

# Digital economy as a basic incentive of vertical integration in a rare earth industry

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**Abstract** — The application of high technologies in the country's economy increases the efficiency, productivity and growth potential of a business, as well as its level of competitiveness in the market. The digital economy as one of the indicators of the scientific and technological development of a country has a significant beneficial effect on the development of its innovative entrepreneurship. The core of the digital economy is the production of high-tech products, while the rare-earth industry is the basis for the development of all innovations, which represents the need to study their development in modern conditions. The purpose of this study is to identify factors affecting the rare-earth industry in the conditions of digitalization of the economy. The logic of the study is as follows: first, the role of the rare-earth sphere in the production of digital products is substantiated, then the problem of the Chinese monopoly in the field of rare-earth metals, which impedes the development of the rare-earth market and is a threat to the development of the digital economy, is revealed. In this regard, it seems necessary to trace the pace of development of the rare-earth sector and the digital economy, as well as determine the strength of financial leverage in assessing the upper and lower stages of production of rare-earth metals, then the patterns of the distribution of added value between participants in production chains are analyzed, and finally the justifications for the development vertically integrated

production "from raw materials to technology" are given, as well as a suggestion of optimization of production flows within abovementioned structure.

**Keywords** — digital economy, digitalization, rare earth metals, value chain, vertical integration

## I. INTRODUCTION

The beginning of the 21st century is characterized by the active introduction of digitalization processes into the modern economy, which is impossible without the rare-earth sphere. Rare earth metals (REM) are a group of 17 hard-to-mine elements that include scandium, yttrium, and fifteen lanthanides. Despite their name, they are available almost everywhere in the crust. In fact, the 2 least common rare earths, thulium and lutetium, are 200 times more common than gold. Rare-earth elements (REE) play an important role in most industries that use modern technologies, for instance, in instrument and mechanical engineering, nuclear, glass, electronics, defense and nanotechnology products. (Figure 1).

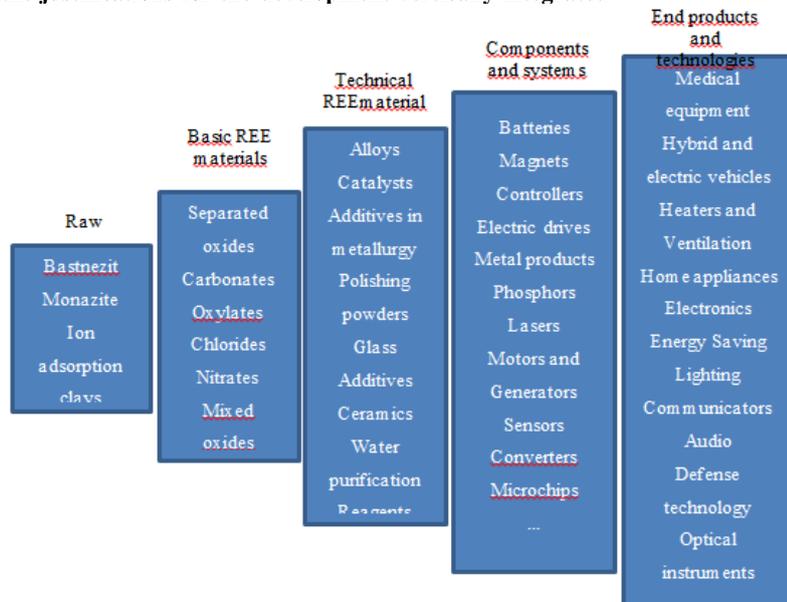


Figure 1. The list of main raw materials sources of rare-earth metals and based on them finished products. Source: [1]

Thus, the usual modern smartphone cannot work without a number of rare earth metals, such as yttrium, lanthanum, terbium, neodymium, gadolinium and praseodymium.

