, economic and social performance of a company given that mining is an activity that can be particularly harmful if improperly controlled. Companies that are transparent about these practices can demonstrate a level of satisfactory performance to these stakeholders and thus benefit from enhanced corporate reputation, brand integrity, ease of recruiting and training, project financing, social license to operate and so on. There are also sources of competitive advantage that can be derived from greater operational efficiencies, as well as the generation of innovative processes. As a result, net operating cash flows and shareholder value can be improved.

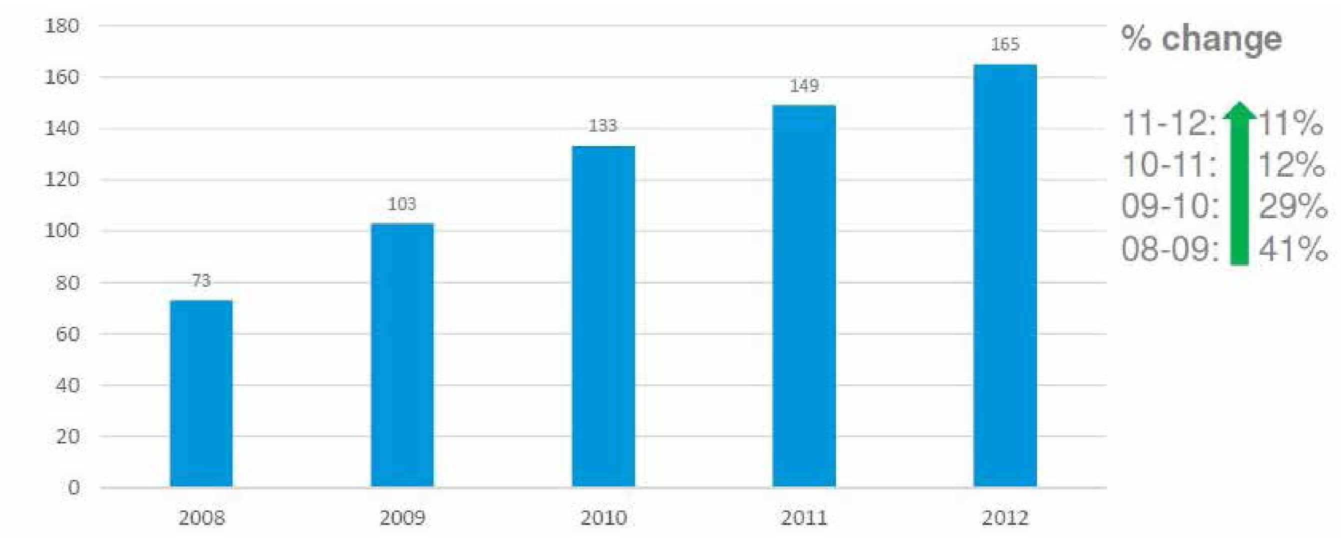


Figure 9. *GRI Mining and Metals Sector Reporting Trend (2008–2012)*
Source: Global Reporting Initiative (2013)

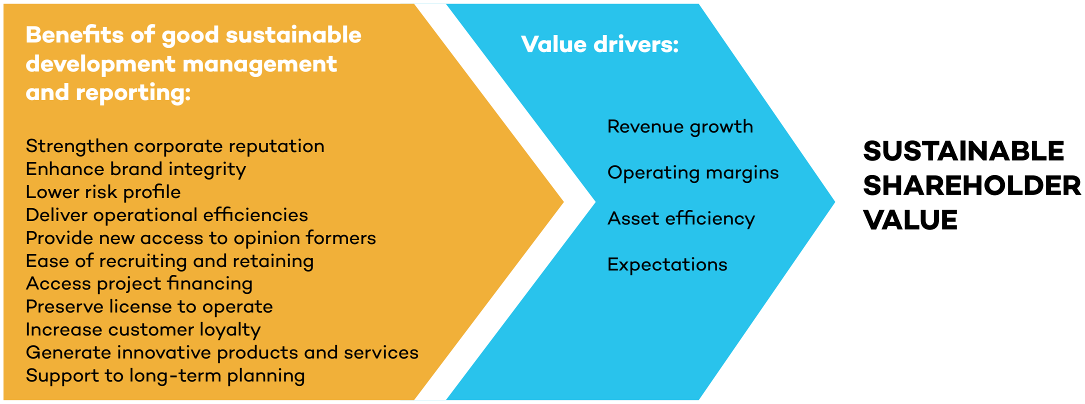


Figure 10. *The Corporate Value of Sustainability Practises and Reporting*
Source: Deloitte (2007).

3.6. SUSTAINABILITY PRACTICE AND REPORTING REQUIREMENTS AT THE COUNTRY LEVEL

A number of countries have shown leadership in the promotion of sustainable mining practices and reporting. Some of these countries are discussed below. At the intergovernmental level, the IGF's Mining Policy Framework (MPF) is being promoted as a comprehensive model that, if implemented, can allow the mining sector to make its maximum contribution to sustainable development in developing countries. In addition, the OECD's Policy Dialogue on Natural Resource-Based Development, which is part of the OECD's Strategy on Development, has aimed to foster knowledge sharing and learning among producing countries on how to ensure more inclusive and broad-based development in the extractive sectors.

Below, we provide examples of the state of sustainable development strategies, reporting and indicator systems of relevance to mining in leading countries. These governments have taken the initiative to explore important sustainable development issues in mining through formal committees and multistakeholder processes, formulate principles and criteria to reflect their approach, and, where needed, reform the regulatory environment. Most of these countries either have or are in the process of implementing monitoring systems and reporting requirements on the environmental, social and economic performance of mining.

Ecuador: In Ecuador, the Mining Law (2009) regulates the mining sector in accordance with the principles of sustainability, precaution, prevention and efficiency, and requires all holders of mining rights to maintain information on the consumption of materials, energy and water and other sustainability impacts (GRI, 2014a). The holders of mining rights must also present annual audits that verify environmental compliance. In addition, in accordance with the Ministerial Agreement 131, all state-owned companies are required to report annually on good environmental practices indicators. Every year, an award is given to the state-owned company that reduced environmental contamination by the largest percentage. Furthermore, all companies listed on the Guayaquil Stock Exchange are required to assess their contribution to sustainable development on an ongoing basis, based in part on environmental indicators taken from the GRI.

Indonesia: In Indonesia, Regulation No. 24/2012 (2012) regulates the energy and mining sectors and requires that any company in mineral or coal concessions provide four-month and yearly reports on environmental protection and community development (GRI, 2014b). In addition, in accordance with the State Owned Enterprise Minister Regulation No. SE-443/MBU/2003 (2003) and No. KEP-05/MBU/2007 (2007), all state-owned enterprises must report on environmental development, as well as partnership and community development programs in an audited report (GRI, 2014). Furthermore, Government Regulation no. 47/2012 (2012) states that Limited Liability Companies that have business activities related to natural resources have an obligation

towards social and environmental responsibility to be carried out by the Board of Directors (GRI, 2014b). It is required that information about the implementation of these practices is contained in the company's annual report. Similarly, publicly listed companies have to submit corporate social responsibility information on topics including environmental performance, and labour and community practices to the Capital Markets Supervisory Agency in accordance with Regulation No. KEP-431/BL/2012 (2012) (GRI, 2014b).

South Africa: In South Africa, the Sustainable Development Through Mining Program (SDM) was initiated by the Department of Mineral and Energy in 2004 to investigate how the mining industry can best contribute to a national and global transition to sustainable development. As part of this investigation, a set of indicators was developed to monitor mining's contribution to sustainable development (Department of Minerals & Energy, 2014). In compiling these indicators, the SDM reviewed frameworks including the MMSD reports, ICMM principles and the GRI. The Mineral and Petroleum Resources Development Act (2002) and its Amendment Bill (2012) require mining companies to disclose social and labour plans to governments and describe how the social impacts of their operations are to be addressed during and after operations (GRI, 2014c). Further, the Natural Environment Management Act (1998) requires an environmental impact assessment that is to be reported to the authorities. Companies listed on the Johannesburg Stock Exchange must produce an integrated report that details environmental and social performance, as per the King III Code (2009) on an "apply or explain" basis (GRI, 2014c).

India: In India, a high-level committee was initiated in 2005 to review the National Mineral Policy with the aim of introducing best practices in environment management and sustainable development for the mining sector (Government of India, 2012). After studying the sustainability impacts of mineral development and global trends in sustainable development, the Committee recommended the creation of a Sustainable Development Framework (SDF) that would take into account the work of, specifically, the ICMM and the IUCN, and would be composed of principles, reporting recommendations and good practice guidelines. As a document of the Indian Ministry of Mines, the SDF, released in 2011, is being driven forward by efforts to include some of its elements into regulation, undertake joint performance reviews against the SDF, and evaluate applications using additional criteria from the SDF for environmental and other issues.

Canada: In Canada, sustainable development in the mining sector has been an area of leadership for decades. In 2009, a Social License Task Group was assembled by national and subnational governments to develop an evidence-based evaluation model of the social, environmental and economic performance of the mining sector (Government of Canada, 2010). The indicators underlying this model were selected on the basis of international mining practice and the inputs of an external advisory committee, as well as the availability of data. Two reports have since been produced and presented to national and subnational mining ministers in 2010 and 2013 based on this framework.

Chile: In Chile, the Environmental Assessment Service, which is the agency responsible for assessing projects against the Environmental Act, has undertaken initial explorations of the prospect of using indicator systems to monitor the environmental impacts of the mining industry, using the DPSIR framework (Escobar Serrano, 2012). As a result of this investigation, it proposes that differentiating between Pressure and Impact indicators is an important element to incorporate within formal indicator systems. See Box 5.

Box 5. Chile's Environmental Assessment Service Exploration of Incorporating DPSIR within Formal Indicator Systems. Source: Escobar Serano (2012)

THE DPSIR INDICATOR SYSTEM IN THE DIRECT INFLUENCE AREA			
PRESSURE	**STATE**	**IMPACT**	**RESPONSE**
A1. Occupation of Land	Hectares of fertile soil and high mountain vegetation	Loss of high mountain vegetation Loss of wildlife habitat Death and displacement of wildlife. Reduction of landscape quality Disturbance of heritage sites	**Mitigation Measures** to reduce the impacts: 1) Relocation of wildlife, 2) Ex situ reproduction of vegetation and wildlife, 3) Maintaining genetic vegetation and wildlife, 4) Relocation of heritage sites. **Repair Measures** to repair the impact generated we find the Closure Plan of the mining project (restoring habitat).
A2. Atmospheric emissions (traffic activity, crushing stage, milling of ore, etc.).	Concentration of air pollutants.	Respiratory diseases. Loss of wildlife habitat Reduction of landscape quality	**Mitigation Measures** to reduce the pressures: 1) Domes airtight with negative pressure, 2) Hermetic conveyor belts, 3) Stabilization of roads, 4) Technology feedback, etc.
A3. Liquid industrial waste Dumping of rivers and groundwater	Concentration of pollutants in rivers and groundwater	Eventually disease people, wildlife and high mountain vegetation. Loss of wildlife habitat	**Mitigation Measures** to reduce the pressures: 1) Efficient Waterproofing Systems, 2) Containers for spillage, 3) Contingency systems.
A4. Noise emissions.	Concentration noise.	Discomfort and possible diseases. Loss of wildlife habitat	**Mitigation Measures** to reduce the pressures: 1) Install noise barriers, 2) Establish appropriate schedules
A5. Aggregate extraction.	Quantities and extraction surfaces.	Soil loss and habitat. Reduction of landscape quality	Mitigation Measure in order to reduce the pressure favoring underground mining and not open pit. Repair Measure in order to repair the impact generated is necessary to implement actions in the Closure Plan (reprofiling slope, ground cover and restore habitat)
A6. Cutting infrastructure (power lines, roads, water lines, etc.).	Landscape value Presence and number of species of wildlife	Reduction of landscape value Cut the biological wildlife corridor Loss of wildlife habitat	Mitigation Measures to reduce the pressure: 1) underground infrastructure, 2) Roads under the infrastructure to not interfere with the biological wildlife corridor. Repair Measures to repair the impacts, there should be a system of recognition and rehabilitation of affected wildlife.
A7. Extraction of groundwater.	The underground water level.	Decrease the underground water level. Shortage of water that sustains biodiversity sectors	Mitigation Measures to reduce the pressures: 1) infiltration systems and uncontacted water diversions, 2) desalination plants, 3) snow collection systems. Mitigation Measure to reduce the impacts is a Program to encourage rain. Repair Measures to repair the impact generated water is reinjected into the aquifer.

4. REVIEW OF INDICATORS FOR WATER, ENERGY AND FOOD SECURITY

Water, energy and food (WEF) security is a key component of sustainable development and, as such, is a way of operationalizing sustainable development in the context of a region, watershed or community. Building on our review of mining initiatives to incorporate sustainability, this section looks at identifying initiatives that have incorporate WEF security into indicator frameworks irrespective of sectoral activities (e.g., mining). This section reviews and contrasts these indicator systems, while providing illustrative samples of their indicators and high-level categories. WEF security is the third and final link in the causality chain linking the sustainability impacts of mining projects to their ultimate effect on WEF availability and access. Therefore, a key outcome of this chapter is to understand how WEF security itself is measured and monitored at the national, local and household levels. By understanding the context of a mining project on the one hand and WEF security on the other, policy-makers and business decision-makers will be better equipped to analyze and assess the links that join the two together.

While there exists a good number of previous initiatives that have explored assessment methods and indicators for the individual components of WEF security, there are limited examples of indicator systems and decision-support tools that consider the interlinkages across the three domains. The work of the Food and Agriculture Organization (FAO) of the United Nations has pursued the assessment and monitoring of the WEF security nexus in two different initiatives—these are summarized in Section 4.1. Examples of assessment methods and indictors for the individual water, energy and security components are featured in Sections 4.2 through 4.4.

4.1. INTEGRATED ASSESSMENT OF THE WEF NEXUS

The FAO (Flammini, Puri, Pluschke, & Dubois, 2014) has developed a WEF nexus assessment approach aiming to: 1) understand the interactions between water, energy and food systems in a given context; and 2) evaluate the performance of a technical or policy intervention in this given context. Ultimately, the approach developed by FAO informs the development of WEF security-related responses in terms of strategies, policies, planning and institutional support. The approach suggests using a stakeholder engagement process to define WEF-related goals at the appropriate level, with individual goals for water, energy and food. Sustainability aspects in individual water, energy and food systems are highlighted and interlinkages between them are defined. There key aspects are defined as follows:

Sustainable water:

- Access to water resources for different uses
- Sustainable use and management of water resources
- Societies and ecosystems that are resilient to water-related disasters

Sustainable Energy:

- Access to modern energy services
- Efficient use of energy
- Energy produced and consumed is clean/ renewable

Food Security:

- Food availability
- Food access
- Food utilization and nutrition
- Stability of food prices and supply

The indicators compiled under these different categories are listed in Tables 15, 16 and 17.

CATEGORY	INDICATORS
ACCESS TO MODERN ENERGY SERVICES	**Water pumping and groundwater management:** Percentage of annual freshwater withdrawals by sector; per capita renewable water resources; groundwater abstraction/exploitable groundwater; groundwater quality; salinity of groundwater. **Energy for clean drinking water:** Sources of drinking water (piped water, well water); water within 15 minutes; median time to water; desalinated water produced annually. **Water for power generation:** Cooling water required for conventional power plants; total hydropower capacity; ratio hydropower/total energy supply. **Irrigation systems:** Area equipped for power irrigation; % of area that is equipped for irrigation. **Water pollution by fossil energy use:** Contaminant discharges in liquid effluents from energy systems; oil discharges into coastal waters. **Households:** Percentage of households without electricity or commercial energy; % household income spent on fuel and electricity; % population with access to electricity; energy use per capita.
EFFICIENT USE OF ENERGY	**Energy efficient water technologies:** Productivity of irrigated agriculture; independence from imported water and goods; % renewable water stored in large dams; consumption rate of water; utilization of total hydropower capacity; ratio of hydropower to total energy supply; % people using different water pumping technology. **Irrigation systems:** Area equipped for power irrigation; % area equipped for irrigation that is power irrigated; % energy for transporting water for agriculture. **Management of water by utilities:** Percentage of water distribution losses by water utilities. **Water productivity in agriculture:** Cubic metres of water used per unit of value added by sector. **Household:** Household energy intensity.
CLEAN/ RENEWABLE ENERGY	**Dams and hydropower:** UJtilization of total hydropower capacity; ratio of hydropower to total energy supply; total dam capacity (national); primary production of renewable energy. **Bioenergy production:** Water withdrawn for processing feedstock and bioenergy; transport energy intensities; bioethanol and biodiesel production. **Fossil fuel pollutants:** Renewable energy share in national energy and electricity generation; % of increased access to modern energy services due to bioenergy. **Bioenergy competition with food and water use:** Pollutant loadings attributable to fertilizer and pesticide application for bioenergy feedstock production. **Energy for irrigation system:** Area equipped for irrigation drained; % total cultivated area drained; % total area equipped for full control surface irrigation drained. **Cross-cutting/high-level:** Percentage renewable energy/ total energy; fossil fuel energy consumption.
GENERAL INDICATORS OF SUSTAINABLE ENERGY	Percentage of people with improved water access (piped water); access to improved sanitation; annual freshwater withdrawals by sector; water pollution as % of BOD emissions; % improved sanitation facilities; investment in water sanitation; people affected by water-related diseases.

