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Solving the E-Waste Problem (StEP) Green Paper

International policy response towards potential supply and demand distortions of scarce metals

Oliver Whitla[1], Ruediger Kuehr[1], Patrick Wäger[2]

[1] United Nations University

[2] Empa

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Oliver Whitla[1], Ruediger Kuehr[1], Patrick Wäger[2]

[1] United Nations University
Institute for Sustainability and Peace
Operating Unit SCYCLE
Hermann-Ehlers-Str. 10
53113 Bonn
Germany

[2] Empa, Swiss Federal Laboratories for Materials Science and Technology,
Technology and Society Laboratory,
Lerchenfeldstrasse 5
CH-9014 St. Gallen
Switzerland

Corresponding author: kuehr@unu.edu

Abstract

This paper takes account of international policies that relate to potential supply and demand distortions of geochemically scarce metals, using indium and tellurium, which are found in thin film photovoltaics, as examples. The findings of a search among major global institutions for such policies, including initiatives and other actions that may lead to policy shifts, are presented and discussed with regard to how supply risks of the selected metals may be affected by policy, as well as in terms of intergenerational equity. This exploratory study concludes that there is a lack of international policy aimed at affecting change relating to the supply and demand patterns of these metals. Recommendations to change this unsatisfactory situation are offered that highlight the importance of international resource data, the need for academic foundation and relevance to resource efficiency in general.

Table of Contents

1. Introduction 8
2. Intergenerational equity 9
3. Thin film PV cells and geochemically scarce metals 11
3.1. Indium 13
3.2. Tellurium 14
4. Policy measures affecting the supply and demand of scarce metals 16
4.1. Economics and scarcity 16
4.2. World Trade Organization..17
4.3. United Nations (UN) 19
4.4. European Union (EU)...24
4.5. Global Environment Facility (GEF) 25
4.6. Feed-in Tariff as concrete policy measure..26
4.7. Summary 27
5. Recommendations for sustainable policy measures to prevent scarce metals supply restrictions...28
5.1. Data accuracy 29
5.2. Academic foundation 29
5.3. Resource efficiency 30
6. Conclusions 31
7. Bibliography...33

Lists of Figures

Figure 1: Key global statistics that affect natural resource use* 10
Figure 2: Photovoltaic Cell and Module Shipments by Type, 2005-2009 13
Figure 3: World copper production, 2001-2010 15
Figure 4: Renewable electricity policies in EU Member States as of February 2007 27

Acronyms

A-Si	Amorphous silicon
ATS	Antarctic Treaty Secretariat
EIA	Energy Information Administration
CRT	Cathode ray tube
CdTe	Cadmium telluride
CIGS	Copper indium gallium diselenide
CIS	Copper indium selenide
CO_2	Carbon dioxide
CTE	Committee on Trade and Environment (WTO)
DOE	Department of Energy (US)
DSIRE	Database for State Incentives for Renewables and Efficiency (US)
EPIA	European Photovoltaic Industry Association
EC	European Commission
EU	European Union
FiT	Feed-in tariff
FY	Fiscal year
GATT	General Agreement on Tariffs and Trade
GEF	Global Environment Facility
GDP	Gross domestic product
GWP	Gross world product
ICT	Information Communication Technology
IGF	Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development
ITO	Indium tin oxide
ITU	International Telecommunications Union
KWh	Kilowatt hour
LCD	Liquid crystal display
Mb/d	Million barrels per day
MDG	Millennium Development Goal
MEA	Multilateral Environment Agreement
MMTA	Minor Metals Trade Association
NGO	Non-governmental organization

OECD	Organisation for Economic Cooperation and Development
OLED	Organic light-emitting diode
OPEC	Organization of the Petroleum Exporting Countries
PGM	Platinum group metal
PV	Photovoltaic
R&D	Research and development
RoHS	Restriction on the Use of Hazardous Substances (Directive)
RPS	Renewable Portfolio Standard
SCP	Sustainable Consumption and Production Branch (UNEP)
SETP	Solar Energy Technologies Program (US)
SG5	Study Group 5 (ITU)
TiO_2	Titanium dioxide
UNCSD	United Nations Conference on Sustainable Development
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNU	United Nations University
UNU-IAS	United Nations University Institute for Advanced Studies
UNU-ISP	United Nations University Institute for Sustainability and Peace
UNU-EHS	United Nations University Institute for Environment and Human Security
UN	United Nations
USGS	United States Geological Survey
WTO	World Trade Organization

1. Introduction

Despite the early warnings, for example through the Club of Rome in 1972, on the limits of growth resulting from increasing depletion of natural resources to satisfy economic development, resource scarcity has only recently become prominent again on the national political and hence legislative agenda. This is particularly true for geochemically scarce metals, which play a crucial role for emerging technologies that are expected to contribute to a transition towards a more sustainable post-fossil society, such as high performance permanent magnets, solid oxide fuel cells, high-temperature superconductors or thin-film photovoltaics.

Geochemically scarce metals are metals that occur at average concentrations below 0.01% in the earth's crust and include elements such as gallium, indium, platinum group metals (i.e. iridium, osmium, palladium, platinum, rhodium and ruthenium), rare earths (including e.g. cerium, dysprosium, lanthanum, neodymium or praseodymium), tantalum or tellurium (Skinner, 1979; Wäger et al., 2010). The demand for such geochemically scarce metals is expected to significantly increase in the coming years and decades (see e.g. (Angerer et al., 2009); (Schüler et al., 2011); (US DOE, 2010)).

In view of evaluating potential future supply risks, several studies have recently addressed the criticality of geochemically scarce metals (see e.g. (European Commission, 2010); (National Research Council, 2008); (U.S. DOE, 2010)). Depending on the scope, it appears that amongst others, gallium, indium, platinum group metals, rare earth elements and tellurium will be critical[1] or near-critical in the short and medium term. According to a report from the European Commission (2010) (European Commission, 2010), the comparatively high supply risks for these elements are mainly a consequence of the concentration of production within a few countries, in many cases associated with low substitutability standards and low recycling rates.

This paper explores the international policy framework surrounding the supply and demand of geochemically scarce metals, seeking to discover where international policies have advanced to this end. Emphasis is hereby given to geochemically scarce metals used in 'thin film' photovoltaic (PV) power systems, a clean energy technology whose demand is expected to increase in the coming years. Regarding the geochemically scarce metals used in this technology, the focus will be laid on indium and tellurium.

The paper consists of six chapters. Following the general introduction in Chapter 1; Chapter 2 addresses the concept of intergenerational equity, which is considered important in a discussion of potential future access to critical resources. Chapter 3 provides a brief overview of the thin film PV industry and outlines issues related to the supply of indium and tellurium, with a focus on the interdependencies with the

[1] A raw material is labeled critical when the risks of a supply shortage and its impacts on the economy are higher compared to most of the other raw materials (European Commission. Critical Raw Materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials. 2010.)

production of other (base) metals. Chapter 4 explores international policies aimed at changing potential distortions in the future supply and demand of the example scarce metals, concluding with a brief summary. Chapter 5 discusses the findings of the international policy search and offers a list of recommendations and suggests three key areas of focus for a framework for international policy relating to geochemically scarce metals. Our concluding remarks are presented in Chapter 6.

2. Intergenerational equity

The concept of intergenerational equity is crucial to an exploration of the need to address potential future supply and demand distortions of geochemically scarce metals. In the context of sustainable development and the natural environment, intergenerational equity is “fairness in the intertemporal distribution of the endowment with natural assets or of the rights to their exploitation” (OECD, 2001). In other words, the type of world that future generations inherit will be a reflection of decisions made in the present with regard to their access to natural resources.

Global resource use is affected by factors other than the limited nature of a particular resource, raising questions about the degree to which intergenerational equity is considered a critical factor in resource use.

The question of the range and flexibility of options that future generations may have in terms of natural resources is not a new one. The traditional view in economics was that societal demand was essentially determined by individual ‘wants’, whereas the rise of the ‘limit to growth’ concept and equity between generations shifted this demand to an objective standard of ‘need’ (Schachter, 1977).

Using the World Bank key statistical database, we selected several statistical indicators that directly or indirectly affect resource use on a global scale:

- world population
- total world exports of goods and services as a percentage of gross domestic product (GDP)
- GWP (in other words, the world’s GDP)
- life expectancy at birth (global average).

Although not an exhaustive quantitative measurement, these indicators highlight trends that directly affect global resource use. Figure 1 indicates an upward trend across the four global indicators selected. From one perspective these trends represent a veritable success in terms of the WTO’s core principle of trade liberalization, particularly the sharp growth in GWP from around \$1.3 trillion in 1960 to \$48 trillion in 2006. Growth in the export of goods and services as a percentage of GDP is also representative of the increasing internationalized nature of trade. Advances in a variety of fields including nutrition, healthcare and medical science mean that life expectancy at birth has risen from 50 in 1960 to almost 70 years of age in 2006.

