Potential Model to Support the Achievement of Corporate Carbon Neutrality

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Summary

In our article, based on the methodology of internationally known sustainability models, we propose developing a novel, decision support and controlling system to motivate organizations to achieve net zero emissions. The evaluation system fits the GHG Protocol's criteria, considers the emissions of all three Scopes, and provides the opportunity for benchmarking and stress testing. The model supports the management's decisions visually, and it also offers regulators the opportunity to prepare and make industry level decisions. The creation of the new model is especially necessary in a period fraught with geopolitical tensions, when the price and availability of individual energy carriers can change dramatically and rapidly.

Keywords: sustainability risk, carbon accounting, Greenhouse Gas Protocol (GHG), risk assessment, Carbon Disclosure Project (CDP)

JEL codes: D81, G30, Q51

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The European Council and the Council of the European Union give high priority to the climate transition. Under the Paris Agreement, the European Council approved a binding target of at least 40% reduction in economy-wide greenhouse gas emissions by 2030 compared to 1990 (Council Decision (EU) 2016/1841) in the EU. Considering the emergency situations related to climate change and biological diversity, on 14 July 2021 the European Commission published the 'Fit for 55' package – a revision of the commitments defined in the *Paris Agreement* (2016) –, in which the EU agreed to reduce net emissions at least by 55% by 2030 compared to 1990, and to make Europe the first climate neutral continent by 2050. With this measure, the Commission wishes to support the green transition that may contribute to a resilient and sustainable European economy (COM [2021] 550 final).

In order to achieve that, carbon emission pricing is introduced in several sectors, making clean solutions cheaper, and – as a result of additional incomes – ensuring the possibility of fair transition. The Commission supports the more extensive use of renewable energy and the improvement of energy efficiency. Energy consumption is responsible for 75% of the emissions in the EU, and therefore it has a central role in the climate protection efforts of the Commission. The transformation of the energy system may be a key element of economic competitiveness, so the reduction of emissions and the costs of energy for consumers and the industry, the transformation of the energy mix, and the increased share of renewable energy sources are essential. Under the renewable energy directive – 40% target value for the share of renewable energy sources by 2030 – the EU promotes the increased sale of new clean vehicles and cleaner fuels for transport. By now it has become clear that the ability of nature to remove carbon dioxide from the atmosphere has decreased, therefore, in order to achieve the climate policy and environmental objectives, apart from encouraging innovative investments, imposing taxes on energy sources and enforcing the 'polluter pays' principle may significantly contribute to the greening efforts. The joint commitment regulation authorises the Member States to take steps at national level to manage the emissions of the building industry and the transport, agriculture, waste management and small industry sectors. As a result of the proposal, by 2030 emissions from these sectors should be reduced by 40% in the whole EU compared to the status in 2005 (COM [2021] 550 final).

In order to make the decarbonisation processes successful, the EU wishes to support investments by enterprises into clean energy, and it will increase the financing of innovative projects and infrastructure aimed at decarbonising the industry. The Commission draws the attention of the Member States to the fact that the target set for 2030 can only be achieved if a system-level transformation is carried out in the whole economy. The new geopolitical and energy market situation calls for the implementation of the 'Fit for 55' package of the European Commission as soon as possible, and for the acceleration of the green transition. Regarding the difficulties caused by the Russian invasion of Ukraine and the elimination of the energy market problems – in line with the earlier measures – the REPower plan of the European Commission focuses on energy saving, the search for alternative energy sources, and the promotion of investments providing clean energy.

At national level, the implementation of the plans will require the development of an evaluation and qualification system that – in addition to the obligations specified in legal regulations – will encourage economic players to contribute to the successful implementation of the green transition.

In the first part of the article, we present the sustainability models applied at international level and their key characteristic features.

In the second part of the article, we propose an evaluation and ranking model that is based on the methodology of internationally known sustainability models and offers a possibility to create a novel qualifying system that fosters the achievement of carbon neutrality.

In the course of developing the evaluation system, we took the following aspects into consideration:

a it should be in line with the considerations related to the greenhouse gas (hereinafter: GHG) protocol, therefore it should perform evaluation according to the interpretation of Scope 1, Scope 2 and Scope 3 (GHG Protocol, 2004);

b it should provide statements in an integrated way, by interpreting all the considerations together, encouraging the economic players to make continuous improvements in the case of all three Scopes;

c it should be possible to evaluate the results of the organisations on the basis of multiple functions, therefore it should provide an appropriate basis for detailed benchmarking and stress testing for the individual organisations, and among the organisations, too;

d it should provide visual support to the management for their evaluations and decisions;

e it should allow regulators to prepare and make industry and sector level decisions.

THE INDIVIDUAL SUSTAINABILITY MODELS

The issue of climate change is becoming a strong influencing and motivating factor in the operation of global money markets, and it puts more emphasis on the responsibilities of economic players and governments, too (Schaltegger, Zvezdov, Günther et al., 2015). Climate change and the related economic, social and environmental impacts inspired the representatives of various disciplines to create new models.

