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Research and analysis of the megatrend 'increasing scarcity of important raw materials' and the impact of this trend on the achievement of the Sustainable Development Goals (SDGs).

Commissioned
by the Federal Institute for Sustainable Development (FISD)

Summary
Final Version November 2018

Disclaimer:

This is a summary of a detailed scientific report (a 224-page MS Document plus an MS Excel input table and five MS Excel analysis tables). Any ambiguity in this summary should therefore be seen against this background.

Referentie in de literatuur:

Mazijn B., Devriendt S., Blommaert C. and Borgo E. (2018). *Research and analysis of the megatrend 'increasing scarcity of important raw materials' and the impact of this trend on the achievement of the Sustainable Development Goals - Summary*. Instituut vóór Duurzame Ontwikkeling vzw, Brugge.

Content

1. Introduction

1.1. Background

The United Nations General Assembly Resolution 66/288 entitled 'The future we want' contains in Chapter V - *Framework for action and follow-up* a number of paragraphs dedicated to the formulation of Sustainable Development Goals (SDGs) with a view to make these available (as successors to the MDGs) by 2015.[1] This did indeed led, on 25 September 2015, to the approval by the UN General Assembly of a new resolution in which the creation of the Agenda 2030 on Sustainable Development appears as an action plan, with 17 goals and 169 targets to be completed and achieved between 2016 and 2030.[2]

The following, inter alia, is added to the assignment for this study : "*Besides monitoring the implementation of the SDGs, ongoing critical attention must be paid to the elements that are not included, or are insufficiently included, in the 2030 Agenda, or which could have an adverse or beneficial influence on that agenda. Proper monitoring, and constant questioning of the system, can contribute to the identification of necessary additions or inconsistencies in the existing policy for the SDGs. 'Megatrends' are among these influential parameters. By 'megatrends' the FISD means the large, often global changes and developments that will substantially shape our future and significantly influence social, environmental and economic resilience. Megatrends could therefore have a major impact on sustainable development. More practically, this means that these trends will have a probable impact on the SDGs in the medium term, and on the long-term objectives of the federal administration* (2050)."

Even at the time of preparation for Rio+20, more and more reports were being published on 'megatrends' and their interactions. Later, attention was paid to these issues by the European Union and in our own country. One of these megatrends is the increasing scarcity of raw materials. The study assignment expressed it as follows: *"Because the world's population is growing, technology continues to develop and well-being is increasing in general terms, the demand for raw materials is also expanding. For example, there is growing demand for a number of rare metals. But the demand for other raw materials (such as sand, petroleum, etc.) has also increased sharply in the last decade. In addition, stocks of some raw materials are becoming exhausted. That causes tensions and challenges at the international (geopolitical) level and in economic terms (dependency, prices, production, etc.). A scarcity of raw materials will thus be one of the greatest challenges and uncertainties of future decades.*

The assignment consisted of three parts:

a. mapping and describing the megatrend 'increasing scarcity of raw materials' and any subtrends;
b. analysing the impacts of this megatrend on the SDGs;
c. formulating recommendations (inter alia for the methodology).

[1] United Nations (2012). The Future We Want, A/RES/66/288, 27 July 2012.

[2] United Nations (2015). Transforming our World: the 2030 agenda for sustainable development, A/RES/70/1, 25 September 2015.

1.2. Research analytical framework

In order to conduct the research in systematic and coherent way, it is important to keep an analytical framework in mind. The following rationale was followed.

The ultimate goal of the Agenda 2030 plan of action is the achievement of sustainable development worldwide, with global social benefits for everyone (= 'impact'). Striving to attain the 17 SDGs with their 169 targets must ensure, in the short and medium term, on the way to 2030, the behavioural changes and systemic effects (= 'outcome') that will contribute to sustainable development. Successfully navigating the pathway between outcome and impact depends on specific conditions or factors. This includes aspects such as preconceptions, incentives or risks, but also the transitional conditions for reaching the ultimate goal.

Achieving the SDGs by 2030 can therefore bring about behavioural change and systemic effects. All stakeholders are expected to play their part through (whether adjusting or strengthening) their activities: cf. the Global Partnership referred to in the United Nations resolution. The development of these activities demands 'input' and delivers 'output', which then contributes to the 'outcome'.[3]

The focus of this research, however, lies on the question of whether the trend towards an increasing scarcity of important raw materials has an impact on the achievement of the SDGs. Against this background, the term 'effect' rather than 'impact' will be used, except when referring to the title of the study. The intention, however, remains the same. Figure 1 uses the term 'resources', i.e. an 'input' for the activities of stakeholders.