However, world population and GDP are also significant factors with an impact on the world’s natural resources, for example in terms of:

(i) The number of people on the planet and the kind of policies they create with respect to natural resource use and technological development

(ii) The type and function of goods and services that make up the world’s GWP in terms of materials used and product life cycles

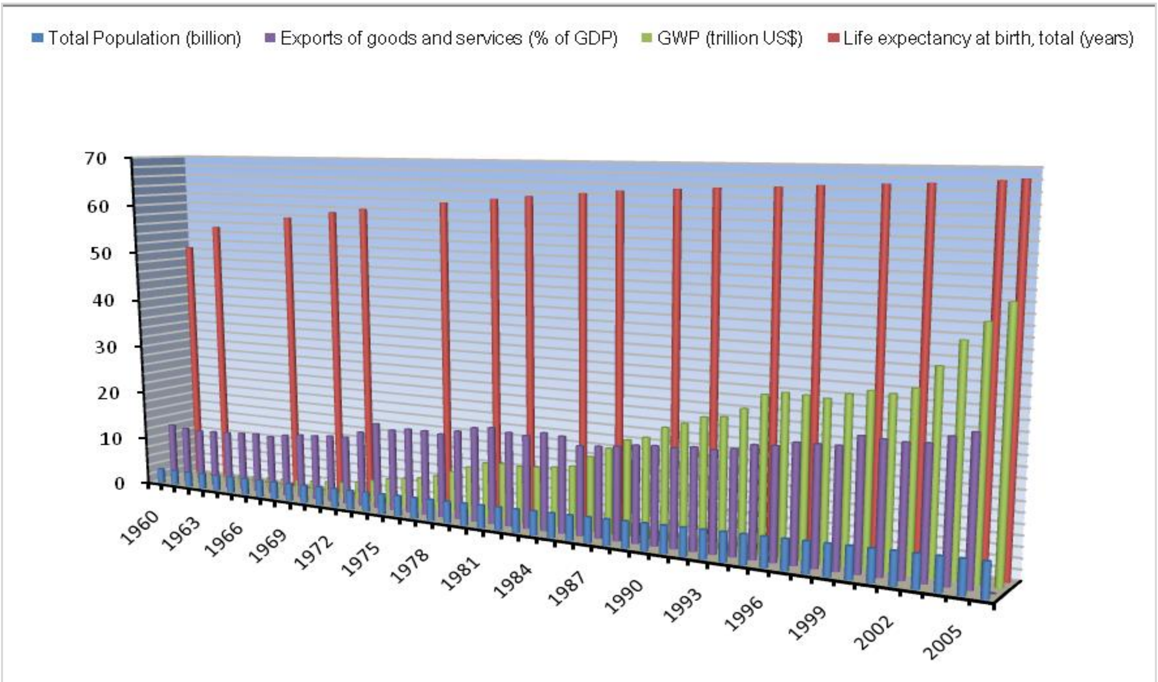

Figure 1: Key global statistics that affect natural resource use*

*The chart is not intended for comparison between categories but to highlight upward trends in each individually. Gaps in 'life expectancy' columns are where data were not available. (Data source: World Bank key statistical database, 2008)

The trends shown in Figure 1, combined with WTO's mandate of deregulative free market liberalism, seem to indicate a difficult policy environment for a global safeguard for future access to non- renewable natural resources.

The OECD publication, *Energy: The Next Fifty Years*, explores patterns that suggest a relative continuation of the trends charted in Figure 1 (OECD, 1999). The study highlights world population demographic projections until 2100, showing not only a steep increase in world population to just under 12 billion in 2100, but also that over two-thirds of these people will be urban dwelling in developing countries.

The publication presents three scenarios for the years 2050 and 2100:

- Case 'A' is 'high growth' with extensive technological development and subsequent high economic growth
- Case 'B' is the 'middle course' with less extensive technological development and economic growth
- Case 'C' is considered as being 'ecologically driven' where large resource transfers from the North to South take place with a high degree of international cooperation centred on environmental protection and international equity.

All three cases project GWP growth; B and C forecast a GWP of $75 trillion by 2050, and the 'high growth' case 'A' a GWP of $100 trillion. The high and middle growth scenarios assume no environmental taxes or restraints on carbon dioxide (CO_2) emissions, whereas the ecologically driven case (C) includes such taxes and emission restraints.

Missing from these projections is perhaps a case 'D' where technological growth continues, with subsequent economic expansion, but where the non-renewable oil reserves run low in 50-60 years and leave a thriving global economy without its major source of fuel and a shortage of renewable industries to substitute the energy production losses. Given the continued rate of population and GWP growth, and the high dependence of the global infrastructure of oil, a scenario of depleted reserves could occur within several decades. To what extent is this equitable for future generations?

By omitting any possibility of shortages of crude oil reserves and insufficient explanations for alternatives, the OECD projections implicitly suggest there are enough known oil reserves to support 12 billion people and the expansion of developing countries until the year 2100. However, the study does note that:

> "with continued exploration efforts and continuing technological progress, accessible and affordable reserves have increased, and this trend will continue to at least 2020. After that all scenarios move away from their current reliance on conventional oil and gas" (OECD, 1999).

Given the perspective of hindsight a decade later, it may seem a bold claim that the world can "move away" from its current reliance on conventional crude oil and natural gas by 2020. In fact the *World Oil Outlook 2007* published by the Organization of the Petroleum Exporting Countries (OPEC) suggests that, by 2030, non-conventional oil supply (including natural gas liquids) will be 20 million barrels per day (mb/d) of the total world supply of 117.6 mb/d (OPEC, 2008). This is certainly an increase from current non-conventional supplies but is not a "moving away" from the conventional 'oil well' supply methods suggested in the 1999 OECD case study. This projected increase in oil use is therefore not underpinned by principles of intergenerational equity, despite the implicit suggestion that a "moving away" from conventional methods will occur at some point.

The trends discussed above show few signs of being mitigated to reflect the dynamics of a finite and non-renewable resource. According to the OECD's definition of intergenerational equity, in this case there is little indication that a 'fairness' exists for future generations to be endowed with natural assets or the rights to their exploitation.

3. Thin film PV cells and geochemically scarce metals

Before thin film PV cells were developed over a decade ago, the predominant type of solar cells were silicon-based. These first generation or 'silicon wafer' cells have been produced for many decades in a variety of shapes and sizes for numerous uses at remote locations requiring power such as rural 'off-grid' properties, lighthouses, offshore oil rigs, telecommunications towers and space-based uses to power satellites and other spacecraft.

However, the 'cost' and 'energy payback time' of these cells meant that, in many cases, solar power was not an economical alternative for potential customers as it could not compete on price with electricity from traditional sources such as coal.

'Cost' refers not only to the materials used, but also the inability of economies of scale to reduce the overall cost of production. 'Energy payback time' refers to the length of time a cell takes to generate the amount of energy used in its production. For example, mono silicon-based PV units need roughly two years,[2] while cadmium tellu-

[2] These statistics are taken from data collected either from systems installed in

ride PV (thin film) cells require only one year (Alsema et al, 2006).

The need for cheaper materials, lower production costs and shorter energy payback time (fuelled by the pressures of a world coming to terms with climate change) eventually drove research into alternative materials to convert solar energy into electricity. A major outcome of this research was several materials that can be applied using a 'thin film' application on a solar panel. Such materials include:

- amorphous silicon (a-Si)
- cadmium telluride (CdTe)
- copper indium gallium diselenide (CIGS) and copper indium selenide (CIS)
- titanium dioxide (including ruthenium) dye-sensitized 'Grätzel cell' (TiO_2).

Before exploring the example elements (Tellurium and Indium) in these materials further, we should first understand the business and policy environment in which thin film solar cells are produced and sold.

Most of the solar research and development activities in the United States are funded through the US Department of Energy (DOE). For example, in November 2007 the DOE announced the investment of $21 million towards the research and development of 'Next Generation Solar Energy Projects' (many of which are thin film) as part of the President's Solar America Initiative (US DOE, 2007). The Solar America Initiative was launched in January 2006 and is led by the DOE's Solar Energy Technologies Program (SETP). Its ultimate goal is to reduce the cost of PV technologies such that the price of PV-generated electricity is close to parity with that of conventional electricity by 2015.

In 1995 the DOE established and funded the Database for State Incentives for Renewables and Efficiency (DSIRE),[3] which is essentially an 'all-in-one' user friendly database and information service for incentives, grants, bonuses, rates, loans, taxation, rules, regulations and policies in relation to energy efficiency across the United States. There is extensive coverage of PV panels in the database.

These ambitious programmes are behind the growth seen in the thin film PV market in the US. Figure 2 highlights the increase in thin film PV shipments over the last several years, with a sharp jump around 2006 when the Solar America Initiative was launched. Sales of 'other' non thin film PVs also increased sharply between 2007 and 2008.

The increases are further highlighted in a US Climate Change Technology Program report published in 2003:

"A new generation of potentially lower-cost technologies (thin films) is entering the marketplace. A 25-megawatt amorphous silicon thin-film plant by United Solar is reaching full production in 2005. Two plants (First Solar and Shell Solar) using even newer thin films (cadmium telluride and copper indium diselenide alloys) are in first-time manufacturing at the MW-scale. Thin-film PV has been a focus of the Federal R&D efforts of the past decade because it holds considerable promise for module cost reductions" (US CCTP, 2003).

