Governing for Energy Transition in Rentier States

by

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Author's Declaration:

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.
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Abstract

Climate change has led to increasingly strong pressures for all states to decarbonize their energy systems and economies. Energy system decarbonization faces socio-institutional barriers to phase out of hydrocarbons, which are highly integrated into global energy and economic systems. To address these barriers, the energy governance literature provides insights into the factors that influence socio-technical transitions, including the transition from hydrocarbon to low-carbon energy. Yet, when it comes to country scales, many of these studies focus on the transition pathways from the perspective of the energy importer and developed countries, leaving perspectives of the hydrocarbon rich developing states relatively unexplored. Unlike the importer countries, hydrocarbon rich countries have local access to fossil fuels, which they subsidize for domestic use, and export for fiscal revenues. These conditions make energy transition a uniquely challenging and path-dependent process for the hydrocarbon exporting countries.

This thesis identifies the salient factors for energy transition to a low-carbon energy system and economy for the hydrocarbon rich-nations that rely heavily on fiscal incomes from fossil fuel exports – referred to as "rentier states" (Mahdavy, 1970). The identification of factors consists of universal, rentier, and country-levels, using a multi-level perspective (MLP) framework. The universal and rentier aspects aim at identifying the factors that increase pressure for (i.e. landscape factors) and resist against (i.e. regime factors) decarbonization of the energy systems and economies, respectively, at global and rentier state levels. The country-level aspect of the research is a case study on Iran – which is a rentier state. The Iranian case study allows to analyze interactions between the identified landscape and regime factors, in the real world-context of a rentier state. The case study identifies the influences of those factors on the path for decarbonizing the energy system and economy in Iran. To fulfil these objectives, the research analyzes the literature and relevant global, regional and national documents in the realms of energy governance, climate, technologies, and political economy. The research uses interviews with former Iranian officials in senior governmental positions to compensate for the scarcity of Iran-related documents and literature relating to energy transition, and to reduce the gap between the academic and real-world standpoints in the research.

The thesis' findings on MLP dynamics among the influential factors on Iran's path for decarbonization identify the centralized governance of the energy system as a leverage regime factor that impedes rentier states' efforts in decarbonizing their economy. Moreover, the thesis concludes that while energy mix and economic diversifications are both necessary approaches for phasing out of hydrocarbon resources and revenues, these strategies may be difficult to be pursued in parallel in the rentier states. In addition, the thesis finds that phasing out of fiscal crude revenues at the upstream of the energy sector [through economic diversification] could obstruct the path for phasing of fossil fuels in the downstream [under energy mix diversification].

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CHAPTER 1

Introduction

This introductory chapter provides an overview of the problem background and motivation for the research enquiry. The study purpose is presented along with the objectives.

1. Introduction

Energy transition to low carbon technologies is on the global agenda for mitigating climate change. However, decarbonization pathways are influenced by socio-technical factors, shaped by unique circumstances in varying nation groups (socio-institutions). For example, phasing out of fossil fuels is anticipated to be different in nations that import fossil fuels for payment versus those that export them for revenue. Hence, despite being a global agenda, energy transition requires context specific studies that account for country-level circumstances and perspectives. This thesis identifies a group of socio-technical factors that influence decarbonization of the energy systems in the countries that rely on hydrocarbon revenues economically – referred to as "rentier states" (Mahdavy, 1970). The identification consists of international, rentier, and country-level phases of study, using a Multi-level Perspective (MLP) framework. The international and rentier phases aim at identifying the socio-technical factors that pressure for (i.e. landscape factors) and resist against (i.e. regime factors) decarbonization of the energy systems, respectively at international and rentier state levels. The country-level phase of the research is a case study on Iran. The Iranian case study allows to analyze interactions between the landscape and regime factors identified in beforehand phases, in the real world-context of a rentier state. The case study, thereby, identifies influences made by those factors on the path for decarbonizing the energy system in Iran as a rentier state.

1.1 Sustainable Energy Transition

Energy transition, in its technical scope, refers to a transformation in fuels and relative technologies (Hirsh and Johns, 2014). Accordingly, sustainable energy transition is a form of transition that pursues decarbonization of energy systems aligned with social, economic, and environmental well-being of the host nation. Governance, climate, technology, domestic political economy, and international political economy are five of the domains entailed in energy transition [interpretated from Sovacool and Florini (2012), Van de Graaf and Colgan (2016), Loorbach et al. (2017)]. These domains are interconnected. For example, cutting a particular type of greenhouse gas (e.g. CO_2) requires replacing incumbent energy carriers with low-carbon ones (e.g. fossil fuels with renewables). Correspondingly, the replacement [i.e. technological transition] entails transformations within the political economy and governance mechanisms between the incumbent and emerging energy systems.

1.2 Significant Gaps in Energy Transition Research

Many studies about sustainable energy transition focus on fossil fuel importers [e.g. Gales et al., 2007; Solomon and Krishna; 2011; Sovacool, 2016], leaving perspectives of the exporter countries [e.g. rentier states] relatively unexplored (Van de Graaf and Verbruggen, 2015). To those, there are scholars who introduce international landscape conditions [see Kohler et al., 2018] that

pressure for decarbonizing energy systems in the global north [e.g. climate change, emergence of renewables]. Despite the international commonality of those landscape conditions, however, decarbonization pathways are anticipated to vary in the rentier states, who rely on hydrocarbon exportation economically (Tagliapietra, 2019). More specifically, the socio-technical regimes in rentier socio-institutions have evolved out of perpetual incomes from hydrocarbon exports, which if halted, could implicate in challenges that are narrowly identified against the rentier states' path for decarbonization.

One challenge is that global decarbonization [supported by affordable low-carbon technologies] would gradually lower hydrocarbon demands and prices, thus shrinking rentier revenues from them (Tagliapietra, 2019). Influences imposed from hydrocarbon devaluation, however, are barely identified against the rentier states' path for local decarbonization. Furthermore, energy decarbonization entails socio-technical reforms such as cutting hydrocarbon subsidies (Li & Sun, 2018), to which economic well-being (e.g. employment, international commerce) in the rentier states [e.g. Iran (Rahimdoust, 2021)] is dependent (Mezher et al., 2015; Ansari and Holz, 2020). The existing literature, however, delivers limited elaborations on the path-dependent characteristics of a sustainable energy transition in the rentier states amid the landscape factors that would potentially arise from global decarbonization policies.

The international landscape factors, regime conditions, and regime-landscape dynamics need to be identified based on socio-technical uniqueness of rentier socio-institutions, so that the rentier states can decarbonize their economy sustainably.

1.3 Sociotechnical Uniqueness of Rentier Socio-institutions

Rentier regimes circulate hydrocarbon revenues from nodes of export into domestic support programs, such as social services or subsidization of energy commodities. The state run-circulation thereby develops path dependent-obstacles to decarbonization.

Most rentier regimes employ centralized governance over hydrocarbon industries. That said, rentier states' governments are the main recipients of the revenues from fossil fuel exports (Tagliapietra, 2019). The revenues therefore are fed into governmental budgets, associating governmental jobs and services (e.g. in healthcare, education, and other social security) with fossil fuel incomes. Hence, if the rentier states want to phase out of fossil fuel exports, they would need to substitute hydrocarbon rents with alternative capital from private taxes or economic diversification. The capital capacity for such alternatives, however, is exploited by the state-owned monopoly of hydrocarbon industries, and the associated circular economy.

Another regime characteristic facing rentier states' path for decarbonization relates to their downstream subsidization of energy carriers for social and industrial uses. From a social viewpoint, low-cost energy carriers promote inefficient use of secondary petroleum products (e.g. fossil fuel-combusted electricity) by the rentier state societies. The inefficiency culminates in overconsumption amplified by developing nature of the economies in the rentier states, which eventually results in energy exploitation. From an industrial perspective, low cost-fossil fuel is the backbone of hydrocarbon-intensive manufacturing (e.g. steel industry) in some rentier states like Iran. Like the social aspect, low-cost fuels encourage revenues from inefficient manufacturing of energy exploitive industries, where commodities are traded at competitively low costs throughout the international markets.

Not only do the above regime characteristics contribute to energy emissions against decarbonization, but they make decarbonization a uniquely path dependent process for the rentier states, unparalleled in non-rentier nations.

2. Introduction to Thesis Purpose and Outline

Rentier states in the global south, as key players in the world's energy regime, have received less attention in terms of case specific studies about energy transition by academia. Such studies, however, are necessary for global energy governance to clarify how the rentier states can cooperate with the rest of the world on their path towards decarbonization. Accordingly, this thesis takes a broad form of a case study to identify key factors that influence the path for energy transition in Iran as a rentier state.

The aim of this thesis is to explore the challenges and opportunities rentier states face in transitioning to a low carbon economy. More specifically, the thesis identifies a group of socio-technical factors that would influence the path towards a sustainable energy transition at international and rentier levels. Afterwards, the thesis will apply the factors to a national level-case study on Iran.

As an OPEC member petroleum exporting developing country, Iran represents a good example of the rentier states. Scrutinizing Iran will contribute to the calibration of a multi-level perspective framework for theoretically examining low-carbon energy transitions over the rentier states. Moreover, Iran has been experiencing petroleum revenue losses under economic sanctions, which if studied, provides lessons for other rentier economies who may face revenue constraints under prospective global climate policies that would pressure for decarbonization.

The research question chosen for the above enquiry is as follows.

'What are the influential factors on transitioning to low-carbon energy, and how would they influence the path for decarbonizing the energy system and economy in Iran as a rentier state?'

2.1 Research Objective and Framework

The research question aims to characterize dimensions of a sustainable energy transition to a low carbon economy for the rentier states. To answer the enquiry, the thesis introduces five sociotechnical domains that are crucial for energy governance. The five domains are interpreted from theoretical energy literature by Sovacool and Florini (2012), Van de Graaf and Colgan (2016), and Loorbach et al. (2017), which include: (1) Governance; (2) Climate; (3) technology; (4) Domestic Political Economy; and (5) International Political Economy. The broader objective for exploring these domains is to identify a group of factors that will *collectively* influence an energy transition in general, in the group of rentier states, and in the rentier state of Iran, as a case study. To further clarify on the sub-objectives of the thesis, the research question is broken down into three smaller questions as introduced in Table 1.

Table 1: *Triple phase breakdown of the research question.*

Phase	***Sub-questions***
International (1)	**Sub-question 1:** *What are the sociotechnical factors and system characteristics that influence energy transitions to a low-carbon economy globally, and how do they interconnect?'*
Rentier (2)	**Sub-question 2:** *What are the controlling factors over energy transition inside the rentier states, which could therefore influence their path to a low carbon energy transition?*
Iran Case (3)	**Sub-question 3:** *What are the interactions between the influential factors on energy transition in the Iranian context*, and how do they collectively influence the path for decarbonizing energy system in Iran?*

**Interactions are set for examination based on the MLP framework, as further elaborated in Chapter 5.*

The thesis design employs a multi-level perspective framework[1] that explores for the answers to above questions in three phases of international, rentier, and national-level (Iran) studies, where the influential factors are identified as landscape[2] factors, regime[3] conditions, and niche[4]-initiatives.

To that end, the international phase of the framework aims to:

(1) Identify a group of landscape factors that pressure for (encourage) energy transitions to low-carbon economy internationally, which are potentially applicable to every state, including the rentier states. And to,
(2) Identify interconnections between the landscape factors and the socio-technical domains they belong to.

Despite focusing on landscape factors that encourage low-carbon transitions, this level of the research also identifies landscape conditions (i.e. external pressures) that may discourage transitions in context specific-occasions (e.g. sanctions, wars). Moreover, the international level of the study also relates to identifying energy system characteristics that are internationally common among the same type-energy systems. For example, there are anticipated energy system characteristics (e.g. techno-economic path dependencies) in the fossil fuel industry that are valid in every nation that uses them, whether or not those fossil fuels are serving a rentier economy. Accordingly, influences from such fossil fuel system characteristics identify as internationally common, as they exist in fossil fuel facilities everywhere, regardless of whether the facilities are used for rentier purposes.

Secondly, the phase for rentier studies aims to:

[1] According to the MLP framework, socio-technical transitions such as energy transitions evolve out of dynamics between three layers of landscape factors, regime conditions, and niche-initiatives [as Introduced by Geels (2002), Geels (2004), Schot and Geels (2008), Geels (2012), Sovacool, (2016)].

[2] Landscapes are the "exogenous developments or shocks (e.g. economic crises, demo-graphic changes, wars, ideological change, (and) major environmental disruption like climate change) that create pressures on the regime conditions which in turn create windows of opportunity for the diffusion of niche-innovations" (Sovacool, 2016, p.4).

[3] Regimes are conditions that dominate and control a socio-technical system. Regimes include socio-institutional structures (e.g. socio-institutional regime of the rentier states) for managing socio-technical operations and dynamics (e.g. energy-economy dynamics) inside them.

[4] Niches refer to protected areas that allow for alternative technologies (e.g. energy technologies) to develop in the regime. Niches are in an uphill struggle for expansion, while not yet dominating their encircling regime. Niches are supported by governmental policies – also known as niche-initiatives (e.g. socio-technical initiatives of subsidy transfer that aim at expanding renewable energy niches), so that they can develop into prospective alternatives to the technologies in the incumbent regime.

(1) Identify a group of regime factors that would confront (control) energy transitions inside the rentier states, which are potentially applicable to Iran. And, to
(2) Compensate for the limited, however growing, literature about energy transition in Iran.

Despite focusing on rentier regime conditions that resist low-carbon energy transitions, this level of the study also identifies rentier regime conditions that may encourage energy transitions to low-carbon energy carriers or a low-carbon economy in the rentier states.

Ultimately, the framework culminates in a real-world context case study on the rentier state of Iran. At this final phase, the framework adopts an MLP approach for applying the already identified landscape and regime factors to the Iranian context, identifying their collective influence on the Iranian path for decarbonizing their energy system and economy. Accordingly, the Iranian case study also concludes on:

(1) Identifying an accumulation of the socio-technical factors that would collectively influence the path for decarbonization in a rentier state, represented by Iran. And,
(2) Explicating dynamics within and between the influential factors identified in phases 1 and 2, in the Iranian context.

In addition to above objectives, each level of the study identifies a group of socio-technical initiatives that may facilitate transitions to a low-carbon economy and energy mix. Such initiatives include those that are universally applicable to every state (at international level), and those that are exclusively explored in the rentier context (at rentier level). That said, the niche perspective of the MLP study is limited to identifying the potential initiatives that may develop into support policies for energy decarbonization (e.g. political economy initiatives of subsidy withdrawal from hydrocarbon resources), which may prospectively integrate with niche programs. Yet, the study does not elaborate on niche programs, and will not design niche scenarios for a low-carbon transition.

When all is said and done, this research serves to clarify the multi-level perspectives of the path for decarbonizing energy systems and economies in Iran-like rentier states. Although the research does not aim at designing a path for decarbonization, it helps policy makers with doing so by articulating the challenges ahead, and identifying a group of factors that will influence the path socio-technically.

2.2 Significance of the Research Topic

Energy related activities are recognized as dominant provenance of the greenhouse gas emissions and the resulting climate change. Thus, it is vital to identify a path for low-carbon energy transition before passing the tipping points for climate change mitigation. Fossil fuel

exporting countries are providers of the energy the world consumes. Therefore, a global transition away from fossil fuels might face resistance from them. Furthermore, there are concerns about upwards emission trends in developing states [as elaborated below according to the British Petroleum data (2019)]. Hence, there is an evident rationale behind studying energy transition governance for the group of rentier states, as '*Developing Exporters'* of oil and natural gas products.

3. Rationale and Background

As Loorbach et al., (2017) assert, a challenge within transition research is "to stay open to new ideas and different types of societal challenges and contexts while maintaining the critical reflexivity and core concepts to facilitate the interdisciplinary exchange" (Loorbach et al., 2017, p. 618). Otherwise, studying sustainability transition may not succeed progressively if researchers of the field stand defensive against new ideas and capacity building towards enlarging the scope for contribution (Loorbach et al., 2017). One concept that requires capacity building is the rationale for proceeding with an energy transition. Although climate change mitigation is emphasized as the principal rationale for energy transition, non-climate (e.g. sociotechnical) co-rationales and co-contributions are key for enlarging a persuasive capacity for non-climate friendly (e.g. rentier) socio-institutions to phase out of fossil fuels. More specifically, nationally persuasive co-rationales for decarbonization are crucial for the rentier states because they rely on hydrocarbon rents as vital sources of income; thus, may not value climate change alleviation solely as other nations do.

Integrating non-climate co-benefits with climate change mitigation values allows for identifying a transition path that is not only a measure for environmentalism, but also in line with sustainable development goals. Concepts such as air pollution reduction (public health), economic well-being, and energy poverty eradication are potential examples of non-climate contributions regarding a low-carbon energy transition. Identifying such co-benefits (i.e. co-rationales for decarbonization) would lead future directions through which energy transitions can be implemented. As an illustration, if strong national grounds are found for a transition to occur in the transportation sector, the alternative technology choices would differ from a potential transition in the residential sector. In other words, to answer the question "why to transition?", clarifies the answer for "where to transition?". The outcome for answering these questions helps to identify energy sector(s) that are best for decarbonization given the nationally persuasive co-benefits and rationales entailed at country-level.

3.1 "Developing" Background

According to the British Petroleum (BP) Statistical Review of World Energy (2019), developing countries are responsible for 40 percent of the total greenhouse gas emissions in the world. This means that in most optimistic scenarios, in which all wealthy countries successfully adhere to their Paris Agreement commitments, the 2050 target of carbon neutrality would remain unachieved if developing nations fail to decrease their share. The BP fact sheet (2019) indicates that no single developing country has been successfully reducing its emissions by 2019; which further highlights the importance of studying decarbonization over the developing world. For example, the developing region of Middle East and North Africa (MENA) has had the second highest rate of emission growth for 3.2% per annum by 2017 (see Figure 1). MENA region hosts many rentier states around vast amounts of hydrocarbon resources in the Northern Sahara, Persian Gulf, and the Sea of Oman.

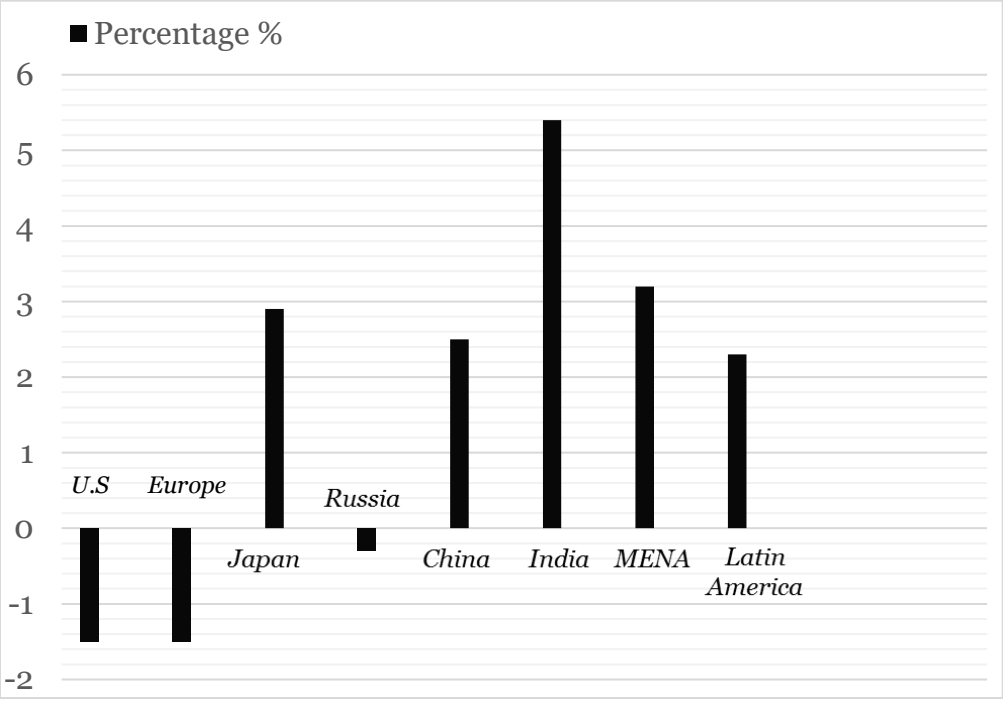


Figure 1: *Emission Growth Rate per Annum 2007-2017 (BP, 2019)*

Moreover, as developing states, Renter States have differentiated responsibilities towards climate change alleviation (Pauw et al., 2019), which may encourage them to postpone decarbonization with minimized accountability. For example, the Paris Agreement's article 9.1 requires developed countries to provide developing states with financial supports for reducing their GHGs; and article 4.15 recognizes economic concerns of the developing countries who would get harmed under global policies for climate change mitigation (Paris Agreement, 2015), which is relevant to the rentier states. Subsequently, the rentier states have the chance of not been taken accountable for not implementing their nationally determined contributions to

climate change mitigation if they do not receive financial aids they would ask for (Pauw et al., 2019, 5), or do not find their economic concerns of losing rentier revenues compensated. The above concerns highlight needs for exploring transition paths for decarbonization, particularly in the context of MENA region developing countries.

3.2 "Hydrocarbon Exporting" Background

The economic harm derived from global climate actions are perceived to be most serious to the developing rentier states that rely on hydrocarbon exports without having a diverse economy. These states may not easily substitute alternative sources for their hydrocarbon incomes due to socio-institutional path dependencies on one single source of revenue. An explicit example of such rentier institutions is the Organization of the Petroleum Exporting Countries (OPEC), which consists of developing states mostly in the MENA region (Van de Graaf and Verbruggen, 2015).

To compensate for the harm from global decarbonization, MENA rentier states may practice destructive courses of actions – such as increasing petroleum production to further cutting the petroleum price – to keep non-crude energy sources uncompetitive (Krane, 2018). Therefore, clarifying the path for energy transition in the OPEC's MENA members is an essential subject of study for a successful decarbonization to be achieved globally. The significance of doing so is not only to prevent potential resistance from the MENA rentier states against a global transition, but for identifying the factors that influence MENA's path towards energy transition amid potential pressures (i.e. landscape conditions) from a carbon constrained world. A clear identification of such a path would encourage the rentier states in MENA to willingly join the international community in phasing out of petroleum fuels.

3.3 Exemplifying the *'Hydrocarbon Exporter'* Background in the OPEC's *'Developing'* States

OPEC states supply 45% of the world's crude, and form 60% of the world's crude trade (World Economic Forum, 2024). However, if the world phases out of hydrocarbon resources, the production capacity of oil producers [such as OPEC] would exceed the global demands for oil, which once supported oil exports (Van de Graaf and Verbruggen, 2015). Such a variance, in subsequence, would free up underground oil resources for the producer countries (Van de Graaf and Verbruggen, 2015), such as the OPEC members. The freed-up resources thus may encourage the affected states to utilize those resources excessively on a domestic scale, which would risk a carbon leakage.

Furthermore, it is notable that most OPEC exports are devoted to other developing countries [see *Table 2*] (OPEC, 2023). Therefore, in case a presumptive transition in the global north decreases north's demands, thus the value and price for oil, OPEC's crude would become even

more affordable for the low-income countries to use. Consequently, there is risk for energy derived GHGs to be shifted further into the south, rather than being cut globally, in a non-holistic nor carbon-neutral transition scenario. The shift (i.e. carbon leakage) is a serious possibility as the OPEC's developing consumers have not been committing to decarbonization policies in the past decade, as earlier illustrated by Figure 1. Such a hypothetical leakage, if comes true, could fail the climate change mitigation.

***Table 2**: OPEC oil destinations of export in 2022 (OPEC, 2023)*

OPEC Export Destination	Percentage of Share
OECD Americas	5%
OECD Europe	18%
OECD Asia Pacific	18%
China	24%
India	13%
Other Asia	16%
Latin America	1-2%
Middle East	1-2%
Africa	3%
Russia	0%
Other Eurasia	0%
Other Europe	0-1%

Lastly, the global phasing out of hydrocarbon energy, with the accompanying loss of resource revenues, could temporally restrict a feasible development of the low-carbon technologies (e.g. renewable niches) in the rentier MENA, if those technologies are not locally developed before a global decarbonization (landscape) is fulfilled. If so, the MENA rentier states would be locked-in their fossil fuel energy system because they would lose rentier incomes without having them invested into transitioning regimes of fossil fuel energy into affordable alternatives of low-carbon.

3.3.1 Energy Backgrounds at Iran-level Study: International Aspects

Following identifying the MLP factors at international and rentier levels, the research framework leads into its final phase, which is a case study on Iran. The Iranian case study is a methodological approach for analyzing dynamics within and between the MLP factors of interest and energy transition in Iran, as a real-world context of a rentier state.

As an OPEC member with high per-capita carbon emissions [according to data from the International Energy Agency (IEA) (2024)], Iran represents a clear case of a rentier state that faces the earlier-discussed conditions for decarbonizing its energy system and economy (e.g. concerns

over transition derived economic harm, developing and exporting natures, domestic path dependencies against phasing out of fossil fuels, and the risk of carbon leakage). Iran is also affected by the U.S economic sanctions, which gives it a distinct landscape condition compared to the other rentier states in the MENA. The U.S sanctions especially target the hydrocarbon backed part of the Iranian economy, which can simulate potential carbon constraints in the future, when rentier economies are prospectively pressured to limit hydrocarbon extractions due to global policies for climate change mitigation.

Transporting hydrocarbon resources to foreign consumers, Iran accesses to the Persian Gulf's strait of Hormoz, as a route that connects the rentier state with international oil markets. In addition to long distance shipping, Iran is also a regional exporter of natural gas [by limited volumes due to high internal demands] through pipelines (U.S Energy Information Administration (EIA), 2024).

3.3.2 Energy Backgrounds at the Iran-Level Study: Domestic Aspects

Having the world's 3rd and 2nd largest proven reserves of oil and natural gas by 2023 (U.S Energy Information Administration, 2024), Iran is of the few countries having dual fuel infrastructures expanded throughout its territory. To that end, Iran's internal energy demand is chiefly met by the natural gas, with contemporaneous supports from oil, hydroelectricity, nuclear power, and non-hydro renewables. As indicated in Figure 2, there is also a limited share for coal in the Iranian energy mix.

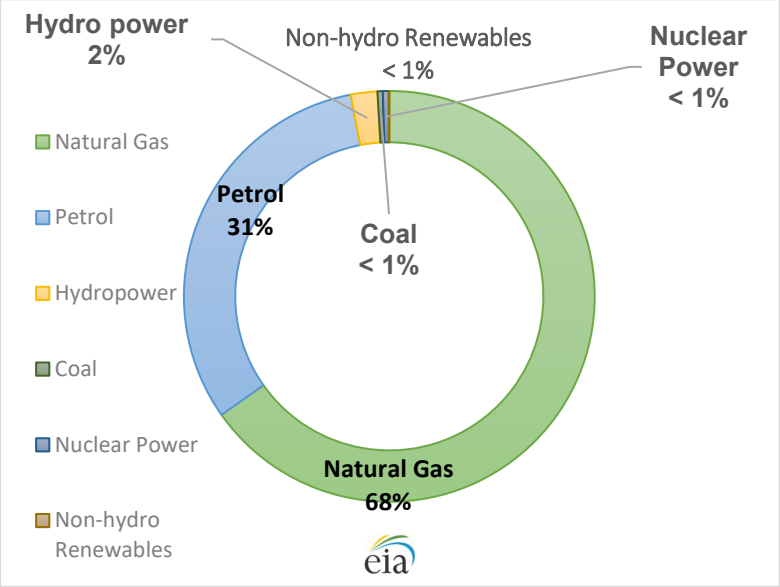


Figure 2: *Iran's total primary energy consumption, share by fuel (2022) excluding traditional biomass and waste.*
Source: U.S. EIA (2024)

Above illustrated natural gas (NG) intensity in the Iranian energy mix has reverberated through high shares of CO_2 and Methane emissions arising from the rentier state's downstream of energy system. According to the International Energy Agency [IEA] (2024), Iran's Methane emissions have counted for 6 million tons in 2023. As for the CO_2 part, Iran's energy-related emissions hit 7.8 million tons of per capita in 2022, which is 696.371 million tons of CO_2 emissions, 68% of which come from natural gas combustion (IEA, n.d.). Accordingly, Iran has been ranked 6th among the top CO_2 emitter countries from fuel combustion (IEA, n.d.), mitigation of which requires a transition towards low-carbon energy carriers inside the rentier state.

4. Conclusion

Availability of oil and NG has respectively supported rentier and carbon intensive regimes of economy and energy system in Iran. Internationally, Iran exports high volumes of oil that provide the state with perpetual incomes. Internally, Iran uses natural gas as a primary source of energy for domestic energy needs (e.g. for residential and industrial uses). As a result, international rents from oil export and internal access to affordable natural gas promote a carbon-intensive energy system and a rentier economy in Iran, both of which depend on hydrocarbon resources. For these reasons, a case study on Iran can elaborate on the international and internal factors associated with phasing out of fossil fuels in similar rentier states. The MLP framework is one potential approach for conducting a case study that elaborates on the above factors and their influence on Iran like-rentier states' path for decarbonizing their economy and energy system.

From an international perspective, rentier states rely on external oil incomes, which makes them vulnerable to global climate policies, such as financial policies for supporting non-fossil energies. Also, from an internal viewpoint, climate change itself drives pressure for phasing out of fossil fuels inside the rentier states, given the fuels' vast contribution to GHG emissions. That said, the MLP structured Iranian case study represents a methodological approach for identifying interactions between the regime and landscape factors that would collectively influence the rentier states' path for economic and energy system decarbonizations. When identified, regime-landscape interactions and their influences can be considered by policy makers in Iran - and similar rentier states - in the pursuit of designing a roadmap for decarbonizing their energy system, which remains out of the scope of this research.

CHAPTER 2

Theoretical Literature Review

Governance is the first domain involved in energy transition governance. This chapter explores the literature about energy governance and transition theory. The chapter identifies a framework for conducting the research based on three major contexts. The first contexts (i.e. socioeconomic context) guides about where to search for the socioeconomic factors that influence energy transitions. The second context introduces the rentier state theory, as a socio-institutional context to which findings of the former context will be later applied for the examination of their dynamics. The third context introduced is the Multi-Level Perspectives (MLP) theory, which will be later used for analyzing energy transition dynamics over the identified factors in the rentier state case study of Iran.

1. Nexus of Sustainability and Governance in Energy Research

The emergence of modern scholarly work on sustainable energy governance goes back to 2005 when the international summit of Gleneagles was held by the G8. Although there was noticeable history of energy research within the decades before, 2005 was the year academia observed energy governance from the lenses of energy security and climate change together (Van de Graaf & Colgan, 2016). Perspectives of energy access were also added to this agenda, which concerned circumstances of developing nations (Gunningham, 2012) and their right for development alongside decarbonization (Newell and Mulvaney, 2013).

The security, climate, and access scopes for energy governance are supported by solid rationales. Krane (2018) underlines natural hazards risks and climate change damage costs as two convincing rationales behind the climate related aspect of energy governance. Complementarily, Van de Graaf and Colgan (2016) introduce fossil fuel price fluctuations among the origins inspiring scholars to adopt a security perspective. From a domestic viewpoint, Cherp et al., (2011), Sovacool and Florini (2012), and Gunningham (2012) add energy poverty eradication as of co-rationales behind energy governance research. The poverty rationale incorporates perspectives of developing nations with respect to energy access.

The 21st century's trilemma for energy security, poverty eradication, and emission mitigation (Gunningham, 2012), therefore, has gained traction to transitioning the energy systems in a way that addresses the above needs. Given the multi-theme drivers for energy transition, there are various socio-technical perspectives based on which energy transition can be defined.

2. Multi-theme Definitions and Rationales for Energy Transition

Energy transition is identified as a socio-technical transition, influenced by socioeconomic, socio-ecologic, and socio-institutional factors (interpreted from Loorbach et al., 2017, and Sovacool, 2016). Given the multi-disciplinary contexts involved in an energy transition, it is essential to define when a transition would be counted as fulfilled to avoid misconceptions in terms of transition scale and meaning. As Sovacool (2016) asserts: "Deciding what one counts includes within its normative assumptions about what an energy transition is; the problem is that analysts do not always make these assumptions transparent" (p. 211).

There are several definitions describing energy transition, which are close in content, meanwhile diverse in scope. An energy transition reflects changes in an energy structure, involving energy carriers, technologies, or prime movers [i.e. a converter of energy to work, such as gas turbines] (Sovacool, 2016). Accordingly, Hirsh and Johns (2014) describe energy transition as a transformation in fuels and relative technologies (Sovacool, 2016). Their definition is close to

Miller et al.,'s (2015), which introduces transitions as "Shifts in the fuel source for energy production and the technologies used to exploit that fuel" (Sovacool, 2016, p. 203). Although this group shares a mutual approach in conceptualizing energy transitions based on technology aspects, their coverage and emphasis on technology characteristics such as resources, carriers, converters, and services vary. To this, O'Connor (2012) introduces the notion of energy transition as the "particularly significant set of changes to the patterns of energy use in a society, potentially affecting [all the four of] resources, carriers, converters, and services" (Sovacool, 2016, p. 203). Another viewpoint is that the impact of switching between [end use] energy products (e.g. Kerosene to LPG, flexible fuel vehicles) can involve a range of limited to radical alterations over the four mentioned technology elements within the energy supply chain (Sovacool, 2016).

Energy transition definitions may also include economic and time perspectives. Fouquet and Pearson (2012) view it as "the switch from an economic system dependent on one or a series of energy sources and technologies to another". In contrast, Smil (2010) characterizes energy transition as "the time that elapses between the introduction of a new primary energy source, or prime mover and its rise to claiming a substantial share of the overall market" (Sovacool, 2016, p. 203).

The 19th century's rationale behind characterizing transition definitions was initially influenced by the industrial revolution, which led to surging toxic emissions that challenged the public health. As interpreted from Melsted & Pallua (2018), 19th century's "energy transition" was initially characterized by the shift from toxic gas emitter fuels to fossil fuels with less toxic discharge. Today, however, global warming is the predominant challenge endangering the well-being of the people's lives on earth (Steg et al., 2015). Among its various drivers, CO_2 emissions - containing 84% of total GHGs - are known as the main leads for the global warming (Steg et al., 2015). Fossil fuels cause about 90% of the CO_2 emissions worldwide, which necessitates a coherent transition away from them to mitigate their warming effect (Davis & Shearer, 2014). Therefore, global warming mitigation is selected to be the core approach for this thesis in defining energy transition.

Regardless of today's climate-derived novel vision for transition, not all experts have been acting progressively on its theorization (Van de Graaf & Colgan, 2016). Particularly, theorizations for transition governance vary when it comes to country scale. States have diverse priorities concerning energy concepts, for instance concerning energy poverty eradication versus energy supply stabilization, respectively among the least and most developed regions (Van de Graaf & Colgan, 2016). Yet, climate change mitigation confers a mutual interest that provides a common platform for theorizing energy transition governance. This thesis recognizes energy transition as climate pressured-replacement of the fossil fuels with low-carbon energy carriers, which requires

interdisciplinary governance over sociotechnical entailments between the carbon intensive (incumbent) and low-carbon (prospective) energy systems.

3. Governance for Energy Transition (Theory)

"Governance in its most basic sense refers to the processes, systems and actors involved in addressing collective problems that individuals and markets cannot solve for themselves, as well as making and enforcing rules" (Sovacool and Florini, 2012, p. 237).

Theoretical research about energy governance uncovers respective contexts about '*what to govern in'* and '*who governs*' energy, socioeconomically and institutionally. These discoveries then lead to identifying a third context about '*how the socioeconomic and institutional contexts for energy transition relate'*.

Energy governance theory is yet too broad of a topic to fit in its entirety in the scope of this research. That said, the theoretical study about energy governance here concentrates on reflections of the above three contexts in the realm of energy transition, namely the 'what', 'who', and 'how' contexts of governance for energy transition. The three reflections respectively include socioeconomic (e.g. Newell and Mulvaney, 2013; Loorbach et al., 2017), socio-institutional (e.g. Carin and Mehlenbacher, 2010; Mahdavy, 1970; Florini and Sovacool, 2009; Beblawi and Luciani, 1987 & 2015), and dynamic [i.e. interactive] (Loorbach et al., 2017) contexts for energy transition governance.

The *'socioeconomic context'* refers to discussions about objectives of interest in energy transition governance (e.g. fairness, sustainability). This context introduces five domains including governance, climate, technology, international political economy, and domestic political economy, which contain socioeconomic and ecologic factors that influence energy transitions. '*The socio-institutional context*' highlights differences among hierarchies who are responsible for governing energy in the global north and south (e.g. IEA versus OPEC states). This context then concentrates on the rentier states, as the hierarchies of interest for this research. Lastly, the '*dynamic context*' elaborates on the multi-context (i.e. multi-level) interactions that happen between the socio-economic and socio-institutional factors that influence an energy transition.

4. Theorization of Sustainability Governance for Energy Transition

4.1 Socioeconomic Context

To theorize governance for energy transition objectively, fundamental questions on both sides of "governance" and "energy transition" need to be considered. 'How can a transition be just?'

is one of the questions that provides guidance on the qualities and target groups for energy transition. Newell and Mulvaney (2013) consider a just transition responsible for taking care of vulnerable communities. Such communities include those suffering from energy-related climate change, poverty, and security risks. The vulnerable terminology also applies to people who live in carbon dependent economies, where a transition towards low carbon can enforce spatial distortions on the carbon-related employment.

"What should be governed in energy, and how?" (Cherp et al., 2011, p. 76) is the other question relating to transition theory, which consists of socio-economic (what) and dynamic (how) enquiries. Clarifying the former part, several potential domains involved in energy governance should be incorporated. This is because a socio-technical energy transition consists of socioeconomic themes, which include factors that influence the transition. This multi-theme type of problem solving demands a holistic approach, which embraces "a variety of technological, social [e.g. politics], economic, ecological [e.g. climate and emissions], and institutional [governance] factors in the analysis" (Loorbach et al., 2017, p. 608). To have these factors identified it is necessary to explore the socioeconomic domains to which the influential factors belong.

The first influential domain on governing for energy transition is the governance itself. Governance disciplines are reflected in political ecology (e.g. conflicts over natural resources) and ecological modernization (e.g. environmental regulations) approaches of transition research (interpreted from Sovacool, 2016). Given its multi-disciplinary coverage, the domain of governance expectedly leads the rest of the domains that are influential on energy transition. This is the reason for energy governance to be reviewed in this early chapter, despite later elaborations in Chapter 4 (part B) that discuss energy governance specifically in the context of the rentier states.