The world market of rare-earth metals is characterized by rapid growth in demand from high-tech industries, on the one

hand, and the monopolization of the production of rare-earth metals, on the other. About 80% of rare earth metals in the world are produced in China, and in 2013, Chinese companies controlled 42% of their global reserves. [2] Such a dependence on the supply of critical rare earth metals from China

constitutes an impermissible threat to the economic and technological security of every supplier of rare earths. At the moment, production in Russia is no more than 2 thousand tons of rare-earth metals (2% of world production) [3], at the same time, there were produced only raw materials, which were sent for processing outside the Russian Federation. Without structural changes in the industry and a change in the paradigm of thinking, the country's share in the global volume of REE production will only decrease, while the deficit will increase. According to forecasts of Rostec, a state corporation, by 2020 the demand for rare-earth metals in Russia will reach 5-7 thousand tons per year, according to a more optimistic scenario - almost 13 thousand tons. Domestic demand is almost completely satisfied by imports from China. At the same time, Russia has the full potential not only to provide for its own needs (which is currently the "minimum plan"), but also to enter the world market. So, Russia is the world's second player in stocks of rare-earth metals - 19 million tons (17% of world reserves) [4].

Despite the small amount of research linking rare earth metals and the digital economy, a summary of the data reveals 4 hypotheses about the mutual influence of digitalization and the rare earth industry:

- The level of development of the digital sector is directly proportional to the development of the REE industry;
- REE contribute to the high financial leverage, despite the small amounts of its usage per high-tech product unit;
- The main value of REE products is formed at the final stages of the production chain;
- Enterprises for the production of digital products should be built by the vertical principle and consider optimization of production flows.

Let us take a closer look at each of them.

## II. METHODOLOGY

The research methodology includes quantitative statistics, methods of comparative analysis, as well as analysis of scientific works on the digital industry transformation and the development of the rare-earth metal industry. In response to the application of these approaches, the market assessment comes from different points of view, which provides a complete understanding of the processes in the studied industries. Scientific sources include electronic publications, scientific journals and articles in online newspapers. Especially important resources are government strategies adopted in different countries. They are the fundamental basis for this analysis, as they contain information on structural changes in the industries, as well as factors affecting the development of a particular area. The main sources that provide actual data on

the market for rare earth elements are the US Geological Survey, as well as annual reports from various manufacturers of digital technologies and rare earth products. Important and reliable sources include the annual reports of the Solikamsk Magnesium Plant and the Financial Times newspaper.

The correlation of the digital economy and the rare-earth sphere is traced in many government documents, for example, the Digital Economy of the Russian Federation program identifies priority areas for the development of certain groups of organizations, which include: high-tech domestic companies, defense industry enterprises, IT enterprises, legal entities institutions and others. In the program "Development of industry and increase of its competitiveness", adopted on April 15, 2014 the necessity of the development of the rare-earth sphere in order to avoid their shortage in the high-tech industry in the future is substantiated. Other relevant documents are the Decree of the President of the Russian Federation of May 7, 2018 No. 204 "On the national goals and strategic objectives of the development of the Russian Federation for the period until 2024", as well as the development of the state program "Scientific and Technological Development of the Russian Federation". Accordingly, nowadays it is extremely important to determine the mutual influence of the sphere of digital technologies and the rare-earth industry, as the main driving factors of the economy.

All of the above sources make a significant contribution to the feasibility of this study, due to their relevance and reliability, which allows for a qualitative assessment of the data.



## III. RESULTS AND DISCUSSION

### A. The correlation of the development level of the digital sector and consumption of rare-earth metals

In modern conditions, there is a bilateral influence of the digital economy and the rare earth sphere.

Firstly, digitalization influences for the most part administrative processes in the rare-earth industry, since the exchange of information is becoming increasingly dominant and the role of economic agents takes on completely new content with the development of innovations such as cloud technologies, smart factories and networks, robots, artificial Intelligence. With the introduction of various systems, the transformation of the costs of their implementation, as well as risks during the implementation of a project (Figure 2).

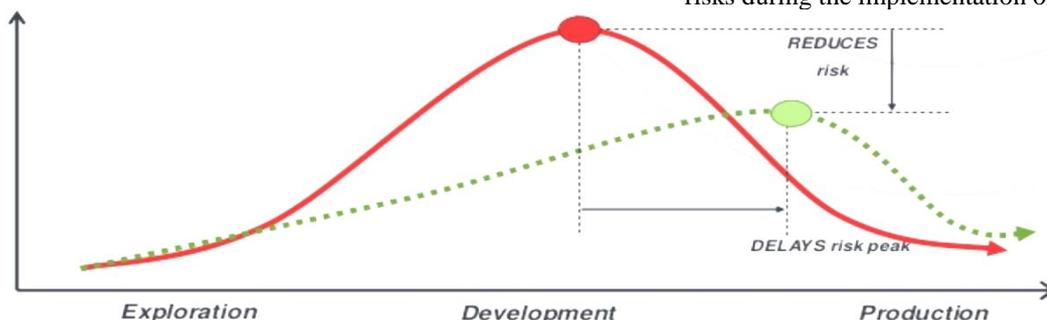


Figure 2. Transformation of exploration project risks in a digital economy. Source: based on [5]

