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Assessment of the Energy Sustainability

along the Belt and Road

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ABSTRACT

Nowadays sustainability is a very current and discussed theme, which can be found in a wide variety of different interpretations and fields of application. One of its main characteristics is indeed the multidimensionality and interdisciplinarity, which allows its applicability in countless situations, from the international environmental policies, to industrial and business context, to urban planning guidelines and even to our everyday life. In particular, in our analysis we focused on a concept of sustainability more oriented towards energy and environmental safeguard. In fact, our sustainability model is based on four sectors, namely society, economy, energy and environment, which must be equally protected and enhanced to reach the sustainable development. These concepts are the foundation of our assessment of the energy sustainability along the Belt and the Road, or the new Silk Road. Belt and Road Initiative, abbreviated BRI, is a series of investments and projects of international cooperation with China, which has recently become an opportunity to spread and implement the principles of sustainability on a global scale. At the moment, there are 130 countries in all continents taking part in BRI, but this analysis focuses on Eurasia. In particular, firstly we identified 80 BRI countries in the continent and then we selected the 30 countries which contributed the most to energy consumption, imports and exports in the region. We produced an overview on the present state of energy sustainability of these chosen 30 BRI countries, mainly focusing on the energy and electricity sector, on environmental impacts and air pollution, on the relationships between energetic and economic parameters and on the carbon pricing mechanisms. In addition, after a literature search on the sustainability definitions and assessment tools, we decided to apply our interpretation of energy sustainability, by implementing an integrated analysis to quantify the sustainability level in the 30 BRI countries. Thus, we identified 15 parameters in the four sustainability sectors, and we used Multi Criteria Decision Analysis and specifically PROMETHEE II as an aggregation method. In this way, we were able to elaborate the KPIs to obtain a unique parameter, used as sustainability result of the country and as a base to make a sustainability ranking of BRI countries. We repeated this type of analysis for a time period which goes from 2010 to 2016, to study how this outcome changes during the years and thus how sustainability changes in this countries with time. The study also included a sensitivity analysis, to evaluate the impact and to justify the choice of some input data, like the preference and indifference indexes and the weights assigned to criteria. Finally, to complete the description of the sustainability along BRI, a sectoral analysis was produced to evaluate the development level of BRI countries in the single sustainability spheres.

SOMMARIO

La sostenibilità è un tema molto attuale e discusso ai giorni nostri e si può trovare in un gran numero di interpretazioni e campi di applicazione diversi. Tra le caratteristiche principali della sostenibilità stessa c'è di fatti la multidimensionalità e l'interdisciplinarità, che ci permette di poter parlare di sostenibilità in innumerevoli situazioni, dalle politiche ambientali internazionali, all'ambito industriale e aziendale, alle direttive di pianificazione urbana e perfino nella nostra quotidianità. Nella nostra analisi, in particolare, ci siamo soffermati su un significato della sostenibilità più orientato al mondo dell'energia e della salvaguardia ambientale. Infatti, il nostro modello di sostenibilità si basa su quattro settori, società, economia, energia e ambiente, che devono essere in egual misura tutelati e potenziati per raggiungere lo sviluppo sostenibile. Questi concetti sono alla base della nostra analisi sulla sostenibilità energetica lungo Belt and Road, o anche chiamata Nuova Via della Seta. La Belt and Road Initiative, abbreviata BRI, è una serie di investimenti e progetti di cooperazione internazionale con la Cina, che di recente è diventata anche un'occasione per diffondere e mettere in pratica i principi della sostenibilità su scala globale. Al momento ci sono 130 paesi in tutti i continenti che partecipano alla BRI, ma in questa analisi ci siamo concentrati sull'Eurasia. In particolare, abbiamo dapprima individuato 80 paesi BRI nel continente, di cui poi abbiamo selezionato i 30 paesi che contribuivano maggiormente ai consumi, import e export energetici nella regione. Di questi 30 paesi BRI selezionati, abbiamo prodotto una panoramica sullo stato attuale della sostenibilità energetica, concentrandoci principalmente sul settore energetico ed elettrico, sugli impatti ambientali e sull'inquinamento atmosferico, sulle relazioni tra parametri economici ed energetici e sui meccanismi di carbon pricing eventualmente introdotti. In seguito, dopo una ricerca in letteratura sulle definizioni di sostenibilità e sui vari strumenti per produrne una valutazione, abbiamo deciso di applicare la nostra interpretazione di sostenibilità energetica e di quantificare con un'analisi integrata il livello di sostenibilità dei 30 paesi BRI. Abbiamo quindi individuato 15 parametri nei quattro settori della sostenibilità e ci siamo serviti come metodo di aggregazione della Multi-Criteria Decision Analysis MCDA, più nello specifico del metodo PROMETHEE II. In questo modo siamo stati in grado di elaborare i KPIs al fine di ottenere un unico parametro, utilizzato come risultato del livello di sostenibilità del paese e come base per produrre una classifica della sostenibilità nei paesi BRI. Abbiamo poi ripetuto questo tipo di analisi in un arco temporale che va dal 2010 al 2016, per studiare anche come varia negli anni questo risultato e quindi come cambi la sostenibilità all'interno di questi paesi nel tempo. Lo studio è stato inoltre soggetto ad un'analisi di sensibilità, per valutare l'impatto e giustificare la scelta di alcuni parametri di input, come gli indici di preferenza e indifferenza e i pesi dati ai vari criteri. Infine, per completare il quadro sulla sostenibilità lungo BRI, è state prodotto uno studio settoriale per valutare il livello di sviluppo dei paesi BRI nelle varie sfere della sostenibilità.

CONTENTS

1 INTRODUCTION

1.1 GLOBAL ENERGY CONTEXT

In the fast-changing world of the latest years, the energy sector has played and still holds a key role in national agendas worldwide, and it has been involved itself in structural changes of great importance. On the global scale, the energy demand is increasing rapidly, and this is due to several factors. On one hand, this growth has always been based on the economic development of the most powerful and industrialized nations, on the other hand, the world needs more energy to face new challenges, for example the progress of new countries towards the industrial revolution. In 2018, the global energy demand increased of +2.3%, which is almost the double of the growing pace of the last 10 years. China, United States US and India are the countries which contributed the most to this increment in energy demand, for about 70% of it [1]. Looking at the future, the World Energy Council (WEC) envisages an increase of primary energy demand from 2020 to 2040 in all its expected scenarios, highlighting that the main contributor to this growth will be Central Asia, including India [2]. Going into detail on the 2018 growth, the energy demand increase covered all energy commodities with respect to the previous year. The year 2018 was still dominated by strong demand growth for fossil fuels, which continue to represent 81% share of the world primary energy demand, as reported by IEA [1]. According to British Petroleum BP, the fuel which experienced the greatest increment was natural gas, in both consumption and production. The natural gas consumption escalated to a level of +5.3%, representing the fastest growth rate since 1984 [3]. The broader use of natural gas was favoured by the renowned shale gas revolution in US, which made US the first natural gas producer and consumer in the world. Also, China played an important role by intensifying its natural gas use by +18%, in accordance with new environmental policies [3]. Europe, which strongly relies on natural gas, showed on the contrary a slight reduction both in production and in consumption, but still maintaining a durable dependence on Russian exports via pipeline. Natural gas was not the only fossil fuel to grow in demand in 2018, but even coal, which is the most polluting of fossil fuels, showed an increment in both consumption and production, for the second consecutive year, due to a larger use in power sector. Asia represented the core of this increment and in particular, India and China accounted for most of the growth in both production and consumption. These countries experienced also a boost in the deployment of renewable energy sources RES in 2018, but still the energy demand growth imposed a greater use of coal regardless. Finally, oil demand grew as well as a result of the vast energy demand in China and in India. US was the third main contributor to the growth of oil demand, but at the same time it constituted a fundamental input for the increase of production. Relying on fossil fuels and increasing their shares in the energy mix has always raised concerns of different nature in the most industrialized and dependent countries. First of all, this type of resources is not homogeneously distributed all over the world, but it is rather concentrated in specific areas, especially for oil and gas, which for example Middle East is particularly abundant. This resulted in an energy security issue of primary importance, as soon as these areas become politically unstable, as it happened with the oil crises in the 1970s. Nowadays, new geopolitical concerns involve the oil chokepoints, identified in the Strait of Hormuz, the Strait of Malacca, the Suez Canal, the Bab el-Mandeb Strait, the Turkish Straits, and the Panama Canal, as reported by US Energy Information Administration EIA [4]. Oil supply disruptions in these problematic points might lead to higher energy costs and higher world energy prices. In support of these increasing concerns, recently oil tankers were attacked while transiting through the Strait of Hormuz, in June 2019. Also, natural gas has been at the centre of geopolitical issues and energy security risks in Europe, during the political tensions and disputes between Russia and Ukraine. In addition, the vast utilization of fossil fuels entails a series of significant environmental impacts, leading to serious risks and damages for both the environment and the society. First of all, it is commonly known that fossil fuel combustion produces carbon dioxide CO_2 and other polluting flue gases and particulate matter PM, which are dangerous for the atmosphere and for people's health. Carbon dioxide, together with the other Greenhouse Gases GHG emissions, generated by anthropogenic activities, contribute to the rise of the global temperature and in the end to climate change. According to IEA, the high energy demand growth and use of fossil fuels in 2018 resulted in a new peak of global emissions of CO_2, equal to 33 243 Mt, with an annual increase of +1.9%, which was the highest rate since 2013 [1]. Since the 1980s, awareness about environmental protection and climate change kept rising on global scale and people started to question the utilization of fossil fuels, not only for energy security issues, but also for environmental concerns. In Paris agreement, which is the latest international agreement about environment, signed in 2016, countries make a commitment to take action against climate change, not only by reducing the emissions, but also by implementing measures of mitigation and adaptation to climate change. In fact, according to the IPCC special report on global warming, "20–40% of the global human population live in regions that, by the decade 2006–2015, had already experienced warming of more than 1.5°C above pre-industrial in at least one season" [5]. Climate change is indeed a phenomenon which is already taking place in the world and according to a recent study by IEA, unusual weather conditions cause one-fifth of the energy demand growth in 2018, since the extremely hot summer and cold winter resulted in an increase in cooling/heating service demand [6]. Considering that the power sector represents one of the main contributions to GHG emissions, now it is of utmost importance to implement the transition towards a low-carbon energy system. RES technologies are rapidly spreading, and they accounted for a third of the growth of power generation, but still the high growth in energy demand obstructed a further decarbonization of the power sector [3]. The world is changing, but it also needs to change and, in that respect, the publication of "The limits of growth" in 1972 gave a new perspective about economic growth and the need to abandon the idea of development "at all costs". In a world that needs to face new challenges like climate change and the depletion of resources, the only solution is to orient the energy and economic system towards the idea of "sustainable development". The concept of sustainability was born in the 1980s and it is a new model of growth, in compliance with the limits of biosphere and the need of every nation and future generations. Since then, increasing efforts have been made worldwide to raise awareness and implement the concept of sustainability. One of the biggest step forward has been made with the adoption of the 2030 Agenda for Sustainable Development by all United Nations UN members in 2015. At its core there are 17 Sustainable Development Goals SDGs, which are common objectives to reach a broader and global peace and prosperity, in the respect of the people and the environment. To stress the importance of the decarbonization of the energy sector and the fight against climate change, two SDGs are dedicated to these topics, respectively the Goal 7th "Ensure access to affordable, reliable, sustainable and modern energy to all" and the Goal 13th "Take urgent action to combat climate change and its impacts". In this shared vision, a key word is "partnership", which is at the centre of the 17th Goal "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development" [7]. The international cooperation towards sustainability is essential and in this framework the Belt and Road Initiative BRI fits into the context. The BRI is a strategic development programme, launched by the Chinese government in 2013, whose aim is to boost trade and connectivity, so to reach win-win cooperation between countries and mutual benefits. BRI is a global partnership which involves 130 countries around the world, and it has China at its core, which is one of the most powerful and influencing country in the world. During the Second Belt and Road Forum in April 2019, the president Xi Jinping has stated that BRI should be an "open, green and clean cooperation" and he has underlined the need "to pursue high standard cooperation to improve people's lives and promote sustainable development" [8]. The openness of China towards sustainability and environmental protection is a big sign of change, considering its past heavy reliance on coal. This will to change should be sustained and helped by European Union, which cooperates with China and it has always been the leader in environmental policies. In this sense, BRI might become a unique opportunity to consolidate the idea of sustainable development around the world and to shape our common future.

1.2 AIM OF THE THESIS

Sustainability is the right path to follow to face the new global challenges, with respect for all human beings and environment. In this regard, it is necessary to implement policies and action plans, which can guide society towards a new and sustainable model of development. So, policy makers are called to orient their work towards sustainability and to include it in every political decision. To make effective choices, they should rely on scientific data and knowledge, which is conveyed to them through the consultation with experts. Scientists and analysts in fact should provide all the means to decision makers to produce the optimal policy and to adapt it to the situation. Reports, analyses and assessments are useful tools which can help the political class to understand the present situation and the occurring physical phenomena, and to see the impacts and the possible consequences of their actions. Considering sustainability, these considerations are even more valid, since it is a complex concept which involves all sectors of society and many disciplines. Thus, it can be of enormous benefit to have a scientific and comprehensive tool, which can summarize and elaborate all the different information on society and environment in a simple way. Our analysis is inserted in this framework and it aims at measuring and studying the level of sustainability in different countries. In particular our areas of interest are the Eurasian countries involved in the Belt and Road Initiative, which is a set of plans and agreements to increase the international cooperation with China. Given the vast diffusion of BRI around the world, it represents a good opportunity to make progresses towards environmental protection and sustainable development on a global scale. In this sense, the present work can be used as a tool to evaluate the strengths and the criticalities of the BRI countries in reaching sustainability and to help the decision-making process. In fact, we have collected and selected data, and we have produced an overview on the present state of energy sustainability in these countries, with the most updated and reliable data found. In addition, we have produced an integrated analysis to assign a sustainability result to each of the selected countries, in order to make comparisons and to obtain a ranking, from the most to the least sustainable country of the Eurasian region of BRI. We have also replicated the analysis considering different years, so to evaluate the evolution towards sustainable development in time. Overall, we have produced a detailed analysis on the sustainability along BRI, which can be used, by politicians or other scientists, as a comprehensive view of the many facets of sustainability in Eurasia or as a starting point for new studies and analyses on this theme.

1.3 OUTLINE OF THE THESIS

In chapter 1, there is an introduction to the present work, starting with a synthetic view on the framework where this analysis is inserted, that is the energy and sustainability trends on the global scale. It follows a description of the aim, possible applications and the structure of the thesis itself. In chapter 2, it is provided an overview of the present state of the energy sustainability along the BRI. Firstly, there is an explanation about what is BRI and which are the geographical areas included in our analysis. Then, the chosen BRI countries are analysed from different point of views, which consist in a focus on the energy and electrical system, the environmental impacts and air pollution, the relationships between energy and economic indicators and the carbon pricing mechanisms. Chapter 3 is a study on the concept of sustainability. We have done a literature search to report the definition of sustainability, its founding ideas and the main applications and variations on theme. In addition, we have provided our interpretation of sustainability, which is based on four sectors, namely society, economy, energy and environment. Chapter 4 describes the various methods to perform a sustainability assessment and it introduces the Multi Criteria Decision

Making, which is the tool that we have used. Moreover, the chapter presents a focus on the MCDA method called PROMETHEE II and it explain how it works and its main features. Then, it follows a description of the 15 Key Performance Indicators KPIs, on which we have based our analysis, and the approach used to assign weights. In chapter 5, the results of the sustainability assessment are presented, with an introductory note on the choice of the preference and indifference indexes used in the analysis. Two types of outcomes are shown, the actual sustainability level per year of the BRI countries and their improvements in time towards sustainable development. In addition, it is included a sensitivity analysis on the preference and indifference indexes to prove the validity of our choice. Finally, in chapter 6 there is a focus on the different spheres of sustainability in BRI countries. At first, a new weighting method is introduced, and the sustainability assessment has been repeated, to investigate how the results change with small variations of the weights of criteria. Then, this new weighting approach, which assign the weights considering one sector at a time, is used in a sectoral analysis, which shows the level of development of each pillar of sustainability along BRI.

2 BRI AT A GLANCE

2.1 WHAT IS THE BRI?

Historically Eurasia has always been a continent characterized by a dense network of commercial exchanges between different populations. One of the most well-known path of trade was undoubtedly the so-called Silk Road, which connected the Western world to Far East countries for centuries. Actually, there was not a single path, but rather multiple routes, both by land and by sea, without a particular name. In fact, the term "Silk Road" has been more recently coined in 1877 by a German geologist, Baron Ferdinand von Richthofen, who referred to this conjunction of routes as "Die Seidenstrasse", The Silk Road [9]. The origin of the Silk Roads dates back formally to the Han dynasty, which was in power in China from 206 B.C. to 220 A.D, but the transport of goods occurred even before, during the Achaemenid Empire and the empire of Alexander the Great [9]. The mention to silk is due to the fact that silk was one of the most precious product imported to Western countries, which remained a Chinese monopoly for about 3,000 years [10]. Silk was at the centre of the trades since it was considered an exotic luxury, but the economic exchanges included a wide variety of goods, such as fruits, vegetables, tools, animals, spices, metal work, craft products and so on. The commerce through the silk roads has been going on for centuries and these paths had been used up until 19th century. Aside from the trade, this network between West and Far East also allowed the exchange of ideas, culture, knowledge, science, religion, art, which in the end shaped the civilization of the Eurasian people. This legacy from the ancient Silk Road nowadays has been revisited with the Belt and Road Initiative. BRI is a strategic development programme, announced by the Chinese President Xi Jinping during its visits to Kazakhstan in September 2013. In this occasion, at the Kazakhstan's Nazarbayev University, he delivered the speech "Promote People-to-People Friendship and Create a Better Future", in which he, recalling the ancient Silk Road, proposed to build together a new "Silk Road economic belt with innovative cooperation mode and to make it a grand cause benefiting people in regional countries along the route" [11]. The proposed Silk Road Economic Belt is a new economic area in Eurasia, along the ancient terrestrial Silk Road, with the aim of creating new commercial trades and building new transport infrastructure, such as railways and motorways [12]. In October 2013, the President Xi Jinping, with its speech at the Indonesian parliament, also suggested the creation of the 21st Century Maritime Silk Road, to complete the Chinese cooperation projects also including the South China Sea and the Indian Ocean region [13]. These two projects were later designed together as One Belt One Road OBOR, in Chinese 一带一路 [yi dai yi lu], to express the unified Chinese vision of creating a partnership between Eurasia and Africa by land with the economic belt and by sea with the maritime silk road. The name of this programme changed in Belt and Road Initiative BRI in 2016, according to the Central Compilation and Translation Bureau of the Peoples' Republic of

China, as well as the Chinese Academy of Social Sciences, because the translated name One Belt One Road did not express the plurality and variety of the routes and projects of the initiative [14]. The focus of the BRI in the areas highlighted by the Silk Road Economic Belt and the 21st Century Maritime Silk Road, are summed up in six main economic corridors, as showed in figure 1, which are:

- *New Eurasia Land Bridge*, which is a railway connecting China and Europe passing through Kazakhstan, Russia, Belarus and Poland.
- *China, Mongolia, Russia Economic corridor,* which include a railway and the steppe road between these countries and also a connection with the Eurasia Land Bridge.
- *China, Central Asia, West Asia Economic corridor,* which creates a connection between Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan, Iran, and Turkey.
- *China Indochina Peninsula Economic Corridor,* which include Viet Nam, Thailand, Lao People's Democratic Republic, Cambodia, Myanmar, and Malaysia.
- *China, Pakistan Economic Corridor,* which will connect Kashgar city in Xinjiang Province with Gwadar and its commercial and military port, in Pakistan.
- *China, Bangladesh, India, Myanmar Economic Corridor,* which will connect the previously cited countries. It is also the most problematic one due to security issues between China and India. [15]

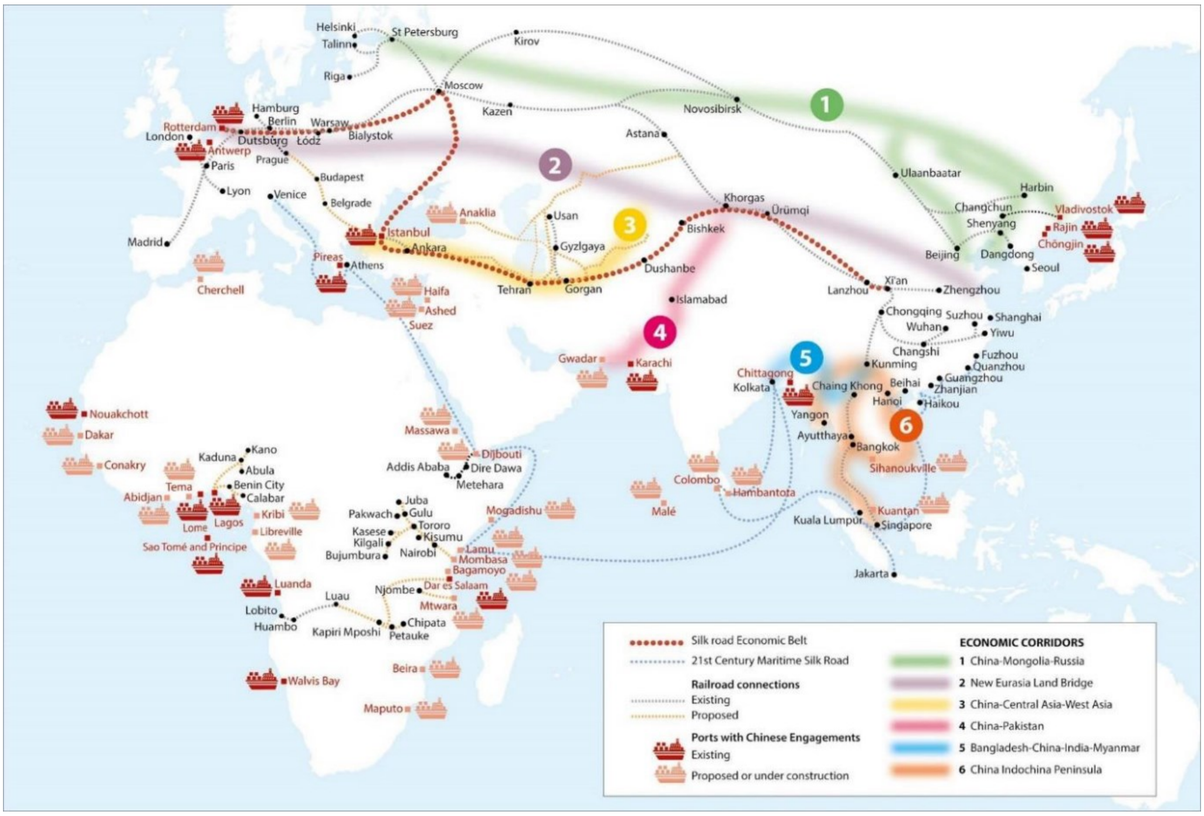

Figure 1: the six main economic corridors of BRI. Source: OECD research [15]

Concerning the actual objectives and regulation of the BRI, the Chinese government released a series of "white papers", including "Vision and actions on jointly building Silk Road Economic Belt And 21st-Century Maritime Silk Road", in March 2015. In this document, the principles guiding the BRI are expressed, the so-called Five Principle of Peaceful Coexistence, which are: mutual respect for each other's sovereignty and territorial integrity, mutual non-aggression, mutual non-interference in each other's internal affairs, equality and mutual benefit, and peaceful coexistence [16]. Moreover, the major goals of the initiative are presented, divided into five groups of priority, namely policy coordination, facilities connectivity, unimpeded trade, financial integration and people-to-people bond, as summarized in table 1.

Priority	Action
Policy coordination	• Promote intergovernmental cooperation • Expand share interests • Enhance mutual political trust • Coordinate strategies and policies to implement large scale projects
Facilities connectivity	• Improve the connectivity of national infrastructure • Form infrastructure network connecting Asia, Europe and Africa • Promote green and low-carbon infrastructure • Advance transport infrastructure by land and by sea • Promote cooperation in the connectivity of energy infrastructure and working for the security of energy supply • Build cross-border power supply networks, optical cable and communication trunk line network
Unimpeded trade	• Expand trading areas and mutual investment areas • Create mechanisms that facilitate free trade • Reduce costs and risks along the supply chain • Open free trade areas • Increase the cooperation in the exploitation and development of conventional and renewable energy sources, • Push forward cooperation in emerging industries
Financial integration	• Establish financial institutions for funding BRI projects • Expand local currency swap • Ensure currency stability • Facilitate interbank and multilateral cooperation • Enhance cooperation on financial regulation.
People-to-people bond	• Promote extensive cultural and academic exchanges • Promote cultural events • Increasing personnel exchange • Expanding tourism • Strengthen cooperation on health and medical assistance • Increase the cooperation in science and technology • Encouraging cooperation between think tanks and non-governmental organizations

Table 1: Summary of the main priorities and goals of BRI. Source [16]

BRI was born from the Chinese enthusiasm for infrastructure development which contributed to so-called "China miracle" and the fast-economic growth of the country. Infrastructure development represents indeed the backbone of the programme itself, which often results in agreements, plans, investments, projects, to build connections of various kind. Lately, the focus of BRI has broadened up from economic and technological development to include sustainable development and energy related issues. In fact, in May 2017, the Chinese government release "The Belt and Road Ecological and Environmental Cooperation Plan", in which the importance of the eco-friendly side of BRI is emphasized [17]. In this document, it is firstly declared the BRI commitment to the 2030 Agenda for Sustainable Development Goals and then the actual objectives to work together towards sustainable production and consumption, as shown in table 2.

Objective	Action
Policy coordination	• Share information, concepts and good practises of ecological civilization • Improve cooperation mechanisms and platform for environmental protection • Promote cooperation of social organization and think tank
Respect Laws and Regulations to Promote International Production Capacity Cooperation and Eco-friendly Infrastructure Construction	• Implement a guidance on promoting Green Belt and Road • Encourage enterprises to strengthen environmental management • Facilitate the disclosure of corporate environmental information with reports • Advance infrastructure construction in eco-friendly way by promoting green low-carbon construction, operation and management of infrastructure • Upgrade environmental protection of industrial parks
Promote Sustainable Production and Consumption and Boost Green Trade	• Facilitate trade of environmental products and services • Enhance international cooperation on green supply chain
Increase Support for Green Financing to Boost Financial Integration	• Formulate green financial policy • Establish green development fund • Guide green-oriented investment decisions
Carry out Eco-Environmental Protection Projects and Activities to Enhance People-to-People Bonds	• Deepen cooperation on environmental pollution control and treatment • Push forward ecological protection cooperation • Enhance cooperation on scientific and technological innovation • Provide more support to green demonstration projects

Table 2: Summary of objectives and actions of BRI Ecological and Environmental Cooperation Plan. Source [17]

2.2 BRI FROM A GEOGRAPHICAL POINT OF VIEW

BRI started as a project to promote cooperation and trade between China and Asian countries, but in few years, it has grown significantly, pointing out the key role of China in influencing the international economic system. After the initial proposal of the initiative in 2013, there were 65 countries involved in the China's official Action Plan for the BRI launched in March 2015 [15]. In May 2017 the first Belt and Road Forum BRF for International Cooperation was held in Beijing and in this occasion 30 international heads of state, including the President Xi Jinping, were present, together with about 30 more government representatives [18]. The Forum has served basically to reaffirm the basic objectives and motivations for BRI and to celebrate the global dimension of this ambitious project. According to the President Xi Jinping, in the end 68 countries and international organizations took part in agreements in the framework of BRI [18]. In April 2019 a second Belt and Road Forum was held in Beijing, with the participation of 37 world leaders and delegates from over 150 countries around the world [19]. In the end a joint communique was released, summarizing the main concepts of their round table. Basically, it was underlined that BRI cooperation should be guided by the principle of environmental sustainability, inclusive connectivity and social responsibility with zero tolerance in anti-corruption. In fact, BRI brand was damaged with scandals since the first BRF in 2017 and the second BRF was an occasion to repair from this situation and reassure China's partners. According to the government press release, 125 countries and 29 international organizations signed BRI cooperation documents [20]. At the end of January 2020, according to the Belt and Road Portal, China signed 200 cooperation documents for BRI with 130 countries and 30 international organizations [21]. The list of BRI partner countries is reported in table 3.

Continent	**Countries**
Africa	Sudan, South Africa, Senegal, Sierra Leone, Ivory Coast, Somalia, Cameroon, South Sudan, Seychelles, Guinea, Ghana, Zambia, Mozambique, Gabon, Namibia, Mauritania, Angola, Djibouti, Ethiopia, Kenya, Nigeria, Chad, Republic of Congo, Zimbabwe, Algeria, Tanzania, Burundi, Cape Verde, Uganda, Gambia, Togo, Rwanda, Morocco, Madagascar, Tunisia, Libya, Egypt, Equatorial Guinea, Liberia, Lesotho, Comoros, Benin, Mali, Niger.
Asia	Korea, Mongolia, Singapore, East Timor, Malaysia, Myanmar, Cambodia, Vietnam, Laos, Brunei, Pakistan, Sri Lanka, Bangladesh, Nepal, Maldives, United Arab Emirates, Kuwait, Turkey, Qatar, Oman, Lebanon, Saudi Arabia, Bahrain, Iran, Iraq, Afghanistan, Azerbaijan, Georgia, Armenia, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Thailand, Indonesia, Philippines, Yemen.
Europe	Cyprus, Russia, Austria, Greece, Poland, Serbia, Czech Republic, Bulgaria, Slovakia, Albania, Croatia, Bosnia and Herzegovina, Montenegro, Estonia, Lithuania, Slovenia, Hungary, North Macedonia, Romania, Latvia, Ukraine, Belarus, Moldova, Malta, Portugal, Italy, Luxemburg.
Oceania	New Zealand, Papua New Guinea, Samoa, Niue, Fiji, Federated States of Micronesia, Cook Island, Tonga, Vanuatu, Solomon Islands, Kiribati
South America	Chile, Guyana, Bolivia, Uruguay, Venezuela, Suriname, Ecuador, Peru
North America	Costa Rica, Panama, El Salvador, Dominica, Trinidad and Tobago, Antigua and Barbuda, Grenada, Barbados, Cuba, Jamaica.

Table 3: List of countries which have already signed BRI cooperation documents. Source: [21]

2.2.1 Focus on Eurasia

In our analysis on BRI, we decided to focus on Eurasia, so excluding BRI partner countries in Africa, Oceania and in America. The countries in Europe and in Asia which signed cooperation agreement in the framework of BRI are certainly included in the study, but other countries have been considered as well. In particular, we decided to include the whole Europe, since BRI projects and plans involve these areas, even though not all the members of European Union signed memorandum of understanding with China. In recent years, the relationships between China and European Union are quite ambiguous. On one hand, Eastern European countries have already joined BRI and also Italy, one of the founding member of EU, decided to take part in BRI by signing three memorandum of understanding in the BRI in March 2019. On the other hand, the rest of EU seems to be less in favour of BRI, with France and Germany which raise concerns about the industrial competition with China [22]. The signs of this stance can be found in the "EU-China a strategic outlook" in which it is stated that "China is, simultaneously, in different policy areas, a cooperation partner with whom the EU has closely aligned objectives, a negotiating partner with whom the EU needs to find a balance of interests, an economic competitor in the pursuit of technological leadership, and a systemic rival promoting alternative models of governance. This requires a flexible and pragmatic whole-of-EU approach enabling a principled defence of interests and values" [23]. Overall, EU as a whole is still sceptical whether join BRI or not, but EU welcomes initiatives to interconnect Europe and Asia and it is in favour of signing investment agreements. In this sense, all EU members have been included in our analysis on BRI. On the contrary, India, which is another vast country of greatest importance and China's neighbour, has been excluded from the study. Despite the fact that it is involved in one of the six main economic corridor of BRI, namely Bangladesh-China-India-Myanmar BCIM corridor, little progress has been made in this regard and India started to boycott BRI, due to some geopolitical tensions between the countries. India turned down China's invitation to both BRF and in particular expressed concern about the China-Pakistan Economic Corridor CPEC, passing through some area in the region of Kashmir occupied by Pakistan [24]. For all these reasons, even if there are still cooperation projects in progress between China and India, India was not included in the study on BRI countries. In the end, for our analysis a total of 80 BRI countries in Eurasia have been defined, with a total area of 50,984,102 km^2, as reported in table 4 according to the UN classification by region.