The second influential domain is climate. GHGs are known as the main drivers of the earth's temperature increase and climate change. As measures indicate, atmospheric GHGs are in record accumulations today, disrupting our planet from reflecting the solar radiation it receives. Sea level rises, precipitation pattern changes, and natural hazard expansions, are few of the many signs of a climate that is not circulating on its supposed rhythm [United States Environmental Protection Agency (EPA), 2024]. Phasing out of the technologies that release GHGs hence is an essential of climate change mitigation. In other words, GHGs connect the domain of climate with energy technologies, which produce emissions in various types (e.g. GHGs, pollution) and magnitudes.

Subsequently, energy technologies form the third influential domain on energy transition. As stated by the IEA (2023), energy related activities have discharged over 41.3 giga tons of carbon dioxide equivalent-GHGs in 2022, 89% of which are CO_2 emissions from energy consumption and industrial activities. The above mentioned volume of GHGs from energy sector, therefore, highlights the need for decarbonizing energy technologies for climate change mitigation. The energy sector encompasses three phases of upstream production (e.g. fossil fuel extraction and refinement), distribution (e.g. pipelines, grid), and downstream utilization (e.g. industrial heat, residential power use). Hence, transitioning from carbon intensive-technologies to low-carbon alternatives would require limited to extensive changes in energy resources, distributors, and convertors (interpretation from Cherp et al., 2011, and Sovacool, 2016).

Yet, transitioning towards low GHG-technologies is not promising to succeed on its own (Arent et al., 2017); rather, it requires governance and policy managements, such as over the political economies entailed in the incumbent and emerging energy systems (Sovacool, 2016; Arent et al., 2017). The political economy of energy governance embraces domestic and international domains, which the thesis considers as the fourth and fifth influential domains on the energy transition. From a domestic perspective, "economic condition, resource endowment, and structure of a country determine management [of the] policies" that affect countries' political acceptance for decarbonizing their economy, for instance through carbon pricing (Arent et al., 2017, p. 214).

From an international viewpoint, the above conditions may divide nations into various political economy groups such as developed versus developing, and hydrocarbon exporter versus importer states, who have contrasting interests that may oppose economic decarbonization (Arent et al., 2017). For example, developing countries that receive fiscal revenues from hydrocarbon exports are not willing to lose them, amid their concerns for development and limited resources for decarbonizing their energy system (Arent et al., 2017). On the other side, neither are high income countries willing to pay for the high costs of a low carbon transition due to political or social reluctance, despite having the financial capital for doing so. Consequentially, there emerge different types of conflicts of interests against decarbonization among countries with varying socio-institutional structures (Arent et al., 2017).

4.2 Socio-institutional Context for Energy Transition Governance

Further theoretical questions to ask about governance for energy transition involve socio-institutional aspects. Examples include 'who governs or should govern energy?' (Carin and Mehlenbacher, 2010; Florini and Sovacool, 2009); 'which group would receive advantages from energy transition?', and "who would have to pay the costs of providing the governance" for a transition? (Sovacool and Florini, 2012, p. 254). Energy transition also depends on the socio-

geographic targets [and circumstances] within the socio-institutional context where the transition is to be implemented. To know whether a transition is to transpire globally, in a particular state, province, or rather within a particular segment of society (e.g. rural communities dependent on a particular source of energy) clarifies the path the transition proceeds through (Sovacool, 2016).

4.2.1 Global South versus North Perspectives for Energy Governance and Transition

While Sovacool recognizes the need for distinguishing between socio-geographical characteristics for energy transition, most studies concentrate on energy transition in the global north, which relies on energy importation. However, the climate rational for energy transition reminds us of the significance of a low carbon transition in the global south as well, where states face increasing emissions due to the developing status of their social economy. More importantly, among the global south states are nations that export energy carriers, whose interests and conceptualization for energy transition run contrary to those of the energy importers in the north. Such conceptual contrast could subsequently challenge a south-north cooperation for a globally consistent transition to low carbon economy.

Concerning the development status, population growth in emerging economies and developing countries is known as the cause behind the growing utilization of fuels historically (Fouquet & Pearson, 2012). Therefore, energy transition among today's developing states is a requirement for cutting energy emissions, supporting the climate change mitigation rationale behind the energy governance. Nevertheless, "so far developing countries and their sustainability challenges have been only sporadically addressed in transitions research even though the urgency and gravity of the problems are enormous" (Loorbach et al., 2017, p. 618).

With respect to the exportation background, and when it comes to institutional interests in energy governance (for example in energy security objectives), some hierarchies are too much in contrast to be able to recognize each other as legitimate (Van de Graaf and Colgan, 2015). The International Energy Agency and OPEC, respectively in the global north and south, are two organizations in line with this comment. On the OPEC side, for example, energy security refers to stability in petroleum demand, ensuring continuation of the rents from petroleum exports. On the IEA branch, however, energy security is defined by stability of petroleum supply, because IEA members rely on petroleum imports socioeconomically. Therefore, not only are the OPEC and IEA opposing in terms of founding members (global south versus north) and interests (rentier versus importer), but they are also antithetical to their conceptualization about energy security for supply versus demand. The oppositions, therefore, could form competitively contrasting objectives for energy transition among the global north and south.

Competition over contrasting interests between the OPEC-like rentier states and IEA-like energy importers underlines the crucial need for exploring risks and possibilities of a south-north collaboration for energy transition. Yet, most energy transition studies are conducted from the lenses of global north countries; and standpoints of southern rentier nations (e.g. MENA rentier states) have received relatively less attention. The following sub-section overviews the rentier states' position in terms of energy governance.

4.2.2 Governance in the Fossil Fuel Exporting and Developing Countries (Theory)

In 1970, Hussein Mahdavy introduced the rentier state theory, examining the economic burgeoning of Iran and MENA countries. The term "rentier state" is an upper category for the group of crude exporting countries. As Beblawi and Luciani (1987 & 2015) built on Mahdavy's framework, rentier states share three characteristics in common. First, they depend on significant amounts of uninterrupted external revenues to maintain their economy. These revenues reduce rentier states' needs for improving on domestic productions. Second, a fraction of the rentier state societies develops these revenues; most people are involved in their distribution or utilization only. Third, in the rentier states central administrations are the main recipients of the external revenues (Tagliapietra, 2019).

Motivated by the external incomes, rentier states depend less upon budgetary inputs from taxation. This absence of need for societal support potentially harms democracy and legitimacy. Indeed, "the fundamental principle of democracy, 'No taxation without representation', finds in rentier states its mirror image, 'No representation without taxation'. That is, untaxed citizens are less likely to demand political participation" (Tagliapietra, 2019, p. 4). Moreover, rentier incomes also promote a social presumption that "income is not related to work and risk bearing, but to chance or situation" (Tagliapietra, 2019, p. 4). This is perhaps why Beblawi and Luciani (1987) believe that the "rentier states tend to give rise to second order rents, such as real estate and financial speculation" (Tagliapietra, 2019, p. 4).

4.2.3 Public Sector versus Private Sector Regime in the Rentier States

In the absence of productivity and accountability, how is the socio-economic governance organized in the rentier states?

Centralized administration is a common form of energy governance in many rentier states [e.g. Mohammadi and Danaee Fard's review of Iran (2019), Boukhatem's review of Algeria (2022), Tagliapietra's highlights on Kuwait (2019)]. Beblawi and Luciani (1987 & 2015) define a key function for rentier administrations that is to dispense their rentier incomes to their people (Tagliapietra, 2019). Such dispense can happen in shape of welfare, subsidies (e.g. Rahimdoust [2021] highlights on Iran), social services (Boukhatem highlights on Algeria [2022]), etc. Economic

productivity in rentier states thus is not an essential element of survival given the continual and guaranteed rentier revenues. Instead, the states may persist on exogenously-fed development unless being obliged to improve on internal production. Such governance relationship between the administration and workforce absolutely contrasts that of "production states, which have to subtract – via taxation – resources from those that originally possess them and reallocate them to others in the society on the basis of an asserted common interest – which ultimately requires democratic legitimation" (Tagliapietra, 2019, p. 4).

4.3 Dynamic Contexts of Energy Transition Governance

Concerning the multi-context characteristics discussed about socio-technical transitions, transitioning from one energy technology to another is also transitioning between the socio-economic and socio-institutional structures around the two. Therefore, governing for energy transition is a multi-context (i.e. multi-level) problem including socioeconomic and socio-institutional perspectives. To that end, as the energy system transitions, it faces socioeconomic influences that either encourage or resist the transition respectively at external (outside the socio-institutional structure that hosts the energy system) and internal levels. Therefore, it is essential to have a conceptual framework through which these levels can be integrated, and their interaction (i.e. dynamics) can be analyzed under a common lens. To do so, the researcher needs to identify the influential factors arising from each perspective, sorting them based on the type of influence they impose amid interacting with other factors in the transition process. A well elaborated framework that is applicable to this purpose is the "multi-level perspective (MLP)" framework (as elaborated by Geels, 2002; Sovacool, 2016; and Loorbach et al., 2017).

According to the MLP framework, socio-technical transitions evolve out of an interacting platform that consists of three types of influences, which are categorized as regimes, niches, and landscape conditions. A regime is a presently leading and dominating system. Regimes include socio-institutional structures (e.g. socio-institutional regime of the rentier states) for managing socio-technical dynamics (e.g. energy-economy dynamics) inside them. Niches refer to protected areas that allow for alternative technologies (e.g. energy technologies) to develop in the regime. Niches technologies are in an uphill struggle for expansion, while not yet dominating their encircling regime. Niches are supported by governmental policies – also known as niche-initiatives (e.g. socio-technical initiatives of subsidy transfer that aim at expanding renewable energy niches), so that they can develop into prospective alternatives to the technologies that dominate the incumbent regime. Lastly, landscape conditions are translated as the "exogenous developments or shocks (e.g. economic crises, demo-graphic changes, wars, ideological change, [and] major environmental disruption like climate change) that create pressures on the regime which in turn create windows of opportunity for the diffusion of niche-innovations" (Sovacool,

2016, p. 205) [e.g. socioeconomic repercussions from GHG emissions such as climate change and global policies for climate change mitigation].

4.3.1 Dynamical Interactions between Regime, Niche, and Landscape Influences and the Role for Governance (Theory)

Based on the MLP framework, a transition path from a current regime to its encircled niches (prospective regime technologies) proceeds through four steps of predevelopment, take-off, acceleration, and stabilization (Loorbach et al., 2017). In the pre-development stage, niche-technologies are not sufficiently developed for a transition, rather they are under development. Therefore, it is crucial to keep an eye on the "up-scaling process, ensuring sufficient time for a 'formative phase' of experimentation and small-scale development [of the niches] … before pushing for the expansion" (Fouquet and Pearson, 2012, p. 5) of the niches over the regime [industries]. Afterwards, "as the broader societal context changes and new radical alternatives [i.e. niches] develop and emerge, regimes inevitably will enter a process of increased stress, internal crises, destabilization, and shock-wise systemic reconfiguration" (Loorbach et al., 2017, p. 605). Regimes in the meantime are historically path-dependent on the dynamics that are co-evolved inside them. Therefore, regimes lack the required flexibility for the change [that is demanded by the internal crises], which makes them face increased tractions [amid resisting the internal crises]. The increased traction here delivers a tipping point for the external crises (landscape conditions), which should the tipping points occur, would catalyze the chaotic rearrangement of the regime to be replaced by (be transitioned to) one or more of the pre-developed niches, to shape a new regime (Loorbach et al., 2017).

The above discussed MLP framework is applicable to the rentier states' pursuit of transitioning to a low carbon energy system. Rentier states' fiscal dependence on hydrocarbon incomes (Tagliapietra, 2019) nurtures a regime of political economy that resists phasing out of the fossil fuels due to budgetary needs for the rentier revenue. However, climate change mitigation policies such as carbon pricing (Arent et al., 2017) are external landscape factors that pressure for decarbonizing energy systems internationally, endangering rentier states' hydrocarbon incomes. The consequential traction between the rentier regimes' resistance against decarbonization and the climate pressures on them for decarbonizing their energy system creates an opportunity for the low carbon niche technologies to thrive in the rentier regimes. Low carbon technology options may have already been pushing for expansion internally following potential crises inside rentier regimes [e.g. energy deficiency, fossil fuel-derived air pollution (Chapter 4)], power of which will be stimulated by the external landscape conditions.

4.3.2 MLP Approach towards a Multi-context Sustainability Governance

When all is said and done, the MLP framework views energy transition as a phenomenon that happens naturally and chaotically. Accordingly, governance is recognizable as an influential domain in terms of directing energy transitions towards desirable directions. Here, a desirable direction refers to a transition path towards a [new] regime that is compatible with the nexus of sustainability, with social, economic, and environmental well-beings included. To do so, governance factors must manage the way system entities are disposed to generate solutions to their encompassing societal problems (Loorbach et al., 2017), such as global pressures for climate change mitigation in the case of the rentier states.

Achieving the above objectives, governance solutions facilitate the cooperation required between varying organizations "by adding the perspective of transitions as regime shifts in societal systems that are by definition (partly) initiated outside incumbent structures, vested interests, and dominant institutions during predevelopment and destabilization" (Loorbach et al., 2017, p. 605). This hints at the essence of employing socio-technical novelty in primary steps of MLP transitions, planning for confronting incumbent system destabilization, and institutionalizing arising systems [to which an incumbent regime transitions] (Loorbach et al., 2017).

Accordingly, energy transition to non-fossil fuel energy carriers has to be purposefully directed or engineered (Fouquet and Pearson, 2012) for the rentier states to be able keeping up with the tipping points of climate change alleviation. To that end, governance for clean energy transitions would differ from many of the previous transitions, which have naturally taken place as a cause of enhanced affordability and/or availability of discovered/invented energy resources and technologies (Sovacool, 2016).

5. Statements of Multi-context Interconnections in Energy Transition

Energy Transition is a key potential response to support energy security, access, and climate wellbeing improvements. Therefore, theories and definitions around energy transition are proposed from various socioeconomic and socio-technical angles. Those include sustainability governance, emissions, technology, economy, and security. The five domains require exploration responding to the Van de Graaf and Colgan's (2015) five introduced energy scopes with governance gaps. This equivalence is not coincidental as governance for energy transition to low carbon is a relatively new, thus, not fully identified problem.

While it is necessary to explore the above five domains to identify how they pressure for energy transitions at global level, it is important to note that their pressure would impose exclusive

influences in varying states, which will cause state-exclusive responses to energy transition. For example, energy transition to low carbon is socio-institutionally complex for the rentier states who depend on their vested interests in hydrocarbon exports. Such interests are unique, and not applicable to the importers of hydrocarbons in the global north. Unparallel socio-institutional interests cause contrasting circumstances in response to the socioeconomic factors that pressure for energy transition over the rentier states versus over the importers of their energy products in the global north. Accordingly, there is a crucial need for identifying the path for energy transition in the rentier states and global north to avoid failing a collaboration for effective global decarbonization. Meanwhile, most studies of sustainable energy transition focus on energy transition in fossil fuel importer states, leaving socio-institutional perspectives of the rentier states relatively unexplored.

The MLP framework is a useful approach for analyzing the interactive dynamics within the socioeconomic factors that influence energy transitions in specific socio-institutional contexts. Employing the MLP requires identifying and categorizing the influential factors into regimes, landscapes, and niches (i.e. MLP tenets). Moreover, the intersection of timing and governance produces a tipping point for a sustainable transition. If the sustainability niches are not well-prepared before landscape level-conditions escalate, the transformation of the regime would not necessarily culminate in a sustainable system. For instance, there are risks for the incumbent regimes getting locked in their path-dependencies [such as on fossil fuel energy systems and rentier economies], or collapsed under increasing pressures imposed by outer landscape conditions.

Accordingly, identifying MLP factors is a prerequisite for engineering a path for the rentier states transitioning to a low carbon energy system sustainably. An essential of doing so is identifying the landscape factors (e.g. those arising from climate change mitigation policies, expansion of renewables, etc.) that pressure for decarbonizing energy systems and economies internationally. Moreover, as developing exporters of the fossil fuels, rentier states employ exclusive regime structures for energy governance. It is significant to identify the socioeconomic factors entailed in such structures in correspondence with the landscape conditions they are exposed to for analyzing regime-landscape interactions. After identifying the MLP factors amid their dynamics, the thesis can identify their collective influences on the rentier states' path towards transitioning to a low carbon energy system and economy.

6. Literature Review Conclusions and Propositions of Contribution to Research Approach

As presented above, the theoretical literature review began with an introduction to 21st century's rationales and scopes for energy governance concerning the higher and lower income countries. Research papers on this topic included scholarly works by Newell and Mulvaney (2013), Gunningham (2012), Van de Graaf & Colgan (2015), and Krane (2018). The literature review then narrowed down into arguments about energy governance in the realm of energy transition, where transition definitions were conceptualized from economic, temporal, and socio-technical perspectives. To that end, review of energy transition concepts and definitions, such as by Hirsh and Johns (2014), Miller et al. (2015), Sovacool (2016), Fouquet and Pearson (2012), Melsted and Pallua (2018), and Cherp et al. (2011) served the thesis towards adopting its own definition for energy transition, which concerns a climate pressured-phase out of the fossil fuels into low carbon surrogates. Concluding on its introductory sub-sections, the literature review led the thesis into three contextual approaches for theorizing energy transition and building a framework to pursue its objective in identifying – not designing – the path for decarbonizing energy systems in the rentier states. The multi-context approaches included socioeconomic [and ecologic], socio-institutional, and dynamic perspectives of energy transition, articulated by experts in energy transition theorization such as Mahdavy (1970), Beblawi and Luciani (1987 & 2015), Florini and Sovacool (2009), Carin and Mehlenbacher (2010), Cherp et al. (2011), Newell and Mulvaney (2013), and Loorbach et al. (2017).

The socio-economic approach intends to identify international landscape factors that encourage transitioning to a low-carbon energy system, such as tipping points for climate change mitigation. Therefore, the 'socio-economic' term may also be referred to as socio-ecologic because it is inclusive to the domain of climate given the interconnections between the socio-economic and socio-ecological well-beings. For more information, Loorbach et al. (2017) dissert that:

> The socio-ecological approach has its roots in ecology and resilience theory (Hotelling, 1973), seeking to understand (in)stability in ecosystems but evolved to look at coupled socio-ecological systems. Transitions in ecosystems are understood as nonlinear shifts from one attractor basin to another passing certain "tipping points." These shifts from one dynamic equilibrium to another are nonlinear, almost irreversible, and follow a pattern of buildup, stabilization, breakdown, and recovery (Gunderson and Holling, 2002). Within the resilience approach, the interplay between such ecological transitions and the societal context is addressed, and it examines the way in which this context pushes ecosystems beyond tipping points and planetary boundaries (Rockstorm et al., 2009; Galaz et al., 2012). Research on planetary boundaries provides a frame of reference for mapping and assessing the accelerated impacts of anthropogenic activities and connects with the ways the UN Sustainable Development Goals can facilitate a process of tackling global change by addressing the interconnected planetary boundaries. Planetary

> boundaries provide also the frame of reference for actions required to re-establish planetary resilience. (P. 611)

Secondly, the socio-institutional approach aims at identifying regime factors that control decarbonization inside nations. To that end, the socio-institutional approach also concerns the techno-geographic system characteristics of the states that are exposed to international landscape conditions that pressure for decarbonization. Although the landscape factors are internationally common, their effect – and therefore dynamics at country level – are anticipated to vary among nations with varying socio-institutional regime conditions and geographic characteristics. Consequentially, the variations would reverberate through contrasting circumstances at local level in spite of common landscape conditions for low-carbon energy transitions. Accordingly, the literature review highlights conflicts of energy-related interests among the hydrocarbon exporter versus importer countries, as well as the developing versus developed nations in the global south and north. Following the research topic and its aim at characterizing energy transition for the rentier states, this part of the literature review narrows the focus down into highlighting the socio-institutional characteristics embedded in the rentier states. The literature review discussed such highlights based on Mahdavy's (1970) dissertation through which the rentier state theory was articulated for the first time. That said, the socio-institutional context of the literature review structures the middle part of the thesis framework in identifying regime characteristics for energy governance, particularly for the rentier states. Researchers that employ a socio-institutional approach spotlight the inherent political nature of sustainability transitions given their stress on structural change. At the same time, coupled emphasis is on socio-political transitions and core based governance towards decentralization, and third-party energy co-organization (Loorbach et al., 2017). As Loorbach et al. (2017) add:

> [socio-institutional approaches] Draw from social sciences such as economics, political science, sociology, governance studies, and geography. We refer to these as socio-institutional, as these approaches identify institutionalized cultures, structures, and practices (Van Raak, 2016) as regimes in which transitional change takes place. These approaches often focus on specific sectors or geographical areas that face persistent problems. Although technologies might play an important role in understanding transitional change, the emphasis is rather on how incumbent routines, powers, interests, discourses, and regulations create path dependencies and how these are challenged by (transformative) social innovations. (P. 610)

Lastly, the literature review introduces the MLP approach for identifying dynamics between the international landscape factors and internal regime factors that would influence energy transitions in rentier socio-institutions. To that end, the literature review refers to research works relating to MLP theorization such as by Geels (2002), Schot and Geels (2008), Sovacool, (2016), and Loorbach et al. (2017). The dynamic context of the literature review contributes to the later

part of the thesis framework in adopting a multi-level perspective approach for identifying the collective influences that landscape-regime dynamics impose on the rentier states' path for decarbonizing their energy system and economy.

CHAPTER 3

Methods and Approaches

This chapter elaborates on the methods and approaches employed for achieving the thesis objectives. Literature and document analysis, case study, and interviews are some of the methodological tools and approaches that are used in this thesis.

1. Introduction to Research Approaches Towards Thesis Objectives

The literature review introduced the socio-economic and socio-intuitional approaches for identifying multi-level perspectives of a low-carbon energy transition. The two contextualized approaches are followed in the thesis Chapters 4 and 5. Chapter 4 aims at identifying the socio-economic (Chapter 4: part a) and socio-intuitional (Chapter 4: part b) factors that respectively influence energy transitions at global and rentier levels. Thereafter, Chapter 5 aims at identifying the interactions between the influential factors identified in Chapter 4. Chapter 5 also identifies the collective influences that those factors impose on the rentier states' path towards energy transition, through applying them to a case study on the rentier state of Iran. Aiming for the above identifications, Chapter 4 employs two steps of document analyses and Chapter 5 uses document analyses coupled with interviews, as three methodological steps towards achieving thesis objectives in identifying the path for a low-carbon energy transition in Iran-like rentier states.

In Chapter 2, the theoretical literature review on energy governance introduced governance, climate, technologies, domestic political economy, and international political economy as five domains that face research gaps relating to energy governance for sustainability transitions. The five domains are accordingly explored through document analyses and a rentier state case study on Iran, respectively in the Chapters 4 and 5 of the thesis. To achieve the thesis objective in identifying the influential factors arising from the five socioeconomic domains, it is vital that each domain be explored internationally, and in the context of rentier socio-institutions. The international phase of the thesis aims at identifying factors that each domain contains in terms of pressures for low carbon transitions at global level (Chapter 4 part a). When it comes to the socio-institutional context, the thesis approach aims at identifying factors that each domain contains in terms of resistance against low-carbon energy transitions at rentier levels. It is essential to note that the five introduced socioeconomic domains are not isolated, but co-related and interactive. Therefore, it is necessary to interpret their interconnections and dynamics.

2. Breakdown of the Methodology Steps and Approaches

The thesis employs three methodological steps to explore the five domains, which include: literature and document analyses (exploring influential domains on energy transition at international and rentier levels broadly), and, applied in the context of a case study of Iran, document analyses and interviews. The interviews are integrated with the case study in Chapter 5. Altogether, the three methodological steps pursue a multi-level perspective framework for accumulatively identifying the socioeconomic and ecologic [e.g. climate] factors that would collectively influence the rentier states' path for decarbonizing their energy system and economy.

2.1 Steps One and Two (Chapter 4 - Parts a and b): Literature/Document Analyses

Chapter 4 employs literature and document analyses as method for exploring a group of influential domains on energy transition at international and rentier levels. The literature and document analyses consist of two phases. Phase 'a' of the Chapter 4 serves the thesis' socioeconomic approach in identifying international landscape conditions over transitioning to a low carbon economy. This phase analyzes the findings from literature and documents in the socioeconomic and ecological contexts, where the influential factors that pressure for low carbon energy transitions are identified at international level. Phase 'b' identifies energy regime conditions in the rentier states under the five domains of the study. This phase analyzes governmental and academic documents as well as energy and transition literature in the socio-institutional context of the rentier states in the MENA region, where energy related-regime conditions are identified at rentier level.

Moreover, both phases use statements of propositions [i.e. premises] for serving the thesis objectives in terms of identifying interconnections within the identified factors at the same level. This includes the interconnections within landscape factors at international level, and the interconnections within regime factors at rentier level (not the multi-level regime-landscape dynamics). In other words, thesis premises highlight the literature and document findings about same-level interconnections, to identify how a set of landscape/regime factors in one domain may indirectly influence the path for energy transition through creating/influencing fellow landscape/regime conditions in the same domain, or another domain. In the pursuit of the above objective, document analyses follow a deductive content approach, where the findings from each domain are extrapolated in the context of their influence on energy transition in the fossil fuel exporting developing countries [i.e. rentier states].

Finally, the dynamic approach is reflected in Chapter 5, which identifies the multi-level dynamics of the landscape-regime interactions in a rentier-context case study on Iran. Table 3 exemplifies a group of literature and documents that have contributed to the thesis' analyses relating to each five domains at international and rentier levels of the literature and document analyses.

Table 3: Examples of material contributions to literature and document analyses in Chapter 4

Levels / *Domains*	**International Landscape Identifications**	**Rentier Regime Identifications**
Governance	None*	Boukhatem (2022), Beblawi and Luciani (1987 & 2015), Tagliapietra (2019), Nakhle (2020)
Climate	Cowern (2018), IPCC (2013), Jhun et al. (2015), Lammel & Graßl (1995), Roberto F. Aguilera, & Roberto Aguilera (2012), Taheri et al. (2022), Thompson et al. (2016), United States Environmental Protection Agency (2023), United States Environmental Protection Agency (n.d), National Iranian Steel Company (2020)	Boukhatem (2022), Lamb & Minx (2020), Sofuoğlu & Ay (2020), Waha et al. (2017)
Technology	Ansari & Holz (2020), Cherp et al. (2011), Fouquet & Pearson (2012), O'Connor's (2012), Solomon & Krishna, (2011), Sovacool (2011) & (2016)	Boukhatem (2022), Farnoosh et al. (2014), Mezher et al. (2015)
Domestic Political Economy	Arent et al. (2017), Foster et al. (2017), Gibbins & Chalmers (2008), Hong et al. (2023), Springmann (2012), Howarth et al. (2014), Sinn (2008), Jewell et al. (2018), Li & Sun (2018), Lin & Li (2015), Monasterolo and Raberto (2019), Newell and Mulvaney (2013), Schwanitz et al. (2014), Sovacool (2011), Steg et al. (2015), Van de Graaf & Verbruggen (2015)	Al-Sarihi and Cherni (2023), Ansari and Holz (2020), Azadi et al. (2016), Boukhatem, (2022), Iranian Fuel Conservation Company, (2016), Lamb and Minx (2020), Mercure et al. (2018), Nakhle (2020), National Iranian Steel Company (2020), Rahimdoust (2021), Tagliapietra (2019), Wittmann (2013)
International Political Economy	Arent et al. (2017), Cherp et al. (2011), Hong et al. (2023), Krane (2018), Springmann (2012), Sovacool and Florini (2012), Van de Graaf and Verbruggen (2015), WTO 1994: Preamble, emphasis added, WTO 1996, a: 20	Boukhatem (2022), Nakhle (2020)

**Given the fact that the domain of governance is inherently an internal domain, general perspectives of governance are covered by theoretical literature review on energy governance, as reflected in* Chapter *2 (as the pre-step of research methods for building the research framework). Thus,* Chapter *4 omits the domain of governance at the international level (phase a) of analysis for later discussing it at the rentier-level analyses (phase b), where the regime factors of energy governance are explored in the socio-institutional context of the rentier states.*

2.2 Step three (Chapter 5): Case Study and Interviews

On its final step, the thesis employs a case study - as a research approach - for applying the identified landscape and regime factors to the real-world context of a rentier state. The case study allows for identifying the impacts of global landscape conditions on a rentier state to examine rentier regime responses to such landscape conditions. The MLP framework is employed for analyzing the interplay of the landscape and regime factors and their influence on the path for the niche-initiatives to decarbonize the energy system and economy in the rentier state case of study, which is represented by Iran.

The case study, as the broader research approach of this step, uses two methods including:

(a) Iran related document analyses and,
(b) interviews.

(A) Iran related document analyses

The Iranian case study integrates the socioeconomic context of universal landscapes over energy decarbonization into the socio-institutional context of energy governance in rentier regimes. The case study begins with analyzing Iran's regime conditions in the realms of governance, climate, energy technologies, domestic political economy, and international political economy. Iran related analyses cover a wide range of academic and non-academic documents such as Iranian ministerial publications, industrial and parliamentary reports, and governmental data sheets. The documents have been explored for from: Portals of the Iranian departments of power, Petroleum, and Environment, Tehran Chamber of Commerce, Industries, Mines and Agriculture, British Petroleum (BP) review of countries' energy outlook, the United States Energy and Information Administration (EIA), International Energy Agency's (IEA) state profile, Iran's Intended National Determined Contributions (INDC) submitted to the United Nations' Framework Convention on Climate Change (UNFCCC), the Paris Agreement, and the OPEC reports about members' energy profiles.

A primary aim for employing document analyses in the Iranian case study is to discover interconnections between the regime factors [identified in Chapter 4, phase (b)] at the country-level study of Iran. Moreover, the Iranian document analyses identify Iran-related sanctions as exceptional landscape conditions that are exclusive to Iran. That said, Chapter 5 enables an increasing resolution for identifying the interplay of the globally common (Chapter 4-part a), rentier common (Chapter 4-part b), and Iran-exclusive (Chapter 5 [e.g. sanctions]) MLP factors, and their influence on energy transition in the rentier states. To that end, the thesis employs a deductive content analysis approach, where the focus is set on the factors' collective influences on Iran's path towards decarbonizing its energy system and economy, as a real-world context for the rentier states.

(B) Interviews

The other method used in the case study is conduction of semi-structured interviews. At this point the research integrates findings from the document analyses with interview data retrieved from former governmental officials whose expertise relates to the energy sector in Iran. Interviews allow the real world-perspectives of the experienced ex-officials to support the validity of the findings from the academic analyses. Also, discussing the regime-landscape interactions in the Iranian context, the interviews compensate for the shortage of exclusive documents and data on the Iranian perspectives for energy transition. The interview questions also provide an opportunity for integrating Iranian former officials' viewpoints about barriers to, and initiatives for a low-carbon transition in Iran with findings from document analysis. The integration contributes to validating the research findings from multi-level perspectives.

Interviews conducted for the above purposes were semi-structured. They present categorized groups of questions about influences from the five socioeconomic domains of interest on energy governance and transition in Iran. "A primary benefit of the semi-structured interview is that it permits interviews to be focused while still giving the investigator the autonomy to explore pertinent ideas that may come up in the course of the interview" (Adeoye-Olatunde and Olenik, 2021, p. 1358). Moreover, the semi-structured interviews support receiving unique standpoints of the Iranian officials, instead of stopping at document derived-interpretations about energy transition in the rentier state. The interviews are conducted through one-on-one online meetings, calls, and questionnaires. The recruitment process of the interviewees was done through non-probability purposive sampling [see Figure 3] (Adeoye-Olatunde and Olenik, 2021).

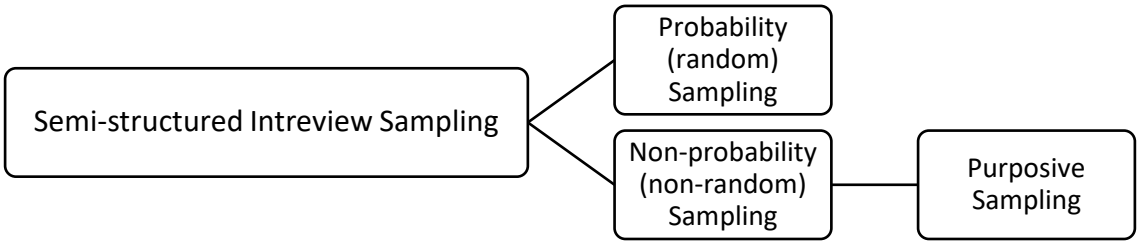


***Figure 3**: Recruitment Sampling of the Semi-structured Interviews*

The total team of the recruited interviewees includes five former Iranian officials with governmental experience and expertise relating to the five socioeconomic domains of the research. Particularly, the interviewees are former senior officials from the Iranian offices of:
the Vice-president in Legal Affairs, the Vice-president in Science and Technology, the Ministry of Petroleum, the Ministry of Power, and the Ministry of Foreign Affairs.

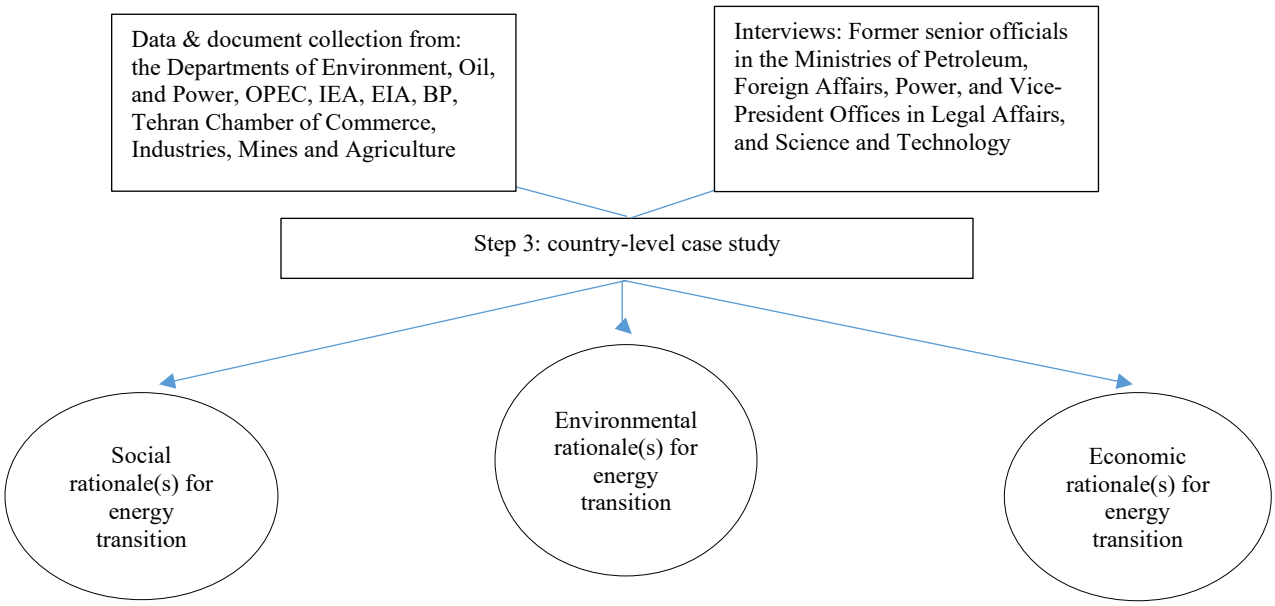


Figure 4: *Methods and subjects of research in step 3*

2.2.1 How is the Interview Data Synthesized in the MLP Framework for Responding to Thesis Sub-objectives at National (Case Study) Level?

The interview questionnaires consist of the same domains of questions in line with the five socioeconomic domains of the study, as identified in the step 2 (Chapter 4) of the research methods [including document analyses part (a) for landscape factors, and (b) for regime factors]. The interview questions apply multi-level perspectives of the identified factors to the Iranian context, identifying their influence on the rentier state's path for energy decarbonization. To that end, the contribution from interview data is through providing opportunity for analyzing interactions between the already identified regime and landscape factors at international and rentier levels, at the country-level of Iran. Given the fact that no active niches were found in Iran, the study explores niche perspectives in terms of potential initiatives that may develop into support policies for energy decarbonization, prospectively (e.g. political economy initiatives of subsidy withdrawal from hydrocarbon resources). To that end, the interview questions provide the MLP framework with qualitative data on initiatives for energy decarbonization - referred to as niche-initiative - by questioning about the initiatives' effectiveness for facilitating a path for decarbonizing the energy system and economy in Iran. The questions also inquire about the interconnections between the five domains, which are analyzed through propositions of document analyses (i.e. premises in Chapter 4), as explained in the step 2 of the research methods. Accordingly, the process for analyzing the interview data resembles a deductive content analysis where the findings from document analyses are extrapolated in the light of

former officials answers – who have real world experience in Iran's energy sector. This helps with realistically envisaging – not designing – a path for energy system decarbonization.

Additionally, the interview data provides information about distinct regime conditions in the socio-institutional context of Iran. Feeding Iran's socio-institutional information into the MLP framework allows to recognize and analyze the MLP dynamics within and between the Iranian-context regime factors and the globally identified landscape conditions (such as dynamics between the landscape condition of international climate tariffs and Iran's fiscal reliance on exporting carbon-intensive commodities). Analyzing such dual-scale (Iran's local versus global scale) interactions contributes to discovering potential strategies – including a range of positively joining versus negatively resisting options – that Iran can exert in response to the international climate actions for decarbonizing energy systems and economies. Moreover, and from a domestic viewpoint, the interviews cover data for identifying Iran's strategy options in response to governing a group of sub-niche-initiatives, sub-landscape conditions, and sub-regime factors (that may arise from the influential factors under the five domains of the study) towards implementing a sustainable energy transition. The above identifications contribute to clarifying how Iran's potential approaches for energy transition correlate (e.g. align or oppose) with the global path for decarbonizing energy systems and economies, based on the MLP lenses. Recognizing sustainability governance over Iran's potential responses to global decarbonization, the socio-economic and environmental aspects of each possible response are examined by interview questions, which are grouped based on the five domains of the study.

Figure 5 illustrates a conclusion on the three steps of the research framework and methods for achieving the thesis objectives in terms of identifying the MLP factors, their interconnections, dynamics, and influences over the Iranian path towards decarbonizing their energy system and economy.