Secondly, the rare-earth sphere has a direct impact on the very possibility of the development of the digital economy, since according to <https://www.econ.msu.ru/sys/raw.php?o=53707&p=attachment> the digital economy is the largest consumer of rare-earth

metals. As a result of analyzing the growth graphs of the information technology market and the projected demand for rare earth metals in the world (Figure 1 and 2), we can conclude that the indicators in these areas are directly dependent.



Figure 3. IT Services market size and forecast, 2015-2024 (US\$ Billion). Source: [6]

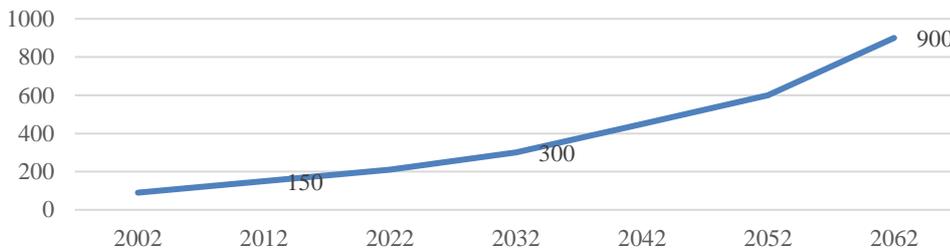


Figure 4. Dynamics of the current and future world demand for rare earth metals (thousand tons TR2O3). Source: [4]

As it was already revealed in the previous paragraph, the production of finished products strongly depends on the presence of rare earth elements used in the production of components (for example, a battery for a smartphone, LEDs for a monitor, etc.) Moreover, in the future, the additional dynamics of growth of the digital sector will be to promote the development of infrastructure, the adoption of technology by users, which will inevitably lead to an increase in the demand for rare earth metals.

*B. The financial role of REE-industry in the production of high-tech products*

Using the statistics provided in international reports, it is possible to establish with greater accuracy the influence of the upper divide on the lower in the rare-earth industry. Despite its total cost of about 5.38 billion US dollars, rare earths play an important role in downstream markets with a total value of about \$ 6.2 trillion [9]. In the USA and Canada alone, rare earth metals contribute to annual economic production equivalent to \$ 350 billion, and also create 620,000 jobs. Considering the global consumption of REE, the following table shows the effect of rare earth elements on the basis of their application [7].

TABLE I. INFLUENCE OF REE MARKET ON END PRODUCTS

Application area	Percentage of total production (%) [8]	The cost estimate of REE (in US dollars)	Market impact	Financial impact (%)	Downstream Markets
Catalysts	30	1,61	1 860	1 152	Automotive industry, oil refining
Ceramics	4	0,22	248		Coatings
Glass	14	0,75	868		High-quality optics, grinding and polishing glass
Magnets	24	1,29	1488		Electronics, Hybrid and Energy Vehicles
Alloys	18	0,97	1116		Green technology, metallurgy
Phosphors	6	0,32	372		Semiconductors
Other	4	0,22	248		Water purification, medical equipment
Total	100	5,38	6 200		

Source: [8]-[10]

As can be seen from the table above, the final manufacturer has a financial dependence on rare earth elements of more than 1000 percent<sup>3</sup>. At the same time, rare-earth elements make up 0.0009 percent of the procurement costs that companies spend on the purchase of this product. That is, REEs constitute a small share, but have a huge impact on the market for final products. The estimated financial leverage may deviate from the actual value, since other materials also add some value to the products. However, without rare earth elements, these products could not provide the functions that they perform, which reflects the strategic importance of REE for their final use. Traditionally produced by our industry products do not require tangible quantities of rare-earth metals. For example, the magnetic industry and the production of artificial rubber use only one element out of seventeen in small quantities. In

line with this, it can be concluded that significant demand is created in the consumer and industrial markets, which require, above all, rare earths, in accordance with the requirements of the final product on the market, and secondly, the promotion of research and development (R & D). As historical analysis shows, demand influences R & D progress.