Table 14. *Water-Energy Security Nexus*
Source: Flammini, Puri, Pluschke & Dubois (2014)

CATEGORY	INDICATORS
ACCESS TO WATER RESOURCES FOR DIFFERENT USES	**Total allocation by sector:** Total water withdrawal (km^2/year) by agriculture, industry and municipality; agricultural, industrial and municipal withdrawals as % total water withdrawal; duration, magnitude, timing of deficiency in delivery of water demand. **Livestock production:** Livestock total per hectare of agricultural area (livestock/ ha); bacterial numbers and the presence of coliform organisms; feed-water productivity and feed conversion efficiency. **Inland fisheries and aquaculture:** Change in freshwater fish production (aquaculture and capture/yr); levels of ph; levels of alkalinity; nitrogen and phosphorous concentration **Economic water scarcity:** Rural population with access to water supply; % investment in irrigation/total public spending **Provision of clean and safe water for food preparation:** Percentage of population with access to improved water source (urban and rural); % population with access to an improved sanitation facility; population affected by water borne disease; number and % of population that is undernourished; % population using improved water technologies and sanitation facilities; household dietary diversity and number of meals per day; average household water usage/day.
SUSTAINABLE WATER MANAGEMENT	**Availability of freshwater resources for agriculture:** Precipitation in volume; internal renewable water resources; total actual renewable water resources; total actual renewable water resources per capita; dependency ratio. **Crop production:** Percentage of the cultivated area equipped for irrigation; value of irrigated output as share of total agricultural output; value of irrigated output as multiple of value of rain-fed output; % freshwater withdrawal as % total actual renewable water withdrawal; total groundwater abstraction/exploitable groundwater; brackish/saline groundwater at shallow and intermediate depths; area salinized by irrigation of total harvested irrigated crop area (ha); % salinized soils by irrigation/arable land; % area equipped for full control surface irrigation drained; use of agricultural pesticides and fertilizers (nitrogen, phosphate, potash); share of major ions, metals, nutrients, organic matter and bacteria in watershed. **Livestock production:** Concentration of nitrogen, ammonia and phosphorous; concentration of antibiotics in watershed. **Groundwater resources:** Actual renewable groundwater resources; actual groundwater entering and leaving the country; wastewater resources; direct use of treated municipal wastewater for irrigation purposes/total treated municipal waste water; direct use of agricultural drainage water; produced municipal wastewater; treated municipal wastewater. **Water desalination for irrigation:** Desalinated water production; desalinated water used for irrigation (km^2/ yr). **Land use:** Runoff co-efficient; net recharge rate of groundwater; erosion rate or sediment load in river/ upstream drainage area; net annual rates of conversion between land-use types caused directly by bioenergy feedstock production. **Water-forestry interactions:** Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production. **Social water stress:** Renewable water resources per capita (m^3) adjusted by HDI; relative social water stress index; share of food expenditure for the poor. **Water storage:** Total dam capacity; total dam capacity per capita; total exploitable water resources disaggregated by total regular and irregular renewable surface groundwater; water storage capacity per person.

Table 15. *Food-Water Security Nexus*
Source: Flammini, Puri, Pluschke & Dubois (2014)

RESILIENT SOCIETIES AND ECOSYSTEMS	**Water stress due to agriculture:** Total freshwater withdrawals by irrigated agriculture; surface and groundwater withdrawals for agriculture as % total renewable water resources; agricultural water security index; area salinized by irrigation. **Dependency on food imports:** Dependency ratio; cereal import dependency ratio; depth of food deficit. **Food prices increase during water-related disasters:** Domestic food price index; % water expenditure as total of household expenditure; domestic food price index of key food and non-food commodities. **Water governance:** Global corruption report in the water sector. **Climate change and agricultural water management:** Precipitation variability; total agricultural water managed area. Total area of agriculture; % area equipped for irrigation actually irrigated; area equipped for irrigation by type of irrigation (surface, sprinkler, localized); area that is potentially irrigable.
GENERAL INDICATORS OF SUSTAINABLE WATER	Average value of food production; average dietary energy supply adequacy; import quantity index of agricultural products; change in cropland use; area of land/soils under sustainable management; domestic food price volatility; per capita food production variability; per capita supply variability.

Table 15. *Food-Water Security Nexus*
Source: Flammini, Puri, Pluschke & Dubois (2014)

CATEGORY	INDICATORS
ACCESS TO MODERN ENERGY SERVICES	**Yields increase and income:** Energy used in agriculture and forestry; agricultural machinery, tractors in use in agriculture; direct on-farm energy consumption; direct use of fossil fuel energy in agriculture per unit value output. **Energy for irrigation and improved yields:** Energy for power irrigation in agriculture per agricultural production; energy consumed in fisheries per fish product production. **Increased yields on food prices:** Agricultural machinery, tractors in use; share of household income spent on fuel and electricity. **Food processing technology:** Household energy use for each income group and corresponding fuel mix; reduction of food loss/amount of energy used for food processing. **Cooking:** Forest area damaged by human activity: forest operations and other; % population using solid fuels; % households using traditional fuels (disaggregated by fuel). **Renewables:** Bioenergy used to expand access to modern energy services; total volume of removals from forests; woodfuel from forests in volume; MEPI Index. **Energy subsidies and high/stable yields:** Variation of production of the four main; crops/modern energy used in agriculture. **Underground water pumping:** Percentage of agricultural land classified as having moderate to severe water erosion or wind risk. **General:** Percentage of households without electricity or commercial energy, or heavily dependent on non-commercial energy; energy use (kg oil equivalent) per USD1,000 GDP.

Table 16. *Food-Energy Security Nexus*
Source: Flammini, Puri, Pluschke & Dubois (2014)

EFFICIENT USE OF ENERGY	**Agricultural productivity:** Change in yield/amount of modern energy used for farming; agricultural energy intensities; energy used in agriculture per gross agriculture production. **Energy efficient and economic return:** Economic value of food products/ reduction of use of non-renewable energy in agriculture. **Livestock production:** Size of "animal waste to energy" systems in the country. **Improved cooking efficiency:** Percentage of households with access to modern cooking energy. **New technologies and practices in agriculture:** Agriculture, value added of GDP. **Food transport:** Energy associated with transport of a national food basket.
CLEAN/ RENEWABLE ENERGY	**Energy bill:** End-use energy prices by fuel and sector; economic value of agricultural products; net energy imports; pump price of gasoline and diesel (USD/litre); direct on-farm energy consumption, per agricultural produce. **Bioenergy:** Woodfuel production by volume and value; land use and land-use change related to bioenergy feedstock production; % land used for new bioenergy production; bioethanol and biodiesel production; pump price for gasoline and diesel; total jobs in bioenergy sector. **Renewables:** Percentage of renewable energy used in agriculture as a proportion of total energy used in agriculture. **Wood energy:** Forest area damaged by human: forest operations and other; change in forest area over the last 10 years as a % of total forest area. **Delinking the food and energy markets:** Percentage of renewable energy used in agrifood system; change in consumption of fossil fuels and traditional use of biomass. **Fossil fuel energy consumption:** Primary production of renewable energy.
GENERAL INDICATORS OF SUSTAINABLE ENERGY	Average value of food production; share of food expenditure for the poor; domestic food price index; depth of food deficit; prevalence of food inadequacy; cropland per gross production value of agriculture; % people with access to improved water access; access to improved sanitation; domestic food price volatility; per capita food production variability; per capita food supply variability.

Table 16. *Food-Energy Security Nexus*
Source: Flammini, Puri, Pluschke & Dubois (2014)

Using an integrated analysis approach called the Multi-Scale Integrated Assessment of Society and Ecosystem Metabolism (MuSIASEM), the FAO has used three case studies to demonstrate how "flows" of food, energy, water and money are interconnected, and how these influence each other (Giampietro, et al., 2013). The three case studies include:

1. An analysis of the option to produce biofuel from sugarcane in the Republic of Mauritius. This country uses 78 per cent of its agricultural lands and 90 per cent of its water for producing sugar cane. Comparisons are made to another scenario in which Mauritius uses this land and water to produce food crops to improve self-sufficiency. It offers suggestions as to how these options would affect WEF security for the people of Mauritius.

2. An exploration of the future of grain production in the Indian state of Punjab. Punjab contributes 45 per cent of the wheat and 25 per cent of the rice to India's central food pool. The case study explores whether it may be desirable to reduce subsidies on electricity for groundwater pumping and minimum support prices for food grain purchases from farmers, from a WEF security perspective.

3. An assessment of two alternative energy sources to produce electricity in the Republic of South Africa. Concentrated Solar Power (CSP) was compared with wood biomass for electricity production in terms of their ability to meet demand for electricity consumption in place of fossil fuels.

4.2. WATER SECURITY INDICATORS

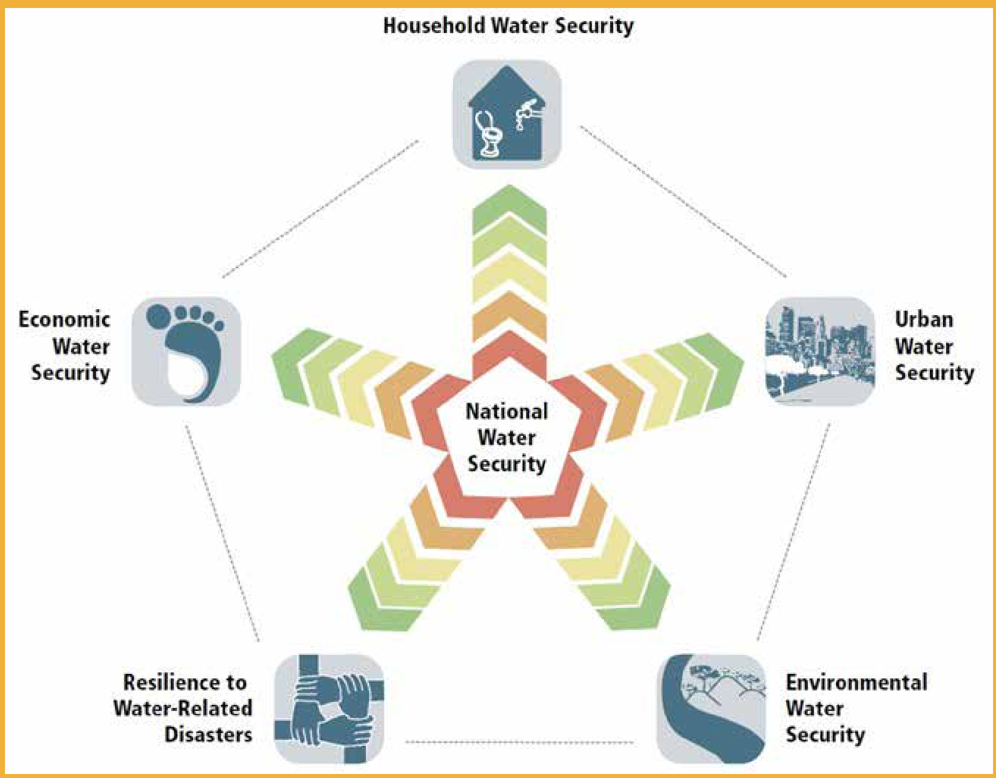
Water security is often seen as a multilevel construct, as it is a critical variable for development and human well-being across different societal functions. In particular, a society enjoys water security (Asian Development Bank, 2013) when it successfully manages water resources to:

- Satisfy household water and sanitation needs in all communities (drinking water, sanitation, hygiene).
- Support productive economies in agriculture, industry, and energy.
- Develop vibrant, livable cities and towns (water supply, wastewater treatment, drainage).
- Restore healthy rivers and ecosystems (watershed disturbance, pollution, water resource development, biotic factors).
- Build resilient communities that can adapt to change (exposure, vulnerability, coping capacities).

This five-dimensional framework recognizes the tensions between different uses of water (e.g., economic vs. household), but also contributes to building a shared vision by providing the basis for a comprehensive definition of water security.

The water tensions between development projects (i.e., mining) and residential communities can thus be seen in terms of the dynamics of competing uses for water between economic and household actors. The indicators underlying this framework are presented in Box 6.

Box 6. Water Security Indicators Across Five Dimensions



Household Water Security Indicators

- *Access to piped water supply (%)*
- *Access to improved sanitation (%)*
- *Hygiene (age-standardized disability adjusted life years per 100,000 people for the incidence of diarrhea)*

Economic Water Security Indicators

- *Productivity of irrigated agriculture*
- *Independence from imported water and goods*
- *Resilience (percentage of renewable water resources stored in large dams)*
- *Productivity (financial value of industrial goods relative to industrial water withdrawal)*
- *Consumption rate (net virtual water consumed relative to water withdrawn for industry)*
- *Utilization of total hydropower capacity*
- *Ratio of hydropower to total energy supply*

Resilience to Water-Related Disasters Indicators

- *Exposure (e.g., population density, growth rate)*
- *Basic population vulnerability (e.g., poverty rate, land use)*
- *Hard coping capacities (e.g., telecommunications development)*
- *Soft coping capacities (e.g., literacy rate) Urban Water Security Indicators*
- *Water supply (%)*
- *Wastewater treatment (%)*
- *Drainage (measured as the extent of economic damage caused by floods and storms)*

Environmental Water Security Indicators

- *Cropland*
- *Imperviousness*
- *Livestock density*
- *Wetland disconnection*
- *Soil salinization*
- *Nitrogen*
- *Phosphorous*
- *Mercury*
- *Pesticides*
- *Total suspended solids*
- *Organic loads*
- *Potential acidification*
- *Thermal impacts from power plant cooling*
- *Dam density*
- *River network fragmentation*
- *Relative water consumption compared to supply*
- *Agriculture sector water stress*
- *Residency time change downstream from dams*
- *Non-native species*
- *Catch pressure*
- *Aquaculture*

Source: Asian Development Bank (2013)

Water security is also sometimes referred to as a way to articulate the role of water in national and international peace and stability due to its transboundary nature and significance as a "fugitive resource" (UNEP, 2006). However, it also extends to how a country manages its own water resources to achieve stability and economic development (Mason & Calow, 2012). In regions with uneven temporal and spatial distribution of water, supports such as water storage, hydraulic infrastructure, distribution and groundwater availability are especially salient determinants of economic growth and well-being.

In order to account for the dynamics of different environmental, climatic, and societal pressures and feedbacks that affect water security, some indicator systems differentiate between drivers and pressures (e.g., Driver-Pressure-State-Impact-Response frameworks, Pressure-State-Response frameworks). In doing so, users are better able to identify and monitor cause and effect relationships (Global Water Partnership, 2014). In addition, using integrating water indicators helps ensure that key resources and processes are taken into consideration and prevents the occurrence of unintended consequences from a more siloed approach (Global Water Partnership, 2014).

WATER STRESS	COPING CAPACITY	
	LOW	**HIGH**
LOW	**Water security issues:** • Vulnerability to floods • Pollution • Increasing need for water and sanitation services **Increasing water security through:** • Development of an appropriate stock of infrastructure (storage, flood control, etc.) • Proper legislation and adequate institutions • Integrated and comprehensive water planning	**Water security issues:** • Mitigate for past, present and future pollution • Ecosystems need for water • Legal frameworks ensuring access for all **Increasing water security through:** • Effective legal frameworks at a range of scales • Economic incentives • Ethical management
HIGH	**Water security issues:** • Water demand growing fast • Water availability falling to crisis level • Overexploitation of groundwater • Shortages compounded by pollution • Low efficiency of irrigation • Vulnerability to floods/droughts **Increasing water security through:** • Optimal mix of increasing supply and managing demand • Strengthening the institutional capacities and adopting a more cohesive and integrated legal framework • Developing appropriate mechanisms for inter-sectoral water allocation	**Water security issues:** • Declining water resources • Pollution abatement • Environmental requirements • Conflicts of use **Increasing water security through:** • Water conservation and reuse • Sustainable policies and legal frameworks and institutions for water management and dispute prevention and resolution • Strengthening waste water and pollution control through enforceable legal and institutional mechanisms

Table 17. *Water Security Matrix*
Source: Ait-Kadi and Arriens (2012)

When dealing with household water security in communities affected by natural processes such as climate change or human activities (e.g., mining), there are two factors that precede all others in their importance: 1) water stress and 2) capacities to cope with changes. Thus a community water security matrix can be developed (Table 17).

At a higher level, UN-Water tracks the performance of the "water sector from the perspective of a sustainable development objective." It proposes to classify water indicators as "context indicators," "functioning indicators" and "governance indicators." Through a joint assessment of these dimensions, it suggests that a construction of "performance indicators" can be achieved (UN-Water 2009).