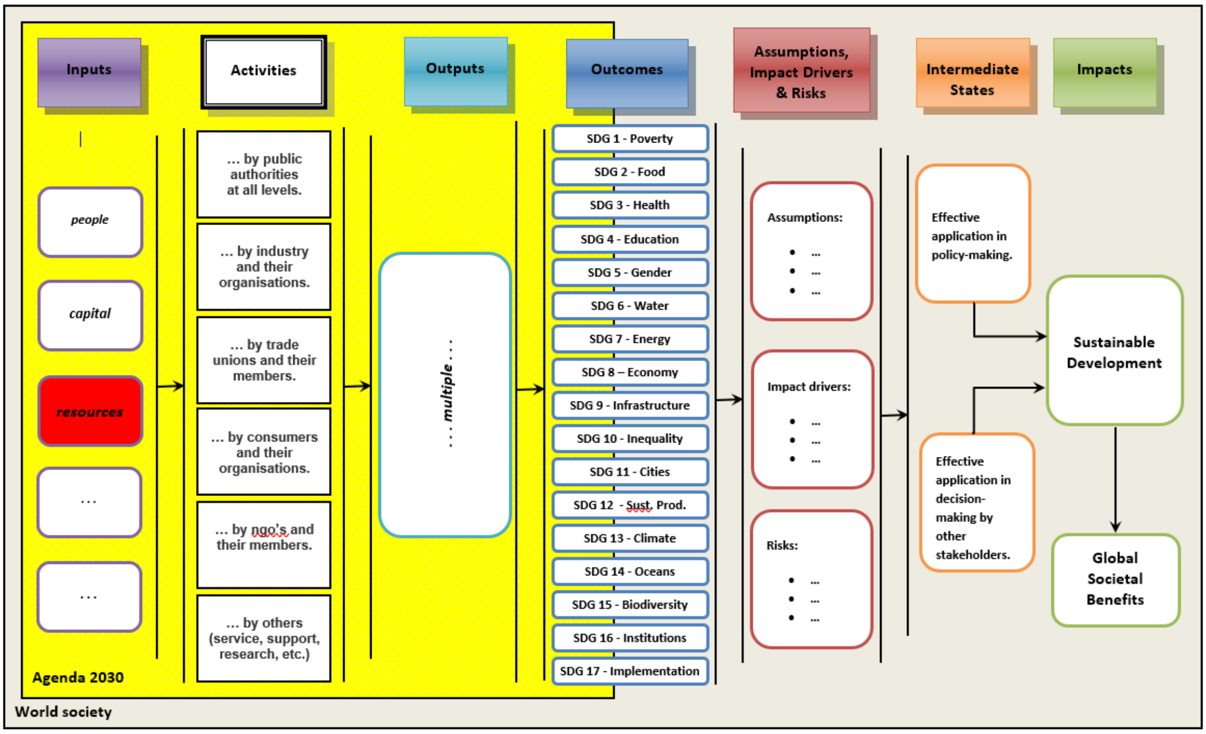

Figure 1 - Schematic representation of Agenda 2030 (including SDGs) in an 'Outcome to Impact' analytical framework.

[3] While the SDGs themselves can obviously be seen as an 'outcome', some of the targets should rather be described as 'outputs'.

From the preceding point we recall that we must define what is meant by ‘activities’, as the basis for generating ‘output’ and contributing to ‘outcome’ (read: the SDGs), and which ‘important raw materials’ will be discussed in this research.

Activities

The assignment did not explicitly state whether the effect on achieving the SDGs refers to the global, European or Belgian domestic level. The researchers have assumed that the best approach is ‘the effect on our country’. This also has the advantage of not falling into generalities, and being as accurate as possible.

In our country (and by extension in Europe) activities are characterised on the basis of their NACE code: the degree of detail extends to a five-digit classification.[4,5] This research took an incremental approach, as more detail appeared necessary.

Important raw materials

The assignment refers to three groups of important raw materials: ‘rare metals’, ‘petroleum’ and ‘sand’. For the purposes of the study, these were defined as follows:

- ‘rare metals’: these metals that were or are mentioned in the European Commission’s notices on the list of raw materials that are critical for the EU (from 2011, 2014 and 2017), including REEs;[6;] to these tellurium and lithium are added;
- ‘petroleum’: the various forms of petroleum as described by the International Energy Agency in their publications, tested against the sorts imported into Belgium;[7]
- ‘sand’: the different types of ‘sand’ as described in the regulations for land or sea extraction in our country, tested against the sorts imported into Belgium.

‘Open space’ was also considered as a rare ‘raw material’, in particular in terms of available open space for agriculture, woods and other applications (see the FAO[8] data).

The scarcity of raw materials for a society at a given moment is not only determined by geological factors, but also by social, environmental, political and geopolitical and technical factors. Like the EC in its resolutions and in other international analyses, this research also takes this into account.

Risk of influence by scarcity of a raw material

In practice, completing the analytical tables as formulated in the assignment demands preparation by drawing up a risk matrix. A risk is determined by the probability that a phenomenon will occur (in this instance, the ‘scarcity of the raw material’) and the effect that

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[4] See https://statbel.fgov.be/nl/over-statbel/methodologie/classificaties/nace-bel-2008 (last accessed on 19/9/2018).

[5] Note that the diagram in Figure 1 comprises the activities of all stakeholders; this is also reflected in the activities as listed in the NACE code.

[6] See http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en (last accessed on 19/9/2018).

[7] See e.g. https://www.iea.org/topics/oil/ (last accessed on 19/9/2018).

[8] FAO: Food and Agriculture Organisation

the scarcity of the raw material has (in casu, on economic, environmental and social resilience).

The probability can then be given a score as follows: 'virtually certain', 'likely', 'possible', 'unlikely', 'remote'. Each score corresponds to a given level.

However, we note that in this research, both positive and negative evaluations can be reached. That means that there may be a risk or an opportunity.

The traditional approach then ascribes a rating, whereby

R (risk or opportunity) = P (probability) x I (Impact)

This data can be normalised on a scale from - 4 to +4 (as indicated in the analytical table), where necessary taking account of factors that exacerbate the effect of the scarcity of raw materials.

2. The megatrend and sub-trends

2.1. General description of the megatrend

In 1972, at the time of the United Nations Conference on the Human Environment in Stockholm, the report 'Limits to growth' (Meadows D. et al.) addressed the future effects of post-war production and consumption. The use of energy and raw materials, environmental emissions and population growth played a large part in the model even then. Nonetheless, it was not until 2007 that an intergovernmental organisation, the United Nations Environment Programme (UNEP), established the International Resource Panel (IRP). Step by step, the IRP provided a thorough-going scientific basis for this social challenge.[9] The IRP report 'Assessing Global Resource Use' describes the challenge that faces the world (IRP, 2017): if we carry on with 'business as usual' the expectation is that between now and 2050 the consumption of raw materials will double, rich countries will consume ten times as many raw materials as poor countries, and the planetary limits will be exceeded (see the figure below).

Left in Figure 2 these developments are depicted for an unchanged policy in four categories of natural resources: biomass, fossil fuel, metal ores and minerals. This trend will apply throughout the world, including (and especially) in Europe.

It is worth noting that if measures are taken (to the right of the figure) there is still an increase if policy changes are introduced, but that this can only be slowed down if an ambitious climate policy is coupled with a far-reaching effort to promote the efficient use of raw materials (cf. 'Climate Plus').

