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BUMP IN THE ROAD TO GLOBAL ENERGY TRANSITION: THE BOTTLENECKS OF THE CARBON MARKETS

WYBOISTA DROGA DO GLOBALNEJ TRANSFORMACJI ENERGETYCZNEJ – WYZWANIA ZWIĄZANE Z RYNKAMI UPRAWNIEŃ DO EMISJI DWUTLENKU WĘGLA

*Majid Asadnabizadeh**

ABSTRACT

This study develops a theoretical framework to assess the key drivers of carbon markets, that is, carbon markets approach in the global energy transition. The developed Global Low Carbon Energy Transition (GLCET) framework is then applied to the six metareviews of the literature, with the exception of the literature reviews of Groups 1 and 2 (Section 2). Based on this metareview, the study also considers the key drivers of the GLCET, namely, DE carbonisation of the power sector, fossil fuel phase-out, geopolitical security. Based on the MOSCOW technique, the author concludes that DE carbonisation of electricity is very important and critical (MO), phasing out fossil resources is challenging but requires some solutions (S) and in third place (W) the impact of geopolitical security on GLCET is not very important. The author's main recommendation is to develop a more qualitative framework to understand the main challenges of the global energy transition.

ABSTRAKT

W niniejszym artykule opracowano teoretyczne ramy oceny kluczowych czynników napędzających rynki uprawnień do emisji dwutlenku węgla, a więc dotyczące podejścia opartego na rynkach emisji dwutlenku węgla w globalnej transformacji energetyki. Opracowane ramy globalnej transformacji niskoemisyjnej energii (GLCET) są następnie stosowane do sześciu metaprzeglądów literatury, z wyjątkiem przeglądów literatury grup 1 i 2 (sekcja 2). Na podstawie tego metaprzeglądu w badaniu uwzględniono również kluczowe czynniki GLCET, a mianowicie karbonizację sektora energetycznego, stopniowe wycofywanie paliw kopalnych, bezpieczeństwo geopolityczne. Opierając się na technice MOSCOW, autor konkluduje, że karbonizacja energii elektrycznej jest bardzo ważna i krytyczna (MO), stopniowe wycofywanie zasobów kopalnych jest trudne, ale wymaga pewnych rozwiązań (S), a pozycjonowany na trzecim miejscu (W) wpływ bezpieczeństwa geopolitycznego na GLCET nie odznacza się ważnością. Głównym zaleceniem autora jest opracowanie ram badania jakościowego pozwa-

* Maria Curie-Skłodowska University in Lublin, Faculty of Political Science and Journalism.

lającego zrozumieć główne wyzwania globalnej transformacji energetycznej.

Keywords: global energy transition; carbon market; low carbon energy

Słowa kluczowe: globalna transformacja energetyczna; rynek emisji dwutlenku węgla; energia niskoemisyjna

INTRODUCTION

Energy is a very important issue in the world. Although there are different types of global environmental problems (e.g., climate change), energy security is the central problem that requires global change. The centerpiece of the solution to the climate problem is the Global Energy Transition (GET), it is driven by carbon markets. As carbon markets are seen as an important step towards GET, countries have set targets at the global level (e.g., in the Kyoto Protocol – KP, and the Paris Agreement – PA) to promote global cooperation for zero emissions. Several studies have looked at carbon markets to understand the drivers of global climate change. Most of these studies have used quantitative methodologies and models (e.g., cap-and-trade systems, integration models based on the SVR) or decision-making frameworks and have concluded that they are the main reason for bottlenecks in carbon markets. Given that the ultimate purpose of scientific research is to inform the authors, the researchers, on finding and performing appropriate methods, these studies were not fully effective. Simply put, it would not be a meaningful analysis to suggest that an integrated model based on SVR is the main driver for carbon markets to solve the GET. In this respect, one of the main challenges for the GET process based on this literature is how to measure the credit framework for carbon markets. There are also some studies in the GET literature that have included indicators of energy liberalisation, finance, and equity in their studies, in addition to the costs and benefits of carbon markets. Moreover, many of these studies have developed a set of indicators without providing a theoretical framework for such a case.

To contribute to this debate, the author considers the main drivers of the carbon market for the analysis of GET. It has some advantages: it can theoretically support global climate action by states for the GET. The main drivers of the carbon market are DE carbonisation of electricity, fossil fuel phase-out, and geopolitical security (Figure 1). Moreover, these carbon market indicators towards GET are the crucial options for global climate change governance. One

of the most important features of carbon market indicators is that they can improve some areas of climate change, namely reducing global carbon dioxide (CO^2) emissions, energy security and sustainable development. Among them, global CO^2 emissions are attracting much attention because of the urgency of the issue for the world community. In Environmental Science and Pollution Research, for example, the impact of the energy transition on carbon emissions is considered (Alola & Joshua, 2020).