In the specific context of mining, the water system may be impacted in different ways depending on the stage of the mining project, raising the need for different indicators across these stages (Miranda & Sauer, 2003). The most serious of these water impacts occur in conjunction with toxic waste disposal and water consumption at the extraction and processing phases (Miranda & Sauer, 2003). Where water issues are divided into water quality and water quantity concerns, water quality is thought to be the most significant. The mining industry is a relatively small user of water when compared to other sectors like agriculture

CATEGORY	DESCRIPTION	SAMPLE INDICATORS
CONTEXT	These indicators relate to the natural context (e.g. water availability, rainfall), to infrastructure (such as water treatment capacity, or storage), or to human and economic capitals.	• Precipitation • Surface water actual • Groundwater recharge • Storage capacity • Irrigation area
FUNCTIONING	Functioning relates to inputs, outputs and outcomes (e.g. water use intensity). These indicators relate to describing the dynamic functioning of the water sector at the national level (e.g. water withdrawals, water depletion or wastewater actually treated).	• Total water withdrawals • Desalination production • Water demand per sector • Population connected to drinking water/ sewage • Water quality (nitrate)
GOVERNANCE	These indicators track the possible explanations behind the different levels of performance achieved between a given territory and different benchmark territories. The breadth of governance indicators must embrace territorial water resources and water uses management to provide an insightful diagnosis of possible weak spots in need of further investigation and possible improvement or reforms.	• Water is mainstreamed in development policies • Formal involvement of stakeholder groups • Water resource issue assessment • Regulatory instruments and enforcement • Capacity development of government staff
PERFORMANCE	These indicators add an element of evaluation. Performance assessment relates to considering the functioning of the sector in relation to its objectives and within a given context. Issues of efficiency/productivity, effectiveness and impact can be considered (e.g. access to water supply and sanitation or value added in agriculture or industry).	• Population with access to improved water sources/ sanitation • Changes in agricultural water productivity • Threatened freshwater species • Change in hydropower

Table 18. *Categories of Indicators to Understand the Water Sector*
Source: UN-Water (2009)

STAGE	POTENTIAL ISSUES
Exploration (surveying, drilling, trench blasting, camp and road construction, mine construction)	• Sediment runoff, increased suspended sediment load to surface waters • Spills of fuels and other contaminants
Mineral extraction (blasting, ore stockpiling, waste pilling)	• Chemical contamination of surface and ground waters • Toxicity impacts to organisms (terrestrial and aquatic plants and animals) • Altered landscapes from mine workings (e.g., open pits, changes in stream morphology) Increased erosion and siltation • Altered patterns of drainage and runoff • Water consumption: dust suppression, mine camps, evaporative losses from clean water storage dams, water used to cool equipment • Decreased groundwater resources due to dewatering pits • Reliance on power from water-dependent sources (hydro and thermal)
Processing (mining, smelting, refining)	• Discharge of chemicals and other wastes to surface waters • Water consumption: water used in mineral separation and benefication, slurry lines • Reliance on power from water-dependent sources (hydro and thermal)
Mine-closure/post-operation (revegetation, fencing, monitoring seepage)	• Persistent contaminants in surface and groundwaters • Long-term water treatment • Persistent toxicity to organisms • Permanent landscape changes

Table 19. *Summary of Water-Related Issues at Different Mining Stages*
Source: Miranda and Sauer (2003)

and residential consumption. Water consumption occurs when ores are ground to separate minerals from the rock; when materials are washed and transported; to control dust; and to cool machinery (Miranda & Sauer, 2003). Water quality is affected through: 1) waste rock and ore stockpiles, which, being left uncovered, are a source of acid mine drainage; and 2) tailings, which can leach into groundwater or contaminate surface water following an impoundment breach or the intentional or unintentional release of tailings into nearby streams (Table 20).

Finally, some indicator systems integrate water with food security to account for the interconnections between these systems (Parris, Way, Metzler, Cicone, Manley, & Metzler, 2002). Precipitation and vegetation dynamics, for instance, are highly correlated and can be used to identify the risk and likelihood of food emergencies as a result of drought or other related conditions that affect the food system (Parris, et al., 2002). Water balance, which can be narrowly defined as the difference between local water supply and demand or the flow of water in and out of a system, is also related to food balance. Additionally, using the World Bank's six indicators of "good governance," it has been shown that measures of good governance account for about 80 per cent of the capacity of people to overcome challenges related to short-term stressors and food emergencies. This integrated approach to water and food system monitoring has also been promoted in an Arctic context, especially with regards to food safety and water quality (Nilsson & Evengard, 2013).

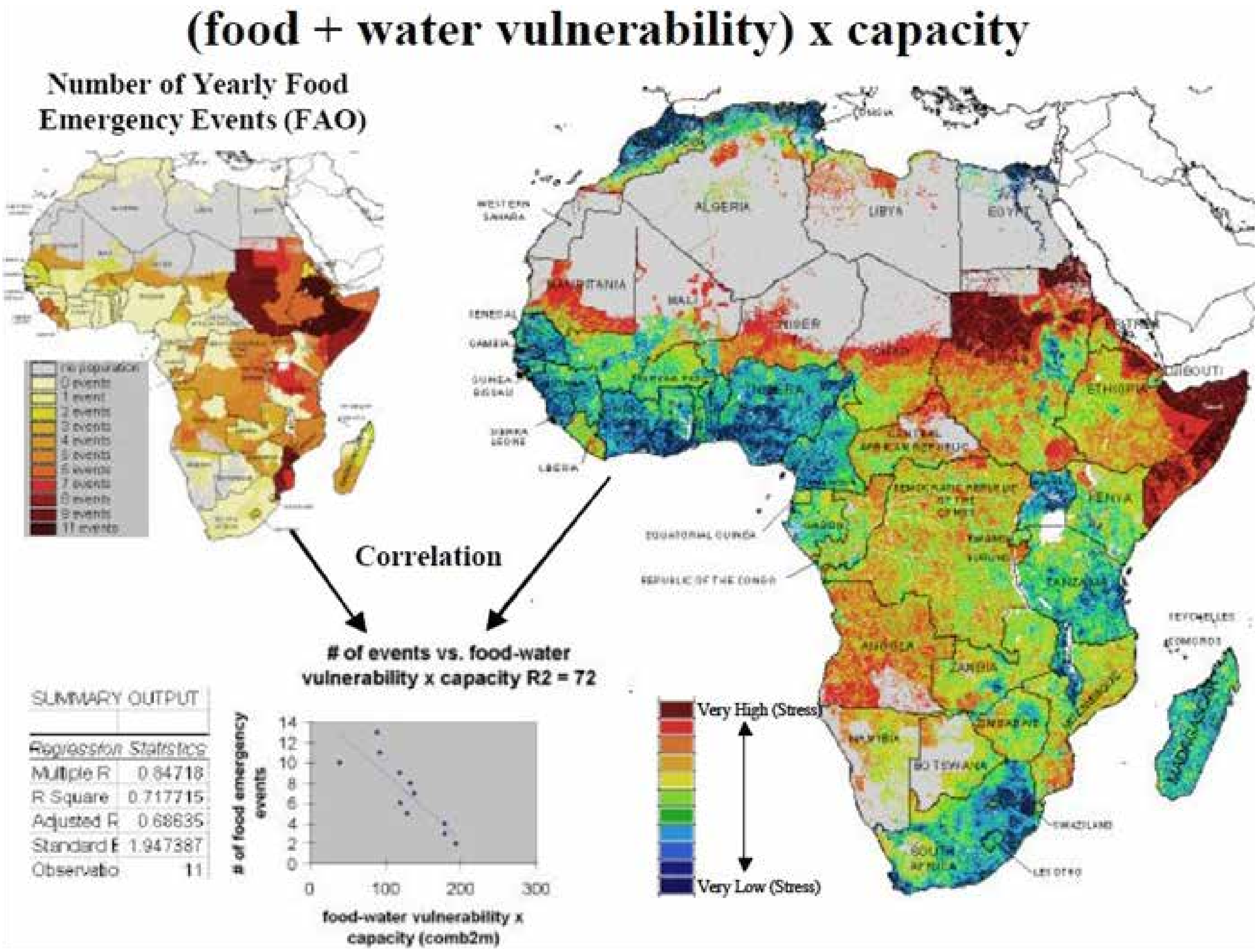


Figure 11. *Water Indicators are Correlated with Food Indicators*
Source: Parris et al. (2002)

4.3. ENERGY SECURITY INDICATORS

Energy security is traditionally thought of as a national and human security concern, having emerged in the first half of the 20th century as a concern over the secure supply of fuel for armies and naval fleets (Cherp, et al., 2012). Today, energy security is associated with the need to ensure sustainable energy production, stable supplies and control price volatility. The latter of these issues is especially harmful to developing countries, where short blackouts can lead to major economic losses. At the household level or individual level, energy security is attained through sufficient access to modern cooking fuels and at least the bare minimum of electric lighting for reading or other household and productive activities. As an individual in rural areas or developing moves through the energy ladder, from more simple and traditional fuels such as animal power, candles and wood, to more advanced fuels like electricity and refined gasoline, he/she becomes increasingly energy secure at least in terms of energy quality (Sovacool, 2013b). Thus households and countries (as aggregates of households) typically move from energy systems supporting basic human needs to those supporting more sophisticated activities constituting modern society as experienced in industrialized countries (UNDP, 2010).

The International Energy Agency (IEA) and the International Atomic Energy Agency (IAEA) developed a set of indicators for sustainable energy development (ISED) that assessed the multiple aspects of energy security both at the household and national levels (IEAE/IEA, 2005). Some of the most important impacts resulting from poor energy security—aside from economic losses—relate to household health. There are ongoing concerns related to: indoor air pollution that results from using rudimentary cooking fuels (dung, charcoal, firewood); physical injury from fuelwood collection; and poor refrigeration and medical care where there is a lack of electricity. One important indicator is the extent of disparity among households, for example, between rich and poorer households.

At the national level, concerns for energy security put in focus high-level indicators such as the diversification of an energy mix and the dependency of imported sources of energy (Sovacool, 2013b).

LEVEL 1

BASIC HUMAN NEEDS

Electricity for lighting, health, education, communication and community services (50-100 kWh per person per year)

Modern fuels and technologies for cooking and heating (50-100 kgoe of modern fuel or improved biomass cook stove)

LEVEL 2

PRODUCTIVE USES

Electricity, modern fuels and other energy services to improve productivity:

- Agriculture: water pumping for irrigation, fertilizer, mechanized tilling
- Commercial: Agricultural processing cottage industry
- Transport: fuel

LEVEL 3

MODERN SOCIETY NEEDS

Modern energy services for many more domestic appliances, increased requirments for cooling and heating (space and water), private transportation (electricity usage is around 2000 kWh per person per year)

Figure 12. *Incremental Levels of Energy Services and Access*
Source: UNDP (2010)

Mining projects can affect energy security by electrifying and catalyzing energy infrastructure developments in rural areas. Further, the foreign exchange gained through mineral exports can help improve the ability to purchase energy commodities from abroad.

SECTOR	ENERGY SERVICE	DEVELOPING COUNTRIES			DEVELOPED COUNTRIES
		LOW-INCOME HOUSEHOLDS	MIDDLE-INCOME HOUSEHOLDS	HIGH-INCOME HOUSEHOLDS	
Household					
	Cooking	Wood (includes wood chips, straw, shrubs, grasses, and bark): charcoal; agricultural residues: and dung	Wood, residues, dung, kerosene, and biogas	Wood, kerosene, biogas, liquefied petroleum gas, natural gas, electricity, coal	Electricity, natural gas
	Lighting	Candles and kerosene (sometimes none)	Candles, kerosene, paraffin, and gasoline	Kerosene, electricity, and gasoline	Electricity
	Space heating	Wood, residues, and dung (often none)	Wood, residues, and dung	Wood, residues, dung, coal, and electricity	Oil, natural gas, or electricity
	Other appliances	None	Electricity, batteries, and storage cells	Electricity	Electricity
Agriculture					
	Tilling or plowing	Hand	Animal	Animal, gasoline and diesel (tractors and small power tillers)	Gasoline and diesel
	Irrigation	Hand	Animal	Diesel and electricty	Electricity
	Post-harvest processing	Hand	Animal	Diesel and electricty	Electricity
Industry					
	Milling and mechanical	Hand	Hand and animal	Hand, animal, diesel and electricity	Electricity
	Process heat	Wood and residues	Coal, charcoal, wood and residues	Coal, kerosene, wood, residues, and electricity	Coal, napthene, electricity
Primary Technologies					
		Cookstoves, three stone fires, lanterns	Improved cookstoves, biogas systems, solar lanterns, incandescent and compact fluorescent light bulbs	Improved cookstoves, biogas systems, liquefied petroleum gas, gas and electric stoves, compact fluorescent light bulbs, light emitting diodes	

Table 20. *The Energy Ladder. Source: Sovacool (2013a)*

CATEGORY	THEME	INDICATORS
SOCIAL	Accessibility	• Households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy • Total number of households or population
	Affordability	• Household income spent on fuel and electricity • Household income (total and poorest 20% of population)
	Disparities	• Energy use per household for each income group (quintiles) • Household income for each income group (quintiles) • Corresponding fuel mix for each income group (quintiles)
ECONOMIC	Overall use	• Energy use (total primary energy supply, total final consumption and electricity use) • Total population
	Production	• Proven recoverable reserves • Total energy production • Total estimated resources • Total energy production
	End use	• Energy use in industrial sector and by manufacturing branch • Corresponding value added • Energy use in agricultural sector • Corresponding value added • Energy use in service/commercial sector
		• Corresponding value added • Energy use in households and by key end use • Number of households, floor area, persons per household, appliance ownership • Energy use in passenger travel and freight sectors and by mode • Passenger-km travel and tonne-km freight and by mode
	Prices	• Energy prices (with and without tax/subsidy)
	Imports	• Energy imports • Total primary energy supply
	Strategic fuel stocks	• Stocks of critical fuel (e.g., oil, gas, etc.) • Critical fuel consumption
ENVIRONMENTAL	Climate change	• Greenhouse gas emissions from energy production and use • Population and GDP
	Air quality	• Concentrations of pollutants in air • Air pollutant emissions
	Water quality	• Contaminant discharges in liquid effluents
	Soil quality	• Affected soil area • Critical load
	Forest	• Forest area at two different times • Biomass utilization

Table 21 *IEAE/IEA Indicators for Sustainable Energy Development*
Source: IEAE/IEA (2005)

ENVIRONMENTAL (CONT.)	Solid waste generation and management	• Amount of solid waste • Energy produced • Amount of solid waste properly disposed of • Total amount of solid waste • Amount of radioactive waste (cumulative for a selected period of time) • Energy produced • Amount of radioactive waste awaiting disposal • Total volume of radioactive waste

Table 21. *IEAE/IEA Indicators for Sustainable Energy Development*
Source: IEAE/IEA (2005)

DIMENSION	COMPONENT	METRIC	UNIT	DEFINITION
Availability	Security of supply	Total primary energy supply per capita	Thousand tons of oil equivalent (ktoe)	Total primary energy supply comprises the production of coal, crude oil, natural gas, nuclear fission, hydroelectric, and other renewable resources plus imports less exports, less international marine bunkers and corrected for net changes in energy stocks
	Production	Average reserve to production ratio for the three primary energy fuels (coal, natural gas, and oil)	Remaining years of production	Ratio of proven recoverable reserves at the end of a given year to the production of those reserves in that year
	Dependency	Self sufficiency	% energy demand by domestic production	Percentage of total primary energy supply divided by total primary energy consumption
	Diversification	Share of renewable energy in total primary energy supply	% of supply	Share of geothermal, solar, wind, hydroelectric, tidal, wave, biomass, municipal waste, and biofuel based energy in total primary energy supply
Affordability	Stability	Stability of electricity prices	% change	Percentage that retail electricity prices have changed every five years
	Access	% population with high quality connections to the electricity grid	% electrification	Combined percentage of urban and rural electricity customers with reliable grid connections compared to all people in the country
	Equity	Households dependent on traditional fuels	% of population using solid fuels	Percentage of the population that relies on solid fuels as the primary source of domestic energy for cooking and heating. Solid fuels include biomass, wood, charcoal, straw, crops, agricultural waste, dung, shrubs and coal
	Affordability	Retail price of gasoline/petrol	Average price in USD PPP for 100 l of regular gasoline/petrol	Actual prices paid by final consumers for ordinary gasoline inclusive of all taxes and subsidies

Table 22. *Dimensions, Components and Metrics Comprising National Energy Security*
Source: Sovacool (2013a)

Technology development and efficiency	Innovation and research	Research intensity	% government expenditures on research and development compared to all expenditures	Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development
	Energy efficiency	Energy intensity	Energy consumption per Dollar of GDP	Total primary energy consumption in British Thermal Units per Dollar of GDP (2005 US dollars PPP)
	Safety and reliability	Grid efficiency	% electricity transmission and distribution losses	Electric power transmission and distribution losses include losses in transmission between sources of supply and points of distribution and in the distribution to consumers, including pilferage
	Resilience	Energy resources and stockpiles	Years of energy reserves left	Reserves of coal, oil, gas and uranium divided by total final energy consumption
Environmental sustainability	Land use	Forest cover	Forest area as percent of land area	Forest area is land under natural or planted stands of trees of at least 5 min situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.
	Water	Water availability	% population with access to improved water	Improved sources include household connections, public standpipes, boreholes, protected wells, and/or spring and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 l a person a day within 1 km of dwelling
	Climate change	Per capita energy-related carbon dioxide emissions	Metric tons of CO_2 per person	Annual tons of sulfur dioxide emissions from fuel combustion divided by total national population
	Pollution	Per capita sulfur dioxide emissions	Metric tons of SO_2 per person	Mean score given for the six categories of accountability, political stability, government effectiveness, regulatory quality, rule of law, and corruption
Regulation and governance	Governance	Worldwide governance rating	Worldwide governance score	Total value in USD of net exports of coal (including coke and briquettes), crude petroleum, and natural gas (including liquefied natural gas)
	Trade and connectivity	Energy exports	Annual value of energy exports in 2009 USD PPP — (billions)	Total government expenditures on direct and indirect energy subsidies divided by the national population
	Competition	Per capita energy subsidies	Cost of energy subsidies per person (2009 USD PPP)	% of data points complete for this index out of all possible data points
	Information	Quality of energy information	% data complete	

Table 22. *Dimensions, Components and Metrics Comprising National Energy Security*
Source: Sovacool (2013a)

4.4. FOOD SECURITY INDICATORS

The Rome Declaration on World Food Security, which formed the basis of the first Millennium Development Goals, defined food security as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This definition was reconfirmed at the World Summit of Food Security in 2009, and extended to include the four pillars of food security: "availability, access, utilization and stability" (FAO, 2009).