Federal research and development (R&D) efforts continue, with $22 billion having been invested since fiscal year (FY) 2001 and with $4.4 billion requested for FY2009 (US CCTP, 2008).

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southern Europe or with an irradiation of kWh/m^2/year.

[3] This is an ongoing project run jointly by the North Carolina Solar Centre and the Interstate Renewable Energy Council (IREC).

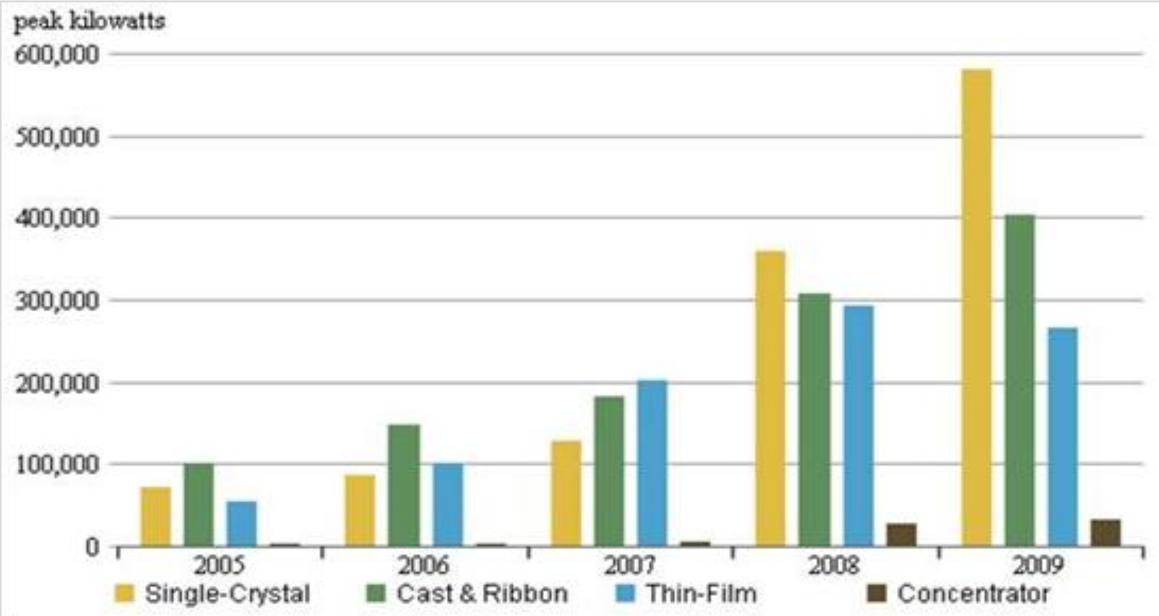

Figure 2: Photovoltaic Cell and Module Shipments by Type, 2005-2009

(Source: U.S. Energy Information Administration (EIA), Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey.)

Despite the overall growth in production within the thin film PV industry (Figure 2), its current market share of around 25% compared to Crystalline cells (iSuppli Market Research, 2009) highlights the relative immaturity of the global thin film PV market. Growth is projected to continue, however, reaching 31% by 2013 (iSuppli Market Research, 2009). This growth will place increased demand upon the raw materials used in thin film PV cells, including indium and tellurium.

On the supply-side, there are also widely differing conclusions among industry specialists regarding indium and tellurium availability[4] (ICEPT/WP/2011/01). Hence, increased demand coupled with a wide variance in estimates of availability, are contributing factors in the need for an appropriate policy response.

[4] Please see ICEPT Working Paper, page 7, Table 2

3.1. Indium

Indium is used in the production of copper indium gallium diselenide (CIGS) thin film PV cells. It is a scarce metal, ranked 61st among elements in their natural form found within the Earth's crust in terms of abundance (USGS, 2004).

Indium is produced primarily as a by-product of zinc refinement (USGS, 2008d). Although there are no precise data on global indium reserves, indium production is generally a function of zinc refining. Like tellurium, an abundance of zinc does not automatically indicate a plentiful supply of indium because of the tiny amounts of indium (28 grams) able to be produced per ton of zinc. Global indium refinery production was 510 tons in 2007,[5] with global reserves estimated at 11,000 tons (USGS, 2008d).

[5] This figure does not include the United States.

Recovery efficiency is an increasingly important factor in the supply of geochemically scarce metals, as there typically are considerable inefficiencies along a geochemically scarce metal's life cycle from primary production and manufacturing to product use and recycling (Hagelüken and Meskers, 2010, p.193).

Rapid changes are influencing the demand for indium. Indium's primary use is in indium tin oxide (ITO) thin film coatings, such as liquid crystal displays (LCDs) for televisions and computer screens including organic light-emitting diodes (OLEDs). ITO represents approximately 84 per cent of global indium consumption (USGS, 2008d), including for new applications in thin film PV cells.

Further advances in LCD technology and product quality, combined with widespread conversion by consumers from older style cathode ray tube (CRT) sets to LCD displays and marketing strategies by manufactures to encourage consumers to purchase larger LCD screens (Bainbridge, 2008), are all leading to increasing demand for indium.

Use of secondary production techniques such as recycling could counteract supply concerns related to increased demand. Several large secondary indium producers in the Republic of Korea and Japan have announced plans to further increase their recycling capacity (USGS, 2008d); however, as mentioned earlier, indium is primarily sourced via zinc production.

Increased demand for indium occurs through, for example, flat screen monitors. The major LCD manufacturers are working to develop progressively larger panel displays requiring even more indium. Given the scarce nature of indium and the estimated decades of global reserves remaining, this trend raises many questions concerning reserves and production. LCD screens use substantially less power than their CRT counterparts (Timmins, 2004); however, does this factor outweigh the need for a deeper discussion on securing the continued medium to long term availability of indium?

Research has begun to find a substitute for indium in LCD screens. One possible option is aluminium oxide (modified at the nano level to allow electrical conductivity); but though more abundant, its production is energy intensive and generates problematic waste (Grimes et al, 2008).

3.2. Tellurium

Tellurium is used in the production of cadmium telluride PV cells. It is a geochemically scarce element which is generally produced as a by-product of copper. 90 per cent of global tellurium is produced from anode slimes collected from electrolyte copper refining (USGS, 2008b). It is therefore necessary to outline the current production and usage patterns for copper in order to understand their effect on tellurium.

Global production of copper in 2007 was approximately 15.6 million tons, while a 'preliminary assessment' estimated that global land-based reserves exceeded 3 billion tons, plus an estimated 700 million in deep-sea nodules (USGS, 2008c).

Very small amounts of tellurium are recovered per ton of copper produced. A study by Green (2006) based on data from a four-year survey of copper refineries (1999-2003) suggested that previous estimates of tellurium availability from copper anode slime should be revised.

The study found that approximately 105 grams of tellurium are available per ton of copper, almost half the amount of previous calculations and equivalent to a total world production of 12.4 million tons of copper in 2005. The approximate quantity of tellurium that could be extracted from this quantity is just 430 tons. So what was the 'actual' tellurium production for 2005? The study estimates 304 tons, which leaves a gap of just 126 tons between total world production and total available quantities of tellurium.

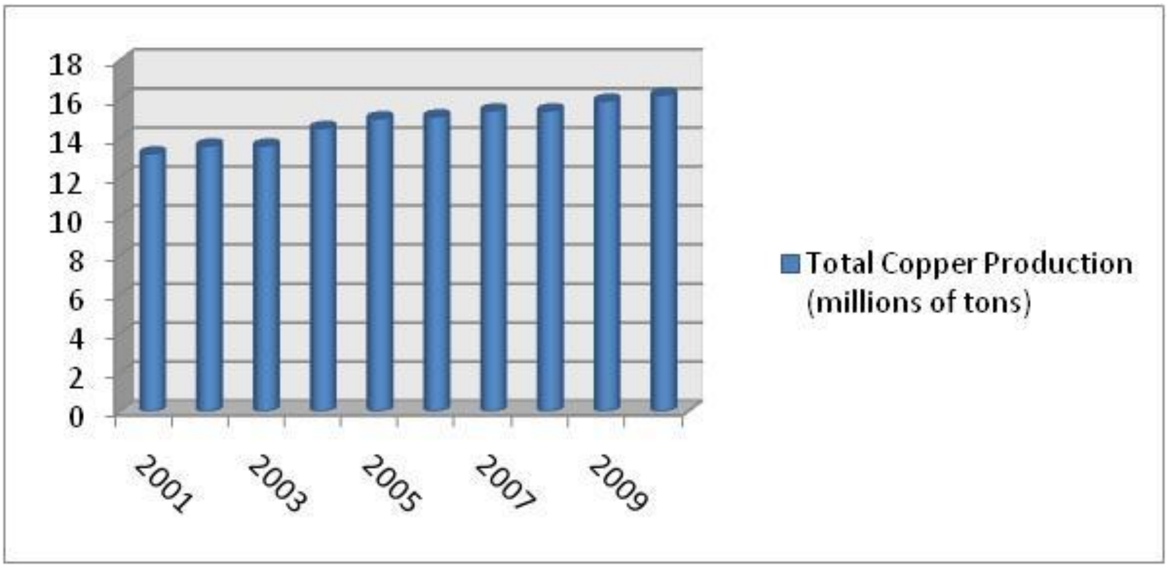

Figure 3: World copper production, 2001-2010

(Data source: USGS Mineral Commodity Summaries: Copper; available from http://minerals.usgs.gov/minerals/pubs/commodity/copper/)

According to the US Geological Survey (USGS), in 2007 "there was a sharp increase in demand for high-purity tellurium for cadmium telluride solar cells" and that "tellurium consumption also increased in thermal cooling application" [6] (USGS, 2008b). This suggests the possibility of increased demand for tellurium beyond what is possibly available from copper refineries. Tellurium is used in re-writable CDs and DVDs, flash memory, digital cameras and in new high storage discs, as well as CdTe photovoltaic cells.