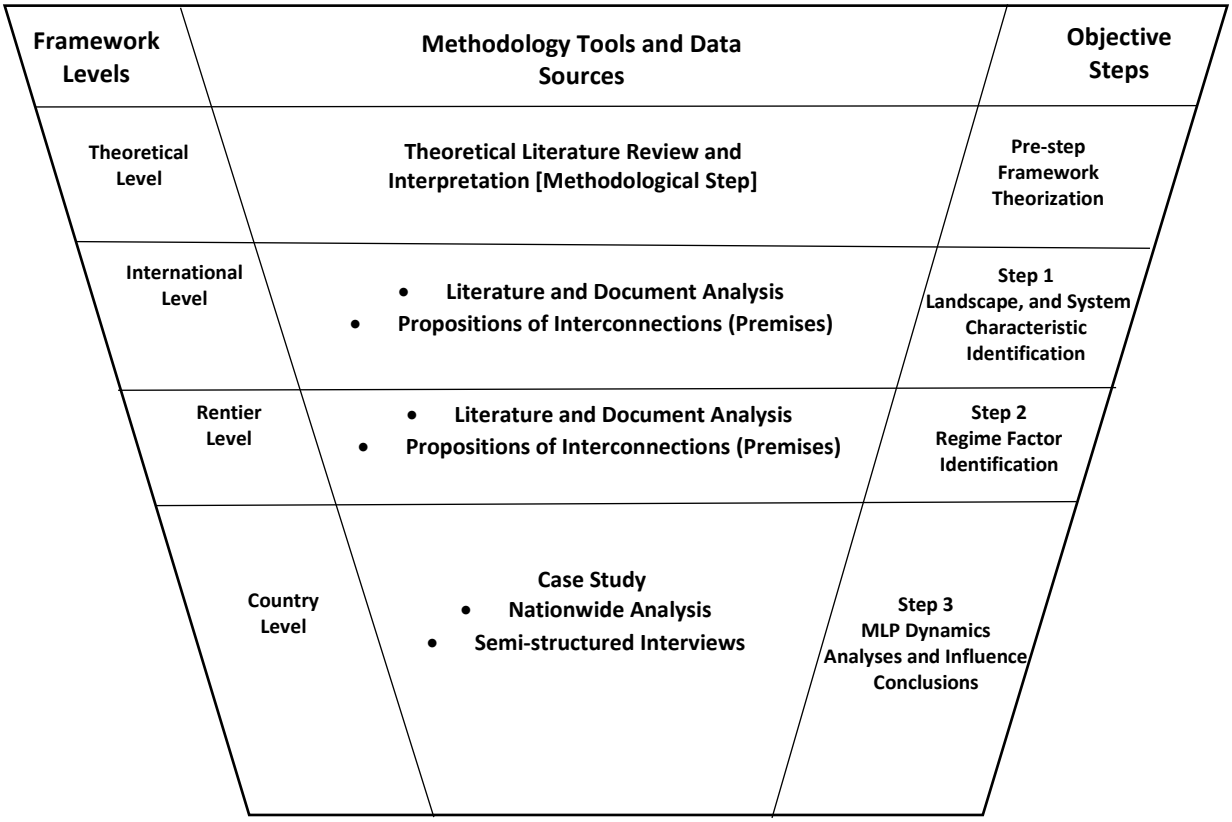


Figure 5: *Respectively narrowing focus of the methods and objectives throughout the framework.*

3. Research Restrictions

As this research required interviews with former Iranian officials in internal and international governmental affairs, there have been risks for interview requests being rejected. That said, one of the purposively recruited interviewees, who refused to sign a consent form, was replaced by another interviewee.

Furthermore, the interview phase of the research was postponed following the process for ethics application and approval at university level. To that end, the ethics application coincided with the Covid-19 pandemic, which required a considerable time to be spent on the application preparation and approval due to covid related health concerns. Despite preparing all the safety plans and having them approved by the responsible university office(s), the interviews were eventually conducted remotely. As for the interview shortcomings, one important case is the exclusion of private sector actors from participation. To that end, all the interviewees are categorized as former governmental officials. The shortcoming [of missing the perspectives of Iran's private sector on energy transition governance] is however compensated for by broad levels of document analyses at universal and regional levels, as conducted in advance of the Iranian case study.

CHAPTER 4

Document Analysis

This chapter consists of two Parts. Part (a) explores the socioeconomic context of the next four domains that involve energy transition, beyond the already explored domain of governance in the CH2. The four domains include climate, technology, domestic political economy, and international political economy. International factors that encourage a low carbon energy transition are identified under each domain. Part (b) explores the same domains aligned with the domain of governance in the socio-institutional context of the rentier states in the MENA region. Key factors that resist/direct energy transition in the MENA rentier states are identified under each domain in Part (b). The identifications will be later applied to the Iranian case study in the CH5.

Introduction

The theoretical literature review of energy governance in Chapter 2 introduced five socioeconomic domains that involve energy transition. These domains need to be explored so that the influential factors they include are identified. The term 'influential factors' in this thesis refers to those that influence the path for energy transition to a low-carbon economy. The objective for identifying influential factors arises from the theoretical enquiries of knowing 'what influences energy transitions?' and 'what to govern for a sustainable energy transition?'

Van de Graaf and Colgan (2016) underline five energy related themes with respective research gaps for governing energy systems [Chapter 2]. These themes are: "good governance", "environment", "economic development", "energy security", and "international security". As elaborated by the literature review, the parallel gaps include five socioeconomic domains around: 1) Sustainability Governance 2) Climate 3) Technologies 4) Domestic political economy of energy, and 5) International political economy of energy. Exploring the above domains in the realm of transition is a vital step toward identifying key factors that influence a path for energy transition universally, including in the rentier states.

When exploring the socioeconomic contexts of the domains, certain factors impose different types of influences (as niches, landscapes, and regime factors) in terms of pressuring for, or resisting against a low-carbon energy transition. The first part of this document analysis focuses on identifying socioeconomic factors that encourage (pressure for) decarbonizing energy systems at global level. However, it also discusses universal system characteristics and niche-initiatives that are potentially responsive to the landscape factors identified. Accordingly, this part of the document analysis omits the domain of governance - which exclusively and inherently relates to socio-institutional context of energy transitions at country level - and begins the analysis with the domain of climate. Thereafter, the second part of the document analysis focuses on regime factors that resist energy transition in rentier socio-institutions. All of the identified factors, including global landscapes, system characteristics, and rentier regime conditions will be later applied to a country level case study on Iran, which represents a real-world context for the rentier states [Chapter 5]. The country level study allows for conducting a dynamic MLP analysis of interactions between the landscape and regime factors, to identify their collective influence on the rentier state's path for energy system and economic decarbonization.

Part A – Identifying International Factors in the Socioeconomic Context

1. Domain of Climate

The energy sector's reliance on hydrocarbon fuels has been a major driver of emissions that cause climate change and endanger public health. According to the International Energy Agency (2023), GHG discharge from fuel combustion exceeded 41.3 giga tons of carbon dioxide equivalents in 2022, hitting 89% of the total emissions released from the energy sector. The other climate-derived landscape condition is air pollution, which happens under the release of toxic emissions when fossil fuels are combusted. Unlike the GHGs' global effect, air pollution is a local landscape condition, which pressures the public health.

An integrative climate policy for transitioning to low-carbon energy can mitigate both GHG and air pollution conditions. More interestingly, there are models that indicate the costs for GHG mitigation may be offset by the co-benefits from air pollution mitigation under an integrative energy transition to low-carbon energies (Saari, 2015; Thompson et al., 2016). The compromise would encourage globally long-term climate actions with local and short-term benefits.

Sub-sections below elaborate on the global warming and health endangering emissions as two climate-derived landscape factors that encourage decarbonizing energy systems. As studies suggest, GHG emissions pressure for a timely decarbonization that keeps up with the tipping points of climate change mitigation. On the other side, decarbonization also reduces air pollution, which provides co-benefits in preserving human health and saving spendings on healthcare.

1.1 GHG Emissions and Energy Transition

Timing dynamics of transitions are subjective. To this, indicator settings (*what and when to count for a transition?)* are key to determining the status of a transition (Sovacool, 2016). Concerning *climate-derived* transitions to non-GHG-intensive energies, atmospheric accumulation of energy related-GHGs is an important indicator for assessing the transitions progress. The warming impact of the GHGs, however, is a variable of time. Particularly, different GHGs cause varying warming impacts when considered in different timespans (e.g. in 30 years or 70 years), because not all GHG compositions trap the same amount of solar heat, nor all of them last for the same duration in the atmosphere. To that end, each GHG emission has a time-variable Global Warming Potential (GWP) that indicates severity of its warming impact compared to the warming impact of CO_2 over a specific timespan (Howarth et al, 2014).
Below section exemplifies how the GWP aspect of the GHGs functions, and how it influences the path for a sustainable energy transition.

1.2 GWP Influences on Temporal Aspects of Energy Transition (CO_2 and CH_4 examples)

For example, while methane triggers severer warming impacts than CO_2, atmospheric lasting time of methane is only twelve years whereas the CO_2 stays stable for a hundred years or more (Howarth et al., 2014). In accordance, "at the 20-year timescale, total global emissions of methane are equivalent to over 80% of global carbon dioxide emissions [in terms of their global warming impact]. And at the 100-year timescale, current global methane emissions are equivalent to slightly less than 30% of carbon dioxide emissions" (Howarth et al, 2014, p. 54). Therefore, the temporal aspects of GHGs' GWP would influence favorability of fuel choices for energy transition in terms of keeping up with the tipping points of climate change mitigation. This is because each fuel emits varying mixtures and intensities of various sorts of GHGs when combusted. For example, liquid oil causes more shares of CO_2 than natural gas, while NG facilities leak considerable shares of methane emissions. In other words, "the time frame over which we compare the two gases is therefore critical, with methane becoming relatively less important [in warming impact] than carbon dioxide when the time-scale increases" (Howarth et al, 2014, p. 52). Accordingly, some scholars mention advantages for natural gas as a transitional fuel against climate change by citing quantitative models such as Global Energy Market (GEM) concerning 50-100 year time terms (Roberto F. Aguilera, and Roberto Aguilera, 2012). However, another group of scientists confidently deny any transition potentials for natural gas. This group emphasize on disastrous warming impacts from natural gas in 20-year time scale, which they believe is a temporal tipping point (deadline) for addressing the global warming (Howarth et al., 2014).

1.3 Other GHG Emissions (SO_2 and SO_X)

SO_2 and NO_X are other emission species that contribute to landscape conditions for atmospheric warming, which are highly released through extreme combustion of fossil fuels such as natural gas (National Iranian Steel Company, 2020). The SO_2 has a negative GWP in lower stratosphere. Yet, it is considered as an indirect greenhouse gas due to the restrictive impact it makes on the atmospheric capacity for oxidization. The SO_2 reacts with Hydroxyl (OH), which is one of the three primary atmospheric oxidants that are consumed for the removal of GHGs (e.g. CO and CH_4) from the atmosphere. The OH is very short-lived, thus exists by limited volumes. Hence, the more OH is consumed for SO_2 oxidization, the less OH remains available for the removal of the very global warmer CO and CH_4. A similar correlation happens between SO_2 and Ozone (O_3). Ozone is the primary source for OH. Ozone is also another one of the short-lived oxidants in the atmosphere. SO_2 reactions with Ozone and OH therefore provide room for the GHGs to escape oxidization and continue with their warming effect (Ward, 2009). Nevertheless, SO_2 may cause a cooling effect too if injected into lower troposphere through a controversial geo-engineered process (Cowern, 2018), which remains out of the scope of this research.

The other group of parallel emissions that are co-produced through the utilization of fossil fuels (e.g. natural gas) belongs to NO_X species. NO_X molecules have the ability of absorbing solar infrared energy, with global warming potentials of 30 to 33, and 7 to 10 respectively in 20- and 100-year time frames. NO_X contribution to the configuration of Ozone at tropospheric levels is a predominant driver of its (indirect) global warming impact (Lammel, & Graßl, 1995).

1.4 Non-GHG Emissions (Air Pollution)

Notwithstanding the climate benefits and negatives, there exist further emission related-influences following choosing a particular energy carrier as transitional fuel. Such influences may pressure governments' favor regarding technological aspects of the path they seek for transition. Mitigation or escalation of air pollution is one of these influences, which must be taken into account prior to implementing a vast transition to a new energy carrier.

For example, SO_2 is one of the toxic species that is released in high quantities when combusting specific types of fossil fuels - such as Diesel, Mazut, gasoline fuels – as used in power and transportation sectors (Iran Energy Balance Sheet of 2021-2022, 2023). SO_2, however, pressures the local public health by increasing vulnerabilities of people with asthma. SO_2 emissions also threaten the environmental health by participating in reactions that produce particulate matter (PM) pollution and other forms of toxic SO_X compositions. Some SO_X compositions and PMs are recognized as dangerous for the humans' respiratory organs. (National Iranian Steel Company, 2020; United States Environmental Protection Agency, 2024).

Another pollutant co-product of fossil fuels combustion is NO_X. Notwithstanding its climate effects, NO_X counts as air pollution if accumulated near the earth's surface. Although excessive NO_X reacts with and removes Ozone during the nighttime when the sun light is absent, NO_X leads into formation of Ozone under solar radiation during daytime. Near earth Ozone however is an environmental pollution due to risking humans' immune system and potentially leading to chronic lung diseases (Jhun et al., 2015; Taheri et al., 2022; Lammel, & Graßl, 1995; United States Environmental Protection Agency, n.d; Thompson et al. 2016).

Concluding on the above discussions, SO_2, SO_X, NO_X, and near earth-Ozone are four co-products of fossil fuel combustion that impose landscape conditions on human's environmental health, which are paralleled with the GHGs' pressure for global warming. The above climate factors, therefore, collectively encourage phasing out of the fossil fuels.

1.5 Integrative Climate Policy

Whether it's to address global warming or local air quality, transitioning to clean energy is a potential solution to mitigate harmful emissions. This is because fossil fuels mutually produce both the Greenhouse and non-Greenhouse gas emissions. In order to integrate the two mitigation objectives, however, it is necessary to distinguish between natures of the-Greenhouse and non-Greenhouse gasses, temporally and spatially (Thompson et al. 2016).

GHGs influence the climate over mid and long terms [e.g. decades to centuries]. Their influence is imposed following their atmospheric accumulation, and regardless of their point of origin. Subsequently, mitigating GHGs over one continent could contribute to the climate continents away, and globally. On the other side, non-Greenhouse emissions risk their local/regional environment over short term [e.g. hours to days]. Their impact is enforced based on ground level accumulations, and sometimes through the formation of secondary pollutants [e.g. NO_2 role in sourcing ground level Ozone pollution] (Thompson et al. 2016).

That said, mitigation of non-GHG species (e.g. NO_X and SO_X compositions that are co-emitted following the combustion of fossil fuels) reflects local benefits (Thompson et al.'s, 2016) from energy transitions that aim for mitigating the climate change. The dual objectives, however, had better be pursued under one comprehensive climate policy as suggested by Thompson et al.'s (2016) United States Regional Energy Policy (USREP) modelling of "Cap and Trade" (CAP) and "Clean Energy Standard" (CES) scenarios. According to the Thompson et al, if the GHGs are caped in a limited area, non-GHG pollution may leak regionally, causing health dis-benefits elsewhere. The leakage happens through availability of excessive hydrocarbons from the caped areas, which creates low-price markets for hydrocarbons in non-caped zones.

Moreover, an incomprehensive distributional management of emissions may spawn GHG (e.g. CO_2) leakages as they do about non-GHGs pollutants. Meanwhile, not many GHGs are sensitively toxic at ground level-accumulations. Hence, GHG leakages remain acceptable as long as a net negative reduction is maintained desirably from a climate perspective (Thompson et al., 2016).

1.6 Propositions of Climate Landscape Conditions (Premise #1)

GHGs and air pollution are the by-products of fossil fuel combustion in fossil fuel-backed energy technologies, which respectively risk the global warming and the local public health. The two types of the gases are thus influential on creating landscape conditions over the global and local climate, which encourages phasing out of fossil fuels as the mutual source for both types of the gases. Accordingly, an integrative climate policy that mitigates both emissions will benefit from offsetting the costs for climate change mitigation, at global level, by local benefits from healthcare savings through air quality improvement (Thompson et al., 2016; Saari, 2015). Such

an offset has appeal for nations who do not value climate change mitigation solely, and look for short-term revenues. An integrative energy transition for emission mitigation, however, has to recognize emissions' characteristics, the way they impact their surrounding climate, and the fuels they emanate from.

Greenhouse and non-greenhouse emissions influence the climate in different forms, which influences strategies for their mitigation. On one hand, the GHG's causation of the global warming occurs in diverse timeframes because each GHG has its own GWP value of particular. Such timeframes concern annual and decadal scales, as the warming effect happens amid long-term accumulation of the GHGs at atmospheric levels. On the other side, there are air pollutants that may or may not be categorized as GHGs. Impacts imposed from this group happen amid their temporal intensity at near ground levels (e.g. SO_2's varying impacts in the presence and absence of the sunlight). Therefore, unlike the global warming effect of the GHGs, toxic emissions pressure air quality based on local and hourly concentrations.

The above characteristic varieties of emissions challenge the climate policy for mitigating both species at the same time. For example, non-integrative initiatives such as carbon capture and removal would barely reduce non-carbon air pollution. Or on the other hand, energy saving strategies such as transferring energy subsidies toward non-peak hours of fossil fuel use (Tavanpoure Paveh, 2004; Iran Energy Balance Sheet of 2021-2022, 2023) would 'flatten' energy use peaks for pollution mitigation but leave the total daily combustion of the fossil fuels unchanged [which results in total GHG emissions remaining at unchanged levels].

Yet, there is also opportunity for climate policy to efficiently cut GHG and non-GHG pollutants in parallel through phasing out of fossil fuels. This is because fossil fuel combustion is a predominant and mutual source for both the GHG and non-GHG emissions. Thus, a transition to clean energy would efficiently benefit both the global climate and the local health agendas. As studies underline, climate change mitigation can be expensive; and health revenues from pollution mitigation contribute to compensating for the expenditures on carbon mitigation (Saari, 2015).

The above co-benefits seem most relevant to the rentier states who have vested interests in short-term revenues, thus, lack willingness to prioritize global warming over hydrocarbon incomes. Rentier states do not feel historic responsibility for contributing to long-term global climate actions. They doubt whether returns from such actions are sufficient to compensate for their hydrocarbon incomes. The short-term and local health co-benefits from reducing domestic emissions, however, provide these states with a nationally and financially justifiable rationale for participating in the global climate actions, by transitioning to non-hydrocarbon energy carriers.

1.7 Domain of Climate Conclusions

Despite consensus on recognizing emission mitigation as the primary motive for phasing out of fossil fuels, there has been limited elaboration on how *different* types of emissions would influence the path for transitioning to low-carbon energy. This thesis' analysis of the domain of climate identifies GWP and toxicity as two climate factors embedded in different types of emissions, which make them impose varying pressures on the path for energy transition, in terms of temporal urgency and sectoral priority.

The analysis underlines that GWP variation among the GHGs prioritizes sustainable transitions in the sectors that produce GHGs with higher GWP in short-term, responding to the urgency of the tipping points for climate change mitigation. As this study suggests, the influence from GWP variation among the GHGs is most relevant to the rentier states who access to utilizing different types of carbon-fuels, not just oil, which leads to a diverse mix of GHG emissions over different parts of their energy sector, depending on the fuel(s) each sector combusts.

The other influential factor embedded in emissions is their toxicity. The research suggests that the rentier states' diverse mix of fossil fuel utilization is expected to lead into diverse types of air pollution with varying toxicity characteristics (which is elaborated in Part (b) of this Chapter). Accordingly, the study highlights that the rentier states' energy sectors that produce highest shares of toxic emissions, with dangerous landscape conditions on human health, would receive prioritization for phasing out of the fuels they combust, from a local perspective.

In other words, GHG and toxic emissions are co-products of fossil fuel combustion, contributing to the justification of low-carbon energy transitions in air polluter sectors in the rentier states. Particularly, phasing out of the fossil fuels - in response to global warming landscape pressures – also responds to the rentier states' needs for air pollution mitigation for the preservation of the public health. Such an integrative path towards emission mitigation may help rentier states compensate for the transition costs by the benefits from pollution mitigation, through savings on the healthcare needs forced by the air pollution. Yet, rentier states risk transitioning to other fossil fuel alternatives, which are still high in carbon content.

To that end, emission analysis is conceivably hypothesized as a vital pre-step for identifying technological aspects of a sustainable energy transition. This is because different types of energy carriers trigger various sorts of emissions that influence the climate change and environmental health in different ways. Hence, it is necessary to explicate emission cut objectives that are entailed in alternative energy technologies to identify a technological path for transition. Indeed, technological choices for an integrative energy transition must be consistent with the global

warming tipping points in parallel with the needs for local air quality, for which fossil fuels combustion is a mutual source.

The above findings regarding interconnections between the climate influences and technology choices are most relevant to energy transition in the rentier states, who anticipate a transition to low carbon, rather than zero carbon energy, with their fossil fuel infrastructures involved. As explained in the next section, nations – including rentier nations - face too much path dependency to their incumbent [e.g. hydrocarbon-intensive] energy infrastructures to be transitioning to a zero-emission energy system that consists of 100% renewables.

2. Domain of Technology

Greenhouse gases are emitted under various natural and human involved procedures, the paramount of which are hydrocarbon combustions entailed in the energy sector (EPA, 2024). Therefore, availability of low-carbon energy technologies, paralleled with the pressures from climate change, encourage all countries to phase out of hydrocarbon energy carriers. Additionally, other parallel influences from other landscape conditions (e.g. volatility of crude prices) are critical for amplifying a net pressure for demanding energy transition into a specific direction [e.g. to low-carbon energy alternatives]. Meanwhile, states' vested interests and developments in previous energy infrastructures (e.g. fossil fuel technologies) have been historically restricting prospective transitions to new energy systems. The below section identifies path-dependencies to the incumbent energy technologies as a system characteristic (SC) in any incumbent energy system at universal scale, which could resist the adoption of new energy technologies, or direct the path for transitions to specific directions led by the path-dependencies.

Moreover, below analysis of the domain of technology elaborates on the diffusion of the low-carbon energy technologies from the niche stages to delivering systematic transformation by studying the Brazilian experience of transition from gasoline to ethanol. To that end, the study identifies emergence of the low-carbon energy technologies as an influential MLP factor that encourages low-carbon energy transitions, both as a landscape condition and a niche element. In other words, the study clarifies that availability of the emerging energy technologies initially serves as a landscape condition that encourages energy systems to adopt the emerging technologies for transition. Once adopted, emerging technologies serve as a niche factor, pressuring for expansion from inside the system. As the study concludes, to deliver a transition successfully, niche technologies require compliance with the demands imposed by outer landscape conditions, techno-geographic requirements inside the system, and the path-dependent restrictions formed by the incumbent energy technologies.

2.1 Systematic Transition (Upstream and Downstream)

Energy transitions are path dependent and non-linear (Solomon & Krishna, 2011; Cherp et al., 2011). Even though they end the dominance of incumbent fuels over the energy system in terms of shares, consumption from ex-regime fuels continues to grow in terms of total volume (see Figure 6). Consequently, a prospective transition toward renewable energy may potentially happen in conjunction with continuous, albeit slowed, surge in fossil fuels use and demand (Fouquet & Pearson, 2012). While this conjecture illustrates the non-linearity and path dependency of energy transitions [chiefly derived by stranded incentives and assets in energy related industries], it reveals a threat under which the world might never become emission free if previous transition patterns are followed (Collective interpretation from Ansari & Holz, 2020; Fouquet & Pearson, 2012; Solomon & Krishna, 2011; Cherp et al., 2011). However, this remains as an "if" as there is no common law for energy transitions to follow.

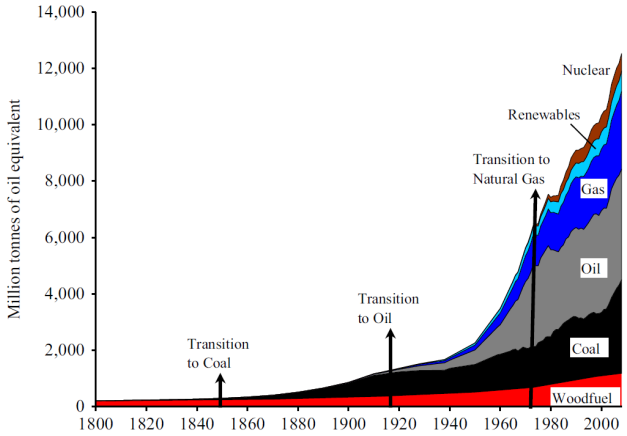


***Figure 6**: Path dependency and non-linearity of energy transitions (Fouquet 2009) – As cited in [and adopted from] Fouquet & Pearson (2012, p. 2)*

Technological transitions may initiate from end use energy products at niche-level and expand later to transform energy resources, carriers, and converters (O'Connor, 2012, as cited in Sovacool, 2016) over the energy system. Brazil's replacement of gasoline with ethanol in response to 1973's oil-embargo (Sovacool, 2011) exemplifies a downstream based (demand side) niche transition that later expanded towards the upstream (supply). Reviewing the Brazilian experience helps with identifying the path for the diffusion of the low-carbon energy technologies, from niche stages in downstream towards delivering a systematic change [transition] in the broader energy system from an MLP perspective. Below discussion regarding the Brazilian experience is conducted in two steps. Step one describes the Brazilian transition path, and step two identifies lessons that can be generalized about the influence of emerging energy technologies for delivering a systematic energy transition.

2.1.1 Step 1: Emergence of Ethanol Fuels and Brazilian Governance of the Landscape Condition

The geographic ability of ethanol production through sugarcane harvesting allowed the Brazilian government to support emergence of the ethanol fuels through a scheme based on two principles: (1) an obligation for gasoline [incumbent] fuels to contain ethanol by at least 10% [low-carbon alternative], and (2) an initiative recommendation to the vehicle factories to voluntarily design conveyances that work with 100% ethanol. Resulting from this partnership between the Brazilian public sector and car manufacturers (i.e. public private partnerships), the ethanol production surged from 220 million litters in 1974, to 2.8 billion in 1979, in a quick period of 5 years within the schemes' phase 1 (Sovacool, 2011).

After deploying financial incentives and in the second phase of the scheme, the number of neat-ethanol vehicles reached 5 million by 1984. The expansion thus transformed other layers of the Brazilian energy system, including energy access, distribution, and production, respectively in the down, mid, and up stream. As for the accessibility services, the majority of the fuel stations in Brazil began selling pure ethanol or ethanol-gasohol blends. Concerning energy distribution, traditional gasoline carriers [e.g. pipes] were equipped with affordable pumps for transporting ethanol. Considering the upstream energy supply, ethanol gas penetrated the onsite [decentralized] power plants in Brazil, which later expanded and transformed the Brazilian electricity sector into a less centralized, less carbon intensive, and more diversified [in terms of fuel combustion] system (Sovacool, 2011).

The above *technological transitions* later transformed the international and domestic political economy of the energy sector in Brazil, and the environmental externalities entailed. Concerning the international political economy, Brazil gained more savings and independence from foreign oil imports, while growing partnerships with global market car manufacturers (e.g. Ford, Volkswagen) for designing ethanol vehicles. Domestically, the national assets in Brazil's sugarcane agriculture industry surged. The surge, however, was accompanied by soil and land use distortions, which required further environmental monitoring. From an emission perspective, sugarcane harvesting contributed to climate change mitigation through natural carbon capture by sugarcane farmlands, however, the harvesting also risked air quality by releasing particulate matter pollution (Sovacool, 2011).

2.1.2 Stage 2: Diffusion of Emerging Technologies into System Transitions (Lessons)

As the Brazilian experience points out, states' willingness for developing alternative technologies within their energy system is influenced by outer landscape conditions. To that end, the Brazilian government already suffered from the volatility of hydrocarbon prices in 1973, which was an outer landscape that had pressured Brazil's transportation sector under increasing gasoline

expenditures. Amid considering alternatives for gasoline, availability of sugarcane-to-fuel (ethanol) technologies was a secondary landscape that encouraged the government to transition from gasoline to ethanol fuels. The transition however did not stop at the downstream level for fuel consumption, rather transformed the Brazilian chains of energy supply and use over the up and down streams of the energy sector, including for transportation and power generation.

Energy sector is distributed over three chains of production (upstream), conversion and transmission (mid-stream), and consumption (downstream). Accordingly, a technological transition to low-carbon energy system is perceived to transform all the three layers (Cherp et al., 2011). Such multi-layer transformations are evident in the Brazilian energy transition, which initially began from the downstream. To that end, the magnitude of shifts from gasoline to ethanol encouraged corresponding transitions in gas stations to utilize ethanol for distribution at country level. Eventually, expansions of ethanol consumption transitioned the regime of fuel supply in Brazil, from importing gasoline to developing sugarcane farmlands - as a new upstream – to provide the transportation and power sectors with ethanol fuels to consume. Accordingly, the study of the Brazilian transition clarifies how transitional technologies diffuse from downstream levels to upstream from a multi-level perspective point of view.

The Brazilian path from gasoline to ethanol also provides guidance on multi-domain interconnections that are involved in technological transitions. Brazil's transition to ethanol did not stop at the technological domain of transportation fueling, but reverberated through governance mechanisms, political economies, and environmental externalities mandated by the new system. As for the governance perspective, initiatives for public private partnership relatively faded out Brazil's sole authorization of the energy sector, by allowing private actors in agriculture industry to support the country's energy supply by sugarcane as a raw energy material. From an economic perspective, the partnerships opened new opportunities for Brazilian businesses to cooperate with international companies in developing low-emission vehicles and trading relative technologies. The ethanol transition also influenced techno-environmental correlations of the energy system. On one side, reducing the use of gasoline by conveyances helped to mitigate GHGs in the transportation sector. Expansion of sugarcane farmlands also added to natural capacities for carbon capture. Yet, these positives were achieved at the cost of land use distortions for developing sugarcane agriculture, which by-produced particular matters as a recognized air pollution. The Brazilian study confirms the idea advanced by Cherp et al. (2011) about energy transition's ability of nurturing techno-geographic interdependencies and weakening individual states' capacity for self-regulating energy systems.

2.2 Propositions of Technology (Premise #2)

The above analyses of the domain of technology highlights four types of interdependencies that influence technological aspects of the path for energy transition through MLP lenses. First, the study confirms that the favorability of transitional technologies depends on the technologies' intrinsic characteristics, and their advantages compared to technologies that dominate the incumbent system. Such advantageousness is weighted based on stakeholders' preferences to energy related qualities (e.g. energy security, carbon intensiveness), which can change over time under the influence of outer landscape conditions (e.g. price fluctuations, climate change). Secondly, the diffusion of niche-technologies into broader energy system is also path-dependent to techno-geographic characteristics of the incumbent system. The more consistent niche-technologies are with the techno-geographic conditions and today's requirements of the system, the higher chance they would have to be substituted for older technologies. Similar to the energy stakeholders' preferences, the geographical conditions of the system may change under the influence of outer landscapes.

Third, older technologies are influential on shaping the technological conditions of the incumbent energy system, in which transitional technologies must emerge. In other words, energy transition to new technologies is also path-dependent [directed] upon conditions created by the incumbent regime technologies. The study confirms the above finding by clarifying how the existence of incumbent gasoline infrastructures (pipelines, stations, fuel-based cars) allowed for a transition to gasoline-ethanol blends to happen through the integration of ethanol-friendly technologies for transition diffusion (dual-fuel cars, ethanol pumps). As Sovacool (2016) also confirms, the rise of an energy technology within a system may depend upon, or correlate with, another technology —meaning it can be a mistake to identify or analyze the emergence of a transitional energy technology on its own – separated from the incumbent technologies that dominate the system.

Lastly, interpretation of the drifts between pre- and post- transition trends (Figure 6) suggests that changing shares of energy types are not influenced by transitions under the same ratio; rather they variably depend on the dynamics between intrinsic characteristics and extrinsic conditions of the niche-technologies and their coevolving system. Intrinsic characteristics include the socio-technical features of the technology choices, and their level of compliance with socio-ecologic conditions in the system that would host them. The intrinsic characteristic include cost, ease of use, and affordability on the technology side. Additionally, availability of resources and conditions in the hosting system are the extrinsic characteristics of the hosting system that niche-technologies must possess consistency for a successful diffusion. For example, there exists limited area of cultivatable land for sugarcane harvesting, or rivers for hydropower generation. Yet, the above restrictions do not apply to the photovoltaic source of energy with unlimited solar radiation. Therefore, solar energy may gain extra favorability compared to

hydropower in arid areas with permanent daytime solar radiation. In contrast, technology cost for electricity conversion and saving is a restrainer parameter in solar technologies, which may cost them favorability compared to combustible fuels in hydrocarbon rich countries. Yet, technology access and ease of transferability are not the same among all combustible fuels, such as between oil, coal, natural gas, and ethanol-gasohol. In addition to the system's internal factors (e.g. niche-factors and system characteristics), landscape factors such as emergence of advantageous alternative energy sources, encourage energy mix share alterations through providing extrinsic pressures for energy transition. Therefore, the energy-mix alterations deeply rely on the adequacy of characteristics between niches, landscapes, and regime conditions. Indeed, depending on how those characteristics respectively interact and respond to de-escalate the conditions imposed by landscape factors, each of the technology options receives a distinct reason for favorability. For example, while the outer landscape of climate change encourages prioritizing a transition away from fossil fuels towards low-carbon energy technologies, a landscape of war or financial sanction would do vice versa against a hydrocarbon rich country that needs to import the low-carbon facilities (e.g. solar) if aiming for such a transition.

2.3 Conclusions

As the study identifies, emergence of new technologies is a landscape factor that pressures energy systems to adopt the emerging technologies as niche-surrogates for the incumbent ones. The success of such an adoption, however, is path-dependent on socio-technical characteristics of (a) the alternative, and (b) the incumbent technologies, (c) the energy system that hosts them, and (d) outer landscape conditions that may support or discourage replacing alternative technologies with the incumbent ones. To that end, the alternative technologies must present competitive characteristics compared to the existing technologies they aim to replace. Those characteristics, therefore, need to be consistent with the socio-technical capacities of the host system and its preferences. System capacity and preferences, however, are dynamic and may change over time under influence of external landscape conditions. For example, a previous system preference for affordability of energy technologies may lose its priority to criteria for climate-friendliness under the external landscape of climate change. Or, similarly, a previous system capacity for hydropower might be lost under continuous droughts following the global warming landscape impacts.

The analyses also suggest that diffusion of the alternative technologies is influenced by technical path-dependencies imposed by the incumbent technologies in the system, which would direct the path for energy transition, especially at initial stages. The Brazilian transition study supports this finding. It was the Brazil's prior path dependency on the regime of hydrocarbon technologies that promoted the ethanol-gasohol blends as transitional fuels in early phases of the transition, before a full transition to ethanol was achieved. Had the path dependencies on gasoline

infrastructures not existed, development of electric car niches might have made a better choice for completely phasing out of hydrocarbons in Brazil, concerning the oil embargo landscape conditions then. But that did not happen since niches for electric transportation were not developed as were the niches for ethanol fuels (e.g. through the availability of sugarcane harvesting), by the time the landscape condition of oil embargo intersected. A Similar path can be envisaged for the rentier states' path for energy transition from other fossil fuels (e.g. natural gas) to other low-carbon alternatives (e.g. hydrogen) to initiate from NG/hydrogen combinations and diffuse later, depending on the techno-geographic availability of those resources in the rentier states that host the transition. However, a transition from gasoline to ethanol is not envisaged to happen in an oil rich country that produces its own gasoline and lacks climate features for sugarcane production.

In conclusion, the analyses of the domain of technology reveal that emerging energy technologies do not impose a landscape condition that evolves into a successful transition in a vacuum. Rather, they need compliance with the socio-technical preferences and capacities in the host system, which are shaped by path-dependencies to the incumbent energy technologies and other landscape conditions. To that end, emerging technologies must offer advantageous characteristics that are compatible with system preferences at superior levels compared to the incumbent energy technologies. For that purpose, emerging technologies (e.g. low carbon energy technologies) need positive interconnections with other landscape conditions (e.g. global warming) that influence energy system preferences (e.g. prioritizing emission mitigation). As the study finds out, such secondary landscape conditions may draw system preferences to the qualities offered by the emerging technologies.

The above analyses of the domain of technology provides guidance on multi-domain interconnections involved in technological transitions. To that end, the study reveals that alignment of specific landscape conditions (e.g. oil embargo, global warming, and emergence of alternative energies) leads into employing governance initiatives to de-escalate such landscape conditions. The public-private partnerships between the Brazilian government, farmers, and international car manufacturers is an example of governance initiatives for de-escalating the oil embargo impacts on fuel prices. Another potential domain for implementing governance initiatives is political economy. As the next section discusses, political economy provides the states with initiative instruments and landscape pressures that encourage utilization of the low-carbon energy technologies to de-escalate global warming.

Domain of Political Economy

Political economy is another domain involved in an energy transition. The political economy of a climate-derived transition consists of domestic and international sub-domains that interact closely. As the world prepares for a carbon-constrained economy, domestic and international political-economy levers are being used for carbon pricing.

From a domestic viewpoint, subsidy removal and carbon taxation are two instruments for carbon pricing. From an international perspective, however, carbon pricing initiatives can appear in the form of climate tariffs to charge the trade of carbon-intensive products. Therefore, MLP influences of the carbon pricing depend on the socio-institutional context of the states who host them. If imposed on the rentier states, the climate tariff form of carbon pricing will pressure a landscape condition on their carbon-intensive industries to decarbonize their activities. When employed internally, carbon pricing may act as a niche-initiative for economic decarbonization inside the same socio-institution (non-rentier or rentier) that employs it.

This section identifies the above dynamics between decarbonization niche-initiatives and landscape conditions arising from carbon pricing among the developed and developing countries. The section then comparatively analyzes how carbon pricing may influence own and global pathways for energy transition, when employed/received by the above two groups of the states. To that end, the analysis reviews the prospective political economic confrontations between nations that use carbon pricing as a niche-initiative (e.g. energy importer countries) and those that receive it as a landscape condition (e.g. carbon tariffs on carbon-intensive-commodity of the rentier states). The discussion concludes that carbon pricing mechanisms may support a net positive transition to low-carbon energy globally, when accompanied by contemporary policies that recognize interests of the involved parties. Otherwise, it may lead to carbon leakage in non-carbon priced areas, which would neutralize the global efforts for decarbonization. As later indicated, such a leakage is more likely to be risked in hydrocarbon exporter developing countries (i.e. rentier states), who are more likely to encounter carbon pricing as a landscape condition, rather than employing it as a niche-initiative.