Region	Countries
Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
Eastern Asia	China, Mongolia
Europe	Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxemburg, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, North Macedonia, Ukraine, United Kingdom
Middle East	United Arab Emirates, Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Yemen
South Asia	Bhutan, Sri Lanka, Maldives, Nepal, Pakistan, Afghanistan, Bangladesh
Southeast Asia	Brunei Darussalam, Indonesia, Cambodia, Laos, Myanmar, Malaysia, Philippines, Singapore, Thailand, Vietnam
Western Asia	Azerbaijan, Armenia, Georgia, Turkey

Table 4: List of the 80 selected BRI countries.

The selected BRI countries in 2018 present a total population of 3676 million people, representing the 48% of the world population, and a total Gross Domestic Product GDP equal to 41091 billion 2010 USD, the 50% of the world GDP [25]. As far as energy is concerned, in 2016 the total BRI Eurasia show a Total Primary Energy Supply TPES equal to 308791 PJ, accounting for 54% of the world TPES, and a Total Final Consumption TFC of 209335 PJ, covering 52% of world TFC [26]. Basically, the selected 80 BRI countries represent about a half of the global GDP and energy supply and consumption, highlighting the greatest importance of the Eurasian region worldwide. As a result, this area is also responsible for a large share of the global CO_2 emissions, for a total of 18303 Mt in 2016, accounting for 57% of the global emissions. To point out the environmental impacts of each country, the emission intensity has been calculated for each BRI partner, as the ratio between the CO_2 emissions and the Gross Domestic Product Purchasing Power Parity GDP PPP. This value represents the CO_2 pollution created per unit of market value added in the production of goods and services. The emission intensity has been further normalized to the average world emission intensity, as shown in figure 2 for Asian countries and 3 for European countries. On the horizontal axis there is the normalized emission intensity 1 which correspond to the world average, above the line there are the countries exceeding the average level and below the countries which a lower emission intensity. It is worth noticing how the almost all countries in Central Asia and Eastern Asia present a higher emission intensity than the world average, while all the other Asian countries are below the global level. In Europe, almost all the countries are below the world average, except some of the Easter Europe countries like Ukraine, Bosnia and Herzegovina and Russian Federation.

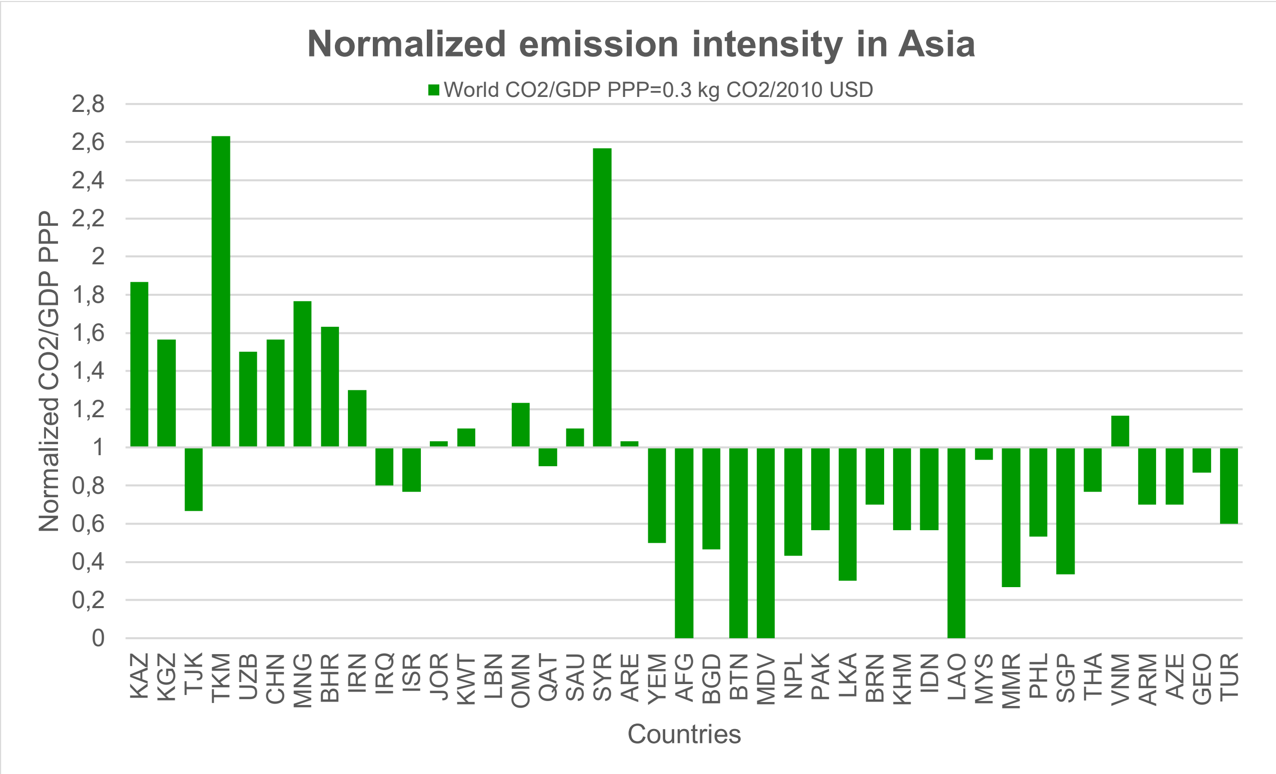

Figure 2: Emission intensity for BRI Asian Countries with respect to World average (level 1). Source: IEA 2016

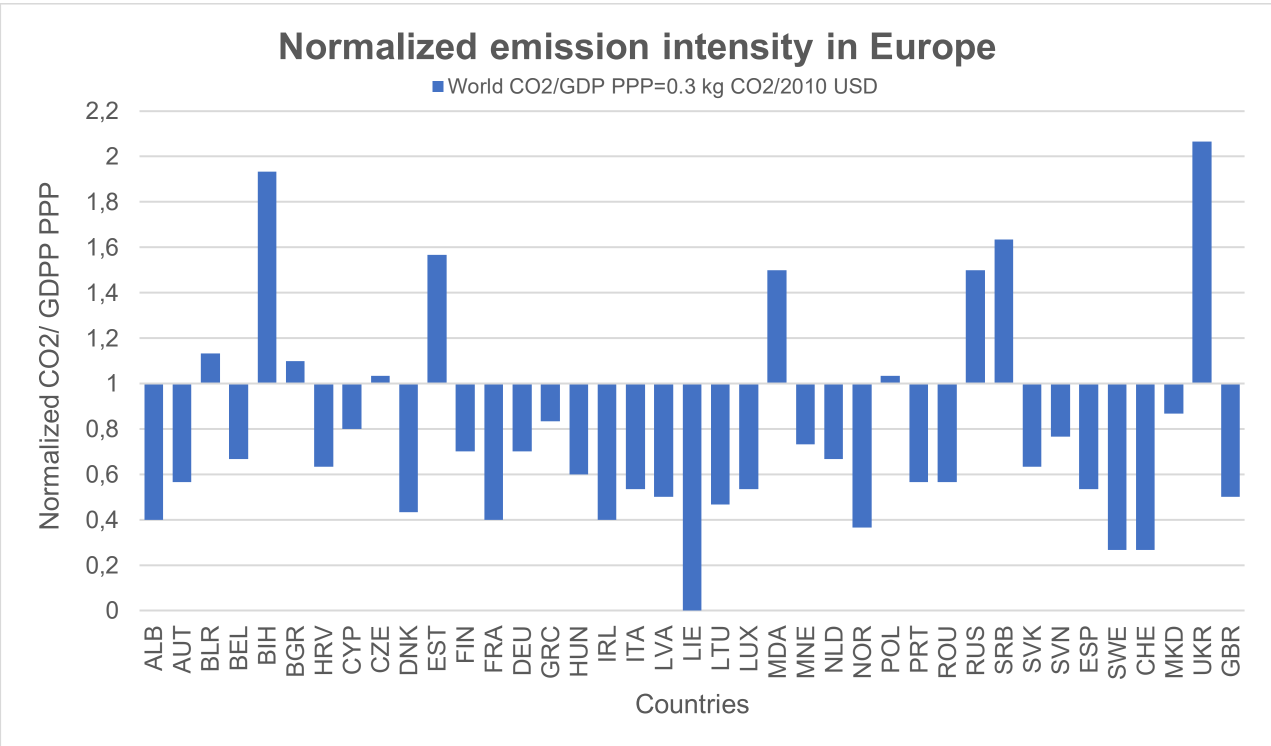

Figure 3: Emission intensity for BRI European Countries with respect to World average (level 1). Source: IEA 2016

2.2.2 Focus Countries for Energy Analysis in Eurasia

Among the 80 designated BRI countries in Eurasia a further selection has been made, to reduce the number of countries to the most influencing and impacting ones. In this way, the 38 European countries except Russian Federation has been grouped in a macro area. In addition, the following criterion for selection has been identified: among the 80 BRI partners, the countries with TFC<0.3%, Imports <0.3% and Exports<0.3% of the total BRI area considered have been neglected. Finally, 30 BRI countries resulted from this choice and they have been pointed out in the figure 4. The resulting list of countries includes Afghanistan, Azerbaijan, Bahrain, Bangladesh, Brunei Darussalam, China, Europe, Indonesia, Iran, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Malaysia, Oman, Pakistan, Philippines, Qatar, Russian Federation, Saudi Arabia, Singapore, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan and Vietnam. Due to a lack of data, Afghanistan has not been considered.

Figure 4: The selected 30 BRI countries. Source: PoliTo.

2.3 THE ENERGY DIMENSION ALONG BRI

As previously mentioned, the infrastructure development and connectivity are the foundation of the BRI. In this sense, the interconnections established or planned between BRI countries often concern energy, which nowadays plays a key role in the stability and prosperity of a country. Chinese government itself decided to promote an initiative such as BRI, not only to boost Chinese economic growth and influence, but also to gain greater energy security. The Chinese ultimate goal is to create an integrated network of supply and value chains, in particular in the production, transportation and energy sectors [27]. So, to analyse the present status of BRI countries and their relationships, it is of utmost importance that the energy dimension is considered. The parameters selected to implement this study on the energy dimension of BRI are the Total Primary Energy Supply TPES, Total Final Consumption TFC and Net energy imports. The TPES represents the gross amount of energy available for a country, whereas the TFC is the effective quantity of energy that has been used by end-users. Finally, the Net energy imports is the difference between energy imports and exports, which is a measure of the self-sufficiency of a country. In table 48 in Appendix I, the parameters have been systematically reported with name, symbol, definition and unit of measure. In table 1, data concerning the selected 30 BRI countries have been reported, including the total for each region and the overall total.

Country	TPES			TFC			I		
	[PJ]	p.u. wrt China	% TOT	[PJ]	p.u. wrt China	% TOT	[PJ]	p.u. wrt China	%TOT
Kazakhstan	3418.20	0.03	1.1%	1576.60	0.02	0.8%	-3441	-0.15	17.2%
Turkmenistan	1155.20	0.01	0.4%	751.80	0.01	0.4%	-2050	-0.09	10.2%
Uzbekistan	1573.60	0.01	0.5%	1122.40	0.01	0.6%	-561	-0.02	2.8%
Total Central Asia	**6147.00**	**0.05**	**2.1%**	**3450.80**	**0.04**	**1.7%**	**-6052**	**-0.26**	**30.2%**
China	123845.80	1.00	41.6%	82453.40	1.00	40.9%	23416	1.00	-116.9%
Mongolia	207.70	0.00	0.1%	139.20	0.00	0.1%	-672	-0.03	3.4%
Total Eastern Asia	**124053.50**	**1.00**	**41.7%**	**82592.60**	**1.00**	**41.0%**	**22744**	**0.97**	**-113.5%**
Europe	66929.90	0.54	22.5%	47635.40	0.58	23.6%	39685	1.69	-198.1%
Russian Federation	30662.30	0.25	10.3%	19668.30	0.24	9.8%	-26144	-1.12	130.5%
Europe and Russia	**97592.20**	**0.79**	**32.8%**	**67303.70**	**0.82**	**33.4%**	**13541**	**0.58**	**-67.6%**
Bahrain	596.40	0.00	0.2%	266.20	0.00	0.1%	-341	-0.01	1.7%
Iran	10369.10	0.08	3.5%	7891.30	0.10	3.9%	-5891	-0.25	29.4%
Iraq	2327.80	0.02	0.8%	776.50	0.01	0.4%	-7279	-0.31	36.3%
Israel	960.60	0.01	0.3%	634.70	0.01	0.3%	632	0.03	-3.2%
Jordan	375.80	0.00	0.1%	254.60	0.00	0.1%	377	0.02	-1.9%
Kuwait	1500.30	0.01	0.5%	803.10	0.01	0.4%	-5751	-0.25	28.7%
Oman	1009.50	0.01	0.3%	851.40	0.01	0.4%	-2222	-0.09	11.1%
Qatar	1770.90	0.01	0.6%	753.50	0.01	0.4%	-7596	-0.32	37.9%
Saudi Arabia	8810.10	0.07	3.0%	5844.40	0.07	2.9%	-18709	-0.80	93.4%
United Arab Emirates	3110.00	0.03	1.0%	2201.10	0.03	1.1%	-5728	-0.24	28.6%
Total Middle East	**30830.50**	**0.25**	**10.4%**	**20276.80**	**0.25**	**10.1%**	**-52509**	**-2.24**	**262.1%**
Bangladesh	1656.10	0.01	0.6%	1204.70	0.01	0.6%	268	0.01	-1.3%
Pakistan	4006.80	0.03	1.3%	3418.20	0.04	1.7%	1125	0.05	-5.6%
Total South Asia	**5662.90**	**0.05**	**1.9%**	**4622.90**	**0.06**	**2.3%**	**1393**	**0.06**	**-7.0%**
Brunei Darussalam	123.90	0.00	0.0%	55.70	0.00	0.0%	-508	-0.02	2.5%
Indonesia	9635.90	0.08	3.2%	6896.80	0.08	3.4%	-8513	-0.36	42.5%

Malaysia	3722.90	0.03	1.3%	2342.50	0.03	1.2%	-298	-0.01	1.5%
Myanmar	808.30	0.01	0.3%	690.80	0.01	0.3%	-363	-0.02	1.8%
Philippines	2294.80	0.02	0.8%	1324.70	0.02	0.7%	1164	0.05	-5.8%
Singapore	1145.20	0.01	0.4%	771.40	0.01	0.4%	3398	0.15	-17.0%
Thailand	5799.80	0.05	1.9%	4082.30	0.05	2.0%	2755	0.12	-13.8%
Vietnam	3391.10	0.03	1.1%	2718.50	0.03	1.3%	594	0.03	-3.0%
Total Southeast Asia	**26921.90**	**0.22**	**9.0%**	**18882.70**	**0.23**	**9.4%**	**-1771**	**-0.08**	**8.8%**
Azerbaijan	595.50	0.00	0.2%	376.50	0.00	0.2%	-1806	-0.08	9.0%
Turkey	5724.10	0.05	1.9%	4096.60	0.05	2.0%	4424	0.19	-22.1%
Total Western Asia	**6319.60**	**0.05**	**2.1%**	**4473.10**	**0.05**	**2.2%**	**2618**	**0.11**	**-13.1%**
TOTAL	**297527.6**	**2.40**	**100%**	**201602.6**	**2.45**	**100%**	**-20034.9**	**-0.86**	**100%**

Table 5: TPES, TFC and Energy Import for selected BRI countries (elaboration on IEA data, 2016)

2.3.1 Total Primary Energy Supply and Total Final Consumption

Generally speaking, BRI countries show similar behaviour and trend for TPES and TFC and, as a result, their shares in the total TPES and TFC of BRI region do not change significantly. This means that the contribution of each country to the regional total of energy produced and consumed remains pretty much the same. China holds the greatest share in the BRI region with 41,6% of the total TPES and 40,9% of the TFC. Europe follows right after and, together with Russian Federation, represents around the 30% of the overall BRI total for both TPES and TFC. China, Europe and Russia are undoubtedly the area with the greatest energy production and use of the BRI region. On the contrary, the region with the smallest amount of energy supply and consumption are Central Asia, Western Asia and South Asia, with shares of the total around 2% for both TPES and TFC. In between there are Middle East and Southeast Asia which represent around 10% of the overall total both in TPES and TFC.

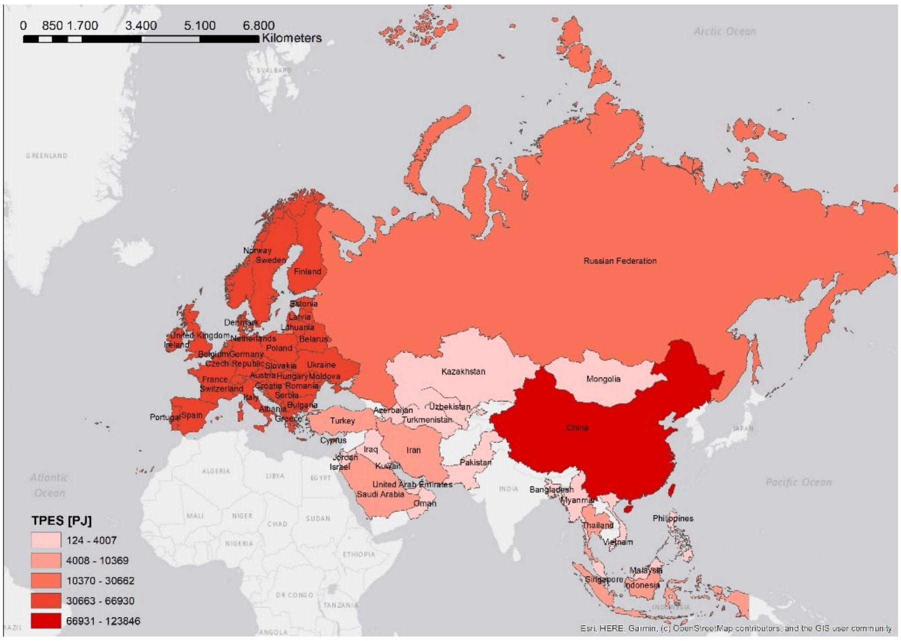

Figure 5: TPES for BRI countries. Source: PoliTo.

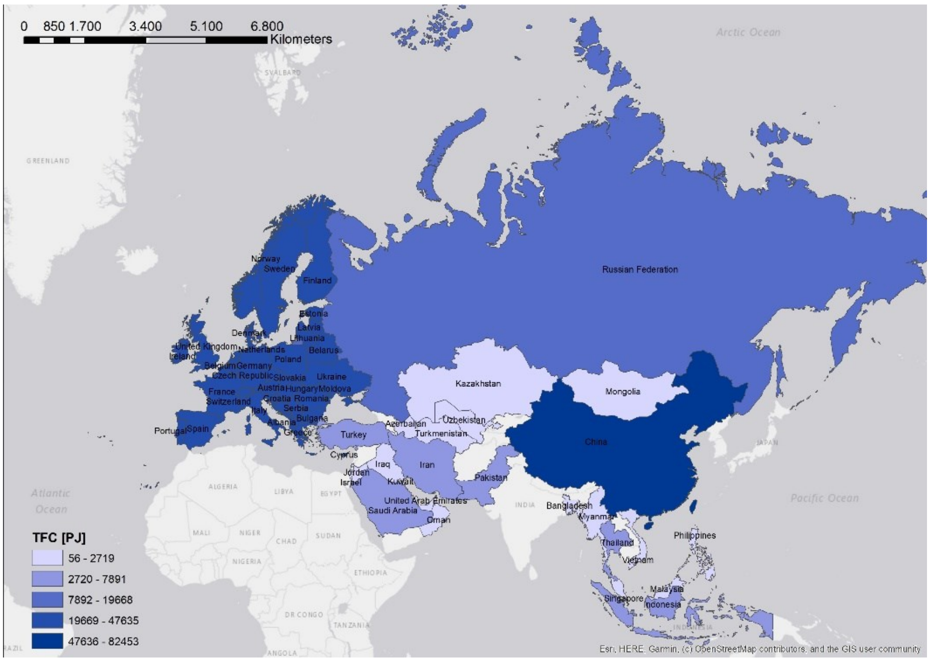

Figure 6: TFC in BRI countries. Source: PoliTo.

2.3.2 Net energy imports

As far as the net energy imports are concerned, the overall BRI region considered can be seen as a net exporter, because we are considering countries which are important energy commodity exporters, such as Russia and Saudi Arabia. Russia, Central Asia and Middle East regions represent the areas with the largest energy export values. On the other hand, China and Europe are countries which are net importers of energy commodities and they rely largely on international exchanges. This is an important aspect to take into account in evaluating the energy security of a country, since in Europe and China the self-production is not enough to fulfil the energy demand. So, in this sense there is the need to diversify the import channels by establishing agreements and collaborations with different countries, whose BRI is just an exemplification.

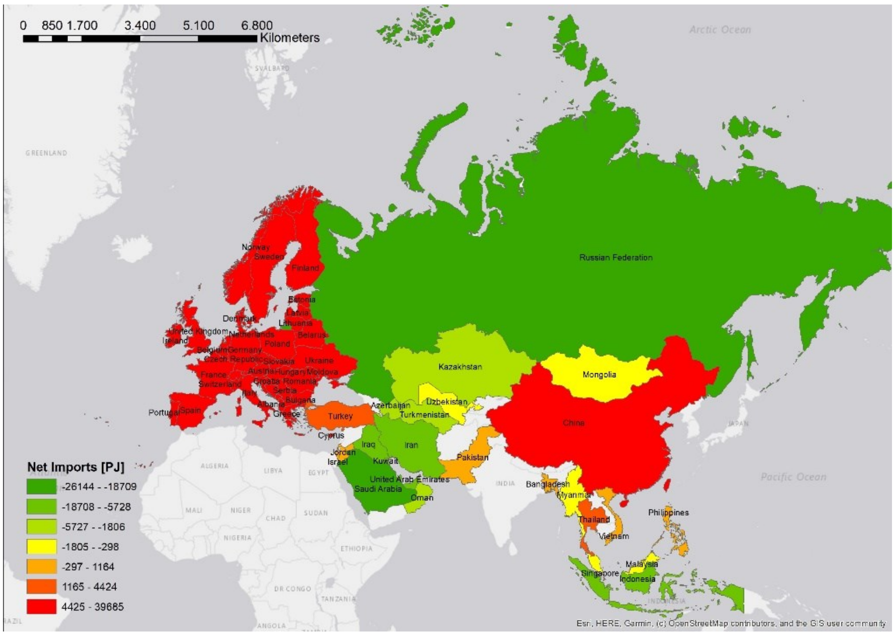

Figure 7: Net energy import for BRI countries. Source:

2.4 ELECTRICITY COMMODITY ALONG BRI

By going into more details about the energy dimension of BRI, electricity production is gaining more and more importance in the world energy framework. In fact, according to IEA, the electricity share of the global final consumption was about the 20% in 2018, but it is expected to rapidly grow [1]. In the IEA's 2040 projections and in particular in the Stated Policies Scenario[1], the growth rate of electricity use is more than the double of the energy demand one, reaffirming the central role of electricity in modern economies. The main applications, which will lead to a boost in electricity use, will be the industrial motors, domestic appliances, cooling services and electric vehicles [1]. In the Stated Policies Scenario[1], the electricity generation worldwide will experience an increment

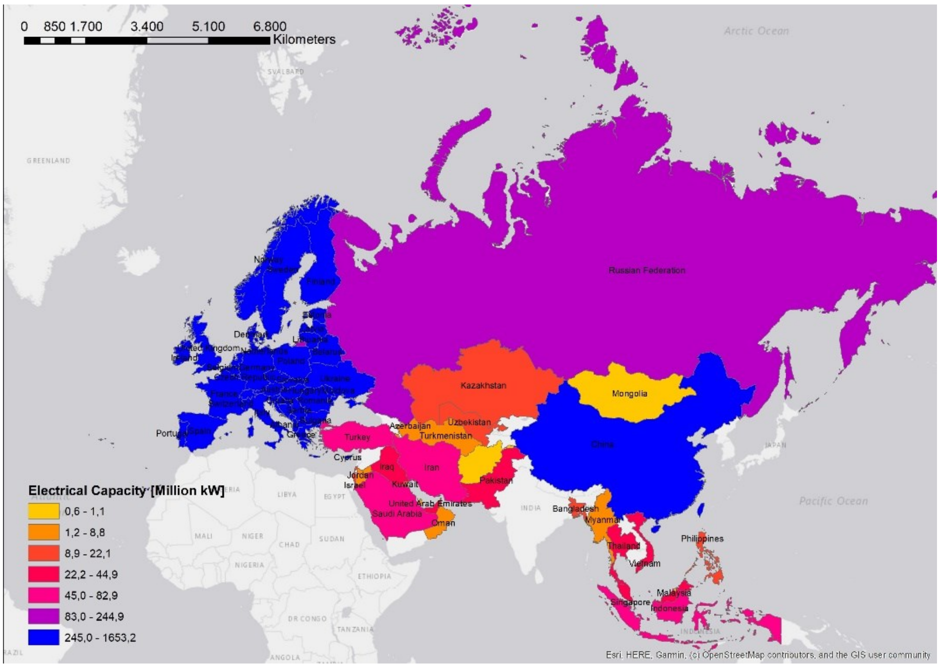

Figure 8: Total installed electrical capacity for BRI countries. Source: PoliTo.

of 55% in the period 2018-2040, which corresponds to roughly 14,800 TWh. This large increase is expected to be caused mainly by Asian countries, with China and India alone accounting for about a half of the growth [1]. Nowadays power sector is undergoing dramatic change, thanks to cost reduction and policy support, which have favoured the increase of renewable share in electricity generation. Electrification can bring lots of benefits, since it reduces local pollution and it is also a strategic mean to get affordable, available and clean energy vector in developing economies. Around the world about 840 million people do not have access to electricity. In this matter, also goal 7 of SDGs addresses the need of a broader electrification, with the target "By 2030, ensure universal access to affordable, reliable and modern energy services, including electricity and clean cooking fuels" [28]. In this sense, the electrification may help the transition towards lower carbon

[1] The Stated Policies is a scenario identified in World Energy Outlook WEO produced by IEA. Differently from Current Policies scenario, which projects the present trends unchanged into the future, the Stated Policies scenario also takes into account the announced policies and intentions and shows their consequences in the future.

energy systems, but it should be coupled with decarbonisation measures, otherwise it results in energy demand increase with possible consequences in emission increase [1, 3].

As shown in figure 8, the countries with the greatest electrical installed capacity are China and Europe with an amount around 1500 Million kW. It is remarkable the gap with respect to Central Asia region, where there is the smallest installed capacity, around tens million kW, and it shows the potentiality of this area in the future. To analyse the electricity production of the BRI region, different parameters have been chosen: total electricity generation, total electricity consumption, fossil fuel electricity generation and non-fossil electricity generation. They have been reported in table 49 in Appendix I, specifying name, symbol, definition and unit of measure. The data of these parameters related to the 30 selected BRI countries have been collected in table 6 and 7, adding the total of each region and the overall total.

Country	Code	Total Electricity generation			Total Electricity consumption		
		[TWh]	p.u. wrt China	% TOT	[TWh]	p.u. wrt China	% TOT
Kazakhstan	KAZ	103.13	0.02	0.7%	92.4	0.01	0.7%
Turkmenistan	TKM	22.53	0.00	0.2%	16.4	0.00	0.1%
Uzbekistan	UZB	61.79	0.01	0.4%	51.3	0.01	0.4%
Total Central Asia		**187.45**	**0.03**	**1.4%**	**160.1**	**0.03**	**1.3%**
China	CHN	6634.90	1.00	47.8%	6302.3	1.00	49.6%
Mongolia	MNG	6.03	0.00	0.0%	6.8	0.00	0.1%
Total Eastern Asia		**6640.9**	**1.00**	**47.9%**	**6309.0**	**1.00**	**49.7%**
Europe	EUR	3299.19	0.50	23.8%	3103.1	0.49	24.4%
Russian Federation	RUS	1094.29	0.16	7.9%	978.4	0.16	7.7%
Total Europe and Russia		**4393.5**	**0.66**	**31.7%**	**4081.6**	**0.65**	**32.1%**
Bahrain	BHR	29.23	0.00	0.2%	27.9	0.00	0.2%
Iran	IRN	307.97	0.05	2.2%	269.9	0.04	2.1%
Iraq	IRQ	87.37	0.01	0.6%	46.4	0.01	0.4%
Israel	ISR	67.7	0.01	0.5%	59.6	0.01	0.5%
Jordan	JOR	20.76	0.00	0.1%	18.7	0.00	0.1%
Kuwait	KWT	72.79	0.01	0.5%	64.9	0.01	0.5%
Oman	OMN	36.13	0.01	0.3%	32.8	0.01	0.3%
Qatar	QAT	45.56	0.01	0.3%	42.9	0.01	0.3%
Saudi Arabia	SAU	347.85	0.05	2.5%	315.4	0.05	2.5%
United Arab Emirates	ARE	134.55	0.02	1.0%	122.7	0.02	1.0%
Total Middle East		**1149.9**	**0.17**	**8.3%**	**1001.2**	**0.16**	**7.9%**
Bangladesh	BGD	73.2	0.01	0.5%	66.1	0.01	0.5%
Pakistan	PAK	131.3	0.02	0.9%	110.7	0.02	0.9%
Total South Asia		**204.4**	**0.03**	**1.5%**	**176.8**	**0.03**	**1.4%**
Brunei Darussalam	BRN	4.2	0.00	0.0%	3.7	0.00	0.0%
Indonesia	IDN	254.87	0.04	1.8%	234.5	0.04	1.8%

Malaysia	MYS	164.50	0.02	1.2%	152.0	0.02	1.2%
Myanmar	MMR	22.42	0.00	0.2%	18.2	0.00	0.1%
Philippines	PHL	94.37	0.01	0.7%	86.1	0.01	0.7%
Singapore	SGP	52.39	0.01	0.4%	51.7	0.01	0.4%
Thailand	THA	186.55	0.03	1.3%	198.0	0.03	1.6%
Vietnam	VNM	198.66	0.03	1.4%	185.4	0.03	1.5%
Total Southeast Asia		**977.9**	**0.15**	**7.0%**	**929.6**	**0.15**	**7.3%**
Azerbaijan	AZE	24.32	0.00	0.2%	20.9	0.00	0.2%
Turkey	TUR	297.28	0.04	2.1%	16.4	0.00	0.1%
Total Western Asia		**321.6**	**0.05**	**2.3%**	**37.3**	**0.01**	**0.3%**
TOTAL		**13875.7**	**2.09**	**100.0%**	**12695.7**	**2.01**	**100.0%**

Table 6: Total electricity generation and consumption in BRI countries. Source: IEA 2017

Country	Code	Fossil Fuel Electricity Generation			Non-Fossil Fuel Electricity Generation		
		[TWh]	p.u. wrt China	% TOT	[TWh]	p.u. wrt China	% TOT
Kazakhstan	KAZ	91.49	0.02	1.0%	11.64	0.01	0.3%
Turkmenistan	TKM	22.53	0.00	0.2%	0.00	0.00	0.0%
Uzbekistan	UZB	53.36	0.01	0.6%	8.43	0.00	0.2%
Total Central Asia		**167.38**	**0.04**	**1.8%**	**20.07**	**0.01**	**0.5%**
China	CHN	4678.33	1.00	50.5%	1863.59	1.00	44.0%
Mongolia	MNG	5.63	0.00	0.1%	0.40	0.00	0.0%
Total Eastern Asia		**4683.96**	**1.00**	**50.6%**	**1863.99**	**1.00**	**44.0%**
Europe	EUR	1433.60	0.31	15.5%	1636.95	0.88	38.6%
Russian Federation	RUS	700.20	0.15	7.6%	390.97	0.21	9.2%
Total Europe and Russia		**2133.81**	**0.46**	**23.0%**	**2027.93**	**1.09**	**47.9%**
Bahrain	BHR	29.23	0.01	0.3%	0.00	0.00	0.0%
Iran	IRN	284.99	0.06	3.1%	22.96	0.01	0.5%
Iraq	IRQ	85.91	0.02	0.9%	1.46	0.00	0.0%
Israel	ISR	65.74	0.01	0.7%	1.69	0.00	0.0%
Jordan	JOR	19.37	0.00	0.2%	1.38	0.00	0.0%
Kuwait	KWT	72.93	0.02	0.8%	0.00	0.00	0.0%
Oman	OMN	36.13	0.01	0.4%	0.00	0.00	0.0%
Qatar	QAT	45.56	0.01	0.5%	0.00	0.00	0.0%
Saudi Arabia	SAU	347.70	0.07	3.8%	0.16	0.00	0.0%
United Arab Emirates	ARE	133.76	0.03	1.4%	0.54	0.00	0.0%
Total Middle East		**1121.30**	**0.24**	**12.1%**	**28.18**	**0.02**	**0.7%**
Bangladesh	BGD	71.94	0.02	0.8%	1.22	0.00	0.0%
Pakistan	PAK	89.62	0.02	1.0%	40.67	0.02	1.0%
Total South Asia		**161.55**	**0.03**	**1.7%**	**41.90**	**0.02**	**1.0%**
Brunei Darussalam	BRN	4.16	0.00	0.0%	0.00	0.00	0.0%
Indonesia	IDN	222.61	0.05	2.4%	18.67	0.01	0.4%

Malaysia	MYS	136.76	0.03	1.5%	26.91	0.01	0.6%
Myanmar	MMR	9.83	0.00	0.1%	12.59	0.01	0.3%
Philippines	PHL	71.18	0.02	0.8%	11.91	0.01	0.3%
Singapore	SGP	50.76	0.01	0.5%	0.17	0.00	0.0%
Thailand	THA	155.93	0.03	1.7%	15.18	0.01	0.4%
Vietnam	VNM	109.28	0.02	1.2%	89.31	0.05	2.1%
Total Southeast Asia		**760.50**	**0.16**	**8.2%**	**174.73**	**0.09**	**4.1%**
Azerbaijan	AZE	22.35	0.00	0.2%	1.81	0.00	0.0%
Turkey	TUR	209.17	0.04	2.3%	79.01	0.04	1.9%
Total Western Asia		**231.51**	**0.05**	**2.5%**	**80.82**	**0.04**	**1.9%**
TOTAL		**9260.01**	**1.98**	**100.0%**	**4237.60**	**2.27**	**100.0%**

Table 7: Total Fossil and Non-Fossil Electricity generation in BRI countries. Source: IEA 2017.