Given the likely continued rise in demand for tellurium, will copper production expand enough to absorb continuing increasing tellurium demand?

[6] The USGS report does note, however, that 'detailed' information on the world tellurium market was not available.

Copper production has been rising steadily over the past several years (Figure 3), though this rise can reasonably be attributed to increased demand for copper, not tellurium. For example, in 2001 China became the world's largest importer of copper (UNCTAD/WTO, 2008); demand has increased rapidly since then, including a 37 per cent rise in copper consumption in the first six months of 2007 (USGS, 2008c).

As noted earlier, we can be relatively certain that tellurium demand will not drive significant increases in copper production due to the tiny amounts recoverable from each ton of copper. Producing 1 ton of tellurium would require roughly 28,000 tons of extra copper to be produced. Unless there is a continuous and equivalent rise in demand within the copper industry, any extra copper produced for the purpose of extracting tellurium would essentially become surplus.

Mining companies would simply not find this profitable, but as the Minor Metals Trade Association (MMTA) points out, this is not the only factor inhibiting tellurium supply:

> "The growth in copper recovery by leaching processes (bio-, or SX/EW) is exerting a downward pressure on supply, as tellurium is not recovered by this copper production method. There is also limited scope to increase secondary tellurium production" (MMTA, 2006).

It is therefore clear that, while tellurium offers inexpensive and efficient solutions for the thin film photovoltaic market, the availability of the metal is currently bound to the supply and demand mechanics of copper and could become an issue without a significant increase in the recovery of tellurium from anode slimes, as it is expected e.g. by DOE, 2010.

4. Policy measures affecting the supply and demand of scarce metals

Before looking specifically for policies and other measures to address potential supply and demand distortions, it is necessary to understand the context in which they could have been developed, i.e. contemporary 'free market' economics. This also provides a perspective of scarcity in both historical economical and contemporary environmental contexts.

4.1. Economics and scarcity

Widely understood as having its roots in the writings of David Ricardo and Adam Smith, the modern market economy is a continuous and amendable extension of their eighteenth century theories. Although Smith's work may not have covered the complexities and scale of modern international commodity trade, it did foresee the creation of free markets, where government control is reduced to a minimum and individuals operate according to their self-interest.

The world-renowned economist Gregory Mankiw describes 'economics' as "the study of how society manages its scarce resources" (Mankiw and Taylor, 2006). The 'scarcity' to which Mankiw refers is one where "society has limited resources and therefore cannot produce all the goods and services people wish to have" (ibid).

The meaning of scarcity used in this paper therefore recognizes the geochemical scarcity of metals but also the potential access to them by future generations.

Scarcity should therefore be understood as being more specific than simply the quantity of limited resources available to meet society's economic wishes and a regulator of price.

It is important to distinguish between these two meanings, as modern economic theory underpins the global trade in 'scarce' resources (economic scarcity), and should therefore be understood when discussing measures to address a potential supply and demand distortion of scarce metals (absolute scarcity).

Modern economics, whilst moving towards 'free' market processes, maintains various degrees of government intervention. Again quoting Mankiw, "*trade policy is a government policy that directly influences the quantity of goods and services that a country imports or exports*" (Mankiw and Taylor, 2006). Trade policy is described by these authors as the use of tariffs or import quotas by governments, generally to protect domestic markets and/or to alter the pricing of goods or services.

National trade policy can therefore affect the supply and demand of geochemically scarce metals and could potentially seek to secure long-term stability against supply and demand distortions based on absolute scarcity. In cases where a particular country is a major producer and/or source of a metal (e.g. copper in Chile or rare earth metals in China), these influences on pricing and exchange are significant for global markets. It is therefore important to investigate the key international institutions and initiatives that regulate, monitor and/or research the global trade in scarce resources.

4.2. World Trade Organization

The World Trade Organization (WTO) replaced its predecessor, the General Agreement on Tariffs and Trade (GATT), in 1995. Its main aim is to liberalize international trade by providing a forum in which members (governments) can negotiate and mandate the rules for a global trading system.

According current Director General, Pascal Lamy, sustainable development was central to the WTO's founding charter (WTO, 2007), as indicated by the setting up of the Committee on Trade and the Environment (CTE). The CTE's mandate covers a range of issues where the principles of trade liberalization and environmental protection meet. Paragraph 51 of the Doha Ministerial Declaration states:[7]

> "51. The Committee on Trade and Development and the Committee on Trade and Environment shall, within their respective mandates, each act as a forum to identify and debate developmental and environmental aspects of the negotiations, in order to help achieve the objective of having sustainable development appropriately reflected." (WTO, 2001)

There is nothing in any of CTE's online publications to suggest that any broad policy measures have been taken to address potential supply and demand distortions of geochemically scarce metals; if such a policy were to arise, it is likely be in the form of a Multilateral Environment Agreement (MEA) as it would relate directly to sustainable resource use.

There are presently over 250 MEAs operating globally that address a variety of environmental concerns, for example:

- Basel Convention on the Transboundary Movements of Hazardous Waste and Their Disposal
- Convention on International Trade in Endangered Species of Wild Fauna and Flora

Recognizing prior to the Doha negotiations in 2001 that many of these MEAs affect international trade, WTO members agreed to negotiate the ongoing relationship between the mandate of Multilateral Environment Agreements and WTO rules. These negotiations occur in special sessions of the CTE and focus on those MEAs with 'specific trade obligations' (WTO, 2008a).

About 20 of the 250 MEAs affect trade policy; according to the WTO, they may restrict the trade of a particular species or products, for example, or allow a country to restrict trade more broadly in some circumstances. The WTO's comprehensive documentation of these MEAs highlights the implications for international trade that signatories to various MEAs may experience (WTO, 2008b).

In terms of an MEA that may affect policy with regards to geochemically scarce met-

[7] The Doha WTO Ministerial Declaration was adopted on 14 November 2001.

als, the Convention on the Regulation of Antarctic Mineral Resource Activities (which came into force in 1998 as the Protocol on Environmental Protection to the Antarctic Treaty) is as close to being considered relevant to our discussion as any other agreement.

The aim of this convention, within the broader framework of the Antarctic Treaty system, is to "*prohibit activities [around mineral resources] that would cause damage to the environment of ecosystems of the Antarctic or effect global or regional climate patterns*" (UNEP, 2005).

The Antarctic Treaty is relevant here insofar as its objective to provide protection of 'mineral resources' in Antarctica in general. Article 7 of the subsequent Protocol on Environment Protection to the Antarctic Treaty states that "*any activity relating to mineral resources, other than scientific research, shall be prohibited*" (ATS, 1998).

The treaty is effectively an outright ban on all mining in Antarctica and hence at present has little influence on the international supply of geochemically scarce metals. It is part of a larger framework of treaties, the Antarctic Treaty System, designed to prevent military conflict in the region. However, the treaty itself is in some ways an example of the possibility that international frameworks can exist to protect mineral resources, a point we revisit in Chapter 7.

Apart from the Antarctic convention on mineral resource activities, there are no other examples of MEAs that affect the WTO's governing rules and principles (WTO, 2008b). Hence, we now turn to the United Nations to examine how international policy influences the supply of geochemically scarce metals.

4.2.1. WTO World Trade Report 2010

In a submission the World Trade Report, 2010, (OECD, 2010a) highlight issues regarding export restrictions in the trade of selected metals and minerals, also known as 'strategic raw materials'. The paper finds several motivational factors influencing export restrictions in strategic raw materials:

- Conservation of natural resources
- Social objectives, such as protection of the environment
- Promotion of downstream industries
- Revenue maximization
- Preservation of reserves for future use

The paper recommends that for export restrictions to be effective towards social objectives such as environmental protection, export restrictions should effect production levels, rather than export volume alone (OECD, 2010a). Moreover that future discussion in this area could work towards establishing a hierarchy of policy measures. This could provide a deeper understanding of those policies that more efficiently achieve their objectives (OECD, 2010a).