This study aims to explore the main challenges of the carbon market as well as its main drivers in a theoretically sound framework and to propose new methodological pathways and insights that could be useful for understanding the global path of the energy transition. The main question of this study is thus: What is the main goal of the GET and how is it feasible? In order to find an effective way to answer the question, in the case of this study, the author first considered the role of carbon markets for such a challenging area. The reason is that carbon markets are an important tool for reducing global carbon emissions and a pathway to GET. Secondly, carbon markets contribute to clean energy and promote GET. The author believes that this study contributes to the existing literature on energy transition in several ways. First, it develops a theoretical framework to assess the function of carbon market drivers alongside the approaches of GET. Second, this study examines the role of the main carbon market approaches for the energy transition pathway. Third, understanding the key drivers of the carbon market as one of the most important streams of global climate policy is important to consider in the energy transition. Fourth, unlike many other studies in literature, this study addresses the issue and variables of the theoretical framework.

The remaining sections of this paper consist of a review of the literature for GET in section 2. Section 3 develops a theoretical framework. Section 4 presents the methodology. The results of the analysis and discussion are included in sections 5 and 6. Section 7 concludes the study with recommendations.

2. REVIEW OF LITERATURE

In this section, the author focuses on two types of studies: papers that examine the path of GET in global low-carbon and renewable energy and the transition to carbon neutrality (i.e., Group 1), and papers that consider Global Energy Security (GES), resilience of socio-ecological systems, economic recovery, governance institutions, nationally determined contributions, the trade-off in renewable energy

deployment and the path of sustainable development (Group 2) as the challenges of carbon markets (Table 1). Table 1 shows the literature, authors, and derived themes.

Table 1. Studies and Characteristics

Group1		
Studies	**Authors**	**Theme**
Why the Global Energy Transition Does Not Mean the End of the Petrostate	Andreas Goldthau, Kirsten Westphal	global low carbon
States, Markets, and Institutions: Integrating International Political Economy and Global Energy Politics	Thijs Van de Graaf, Benjamin K. Sovacool, Arunabha Ghosh, Florian Kern, Michael T. Klare	global low carbon
Energy Transitions or Additions?: Why a Transition from Fossil Fuels Requires More Than the Growth of Renewable Energy	Richard York, Shannon Elizabeth Bell	global renewable energy
Governing Renewables: Policy Feedback in a Global Energy Transition	Jonas Meckling	global renewable energy
Global Energy Transition and Metal Demand	Elmer Rietveld, Hettie Boonman, Toon van Harmelen, Mara Hauck, Ton Bastein	global renewable energy
Why the Carbon-Neutral Energy Transition Will Imply the Use of Lots of Carbon	Jan Mertens, Ronnie Belmans, Michael Webber	transition to carbon neutrality
The Geopolitics of the Global Energy Transition	Manfred Hafner, Simone Tagliapietra	transition to carbon neutrality
Group 2		
The Energy Transition: Key Challenges for Incumbent and New Players in the Global Energy System	James Henderson, Anupama Sen	global energy security
Sustainability Guardrails for Energy Scenarios of the Global Energy Transition	Michael Child, Otto Koskinen, Lassi Linnanen, Christian Breyer	resilience in socio--ecological systems
Global Low-Carbon Energy Transition in the Post-COVID-19 Era	Jinfang Tian, Longguang Yu, Rui Xue, Shan Zhuang, Yuli Shan	economic recovery
Governing Global Energy: Systems, Transitions, Complexity	Aleh Cherp, Jessica Jewell, Andreas Goldthau	governance institutions
Governing the Global Energy Transformation	Maria Pastukhova, Kirsten Westphal	nationally determined contributions
The Rise of Renewables and Energy Transition: What Adaptation Strategy Exists for Oil Companies and Oil-Exporting Countries?	Bassam Fattouh, Rahmatallah Poudineh, Rob West	trade-off in renewable deployment
The Global Energy Transition: Where Do We Go from Here?	James P. Dorian, Malcolm T. Shealy, Dale R. Simbeck	sustainable development pathway

Source: Author's own elaboration.

In the study by Goldthau and Westphal (2019), the global low-carbon state is used to understand GET. The study shows that the world is moving to a low-carbon state and that this is expected to put an end to petrostates and force incumbent oil producers to diversify their economies away from fossil fuels. The question of whether petrostates plan for the long term or engage in a "panic and pump" strategy depends on the extraction costs and social costs of oil production. For Middle Eastern petrostates in particular, it may therefore be very rational to continue to specialise in the high-carbon segment. Another study by Thijs Van de Graaf et al. (2016) on global low-carbon economies assesses the impact of energy issues on international headlines using the research agenda. Since the 1970s, energy policy, technology and security have been discussed as intensively as they are today. Be it the race for energy resources in the Arctic, the rollercoaster ride of oil prices, the transition to low-carbon energy sources, or concerns about nuclear safety. Today's pressing energy challenges have opened an incredibly broad research agenda.