The extraction of non-metallic minerals rises particularly steeply. The use of these minerals (sand, clay, phosphates, salt, diamonds, etc.) will increase dramatically by 2050.

[9] See http://www.resourcepanel.org/ (last accessed on 8/9/2018)

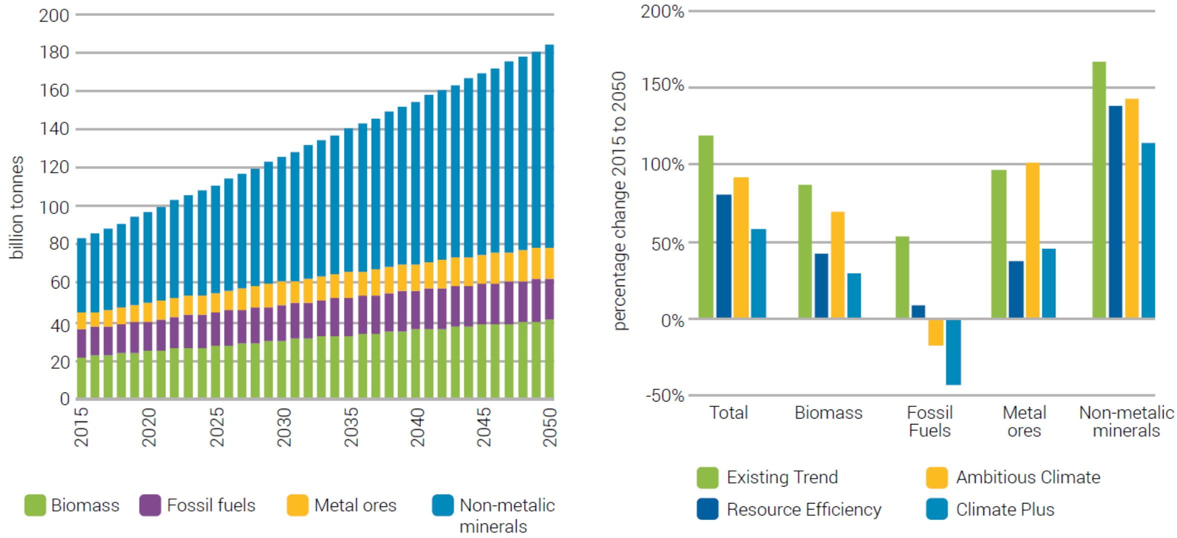

Figure 2 - Global resource extractions:
extrapolation to 2050 for existing trends and for four scenarios (IRP, 2017).

The IRP concludes that decoupling, a system approach and a monitoring system (with targets and indicators) are necessary if the SDGs are to be achieved.

In this respect, the IRP (see also Figure 1) also establishes the link between the megatrend towards 'scarcity of raw materials' and the SDGs. It is emphasised that natural resources provide the materials necessary for human activities (production, consumption, the creation of infrastructure, etc.) at different levels of our society. If problems arise, this can have an effect on whether or not we achieve the Sustainable Development Goals.

* * *

Against this background, it is helpful to emphasise the following developments:

- since the beginning of this century, the population, the spending power of the middle classes and urbanisation have all grown further exponentially;
- over the same period, there has been a decision to promote the greening of energy sources (meaning an effort at 'climate neutrality').

Both developments have increased demand for the same raw materials:

- the quip 'food or oil' illustrates the growing demand for land for food, biochemicals and biofuels;
- the performance of technologies (digitalisation) has improved dramatically through the use of rare earth elements;
- the demand for traditional materials (iron and nickel; sand and gravel, etc.) has risen due to future choices (e.g. the 'hydrogen economy').

This leads to distinguishing the following necessary categories of 'critical raw materials':

- the raw materials defined in the European Commission's notices on the 2017 list of Critical Raw Materials for the EU (COM(2017) 490 final);
- the raw materials that are not on the list, but which have been identified as problematic in international scientific reports: e.g. lithium, sand;
- the raw materials that are not in themselves scarce, but which can play an important role in future development: e.g. nickel in a hydrogen economy.

A special category of 'scarcity' is the hectares for land use for cropland, grazing land, fishing grounds, forestry ...

* * *

As well as the various scientific reports on the scarcity of raw materials, a number of investigatory journalists have also considered this subject (Custers R., 2013 and 2016; Meynen N., 2017; Pitron G., 2018). These are reports based on literature and - in particular - on visits to places where the raw materials are extracted. These show that a worldwide 'war on resources' is under way.

2.2. Critical materials: the subtrends

While intergovernmental organisations have not paid a lot of attention to this trend , it is noticeable that in recent years bodies that assume responsibility for defence or international relations have been publishing reports on the matter. Also traditional institutions are increasingly taking account of criteria other than geological resources (and any economic factors). The result is that the evaluation of scarcity takes into consideration:

- market factors: the likelihood of rapid growth in demand, and the limits on expanding production capacity;
- political factors: the concentration of the offer and the political risk.

This also includes the limits on recycling. Some reports approach the issue from a global perspective, while others consider it in terms of their own continental region (Europe, North America). The findings may differ a little. However, in every approach taken, geopolitical considerations are never far away. This also is reflected in the news today: important players on the global market in raw materials such as China and Indonesia have quite recently seen a period of restrictions on the export of certain metals in order to exercise strategic control over supplies. The reports are also concerned about the impact of a limited number of multinational firms – outside China – that hold the worldwide concessions. Finally, there is the question of whether the capital participations of BRICS countries in OECD countries should partly be seen in the light of this issue.