Domestic Political Economy of Transition – Niche-initiatives and Pathways

3.1 Subsidy Removal

Subsidy removal is a carbon pricing-initiative for supporting low-carbon energy transitions, but its effectiveness is questionable in the absence of additional policies (Li & Sun, 2018). According to EIRIN model outcomes (Monasterolo and Raberto, 2019), subsidy withdrawal promotes energy transition and enhances socio-economic well-being within the developed countries. However, this policy would have little influence on renewable energy production, when followed

by the lower income [e.g. developing] states (Jewell et al, 2018; Monasterolo and Raberto, 2019). Moreover, shifting subsidies from fossil fuels to renewable energy leads to less petroleum demand, thus lower (more affordable) petroleum prices. This shift eventually neutralizes the policy's objective in decreasing fossil fuel consumption (Foster et al., 2017). Such contradictory neutralization is known as the "Green Paradox Theory", introduced by Hans-Werner Sinn in 2008 (Foster et al., 2017). Contemporarily, as Schwanitz et al. (2014) also explain: "a removal of fossil fuel subsidies, if not complemented by other policies, can slow down a global transition towards a renewable based energy system" (P. 882). The reason is that de-subsidization would increase fossil fuel prices initially, leading to less demand for hydrocarbons in short term. In the long term, however, the lessened demands would consequentially decrease the value of the fossil fuels, and culminate in the low prices to resume. Therefore, de-subsidization impacts on increasing the prices would be offset by the decrease of the prices resulted from lower-demands. Affordability of non-subsidized fossil fuels therefore encourages lower-income countries to consume them, which would make low carbon technologies re-encounter a lack of competitiveness (Schwanitz et al., 2014).

3.2 Carbon Pricing

A more progressive step after the abolition of fossil fuel subsidies would be the enforcement of carbon pricing in the format of taxes and tariffs.

3.2.1 Carbon Tax

Taxing carbon-intensive commodities is one option for promoting clean energy developments. Burden of carbon tax can be distributed from the very beginning production phases of a good (on the shoulders of suppliers of the chains) to the end use phases (on the shoulders of consumers). Such distributions would foster green industrial processes (Arent et al., 2017) and green choices for suppliers and consumers. As an example, carbon tax has played a key role in Danish and Brazilian transitions toward wind energy (away from oil) and ethanol fuels (away from gasoline), respectively. The two taxation programs were relatively and equitably devised according to the citizens' consumption bulks (Sovacool, 2011).

Carbon tax regulations, however, face public inertia often (Steg et al., 2015). They weaken domestic industries relative to their foreign rivals where environmental ordinances are in lower effect. Such weakness motivates domestic firms to relocate their plants to regions where climate directives are not as restrictive. The relocation could trigger macroeconomic repercussions such as unemployment (Hong et al., 2023). Respecting either scenarios – industries relocating or non-carbon-constrained rivals outstripping – the carbon tax ability to cut net-emissions falls in doubt due to promotion of carbon leakages from inside to outside the territories that adopt climate

directives. Indeed, carbon tax may not abate global warming unless accompanied with complementary policies (Hong et al., 2023; Springmann, 2012; Arent et al., 2017) for avoiding carbon leakage [which will be discussed in the realm of international political economy].

3.2.2 Barriers to Evaluating Social Costs for Carbon

The study identifies several barriers to carbon pricing. The first challenge found against carbon pricing is valuation of the carbon contents in products. On one hand, carbon elements cause diverse global warming repercussions when existing in different compounds; for instance, the CO_2 emanated from oil combustion and the Methane (CH_4) have different global warming potentials (GWP) (Howarth et al., 2014). On the other side, newly emitted carbons may not be allocated the same price (fine) as the carbons retrieved from capturing and storage, as a decarbonization mechanism. To that end, the captured carbons face even a higher degree of controversial complexity relating to valuation. For example, Van de Graaf and Verbruggen (2015) question the value of carbon capturing by underlining that the process may "expand the use of fossil fuels in filling the permitted 'emission space', including the amount of oil that can be consumed without jeopardizing the 2C target. Yet CCS is fraught with huge uncertainty, technically, economically, and politically" (Van de Graaf & Verbruggen, 2015, p. 458).

Furthermore, accurate calculation of the social cost of carbon plays a key role in carbon pricing. But such quantification is perceived to be another difficult challenge since the marginal damage costs caused by GHGs are not explicit due to dissimilar atmospheric warming degrees of temperature (Arent et al., 2017) over the earth. On the other hand, neither the vulnerabilities nor the benefits behind such damages are evenly distributed as the map for the winners and losers, and liabilities and casualties, are unevenly expanded geographically and inter-generationally (Newell and Mulvaney, 2013; Arent et al., 2017).

3.3 Propositions of Domestic Political Economy (Premise #3)

Reviewing economic policy initiatives assists with clarifying the capabilities and pre-requisites regarding different policy instruments for effective energy transition. Carbon pricing is a fundamental political economy initiative for promoting a climate friendly economy. When it comes to domestic scales, carbon pricing is implemented through removing fossil fuel subsidies and/or issuing carbon taxes. The very basic objective of both is to support energy and non-energy products with lower carbon intensity in supply chain.

The political economy of subsidy removal and carbon taxation, however, is a dynamic and diversifying realm when it comes to different geographies over the global north and south. Economically, impacts imposed by the two differ when deployed in a fossil fuel producer country

versus in an energy importer state. Geographically, climate change damage costs are neither simply countable nor equally distributed on earth, which make carbon pricing a complex process. In accordance, identifying credibility and applicability of carbon pricing is essential for its implementation in different host regions whose people live in varying circumstances socially, technically, and environmentally.

From a national perspective, pricing carbon would not only change the price of a particular fossil fuel product of interests in a fossil fuel dependent economy. Rather, it would influence the whole circular economy involved in the product's supply chain. Accordingly, if the product priced is the very primary source of energy, it will influence the entire economy in a fossil fuel dependent system.

From an international perspective, commodities that use subsidized fossil fuels for production would lose their competitiveness in foreign markets if carbon priced. The loss would be more intensive in the rentier economies with higher indexes of fossil fuel subsidization. Yet, even if carbon pricing is not implemented by the exporters of carbon-intensive commodities at local level, it may still be enforced by their importer partners. Such enforcement can happen through local carbon pricing in the importer state. It can also occur through carbon tariffs, which impose burdens of climate action on the carbon exporters, preventing carbon leakage from carbon constrained territories into non-constrained zones.

4. International Political Economy over Transition

4.1 Carbon Tariffs

To correct taxation deficiencies in transboundary climate ruling (e.g. carbon leakage in global south) and interior economic satisfaction (e.g. losing jobs and international competitiveness), several developed countries have shown interest in tariff mechanisms (Arent et al., 2017). "Carbon tariffs induce external efficiency improvements through indirectly" regulating states that are not bound to emission alleviation (Springmann, 2012, p. 7). When employed at international level, carbon pricing pressures a landscape effect on the carbon-intensive commodities to get decarbonized.

The Border Carbon Adjustment (BCA) is one approach through which carbon tariffs can be implemented. As Arent et al. (2017) explain:

> A BCA is a tariff measure that internalizes carbon emissions into the price of a given imported product. It is, therefore, a fiscal instrument, which is used in complement of carbon emissions reduction tools, such as a carbon market or a carbon tax, and targets

> internationally traded goods. Its primary objective is to level the playing field between domestic producers facing costly climate change measures and foreign producers facing very few. (p. 61)

Carbon tariff mechanisms, however, are criticized over their potential for political tension trajectories. On one side, developed states may manipulate these tariffs for maintaining economic superiority in the name of environment. On the other hand, developing countries [including rentier states] may retaliate such tariffs, for instance by launching trade wars to retrieve their lost revenues (Hong et al., 2023). Accordingly, there are voices discouraging the global north from going too far on tariff impositions.

The World Trade Organization (WTO), through its non-discrimination principle, provides approaches for solving above-exampled tariff disputes. In the light of WTO's "most favored national treatments" based on the "General Agreement on Tariffs and Trade (GATT)":

A- National treatment (article III of the GATT) prohibits discriminatory treatment through internal taxes or other internal charges (article III: 2) between national products and foreign products that are considered like products or directly competitive or substitutable products. It also prevents a WTO member from applying a discriminatory treatment between like national and foreign products through laws, regulations, and requirements; (article III: 4) (GATT 1947: article III)

B- The Most Favored Nation treatment (article I of the GATT) requires that a preference accorded to a product originating in or being exported to a WTO member be extended to similar products originating in or destined for the territories of all other members (GATT 1947: article I). (Arent t al., 2017, p. 68)

The two legal articles restrict room for dispute trajectories by safeguarding foreign "like-products" against discriminatory tariff impositions. Yet, the two do not hinder effective carbon pricing since WTO judges assess the "likeness" of products based on several parameters, one of which is the "consumers' tastes and habits" (WTO 1996, a: 20, as cited in Arent et al., 2017, p. 68). According to this article, governments of importer nations may set tariffs on "like-products" if successfully proving that a foreign "like-product" is not meeting local cultural norms of their society in a particular matter (e.g. in respect for the environment). For example, if a government proves that climate-friendliness is a cultural norm among its society, to which an imported "like-product" is not adhering due to high carbon content, that government may be able to set a tariff on that product (interpreted from Arent et al., 2017).

Such a provision, however, does not guarantee that WTO judges are to withhold developing countries from trading non-climate friendly products. To this end, Goal 7 of the Sustainable Development Goals (SDGs), and the United Nations Framework Convention on Climate Change (UNFCCC), situate climate responsibilities in countries distinct socio-economic circumstances as well as historic contributions to climate change. Such highlights support the global south in carrying on with the international trade (Arent et al., 2017)

4.2 Propositions of International Political Economy (Premise #4)

"BCAs can level the environmental commitment (INDC) [i.e. Intended Nationally Determined Contributions] among countries facing similar responsibilities in climate change" (Arent et al., 2017, p. 72), and promote investments in clean technologies. Such uniformity and promotion however provoke responses of the impacted countries, especially of the rentier states who rely on carbon rooted revenues economically. Therefore, identifying intra-state interactions among the involved parties in energy trade is an essential of identifying carbon pricing influences on the political economy of energy transition at global scale.

To that end, provisions of the WTO employ a 'both sides' approach for supporting fair trade regulations between the global north and south, so that national (e.g. industrial development) and global initiatives (e.g. climate change mitigation) can be pursued without being weaponized for market manipulation. It is doubtable whether such provisions are sufficiently effective, especially when it comes to the nexus of energy trade and climate. Indeed, carbon pricing (including BCAs, carbon tax, etc.) touches a wide range of competitive interests such as relocation of carbon-intensive plants, employment, and international market shares, which promote conflicts between the trade parties.

To alleviate conflicts of interest between incumbent suppliers and consumers of the energy products (e.g. primary crude, secondary petrol, non-energy products such as steel that are energy intensive), multilateral participation in energy governance is necessary. But there is concern about (energy) cooperation being difficult to be initiated at the international scale; hence, one recommendation is to commence it at regional level. It is also important to note that regional levels of partnerships are not free from struggle for effective energy governance either, as seen in the European Union experience and South-Eastern states challenges [see Table 4] in this regard (Sovacool and Florini, 2012).

Table 4: *Brief of "Barriers to Regional Energy governance in South-Asia" adopted from (Sovacool and Florini, 2012, p. 259)*

Technical	Economic	Legal	Political	Social	Environmental
Infrastructure construction and operation	Uncertainty surrounding energy reserves	Inconsistent regulatory frameworks	Contests over sovereignty	Poor participatory mechanisms	Land degradation
	Unknown future energy demand	Unclear protection of property rights	Diplomatic tensions	Lack of transparency	Accidents and spills
	Capital intensity	State control of markets	Protectionism	Relocation, resettlement and human rights concerns	Greenhouse gas emissions and climate change
	Financing	Weak mechanisms for dispute settlement	Lack of sustained leadership		
	Returns on investment	Disagreements over prices and tariffs			

Regional experiences of energy co-organization provide lessons of multilateral governance in particular geographies [e.g. European Union], not panaceas to other areas (Interpreted from (Sovacool and Florini, 2012). For example, global north emission trading systems conceptualize SCC (social cost of carbon) based on global north perspectives. The SCC however varies region by region due to uneven distributional impacts of the climate change. It also varies following the socio-institutional diversities of the states that are harmed by the climate change.

Therefore, narrowing political economy identifications down into socio-institutional case studies is necessary for different regional governance perspectives to interconnect in a global scale. For example, SCC is a determinant of global initiatives for climate change adaptation, mitigation, and indemnification. SCC in the rentier states, however, should not be calculated based on climate externalities only. Rather, it should include path dependencies to the fossil fuel economy, phasing out of which may trigger employment and revenue losses following a transition to low carbon. Similarly, SCC in the rentier states should account for the savings entailed in a low-carbon transition, such as from energy deficiency and health dis-benefits of co-emitted pollutants.

Identification of the above additions and deductions allows for a sustainable equilibrium between climate change adaptation, mitigation, and indemnification under a universally integrated plan of action. Otherwise, any one-sided climate action would risk provoking disputes over the under-privilege parties, which may appear in retaliatory tariffs, price wars, and geopolitical tensions.

4.3 Conclusions

The above studies on political economy identify carbon pricing as an influential factor on encouraging transitions to a low-carbon energy system. As the analyses highlight, carbon pricing can promote energy transition both as a political economy initiative and landscape condition.

When adopted domestically, carbon pricing translates into removing fossil fuel subsidies, which is an initiative to support renewable niches by preserving their market against the formerly subsidized fossil fuels. Yet, as discussed earlier, some models (e.g. EIRIN model) approve of de-subsidization's efficacy for the expansion of renewables in developed countries (Monasterolo and Raberto, 2019), while some other research works (e.g. by Jewell et al. in 2018) criticize the policy's efficacy in the developing world (Monasterolo and Raberto, 2019). Such discussions, thus, question the effectiveness of carbon pricing – as a niche-initiative – when adopted by the rentier states who are mostly developing countries. More importantly, given the rentier states' presumable reliance on fossil fuel subsidies for socio-economic well-being, removing subsidies would not stop at delivering pressure on the hydrocarbons' market, but also on the broader socio-economic well-being in the rentier states. Both of the factors involved in the above suggestion - rentier states' socioeconomic reliance on fossil fuel subsidies and the harm of subsidy removal - are set for examination in the Chapter 5, through a case study on the Iranian carbon-intensive steel industry, and rentier-backed social security.

As the analyses suggest, carbon pricing may also deliver landscape conditions for economic decarbonization. Particularly, the landscape condition happens amid carbon pricing's development into international tariffs on the carbon content of the commodities that are imported from international markets. Such tariffs would deliver a pressure on the commodity providers and exporters to decarbonize their products. Implementation of the international carbon tariffs, however, is identified to be challenging due to calculation difficulties, risks of carbon leakage, and dispute provocations. Concerning the former challenge, uneven distribution of the climate change damage costs is perceived to impede consistent carbon pricing at global level because of geographical variations in the climate change-derived SCC, which is the basis for pricing carbon.

Moreover, the study reveals multiple risks of carbon leakage from the states that implement carbon pricing into those that do not. As the analysis suggests, one form of leakage would happen following the shrinkage of markets against carbon-intensive commodities in tariff-imposer consumer states. The shrinkage would reduce the value of the commodities, making them more affordable for the countries without carbon regulations, possibly the non-rentier developing countries. Such a scenario also encourages companies to relocate their facilities to non-carbon regulated areas, which would lead to further carbon leakage. Another form of leakage happens

when carbon pricing is imposed on the crude form of the fossil fuels, exported by the rentier states, to limit their market in favor of low-carbon energies. Such a scenario would encourage the rentier states to utilize their non-exported fossil fuels at a domestic scale, causing carbon leakage in the downstream of their energy sector. Tariff pressures on the rentier states would also provoke their retaliatory responses to prevent the fossil fuel market loss. Such responses, and their influence on the rentier and global path for energy transition are set for identification in part (b) [rentier level studies] of this chapter.

Although WTO introduces measurements for controlling conflicts of interests between the states who benefit from a green transition (e.g. fossil fuel importers in the global north) and the rentier states who risk losing fossil fuel markets, the conflicts may still lead to disputes between the interested parties. Hence, the study emphasizes the necessity of identifying the conflicts of interests, their potentials for escalation, and their influence on the path for energy transition. The below section explores for the above inquiries regarding the geopolitical consequences of energy transition. Ultimately, the below section aims at identifying the influences from geopolitical dynamics of energy transition at global scale on energy transition at the local scale of the states with conflicting interests over an energy transition to low-carbon.

4.4 Geopolitical Implications of Energy Transition

Energy transitions and geopolitics influence one another. On one hand, prospective low-carbon energy transitions influence energy security conditions amid the in- and post- transition times. On the other hand, geopolitical landscape conditions such as war derived-energy insecurities may also influence (hamper) energy transitions due to prioritizing the needs for energy security. The below sections identify above correlations between energy transitions and energy security among the fossil fuel importing and exporting countries.

4.4.1 Energy Transition Influences on Geopolitics (in-transition span)

In-transition period refers to the span during which the world has partially phased to low carbon, while still demanding fossil fuels for needs that are not yet covered by the low carbon energies. The transitional duration could last for decades, over which the fossil fuel market contracts and hydrocarbon values decline. Amid this span, high-cost generators of hydrocarbons are the first to leave the market; they would be incapable of adjusting to price cuts (Nakhle, 2020). On the other end, more efficient generators (e.g. MENA rentier states) are the ones to exit the last. Hence, despite a downward trend in global hydrocarbon trades totally, there would be more international demand for middle eastern resources proportionally (Nakhle, 2020). Therefore, as the global transition progresses, burdens from the remaining hydrocarbon demands from those not transitioning would concentratedly rely on the middle east resources, which will further

associate the energy security of those not transitioning with MENA energy providers (Nakhle, 2020).

4.4.2 Energy Transition Influences on Geopolitics (Post-transition Span)

Geopolitical landscape conditions of a post-transition renewably-supplied world could be more peaceful, because of: (1) reduced dependency on foreign fossil reserves, (2) possibility of decentralized power generation, (3) availability of alternative rerouting systems for electricity transportation, (4) restriction of supply cut-offs and resource manipulation from producer states, and (5) terminating the global north's intervention in fossil fuel rich countries for securing energy supplies (Vakulchuk et al, 2020).

Meanwhile, low-carbon transitions may also make the incoming geopolitics more confrontational due to: (1) emerging dependencies on critical minerals required for renewable and storage technologies that would transfer conflicts and land-grabs to new resources [such as Indium for solar panels and lithium for batteries], (2) cyber and (3) physical security risks around centralized mega grids, (4) new political alliances over regional grids, and (5) trade wars for manipulating opportunities for international energy markets [including for new opportunities for renewable energy trade, as well as for maintaining export shares in the prospectively shrinking markets of the fossil fuels] (Vakulchuk et al, 2020).

When it comes to weighing geopolitical gains and losses, the majority of authors predict non-fossil-fuel-rich developed states (leaders in renewable energies) as prospective winners respecting a global energy transition to low-carbon. Transitioning to renewable energy provides importer states with economic opportunities [e.g. clean energy jobs]. Also, in terms of energy security blueprints, energy independence gained from expansion of renewables responds to importer states' needs for "resilience through diversification of suppliers, transportation routes or through keeping emergency stocks" (Cherp et al., 2011, p. 79). On the other side, researchers forecast fossil fuel producing [and developing] states to be the main losers, since they would miss a principle source of income, on which they have been relying economically (Vakulchuk et al, 2020).

4.4.3 How May Geopolitical Landscape Conditions Influence Energy Transitions?

Conflicts and instabilities may push energy importer countries towards prioritizing energy security over energy transition and motivate energy exporters to further invest in fossil fuel production and risking stranded assets. An illustration of such hypothesis can be seen in the ongoing European energy crisis following the war between Russia and Ukraine. After Russia stopped providing Europe with the gas it required (i.e. exited the market), the fossil fuel producer state of Algeria became the second major gas supplier of Europe (Boukhatem, 2022). The Algerian

parties agreed to supply Europe with extra 9 bcm of methane between 2023 and 2024 (Boukhatem, 2022). The deal thus strengthened ties between Algerian hydrocarbon economy and energy security in Europe. Meanwhile, the present capacity of Algerian gas fields does not keep up with European energy demands amid the war time. The deficit hence could push the Algerian government trading unconventional energy carriers or expanding gas drilling activities (Boukhatem, 2022). Meanwhile, because "the European Union is preparing to become carbon neutral by 2050, this rise in gas demand [from Europe] will not last long" (Boukhatem, 2022, p. 4). Therefore, If Algeria "invests in new oil and gas discoveries to meet the expanding gas demand from Europe there is a significant risk of lock-in and stranded assets" (Boukhatem, 2022, p. 4). Such risk illustrates the hypothetically described chance of stranded assets in the rentier states that may occur following a prospective global transition away from the fossil fuels.

4.4.5 Conclusions

As the study reveals, energy transition geopolitics are variable of temporal dynamics. Amid the '*in-transition'* spans, energy geopolitics involve competitions over optimized resource exports for the fossil fuel producers, and prioritization of energy security for the consumers. Consequentially, the more the geopolitical landscape conditions cause energy insecurity, the less prioritization will be given to transitioning to low-carbon energy technologies. When it comes to the '*post-transition'* times, geopolitical discussions project competitions over critical materials required for modern energy technologies, which will influence states' geopolitical favors for transitions. For example, it is suggested that the rentier states would not favor losing their privilege of energy security by transitioning to alternative energy carriers for which they lack critical minerals.

As the study concludes, prospective geopolitical transformations can influence states' present-day decision making for energy transitions from a multi-level perspective. For example, manipulation of the raw energy materials that are not available in rentier states is a prospective landscape condition that discourages them from phasing out of fossil fuels to the renewables that require those materials for development. On the other side, landscape risks from oil embargo and hydrocarbon manipulation encourage hydrocarbon importers to develop own renewable facilities to have their energy security apart from dependencies on foreign resources. Yet, this thesis does not look at geopolitics in terms of an independent domain, but rather as possible landscape conditions as a consequence of states political economy confrontations at global level (e.g. fossil fuel importer versus rentier). Indeed, unlike individual domains that introduce active landscape conditions, geopolitical conditions are prospective landscapes, which could influence states' transition strategies at the present time.

5. Part A Conclusions: Summary of Key Factors at International Level

International landscape conditions, niche-initiatives, and techno-climate system characteristics are three groups of the factors that influence energy transitions everywhere. To that end, the international level of the MLP-document analyses was focused on identifying global landscape factors that encourage energy transitions to low-carbon energy systems and economies. Yet, it also identified other key players that influence energy transitions at international level, such as initiatives that support decarbonization (e.g. de-subsidization), landscape conditions that discourage energy transitions (e.g. prospective geopolitical risks of energy insecurity), and techno-climate system characteristics (SC) and requirements that restrict/direct energy transitions. The analysis has discovered the above influential factors by analyzing the contexts of several socio-economic domains that involve energy transitions universally. The socio-economic domains included climate, technologies, domestic political economy, and international political economy.

The global warming effect of the GHGs was the first landscape condition identified to pressure for phasing out of fossil fuels. Next were toxicity effects of non-GHG emissions as the by-products of hydrocarbon combustion. As concluded by the study, the landscape factor of climate change would lead to global actions for climate change mitigation, which would generate secondary landscape conditions. Those landscape conditions include the emergence of low-carbon (e.g. renewable) energy technologies and the political economic policies to support them.

To that end, the study revealed multiple technical path-dependencies that are involved within the diffusion of low-carbon energy technologies. As concluded, evolving from a landscape condition to being adopted as a niche and delivering a successful transition, emerging technologies have to be compatible with the techno-ecological system characteristics of the host nation. For example, transitioning to a solar based-energy system is not perceived to succeed in areas with very (relatively) low solar radiation. The study also suggested that energy system preferences (e.g. for energy affordability versus carbon-intensiveness) are variable of other landscape conditions (e.g. climate change) rather than the emerging technologies. To that end, it was concluded that the emerging technologies must offer advantageous consistencies to the system preferences compared to those offered by the incumbent technologies. Otherwise, they would not gain favorability for being adopted by the system's stakeholders for a transition.

As the study found out, incumbent energy technologies that dominate the system cause another form of path-dependency that influences the early stages of the path for niche-technologies to diffuse. To that end, the study of the Brazilian transition experience indicated how a transition from gasoline to ethanol in a gasoline-dominated energy system was directed to proceed through gasoline-ethanol blends in its early phases. Furthermore, the study confirmed that such

technological diffusions typically initiate from the downstream of the system for energy use. Yet, once active, the diffusion will transition the broader economy, domestic governance, as well as the chains of energy supply and distribution over the whole energy system, as was suggested by (Cherp et al., 2011).

Furthermore, the study identified carbon pricing as a major political economic factor to deliver landscape conditions on energy systems and economies to implement decarbonization. The study confirmed that carbon pricing could also be employed domestically, in the form of fossil fuel de-subsidization, as a universal initiative for decarbonizing own energy systems. Ultimately, it was suggested that carbon pricing landscape factors would lead to escalating disputes between the rentier states in the global south, and non-rentier states in the north, who do not share mutual interests in energy transition economically. As the analyses concluded, those disputes may develop into geopolitical conflicts over energy security in the post transition era, which would influence states' decision making about whether or not to transition. For examples, the studies revealed that fossil fuel importers (who gain energy security through energy mix diversification) would favor transitioning to alternative technologies, especially to those they have the required minerals for local development. On the opposite front, rentier nations would avoid transitioning to energy technologies for which they lack critical minerals for localized developments.

When all is said and done, the international phase of the MLP research confirmed the necessity of narrowing the studies down to a rentier context, to identify the path for energy transition in the rentier states. To that end, the rentier context of the MLP analyses aims at identifying the rentier regime conditions that would host energy transition (e.g. structural governance mechanisms, energy sectors with diverse GHG and pollution mixes) and receive/respond to external landscape factors (e.g. carbon tariffs, market shrinkage, emergence of renewable energies) that pressure for decarbonization. The rentier step of the study identifies some of the potential strategies that the rentier states may employ in response to the above landscape pressures. This level of the study then elaborates on the influence of those responsive strategies on the rentier states and the global paths for a sustainable energy transition.

Part B - Identifying Influential Factors at Rentier Level (Socio-institutional Context of the MENA Rentier States)

On their adaptive path towards a carbon constrained world, MENA rentier states encounter challenges in transition related-domains, such as in governance, domestic and international political economy, emissions, and technologies. Since most MENA nations are socio-institutionally rentier, their path to energy transition is not like other nations that are consumers

of hydrocarbon resources. This part of the document analysis focuses on the regime factors that influence energy transitions in the rentier states; it also mentions a few of the niche-initiatives that may support low-carbon transitions in the rentier states.

1. Governance Barriers to Energy Transition in the Rentier States

State ownership and authorization of the energy facilities is a leverage force against energy transition in the rentier states. As indicated by the following discussions, the governance regime factor of state ownership contributes to secondary regime elements such as corrupt interests in fossil fuel manipulation and lack of transparency, which reinforce hierarchical oppositions to decarbonizing the energy system.

As pointed out by the theoretical literature, rentier states dispense their perpetual rentier incomes to their people (Tagliapietra, 2019). Yet, on its path from government to people, rentier wealth faces the risk of manipulation under state-owned energy firms, as confirmed by Boukhatem's (2022) case study on the rentier state of Algeria. Such manipulation fosters elites' corruptive interests, which resist against transitioning from a rentier economy (such as from the fossil fuel rents in Algeria as discussed by Boukhatem (2022)). Moreover, the analyses of multiple studies on energy governance in rentier states suggest a centralized [and rentier] administration challenges energy transition by causing hierarchal conflicts of interest, bureaucratic discoordination, and ignoring long-term and harmonic energy strategies in the rentier state (interpretations and highlights from Mousavi, 2015; Akbari et al., 2021; Boukhatem, 2022).

As in the Algerian case for example, the energy sector is institutionally administrated under state ministries, and two public firms (also known as Sonatrach and Sonelgaz), which manipulate management of fossil fuels and power. This centralized model thus ignores listening and adhering to voices of the grassroots (Boukhatem, 2022). Algeria also employs a republic system, where the state's president designates "provincial governors, exhibiting a top-down organization in which policy innovations at the local level remain uncommon" (Boukhatem, 2022, p. 12). The very centralized authority, thus, provides Algerian elites with a safe zone for corruption, and strong ability for standing against decarbonization.

1.2 Governance Initiatives to Correct Governance Mechanisms in a Rentier State

As discussed, the study identifies an interconnection between centralized sovereignty over the energy sector and corruptive path dependencies in the hydrocarbon industries among the rentier states [e.g. Algerian centralized governance's allowance for the elite positions to obstruct transparency and accountability to the grassroots]. Accordingly, a potential solution to overcome such shortcomings can be through privatization of the energy sector. There exist several avenues to support effective privatization, one of which is the governance-niche of Small and Medium

Enterprises (SMEs), as reviewed by Tagliapietra (2019). To that end, SME niches are helpful in parallel with initiatives for privatization, economic diversification, and productive career openings to respond to job demands from the expanding youth society. SMEs however struggle with financial inaccessibility in MENA, where only 8% of the lending is being delivered to the small and medium enterprises (Tagliapietra, 2019).

To correct the financial access problems of the SMEs, rectifying the banking governance in MENA is a prerequisite. Such necessity originates from the ongoing financial flow of hydrocarbon exports in the region. Presently, most of the export rents are being transferred between national oil companies (NOCs) and governments directly, without much capitalizing internal banking systems within rentier states (Tagliapietra, 2019). "As a result, the economy can be capital-rich and a net international saver in the hydrocarbons sector, but capital-poor" (Tagliapietra, 2019, p. 5). Therefore, enhanced governance in the banking would help providing sufficient stocks as needed for the SMEs. Such enhancement involves integration of the rentier states' banking systems into universal chains of wealth as well as improving "financial regulatory and supervisory frameworks, with adequate incentives for SME financing" (Tagliapietra, 2019, p. 5).

Moreover, surrogate avenues such as Sovereign Wealth Funds can assist with SMEs capitalization too. Saudi Arabia's Public Investment Fund (PIF), which aims for economic diversification (Tagliapietra, 2019), is an example in this matter. The Saudi PIF is "generally known for its multi-billion investments in companies such as Tesla and Uber – set up a USD 1.1 billion 'fund of funds' to support the development of SMEs in the country" (Tagliapietra, 2019, p. 5).

1.3 Propositions of Energy Governance in Rentier States (Premise #5)

"In the middle-east the public sector dominates the economy, especially as far as the energy infrastructure is concerned, and the participation of the private sector is modest" (Nakhle, 2020, para. 7).

Central and rentier governance over petroleum resources has impeded legitimacy and economic diversification in the rentier states. To fix that, MENA rentier states may ameliorate their banking and fossil fuel trade systems, so that the revenues from hydrocarbon exports can flow into non-hydrocarbon SMEs. Such coordination capitalizes economic diversification and privatization. It also averts SMEs struggling with financial shortcomings. Moreover, the SMEs and banking initiatives liberate hydrocarbon funds from governmental manipulation, and too, restrain room for corruption and path dependent unproductivity. Reformed governments then can compensate for their budgetary needs through SMEs taxation, which brings them accountability. A direct move towards privatization is, however, uncommon among the rentier states given hierarchical interests in state domination over energy infrastructures. Additionally, neither is the private

sector in the rentier states strong enough to take over the energy sector, which has been historically reliant on governmental supports. Here, employment of the Public Private Partnerships can open a window of opportunity for the private parties to be incorporated into privatization of the energy sector, alleviating the state owned-regime oppositions against decarbonization.

1.4 Conclusions

Rigid governmental authorization of the energy sector is a key regime factor in the rentier states' governance over energy facilities, which challenges their path for economic decarbonization. The state authorization shelters corrupt interests of elites in the fossil fuel industry by interrupting public transparency. As the study reveals, repercussions from state ownership are not limited to operation of hydrocarbon facilities, but embracing the banking systems that transfer hydrocarbon revenues. Had those revenues been accessible to private corporations, they could have been used as capital investments for boosting economic diversification by supporting non-fossil fuel businesses in the private sector.

As the rentier states lack strong corporate structures in the private sector, one suggestion for them is to initiate the process of privatization through fostering Small and Medium Enterprises (SMEs). As the study finds out, non-hydrocarbon SMEs provide centralized governments with capital from taxation, which compensate for the budgetary needs for fossil fuel incomes. In order for that, however, non-hydrocarbon SME niches require capital investments – such as from hydrocarbon revenues – that are manipulated by the state. To that end, formation of the public private partnerships in the fossil fuel industry is an identified governance initiative for transferring hydrocarbon funds into non-hydrocarbon SMEs.

International and Domestic Political Economy of Fossil Fuels in Rentier States

Economic reliance on fossil fuel exportation is one of the most visible regime factors involved in the rentier states' international political economy. Incomes from fossil fuel exports are the main sources that support the Gross Domestic Products (GDP), fiscal revenues, and economic growth of the rentier states. So, as the world transitions to affordable low-carbon energies, rentier states have an urgency for implementing techno-economic initiatives to adapt to shrinking oil markets by economic diversification. Otherwise, there is risk that rentier states would engage in non-climate friendly initiatives against their own and global energy transitions for saving rentier revenues.

When it comes to domestic scale, rentier revenues foster social services such as in healthcare, education, and subsidized access to energy in many rentier states, such as Algeria (Boukhatem,

2022). Accordingly, external reliance on hydrocarbon incomes and internal path-dependencies on rentier backed-social services challenge the rentier states' path for transitioning away from hydrocarbon exportation.

This section identifies the above regime factors and initiatives and analyzes their collective influences on the international and domestic political economy of energy system decarbonization in the rentier states. The following section addresses the international aspects.

2. International Aspects of the Rentier States' Fossil Fuel Backed-Economy

In 2017, MENA states supplied 37% of universal crude production, and 22% of gas. Fossil fuels in MENA thus have manipulated three economic indicators: GDP, fiscal revenues, and international commerce diversification. Regarding the GDP, hydrocarbon rents have contributed by 23% to the gross domestic products in the Kingdom of Saudi Arabia (KSA) and Oman, 38% in Iraq, and 90% in Kuwait, in 2017. Similarly, conventional resources have dominated governmental revenues up to extraordinary levels, such as to 67% for Saudi Arabia, 90% for Kuwait, 75% for Qatar, and 60% for Algeria. Respecting to the exports, MENA's economic diversification has been surrounded by oil and gas likewise, which have formed 80% of the KSA's total external trade in 2017, along with 90% of the Kuwait's, 86% of the Qatar's, and 95% of the Algeria's in the same year (Tagliapietra, 2019).

Therefore, encircling 50% of the earth's hydrocarbon fields (Tagliapietra, 2019), the Middle East and North Africa have been privileged with fossil fuel incomes historically. However, this privilege is dependent on international markets, which might shrink in the future. As Tagliapietra (2019) claims, such shrinkage could get triggered under competitiveness improvement of the renewables (e.g. affordability, efficiency). Such contraction, amid a global aim for transitioning to low carbon, would lead to hydrocarbons devaluation. Hence, rentier states in the MENA need to diversify their economy, otherwise, they could lose some 25 to 40 percent in revenues by 2040 (Tagliapietra, 2019). A similar loss would account up to "USD 7 trillion over the period to 2040 in Russia, Saudi Arabia, Iraq, United Arab Emirates and Nigeria. For comparison, this is more than two-and-a-half times the combined GDP of the Middle East and Nigeria" in 2019 (Tagliapietra, 2019, p. 2).

Although MENA rentier states have taken ameliorations to cut their reliance on crude, these efforts have been occasional and relative to low oil price spans (Boukhatem, 2022; Tagliapietra, 2019). The MENA rentier states though had better keep up with the reforms. Not only could reforms help with avoiding financial losses from volatility of the crude price, but also they would assist with adapting to international transitions. Otherwise, emergence of affordable low-carbon

energy alternative coupled with prospective global climate actions for carbon pricing, would push rentier states towards employing initiatives for maintaining rentier revenues, some of which are not desirable for energy transition.

2.1 Rentier States Political Economy Initiatives in Response to Global Decarbonization

Given the above economic dependencies on oil revenues, rentier states may want to respond to preserve their fiscal incomes if encountering climate landscape conditions on their fossil fuel market. While some of their potential responses support energy transition (e.g. economic diversification, Join-in strategies), many of them would confront decarbonization (e.g. 'dig-in', 'throw-in', 'cut-offs', and 'price war' strategies).

2.1.1 Throw-in, Dig-in, and Join-in Strategies

As Krane (2018) exemplifies, fossil fuel producers might contend that high investments in mitigation efforts would exceed indemnification costs triggered by the climate change, concluding that a 2 ℃ warming target is not economically worth averting climate harms [at national scale] (Krane, 2018). While introducing such preference for indemnification costs as "throw in" strategy, Krane (2018) refers to "Dig in" and "Join in" as two other strategies available for fossil fuel producers in response to their climate action. The primary goal for both initiatives is to maintain fossil fuel revenues. Through "join in" strategy, producer states - at an internal scale - join types of energy initiatives that foster fossil fuel revenues in parallel with contributing to climate change alleviation as a secondary purpose. For example, enhancing energy efficiency and leakage repair are interpretable as two "join in" courses of action. Not only such efforts cut emissions but also free up more resources for export. On the other hand, the "Dig in" strategy aims at preserving fossil fuel markets and revenues through competitiveness improvement of the hydrocarbon-derived products and technologies, for instance through investing in fossil fuel consuming technologies in the states that aim at climate action policies [to protect such technologies from transitioning to using non-hydrocarbon energy sources] (Krane, 2018).

2.1.2 Exemplifying 'Price Wars', 'Cut-offs', and 'Economic Diversification' in the OPEC Political Economy Responses Against Energy Transition

There are many energy-economic models that predict erosions for the organization of petroleum exporting countries [OPEC] (Van de Graaf and Verbruggen, 2015). Yet, the structure for fossil fuel economy among OPEC states is not the same, rather there exist social and technical varieties.

Van de Graaf and Verbruggen (2015) divide OPEC members into two groups. On one hand there are lower-population members with access to cheap petroleum reserves. This group (e.g. Saudi Arabia, Kuwait) favors to increase oil production hoping for decreasing the oil price, so that they

can keep non-OPEC producers and non-oil transitional energies out of the market. Saudi Arabia and a couple of southern Persian Gulf states are in the frontline of this branch.
On the opposite side, there are more densely populated nations with access to both cheaper and more expensive [relative to the former branch] resources. This group (e.g. Iran, Venezuela) prefers to cut on oil production to benefit from increased oil prices before a global energy transition happens and international oil market shrinks.