Unfortunately, political scientists and other social scientists have lagged behind their colleagues in the natural sciences, engineering, and economics in addressing these questions. During the turbulent era of oil shocks, some researchers did pay attention to energy issues and oil in particular, but this attention was short-lived. Only recently, after two decades of relative neglect, have political scientists begun to rediscover energy and its transformation as an important field of study (De et al., 2016). In addition, the review and analysis of the literature has shown that GET has a stronger link to Global Renewable Energy (GRE) from *Energy Transitions or Additions? Why a Transition from Fossil Fuels Requires More Than the Growth of Renewable Energy*; *Governing Renewables: Policy Feedback in a Global Energy Transition*; and *Global Energy Transition and Metal Demand* analysis. After careful review of this study, it can be concluded that the study has shortcomings in terms of a theoretical rationale, as no theoretical background is given for the structure of the paper and the topic. The review and analysis of the studies (e.g., *Energy Transitions or Additions? Why a Transition from Fossil Fuels Requires More Than the Growth of Renewable Energy*; *Governing Renewables: Policy Feedback in a Global Energy Transition*; and *Global Energy Transition and Metal Demand*) showed a direct link to the global renewable energy theme (GRE) through the understanding function of the Global Carbon Market (GCM) for GET.

York & Bell (2019) examined the function of GRE in relation to carbon markets and GET by asking whether an energy transition is currently underway, with

renewable energy sources replacing fossil fuels They found that mundane energy resources play an important role in determining carbon markets in the GET. They argued that the older energy source continued to grow despite the rapid growth of the new source. However, this study can be improved by considering the feedback with policy. Meckling (2018) examined global renewable energy governance as a determinant of policy feedback for GET. The results achieved show that complex global problems such as climate change are not solved through intensive international cooperation, but through complex systems of governance at different levels. This includes the global governance of renewable energy, the world's fastest growing source of electrical energy. Their study assumes that policy feedback to carbon markets helps explain the evolution of renewable energy governance. The extent to which policy expands or restricts market opportunities for companies significantly influences the coalitions that form to support new institutions and GET. Rietveld et al. (2018) analysed the broad concern for commodities for energy transition issues. The study found that the situation in 2010 was of course different than at the time of writing. A widely supported COP21 PA had not yet been signed and urgency was felt at a very different level. In 2018, concern about the future of our climate is felt in societies around the world. In the heat of these debates, understandably, much less attention is paid to issues of physical implementation of energy technologies based on carbon markets for a better GET. One such issue is the timely availability of metals that are essential for renewable energy technologies.

A recent study by Mertens et al. (2020) observes the role of the transition to carbon neutrality in GET. It states that electrification and gasification go hand in hand and are crucial on our way to a carbon neutral energy transition. This study proposes to explore the role of hydrogen in this pathway, which is insufficient mainly due to the challenges associated with its transport and storage. Therefore, based on carbon markets, other "molecules" are needed on the path to a carbon neutral energy transition. This study argues that carbon will be an important and necessary chemical element in many of these molecules to achieve our goal of carbon neutrality. This carbon must be taken from the biosphere or recycled from biomass/biogas rather than from fossil resources. Furthermore, a recent study by Hafner and Tagliapietra (2020) (GET) analyses the historical energy transition driven by increasingly stringent decarbonisation policies and rapid advances in low-carbon technologies. The findings show that the large-scale shift to low-carbon energy based on carbon markets is disrupting the Global Energy System (GES), impacting entire economies, and changing political dynamics within

and between countries. Written by leading energy scholars, this study examines the economic and geopolitical implications of GET, both from a regional and thematic perspective. Due to its scope, the book is suitable for generalising these issues to researchers in the fields of energy, climate change and international relations, as well as to professionals working in the energy sector. The second strand of literature is based on the studies that have used GES, resilience in socio-ecological systems, economic recovery, governance institutions, nationally determined contributions, the trade-off in renewable energy deployment, and the sustainable development pathway as variables for carbon markets towards GET.

The most recent qualitative and quantitative studies in this area of research have been conducted recently by Tian et al. (2022); Henderson and Sen (2021); Pastukhova and Westphal (2020); Dorian et al. (2020). However, the studies by Fattouh et al. (2019), Child et al. (2018) and Cherp et al. (2011) are somewhat older and fall within the scope of this section. Tian et al. (2022) examined the links between carbon markets and GET for economic recovery. In terms of the function of carbon markets, they found that more and more voices are calling for a (green) stimulus programme that will revitalise the economy without endangering the environment. They also provided a detailed discussion on the impact of the current global stimulus package on the energy transition (Tian et al., 2022). Henderson and Sen (2021) looked at GES and carbon market implications for the GET after the key linkages. The authors pointed to the Intergovernmental Panel on Climate Change (IPCC) and its impact on the growing commitment of governments and businesses around the world to net-zero emissions targets, which is an encouraging sign that the reality of the global climate crisis is now understood, but also a stark reminder that action, not just words, is needed if the rise in global temperatures is to be limited to 1.5C this century. While the overall goal of the energy transition is clear, the pathways to efficient decarbonisation are not obvious and could vary depending on the context. They have tried to summarise the main challenges and consequences of GET, both for carbon markets and energy security.