Intergovernmental Panel on Climate Change (IPCC) model

In the current annual report of the Intergovernmental Panel on Climate Change (hereinafter: IPCC) the phenomena and risks generated by climate change are given special focus (IPCC, 2022). The IPCC report describes the sustainability risks with three sets interacting with each other, with a focus on climate hazards, and the vulnerability and exposure of the social systems and of the ecosystem. Economic factors are treated as one of the key subsystems within the social systems.

Greenhouse Gas Protocol (GHG Protocol) model

Supporting the efforts to reduce greenhouse gas (GHG) emissions is one of the most important tasks of science as well as economic players. The recommendations of the protocol related to greenhouse gases basically divide the carbon dioxide emissions of entities into three groups as follows:

- Scope 1: emissions originating from operations owned or controlled by the entity;
- Scope 2: emissions from the production of the consumed, purchased or obtained electricity, steam, heating or cooling;
- Scope 3: all indirect emissions outside Scope 2, which occur in the value chain of the entity, including upstream and downstream emissions, too (GHG Protocol, 2004).

Carbon Disclosure Project (CDP) model

The Carbon Disclosure Project (hereinafter: CDP) operates an extensive qualification system to encourage actors, from entities to towns, to take steps to reduce climate change in the use of air, water and soil, among sustainability risks. The CDP qualification system considers GHG emission as a key element, and every year discloses the entities submitting reports with the highest rates (A list), thus motivating players to reduce emissions (CDP, 2021).

Partnership for Carbon Accounting Financials (PCAF) model

The Partnership for Carbon Accounting Financials (hereinafter: PCAF) developed recommendations about GHG accounting issues for players in the financial sector to offer support in order to facilitate the measurement of financed emissions (PCAF, 2020). This work was also qualified by the GHG Protocol for the recommendations regarding Scope 3 emissions. Moreover, on the basis of the GHG Protocol, Finans Danmark produced its own recommendations for financed emissions, making similar statements for the PCAF recommendations about specific calculation rules and structures. (Finans Danmark, 2020)

University of Cambridge Institute for Sustainability Leadership (CISL) model

The University of Cambridge Institute for Sustainability Leadership (hereinafter: CISL) is increasingly active in publishing reports and recommendations about incentives, methods, processes and proposals supporting sustainable economic development. In their understanding, the economy is currently in a phase of preparation for the transformation, as the CISL calls it, 'banking as usual' (CISL, 2020).

Apart from their statements concerning the present, the 'new normal' operation is projected for around 2050, when the economy will have zero emission (CISL, 2021). According to CISL analyses, efficiency-focused thinking is currently blocking the move toward a low-carbon economy. At the same time, we can see the intention of banks to facilitate and promote this process. In line with the vision of CISL, in McKinsey's 2021 ESG report a carbon emission reduction of 25% is set as a target compared to the base year of 2019, for the Scope 1 and Scope 2 emission values projected for businesses (McKinsey, 2021).

SUSTAINABILITY RISKS, EVALUATION METHODS AND REQUIREMENTS FOR THE MODEL

In addition to contextual models, more an more published works aim at reducing sustainability risks, typically at the level of production and operation processes (von Ahsen, Petruschke, Frick, 2022).

Sustainability risks

In the case of sustainability risks, the focus is primarily on industries represented by the clients of the banking sector. In these models, the number of risk evaluation dimensions is usually limited to two (Schulte, Knuts, 2022; Losiewicz-Dniestrzanska, 2015); three dimensions are considered only in a few cases (Makajic-Nikolic, Petrovic, Cirovic et al., 2016; Valinejad, Rahmani, 2018).

In the case of two evaluation dimensions, the analysis basically builds on the risk matrix methodology (Losiewicz-Dniestrzanska, 2015), while in the case of three dimensions, the methodological basis is either failure mode and effects analysis (Poulikidou, Björklund, Tyskeng, 2014), or an approach related to the latter, but basically relying on the identification of partial risks (Bognár, Benedek, 2021). It is a characteristic feature of each method that the quantification of risk can be interpreted in the light of the evaluation factors.

In the first step, the individual risks are qualified on the basis of specific evaluation factors on a given scale, then these scale values are multiplied by each other to obtain the risk value. Based on that, it is possible to rank the individual risks, so we can determine which risks could be considered critical, and when it is necessary to introduce risk mitigating measures as quickly as possible. With these techniques, the evaluation of the received results is ensured continuously, supporting decision making at the organisation (Fekete, 2022).

Evaluation methods – requirements for the model

Based on the methodology of internationally known sustainability models, we propose development of a novel decision support and controlling system to motivate organizations to achieve carbon neutrality. The evaluation system is in line with the criteria of the GHG Protocol, takes the results of all three Scopes into consideration, allows benchmarking and stress testing, supports management decisions visually (as well), and allows regulators to prepare and make industry and sector level decisions.

Adjustment to the GHG Protocol criteria

The methodological proposal is aimed at the development of a new type of qualification system. However, the proposal does not wish to assess the carbon emissions of entities; in this respect the GHG Protocol and the PCAF recommendations are to be followed.

The model has to support the entity in selecting future development directions. The comparability of the individual organisations' activities belonging to the same industrial category is a requirement for the method.