A systematic review of food security interventions suggests that household food access is determined by a combination of its food production, household income and household assets such as food stocks and capital which may serve as buffers when the food system is in periods of stress (Ministry of Foreign Affairs of the Netherlands, 2011). At the local and national levels, food availability determines the ability of households to procure sufficient quantities of food as long as the price of these commodities is affordable. Further, an extensive list of indicators was compiled and reviewed to measure the

CATEGORY	INDICATORS
Food utilization	• % population malnourished • % children under five years malnourished • % child mortality under five years
Food access	• % of population meeting energy requirements • % eating three meals/day • Average energy intake
Food access stability	• % households being food secure all year • Number of months per year that households declare being food secure
Household income, purchasing power	• % living above/below poverty threshold • Average annual income • Average annual farm income
Household food production	• % households producing sufficient food • Staple food production
Food price	• % increase in food price • Food price relative to wages
Household buffer	• Buffer food stock, above a minimum stock • Buffer capital or assets
Production	• Yield (kg/ha)
Value chain	• On-farm added value • Off-farm added value
Market regulation	• Price difference producers (rural)/consumers (urban) • Farmer use of inputs
Land security	• Number of farmers with certificates • Area certified • % of farmers renting out land • % of farmers renting in land

Table 23. *Indicators to Measure the Determinants of Security across Many Aspects of the Food System*
Source: Ministry of Foreign Affairs of the Netherlands (2011)

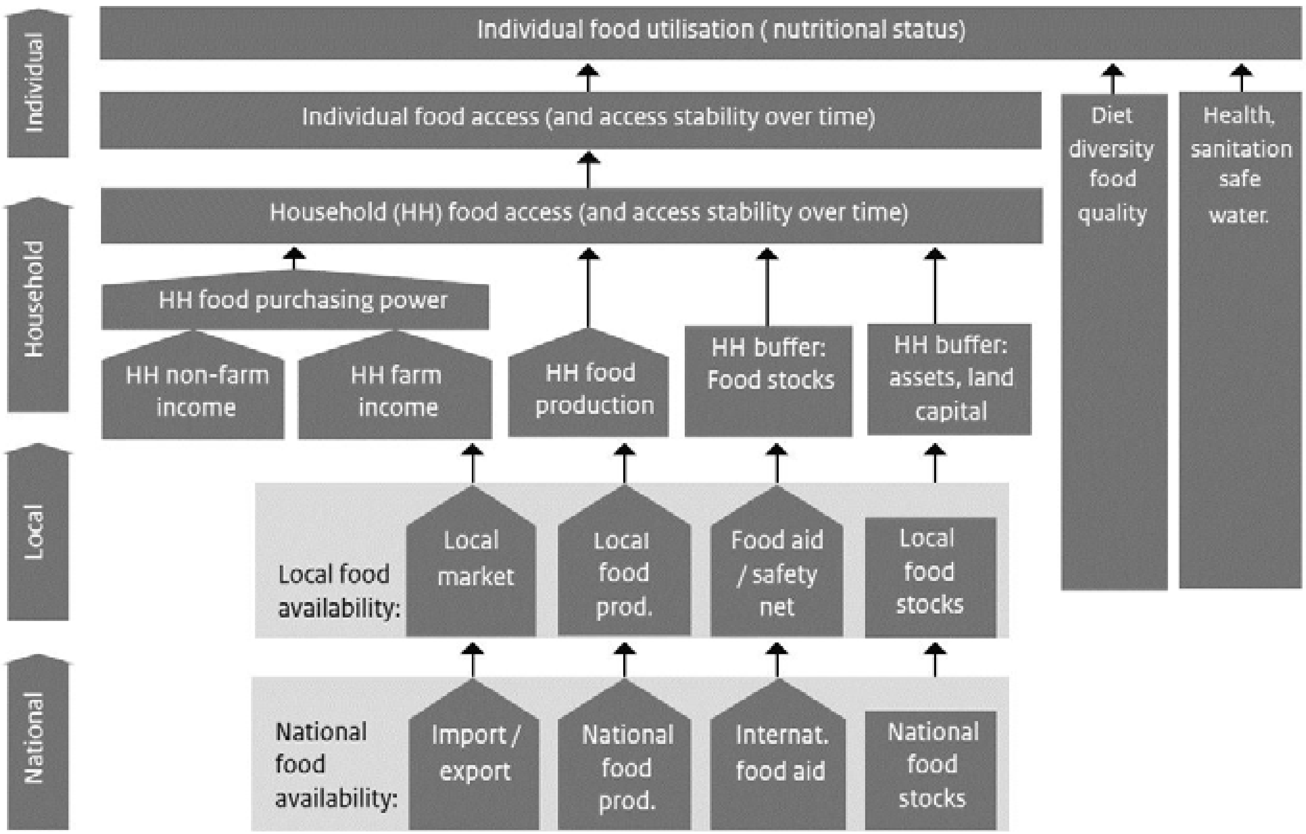


Figure 13. *Linkages Between Levels and Food Security Components*
Source: Ministry of Foreign Affairs of the Netherlands (2011)

determinants of security across many aspects of the food system as contained in studies published in English and French between 2001 and 2011 (Table 23).

A report by FAO suggests a need to organize indicators in three different analytical categories to represent the different levels of an evaluation (Aurino, 2014). As illustrated in Figure 13, the first category aims to provide a high-level synthesis, yet still a comprehensive snapshot of food security at the national level through a core set of indicators. This first set of indicators facilitates the comparability of indicators across different countries or points in time. The second category aims to provide a list of factors that serve as key determinants and underlying causes of the food security status, thus shedding light on possible actions or points of intervention to improve food security. The third and final category aims to capture the structural conditions of food security through input indicators that help shed light on the policy framework supporting food security.

Because food, along with water, is such a basic component of life, risk analysis and early warning indicators are also important components of a food security monitoring system (Kaaria, Mikkelsen, Mwanundu, & Slaviero, 2012). These allow for the detection of phenomena that can negatively impact food security and monitor their occurrence over time. These indicators fall under three categories (Kaaria, Mikkelsen, Mwanundu, & Slaviero, 2012) as described below and in Table 24.

	FAO/CFS INDICATORS TO MONITOR FOOD SECURITY AT COUNTRY LEVEL (KEY INDICATORS FOR MONITORING)	UNDERLYING DETERMINANTS What are the direct, or proximate causes of low performance in each dimension? (INDICATORS FOR ACTION AND MODELING)	STRUCTURAL CONDITIONS What are the underlying, distal, causes of food insecurity in each dimension? (INDICATORS FOR IN-DEPTH COUNTRY FS ASSESSMENT)
AVAILABILITY Physical supply of food from all possible sources (i.e. production, net imports, food aid, etc.)	Dietary Energy Supply, DES *(kcal/ per person/ per day)* Share of dietary energy supply from staples (cereals and starchy roots), %	PRODUCTION: Cereal yields, hg/ha Livestock production index Agricultural spending in R&D, % *Agricultural GDP* TRADE: Food imports, % *merchandise exports* Aid per capita, *ton/ per person*	Metereological data Natural resources (eg. agricultural land ppm water...) Inputs agricultural production (eg. fertilisers use, pest management, extension services...) Agricultural spending, % *GDP*
ACCESS Physical, economic, and social ability to acquire adequate amounts of food through a combination of different sources (i.e. own stocks, home production and collection, purchases, barter, gifts, borrowing, remittances, aid, etc.).	Prevalence of Undernourishment, *PoU, %* Share of food expenditure in total expenditure for the 20% poorest households, % Perceived food insecurity, %	PHYSCIAL: Road density, *(km of roads per 100 sq. km of land)* ECONOMIC: Relative level of consumer prices Food prices volatility GDP per capita, *PPP* Employment to population ratio, 15+, total *(%)* SOCIAL: Under five mortality rate, % *1000*	Infrastructure (storage facilities, roads...) Governance and civil security Information on markets Economic performance (economic growth, unemployment...) Social Protection expenditure, % *GDP*
UTILIZATION a. Households' use of the food to which they have access b. Individual efficiency in biologically converting nutrients in order to meet their specific nutritional and health needs.	Prevalence of stunting (height for age), % *children 0-59 months* Prevalence of wasting (weight for age), % *children 0-59 months* Prevalence of malnourished women, *% women with BMI <18.5*	QUALITY FOOD: Prevalence of children receiving a minimum acceptable diet, % *children 6-23 months** Women dietary Diversity Index* MICRO-NUTRIENTS: Vitamin A supplementation coverage rate, *% of children ages 6-59 months* Consumption of iodized salt, *% of households* Prevalence of Anemia, *% population* NON-FOOD ITEMS: Improved Water source, *% population with access* Improved Sanitation facilities, % *Population with access* Female adult literacy Female enrollment rate, secondary	Nutritional programs Health expenditure per capita, PPP Information of population health status (prevalence of HIV, malaria, etc.) Investments in water and sanitation Education expenditure per capita, public-private partnerships

Figure 14. *Categorization of Food Security Indicators on Three Levels of Analysis*

Source: Aurino (2014)

- Environmental conditions: Environmental factors such as drought, more variable rainfalls, seasonal temperatures, El Niño/La Niña events and flooding are expected to be increasingly relevant in the face of climate change.
- Economic conditions: The price of commodities following the food-fuel price rise in the 2007–08 crisis and again in 2011–12 has increased interest in the impact of these events on community and household food security.
- Governance: In light of various pressures on the food system, governments have a role to play in alleviating potential harm on the population at large and the poor in particular.

A report jointly commissioned by FAO and the International Indian Treaty Council (IITC) suggests that efforts are needed to better take into account the reciprocal culture-land/resource relationships that are fundamental to indigenous people (Woodley, Crowley, de Pryck, & Carmen, 2009). More specifically, indicator systems need to reflect the unique food and livelihood systems

HAZARDS AND SHOCKS		
ENVIRONMENTAL CONDITIONS	ECONOMIC CONDITIONS	GOVERNANCE
Rainfall anomaly /differences	Macroeconomic data: • Growth rate • Inflation rate • External balance • Remittances	Coordination of food security • Program and disaster management • Sector support and social protection measures
Seasonal rainfall forecast (medium-term climate outlook)	Consumer price index (CPI) i.e. real prices, cost of food basket	Trade policies • Regulation of exports and imports • Import tariffs
Normalized difference vegetation index (NDVI)	Food imports	Government policy and actions in domestic food markets • Strategic food reserves • Price stabilization measures • Safety net programs
El Niño Southern Oscillation (ENSO)	Migration patterns	Conflicts/IDPs/refugees • Number of IDPs, refugees and returnees, small arms flow, • Number of incidents • Assistance provided (food, cash, health, etc.) • Access to economic/ productive resources
Inundation and floods		
Cyclones, hurricanes and earthquakes		
Pest/locust outbreak		
Pasture and water shortages		
Livestock diseases/death		

Table 24. *Indicators for Risk Analysis and Early Warning*
Source: Kaaria, Mikkelsen, Mwanundu and Slaviero (2012)

that underpin the well-being of indigenous people. Various UN declarations, conventions and covenants promote indigenous people's right to food and include cultural and related indicators. It is recommended that the Sustainable Livelihoods framework be used as a tool for understanding relationships between the cultures of indigenous people and food/agro-ecological systems in terms of how interactions with the natural environment might influence their livelihood, food security and well-being (Woodley, Crowley, de Pryck, & Carmen, 2009). The indicators were classified according to five category areas based on evidence from literature (Woodley, Crowley, de Pryck, & Carmen, 2009):

1. Access to, security for and integrity of lands, territories, natural resources, sacred sites and ceremonial areas used for traditional food production, harvesting and/or gathering and related cultural and ceremonial purposes.
2. Abundance, scarcity and/or threats to traditional seeds, plant foods and medicines, and food animals, as well as cultural practices associated with their protection and survival.
3. Use and transmission of methods, knowledge language, ceremonies, dances, prayers, oral histories, stories and songs related to traditional foods and subsistence practices, and the continued use of traditional foods in daily diet as well as in relevant cultural/ ceremonial practices.
4. Capacity by Indigenous Peoples for adaptability, resilience, and/or restoration of traditional food use and production in response to changing conditions including migration, displacement, urbanization and environmental changes.
5. Ability of Indigenous Peoples to exercise and implement their rights including self-determination and free, prior and informed consent, as well as their self-government structures, to promote and defend their food sovereignty, which is the ability to control the policies and mechanisms of food production, and related aspects of their development.

The IISD's CRiSTAL Food Security Tool, which aims to assess how stressors brought about by climate change may affect the food security of vulnerable communities, also takes into account the particular livelihood determinants of affected households. With this information, it assists decision-makers and communities in developing approaches to better adapt to the stressors of climate change. A set of resilience indicators was developed to measure how different communities may be affected by climate change stressors. The CRiSTAL assessment (Tyler, et al., 2013) is guided by five levels of questioning (Figure 15):

1. Household food utilization: Which members of the household have access to which types of food (e.g., sufficient nutritional value and equitable sharing of food), and do households have appliances for cooking and food storage and whether there are common health issues that would compromise food utilization (food safety)?
2. Food access: What are the different groups or access paths in use by the affected population and how are these affected by the climate stressor?
3. Food availability: There are two sets of issues related to food availability at the community level. First, for the dominant modalities of food access analyzed in the previous step, how is food made available? Second, where a minority of people is particularly vulnerable to climate disruptions because of their food access modalities (e.g., complete reliance on subsistence production), but this differs from the dominant pattern of access for the community as a whole, how is food made available to this particular group?

CATEGORY	INDICATOR EXAMPLES
Access to, security for and integrity of lands, territories, natural resources, sacred sites and ceremonial areas…	• Percentage of lands, territories and subsistence resources used traditionally by Indigenous Peoples for subsistence and food production to which they still have full access. • Percentage of lands, territories and natural resources used traditionally for food production (farming, fishing, hunting, gathering, herding) currently being used by Indigenous Peoples compared to benchmarks established in the past. • Frequency of conflict over territory and natural resources, number of court cases and disputes filed.
Abundance, scarcity and/or threats to traditional seeds, plant foods and medicines, and food animals…	• Percentage of traditional subsistence food resources (plant and animal) that are intact, viable, productive, healthy and free from contamination (toxins, GMO's etc.). • Changes in monthly/yearly harvests of food plants and animals used traditionally and reasons for any decrease. • Number of traditional food plants and animals that have been declared endangered, have decreased in numbers, and/or have disappeared. • Number of active programs in Indigenous communities to restore plant or animal food species and/or their habitats and measure the impacts.
Use and transmission of methods, knowledge language, ceremonies, dances, prayers, oral histories, stories and songs… continued use of traditional foods…	• Percentage of community households that use traditional/ subsistence foods as a regular part of their diet, compared to an agreed upon number of years in the past (5, 10 or 25 depending on community history). • Percentage of community members who know traditional methods for food gathering/production/ preparation including the traditional language, songs, dances, stories and • ceremonies associated with these practices. • Percentage of indigenous youth in a community/tribe/nation who perceive or express that their traditional foods and subsistence practices as relevant in today's world.
Capacity by Indigenous Peoples for adaptability, resilience, and/or restoration of traditional food…	• Percentage of persons/youth that leave the community on a seasonal, semi-permanent (for at least two years) or permanent (five years of more) basis for employment/economic/subsistence or other reasons. • Number of new culturally and environmentally sustainable technologies or methods in use or under development for food production or related activities. • Existence of and extent of participation in community-based discussions and decision making regarding the need and/or desirability for adapting traditional methods and food sources to changing conditions.
Ability of Indigenous Peoples to exercise and implement their rights including self-determination and free, prior and informed consent…	• Number of development projects/proposals from outside Indigenous communities that respect and uphold the rights of free prior informed consent, self-determination and development. • Number of consultations for program planning, implementation and evaluation with community members and representatives by states, outside agencies or other entities.