C. Rare Earth Metals Value Chain

In order for rare-earth elements to be suitable for use in the final product, many intensive processes are required. Downstream operations in the supply chain include the production of components, which, for the most part, determine the cost of the finished product. A feature of the rare earth industry is that the main cost is formed at the final stages of the production chain (figure5)

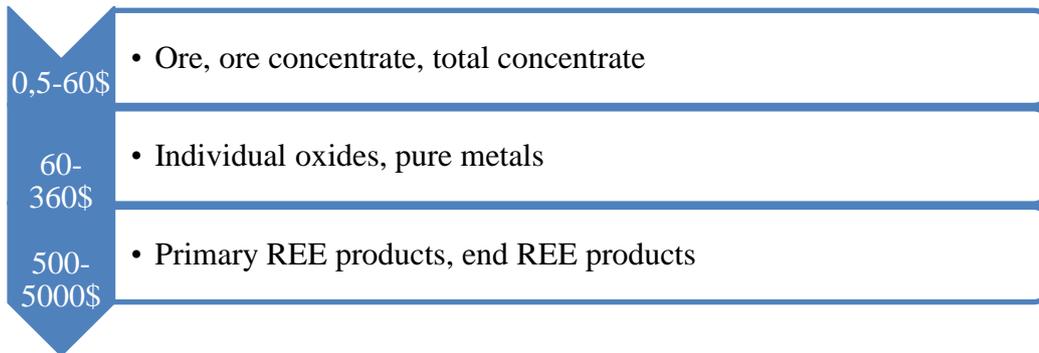


Figure 5. The growth of added value of rare-earth metals (\$ per 1 kg of rare-earth metals).Source: [4]

For example, the transition from oxides to pure metals increases the price of products by more than 4 times. (figure 6)

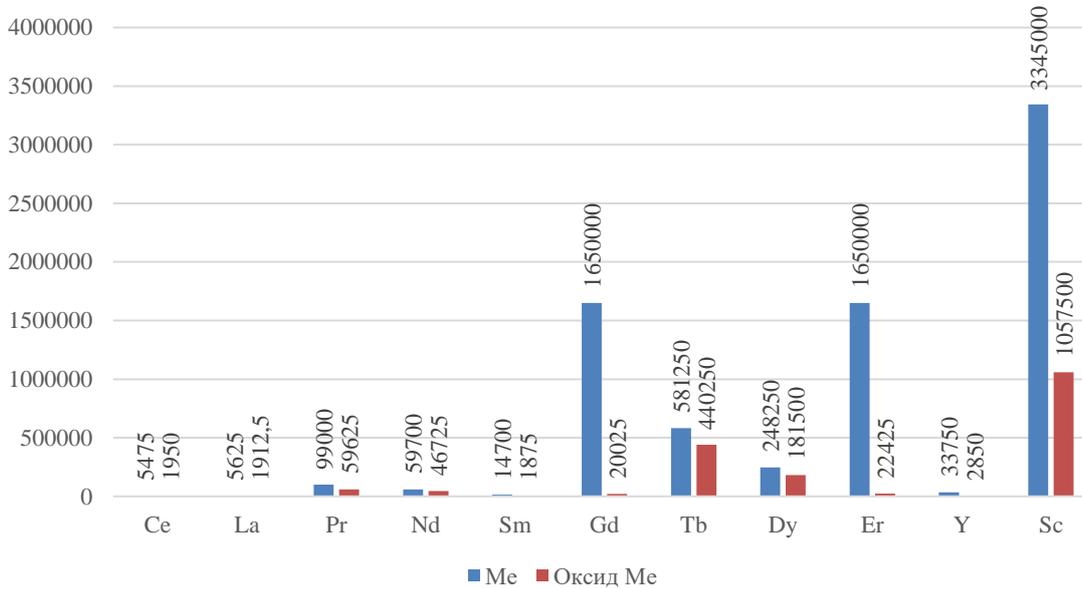


Figure 6. Difference in prices for pure metals and their oxides, (\$ per 1 t of rare-earth metals). Source: [11]

\* Information on contract prices for rare-earth elements is not open, as REEs do not belong to mass exchange goods. The above information reflects mainly the prices of Chinese suppliers.