The GHG Protocol and the CDP make statements from several aspects, aiming at the achievement of a carbon neutral economy (GHG Protocol, 2004; CDP; 2021), as the operational evaluation models also provide assessments according to multiple considerations (von Ahsen, Petruschke, Frick, 2022). The proposed model should also follow operation according to multi-factor evaluation methods, as achieving a carbon neutral economy is one of the most complex problems of our age.

We can find a number of promising initiatives – scientific articles – for the definition of the evaluation factors of models. Good practices include a model based on the logic of SWOT analyses, approaching evaluation from the perspective of opportunities and threats (Schulte, Knuts, 2022). While offering promising solutions, they are difficult to adjust to the robust concept of the GHG Protocol, as they operate according to different considerations. Therefore, when creating the required model, one of the conditions was that it should be in line with the GHG Protocol considerations (GHG Protocol, 2004), so it should perform assessments according to the interpretation of Scope 1, Scope 2 and Scope 3.

Ensuring opportunities for continuous development in an integrated way

In line with other qualifying models, the vision and development concept of the CISL and the CDP follow the logic of continuous development, and assume the inclusion of qualification points from time to time (CISL, 2021; CDP, 2021). Therefore, the qualification system should be able to monitor changes in the given periods and the development paths.

The requirements for the evaluation model include the ability to make statements in an integrated way, with the joint interpretation of considerations. This is how it should encourage economic players to achieve continuous development in the case of all three Scopes. The measurement and estimation methods of Scope 3 are the most diverse and costly (GHG Protocol, 2011), therefore they present serious data collection and financial challenges to economic players – primarily to small and medium-sized enterprises (hereinafter: SMEs).

As we do not wish to distinguish between the stakeholders of the economy, the model should be able to play this role independently of company size. Independence from company size is an important aspect, because in spite of the fact that a lot of studies discussed the environmental practices of SMEs over the past years, the greener management of external (such as supplier) relations has not been a central issue (Vörösmarty, Dobos, 2020). For the SMEs, the model should take qualifications according to Scope 1 and Scope 2 into consideration as long as they cannot be qualified according to Scope 3. This kind of 'lenience' requires high flexibility in the structure of the evaluation model, but it seems to be necessary, particularly as we know that in the case of Hungarian companies, the accounting of Scope 3 emissions is still at an early stage (Csutora, Harangozó, 2019).

Evaluation option provided by the functions – benchmarking and stress testing

As a requirement for the model, it should allow results to be evaluated in the same industries and sectors on the basis of multiple functions, too (results of multiple organisations, as well as an organisation's own results).

In the case of both the risk matrices and the sustainability failure mode and effects analysis methods, the multiplication of factor values is the most common method in literature (Schulte, Knuts, 2022; Losiewicz-Dniestrzanska, 2015; von Ahsen, Petruschke, Frick, 2022). Besides, the addition and square methods with their proved robust basic evaluation features provide evaluation functions of a different nature the application of which may strengthen multi-criteria assessment, along with the product of multiplication (Bognár, Hegedűs, 2022).

Visual support to management and executive bodies

The model should be able to provide significant visual support to management and executive bodies, and that helps the preparation and evaluation of decisions, and ensures the possibility of planning in defining steps to achieve carbon neutrality.

Provision of industry and sector level decision support to regulators

The possibility of industry and sector level comparisons is of key importance for the regulators. If a given organisation emits carbon dioxide in several industries, the emission data should be provided for the whole organisation and according to industrial and sectoral categories as well in order to allow for comparison. For the model, industry and sector level data can be interpreted in the same way as an organisation's comprehensive data.

Integrated evaluation options

With the presentation of the integrated evaluation options (hereinafter: evaluation options according to Scope 1, Scope 2 and Scope 3) and with the description of the

Carbon Accounting Map methodology, we will describe the possible applications of the model.

Description of the integrated carbon emission evaluation model

Let $\boldsymbol{S}=(s_1, s_2, s_3)$ denote an entity that has three typical characteristics according to the GHG Protocol: s_1 is the Scope 1 emission, s_2 is the Scope 2 emission, and s_3 is the Scope 3 emission. The Scope emissions can be expressed on high (tonne of CO_2 equivalent) and low measurement scales, too.

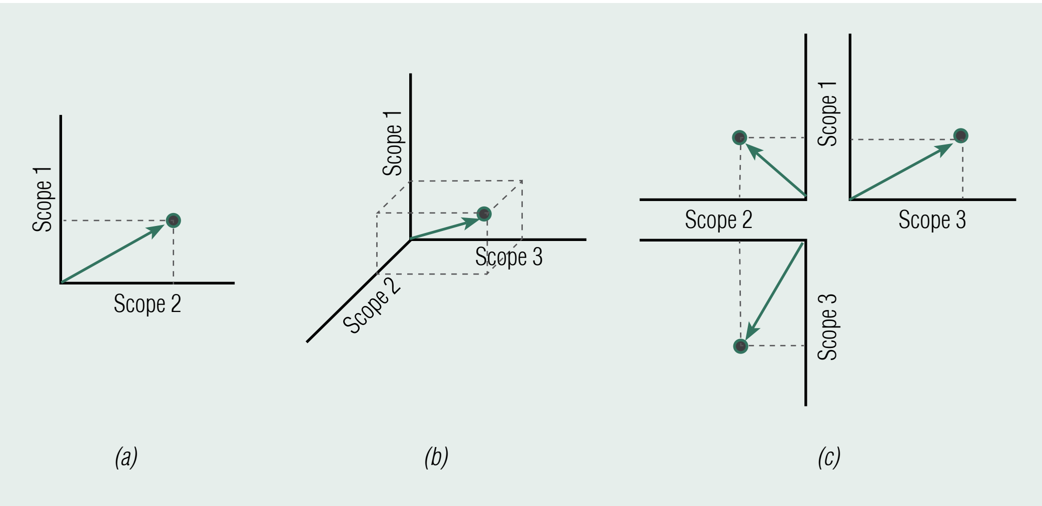
It may be justified to apply the low measurement level in a case when the exact expression in tonne of CO_2 equivalent would not yet be feasible because of the accuracy of the current assessment methodologies. For the low measurement level, categories are usually defined on a scale of one to ten (sometimes one to five). The higher the s_1, s_2 and s_3 value, the higher carbon emission it represents.