Table 1 - Probability factor (and related probability class) for the raw materials in question

	P factor	P class
Group 'Metals'		
Antimony	7,5	Likely
Beryllium	4,2	Possible
Bismuth	6,7	Likely
Cerium	10,0	Virtually certain
Chromium	1,6	Remote
Cobalt	2,8	Unlikely
Dysprosium	9,1	Virtually certain
Erbium	9,1	Virtually certain
Europium	6,0	Likely
Gadolinium	8,9	Virtually certain
Gallium	2,5	Unlikely
Germanium	3,3	Unlikely
Hafnium	2,3	Unlikely
Holmium	9,5	Virtually certain
Indium	4,2	Possible
Iridium	4,9	Possible
Lanthanum	9,5	Virtually certain
Lithium	1,8	Remote
Lutetium	9,5	Virtually certain
Magnesium	7,0	Likely
Neodymium	8,4	Virtually certain
Niobium	5,4	Possible
Palladium	3,0	Unlikely
Platinum	3,7	Unlikely
Praseodymium	8,1	Virtually certain
Promethium	NA	NA
Rhodium	4,4	Possible
Ruthenium	6,0	Likely
Samarium	7,9	Likely
Scandium	5,1	Possible
Tantalum	1,8	Remote
Tellurium	1,2	Remote
Terbium	8,4	Virtually certain
Thulium	9,5	Virtually certain
Tungsten	3,2	Unlikely
Vanadium	2,8	Unlikely
Ytterbium	9,5	Virtually certain
Yttrium	6,7	Likely
Group 'Petroleum'		
Petroleum	9,0	Virtually certain
Group 'Sand'		
Construction sand	5,0	Possible
Infill sand	2,0	Unlikely
Quartz sand	3,0	Unlikely
Group 'Land use'		
Cropland	9,0	Virtually certain
Forests Products	9,0	Virtually certain
Grazing Land	9,0	Virtually certain
Fishing Grounds	8,0	Virtually certain
Built-up Land	7,0	Likely

Table 1 gives an overview of the probability factor (and related probability class) for each of the raw materials in question. Below follows a short description of each of the raw materials in each of these groups. For more detailed information, please consult the research report, which contains a fact sheet for each of the raw materials.

Metals

The study considers 38 metals. The probability that a metal will become scarce is indicated by a score on a scale from 0 to 10 (based on the supply risk factor published by the European Commission). This demonstrates that the probability of scarcity is 'remote' for 4 metals, 'unlikely' for 8, 'possible' for 6, 'likely' for 7 and 'virtually certain' for 12 metals. It is no surprise that this mainly concerns rare earth elements (REEs).

China and Brazil jointly account for around 60% of the global reserves of REEs. The production of rare earth elements will rise between now and 2025 by at least 10% but perhaps by 25% and, if demand rises steeply, by as much as 50%. Applications are in the area of high technology: catalysts and magnets account for about half. In addition, it appears that the substitution by other elements often faces technological or economic objections.

Petroleum

The OPEC countries hold the largest reserve of stock at 74%, and the highest crude oil production at 42% (2016). The IEA (2017) expects that demand for oil will continue to rise until 2040, though at a slower rate. It adds: "*China overtakes the United States as the largest oil consumer around 2030, and its net imports reach 13 million barrels per day (mb/d) in 2040.*" It is of course the case that the United States will be a net exporter by the end of the 2020s due to non-conventional oil extraction.

Various processes (refining or cracking) are used to convert petroleum into different raw materials and fuels. Petrol, diesel, fuel oil, lubricants, kerosene, plastic, and asphalt (from bitumen) are all finished petroleum products. In Belgium just 20% after conversion is not (directly) burnt but applied in products.

The study, however, suggests that it is 'virtually certain' that petroleum will become scarce.

Sand

The three main types of 'sand' quarried in Belgium are:

1) construction sand (concrete sand + masonry sand; gravel)
2) infill sand (fine or coarse sand with a high level of impurities)
3) quartz sand (glass sand, silicon-rich sand)

Belgium has four sources of supply to meet the need for sand: 1) the land and the rivers, 2) foreign countries 3) secondary raw materials (recycling or as a by-product) and 4) the North Sea. In Belgium the regulation of quarrying 'sand' is a regional competence on land, and a federal competence on the Belgian continental shelf. Thus for each of these categories (infill sand, construction sand and quartz sand) the location of the site of extraction must be taken into account.

Reserves are controlled and determined by surface use and/or environmental concerns and quality requirements.

It is ‘possible’ that construction sand will become scarce, but there is ‘unlikely’ to be a scarcity of the other two types.

Land

The study investigates the addition of ‘space’ - alongside ‘metals’, ‘oil’ and ‘sand’ - as a scarce raw material. In contrast with raw materials such as rare metals or sand, however, ‘land’ is not contained in an end product, and we cannot therefore describe it as a ‘raw material’. Of course land is *used* for the purposes of production (cropland, grazing land, forests, fishing grounds) or in order to set up infrastructure (built-up land).

So when we talk about ‘land’ in the context of raw materials, the ‘land’ itself is not the raw material so much as all the (renewable) raw materials derived from it. ‘Land’ is an *environmental medium* delivering ecosystem services, and it can be damaged so that it is less able to deliver those ecosystem services in the future (in the form of renewable raw materials such as food, wood, fibre, etc.) The most far-reaching scenario is when the land is used for building and infrastructure. Then the land is taken ‘out of service’, as it were, and can no longer create renewable raw materials.

In short, the land itself is not the raw material, but rather the whole range of renewable raw materials that are produced on that land.

It is therefore difficult to apply the methodology (see *1.2. - Research analytical framework*). Although the issue of scarcity due to land-use both within and outside Belgium was extensively described in the research report, it was taken no further in this study.

3. Analysis of the effects of the megatrend on SDGs

The previous chapter contained a general description of the megatrend ‘scarcity of raw materials’ and a short summary of the detailed data for the categories ‘metals’, ‘petroleum, ‘sand’ and ‘land’. It provides the information on which to proceed with the analysis step by step. Note that the data that is collected and processed in each step is reported in an MS Excel table (with a note on methodology) in the full version of the research report.

3.1. Relevance

Against the background of the ‘research analytical framework’ (see above) it is important to set out in detail the relevance of the scarcity of raw materials for Belgium. For this a number of points have been selected and clarified. Figure 3 provides a schematic overview.