The transition from a technical degree of purity of the metals themselves to a higher one also significantly (by a

factor of 10 or more) increases their price. The maximum level of purity of rare-earth elements according to the catalogs of foreign firms is 5N (table 3), while the content of impurities of common elements is controlled (aluminum, calcium, copper, iron, magnesium, silicon).

TABLE II. THE MOST POPULAR MARKS OF REM AND THEIR PURITY

Purity (%)	Mark
99	2N
99,9	3N
99,99	4N
99,999	5N

Source: [12]

It should be noted that the requirements for the level of purity of substances, as a rule, are determined experimentally and depend on the field of use. For example, to obtain permanent magnets (PM), a purity of rare-earth metals of 95–98% is sufficient (especially with regard to accompanying rare-earth metals). Recently, however, in the manufacture of PM more and more attention is paid to the purity of the REM. There is evidence of a significant dependence of the magnetic characteristics of the magnets on the purity of rare-earth metals in their composition. To improve such characteristics as the coercive force, responsible for the thermal and temporal stability of the sintered magnets, alloying of the basic chemical

composition is carried out ( $Nd_{14-15}Fe_{oct}B_{6-8}$ ) by rare earth elements Dy and Tb. However, due to the high cost of heavy rare earth metals and the total monopoly on the production of rare-earth metals in China, considerable attention is paid to their savings, reduction of consumption in permanent magnets through the development of new technologies for their production. Therefore, it is extremely important not only for the enterprise, but also for the country as a whole, to bring the production to the end of the technological chain with the production of high value-added products. According to this scheme, this industry is developing in China, where the policy in the field of REE is thought for the future. (figure 7)

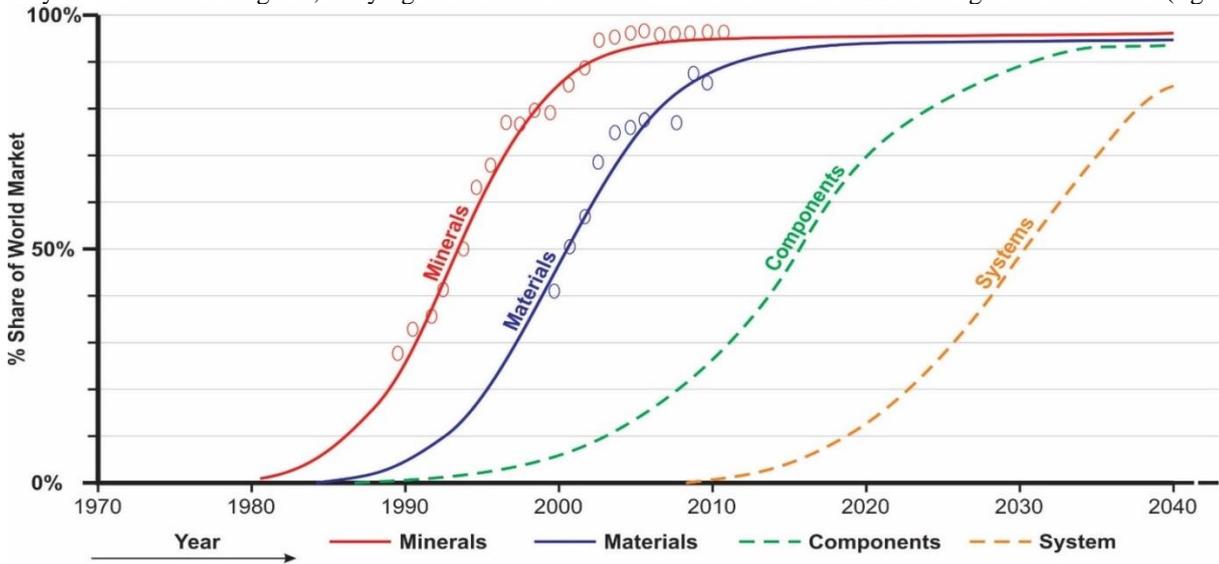


Figure 7. China's market share in the REE value chain. Source: [13]

D. Justification of the vertical integration in the conditions of digital economy

As defined in the previous sections, the main cost is formed at the final stages of production of rare-earth metals, respectively, revealed the need to "bring the entire production to the end", where the end user will be high-tech production, in

our case, let's take as an example the production of smartphones. At the same time, an important issue is the production flows at such an enterprise. All products are divided into the one that is produced for the company's own needs, and which is sold on the market (figure 8).