However, Pastukhova and Westphal (2020) analysed nationally determined contributions (NDCs) during the process of the PA and its rulebook. They argue that multi-level governance structures are necessary to enable, facilitate and accelerate NDCs for energy transition on the ground. They argue that it is necessary, first, to go beyond the normative and goal-oriented idea behind the term "transition" and, second, to include the systemic aspects of energy transformation. They also argue that the existing architecture is from the past and is

neither suitable to regulate the energy transition nor reflects the processes taking place in today's world. In a further step, the authors emphasise that the energy transition has and will have enormous techno-economic, socio-technical, and political impacts that have both internal and external dimensions. But they did not specifically examine the function of global carbon market for the GET. In studies published in *Energy Research & Social Science*, other authors looked at the energy transition on several levels and pointed out that the energy transition requires targeted, coordinated, multi-level efforts to develop more sustainable ways of producing, distributing, and using energy (Wilson & Tyfield, 2018). Previous research on the optimal dispatch of power systems for energy transition has focused on analysing energy transition at multiple levels. This research from Energy Reports argues that carbon emissions from multi-energy systems need to be addressed based on a multi-objective model for a minimum carbon emissions target (Guo, Ye, & Zhao, 2022). Dorian et al. (2020) examined the role of carbon markets on the path to sustainable development in the same year. The author argues that the world is currently in a turbulent transition phase in the energy sector. Although renewable energy and other new technologies promise far lower carbon emissions in power generation and transport, there are major uncertainties and challenges about how far and how fast the world can move forward. The 1.5C to 1.65C sustainable development pathway proposed in the World Energy Outlook can be a practical carbon market mechanism for better GET.

In addition, some studies have examined trade-offs in the use of renewable energy, the resilience of socio-ecological systems and governance institutions (Fattouh et al., 2019; Child et al., 2018; Cherp et al., 2011). Fattouh et al. (2019) argue that due to high uncertainty, oil companies need to develop strategies that can succeed under a variety of possible future conditions in the carbon market. For oil-exporting countries, the use of renewable energy is not a disadvantage, as such investments can free up oil and gas for export markets, improving the economic viability of domestic renewable energy projects. In the long run, however, the biggest challenge for many oil countries is to diversify their economies and incomes, as this is the ultimate hedge against GET. Child et al. (2018) examined social and economic aspects, such as limiting air pollution, providing universal access to modern energy services, and improving energy efficiency through electrification of energy services, which are emerging as new paradigms in carbon markets for modelling energy scenarios. All the GET scenarios studied have failed to adequately describe the critical role of flexibility in future energy

systems based on a high share of renewables, such as storage, grids, demand response, supply-side management, and carbon markets. The concept of resilience in socio-ecological systems was also not adequately addressed in the GET. Cherp et al. (2011) reviewed the reductionist approach of analysing governance institutions and mechanisms in isolation from each other. Instead, the authors view governance systems as complex and historically rooted "arenas" that co-evolve with the GET problems they address. They argue that governance in each of these areas can be improved through stronger linkages with carbon markets.

3. THEORETICAL FRAMEWORK

After analysing the first and second strands of literature types, one can understand that although the first group of existing studies has strong evidence of the relationship between carbon markets and the GET, the second group of studies hardly explores this relationship to answer the research question. This section therefore explains the theoretical basis of the framework, which relates the main GET variables based on the Group 1 literature (Table 2).

Table 2. Method for Creating the Theoretical Framework

Literature Group	Number	Theme	Key variables	Theoretical framework
1	*2*	*Global low carbon*	*Global low carbon*	*Global low-carbon energy transition* (GLCET)
1	*3*	*Global renewable energy*	*Energy*	
1	*2*	*Transition to carbon neutrality*	*Transition*	

Source: Author's own elaboration.

The theoretical basis of the study on the role of the carbon market in the GET is generally attributed to the table prepared by the author (Table 1), which is based on the categorisation of pieces of literature. The author started from the principle that the structure of the grouping and the relations between Groups 1 and 2 determine the content of the main theories and approaches. This becomes clear when comparing two simple groups (two authors, three authors). In Group 1, authors Andreas Goldthau and Kirsten Westphal can explain and evaluate game theory, and Richard York and Shannon Elizabeth Bell teach supply-side

approaches. Goldthau and Westphal note that there is a game-theoretic function linking the role and output of carbon markets to GET via extraction costs and the social costs of oil extraction. Arguably, the global community believes that GET must control oil producers and change the long or short game between these types of states. In 2019, energy and social scientists Richard York and Shannon Elizabeth Bell used a supply-side framework to describe the link and interaction between carbon markets and GET. The supply-side framework has been used to study the price of fossil fuel extraction and importation through a system of carbon fees and dividends. One such approach, alongside carbon markets, is to reduce the growth of total electricity production for the energy transition, also known as capping the grid.

The content of the theories in Group 2 will differ from that of the theories in Group 1. This difference is due to the different structure of the three frameworks. The theoretical framework by Child et al. (2018) addressed well the qualitative and semi-quantitative approaches on the function of carbon markets. Michael Child's aim was to identify production sites and ecosystem services. This framework adds value to economic valuation and multi-criteria decision analysis to define GET. Cherp et al. (2011) discuss the reductionist framework in which governance institutions and mechanisms are analysed in isolation from each other to understand GET. They argue that GET needs a balance between determination and efficiency. The current complexity of GET is therefore an opportunity to create a polycentric governance system. In addition to these two frameworks with the structure of GET, the win-win framework was also considered. Dorian et al. (2020) argue that a win-win framework reduces climate pressure by eliminating poverty associated with GET.