2.4.1 Electricity production and consumption

As seen in energy supply and consumption, China holds the greatest share of both electricity generation and consumption, covering almost 50% of the overall total. It is followed up by Europe, which is the second greatest electric producer and consumer, but it generates only the 50% of China production. Russia, Middle East and Southeast Asia are the other important actors in the electricity field, but the gap with respect to China is even larger, representing about 15% of China production and consumption. The regions with the smallest shares are Central, South and Western Asia, which contribute about 1-2% to the overall total for electricity supply and use.

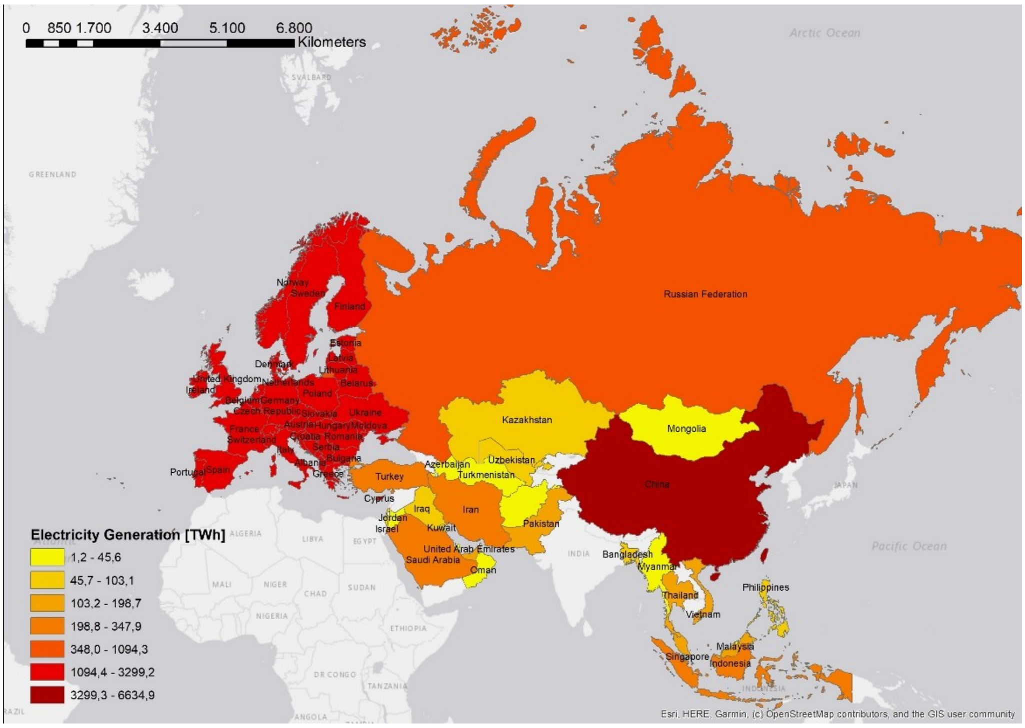

Figure 9: Electricity generation in BRI countries. Source: PoliTo.

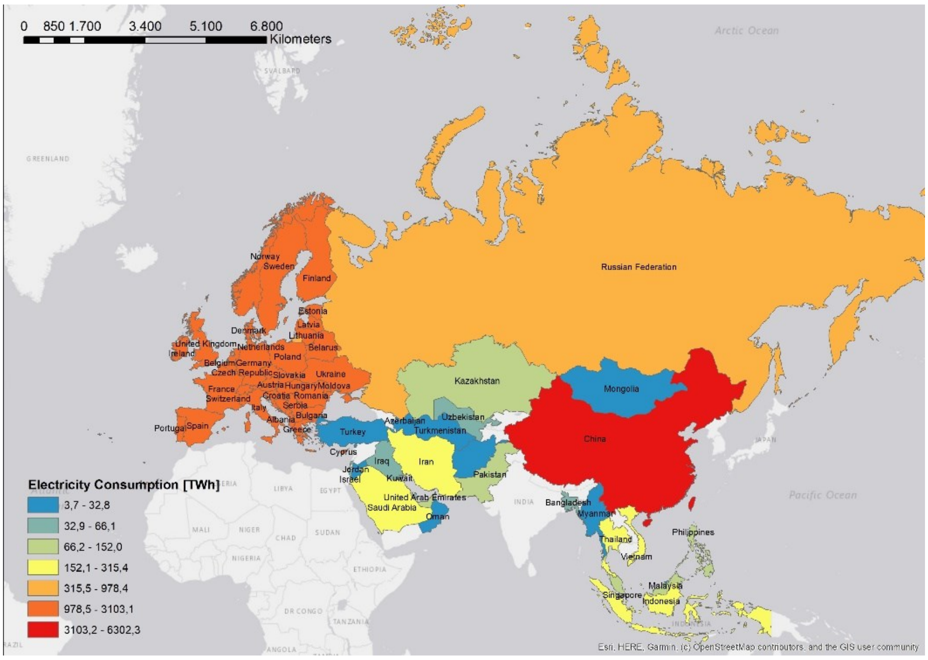

Figure 10: Electricity consumption in BRI countries. Source: PoliTo.

2.4.2 Electricity production by commodity

As far as the composition of the electricity generation is concerned, the analysis focuses on electricity generation from fossil fuels and from non-fossil resources. It is possible to notice how in both cases, China and Europe represent the greatest producer in the BRI region, but the difference

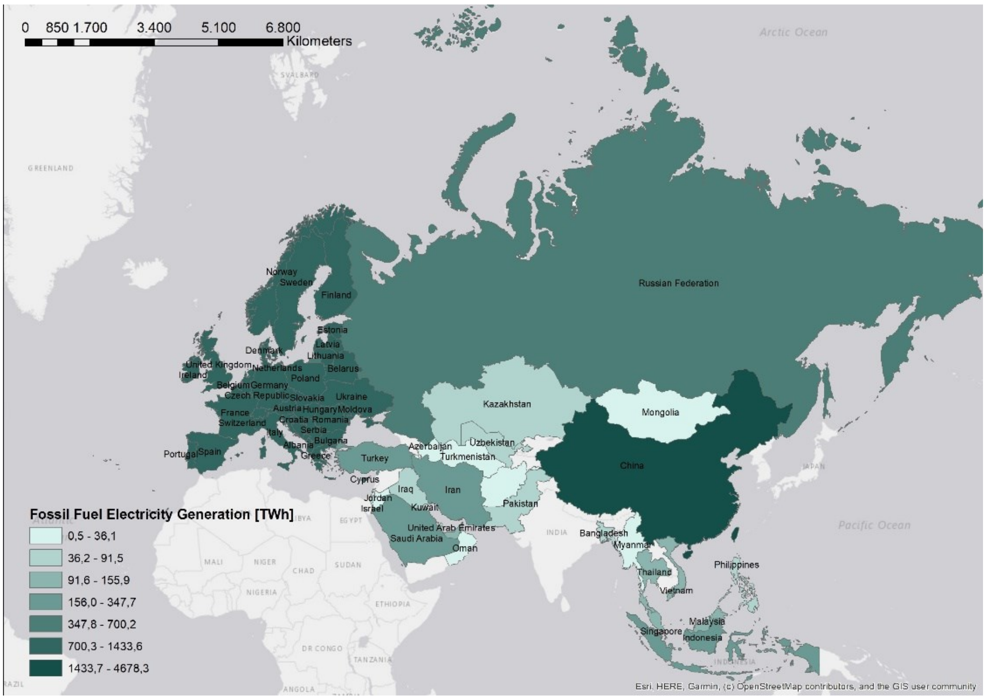

Figure 11: fossil fuel electricity generation in BRI countries. Source: PoliTo.

is that their electricity production from fossil fuels is an order of magnitude higher than the one from non-fossil supply. China has an outstanding electricity production from fossil fuels, 50% of the overall total, which outruns Europe covering just 15% of the overall total. Another important contribution in the generation from fossil fuels is represented by the Middle East region, which contributes to 12% of the BRI total. Considering the electricity generation from non-fossil resources, China and Europe again are the leaders of the category, but in this case, they show rather similar values, with a generation equal to about 40% of the overall total.

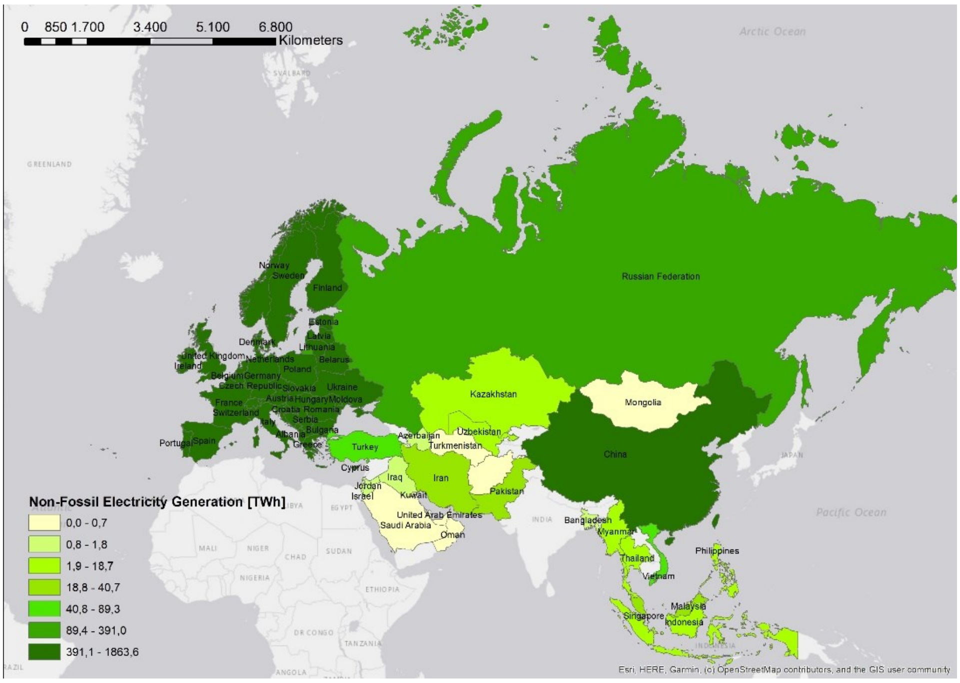

Figure 12: Non-fossil fuel electricity generation in BRI countries. Source: PoliTo.

In fact, European non-fossil generation is 88% of the Chinese one, even if the total electricity generation of these two areas is remarkably different. This occurs thanks to Europe's leading role in renewable energy and environmental-friendly policies and also thanks to the recent Chinese interest in this matter. Finally, the rest of the non-fossil generation is covered by all the other BRI countries, with a special mention to Russia, which covers the 9% of the overall total and 20% of the Chinese generation. Finally, the analysis of the electricity generation by commodity has been further implemented by considering the diversification of the electricity generation mix. To do so, a new index has been introduced, adapting the Shannon diversity index. This index, called S, is a way to quantify how much the power sector of a country is dependent on a specific energy source or, on the contrary, if it relies on many resources. It is defined as follows:

$$S = \frac{D}{D_{max}}$$

$$D = -\sum_{i=1}^{M} P_i * \ln(P_i)$$

$$D_{max} = -\ln\left(\frac{1}{M}\right)$$

Where P_i are the shares of each commodity over the total electricity generation and M is the total number of commodities considered. The electricity resources taken into consideration are coal, oil, natural gas, hydroelectric energy, nuclear energy, photovoltaic energy and wind energy. If the index S is zero it means that there is no diversification in the electricity generation, while 1 is equivalent to a prefect diversification. The following table reports the values of S for the BRI countries under consideration.

Country	Code	S
Kazakhstan	KAZ	0.45
Turkmenistan	TKM	0
Uzbekistan	UZB	0.30
China	CHN	0.52
Mongolia	MNG	0.24
Europe	EUR	0.85
Russian Federation	RUS	0.67
Bahrain	BHR	0
Iran	IRN	0.32
Iraq	IRQ	0.38
Israel	ISR	0.42
Jordan	JOR	0.35
Kuwait	KWT	0.33
Oman	OMN	0.07
Qatar	QAT	0
Saudi Arabia	SAU	0.34
United Arab Emirates	ARE	0.05
Bangladesh	BGD	0.33
Pakistan	PAK	0.79
Brunei Darussalam	BRN	0.03
Indonesia	IDN	0.53
Malaysia	MYS	0.55

Myanmar	MMR	0.46
Philippines	PHL	0.59
Singapore	SGP	0.08
Thailand	THA	0.45
Vietnam	VNM	0.56
Azerbaijan	AZE	0.25
Turkey	TUR	0.66

Table 8: Diversification of the electricity generation mix in BRI countries. Elaboration on IEA 2017 data.

The results show that the most diversified country in terms of the variety of the electricity generation mix is Europe, followed by Pakistan, Russian Federation and Turkey. On the other hand, the Middle East and Central Asia countries are highly dependent on a limited number of energy commodities to produce electricity. This is the case in particular for Turkmenistan, Bahrain and Qatar, which use only one kind of energy source, that is natural gas. In this framework, China follows the trend of the Southeast Asia region, presenting a value in between, equal to 0.52.

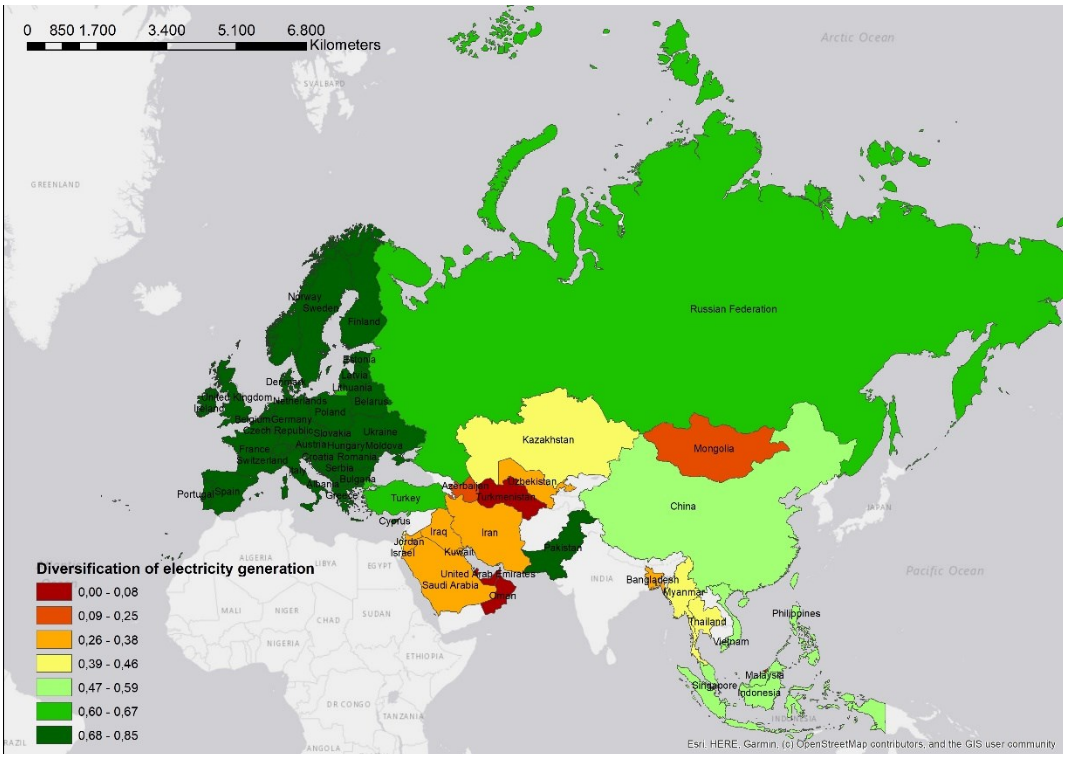

Figure 13: Diversification of the electricity generation mix. Source: PoliTo.

2.5 Environmental Impacts along BRI

Climate change and environment protection have been at the centre of debates worldwide, gaining importance since the 1980s, and now it is no more possible to ignore the environmental footprint of policies and actions. UN took several initiatives to mobilise countries to reduce environmental impacts and to work towards the sustainable development. In 1988 United Nations decided to found the Intergovernmental Panel on Climate Change IPCC, "noting with concern that the emerging evidence indicates that continued growth in atmospheric concentrations of 'greenhouse' gases could produce global warming with an eventual rise in sea levels, the effects of which could be disastrous for mankind if timely steps are not taken at all levels" [29]. The foundation of the IPCC aimed at giving a scientific base to climate change through the publication of reports in order to make effective political decisions. The work done by IPCC during the years has contributed to the signing of important treaties and agreements, such as United Nation Framework Convention on Climate Change UNFCCC in 1992, Kyoto protocol in 1997 and lately Paris Agreement in 2016. The main goal of Paris Agreement is "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" [30]. In addition, UN announced and adopted the 2030 Agenda for Sustainable Development, in order to change our economic and energy system towards a new one, which can operate in compliance with the people, environment and future generations. Nevertheless, a new global peak in CO_2 emission was reached in 2018 due to the growth of energy demand [1]. Considering the vast contribution of the selected BRI countries to the global energy supply and use, it becomes mandatory to analyse the environmental impacts of BRI countries, to study the present situation and define possible solutions and effective policies to reduce climate change and its catastrophic effects on mankind. This has been done by choosing five parameters, as shown in table 50 in Appendix I, which are: total carbon dioxide emissions, total greenhouse gas emissions, total nitrous oxide emissions, hydrofluorocarbon emissions and PM 2.5 exposure. All these indexes should outline the environmental footprint of the different countries. Finally, table 9 and 10 summarize the data collected for the 30 selected BRI countries with respect to the chosen parameters.

Country	Code	Total CO2 emissions			Total GHG emissions		
		[Mt CO2 eq]	p.u. wrt China	% TOT	[Mt CO2 eq.]	p.u. wrt China	% TOT
Kazakhstan	KAZ	248.70	0.02	1.2%	352.30	0.03	1.3%
Turkmenistan	TKM	74.80	0.01	0.4%	123.50	0.01	0.5%
Uzbekistan	UZB	97.10	0.01	0.5%	166.00	0.01	0.6%
Total Central Asia		**420.60**	**0.04**	**2.1%**	**641.80**	**0.05**	**2.4%**

China	CHN	10582.30	1.00	52.6%	13000.30	1.00	49.0%
Mongolia	MNG	17.40	0.00	0.1%	46.00	0.00	0.2%
Total Eastern Asia		**10599.70**	**1.00**	**52.7%**	**13046.30**	**1.00**	**49.2%**
Europe	EUR	3420.40	0.32	17.0%	4399.00	0.34	16.6%
Russian Federation	RUS	1642.50	0.16	8.2%	2239.00	0.17	8.4%
Total Europe and Russia		**5062.90**	**0.48**	**25.2%**	**6638.00**	**0.51**	**25.0%**
Bahrain	BHR	33.10	0.00	0.2%	39.20	0.00	0.1%
Iran	IRN	621.00	0.06	3.1%	821.00	0.06	3.1%
Iraq	IRQ	168.00	0.02	0.8%	242.50	0.02	0.9%
Israel	ISR	68.40	0.01	0.3%	82.70	0.01	0.3%
Jordan	JOR	25.60	0.00	0.1%	30.70	0.00	0.1%
Kuwait	KWT	92.50	0.01	0.5%	120.30	0.01	0.5%
Oman	OMN	75.70	0.01	0.4%	101.90	0.01	0.4%
Qatar	QAT	94.80	0.01	0.5%	167.00	0.01	0.6%
Saudi Arabia	SAU	602.30	0.06	3.0%	704.00	0.05	2.7%
United Arab Emirates	ARE	196.20	0.02	1.0%	234.20	0.02	0.9%
Total Middle East		**1977.60**	**0.19**	**9.8%**	**2543.50**	**0.20**	**9.6%**
Bangladesh	BGD	79.30	0.01	0.4%	220.70	0.02	0.8%
Pakistan	PAK	170.70	0.02	0.8%	412.80	0.03	1.6%
Total South Asia		**250.00**	**0.02**	**1.2%**	**633.50**	**0.05**	**2.4%**
Brunei Darussalam	BRN	6.40	0.00	0.0%	12.00	0.00	0.0%
Indonesia	IDN	489.90	0.05	2.4%	946.80	0.07	3.6%
Malaysia	MYS	248.90	0.02	1.2%	315.00	0.02	1.2%
Myanmar	MMR	25.10	0.00	0.1%	146.30	0.01	0.6%
Philippines	PHL	114.50	0.01	0.6%	201.10	0.02	0.8%
Singapore	SGP	50.30	0.00	0.3%	57.80	0.00	0.2%
Thailand	THA	272.00	0.03	1.4%	405.20	0.03	1.5%
Vietnam	VNM	200.00	0.02	1.0%	336.80	0.03	1.3%
Total Southeast Asia		**1407.10**	**0.13**	**7.0%**	**2421.00**	**0.19**	**9.1%**
Azerbaijan	AZE	32.40	0.00	0.2%	54.40	0.00	0.2%
Turkey	TUR	367.20	0.03	1.8%	525.90	0.04	2.0%
Total Western Asia		**399.60**	**0.04**	**2.0%**	**580.30**	**0.04**	**2.2%**
TOTAL		**20117.50**	**1.90**	**100.0%**	**26504.40**	**2.04**	**100.0%**

Table 9: Total CO_2 and GHG emissions in BRI countries. Source: IEA 2015.

Country	Code	Total N2O emissions			HFC - Industrial processes			PM 2.5 air pollution
		[Mt CO2 eq.]	p.u. wrt China	% TOT	[Mt CO2 eq.]	p.u. wrt China	% TOT	[mg/m3]
Kazakhstan	KAZ	14.60	0.03	1.1%	0.60	0.00	0.2%	14
Turkmenistan	TKM	5.10	0.01	0.4%	0.10	0.00	0.0%	22
Uzbekistan	UZB	12.60	0.02	1.0%	1.00	0.01	0.3%	28
Total Central Asia		**32.30**	**0.06**	**2.5%**	**1.70**	**0.01**	**0.5%**	**21**

China	CHN	512.90	1.00	39.4%	199.10	1.00	55.7%	53
Mongolia	MNG	6.50	0.01	0.5%	0.00	0.00	0.0%	40
Total Eastern Asia		**519.40**	**1.01**	**39.9%**	**199.10**	**1.00**	**55.7%**	**47**
Europe	EUR	289.70	0.56	22.3%	111.70	0.56	31.3%	14
Russian Federation	RUS	87.60	0.17	6.7%	33.50	0.17	9.4%	16
Total Europe and Russia		**377.30**	**0.74**	**29.0%**	**145.20**	**0.73**	**40.6%**	**15**
Bahrain	BHR	0.20	0.00	0.0%	0.00	0.00	0.0%	71
Iran	IRN	27.20	0.05	2.1%	0.00	0.00	0.0%	39
Iraq	IRQ	7.20	0.01	0.6%	0.00	0.00	0.0%	62
Israel	ISR	2.30	0.00	0.2%	2.00	0.01	0.6%	21
Jordan	JOR	1.10	0.00	0.1%	0.20	0.00	0.1%	33
Kuwait	KWT	0.80	0.00	0.1%	0.90	0.00	0.3%	61
Oman	OMN	1.20	0.00	0.1%	0.30	0.00	0.1%	41
Qatar	QAT	0.60	0.00	0.0%	0.00	0.00	0.0%	91
Saudi Arabia	SAU	8.20	0.02	0.6%	0.30	0.00	0.1%	88
United Arab Emirates	ARE	2.40	0.00	0.2%	0.00	0.00	0.0%	41
Total Middle East		**51.20**	**0.10**	**3.9%**	**3.70**	**0.02**	**1.0%**	**55**
Bangladesh	BGD	19.40	0.04	1.5%	0.00	0.00	0.0%	61
Pakistan	PAK	47.80	0.09	3.7%	0.00	0.00	0.0%	58
Total South Asia		**67.20**	**0.13**	**5.2%**	**0.00**	**0.00**	**0.0%**	**60**
Brunei Darussalam	BRN	0.10	0.00	0.0%	0.40	0.00	0.1%	6
Indonesia	IDN	103.90	0.20	8.0%	0.00	0.00	0.0%	17
Malaysia	MYS	13.70	0.03	1.1%	0.10	0.00	0.0%	16
Myanmar	MMR	22.60	0.04	1.7%	0.00	0.00	0.0%	36
Philippines	PHL	15.30	0.03	1.2%	0.00	0.00	0.0%	18
Singapore	SGP	1.70	0.00	0.1%	2.20	0.01	0.6%	19
Thailand	THA	23.00	0.04	1.8%	0.00	0.00	0.0%	26
Vietnam	VNM	22.70	0.04	1.7%	0.00	0.00	0.0%	30
Total Southeast Asia		**203.00**	**0.40**	**15.6%**	**2.70**	**0.01**	**0.8%**	**21**
Azerbaijan	AZE	2.70	0.01	0.2%	0.10	0.00	0.0%	20
Turkey	TUR	48.70	0.09	3.7%	4.70	0.02	1.3%	44
Total Western Asia		**51.40**	**0.10**	**3.9%**	**4.80**	**0.02**	**1.3%**	**32**
TOTAL		**1301.80**	**2.54**	**100.0%**	**357.20**	**1.79**	**100.0%**	**37**

Table 10: other atmospheric pollutants in BRI countries. Source: IEA 2015 except from PM 2.5 air pollution from World Bank 2017.

2.5.1 CO_2 and total GHG emissions

Considering both the CO_2 and more generally GHG emissions, it should be notice that the values and the shares of the countries have similar trends, since CO_2 emissions often constitute the great majority of GHG emissions. Even for environmental impacts, China is the country with the highest amount of CO_2 and GHG emissions among all the BRI countries and it covers about 50% of the overall share in both categories. The second largest contribute to polluting emissions comes from Europe and Russia, which together tough, reach just ah half of the emissions produced by China.

The rest of the total emissions are spread between all the other BRI regions, with a special mention for Middle East which represents about 10% of the overall total and 20% of China's emissions.

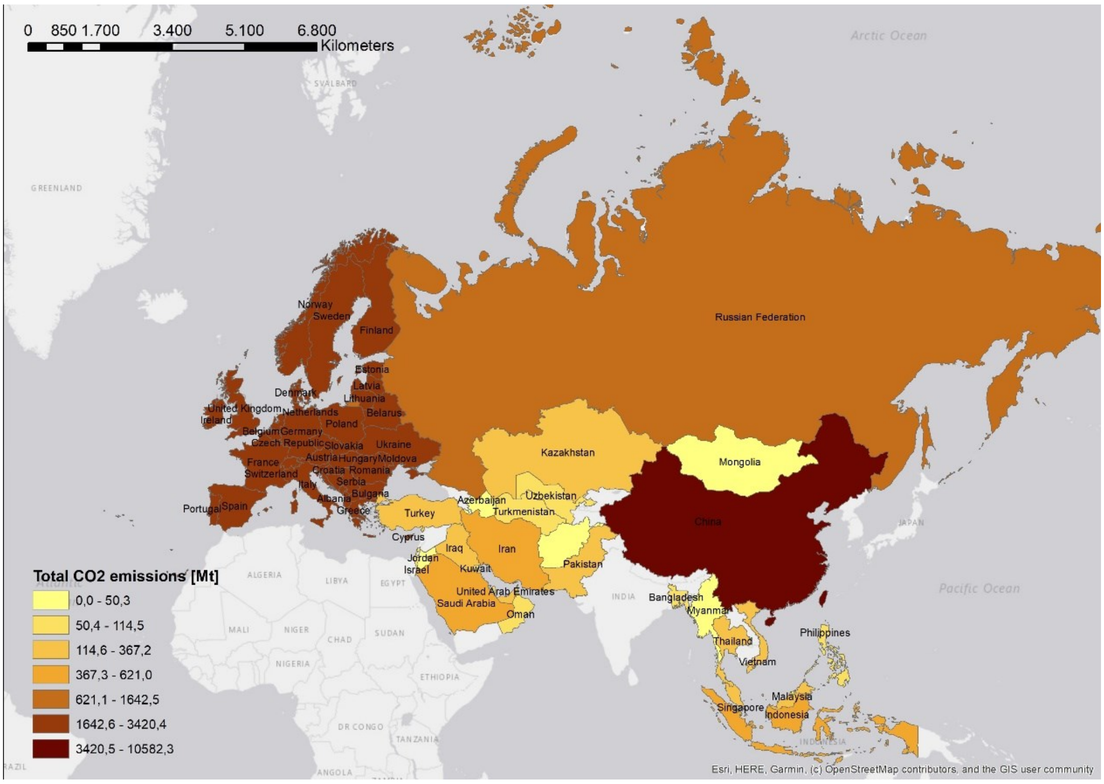

Figure 14: total CO_2 emissions in BRI countries. Source: PoliTo.

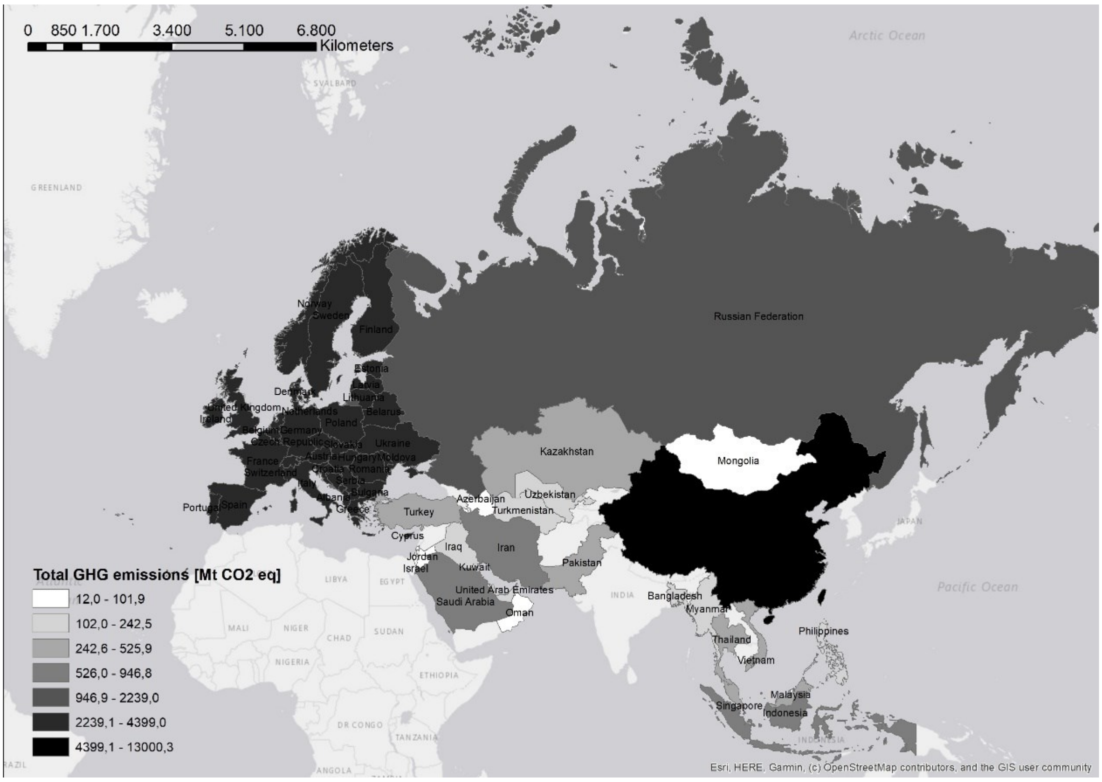

Figure 15: total GHG emissions in BRI countries. Source: PoliTo.