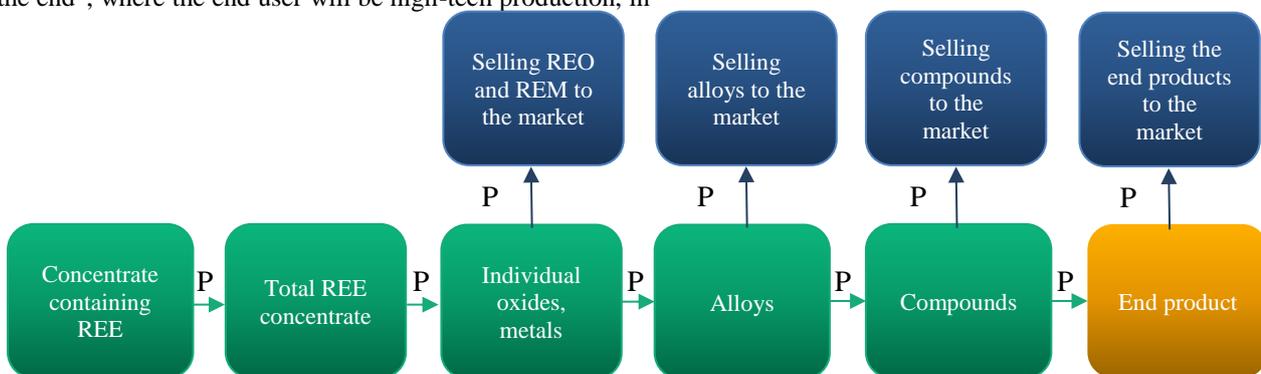


Figure 8. Product sales scheme in an integrated company

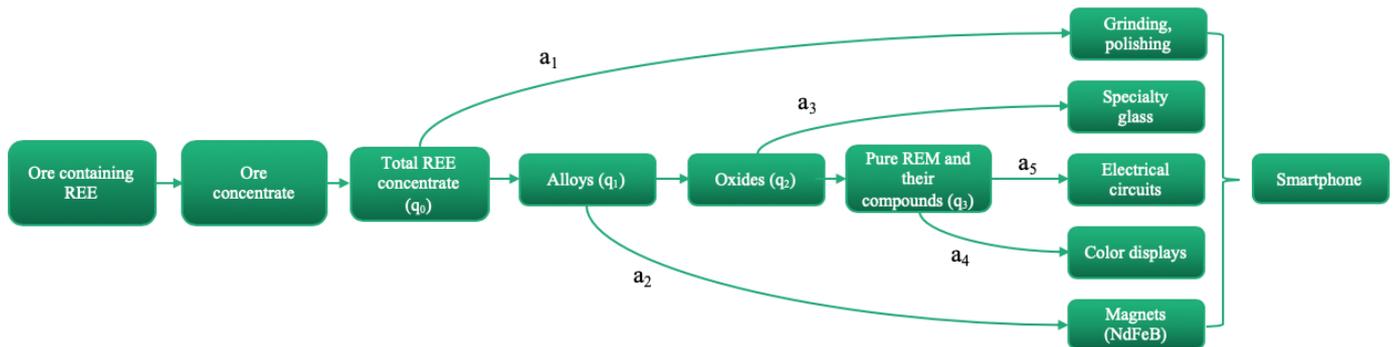
$P_t$  – sales of products within the company;  $P_r$  – sales of products to foreign markets