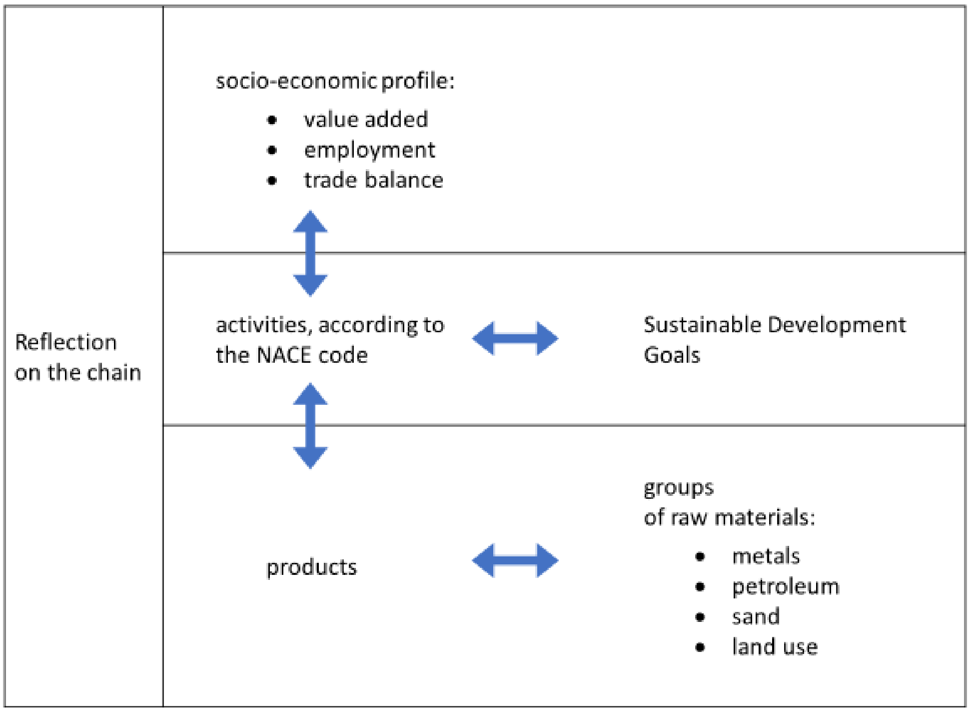

Figure 3 - Schematic overview of the research into relevance to Belgium

The first step establishes the relationship between raw material categories investigated, the products in which they occur and the economic activities generating these products. This uses firstly the detailed information gathered, as mentioned above, and secondly a combined PRODCOM/NACE table[10].

The second step creates a socio-economic profile for each NACE category, i.e. in accordance with the grouping used by EUROSTAT and STATBEL.

The third and final step establishes the link between the NACE divisions and the SDG targets. Note that – in line with the 'research analytical framework' (see above) - the SDG targets that only relate to the Global South are not included. This means that 144 of the 169 SDG targets are investigated from the perspective of social responsibility in the broad sense of the term.[11]

In each cell of the table where the focus is not exclusively on the Global South, where an SDG/Target intersects with a NACE section, the reciprocity of the relationship between them was investigated.

* * *

The link was thus established between economic activities in Belgium and the corresponding SDG targets. It is already apparent that focusing on NACE categories and focusing on the targets (rather than just on the SDGs, as often happens in the literature) introduces nuances.

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[10] NACE stands for 'Nomenclature statistique des Activités économiques dans la Communauté Européenne' and it is a classification of economic activiteis; PRODCOM means 'PRODucts of the European COMmunity' and it relates to a classification according to products.

[11] NACE division T – Activities of households and U – Activities of extraterritorial organisations were omitted from the study.

Of the 144 SDG targets under consideration, there are 19 that over (almost) the whole range have (some) influence on economic activity but not the other way around, while there are 39 SDG-targets that over (almost) the whole range (almost always) have a reciprocal influence. For one SDG (SDG 2 – Food) no target was influenced by (almost) all NACE groups.

When NACE divisions were considered, it is clear that of the 19 (i.e. excluding T and U) there were three (M – Professional, scientific and technical activities; O – Public administration, etc.; S – Other services activities) that can contribute to all the SDG targets, and vice-versa. Eight sections, A (Agriculture, forestry and fishing), C (Manufacturing), G (Wholesale and retail trade), I (Accommodation and food service activities), K (Financial and insurance activities), N (Administrative and support service activities), P (Education) and Q (Human health and social work activities) can contribute to (somewhat) more than half the SDG targets, and vice versa. For one section (L – Real estate activities) the contribution to SDG targets is difficult to estimate, and vice versa.

The following should also be noted:

- the scarcity of raw materials has a **direct** influence when there is an effect on material flows; the (old) classification into primary, secondary, tertiary and quaternary sectors operates similarly; consequently, it seems reasonable to focus on the primary and secondary sectors, but …
- researchers also noted that material flows also go to other NACE divisions (e.g. F – Construction) under the secondary sector (= NACE divisions C to F), if only because some raw materials are lifted directly from abroad without passing via divisions A, B and C;
- the researchers also explain that, for the NACE divisions G to S, the tertiary and the quaternary sectors, this is actually due to an **indirect** influence and may be regarded as a ‘reflection on the chain’ (see *Figure 3 - Schematic overview of the research into relevance to Belgium*);
- a reflection on the chain is obviously also of importance for and within the NACE divisions A to F, i.e. the primary and secondary sectors;
- it appears that sometimes there is neither a direct nor an indirect influence on an SDG target; drawing a line is a difficult exercise, and would in fact need to be the result of a participative co-design with stakeholders.[12]

3.2. Significance

After determining the relevance of the ‘scarcity of raw materials’ megatrend to economic activities in Belgium, which may or may not be important for achieving the SDG targets, the question of the significance arises, both for raw materials in themselves and in relation to the economic activities in which they are directly applied.

The significance for the respective raw materials is approached by investigating the influence on economic, environmental and social resilience via a number of criteria. The figure below lists these criteria.

[12] This would be a comprehensive exercise in which 10816 cells in the matrix of the input table (including the Global South and NACE sections T and U) would have to be assessed on the existence of a (non-)reciprocal relationship and on the influence of the scarcity of each group of raw materials. This has currently been done within the research team (excl. the global south and NACE sections T and U).