Table 25. *Indicators on Indigenous Peoples' Food Security*
Source: Woodley, Crowley, de Pyck & Carmen (2009)

UNDERSTANDING THE FOOD SYSTEM

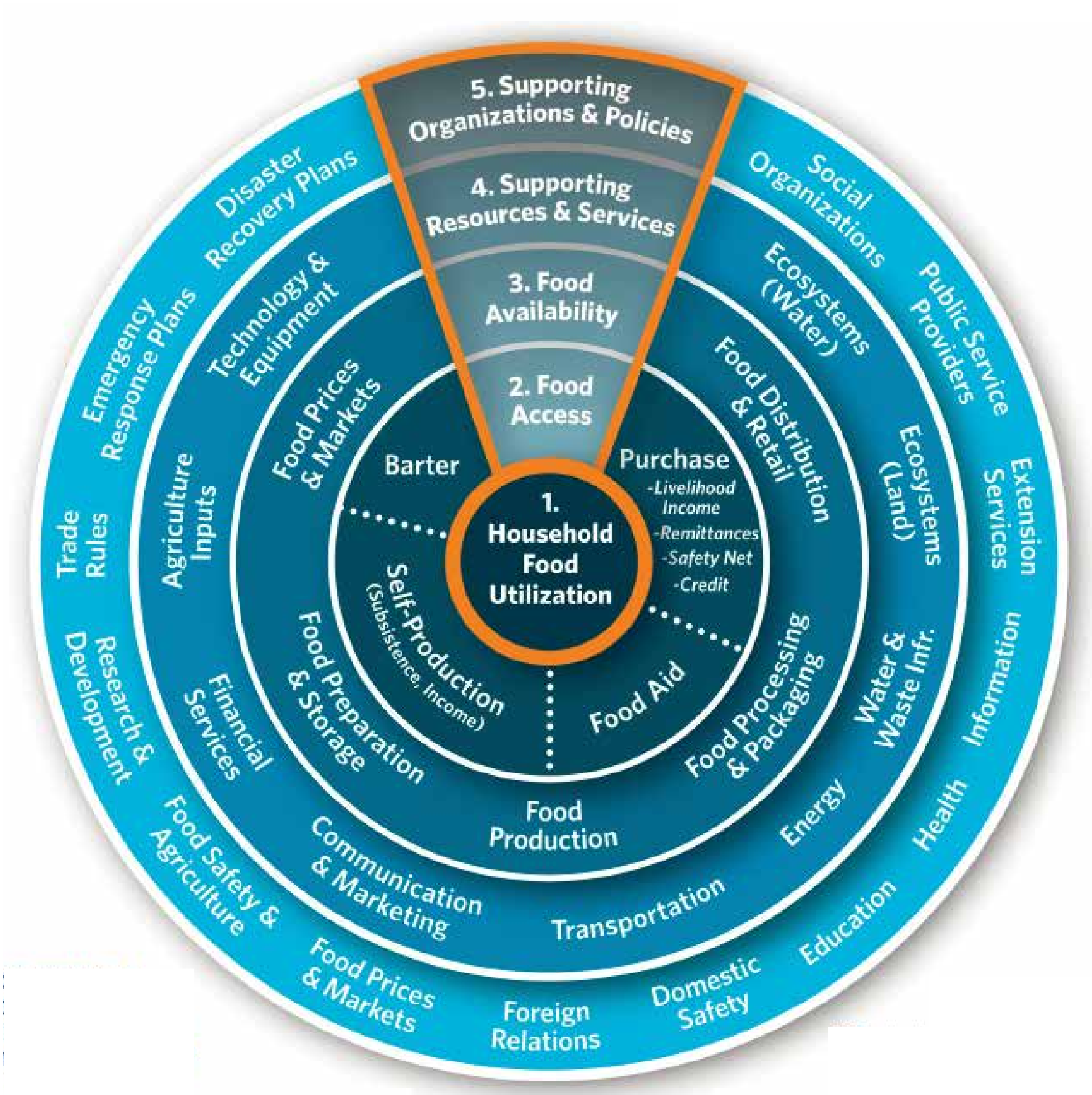


Figure 15. *IISD's CRiSTAL Food Security and Resilience Assessment Framework*
Source: Tyler, et al. (2013)

4. Supporting resources and services: For the main modalities of food access and availability already identified, what natural and built resources and services are most heavily relied on?

5. Supporting organizations and policies: How does the responsiveness of support organizations and policies enable the affected populations to act in the face of food security and climate change concerns?

UNDERSTANDING THE RESILIENCE OF THE FOOD SYSTEM

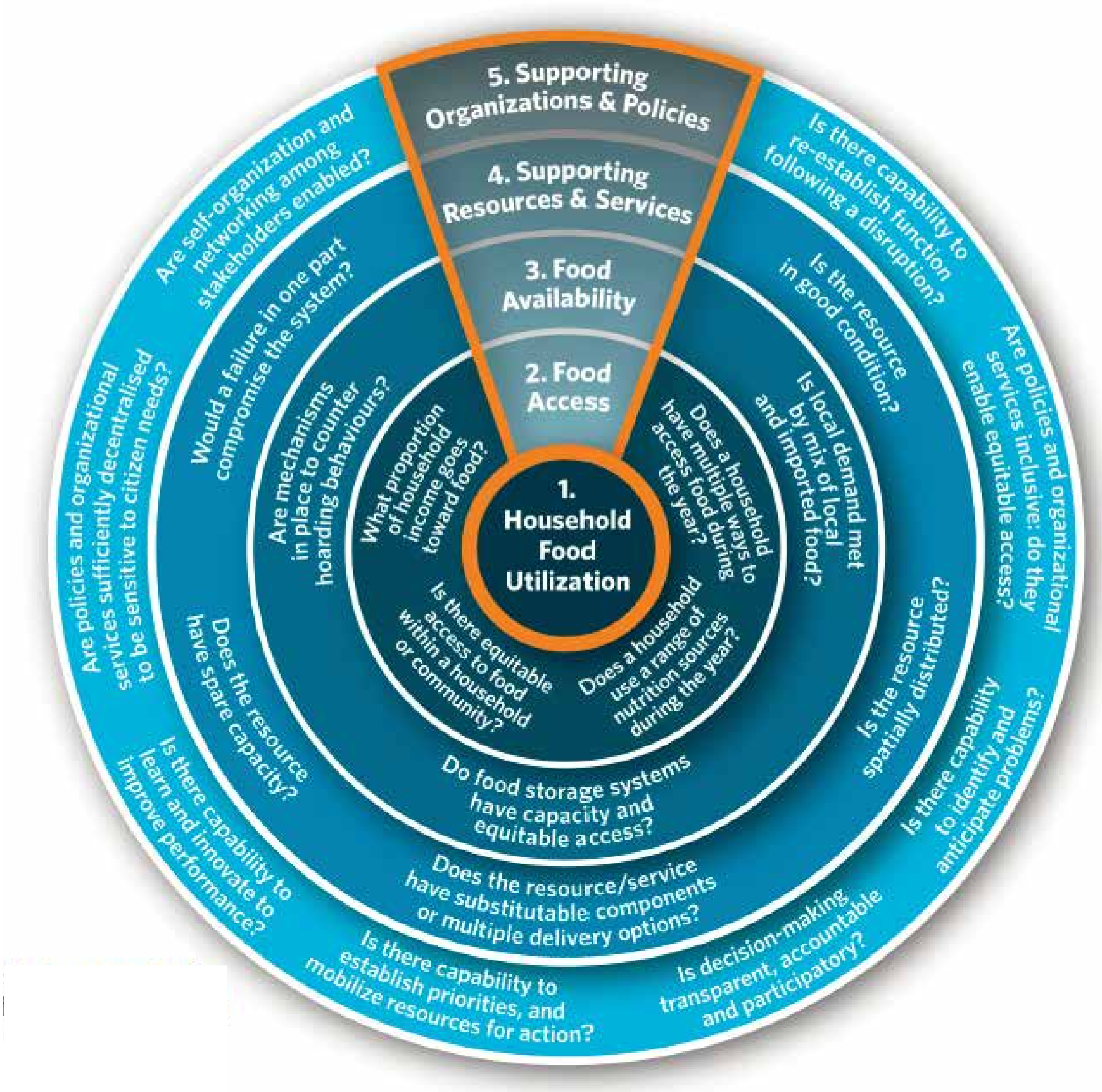


Figure 15. *IISD's CRiSTAL Food Security and Resilience Assessment Framework*
Source: Tyler, et al. (2013)

In operationalizing and measuring these high-level constructs, indicator systems can be developed to keep tabs on food security developments and inform policy-making (Table 26). The use of process-based indicators can help ensure that responses and policy-making are sufficiently inclusive of the views of affected population, and make full use of their capabilities and assets (Table 27).

SYSTEM	RESILIENCE-BUILDING ACTION	INDICATORS
UTILIZATION	Diversify diets for better nutrition: Establish family gardens and small-scale livestock rearing to complement diets with vegetables, diary and meat products; run education campaigns about healthy diets.	• Amount of food consumed by type, quantity and frequency per household (HH) member • Percentage of HHs consuming vegetables.
	Improve nutrition through equality: Include gender issues in monitoring systems; build capacity on gender issues.	• Records of weight, size, age and weight/age ratios by women, men and children; infant malnutrition index. • Rates of infant morbidity.
	Improve human health: Increase access to community health care; raise awareness on disease prevention; support and ensure the functioning of health committees.	• Percentage of people affected by respiratory and gastrointestinal diseases. • Percentage of people vaccinated against diseases. • Percentage of HHs with access to a functional sanitation service. • Percentage of HHs having attended awareness-raising talks on hygiene & health related topics.
	Food preparation and conservation: Invest in energy and storage systems, in particular in rural electrification programs; ensure access to efficient cook stoves; ensure access to small-scale storage; ensure access to safe water.	• Percentage of HHs possessing enhanced cook stoves/ refrigeration systems/ silos. • Percentage of HHs using safe food preparation techniques • Percentage of HHs with more than one storage facility. • Percentage of HHs with access to electricity. • Percentage of HHs with access to drinkable water.
ACCESS	Diversify income sources: Expand tourism activities; create microenterprises and employment opportunities, especially for women.	• Percentage of HHs with more than one income stream. • Percentage of HHs dedicating more than x per cent of their income to food purchase. • Percentage of income sources available to single women and to older people.
	Diversify access strategies and improve nutrition: Foment microenterprises and tourism; diversify food production sources and support nutritious diets through family gardens and small-scale Livestock rearing; design food aid programs to support nutritional gaps through the regular school meals.	• Percentage of HHs depending on only one access strategy throughout the year. • Percentage of HHs with income during summer season. • Percentage of HHs consuming vegetables. • Food products distributed per year through the food aid program to schools.
	Improve land tenure equality: Improve access to community lands and pastures for poor HHs, free access to seed banks or create seed funds in banks available to communities at low interest rates.	• Percentage of income sources for single women/elderly. • Percentage of HHs possessing (small) amounts of land.
AVAILABILITY	Increase sustainable production: Use more resistant crop varieties, diversify crops, adopt crop rotation and intercropping methods, adopt agroforestry and other soil conservation methods (e.g., using organic fertilizer), micro-irrigation schemes; establish family gardens & and small-scale livestock rearing. Expand and increase access to storage: Climate-proof storage infrastructure (including spatial distribution); build capacity for low-cost storage (traditional silos); regular maintenance and monitoring of storage facilities; improve rural access to electricity/ energy networks that support storages.	• Percentage of HHs possessing refrigeration systems. • Percentage of HHs (or producers) possessing more than one storage facilities. • Percentage of fishermen affiliated with a cooperative storage centre. • Percentage of HHs with access to electricity.

Table 26. *Resilience Indicators for the Core Food Systems' Elements Clustered by their Focus*
Source: Zamudio, Bizikova, & Keller (2014)

AVAILABILITY (CONT.)	Local versus external food production: Improve food transport options and modes; strengthen local production by, for example, promoting technology transfer and available financial mechanisms; substitute imports for local production when possible to reduce dependence on foreign markets.	• Records of quantity of food produced within community per season/cycle versus imported food. • Percentage of HHs with access to multiple markets.
	Increase access to markets and better prices: Organize (or strengthen) producers into associations/cooperatives to ensure better prices through wholesale production and lower transaction costs; improve access to market information; improve storage systems to allow for a better control of selling times; reduce number of intermediaries; improve access to small funds; support local and municipal mechanisms to control hoarding behaviours such as through penalties in local risk management protocols.	• Number of existing cooperatives. • Percentage of production (beans, corn and coffee) commercialized in cooperatives. • Available rural credits and % producers with access to credits. • Seasonal price variations of main food items.

Table 26. *Resilience Indicators for the Core Food Systems' Elements Clustered by their Focus*
Source: Zamudio, Bizikova, & Keller (2014)

PROCESS	INDICATORS
Vulnerability of policy against climate hazards	• Number and types of meetings and capacity-building sessions to ensure that the relevant government officials have a good level of comprehension and knowledge about the regulations and policies relevant for food security. • Number and types of policies/strategies in which the mainstreaming of policy on food security was completed.
Build resilience to specific parts of the system (resource/ service)	• Number of policies whose priority is ensuring universal access. • Number of objectives complementary to relevant policies to ensure an integrated approach to resource management (e.g., to water resource management, land management).
Transparent and responsible decision making	• Number of publicly available policy assessment reports. • Number and types of physical or virtual portals to access information on policy decisions and reviews. • Number and types of mechanisms in place for actors to provide regular inputs or opinions on the implementation and usefulness of the policy. • Number and types of annual forums to discuss and evaluate the policy's progress with stakeholders. • Number and accessibility of social audits; audits (modes of dissemination by local office, online, mail).
Multistakeholder participation in design and implementation	• Number of targeted participants from different social groups to ensure well-represented participation of stakeholders in consultations for design and implementation of policy. • Number and types of regular consultations bringing together sectoral representatives (e.g., agriculture, rural development, trade, forestry, infrastructure development).
Ability to apply lessons learned and avoid repeating failures and support best practices	• Number of capacity-building workshops on prevention, mitigation and risk management and how to access necessary resources. • Ability of the early warning systems and meteorological stations to cover the focus area and provide timely information. • Number of forums and networks that promote the share of best practices.
Decentralization to the most effective level	• Number and types of resources (including budget) available to regional offices/governments to use for local needs. • Types and location of regional committees that feed local information/needs to central office (frequency and type of information provided to the local level).

Table 27. *Process-Based Indicators that Showcase the Design and Implementation of Policies and Programs Aiming to Promote Food Security*
Source: Bizikova, Echeverria, Zamudio & Keller (2014)

5. THE WEF SECURITY ANALYSIS TOOL FOR MINING: ASSESSING THE BENEFITS AND IMPACTS OF MINING ON WEF SECURITY AND IDENTIFYING KEY ACTIONS AND INDICATORS

To assist mine operators, community organizations and policy-makers in better understanding the influence mining has on community and regional water-energy-food security, IISD created the WEF security analysis tool for Mining (WEFsat-Mining). This tool translates the conceptual framework outlined in Section 2 into a practical set of steps for assessing the benefits and impacts of mine development on WEF security. This section provides an overview of the tool and the menu of indicators that it contains for helping stakeholders monitor and report on changes in WEF security.

5.1. OVERVIEW OF WEFsat-MINING

WEFsat-Mining is a Microsoft Excel-based analytical tool developed by IISD to enable community and mining stakeholders to obtain an integrated view of the potential benefits and impacts of mining operations on WEF security. A separate document (*WEFsat-Mining User Guidance Manual*) outlines in greater detail how users can navigate this tool.

The tool uses the WEF security framework outlined in Section 2 to engage stakeholders in an assessment of: (i) the current status (and linkages) of the availability of and access to water, energy and food, and the array of infrastructure (built and natural) and policies that support their use; (ii) the potential benefits and impacts of mining on these WEF security components; and (iii) the actions necessary to realize potential benefits and mitigate impacts. The tool also helps users identify indicators that can be used to track the status and trends of WEF security components and the potential mining benefits and impacts, along with progress toward key actions.

WEFsat-Mining consists of 10 worksheets to facilitate a comprehensive assessment of WEF security in the context of a specific community or collection of communities, as influenced by an existing or proposed mining operation (Figure 16).

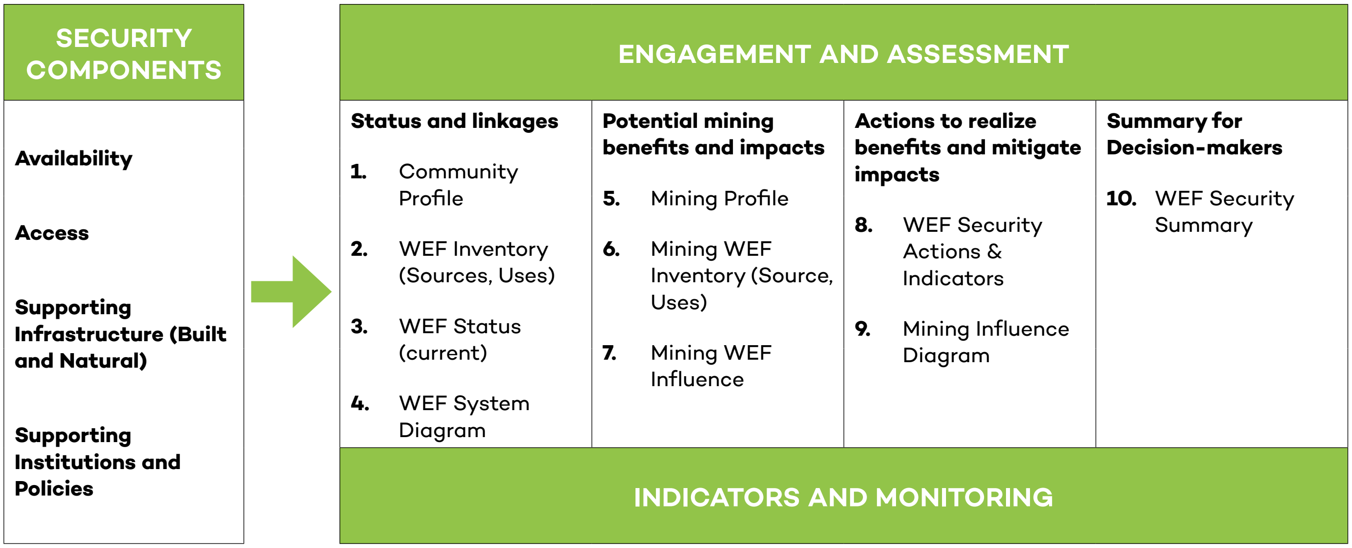


Figure 16. *IISD's WEF Security Analysis Framework Applied to the Assessment of Potential Mining Benefits and Impacts*

5.2. WEFsat-MINING WORKSHEETS

A summary of each of the 10 worksheets is provided below. For details, refer to WEFsat-Mining User Guidance Manual.