It can be stated that the existing literature on GET has the signal of game theory, supply-side framework, semi-quantitative framework, reductionist framework and win-win framework, but the pieces of literature do not take into account the structure of the GLCET in analysing the role of carbon markets for the problem GET. This study is thus an attempt to contribute to the existing types of literature and issues by applying GLCET alongside carbon markets and GET. Understanding the global low-carbon energy transition, as one of the mainstream carbon markets, is relevant to GET.

4. METHOD

To compile the list of studies, the author used the systemic review process that ensures the widest possible search. I started with an investigation in Google Scholar using the following search terms:

I. Carbon markets
II. GET

I searched from 2011 to present and then reviewed all the articles on the first 5 pages found in each keyword search. I included only those articles that met several criteria for categorisation (1, 2). First, the article must contain a qualitative or quantitative assessment of carbon markets. Moreover, articles should apply some kind of related conclusion aimed at triggering the energy transition signal. Second, the articles should include low-carbon, renewable energy that evaluates the performance of GET. Third, articles are included if they have been peer-reviewed. Grey literature is also included. One of the articles that includes both groups is grey literature published by the International Association for Energy Economics (IAEE). The articles were coded and categorised by the author. The initial review and grouping resulted in a total of 14 articles. 6 articles assessed the performance and importance of carbon markets for GET based on other studies. The author then proceeded to snowball and read all 20 articles (Groups 1, 2 and six metareviews) for additional arguments. So, I reviewed a total of 20 articles to see if they would be included in this assessment. Of the 20 articles reviewed, a total of 14 met the above criteria and were included in the first round of analysis. Six articles were meta-analyses that were read with a view to following the theoretical framework but were not assessed in Section 2 as they conducted an independent ex-post analysis. These are specific criteria that have yielded a relatively modest number of studies. However, this narrow approach is significant because ex-post assessment is the only analysis that can help understand the global indicators of the transition to low-carbon energy for carbon markets GET.

5. TRACKING FRAMEWORK

5.1. Global Low Carbon Energy Transition Indicators

No single indicator can fully capture the complexity of the GLCET. As carbon markets are responsible for global emissions and the energy sector, they contribute most to the GLCET. If we ask whether carbon markets are necessary for GLCET, key market drivers can both guide effective global climate action and drive GLCET as a result. The GLCET is the result of the DE carbonisation of the power sector, fossil fuel phase-out, and geopolitical security. These indicators decipher the key drivers of carbon markets that ultimately determine their significant contribution to the GLCET (Figure 1).

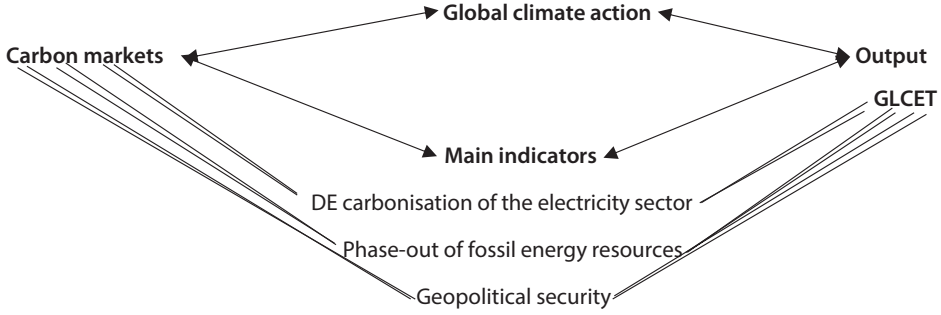

Figure 1. Key Drivers of Carbon Markets Determining Their Significant Contribution to the GLCET

Source: Author's own elaboration.

5.1.1. DE carbonisation of the electricity sector

Electricity is the most decarbonised energy sector because of its ability to integrate renewable energy sources and the one that, more than any other, enables a real increase in energy efficiency (*Regulatory Principles and Actions Relating to Energy Decarbonisation…*, n.d.).

The author assesses how carbon market drivers influence the global transition to low-carbon energy using different approaches, see typologically ordered Table 3. The author uses the typologically ordered table to analyse and compare

different approaches or frameworks (e.g., nexus approach, hydrogen approach) of carbon market drivers.

Typologically Ordered Table 3. Overview of the Main Carbon Market Drivers in GLCET

GLCET indicator	Drivers of the carbon market	Approach considered
1	DE carbonisation of the electricity	Nexus approach
2	DE carbonisation of the electricity	Hydrogen approach

Source: Author's own elaboration.

Nexus approach

The issue of DE carbonisation of the electricity sector is addressed with a newly proposed approach by Watari et al. (2019). This approach (Nexus) argues the TMR (Total Material Requirements) model by including minerals and energy resources for the GET. It is therefore increasingly important to take a holistic and dynamic view of the impacts of large-scale energy transition on resource flows, including hidden flows such as mine waste, as well as direct flows. It is a systematic model that can quantify resource flows of both minerals and energy resources in the context of the energy transition, using stock-flow dynamics and the concept of TMR.