2.5.2 Other GHG gases and pollutants

Going more into details about the other GHG and polluting gases, nitrous oxides, hydrofluorocarbon emissions and PM 2.5 air pollution have been taken into account. Nitrous oxides are a class of chemical compound generally referred as NOx in which NO and N_2O are most abundant. N_2O is important greenhouse gas and according to the Fifth Assessment Report (AR5)

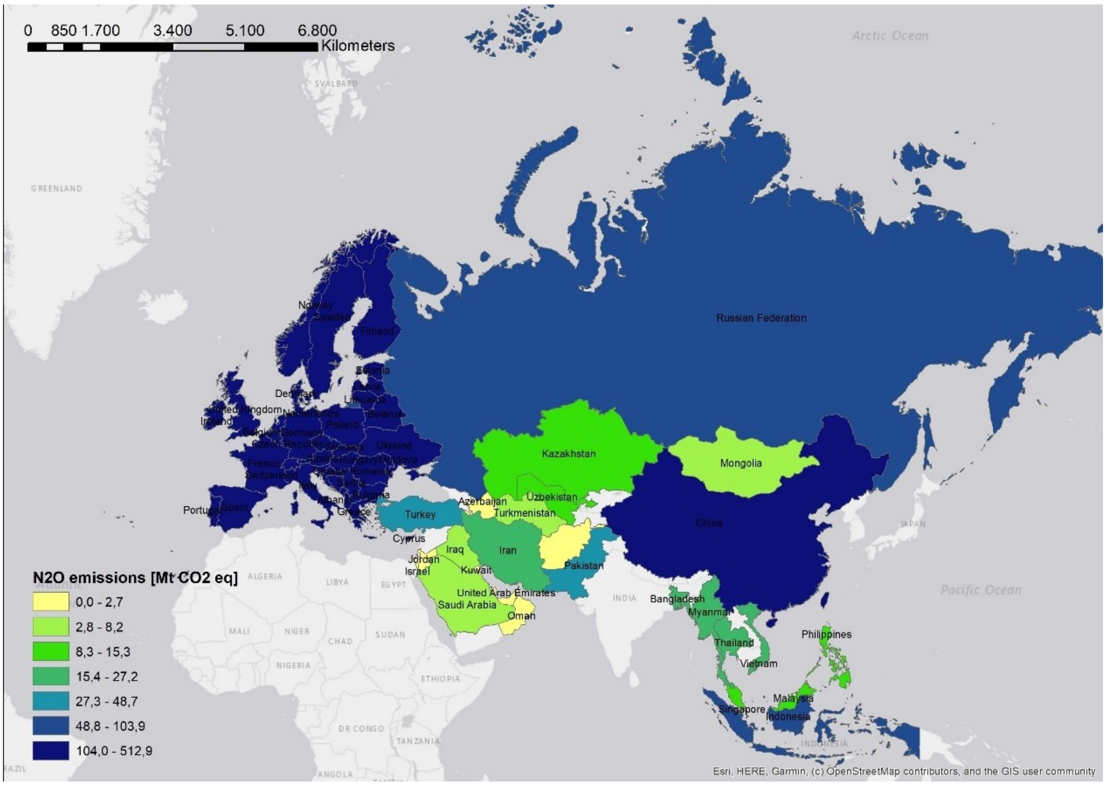

Figure 16: N_2O emissions in BRI countries. Source: PoliTo.

of IPCC his global warming potential GWP of 265 times that of CO_2 for 100 years. It is also a polluting gas which contributes to the depletion of the ozone layer [31]. Anthropogenic N_2O emissions are mainly from agricultural activities and biomass and fossil fuel combustion. The largest emitters of N_2O are China again, which contributes to about 40% of the overall total, Europe and Russia with a share of 29% and Southeast Asia, which covers 16% of the total.

Hydrofluorocarbon or HFC emissions have been also considered in the evaluation of the environmental footprint of BRI countries, since they are another important greenhouse gas responsible of global warming. HFC is a general class of gases, typically used as refrigerants in industrial processes. Their Global Warming Potentials vary a lot: there are high-GWP gases with GWP equal to tens of thousands the potential of CO_2 over 100 years and other gases like R-152a, whose GWP is equal to 124 [32]. In this framework, China is the country with the highest emissions, covering 55% of the overall total. The region Europe and Russia shows the second highest value of emissions, with a share of 40% of the total, and together with China they represent almost all the HFC emissions of BRI area.

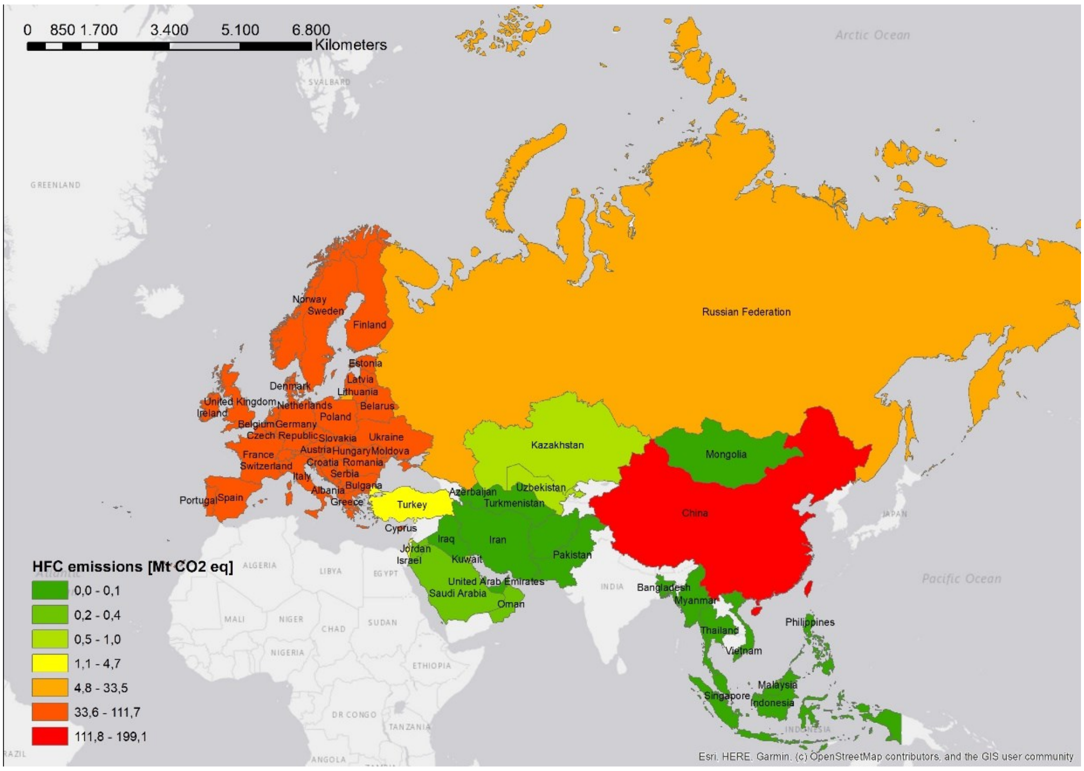

Figure 17: HFC emissions in BRI countries. Source: PoliTo.

Finally, level of exposure to PM 2.5 has been considered to quantify the air pollution, to which the population of BRI countries has been subjected. PM 2.5 is the particulate matter, so small particles suspended in air with a diameter of 2.5 micrometres. According to Health Effects Institute, exposure to PM2.5 contributed to 4.1 million deaths from heart disease and stroke, lung cancer, chronic lung disease, and respiratory infections in 2016 [33]. So, in this sense, it is not just a matter of environmental protection, but it is also a public health issue. In the present study, the annual mean exposure was considered, so the

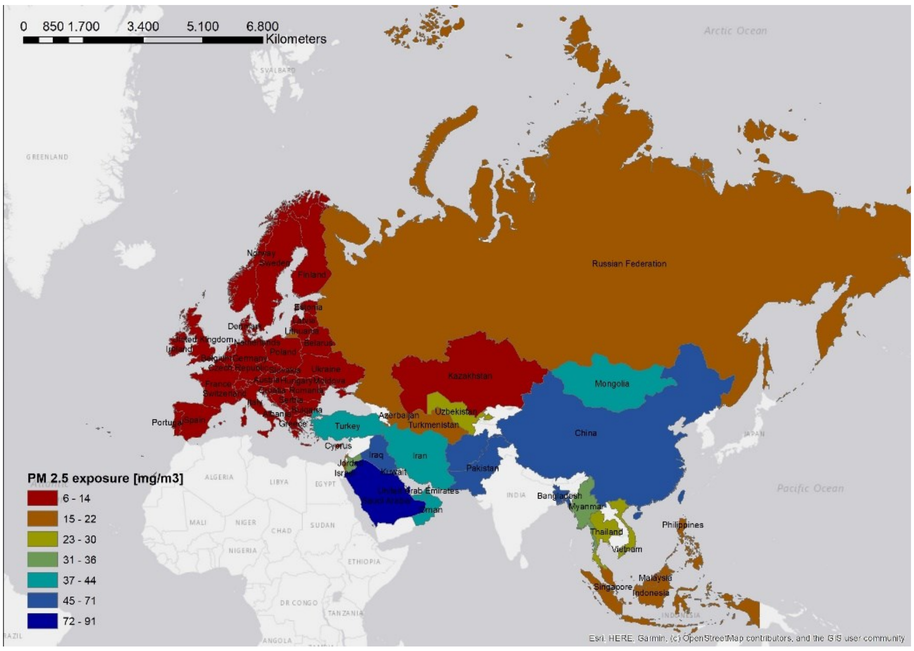

Figure 18: PM 2.5 levels of exposure for BRI countries. Source: PoliTo.

overall total and regional totals were calculated as the average of the country levels of exposure considered. The countries with the highest level of exposure are in the Middle East region and they are Qatar and Saudi Arabia, with values of 91 and 88 mg/m^3 as annual average exposure. China as a value comparable to the Middle East average, about 55 mg/m^3. Europe in this category as one of the lowest annual level of exposure to PM 2.5 thanks to air quality standards in EU legislation.

2.6 Energy and Economics along BRI

Considering the importance of the energy sector in the society at a global scale, it is essential to examine its relationship and cause-effect relations with economics. In industrialized countries, energy sector has a key role in the economic system, since it is a necessary resource for economic production of every single good and service and therefore it is the backbone of the economic growth. Energy sector might be a small share of GDP in countries which do not rely on oil and gas production, but its influence on economy is undeniable: stable energy supply and prices are positive for production, its high capital spending flow contributes to job creation and its broad supplier network and multiplier effect lead to economic benefits [34]. The parameters used to correlate energy and economics are GDP, GDP on purchasing power parity, energy intensity and carbon intensity, as shown in table 51 in Appendix I. Table 11 reports all the data for the selected BRI countries with respect to the above-mentioned parameters.

Country	Code	GDP PPP			Energy intensity (TPES/GDP PPP)			Carbon intensity (CO2/GDP PPP)		
		[billion 2011 USD]	p.u. wrt China	% TOT	[MJ/USD 2011]	p.u. wrt China	% TOT	[KgCO2 / USD 2010 PPP]	p.u. wrt China	% TOT
Kazakhstan	KAZ	452.1	0.02	0.7%	8.36	1.31	179.0%	0.56	1.19	177.3%
Turkmenistan	TKM	100.2	0.00	0.2%	13.31	2.09	285.0%	0.79	1.68	250.2%
Uzbekistan	UZB	205.7	0.01	0.3%	8.35	1.31	178.8%	0.45	0.96	142.5%
Total Central Asia		**758.0**	**0.03**	**1.2%**	**8.1**	**1.27**	**173.6%**	**0.6**	**1.18**	**175.7%**
China	CHN	22543.8	1.00	35.4%	6.37	1.00	136.3%	0.47	1.00	148.8%
Mongolia	MNG	38.7	0.00	0.1%	6.16	0.97	132.0%	0.53	1.13	167.8%
Total Eastern Asia		**22582.5**	**1.00**	**35.4%**	**5.5**	**0.86**	**117.6%**	**0.5**	**1.00**	**148.6%**
Europe	EUR	19543.0	0.87	30.7%	3.69	0.58	79.0%	0.18	0.38	57.0%
Russian Federation	RUS	3763.2	0.17	5.9%	9.65	1.52	206.7%	0.45	0.96	142.5%
Total Europe and Russia		**23306.2**	**1.03**	**36.6%**	**4.2**	**0.66**	**89.7%**	**0.2**	**0.46**	**68.8%**
Bahrain	BHR	65.9	0.00	0.1%	9.81	1.54	210.0%	0.49	1.04	155.2%
Iran	IRN	1540.7	0.07	2.4%	7.13	1.12	152.6%	0.39	0.83	123.5%
Iraq	IRQ	598.2	0.03	0.9%	3.97	0.62	85.0%	0.24	0.51	76.0%
Israel	ISR	299.0	0.01	0.5%	3.53	0.55	75.6%	0.23	0.49	72.8%
Jordan	JOR	82.7	0.00	0.1%	4.84	0.76	103.6%	0.31	0.66	98.2%

Kuwait	KWT	271.1	0.01	0.4%	5.49	0.86	117.5%	0.33	0.70	104.5%
Oman	OMN	177.9	0.01	0.3%	5.93	0.93	127.0%	0.37	0.79	117.2%
Qatar	QAT	313.0	0.01	0.5%	5.95	0.93	127.4%	0.27	0.57	85.5%
Saudi Arabia	SAU	1651.1	0.07	2.6%	5.52	0.87	118.2%	0.33	0.70	104.5%
United Arab Emirates	ARE	641.6	0.03	1.0%	5.10	0.80	109.2%	0.31	0.66	98.2%
Total Middle East		**5641.2**	**0.25**	**8.9%**	**5.5**	**0.86**	**117.0 %**	**0.4**	**0.75**	**111.0%**
Bangladesh	BGD	625.9	0.03	1.0%	3.12	0.49	66.9%	0.14	0.30	44.3%
Pakistan	PAK	1045.8	0.05	1.6%	4.36	0.68	93.4%	0.17	0.36	53.8%
Total South Asia		**1671.7**	**0.07**	**2.6%**	**3.4**	**0.53**	**72.5%**	**0.1**	**0.32**	**47.4%**
Brunei Darussalam	BRN	30.8	0.00	0.0%	4.16	0.65	89.0%	0.21	0.45	66.5%
Indonesia	IDN	3106.5	0.14	4.9%	3.50	0.55	74.9%	0.17	0.36	53.8%
Malaysia	MYS	888.4	0.04	1.4%	4.75	0.75	101.6%	0.28	0.60	88.7%
Myanmar	MMR	318.1	0.01	0.5%	2.94	0.46	63.0%	0.08	0.17	25.3%
Philippines	PHL	847.1	0.04	1.3%	3.13	0.49	67.1%	0.16	0.34	50.7%
Singapore	SGP	508.0	0.02	0.8%	2.56	0.40	54.8%	0.1	0.21	31.7%
Thailand	THA	1173.7	0.05	1.8%	5.48	0.86	117.4%	0.23	0.49	72.8%
Vietnam	VNM	631.4	0.03	1.0%	6.27	0.98	134.2%	0.35	0.74	110.8%
Total Southeast Asia		**7503.8**	**0.33**	**11.8%**	**3.6**	**0.56**	**76.8%**	**0.2**	**0.40**	**59.4%**
Azerbaijan	AZE	159.186 6	0.01	0.2%	3.89	0.61	83.3%	0.21	0.45	66.5%
Turkey	TUR	2081.6	0.09	3.3%	3.12	0.49	66.7%	0.18	0.38	57.0%
Total Western Asia		**2240.8**	**0.10**	**3.5%**	**2.8**	**0.44**	**60.4%**	**0.2**	**0.38**	**56.5%**
TOTAL		**63704.3**	**2.83**	**100.0 %**	**4.7**	**0.73**	**100.0 %**	**0.3**	**0.67**	**100.0%**

Table 11: GDP PPP, energy intensity and carbon intensity for BRI countries. Source: World Bank 2018 for GDP PPP, energy and carbon intensity elaborated from IEA data, 2016

2.6.1 Energy and Carbon Intensity

The energy intensity is a parameter which give a measure of the use of energy resources to produce a unit of added value in GDP. It is calculated as the ratio of Total Primary Energy Supply TPES and GDP PPP. A widely observed characteristic is the fact that the most industrialized countries tend to reduce their energy intensity over time, by implementing energy efficient policies and technologies. In fact, after a rapid increase in energy intensity during the industrialization phase of a country, there is a plateau and successive decrease in energy intensity, thanks to the shift from industrial-based to service-based economic system and to efficiency improvements [35]. This is the case of two areas with comparable GDP PPP: Europe, which has a low value of energy intensity, and China, which shows a lower energy efficiency of the economy, but it is moving towards a less energy intensive economic system. Russia has one of the highest levels of energy intensity together with Central Asia and Middle East countries.

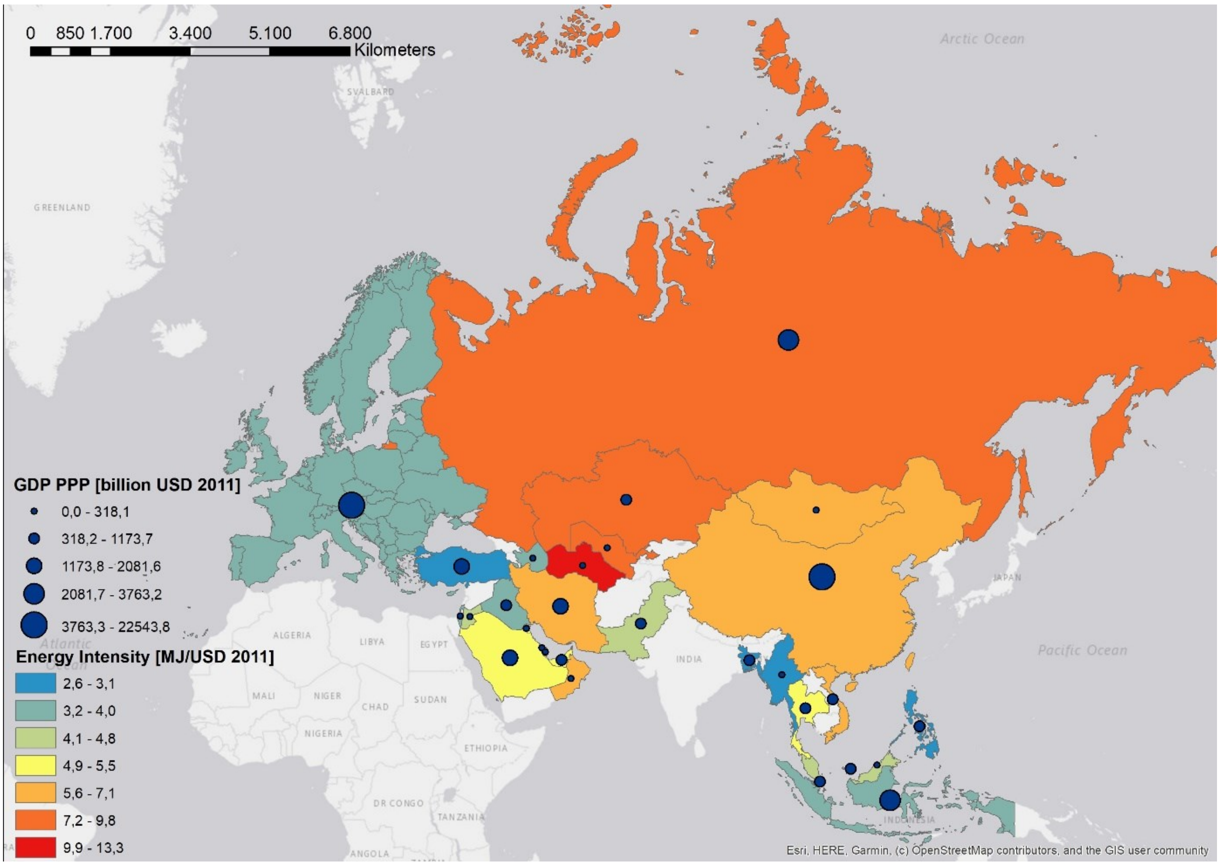

Figure 19: Energy intensity for BRI countries, with respect to GDP PPP values. Source: PoliTo.

Another important parameter to evaluate is the carbon intensity, which is the amount of emitted CO_2 per unit of value added in GDP. It is included in the energy and economics analysis, together with energy intensity, because energy sector is deeply connected to economy, but it also contributes to a large share of the polluting emissions. So, it becomes important to integrate the environmental effects that energy sector and economy cause, by adding how much pollution is generated while producing economic growth. Like energy intensity, the lower is the value of carbon intensity, the more environmental-friendly is the economic system. In addition to energy efficiency, clean technologies and processes should be encouraged so to reduce the environmental impacts of economic development. Sustainability and sustainable development are fundamental aspect to consider, since awareness on environmental protection and climate change is constantly rising in the global framework. Thanks to environmental policies, Europe has indeed one of the lowest levels of carbon intensity. On the contrary, China, Russia, Central Asia and Middle East show similar values of high carbon intensity, highlighting the necessity for these areas to implement more environmental measures, in order to reach a more sustainable development.

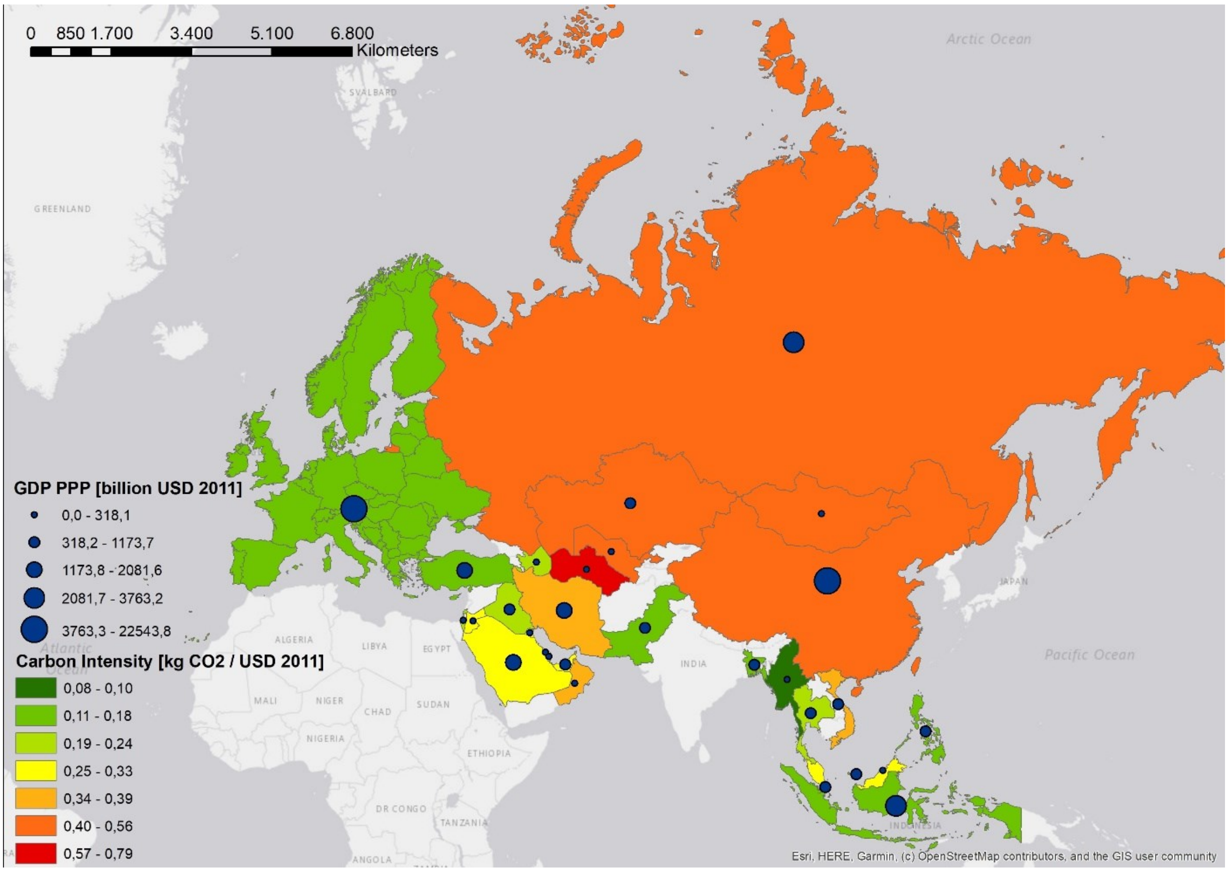

Figure 20: Carbon intensity for BRI countries, with respect to GDP PPP. Source: PoliTo.

2.7 CARBON PRICING ALONG BRI

2.7.1 Introduction

Given the increasing awareness on environmental issues and climate change, the perspective on polluting emissions have started to change, from an obvious consequence of an economic activity, to a cost which has not yet taken into account. Pollution is indeed a negative externality, that is a social cost of production, which is not considered in the market price, but it is paid in terms of negative impacts by the population and environment. To face this issue, governments have put a price on carbon by introducing carbon pricing mechanisms, so that the cost of emissions will be corrected and paid by who is responsible for the pollution. In this way there is a financial incentive for emitting entities to reduce their environmental impacts and consequently their taxes and, on the other hand, governments gain a new source of revenues, which can be used to increase the spending or reduce other taxes. There are two main kinds of carbon pricing, carbon tax and Emission Trading System (ETS). Carbon tax is a tax imposed on goods and processes which create pollutant emissions. It is a price tool, in the sense that governments act on the price paid by emitting entities, which can decide the amount of emissions produced. ETS instead is a cape and trade system of GHG emission allowances which are negotiable: ETS is a quantity tool since the government decides the maximum level of emissions and consequently the maximum number of allowances, but the market price for GHG emissions is fixed by the supply and demand for allowances. Introducing a carbon pricing mechanism results in multiple benefits for the environment and population, both direct effects by reducing the level of pollution and indirect effects by new green investments and projects by the government. On the other hand, a carbon pricing mechanism can lead to the so-called carbon leakage, which is the transfer of companies and industrial activities towards countries without carbon pricing measures. To avoid this phenomenon, a carbon border tax can be introduced for the carbon intensive goods, which enter countries with carbon pricing mechanisms. Some BRI countries have introduced some forms of carbon pricing measures or they are considering or planning to introduce it in the future, as reported in table 12. In Appendix I table 52, there is the list of the parameters used to evaluate carbon pricing with their characterization [36,37,38].

2.7.2 Carbon Pricing Data

Country	Code	Type of carbon pricing	Status	Type of jurisdiction covered	Jurisdiction Covered	Value (billion USD)	Tax rate (USD/tCO2)	Share of emissions covered (%)
Kazakhstan	KAZ	ETS	Implemented	National	Kazakhstan	0	0	50
Turkmenistan	TKM	NO	Not present					
Uzbekistan	UZB	NO	Not present					
China	CHN	ETS	Scheduled	National	China	0	N/A	30
		ETS	Implemented	Sub national	Beijing	0.43426	8	45
		ETS	Implemented	Sub national	Chongqing	0.38360	3	40
		ETS	Implemented	Sub national	Fujian	0.63679	3	60
		ETS	Implemented	Sub national	Guangdong	0.98017	2	60
		ETS	Implemented	Sub national	Hubei	0.59734	2	35
		ETS	Implemented	Sub national	Shanghai	0.96856	6	57
		ETS	Implemented	Sub national	Shenzhen	0.21163	4	40
		ETS	Implemented	Sub national	Tianjin	0.21676	1	55
Mongolia	MNG	NO	Not present					
Europe	EUR	ETS	Implemented	Regional	EU	31.76017	9	45
Russian Federation	RUS	NO	Not present					
Bahrain	BHR	NO	Not present					
Iran	IRN	NO	Not present					
Iraq	IRQ	NO	Not present					
Israel	ISR	NO	Not present					
Jordan	JOR	NO	Not present					
Kuwait	KWT	NO	Not present					
Oman	OMN	NO	Not present					
Qatar	QAT	NO	Not present					
Saudi Arabia	SAU	NO	Not present					

United Arab Emirates	ARE	NO	Not present					
Afghanistan	AFG	NO	Not present					
Bangladesh	BGD	NO	Not present					
Pakistan	PAK	NO	Not present					
Brunei Darussalam	BRN	NO	Not present					
Indonesia	IDN	NO	Not present					
Malaysia	MYS	NO	Not present					
Myanmar	MMR	NO	Not present					
Philippines	PHL	NO	Not present					
Singapore	SGP	Carbon tax	Implemented	National	Singapore	0	4	80
Thailand	THA	Undecide d	Under consideration	National	Thailand	0	0	N/A
Vietnam	VNM	ETS	Under consideration	National	Vietnam	0	0	N/A
Azerbaijan	AZE	NO	Not present					
Turkey	TUR	ETS	Under consideration	National	Turkey	0	0	N/A
Denmark	DNK	Carbon Tax	Implemented	National	Denmark	0.59317	29	40
Estonia	EST	Carbon tax	Implemented	National	Estonia	0.00311	2	3
Finland	FIN	Carbon tax	Implemented	National	Finland	1.60941	76	36
France	FRA	Carbon tax	Implemented	National	France	9.55096	55	35
Ireland	IRL	Carbon tax	Implemented	National	Ireland	0.55171	29	49
Latvia	LVA	Carbon tax	Implemented	National	Latvia	0.01001	5	15
Netherlands	NLD	Carbon tax	Under consideration	National	Netherlands	0	0	N/A
Norway	NOR	Carbon tax	Implemented	National	Norway	1.72489	57	60
Portugal	PRT	Carbon tax	Implemented	National	Portugal	0.17089	10	29
Slovenia	SVN	Carbon tax	Implemented	National	Slovenia	0.09168	21	24
Spain	ESP	Carbon tax	Implemented	National	Spain	0.21696		
Sweden	SWE	Carbon tax	Implemented	National	Sweden	2.82118	139	40
Switzerland	CHE	Carbon tax	Implemented	National	Switzerland	1.23187	102	33
Ukraine	UKR	Carbon tax	Implemented	National	Ukraine	0.00411	<1	71
United Kingdom	GBR	Carbon tax	Implemented	National	United Kingdom	1.14486	25	23

Table 12: data on carbon pricing collected for BRI countries with a focus on European countries. Source: World Bank 2019 and Institute for Climate Economics, Global Carbon Account 2018.

As it is possible to notice, the majority of BRI countries still do not have carbon pricing mechanisms. In the whole Asia and Middle East region, only Kazakhstan has implemented a carbon pricing measure on a national level, that is ETS, but the annual mean value registered is way too low. China has planned to introduce a national ETS, but at the moment just eight jurisdictions have

ETS. Finally, only Turkey, Thailand and Vietnam are taking into consideration the idea of adopting a carbon pricing measure. Europe is by far the leader in environmental policies and not only it has an ETS on regional level, but some countries have also decided to implement a carbon tax on the national level. Table 12 in fact presents a focus on European countries at the hand in order to show the countries with an implemented carbon tax, which are the only ones in the whole BRI region together with Singapore. Progress have been made, both on the conceptual and practical side, but they are still not enough, since in the majority countries with carbon pricing mechanisms the tax rate is still too low to meet the objectives of emission reduction and the goal on the global temperature increase. United Nations Global Compact incites the companies themselves to set an internal price on carbon at least equal to 100 $/tCO2 to stay in the 1.5-2°C temperature increase pathway [39].