To categorize initiative responses for the group of petroleum exporting countries on the basis of the above-mentioned discussion, one choice could be the initiation of "price wars". The term of "price wars" refers to competitions that are either internal (fossil fuel producer vs fossil fuel producer) or external (fossil fuel producers vs renewable producers), in which producer parties export petroleum in highest - technologically feasible - volume along with least - economically possible - price. As a result, they can retain more share in an internationally contrasting market of energy. Petro-states may also "cut-off" their production, which means restricting their supplies through making "quota agreements" between themselves. This policy would support the saving of fossil fuel revenues in total and preserve the monetary value of the petroleum products correspondingly. A third policy option is deploying energy efficiency improvements in the up and down streams of the energy system. This approach reduces GHG emissions, and too, frees up more resources for transport. Lastly, a fourth strategic response would be economic diversification. Diversification decreases governmental reliance on petroleum exports, lowers geopolitical vulnerability of the GDP to single-sourced international energy markets, and supports climate change alleviation (Van de Graaf and Verbruggen, 2015).

In essence, it is recognizable that rentier responses such as economic diversification and join-in strategies contribute to transitioning to low-carbon energy both inside the rentier states, and at global scale. In contrary, while the cut-off strategy encourages hydrocarbon importers for transitioning to alternative energy carriers, it leaves rentier states with freed up resources for domestic use, which would hamper rentier states' own path for energy decarbonization, and cause internal carbon leakage. Lastly, price war strategies are anticipated to impose an antithetical influence compared to cut-offs. By providing extremely affordable fossil fuels to the international markets, rentier price wars discourage energy importers from transitioning to alternative energy carriers. Price wars also require rentier states to export higher volumes of fossil fuels to compensate for the lower energy prices and maintain their rentier revenues. Therefore, they will be encouraged to save resources domestically, such as through implementation of join-in strategies and domestic transitions to low-carbon energies, so that they can free up resources from domestic use for international export.

Nevertheless, rentier price wars are not just against low-carbon rivals, but also against themselves. In a price war market, each rentier state would seek most possible market shares, so that it can fully cover its budgetary needs with de-valuated fossil fuel incomes.
Also, the less fossil fuel a rentier state exports, the higher oil price - also known as breakeven oil price - is required for it to cover its fiscal needs fully with rentier revenues. In addition to the market share effect and fiscal needs, breakeven oil prices are variables of fossil fuel maintenance costs which are not the same for all rentier states.

2.2 Breakeven Oil Prices and Upstream Deficiencies in Fossil Fuel Economy

Rentier states in MENA generate crude at lower expense compared to non-rentier hydrocarbon rich nations (e.g. Canada) elsewhere. Nevertheless, there are rentier states struggling with higher maintenance costs relatively, compared to other rentier states (see Table 5). Such costs are high to the extent they can turn budgets of the affected rentier states (e.g. Iran) into net negative if the international price of oil drops below the fiscal breakeven oil price level. This form of budgetary imbalance takes place as an economic regime condition that arises from mature hydrocarbon infrastructures. It also takes place amid insufficient revenues from non-oil (alternative) commodities, where poor economic diversification neutralizes the privilege of being a low-expense generator of fossil fuels by creating vulnerabilities to “high fiscal breakeven oil prices” (Nakhle, 2020, para. 12).

Breakeven oil prices have recently hit the international value of crude, triggering budget shortfall in some MENA states. Yet, if diversifying their economy, MENA rentier nations may keep on petroleum trades under the dropping crude prices with less harm during the transitional span (Nakhle, 2020). What happens next to MENA economy afterwards a progressive and universal transition “largely depends on whether the region’s oil and gas producers have wisely reinvested their hydrocarbon revenues so that future incomes from financial investments will exceed that from hydrocarbon exports” (Nakhle, 2020, para. 14). If so, non-hydrocarbon assets that are developed by hydrocarbon rents may last even after omission of hydrocarbon resources from the MENA’s financial economy (Nakhle, 2020).

***Table 5**: Fiscal breakeven oil prices among MENA oil exporters [USD per barrel]*
(IMF, 2019, as cited in Nakhle, 2020, paras. 12-14 [table]) – adopted from Nakhle (2020)

	2017	2018	2019	2020*	2021*
Algeria	91	101	105	157	109
Bahrain	113	118	106	96	84
Iran, I.R. of	65	68	244	389	320
Kuwait	46	54	53	61	60
Libya	103	69	49	58	70
Oman	97	97	93	87	80
Qatar	51	48	45	40	37
Saudi Arabia	84	89	83	76	66
UAE	62	64	67	69	61

2.3 Global Aspect Conclusions

When all is said and done, it is identified that extreme reliance on fossil fuel revenues is a major regime factor in the rentier states political economy. If not diversifying their economy or joining the global efforts for decarbonization, rentier states would be pushed towards taking climate-destructive initiatives for maintaining rentier revenues. The study confirms that climate destructiveness of those initiatives, however, is not alike, neither is their favorability for various types of the rentier states. For example, there are cut-off initiatives that interest rentier states with high breakeven oil prices. As the analyses suggest, although cut-off strategies support the path for global transitions, they obstruct the transition path for rentier states that employ them. On the other hand, there are price war strategies, which interest rentier states with lower breakeven oil prices. As the study reveals, although the price war strategies support energy transitions and decarbonization inside rentier states, they impede global efforts in transitioning to low-carbon alternatives through creating overly affordable fossil fuel markets. Ultimately the study suggests that neither strategy is climate friendly as they impede a low-carbon transition either domestically or at the global scale.

3. Domestic Political Economy: Downstream Path Dependencies in Fossil Fuel Economy

Rentier reliance on fossil fuels does not stop at macroeconomic scales, but creeps into domestic aspects of political economy. As below sections elaborate, rentier dependencies on fossil fuel incomes and resources are evident over social services, industries, employment, energy access, and energy efficiency in the MENA, where interdependencies are shaped by (state owned) hydrocarbon resources and revenues (Boukhatem, 2022; Tagliapietra, 2019).

3.1 Social Services

The socio-economic security in rentier MENA is supported by affordable availability of hydrocarbon resources (as interpreted from Al-Sarihi and Cherni's (2023) study on Oman, Rahimdoust's (2021) study on Iran, and Boukhatem's (2022) study on Algeria). The support embraces both the energy access and non-energy societal services. The hydrocarbon rich state of Algeria, for example, has been able to extend a territorial energy access of 99.8 percent over its 44 million population as of 2020 (Boukhatem, 2022). As for non-energy services, fossil fuel rents have been assisting the Algerian government supplying its citizens with basic needs ranging from "food to healthcare and education, and in providing them with a standard of living that exceeds that of many countries in the region" (Boukhatem, 2022, p. 3). Similarly, fossil fuel incomes have been a backbone to free education and healthcare programs in Oman (Al-Sarihi, 2023).

3.2 Manufactural Development

Concerning the energy-intensive industries, it is the affordability of the fossil fuels that create the value-added to non-hydrocarbon manufacturing (in MENA). Indeed, fossil fuel energy carriers supply industries with (affordably subsidized) chains of chemicals and processing (including for mining, extractions, and refineries). Such linkage pushes MENA's non-energy and non-governmental entities (e.g. construction sectors) to reliance on central governments (that are state heads for energy administration) as providers of subsidized fossil fuel (Tagliapietra, 2019).

Iranian Steel industry (Rahimdoust, 2021) is an example in this matter. Large subsidy allocations have nurtured Iranian steel manufacturing by creating excessive amounts of value-added. Therefore, the Iranian steel industry (similar to other manufacturing sectors) favors energy intensive means of production, despite availability of lower energy dependent methods. Iran utilizes 650 to 750 cubic meters of natural gas per ton production of steel. This amount is by 30% higher than the world's average for steel industry, which excludes the subsidized energy used for the chains of mining and transportation behind the total value-added for the steel production. Fossil fuel subsidies if abandoned, would trigger extreme decline in the value-added, and trigger employment shortfall. (National Iranian Steel Company, 2020, Iranian Fuel Conservation Company, 2016; Rahimdoust, 2021).

3.3 Employment

Respecting employment, fossil fuels (revenues) have contributed to costly over-expansion of the public sector in the MENA. For example, "in Saudi Arabia, Iraq and Kuwait the public sector wage bill amounts to almost one-fifth of GDP, as 30% of Saudi and Iraqi workforce and 15% of Kuwait workforce are employed in the public sector" (Tagliapietra, 2019, p. 2). This over-growth is even

further seen among the Gulf Cooperation Council Countries (GCC), where the public labor receives 150 to 250 percent more in salaries versus the non-public. As a result, there nurtures career unproductivity following [the guarantee of] rentier-backed governmental payments to the public labor [that is employed for non-crucial positions], as well as an imbalance between the public and private jobs. Such repercussions subsequently hinder economic diversification; they withhold non-governmental firms from progressing in globally competitive stages, and gaining shares in foreign markets (Tagliapietra, 2019).

3.4 Energy Use Diversity

Following the extreme reliance on hydrocarbon resources, MENA countries have minimal diversities of non-hydrocarbon carriers in their energy mix. This is most visible in countries such as Kuwait and KSA where crude and gas supply energy and power at almost 100% (Nakhle, 2020). Taking other West Asian countries into account, oil and gas have made 25% and 70% of the supply shares in the region, respectively in 2018. The overall supply from other sources has been little, where the nuclear, solar, wind, hydro, and non-hydro renewables altogether shape less than 4 percent of the total energy contributions in Western Asia (Nakhle, 2020). To grow more competitively, the nuclear and renewable alternatives in particular would need comprehensive financial support from the administrations. To be comprehensive, the support should cover the entire system expenses of such modern energy technologies. This includes costs of energy storage for renewables, and investment requirements for nuclear infrastructures (Nakhle, 2020).

3.5 Energy Efficiency

Beyond social security, manufacturing, employment, and domestic utilization, fossil fuels also influence energy efficiency in the MENA. This influence happens through enabling excessive subsidies. The Iranian government, for example, spent most hydrocarbon subsidies universally in 2017, hitting 10% of the state's GDP. As for the other rentier states, energy subsidies amounted to "USD 37 billion in Saudi Arabia, to USD 9 billion in the United Arab Emirates, and to around USD 7 billion in both Iraq and Kuwait" (Tagliapietra, 2019, p. 3). Such subsidies implicated opportunistically wasteful energy behaviors in over production and demand. They also trigger financial losses domestically, where the governments exchange resources for a small price compared to their international worth. Huge gaps between actual fossil fuel prices and the subsidized (domestic) prices that do not include generation expense restrain competitiveness of renewables from growing within the interior system (Tagliapietra, 2019). As seen in the KSA for example, the average electricity cost for households is 80% below the worldwide mean. Akin to the KSA, other rentier states in the MENA are continuing on subsidized power distribution for households, such as Kuwait where the cost for residential power has remained consistent for more than half a century (Tagliapietra, 2019).

4. Interconnections between the Up and Down Stream

As interpretable from the documents, energy transition would act as a gear between domestic and global political economy for hydrocarbons, connecting the upstream with downstream in the rentier states.

If MENA governments cut domestic utilization of oil and gas, more resources will become available for export, and more revenues for gain. Such rents if injected into low-carbon facilities domestically, could foster the transition in downstream (Nakhle, 2020). The impacts of such investments can be significant; for example, KSA combusts above a million barrels of crude to generate electricity for cooling on a hot day (Nakhle, 2020), which can be saved for exports to capitalize a downstream transition to renewables. Yet, such a cycle would capitalize MENA's energy transition to low-carbon by incentivizing fossil fuel transports to rest of the earth (Nakhle, 2020). Those transports though are not climate friendly. Therefore, they could get devalued under international climate taxes, potentially in the future (Boukhatem, 2022). They may not last for long either. Because a prospective climate action "will require leaving a significant proportion of known coal, oil and gas reserves in the ground" (Boukhatem, 2022, p. 4). Nevertheless, domestically generated and replaced clean energy may be used as a new commodity to be substituted for hydrocarbon exportation (Boukhatem, 2022), keeping the rentier economy alive.

5. Political Economy Barriers to a Just Energy Transition in MENA

MENA's path to clean energy, notwithstanding its benefits and necessity, is not an easy cross. Rather, it involves dependencies that are deeply rooted in the political economy. Social services (e.g. healthcare, education, etc.), employment, industries, and energy access represent a small index of rentier states public wellbeing stimulated by the availability of fossil fuels.

A changeover to clean energy hence must not be looked at under lenses of revenues only, but under the impacts a changeover would make on the well-being and quality of the people's lives (Boukhatem, 2022). A transition to be socio-economically just, needs not harm such well-being (Boukhatem, 2022), but rather improve societal shortcomings while mitigating the climate change.

By reviewing the Algerian case study (Boukhatem, 2022), several barriers to a fair transition are identified socio-politically and economically. Similar to the other rentier states reviewed, energy-economic obstacles in Algeria (as discussed below) correlate with the state's energy sector in the up and downstream, connecting domestic well-being with international affairs.

As an old hydrocarbon exporter, the Algerian government is pledged to long-term agreements for fossil fuel trade with foreign partners. Legal responsibility from such agreements challenges the country's aim for any environmental transition to low carbon. Likewise, and from a socio-

economic perspective, pledges for export have limited Algeria's capacity for internal electricity supply (Boukhatem, 2022), where the population is expanding by 2%/annum and seeking additional power (Boukhatem, 2022). The deficit thus hinders the balance for available energy capacities between foreign trade versus domestic need (Boukhatem, 2022).

On the other side, Algerian people are not profiting from their national asset of fossil fuel rents justly. Instead, there exists dominance from political elites over fossil fuel advantages (Boukhatem, 2022). That said, a sustainable transition may help the Algerian economy equitably redistributing its national resources. Such essentials, in parallel with mitigating the dependency on hydrocarbon rents for welfare and development, support the climate rationales behind transforming the energy system in Algeria (Boukhatem, 2022).

6. Propositions of Governance and Political Economy for a Just Energy Transition in MENA (Premise #6)

From the lenses of climate justice, developing nations "did not benefit much from industrial development and historically have not been responsible for causing the climate crisis, yet they are the most affected when it comes to the impacts of climate change" (Boukhatem, 2022, p. 3). Meanwhile, climate change mitigation has been no priority over economic progress in the rentier states (Boukhatem, 2022), especially among those in MENA.

Moreover, fossil fuel exports cause socio-institutional and economic lock-ins in the exporter countries. Labor unproductivity, small growth of the private sector, non-diversified economy, and fiscal needs for high breakeven prices are some of the identified path dependencies the rentier states confront. The above negatives, consequentially, weaken the rentier states' capability of implementing a successful energy transition, which requires socio-institutional strengths such as a productive labor force for diversifying the economy.

The study identifies centralized governance as a key regime factor to nurture the above socio-institutional deficiencies against the path for economic decarbonization in the rentier states. The above identified deficiencies add to the rentier states' vulnerability to international transitions to non-hydrocarbon energies, which deliver landscape conditions on shrinking rentier markets. To that end, sustainable governance is crucial for energy transitions in the rentier states, where both the up and down streams are involved. As Tagliapietra (2019) confirms, national governance mechanisms, if adapted responsibly in MENA, could make international transitions become "positive input[s] for MENA hydrocarbon exporters, a stimulus to consider economic diversification as an unavoidable pathway, to be pursued in order to guarantee future economic

prosperity in any scenario – and therefore even in a low-carbon world scenario" (Tagliapietra, 2019, p. 6).

7. Conclusions

Fossil fuel incomes and resources have been contributing to path dependent-developments in the rentier states, which would challenge them in their pursuit of transitioning to a low-carbon economy.

Internationally, oil and gas revenues are the backbones of GDP, fiscal incomes, and economic growth in the rentier states. Therefore, rentier administrations would expectedly oppose transition paths that culminate in losing those revenues without offering reliable alternatives through economic diversification. Yet, neither rentier revenue from oil nor gas is reliable in the long term. The more fossil fuel infrastructures age, the more maintenance costs they require, which leads to increasing breakeven oil prices for the rentier states. Accordingly, maintenance costs and increasing breakeven oil prices are two of the regime conditions in rentier economies that rarely favor transitioning the economy towards non-fossil fuel incomes, especially in light of climate change and consumers' transition to the low-carbon technologies that are getting more affordable than before. From a domestic perspective, money from trading hydrocarbons is directly fed into the treasuries in rentier states, which correlates governmental services, as in social security, with those revenues. Transitioning away from oil and gas commerce may hence encounter opposition from stakeholders in public services, including from the middle and low-income class people in rentier states.

In addition to the above regime conditions arising from hydrocarbon incomes, rentier states also struggle with techno-industrial developments that are path-dependent on affordable access to hydrocarbon resources. Indeed, availability of fossil fuels in vast amounts has encouraged rentier governments to subsidize those resources for providing affordable energy access to their citizens and industrial stakeholders. The regime factor of subsidization has consequentially led to overconsumption of the hydrocarbon resources as a secondary regime condition. Yet, phasing out of subsidized fuels would encounter resistance from the energy stakeholders, for instance from the carbon-intensive industries, which would lose their competitiveness in international markets if utilizing non-subsidized energy for producing energy intensive commodities.

Therefore, if rentier states are forced to adopt decarbonization without having their missing interests compensated, they may engage in destructive initiatives, which could hinder a comprehensive path to decarbonization over the globe. To that applies initiatives for price wars which aim at outpacing alternative energy rivals in the international markets. Another initiative

is cutting off oil supply, which rentier states may employ to threaten importers' energy security in response to their climate actions. In addition to energy security implications, cut-off initiatives would free up extra fossil fuels inside the rentier states, the availability of which would impede their transition to alternative energy carriers. In conclusion, join-in strategies and energy mix diversification appear to be two feasible initiatives for the rentier state to employ on their path for decarbonizing their energy system and economy.

8. Technical and Environmental Regime Conditions versus Opportunities Regarding Energy System Decarbonization in Rentier States

GHG and Pollution intensiveness are connatural regime conditions entailed in infrastructures for upstream fossil fuel production. Such emissions can be set as targets for mitigation through technical initiatives such as carbon capture and removal for join-in decarbonization. Although such initiatives impose slight costs per ton of CO_2 eq reduction from the oil and gas facilities, they have to be offset because of high amounts of GHGs emitted by the upstream of the petroleum industry. As explained in the next sub-section, technical barriers arising from regime conditions entailed in fossil fuel industries impede in offsetting the costs of join-decarbonization initiatives in rentier states' upstream of the hydrocarbon industry.

When it comes to the downstream, the arid climate conditions in many rentier states (such as in MENA) support initiatives for energy mix diversification, particularly through adoption of solar technologies. Yet, socio-technical obstructions, such as huge width of land area for grid expansion, and lack of political will are some of the barriers to the rentier states efforts for implementing energy mix diversification through renewable energy developments in downstream.

8.1 Techno-climate Regime Conditions over Join-in Decarbonization at Upstream

Operations for extraction, transportation, and processing of oil and gas in resource rich-countries cause 15% of the energy related emissions on earth, which equated to 5.1 billion tons of CO_2 eq in 2022 (International Energy Agency, 2023). Almost 3 billion tons of these emissions come from the oil industry, while the remaining 2 billion originate from natural gas facilities (IEA, 2023). As for their details, methane emissions from leaking and venting form 57% of the total GHGs released from the oil and gas industry. Refinery heat and power systems, and extraction activities (including drilling) and flaring come second and third, by causing 20% and 15% of the industry's emissions respectively (Beck et al., 2020). Therefore, the CO_2 and CH_4 emissions, aligned with NO_X species from the flaring of associated gasses in rentier states, implicate in climate change effects at the global level.

Joining the international community for climate change mitigation, rentier states may employ technological initiatives to reduce the carbon intensiveness of their fossil fuel products. To that end, the predominance of CH_4 emissions from leaks and venting makes them a priority for decarbonization, which can happen through deployment of "leak detection and repair" systems (Beck et al., 2020). As for extraction and flaring, rentier states may adopt carbon capture and storage technologies for using the captured methane and CO_2 for Gas to Power technologies, or for reinjecting them into oil fields for supporting enhanced oil recoveries aligned with decarbonization, according to Khalili-Garakani et al.'s (2021) study on Iran's fossil fuel industry. Unlike in non-oil and gas industries where carbon capturing is expensive as much as $100 to $200 per ton of CO_2 eq stored, the initiative is incomparably cheap in oil and gas industries, for as much as $20/ t$CO_2$ eq for selected processes (Beck et al., 2020).

Yet, while the slight costs from upstream join-in strategies may be compensated through reducing resource wastes particularly on the gas side, techno-climate regime conditions of the fossil fuel industry may prevent rentier states from achieving such offsets. For example, commercializing the captured gas through pipelines is techno-economically viable for large markets in short distances, for instance, for domestic markets, according to the Khalili-Garakani et al.'s (2021) investigations. Domestic markets for fossil fuels, however, are subsidized in the rentier states, which impedes rentier governments in making profits through selling them to their own stakeholders. On the other hand, exporting the captured gas would impose financial expenses due to needs for pressure boost stations for long-distance transport of the fossil fuels through pipelines (Khalili-Garakani et al., 2021). Additionally, exporting the captured GHGs through long-distance pipelines would also neutralize the environmental advantages of carbon capturing by providing room for leakage on the pipeline's way to export.

In essence, the GHG intensiveness can be recognized as an inherent factor in the technological regime of oil and gas industries. Those emissions are not inevitable, but avoidable through join-in courses of actions, such as through carbon capture and storage. Yet, the techno-climate regime conditions involved in fossil fuel transportation (e.g. pipeline costs and leakages), paralleled with economic regime conditions in the rentier states (e.g. subsidization), may thwart rentier states' efforts in sustainably offsetting the costs from join-in decarbonization by gains from energy saving. The obstructions, therefore, may discourage rentier states from implementing join-in initiatives for decarbonizing their energy system at upstream.

8.2 Techno-climate Regime Conditions over Energy Mix Diversification and Relevant Initiatives

While techno-climate regime requirements (e.g. availability of energy sources, ease of use) for transitioning to a low-carbon energy system (Chapter 4, Part A) are available in many rentier

states in the MENA region (e.g. high solar radiation), there are other socio-technical regime conditions that prevent rentier states from successfully launching transitions to low-carbon energy. Boukhatem's (2022) review of the state of Algeria exemplifies a group of techno-climate conditions that have been supporting/impeding the Algerian government's efforts in diversifying their energy mix in the downstream of their energy sector.

The state of Algeria receives 2 to 3 thousand hours of solar energy on 80% of its land (Boukhatem, 2022). This input is enough for +169,400 tw/hr of power generation, exceeding the country's annual use by 5000 times (Boukhatem, 2022). The extra production may be exported to the European energy partners, the proxies of which are supported by the Algerian geography (Boukhatem, 2022).

In 2011 (updated in 2015), the Algerian government launched The National Program for the Development of Renewable Energy and Energy Efficiency (PNEREE), for transitioning to renewable energy. The PNEREE had prioritized solar and wind technologies and targeted 3000 MW of Photovoltaic (PV) power generation, align with 1010 MW of Wind, 360 MW of Biogas, and 5 MW of Geothermal by 2020. As a strategy for achieving these targets, the program aimed at reducing investment costs for renewable technologies, especially for the PV. Nevertheless, the actual achievements gained were as small as 13.33% of progress for the PV, 4% for the wind, and zero percent of progress for the Biogas and Geothermal (Boukhatem, 2022). Potential reasons behind such failure included the absence of political will, cooperation, monitoring, and evaluation (Boukhatem, 2022).

In a second attempt, in December 2021, the Algerian administration commenced another energy scheme, known as SHAEMS. The SHAEMS hopes for 15000 MW renewable capacity by 2035. Initiatives that are employed in SHAEMS include: public and private partnerships and investments, long term electricity acquisition offers, reducing responsibility over local utilization of manufacturing equipment, and enabling open market options such as +50% international share for projects ownership (Boukhatem, 2022).

8.3 Socio-technical Barriers to Energy Transition in Rentier MENA

Although potentials for the Algerian solar power are promising, there are technical obstacles making it expensive. The obstacles originate from separation between the nodes of supply and demand for the Algerian solar energy. To this respect, Algerian cities with most energy requirement are in the country's northern areas mostly. On the supply side, Algerian Sahara is the land that receives most photovoltaic radiation for electricity generation. The Sahara exists over the Algeria's south. Hence, the socio-geographic distance between the hubs for electricity

use and generation turns photovoltaic structures 30% more expensive in Algeria in comparison to their international mean (Boukhatem, 2022).

Other socio-technical barriers to the expansion of low-carbon energy technologies in the MENA include: lack of domestic access to efficient low-carbon technologies, lack of openness to international markets, lack of policies that promote human capital, corruption, lack of intra-regional trade (Ansari and Holz, 2020), fossil fuel subsidization (Al-Sarihi and Cherni, 2023), lack of electricity tariffs, lack of institutional frameworks for phasing out of rentier economies, abundance of already available fossil fuel resources, lack of historic responsibility for climate change, and risks for geopolitical losses [Chapter 4, Part A] (Ansari & Holz, 2020).

9. Propositions of Rentier Document Analyses (Premise #7)

Oil and gas exporters mostly use subsidy mechanisms for internal poverty attenuation and international revenues (Ansari and Holz, 2020). Therefore, when it comes to fossil fuel rich nations, carbon lock-in is not only about upstream production, but also residential, transportation, and consumer industries sections (Ansari and Holz, 2020). Hence, cutting subsidies and transitioning to a lower carbon energy mix may not guarantee a total decarbonization as such climate good could be decisively declared to, and circumvented by, saving more resource for exports (Ansari and Holz, 2020).

Given the radical subsidization of hydrocarbon resources in MENA, prices there do not support energy efficient behaviors. In power generation in particular, demand rise for hydrocarbon-based electricity is outpacing economic growth rate in the region (Mezher et al., 2015). Saudi Arabia, Qatar, Algeria, United Arab Emirates (UAE) Kuwait, Iraq, Egypt, and Iran are examples of MENA countries that might confront negative consequences if not resolving the ongoing unsustainability in their demand-supply chain of carbon dominated power industry. Such unsustainability would cause nations such as UAE and Iran miss revenues from fossil fuels, which could have been saved for export. The unsustainability also implicates in domestic shortages of hydrocarbon rooted energy supply; Iran and UAE are already importing more natural gas than they did in the past (Mezher et al., 2015). In the case of Saudi Arabia and according to Farnoosh et al.'s (2014) estimation regarding their energy sector in 2020, the rentier state was capable of adding 0.5 million barrels of crude to its exports per day, strengthening its political role in the OPEC and the international energy market, if decarbonized its power industry.

In order for resolving the above mentioned shortcomings, MENA states have employed several schemes of energy transition such as: Kuwait's implementation of "70 MW renewable energy complex consisting of 10 MW solar PV, 10 MW wind and 50 MW solar CSP [concentrated solar

power] energy", Saudi Arabia's 2030 plan for CSP supply up to 25,000 MW, solar PV up to 16,000 MW, wind up to 7,000 MW, biomass up to 3,000 MW, and geothermal energy up to 1,000 MW, Iraq's "electricity production from renewable energy by 5% by 2030", and UAE's "target of 5% total energy supply from renewables by 2030" (Mezhar et al., 2015, Table 3). Nevertheless, these schemes can reflect emission reduction endeavors in terms of join-in strategies (as explained by Krane [2018]) to free up more resources for export. The United States Energy Information Administration's (EIA) reference scenario (2012) adds to such skepticism by mentioning that the organization of petroleum exporting countries must raise petrol generation up to almost 25% to keep its share in the international oil trade in 2030 (Mirchi et al., 2012).

Notwithstanding the intentions for MENA states transitioning towards low carbon, such transitions are subject to face several political economy constraints. As Wittmann (2013) concludes:

> Only an adjustment of in-country fossil fuel pricing policy, possibly combined with an alternative way of government market intervention as well as a shift in the general attitude towards the way energy resources are consumed and valued, might bring about the necessary changes to give nations rich in fossil fuel resources a chance and an incentive to transition. (p. 965)

Moreover, transitioning away from carbon fuels declines employment opportunities promoted by fossil fuel industries (Mercure et al., 2018). That said, the fossil fuels' industrial share in GDP, hydrocarbon backed exports, and electricity generation resist against any climate legislation for replacing hydrocarbon subsidies with carbon pricing in the rentier states (Lamb and Minx, 2020). "Exposure to fossil fuel extraction activities, supply-side coal dependency, the countervailing absence of climate policy constituencies, a lack of democratic norms, exposure to corruption, a lack of public climate awareness, and low levels of social trust" (Lamb and Minx, 2020, p. 6) are some other political economy constraints against climate policy in varying groups of nations, with potential applicability to the rentier states.

Another huge disruption to climate policy over the MENA region, which would de-prioritize climate legislation due to occurrence of instability, is brought by the climate change itself (Sofuoğlu and Ay, 2020). Seventy percent of agriculture in MENA is rain-irrigated, which if reduced under global warming would result in food insecurity (Sofuoğlu and Ay, 2020). Such insecurity pushes huge numbers of farming labor to immigrate to cities given the agriculture's high employment share in the region (Sofuoğlu and Ay, 2020). On the other hand, climate derived poverty over farmer households in MENA encourages terrorist organizations misusing such a circumstance through taking control over farmlands and supporting vulnerable communities in exchange with asking for their participation in violent activities, and support for the terrorists'

presence in the country-sides. For example, ISIS expansion over Iraq's farmland suburb came after series of frequent droughts (Sofuoğlu and Ay, 2020). Another – more internationally integrated - example is the Egyptian people demonstrations over increased food prices, which was due to lessened wheat imports from China following the winter drought in that country (Sofuoğlu and Ay, 2020). These experiences underline the fact that "in global governance, climate stabilization must be placed on par with economic development, human rights, democracy, and peace" (Rockstrom et al., 2017, p. 1271).

It is also important to note that economic reliance on fossil fuels has been long known as a weakness due to fragility of the crude's international value, which has been fluctuating regardless of global transition directions. As Boukhatem (2022) elaborates, the Algerian hydrocarbon dependent economy contracted by 6% following the oil value decline amid the Covid-19 pandemic. Such reliance forced the Algerian government cutting social security services by 30% at the time. As an aftershock, the Algerian administration faced about 500,000 unemployment cases in 2020, as well as a budget deficit of 18.4% of GDP in 2021 (Boukhatem, 2022).

10. Conclusions

Energy governance regime conditions in the rentier states are classified into two groups following the study's employment of the MLP lenses. The first group of the identified regime conditions represent rentier reliance on the hydrocarbon incomes, which are derived from crude exports at the rentier states' upstream of fossil fuel industry. And the second group are the regime conditions represent reliance on hydrocarbon resources that are primary sources for energy consumption in the rentier states' downstream. The two groups are correlated to the extent that one regime condition may cause the other. Moreover, both groups of the regime conditions are influenced by a broader regime condition, which is the centralized state ownership of the hydrocarbon resources and revenues by rentier governments in the up and down stream of their energy system.

Most rentier states in MENA have state-owned control over hydrocarbon industries, where the revenues are flown into capitalization of governmental services (e.g. social security). The rentier incomes also dominate MENA states' governmental budgets, making the public-sector employment inefficiently reliant on the fossil fuel incomes. The study reveals that the centralized control of the rentier incomes and fossil fuel resources allows for industrial manipulation of those assets and corruption, which are secondary regime elements in rentier socio-institutions.

As the study confirms, substituting private SME taxes for hydrocarbon rents is a possible niche-initiative for the rentier states to phase out of the rentier economy. SME niches also help with

economic diversification. The capital investment required for economic diversification through nurturing SMEs, however, is exploited by the state-owned manipulation of the hydrocarbon sector, where export incomes are financed directly from national oil companies [NOC] into state treasuries. The monopolized financing hence leaves the banking system and other sources for non-oil investments short of capital in rentier states.

Another stream of MENA hydrocarbons flows into the rentier states' own downstream, where the costs for energy carriers are consistently fixed through legislation [e.g. Kuwait]. There, the residential and industrial sectors are privileged of affordable access to fossil fuels, thanks to a rigid regime condition for subsidization supported by the rentier states' political economy. From a residential viewpoint, mass subsidization leads to inefficient utilization of gasoline and electricity as techno-economic regime conditions. The inefficiencies therefore trigger overconsumption, energy waste, and energy shortage as consequential regime situations. From an industrial standpoint, subsidized fossil fuels also support hydrocarbon-intensive industries. Like the residential branch, affordable fuels promote inefficient manufacturing methods in energy-intensive industries such as for steel production in Iran, where the products are exported at competitive costs internationally.

Regarding the international aspect of political economy, hydrocarbon rents are the backbone of GDP, fiscal revenues, and the international commerce in MENA. The regime condition of economic reliance on hydrocarbon incomes hence makes MENA rentier states vulnerable to external (global) transitions as a potential landscape condition (Part a). Such a reliance also weakens economic diversification, and demands high breakeven oil prices for the rentier states to be able covering their fiscal needs solely through crude revenues. Another factor that pushes for high breakeven oil prices is the maintenance costs for aging fossil fuel facilities, which is an innate technological regime condition in the fossil fuel industry.

In addition to revealing the above challenges ahead of economic decarbonization, the analyses provide insights on the path-dependencies against the rentier states' path to a low-carbon energy system. As the study suggests, those path-dependencies originate from the already existing regime conditions as well as compatibility requirements with techno-climate system characteristics in the rentier states. For example, rentier states have been long focusing on the means for fossil fuel distribution (e.g. tanker fleets, pipelines), which may have pushed them back from developing infrastructures required for electricity transmission (e.g. mega grids), which are demanded for electrification based-transitions at nation-wide scales. As for the system requirements, the study projects that the rentier states would not willingly transition to energy technologies for which they lack critical minerals, which is a potential techno-geopolitical factor for them resisting against specific types of transitions.

Accordingly, if external landscape factors (e.g. global policies for climate change mitigation) pressure rentier states for phasing out of fossil fuel resources and incomes without recognizing rentier regime limitations and techno-ecological requirements, rentier states may respond with political economy strategies that may impede their own/global efforts for transition. To that end, 'throw-in', 'cut-offs', and 'price wars' are three climate destructive initiatives identified that rentier states may employ in response to global landscape conditions for transition. The study finds out that the throw-in and cut-off strategies would obstruct rentier states' own path for decarbonization, respectively by giving preference to climate change damage costs, and promoting domestic carbon leaks by freeing up resources for own consumption. The study also suggests that the price war initiatives would hamper external transitions through delivering a competitiveness confrontation against low-carbon energy adversaries.

In summary, Table 6 presents a group of the socio-technical factors that are accumulatively identified as influential on energy transitions at universal and rentier-levels of the document analyses. The factors are categorized as energy system characteristics (SC), niches-initiatives (N), Regime conditions (R), and landscape factors (L), following the MLP classifications. In order to identify their dynamics and collective influences on energy transition, the identified factors will be applied to a case study in the real word context of a rentier state in the next chapter.

Table 6: *Multi-level perspectives of the universal and rentier influential factors on energy transition*

Domain of the Influential Factor	Encouraging a Low-Carbon Transition	Depending on Socio-institutional and Geographic Context	Resisting a Low-Carbon Transition
Governance	• Development of the SMEs **(N)**	• Centralized Governance **(R)**	• Hierarichal Deficiencies **(R)** • Fossil Fuel Industry Manipulation **(R)**
Climate	• GHG Emissions **(L)** • Air Pollution **(L)**		
Technical	• Energy Overconsumption **(R)** • Energy Mix Diversification **(N)** • Emergence of Alternative Low-carbon Technologies (e.g. renewables) **(L)**	Techno-climate System Requirements **(SC)**	• Path-dependent Technology lock-in **(R, SC)** • Carbon-intensive Industries **(R)** • Increasing Maintenance Costs for Aging Hydrocarbon Infrastructures **(R)**
Domestic Political Economy	• Subsidy Removal **(N)** • Domestic Carbon Tax **(N)** • Privatization **(N)**		• Social Security Path-dependencies on rentier Incomes **(R)** • Employment Path-dependencies on rentier Incomes **(R)** • Banking System Path-dependencies **(R)** • Throw-in Strategies **(N)**
International Political Economy	• International Commerce Diversification **(N)**	• Cut-off Strategies **(N)** • Join-in Strategies **(N)** • Carbon tariffs **(N, L)**	• Price War Strategies **(N)** • Dig-in Strategies **(N)**
Geopolitics		• Trade War Strategies **(N)** • Critical Minerals **(SC, L)**	

Although most of the landscape and regime factors that influence energy transitions are common, respectively over the globe and among the rentier states, their dynamics may impose unique influences on the path for energy transition at specific rentier states. Therefore, case-based studies are helpful to analyze the MLP factors' dynamics for identifying their influences on energy transition. Such identifications in the context of one rentier state would resultantly provide lessons that can be applied to establishing a framework for studying the path for governing a green energy transition in other rentier states.

CHAPTER 5

Country Level analysis (Iran case study)

This chapter studies the priorly identified regime factors in the real world-context of Iran as a rentier state. It then introduces the geopolitical landscape factor of techno-economic sanctions on the Iranian fossil fuel industry and economy. In conclusion, the chapter analyzes the above regime-landscape dynamics in the Iranian context and identifies their collective influence on the Iranian path towards decarbonizing its energy system and economy. At the end, the chapter verifies its findings through interview discussions with former Iranian officials in energy governance, integrating their real-world experiences and perspectives.

1. Introduction to the Iranian Case of Study

Iran's GDP and international commerce are privileged from oil sales, revenues of which support the state's rentier budget (Karimi and Kiasar, 2018b). Also, 97.5 percent of the total primary energy supply in Iran is provided by fossil fuels (Noorollahi et al., 2021), which are domestically subsidized for downstream consumption (Research Center of Islamic legislative Assembly of Iran, 2020). Accordingly, Iran represents an evident case of the rentier states who face internal lock-ins in hydrocarbon resources, which could influence their adaptive path to decarbonization. From an external perspective, however, the study identifies multiple ongoing and prospective pressures on the Iranian rentier economy, respectively through exclusive economic sanctions (Moradi et al., 2023), and prospective climate constraints on oil sales (Hong et al., 2023). The Iranian case study aims at identifying dynamics between the above multi-level perspectives [MLP] (Geels and Schot, 2007) of the Iranian energy system and economy, as a real-world context for the rentier states. Using the MLP framework, the case study concludes on the collective influences those dynamics impose on Iran's transition path to a low carbon energy system.