The proposed model was applied to the International Energy Agency's scenarios up to 2050, taking into account 15 power generation and 5 transport technologies.

In the transport sector, on the other hand, the spread of electric vehicles could lead to a sharp increase in TMR flows associated with mineral production, which could offset a decrease in energy resource flows (Watari et al., 2019). The authors of this study emphasise that a global low-carbon energy transition (GLCET) cannot be achieved without DE carbonising electricity and designing resource cycles with a nexus approach.

Hydrogen approach

Quarton et al. (2020) research supports the global low-carbon energy transition (GLCET), even as they identify a hydrogen approach to the DE carbonisation of

the power sector. As the transition of GES from fossil to low carbon is difficult, they face many challenges, especially in terms of energy security and flexibility. Quarton et al. (2020) argue that hydrogen can help address these challenges, as it can be used as a fuel for transport, for heating, for energy storage, for conversion to electricity, and in industry. Despite these possibilities, hydrogen has played only a limited role in influential global energy scenarios. While more recent studies are beginning to include hydrogen, the role it plays in the DE scenarios for carbon-based electricity is extremely inconsistent.

5.1.2. Phase-out of fossil energy resources

This indicator tracks the reduction of fossil fuel use and production to zero in GET and provides information on how the GLCET is getting off the ground by phasing out fossil fuels (see: typologically ordered Table 4). The author uses the typologically ordered table to analyse and compare different approaches or frameworks (e.g., pandemic impact of COVID-19, coal-dependent approach) of carbon market drivers.

Typologically Ordered Table 4. Overview of the Main Carbon Market Drivers in GLCET

GLCET indicator	Drivers of the carbon market	Approach considered
1	Phase-out of fossil	Impacts of the COVID-19 pandemic approach
2	Phase-out of fossil	Coal-dependent approach

Source: Author's own elaboration.

Impacts of the COVID-19 pandemic approach

The initial scientific studies and debates are largely conceptual and focus on the significance of the COVID-19 pandemic approach (Quitzow et al., 2021). This analysis has highlighted the main implications of the COVID-19 pandemic for the global energy sector and assessed the impact of related policies on the prospects for a transition to a global low-carbon energy transition. The authors differentiate between different types of countries and different dimensions of energy supply. Secondly, they look at the impact of the crisis on the main exporters of oil and gas resources, focusing on a selection of G20 countries.

This threatens the achievement of international climate targets and points to the need for concerted international action to phase-out fossil energy resources. COVID-19 crisis deepens the divide between leaders and laggards of the GET. While COVID-19 pandemic has been a major issue in the global community, the Russia-Ukraine war poses a growing challenge to the GET. Russia's invasion of Ukraine was another impetus for some countries to accelerate GLCET. For example, Germany, as one of the countries with a high dependence on fossil fuel imports, has accelerated its switch to renewable energy to counter the possible cut in energy imports from Russia (Zakeri et al., 2022). One of the updated studies by Julia Korosteleva (2022) proves that the world economy, which has not yet fully recovered from the global COVID-19 pandemic and has no successful energy transition to show for it, is facing the Russian-Ukrainian war. Energy dependence, especially on gas imports from Russia, needs to be reduced and this remains a compelling challenge for the European economy. The Russia-Ukraine war will accelerate the EU's transition to a low-carbon energy supply, which is at the heart of the EU's dual objective (Korosteleva, 2022).

Coal-dependent approach

Coal has played a central role in the development of many advanced and developing communities around the world. According to a report by the International Energy Agency (IEA) (2022), global coal consumption has increased and will reach an all-time high in 2022 and remain at a similar level in the coming years. There are several reasons for this. First, heat waves and droughts in some regions have driven up electricity demand and reduced hydropower, while nuclear power generation has also been very weak, especially in Europe, where France has had to shut down nuclear reactors for maintenance. The second reason is high gas prices following Russia's invasion of Ukraine and the resulting supply disruptions, which have led some countries to turn to relatively cheaper coal this year (Chestney, 2022). Moreover, based on BP Statistical overview of world energy (2022) comparison of emissions from coal with oil and natural gas, burning coal emits about 210 pounds of CO^2 per million British Thermal Units (BTU) of energy. In comparison, oil emits about 160 pounds of CO^2 per million BTU and natural gas emits 117 pounds of CO^2 per million BTU. The combustion of coal therefore produces more carbon dioxide per unit of energy than oil or natural gas. Burning coal in power plants also produces a lot of other harmful emissions. So, countries need to seriously consider whether coal is an important factor in the GET (Rapier, 2022).