In the subsequent Raw Materials workshop of the Working Party of the Trade Committee, the Chairpersons' findings included several relevant points to the discussion in this Green Paper:

- Recognition of the significance of export restrictions on the world trade of raw materials
- Recognition that export restrictions effect a wide range of products
- A global challenge that presents a strong case for international cooperation in dealing with the issue

- Export restrictions generate economic inefficiency through the distortion of resource allocation (OECD, 2010b)

The export restrictions discussed in the workshop, including the findings of the submission in the World Trade Report (OECD, 2010a) are therefore important aspects to the broader discussion of scarce metals supply in this paper. As a domestic policy response, export restrictions indicate the difficulties faced to reach an international coordinated policy response to potential future supply distortions of scarce metals.

4.3. United Nations (UN)

Through its charters, treaties, conventions, mandates, agreements and protocols, the United Nations is permanently engaged with policy decisions around the world. As highlighted earlier, a policy that seeks to secure the future supply and demand of geochemically scarce metals is a probable component of the notion 'sustainable use of natural resources'. With this in mind we now focus our search for measures affecting the supply and demand of scare metals within several UN agencies and affiliates.

4.3.1. United Nations Millennium Development Goals (MDG)

The UN Millennium Development Goals (MDG) were put forward to address the world's most urgent issues. Goal 7 is to 'ensure environmental sustainability' and aims to address the following issues:

- forest coverage
- carbon dioxide emissions
- consumption of ozone-depleting substances
- fish stocks
- water use and sanitation
- terrestrial and marine environment protection
- species extinction.

There is no indication within MDG 7 of anything that specifically addresses the supply and demand of geochemically scarce metals (MDG Monitor, 2008). This is likely to be attributable to the MDG's broad focus on the quality of air, water, food and the rate of extinction among other species.

While the depletion of indium, for example, may have dramatic consequences for our ability to produce particular technologies, and perhaps other unknown long-term effects, it does not help to directly alleviate poverty in the short term. This highlights the fact that 'ensure environmental sustainability' is a broad term.

Without specific measures to address the use of geochemically scarce metals, which are perhaps several times more binding than a 'goal', we may find ourselves beyond a point at which suitable measures can be taken. Forest coverage, carbon dioxide emissions and fish stocks, for example, can be quantified to the extent to which definite action can be planned to mitigate serious outcomes. Less is known, for example, about the quantities of indium or tellurium and potential future supply and demand dynamics. This level of uncertainty invokes the need to reflect on the 'Precautionary Principle' (see Section 6.3.3).

4.3.2. United Nations Environment Programme (UNEP)

Mineral resource depletion is acknowledged by the United Nations Environment Programme (UNEP) to be an urgent issue. UNEP's Sustainable Consumption and

Production (SCP) Branch advises that metals such as copper (directly linked to the supply of tellurium), silver and gold are projected to run over their reserve base by 2050. Furthermore, the branch suggests that indium is expected to "run out within the next 15-20 years" and cites the extraordinary price surge it experienced from $60 per kilogram in 2003 to over $1,000 per kilogram in 2006 (UNEP-SCP, 2008a). Although this dramatic price increase highlights the market's reaction, we shall look closer for any policy related studies or discussion directed at effecting potential supply distortions.

The SCP Branch, under the Division of Technology, Industry and Economics within UNEP, is charged with supporting the development and implementation of policies that promote sustainable consumption and production. One mechanism of particular relevance is the International Panel for Sustainable Resource Management (Resource Panel), which was established in November 2007 and has a mandate:

- To gather information on the use of renewable and non-renewable resources and related sustainability impacts
- To provide scientific assessments of environmental impacts and policy advice on the efficient use of natural resources (UNEP-SCP, 2008b)

The Resource Panel has published the first of six reports covering a broad range of issues relevant to scarce metals (UNEP-SCP, 2010).

The first report 'Metal Stocks in Society' attempts to quantify in-use stocks for five metals (aluminium, copper, iron, lead and zinc). The study uses both "top-down" and "bottom-up" methods to quantify metals stocks. The "top-down" method offering larger 'temporal and spatial' scale to the results, with a trade-off in detail, whilst the "bottom-up" method offers more detailed and 'spatially explicit' results (UNEP-SCP 2010). The paper concludes that in-use stocks only become valuable once the information can be used to formulate potential future scenarios regarding use intensity, discard and re-use patterns. Furthermore, the report recognizes the challenges ahead in the need for continued improvements in evaluating stocks and overall rates of growth and decay (UNEP-SPD, 2010).

The next five reports will cover a broad scope of issues relating to scarce metals, concluding with a report entitled 'Critical Metals and Metal Policy Options'. This final report in the series, drawing on the findings of the previous five reports, is therefore a specifically relevant international policy discussion of scarce metals. Moreover, that the findings include data on zinc, which we have noted to be extensively relevant to indium supplies, and copper, which is relevant to tellurium supplies.

Speaking at Green Week in June 2008, the Deputy Executive Director of UNEP, Angela Cropper, noted that the Resource Panel includes representatives of civil society and support from many governments around the world, including the European Commission and described it as part of the broader need to meet the "challenges of decoupling economic growth from environmental degradation" (UNEP, 2008c).

The SCP Branch's annual publication, *Planning for Change* (UNEP-SCP, 2008d), presents guidelines on how national governments can approach the creation of sustainable consumption programmes and emphasizes the importance of:

- Obtaining high-level commitment
- Establishing multi-stakeholder processes
- Setting objectives and indicators, preferably integrated with existing strategies on sustainable development and poverty reduction

Although essentially directed at national governments, the document is the result of collaboration between governments and could therefore be considered an international guideline. While the guidelines are not a binding international policy, the collaboration and coordination necessary to achieve them is an important early phase.

4.3.3. United Nations University

The 14 specialized United Nations University (UNU) institutes around the world are each dedicated to particular research foci that represent the broader challenges faced by United Nations' agencies. As discussed above, the study of geochemically scarce metals could, or perhaps should, be considered to fit within the 'sustainable development of natural resources' framework and one of the research programmes listed in the UNU charter is aimed at 'the environment and the proper use of resources'.[8]

UNU Institute of Advanced Studies

The various UNU research arms are engaged in a range of topics relating to sustainable resource use. For example, the UNU Institute of Advanced Studies (UNU-IAS) has published a paper that explores the implications of the Precautionary Principle on policy decisions for trade and the WTO (UNU-IAS, 2005).

The Precautionary Principle is a common component of MEAs and stems from a number of cases of serious environmental degradation that were not prevented in time to reverse or adequately slow the degradation. Such experiences provided greater understanding of 'known' and 'potential' risks, enabling attempts to anticipate environmental harm despite the magnitude of uncertainty in risk perception (OECD, 2002).

The Precautionary Principle has particular relevance to any policy or regulatory action to stem the depletion of naturally occurring scarce metals from the Earth's crust. As discussed in Chapter 5, there are insufficient data on tellurium and indium to generate an accurate picture of their reserves and the subsequent point at which they could be depleted beyond further economic use.

The UNU-IAS research found elements of the Precautionary Principle within the following WTO agreements (UNU-IAS, 2005):

- Agreement on Sanitary and Phytosanitary Measures
- Agreement on Technical Barriers to Trade
- Cartagena Protocol on Biosafety.

There was no indication of the Precautionary Principle, within or outside an MEA, interacting with the WTO trade system in terms of geochemically scarce metals.

The UNU-IAS paper concluded that recent interpretations by the WTO on the parameters surrounding the use of precaution found that, while countries are permitted to take precautionary measures in particular circumstances, they will face challenges if required to defend a precautionary action before the WTO Dispute Settlement Body. In other words, precaution is a difficult concept to codify directly into law and particularly WTO trade law.

UNU Institute for Environment and Human Security

The various research paths followed by the UNU Institute for Environment and Human Security (UNU-EHS) underpin the connections between environmental issues and their impact on human security. This

[8] For the UNU Charter, see: www.unu.edu/hq/rector_office/charter.htm

includes, for example, research that focuses on international environmental governance and how this relatively new phenomena operates within the parameters of international relations (Rechkemmer, 2006). The development of a policy to secure the supply of scarce resources is likely to benefit from such studies.

UNU Institute for Sustainability and Peace

The UNU Institute for Sustainability and Peace (UNU-ISP) takes an innovative, integrated approach to sustainability – one that encompasses global change, development, peace and security. Its first Operating Unit in Germany, SCYCLE, began work on 1 January 2010 and incorporates the activities of the former UNU Zero Emissions Forum (ZEF) European Focal Point.

ZEF was a dedicated forum within the UNU structure in which representatives from business, government, academia and non-governmental organizations (NGOs) collaborated on how to achieve the goals of the 'zero emissions' concept. This concept has direct relevance to geochemically scarce metals as it:

> "advocates an industrial transformation whereby businesses emulate the sustainable cycles found in nature and where society minimizes the load it imposes on the natural resource base and learns to do more with that [sic] the earth produces" (UNU-ZEF, 2008).

Related publications indicate a theoretical framework in which a policy approach towards securing the supply of geochemically scarce metals could take shape. For example, what kind of strategic approaches for the sustainable use of resources exist at the junction between the needs of human activity and ecological longevity? (Kuehr, 2000), or how should materials be measured in terms of the total quantity required to produce a particular product(s), and what are the implications of this for the concept of 'resource productivity'? (Schmidt-Bleek, 1999).