In the case of each organisation, the aggregate carbon emission value can be calculated with the combined evaluation of the applied dimensions, using mathematical operation $\otimes$. The higher the aggregate value, the more serious the relatively harmful effect of the organisation's carbon emission. The basis of the $\otimes$ operation is usually multiplication, addition or square, but, of course, other operations are also possible.

Figure 1 shows three novel evaluation techniques that are based on an evaluation method known in literature, and that can be used to perform an integrated evaluation of the results achieved on the basis of the individual Scope categories along the individual dimensions. Part *(a)* of *Figure 1* builds on the risk matrix (Losiewicz-Dniestrzanska, 2015), part *(b)* on failure mode and effects analysis (von Ahsen, Petruschke, Frick, 2022), while part *(c)* on the partial risk map (Bognár, Benedek, 2021).

Figure 1

POSSIBLE INTEGRATED EVALUATION METHODS OF CARBON EMISSION ON THE BASIS OF THE GHG PROTOCOL



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Carbon Matrix model

Part *(a)* of the figure shows the possibility when the Scope 3 dimension is not involved yet. In these cases, assessments according to Scope 1 and Scope 2 are possible. The application of models based on Scope 1 and Scope 2 is justified by the fact that smaller organisations are also able to use them, so these models can help them progress toward carbon neutrality.

In the model based on Scope 1 and Scope 2, let ***S*** denote the integrated carbon dioxide emission (Carbon Exposure) value of an entity *CE(**S**)*, which can be calculated using the following formula.

$$CE(\boldsymbol{S})=s_1 \otimes s_2$$

The methodology relies on an evaluation vector, which consists of two factors (Scope 1 and Scope 2) [see Figure 1 Part *(b)*].

Carbon Emission Analysis model

If the Scope 3 emission values can also be estimated, two options can be identified for the definition of the integrated carbon emission. One of them is related to the failure mode and effects analysis method, and to its index, i.e. the risk priority index. The name of the model based on Scope 1, Scope 2 and Scope 3 emissions is Carbon Emission Analysis, and it indicates the Carbon Priority Index of entity ***S*** *CPI(**S**)*.

$$CPI(\boldsymbol{S})=s_1 \otimes s_2 \otimes s_3$$

Part *(b)* of *Figure 1* presents the *CPI(**S**)* value. This method can be recommended only to organisations that are able to provide the value of Scope 3, as the methodology does not give any result without that. The method uses an evaluation vector too; in this case, it calculates the carbon priority index by using all three Scope values.

The application of the model can be recommended if all three Scope values have almost identical relative values compared to each other. In reality, this situation is less frequent, as the enterprises are characterised by a diversity of various organisational profiles, industrial characteristics and targeted areas of usage. The biggest challenge is to reduce the emission of supply chains, therefore the values of Scope 3 are expected to be higher compared to the other two emission areas.

Carbon Accounting Map (CAM) model

The Carbon Accounting Map (hereinafter: CAM), which is based on the partial risk map, also uses three dimensions, but carries out the evaluation on the basis of three evaluation vectors. This technique is able to show realistic and relatively significant differences in the case of Scope dimensions, and to direct the attention of management and regulators to the area with the poorest performance. The method uses the following formula to estimate the aggregate carbon emission in the case of a given ***S*** organisation, where *CN(**S**)* is the Carbon Number.

$$CN(\boldsymbol{S})= max\{s_1 \otimes s_2,\ s_1 \otimes s_3,\ s_2 \otimes s_3\}$$

Part *(c)* of *Figure 1* presents the logic of *CN(**S**)*. It can be deduced from the formula that the method first carries out 3 two-dimension estimations in the matrices formed by the Scope 1 vs. Scope 2, Scope 1 vs. Scope 3, and Scope 2 vs. Scope 3 dimensions, then compares the results of these with each other, and takes the highest value (i.e. the most significant aggregate carbon emission value according to the three intersections) into consideration. This way it directs attention, in an operational way, to the least developed areas, and points out the key directions of possible development strategies.

Compared to the CEA methodology, the main advantage of the CAM is that the

CAM methodology – that relies on the basis of the partial risk map – does not fail to provide the key differences among individual organisations, as it is the case with the CEA technique based on the risk priority index (see *Table 1*).