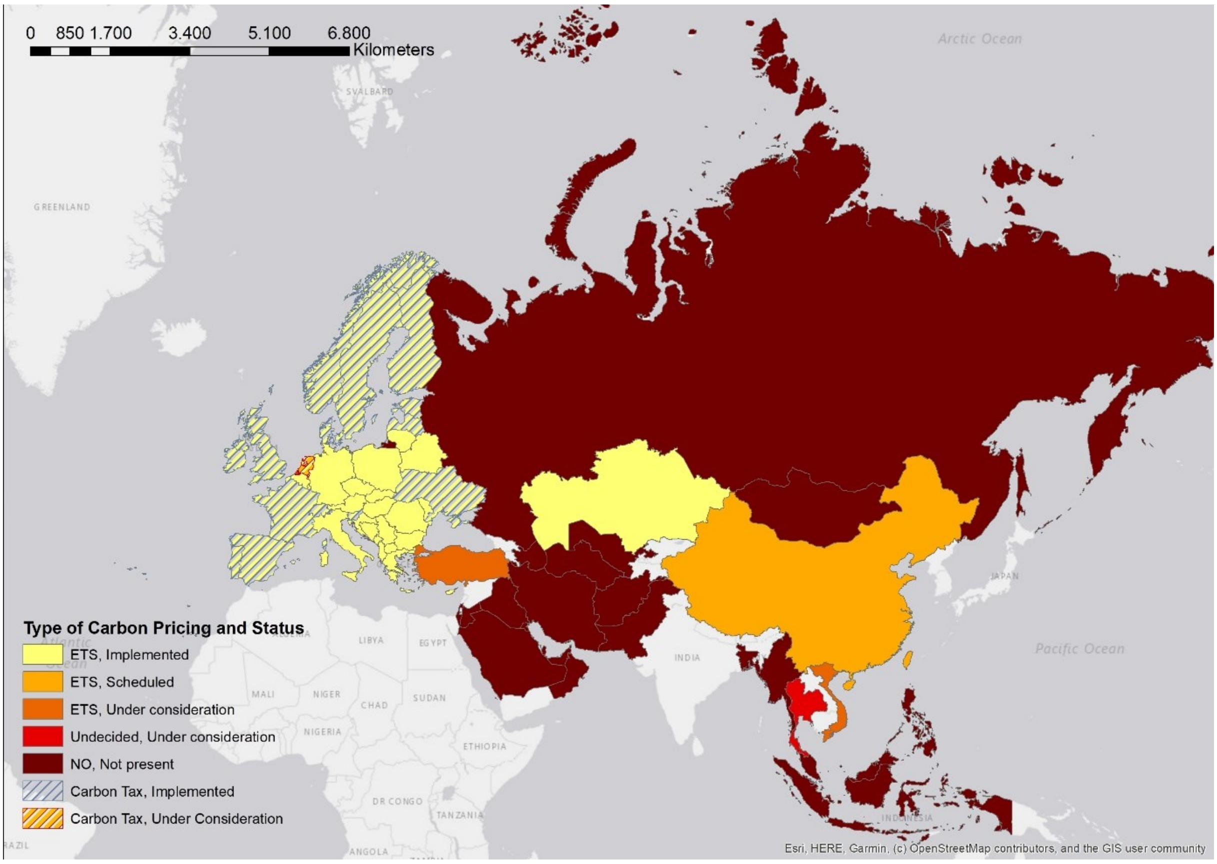

Figure 21: carbon pricing mechanisms along BRI. Source: PoliTo.

3 SUSTAINABILITY

3.1 INTRODUCTION

The concept of sustainability began to spread in the mid-1980s and in this period the World Commission on Environment and Development, often referred as Brundtland Commission, gave one of its most iconic definition. In the report "Our Common Future" (1987), sustainability is present in the sense of sustainable development, which is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [40]. In this occasion, it was pointed out the necessity to implement a global environmental protection program and a new way to manage natural resources. At the core of sustainability there is a new and deeper kind of attention to the state of Earth's biophysical environment. In fact, it takes the concept of environmental protection, which is the mitigation and prevention of environmental impacts and damages, to the next level, expanding the view to the dynamism of the whole planet and including a long-term perspective. For the first time with the Brundtland Commission, a new time dimension was indeed explicated in the sustainability definition, including a cross-generation concern and the focus on the future. In this view, the current utilisation rate of natural resources is no longer sustainable to guarantee the preservation in the coming years. On one hand, at this pace the continuous use and damage of Earth's resources will lead to their depletion, on the other hand the utilization itself of some resources has become harmful for environment and a typical example of these issues is represented by oil reserves. Sustainable economic development, related to the wider concept of sustainability, was born to substitute the traditional notion of economic growth, which starts to become unsuitable to face modern challenges, like protecting the environment and the needs of future generations. In fact, in the traditional neoclassical economic theory, the economic growth is the ultimate goal to focus on, since it is considered the only way to elevate human condition and the standards of living. To increase economic development, it is historically taken from granted that some natural resources must be used. Aiming at economic growth, everything can be considered expendable and a trade-off between a greater economic added value and the environmental safeguard is likely to be reached. Sustainable development challenges this idea of development "at all costs" and tries to incorporate other dimensions in the concept of growth, like the social and the ecological ones. The GDP growth does not seem to be an appropriate indicator of human well-being anymore. As the Nobel laureate Robert Solow, professor of economics at Massachusetts Institute of Technology, stated "the conventional totals, gross domestic product (GDP) or gross national product (GNP) or national income, are not so bad for studying fluctuations in employments or analysing the demand for goods and services. When it comes to measuring the economy's contribution to the well-being of the country's inhabitants, however, the conventional measures are incomplete" [41]. However, the concept of sustainability does not want to remove importance from economic development and does not necessary entail the idea of "anti-growth" or "no growth". It is true that in the literature there are example of promulgation of "no growth", first and foremost Thomas Malthus, who proposed in the 18th century to control the population growth in the first place, in order to avoid a future collapse of planet Earth due to overpopulation [42]. On the other hand, there are also optimists who believe that technology will help in increasing the ability of Earth to sustain humans and that there is no need to prevent growth, only a new development model should be implemented. In fact, the connection between the economic growth and the environmental degradation is often found in the traditional consumption. Reduce human consumption can be a useful mean to implement sustainability, but also promoting a new way of consuming can be the solution of the unsustainability problem. Improving the efficiency of the production system and finding new consumption patterns are some implementing tools, which can guarantee the optimal management of resources and minimization of waste.

3.2 Sustainability Initiatives Around the World

To change the ways the society consumes, it is important to focus on the individual behaviour of consumers and how to modify it, in order to reach a greater level of sustainability in the demand side of goods and services. Government and public policies can make an important contribution in guiding the choices of people, by spreading the concepts of sustainability and the ecological consequences of human actions, incentivizing eco-friendly behaviours and promoting sustainable activities and investments. In the pursuit of sustainability, efforts have been concentrated in trying to persuade governments around the world on the importance of sustainable development, so to implement national policies and laws in its favour. At the moment though, it is possible to just work on the voluntary participation of countries to international agreements and treaties on sustainability issues, which does not necessary result in enacted national policies. In fact, there is no authority around the world which has the responsibility to guide countries in putting in force policies related to the agreements they signed [43]. In this sense, United Nations UN made the major contribution to encourage countries towards voluntary action about sustainability, by organizing international events, founding some organizations and mediating agreements. The most important UN actions has been summed up in the following updated list, based on the summary made by K. E. Portney in his comprehensive book about sustainability [43]:

- The creation of World Commission on Environment and Development, often referred as Brundtland Commission, and its report "Our Common Future", 1987
- The Montreal Protocol on Substances that Deplete the Ozone Layer, 1987
- The creation of Intergovernmental Panel on Climate Change IPCC by the World Meteorological Organization and the UN Environment Programme, 1988

- The UN Conference on Environment and Development, namely the "Earth Summit" in Rio de Janeiro and its resulting treaty UN Framework Convention on Climate Change UNFCCC, 1992
- The Kyoto Protocol, which was in support of UNFCCC and defined limits for greenhouse gases emissions, 1997
- The UN Earth Summit +5 Conference in New York, 1997
- The definition of the eight 2000 UN Development Goals MDGs, 2000
- The European Union Sustainable Development Strategy, based on commitment taken in "Rio declaration", 2001
- The UN World Summit on Sustainable Development in Johannesburg, 2002
- The UN World Summit on the Millennium Goals +5 in New York, 2005
- The UN Climate Change Conference in Copenhagen, 2009
- The UN Environmental Programme "Green Economy Report", 2011
- The UN Conference on Sustainable Development, so-called "Rio +20", 2012
- The 2030 Agenda for Sustainable Development and the definition of 17 Sustainable Development Goals SDGs, 2015
- The UN Climate Change Conference COP 21 in Paris and the resulting Paris Agreement, 2015-2016

In addition to these UN initiatives, also some Non-Governmental Organizations NGOs produced some activity program for sustainability, like the Organization for Economic Cooperation and Development with the "Green Growth Strategy" and World Bank with the "Sustainability Development Program" [43]. Overall, despite the international efforts, there are few examples of sustainability policies and programs actually put in force worldwide. One of the successful examples of these is represented by the European Union, which has always been a leader in environmental protection. EU instituted a series of sustainability programs and policies in its member states, which have already been implemented. For example, the Ecolabel established in 1992, which certifies goods and services with reduced environmental impacts, or the Emission Trading System ETS program to reduce greenhouse gas emissions. As far as China is concerned, one first sign of change occurred after participating at the Earth Summit in Rio de Janeiro, when the Chinese government released the "China's Agenda 21, White Paper on China's Population, Environment and Development in the 21st Century" in 1994. This document confirmed the adhesion of China to the idea of sustainable development and presented the following topics as the main areas of focus: the role of social development in particular the improvement of education, health and standards of living, the issues of population, environmental protection and management of natural resources and the capacity building for sustainable development [44]. However, after years of heavy pollution, nowadays China decided to fight its notorious pollution even more with a new sustainable program, which includes the "2018-2020 Three-year Action Plan for Winning the Blue Sky War" for the improvement of air quality, by reducing the sulphur dioxide, Volatile Organic Compounds VOCs and nitrogen oxides emissions and by decreasing the concentration level of Particulate Matter PM 2.5 in cities. In this policy there is a direct reference to the aim of "large reductions in total emissions of major pollutants in coordination with reduction in emissions of greenhouse gases", addressing the efforts to tackle climate change [45]. In addition, in the framework of BRI, the Green Finance has been established, which is a key instrument to implement sustainability and it is defined as "financing of investments that provide environmental benefits in the broader context of environmentally sustainable development". The Green Finance is a set of financial tools which comprehend green bonds, which is a way to raise money on the market to support eco-friendly projects, green loans, another way to fund sustainable projects without passing through the market, and green insurance, which covers for compensation for environmental degradation [46]. Focusing on governmental plans and international cooperation seems spontaneous while looking at sustainability, which is a concept founded on the macro scale view of the whole planet. However, it is essential to increase efforts to spread sustainability in an effective and capillary manner, by enacting policies at national level and by collaborating with sub national institutions and jurisdictions. In this way the concept of sustainability can be applied at national level but also at local level, reaching the consumers, that, with their individual contribution, can work together towards the sustainable development.

3.3 THE FUNDAMENTAL CONCEPTS IN SUSTAINABILITY

3.3.1 The Three E's of Sustainable Development

It is difficult to provide a precise definition of the word sustainability, since it is a term which includes a variety of different concepts and involves a wide array of applications. As previously mentioned, a first definition of sustainability was indicated by the so-called Brundtland Commission in the report "Our Common Future" in 1987. In this case sustainability was used in the sense of sustainable development, which is a term quite often used in literature as a synonym of "sustainability" and it is so deeply intertwined with it that it is complicated to distinguish them [47]. Sustainable development is a development model in which three main components or pillars can be identified: economic development, the social development or equity and the environmental protection.

- *Economy*, which represents the importance of the economic growth and the economic feasibilities of initiatives and activities.
- *Environment*, which reinforces the commitment to stop the environmental degradation and rethink the management of natural resources to avoid their depletion.
- *Equity*, which expresses the need to reach a wider social justice and distribution of services and means to guarantee a decent life for all.

In fact, at the core of sustainable development there is a new idea of economic growth, which respects and preserves the biosphere and at the same time is capable of sharing wealth and wellness with all people and future generations. The basic principle guiding sustainable development is that the success achieved in one pillar should not damage another one. This 'three element' definition is widely spread in literature and it is not clear if it originated from the Brundtland Report itself, the Agenda 21 or the 2002 World Summit on Sustainable Development [47]. However, Environment, Economy and Equity constitute the so-called "The three E's of Sustainability" and they are often represented as three overlapping circles, to express the common area of interest in reaching sustainability, which is located at the intersection of all the circles. Another and complementary way to express the triple foundation of sustainable development is by using the so-called "the Sustainable Development Triangle", as shown in figure 22. This way to describe the sustainable development was produced by S. Campbell in 1996, who applied it to urban planning [48]. This representation highlights the conflicting goals and priorities of the three constituent elements, located in the corners of the triangle. Along the sides of the triangles, the author indeed identified the conflicts between the concepts at the vertexes. First of all, there is the property conflict between Economy and Equity, since there has always been a tension between the public and private interest in administrating property. This conflict is fuelled by the fact that the private sector opposes the social intervention in establishing a private property over a commodity and at the same time it needs the public sector to benefit from the social aspect of the good in question. Then, there is the resource conflict between the Environment and Economy since on one hand, economic production needs the utilization of natural resources producing environmental impacts and on the other hand, it wants to prevent the depletion of natural resources, in order to feed the supply chain in the future. Finally, the third conflict is the development conflict involving Equity and Environment, which is based on the traditional dispute between economic growth and social development. In fact, to preserve the environment and avoid climate change, it might be necessary to slow down the economic growth and this is particularly true in developing countries. In this places a fast-economic development can produce a wider wellness of the population, but simultaneously it can result in greater greenhouse gas emissions and environmental disasters [48]. Planners at local level and policy makers at national and international level should be able to reconcile these diverging interests and turning conflicts into opportunities to cooperate, in order to reach common goals. At the core of the problem, there is the interdependencies between the three pillars, whose goals can be simultaneously achieved by increasing the economic development. In this way, greater means are available to be shared among people and they can be used to guarantee environmental protection. In effect, as the Brundtland Reports states "if large parts of the developing world are to avert economic, social, and environmental catastrophes, it is essential that global economic growth be revitalized" [40].

3.3.2 The Origin and Applications of Sustainability

In order to give a comprehensive description of the term sustainability, it may be useful to investigate the different concepts and variations on theme, which contribute to its definition. In his book based on sustainability [43], K. E. Portney reported two main works which have tried to define the founding ideas behind sustainability, and these are "Global Sustainability: toward definition" by B. Brown et al. [49] and "The evolution of sustainability" by C. Kidd [50]. Going into details, the article by B. Brown et al. identifies six principal roots of the concept of sustainability, namely sustainable biological resource use, sustainable agriculture, carrying capacity, sustainable energy, sustainable society and sustainable economy and sustainable development. The sustainable biological resource use means an optimal management of natural resources, which allows the maximum yield possible, while guaranteeing the continuous replacement of renewable stock. It is a concept applied to biological self-renewing resources, such as forests and fisheries, in order to avoid their depletion after an excessive exploitation. A similar intention is expresses in the idea of sustainable agriculture, in which is not just focused on maximizing the crop production, but also on maintaining the productivity of the land. The carrying capacity is a concept often used as definition of sustainability and it refers to the ability of an area to sustain humans in the long term. It is possible to distinguish between maximum carrying capacity and optimal carrying capacity.

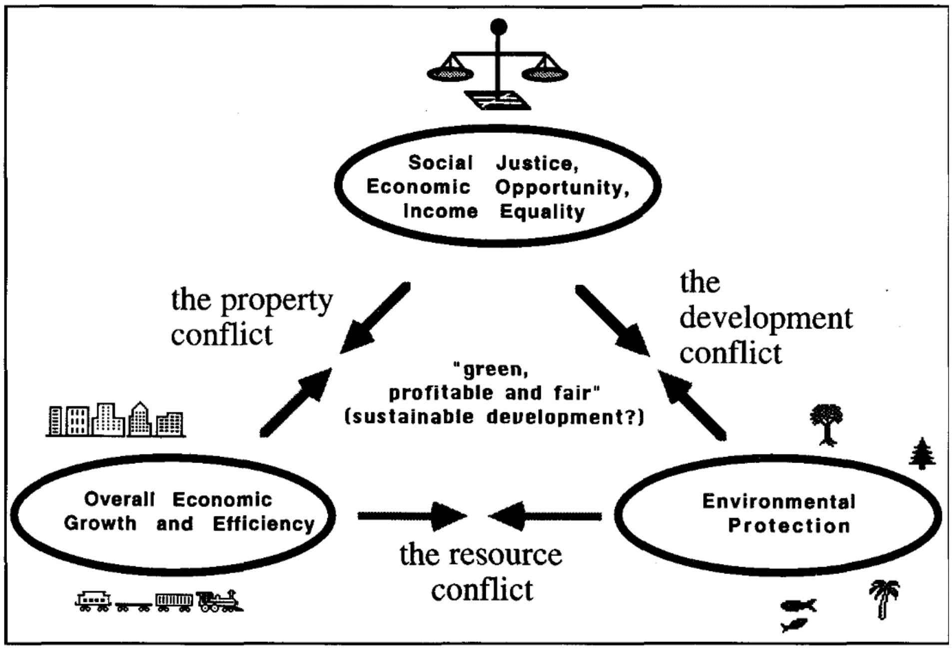

Figure 22: The Sustainable Development Triangle. Source: [48]

The maximum carrying capacity is the highest number of individuals which a defined portion of Earth can support on the verge of collapse, while the optimal carrying capacity is a smaller amount of human beings which the same area can sustain without any particular issues. Although on the global scale Earth's carrying capacity is finite, the carrying capacity of an area is subjected to change, since it can be reduced by unsustainable practises leading to environmental degradation or it can be increased by technology and investments oriented towards environmental care. The fourth root identified by B. Brown et al. is sustainable energy, which is a widely discussed topic as far as sustainability is concerned. Sustainable energy relates to the fact that not only fossil fuels are a limited resource and they might be depleted in the near future, but also to the fact that burning them is itself an environmental issue, since they contribute to the greenhouse effect. So, in order to be sustainable, the energy sector must change and rely more on renewable energy sources, like solar, wind, hydro and even nuclear energy, so to decrease the emissions. Sustainable energy can also include the idea to reduce the energy demand in the first place, as a mean to reduce environmental impacts. Sustainable society and sustainable economy indicate the importance of social and economic development to improve living standards of the population and to guarantee the human prosperity in the future. In this respect, there is also a clear reference to one of the sustainability pillars, equity and social justice, whose aim is to fairly distribute wellness among everyone. Finally, it is presented the recurring theme of sustainable development, as a new model to build the future of society on, in order to pursue growth in compliance with the limits of the biosphere. In fact, the sustainable development advocates a greater attention for the management of natural resources, whose damages can threat the economic development itself.

On the other hand, C. Kidd finds the historical basis of sustainability in other six concepts or "strains of thought", which are ecological/ carrying capacity, natural resources/ environment, biosphere, critique of technology, no growth-slow growth and eco development. Again, in the first three concepts, it is reaffirmed the finite ability of Earth to support human beings, since its natural resources are limited, and they can be indefinitely damaged by human activities. In the end, the environmental degradation not only affects the planet, but also can compromise the economic growth, which relies on the raw materials provided by the environment. The critique of technology refers to the fact that technology was primarily used to implement environmental damages instead of preventing them. In addition, there is the concern that orienting the technological means towards sustainability will just result in postponing environmental degradation and delaying a direct action, which could stop unsustainable activities in the first place. Ultimately, all these considerations applied to the macro scale lead to the strain of thought of no growth-slow growth, with greater attention to the population growth, due to the limited carrying capacity of Earth. In the end, once again there is a special mention to eco development, which is kind of a synonym of sustainable development.

On top of these concepts which constitute the roots of sustainability, there are other important applications and variations on the theme worth mentioning. First of all, sustainability has not just been applied to public sector, but also to private one, creating the idea of sustainable business. Sustainable business seems a contradiction, but efforts in persuading businesses and industries to pursue sustainability contributed to the creation of the so-called "Green Economy". Green Economy is the ensemble of economic activities devoted to spreading and implementing sustainability and eco development. In addition, businesses have been encouraged to fulfil the requirements of "eco-efficiency", by reducing the material and energy wastes, and to follow the guideline of environmental risk management, to avoid environmental disasters. Over the years there have been several initiatives to promote sustainable business, including the last World Economic Forum annual meeting in Davos, in January 2020, on the theme "Stakeholders for a Cohesive and Sustainable World". Finally, another important application of the concept of sustainability comes from the notion of sustainable communities and in particular, sustainable cities. Cities take on the rule of important clusters of sustainability and in some cases, they have been even at the forefront with respect to the national policies, like for example the environmental progress reached in San Francisco, California, compared with the sustainable commitment of the federal government of United States. This shows the opportunities underlying a multi-scale and capillary diffusion of sustainability, from the international level to the local one.

3.3.3 The Goals of Sustainability

Since the beginning, sustainability has mainly focused on finding solutions and alternatives to avoid or at least reduce environmental impacts. Its main targets involve ecological issues and firstly tackling climate change through the emission reduction. In particular, efforts have been orientating towards mitigating extreme weather events and the sea-level rise, which would be devastating for human beings. In latest years not only mitigation actions, but also adaptation measures have been included in the environmental policies, in order to increase resiliency and ensure protection to the population and the biosphere. Aside from the urgency of the climate change situation, sustainability also aims at the safeguard of water and land. The management of water resources is another important issue to be solved, since the current water use is not sustainable as can be seen from the reduction of fresh water supplies around the world. In addition, the sea level rise may have an impact on freshwater resources, leading to possible shortages of supply and an increased energy demand for desalination. Protecting land from intensive farming and pollution is another key goal of sustainability, which should ensure its productivity and wellbeing in the future to support next generations. In this respect, great attention has been given to the goal of avoiding the release of toxic, polluting or hazardous substances into the environment. First of all, attempts have been made to reduce the production of these materials in industrial processes and in the cases in which they are necessary, the procedures of environmental risk management and environmental remediation have been defined and enacted.

In addition to all the aforementioned targets, United Nations defined a comprehensive list of all the sustainability goals in its 2030 Agenda for Sustainable Development and they surely involve environmental targets, but also encompass all the issues and challenges that the world needs to face to reach sustainability. The Sustainable Development Goals SDGs are 17 and they have been summarized in the table below.

Symbol	SDG	Main Targets
	End poverty in all its form everywhere	• By 2030, eradicate extreme poverty for all people everywhere and reduce at least by half the proportion of men, women and children of all ages living in poverty. • Implement nationally appropriate social protection systems and measures for all and ensure equal rights to economic resources, as well as access to basic services. • Ensure significant mobilization of resources to provide means for developing countries and create sound policy frameworks based on pro-poor and gender-sensitive development strategies.
	End hunger, achieve food security and improve nutrition and promote sustainable agriculture	• By 2030, end hunger and ensure access by all people to food all year round and end all forms of malnutrition. • Double the agricultural productivity and incomes of small-scale food producers, including through secure and equal access to land, other productive resources and services. • Ensure sustainable food production systems and implement resilient agricultural practices and maintain the genetic diversity of seeds and animals. • Increase investment in rural infrastructure, agricultural research and extension services and also prevent trade restrictions in world agricultural markets.
	Ensure healthy lives and promote well-being for all at all ages	• By 2030, reduce the global maternal mortality ratio and end preventable deaths of new-borns and children under 5 years of age. • End the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat other communicable diseases. By 2030, reduce by one third premature mortality from non-communicable diseases. • By 2020, halve the number of global deaths and injuries from road traffic accidents. • Achieve universal health coverage and access to essential health-care services and access to medicines and vaccines for all. • By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination
	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	• By 2030, ensure that all girls and boys have access to pre-primary education, ensure that all complete primary and secondary education and ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education. • Increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship. • Eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable people. • By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy
	Achieve gender equality and empower all women and girls	• End all forms of discrimination against all women and girls everywhere and eliminate all forms of violence in the public and private spheres. • Recognize and value unpaid care and domestic work through the provision of public services, infrastructure and social protection policies.

		• Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life. • Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property.
6 CLEAN WATER AND SANITATION	Ensure availability and sustainable management of water and sanitation for all	• By 2030, achieve universal and equitable access to safe and affordable drinking water for all and access to adequate and equitable sanitation and hygiene. • Improve water quality by reducing pollution, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater. • Implement integrated water resources management at all levels and protect and restore water-related ecosystems. • Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes.
7 AFFORDABLE AND CLEAN ENERGY	Ensure access to affordable, reliable, sustainable and modern energy for all	• By 2030, ensure universal access to affordable, reliable and modern energy services and increase substantially the share of renewable energy in the global energy mix. • Double the global rate of improvement in energy efficiency. • Enhance international cooperation to facilitate access to clean energy research and technology. • Expand infrastructure and upgrade technology for supplying sustainable energy services for all in developing countries.
8 DECENT WORK AND ECONOMIC GROWTH	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	• Sustain per capita economic growth and achieve higher levels of economic productivity and improve progressively global resource efficiency to decouple economic growth from environmental degradation. • Achieve full and productive employment and decent work for all women and men and reduce the proportion of youth not in employment, education or training. • Take effective measures to eradicate forced labour, end modern slavery and human trafficking, protect labour rights and promote safe and secure working environments for all workers. • Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	• Develop quality, reliable, sustainable and resilient infrastructure and promote inclusive and sustainable industrialization. • Increase the access of small-scale industrial and other enterprises to financial services. • Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries. • Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and adoption of clean and environmentally sound technologies and industrial processes
10 REDUCED INEQUALITIES	Reduce inequality within and among countries	• By 2030, empower and promote the social, economic and political inclusion of all, reduce inequalities of outcome and adopt policies, especially fiscal, wage and social protection policies. • Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions.

		• Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies. • Implement the principle of special and differential treatment for developing countries in accordance with World Trade Organization agreements.
11 SUSTAINABLE CITIES AND COMMUNITIES	Make cities and human settlements inclusive, safe, resilient and sustainable	• By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums. • Provide access to safe, affordable, accessible and sustainable transport systems for all. • Reduce the adverse per capita environmental impact of cities, with special attention to air quality and waste management. • Substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards mitigation and adaptation to climate change.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Ensure sustainable consumption and production patterns	• By 2030, achieve the sustainable management and efficient use of natural resources and implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns. • Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle and substantially reduce waste generation. • Encourage companies, especially large and transnational companies, to adopt sustainable practices. • Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions.
13 CLIMATE ACTION	Take urgent action to combat climate change and its impacts	• Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters and integrate climate change measures into national policies, strategies and planning • Improve education, awareness-raising and capacity on climate change mitigation, adaptation and impact reduction • Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change and fully operationalize the Green Climate Fund
14 LIFE BELOW WATER	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	• Prevent and reduce marine pollution of all kinds, sustainably manage and protect marine and coastal ecosystems and minimize and address the impacts of ocean acidification. • Effectively regulate harvesting and end overfishing and other destructive fishing practices. • Increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources. • Increase scientific knowledge, develop research capacity and transfer marine technology.
15 LIFE ON LAND	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	• Ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services. • By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally. • By 2030, combat desertification, restore degraded land and soil. • Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and protect and prevent the extinction of threatened species

16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	• Reduce all forms of violence and related death rates everywhere. End abuse, exploitation, trafficking and all forms of violence against and torture of children. • Promote the rule of law at the national and international levels and ensure equal access to justice for all. Develop effective, accountable and transparent institutions at all levels. • Reduce illicit financial and arms flows and combat all forms of organized crime. Substantially reduce corruption and bribery in all their forms. • Ensure public access to information and protect fundamental freedoms.
17 PARTNERSHIPS FOR THE GOALS	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	• Enhance North-South, South-South and triangular regional and international cooperation on and access to science, environmentally sound technology and innovation. • Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships to support the achievement of the Sustainable Development Goals in all countries. • Promote a universal, rules-based, open and equitable multilateral trading system under the World Trade Organization and increase the exports of developing countries. • Respect each country's policy space and leadership to establish and implement policies for poverty eradication and sustainable development. • By 2030, build on existing initiatives to develop measurements of progress on sustainable development that complement gross domestic product.

Table 13: Summary of the Sustainable Development Goals in UN 2030 Agenda for Sustainable Development. Source: [7]

3.4 PROPOSED DEFINITION OF SUSTAINABILITY

In our analysis on the sustainability along BRI, it was necessary to define our interpretation of the term sustainability, considering the wide array of concepts and applications of this term, as reported in the previous paragraphs. We took as our basis the subdivision of sustainability into fundamental elements or pillars and the representation through overlapping circles. In our case though, we identified four main dimensions of sustainability, namely environment, economy, society and energy, as shown in figure 23.

These pillars of sustainability have been defined as follows:

- *Environment* clearly refers to the concern and attention dedicated to environmental issues and to climate change, which can affect the health and well-being of the world population. In our analysis the main focus was the emissions of atmospheric pollutants, their impacts and the possible application of related regulations.
- *Economy* included the importance of economic development into the analysis of sustainability in the various countries. Indicators such as GDP PPP were surely taken into account, but also relevant aspects were considered, such as the employment rate and the self-sufficiency of the country.

- *Society* recalls the concept of equity and justice and generally means social development of the country. It ranges from health indicators and exposure to environmental risks to the access to economic resources and services.
- *Energy* is basically the novelty of our definition of sustainability and the fourth pillars added to the traditional 3 E's of sustainable development. Energy has been inserted to stress the key role that it plays in tackling climate change and in ensuring the stability and prosperity of a country. Energy mainly refers to the dependence on fossil fuel of a country and its implementation of environmentally friendly technologies and policies.

Each of the pillar has the same importance as the other ones, since no dimension of sustainability should be preferred, in order to improve them all together and reach sustainable development. For all the designed dimension of sustainability, parameters have been chosen, accordingly to the availability of data, to report the most important characteristics and challenges of each sector in the pursuit of sustainability, as reported in chapter 4.

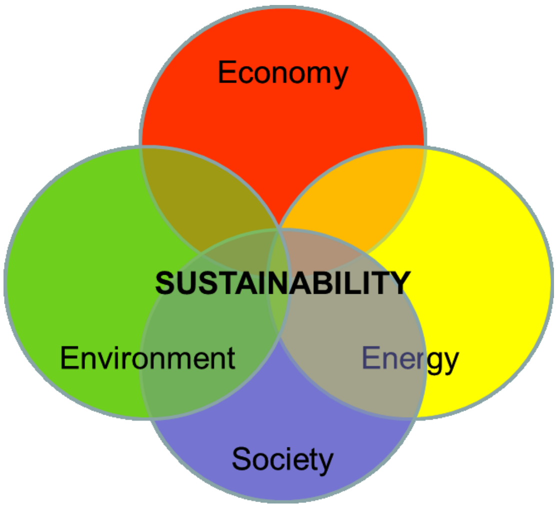

Figure 23: Visual representation of our definition of sustainability.

4 METHODOLOGY FOR SUSTAINABILITY ASSESSMENT

4.1 HOW TO ASSESS SUSTAINABILITY?

In chapter 3, it has been provided the explanation of the term sustainability, together with its applications, variations on theme and main goals. The importance of sustainability is undeniable and over time it has played a central role in international agreements and events worldwide. Efforts have been made to put in force sustainability plans and programmes, and the implementation of sustainability policies relies on the fact that some improvements are expected in environmental, social and/or economic issues. Actually, there is still little research on the effects of the application of these policies, once they have been enacted. The measurement of the sustainability programmes outcomes is fundamental, not just as a proof of their value, but mainly to analyse their effectiveness in reaching sustainability results. It should be studied how a country is evolving towards sustainability, if sustainability plans are managed in the optimal way or if it is the case to correct the course, in order to meet the sustainability goals. Create a sustainability policy is not enough, sustainability should be assessed through measurements and more data available, in order to evaluate how the policy is implemented and how it is impacting the environment and the population over time [43]. In his comprehensive work about the tools to assess sustainability [51], B. Ness et al. gave a review of all the most important methods applied in this regard and divided them into categories, as summarized in the table below.