4.3.4. United Nations Conference on Trade and Development (UNCTAD)

The Trade, Environment and Development (TED) Branch of UNCTAD currently has around 45 publications relating to issues arising from the convergence of trade and sustainable development. Like the Millennium Development Goals, there are no publications/projects that look specifically at potential distortions in the supply and demand of geochemically scarce metals. The rationale described above for MDGs may also apply here partially, i.e. the focus of the TED Branch is more on urgent human and environmental needs, deemed to be of higher priority by UNCTAD. Broadly speaking, the TED Branch is concerned with:

(i) Market access – the way in which environmental regulations in developed nations affect access to markets

(ii) Environmental goods and services – a situation where increased trade through liberalization comes with positive environmental outcomes

(iii) Organic farming – the promotion of organic agriculture

(iv) Indigenous knowledge – the protection of indigenous knowledge, innovations and practices in tandem with socio-economic development (UNCTAD-TED, 2008)

As geochemically scarce metals are found in both developed and developing countries, points (i) and (ii) are directly relevant to international approaches to address potential distortions in international supply and demand, particularly with respect to the ownership of supply chains and equality in pricing mechanisms.

The TED Branch of UNCTAD is a potential contributor to the formation and implementation of policy on the secure supply and demand of geochemically scarce metals, particularly with regard to capacity building and the ramifications that such a policy could have on developing nations. For example, 70 per cent of the known world reserves of indium are found in China[9] (USGS, 2008d).

Looking at the mining sector more broadly, UNCTAD and several UN and governmental agencies support Global Dialogue's Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF). The forum's key goal is to enhance the contribution by the mining sector to sustainable development and poverty reduction (UNCSD, 2010).

In IGF's report to United Nations Conference on Sustainable Development (UNCSD) there are indications of how industry and government can undertake sector-wide initiatives that address areas of common concern relevant to our discussion. For example *"…the forum has now become the leading global intergovernmental policy forum on mining and sustainable development. Membership is open to all member countries of the United Nations that have an interest in effectively managing their mining/metals sector in a manner that optimizes its contribution to sustainable development."* (IGF, 2010).

It could therefore be expected that a policy to secure scarce metals supply, which is directly relevant to the mining sector, would be supported by the aims of the IGF. Not only because IGF is an intergovernmental policy forum but because its aims are also consistent with the notion of sustainable development and therefore includes several of the questions raised in this paper concerning scarce metals supply.

4.3.5. International Telecommunications Union

Functioning as the United Nations specialized agency for information and communication technologies (ICT), The International Telecommunications Union (ITU) covers three 'sectors' or areas in the field of ICT; (i) radio communications, (ii) Standardization and (iii) Development. These three sectors operate through conferences and meetings and include 'Study Groups' that are each established with a specific focus to, for example, *"…cooperatively develop systems, share best practice, and formulate principles and guidelines that will serve the interests of the industry as a whole."*.(ITU, 2011)

Study Group 5 (SG5) is currently tasked, among other foci, with the question of Environmental protection and Recycling of ICT Equipments/facilities (ITU, 2011b). This question includes, but is not limited to, the recycling of ICT equipments to minimize environmental damage and reduce greenhouse gas emissions. Furthermore, SG5 is tasked to "*Motivate ITU members to share their national experiences and spread the collected knowledge related to environmental and sustainability aspects of laws or directives."*(ITU, 2011). The outcome of this research and sharing of national experiences is therefore an important consideration in the context of scarce metals supply and demand. Particularly as it links supply and demand with industry collaboration on production and recycling techniques and is operating at the international level required for an effective policy response.

[9] The appendix to the USGS 2008 mineral commodity profile on indium defines reserves as: "that part of the reserve base which could be economically extracted or produced at the time of determination".

4.4. European Union (EU)

In 2005 the Commission of the European Communities presented its Thematic Strategy on the Sustainable Use of Natural Resources to the EU parliament. The strategy recognizes that no competition need exist between the EU's goals of economic growth and effective environmental management (EU, COM/2005). The strategy's broad aims are to:

- Improve our understanding and knowledge of European resource use, its negative environmental impact and significance in the EU and globally
- Develop tools to monitor and report progress in the EU, Member States and economic sectors
- Foster the application of strategic approaches and processes both in economic sectors and in the Member States and encourage them to develop related plans and programmes
- Raise awareness among stakeholders and citizens of the significant negative environmental impact of resource use (EU, COM/2005)

Covering a broad spectrum of questions regarding sustainable resource use, the communication sets out the policy space in which an initiative to secure the supply of scarce metals is likely to develop. The EU's attempt to understand resource use patterns broadly, both regionally and globally, is commensurate with more focused specific projects taking place regarding scarce metals, such as UNEP's Resource Panel 'Metal Stocks in Society' listed earlier, or as will now be discussed, the EU's Raw Materials Initiative.

4.4.1. Raw Materials Initiative

The EU's recent 'Raw Materials Initiative' is a response to its dependence on 'high-tech' metals and their role in the development of 'environmental technologies' that seek to increase efficiency and lower greenhouse gas emissions (EC, 2010a).

An early product of this initiative was the report, *Critical Raw Materials for the EU: Report of the Ad-hoc Working Group on Defining Raw Materials* (EC, 2010b), which nominates a group of 'critical' materials based on the criteria of 'supply risk', 'economic importance' and environmental risk. Indium, among other geochemically scarce metals, is considered one of these critical materials. Tellurium was not selected, probably failing to meet the criteria because the majority of its production and reserves are more evenly spread across the globe than the critical metals. It also has several substitutes for most of its uses, despite some losses in production efficiency and product characteristics (USGS, 2008b).

The Working Group regards the 14 raw materials listed in its report as critical raw materials at EU level because they are of high economic importance and have a high supply risk. This high supply risk is mainly because a high proportion of their worldwide production comes from:

- China (antimony, fluorspar, gallium, germanium, graphite, indium, magnesium, rare earths, tungsten)
- Russia (platinum group metals[10])
- Democratic Republic of Congo (cobalt, tantalum)
- Brazil (niobium and tantalum).

[10] The platinum group metals (PGMs) are platinum, palladium, iridium, rhodium, ruthenium and osmium.

This production concentration, in many cases, is compounded by low 'substitutability' and low recycling rates (EC, 2010b).

The report concludes with a range of recommendations, several of which are relevant to the international policy search undertaken in this paper. First, there is a recommendation that the formulation of polipolicy measures be developed towards metals on a case-by-case basis. This recommendation is in response to the Working Group's findings that the quality of primary supply differs extensively according to either the country involved or the supplying company or trader (ibid, p. 49).

Secondly, recommendations are offered that address the broader trade and investment policy questions of raw materials strategy. These include but are not limited to:

> "Consider the merits of pursuing dispute settlement initiatives at WTO level so as to include in such initiatives more raw materials important for the EU industry; such actions may give rise to important case law so long as existing GATT rules lack clarity and are limited in scope.
>
> Continue to raise awareness on the economic impact of export restrictions on developing and developed countries in various multilateral fora, such as WTO or the OECD" (ibid, p. 50).

These recommendations hold direct relevance to the recommendations proposed in this paper. Furthermore, the Raw Materials Initiative is a regional example of the early stages of policy formation seeking to address potential supply and demand distortions of geochemically scarce metals.

The motivating rationale for the Raw Materials Initiative is given in the subtitle ('Meeting our Critical Needs for Jobs and Growth in Europe') of the Communication from the European Commission to the European Parliament and Council proposing its establishment (EC, 2008). In other words, the initiative seeks to secure a stable supply and demand structure of these materials, recognizing their importance to employment and competition in the EU.

4.4.2. Restriction of Hazardous Substances (RoHS) Directive

The EU's Restriction of Hazardous Substances (RoHS) Directive (EU, 2003) is another example of an international (regional) policy affecting the resource supply of geochemically scarce metals. In this case the policy decreases supply via reduced demand for those particular resources. However, its basis is not scarcity but concerns regarding the environmental toxicity of the resources.

Since 1 July 2006, when the directive came into effect, Member States have been required to restrict the use of six key substances used in the production of new electronic and electrical equipment. Cadmium is one of those six substances but its use within CdTe photovoltaic cells is not restricted. This is because the level of cadmium exposure and perceived risk to humans or the environment during the CdTe photovoltaic life cycle is very low and processes exist for safe disposal or recycling in end-of-life scenarios (Fthenakis, 2004).

4.5. Global Environment Facility (GEF)

The GEF is the highest funded global environment programme, but lacks any direct policy initiatives that address potential supply distortions of geochemically scarce metals. Although a comprehensive environmental programme, as with UNEP, there are a number of other environmental concerns that are likely to absorb its time, finances and attention due to their more urgent impact on human welfare or the environment.

The GEF's main focus is on biodiversity, climate change, international waters, land degradation, ozone depletion and persistent organic pollutants (GEF, 2008a) – an understandably broad mandate with numerous overlaps with the United Nations Development Programme (UNDP), UNEP and many bilateral agencies. However, GEF's links with large international bodies (including UNEP and the World Bank), combined with the support of its member base, put it in an ideal position to act with regard to international policy to secure geochemically scarce metals.