Formally, CAM can be specified with the structured organisation of the following matrices.

$$A_{s_1,s_2}=(a_{s_1,s_2})\in\mathbb{N}_+^{i\times j}.$$
$$A_{s_1,s_3}=(a_{s_1,s_3})\in\mathbb{N}_+^{i\times k}.$$
$$A_{s_2,s_3}=(a_{s_2,s_3})\in\mathbb{N}_+^{j\times k}.$$

As CAM will quantify the aggregate Scope values in the case of a given ***S*** organisation, let the carbon pattern of organisation ***S*** in the CAM map be denoted by $p(\mathbf{S})=p(s_1,s_2,s_3):=(s_1\otimes s_2, s_1\otimes s_3, s_2\otimes s_3)$. *Figure 2* shows the position of a possible pattern in the CAM.

For the definition of the carbon number, we present three different aggregation functions – one amount, one product and one square function.

$$CN_A(\mathbf{S})= max\{s_1+s_2, s_1+s_3, s_2+s_3\}$$
$$CN_M(\mathbf{S})= max\{s_1\cdot s_2, s_1\cdot s_3, s_2\cdot s_3\}$$
$$CN_S(\mathbf{S})= max\{s_1^2+s_2^2, s_1^2+s_3^2, s_2^2+s_3^2\}$$

Depending on the measurement sensitivity of carbon emission, any number of various values may be generated, if emissions can be measured on a continuous scale, for instance in tonne of $Co2_2$ equivalent. In the case of typical qualification scales – scales from one to four and one to ten – this methodology has proved to provide robust ranking results, so it can be recommended for the definition of the rankings of organisations, irrespective of the typical scale used for the assessment (Bognár, Hegedűs, 2022).

In this article, we present the method by using a qualification scale that supports the illustration of the model better. The individual functions cannot only give different values in the case of the same ***S*** organisation, but may rank the individual organisations in different ways, even compared to each other. Taking advantage of that, the organisations may be examined with evaluation functions of different focuses, the totality of which also allows for a complex evaluation in respect of carbon emissions.

Benchmarking options of the Carbon Accounting Map

The $CN_A(\mathbf{S})$ forms linear, the $CN_M(\mathbf{S})$ forms

Table 1

COMPARISON OF EXAMINED MODELS

Methodology	Carbon Matrix – CM	Carbon Emission Analysis – CEA	Carbon Accounting Map – CAM
Base methodology	Risk matrix	Failure mode and effects analysis	Partial risk map
Number of evaluation vectors	1	1	3
Evaluation factors (Scope)	1.2	1,2,3	1,2,3
Indicator	Carbon Exposure (CE)	Carbon Priority Index (CPI)	Carbon Number (CN)
Evaluation dimensions	2-dimension	3-dimension	2-dimension (3x)
Proposed size of organisation	Small and medium size	Large size	Large size

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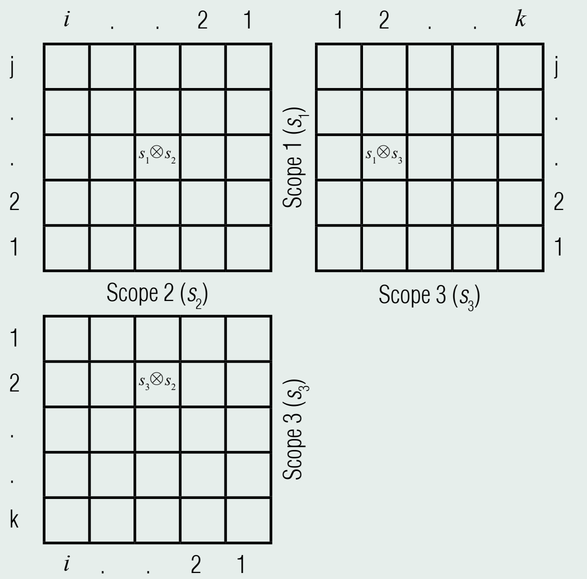
Figure 2

