Conservation and rational use of natural resources: methods of circular economy assessment

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Abstract. Issues of resource conservation in terms of inclusion of raw materials and advanced technologies of environmental management are indisputably important in modern production and consumption development. The scientific community focuses on the development of technological methods for cyclic use of raw materials, construction of logistics supply chains, introduction and modernization of circular processes in production. The next logical stage of the study is to analyse various tools for assessment of circular economy development, promoting conservation and sustainable use of various natural resources; the article defines the main differences and results of the analysis. Carried out with the financial support of the Grant of the President of the Russian Federation to support young scientists Candidates of Sciences in the study MK-587.2019.6 "Development of theoretical and methodological foundations of the concept of circular economy as a new trend in the formation of sustainable socio-economic space."

1. Introduction.
The circularity concept has undeniable relevance, it is considered as an oriented process of modernization for the linear model of the economy to achieve qualitative development of various socio-economic phenomena. A historical review was previously presented, it covers circular economy emergence and formation and its relationship with new industrialization phenomenon; a variety of interpretations of "circular economy" concept was studied and main approaches to its formation were determined [5]. The authors described in detail using the circular economy model by countries on specific examples of enterprises characterizing introduction of main business models of the circular economy [2, 3]. The next logical stage is to study methodological aspects of assessing circular economy development.

The purpose of the article is to analyse various methodological approaches to the assessment of circular economy development in the socio-economic space, necessary for further development and testing a new assessment tool. Poor and insufficient elaboration of a methodological approach to the concept of circularity in Russian-language sources is indisputable fact testifying to scientific novelty.

Statistical information accumulated in various areas of socio-economic development, as a rule, is not informative and requires a thorough competent analysis. Indication is applied for quantitative and qualitative analysis of various indicators. This methodological approach has gained wide relevance in natural sciences, providing further insight into the causal relationship between the studied phenomena. The indicators used during the assessment offer a clearer view of the system state under study, which is influenced by a set of internal and external factors. The basic principles of indicators construction...
include aggregation and creation of indicator systems; at the same time, classical formation of an indicator is focused on presentation of the degree of achieving the reference value [4].

2. Main part.
In 2019, a group of scientists, after studying more than fifty-five different approaches to circular economy assessment "... that are developed and used by scientists, companies, environmental organizations, government agencies, created their taxonomy based on the needs arising from application of such indicators, including ten categories for differentiation and definition of C-indicators driven by the principles of the circular economy..." [25].

The categories/criteria identified by authors for proposed taxonomy of C-indicators include:
1) level (micro, meso, macro);
2) cycle (conservation, reuse / recovery, recycling);
3) performance (internal, impact);
4) perspective (actual, potential);
5) usage (for example: improvement, comparison, communication);
6) transversality (general, branch);
7) size (one, several);
8) units of measurement (quantitative, qualitative);
9) format (for example: a web-based tool, Excel-formula);
10) sources (scientists, companies, agencies) [25].

C-indicators can be considered as extraordinary incentives to move to a more advanced level of circularity.

A detailed analysis of methods for assessing circular economy development is beyond the scope of this article, so it briefly presents only a few.

In 2007, in China the scientific literature gives the earliest references to the indicators of circular economy evaluation. The first system of indicators "... is based on the 3R principles and is designed to promote the application of circular economy, assess the overall effectiveness of practices and support processes..." [17]. In 2011, the Regional Circular Economy Index System was introduced, based on three indicators, according to the 3R imperatives: pollution reduction, waste recycling and recycling of materials [22].

In 2011, researcher J. Guo-gang presented an index system for assessing the level of circular economy development, consisting of 16 indicators grouped into four groups:
1) consumption (water consumption per million GDP, water consumption per capita, elasticity in water use, energy consumption per million GDP);
2) environmental violations (norms of industrial wastewater discharge, level of harmlessness of household garbage, application of chemical fertilizers per unit of acreage);
3) waste management (urban wastewater treatment per capita, integrated solid industrial waste utilization rate, resource utilization network coverage, "three waste" utilization rate);
4) social development (GDP per capita, urbanization rate, unemployment rate, Engel coefficient, GDP growth) [19].

In 2012, a group of scientists led by Yu. Geng suggested a system of indicators structured into two groups for evaluation:
- macro-level (22 indicators);
- industrial park (12 indicators).

This system is designed to facilitate methodological processes of introduction of circular economy and increase attention to environmental problems (Geng Y., Fu J., Sarkis J., Xue B., 2012) [17].

In 2013, in China, the Ministry of Environmental Protection (MEP) drafted indicators system for circular economy assessment at the meso-level based on 21 indicators divided into four groups: economic development, waste management, pollution control, administration and management [20].