4.6. Feed-in Tariff as concrete policy measure

Moving now to a specific policy relevant to our search, the concept of 'feed-in tariff' (FiT) has had considerable success in boosting solar power generation in Europe, particularly in Germany.

According to the European Photovoltaic Industry Association (EPIA), a FiT has three simple components:

(i) The producer of solar electricity has the right to feed that electricity back into the public grid.

(ii) The producer of solar electricity receives a premium tariff per generated kilowatt hour (kWh), reflecting the benefits of solar electricity compared with electricity generated from fossil fuels or nuclear power.

(iii) The producer of solar electricity receives this tariff for a fixed period of time.

Although simple, this policy was difficult to establish and took significant effort primarily due to reluctance from power utilities to allow solar-generated electricity to be fed into the grid (EPIA, 2008a).

The FiT is essentially a financial incentive and as such, a powerful policy tool affecting the demand of geochemically scarce metals used in thin film PV cells. For example, the FiT has been directly attributed to Germany's world leading increases in installed PV capacity (Sawin, 2008), with a record 3,800 megawatts installed in 2009, bringing Germany's total installed capacity to 9,800 for that year (Earth Policy Institute, 2010).

The FiT is consistent with broader policy efforts towards renewable energy capacity in Germany. Germany's Renewable Energy Sources Act (EEG) revised its targets in 2008 for renewable energy as a proportion of total energy supplies from 20 per cent to 25-30 per cent by the year 2020 (BMU, 2008). More recently, a new target of 80 per cent renewable energy by 2050 with pathways also presented for 100 per cent in the same time frame (BMU, 2011).

Although thin film PV cells represent only a small portion of the PV market (7.6 per cent as of 2006), EPIA states that thin film technology is expanding at a faster rate than non-thin film technologies and is projected to achieve a 20 per cent market share by 2010 (EPIA, 2008b).

Feed-in tariffs are therefore a powerful regional policy tool, as demonstrated by the number of European countries (Figure 4) that have employed them in order to meet their renewable energy targets.

As highlighted in Figure 4, European governments are using either a feed-in tariff or Renewable Portfolio Standard (RPS),[11] or a mix of both, as renewable energy policy tools. The FiT in particular is a broad re-

[11] RPS is a regulatory mechanism that requires increased production of energy from renewable sources.

gional policy measure that affects the supply and demand dynamics of non-renewable resources, including thin film PV cells. With regard to international policy measures and scarce resources, similar approaches may be effective in encouraging alternative methods and production techniques in the thin film PV industry.

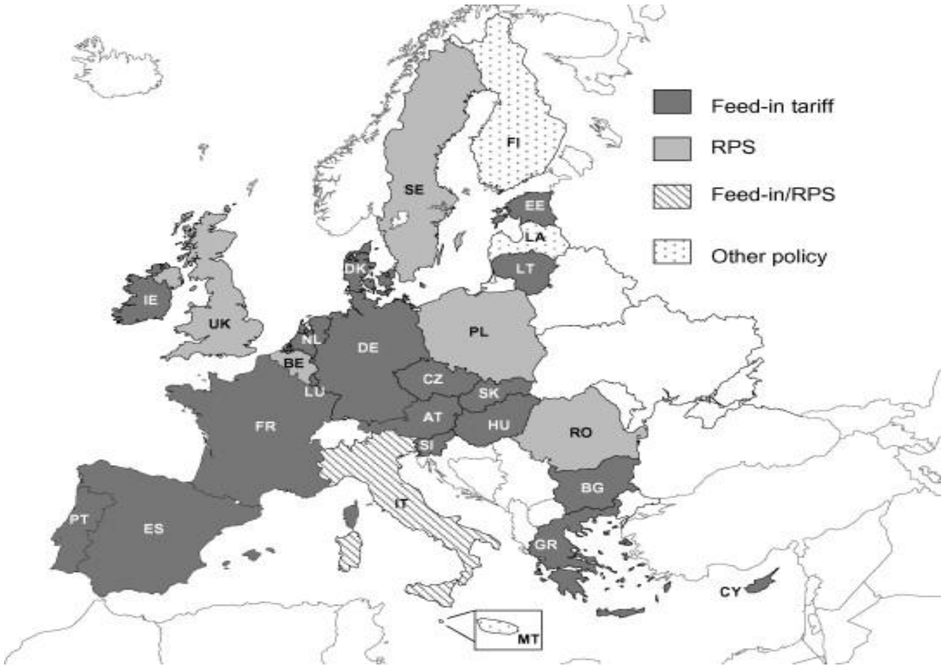

Figure 4: Renewable electricity policies in EU Member States as of February 2007

(Source: Rickerson et al, 2007)

4.7. Summary

Through the investigation of a multitude of international organizations, we have found no international policy that specifically seeks to address potential future supply and demand distortions of indium and tellurium – two geochemically scarce resources vital for the long-term success of the thin film PV industry. However, there are several encouraging developments that indicate progress towards such a policy response.

Most importantly, UNEP's SCP Branch and its International Panel for Sustainable Resource Management have taken up the issue of scarce metal supply as a serious concern. The Resource Panel has been commissioned to undertake six reports, the first of which was reviewed here, that will provide a deeper understanding of scarce metal usage, supply and subsequent policy suggestions. Valuable contributions may be offered by the mining sector as further information and policy suggestions are raised by IGF's goals.

The European Union's Raw Materials Initiative is a regional response directly relevant to geochemically scarce metals. Through the initiative we have observed the early stages of criteria and criticalities being applied to high tech scarce metals necessary for the EU. The initiative also fits within the larger policy discussion and awareness raising taking place at the EU level in the thematic strategy for sustainable resource use.

The World Trade Report 2010 included a workshop discussion on the question of export restrictions among strategic raw materials. Issues observed took potential supply disruptions into account and indicated a need for an international cooperative approach.

Also encouraging is that the World Trade Organization has become increasingly engaged with Multilateral Environmental Agreements that affect trade directly. Thus, if an international policy to secure the supply of these geochemically scarce metals were to be developed, mechanisms and options already exist through with WTO.

There are also many instances in the UN from the Millennium Development Goals to the research focus of United Nations University projects where themes that fall under the mantra 'sustainable resource use' are being covered.

In this sense the framework for specialized research on such a policy already exists to a certain extent. It is not an inherently new concept that needs to first be scrutinized solely on the validity of its claims. For example, we are unsure of indium's exact reserves yet we understand why it is extracted, how it is extracted and that its quantity is limited. Unless there is a global consensus that the depletion of indium is acceptable, one would hope to see research that looks further into the nature of the problem, from which solutions to this and other scarce metal problems could be made available.

5. Recommendations for sustainable policy measures to prevent scarce metals supply restrictions

First, there are several important themes regarding policy recommendations for geochemically scarce metals that were outside the scope of this paper but need to be outlined as they are part of the broader picture of global resource use. The following points are drawn from recommendations in a policy paper compiled by the Development and Peace Foundation (Bleischwitz and Bringezu, 2007) for the German government and more broadly the EU:

(i) Appropriate sustainability standards and certification processes should be further developed and incorporated into the global trade system. This includes a 'risk radar' programme to watch for 'strategic metals'. The WTO is already engaged with several multilateral environment agreements where they directly affect trade, so the framework for such standards already exists. However, the rules within the WTO that see resource extraction as trade-neutral should be reviewed.

(ii) UNEP should be strengthened and upgraded to 'specialized agency' status.[12]

(iii) European development cooperation should be expanded. Programmes should focus on three main pillars of resource management, revenue management and environmental protection.

[12] Special agency status would allow UNEP to operate autonomously and/or with any other of the 15 specialized agencies such as UNESCO and WTO to achieve its goals under the Economic and Social Council of the United Nations.

(iv) An initiative should be launched to establish an international agency dedicated to resource management, linked with initiatives in the renewable energy sector.

Although these policy suggestions from Stefan Bringezu and Raimund Bleischwitz are aimed at an EU audience, they fit within the broader context of global resource use (see Bleischwitz and Bringezu, 2009).

The policy suggestions offered below fall into a similar context.

5.1. Data accuracy

We saw earlier that precise estimates of the global stocks and flows of indium and tellurium are difficult to ascertain. Therefore, the first recommendation here for international policy to address potential future supply and demand distortions of these metals is for an increased quantitative understanding of global usage and re-use patterns, and reserve bases. This may be approached, for example, by either 'top down' or 'bottom up' methodologies outlined by the UNEP's Resource Panel.

Improved data accuracy in this regard provides a foundation for policy recommendations. For example, a revision of statutes that allow companies to withhold extraction data would assist initiatives such as the Resource Panel in their efforts to form more appropriate policy recommendations.

The Global Environment Facility provides a good example of the central theme of this recommendation. To propose a project within the GEF, two broad criteria must be met (GEF, 2008b):

(i) The project must reflect national or regional priorities, and have the support of the country or countries involved.