To achieve its objectives, the case study analyzes Iran related-regime and landscape factors, as well as potential niche-initiatives for decarbonizing its energy system. The study begins with overviewing regime characteristics entailed in Iran's governance, domestic political economy, technologies, climate, and international political economy. The regime discussions are based on the regime factors identified in the Chapter-4/phase-B of the thesis' document analysis at rentier level. The case study does not look for re-identifying new regime factors that are exclusive to Iran, but rather validating the already identified factors in the Iranian case, which lets the conclusions be applicable to other rentier states. The study then proceeds with adding a landscape level of analysis as a pre-step for analyzing regime-landscape dynamics in the Iranian context. Similarly, the landscape conditions are derived from the factors identified in the Chapter-4/phase-A of the thesis, with an emphasis on sanction landscape conditions, which pressure the Iranian rentier economy (Moradi et al., 2023) but not others of the rentier states. Altogether, analyzing regime-landscape interactions allows for identifying their collective influence on Iran's path towards decarbonizing their energy system and economy.

The case study also examines the niche-initiatives that may contribute to decarbonizing rentier economies like Iran. As explained in the methods chapter, the niche part of the discussion is integrated with the sociotechnical initiatives that may potentially support those niches - referred to as the niche-initiatives. This is to compensate for the missing of low-carbon energy niches in Iran, perspectives of which are necessary for an MLP analysis. The case study explains that the Iranian path for transition is most likely to be initiated through niche-initiatives under join-in strategies (Chapter 4). Decarbonization through energy efficiency improvement is an example of join-in transition strategies towards a low-carbon energy system (Krane, 2018). Accordingly, the

niche-initiative part of the case study focuses on the sociotechnical initiatives that support decarbonization through energy efficiency improvements – referred to as join-in decarbonization.

Part A – Socioeconomic Regime Factors in the Socio-institutional Context of Iran

2. Domain of Governance

Iranian energy system is administrated by two ministries: The Ministry of Oil - responsible for fossil fuels and the Ministry of Power - responsible for electricity production and distribution. As Akbari et al. (2021) underline, the above dual governance causes conflicts of interests and inhibits integrated management, which in turn restricts the capital and legal instruments that are required for the government to launch long term energy initiatives - such as for decarbonization. Non-methodical patterns towards energy (over-)consumption is another side effect of this dual governance mechanism (Mousavi, 2015; Akbari et al., 2021).

A 2001 study by The Research Center of Islamic legislative Assembly of Iran acknowledges that merging Iran's ministries of power and petroleum is needed for having one integrated body in charge of the state's energy administration (Akbari et al., 2021). The study encourages for outlining a clear mission for the amalgamated ministry to avoid overlapping responsibilities after the two ministries are merged (Akbari et al., 2021). Stepping toward an integration back in 2011, Iran's parliament enacted a bill on establishing a supreme council for energy management, where parties on energy use and supply can gather for cooperation. Whereas, the council has not achieved its mission ideally, mostly due to lack of adjustment between the overlapping [and conflicting] structures within and between the ministries of oil and power, and the council (Akbari et al., 2021; Nowruzi & Pilehforosh, 2018).

Iran's state-owned regime of energy governance also constrains the country's renewable facilities to make limited contributions to the energy mix [at less than 1% according to the U.S EIA (2024)]. To answer why and how, Mohammadi and Danaee Fard (2019) point to budget constraints in the Iranian ministry of power, which is already indebted to fossil fuel-based electricity generators, thus in need of private capital for purchasing renewable electricity from the private sector. Mohammadi and Danaee Fard (2019) suggest that employment of public-private partnerships (PPPs) could enable the capital needed for the government to ensure long-run contracts with private parties and procure investments by guaranteeing competitive rates for purchasing renewable electricity per kilowatt hour. Nevertheless, a broad economic privatization program has not been launched as effectively as necessary to achieve the above initiative for energy transition through private capitalization. One of the possible reasons for that could be the establishment's interest in keeping legal and financial dominance over the economy [e.g. enterprises including for energy supply], and the corruption involved (Azadi, 2019).

In essence, the state ownership of the Iranian energy system is identified as a leverage regime factor to challenge governance of a low-carbon energy transition. As indicated by the documents, the state ownership correlates with the lack of capital for renewable developments, and the missing of an integrated legal system for administering long term plans for energy transition from hydrocarbon resources (administrated by the ministry of oil) to renewable facilities (administrated by the ministry of power). Although multiple studies elaborate on the rectification of such *administrative path dependencies* through privatization and integrated governance [e.g. privatization through PPPs, energy chain valuation and finance, government interference in market] (e.g. Akbari et al., 2021; Mohammadi and Danaee Fard, 2019), they do not identify how such rectifications coordinate with a potential path for transitioning to a low carbon economy. Documents also mention potentials for corruption and disadvantageous conflicts of interests among the Iranian ministers of oil and power, but omit delivering further explanations. It is important to identify these conflicts and their reflections in the Iranian political economy, which is necessary to analyze their influence on the rentier state's path towards decarbonizing the economy.

3. Domain of Domestic Political Economy

The governance related-regime factor of state ownership connects with the Iranian domestic political economy through supporting fossil fuel subsidization as a secondary regime factor. Although subsidization can be found in every state's energy economy, it is the centralized ownership of the energy facilities in the rentier states that enables lobbying for sustaining subsidies. Political motives for subsidy sustainment may also originate from conflicts of interests between bureaucratic bodies that oversee the nation's energy assets (Akbari et al., 2021; Taherifard and Akhavan, 2009). Identifying the above origins helps with locating political barriers to fossil fuel de-subsidization. It also helps with discovering the interplay of subsidization and centralized energy governance as multi-domain regime factors, and uncovering their collective influence on Iran's path for economic decarbonization. This section overviews political origins of hydrocarbon subsidization in the Iranian power sector. It then identifies economic reflections of those subsidies in the Iranian residential and industrial sectors by presenting data for governmental spendings on energy subsidies.

The Iranian ministry of power owns 42.5% of the power plants in Iran, which consume subsidized Natural Gas (NG) provided by the ministry of oil (Iran Energy Balance Sheet of 2021-2022, 2023). State ownership of these plants enables them to lobby for sustaining subsidies for fuels they consume. The subsidization, therefore, cheapens the price for the fossil fuels and makes energy efficiency improvement economically uncompetitive. Energy efficiency improvement, however, is a crucial part of join-in decarbonization strategies, which aim at decarbonizing the energy system

through decreasing the fossil fuel demands (Krane, 2018). Moreover, energy subsidies do not serve the Iranian public evenly either, as 49.2% of the power plants in Iran are owned by private sectors or industries that utilize subsidized power [through built-in factory power plants] (Iran Energy Balance Sheet of 2021-2022, 2023). Some of these power plants and industries export their products, with the subsidized resources included [e.g. subsidized power or fossil fuels consumed for commodity production] (Taherifard and Akhavan, 2009). However, prices for the subsidized resources do not vary based on their ownership status (whether they are public owned and used or private) or market target (whether they are sold in domestic markets or through international exports). Hence, there is skepticism about manipulation and corruption over the subsidies given to the private sector for the commodities they export. In particular, the manipulation skepticism arises from private sector's ability to exploit subsidies for self-benefits, which is in contrary to the subsidies' rationale of contributing to the state's economic well-being (Tavanpoure Paveh, 2004) [e.g. to the GDP and employment]. On the other side, the corruption concern arises from potentials for subsidy exploitation in the sectors that have public-private ownership. For example, there are major Iranian steel companies whose stock is owned by both the public and private sectors amid a non-methodical implementation of the Iranian constitutional privatization law in 2008 and onwards (Ahmadi, 2021). To that end, the public body can lobby for fuel subsidies at governmental levels, for their private partners to receive financial interests.

3.1 Fossil Fuel Subsidies in the Iranian Power, Residential, and Industrial Sectors

NG provides 80% of the fuel needed for electricity generation in the Iranian power plants, where the remaining 20% is covered by liquid fossil fuels (Iran Energy Balance Sheet of 2021-2022, 2023). According to the Research Center of Islamic legislative Assembly of Iran (2019b), 39% of the Iranian governmental spendings on NG subsidies [in 2018-2019] have been allocated to the power sector. To that end, the average cost of subsidized NG provided for power supply has been 0.9 cents/m3. This amount is 92% less than the international expense of the NG Iran exports, valued for 11 cents/m3. In addition to the NG subsidization, the Iranian government also subsidizes the electricity generated by the power plants. The average domestic cost for electricity in Iran has been 0.6 cent/kwh in 2018-2019. This amount shows 89% subsidization comparing to the average expense of the Iranian generated electricity, valued for 5.5 cent/kwh at the same period. Taking both the NG and electricity subsidies into account, the Iranian government has spent 13.6 billion dollars in hidden[5] power subsidization in just one annum (Data retrieved from Iran Energy Balance Sheet of 2021-2022, 2023; the Research Center of Islamic legislative Assembly of Iran, 2019a).

[5] Hidden Subsidies refer to those calculated based on dollar value of the subsidized products, as if they were sold in international markets (The Research Center of Islamic legislative Assembly, 2019).

The above regime of subsidization encourages non-efficient uses of energy in the downstream of the Iranian energy system. For example, energy consumption per capita in the Iranian residential and industrial sectors – including transportations - are 2.1 and 1.5 times higher than the global average. Out of surprise, the residential and industrial sectors [excluding transportation] receive the highest shares from the government's 13.6 B$ spending on power subsidies, respectively for 4.7 and 3.4 billion dollars (Research Center of Islamic legislative Assembly of Iran, 2019b). Excluding the liquid fuels, consumption per capita for NG in the Iranian sectors [all sectors average] is 6.1 times higher than the word's average (Iran Energy Balance Sheet of 2021-2022, 2023). Such inefficiencies can subsequently hinder join-in efforts for decarbonization, which aim at mitigating GHG emissions through more efficient use of fossil fuels. The subsidy derived-inefficiencies also nurture overconsumption in energy technologies leading to shortages in energy supply. Accordingly, the next section elaborates on identifying overconsumption and energy outage as two regime factors in the downstream of the Iranian energy system. It then identifies the relationship between subsidization and path-dependent developments on subsidized NG.

4. Domain of Technologies

Natural gas energy carriers support most of the energy consumed in the Iranian downstream of energy sectors. Natural gas and fossil fuel subsidization, however, has reverberated through overconsumptions and deficiencies in the Iranian regime of fossil fuel industry, inhibiting the balance of energy supply and consumption in the rentier state. Deficiency regime conditions, consequentially, favor initiatives for energy efficiency improvement and energy mix diversification to back the energy access in Iran's downstream. Yet, subsidy reliant developments are expected to challenge the path for efficiency improvements and energy source diversification through renewable developments over the energy mix.

Iran embraces 32.8 trillion cubic meters of estimated NG resources (Iran Energy Balance Sheet of 2021-2022, 2023), which is over 18% of the NG reservoirs on earth [World reserves data from Xu and Bell-hammer (2023, December 4)], and over 33% of the OPEC territories (Karimi and Kiasar, 2018a). Accordingly, Iran has revolutionized its natural gas production from around 20 billion cubic meters per year (bcm/y) in 1990 to 160 bcm/y in 2012 (Tagliapietra, 2014), replacing oil with NG for domestic energy supply. Out of each 100 units of the Iranian supplied NG, 32.4 are used for generating electricity in power plants, 40.6 for heat in households, and 28.1 in industries (Iran Energy Balance Sheet of 2021-2022, 2023). The subsidized regime of NG over the energy sectors, however, influences a disinclination to energy efficiency initiatives (e.g. de-subsidization), which triggers over-consumption and energy outage as two technological regime factors (Noorollahi et al., 2021).

The below sub-section identifies the relationships between subsidization and overconsumption in Iran's manufactural developments that are path-dependent on NG subsidies. Thereafter, the

section after analyzes the relationships between subsidization and outages of the electricity supply in the Iranian downstream of fossil fuel backed-energy regime. As discussions will indicate, burdens of energy outage are derived by overconsumption in several Iranian energy sectors, including the residential and industrial sectors, which are stakeholders in subsidized NG. It is identified that Iran has sufficient techno-ecologic capacities for developing low-carbon energy infrastructures (e.g. soar, hydrogen), which may cover for the ongoing energy outages in parallel with promoting energy mix diversification. Yet, as elaborated by the rest of the analyses, there are techno-economic system restrictions that obstruct the path for Iran to transition its energy system into a lower-carbon mix.

4.1 Industrial Path-Dependency to Energy Subsidies, and Overconsumption (Steel Example)

Given the Iranian power plants' reliance on NG by 80% (Iran Energy Balance Sheet of 2021-2022, 2023), there appears some strong path dependency on NG subsidies in the Iranian sectors that consume power. To that end, the industrial sector consumes 35 percent of the total power generated in Iran, 33 percent of which is used in steel manufacturing. Extreme energy intensity in the steel sector, thus, triggers dependencies on energy subsidies, where 30 percent of the final price [expense] for the Iranian steel comes from energy utilization. Totally, natural gas, power, and coke provide the energy utilized for steel processing by 73, 19, and 7 percent respectively (Rahimdoust, 2021). Therefore, the Iranian steel industry, presents an ideal example of a path-dependent development evolved out of a techno-economic regime of NG subsidization.

The techno-economic vulnerability to natural gas (NG) subsidization is evident through comparing the Iranian steel price before and after legislation of the *"deliberative subsidy reforms act"* by the Iranian government, which fostered socio-economic challenges. Since the bill was enacted in 2009 - hoping for enhanced and just accessibility to national resources - until 2019, the expense for the Iranian steel has surged by 271 percent due to NG de-subsidization. As a result, international market for the Iranian steel weakened, albeit surviving financial losses thanks to increasing value of the U.S dollars gained relative to the Iranian Rials exchanged (i.e. dropping value of the Iranian currency). Such weakness is of potential to slow down rates of development over the Iranian industry to the extent it culminates in unemployment, and future needs for importing strategic goods such as the steel. That if happens, triggers a reliance on foreign steel markets, shaping extra geopolitical vulnerability (Rahimdoust, 2021).

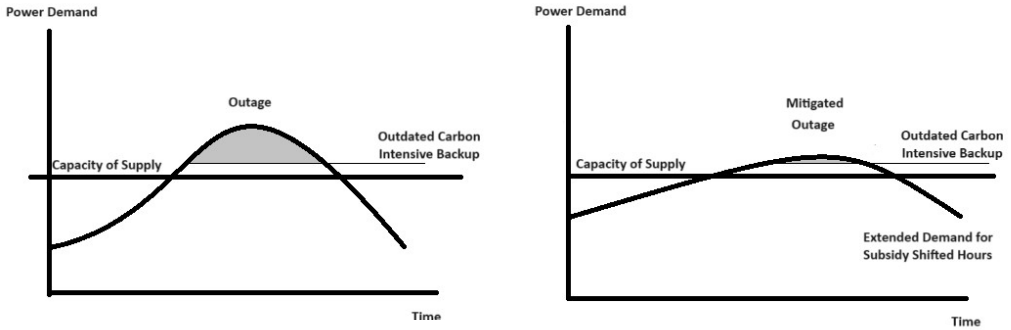
The overconsumption of NG in the Iranian steel industry is a clear consequence of NG subsidies. Excluding power, mining, and transportation, each ton of steel consumes 650 to 750 cubic meters of NG for production in Iran. To envisage a comparison, this amount is 7 times bigger than the NG used for cement manufacturing in the country, and 30% higher than the global average for steel

manufacturing. In other words, huge subsidy allocations have nurtured Iranian steel manufacturing (and other manufacturers similarly) in a way it favors energy intensive means of production, despite availability of lower energy dependent methods (National Iranian Steel Company, 2020; Iranian Fuel Conservation Company, 2016; Rahimdoust, 2021). Moreover, Iran's Ministry of Industry, Mining, and Trade plans for further expanding the steel productions up to 55 tons per annum by 2025. Such expansion would rise natural gas consumptions up to near 19 billion cubic meters per year in the sector, exceeding the world's average by 40% (National Iranian Steel Company, 2020; Iranian Fuel Conservation Company, 2016; Rahimdoust, 2021).

The above prospective spike would intensify the steel sector's economic reliance on NG subsidies. It would also impose extra pressure on the regime of NG supply in the country, which confronts temporal outages in winter seasons, when demands for NG are at peak for heating (National Iranian Steel Company, 2020). Moreover, the spike would place additional burden on the technological regime of power supply in the country, which combusts NG for electricity generation, (Iran Energy Balance Sheet of 2021-2022, 2023). The next sub-section elaborates on interconnections between overconsumption and energy outage as two technological regime factors entailed in electricity generation in Iran.

4.2 Techno-economic Regime Factors in NG Dependent Industries (Power Industry Example)

Subsidy derived overconsumptions lead to electricity shortages as secondary regime conditions, which happen amid peak times of electricity use, particularly in the summer seasons when demands for cooling are at max (Iran Energy Balance Sheet of 2021-2022, 2023). This type of shortage reflects deficiency in power generation, not in fuels supplied to the power plants. In other words, the shortage comes from limited capacity of the installed power plants for generating electricity, despite availability of natural gas and other fuels for utilization by the plants. Therefore, although the shortage is very extreme to the extent it causes outage (see *Figure 7a*), it is limited to a few hours on a few days amid particular seasons. As result, it is not economically efficient for the government to develop new plants to cover the periodic shortage. Rather, the ministry of energy transfers electricity subsidies from peak to non-peak hours, flattening the temporal curve of the power demand (see *Figure 7b*). That said, the subsidy transfer is limited to electricity subsidies and will not reduce the total NG combustion. Instead, it changes temporal patterns of NG combustions (Tavanpoure Paveh, 2004; Iran Energy Balance Sheet of 2021-2022, 2023).



b) Pre-transfer dynamics a) Post-transfer dynamics

***Figure** 7: Analytical illustration of the effect of subsidy transfer initiative on dynamic intersections between power demand, outage, and non-efficient backup*

The above transformation helps mitigating the power outage and the following air pollution; yet it can also contribute to decarbonization as follows.

Amid the outage peaks, the Iranian government - thanks to availability of subsidized fuels in vast amounts - reconnects its outdated power plants that are detached from the grid in normal (non-peak) situations (*Figure 7*). These plants are low efficiency, which means they require extra fossil fuels for generating a fixed portion of electricity (Iran Energy Balance Sheet of 2021-2022, 2023). As result, the outdated plants release more than normal GHG emissions for generating electricity in the peak hours. Therefore, although the subsidy transfer's aim is at outage mitigation, it also supports join-in decarbonization through efficiency preservation by minimizing needs for using outdated power plants that combust NG excessively. On the other side, unsustainable peak coverage by the outdated plants also culminates in more governmental spendings on gas and power subsidies because the peak time electricity is more expensive when provided by the inefficient plants that require excessive fuels. Therefore, the subsidy transfer initiative can similarly mitigate such spendings if flattening the peak curve to an effective extent (Tavanpoure Paveh, 2004).

4.3 Decarbonization through Energy Efficiency Improvement (niche-initiatives, regime path-dependencies, and system characteristics)

The technical regime factors of overconsumption and seasonal energy shortage have pushed the Iranian government to integrate energy efficiency and equity values into power pricing. Resultantly, subsidies in the power sector are more justly distributed in Iran relative to other sectors (Tavanpoure Paveh, 2004). To that end, the Iranian government individualizes power charges based on consumers' consumption bulks and geographical needs for power. Such individualization can prospectively extend as a join-in strategy that decarbonizes power through de-subsidization of the fossil fuel backed electricity. Power de-subsidization, however, confronts

socio-technical challenges, which will be elaborated later in this sub-section (Iran Energy Balance Sheet of 2021-2022, 2023; Tavanpoure Paveh, 2004).

The Iranian initiative for equitable efficiency individualizes power prices based on 'consumption norms', where overconsumption is fined, and consumption saving is rewarded with discounts over the power price. The so-called 'consumption norms' are defined based on the natures of use and geography. As for the use, the government divides power users into residential, agricultural, industrial, public (e.g. city), and other (i.e. minority users) users. Each class receives its own range of 'consummation norm' where the electricity bills are calculated according to pre-defined levels of energy intensiveness recognized as 'normal' for each class's activities. As for the geographical aspect, the government zones the country based on climate indicators of temperature and humidity. The zonation enables adjusting power charges based on viable needs for cooling as imposed by geographical conditions (Iran Energy Balance Sheet of 2021-2022, 2023).

The above customization can be applied to de-subsidizing power based on climate externalities derived by each user class (e.g. charging for out of 'norm' GHGs or air pollution released per kw/h of power consumption). Meanwhile, some studies suggest that de-subsidization would confront path-dependent resistance from the power users in Iran. In terms of the residential users, for example, Moumivand et al., (2014)'s ARDL (Auto Regressive Distributed Lag) model projects a maximum limit of 10% power saving following a subsidy removal. The authors point to electricity as a secondary [mid-stream] energy for the Iranian residential sector, around half of which is consumed by day-long working appliances. Such appliances (e.g. refrigerator) are low cost and low efficiency. They have been privileged of market preference under the absence of monetary valuation for energy saving and efficiency improvement following low energy prices. Yet, Moumivand et al., (2014) add that the [average] Iranian household income is not sufficient for replacing low-efficiency appliances with efficient ones to an effective extent that supports energy efficiency by de-subsidization [beyond 10%].

4.4 Decarbonization through Energy Mix Diversification (initiatives, regime factors, and system characteristics)

Technical characteristics of the Iranian ecological system support several types of renewable energies, such as solar, geothermal, wind, and hydropower (Moshiri et al., 2015). To that adds the advantage from on-site availability of some types of renewables compared to fossil fuels' requirement for transportation. But renewable energies face competition shortcomings compared to fossil fuels' regime of subsidized economy (Mousavi Dorcheh et al., 2018). And hence, the Iranian government needs various kinds of initiatives to re-balance the above influential factors in favour of the renewable energies to gain more share in Iran's energy mix. Such initiatives, however, have not been so far successful, due to internal strength of regime

oppositions coupled with external landscape conditions that are to be elaborated later in this chapter.

Iran's ecological and climate system allows for developing renewable energies sourced from the wind, earth, sun, and water streams. Moshiri et al. (2015) review a group of analytical works that approximate Iran's potentials for each renewable energy. As they conclude, Iran can generate 22TWh of power per year from wind, and 5.25 TWh from geothermal by 2030. Also, Iran receives above 2000 KWh of solar radiation (Mousavi Dorcheh et al., 2018) per square meters per year in average, thanks to a mean of 280 annual sunny days over 90% of their land (Ghorbani et al., 2017). High solar irradiance provides a significant capacity for both the photovoltaic and concentrated solar plants (CSP). While estimations for CSP power generation account for 94TWh/year by 2030, there is as little as 0.007 TWh projection for photovoltaic plants (Moshiri et al., 2015), which can be interpreted as an impact of sanction derived techno-financial constraints (Mousavi Dorcheh et al., 2018) against accessing to the technology and investment requirements for photovoltaic developments. Lastly, Moshiri et al. (2015) estimate the possibility of 17.3 TWh of hydropower electricity generation in Iran by 2030, from the present capacity of around 12,200 TWh per year (Iran's Energy Balance sheet for 2021-2022, 2023).

Beyond techno-geographic compatibilities, energy mix diversification through renewable developments is also encouraged by technological deficiencies in the fossil fuels' regime of distribution. As stated in Iran's Energy Balance sheet for 2021-2022 (2023), northern provinces in the rentier state rely on importation of energy carriers from neighboring countries of Turkmenistan and Azerbaijan, which is due to the provinces distance to Iranian fossil fuel reserves, which are mostly concentrated in the country's south and southwest. The gap therefore requires costly tanker fleets and pipelines for fossil fuel transportation. Yet, Iran's northeastern provinces are not densely populated enough for justifying establishment of new offshore routes for hydrocarbon transportation. The similar condition applies to the rural areas in Iran east, which can receive energy access through the advantage of on-site (off-grid) renewable instalments, particularly of the solar technology. Lastly, the seasonal and periodic energy shortages (Figure 7) are the other technological regime conditions encouraging for energy mix diversification. To that end, while the limited energy shortages pictured in Figure 7 may not justify investments in building new fossil fuel power plants, they provide opportunity for small scale and off-grid solar panels to supply the coverage needed, and gain share in the state's energy mix.

Contrasting the above encouragements, there are system characteristics in renewable technologies that are incompatible with techno-ecological conditions of Iran, challenging energy mix diversification. As for the hydropower for example, Iran receives less than 1/3 of the global average in precipitations (Ghorbani et al., 2017). Therefore, any progress from hydropower in the Iranian energy mix is questionable given the global warming derived droughts and ongoing

tensions in the country's water supply. Despite Moshiri et al.'s (2015) projection, Iran's capacity for hydropower generation has remained nearly consistent between around 12,000 and 12,200 TW/year, between 2021 and 2015, when the projection was made (Iran's Energy Balance sheet for 2021-2022, 2023).

Regarding the on-grid solar energy plants, higher investment expenditures compared to fossil fuel plants (Aryanpur et al., 2019), including for high investments in energy storage (Ghorbani et al., 2017) are two of the barriers to phasing out of fossil fuels to solar energy in Iran. To that adds a reverse relationship between solar plants' efficiency and temperature, which reduces their productivity in central Iran, where receives most solar irradiance (Gorjian et al., 2019). In addition to high temperatures, Iranian deserts suffer from dust hazards, which further decrease productivity of the solar plants without self-cleaning technologies in place (Gorjian et al., 2019). Lastly, concerning the earth-thermal, the considerable distance between the limited nodes for geothermal energy generation and nodes for consumption prevents earth-thermal from being a significant provider of heat as it is of power (Moshiri et al., 2015).

Considering the equilibrium between inducements and deterrents to energy mix diversification, the influences from technical regime conditions and system characteristics are critical. To that end, it is clarified that regime deficiencies in the technological domain of fossil fuel industry provide large room, thus big encouragement, for the renewable technologies to thrive. This is unlike the negative influences from the regime condition of fossil fuel subsidization, which blocks renewable transitions through competitiveness obstructions. Moreover, renewable technologies rely on specific system requirements, some of which are supported by, and some of which are inconsistent with, techno-ecologic characteristics of the Iranian climate. Yet, to have a more accurate picture about how each side weights, it is important to not miss the externalities and influences that arise from the climate factor of emissions, which motive energy transitions internally as regime condition (next section), and externally as a landscape (Chapter 4-Part a).

4.5 Conclusions and Statements of Techno-climate Interplay

When all is said and done, it is evident that fossil fuel (e.g. natural gas) subsidization has reverberated through path-dependent developments in the Iranian sectors for power generation and industrial manufacturing. Those developments confront lock-ins in subsidized fossil fuels, and low-efficient technologies that overconsume energy in the residential (e.g. for home appliances), and industrial (e.g. for steel manufacturing) sectors. It is clarified that the subsidy dependent developments could act as regime actors that oppose de-subsidization, initially. Nevertheless, it is also clarified that subsidies – when allocated at extreme levels - implicate in energy shortages derived by over-consumption and inefficient use of resources, which lead to a feedback loop that pressures the system for energy saving. To that end, the Iranian government may employ

initiatives of energy price individualization for justly removing the priorly allocated subsidies based on overconsumption behaviors of sectoral stakeholders. As subsidy removals are justified for tackling energy shortage and in-efficiencies, they also cut on hydrocarbon demands, and thus contribute to decarbonization through energy efficiency improvement.

On the other hand, Iran may also diversify its energy mix through the renewables, which can cover for energy shortages and deficiencies derived from fossil fuel overconsumption. As identified, Iran has techno-climate potentials for developing several types of renewable energy technologies, including for solar, wind, and geothermal. Although there are techno-climate inconsistencies that may challenge energy mix diversification through renewable developments, their weight could be mitigated by taking emission reduction effects of such renewable developments into account. As the next section elaborates, reducing greenhouse gases from the energy sector will be a key contributor to Iran's compliance with its Paris Agreement commitments, as the sector is a predominant source for GHGs in the rentier state (Iran's Energy Balance sheet for 2021-2022, 2023).

5. Domain of Climate

According to the EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database (2023), Iran emits 1.8% of the total GHGs worldwide, which equates to 951.984 million tons of CO_2 equivalent emissions per annum [2022]. Those emissions are dominated by CO_2, CH_4, and N_2O species, which shape up to 72.1, 23, and 3 percent of the GHGs emitted in Iran, respectively. Given the Iranian energy system's activity over both sides of fossil fuel supply and use, Iran's energy emissions arise from both the up and down streams of the energy system. Fossil fuel production and consumption also cause various types of non-GHG pollution over the energy infrastructures, which endanger the public health. Accordingly, extreme GHG emissions and non-GHG pollution are two regime factors entailed in Iran's hydrocarbon backed-energy system, like other rentier states. This section overviews sectoral entities that are responsible for nurturing the above-mentioned climate factors. It also highlights some of the socioeconomic and environmental threats that arise from the emission intensive regime of climate in Iran.

Unlike the fossil fuel importer nations that have GHG emissions mostly from energy use, over 200 Mt CO_2 eq of GHGs in Iran belong to fossil fuel exploitation [at upstream level] (EDGAR, 2023). A predominant source for those emissions is the flaring of 17.4 billion cubic meters NG per annum (Shahab-Deljoo, 2023). As Roche et al. (2018) state in Iran's Country Report for Implementation of their Nationally Determined Contributions, flared emissions may have shaped up to 19% of the total emissions in Iran, counting for 150 Mt of greenhouse gasses in 2018 (Khalili-Garakani et al., 2021). The report also recognizes difficulties against monitoring flaring and refers to lower-hand

approximations that estimate flaring shares between 7% to 10% of the total emissions in Iran (Roche et al., 2018). Regardless of the over/underestimations, however, there is consensus about flaring's impacts on the Iranian economy, which wasted 3.7 billion dollars of potential NG incomes for the rentier state in 2021 (Shahab-Deljoo, 2023).

When it comes to the downstream of energy system for energy use, electricity generation is the biggest contributor to the GHGs in Iran (EDGAR, 2023). According to Iran's Energy Balance sheet for 2021-2022 (2023), Iranian power plants utilize 67.3 bcm of NG for electricity generation, which is 28.1% of the total NG utilized in the country. Consequentially, power generation has been responsible for a noticeable percentage of the GHG emissions in Iran, including for 29.95% of the CO_2 (200,024,774 tons), 6.96% of the CH_4 (4509 tons), and 5.54% of the N_2O (641 tons). Beyond their global warming effect, Iranian power plants emit air pollutants that endanger public health and impose financial externalities on the healthcare system. The power plants produce 41.74% of the NO_x pollution and 35.46% of the SO_2, which is both a toxic pollution and a Greenhouse gas. (Iran Energy Balance Sheet of 2021-2022, 2023; Ward, 2009; United States Environmental Protection Agency, 2023). Therefore, a need for decarbonization is identifiable in the Iranian power sector from local (public health) and global (climate change) perspectives. However, the sector's reliance on subsidized fossil fuels is anticipated to oppose a prospective decarbonization.

After electricity generation, the residential sector and buildings (including commercial and public entities), transportation, and industrial manufacturing are other sectors with highest shares in releasing GHGs in Iran. The residential and building sectors have been responsible for approximately 163 Mt of CO_2 emissions from energy use, causing 24.39% of the CO_2 emitted in downstream (Iran's Energy Balance Sheet for 2021-2022, 2023). These sectors have also contributed to around 241 thousand tons of non-CO_2 emissions including NO_X, SO_2, SO_3, CO, SPM, CH_4, and N_2O species (Iran's Energy Balance Sheet for 2021-2022, 2023).

On the other side, the transportation sector has been responsible for 21.19% of the CO_2 production in the country, equating to over 141 Mt of volume. Despite being on the third place in terms of total emission causation, the transportation sector leads sectoral shares in non-CO_2 pollution in Iran, such as for CO by 98% (9 Mt), CH_4 by 83% (54 Tt), SPM by 77% (309 Tt), N_2O by 56% (7Tt), SO_3 by 42% (5Tt), SO_2 by 40% (392Tt), and NO_X by 45% (934 Tt), equating to over 10.5 Mt of non-CO_2 species (Iran's Energy Balance Sheet 2021-2022, 2023). The significant point for highlighting such a lead is that many of these species are recognized as toxic (Chapter 4 – part a), which will continue to risk the public health in the absence of an integrated strategy (Integration between GHG and non-GHG pollution mitigations) for phasing out of the fossil fuels (e.g. decarbonization through Carbon Capture and Storage [CCS] technologies). For example, NO_X and Ozone are well-known pollutants that endanger the public health in Iran's capital during the early morning and sunset peaks of traffic jam (National Iranian Steel Company, 2020; Taheri et al.,

2022). It is also worthy of note that emissions from the Iranian transportation sector have been growing 5.9% per annum, which is the fastest rate of emission growth among all Iranian sectors (Roche et al., 2018).

The fourth top Iranian sector behind releasing GHG emissions is the industrial sector, which is responsible for around 128 Mt of CO_2 emissions, as well as 355 thousand tons of emissions in NO_X, SO_2, SO_3, CO, SPM, CH_4, and N_2O species (Iran's Energy Balance Sheet for 2021-2022, 2023). CO_2 emissions from industrial sector equate to 19.14% of the total CO_2 released from energy use in the Iranian downstream (Iran's Energy Balance Sheet for 2021-2022, 2023). Among all the Iranian industries, steel manufacturing is the most energy [hydrocarbon] intensive (Rahimdoust, 2021) by causing 78 Mt of CO_2 emission, including directly through streel manufacturing (up to 64 Mt), and indirectly through power use for steel production (up to 14 Mt). Iranian steel industry also co-produces SO_X and NO_X toxic pollutants by over 1800 and 1400 mg/nm^3, which risk the public health of the local residents and ecological environment (National Iranian Steel Company, 2020).

The above data speaks about an uneven distribution of emission species over the Iranian energy sectors as a techno-climate regime condition. Given that the climate effects of emissions vary among the species, for instance in terms of temporal Global Warming Potentials or health consequences, an uneven distribution of them would influence the path for energy transition in terms of target selection. For example, if Iran aims at prioritizing mitigating CH_4 emissions due to methane's destructive climate effects in short-term horizons, while offsetting the costs for doing so by health benefits, it may prioritize implementing a transition over the transportation sector, which co-produces highest magnitudes of CH_4 and air pollution among all sectors. On the other hand, by capturing CO_2 and methane and commercializing them in the international markets Iran would cut GHGs at the upstream of its fossil fuel industry. Yet, the analysis stops at above identifications about how the uneven sectoral distribution of various emission species – as a climate regime condition – directs the path for energy transition. The analysis avoids suggesting a sectoral transition path to look into because it requires much more of analysis including of costs and benefits, temporal dynamics, and feasibility investigations.

6. Domain of International Political Economy

Iran's vast access to hydrocarbon reserves has encouraged adopting a rentier economy, where the GDP, fiscal incomes, and international trade are predominated by, and therefore dependent on, fossil fuel exportation. The above regime conditions have consequentially led into secondary regime conditions such as non-linearity and uncertainty of the rentier state's economic growth, which is a variable of the price and volume of the oil Iran exports. Those uncertainties resultantly

reverberate through difficulties in treasury planning and budgetary deficits as consequential regime conditions in the third place. Furthermore, like any rentier state, Iran confronts maintenance costs for recovery of its aging fossil fuel infrastructures. As azadi et al. (2016) estimate, maintenance expenditures are high enough for imposing a plateau effect on Iran's rentier incomes from crude exportation.

6.1 Iran's Economic Reliance on Hydrocarbons – Regime of International Political Economy

Iran has around 157 billion cubic meters of estimated crude oil, which is 10% of the proven oil on earth and 13% of the OPEC territories (Karimi and Kiasar, 2018a). Oil resources thus have nurtured a rentier regime over the Iranian political economy, which is identifiable by the economic indicators of GDP, fiscal revenues, and international commerce. Oil rents have formed 19.6% of the Iranian GDP, and 37% of the total fiscal revenues fed into the governmental budget. In parallel, oil exports have supported 67% of the international incomes from commerce of commodities and services by Iran. Excluding the services and counting for the commodities only, oil rents hit 71.5% of the incomes Iran earns from international trade (Karimi and Kiasar, 2018b)[6].

The economic reliance on hydrocarbons has contributed to regime conditions such as non-linearity of the economic growth and its path-dependency on hydrocarbon revenues in Iran. As interpretable from the above indicators, economic growth in Iran is dependent on variables such as the international price for oil, efficiency of petroleum infrastructures, and ability for hydrocarbon exports. Consequentially, the rentier structure of the economy entails non-linear shifts in key economic indicators following fluctuations in variable dependencies, such as the price for oil, or abilities to oil export. For instance, Iran experienced 1.8% of economic growth in the short span of spring 2018, 1.2 of which were achieved by the added value from the oil sector (Karimi and Kiasar, 2018b). Nevertheless, the country's economic growth dropped to minus 6.5% in 2019-2020 [Central Bank of Iran, 2021]. The drop occurred amid the U.S sanctions on the Iranian oil sector, which shrank the sector's GDP by 37.8%, causing minus 7.4% of relative share from the oil sector to the 2019-2020 economic growth (Central Bank of Iran, 2021).

The above non-linearity and path-dependencies respectively develop into uncertainties and vulnerabilities as secondary regime elements in the Iranian political economy. As for the uncertainties, non-linear fluctuations within the above variables inhibit government's ability of having a reliable estimation of its annual fiscal incomes from oil export, which brings ambiguity to budget planning (Ghalevandi and Zandi, 2021). To that end, the Iranian government frequently

[6] Data is driven from spring 2018, presenting a near zero sanctions scenario after the JCPOA. Onwards spring 2018, the United States imposed an 'extreme pressure campaign' on the Iranian oil industry followed by unprecedented sanctions in August 2018 and onwards. Impacts from the sanctions are further discussed in later sections.

confronts budget shortfalls, which increases risk of inflation (Ghalevandi and Zandi, 2021). On the other hand, dependencies on oil prices, ability of exports, and technological efficiency make the Iranian economy vulnerable to geopolitical landscape factors (e.g. war, sanctions) that may affect those variables. The section below pictures Iran's vulnerabilities to technological deficiencies and international landscape conditions over its ability of efficient production and exportation of the fossil fuels.