In 2015, C. Ruiter (2015) proposed "the Circular Economy Performance Index", acting as a useful tool for assessing the level of business circularity. The system consists of 25 key performance
indicators (KPI) of the circular economy, classified into three levels according to impact degree: high (red), medium (orange) and low (green). According to the obtained calculated values the analyzed object can be assigned to one of five categories: "non-compliance", "compliance", "beyond compliance", "integrated strategy", "goal/mission", providing an opportunity to quickly realize shortcomings in the circular economy concept implementation [23].

In 2015, "EU Resource Efficiency Scoreboard 2015" presents "... a system for assessing the circularity of economy on 32 indicators formed into a three-level system: a common leading indicator of "resource productivity"; a second-level dashboard of additional macro indicators for materials, land, water and carbon; and a third-level of thematic indicators to measure progress towards key thematic goals, as well as actions and milestones set out in the road map..." [16, 28]. They are grouped into main topics and sub-topics:

- resource productivity (main indicator);
- dashboard indicators (materials, earth, water, carbon);
- transforming the economy (turning waste into resources, supporting research and innovation; pricing correctly);
- nature and ecosystems (biodiversity; clean air; land and soil);
- key areas (solving the food problem; improving buildings; ensuring effective mobility) [16, 28].

Resource productivity is the main indicator of the evaluation system under consideration. It is used as a measure of resource efficiency, i.e. how effectively an economy uses material resources to produce products and services available in the market. It is an absolute indicator, measured in euros per kg and monitors the dynamics of changes (2000 is considered as a base year). The efficiency of resources use by the state largely depends on the structure of national economy, the size and structure of international trade, while the economy is able to create more wealth without a proportional increase in resource consumption [16, 28].

In 2015, Ellen MacArthur Foundation, GRANTA Design and LIFE, developed an indicator “The Material Circularity Indicator” (MCI) presented in “Circularity Indicators: An Approach to Measuring Circularity. Methodology” [14].

Along with the MCI indicator in the Circular Metrics Landscape Analysis report 2018, The World Business Council for Sustainable Development (WBSCD) identifies three other important tools for assessing the circular economy:

1) the Life Cycle Assessment (LCA) is a method of assessing the environmental impact associated with all stages of the product life cycle from extraction of raw materials to disposal; it is an indirect tool used in the circular economy, but, nevertheless, so-called "life cycle analysis" (or "ecobalance") is extremely important;

2) the Circular Economy Toolkit (CET) is an assessment method that identifies and evaluates the potential improvement in circularity of products, i.e. it is also associated with life cycle analysis. This is an online test without score points, which includes 33 questions, developed at the University of Cambridge. Questions are divided into 7 subcategories according to the stages of product/service life cycle. It is presented as a web page and gives a qualitative assessment, structured into three categories (low, medium, high);

3) circular economy Indicator (the Circular Economy Indicator Prototype, CEIP) evaluates the performance of cyclic products. Developed on the basis of calculation functions of MS Office Excel, using a questionnaire with a score system of assessment, consisting of fifteen questions divided into 5 stages of a life cycle, namely: design or redesign; manufacture; commercialization; use and end of life. Presented as a spreadsheet in an Excel file, gives a quantitative estimate, measured in % [12, 18, 23, 24, 27].

In 2019, a group of researchers (Z. Steinmann Z. J. N., Huijbregtsa M. A. J., Reijndersbb L., 2019) proposed the material quality circularity index (Qc), where the numerator expresses the net energy savings due to processing of primary material (MJ / kg) and the denominator is the embodied
energy of 1 kg of primary material (MJ/kg), which can be attributed to the evaluation indicators of the circular economy at the micro-level [26].

In 2019, A. Avdiushchenko A., Zając P. proposed a system of evaluation "Circular Economy Indicators" which includes 25 indicators divided into 7 groups:

- **economic development** (GDP per capita, average life expectancy at birth for men, registered unemployment rate, poverty risk level);
- **zero economy** (municipal waste collected selectively in relation to the total amount of municipal waste collected; municipal waste collected per inhabitant; industrial and municipal waste water requiring treatment; expenditures on fixed assets serving environmental protection and water resources management related to waste processing and disposal);
- **innovation economy** (research and development expenditures per capita, fixed prices; average share of innovative enterprises in the total number of enterprises; adults involved in education and training; patent applications per 1 million inhabitants);
- **energy efficiency and renewable energy** (share of renewable energy sources in total electricity production; expenditures on fixed assets serving environmental protection and water resources management related to energy saving per capita; electricity consumption);
- **low-carbon economy** (emissions of carbon dioxide from plants particularly harmful to air purity; emissions of particles; cars; pollutants remaining or neutralized in pollutant reduction systems in common pollutants produced from plants particularly harmful to air purity; costs of fixed assets serving environmental protection and water management related to air and climate protection);
- **smart economy** (households with a personal computer with broadband Internet connection; businesses with broadband Internet access);
- **spatially efficient economy** (forest cover indicator; urban greenery and the share of parks, lawns and green areas in residential areas in the total area; urbanization coefficient) [9].