Status and Linkages

- *Worksheet #1* – Community Profile: To identify and describe the communities that are situated within the WEF systems of the existing or proposed mining operation.
- *Worksheet #2* – WEF Inventory: To identify the sources and uses of water, energy and food in the communities and the linkages among them (i.e., electricity used to power water pumps that are used to irrigate crops).
- *Worksheet #3* – WEF Status: To describe the current status of the WEF security components relevant to each water, energy and food source (i.e., availability, access, supporting infrastructure [built and natural], and supporting institutions and policy).
- *Worksheet #4* – WEF System Diagram: A systems mapping palette to enable a facilitator to work with stakeholders to visually draw the existing sources and uses of water, energy, and food and their linkages.

Potential Mining Benefits and Impacts

- *Worksheet #5* – Mining Profile: To describe the characteristics of the existing or proposed mining development at two specific points in time: full operations and full closure. The temporal perspective is important, as the potential benefits and impacts of mining may be different during operations and after the mine closes.
- *Worksheet #6* – Mining WEF Inventory: To describe any new water, energy and food sources introduced by the mine, as well as the new uses resulting from the mine.
- *Worksheet #7* – Mining WEF Influence: To identify the potential benefits and impacts of mining (during both operations and closure) on the availability and accessibility of key

sources of water, energy and food as well as the supporting infrastructure (both built and natural) and supporting institutions and policies.

Actions and Indicators

- *Worksheet #8* – WEF Security Actions and Indicators: This worksheet compiles all of the potential benefits and impacts of mining in one place and enables stakeholders to work together to identify key actions to help realize potential benefits and mitigate impacts of mining. This sheet also provides menus of possible indicators that could be used to track the status and trends of the WEF security components as well as the potential mining benefits and impact, and progress toward necessary actions.
- *Worksheet #9* – Mining Influence Diagram: This worksheet is the same as the WEF System Diagram Worksheet #4 and provides a canvas to depict the specific influences of mining development on the original WEF security system.

Summary for Decision-Makers

- *Worksheet #10* – Summary for Decision-Makers: This worksheet compiles the information from the previous worksheets into a summary format. Show and hide buttons enable users to select which information to display.

5.3. INDICATOR MENUS FOR TRACKING WEF SECURITY

WEFsat-Mining provides menus of example indicators recommended in the literature for tracking the various components of WEF security. Many of these indicators were previously listed in Section 4. Annex A provides a compilation of these indicators organized according to the WEF security framework used in this Resource Book and in WEFsat-Mining.

Described across the various WEF security components in Annex A are three different types of indicators. The first are referred to as “state-of” indicators. These indicators help track the state of the various WEF security components over time (i.e., water quality and quantity). These status indicators are colour coded in black text.

A a second group of indicators are referred to as “pressure” indicators. These pressure indicators help track the sources of potential mining benefits (i.e., number of mine jobs; average salary) and impacts (i.e., tonnage of acid-generating waste rock disposed; constituent concentrations in tailings ponds). The “pressure” type indicators are colour coded red in the composite table.

A third type of indicator presented in Annex A is called “response” indicators. These response indicators help track the types of and changes in supporting infrastructure (built and natural) and supporting institutions and policies. The “response” type indicators are colour coded blue in the table.

These example indicators can all be viewed in the example menus in WEFsat-Mining. These menus also allow users to input and save new indicators that are specific to their own circumstances and that may not yet be listed in the menus. This feature in the tool is particularly important when identifying indicators for the actions identified to realize potential mining benefits or mitigate impacts. These types of indicators represent a fourth type of indicator that can be referred to as “key performance indicators” or KPIs. Such indicators describe progress in the implementation of specific actions (i.e., job training programs or tailing effluent water treatment).

6. ENGAGEMENT PRACTICES FOR INVESTING IN A WEF-SECURE FUTURE

Community engagement is the foundation for investing in a WEF-secure future. This section provides an overview of stakeholder engagement practices in a mining sustainable development and outlines a specific participatory process for creating a Regional Landscape Investment and Risk Management Strategy for Water, Energy and Food Security.

6.1. OVERVIEW OF STAKEHOLDER ENGAGEMENT PRACTICES IN A MINING CONTEXT

Mining companies can have a role in improving the capacity of communities to engage with governance, policy and private sector decision-makers and enhancing their representation within negotiations and ongoing development assessment and planning processes. The governance institutions and mechanisms of communities can be enhanced by helping to ensure greater citizen participation into the assessment of problematic issues and opportunities. Further, the power of these individuals and communities can be enhanced within negotiations with governments and the private sector, to assist them in bringing greater influence to policies, and gain a role in the planning and control of development activities in the region.

Because mining companies often have a significant influence on the governance of nation states—and governments have a role in ensuring both that the policy landscape is conducive to attracting mining investments and respects the interests of local communities—mining companies can strive to enhance the participation of under-represented groups in public and private policy decisions. A community's ability to participate in decision-making processes relating to mine development is often impeded by knowledge gaps. Capacity building (such as providing funding for enabling communities to afford independent advisers, travel and meeting costs, legal and negotiations training, and covering the costs of a lead negotiator) may be required to ensure that the community has the ability to participate in negotiations with the mining company (ICMM, 2010b). Furthermore, the representation of minority groups and local communities within public policies and political discourse can be enhanced through the concerted efforts of mining companies.

Engagement with communities is a process that is in continuous development throughout the life cycle of the mining project. A high level of engagement with communities that are affected by mining helps to ensure that these stakeholders have meaningful opportunities to have their views taken into account in relation to planning and decision making for these projects or related activities that have a significant impact on their lives. These processes should be characterized by two-way communications and depend on good faith from both companies and communities. Successful engagements are those that allow both parties to maximize benefits along parameters of shared interests.

Photo: Daniella Echeverría

STAGE	PRACTISES
Plan	• Identify and prioritize who to engage with • Understand community concerns and identify pressing issues • Allocate sufficient time, resources, skills, and staff capacity
Set Goals	• Understanding the purpose of engagement and desired outcomes • Aim to be inclusive • Aim for mutual benefits
Engage	• Use a variety of informal and formal engagement techniques chosen to suit the context • Communicate the purpose of engagement early • Communicate candidly, effectively, openly, honestly • Share evidence-based knowledge and information • Record and document the process
Reflect/ improve	• Report to stakeholders on outcomes of engagement • Report to own organization on process (for learning) and outcomes (for staff engagement) • Make improvements

Table 28. *Best Practices for Stakeholder Engagement*
Source: Shift (2013).

Photo: Dimple Roy

EXPLORATION	DEVELOPMENT	OPERATION	CLOSURE
7-10 YEARS	**5-10 YEARS**	**5-30 YEARS**	**2-10 YEARS**
Maximizing contributions to sustainable development throughout the project life cycle →			
Discussion and negotiations to access land, identify sites of cultural importance, provide communities with information on the project timelines and activities.	Further discussion and negotiation to ensure ongoing permission to access land, include the community in baseline studies, and to convey information about project development.	Understand and address community concerns. Develop tools to listen and respond to community concerns and to monitor the implementation of any negotiated agreements.	Involve external stakeholders in post-mine land use planning. Communicate a timetable for closure. Liaise with government
Manage expectations and address community concerns. Consider negotiating a formal agreement.	Establish consultative forums and structures. Understand and address community concerns about large-scale development. Manage community expectations in regards to employment and other opportunities. Liaise with neighbours to manage amenity and access issues. Consider negotiating a formal agreement.	Participate in consultative groups and forums.	Departments to reduce the impacts of closure. Deal with anxiety and uncertainty in the community regarding closure and possible unemployment.

Table 29. *Engagement of Communities throughout the Mine's Life Cycle*
Source: Adapted from Shift (2013).

Adequate engagement processes ensure that, at a minimum, human rights infringements are prevented, and that important measures are put in place so that the community's needs can best be met within the context of the particular determinants of their livelihoods and well-being in the long-run. From the perspective of mining companies, effective engagement processes also allow them to manage the risk of opposition to the mine, and also serves as a way to minimize conflicts with local communities.

Some engagement processes result in the negotiation of community development agreements that formally define the relationship and obligations of the mining company with relevant communities. These can take various forms such as Impact Benefit Agreements, Partnership Agreements, Community Development Initiatives, Social Trust Funds, Empowerment Agreements and Landowner Agreements.

6.2. ENGAGEMENT USING "THE 7 QUESTIONS TO SUSTAINABILITY"

The Seven Questions to Sustainability (7QS) Assessment Framework was created in 2004. It was motivated by a desire to apply the ideas of sustainability in a practical way on the ground—in a way that is meaningful to explorer, mine manager, mill superintendent, community leader or public interest group. To address this challenge, IISD through the Mining, Minerals and Sustainable Development (MMSD) initiative in North America convened a work group of 35 individuals representing a broad range of interests and charged them with developing a set of practical principles, criteria and/or indicators that could be used to guide or test mining/minerals activities in terms of their compatibility with concepts of sustainability.

Work on this front began with a review of 10 recent initiatives from government, the mining industry, non-government organizations, indigenous people and the financial services sector. After significant deliberation, seven topics were identified that were deemed essential for consideration. For each of these, a question was crafted to be applied to any given project or operation.

From the 7QS falls a hierarchy of objectives, indicators and specific metrics. Simultaneously, the starting point for assessing the degree of progress is provided by an "ideal answer" to the initial question. In this way a single, initial motivating question—is the net contribution to sustainability positive or negative over the long term?—cascades into progressively more detailed elements that can be tailored to the project or operation being assessed.

Figure 17. *The Seven Questions to Sustainability – How to Assess the Contribution of Mining and Minerals Activities*
Source: IISD (2002)

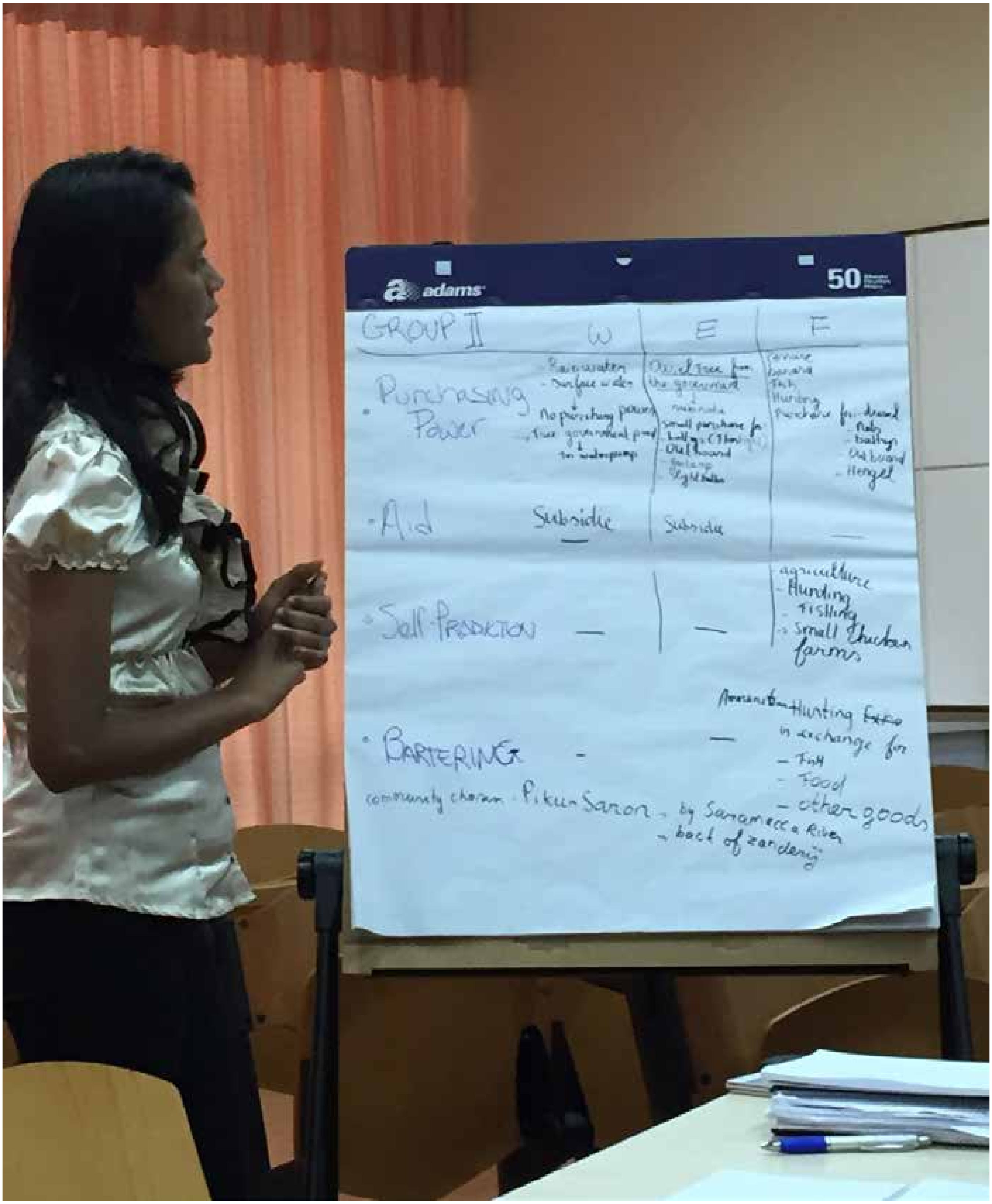


Photo: Dimple Roy

The Tahltan Mining Symposium was one application of the 7QS framework. The symposium was convened by the Tahltan First Nation and brought together 28 Tahltan representatives and nine from industry and government. Its purpose was to: (1) review the relationship between the Tahltan people, their land and the mining industry; and (2) build a strategy to guide that relationship in the future. Seeking a win–win outcome and guided by the 7QS assessment template, the 38 participants considered past, present and potential future conditions as a foundation for ensuring positive outcomes for the Tahltan people and their territory in the years to come. The aim of the resulting strategy was to:

1. Send a signal that the Tahltan people are supportive of mining and mineral activity on their land under conditions that such activities respect Tahltan concerns and lead to a fair distribution of costs, benefits and risks to implicated parties.
2. Facilitate Tahltan participation in mining and mineral activity, not only through direct and indirect employment, but also in terms of overall management/co-management as well as the broad perspective of seeing a fair distribution (considering all participating interests) of all benefits, costs and risks.
3. Ensure that the broad range of concerns raised in the 7QS are addressed, in particular the health/social/cultural and environmental implications of mining/mineral activity.
4. Ensure that in the future, mining and mineral activity in Tahltan traditional territory is a win–win for all implicated interests: the Tahltan people, mining/mineral interests, government and others.

Out of Respect, the symposium report, describes the process and documents of the resulting strategy (IISD, 2004). It serves to effectively demonstrate the application of the 7QS assessment approach while facilitating a constructive and practical way forward for the Tahltan people.

6.3. CREATING A REGIONAL LANDSCAPE INVESTMENT AND RISK MANAGEMENT STRATEGY FOR WATER, ENERGY AND FOOD SECURITY

In its 2013 report, *The Water-Energy-Food Security Nexus*, IISD set out to create a practical planning and decision-support framework for landscape investment and risk management in WEF security (Bizikova et al., 2013). A participatory scenario planning process was laid out to enable key stakeholders in a region to deliberate over the state of WEF security, envision a desired future, and create a pragmatic investment plan for achieving WEF security. The planning process consists of four main stages as outlined in Figure 18. The assessment of WEF benefits and impacts resulting from mining as outlined in this document and in the accompanying WEFsat-Mining represents the first step in the first stage of the overall planning process for regional WEF security. The sections that follow provide an overview of the four main planning stages for achieving a WEF-secure future

6.3.1. STAGE 1: ASSESSING WEF SECURITY

The process of bringing stakeholders together in a watershed or other landscape-defined place necessarily begins with an assessment and discussion of the current status and trends of key aspects of water, energy and food security. Undertaking such an assessment requires a clear picture of the system to be assessed; this highlights the importance of the analytical framework and tool developed in this report.

Figure 18. *A Participatory Scenario Planning Process for Landscape Investment and Risk Management in Water, Energy and Food Security*
Source: Bizikova et al. (2013)

This stage also includes a broader historical analysis to understand the regional landscape with respect to how it has changed over time, as well as why and how stakeholders have adapted to change—and were drivers of change themselves—in the context of WEF security issues.