Influence on the economic resilience	Influence on the environmental resilience	Influence on the social resilience
Criteria	**Criteria**	**Criteria**
Price evolution Price volatility	Embodied energy Carbon footprint NOx emissions SOx emissions Water consumption Ecotoxicity Biodiversity Environmental impact	Human Toxicity HDI

Figure 4 - Schematic presentation of the research into the significance of raw materials groups

In practice, it was here examined whether the use of a raw material might come under additional pressure. This may occur for the following reasons:

- in terms of economic resilience:
  high levels of price changes and/or price volatility lead to greater uncertainty;
- in terms of environmental resilience:
  high values for 'embodied energy', 'carbon footprint', NOx- and SOx emissions and water consumption can lead to stricter environmental legislation; high ecotoxicity or increased pressure on biodiversity can also play a role here;
- in terms of social resilience:
  just as ecotoxicity plays a significant role in environmental resilience, the impact of toxicity on workers should not be underestimated; social circumstances, expressed via the HDI indicators in the countries of origin, are also taken into account.

As indicated, the question of the significance of the 'scarcity of raw materials' megatrend for the economic activities in our society to which they are directly applied, also arises. Data were collected for all the economic activities (using the NACE classification, i.e. to two digits) in respect of added value, the number of employed persons and the trade balance.

With these data it is possible - as explained above in section *1.3. Research analytical framework* - to calculate Ri. This is the risk of scarcity of a raw material, determined by the probability that a phenomenon will occur (in this instance, the 'scarcity of the raw material 'i' = 'Pi') and the effect that the scarcity of the raw material 'i' has (in casu, on economic, environmental and social resilience = 'Ei').

Rj can also be calculated, i.e. the risk of scarcity of the raw materials in question in the economic activity, determined by the probability that a phenomenon will occur (in casu, the 'scarcity of the raw materials in question Pi, which are used in this economic activity) and the effect that the scarcity of the raw material 'i' has (in casu on economic, resilience = 'Ej' of this economic activity).

3.3. Influence on SDG targets

The previous steps assembled all the information necessary in order to investigate the influence on the SDG targets. An important aspect is establishing the link between the economic activities (NACE) and the SDG targets and then allocating a score of -1, 0 or +1 depending on the influence (negative, none, positive).

These values associated with NACE sections A to F, i.e. the primary and secondary sectors (cf. material flows), are then used to calculate the Rij for each group of raw materials ('metals', 'petroleum' and 'sand') and the Rj. Taken together, this finally gives the Rij for each of the groups of raw materials and in the total: Rmij, Rpij, Rsij and Rij (see *1.2. Research analytical framework*) The data for substitutability and the influence on economic activities in the tertiary and quaternary sectors are used for a 'reflection on the chains'. These data are used to complete the analytical tables.

Finding an answer to the question of 'Investigation and analysis of the megatrend towards an increasing scarcity of important raw materials and the impact of this trend on the achievement of the Sustainable Development Goals (SDGs).' is an exceptionally complex matter. The research results must be read with due caution. The methodological discussion points are addressed in a separate document.

Input for the analytical tables

The Pi-factor gives the probability that the phenomenon 'scarcity of raw material' will occur. 47 raw materials were researched. The top 20 raw materials where there is 'virtually certain' to be a problem of supply are mainly rare earth elements, petroleum and land-use.[13] At the bottom of the list come raw materials which are often mentioned (lithium, cobalt, platinum … and 'sand'), for which the European Commission suggests that supply <u>un</u>certainty is 'unlikely' or 'very unlikely'.

The Ei-factor is the effect that the raw material 'i' is determined to have on economic, environmental and social resilience.

Influence on economic resilience

In comparison with the supply risk, the picture here is somewhat different. The top 20 still includes a number of rare earth elements, but it primarily consists of metals in the palladium group, cobalt, etc. Raw materials in the 'sand' group are at the bottom of the list.

Influence on environmental resilience

Again, metals from the palladium group top the list. Raw materials in the 'petroleum' and 'sand' groups, along with magnesium and tungsten, are at the bottom of the list.

Influence on social resilience

In general terms, the bottom of the list is the same for social resilience. The list is headed by critical metals important for new (clean) technologies (Be, Li, Te, In, Ga).

The Ri is the risk of scarcity of a raw material 'i'; this is calculated by multiplying the respective Pi and the general normalised average of the Ei factors.

[13] As indicated above, 'land-use' cannot be analysed further.

The top 20 includes 15 rare earth elements. A number of metals, including the palladium group, and ‘petroleum’ can also be found. Raw materials at the bottom include the ‘sand’ group.

* * *

The Ej factor refers to the economic resilience of the economic activity ‘j’ determined on the basis of the added value, the persons employed and the trade balance. It should first be noted that only sectors in the primary and secondary sectors were ranked because of the ‘material flows’ argument (see above).

The construction industry, the manufacture of chemical products, the manufacture of foods, drinks and tobacco products and the manufacture of pharmaceutical raw materials and products emerged at the top. These are followed by various ‘sub-sectors’ of ‘the metal sector’ and ‘the agriculture sector’. At the bottom end, we mostly find the other primary sector economic activities.

There is a summary – based on the fact sheet produced for each of the raw materials – of the economic sectors (in accordance with grouped NACE divisions) in which a raw material is used.

Of these metals, lithium, neodymium and vanadium are used in seven sectors, while antimony, cerium and praseodymium are used in six. Six metals are only used in one sector. Petroleum is important for 17 of the grouped economic activities, while quartz sand is used in 15 sectors. Note that many sectors are dependent on land-use.

The Rj is the risk of scarcity of a raw material ‘i’ in the economic activity in question; this is calculated by multiplying the respective Pi and Ej factors.

The economic activities are led by a large margin by ‘C20 - Manufacture of chemical products’ and ‘C23 - Manufacture of other non-metallic mineral products’, followed at a distance various ‘sub-sectors’ of ‘the metal sector’.