	Main categories	**Sub-classes**
Sustainability assessments	Indicator and indexes	Non-integrated Indicators
		Integrated indicators
		Regional flow indicator
	Product-related Assessments	Life Cycle Assessment
		Life cycle costing
		Product material flow analysis
		Product energy analysis
	Integrated Assessments	Conceptual Modelling and System Dynamics
		Risk analysis and uncertain analysis
		Vulnerability analysis
		Cost Benefit Analysis
		Impact assessments
		Multi Criteria Analysis

Table 14: Summary of the main categories and classes of sustainable assessments, source: [51]

There are three main categories of sustainability assessment tools, namely indicators and indexes, product-related assessments and integrated assessments. The first group encompasses all the sustainability assessments based on the measurement of a parameter, namely indicator, or on the elaboration of multiple indicators into an overall index. This category is further divided into three subclasses, the non-integrated indicators, the regional flow indicators and the integrated indicators. For all the three subclasses, indicators can be aggregated into an index, but the difference is that for the non-integrated indicators, there is just a parameter or an index for each field of application of sustainability. Some well-known application of non-integrated indicators for sustainability assessment are the Environmental Pressure Indicator EPIs by Eurostat, in which there are different indicators for nine themes ranging from resource depletion to air pollution, and the group of about 50 indicators used by United Nations Commission on Sustainable Development UNCSD. On the contrary, the integrated indicator category involves indicators or indexes which combine different sectors and fields of application of sustainability. For example, the sustainable national income belongs to this group, since it is a single parameter which tries to compensate the limits of GDP in expressing the wellness of a country, by including environmental aspects in its definition. Another example is the Wellbeing Index WI, created for the occasion of the World Summit for Sustainable Development in Johannesburg 2002, in which there are two aggregated indexes, namely Human WI and Environmental WI, which are integrated with equal importance in the so-called "Barometer of Sustainability". Finally, the third sub-group of indicators and indexes category refers to the regional flow indicators. They are also non-integrated as the first subclass, but they consist in a smaller group focused on material and energy flows of an area, so to reduce wastes and increase the efficiency of production processes. The second main category of sustainability assessment tools present similarities to the regional flow indicators, since they both deal with physical flows. The product-related assessments though are not representative of a region, but they rather focus on the energy and material flows along the production chain and the consumption patterns of a good or service. Special attention is given to the use of natural resources and environmental impacts. One of famous case of product related assessment is the Life Cycle Assessment LCA, which is a consolidated tool designed to identify the environmental impacts of a product, from the preliminary stage of production, like the raw material procurement, through all the production processes and operational uses, to its final disposal. The other product-related assessments can be further classified into life cycle costing, product material flow analysis and product energy analysis, if the main points of interest over the product lifetime are the costs, the material flows or the energy flows respectively. Finally, the last category of sustainable assessment tools is represented by the integrated assessments, which are the implementations of methods capable of dealing with complex systems. Integrated assessments are particularly suitable in sustainability assessment, since they can include multiple aspects, like environmental and social issues, in accordance with the wide definition and application of the sustainability itself. They can also be applied to different levels and scales, from the analysis of a project in a limited area to a study on a national policy. Even integrated assessments have been further divided into different subclasses, which are conceptual modelling and system dynamics, risk analysis and uncertainty analysis, vulnerability analysis, Cost Benefit Analysis CBA, impact assessments and Multi Criteria Analysis MCA. The conceptual modelling and system dynamics refer to actual models of the system under analysis. The conceptual modelling though is a rather soft system modelling, which can be used for a preliminary description of the system in qualitative terms and an initial way to select the most critical area to focus on. Instead, the system dynamics provide a more precise computer model, which is also useful to determine the evolution of the situation over time. A typical example is the Regional Air pollution INformation and Simulation RAINS, which is an air pollution model created by the International Institute for Applied Systems Analysis IIASA. The risk analysis is the assessment of potential damages weighted by their frequency of occurrence. It starts from the identification of hazards and the definition of the most critical events, which are studied in qualitative or quantitative terms. Since it deals with risks and frequencies, risk analysis cannot be separated from uncertainty analysis, which is at the core of the method itself. Risk analysis can be applied to a wide array of situations, but when it considers the environmental and social spheres, it can be considered a sustainability assessment. Related to risk analysis, there is the vulnerability analysis which focuses on the sensitivity of a system to transform impact into potential damages. Vulnerability analysis have been applied to different society and areas to study their vulnerability and resilience level to climate change. Continuing on the integrated assessment tools, CBA is a method used to compare the costs to the expected benefits of a public or private investment. It can be applied to sustainability policies, for example to evaluate social costs and benefits, considering different alternatives. Another way to assist in the policy making or project approval processes is the application of impact assessments. In particular there are three main typologies of impact assessment, which are the Environmental Impact Assessment EIA, focused on the identification of environmental impacts of large projects, the Strategic Environmental Assessment SEA, which is applied to strategic plans and the Sustainability Impact Assessment SIA, which evaluate environmental, economic and social impacts of policy actions. Finally, the last integrated assessment considered is MCA, which is a tool particularly suitable in the situation where criteria are in competition with each other and there are divergent interests. MCA in this case finds the optimal solution as a trade-off among the different objectives. This tool is interesting in the sustainability field, since there are a lot of different aspects of sustainable development, often competing. In addition, due to variety, data from measurements come in quantitative terms, like the polluting emissions, but some criteria can also be qualitative, like the parameters in social surveys. For all these reason, it is the method we choose for implementing our analysis on the evaluation of the level of sustainability in the BRI countries.

4.2 MULTI CRITERIA DECISION ANALYSIS

4.2.1 Overview and uses

Multi Criteria Decision Analysis MCDA or Multi Criteria Decision Making MCDM is a set of tools, which deal with problems of decision making in situations where there is a wide array of parameters with conflicting interests. It is not clear when MCDA originated, but Benjamin Franklin

(1706-1790) was one of the first to follow a process for taking political decisions which can be associated to MCDA methods. At the turn of 20th century, Vilfredo Pareto also gave an important contribution to the mathematical foundations of optimization problems with multiple criteria and interests [52]. Nevertheless, it has been decided to set the beginning of the MCDA not until the conference on "Multiple Criteria Decision Making", which was an event organized in 1972 at Columbia University in South Carolina [53]. From that point on, MCDA methods have been developed and they have rapidly gained the important and active role they play today in the framework of operations research. The main characteristic of MCDA is the capability to manage and elaborate multiple criteria, in order to keep all the different parameters in consideration. In fact, it is particularly useful in complex problems with lots of variables and competing interests, so to have a systemic overview of all the relationships between criteria and to find the preferred solution taking everything into account. In fact, it may happen that there is not a single optimal solution, so in these situations, MCDA can come in handy for identifying the best trade-off which better reflects the priorities of the decision-maker. Another important feature in this regard is the ability to include both quantitative and qualitative data into the analysis, which is quite useful to include parameters with different nature, from measurements of numerical values to qualitative ranges. Thanks to its inclusiveness and linearity, it is a powerful mean of communication between stakeholders, analysists and scientists. The aim of MCDA is indeed to help policy and decision makers by raking, selecting and/or comparing a set of alternatives with respect to different interests and perspectives. In this sense, the applicability of these methods is quite wide, and MCDA has been used in numerous situations and in many different fields, like economics, finance, mathematics, health care, environmental protection and so on. In environmental application area, MCDA have been able to express its full potentiality, by including knowledge on economic, social and ecological issues. According to I. B. Huang et al [54], many studies about the application of MCDA to environmental policies proved its beneficial contribution to the decision process and the acceptance by public opinion. In this perspective, MCDA can be a valid tool also to analyse the different alternatives in the pursuit of sustainable development and in assessing sustainability, as it is analysed in the next chapter.

It is also important to notice that MCDA is a procedure which involves subsequent steps and some of them present different alternatives of implementation. The starting point of all MCDA methods is the selection of criteria. The different parameters which have an impact in making the decision should be collected, compared and evaluated, since they must fulfil some requirements to be considered suitable to the analysis. In decision-making related to energy and environmental issues, the main conditions are that criteria should be:

- *systemic*, that means that they should be representative of the essential characteristics of the system considered;
- *consistent*, so they must be relevant to the aim of the decision-making process;

- *independent*, which means that they should not be connected or reliant on other criteria at the same level;
- *measurable*, so it should be able to evaluate them in quantitative terms or at least to define them by qualitative ranges.
- *comparable*, which stands for the possibility to compare the different criteria [55].

Once the criteria have been defined, the second stage of MCDA process is the identification of a weighting method, to express the relative importance of criteria in making the decision. There are two primary method to assign weights: the equal weight method, which simply give the same priority to all the criteria, and the rank-order weighting methods, which on the contrary establish different importance to the criteria [55]. In the latter case, different weights can be assigned using subjective methods, which use the opinion of relevant people and experts, objective methods, which are based on measurements and information, or a combination of the two. After the selection of criteria and the definition of their weights, there is the third step and central core of MCDA, which is the choice and the implementation of the actual algorithm to rank the alternatives and establish the preferred solution of the decision-making problem. During the years, many MCDA methods have been created and improved, but generally speaking they can be divided into three main categories: elementary methods, unique synthesizing methods and outranking methods [55]. The elementary methods include simple tools to rapidly define the best alternative, like the weighted sum method, in which the preferred option is the one with the highest score, calculated as the sum of each criteria multiplied by its weight. In the unique synthesizing methods, the different perspectives of the problems contribute to the identification of a single function to be optimize. Examples of this category are: Analytical Hierarchy Process AHP method, which is a type of weighted sum method for criteria ordered hierarchically; TOPSIS, in which the main principle is that the ideal alternative has the best level for all criteria and the selected best option is the closest to the ideal alternative; MCDA combined fuzzy logic, in which fuzzy set theory is involved to better describe human judgment and qualitative criteria. Finally, the last category is represented by outranking methods, like Elimination et choice translating reality ELECTRE or Preference ranking organization method for enrichment evaluation PROMETHEE. These algorithms use outranking relations between alternatives to get to the final ranking of all the options. Outranking relations are binary relations defined on a set of alternatives in a way that for any pair of options there are sufficient arguments to say that one alternative is at least as good as another one, while simultaneously there are any strong reason to say the opposite [55]. The strength of this class relies on the fact that they allow criteria to be incomparable. Finally, the last step in the MCDA process is the possible application of aggregation methods, which are ways to aggregate the results from different MCDA algorithms. The main possibilities in this regard are the voting methods or mathematical aggregation methods [55]. For the voting methods, the best alternative is chosen considering the number of votes each alternative has received. Whereas, for mathematical aggregation methods, we can distinguish between hard aggregation methods, in which the decision-maker intervention is not required and the ranking order is reached mathematically, and soft aggregation methods in which the decision-maker is required and the final results are obtained through negotiation of decision-makers [55]. To this overview on MCDA, it follows a section with a review of MCDA methods applied to sustainability assessments and a focus on PROMETHEE II which will be the selected method to implement our sustainability analysis.

4.2.2 MCDA in sustainability assessment

As mentioned before, Ness et al. [51] categorised MCDA as an integrated method to assess sustainability and it might be particularly useful in this regard, thanks to its capability to deal with criteria of different fields, different nature and different objectives. The main used MCDA algorithms for sustainability assessments are the Multi Attribute Utility Theory MAUT and AHP which belong to the unique synthesizing methods, ELECTRE and PROMETHEE which are the most famous example of outranking methods and finally Dominance Based Rough Set Approach DRSA, from the new Artificial Intelligence domain applied to MCDA. All of these methods have been considered and evaluated with respect to their suitability to sustainability evaluation in the analysis by M. Cinelli et al [56]. In their research, they have reviewed these five typologies of MCDA though a set of ten criteria, considered necessary to perform sustainability assessment. The comparison criteria are divided into three groups, which are scientific soundness, feasibility and utility. The scientific soundness category includes the use of qualitative and quantitative data, life cycle perspective, weights typology, threshold values, compensation degree, uncertainty treatment/sensitivity analysis and robustness. The feasibility domain contains the software support and graphical representation and the ease of use. Finally, the utility refers to the learning dimension of the methods. For each of the ten criteria, the MCDA methods are evaluated as “good”, “intermediate” or “poor”, according to their level of ability to fulfil the requirement. All the MCDA methods under consideration can deal with both qualitative and quantitative information and all of them provide the possibility of a life cycle view, which are both fundamental points in studying the various aspects of sustainability. As far as the weight typology is concerned, the main distinction is between methods which use weights as trade-offs with high interdependence, like MAUT and AHP, and methods which consider weights just as importance coefficients, like ELECTRE. The situation is less clear for PROMETHEE, since according to its founders has a similar weight typology as ELECTRE, but other analysts have stated the opposite. Instead for DRSA the comparison criterion is not applicable, since it does not require the weight definition directly from decision makers, but it obtains it indirectly. Considering thresholds, MAUT and AHP do not involve the use of threshold values, while ELECTRE and PROMETHEE truly rely on thresholds, which constitute some basic inputs of the model. In fact, ELECTRE requires the definition of preference, indifference and veto threshold, whereas PROMETHEE just the first two. DRSA provide the possibility to establish thresholds from decision rules. Another important comparison criterion is the compensation degree among criteria and sustainability spheres. MAUT and AHP are strongly compensating, since they belong to the class of unique synthesizing method, which elaborate all the criteria to form a single value. On the other hand, ELECTRE, PROMETHEE and DRSA avoid compensation and provide a strong concept of sustainability. In their implementation, there is no possibility to counterbalance a bad outcome in some criteria with a good performance in another one, which instead can occur in previous two aggregating methods. Thanks to the use of thresholds, ELECTRE and PROMETHEE also permit to handle simply the problem of uncertainty treatment in input. MAUT and DRSA can cover a sensitivity analysis on both criteria weighting and scoring, while AHP only on criteria weights. Another crucial characteristic in the sustainability assessment is the robustness of the method. It refers to its ability to not be altered in the final ranking of alternatives, in the event that some of them are added or deleted. The only method which performs well in this regard is MAUT, because it analyses each alternative independently, so it does not change its final score depending on the options involved. All the other considered methods can be affected by rank reversal with the modification of alternative, because ELECTRE, PROMETHEE and DRSA are structured on outranking relations, so they are intrinsically bounded to the actual set of alternatives. AHP provide a dependent evaluation of alternatives as well. Moving to the software support, each MCDA method have its set of software for the actual implementation, and most of them present even a good quality graphical capability, except from the case of ELECTRE and DRSA. As far as the ease of use is concerned, MAUT and AHP provide a user-friendly interface of the software, but they are considered more difficult to understand from the point of view of the decision makers. Even worse in the case of ELECTRE in which policy makers should identify too many data, including the different types of thresholds. PROMETHEE also present the same issue with the time-consuming definition of thresholds, but it is considered easier than ELECTRE. In this category, the best one is DRSA which does not need the direct identification of parameters by the decision maker and also present simple decision rules, in the form of "if... then" statements. Finally, the learning dimension refers to the ability of the software to allow comparisons between results giving different inputs. Most of the MCDA software considered does not include this possibility, except from AHP Expert Choice and the PROMETHEE software which provides the function of "multi scenario analysis". All in all, PROMETHEE is one of the best MCDA method for sustainability analysis since it presents almost all the qualities considered necessary and it performs well with respect to the other algorithms. Considering also the familiarity of our research group with PROMETHEE, in the end it has been chosen as the MCDA to implement our sustainability assessment along BRI.

4.2.3 PROMETHEE II: Working principles

The PROMETHEE is a MCDA method created by J. P. Brans, who for the first time showed and explained this algorithm in 1982, during a conference titled "L'Ingéniérie de la Décision. Elaboration d'instruments d'Aide à la Décision" at the Université Laval in Québec. Brans at first conceived the versions PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking), which have been further developed during the years and applied to different fields, like banking, industrial location, manpower planning, water resources, investments, medicine, chemistry, health care, tourism, ethics, dynamic management [57]. As stated before, PROMETHEE II is an outranking method, in which different alternatives are evaluated and compared pairwise, according to a finite number of different criteria. PROMETHEE as all the other MCDA methods, is a procedure defined by consecutive steps which will lead us to the final ranking of alternatives and in our case, the sustainability assessment in BRI countries. At first, data should be collected, and the most representative criteria should be selected. Criteria should present all the necessary qualities for the energy and environmental decision problems, which are being systemic, consistent, independent, measurable and comparable. After that, weights should be assigned to all the selected parameters and in this regard, there are different possible methods to do so. The full list and the details of the chosen criteria and corresponding weights for our sustainability assessments are reported in the next chapter. Once all the information in input has been defined, the values of the characterising parameters should be collected in a matrix, as shown below.

		CRITERIA			
		C1	**C2**	**C3**	**C4**
ALTERNATIVES	**A1**	s11	s12	s13	s14
	A2	s21	s22	s23	s24
	A3	s31	s32	s33	s34
	A4	s41	s42	s43	s44

Table 15: Generic structure of data in input for PROMETHEE method.

In this structure for all the alternatives, generically identified with the letter A, there are the corresponding values of each criteria, marked with letter C. The data are in general called s for score and the numbers refers to the alternative and the criterion respectively.

The second step is to build difference matrices for each criterion. The difference matrix is a matrix in which pair-wise comparisons are performed and so, for each criterion, the difference between the scores of two alternatives is performed, as shown below for the generic k-th criterion. In this way, considering N criteria and M alternatives, there will be N matrices with the dimensions M x M and the main diagonal composed of zeros, since it represents the comparison and so the difference between the same alternative.

C_k	A1	A2	A3	A4
A1	s1k-s1k	s1k-s2k	s1k-s3k	s1k-s4k
A2	s2k-s1k	s2k-s2k	s2k-s3k	s2k-s4k
A3	s3k-s1k	s3k-s2k	s3k-s3k	s3k-s4k
A4	s4k-s1k	s4k-s2k	s4k-s3k	s4k-s4k

Table 16: Generic representation of a difference matrix for PROMETHEE method.

Once all the difference matrices are calculated, it is the moment to implement the third step and create preference matrices for each criterion. The preference matrix is a matrix composed of values p_{ij} , where i indicates the alternative and j the criterion as usual. The preference values define the distance of each pair-comparison from the best solution. There are different ways to define the criteria function, which is the relation that associate a preference value to each difference included in the difference matrices. The most used typologies are usual criteria, quasi criteria or U-shaped criteria, criteria with linear preference or V-shaped criteria, level criteria, criteria with linear preference and indifference or V-shaped with indifference criteria, and Gaussian criteria [57]. In our analysis we have decided to use the type 5, which is the V-shaped with indifference criteria, defined as follows:

$$P(d) = \begin{cases} 0, \ d \leq q \\ \frac{d-q}{p-q}, \ q < d \leq p \\ 1, \ d > p \end{cases} \quad (1)$$

where d is the generic difference between two values and P(d) is the preference value associated to d, which is a number always between 0 and 1. In addition it is necessary to define for each criterion a preference value p and an indifference value q, which will be compared to the values of the difference matrices d. The preference value p defines an upper threshold for the criterion: if the difference between two scores, so a value in a difference matrix, is higher than the preference value p, it will have a value 1 in the preference matrix. That means that the comparison between two score is very close to the best and it has great importance in the decision process. On the contrary, the indifference value q indicates a lower limit for the criterion: if the difference between two scores is lower equal to the indifference value q, it will have a value 0 in the preference matrix. That means that the comparison between two score is not significant in the choice of the best alternative. If the difference between two scores is in between p and q, it will assume an intermediate value in the preference matrix, which can be calculated for example with a linear interpolation. The graphical representation of the criteria function used in shown in figure 24.

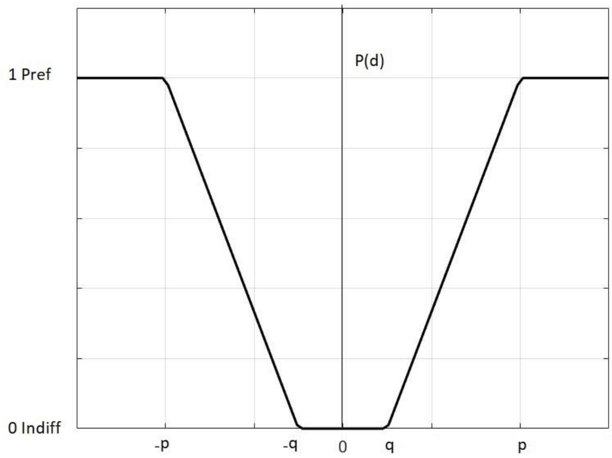

Figure 24: graphical and general representation of the type 5 criteria function for PROMETHEE.

In the end, calculating all the P(d) for each difference for all the criteria, preference matrices are obtained, like the following one for the generic k-th criterion. Again, in the end, there will be the same number of preference matrices as the difference ones, so N matrices for N criteria with the dimension M x M alternatives.

C_k	A1	A2	A3	A4
A1	p11	p12	p13	p14
A2	p21	p22	p23	p24
A3	p31	p32	p33	p34
A4	p41	p42	p43	p44

Table 17: Generic representation of a preference matrix for PROMETHEE method.

Then, the flows must be calculated which are needed to get to the final solution and raking of the alternatives. Flows can be positive or negative and they refer to the capability or not of an alternative to outrank or be outranked by the others, perform good or bad respectively. The positive flow represents the strength of each alternative while the negative one is its weakness [57]. Flows are contained in a R matrix, which is a matrix composed of the generic value r which is defined as follows:

$$r_{ij} = \sum_{k=1}^{N} P_k(A_i, A_j) * w_k \qquad (2)$$

So, considering the alternatives A_i and A_j and the k-th criterion, the generic value r_{ij} is the sum of all preference values of each criterion P_k multiplied by the weight, generically called w, of the criterion considered. Finally, there will be a single matrix with the dimension M x M alternatives, since all the criterion will be considered together in a cell, where two alternatives are compared. The positive flows are the sum by row of the elements of the R matrix, while the negative flows are the sum by columns. An example has been reported below.

R matrix	A1	A2	A3	A4	Φ_+
A1	r11	r12	r13	r14	$\Phi_{+,1}$
A2	r21	r22	r23	r24	$\Phi_{+,2}$
A3	r31	r32	r33	r34	$\Phi_{+,3}$
A4	r41	r42	r43	r44	$\Phi_{+,4}$
Φ_-	$\Phi_{-,1}$	$\Phi_{-,2}$	$\Phi_{-,3}$	$\Phi_{-,4}$	

Table 18: generic representation of a R matrix and positive and negative flows for PROMETHEE method.

Finally, the net flow for the single alternative is calculated as the difference between positive and negative flows for the given alternative, as follows:

$$\Phi_{net,j} = \Phi_{+,j} - \Phi_{-,j} \qquad (3)$$

The net flow defines the final ranking of the alternatives, considering that the highest value determines the best alternative. In addition, it should be noted that the net flow can be positive or negative, since it is the balance between the outranking strength and weakness of each alternative.

4.3 KPIs TO ASSESS SUSTAINABILITY

4.3.1 Sustainability KPIs: definition and properties

Getting to the heart of the sustainability assessment through MCDA, different criteria have been taken into consideration to measure the level of sustainability in the 30 selected BRI countries. At first a research in literature was carried out to investigate which are the most suitable and representative parameters for the sustainable development. Most of the analysis about sustainability evaluation focused on western countries, probably due to a wider and more available dataset. There are a lot of information, both quantitative and qualitative, for the most industrialized countries, thanks to the scientific measuring and monitoring systems and the social surveys and reviews. For example, Eurostat releases a detailed report every year to assess the progress towards the sustainable development and the UN SDGs for all the countries in European Union. On the contrary, the BRI area not only lacks such informative reviews, but sometimes also data itself is missing or not available to implement this kind of studies. This is particularly true for some countries like Afghanistan, which are completely absent or present very old data in some of the most used databases like the one from IEA or World Bank. In addition, even when information is available, it should be checked on quality, compliance with the standards and compatibility with other databases. Taking everything into account, it was difficult to apply the same criteria and parameters from studies on most developed countries, to the variety of the selected BRI area. So, in the end, we created a database with all the quality information available on this set of 30 BRI countries for different years and we selected all the parameters which provided a complete time series for a certain period for all the countries involved. Among all the resulting criteria, we defined the most appropriate criteria for our sustainability evaluation. First of all, they had to reflect our definition of sustainability, based on four dimensions, namely economy, society, energy and environment. Thus, the chosen indicators had to involve at least one of these sectors. Then the criteria had also to fulfil the MCDA requirement for energy and environmental assessments, which are being systemic, consistent, comparable, measurable and independent. The latter was the quality which needed to be checked by measuring the level of interdependencies between the sustainability indicators, as indicated in the next chapter. Finally, we ended up with the following list of 15 Key

Performance Indicators KPIs to assess the sustainability in BRI countries, with a complete time series from 2010 to 2016:

- *Urbanization rate*, which is the percentage of population living in cities or areas defined as urban, divided by the total population. It is an important parameter with respect to the industrialization of a country.
- *Life expectancy at birth*, which refers to the number of years that a new-born is expected to life by maintaining the present mortality rate throughout its life.
- *Mortality rate, infant,* which is the measure of the number of infants who died before the first year of age, with respect to 1,000 live birth per year. Together with the life expectancy at birth, they are relevant indicators for the medical and health care services for a country.
- *Access to electricity,* which is the percentage of the total population for which it is guaranteed a simple and stable access to the electric grid and electricity services.
- *Air pollution deaths,* which is a measure of the number of deaths caused by air pollution with respect to 100,000 deaths per year.
- *PM 2.5 level of exposure*, which means the mean annual exposure of the population to a concentration of suspended particles with an aerodynamic diameter of less than 2.5 microns, which can cause severe health damages to the respiratory system. Together with air pollution deaths, they account for the environmental and social impacts caused by emissions of atmospheric pollutants.
- *GDP PPP per capita¸* which is the gross domestic product measured in international dollars, thanks to the conversion using purchasing power parities, divided by the total population. It is a preliminary way to express the economic prosperity of a country, but it should be coupled with other socio-economic indicators to evaluate the actual status of the population.
- *Employment to population ratio,* which indicates the percentage of the total population employed. The condition of employment is given by a person in the working age, so aged 15 or older, who was occupied in producing goods or services for pay or profit, during a period of time. This is another socio-economic parameter to assess the well-being of the population.
- *Carbon pricing measures,* which refers to the actual implementation, scheduling or consideration of carbon pricing mechanisms in the whole nation or in smaller jurisdictions. The carbon pricing measures can be the Emission Trading System ETS or the carbon tax. They have been quantized as 1 if a carbon pricing measure is implemented at national level, 0.7 if a measures is implemented in some areas, 0.5 if a measure is under consideration. This is a measure of how the externalities for the emission are paid by the most polluting sectors, instead of by the population and environment. In the area where

they are implemented, the health of people and environment is more protected, and polluting emissions should decrease.

- *TPES per square metres*, which represents the total internal energy demand of a country, constituted of power generation, other energy sector and total final consumption, divided by the total area of the country under consideration. It is a measure of the domestic energy needs, independently from the vastness of the country.
- *% RES in electricity generation,* which identifies the percentage of the output of electricity produced by renewable energy sources, over the total output of electricity produced. It defines the penetration of renewables in the electricity mix in a given country.
- *Total self-sufficiency,* which is the ratio between the total domestic energy production and the total primary energy supply TPES. In fact, it is a measure of how a country is able to meet its energy demand, without relying on energy imports.
- *Electricity consumption per capita,* it is the actual amount of electricity consumed by end-users, so the electricity generation and imports minus the esports and the losses, divided by the total population. It is an indicator of the energy consumption of a country and it is also related to the efficiency of the energy system.
- *Total CO_2 emissions*, which is the total amount of carbon dioxide emissions, caused by burning fossil fuels. The large quantity of CO_2 emitted represent one of the biggest contribution to the greenhouse effect, even if it is not the only atmospheric pollutants, nor the most dangerous.
- *% Forest area*, which refers to the percentage of land area under natural or planted trees for at least 5 meters in situ, excluding agricultural and green urban areas.

For more details on the units of measures and database source of the sustainability KPIs, the table 53 in Appendix I reports the main characteristics of each criterion.

4.3.2 KPIs interdependencies

As stated before, one of the main qualities of the criteria to be checked is the fact that all of them should be independent, in order to adopt MCDA methods for the analysis. This control has been done by making pairwise comparisons of the KPIs through regression analysis. A statistical model has indeed been created through the use of Excel, to show the relationship between two KPIs. The coefficient of determination R^2 has been obtained, which is a proportional value between 0 and 1 and it expresses the level of quality of the regression model. If it is high, showing a value above 0.7-0.8, it means that the two variables are correlated, and their relation is well represented by the statistical model. All the information available has been used to calculate R^2. So, taking two criteria, the corresponding data related to each country, for the same year, have been compared to check on interdependencies. Table 19 reports all the values of R^2 for all the KPIs. The highest values are recorded for life expectancy-mortality, urbanization rate-mortality rate, air pollution deaths-access to electricity, GDP PPP per capita-urbanization rate, electricity consumption per capita- GDP PPP per capita. It should be noticed that no R^2 exceeds 0.7, so all the KPIs can be considered independent and they can be used in the sustainability assessment through PROMETHEE.

R^2	Urb rate	Life expectancy	Mortality rate	Electric access	Air pollution deaths	PM 2.5 exposure	GDP PPP per capita	Employment ratio	TPES/ m^2	% RES	Self sufficiency	Electric consumption	CO2 tot	Forest area
Urb rate		0.47	0.51	0.33	0.38	0.02	0.57	0	0.17	0.38	0.08	0.58	0.01	0.07
Life expectancy	0.47		0.66	0.34	0.42	0	0.39	0.05	0.18	0.15	0.01	0.33	0.02	0
Mortality rate	0.51	0.66		0.44	0.46	0.01	0.3	0.04	0.08	0.19	0.01	0.34	0.03	0.01
Electric access	0.33	0.34	0.44		0.54	0.04	0.14	0.01	0.02	0.28	0.03	0.17	0.02	0
Air pollution deaths	0.38	0.42	0.46	0.54		0.12	0.18	0	0.06	0.21	0.03	0.13	0	0.01
PM 2.5 exposure	0.02	0	0.01	0.04	0.12		0.05	0	0	0.01	0.06	0.09	0.01	0.32
GDP PPP per capita	0.57	0.39	0.3	0.14	0.18	0.05		0.21	0.16	0.2	0.3	0.7	0.02	0.01
Employment ratio	0	0.05	0.04	0.01	0	0	0.21		0.03	0	0.09	0.24	0	0.02
TPES/ m^2	0.17	0.18	0.08	0.02	0.06	0	0.16	0.03		0.04	0.04	0.17	0.01	0
% RES	0.38	0.15	0.19	0.28	0.21	0.01	0.2	0	0.04		0.12	0.21	0.03	0.15
Self sufficiency	0.08	0.01	0.01	0.03	0.03	0.06	0.3	0.09	0.04	0.12		0.18	0.04	0.01
Electric consumption	0.58	0.33	0.34	0.17	0.13	0.09	0.7	0.24	0.17	0.21	0.18		0	0.04
CO2 tot	0.01	0.02	0.03	0.02	0	0.01	0.02	0	0.01	0.03	0.04	0		0.01
Forest area	0.07	0	0.01	0	0.01	0.32	0.01	0.02	0	0.15	0.01	0.04	0.01	

Table 19: level of interdependencies among sustainability KPIs.

4.3.3 Weighting method for KPIs

Once all the sustainability criteria have been identified and all their requirements have been controlled, a weighting method had to be defined to assign the relative importance to all the selected KPIs. Weights should be indicated by the policy maker, which expresses the priorities in making the choice and/or ranking the alternatives. In our case, we have decided to start from our definition of sustainability and build a structured method to identify the weights of the criteria. First of all, since sustainability is made up of 4 sectors, we have decided to assign the same weight for each category, so 25% each, in compliance with the fact that to reach sustainable development no sector of sustainability should be sacrificed in favour of another one. Then, during a meeting of our research group, we have decided to which sector every criteria should belong, by marking them with an X, as shown in table 20. We have also agreed to give more importance to the KPIs which involve more than one sector, since they better reflect the idea of sustainability based on multiple concepts. Thus, we have divided the total weight of each sector, 25%, by the number of identified KPIs for that category and we have obtained the sectoral unit weight. This is a portion of the total sectoral weight that every KPI in the group has. Finally, considering each sustainability criteria, the final weight has been calculated as the sum of all sectoral weights in which the parameter is involved. The weights in the last column are the ones actually used in our sustainability assessment.

KPIs	Society	Economy	Energy	Environment	Sectors involved	Weight
Urbanization rate	X	X			2	**7.5%**
Life expectancy at birth	X				1	**2.5%**
Mortality rate, infant	X				1	**2.5%**
Access to electricity	X		X		2	**6.1%**
Air pollution deaths	X			X	2	**6.7%**
PM 2.5 level of exposure	X			X	2	**6.7%**
GDP PPP per capita	X	X			2	**7.5%**
Employment to population ratio	X	X			2	**7.5%**
Carbon pricing	X	X	X	X	4	**15.2%**
TPES per m^2			X		1	**3.6%**
% RES in electricity gen			X	X	2	**7.7%**
Total self sufficiency		X	X		2	**8.6%**
Electricity consumption per capita	X		X		2	**6.1%**
CO2 tot			X	X	2	**7.7%**
Forest area				X	1	**4.2%**
# KPIs per sector	10	5	7	6		
Tot weight	25%	25%	25%	25%		
Sectoral unit weight	**2.5%**	**5.0%**	**3.6%**	**4.2%**		

Table 20: scheme of the weighting method for KPIs used for PROMETHEE.

