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APPLICATION OF INDICATOR-BASED ANALYSIS FOR SECTORSPECIFIC EVALUATION OF THE INDUSTRIAL ENERGY TRANSITION

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Abstract: *A signifiant reduction of greenhousegas emissions is necessary in order to limit the effects of climate change. This requires a transition of the energy system. Especially the industry sector as major emittent of greenhouse gases faces massive changes towards a more sustainable operation. Several approaches are applied to realize a industrial energy transition. On a global level, this leads to very comlex processes that are difficult to capture and evaluate. Heterognous industry sectors are difficult to compare ragarding their progress towards a more sustainable operation. One approach to allow such a transparent evaluation of the industrial energy transition is proposed by the indicator-based methodology. Capturing the status of the industry sector by indicators allows a quantitative evaluation which makes the progress of the transition more transparent. Based on such an evaluation of the status quo of the industrial energy transition, political measures can be derived. Also, it can be assessed which political framework conditions and subsidy schemes have led to which output. Overall, a deeper understanding of the transition process helps to make more profound decions and thereby improve the development of the industry sector towards sustainability.*
Keywords: *Energy transition, industry sector, evaluation methodology, sustainable development*

INTRODUCTION

Due to their high energy demands, industry sectors face the challenge of transforming their energy systems in order to reduce their greenhouse gas emissions (de Bruyn et al. 2020, 13). Like e.g., Gielen et al. (2019) and Korkmaz et al. (2020), many studies and research works therefore analyze how transformation pathways can look like which meet the given emission budgets (Wiese et al. 2022, 2). The complexity of this challenge, however, lies in the fact that, in addition to the target dimension of environmental sustainability, for which a reduction of greenhouse gases is aimed for, the target dimensions of energy equity and energy security play an equally important role (Liu et al. 2022). Especially in the industry sector, energy-related costs are of great importance. These often determine competitiveness on global markets (Hutton et al. 2021, 2). In this regard, the European energy-intensive steel industry fears serious disadvantages due to the additional costs resulting from the European emissions trading system (Naegele and Zaklan 2019). The target dimension of security of supply came even more into the picture through the war in Ukraine and the resulting energy crisis in Europe.

Hence, in order to carry out a comprehensive assessment of the industrial energy transition towards a sustainable energy system, it is necessary to include the three target dimensions energy security (security of supply), energy equity (economic competitiveness) and environmental sustainability (Marti and Puertas 2022). These are defined as the energy policy triangle (Herzig 2021). In contrast to the transformation pathways, which can be used to derive recommendations for action based on assumptions and scenarios about future developments, an assessment of the energy transition's status quo enables a comparison between industrial sectors with regard to all target dimensions combined (Bączkiewicz and Kizielewicz 2021).

Including these three target dimensions requires a high level of transparency as the dimensions can be implemented in multiple ways. Therefore, in the proposed methodology indicators are to be applied to each dimension which allows to quantitatively capture the progress of the industrial energy transition.

RESEARCH METHODOLOGY

Starting point for an indicator-based analyses is the identification of indicators. According to the United Nations, so-called "SMART criteria" apply to a suitable and well-chosen indicator, which means that it is described by the following attributes (Diabré 2002, 68): specific (S), measurable (M), attainable (A), relevant (R) and trackable (T).

This implies that an indicator directly refers to the issue it is aimed for. Also, it should be possible to collect the necessary information for the indicator (attainability) and then measure and track it. By fulfilling these requirements and being relevant at the same time, the indicator is eligible in a theoretical, methodological, practical and political way (Meyer 2004).

This theory behind the identification of indicators is therefore considered in the process of developing the indicators for the analysis. However, as the application of the described methodology mainly has the target to validate the proposed methodology, the evaluation of possibly suited indicators is also affected by that. It makes a difference whether an indicator is used in a purely practical context within an established method, meaning that measuring the indicator as precise as possible is most relevant, or whether it is more relevant to be able to capture the actual issue. In the context of validating that the proposed methodology is eligible to assess the progress of the industrial energy transition, the focus is on identifying indicators that can capture this complex process and refer to the transition. Therefore, it is rather acceptable to not have ideal measurements or data for the indicators instead of applying non-suitable indicators. If the methodology can be considered applicable as a result of this analysis, it proves that it would be worth to further improve the measuring quality, e.g. by using non-freely available data. This is especially relevant as the methodology is supposed to be applied repeatedly in order to provide continuous insights into the industrial energy transition process.

In the context of energy system analyses, Flues et al. (2012) translate the beforementioned "SMART-criteria" into the four criteria target reference, availability, transparency and comprehensibility. Moreover, when using the indicators for modeling purposes the fifth criterion of being applicable to be modelled is added (Koch et al. 2020, 4).