Thus, my review and analysis of the drivers of the carbon market based on the GLCET indicator shows that the coal-dependent approach to fossil fuel divestment is important. The study *Complexities and Contradictions in the Global Energy Transition: A Re-evaluation of Country-Level Factors and Dependencies* has taken a different approach to the fossil fuel phase-out. This study proposes a carbon-based approach. The analysis by Svobodova et al. (2020) supports the results from Section 5 (GLCET) Indicators, although they show a coal-dependent approach for the fossil fuel phase-out indicator. Overall, the results of the study suggest that nation states have the potential to adapt to global coal phase-out targets. First, 118 countries were characterised according to their ability to phase-out coal and then divided into 4 country groups. Second, the groups were categorised according to their level of carbon contribution. Green growth is widely touted as a lever for sustainable economic growth. They argue that political platforms that postpone climate action become deeply unpopular in most democratic societies. The fundamental question, however, remains how coal-dependent nations will stabilise their economies without coal and GLCET. Another study in *Renewable and Sustainable Energy Reviews* argues that to stabilise the global economy without coal, we need lower emission reductions in coal-dependent countries, but we also need the long investment inertia in the energy sector for a transition, which is associated with higher levels of institutional and behavioural coal lock-in[1] and can reduce blockage by coal-dependent countries (Roemer & Haggerty, 2021). In a recent study, a further argument is made that meeting these challenges is to facilitate and support coordinated regional planning that integrates energy system and economic development approaches. To stabilise the non-coal economy and address the problem of stabilising and replacing revenue losses, states must remove barriers to revenue saving and expand the range of financial instruments that allow communities to break fiscal dependence on coal revenues (Arens, Åhman, & Vogl, 2021).

5.1.3. Geopolitical security

The geopolitical security indicator gives a taste of the types of approaches being considered. Similarly, tracking the geopolitical security in GLCET indicates the trajectory of the regional energy governance approach and the multilateral

[1] A state of an energy system in which there are high capacities of coal-fired power plants in the energy system.

approach (see: typologically ordered Table 5). The author uses the typologically ordered table to analyse and compare different approaches or frameworks (e.g., regional energy policy, multilateral approach) of carbon market drivers.

Typologically Ordered Table 5. Overview of the Main Carbon Market Drivers in GLCET

GLCET indicator	Drivers of the carbon market	Approach considered
1	Geopolitical security	The regional energy governance approach
2	Geopolitical security	Multilateral approach

Source: Author's own elaboration.

The regional energy governance approach

Van de Graaf & Colgan's (2016) findings suggest that geopolitical security as a carbon market diversion has roots in regional energy policy. They argue that the past few years, the regional energy policy approach has become an important new field of enquiry for carbon market and geopolitical security studies in recent years. Also, they ask the questions of how the energy sector is governed at the global level, by whom and with what consequences. By focusing on governance, they broaden and enrich the geopolitical and regional energy governance perspective that has long been, and still is, the dominant perspective for GLCET analysis.

Multilateral approach

Four Scenarios of the Energy Transition: Drivers, Consequences, and Implications for Geopolitics research establish a multilateral approach with insights into the geopolitics of the ongoing GET. The real point in the process of geopolitical security is the multilateral approach. Only with a multilateral approach can we identify geopolitical security issues to fill the gap in the GLCET. Not taking into account geopolitical security drivers of the carb market could make it more difficult to maintain the path to the GLCET (Bazilian et al., 2020).

6. DISCUSSION

Since the main goal of the GET is to move towards GLCET, in this section the author provides a broader context for understanding the feasibility of the GET. The author addresses which of these approaches may be important: the MoSCoW prioritisation technique. MOSCOW is the most frequently cited technique for prioritising software requirements. It consists of four criteria, namely, "Must", "Should", "Could", and "Won't" (Shah Jahan et al., 2019). "Must" requirements need to be critical for the current situation to be successful. "Should" requirements are important to be included in the process but not necessarily important to improve the current situation, they must be circumvented in some way. "Could" have been a nice addition to the process, but they have no bearing on the success or failure of the process but are still nice if included. "Won't" requirements are those that are least critical to the time or success of the process and can therefore always be added later if time and resources allow (Asghar et al., 2017).

The author's review and analysis in the previous section (i.e., the tracking framework) has shown that DE carbonisation of electricity is very important and critical (MO, Figure 2), based on the requirements for the global low-carbon energy transition. The use of the concept of integrated resource flows (Watari et al., 2019, p. 96) and the presentation of hydrogen in GET (Quarton et al., 2020, p. 82) reflect this belief in its effectiveness. In the international journals, there is one review of trends and gaps (Cronin, Anandarajah, & Dessens, 2018) and one decarbonisation model (Pye & Bataille, 2016) that cover the great importance of DE carbonisation of electricity for GLCET.

Second, compared with MO, S (Figure 2) is relatively painful and difficult to omit compared to MO, but requires some solutions to manage. The author's assessment of carbon market drivers in the GLCET shows that the impact of the COVID-19 pandemic and the coal-dependent approach does not deepen the high significance between the fossil fuel phase-out and the GLCET. The results show that the phase-out of fossil fuels in the current situation with COVID-19 effects and coal-based economies establishes an important but not decisive relationship. In other words, fossil fuel phase-out shares a trend with these approaches. To support this view, the author has reviewed and assessed the principles for an orderly phase-out of the above approaches for equity and climate justice (Muttitt & Kartha, 2020) and supported the analysis and results of the typologically ordered Table 4.