(ii) It must improve the global environment or advance the prospect of reducing risks to it.

A project could be proposed that attempts a detailed global evaluation of the current stockpiles of critical (towards current and future technologies) and scarce (geochemically) metals. The project could include the need for companies to provide necessary extraction data and known reserve bases, particularly some of the state-owned enterprises in OPEC member states and China. Such a project would:

- Reflect regional, if not global priorities
- Have support of the countries involved as it would relate directly to their own long-term economic self-interest
- Improve the global environment through a more detailed understanding of available resources and efficiency across product/element life cycles

The benefits of more accurate information in this regard would be a clearer understanding of current global reserves and usage patterns and clearer projections of future trends when combined with relevant global supply and demand data.

5.2. Academic foundation

A policy measure that addresses a potential future distortion of the supply and demand of geochemically scarce metals should be based soundly on high quality specialized academic research. This paper highlights several institutions that are already contributing to this field.

The Resource Panel's '*Metals in Society*' is an initial example. At the conclusion of the sixth report in the series, a better academic understanding is expected to emerge and should be coordinated with other leading efforts in the field to inform future research directions.

For example, the EU Raw Materials Initiative draws upon a wide range of professionals across several fields, particularly materials science. A coordinated response, though understandably difficult, is required at the international level.

The UNU-IAS investigation of the Precautionary Principle's interactions with WTO trade law is another good example of academic foundations in the socio-political context. In this case the Precautionary Principle (something difficult to test, measure or define) has been studied in terms of its influence on the more quantifiable paradigm of WTO trade relations.

Similar situations are likely to arise as attempts are made to avoid distortions in the supply of scarce metals. For example, what group or organization defines the point at which we should consider a metal as scarce? Are we able to calculate that point with any certainty or should action be taken urgently under the Precautionary Principle despite the ambiguities? How can we define the value that future generations may place on these resources? Will they need them at all?

Policy at such a scale will require a great degree of cooperation across many layers of international society. It should eventually propose that the extraction and use of scarce metals, and perhaps all natural resources, is undertaken in ways that avoid potential detrimental supply distortions and environmental degradation. This covers actors involved across the whole cycle of the material's lifespan, or 'cradle to grave' from ore to product to end-of-life or re-use. Without thorough and coordinated academic support, the divergent interests of so many stakeholders are likely to pull in opposite directions and leave the policy measures struggling to gain stability.

5.3. Resource efficiency

The need for a policy to secure the supply of geochemically scarce metals comes at a time where increasing focus is being placed on resource efficiency in a broader sense. Such policy could not be formed in a vacuum and is relevant to widespread changes in how societies utilize resources.

At the far edge of these changes, for example, are discussions of entire product life cycles or the term 'cradle to grave'. William McDonough and Michael Braungart have expanded this term under the phrase 'cradle to cradle'. To them, a structural shift needs to take place from the very roots of our contemporary notion of resource use. They are clear as to the inspiration for their idea – nature. They propose that the concept of waste is unknown in nature, but is instead the building blocks for the next 'cradle' as the cycle continues. They believe this concept should be integrated into the way in which we use resources to build our societies. For example, on the type of materials commonly found in landfills, they explain:

> "They are the ultimate products of an industrial system that is designed on a linear, one-way, cradle-to-grave model. Resources are extracted, shaped into products, sold and eventually disposed of in a 'grave' of some kind, usually a landfill or incinerator. You are probably familiar with the end of this process, because you, the customer, are responsible for dealing with its detritus. Think about it: you may actually be referred to as a consumer, but there is very little that you actually consume – some food, some liquids. Everything else is designed for you to throw away when you are finished with it. But where is 'away'? Of course, 'away', does not really exist. 'Away' has gone away" (McDonough and Braungart, 2002).

This concept, whilst speaking broadly to resource use in general, supports much of the work already under way to further our understanding of scarce metals use.

Whilst most of the findings in this paper relate to the scarce metals themselves, a broad understanding of resource efficiency should include studies focused on the individual consumer and the role they play. In this sense technical scientific data and social scientific data can be compiled to provide a broader foundation for policy decisions.

6. Conclusions

There is a need for international policies to prevent potential supply and demand distortions of geochemically scarce metals. There are currently no indications that such policy exists within the international institutions that regulate trade, though we have presented examples of international research and projects that begin to explore the necessary parameters for the beginnings of such policy.

We have also highlighted the question of the economic needs that future generations may have in terms of their access to resources. Geochemically scarce metals used in the production of thin film PV cells (e.g. indium and tellurium) have been used to indicate the problems that could arise from dramatically increased demand in that industry. We have seen that estimates on reserve figures are vague at best, particularly with regard to indium, which should present a case for further caution than has been shown to exist internationally.

Despite the difficulties surrounding the extent, for example, of remaining indium supplies and usage patterns, we have highlighted the need for an appropriate international policy response to the problem of geochemically scarce metal use.

The rationale that underpins the need for a policy response towards geochemically scarce metals is especially relevant to those resources used in a rapidly expanding high-tech renewable energy industry such as thin film PV cells. This includes the coordinated scientific response through such initiatives as UNEP's Resource Panel reports, but in particular with scarce metals such as indium, a need for the application of the Precautionary Principle.

Indicators such as world population and gross world product (GWP) show in broad terms the exponential growth of needs that society has upon the earth's resources. For example, the OECD case study on energy estimated a world population of 12 billion by 2100 but lacked a model to deal specifically with a potential shortage of oil to supply global growth. In contradiction to the OECD study, OPEC modelling forecast the increased use of oil expected for the coming decades, with a relatively small increase in the use of non-conventional fuels.

Modern research capacities are focused on the problem of resource scarcity, as seen with the work of the Resource Panel and the Raw Materials Initiative in Europe. However, the transformation of such research into concrete international policy initiatives is now of critical importance.

We should also note the need for further research that analyzes theories of scarce metal supply and demand – a topic not covered in this paper. Such analysis may indicate how society can approach questions of metal scarcity on a theoretical level, drawing from both social and material science, and would help to lay the foundations for further studies into other geochemically scarce metals. Further studies may also extend their scope to other metals that qualify as both 'scarce' but are also at the mercy of increasing systems of demand.

To complement theoretical advances, continued attention should be given to the practical activities that protect scarce resource depletion such as:

- More efficient design and production methods
- Recycling and re-use networks
- Consumer awareness of the major issues.

In conclusion geochemically scarce metals can be considered as an important foundation from which modern society creates itself and hence its future. It is inequitable to deny future generations' access to these tools. We should be able to justify how and why we are providing fewer available resources to future generations, particularly those resources within industries that have the potential to provide sustainable outcomes such as solar power.

The LCD screens and high-tech gadgets in which the majority of indium is used today will be probably broken or obsolete within several decades. Technological advances, recycling and material substitution are beneficial, yet by leaving the problem predominantly to market forces in the absence of a policy response, we are potentially limiting the security of supply of critical metals to future generations.

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"StEP envisions a future in which societies have reduced to a sustainable level the e-waste-related burden on the ecosystem that results from the design, production, use and disposal of electrical and electronic equipment. These societies make prudent use of lifetime extension strategies in which products and components – and the resources contained in them – become raw materials for new products."

Our name is our programme: solving the e-waste problem is the focus of our attention. Our declared aim is to plan, initiate and facilitate the sustainable reduction and handling of e-waste at political, social, economic and ecological levels.

Our prime objectives are:

- Optimizing the life cycle of electric and electronic equipment by
  - improving supply chains
  - closing material loops
  - reducing contamination
- Increasing utilization of resources and re-use of equipment
- Exercising concern about disparities such as the digital divide between industrializing and industrialized countries
- Increasing public, scientific and business knowledge
- Developing clear policy recommendations

As a science-based initiative founded by various UN organizations we create and foster partnerships between companies, governmental and non-governmental organizations and academic institutions.

StEP is open to companies, governmental organizations, academic institutions, NGOs and NPOs and international organizations which commit to proactive and constructive participation in the work of StEP by signing StEP's Memorandum of Understanding (MoU). StEP members are expected to contribute monetarily and in kind to the existence and development of the Initiative.

StEP's core principles:

1. StEP's work is founded on scientific assessments and incorporates a comprehensive view of the social, environmental and economic aspects of e-waste.
2. StEP conducts research on the entire life cycle of electronic and electrical equipment and their corresponding global supply, process and material flows.
3. StEP's research and pilot projects are meant to contribute to the solution of e-waste problems.
4. StEP condemns all illegal activities related to e-waste including illegal shipments and re-use/ recycling practices that are harmful to the environment and human health.
5. StEP seeks to foster safe and eco/energy-efficient re-use and recycling practices around the globe in a socially responsible manner.

Contact:

StEP Initiative
c/o United Nations University
Institute for Sustainability and Peace (UNU-ISP)
Operating Unit SCYCLE
Hermann-Ehlers-Str. 10
53113 Bonn, Germany
Phone: +49-228-815-0271
Fax: +49-228-815-0299
info@step-initiative.org
www.step-initiative.org
www.isp.unu.edu

UNITED NATIONS UNIVERSITY