A final task of this stage is to identify future risks and opportunities in WEF security in the region. This builds on the WEF status assessment and historical analysis and takes a prospective view of the key stresses of the past to assess their potential to manifest as key risks of the future (i.e., weather variability, population change, fiscal crises, health pandemics). Existing projections from the literature can be used as the basis for this forward-looking assessment of risks.

6.3.2. STAGE 2: ENVISIONING FUTURE LANDSCAPE SCENARIOS

The objective of this stage is to craft plausible scenarios of the future as framed by the most important and uncertain drivers of change in the region. The starting point for doing so is building a shared set of principles that can guide a more refined articulation of a desired future for WEF security and what benefits society can expect from it. This does not require detailed elements of the future landscape, such as a particular type of energy system, types of water use, or sources of nutrition; rather, we suggest participants deliberate to describe the desired characteristics of their landscape, such as efficient use of resources. It is during this task that the notions of excess natural capital (i.e., water and forests) and social capital (i.e., water user groups, soil conservation associations, etc.) are discussed as hedges against future risks, as opposed to the more traditional economic approach of conserving enough resources to meet demand.

The plausible stories of the future provide the context for participants to discuss actions for ensuring WEF security. This is done by taking two stances: one adaptive and one transformative (Kahane, 2012). From an adaptive stance, participants are asked what opportunities and threats each scenario presents and what specific strengths and weaknesses these illuminate. From that information, adaptive actions can be identified to leverage opportunities or mitigate risks. From the transformative stance, participants are empowered to shape the actual realization of a given scenario and are asked which future scenarios are better for community/ organization/business. Within this context, participants can then deliberate prospective roles and responsibilities in making the desired future scenarios happen—essentially asking what does the future need from each person/group? This task provides a menu of robust actions (i.e., those that make sense in most scenarios and involve mostly no regrets) and those that are triggerable (i.e., those actions that make sense only for certain situations and might need more information before being implemented) (Swanson, Barg, Tyler, & Venema, 2010). The shared understanding of a desired future scenario (or elements thereof) and menu of adaptive and transformative actions provides the foundation for the next stage: creating a practical investment strategy for the future.

6.3.3. STAGE 2: ENVISIONING FUTURE LANDSCAPE SCENARIOS

The purpose of this stage is to develop a specific investment strategy for ensuring the WEF security of the region or basin. This stage involves multiple engagements with various stakeholders as well as larger multistakeholder meetings. Central to these engagements is a shared, innovative and motivating story of a future landscape than can deliver water, energy and food security in a sustainable and resilient manner. This requires taking the desired scenario story from Stage 2 (or compiling desired elements across several scenarios), branding it, and actively communicating it across the region or basin. A modality for active communication of the desired future scenario is engaging more stakeholders in various sectors to better understand their adaptive and transformative roles and responsibilities.

A key output of this stage is a regional investment strategy and scaling mechanisms that can deliver WEF security for the basin or region. This is a shared document meant to represent a strategy owned by the participants in the process, a document that ideally is representative of the aspirations of the basin and region as a whole. The strategy is implementation-orientated in that the adaptive and transformative actions are backed by specific financial and policy mechanisms to enable their implementation. The strategy must present a comprehensive business case that openly and transparently discusses risks and mitigating/hedging actions that are built into the strategy directly as specific forms of excess natural and social capital. The strategy must describe the implementation mechanisms that are adaptive and transformative for the basin or region as a whole.

6.3. STAGE 4: TRANSFORMING THE SYSTEM

Transformation demands action, and action requires communication—and lots of it. While the very undertaking of the participatory scenario planning tasks of Stages 1 through 3 is a form of active communication in and of itself, a separate communication plan is imperative, one that can effectively market the investment strategy and build the necessary public, financial and policy support for scaling up actions. Experience shows that significance of this task cannot be overemphasized, though it is often poorly executed.

One of the most important mechanisms for implementation is the clear identification of an organization or formal consortium of organizations that is accountable for the implementation of the investment strategy. While it is certainly the case that action from a range of stakeholders is necessary to implement the plan, some defined entity must be identified as the steward of the plan so that it can report on progress to the broader public in a transparent and accountable manner.

Adaptive management of a complex and transformative process is fundamental to successful implementation (Tomar & Swanson, 2009). This is because it is not possible to predict what actions will work well (and which will not) in dynamically commingled economic, social and environmental systems. Therefore, a regular and formal process of monitoring progress, learning from successes and failures, and actively adapting and improving performance is required to change what is not working (and to abandon actions in certain situations) and strengthen what is working (Pintér et al., 2012).

The identification and monitoring of a suite of outcome and output indicators, as put forth in this document and the accompanying WEFsat-Mining in the context of a specific development activity (i.e., mining), and the continual and transparent communication of this information, is a critical part of the participatory planning process and the adaptive management of implementation of a broader regional investment strategy in WEF security.

7. SUMMARY

With the scarcity of mineral resources and the influential nature of mining activities, the creation of positive relationships between companies and surrounding communities is critical. Whereas mining developments have historically been simplistically framed as an important contributor to economic growth, with potentially significant destructive effects on the environment, the last several decades have seen the emergence of a collaborative approach to mining developments, and a greater understanding of the diverse benefits and impacts of mining. This resource book traces various initiatives to incorporate and monitor sustainability in the context of mining.

WEF security is presented as a tangible and measurable way of operationalizing sustainable development. Unfortunately, little progress has been made to understand the effect of mining on WEF security in communities. Through this resource book, we examine the various attempts of identifying, assessing and/or monitoring components of WEF security in the context of mining. We stress the need for robust and inclusive indicators to understand and monitor WEF security and, in a parallel effort, provide a Microsoft Excel tool to assess and develop indicators for this process.

This resource book provides information for companies, communities and governments to understand and monitor WEF linkages in the context of mining developments

The WEF Security Assessment Framework (Section 2.1), WEFsat-Mining (Section 5) described in this document, and the broader Participatory Planning Scenario Planning process (Section 6.3), provides a set of approaches and tools adapted specifically for understanding and planning for WEF security in the context of mining development and operations. This resource book is seen as a foundation for future landscape investments for a WEF-secure future.

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ANNEX A.

(Black text = "state of" WEF indicators; Yellow = mining "pressure" indicators; Green = other "pressure" indicators; Blue = "response" indicators).

		EXAMPLE INDICATORS		
		WATER SECURITY	ENERGY SECURITY	FOOD SECURITY
AVAILABILITY	SOURCES	**ADB (2013):** Water supply (%), wastewater treatment (%); hygiene (age-standardized disability adjusted life years per 100,000 people for the incidence of diarrhea); nitrogen; phosphorous; mercury; pesticides; total suspended solids; potential acidification; aquaculture; organic loads; thermal impacts from power plant cooling; dam density; river network fragmentation; agriculture sector water stress; residency time change downstream from dams; non-native species; catch pressure. **UN Water (2009):** Precipitation; Surface water actual; Groundwater recharge; Water quality (nitrate); Desalination production. **Aurino (2014):** % population with access to improved water source; % population with access to improved sanitation. **GRI (n.d.):** Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the reporting organization's discharges of water and runoff; Total water discharge by quality and destination; Total water withdrawal by source; Water sources significantly affected by withdrawal of water; Percentage and total volume of water recycled and reused; Total number and volume of significant spills. **Azapagic (2004):** Liquid effluents; Total volume of water discharged into waterways; Total volume of tailings and disposal methods; Percentage of permitted sites causing	**IEAE/IEA (2005):** Proven recoverable reserves; Total energy production; Total estimated resources; Energy imports; Total primary energy supply; Stocks of critical fuel (e.g., oil, gas, etc.). **Sovacool (2013):** Total primary energy supply per capita; average reserve to production ratio for the three primary fuels (coal, natural gas and oil); Self-sufficiency; share of renewable in total primary energy supply; years of energy reserves left. **FAO (2014):** Utilization of total hydropower capacity; ratio of hydropower to total energy supply; total dam capacity (national); primary production of renewable energy; transport energy intensities; bioethanol and biodiesel production; renewable energy share in national energy and electricity generation; % of increased access to modern energy services due to bioenergy; % renewable energy/ total energy; woodfuel production by volume and value; land use and land-use change related to bioenergy feedstock production; % land used for new bioenergy production; bioethanol and biodiesel production; pump price for gasoline and diesel; total jobs in bioenergy sector; change in forest area over the last 10 years as a % of total forest area; primary production of renewable energy.	**UN Water (2009):** Threatened freshwater species. **Parris et al. (2002):** # of food emergencies vs. food-water vulnerability x capacity. **MOFN (2009):** Yield (kg/ha); Number of farmers with certificates; Area certified; % of farmers renting out land; % of farmers renting in land. **Aurino (2014):** Dietary energy supply; Share of dietary energy supply from staples; Cereal yields; Livestock production index; Food imports; Meteorological data; Fertilizer use; Pest management; Nutrition programs. **Kaaria et al. (2012):** Food imports; Rainfall anomaly and differences; Seasonal rainfall forecast (medium-term climate outlook); Normalized difference vegetation index (NDVI); El Niño Southern; Oscillation (ENSO); Inundation and floods; Cyclones, hurricanes and earthquakes; Pest / locust outbreak; Pasture and water shortages; Livestock diseases / death. **FAO (2014):** Livestock total per hectare of agricultural area (livestock/ ha); bacterial numbers and the presence of coliform organisms; feed-water productivity and feed conversion efficiency; change in freshwater fish production (aquaculture and capture/yr); number and % of population that is undernourished; household dietary diversity and number of meals per day; % of the cultivated area equipped for irrigation; value of irrigated output as share of total

		downstream and/or underground water quality problems relative to the total number of permitted sites; Describe any measures put in place to prevent acid main drainage, if applicable; Describe any measures put in place to prevent tailings dam(s) failure; Breakdown of substances discharged with liquid effluents; Percentage of total water reused (e.g., cooling, waste and rain water) relative to the total water withdrawn for source. **FAO (2014):** Sources of drinking water (piped water, well water); groundwater quality; salinity of groundwater; desalinated water produced annually; contaminant discharges in liquid effluents from energy systems; oil discharges into coastal waters; independence from imported water and goods; % water distribution losses by water utilities; pollutant loadings attributable to fertilizer and pesticide application for bioenergy feedstock production; water pollution as % of BOD emissions; levels of ph; levels of alkalinity; nitrogen and phosphorous concentration; precipitation in volume; internal renewable water resources; total actual renewable water resources; total actual renewable water resources per capita; actual renewable groundwater resources; actual groundwater entering and leaving the country; treated municipal wastewater; desalinated water production; runoff co-efficient; net recharge rate of groundwater; erosion rate or sediment load in river/ upstream drainage area; renewable water resources per capita (m^3) adjusted by HDI; relative social water stress index; total exploitable water resources disaggregated by total regular and irregular renewable surface groundwater; population affected by waterborne disease. **SDSN (2015):** Proportion of total water resources used (MDG Indicator); BOD.		agricultural output; value of irrigated output as multiple of value of rain-fed output; % freshwater withdrawal as % total actual renewable water withdrawal; total groundwater abstraction/exploitable groundwater; brackish/saline groundwater at shallow and intermediate depths; area salinized by irrigation of total harvested irrigated crop area (ha); % salinized soils by irrigation/arable land; % area equipped for full control surface irrigation drained; use of agricultural pesticides and fertilizers (nitrogen, phosphate, potash); share of major ions, metals, nutrients, organic matter and bacteria in watershed; concentration of nitrogen, ammonia and phosphorous; concentration of antibiotics in watershed; direct use of treated municipal wastewater for irrigation purposes/total treated municipal waste water; direct use of agricultural drainage water; produced municipal wastewater; cereal import dependency ratio; depth of food deficit; precipitation variability; total agricultural water managed area. Total area of agriculture; % area equipped for irrigation actually irrigated; area equipped for irrigation by type of irrigation (surface, sprinkler, localized); area that is potentially irrigable; average value of food production; average dietary energy supply adequacy; import quantity index of agricultural products; change in cropland use; % agricultural land classified as having moderate to severe water erosion or wind risk; economic value of food products/ reduction of use of non-renewable energy in agriculture; prevalence of food inadequacy; cropland per gross production value of agriculture. **SDSN (2015):** Proportion of population below minimum level of dietary energy consumption (MDG Indicator); Proportion of population with shortfalls of any one of the following essential micronutrients: iron, zinc, iodine,

				vitamin A, folate, and vitamin B12 – indicator to be developed
	USE AND UTILIZATION	**ADB (2013):** Relative water consumption compared to supply; productivity of irrigated agriculture; independence from imported water and goods; financial value of industrial goods relative to industrial water withdrawal; consumption rate (net virtual water consumed relative to water withdrawn for industry). **UN Water (2009):** Irrigation area; Total water withdrawals; Water demand per sector; Changes in agricultural water productivity; Change in hydropower **Aurino (2014):** Investment in water and sanitation. **FAO (2014):** % annual freshwater withdrawals by sector; per capita renewable water resources; groundwater abstraction/ exploitable groundwater; median time to water; cooling water required for conventional power plants; total hydropower capacity; ratio hydropower/ total energy supply; area equipped for power irrigation; % of area that is equipped for irrigation; productivity of irrigated agriculture; area equipped for irrigation drained; % total cultivated area drained; % total area equipped for full control surface irrigation drained; consumption rate of water; cubic metres of water used per unit of value added by sector; water withdrawn for processing feedstock and bioenergy; annual freshwater withdrawals by sector; Total water withdrawal (km²/year) by agriculture, industry and municipality; agricultural, industrial and municipal withdrawals as % total water withdrawal; % investment in irrigation/total public spending; desalinated water used for irrigation (km2/ yr); total freshwater withdrawals by irrigated agriculture; surface and groundwater withdrawals for agriculture as % total renewable	**IEAE/IEA (2005):** Energy use (total primary energy supply, total final consumption and electricity use); Critical fuel consumption; Total population; Energy use in industrial sector and by manufacturing branch (and value added); Energy use in agricultural sector (and value added); Energy use in service/commercial sector (and value added); Energy use in households and by key end use; Number of households, floor area, persons per household, appliance ownership; Energy use in passenger travel and freight sectors and by mode; Passenger-km travel and tonne-km freight and by mode. **Sovacool (2013):** Annual value of energy exports. **GRI (n.d.):** Direct energy consumption by primary energy source; Indirect energy consumption by primary source; Energy saved due to conservation and efficiency improvements; Initiatives to provide energy-efficient or renewable energy based products and services, and reductions in energy requirements as a result of these initiatives; Initiatives to reduce indirect energy consumption and reductions achieved. **Azapagic (2004):** Breakdown by type of the amount of the primary energy used (including natural gas, diesel, LPG, petrol and other fuels); Breakdown by type of the amount of the secondary energy (electricity and heat) used and exported; Energy from renewable sources used and exported; Total primary and secondary energy used; Percentage of renewable energy used relative to total energy consumption. **FAO (2014):** % households without electricity or commercial energy; % household income spent on fuel and electricity; % population with access to electricity; energy use per capita;	**MFAN (2011):** % population malnourished; % children under 5 years malnourished; % child mortality under 5 years; % of population meeting energy requirements; % eating 3 meals/ day; Average energy intake; % households being food secure all year; Number of months per year that households declare being food secure; On-farm added value; Off-farm added value. **Aurino (2014):** Prevalence of undernourishment; Perceived food insecurity; Under 5 mortality rate; Prevalence of stunting; Prevalence of wasting; prevalence of malnourished women; Prevalence of children receiving minimum acceptable diet; Women dietary diversity index; Vitamin A supplementation coverage rate; Consumption of iodized salt; Prevalence of anemia. **Kaaria et al. (2012):** Migration patterns. **SDSN (2015):** Crop yield gap (actual yield as % of attainable yield).

		water resources; agricultural water security index. **SDSN (2015):** Percentage of rural population using basic drinking water (modified MDG Indicator); Proportion of rural population using basic sanitation services (modified MDG Indicator); Proportion of the population using an improved water source.	% area equipped for irrigation that is power irrigated; % energy for transporting water for agriculture; utilization of total hydropower capacity; ratio of hydropower to total energy supply; household energy intensity; fossil fuel energy consumption; net annual rates of conversion between land-use types caused directly by bioenergy feedstock production; energy used in agriculture and forestry; agricultural machinery, tractors in use in agriculture; direct on-farm energy consumption; direct use of fossil fuel energy in agriculture per unit value output; energy for power irrigation in agriculture per agricultural production; energy consumed in fisheries per fish product production; share of household income spent on fuel and electricity; household energy use for each income group and corresponding fuel mix; reduction of food loss/amount of energy used for food processing; forest area damaged by human activity: forest operations and other; % population using solid fuels; % households using traditional fuels (disaggregated by fuel); bioenergy used to expand access to modern energy services; total volume of removals from forests; woodfuel from forests in volume; MEPI Index; energy use (kg oil equivalent) per USD1,000 GDP; change in yield/amount of modern energy used for farming; agricultural energy intensities; energy used in agriculture per gross agriculture production; direct on-farm energy consumption, per agricultural produce; % renewable energy used in agriculture as a proportion of total energy used in agriculture. **SDSN (2015):** Share of the population with access to modern cooking solutions (%); Share of the population with access to reliable electricity (%); Share of households without electricity or other modern energy services; Percentage of population using solid fuels for cooking.	