CARBON PATTERN IN THE CAM



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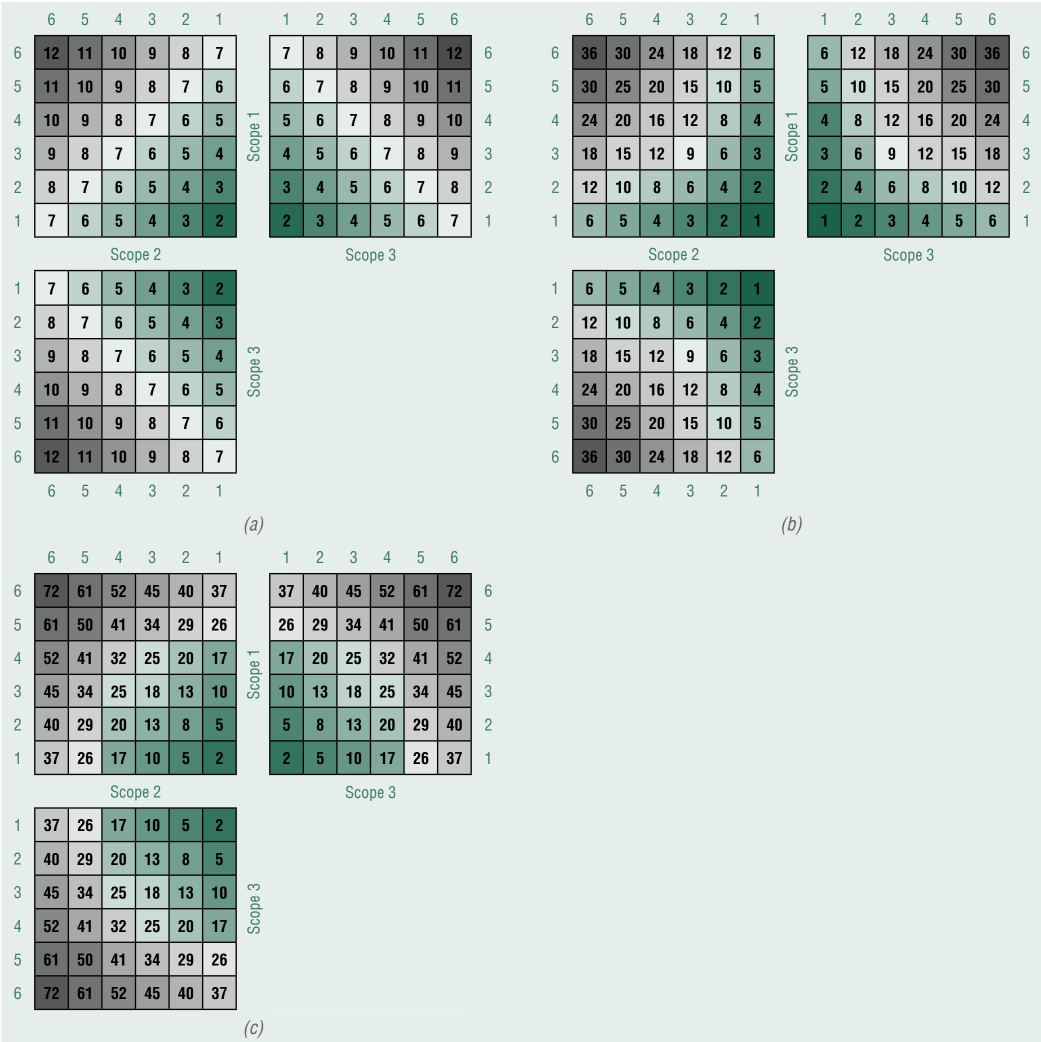
concave, and the $CN_s(\mathbf{S})$ forms convex border lines in the CAM matrices, observed from the origin. Before presenting the application of the individual functions in detail, the typical differences among CAM models can be described with black and green colours, similarly to *Figure 3.* The pattern of the colours carries a visual message, indicating the position of the CAM pattern of a given organisation compared to other organisations. This position forms the basis of ranking among organisations. Green colour means very good carbon emission results, while black means very poor results in the model.

Based on the above it is obvious that the different aggregation functions allow different benchmarkings on the organisations, according to different characteristics. As a result of this testing, it will be possible to show in which matrix a given organisation has stronger or relatively weaker position. Based on that, we can suggest development directions for the creation of further strategies, which may result in a distribution of resources in the reduction of carbon emission that will deliberately improve the image of the organisation and facilitate the achievement of specific emission reduction.

The individual functions should be applied with caution. For instance, at a company that is still at the beginning of its journey to becoming carbon neutral in respect of Scope 3, it is hardly possible that even with quite good Scope 1 and Scope 2 results it could take a good position in the case of a square function. Indeed, it is the square function that punishes most the organisations that have poorer results, even if it is in one dimension only (see part *(c)* of *Figure 3*). Naturally, the s_1=1, s_2=1, s_3=1 pattern is positioned in the first place by each function, thus encouraging organisations to proceed in that direction.

Figure 3

BENCHMARKING IN THE CAM MODEL IN THE CASE OF A QUALIFICATION SCALE OF ONE TO SIX



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The sequence generation of the method is obviously very simple. You should proceed from the black extreme values toward the origin in a way that you always step to the next smaller cell with the highest value. In any matrix, when the given step takes you to a cell containing an organisational profile element, you should mark the cell. This is the way to record that in the particular evaluation intersection, that organisation was the weakest. It can still happen that the organisation performs well in the other two matrices, but all in all, it has a week leg. This week leg denotes the carbon number.

Owing to the nature of the method, it will immediately, and in the case of any evaluation function, punish the organisation that shows low performance according to two evaluation aspects.

Returning to the function in part *(c)* of *Figure 3*, we should emphasize that the function 'punishes' a company even in a case when it achieved poor results only according to one evaluation aspect, but has excellent results in the other two. This is the toughest evaluation function, exactly because of this characteristic. The independent application of the function may be worthwhile only in the case of the more advanced Scope 3 emission reduction; it is more realistic to use it jointly with the other two functions. The function in part *(b)* of *Figure 3* is sensitive to the case when performance is only of medium level for all three factors. The function in part *(a)* of *Figure 3* is a well-balanced evaluation form, with a focus between the formerly presented two functions.