5 THE ASSESSMENT OF SUSTAINABILITY

5.1 AIM AND METHOD

As mentioned in the previous chapters, the aim of the analysis is to perform a sustainability assessment in the 30 selected BRI countries. The sustainability evaluation consists of a ranking of all the countries according to their sustainability level per year, from 2010 to 2016. This has been done by using MCDA methods and in particular PROMETHEE II, which provides a structured and systemic way to get to the final ranking of alternatives. In fact, the alternatives in our case are the 30 BRI countries in Eurasia, while the criteria are the 15 Sustainability KPIs, identified in chapter 4. These criteria are referred to 4 groups, which are the fundamental concepts of sustainability, according to our definition, namely society, economy, energy and environment. Each sector of sustainability has its overall weight, defined equal to the other ones, to respect the basic principle of sustainable development, which is to prevent that a sphere of sustainability is privileged with respect to another one. To stress this concept, a greater importance has been assigned to KPIs which include more than one pillar of sustainability, in accordance with this multisectoral view. In the end, different weights have been assigned to each sustainability criteria, by following the weighting method explained in the last chapter. Once all the KPIs and their respective weights have been identified, all the information have been used as inputs for a MATLAB code, which implements the PROMETHEE algorithm. Thus, the 30 selected BRI countries have been ranked according to their final net flow, for each year, from 2010 to 2016, taking all the sustainability KPIs into account. It should be noticed that during the implementations of the MCDA method, two more parameters are required for every KPI, which are the threshold values for preference and indifference, identifies with the letters p and q respectively. Preference and indifference indexes have been defined for each sustainability criteria and updated each year, by using a method which will be explained in the following sections. All the outcomes from the MATLAB code have been collected and re-organized in Excel files for a post processing. Here, in addition to the sustainability ranking of the BRI countries, it has been studied the improvement towards sustainable development during the years. To do so, it has been calculated the difference between the sustainability outcomes of a country in two consecutive years and between the first year considered 2010 and the last one 2016. In this way, it was possible to assess if a country had improved its sustainability status with respect to the previous year or during the whole period considered. Our analysis was inspired by a study of the University of Belgrade, which ranked the EU countries with respect to their sustainability performance using MCDA PROMETHEE II [58]. We have decided to implement their idea of sustainability assessment to the Eurasian area of BRI, also including the evaluation of sustainability results over time. Finally, a sensitivity analysis has been performed on the values of preference and indifference thresholds, in order to evaluate how the sustainability result is affected by the choice of these indexes.

5.2 Sustainability Assessment along BRI

5.2.1 Choice of preference and indifference indexes

Preference and indifference indexes are two thresholds that should be provided as inputs in the PROMETHEE algorithm. In general, they should be indicated by the decision maker, in addition to the weights of the criteria, and they are one of the reasons why PROMETHEE is considered quite complex and time intensive from the policy maker's side. In fact, for each KPI, the decision maker should define an upper threshold, for which a difference between two alternatives is relevant, and a lower threshold, for which the difference is not important for the choice. In our case, we have decided to use a structured method to define the preference index p and the indifference index q. Considering each KPI at a time, for every year of the analysis, we have looked for the maximum value of difference among all the alternative comparisons. Then, the preference and indifference values are defined as a percentage of the maximum difference found. This procedure then has been repeated for all the KPIs for all the years from 2010 to 2016. The difficulty has been to choose the most appropriate values of percentages, so we have rerun the code several times with different values for p and q, which have constituted the base for the sensitivity analysis at the end of the chapter. All the percentages adopted for the calculation of p and q are reported in table 21. As far as the preference index is concerned, we have decided to select a range between 50% and 90% of the maximum difference. The reason is that the preference index is the threshold, which define the limit for the preference of one alternative over the other one, so it should be a medium/high level of difference between two alternatives. The same, but in reverse, has been applied to indifference index, which varies from 6% to 18%, since it is a threshold for not considering a comparison as relevant. A too high value would have resulted in excluding too many alternative, because it is already a percentage of the maximum difference among the alternatives. Thus, low percentages have been chosen for q.

P [% of max difference]	**Q** [% of max difference]
50	6
60	9
70	12
80	15
90	18
90	6
50	18

Table 21: values of preference and indifference index used in the analysis.

Moreover, concerning the values of p and q, we have also considered the fact that some of the KPIs should be minimized and other maximized. Generally speaking, the PROMETHEE II is structured to maximize the criteria, but in our case, there are also KPIs which should be undoubtedly minimized like the mortality rate or the CO_2 emissions. There are several ways to deal with this issue. For example, by inverting the order of the difference between two alternatives, in order to have a positive value and eventually choose the first alternative, which present actually the smallest value of the criterion under consideration. In our case, we have decided to maintain the order of the difference between alternatives, but to use the criteria function of the second quadrant, so with negative values of preference and indifference indexes, as shown in figure 24 of chapter 4. Thus, in the case of minimizing a criteria, when a difference between two alternatives is negative, meaning that the first country shows a much smaller value of the KPIs with respect to the other one, if the difference is relevant, the first alternative is chosen. Table 22 reports the different objective functions, maximizing or minimizing, for each sustainability KPI used in the analysis. It is important to notice that there are some criteria which is not immediately clear if they should be maximized or minimized. This is the case for example of the electricity consumption per capita, because on one hand a high value means that the population has the possibility to use electricity services for higher standards of living and for economic activities. On the other hand, a high value of electricity consumption per capita can also mean that the efficiency of the electricity system is quite low, considering that the electrical consumption is expected to decrease in the most industrialized countries for quality improvement of the electrical system. In our analysis, we have chosen to minimize only the criteria which should undoubtedly be minimized, leaving unchanged the rest of the KPIs. The main reason behind this decision is because we are dealing with developing countries for most of the cases, so going back to the example of the electricity consumption, generally in these areas, a higher value means higher quality of life.

KPIS	Objective Function
Urbanization rate	Maximize
Life expectancy at birth	Maximize
Mortality rate, infant	Minimize
Access to electricity	Maximize
Air pollution deaths	Minimize
PM 2.5 level of exposure	Minimize

GDP PPP per capita	Maximize
Employment to population ratio	Maximize
Carbon pricing	Maximize
TPES per m^2	Maximize
% RES in electricity gen	Maximize
Total self sufficiency	Maximize
Electricity consumption per capita	Maximize
Total CO_2 emissions	Minimize
Forest area	Maximize

Table 22: Different objective functions for the sustainability KPIs used in the analysis.

5.2.2 Sustainability analysis per year

Once all the sustainability KPIs, weights and values for preference and indifference indexes have been set, the next step consist in the elaboration of all the information together, by implementing the PROMETHEE method through the MATLAB code. As mentioned before, we have repeated the analysis for different values of preference and indifference thresholds, but the first and preferred ones are p=70% and q=12% of the maximum difference. The choice is based on the fact that it is a value in between the percentages considered and it seems appropriate, but it has been further validated by the sensitivity analysis reported in the next chapter. Thus, the sustainability assessment has been performed, including all the listed 15 KPIs from 2010 to 2016, covering the 30 selected BRI countries in Eurasia. In the end the number of countries involved are in total 29, since Afghanistan would have been included, but it does not present available data. In the following tables, the top 10 countries with the highest and lowest level of sustainability outcome are reported, from 2010 to 2016, with a value of p and q equal to 70% and 12% of the maximum difference respectively. The tables report the sustainability outcome or result of each BRI country, which corresponds to the final net flow of the algorithm PROMETHEE II. As explained in chapter 4, the net flow can be positive or negative, referring to the strength to outrank or weakness to be outranked of each alternative respectively, compared to all the other ones. According to the sustainability results, the countries have been ranked from the highest value of net flow to the lowest. For more details, appendix II provides tables with the full list of countries per year and the sustainability outcomes, according to the different percentages of preference and indifference indexes considered in the analysis.

Rank	2010		2011		2012		2013	
1	Brunei	6.74	Brunei	6.41	Brunei	6.53	Brunei	6.47
2	Qatar	6.35	Qatar	6.39	Qatar	6.06	Europe	5.61
3	Europe	5.29	Europe	5.39	Kuwait	5.56	Qatar	5.61
4	Singapore	5.04	Kuwait	5.35	Europe	5.44	Kuwait	5.04
5	Kuwait	4.88	Singapore	5.10	Singapore	4.91	Singapore	4.73
6	UAE	3.27	UAE	3.45	UAE	3.50	Kazakhstan	3.79
7	Bahrain	2.27	Bahrain	2.22	Bahrain	1.99	UAE	3.07
8	Azerbaijan	1.87	Israel	1.74	Russia	1.66	Bahrain	1.88
9	Israel	1.69	Russia	1.59	Israel	1.58	Russia	1.41
10	Russia	1.43	Malaysia	1.42	Oman	1.31	Israel	1.32

Table 23: top 10 BRI countries with the highest level of sustainability result from 2010 to 2013.

Rank	2014		2015		2016	
1	Brunei	6.09	Brunei	6.03	Europe	5.96
2	Europe	5.88	Europe	5.98	Brunei	5.67
3	Qatar	5.55	Qatar	5.29	Qatar	5.30
4	Kuwait	5.03	Singapore	4.65	Singapore	4.52
5	Singapore	4.69	Kuwait	4.55	Kuwait	4.46
6	Kazakhstan	4.01	Kazakhstan	3.83	Kazakhstan	3.80
7	UAE	3.02	UAE	2.99	UAE	3.00
8	Bahrain	1.80	Bahrain	1.74	Bahrain	1.40
9	Russia	1.50	Russia	1.34	Russia	1.38
10	Israel	1.18	Israel	1.20	Malaysia	1.17

Table 24: top 10 BRI countries with the highest level of sustainability result from 2014 to 2016.

As shown in table 23 and 24, Brunei Darussalam presents the highest sustainability outcome of the 29 BRI countries considered, for most of the years. In fact, it presents positive values and features for most of the considered KPIs. For example, due to the fact that it is a relatively small country, it surely has limited environmental impacts, with respect to more extended nations, like China. In fact, Brunei's surface is equal to 0.06% of the surface of China and 2% of the surface of Italy and it is the third smallest country in the 30 selected BRI, after Singapore and Bahrain. In 2016, Brunei reported indeed the lowest level of CO_2 emissions in the area and it has 72% of its surface covered by forests. In addition to its limited territory, it presents a rather small population of about half a million inhabitants, with the third highest level of GDP PPP per capita in 2018 in the selected BRI region. Brunei is in fact a small and wealthy country, with the economy that relies on the production and exports of oil and natural gas, accounting for nearly 60% of its GDP [59]. According to the Oil and Gas Journal, Brunei holds the fourth largest proved oil reserves in Asia, with a total amount of 1.1 billion barrels in 2018, as also reported by BP [3]. Considering its modest domestic demand of fossil fuels, it has a very high level of self-sufficiency and it sells most of the produced oil and gas to the major consuming countries in Asia. For its electricity generation, Brunei uses almost only natural gas, which is the least polluting of fossil fuels, and it is implementing a program to increase the share of renewable sources in the electricity mix to 10% by 2035 [59]. For all these reasons, Brunei shows the highest sustainability result in the BRI region, according to the KPIs that we have selected. Surely Brunei is affected by other criticalities, like social issues and lack of human rights and fundamental freedoms, which unfortunately have not been included in our analysis.

Europe is an area which is always in the highest positions, but still not the first one until 2016. This is caused by the fact that Europe is not a country, but it represents a set of countries with very different characteristics and behaviours. There are European countries which are well-known for being particularly sustainable and environmentally friendly worldwide, like Norway and Sweden, but there are also other European countries with lower level of environmental protection, which still heavily rely on coal, like Poland. Across Europe, there are also a wide gap between the wealthy countries which performs well also in the socio-economic indicators and other countries which still lack a stable economy and social welfare. Thus, in this preliminary phase, Europe presents the average values calculated on all these different countries and the good performance of some countries is levelled off by the bad performance of other ones. In Appendix III, there is a focus on Europe, which is separated and some of the European countries are included in the analysis, making a contribution by themselves.

Other countries in the first positions are the Middle East nations, like Qatar and United Arab Emirates, and Singapore. These countries, similar to Brunei, are relatively small, thus creating less environmental impacts, and quite wealthy, thanks to their economy based on the production of fossil fuels or their refining industries. Finally, it should be noticed how Kazakhstan enters the top 10 countries for sustainability outcome in 2013, maintaining the 6th position until 2016, while in 2012 was ranked 14th. This is caused by the fact that not only almost every value of KPIs improves from 2012 to 2013, but mainly because Kazakhstan decided to implement a carbon pricing mechanism in 2013, in the form of ETS. Carbon pricing is a KPI with great value in our analysis since it covers all the spheres of sustainability, involving energy and environment sector in the first place but having consequences also on the social and economic one.

Rank	2010		2011		2012		2013	
20	Jordan	-1.74	Turkmenistan	-1.70	Iran	-1.82	Turkmenistan	-1.90
21	Turkmenistan	-2.07	Jordan	-1.75	Jordan	-1.97	Iran	-2.08
22	Mongolia	-2.34	Mongolia	-2.44	Mongolia	-1.98	Jordan	-2.32
23	Iraq	-2.57	Iraq	-2.46	Iraq	-2.23	Mongolia	-2.55
24	Philippines	-2.79	Philippines	-2.80	Philippines	-3.09	Iraq	-2.59
25	Uzbekistan	-2.85	Uzbekistan	-3.22	Uzbekistan	-3.25	Philippines	-3.50
26	Myanmar	-3.50	Myanmar	-3.54	Myanmar	-3.70	Uzbekistan	-3.64
27	China	-4.62	China	-4.83	China	-4.41	Myanmar	-4.11
28	Pakistan	-6.92	Pakistan	-7.58	Pakistan	-7.41	Pakistan	-7.73
29	Bangladesh	-7.91	Bangladesh	-7.85	Bangladesh	-7.85	Bangladesh	-7.95

Table 25: top 10 BRI countries with the lowest level of sustainability result from 2010 to 2013.

Rank	2014		2015		2016	
20	Turkmenistan	-1.84	Turkmenistan	-2.08	Mongolia	-1.75
21	Mongolia	-2.27	Iran	-2.13	Iraq	-2.06
22	Iran	-2.29	Iraq	-2.16	Iran	-2.15
23	Iraq	-2.38	Jordan	-2.38	Turkmenistan	-2.24
24	Jordan	-2.54	Mongolia	-2.62	Jordan	-2.61
25	Philippines	-3.16	Philippines	-3.34	Philippines	-3.19
26	Uzbekistan	-3.55	Uzbekistan	-3.45	Uzbekistan	-3.47
27	Myanmar	-4.20	Myanmar	-4.04	Myanmar	-4.31
28	Pakistan	-7.57	Pakistan	-7.37	Bangladesh	-7.44
29	Bangladesh	-8.32	Bangladesh	-7.76	Pakistan	-7.72

Table 26: top 10 BRI countries with the lowest level of sustainability result from 2014 to 2016.

Moving to the BRI countries with the worst sustainability results, table 25 and 26 show how all the South Asia countries, namely Pakistan and Bangladesh, are always ranked last from 2010 to 2016. This outline the need, but also the opportunity, to change towards sustainable development, which might be favoured and sustained, in a preliminary phase, by foreign green investments. The region of Eastern Asia is also located at the bottom of the list, with Mongolia and China among the 10 worst sustainable countries. It should be noticed though, how China, from the third last result in the period 2010-2012, drastically improves its performance from 2013 onwards, leaving the last positions of the ranking. China is a country which is not included in the top 10 countries for the sustainability outcome, but it experiences fast progress towards sustainability during the selected period, as it is shown in the next section. The improvement is particularly evident in 2013, thanks to the adoption of an ETS system in some jurisdictions of the country, in parallel with what happened in Kazakhstan in the same year. Aside from Kazakhstan, the rest of Central Asia belongs to the last positions of the sustainability classification, together with some countries of the Middle East region. As in Central Asia, here there is also great variety, from Qatar and Kuwait in the top 5, to Jordan, Iraq and Iran in the last positions for sustainability. Finally, the only two countries of the South East Asia with a bad sustainability performance are Philippines and Myanmar.

5.2.3 Improvements towards sustainability

In addition to all the considerations on the final sustainability results of the BRI countries, we have decided to fully implement the idea behind the study of the University of Belgrade [58]. Thus, we have calculated the difference of the final net flows of each country between two consecutive years, for the whole period considered, as showed below.

$$\Delta\Phi_{net\ flow} = \Phi_{net\ flow,\ t2} - \Phi_{net\ flow,\ t1} \qquad (4)$$

In equation 4, t is the generic year and ΔΦ is the difference between two final net flow for the same country, going from year t1 to year t2, with t2>t1. In this way, it was possible to see how the countries are improving towards the sustainable development or not. The values of preference and indifference indexes are again set equal to 70% and 12% of the maximum difference found among the alternatives for each KPI, in accordance with what has been done for the sustainability results. The following tables report the top 10 countries for highest and lowest sustainability improvements per year, in the period 2010-2016. Moreover, the map reported in figure 25 presents the overall progress towards the sustainable development, showing the difference between net flows of 2010 and 2016.

Rank	2010-2011		2011-2012		2012-2013	
1	Kuwait	0.47	Mongolia	0.46	China	4.00
2	Saudi Arabia	0.38	China	0.41	Kazakhstan	3.86
3	Turkmenistan	0.36	Vietnam	0.32	Europe	0.17
4	Vietnam	0.36	Iraq	0.23	Brunei	-0.06
5	UAE	0.17	Kuwait	0.21	Bangladesh	-0.09
6	Russia	0.16	Pakistan	0.18	Bahrain	-0.12
7	Iraq	0.12	Oman	0.13	Turkey	-0.15
8	Europe	0.10	Brunei	0.12	Malaysia	-0.16
9	Malaysia	0.08	Saudi Arabia	0.10	Singapore	-0.18
10	Turkey	0.07	Kazakhstan	0.10	Saudi Arabia	-0.21

Table 27: top 10 countries with highest sustainability improvements per year from 2010 to 2013.

Rank	2013-2014		2014-2015		2015-2016	
1	Philippines	0.34	Turkey	0.91	Mongolia	0.87
2	Mongolia	0.28	Bangladesh	0.56	Bangladesh	0.32
3	Europe	0.26	China	0.50	Saudi Arabia	0.31
4	China	0.26	Iraq	0.22	Philippines	0.15
5	Kazakhstan	0.22	Pakistan	0.20	Thailand	0.12
6	Vietnam	0.21	Jordan	0.16	Iraq	0.10
7	Iraq	0.21	Myanmar	0.16	Azerbaijan	0.10
8	Pakistan	0.16	Iran	0.15	Oman	0.08
9	Uzbekistan	0.10	Thailand	0.13	China	0.08
10	Russia	0.09	Europe	0.11	Malaysia	0.06

Table 28: top 10 countries with highest sustainability improvements per year from 2014 to 2016.

Considering the countries with the highest improvement rates, the best case is represented by Europe. In fact, not only Europe has always turned out to be one of the most sustainable countries in the BRI region, but it has also been included among the countries with the highest improvement in sustainability in time. In four cases, its progress towards sustainable development is in the top 10 highest ones and it shows the third highest overall improvement from 2010 to 2016. This is in accordance with the fact that Europe has always been the avant-garde of environmental protection and sustainability around the world. Aside from Europe, the countries with the highest improvement rate of sustainability are represented by China and Kazakhstan, which have been ranked respectively first and second country for overall sustainability progress from 2010 to 2016.

China and Kazakhstan show different levels of sustainability, which is medium/low for China and medium/high for Kazakhstan, but they have in common a rapid recovery of different positions in the classification. As mentioned before, they experienced indeed a rapid boost to their sustainability results, thanks to their increasing performances of most of the KPIs and in particular thanks to the implementation of carbon pricing mechanism. Other cases worth noticing are Bangladesh and Iraq, which have been counted among the top 10 countries with worst sustainability results for most of the years considered. As far as the sustainability progress is concerned though, they are improving at the highest rates. In fact, not only they are often present among the countries with the best annual improvements, but Iraq and Bangladesh are respectively the 5th and 6th in the overall ranking of sustainability progress from 2010 to 2016. This sounds like good news in areas where there is the need to pursue the sustainable development. Other countries which present a medium/low level of sustainability outcome, but showing high rates of improvements, are Mongolia, Turkey, Vietnam, Saudi Arabia and Malaysia.

Rank	2010-2011		2011-2012		2012-2013	
20	Myanmar	-0.04	Myanmar	-0.16	Azerbaijan	-0.37
21	Bahrain	-0.05	Thailand	-0.16	Uzbekistan	-0.40
22	Kazakhstan	-0.05	Israel	-0.16	Myanmar	-0.41
23	Mongolia	-0.10	Singapore	-0.19	Philippines	-0.42
24	China	-0.20	Azerbaijan	-0.20	Thailand	-0.42
25	Oman	-0.23	Jordan	-0.22	UAE	-0.43
26	Brunei	-0.33	Bahrain	-0.22	Qatar	-0.45
27	Uzbekistan	-0.37	Iran	-0.27	Vietnam	-0.46
28	Azerbaijan	-0.55	Philippines	-0.29	Kuwait	-0.52
29	Pakistan	-0.66	Qatar	-0.32	Mongolia	-0.57

Table 29: top 10 countries with lowest sustainability improvements per year from 2010 to 2013.

Rank	2013-2014		2014-2015		2015-2016	
20	Qatar	-0.06	Philippines	-0.18	Vietnam	-0.07
21	Bahrain	-0.08	Kazakhstan	-0.18	Kuwait	-0.08
22	Myanmar	-0.09	Indonesia	-0.22	Israel	-0.11
23	Israel	-0.14	Azerbaijan	-0.23	Singapore	-0.13
24	Thailand	-0.14	Vietnam	-0.24	Turkmenistan	-0.16
25	Iran	-0.20	Turkmenistan	-0.24	Jordan	-0.23
26	Jordan	-0.22	Qatar	-0.26	Myanmar	-0.27
27	Bangladesh	-0.37	Saudi Arabia	-0.33	Bahrain	-0.34
28	Brunei	-0.37	Mongolia	-0.35	Brunei	-0.35
29	Turkey	-0.45	Kuwait	-0.48	Pakistan	-0.36

Table 30: top 10 countries with lowest sustainability improvements per year from 2014 to 2016.

Moving to the countries with the lowest sustainability progress, the worst situation is represented by Pakistan, Jordan, Myanmar and partially Philippines. They already show sustainability results among the top lowest ones, for most of the years, and, in addition, they do not seem to be improving their status. In fact, they have been often ranked in the last positions for the sustainability growth per year and they are even included in the top low improvements of the overall classification from 2010 to 2016. Even if Philippines, for example, shows the highest progress towards sustainable development in 2014 with respect to 2013, still it is not enough to counterbalance other years of sustainability worsening and the already low level of sustainability in the first place. Another category which is worth mentioning are Singapore, Brunei Darussalam and some of the Middle East countries, namely Kuwait, Bahrain and Qatar. All these countries present the top highest sustainability results for every year considered, but on the other hand, they are also included among the top worst sustainability improvement of the same period. This is the major difference with Europe, which holds a high sustainability level and keeps improving it, while these wealthy and small countries seem to move backwards, not pursuing the sustainable development. In fact, a significant case is represented by Brunei and Qatar, which happened to be always in the first three positions of the sustainability ranking with Europe, but they also present the second and third last improvement in sustainability from 2010 to 2016. Finally, there are Thailand, Israel and Azerbaijan which are often included in the lowest annual sustainable improvements and in particular, Azerbaijan which have been ranked last in the overall classification from 2010 to 2016.

To sum up, the following map shows the overall sustainability improvement from 2010 to 2016 highlighting in green the area with a positive improvement, while in red the most critical areas with the lowest rankings.

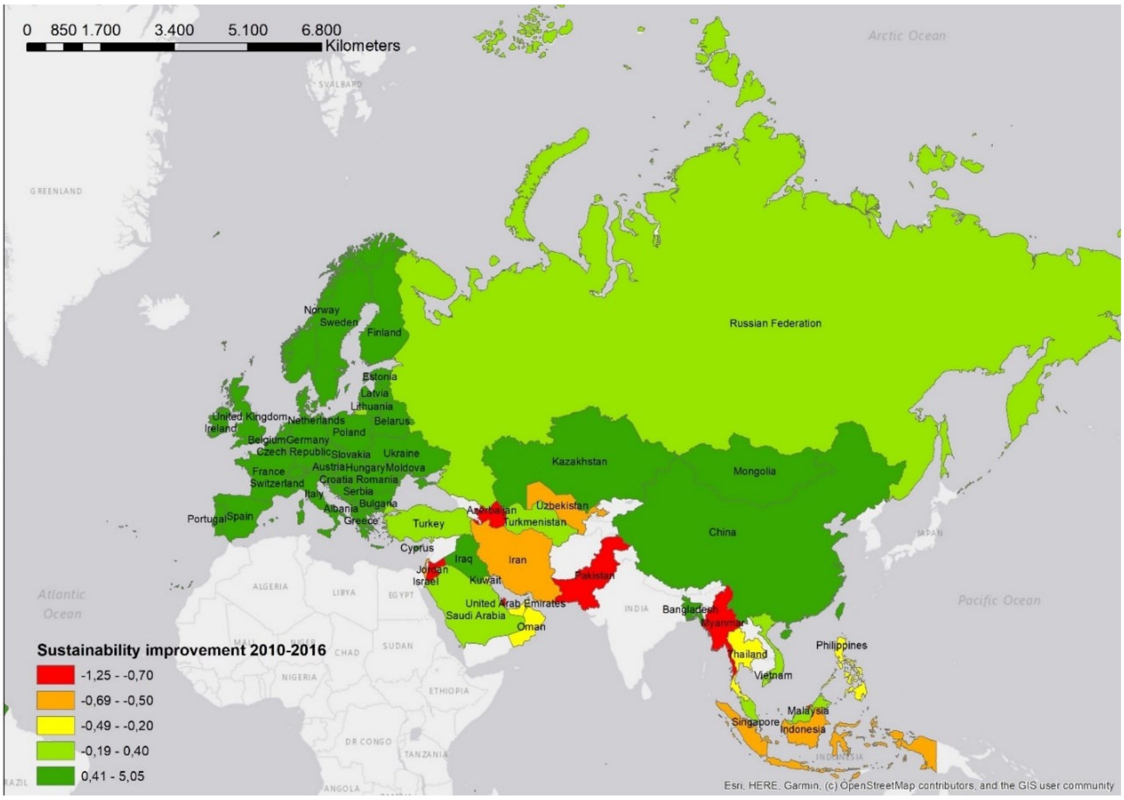

Figure 25: overall sustainability improvement in BRI countries from 2010 to 2016. Source: PoliTo.

5.3 SENSITIVITY ANALYSIS ON PREFERENCE AND INDIFFERENCE INDEXES

Preference and indifference indexes, p and q respectively, are two thresholds of the PROMETHEE method, which are defined for each criteria and should be provided by the decision maker. As mentioned in the previous chapter, in our analysis we have implemented an algorithm to calculate the value of preference and indifference indexes for each KPI and to update them every year. It is based on finding the maximum difference between the alternatives and then obtaining the value of p and q by choosing a percentage of the maximum difference itself. The difficulty was the identification of the most suitable percentages, so we have decided to define a range of possible values both for p and for q, reported in table 21 of chapter 5.2.1. In this way, we have rerun the MATLAB code each time with different values of p and q and we have studied the result in a sensitivity analysis. Once we have collected all the results, for each year, we have analysed the final sustainability result of each country, in the seven different configurations of p and q chosen. Thus, for each year and for each alternative, we have calculated the average values μ, the standard deviation σ and the relative standard deviation σ*, as reported in the following equations:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (5)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}} \qquad (6)$$

$$\sigma^* = \frac{\sigma}{|\mu|} \qquad (7)$$

In equation 5, 6, 7, x is the value of the generic alternative i, and N is the total number of alternatives. In this way, it has been possible to calculate the average value of the sustainability result of each country and how it is influenced by changing the values of p and q. Given the large amount of data, we have decided to report a plot with error bars, in which the central value is the average of the sustainability results, for each country for each year, and the uncertainty is represented by the standard deviation. In this way, the most representative data are displayed in the 6 figures below. It worth noticing how for some countries like Kazakhstan, Thailand and Indonesia the error bar is very small, while for other countries, like Bangladesh, Pakistan and Brunei Darussalam, the standard deviation is quite high and depending on the values of p and q chosen, their results might change of some positions.

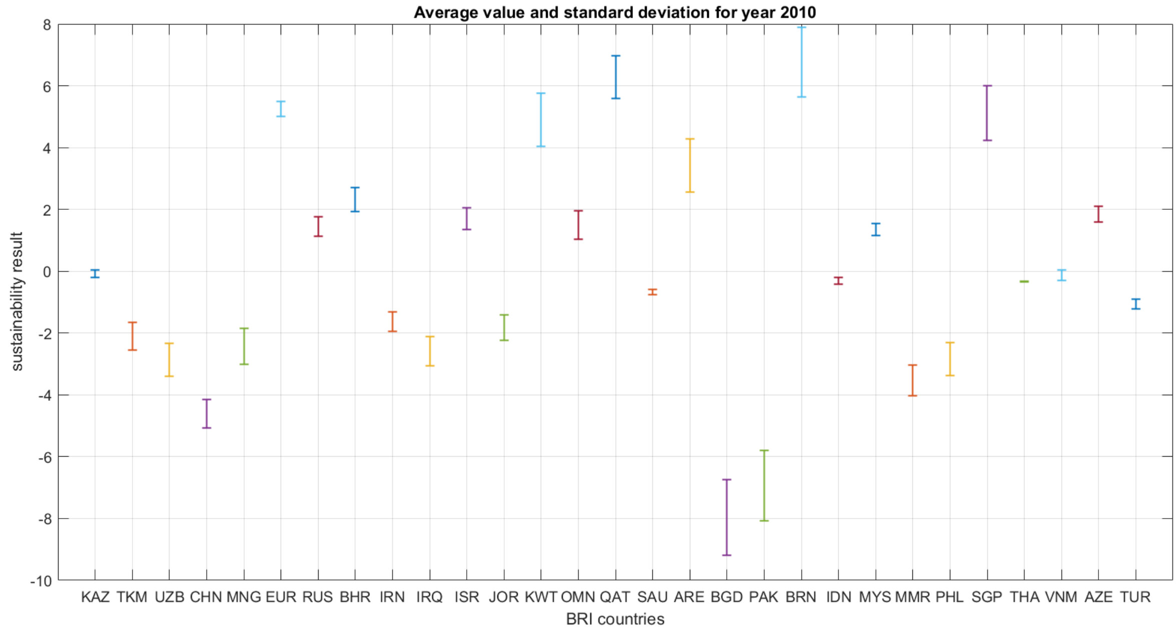

Figure 26: average sustainability results and standard deviation for the BRI countries in 2010.

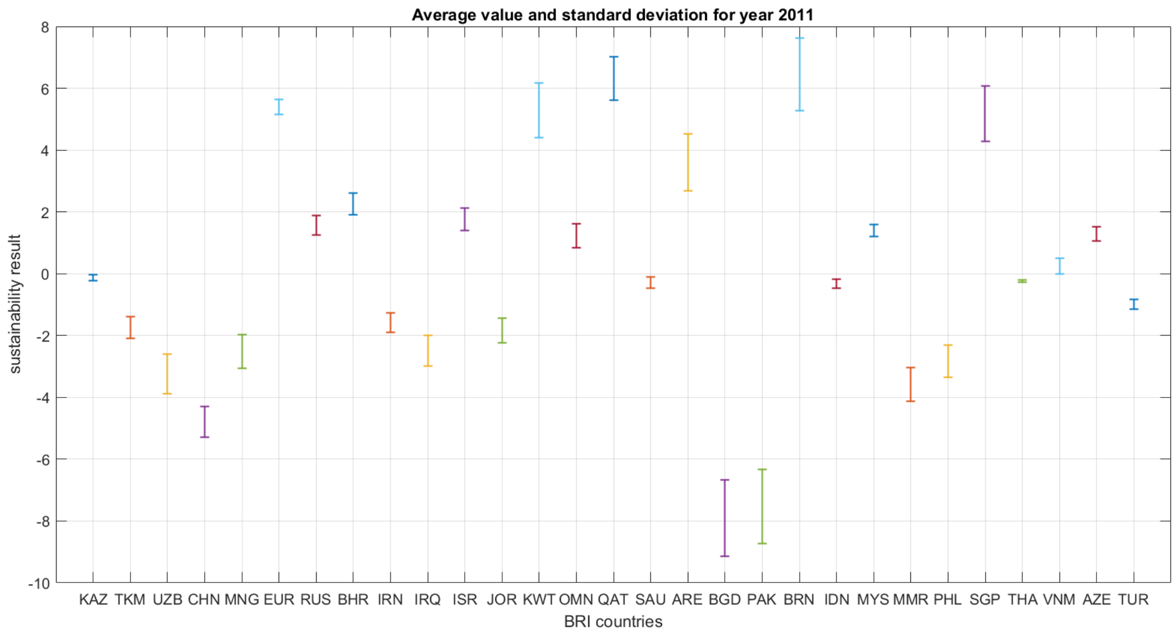

Figure 27: average sustainability results and standard deviation for the BRI countries in 2011.