* * *

When establishing the analytical framework (see above) attention was drawn to the causality between the application of resources (input), social/economic activities and their results (output), resulting in behavioural change (outcome) and finally the achievement of sustainable development (impact).

There are 56 of the 144 targets (cf. focus on the intra-national context) for which there is a reciprocal relationship for all the grouped economic activities. For 19 targets, the NACE activity in Belgium is directly/explicitly/specifically influenced as the SDG target is achieved (e.g. by other factors, such as a consistent government policy). To this one SDG target (16.5) for which an inverse relationship exists can be added. For the remaining targets (around 50%) the relationship depends on the economic activity in question.

Where a link can be established between the SDGs and the grouped NACE divisions, the question then arises as to whether the megatrend towards ‘scarcity of raw materials’, in this instance ‘metals’, ‘petroleum’, ‘sand’ and ‘land’, has a positive (1), neutral (0) or negative (-1) influence.

8 SDG targets have a negative influence across the board, i.e. for all economic activities. 59 targets were marked ‘0’, i.e. their influence is neither positive nor negative; it should be pointed out that for 12 of the targets, the scarcity of raw materials can both form an obstacle

to achievement and simultaneously make it easier to achieve because of a reduction in pollution: -1 and 1 cancel each other out. This last is reflected in the analytical table. There are also 13 SDG targets on which the scarcity of raw materials has a positive impact. The remaining 64 targets present a mixed picture, depending on the economic activity.

The assignment required presentation of an analytical table completed per raw materials category ('metals', 'petroleum' and 'sand'), identifying both the positive and negative influences on a scale of '0' to '+4' and from '0' to '-4' respectively. Note that an analytical table was also drawn up for the total Rij. An analysis was also conducted of the Rj factor, i.e. the risk of scarcity of a raw material 'i' in the economic activities in question that are important to the achievement of the respective SDG targets. This is discussed below.

Results in the analytical tables

Based on the summary in each of the five analytical tables, the following observations may be made:

- a comparison of the summaries reveals that it is primarily the risk of scarcity of metals and petroleum that plays a crucial role in terms of positive or negative influence;
- for *SDG 1 – Poverty, SDG 5 – Gender* and *SDG 10 – Inequality*, there are neither positive nor negative influences; nor, in these analyses for *SDG 2 – Food security,* though it is known that 'land-use' exercises significant influence in this respect.
- for *SDG 4 – Education*, *SDG 7 – Energy*, *SDG 15 – Biodiversity* and *SDG 16 – Institutions* there are negative influences but no positive influences; for these items, as for *SDG 3 – Health*, *SDG8 – Economy*, *SDG 9 – Infrastructure*, *SDG 11 - Cities* and *SDG 17 - Implementation*, where positive influences are nevertheless present, the balance is negative.
- For *SDG 12 – Sustainable production and consumption* and *SDG 14– Oceans* the pattern is reversed: here only positive influences are observed, no negative influences;
- in the cases of *SDG 6 – Water* and *SDG 13 – Climate,* positive and negative influences cancel each other out in this research.

Tables 2 and 3 give more details.

Note that it was explained above that the scarcity of land for use could not be quantified in this methodology, due to the limitations of the study, but that the 'supply risk' is considerable (see above). This (and the scarcity of other resources, e.g. 'water') could therefore substantially influence and exacerbate the overall risk for SDG targets (cf. Rij).

Table 2 - Targets for which the scarcity of raw materials poses the significant risk of a negative influence

The table lists the 23 targets for which the scarcity of the raw materials investigated ('metal', 'petroleum' and 'sand') poses the explicit and significant risk of a negative influence. 'Explicit' because there are a further eight targets for which both positive and negative influences exist; these are not included.

SDG	Targets	Score	Critiacal Raw Materials	Sectors (NACE)
3	**3.3., 3.4., 3.5., 3.8., 3.9., 3.b.**	**All -2**	Metals (Gadolinium, Lithium), Petroleum	C21 (plus indirect via especially C26 and C32)
4	**4.4.**	**-4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	4.a.	**-2**	Sand (construction, infill, quartz)	F41-F43
7	**7.1., 7.2.**	**Both -3**	Metals (Antimony, Chromium, Indium, Kobalt, Neodymium, Tellurium, Vanadium), Petroleum, Sand (quartz)	D35 (plus indirect via metal sectors)
	7.a.	**-3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
8	**8.1., 8.2., 8.3.**	**All three -4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
9	**9.2.**	**-3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	11.1., 11.2.	**Both -2**	Metals (Antimony, Chromium, Indium, Kobalt, Neodymium, Tellurium, Vanadium), Petroleum, Sand (quartz)	D35 (plus indirect via metal sectors)
	11.3.	**-3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
15	**15.6.**	**-2**	Metals (Gadolinium, Lithium), Petroleum, Sand (construction)	A3 and C21
16	**16.4.**	**-4**	Metals (Antimony, Chromium, Dysprosium, Gadolinium, Kobalt, Lithium, Magnesium, Neodymium, Niobium, Praseodymium, Samarium, Scandium, Tantalium, Tellurium, Terbium, Vanadium, Wolfraam), Petroleum, Sand (quartz)	C25
17	**17.11., 17.12, 17.13**	**All three -4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	17.12.	**-4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	17.13.	**-4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors

Table 3 - Targets for which the scarcity of raw materials poses the significant opportunity of a positive influence

The table lists the 13 targets for which the scarcity of the raw materials investigated ('metal', 'petroleum' and 'sand') poses the explicit and significant opportunity of a positive influence. 'Explicit' because there are a further eight targets for which both positive and negative influences exist; these are not included.