Carbon Accounting Map and robustness testing

Evaluation according to the three functions already provides a good basis for detailed benchmarking and even stress testing for the individual organisations, and among organisations, too. Rankings among the evaluated organisations can differ, so if we compare the rankings, we can examine whether the position of a given organisation on the map is robust or not. The robustness test can be easily carried out with the rank correlation (for example Spearman's rho or Kendall's tau calculation) or with the rank concordance examination (for example Kendall's W) of organisation rankings provided by the various evaluation functions. In this work, two rankings are compared with Spearman's rho (Spearman, 1904) value, while the comparison of several rankings are based on Kendall's W (Kendall, 170) value.

Spearman's rho may have values between –1 and 1. The closer the rho value to one, the more identical the two rankings, and the closer it is to minus one, the more opposite the two rankings are to each other; in the case of zero value, the two rankings are independent of each other.

Kendall's W may have values between 0 and 1. The closer the W value to one, the more identical the rankings, and the closer it is to zero, the more opposite they are to each other.

During the examinations, for both the rho and W values, taking into account the quantitative characteristics of the case illustration, a one per cent significance level is considered acceptable. The objective of the robustness test is to allow the regulator to get a picture about the distances between the industry players or their segments on the road to carbon neutrality.

Now we are going to present an illustrative example relating to the results of the various evaluation functions of the methodology, which we will explain and put into context with the existing theories in the next chapter.

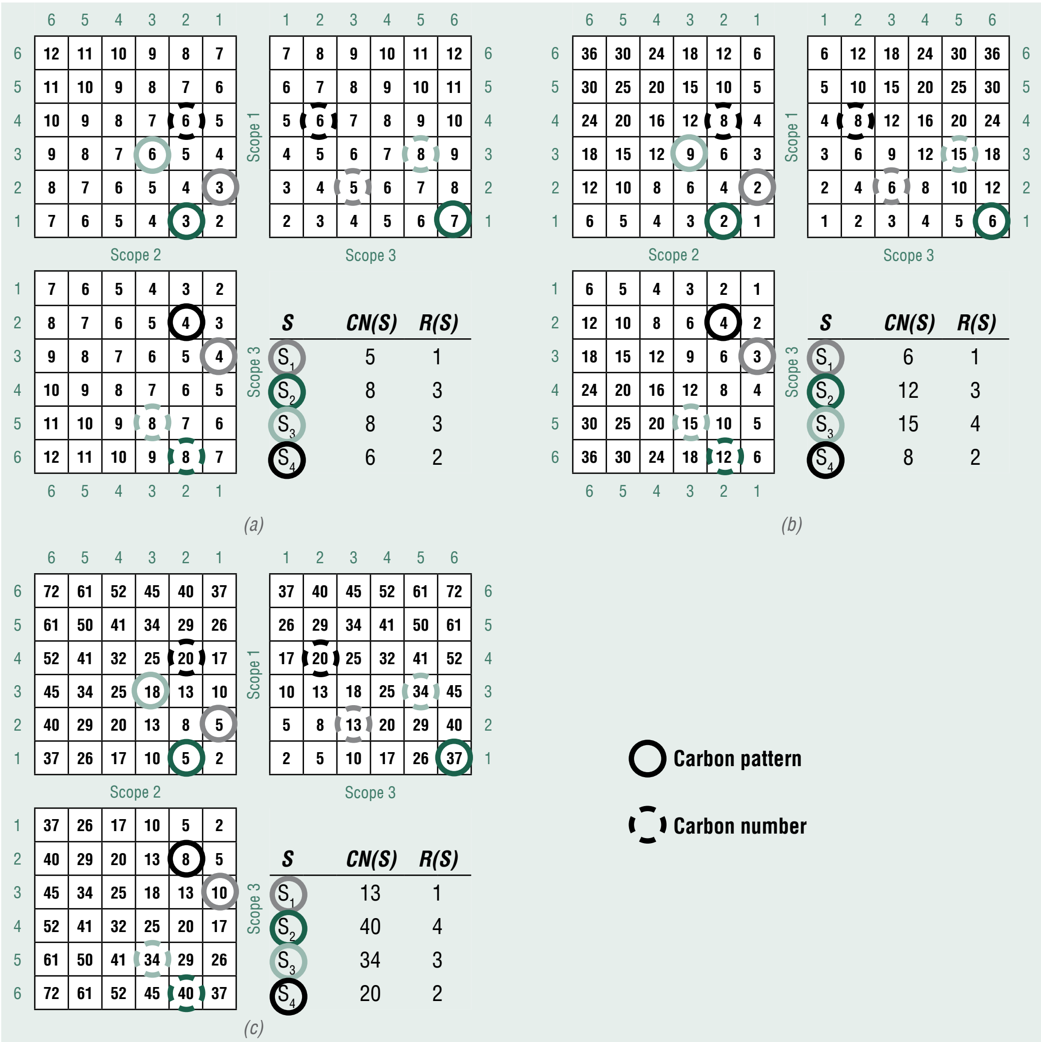
Modelling the difference between the evaluation functions – possible carbon patterns of organisations

The differences between the evaluation functions and the presentation of the results are modelled through our case illustration, whereby we show the differences between the priorities of individual evaluation functions and the robustmess of results.