	PROCESSING			
	STORAGE	**ADB (2013):** Resilience (percentage of renewable water resources stored in large dams). **FAO (2014):** % renewable water stored in large dams; total dam capacity; total dam capacity per capita; water storage capacity per person.		**Aurino (2014):** Infrastructure (storage facilities). **Kaaria et al. (2012):** Strategic food reserves.
	DISTRIBUTION	**ADB (2013):** Access to piped water supply (%); access to improved sanitation (%). **UN-Water (2009):** Population with access to improved water sources/ sanitation; Population connected to drinking water/ sewage. **FAO (2014):** % people with improved water access (piped water); access to improved sanitation; % improved sanitation facilities; investment in water sanitation; rural population with access to water supply; % population with access to an improved sanitation facility; % population with access to improved water source (urban and rural); population affected by waterborne disease; % population using improved water technologies and sanitation facilities; average household water usage/day; water within 15 minutes; median time to water.	**IEAE/IEA (2005):** Households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy. **Sovacool (2013):** % population with high-quality connections to the grid; % electricity transmission and distribution losses. **FAO (2014):** % households without electricity or commercial energy, or heavily dependent on non-commercial energy; % households with access to modern cooking energy.	
	MARKETS	**FAO (2014):** % water expenditure as total of household expenditure; global corruption report in the water sector.	**IEAE/IEA (2005):** Energy prices (with and without tax/subsidy). **Sovacool (2013):** Stability of electricity prices; retail price of gasoline/petrol; Per capita energy subisidies. **FAO (2014):** End-use energy prices by fuel and sector; economic value of agricultural products; net energy imports; pump price of gasoline and diesel (USD/litre).	**MOFN (2009):** % increase in food price; Food price relative to wages; Price difference producers (rural)/consumers (urban) **Aurino (2014):** Relative level of consumer prices; Food prices volatility; **Kaaria et al. (2012):** Growth rate; Inflation rate; External balance; Consumer price index (CPI) i.e. real prices, cost of food basket; Price stabilization measures; **FAO (2014):** Domestic food price index; domestic food price index of key food and non-food commodities; domestic food price volatility; per capita food production variability; per capita

				supply variability; average value of food production; share of food expenditure for the poor; domestic food price index; depth of food deficit; domestic food price volatility; per capita food production variability; per capita food supply variability.
ACCESS	PURCHASING POWER (livelihood income, remittances, credit)	**IEAE/IEA (2005):** Household income spent on fuel and electricity; Household income (total and poorest 20% of population); Energy use per household for each income group (quintiles); Household income for each income group (quintiles); Corresponding fuel mix for each income group (quintiles). **MOFN (2009):** % living above/below poverty threshold; Average annual income; Average annual farm income. **Aurino (2014):** Share of food expenditure in total expenditure for the 20% poorest households; Employment-to-population ratio. **Kaaria et al. (2012):** Remittances; Access to economic and productive resources. **GRI (n.d.):** Total workforce by employment type, employment contract, and region; Total number and rate of employee turnover by age group, gender, and region; Benefits provided to full-time employees that are not provided to temporary or part-time employees, by major operations; Coverage of the organization's defined benefit plan obligations; Range of ratios of standard entry-level wage compared to local minimum wage at significant locations of operation; Policy, practices, and proportion of spending on locally based suppliers at significant locations of operation; Composition of governance bodies and breakdown of employees per category according to gender, age group, minority group membership, and other indicators of diversity; Ratio of basic salary of men to women by employee category; Total number of incidents of discrimination and actions taken; Procedures for local hiring and proportion of senior management hired from the local community at locations of significant operation; Percentage of employees covered by collective bargaining agreements; Minimum notice period(s) regarding operational changes, including whether it is specified in collective agreements; Number of strikes and lockouts exceeding one week's duration, by country; Operations identified in which the right to exercise freedom of association and collective bargaining may be at significant risk, and actions taken to support these rights; Operations identified as having significant risk for incidents of child labour, and measures taken to contribute to the elimination of child labour; Operations identified as having significant risk for incidents of forced or compulsory labour, and measures to contribute to the		
		elimination of forced or compulsory labour; Number (and percentage) or company operating sites where artisanal and small-scale mining (ASM) takes place on, or adjacent to, the site; the associated risks and the actions taken to manage and mitigate these risks; Total number of operations taking place in or adjacent to Indigenous Peoples' territories, and number and percentage of operations or sites where there are formal agreements with Indigenous Peoples' communities. **Azapagic (2004):** Number of direct employees (on company payroll); Number of indirect employees (e.g. contractors, consultants) expressed as full-time equivalents; and Percentage of indirect relative to direct jobs; Net employment creation expressed as percentage contribution to employment in a region or country; Employee turnover expressed as percentage of employees leaving company relative to the total number of new employee; Total payroll costs and benefits (including pension and redundancy payments) broken down by region or country; Total costs of employment as percentage of net sales; Health, pension and other benefits and redundancy packages provided to employees as percentage of total employment costs; Ratio of lowest wage to national legal minimum, breakdown by country; Percentage of contracts that are paid in accordance with agreed terms, with an explanation, if appropriate; Percentage of local suppliers, relative to the total number of suppliers; Percentage of women employed relative to the total number of employees; Percentage of women in senior executive and senior and middle management ranks; Percentage of ethnic minorities employed relative to the total number of employees, with an explanation of how representative that is of the regional or national population makeup; Percentage of ethnic minorities in senior executive and senior and middle management ranks; Percentage of sites with "fly-in, fly-out" operations relative to the total number of sites; Percentage of employees sourced from local communities relative to the total number of employees; Percentage of employees that are shareholders in the company; Ranking of the company as an employer in internal surveys; Policy and		

		procedures involving consultation and negotiation with employees over changes in the company (e.g. restructuring, redundancies etc.); Statement on whether the company conforms with the International Labour Organization Conventions on the Right to Organize (nos. 87 & 98); Specify any verified incidences of non-compliance with child labour national and international laws; Summary of the policy to prevent forced and compulsory labour as specified in ILO Convention No. 29, Article 2; Percentage of quarries/mines on sites sacred for indigenous people relative to the total number of quarries/mines. **Woodley et al. (2009):** % persons/youth that leave the community on a seasonal, semi-permanent (for at least 2 years) or permanent (5 years of more) basis for employment/economic/subsistence or other reasons.
	AID (direct provision, safety nets, subsidies)	**Aurino (2014):** Aid per capita (tons/person); Social protection expenditure (% of GDP). **Kaaria et al. (2012):** Sector support and social protection measures; Safety net programs; Assistance provided (food, cash, health, etc.). **GRI (n.d.):** Direct economic value generated and distributed, including revenues, operating costs, employee compensation, donations and other community investments, retained earnings, and payments to capital providers and governments. **Azapagic (2004)**: Percentage of revenues that are redistributed to local communities from the relevant areas of operation, relative to the net sales; Investments into community projects (e.g. schools, hospitals, infrastructure) as percentage of net sales; Specify any community projects in which the company has been involved. **FAO (2014):** Share of food expenditure for the poor.
	ROCESSING (household and communal water sources, off-grid power, individual and communal gardens)	**Sovacool (2013):** Households dependent on traditional fuels. **MOFN (2009):** % households producing sufficient food; Staple food production; Household buffer food stock, above a minimum stock; Household buffer capital or assets. **Woodley et al. (2009):** % lands, territories and subsistence resources used traditionally by Indigenous Peoples for subsistence and food production to which IPs still have full access; % lands, territories and natural resources used traditionally for food production (farming, fishing, hunting, gathering, herding) currently being used by Indigenous Peoples compared to benchmarks established in the past; % traditional subsistence food resources (plant and animal) which are intact, viable, productive, healthy and free from contamination (toxins, GMOs etc.); Changes in monthly/yearly harvests of food plants and animals used traditionally and reasons for any decrease; Number of traditional food plants and animals which have been declared endangered, have decreased in numbers, and/or have disappeared; % community households which use traditional/ subsistence foods as a regular part of their diet, compared to an agreed upon number of years in the past (5, 10 or 25 depending on community history); % community members who know traditional methods for food gathering/production/preparation including the traditional language, songs, dances, stories and ceremonies associated with these practices; % indigenous youth in a community/tribe/nation who perceive or express that their traditional foods and subsistence practices as relevant in today's world. **GRI (n.d.):** Sites where resettlements took place, the number of households resettled in each, and how their livelihoods were affected in the process. **Azapagic (2004):** Number of proposed developments that require resettlement of communities, with a description, if applicable.
SUPPORTING INFRASTRUCTURE	**BUILT**	
	TRANSPORTATION	**Aurino (2014):** Road density. **UNDESA (2007):** Proportion of urban households with access to reliable public transportation; Access to all-weather road (% access within [x] km distance to road). **FAO (2014):** Energy associated with transport of a national food basket

	COMMUNICATION	**ADB (2013):** Hard coping capacities (e.g., telecommunications development) **SDSN (2015):** Number of internet users per population; Fixed telephone lines per 100 population; Mobile cellular telephone subscribers per 100 population
	DRAINAGE	**ADB (2013):** Drainage (measured as the extent of economic damage caused by floods and storms)
	SANITATION AND WASTE	**ADB (2013):** Wastewater treatment (%) **IEAE/IEA (2005):** Amount of solid waste; Amount of solid waste properly disposed of; Total amount of solid waste; Amount of radioactive waste (cumulative for a selected period of time); Amount of radioactive waste awaiting disposal; Total volume of radioactive waste; Contaminant discharges in liquid effluents. **Sovacool (2013):** Per capita sulfur dioxide emissions; Per capita energy-related CO2 emissions. **GRI (n.d.):** Total weight of waste by type and disposal method; Total amounts of overburden, rock, tailings, and sludges and their associated risks; Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally. **e3Plus:** Fuels and Petroleum Products; Use of Drums and Other Containers; Refuelling Operations; Transporting Fuel and Petroleum Products; Handling Fuels and Oils on Water; Propane and Other Liquefied Petroleum Gases; Transport and Storage of Explosives; Handling of Fuses and Blasting Caps; Blasting; Solvents and Paints; Drilling Fluids; Pesticides and Herbicides; Acids and Bases; Antifreeze. **Azapagic (2004):** Total hazardous and non-hazardous solid waste and breakdown by type and description of disposal methods; Percentage of permitted sites that have a problem of land contamination relative to the total number of permitted sites. **IRMA:** Land Application Disposal (LAD). **FAO (2014):** Size of "animal waste to energy" systems in the country.
	NATURAL	
	Ecosystem goods and services other than water, fuel and food sources: erosion control, water purification, biological control, pollination, storm protection, air quality	**ADB (2013):** Wetland disconnection; soil salinization. **IEAE/IEA (2005):** GHG emissions from energy production and use; Concentrations of pollutants in air; Air pollutant emissions; Affected soil area; Critical load; Forest area at two different times; Biomass utilization. **Sovacool (2013):** Forest as a percent of land area. **MOFN (2009):** Farmer use of inputs. **GRI (n.d.):** Total direct and indirect greenhouse gas emissions by weight; Other relevant indirect greenhouse gas emissions by weight; Initiatives to reduce greenhouse gas emissions and reductions achieved; Emissions of ozone-depleting substances by weight; NO, SO, and other significant air emissions by type and weight. **Azapagic (2004):** Emissions of greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6), breakdown by substance; Equivalent number of fully grown trees that would be required for sequestration of the total CO_2 emissions; The amount of CO_2 emissions that can (theoretically) be sequestered by the trees planted by the company; Net emissions of CO_2 (total CO_2 emissions minus CO_2 emissions potentially

		sequestered by trees); Emissions of ozone-depleting substances, breakdown by substance; Emissions of acid gases (NOx, SO_2 and other), breakdown by substance; Toxic emissions (including heavy metals, dioxins, crystalline silica and others), breakdown by substance; Other emissions - breakdown by substance. **GRI (n.d.):** Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas; Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas; Amount of land (owned or leased, and managed for production activities or extractive use) disturbed or rehabilitated; Habitats protected or restored; Strategies, current actions, and future plans for managing impacts on biodiversity; The number and percentage of total sites identified as requiring biodiversity management plans according to stated criteria, and the number (percentage) of those sites with plans in place; Number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk; Number and percentage of operations with closure plans. **Azapagic (2004):** Description of the major impacts on biodiversity associated with company activities and/or products and services in terrestrial, freshwater, and marine environments; Number of IUCN Red List species with habitats in areas affected by operations; Description of the activities for habitat protected or rehabilitation; Summary of the biodiversity policy; Number of sites rehabilitated; Total land area rehabilitated; Percentage of the land area rehabilitated relative to the total land area occupied by the closed mines/quarries, awaiting rehabilitation; Number of awards for rehabilitation and a summary, if applicable; Number of sites officially designated for biological, recreational or other interest as a result of rehabilitation; Net number of trees planted (after thinning and after subtracting any trees removed for the extraction activities); Total area of permitted developments (quarries/mines and production facilities); Total land area newly opened for extraction activities (including area for overburden storage and tailings); Percentage of newly opened land area relative to total permitted developments. **e3 Plus:** Erosion Control including minimizing disturbances, clearing of vegetation, soil conservation, trenches and pits, managing soil on slopes, soil stabilization; Managing drainage and runoff; Vegetation management; Controlling sediment. **UNDESA (2007):** Fragmentation of identified key habitat; Protected areas overlay with biodiversity (national level; Red List Index by country and major species group); Change in threat status of species (This indicator is an index based on the number of species in each category of the IUCN Red List (Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, Extinct), and the number of species changing categories between assessments as a result of genuine improvement or deterioration in status; Abundance of key species; share of forest area in total land area; Land-use change; Land degradation (The share of land which due to natural processes or human activity is no longer able to sustain properly an economic function and/or the original ecological function). **SDSN (2015):** The marine trophic index (measures the change in mean trophic level of fisheries landings).
SUPPORTING INSTITUTIONS	**INSTITUTIONS**	
	UTILITY BOARDS	
	USER ASSOCIATIONS AND CO-OPS	**Aurino (2014):** Agriculture extension services.

	EDUCATION AND TRAINING	**Aurino (2014):** Female adult literacy; Female enrolment rate, secondary; Education expenditure per capita. **GRI (n.d.):** Average hours of training per year per employee by employee category; Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career endings; Percentage of employees receiving regular performance and career development reviews. **Azapagic (2004):** Percentage of hours of training (excl. health and safety) relative to the total hours worked (e.g., management, production, technical, administrative, cultural etc.); Number of employees that are financially sponsored by the company for further education; Summary of programs to support the continued employability of employees and to manage career endings; Investment in employee training and education as percentage of net sales. **UN-Water (2009):** Capacity development of government staff. **UNDESA (2007):** The proportion of the adult population aged 15 years and over that is literate; Proportion of children receiving at least one year of a quality pre-primary education program; Early Child Development Index (ECDI); Primary completion rates for girls and boys.
	SAFETY OVERSIGHT	
	LAW ENFORCEMENT AND SECURITY	**Sovacool (2013):** Worldwide governance score. **Aurino (2014):** Governance and civil security. **Kaaria et al. (2012):** Number of small arms flow, number of incidents. **Woodley et al. (2009):** Frequency of conflict over territory and natural resources, number of court cases and disputes filed.
	MONITORING & REPORTING	**Sovacool (2013):** Quality of energy information. **Woodley et al. (2009):** Number of consultations for program planning, implementation and evaluation with community members and representatives by states, outside agencies or other entities. **IRMA:** Water quality monitoring program; Water quality sampling; Water quality criteria and "trigger levels"; Publication of water monitoring results.
	POLICIES AND PLANS	
	RESOURCE USE AND ALLOCATION	**UN-Water (2009):** Water is mainstreamed in development policies; Formal involvement of stakeholder group; Water resource issue assessment; Regulatory instruments and enforcement. **Woodley et al. (2009):** Number of active programs in Indigenous communities to restore plant or animal food species and/or their habitats and measure the impacts; Number of development projects/proposals from outside Indigenous communities that respect and uphold the rights of free prior informed consent, self-determination and development. **Azapagic (2004):** Summary of the policy for protection of land rights and for land compensation; Summary of a Community Sustainable Development Plan to manage impacts on communities in areas affected by its activities during the mine operation and post-closure; Summary of mine energy policy; Summary of the policy for the closure and rehabilitation. **FAO (2014):** Area of land/soils under sustainable management.
	CLIMATE CHANGE ADAPTATION	**Woodley et al. (2009):** Existence of and extent of participation in community-based discussions and decision making regarding the need and/or desirability for adapting traditional methods and food sources to changing conditions.

	DISASTER RECOVERY AND RISK MANAGEMENT	**Kaaria et al. (2012):** Program and disaster management. **e3Plus:** Mine spill management including Inspections, Media, Response and Mitigation; Spill Kits; Spill Report Form. **Azapagic (2004):** Describe any measures put in place to prevent acid main drainage, if applicable; Describe any measures put in place to prevent tailings dam(s) failure; Total fund for mine closure and rehabilitation, including mitigating the post-closure environmental and social impacts.
	R&D AND INNOVATION	**Sovacool (2013):** % gov expenditures on R&D compared to all other expenditures. **Aurino (2014):** Agriculture spending in R&D. **Woodley et al. (2009):** Number of new culturally and environmentally sustainable technologies or methods in use or under development for food production or related activities.
	OTHERS	**Kaaria et al. (2012):** Regulation of exports and imports; Import tariffs; Number of IDPs, refugees and returnees.

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