These criteria are to be considered in the identification process of the indicators. After all indicators are collected, the weighting factor for each dimension and indicator needs to be determined. Assigning weightings to the three dimensions determines the overall performance in the energy transition of a national industry sector within the quantitative analysis. For instance, if a country improved significantly in the dimension Environmental Sustainability however on the cost of shortcomings in the other two dimensions, the overall performance within the evaluation depends on how the dimension Environmental sustainability is weighted in comparison to the other two dimensions. Hence, these weightings play crucial role in the evaluation. The main target as part of this structure is the realization of a sustainable energy transition of the industry sector which is assessed through the proposed methodology. All three dimensions are integral for a successful industrial energy transition. However, the importance of each dimension is perceived differently as political decisions entail compromises. Therefore, in different scenarios different weighting factors can be applied in order to reflect the relevance of the three dimensions among each other.

To empirically determine these weighting factors a survey is conducted. The result of this survey is then implemented into the analysis.

Multi Criteria Decision Analysis

Within the proposed methodology, the identified indicators as well as the weightings are processed in a Multi Criteria Decision Analysis (MCDA) in order to derive quantitative results which evaluate the progress of the industrial energy transition.

An important advantage of using MCDA is that it can take into account aspects that are evaluated in different ways, so that, for example, not all objectives need to be assessed monetarily. This allows to take into account e.g., social, technical, or environmental objectives at the same time and analyze them among each other in order to give recommendations for action (Geldermann 2014).

As various MCDA methods exist, which determine the way the indicators and weightings are processed, the starting point is to choose one MCDA method that enables the methodology to generate quantitative results. The use case in this analysis implicates a limited number of opportunities (dimensions and indicators) to choose from. There is no continuous solution space as only three dimensions with a limited number of indicators exist. Therefore, for the purpose of the proposed methodology a Multi-Attribute Decision Making method (MADM) is to be applied.

MADM methods are categorized into two approaches which are classical MADM-methods and outranking approaches. For the purpose of the methodology in this analysis the application of classical MADM-methods is the preferred method. The reason for this is that these classical MADM-methods contain an overall utility value which is again composed of other utility values (Geldermann 2014). This allows to implement a value that assesses the overall industrial energy transition which takes into account the individual value from each of the three dimensions. In this way, the assessment of each industrial energy transition can be expressed by one utility value which aggregates and expresses all complex preferences that are included in the evaluation. According to Geldermann (2014, 12) a convenient implementation as well as an understandable logic behind is considered as main advantage of classical MADM approaches which makes it eligible to be applied as part of the proposed methodology.

FINDINGS

As a basis for the identification process of indicators for the MCDA, the research paper from Koch et al. (2020) is used. In this paper, the authors conduct an indicator-based multi-criteria assessment of the German energy transition for which they identify in total 314 indicators in a broad literature review. These indicators are categorized into the four dimensions Energy Equity (101), Energy Security (59), Environmental Sustainability (65) as well as a social dimension (89). As the social dimension is not part of the analysis, these indicators are not considered further.

Three steps were defined in order to transfer the 255 indicators (excl. the social dimension) from Koch et al. (2020) into the final indicators which reflect the industrial energy transition. For this process the defined criteria are applied. Figure 1 shows the remaining indicators after each step.

Step 1: In the first step it is evaluated whether the 255 indicators can content-wise be referred to the industry sector. As many indicators aim to measure developments or situations that do not have any relevance to the industry sector, these are not used for the MCDA in this analysis. These indicators (e.g., indicators that directly refer to the energy consumption of private customers) do not reflect the industrial energy transition and are therefore eliminated in step 1. With regards to the previously defined criteria, this means that the remaining 130 indicators fulfil the beforementioned criteria 'specific', 'target reference' and 'relevant'.

Step 2: In the second step the remaining indicators are examined regarding the criteria 'attainable' and 'measurable'. This aims to eliminate indicators which do not allow to capture the industrial energy transition separately from the overall country. Indicators that apply to a very broad field of the energy transition therefore are eliminated in this step. However, this is not the case if they can be adapted in a way that they directly refer to the industry sector. If this is possible, the original indicator is adapted. This is a significant aspect of the second step as this practically enables the focus on the energy sector. Besides that, indicators that measure developments that are most significant for the industry sector, even though they do not directly refer to it are not eliminated. Hence, all indicators that remain after step 2 are suitable to measure the industrial energy transition.

Step 3: For the remaining indicators data must be available in order to be used in the analysis. Hence, the criteria 'available' and 'trackable' need to be fulfilled. Therefore, in the third step of the indicator identification process all available data is collected. For the 21 indicators all necessary quantitative data could be found as shown in figure 1. These remaining indicators are the final indicators for the MCDA as they fulfill all previously defined criteria.