6.2 Interplay of International Political Economy, Upstream Deficiencies and Techno-climate Landscape Factors

When it comes to the upstream, there is an average 6% per annum decrease in productivity for the Iranian oil wells, which can be compensated for through utilization of some new oil fields by 2025 (Azadi et al., 2016). The compensation, however, would be costly by requiring "operation of many more wells, injection of increasing share of the produced natural gas, use of artificial lift, and heavy investment in … recovery practices" (Azadi et al., 2016, p. 3). As estimated by Azadi et al. (2016), above maintenance operations contribute to constraining Iran's capacity of crude production and gross profits out of fossil fuel export (Azadi et al., 2016). For example, despite chances for increasing capacity of crude generation by 4.4 mmb/d by 2040, it is unlikely for Iran to be able increasing profits from crude exportation onwards 2025 above to a maximum level of $150B per annum (Azadi et al., 2016). The plateau impact on the fossil fuel incomes would therefore risk Iran's economic growth in the long-term, and make it vulnerable to external landscape factors that may further disrupt rentier incomes.

Climate change mitigation and emergence of *unconventional commodities* are two international landscape factors interrupting political economy of the Iranian hydrocarbon industry. As the world phases out of petroleum and becomes less vulnerable to medium-size suppliers, the likelihood for the Iranian crude remaining unused in vast volumes rises. A global climate action if happens, could push Iranian administration losing a noticeable amount of fortune stranded in fossil fuel investments. Those stranded assets, in a presumed oil price of $60/barrel, would be worth 10 to 20 times bigger than the country's economy size in 2019. Therefore, the coverage from the Iranian petroleum exports on social security is subject to decrease. Such a decrease will then prompt the government to increase taxes or cut services. This is while direct taxation has had a historically low share – below 10% - in the Iranian GDP; which if expanded, can improve social accountability from the administration (Azadi and Mirramezani, 2019; Azadi 2019; Azadi et al., 2016).

Moreover, affordable shale commodities are expected to transform the market unfortunately against conventional resources too. Although the Iranian expenditures on producing crude have been low, around $10 per barrel (California Energy Commission, 2021), this amount is anticipated to turn more expensive due to aging and depletion of the oil fields. As Azadi et al. (2016) estimate,

over 70% of the Iranian oil extraction will be through costly reservoirs with more than %50 of depletion rate by 2040. As for the shale rival, however, the production cost has been dropping 1%/annum for three years in a row in the U.S; more cuts are expected to occur. In addition to the affordability trends, the timespan for shale oil projects from initiation to operation is considerably lower than of those for conventional oil fields, which is another competitive advantage for unconventional technologies (Kimani, 2023; Azadi, 2019; Azadi et al., 2016).

6.3 Conclusions and Statements of the Interplay between International Political Economy, Upstream Deficiencies, and Prospective Landscapes

The regime conditions of economic reliance on oil and maintenance costs for petroleum facilities have tied Iran's economic growth and treasury planning to external factors, such as the price and volume of the oil Iran may export. Given that the two factors are never consistent but variable, Iran suffers from uncertainty and non-linearity in economic growth and treasury shortcomings as secondary regime elements. Resultantly, the above regime conditions have made the rentier state economically vulnerable to techno-climate landscape factors that may disrupt oil production, exports, and revenues. Emergence of low-carbon energy technologies (e.g. renewables [Chapter 4 – part a]), unconventional opponents (e.g. shale oil), and global actions for climate change mitigation (e.g. carbon tariffs, climate sanctions) are three prospective landscape factors in this matter. Yet, although the above landscape conditions are prospective, which may challenge analyzing their influences at the present time, Iran confronts ongoing landscape constraints in form of international sanctions on its fossil fuel industry. Analyzing Iran's sanction influences would therefore contribute to resembling a simulation about how the prospective techno-economic landscape conditions would influence the rentier states' path to decarbonizing their energy system and economy.

7. Part B - International Landscape Conditions over Iran's Rentier Reliance on Hydrocarbons

In addition to the previously identified landscape factors that pressure every state for transitioning to a low-carbon economy (Chapter 4- Part a), there have been exclusive landscape conditions on the Iranian energy system in form of geopolitical tensions, war, and sanctions. This section aims at identifying Iran exclusive-landscape conditions on the rentier state's privilege of oil revenues, and its rentier reliance on hydrocarbon exports in the realm of international political economy.

Iran's oil revenue per capita experienced an all-time record peak during 1975-1976 when oil exports reached 5.3 million barrels per day (mmb/d), and oil rents formed a record high of 42 percent of the state's GDP. After the Iranian revolution (1979), followed by Iraq's war with Iran

(1980), Iran's petroleum exports dropped to 0.92 mmb/d, which later grew to 1.65 mmb/d by the end of the war time (1988). This period (1987-1988) coincides with a low oil share of 5 percent in the country's national GDP.

Thereafter, thanks to a chapter of peace, diplomacy, and industrialization (1990-2004), and followed by further investments in upstream technologies, Iran crude exports were stabilized above 2 million barrels per day. Subsequencially, the state experienced its post-revolution peak of fossil fuels exportation and contribution to the GDP, respectively of 2.6 mmb/d and 25 percent, in 2005 and 2006. Although the portions were later flattened under U.S sanctions on the Iranian petroleum industry, Iranian oil revenue per capita continued to grow by 2011, supported by the globally surging price of the crude in the mid-2000s'. Meanwhile, Iran's domestic use of crude also rose throughout this time from 0.7 mmb/d (1976) to 1.6 mmb/d (2011) given the state's developing nature and aim for industrialization, which restricted further potentials for export (Data from: Azadi and Mirramezani, 2022; Azadi, 2019).

Onwards 2011, Iran faced an evident shrinkage of oil sales from 2.0 to 1.0 million barrels per day from 2011 to 2012, with 20 and 19 percent of respective GDP share (Data from Azadi and Mirramezani, 2022). The cut was motivated by tensions around the Iranian nuclear energy program, as well as sanctions imposed on the country's oil industry. That said, sanctions have resulted in constraints on the capital [and technological] access required for upgrading the upstream petroleum industry in Iran, where aging wells confronted deficiency and thus a surging need for maintenance [interpretation from Sobhan Energy (n.d.a)]. Although the downward trend was temporarily halted under the Iranian nuclear agreement – also knowns as the Joint Comprehensive Plan of Action (JCPOA) – with the group of 5 + 1 states and the European Union, it recommenced with further acceleration after the U.S withdrew from the deal in 2018.

Following the U.S withdrawal, 2019 coincided with new waves of the U.S sanctions and consequential techno-capital constraints, which decreased Iran oil exports to 0.62 mmb/d, and GDP share to 7 percent, in a significant contraction compared to the respective post-JCPOA levels of 1.88 mmb/d and 11 percent. The amounts were further lessened to 0.29 mmb/d for oil exports and 6% for GDP share in 2020, affected by the Covid-19 pandemic. As a result, Iran has been losing its petroleum market to energy adversaries such as Russia, Saudi Arabia, and the United States (Karimi and Kiasar, 2019; Azadi et al., 2022; Azadi, 2021; Azadi and Mirramezani, 2022; Azadi, 2019). Figure 8 presents a time series of the Iranian petroleum exports between 2011 and 2020. As indicated below, fluctuations imposed by external pressures (landscape factors) such as infliction and removal of the sanctions, have explicitly affected the trend in the last decade.

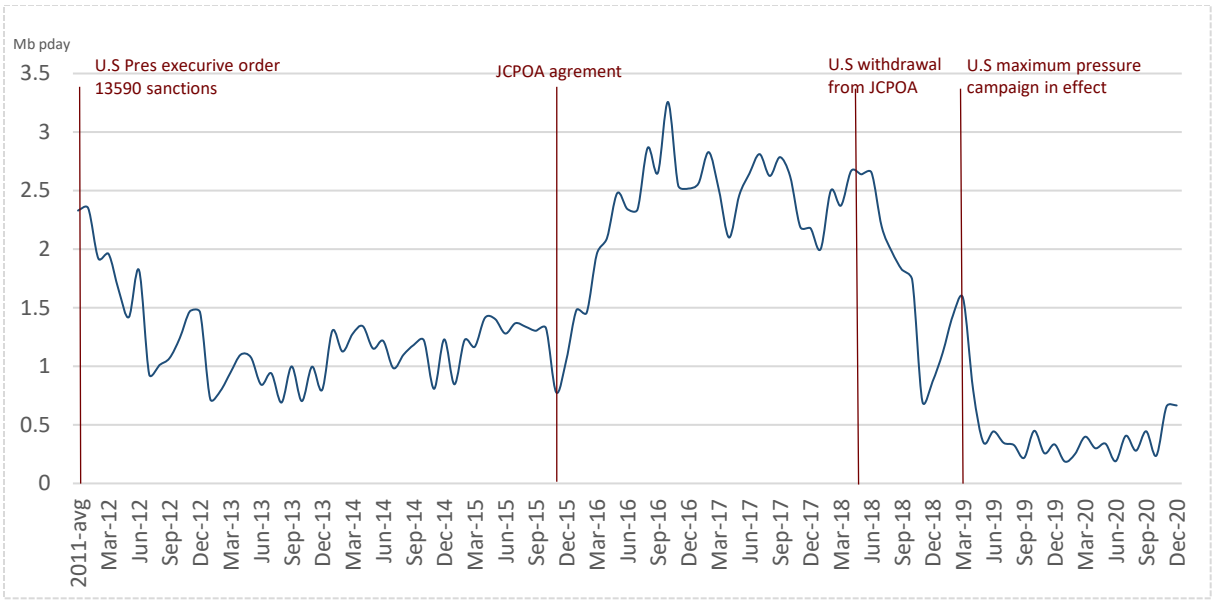


***Figure 8**: Iran's crude oil and condensate exportation*
Data Sources: The World Bank, Tehran Chamber of Commerce Industries Mines and Agriculture, and the U.S Energy Information Administration from Clipper Data, LLC.

In the first quarter of 2021, however, Iran signed a 25-year strategic deal with China that consisted of economic agreements including for cooperation in the energy sector (Associated Press, 2021 March). According to Sobhan Energy's [an Iranian energy think thank] (2020 & n.d.b) report, the deal included China's considerable investments in the Iranian oil and gas industries, which have been set for implementation after signing the deal in 2021. Accordingly, the data from the U.S EIA (2024) approves of a spike in Iran oil sales in 2021 over 0.6 million barrels per day, which are mostly driven by China. These exports decreased to below 0.6 mmb/d in the second quarter of 2022, mainly due to less demands from China following higher international oil prices and Russia's growing share in their market (EIA, 2024). However, according to the IEA (2024), the exports re-expanded to 1.3 mmb/d in 2023 and anticipate further expansions following the enhanced capacity of oil production in Iran in 2024 (Tehran Times, 2024).

Therefore, whilst relying on fossil fuel incomes as a rentier state, Iran's sanctioned economy is now even further limited in just one market – the China's market – for exporting fossil fuels. According to the Washington Institute for Near East Policy (2023), China's share in the Iranian oil market rose up to 91% in 2023 from 26% in 2017 (Rome and Raydan, 2023) before the two states' deal and the U.S withdrawal from the JCPOA. Yet, there are political economy disadvantages entailed in such sanction derived market reliance that limit the volume and the value of the crude Iran may export. As for the value aspect, for example, financial risks form sanctions have led the Chinese government to request for 15% discounts when purchasing Iranian oil in the U.S dollars in exchange for the Chinese Yuan (Sobhan Energy, n.d.b). As for the volume side also, China's

imports from Iran are limited, and do not necessarily compensate for the whole volume Iran needs in oil sales for avoiding budgetary deficits. Resultantly, the sanction derived restrictions on the volume and value of the crude exports increase the breakeven oil price for Iran, which is the minimum oil price that is necessary for the rentier state to balance its rentier incomes (fiscal revenues) with internal expenditures (budgetary needs) [King Abdullah Petroleum Studies and Research Center, n.d].

Table 7 discloses a meaningful gap between the breakeven oil prices in Iran and other rentier economies in the MENA region onwards the U.S withdrawal from the JCPOA. Altogether, the lacking diversity of non-crude incomes, the oil discounts Iran offers for circumventing sanctions, and the sanction derived restrictions [including economic and technical restrictions] on the Iranian oil industry are three political economy sub-factors that surged the breakeven oil prices for Iran from 68 dollars per barrel in 2018, to 131 dollars in 2022.

***Table 7**: Breakeven oil prices in Iran and MENA (International Monetary Fund, n.d)*

Rentier State / Year	2017	2018	2019 (Beginning of the U.S Maximum Pressure Sanctions Campaign)	2020	2021 (Beginning of Iran China 25-year Strategic Deal)	2022	2023 (Projection)	2024 (Projection)
Algeria	91	101	105	89.6	111.4	109.8	93.8	125.7
Islamic Republic of Iran	65	68	244	228	118.8	131.4	105.1	121.0
Kuwait	46	54	53	64.2	87.6	81.5	81.0	83.5
Libya	103	69	49	141.7	52.2	64.4	65.9	66.0
Oman	97	97	93	86.4	76.7	55.4	57.2	58.1
Qatar	51	48	45	49.3	47.7	46.3	46.5	43.1
Saudi Arabia	84	89	83	76.4	83.6	88.1	93.3	96.2
UAE	62	64	67	51.7	53.0	46.6	51.6	56.7

As the sanctions correlate Iran's petroleum supply with Chinese demands, they also correlate the Iranian path for energy transition with China's policies for energy utilization. For example, if China decides on using more oil on their path for development, it will encourage the Iranian partner towards further investments in fossil fuel technologies beyond domestic needs. In contrary, if the only major crude importer of the rentier state aims at transitioning to a low carbon economy, further hydrocarbon investments will risk becoming stranded assets in Iran. Yet, as China plans for reducing GHG emissions by 2050 through subsidizing renewable energies (Sobhan Energy, 2022), the latter event is more evident to happen. According to Sobhan Energy's analysis of the Chinese energy transition (2022), 50% of the world's total instalments in the wind and solar

energy facilities have taken place in China during 2016 and 2017 following the Paris Agreement, which contributed to reducing almost 46% of China's GHGs in 2017 comparing to 2005 (Sobhan Energy, 2022).

When all is said and done, it is clarified that the geopolitical and sanction landscape factors have been directly affecting Iran's privilege of hydrocarbon revenues. Those landscape conditions are also perceived to associate Iran's energy policy (such as for transition in its up and down streams) with the energy policy and demand management of its sole consumer, China, in its downstream. Yet, the impacts from sanction landscapes on Iran's path to energy transition have to be analyzed in parallel with global landscape factors that pressure for energy transition internationally (Chapter 4, Part a).

The next section concludes on how the Iranian path for energy transition is influenced by international landscape conditions, which include Iran-exclusive sanctions as well as the socioeconomic landscape conditions (e.g. global climate change) that were identified in Chapter 4 (Part A). Given that the landscape influences are not imposed in vacuum, but rather in the socio-institutional context of Iran as a rentier state, the previously identified rentier regime conditions (Chapter 4, Part B; Chapter 5, Part A) are incorporated in the below discussions from the lens of the MLP framework. Accordingly, the following section identifies interactions between the landscape and regime factors in Iran over the realms of energy governance, climate, domestic political economy, international political economy, and technologies. That said, the section concludes on analyzing how the regime-landscape interactions collectively influence the potential initiatives in the Iranian path for transitioning to a low-carbon energy system and economy.

8. Conclusions

8.1 Regime-Landscape Interactions and their Collective Influence on Transition Initiatives

Fiscal reliance on oil rents, as a rentier regime condition, has made the Iranian economy vulnerable to external landscape factors such as the sanction restrictions on fossil fuel trade. These restrictions, as for now, are politically motivated by the controversies between Iran and the West. In the future, however, they can be stimulated by global climate landscape factors, for instance by the imposition of prospective carbon tariffs and climate deterrents on hydrocarbon fuels. Likewise, international sanctions have prevented the Iranian hydrocarbon infrastructures from acquiring stocks and machinery upgrades required for efficiency robustness. These limits have escalated operation costs, and impeded Iran's progress in energy markets against shale oil and non-shale commodity contenders, to which adds low-carbon energy alternatives that would affordably compete with fossil fuels in the near future. Hence, what Iran experiences today in form of curtailments on its fossil fuel technology and exports under sanctions could approximate

to prospective correlations in a climate constrained world, when climate derived-landscape factors (e.g. prospective carbon tariffs, emergence of low-carbon technologies) pressure for hydrocarbons de-valuation and loss of competitiveness.

From a domestic perspective, sanction constraints on the stock and machinery acquirements have obstructed sufficient productivity of energy supply at the Iranian upstream of fossil fuel industry. Such inefficiencies have consequentially triggered an imbalanced response to downstream energy needs (e.g. residential, industrial, etc.), which have been over-growing due to the over subsidized regime of energy access in the rentier state. The regime condition of overconsumption, therefore, has led to seasonal energy shortages as a secondary regime condition in the Iranian energy system. Yet, periodic energy shortages provide a window of opportunity for incorporating small and medium enterprise in low-carbon energy supply to cover the demand gaps. Addition of the low-carbon energy suppliers would also provide the energy intensive manufacturers in Iran with clean energy for producing their products and exporting them without risking climate fines. The low carbon energy enterprises also contribute to a fiscal transition from petroleum rents to a resiliently diversified budget that lives on corporate taxation. As for now, energy intensive manufacturers and corporations in Iran receive their market competitiveness from inefficient use of over-subsidized fossil fuels, which means to tax them instead of crude sails would not count as economic decarbonization, despite resembling economic diversification.

According to the above discussions, Iran's regime of reliance on fossil fuels can be summarized based on two principles. First is a rentier reliance on international incomes from fossil fuel exports for fiscal needs (international scale of a rentier regime). And second is a domestic reliance on subsidized fossil fuel resources for public and industrial use (domestic scale of a rentier regime). As the below sub-section concludes, addressing both in parallel will be challenging, given that de-subsidization efforts for decarbonization in the downstream would discourage economic diversification, and enforce extra dependence on international incomes from crude sails.

8.2 MLP Influences Against Decarbonization at Downstream through De-Subsidization

Cutting energy subsidies or proceeding with providing the economy with the affordable fuel it exhausts, there are challenges to be imposed by the regime conditions entailed in subsidy dependent developments in the rentier states.

If Iran aims at initiating its path for transition from downstream, it will have to de-subsidize fossil fuels for the flourish of low-carbon energy sources. De-subsidization, as a niche-initiative, can weaken fossil fuels' competitiveness against low-carbon alternatives (e.g. renewables) economically, and pave the way for energy transition to a lower-carbon energy mix. Nevertheless, de-subsidization will confront resistance from technological regime conditions, such as path-dependencies of services (e.g. subsidized electricity access) and developments (e.g. carbon

intensive industries) on the utilization of affordable fossil fuels. On the other hand, if the energy subsidies are sustained, they will reverberate through supporting technological regime conditions such as inefficient energy use behaviors and technological overuse of energy (e.g. through preference for residential appliances with high energy index). Eventually, such inefficiencies lead to energy overconsumption and energy shortage as secondary and third regime conditions, which create a feedback loop in terms of encouraging energy efficiency improvements and initiatives such as de-subsidization.

Figure 9 summarizes Iran's technological regime conditions and their feedback loop towards decarbonization through de-subsidization.

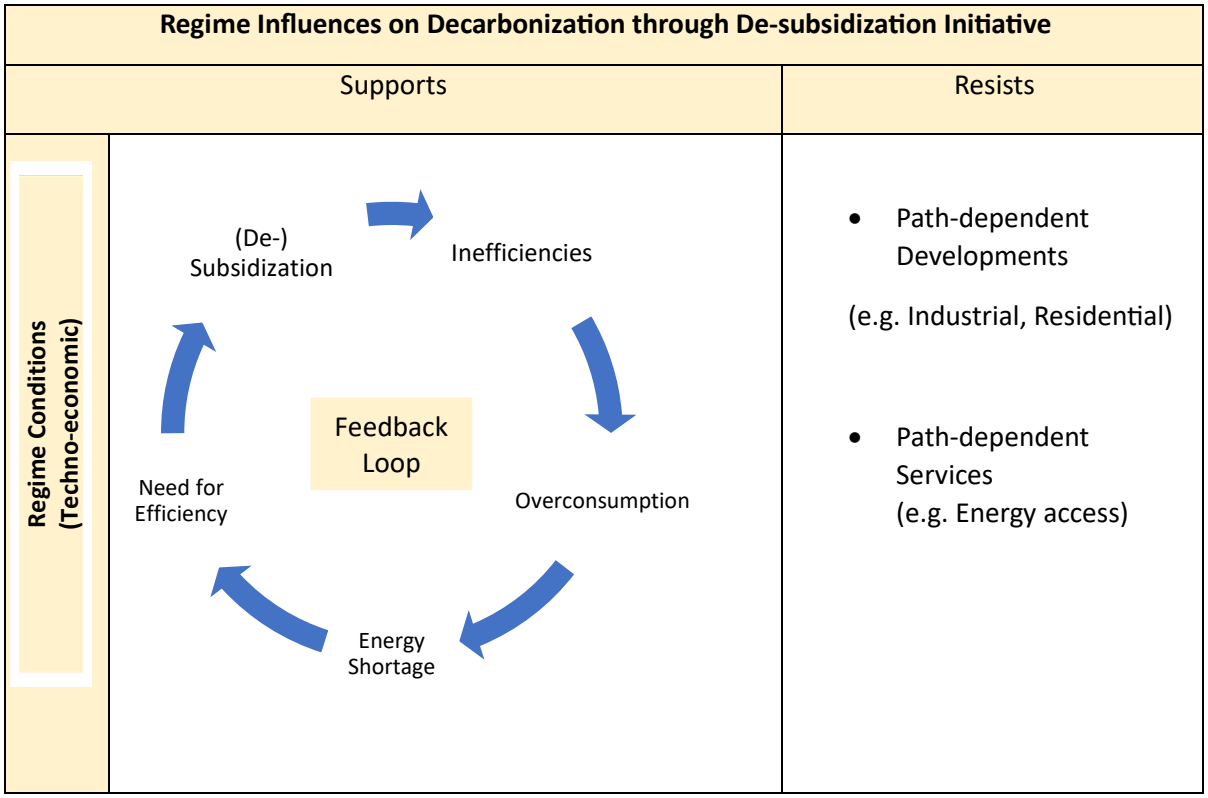


***Figure 9**: Techno-economic Regime Influences on Decarbonization through De-subsidization in Downstream*

As below overviewed, Iranian steel industry provides a clear example of the MLP influences entailed in energy transition through de-subsidization at downstream, versus MLP influences entailed in subsidy continuation.

8.2.1 Steel Industry Example

Subsidy removal seems to be an applicable initiative to the industry class, as they presumably have stocks to invest in adapting to energy efficiency policies for join-in decarbonization. Yet, path-dependencies on fossil fuel subsidies are anticipated to challenge decarbonization through

de-subsidization in the industrial sector. Such path-dependencies are further evident in the industries that capitalize energy subsidies through the exportation of energy intensive products, which they can trade competitively thanks to the added value from energy subsidies. An evident example of such path dependent lock-in is seen in the Iranian steel manufacturing, where the industrial institution has progressively evolved out of utilizing subsidized natural gas and fossil fuel electricity, which altogether count for 30 percent of the final expense for the steel that is manufactured in Iran (Rahimdoust, 2021). As below concluded, decarbonizing the steel industry through de-subsidizing its energy source would thwart economic diversification, impose additional reliance on upstream revenues from trading crude, and encounter opposition from the industrial regime actors.

If the subsidies are cut, they will trigger the steel sector risking industrial unemployment. The claim is supported by the Iranian experience of *"deliberative subsidy reforms act",* a de-subsidization legislation that increased the expense of the Iranian manufactured steel by 271 percent due to NG de-subsidization (Rahimdoust, 2021). As a result, international market for the Iranian steel weakened, which subsequently restricted the employment opportunities that were privileged of added value from fossil fuel subsidies. Steel sector and other energy intensive industries (e.g. cement) contribute to the Iranian index for economic diversification, diversity of international commerce, and fiscal coverage through corporate taxation. Accordingly, shrinking trade of the energy intensive commodities [e.g. steel (Rahimdoust, 2021)] obstructs Iran's initiatives for economic diversification (Rahimdoust, 2021). Removing hydrocarbon subsidies also diminishes Iran's International Commerce Diversity (ICD) amid reducing energy profits of the manufacturers (e.g. steel manufacturers), taxes of whom can feed the state's budget. In the absence of private capital for taxation, however, the government confronts fiscal needs for crude revenues. In other words, subsidization has created a unique path-dependency between the Iranian domestic and international political economy, where the rentier state is locked between fiscal coverage from domestic taxation of hydrocarbon backed industries and international revenues from crude exports. It is also important to note that a prospective transition away from crude-dominated towards non-crude energy-intensive exports does not count as a transition to low-carbon economy since the exported commodities (e.g. steel, electricity) rely extremely on the combustion of hydrocarbons.

On the other hand, if the subsidies are retained, they will encounter socio-technical regime conditions such as over-consumption of NG by steel manufacturers and energy shortages, which do not favor subsidization. Moreover, they will lead to additional industrial vulnerability to environmental landscape factors that would pressure for de-subsidization for mitigating excessive emissions that are released from fossil fuel consumptive activities in steel processing.
Socio-technically, Iran already suffers from natural gas deficiency conditions during low temperature seasons when the demand for space heating peaks. Thus, over-consumption when

enlarged, threatens the well-being of social life and industrial productivity due to lack of access to NG. Similarly, and resulted from the dependency of the power plants on natural gas combustion, there is a nationwide regime condition of power shortage during high temperature seasons in Iran for space cooling (National Iranian Steel Company, 2020).
Environmentally, the steel industry has supported vast release of the greenhouse gasses and toxic emissions, such as CO_2, CH_4, SO_X and NO_X species (National Iranian Steel Company, 2020). Such climate factors make the fossil fuel intensive industry vulnerable to the landscape conditions over the humans' health and climate change. Accordingly, the climate vulnerabilities create pressure for decreasing the use of hydrocarbon energies to mitigate their emissions.

That said, there identifies a prospective landscape condition over Iran's political economy for trading non-crude but hydrocarbon-backed commodities (e.g. steel) under imposition of international carbon tariffs, and environmental regulations on the carbon-intensive products. Although no carbon tariffs are presently in place, their effect could equivalate to, or hit, the revenue losses and unemployment risked by de-subsidization[7]. Hence, it would be helpful if Iran improves means of the manufacturing towards more energy efficiency as a join-in climate action and reduces its industrial path-dependency on fossil fuels through commercializing the renewables. To do so, and to avoid the above-explained socio-technical and environmental oppositions, it seems justifiable for Iran to reform prices of its energy-intensive commodities and energy carriers through subsidy removal. Nevertheless, the rentier state has shown reluctance to do so due to security concerns of unrest (Rahimdoust, 2021; National Iranian Steel Company, 2020; Azadi, 2019).

When all is said and done, both the subsidy continuation and removal scenarios will pressure the Iranian energy consuming entities; where the former provokes climate sanctions and carbon tariffs potentially, and the latter raises the final price, thus reduces the competitiveness of the Iranian products in favor of their market rivals. Both avenues would implicate in losing fossil fuel backed revenues, which risks the broader industrial economy and the employment entailed. Therefore, it is recognizable that although subsidy removal might be an effective tool for diminution of the domestically emitted GHGs, the process for doing so will be politically difficult in Iran.

Despite de-subsidization's contributions to decarbonization for the rentier states, it is helpful to also investigate transition paths that do not commence with subsidy removal in downstream. To that end, Iran-like rentier states may find less regime oppositions in beginning the process of decarbonization at international scale, through phasing out of fossil fuel revenues under economic diversification. Although such diversification may not necessarily contribute to the decarbonization of the domestic energy system at first (as above analyzed), it provides

[7] Cost benefit analyses are required for comparatively weighing prospective losses in both scenarios

opportunity for non-crude commodity producers to gradually shift their primary source of energy from the fossil fuels to clean alternatives. The below sub-section further explains on the MLP influences over a transition path that concerns phasing out of the hydrocarbon revenues from trading crude at upstream.

8.2.2 MLP Influences Against Decarbonization at Upstream through Economic Diversification

Overall, the interlay of regime-landscape influences delivers a positive push over the rentier states to phase out of their rentier economy in terms of decreasing their fiscal coverage from fossil fuel exports. Concerning the Iranian case, increasing maintenance costs of mature fossil fuel facilities, global actions for global warming mitigation, and techno-economic sanctions are some of the internal (regime) and external (landscape) MLP factors that encourage freeing the economy from upstream fossil fuel incomes. On the other hand, however, Iran's governmental ownership of the fossil fuel facilities followed by governmental reliance on fossil fuel incomes are two main regime factors to challenge economic decarbonization.

Increasing maintenance costs, as innate regime conditions in fossil fuel technologies (Chapter 4-part b), risk rentier revenues as the fossil fuel facilities age. Moreover, fossil fuel commerce confronts global pressures from climate change mitigation and the expansion of renewable rivals and shale technologies as external landscape factors that push fossil fuels out the energy market. To that adds the sanction landscape conditions on the Iranian fossil fuel industry, which block the industry's achievement of technological machinery, market shares, and investment stocks for efficiency improvements and upgrade. Although Iran's sanctions are exclusive and politically motivated for now, they can resemble prospective carbon tariffs and climate restrictions that may be applicable to every rentier state in the future.

Nevertheless, the state-owned centralized governance of the energy sector, fiscal needs for the fossil fuel revenues, and the reverse relationship between economic decarbonization and diversification in the rentier state are three identified regime conditions that challenge Iran's path for energy transition in terms of economic decarbonization. Yet, while this thesis aims not at suggesting or designing a transition scenario, it identifies that the overall equilibrium of the MLP dynamics over a transition path that commences from economic decarbonization - through phasing out of rentier revenues at upstream - is more supportive than over energy system decarbonization - through de-subsidization. Nevertheless, this is an interpretation only based on a group of encouraging and discouraging MLP influences identified regarding the two paths. The thesis recommends those aiming to design transition scenarios to evaluate how the identified MLP influences weigh in both paths, and what solutions are perceived to minimize opposition forces from the regime conditions.

9. Experts Validating MLP Influences on the Paths to Energy Transition

9.1 Landscape Influences

Following the final stage of the thesis methodology, 5 interviews were held with Iranian energy experts and former officials in order to integrate their real-world vision with the thesis findings at Iran-level studies. The five interviewees have served the Iranian government in senior positions. To comply with privacy safety concerns, interviewees are referred to as senior officials in their former positions.

Most interviewees confirm the research identification of the climate change [and global efforts for its mitigation] and renewable developments as two landscape conditions that threaten Iran's rentier incomes. Yet, there is no consensus about when fossil fuel incomes would peak. To that end, a former senior official in the ministry of oil states that peak projections typically ignore unexpected technological advancements that have potentials to revolutionize energy systems, such as in the storage sector. Such technological advancements, if happening, will expediate the fossil fuels' endgame and transform the global energy mix onwards – as early as – 2040, as explains the former official. In the meantime, he states that high crude prices have been helping renewable energies to thrive and gain share in the energy mix. His remarks validate the research finding regarding how the cut-off strategies (a rentier initiative) promote energy transitions in non-rentier energy systems at global/external level (a landscape condition).

Nevertheless, the idea that MLP factors inside a system (a regime condition or initiatives) may influence an MLP factor outside the system (a landscape condition) has not been included in the MLP framework. To that end, another interviewee states that [many] external consequences indeed originate from local policies and strategies [e.g. sanctions as a consequence of local political agendas, or global warming as a consequence of pro-hydrocarbon energy policies].

Adding to the context, a former official in the ministry of foreign affairs believes no matter how much [low] the prices are [derived by landscape conditions], Iran's low cost of crude production (10$ per barrel) allows the country to export its resources as long as the global price for the fossil fuel is above 10$ per barrel. Yet, shrinkage of fossil fuel prices is not the only landscape that Iran confronts; rather, Iran faces economic sanctions that impede the rentier state's ability of trading fossil fuels regardless of the price levels.

To that end, two Iranian former officials in the ministry of interior and vice-president office in legal affairs approve of the research analyses' identification of sanctions as active landscape conditions, influencing the country's path to energy transition. As the legal expert explains, sanctions block Iran's access to financial investments and technologies that are required for developing renewable energies. The expert adds further information that serves as grounding validation for this finding. According to his explanation, because renewable technologies such as wind, solar, and geothermal, are western developed, they require Iranian labor forces [and

engineers] to receive training sessions for gaining expertise to develop those technologies at a local scale. However, sanction conditions impede the efforts for training the domestic experts needed for renewable developments. Reinforcing the study results regarding how the sanctions have been obstructing a sustainable transition in Iran, the former official's comments exemplify Iran's situation post the JCPOA agreement. Then, the rentier state was contacted by several western investors in renewable facilities [in solar, wind, and geothermal energy], with those contracts being canceled following the U.S withdrawal from the deal. Moreover, sanction landscape conditions [paralleled with other political instability risks in the region (e.g. wars)] have been pushing the Iranian government to employ a short-term approach in resolving short-term crises one after another, and becoming unable/unwilling to prioritize long-term initiatives for issues such as energy transition, adds the former senior official at the ministry of interior.

As is evident from the interviewees' standpoints, the major landscape condition over the Iranian rentier economy is not the shrinking price for crude, especially as the global north is interested in maintaining high oil prices to support the growth of their renewable technologies as a long-term preference for energy security (as stated by the former official in the ministry of oil). Instead, the major landscape factors are the emergence of competitive renewables followed by the shrinking demand for oil use and the sanction disruptions against rentier trade. Together these landscape factors give the rentier state a closing window for investing in maximizing fossil fuel production by 2030 and prioritizing energy mix diversification and economic diversification for onwards 2040.

9.2 Decarbonization Initiatives

The interviewees suggested several initiatives for facilitating the Iranian path towards decarbonizing its energy system and economy. Such initiatives included those for decarbonizing the energy carriers (phasing out of fossil fuel resources through energy mix diversification and energy efficiency improvement) as well as those for decarbonizing the energy economy (phasing out of fossil fuel incomes through economic diversification). Several interviewees provided information that approved of the research analyses' findings regarding the available initiatives for Iran on its path towards a sustainable energy transition.

A former senior official at the Iranian ministry of power validates the research identification of the join-in strategies as effective initiatives for decarbonization through efficiency improvement. As the interviewee explains, "the estimated potential of energy saving [in Iran] is estimated to be 49%" [of total waste], which would contribute to the "reduction of greenhouse gas (GHG) emissions by an amount of 285 million tones of CO_2 per year (Mt/a)". The former official underlines that Iran is losing an equivalence of 1200 Million barrels of oil per annum in energy waste due to inefficiencies, part of which can be saved through expansion of efficient electricity networks over the power sector.

Providing further grounds to the above validation, a former official at the ministry of interior says that the Iranian government is not [sufficiently] apprehensive about energy inefficiencies following its access to vast amounts of fossil fuel incomes [and resources]. Hence, privatizing the energy sector would make private businesses [who don't access to rentier privileges] face the [economic] significance of energy efficiency improvement. As the interviewee adds, government must possess governance over [regulation of] the lands and resources and leave the operation activities to private bodies.

Concerning the technical initiatives and their challenges, a former official in the ministry of power validated the research finding of technical path-dependencies [to the incumbent technologies] as an influential factor on the country's path to energy transition. To that end, the energy expert discusses an initiative that complies with the path-dependencies derived from Iranian hydrocarbon infrastructures. The suggested initiative relates to transitioning from hydrocarbons [such as for heat production] to hydrogen-hydrocarbon combinations [to produce E-fuels] as a low-carbon policy initiative [similar to the Brazilian path to ethanol-gasoline blends for transportation fueling][8]. Interpreting from the discussion, such combinations would not only contribute to energy system decarbonization but also provide an opportunity for the SMEs to use them as a less-carbon intensive business for diversifying the Iranian crude-backed rentier economy. As the former official explains:

> "Green hydrogen can be combined with CO_2 emitted in Iron & Steel, Cement, ceramic and other mining industries to produce E-Fuel. E-Fuel can be used as substitute for petroleum products … [as well as] seasonal peak saving of natural gas. In addition, E-Fuel can be exported. Such an undertaking could enable to produce and use hydrogen in large scale and to initiate hydrogen economy. In the long run green hydrogen could be both used in domestic market and exported."

The above technical initiative also provides an opportunity to low-carbon economic diversification through the private sector, which yet requires capital for investment. As one of the interviewees agrees, Iran may allocate portions of its crude incomes to renewable [or above-like low-carbon] developments for domestic use, so that it can free up more fossil fuels to export before a global transition is fulfilled. Such an initiative provides insights to confirm how energy mix diversification could contribute to economic diversification. To that end, a former official in

[8] Iran has expanded a country-wide system of pipelines that are specifically designed to hold methane carriers due to their specific tolerance for CH_4 pressure. Therefore, while the rentier state may replace fossil fuel power with solar power in a solar-based transition scenario, it may not replace natural gas heat with heat from solar hydrogen (i.e. green hydrogen) because of the hydrogen's pressure incompatibility with the technical regime of gas distribution in Iran. But combining a portion of hydrocarbons - such as methane and CO_2 - with solar hydrogen will result in an adjusted pressure for the produced fuel (E-fuel) to become carriable for the incumbent pipeline facilities. Such combinations, to be greener, can include methane derived from carbon capture processes over the Iranian fossil fuel and carbon intensive industries, as the expert explains.

the ministry of oil says that Iran should also use fossil fuel incomes to widen its base for diverse industrial developments, through non-crude manufacturing and trades (economic diversification).

While non-crude manufacturing and trade refer to diversifying the economy through the production sector, the thesis analysis also identifies an opportunity of economic diversification through the service sector in Iran. A former official in the ministry of interior highlights Iran's advantages in human resources and expertise and discusses economic opportunities within engineering services as a potential option for economic diversification. He also approves of potentials for economic diversification through the production sector, such as through commercializing products from greenhouse agriculture and non-crude petrochemicals.

9.3 Regime Conditions

A key finding of the document analysis at rentier-level was the manipulation of rentier incomes' influence - as a regime factor – on impeding decarbonization of the energy system in Iran. This is reiterated through the interviews with additional context provided on the political economy and governance grounds behind Iran's lack of capital for decarbonizing its power sector. According to a former senior official at the Iranian ministry of interior, Iranian power plants have to buy their fossil fuel resources from the ministry of oil and sell their electricity products to the ministry of power. This is while the Iranian ministry of power is a budget consumer [capital poor] entity at governmental level, whereas the ministry of oil is responsible for supplying the state's budget with 86% of its oil sales [and keeping 14% of the oil incomes for its own maintenance and operation costs]. Therefore, the capital poorness of the power sector is conveyed to the power plants to whom the ministry of power owes money (for the electricity purchased), amid the money they are indebted to the ministry of oil for the hydrocarbons they purchase. The above imbalance described by the interviewee, thus, leaves power plants with insufficient funds for investing in activities other than for operation and maintenance, such as in decarbonization initiatives through efficiency improvement. Interpreting from the former official's suggestion, were the two ministries of oil and power combined, power plants would not confront such owing balances when purchasing their resources and selling their products to one integrated governmental body. The interviewee suggests that the power plants could receive their resources from the combined ministry, generate the electricity, and ultimately receive a service fee according to the value they add to the resources through electricity generation.