Part *(a)* of *Figure 4* shows evaluation according to function $CN_A(\mathbf{S})$, part *(b)* according to function $CN_M(\mathbf{S})$, and part *(c)* according to function $CN_S(\mathbf{S})$. The carbon pattern is identical in each case, because the carbon pattern is created from the three Scope values, but it is independent from the evaluation functions. At the same time, in the case of the various evaluation functions, different $CN(\mathbf{S})$ carbon numbers may be created, therefore the individual organisation

Figure 4

CARBON PROFILES AND CARBON NUMBERS OF ORGANISATIONS IN THE CASE OF THE INDIVIDUAL EVALUATION FUNCTIONS



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performances can be evaluated according to different considerations. The lower the carbon number, the higher it will be in the *R(**S**)* ranking, i.e. the better result it will present in respect of carbon neutrality.

Our sample case illustrates that organisations S_1 and S_4 are different from organisations S_2 and S_3 according to all three evaluation functions.

Organisations S_1 and S_4 are consistently better than organisations S_2 and S_3 , which can be seen visually as well, because their carbon patterns are positioned closer to the centre of the map.

The carbon patterns of organisations S_2 and S_3 take positions further from the centre of the map due to the relatively poorer result achieved in respect of Scope 3. For organisations S_2 and S_3, the development paths are clear if they wish to catch up with better-balanced organisations.

The statistical analysis also supports the visual results. There is no significant similarity among the rankings of the three evaluation functions. Although Spearman's rho values are relatively high, they are not significant (*Table 2*).

It is clear that the relative differences among organisations are still significant, as the various evaluation functions produce significant differences in the rankings. This is proved by the concurrent comparison of the rankings created by the three evaluation functions, too; although the 0.931 value of Kendall's W is rather high, with the 0.039 significance value it is not significant, so there are major differences among the individual rankings. It can be seen in the patterns that the organisations (especially S_2 and S_3) have development potentials on the road to carbon neutrality.

APPLICABILITY

The models described in the article may serve as decision-making and controlling tools for economic players in their commitment to carbon neutrality. The model may offer real decision support to economic players as the importance of decision support solutions increases ((CISL, 2022a, CISL, 2022b). The outlined model behaves in line with the objectives of the CDP evaluation methodology, but does not follow the ranking method of that. The CDP ranks separately along individual evaluation considerations, so it is more permissive from the aspect of carbon neutrality (CDP, 2021).

The present model does not allow this in respect of the different Scope emissions, therefore the organisations may be motivated to pursue a well-balanced development. One of the strengths of the presented model is that it does not support the case when a result achieved in one Scope emission is evaluated positively, while emission in another Scope increases.

In promoting carbon neutrality, it is one of the strengths of the model that it could offer realistic alternatives, independently of company size, in the integrated reduction of Scope 1 and Scope 2 emissions, encouraging organisations to introduce or improve the monitoring of Scope 3 emissions. This, on the basis of models with three dimensions and one evaluation vector, could not be realised (von Ahsen, Petruschke, Frick, 2022; Valinejad, Rahmani, 2018).

For the regulatory side, both the provision of feedbacks and the support of decisions are facilitated by the fact that industry-specific patterns can de determined by involving the right number of organisations, so the efforts made by the individual industrial players to achieve carbon neutrality can be compared.

Table 2

DEVELOPMENT OF SPEARMAN'S RHO VALUES

	Spearmans's rho	significance level
$CN_A(\boldsymbol{S})$ vs $CN_M(\boldsymbol{S})$	0.949	0.051
$CN_A(\boldsymbol{S})$ vs $CN_S(\boldsymbol{S})$	0.949	0.051
$CN_M(\boldsymbol{S})$ vs $CN_S(\boldsymbol{S})$	0.800	0.200

Source: own editing

With the joint application of the three evaluation functions and the assessment of the received rankings, the model is suitable for supporting comparisons within the individual industries.

In comparing the rankings produced in various ways, if any applied rank correlation coefficient takes a high value (two rankings are similar to each other), or any rank concordance coefficient takes a high value (several rankings are similar to each other), the patterns of the industrial players are essentially similar. In this case, based on the profiles, we can examine whether similarity occurs in relatively developed or undeveloped status, and this information is very important in decision-making.

If the coefficients have low values, the patterns are located across a wide spectrum, and the forerunners and the ones behind can be clearly identified.

Looking at it from the regulator's perspective, with targeted strategic incentives, the progress of the various industries to carbon neutrality will also become easier to plan.

SUMMARY

The financial sector is increasingly aware of the pressure to adapt to climate change, as the sustainable future business opportunities point towards carbon neutrality. We can find more and more advanced GHG-based qualification systems in the international literature. However, there are still no models capable of interpreting the three Scope emissions according to the GHG Protocol as each other's functions. In the study, we made a proposal for qualification on the basis of the combined Scope emissions, thus encouraging the process of exploring Scope 3 results and assisting the efforts to reduce Scope emissions.

The deliberate application of the model presented in the study will provide an opportunity to reduce (monitor) emissions at industrial, sectoral and corporate levels, and it will allow regulators to compare individual markets and market segments, thus facilitating (supporting) informed decision-making ■

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