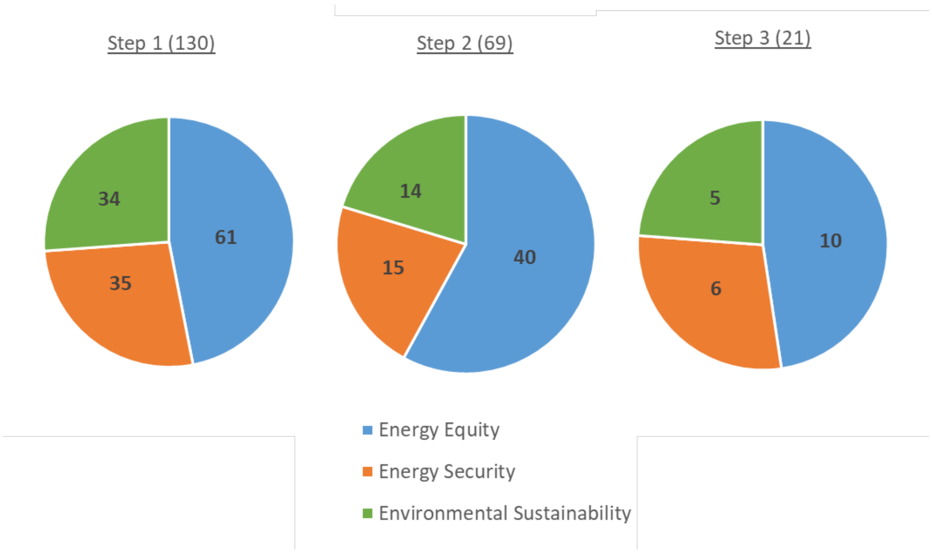

Fig. 1. Number of remaining indicators after steps 1–3

The second essential input for the quantitative analysis is the weighting factors that are to be applied to the three dimensions Energy Equity, Energy Security and Environmental Sustainability. These were collected in a survey in which experts were asked how they perceive the relevance of the three dimensions regarding the industrial energy transition. According to these replies, the dimensions Energy Equity and Energy Security are most relevant for the industry sector. The following weighting factors were gathered through the survey:

Energy Equity = 0,389; Energy Security = 0,379; Environmental Sustainability = 0,232.

RESULTS AND CONCLUSION

As central indicator for the progress of the industry sector's energy transition, the SSIET is introduced. SSIET stands for 'Score for a Sustainable Industrial Energy Transition'. It is calculated by incorporating the weighting factors as well as the identified indicators into the quantitative analysis. The SSIET is the utility value according to classical MADM methods. A high SSIET indicates a good progress regarding the three dimensions of sustainability based on the defined indicators. The SSIET is the final quantitative result of the MCDA.

The application of the proposed methodology creates one SSIET per country per scenario. This SSIET in each scenario allows to compare the progress of the national industry sector that is evaluated by the methodology. Through the generation of quantitative results, the methodology has been proven to be able to be applied practically. In order to finally assess the applicability of the proposed methodology, the generated quantitative results need to be assessed qualitatively.

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ПРИЛАГАНЕ НА АНАЛИЗ, ОСНОВАН НА ПОКАЗАТЕЛИ ЗА ОЦЕНКА НА СПЕЦИФИЧНИТЕ СЕКТОРИ НА ИНДУСТРИАЛНИЯ ЕНЕРГИЕН ПРЕХОД

Резюме: *Необходимо е значително намаляване на емисиите на парникови газове, за да се ограничат последиците от изменението на климата. Това изисква преход в енергийната система. Особено промишленият сектор, който е основен емитент на парникови газове, е изправен пред мащабни промени, насочени към по-устойчиво функциониране. За осъществяването на енергийния преход в промишлеността се прилагат няколко подхода. На глобално ниво това води до много сложни процеси, които трудно могат да бъдат обхванати и оценени. Трудно е да се сравняват разнородни промишлени сектори по отношение на техния напредък към по-устойчиво функциониране. Един от подходите, които позволяват такава прозрачна оценка на индустриалния енергиен преход, е методологията, основана на показатели. Отразяването на състоянието на промишления сектор чрез показатели позволява количествена оценка, която прави напредъка на прехода по-прозрачен. Въз основа на такава оценка на статуквото на индустриалния енергиен преход могат да бъдат изведени политически мерки. Освен това може да се оцени кои политически рамкови условия и схеми за субсидиране са довели до определен резултат. Като цяло по-задълбоченото разбиране на процеса на преход помага да се вземат по-задълбочени решения и по този начин да се подобри развитието на индустриалния сектор към устойчивост.*
Ключови думи: *енергиен преход, промишлен сектор, методология за оценка, устойчиво развитие*

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