The table provides a comparative analysis of the considered tools for assessing the circular economy.

| Year of development | Title** | Authorship / country | Quantity assessment subgroups | Graphical shell | Level of assessment |
|---------------------|---------|-----------------------|-----------------------------|-----------------|--------------------|
| 2006                | The Life Cycle Assessment | LCA                     | -                           | -               | Micro              |
| 2007                | The Regional Circular Economy Index System | RCI | China | 2 | 3 | - | Macro |
| 2011                | Regional Circular Economy Development index | - | J. Guo-gang / China | 4 | 16 | - | Macro |
| 2012                | Material flow analysis to evaluate Circular economy | MFA | Geng Y., Fu J., Sarkis J., Xue B. | 2 | 34 | - | Macro |
| 2013                | Ministry of Environmental Protection CE | MEP | Su B. W. et al. / China | 4 | 21 | - | Meso |
| Year of development | Title** | Authorship / country | Quantity assessment subgroups | Graphical shell | Level of assessment |
|---------------------|---------|----------------------|------------------------------|-----------------|---------------------|
| 2015                | Indicator system for assessing the circular economy | Ruiter C. | 25 | + | Micro, Meso |
| 2015                | The Resource Efficiency Scoreboard | Eurostat European Commission | 32 | - | Macro |
| 2015                | The Material Circularity Indicator | Ellen MacArthur Foundation, Granta Design и LIFE L.H. Verbeek | 2 | + | Macro |
| 2016                | Circular Economy Index for the consumer goods sector |  | 25 | + | Micro |
| 2016***             | The Circular Economy Toolkit | CET Cambridge University | 33 | + | Micro |
| 2016                | The Circular Economy Indicator Prototype | Griffiths, P. Cayzer, S. | 15 | + | Micro, Meso |
| 2018                | Raw Materials Scoreboard 2018 | EIP | 26 | - | Macro |
| 2018                | Monitoring framework for the circular economy | European Commission and Eurostat | 10 | - | Macro |
| 2018                | Adaptation of Monitoring framework for the circular economy for practice in the Republic of Belarus | BEROC / the Republic of Belarus | 14 | - | Macro |
| 2018                | Indicators for a Circular Economy | Vercalsteren A., Christis M., Van Hoof V. | 18 | - | Micro, Meso, Macro |
| 2018                | Circularity Rating Indicator | O. I. Sergienko, E. S. Smaznova, D. V. Razumova | 1 | - | Micro, Macro |
| 2018                | Indicators for evaluation of clusters’ competitiveness through circular economy | K. Razminiene M. Tvaronaviciene | 15 | + | Meso, Macro |
| 2018                | Circular Economy Development Index | Vetrova M. A., Pakhomova N. V., Richter K. K. | 1 | - | Meso |
### Year of development | Title** | Authorship / country | Quantity | Graphical shell | Level of assessment |
|----------------------|-----------------|----------------------|----------|-----------------|------------------|
| 2019                 | Indicator for the circularity of material quality | Steinmann Z.J.N., Huijbregtsa M.A.J., Reijndersb L. | 1 1 | - | Micro |
| 2019                 | Circular Economy Indicators | Avdiushchenko A., Zajac P. | 7 25 | - | Macro |

* the table is compiled by the author using the cited sources in the bibliography list [1-30].
** there are more evaluation tools than are presented in this table.
*** the reliability of this data is in doubt, as the official data source has no date [27].

### 3. Conclusion

The bibliometric method of literature analysis showed that the assessment of circular economy development takes place at three levels: micro, meso and macro. Macro-level indicators are needed for evaluation and monitoring in order to improve various programs at the state level. Micro-level indicators tend to cover 3R imperatives without reflecting the full range of distinctive features of the circular economy, analyzing the environmental friendliness and waste-free production and consumption. At the same time, there is no clear distinction in the set of indicators, in this regard, they can be repeatedly used at the same time. Most of the studied indicators are focused only on one and/or several specific environmental problems than contribute to the estimated subjectivity.

The research carried out in this article has identified several problem areas regarding the methodological approach to the concept of circularity: insufficient statistical coverage of baseline data; lack of in-depth justification of metrics and evaluation systems; lack of a uniform tool for assessing circular economy development. Therefore, it is necessary to develop methodological assessment tools with wider coverage of the spectrum of circular economy paradigm than existing tools, providing relevant integration with real business practices.

An extremely important condition for activating the intensification of transition to the circular economy model is creation of a comprehensive methodological tool for assessing its development, which is required for effective strategic and program planning at the state level.

The continuation of the study, based on the conceptual, theoretical and methodological provisions of the circular economy, should be aimed at improving the assessment tools, which will contribute to the qualitative achievement of the goals of society sustainable development.

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