Source: compiled by the author

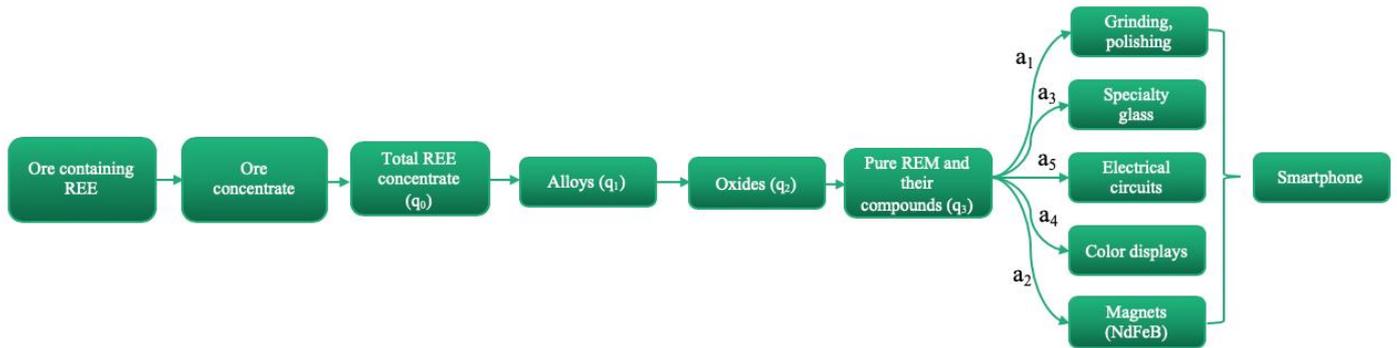
We should keep in mind that selling unseparated REEs is inefficient, since their share of total revenues can be as low as 23%, so only selling oxides, metals, compounds and end products will bring the financial benefit. In addition, the company should sell only those products that remain in abundance. The main aim of the integrated company should be in its own security in intermediate products for the manufacture of the smartphone or computer, for instance.

For the production reasons, depending on specifics of the end product, production flows should be optimized within the

company. Manufacturers of end products mostly have a whole range of production capabilities, which allows to produce the goods required by the customer, depending on the forms and applications, this means that not all REEs need to be highly-purified. (Figure 9). It should be noted that the requirements for the level of purity of substances are determined experimentally and depend on the field of use. For example, to obtain permanent magnets (PM), a purity of rare-earth metals of 95–98% is sufficient (especially with regard to accompanying rare-earth metals). Recently, however, in the manufacture of PM more attention is paid to the purity of the REM. There is evidence of a significant dependence of the magnetic characteristics and the purity of rare-earth metals.



$$Z_S = Z_1 * (q_0 - a_1) + Z_2 * (q_1 - a_2) + Z_3 * (q_2 - a_3) + Z_4 * (q_3 - a_4) + Z_5 * q_4 + Z_P \tag{1}$$



$$Z_S = Z_1 * q_0 + Z_2 * q_1 + Z_3 * q_2 + Z_4 * q_3 + Z_5 * q_4 + Z_P \tag{2}$$

Figure 9 – Optimizing the use of rare earth products at all stages of processing, where  $a_1 \dots a_4$  – the volume of products that are transferred for related purposes

$Z_1 \dots Z_5$  – variable costs per unit;

$Z_P$  – fixed costs;

$q_0 \dots q_4$  – production volume at the corresponding production level

#### IV. CONCLUSIONS

So, the above study allows us to conclude that the development of the digital economy goes side by side with the development of the rare-earth sphere. The growing need for rare-earth metals causes the growth of applications in the production of finished products, such as: petrochemistry, electronics, glass, ceramic industry, metallurgy, nuclear and military industry, etc. It should be noted that China is a strategic threat; it is a monopolist in this field and has pulled finished-product production based on rare-earth elements onto its territory. This step is very reasonable given the fact that value added in the production chain increases with each stage and increases several times in the final levels, which allows

producers at the end of the chain to receive much higher profits than those who are at the middle stage. In this regard, projects in rare-earth areas are often under-funded, despite the acute concern of countries (USA, Russia, Australia, Canada, etc.) in the development of this sector. In order to eliminate this problem, in this industry it is necessary to create a complete production chain “from raw materials to technology” that will uninterruptedly meet the needs of the digital economy, and the company's own supply of raw materials should remain a priority, and then the sale of semi-finished products on the market. In this regard, for each enterprise, production flows should be optimized in accordance with the type of finished products.

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