He also points to inefficacy of the energy subsidies because of their distribution to a large number of population. Such inefficiencies, as he confirms, have reverberated through path-dependent behaviors such as over-consumptions by energy stakeholders in the downstream, including in the

industrial sector (e.g. production of low-efficient fuel-backed vehicles), residential sector, and developers (e.g. residential home developers).

Another key finding of the document analysis was the identification of inefficacious centralized governance as a leverage regime condition in the rentier states, which impedes their path for energy transition. This identification was reiterated through the interviews with additional context provided on centralized governance reverberations through several challenges over energy transition in Iran. A legal expert and former official notes that Iranian governmental bodies [at different sections/ministries] function based on delivering their own sectoral interests in the short-term rather than cooperating for achieving national interests in the long run. This is while energy transition is an interdisciplinary issue that requires significant cooperation at inter-ministerial scales. Although the former legal official approves of the need for a council to integrate governmental bodies in charge of energy governance, he does not believe the Iranian ministries of oil and power could be merged given the heavy duties that each one is responsible for. Furthermore, another interviewee adds that the overly large size of the Iranian government – with around 4 million employees over the country – is a problem that challenges the rentier state to spend high volumes of the rentier incomes on its own operation costs, highlighting it as a governance inefficiency that leads to lack of capital for transition initiatives. The above discussion also validates the study's confirmation of governance inefficiencies, such as labor unproductivity, as regime conditions that prevent the rentier states from capitalizing efficacious investments in economic diversification and energy system decarbonization policies.

Extreme and state-delivered fossil fuel subsidies were the other regime factors against the path for energy transition in the Iranian case study. To that end, a former official in Iran's ministry of power states that "Iranian energy sector is dominated by state monopoly and energy prices are determined by the administration. State administration is not willing to link domestic prices to the international energy prices," which reverberates through creation of an uncompetitive domestic market where fossil fuels block the growth of alternative (e.g. low carbon) energy technologies. However, "If the competitive energy market is established, private sector shall have more incentive to enter into energy market," which would include the market for renewable energies. Accordingly, the former official believes that:

> "The most important course of action could be structural changes in the energy economics in Iran where a competitive energy market could be established, and opportunity costs of primary energy are charged in the energy sector. Energy prices to the final consumers can then be formed in the competitive market and based on the market mechanism."

Otherwise, the Iranian expert warns about state monopoly risks in highly centralized regulated energy systems. As he explains, "in an economy where the state monopoly is dominant, a group of corrupt administration and interest groups establish strong lobby for persistence of energy subsidy. Since the net value of opportunity costs of primary energy is very high, the lobby for energy subsidy gets stronger."

This expert also refers to the unjust regime of fossil fuel subsidy distribution in Iran, which has provided added values for industrial developments that rely unjustly on the high allocations of subsidized fossil fuels. As he adds:

> "Since these industries export their products or sell their products at international prices at the domestic market, major part of their profit is due to low energy prices. In other words, the national economic resources, i.e. net value of opportunity costs of crude oil and natural gas, is made available to the shareholders of energy intensive industries as their profit."

The former senior legal official delivers more context to the subsidy regime conditions in Iran. He begins with clarifying the rationale behind subsidy allocations, which specifically aim at supporting industrial productivity, and the social well-being of vulnerable (low income) households. Yet, as he adds, in its current mechanism, subsidies are given more to higher income households as they consume more of energy resources. The legal expert explains that such a mechanism is in contradiction to the 45th principle of the constitutional law, which prohibits discrimination in the use of natural resources.

He mentions that the unrealistically low energy prices lead to energy waste. Yet, he also highlights that the process for reform must happen gradually to avoid social unrest [concerning the socioeconomic well-being reliance of the people on the price of energy], which was provoked around 5 years ago in response to a governmental decision for suddenly increasing gasoline prices. He also highlights the significance of maintaining low-price energy rates even following the reforms to ensure supports for the low-income and vulnerable households. In addition to the above notion, another interviewee mentioned that if the subsidies were capitalized by the government rather than being dispensed to the large numbers of people, they would enable governmental investments in social service initiatives [one of which could be governmental programs for energy efficiency improvement], producing value added.

When all is said and done, most interviewees approve of the research identification of subsidy-derived inefficiencies, state manipulated energy markets and industries, and non-methodical subsidy allocations as the regime grounds behind extreme GHG emissions and local pollution in Iran. Nonetheless, the lack of political will – from the government – paralleled with a lack of urge – from the society and NGOs – are two of the factors behind the rentier state's lack of climate action for energy transition, as explained by a former senior official at legal affairs. To this adds

the broader fiscal reliance on rentier incomes and the impact of sanctions on increasing the price for emission reduction technologies, which have made such technologies look like luxury products rather than priorities to the public, as the legal expert explains.

Figure 10 illustrates the above findings regarding the role of centralized energy governance in Iran as a leverage regime factor in Iran's socio-technical energy system. As shown, centralized governance over Iran's energy facilities and rentier economy has reverberated through a series of secondary regime conditions over the five socioeconomic domains of the study, challenging the path to a low-carbon energy transition. The state ownership of fossil fuel facilities lets the government manipulate rentier incomes as financial sources that can be spent with weakly overseen social accountability. Another motive for manipulating rentier incomes is the regime of state-run social services that survive on rentier revenues, which if cut, would confront social unrest. Resultantly, even in case there is advantageous value-added in energy transition and economic diversification that benefits national economy, the state would not favor losing rentier incomes for such initiatives or sharing them with the private sector in a circular economy, where the government receives only a portion of the added interests, indirectly through taxation. Besides leaving the private sector capital poor for developing renewable power, state manipulation of the rentier incomes weakens the private sector's capitalization in the hydrocarbon power industry too, which needs capital investments for maintenance improvement. Due to technological deficiencies in the hydrocarbon power industry, Iran faces energy shortages following inefficiencies in utilizing hydrocarbon resources. Following such inefficiencies, the power plants require combusting more fossil fuels for generating a fixed portion of electricity, which leads to production of more GHGs and air pollution.

On the other hand, centralized governance exposes Iran's energy economy to landscape conditions from international sanctions, climate change actions, and emerging markets of alternative energy carriers. To that end, the state ownership of the Iranian hydrocarbon facilities makes them accessible targets to international sanctions to obstruct Iran's rentier incomes, which could be invested in transiting to renewables and diversifying the economy through non-hydrocarbon industrial developments. Moreover, infliction and removal of oil sanctions destabilize the inflow of fiscal revenues to the Iranian economy. Restricted revenue inflow in turn interrupts long-term governmental initiatives, including for energy transition, because such initiatives require reliable economic growth and foreseeable budgetary inputs. Iran-related sanctions also free up the sanctioned resources for domestic subsidization and consumption, enabling a carbon leakage inside the rentier state. The sanction conditions also increase the maintenance costs of Iran's petroleum facilities through imposing technological constraints. Accordingly, increasing maintenance costs in the Iranian petroleum infrastructures at upstream, and emission intensiveness of the energy-consumptive industries at downstream, respectively

expose the Iranian oil market and industrial commodities to emerging energy contenders (e.g. shale oil, renewables) and climate change mitigation policies (e.g. prospective carbon tariffs and constraints), which altogether risk Iran's revenues from international commerce. Therefore, as the world transitions to non-fossil fuel sources of energy, Iran's windows of investing rentier incomes in clean energy and economic diversification may close very fast, especially in case the pressures from above-described landscape conditions intensify.

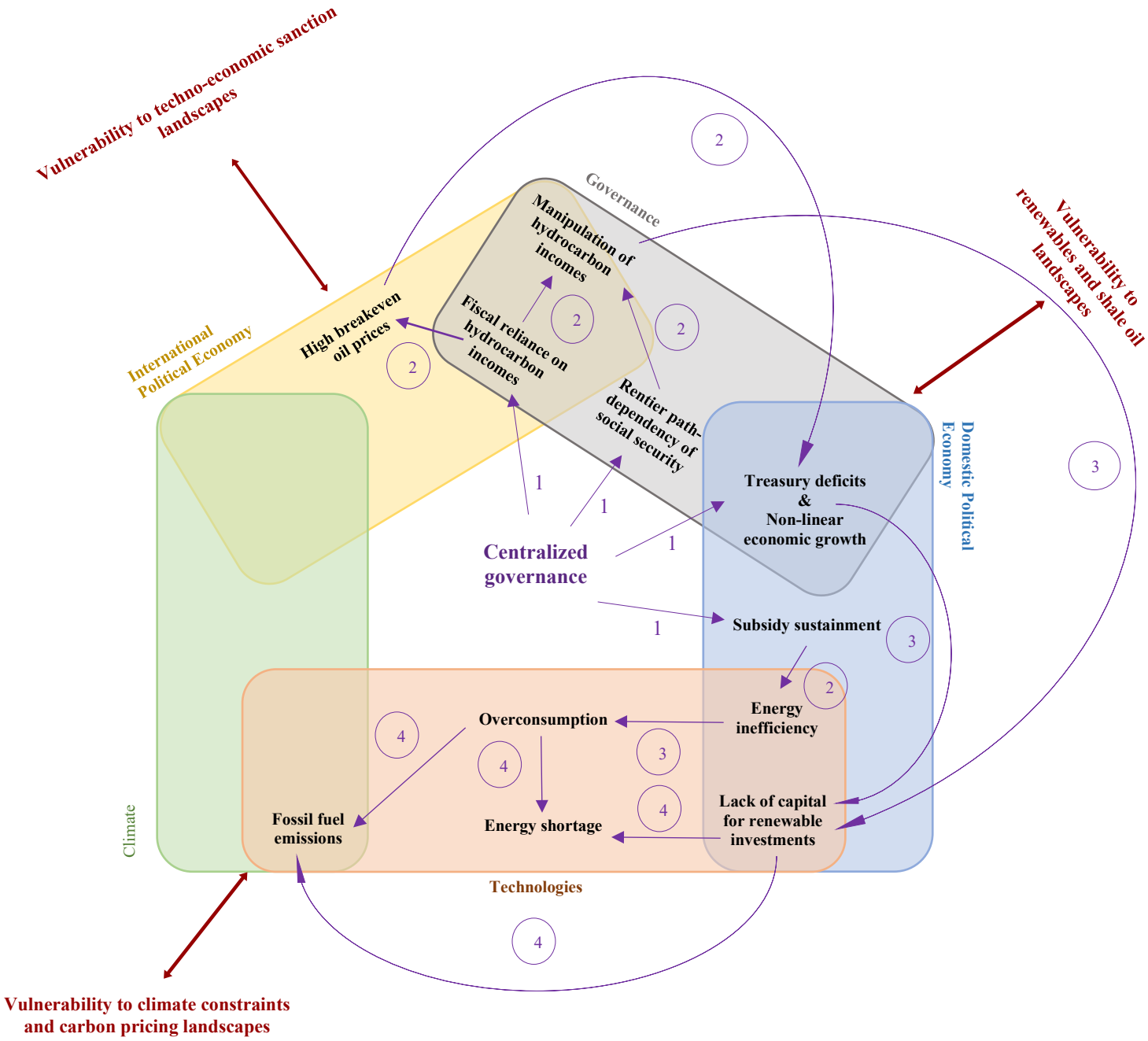


Figure 10: *Centralized governance reverberation through secondary multi-domain regime conditions - leverage schematic*

CHAPTER 6

Conclusions

This chapter summarizes the thesis findings about MLP dynamics and influences on the rentier states' paths for economic decarbonization and transition to a low-carbon energy system.

1. MLP Dynamics of Energy Transitions

According to the multi-level perspective framework, socio-technical transitions - such as energy transitions - evolve out of three layers of landscape, regime, and niche influences. Landscape conditions arise from external factors outside an incumbent energy system, which normally create pressure for energy system transformation. Yet, there may also be occasions when landscape factors push against specific types of transitions (e.g. geopolitical landscape conditions on energy security). On the opposite side, regime factors are the ones dominating an energy system from inside. Regime factors typically resist against transitions. Yet, similar to the landscape conditions, there may be occasions when regime conditions favor specific types of transitions to take place (e.g. energy shortage regime conditions). According to the MLP framework, although the socio-technical landscape conditions are globally common, their influence may vary depending on the socio-institutional regime context of the state on which they impose their pressure.

This thesis focuses on regime-landscape dynamics in the socio-institutional context of the rentier states; and identifies the collective influences from such dynamics on the rentier states' path towards a low-carbon energy transition. As introduced by Mahdavy (1970), rentier regimes are the ones that fiscally rely on perpetual incomes from exporting hydrocarbon resources. Moreover, fossil fuel dependencies for industrial developments, energy access, and social services are other regime conditions in the rentier states. That said, energy transition for decarbonization resembles multiple paths with different but related meanings when it comes to the rentier states.

One path is decarbonizing the rentier economy, which translates into phasing out of rentier revenues from crude exports at upstream of the fossil fuel industry, which happens through economic diversification. And the other one translates into decarbonizing the energy carriers in the downstream of the energy system, which happens through energy efficiency improvement or energy mix diversification. While the two are correlated, they confront varying types of regime-landscape influences on their path to thrive. Accordingly, the thesis identifies a group of international landscape and rentier regime conditions that influence the above two transition paths for the rentier states under the five domains of governance, climate, technologies, domestic political economy, and international political economy. The thesis also identifies a group of socio-technical initiatives and techno-geographic system requirements that respectively facilitate and direct/restrict the above paths for transition. Figure 11 illustrates influences of the MLP factors on the rentier states' path for energy system and economic decarbonization. Thereafter, Tables 8 and 9 present a breakdown of the MLP influences on the rentier states' transition paths respectively towards a low-carbon economy and a low-carbon energy mix.

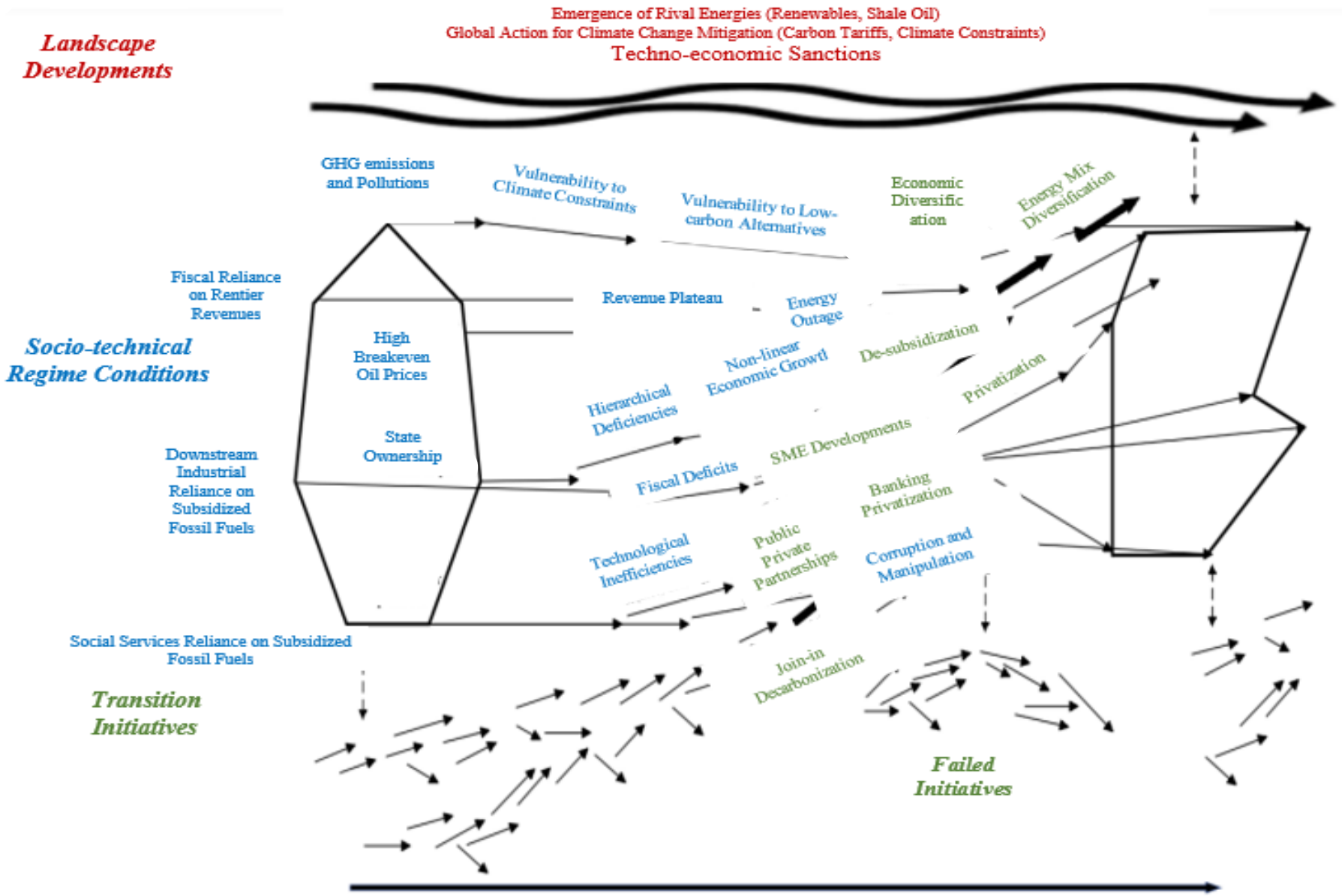


Figure 11: *MLP influences on the rentier states' path for energy transition to low-carbon economy and energy mix*

The basis of the graph is adopted from Cortinovis (2023), which has been a modified adoption of Geels (2002). Permission has been gained from both sides.

Table 8: *MLP influences on economic decarbonization (Landscape [**L**], Regime [**R**], Niche-initiative [**N**])*

Domains	Encouraging	MLP Type of Influence	Discouraging	MLP Type of Influence
Governance	Privatization	**N**	Centralized Energy Governance	**R**
	Public Private Partnerships	**N**	State-owned Energy Sector	**R**
	SMEs	**N**	Corruption and Manipulation of Revenues	**R**
	Fiscal Deficits	**R**	Social Security Path-dependencies	**R**
Climate	GHGs	**L**		
	Air Pollution	**L**		
Technologies	High Maintenance Cost	**R**	Path-dependent Developments	**R**
	High Breakeven Oil Prices	**R**	Inefficiencies	**R**
	Emergence of Renewables	**L**	Energy Overconsumption	**R**
	Join-in Strategies	**N**	Carbon Intensive Industries	**R**
Domestic Political Economy	Non-linearity of Economic Growth	**R**	Subsidization	**R**
International Political Economy	Prospective Carbon Pricing	**L**	Fiscal Reliance on Crude Revenues	**R**
			Techno-economic Sanctions	**L**
			Cut-off Strategies	**N**

Table 9*: MLP influences on energy mix decarbonization*

Domains	Encouraging	MLP Type of Influence	Discouraging	MLP Type of Influence
Governance	Privatization	**N**	State-owned Energy Sector	**R**
			Hierarchical Deficiencies	**R**
			State-Monopolized Banking System	**R**
Climate	GHGs	**L**		
	Air Pollution	**L**		
Technologies	High Maintenance Costs	**R**	Technological Path-dependencies	**R**
	Inefficiencies	**R**	Lack of Critical Resources	**SC***
	Energy Overconsumption	**R**		
	Energy Shortage	**R**		
	Join-in strategies	**N**		
Domestic Political Economy	De-subsidization	**N**	Subsidization	**R**
International Political Economy	Prospective Carbon Tariffs	**L**	Techno-economic Sanctions	**L**
	Price War Strategies	**N**	Geopolitical Instability	

*System Characteristic (**SC**)

As indicated in Tables 8 and 9, there are a few regime conditions and landscape pressures that encourage either economic decarbonization or energy mix diversification, while discouraging the other. For example, while the regime condition of energy inefficiency encourages join-in decarbonization through efficiency improvement (see the feedback loop in Figure 9), it does not necessarily support energy mix diversification when the sanction landscape factors are in place. To that end, the sanction constraints free up additional fossil fuels that may cover for the energy shortages, availability of which discourages prospective investments in alternative (e.g. low carbon) energy technologies. Subsequently, such pairs of regime/landscape dynamics are identified as challenging points that would impede rentier states in implementing both transition paths for economic decarbonization and energy mix diversification in parallel.

The below section reviews how similar consequences apply to economic diversification and decarbonization, where aiming for one pushes the other one to be ignored in a rentier socio-institution.

2. Elaborating on Regime-Landscape Dynamics and Exemplifying their Collective Influences on Iran's Path for Transition as a Real-world Context for the Rentier States

There are rentier-regime and landscape factors that influence the Iranian energy system, locally and externally, domains of which range from governance to technologies, and political economy in international and domestic contexts. These factors, however, are not isolated, rather interactive with each other. Amid their dynamics, they collectively challenge the path for decarbonizing the rentier economy through economic diversification.

In the international context, current sanctions, prospective climate tariffs and unconventional opponents (e.g. shale oil) challenge the Iranian petroleum economy, technologically and commercially. Although such challenges justify the co-rationales behind transitioning to clean energy (e.g. to avoid stranded assets and rentier income fluctuations), they do not help with the process of implementing such a transition. To that end, if the above challenges reduce GDP shares of the rentier exports in Iran, they will leave more resources available for downstream utilization. The freed-up resources will prompt the government to affordably inject them into demanding sectors internally. Such a dynamic stimulates a non-crude diversification of the economy that is supported by fossil fuel rich industries (by facilitating low-cost exportation of the energy intensive products such as steel and cement), which nurtures local subsidization, over-consumptions, and emissions around the hydrocarbon resources that support the economic diversification. The economic diversification and domestic reduction of the subsidies, albeit approaching decarbonization on the same boat globally, function in contrast when deployed in the rentier

states like Iran. If not sustainably managed, redressing subsidies and diversifying economy could suppress each other, reversely neutralizing the aimed decarbonization.

With regards to the domestic context, abandonment of subsidization will increase the production cost of the non-crude energy intensive commodities and obstruct their international competitiveness. Therefore, the energy-inefficient industries in rentier states resist de-subsidization initiatives following their path-dependent development based on the regime of fossil fuel subsidies. The resistance thus challenges decarbonization through efficiency improvement as it requires the removal of hydrocarbon subsidies. As analyses suggest, removing subsidies will weaken such industries and restore the rentier states' budgetary reliance on the GDP revenues from crude exports. The study revealed the above dynamics through analyzing path-dependent developments of the Iranian steel industry (see the Figure 12). The dynamics, however, are applicable to any other energy intensive industry in the hydrocarbon-subsidized rentier states.

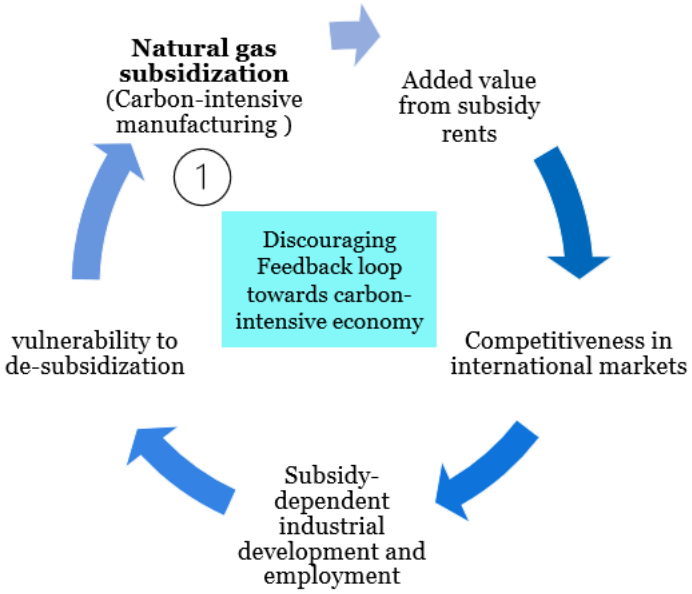


Figure 12: *Path-dependent developments on energy subsidies cause energy inefficiency and high emissions, and resistance against join-in transition strategies*

In contrary, keeping up with the subsidies will intensify overconsumption followed by energy shortage as secondary regime conditions. Frequent energy shortages, however, create feedback loops where the rentier state is forced to implement energy saving initiatives such as subsidy removals, which also would contribute to join-in decarbonization (see the Figure 9, p. 108).

Lastly, financial losses are the other consequences of domestic energy overconsumption. Despite hosting huge reserves of NG, Iran's overconsumption of NG leaves not much of the energy carrier for export. Consequentially, the net international trade for the Iranian NG fluctuates between

near zero and negative levels, pushing one of the world's main reservoir holders of NG into needs for importation.

Although designing a transition path remains out of the scope of this research, it is crucial to design mechanisms that align the multi-level perspectives of a transition (e.g. subsidy reduction niche-initiatives, regime reliance on fiscal oil revenues) together with decarbonization strategies of interest (e.g. economic diversification, join-in strategies) that are germane to the rentier states. It is important to identify potential leverage points that influence a sustainable decarbonization amid the above challenging dynamics between the MLP factors. One potential leverage point is the state ownership of the economy in the rentier states, which includes fossil fuel industries at the up and down streams. State ownership provides room for energy related-subsidy lobbying, manipulation, and corruption. It also puts the state's economy in vulnerable and uncertain conditions against external variables and non-linearities such as techno-economic sanctions and oil price fluctuations. A methodical privatization would free the economy from the path-dependent vulnerabilities and uncertainties amid empowering the private sector growing in capital. Not only may such capital replace crude revenue in funding the governmental budget in form of taxes, but also it can be invested in clean energy technologies if accompanied by properly supportive policies. Sustainable privatization also makes the government smaller, which makes it easier to comprehensively govern for energy affairs, including for intra-ministerial arrangements for transitioning to a low-carbon energy system. Nevertheless, privatization is costly, and so are the investments in non-fossil technologies. Therefore, rentier states like Iran had better accelerate investing their rentier incomes in the above objectives before their window of opportunity closes as the world phases into a carbon constrained era.

3. Conclusions

This study identified more than 30 socio-economic, ecologic, and technical influential factors on rentier energy transitions, revealed their interconnections, and elaborated on their dynamics and influences in the Iranian context. The thesis approach included three phases of deductive content analyses at international, rentier, and country levels, which culminated in the above findings. Below is a summary of three notable results of this study, which are generalized in the context of all rentier states.

3.1.Techno-climate Path-dependencies

The rentier states' path for transitioning to a low-carbon energy system will be highly dependent on their incumbent hydrocarbon infrastructures. As the study finds through lens of the MLP framework, it is not realistic to anticipate rentier states to phase out of fossil fuels towards a zero-emission energy system without the involvement of their hydrocarbon infrastructures.

Rather, it is more likely that their transition – at initial stages – will proceed through adopting new energy technologies that decarbonize fossil fuel utilization, such as through integrating hydrocarbon-hydrogen combinations (to produce E-fuel) and carbon capture and storage mechanisms with their energy system.

Energy transition in the rentier states is also path-dependant on their regime of energy emissions and stakeholders' preferences. Rentier states access to diverse types of fossil fuels for combustion, which emits unevenly diverse emissions over different parts of their energy sector. Hence, the stakeholders' favor in conducting a transition will rely upon climate regime characteristics involved in varying energy sectors (e.g. residential, transportation, non-fossil fuel industries, fossil fuel industries) with varying energy mixes. In other words, rentier stakeholders will prefer a sectoral path for transition with maximized and shorter-term local benefits – such as in energy saving/access and air pollution mitigation – and low expenditures and challenges - such as from technological accessibility.

To that end, the stakeholders' criteria depend on outer landscape conditions that influence such criteria, for instance on the sanctions that block access to specific alternative technologies (e.g. nuclear, CCS), on extreme climate change damages and air pollution that demand prioritizing decarbonization over other criteria, or on geopolitical instabilities that demand prioritizing security criteria over a transition. Therefore, to direct the stakeholders' preferences to the characteristics that are offered by the emerging low-carbon technologies, positive interconnections are required to exist between the landscape conditions to collectively support the low-carbon transition. Otherwise, unparalleled landscape conditions may offset the impacts of each other on the stakeholders' preferences - from an MLP point of view.

3.2. Political Economy Path-dependencies and Approaches

Rentier states confront the dilemma of transitioning to a low-carbon and diversified economy (phasing out of a fossil fuel exports at upstream) or transitioning to a low-carbon and diversified energy mix (phasing out of fossil fuel use at downstream). As the study finds, complex dynamics between multiple regime conditions – such as path-dependent industrial and social developments, fiscal reliance on rentier incomes, and subsidization – challenge the paralleled implementation of both transitions in the rentier states.

As the analyses reveal, phasing out of fossil fuel exports will leave rentier states with freed up resources. Subsidized value of the fossil fuels and demands from fossil fuel consumer industries will resultantly encourage rentier states to utilize those resources domestically and grow in a further fossil fuel-based energy mix at downstream. Similarly, phasing out of fossil fuel consumptions at downstream will free them up for export. Resultantly, lack of alternative

commerce and fiscal demands for rentier incomes to support social services will encourage rentier states to export the freed-up resources, which will impede a low-carbon economic diversification. Neither path will be sustainable, as they culminate in carbon leakage either from the down to up, or from the up to the downstream (Figure 12).

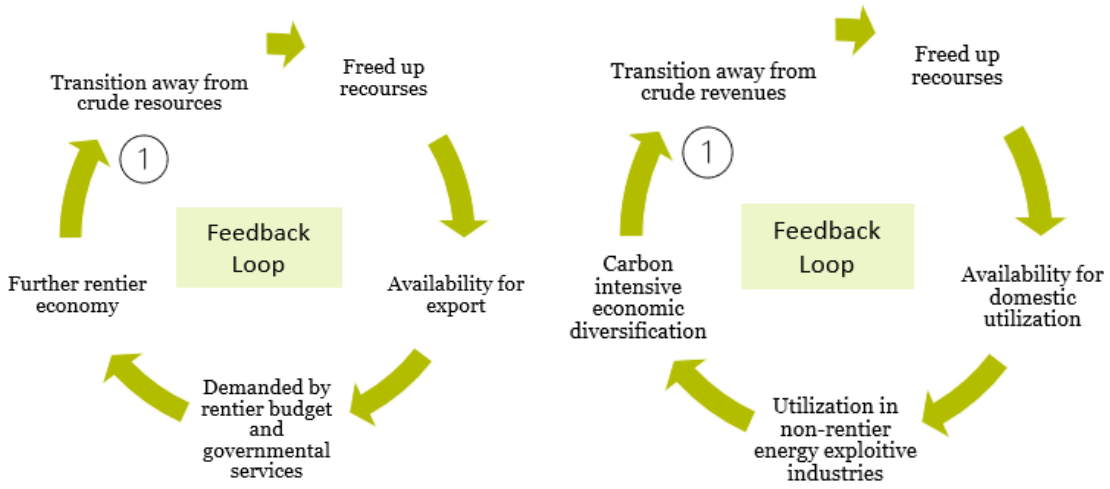


Figure 13: *Rentier feedback loop between the low-carbon energy mix diversification and economic diversification*

The above feedback loops and freed up resources align with unsustainable impacts from the retaliatory strategies rentier states can employ responding to prospective shrinkage in fossil fuel markets. The alignment is further evidence for energy mix diversification, which strengthens the rentier states' ability to conduct price wars. As energy mix diversification ends in freed-up fossil fuels for exports, it enables rentier states to supply more fossil fuels to the market to lower the prices and engage in price war strategies pushing renewable contenders out the market. On the other hand, the economic diversification does not impose a retaliatory impact. Rather, it intensifies risks of the carbon leakage, as do the cut-off strategies, by saving non-exported fossil fuels for the rentier states' own energy consumption at downstream. The effect ultimately impedes transitioning to a lower-carbon energy mix. Neither the price-war nor the cut-off strategy is sustainable as they impede decarbonization efforts respectively at international and rentier levels.

The study suggests that rentier states had better initiate their transition with the path towards low-carbon economic diversification, and decarbonize their downstream activities later. To that end, rentier states have the option of diversifying their economy through the service sector – instead of the production sector – which will limit the room for carbon leakage compared to

economic diversification through industries that would exploit the freed-up resources. A service-based economic diversification also requires fewer capital investments – therefore fewer financial supports from the state - which allows for economic diversification through privatization by providing opportunities to non-state SMEs.

3.3. Centralized Energy Governance

Identification of the centralized energy governance as a leverage regime factor in the rentier states is one of the most remarkable findings of the study. As the analyses reveal, centralized governance of the energy sector and economy in the rentier states reverberates through several other regime conditions – such as fiscal reliance on rentier incomes, subsidy sustainment, treasury deficits, lack of capital investments for renewable developments, social and industrial path-dependencies on hydrocarbon incomes and resources, and non-linear economic growth – altogether challenging energy system and economic decarbonization. As suggested by the study, centralized state ownership of the energy sector in the rentier states – amid the secondary regime conditions it reverberates through - also makes the rentier states vulnerable to external landscape conditions such as imposition of state-targeted sanctions, volatility of crude prices, and shrinkage of hydrocarbon markets following the emergence of renewable energies. While the Figure 10 (p. 108) illustrates the above dynamics in more details, the below Figure 14 is a simplified schematic that shows how the manipulation of hydrocarbon rents and resources – allowed by state ownership of the energy sector in rentier states – leads to obstructing both paths for transitioning to a low-carbon [diversified] economy and energy mix. As below mentioned, the obstruction happens amid interconnections with other state-delivered regime conditions, including social path-dependencies on hydrocarbon incomes and industrial reliance on hydrocarbon subsidies.

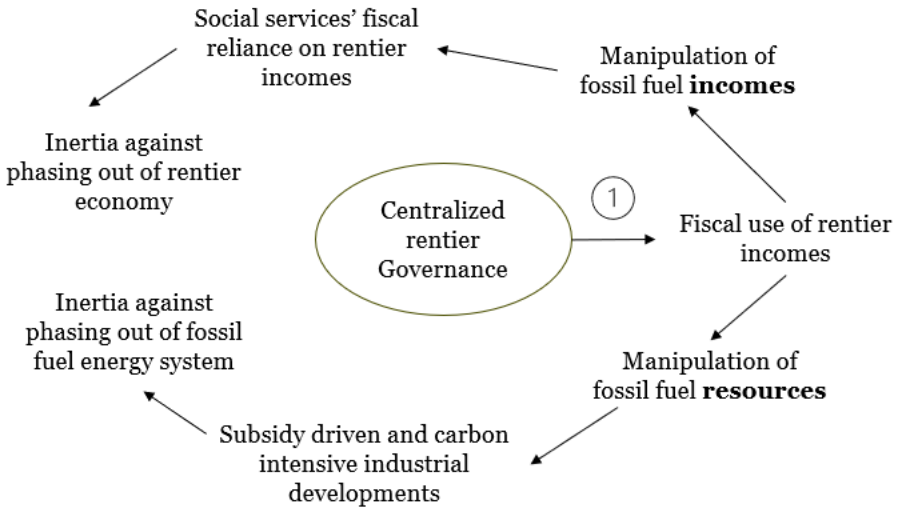


Figure 14: *Centralized governance, a leverage rentier regime condition to challenge low-carbon energy mix and economic diversification*

4. Suggestions for Future Research

Once the MLP factors that push or resist energy transitions are identified for the rentier states, a very helpful idea would be to conduct scenario-based cost benefit analyses to comparatively weigh the magnitude of the influences that are imposed from each factor. Such a comparative sustainability analysis would be a pre-step for discovering or designing a sustainable transition path for diversifying the energy mix inside the rentier states.

Moreover, there is need for future research to focus on transition paths for economic decarbonization, concerning phasing out of fiscal revenues from crude exports. To that end, the thesis' findings about sanctions' influences on Iran's path for economic decarbonization can contribute to simulating a climate constrained world, where rentier socio-institutions are pushed to diversify their economy before the international markets for oil and gas shrink.

Evaluating transition scenarios for energy mix diversification or economic decarbonization, researchers need to recognize the socio-technical varieties that exist among the rentier states. As for the energy mix diversification, the future research will have to recognize the socio-geographic system requirements that are exclusive to their rentier state case of study, such as availability of natural potentials (e.g. hydro, wind, and thermal potentials) that could contribute to the development of low-carbon energy alternatives. Moreover, scholars will need to recognize technical path dependencies in each rentier state's energy system, since such path-dependencies are anticipated to direct the path towards alternative energy sources for transition. Not all rentier exporters of crude have the same path-dependencies over their domestic system of energy supply. For example, Iran employs an extensive but inefficient network of natural gas distribution, while many of other rentier states rely on crude resources for domestic energy consumption.

On the other hand, transition research needs to also recognize alternative commerce potentials that may contribute to low-carbon economic diversification in the rentier states. As for the Iranian example, existence of non-crude industries (e.g. steel, car manufacturing, cement, weaving) has provided the nation with a prospective path for diversifying its economy through further commercialization of non-crude commodities amid the sanction landscapes on their oil exports. Yet, a significant question to follow is how such industries may be decarbonized in terms of energy utilization, simultaneously with phasing out of oil exports. Many of such industries require high volumes of thermal energy for production (e.g. steel, cement), or for their products being operated (Iranian manufactured cars, home appliances) due to path-dependent technological in-efficiencies and preference for inefficient energy consumption following fossil fuel subsidization. Reducing oil exports would free up more oil that would support such inefficient energy needs.

Lastly, except for commercial alternatives, Iranians are privileged of accessing to local human expertise in wide ranges of non-energy professions, thanks to their constitutional support for free education at pre- and post-secondary [including higher education] levels. Availability of local

human resources and expertise enables Iran to follow economic diversification through offering/exporting professional services to neighboring countries. To that end, interested researchers may look into scenarios for investing oil revenues into developing professional service infrastructures (e.g. in medical and educational tourism, engineering laboratories and consulting) and organizing educational policies for commercializing the service sector to support a low-carbon economic diversification. Ultimately, it should be acknowledged that majority of the rentier states may anticipate a more challenging path for economic diversification, especially in case they lack socio-technical infrastructures for non-fossil fuel dependent commerce.

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