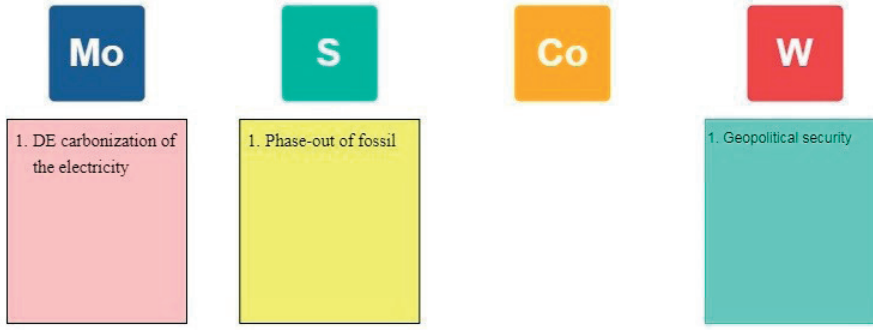

Figure 2. MoSCoW Prioritization – GLCET Model

Source: Author's own elaboration.

Although six of the studies mention MO, S, W, they do not explicitly include them in CO. CO takes time and budget. There is a clear methodological reason for this: evaluating "Could have" (CO) for the GLCET approach is difficult. It requires an assessment of the drivers of the carbon market, which is not as important as "Should have" or "Must have". It also requires more time and budget to identify a specific approach (e.g., energy efficiency in buildings). If one adds this approach to those made to explain the GLCET priority, the overall analysis becomes complex. Therefore, the CO driver is excluded from the studies and approaches reviewed here. "Won't have" requirements is another priority, explaining that geopolitical security in the GLCET is likely to be the result of a regional energy policy and a multilateral approach. The author has found some evidence that shows the real impact of geopolitical security on the GLCET. Two sources illustrate the W-step. *Energy Strategy Reviews* (2019) argues that the geopolitical drama is in the decline of fossil fuels rather than the growth of renewables (Overland et al., 2019). The study *The Geopolitics of the Energy System Transformation: A Review* shows that geopolitical security is not as important as low-carbon energy technologies (Blondeel et al., 2021).

Therefore, the author of this study believes that the proposed method – MOSCOW – is a simple way to identify the main drivers of GLCET compared to previous studies (e.g., business analysis, project management) on energy transition and analysis integrated with carbon markets and main related approaches. Few studies have assessed the GET based on MOSCOW among the main carbon market approaches. The method MOSCOW in this study is a technique used

by the author in developing a new way to identify the key requirements for the future GET, taking into account carbon markets.

7. CONCLUSION

This study examines the GET based on the challenges of carbon markets in relation to the GLCET (i.e., the issue of carbon drivers) for global climate action (GCCA). Unlike other literature that incorporates scenarios in a quantitative way in their analysis of the energy transition, in this study the author has developed a theoretical framework for such an assessment. Furthermore, the author has considered the methodology and analysis of carbon market approaches. Therefore, the results of the study are concrete and sound. The author found that the above factors can be considered as the major determinants of GET in GCCA. I found that DE carbonisation of electricity, phase-out of fossil resources, and geopolitical security contribute to GLCET. The findings of this study could provide effective insights to researchers in designing an effective analytical framework for the GET. GET focus on carbon market challenges tends to be present in relation to climate action. Therefore, climate change and energy transition researchers should continue their supportive assessment for further analysis and development of the global low-carbon energy transition framework.

In addition, researchers will conduct this research in a complementary manner to the other drivers of the carbon market. For example, the DE carbonisation of electricity is an important component of the GLCET. The author's empirical findings, i.e., both the development of the theoretical gap and the methodological assessment in GET, would encourage researchers and authors to consider these components as key drivers of the global low-carbon energy transition. The author stated that the collection of Global low carbon, Global renewable energy, Transition to carbon neutrality topic will bring Global low carbon, Energy, Transition variables. To understand more, researchers may want to introduce other measures. In this regard, categorisation of literature pieces is one of the most important methods as it has some advantages over analysis. Therefore, literature categorisation was considered by the *Academy of Management Annals* (2018), which proposed this method to categorise institutional logics (Durand & Thornton, 2018).

For the process and implementation of the energy transition, it would be useful to have an overview of the GLCET Framework at GET. An effective GLCET

in the context of global climate action consists solely of specific carbon market approaches. These approaches (i.e., the typologically ordered Tables 3, 4, 5) can be seen as a methodological measure to capture the GLCET framework in carbon market challenges. However, considering that GET is a global issue, these methods and measures are not very effective as they lead to more scientific research in carbon and energy studies. Therefore, the author's main recommendation would be to continue the analysis, measures and the creation of a theoretical framework that supports GET.

Finally, the author would like to point out some limitations of this study that could mean further steps for future research. The author's assessment ends with the challenges of carbon markets due to the interaction between markets and renewable energy markets. A future scientific study that takes into account the latest and interesting variables such as the carbon price and the Green Deal would be worth considering. As a method of GET the author uses a systemic review and a metareview. This is one of the best methods to conduct a thorough analysis that can help in categorising the different types of literature and tracking the framework. One can also consider other social science methods and semi-systemic and quantitative methods. These are mostly used in empirical research for the developed political economy of climate change models and energy measures, but the author of this study could not use them because of the qualitative data and methods.

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