SDG	Targets	Score	Critical Raw Materials	Sectors (NACE)
3	**3.9.**	**+3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
8	**8.4.**	**+4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
11	**11.6.**	**+3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	11.b.	**+4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
12	**12.1., 12.2., 12.4.,12.5., 12.6., 12.7., 12.8.**	**All +4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
14	**14.1**	**+4**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors
	14.3.	**+3**	Metals (all), Petroleum, Sand (construction, infill, quartz)	(Quasi) All sectors

As previously explained, the SDGs and targets are the result of a multilateral policy decision at a specific place and time (New York, 25 September 2015). We emphasise this again here because the results of this research could provide guidance as to where the priorities should be set in government policy and the strategy of organisations – against the background of the influence of this megatrend – but this is not enough to make the change.[14]

Interlinkages with other SDGs

Some years ago, research was performed with regard to the links between the SDGs and their targets. Often these interlinkages were investigated for specific situations: at a particular geographical level, in terms of a given policy area, etc. In the literature since the approval of Agenda 2030, more and more references can be found.

[14] The example of SDG 13 – Climate is telling. During negotiations concerning Agenda 2030, including de SDGs, care was taken to avoid coming into conflict with the UNFCC negotiations which later resulted in the Paris Agreement. The SDG targets concerning climate change were thus limited, while it was evident from various studies that the megatrend towards the 'scarcity of raw materials' ('metals', 'petroleum', 'sand', 'land', etc.) ought to be viewed alongside the fight against climate change.

The United Nations have put together a document indicating for each SDG the links with targets in the relevant other SDGs.[15] A distinction is made between explicit and substantive links. The document was proposed as a tool that can be used for other and diverse purposes.

The approach taken in this study is as follows. Two tables were drawn up each listing the targets which are positively or negatively influenced by the 'scarcity of raw materials' megatrend (based on the information in the previous point.) Next the possible presence of a link was investigated. These are indicated in the respective cells in the table. Finally, the tables show where and how a (positive or negative) influence is reflected in other SDGs. This indicates additional reasons for giving priority attention to this SDG target.

The risk of scarcity of the raw materials in question has a primarily negative effect via the following specific SDG targets:

- SDG 7 – Energy: targets 7.1. and 7.2.;
- SDG 8 – Economy: target 8.3.;
- SDG 9 – Infrastructure: target 9.2.;
- SDG 11 – Cities: targets 11.1. and 11.2.;
- SDG 15 – Biodiversity: target 15.6.

The SDGs where this negative influence is reflected are in particular SDG 1 – Poverty, SDG 9 – Economy, SDG 9 – Infrastructure, SDG 10 – Inequality and SDG 12 – Sustainable production and consumption.

Conversely, the risk of scarcity of the raw materials in question has – albeit to a lesser degree - a primarily positive influence via SDG 12, in particular targets 12.4. and 12.8.

It is recommended that these links should be more closely examined and the international publications further monitored.

4. Research conclusions

The assignment entailed investigating and analysing the megatrend towards an 'increasing scarcity of important raw materials' and the impact of this trend on the achievement of the SDGs. In contrast with many other studies, the choice was made to take a detailed approach focusing on the SDG sub-goals or 'targets'. An analytical framework was used to investigate which economic activities contribute to and/or are influenced by the achievement of the SDG targets. It was also important to investigate which raw materials are crucial to these economic activities.

The general description of this megatrend suggests that the global situation is serious for every group of raw materials: 'metals', 'fossil fuels' (including 'petroleum'), 'minerals' (including 'sand'), 'water', 'land-use', etc.: if we carry on with 'business as usual' the expectation is that between now and 2050 the consumption of raw materials will double, rich countries will consume ten times as many raw materials as poor countries, and the planetary limits will be exceeded. The systematic and coherent monitoring of its effects on our society is therefore necessary.

Among the almost 50 raw materials investigated, it is mainly rare earth elements, petroleum and land-use for which there is 'virtually certain' to be a problem of supply in the European

[15] See https://www.un.org/ecosoc/sites/www.un.org.ecosoc/files/files/en/2016doc/interlinkages-sdgs.pdf (last accessed oo 17/10/2018).

Union. At the bottom of the list come raw materials such as lithium, cobalt, platinum … and 'sand', for which supply uncertainty is 'unlikely' or 'very unlikely' for the moment.

However, it is important to establish the relevance of the 'scarcity of raw materials' megatrend for economic activities in Belgium. The question of the significance then arises, both the significance for raw materials themselves and in relation to the economic activities in which they are directly applied. This significance for the respective raw materials is approached by investigating the influence on economic, environmental and social resilience via a number of criteria.

Resilience and supply risk form the basis for calculating the risk of scarcity of a raw material 'i'. The top 20 includes 15 rare earth elements. A number of metals, including the palladium group, and 'petroleum' can also be found. Raw materials at the bottom include the 'sand' group.

When significance is considered in relation to the resilience of the economic activities, it appears that the list is led by 'C20 - Manufacture of chemical products' immediately followed by 'C23 - Manufacture of other non-metallic mineral products. Nor should the risk for various 'sub-sectors' of the 'metal sector' be underestimated.

* * *

When the link is established between the economic activities and each of the SDG targets, it appears the risk of scarcity of the raw materials in question has the greatest negative impact for the targets SDG 17- Implementation, SDG 3 – Health, SDG 7 – Energy, SDG 8 – Economy and SDG 4 – Education. There is a clear positive impact for SDG 12 - Sustainable production and consumption and – to a lesser extent – on SDG 14 – Oceans.

Focusing on the targets suggests that the risk of the scarcity of raw materials is greatest for the health sector (SDG 3), - education and work (SDG 4 and 8, and 9), building and housing (SDG 11), energy supply (SDG 7), and trade and the economy (SDG 17).

However, there are also opportunities, especially where production and consumption must be made sustainable (SDG 12) and when pollution must be prevented (various SDGs).

In addition, the negative and - to a limited degree – the positive influence of the risk of scarcity of the raw materials in question is reflected in other SDGs. In a number of cases, this is a reason for priority attention: e.g. the negative influence on other SDGs exercised by SDG 7 (energy supplies) and SDG 11 (building and housing).

Using the input table, each of the targets can be coupled with the economic activity and the specific raw material which serves as an input.

* * *

It is in any event important to get to know the data and calculations in the MS Excel table in detail.

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