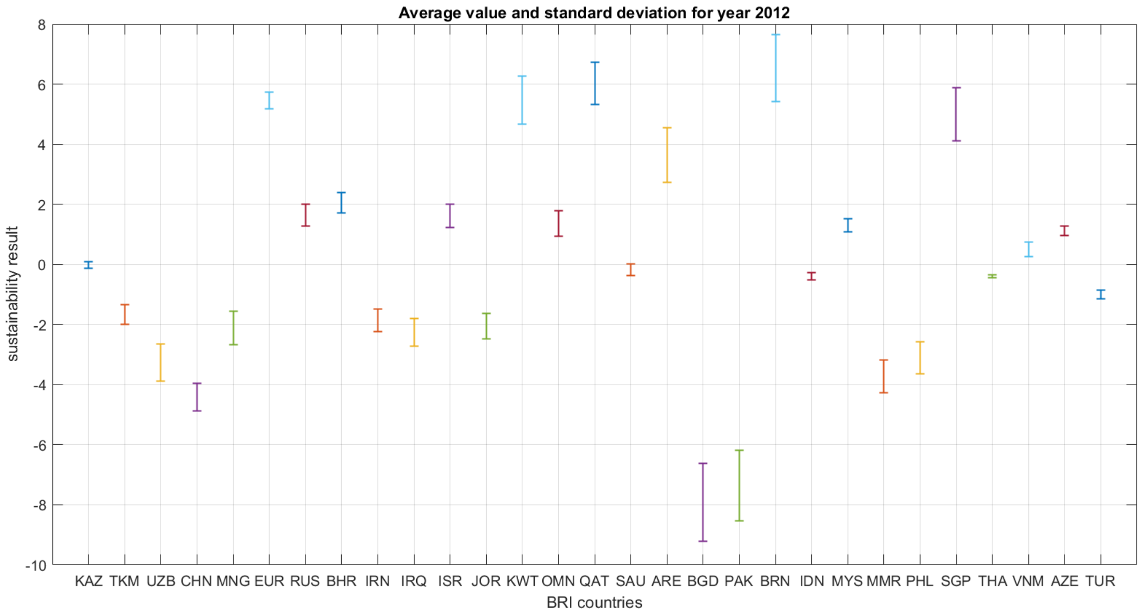

Figure 28: average sustainability results and standard deviation for the BRI countries in 2012.

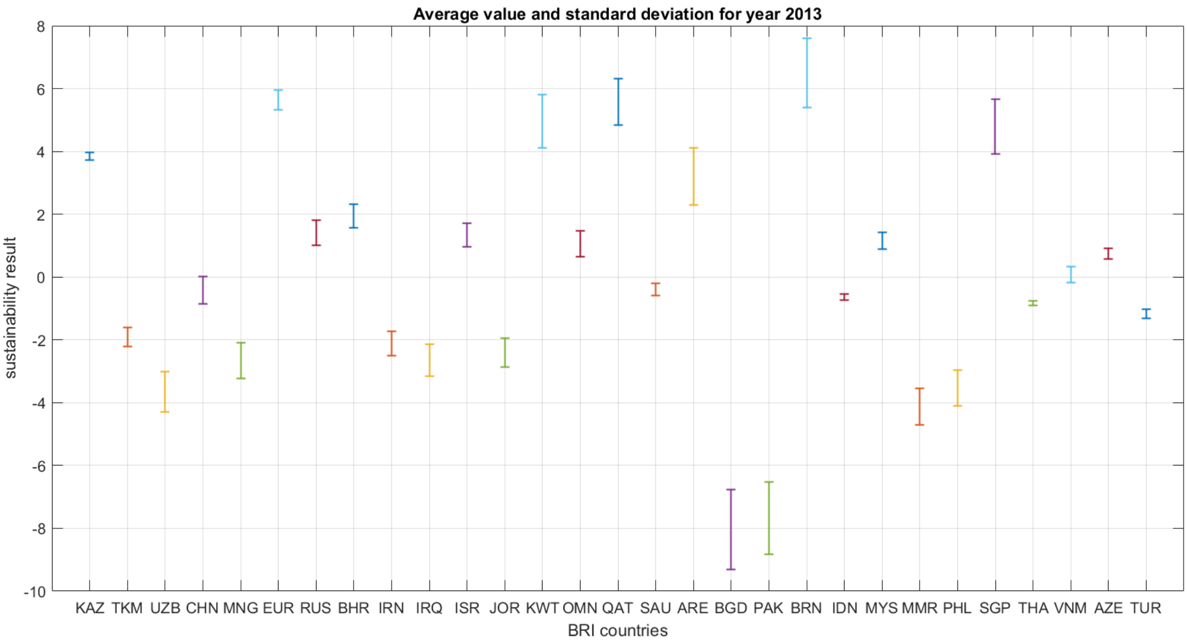

Figure 29: average sustainability results and standard deviation for the BRI countries in 2013.

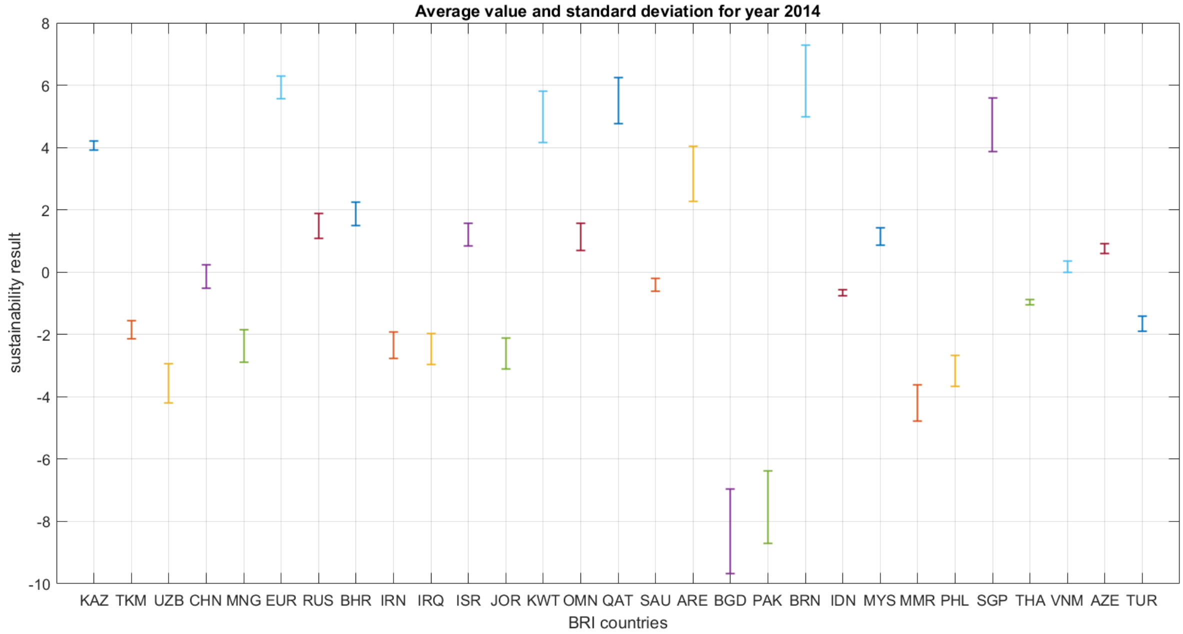

Figure 30: average sustainability results and standard deviation for the BRI countries in 2014.

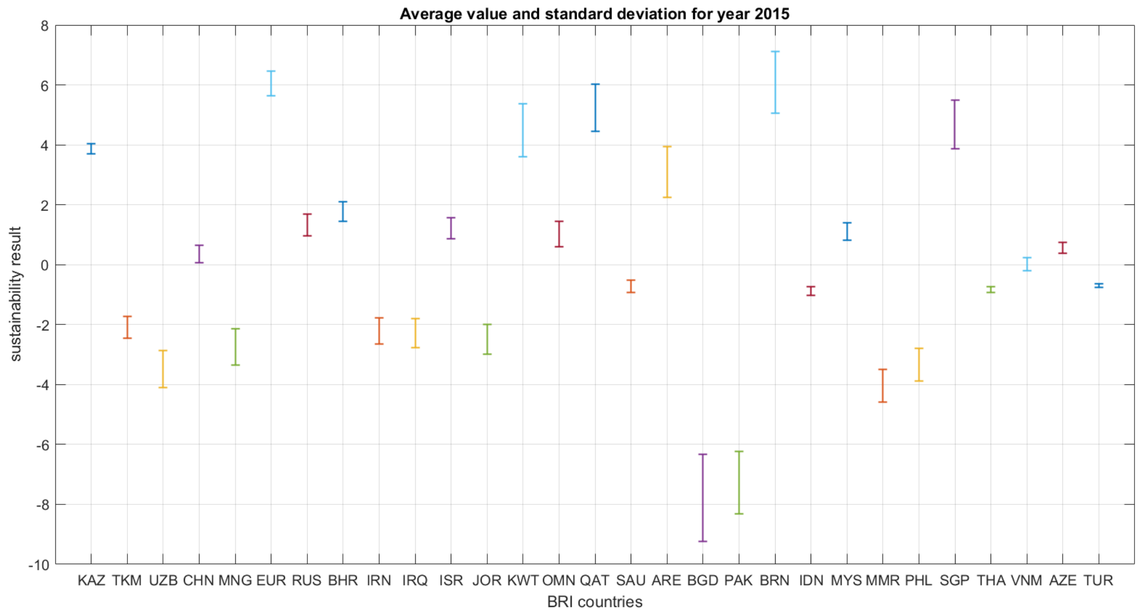

Figure 31: average sustainability results and standard deviation for the BRI countries in 2015.

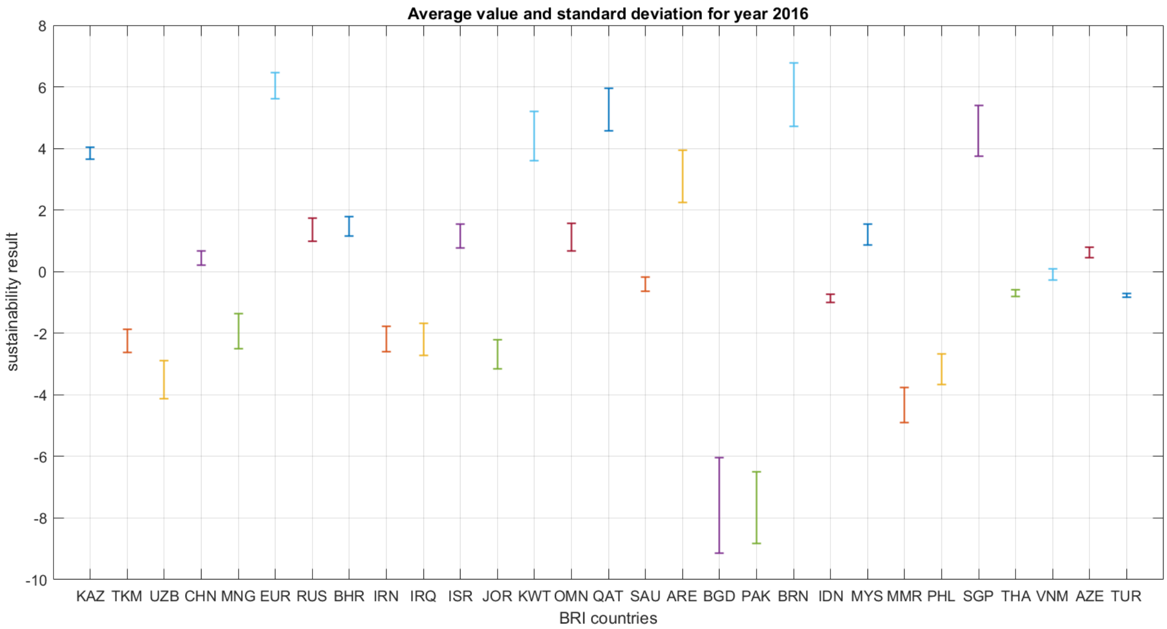

Figure 32: average sustainability results and standard deviation for the BRI countries in 2016.

In the end, we have decided to analyse the distance of each sustainability result from the average, in order to investigate which couple of values for p and q is the most appropriate. Thus, for 203 sustainability results, grouped according to the values of p and q used, we have calculated the difference with the average, and then we have counted the number of times each couple of values of p and q leads to the minimum difference. Figure 33 reports the total number of cases in which each pair of p and q determines the closest results to the average. In this way it has been proved how the values p=70% and q=12%, used in the analysis, are the most suitable of the range.

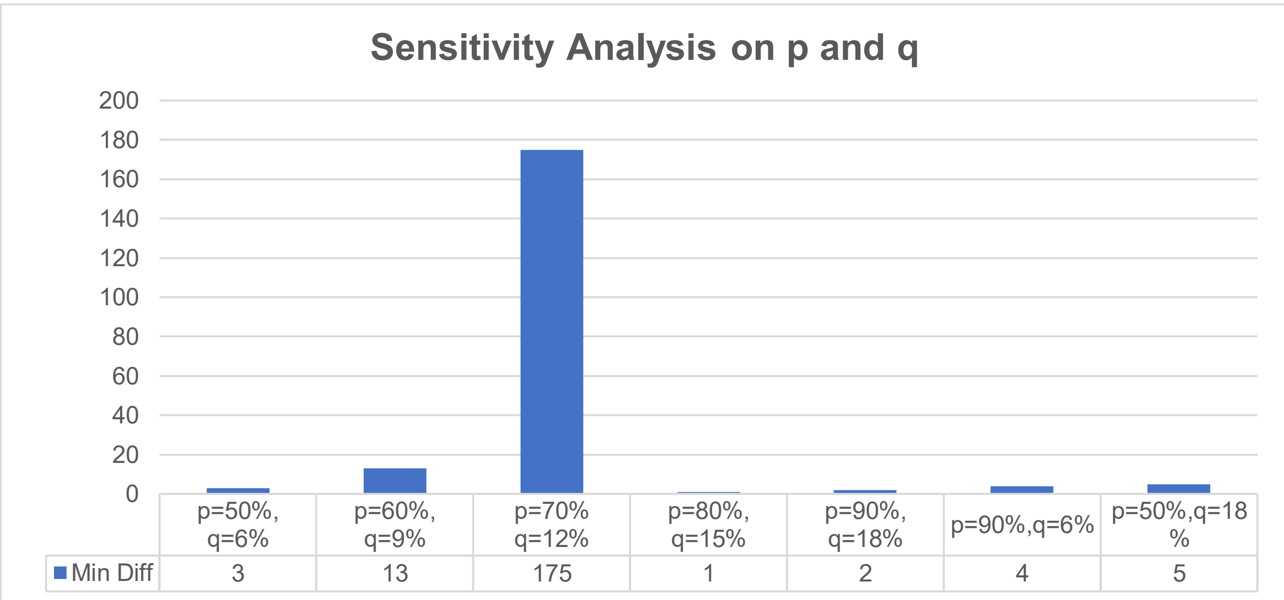

Figure 33: number of times each pair of p and q leads to the minimum distance from the average sustainability result.

6 SECTORIAL ANALYSIS IN BRI SUSTAINABILITY

In this last chapter, we have decided to implement some further analyses to complete our study of the sustainability assessment in the Eurasian region of BRI. Going into more details, at first, we have investigated how a different way to define the weights has an impact on the assessment. In fact, we have already discussed about how the sustainability results are affected by the choice of the preference and indifference values in the sensitivity analysis. The other inputs to MCDA, which may be considered as subjective, are indeed the different weights given to criteria. Thus, we have defined a new weighting method and compared the results with the first approach. For the sake of consistency, we have used the same values of p and q, which have been proven to be the most suitable, so p=70% and q=12%. This alternative weighting method has been of great benefit since it defines the weights of criteria focusing on one sector of sustainability at a time. In this way, the second weighting method has also been used to implement a sectoral analysis of BRI countries. In fact, we have implemented our MCDA PROMETHEE II code to focus on the single spheres of sustainability. Thus, we have ranked the 30 BRI countries according to their level of development for the social, economic, energy and environmental sector, separately. We have used the same sustainability KPIs, thanks to the fact that each criterion has been already assigned to one or more sectors. Through this sectoral analysis, it is possible to investigate which are the sectors more developed or more critical for each BRI countries, where the countries are performing well or where they need to improve.

6.1 ALTERNATIVE WEIGHTING METHOD

Once we have analysed how the sustainability results are affected by the choice of preference and indifference index, we have further investigated how the final net flows of the MCDA method are influenced by the weights assigned to each criteria. Surely, we have maintained the same sustainability KPIs, defined as before, and also the principle of giving the same weights to each sphere of sustainability. Thus, every sustainability sector, namely society, economy, energy and environment, has an overall sectoral weight of 25%, to stress the fact that in reaching sustainable development no sustainability pillars has to be sacrificed in favour of another one. We have also kept unchanged the division of each KPI in one or more sectors, in order to have the list of parameters involved in each aspect of sustainability. In fact, in this new approach, we have focused on each sector, and for each criterion we have identified a level of priority in a scale from 1 to 4. The value 1 is given to criteria which are considered as fundamental and as an indispensable base to develop the sector, gradually decreasing until level 4, which is assigned to parameters evaluated as an extra and not essential. Once the priority levels have been set, the 25% of the overall sectoral weight is divided among the KPIs, by assigning the same weight to the criteria with the same priority level. Finally, for the KPIs belonging to more sectors, the total weight is calculated as the sum of the weights given in the sectoral analysis.

Society	Priority level	25% scale
Urbanization rate	4	1.25%
Life expectancy at birth	1	3.75%
Mortality rate, infant	1	3.75%
Access to electricity	2	2.50%
Air pollution deaths	1	3.75%
PM 2.5 level of exposure	3	1.67%
GDP PPP per capita	2	2.50%
Employment to population ratio	2	2.50%
Carbon pricing	3	1.67%
Electricity consumption per capita	3	1.67%

Table 31: priority levels and sectoral weights for sustainability sphere Society.

As far as society is concerned, priority 1 has been assigned to KPIs involving the health and safety of people, while priority 2 to economic indicators, like the wealth of the population and the labour market. Finally, priority 3 and 4 to energy consumption of the population, carbon pricing and urbanization rates.

Economy	Priority level	25% scale
Urbanization rate	4	1.25%
GDP PPP per capita	1	8.13%
Employment to population ratio	1	8.13%
Carbon pricing	2	5.00%
Total self sufficiency	3	2.50%

Table 32: priority levels and sectoral weights for sustainability sphere Economy.

Considering economic sector, the highest level of priority has been given to the socio-economic indicators of GDP PPP per capita and employment rate. Carbon pricing, total self-sufficiency and urbanization rate are ordered according to a decreasing level of priority from 2 to 4. Carbon pricing has been considered the most important of the three, because it is a way to tax some polluting economic activities, which may involve multiple sector of society, like transportation and energy. Total self-sufficiency is an KPI of just the energy sector and it is related to the production and supply of fossil fuels, while urbanization rate may be an indicator of the industrialization level of a country.

Energy	Priority level	25% scale
Access to electricity	1	5.00%
Carbon pricing	2	3.13%
TPES per square metres	1	5.00%
% RES in electricity gen	1	5.00%
Total self sufficiency	2	3.13%
Electricity consumption per capita	3	2.50%
Total CO_2 emissions	4	1.25%

Table 33: priority levels and sectoral weights for sustainability sphere Energy.

Moving to the energy sector, the level 1 priorities are access to electricity, TPES per square metres, which are parameters describing the dimension and the extent of the energy system, and % RES in electricity generation, which is fundamental for the transition towards a low-carbon future. Priority 2 has been assigned to carbon pricing which deeply involves the energy system, and total self-sufficiency, which is an important indicator also for energy security of the country. Then, electricity consumption per capita has a medium/low priority, since, in the developing countries, an increase in electricity consumption might be an index of higher living standards and the diffusion of energy services, but in the most industrialized economy, it might involve a low level of efficiency of the energy system. Finally, the lowest priority has been assigned to total CO_2 because it is more an environmental parameter and it is partially been accounted giving importance to carbon pricing.

Environment	Priority level	25% scale
Air pollution deaths	1	6.25%
PM 2.5 level of exposure	2	3.3%
Carbon pricing	1	6.3%
% RES in electricity generation	3	2.5%
Total CO_2 emissions	2	3.3%
Forest area	2	3.3%

Table 34: priority levels and sectoral weights for sustainability sphere Environment.

In environmental sector, air pollution deaths and carbon pricing are considered as priority of great importance, since the first assesses one of the most catastrophic impacts of air pollution and the second is a way to avoid that the environment pays for the negative externalities of pollution. Priority 2 has been given to polluting emission indicators, like total CO_2 emissions and exposure to PM 2.5, and to forest area, which is one of the most important carbon sinks together which oceans. Finally, there is % RES in electricity generation which is a mean to reduce environmental damages.

In the end, table 35 summarizes the final weights of each sustainability KPIs, based on the sectoral weights just reported. It is possible to notice how some indicators have lost relevance, like urbanization rate, total self-sufficiency and electricity consumption per capita, while some other KPIs have gain importance, like air pollution deaths and the economic indicators of GDP per capita and employment rate.

KPIs	Society	Economy	Energy	Environment	2° Method Weight	1° Method Weight
Urbanization rate	X	X			**2.50%**	**7.5%**
Life expectancy at birth	X				**3.75%**	**2.5%**
Mortality rate, infant	X				**3.75%**	**2.5%**
Access to electricity	X		X		**7.50%**	**6.1%**
Air pollution deaths	X			X	**10.00%**	**6.7%**
PM 2.5 level of exposure	X			X	**5.00%**	**6.7%**
GDP PPP per capita	X	X			**10.63%**	**7.5%**
Employment to population ratio	X	X			**10.63%**	**7.5%**
Carbon pricing	X	X	X	X	**16.04%**	**15.2%**
TPES per square metres			X		**5.00%**	**3.6%**
% RES in electricity gen			X	X	**7.50%**	**7.7%**
Total self sufficiency		X	X		**5.63%**	**8.6%**
electricity consumption per capita	X		X		**4.17%**	**6.1%**
CO2			X	X	**4.58%**	**7.7%**
Forest area				X	**3.3%**	**4.2%**
# KPIs per sector	10	5	7	6		
Total weight	25%	25%	25%	25%		

Table 35: final scheme of the second weighting method, compared to the first one, used in PROMETHEE.

Once all weights for the KPIs have been set, the MATLAB code for the implementation of PROMETHEE II has been rerun, maintaining the value of p=70% and q=12% of the maximum difference. In this way, it is possible to compare the results with the first weighting approach, as shown in the following tables.

1° weighting method		2° weighting method		1° weighting method		2° weighting method	
2010 Best 5				**2010 Worst 5**			
Brunei	6.74	Qatar	6.44	Uzbekistan	-2.85	Iraq	-3.19
Qatar	6.35	Brunei	6.32	Myanmar	-3.50	Mongolia	-3.55
Europe	5.29	Europe	6.14	China	-4.62	Myanmar	-4.17
Singapore	5.04	Singapore	5.84	Pakistan	-6.92	Pakistan	-7.38
Kuwait	4.88	Kuwait	4.58	Bangladesh	-7.91	Bangladesh	-7.97
2011 Best 5				**2011 Worst 5**			
Brunei	6.41	Qatar	6.49	Uzbekistan	-3.22	Uzbekistan	-3.42
Qatar	6.39	Europe	6.18	Myanmar	-3.54	Mongolia	-3.78
Europe	5.39	Brunei	6.10	China	-4.83	Myanmar	-4.19
Kuwait	5.35	Singapore	5.95	Pakistan	-7.58	Bangladesh	-7.85
Singapore	5.10	Kuwait	4.93	Bangladesh	-7.85	Pakistan	-8.06
2012 Best 5				**2012 Worst 5**			
Brunei	6.53	Europe	6.22	Uzbekistan	-3.25	Philippines	-3.31
Qatar	6.06	Qatar	6.19	Myanmar	-3.70	Uzbekistan	-3.43
Kuwait	5.56	Brunei	6.14	China	-4.41	Myanmar	-4.34
Europe	5.44	Singapore	5.86	Pakistan	-7.41	Bangladesh	-7.85
Singapore	4.91	Kuwait	5.07	Bangladesh	-7.85	Pakistan	-7.97
2013 Best 5				**2013 Worst 5**			
Brunei	6.47	Europe	6.35	Philippines	-3.50	Philippines	-3.78
Europe	5.61	Brunei	5.95	Uzbekistan	-3.64	Uzbekistan	-3.85
Qatar	5.61	Qatar	5.74	Myanmar	-4.11	Myanmar	-4.74
Kuwait	5.04	Singapore	5.69	Pakistan	-7.73	Bangladesh	-8.00
Singapore	4.73	Kuwait	4.53	Bangladesh	-7.95	Pakistan	-8.36
2014 Best 5				**2014 Worst 5**			
Brunei	6.09	Europe	6.60	Philippines	-3.16	Philippines	-3.40
Europe	5.88	Qatar	5.72	Uzbekistan	-3.55	Uzbekistan	-3.72
Qatar	5.55	Singapore	5.71	Myanmar	-4.20	Myanmar	-4.84
Kuwait	5.03	Brunei	5.62	Pakistan	-7.57	Pakistan	-8.12
Singapore	4.69	Kazakhstan	4.45	Bangladesh	-8.32	Bangladesh	-8.30
2015 Best 5				**2015 Worst 5**			
Brunei	6.03	Europe	6.73	Philippines	-3.34	Philippines	-3.64
Europe	5.98	Singapore	5.70	Uzbekistan	-3.45	Uzbekistan	-3.66
Qatar	5.29	Qatar	5.53	Myanmar	-4.04	Myanmar	-4.72
Singapore	4.65	Brunei	5.49	Pakistan	-7.37	Bangladesh	-7.81
Kuwait	4.55	Kazakhstan	4.35	Bangladesh	-7.76	Pakistan	-8.07
2016 Best 5				**2016 Worst 5**			
Europe	5.96	Europe	6.77	Philippines	-3.19	Philippines	-3.38
Brunei	5.67	Singapore	5.60	Uzbekistan	-3.47	Uzbekistan	-3.62
Qatar	5.30	Qatar	5.48	Myanmar	-4.31	Myanmar	-4.97
Singapore	4.52	Brunei	5.16	Bangladesh	-7.44	Bangladesh	-7.36
Kuwait	4.46	Kazakhstan	4.35	Pakistan	-7.72	Pakistan	-8.31

Table 36: comparison between sustainability results adopting the first and second weighting method.

It is worth noticing how the best and worst 5 countries are always the same, using the first and second weighting method, proving that with the sustainability results do not change significantly giving priority to some KPIs rather than others. Surely if the weights are drastically changed, as a consequence, the sustainability ranking will be quite different. Going into more details, the most relevant differences are that in the second weighting approach, Europe reaches the top of the classification from 2012 onwards, while Brunei is among the top 5 highest results, but never the first one. In addition, after 2013, Kazakhstan enters the group of the best sustainability results, with the second weighting approach, as a result of high improvement rates. Even with the second weighting method, China and Kazakhstan hold the first and second position for sustainability progress from 2010 to 2016. In fact, China is not even present among the 5 worst levels of sustainability with the second weighting approach. Aside from this differences, the best and worst sustainability results, in the first and second case, are quite similar, both for values of net flows and for the ranking position of the BRI countries.

6.2 SUSTAINABILITY ASSESSMENT BY SECTOR

Once the second weighting method has been defined, we have produced a more detailed sustainability assessment, analysing each sector of sustainability one at a time. In fact, we have already classified the sustainability KPIs according to the area of interest and we have obtained a list of criteria for each sustainability sector. In addition, thanks to the second weighting approach, we have already assigned the weights of the parameters focused on each sustainability sector. In this case, we have taken the values in tables 31, 32, 33 and 34, defined on a 25% scale, and we have reported them in a 100% scale proportionally. By doing so, it was possible to implement the PROMETHEE II method just on a single sector of sustainability, producing different rankings of countries, devoted to society, economy, energy and environment. The values of preference and indifference indexes have been kept unchanged, with p=70% and q=12% of the maximum difference found. It is true that sustainability is a concept characterized by multi dimensionality, so it is of the utmost importance to evaluate it on the whole, taking every aspect into account and without neglecting or sacrificing any sector. Anyway, it might be also useful to focus on single aspects of sustainability, to see how countries perform in each sector. In the sustainable assessment of BRI countries, this may be a method for each nation to highlight which areas are performing well or to point out which sector show some criticalities and need for improvement. The following paragraphs are focused on one pillars of sustainability at a time, according to our definition of sustainability, and they include tables to report the top 3 best and worst sustainability results and improvement from 2010 to 2016.

6.3 SOCIAL SECTOR

Starting from society, it is possible to notice how the first three countries of the ranking, Singapore, Qatar and Europe, are always the same, for the whole period considered. They also maintain the same order and approximately the same values. Singapore and Qatar are small and wealthy countries, with stable economies relying on fossil fuels production and refinement, so they have many advantages and means to face sustainability challenges in the social field. Despite being an average of a set of countries, the third ranked is Europe, as evidence of a general high level of social welfare and living standards with respect to the rest of BRI countries. Also, the last three countries remain the same for all the years analysed, highlighting the fact there are not drastic changes among the top best and worst nations of the social assessment. The three last countries under consideration, namely Bangladesh, Myanmar and Pakistan, are also in the lowest positions of the total sustainability classification. By looking at the last column of table 38, the countries with the highest improvement rate are Kazakhstan and China, which are also the second and first countries for sustainability progress considering all the sectors. Another big growth in social issues is experienced by Bangladesh, even though it presents one of the worst outcome in the social evaluation. Bangladesh generally shows bad sustainability results, but high improvement pace in the total ranking. Finally, the worst sustainability progresses are represented by two Middle East countries, namely Jordan and Kuwait, and Brunei, which is instead at the top of the total sustainability classification.

Rank	2010		2011		2012		2013	
1	Singapore	9.44	Singapore	9.55	Singapore	9.51	Singapore	9.48
2	Qatar	8.20	Qatar	8.22	Qatar	7.97	Qatar	7.60
3	Europe	7.37	Europe	7.42	Europe	7.25	Europe	7.19
27	Bangladesh	-11.24	Bangladesh	-11.00	Bangladesh	-10.79	Bangladesh	-10.62
28	Myanmar	-12.66	Myanmar	-12.61	Myanmar	-12.63	Myanmar	-12.77
29	Pakistan	-14.18	Pakistan	-14.69	Pakistan	-14.67	Pakistan	-14.92

Table 37: top 3 best and worst BRI countries for the results in social assessment, from 2010 to 2013.

Rank	2014		2015		2016		2010-2016 improvement	
1	Singapore	9.55	Singapore	9.47	Singapore	9.49	Kazakhstan	2.72
2	Qatar	7.72	Qatar	7.60	Qatar	7.50	China	2.70
3	Europe	7.17	Europe	7.00	Europe	7.11	Bangladesh	1.92
27	Bangladesh	-10.83	Bangladesh	-10.09	Bangladesh	-9.32	Jordan	-0.94
28	Myanmar	-12.78	Myanmar	-12.54	Myanmar	-12.70	Kuwait	-0.99
29	Pakistan	-14.87	Pakistan	-15.10	Pakistan	-15.08	Brunei	-1.04

Table 38: top 3 best and worst BRI countries for the results in social assessment, from 2014 to 2016, and overall improvement from 2010 to 2016.

6.4 Economic sector

Moving to the economic sector, the top results of the ranking are represented by Middle East countries, in particular Qatar, Kuwait and United Arab Emirates UAE. It is worth paying attention to the value of the first ranked, Qatar, which presents a wide gap with respect to the rest of the classification and it is almost the double of the second highest result. This means that Qatar shows a great power in outranking all the other alternatives and that it performs much better than the other countries in the considered economic KPIs. As mentioned before, it is probably due to its economy based on fossil fuel production and in particular on the exports of LNG. Another country which is present among the highest positions is Brunei Darussalam, but only in 2010. In fact, from 2011 onwards, UAE outranks Brunei and it is included in the top 3 best result, thanks to its improvement year after year, until it also surpasses Kuwait in 2015 and gains the second position of the economic ranking. On the contrary, considering the worst results, Jordan and Iran are always ranked last and second last for all the considered period of time. The third last position is instead occupied by Turkey or Iraq alternately from 2010 to 2013, while from 2014 onwards it is covered by Pakistan. Finally, as far as the sustainability progress is concerned, Kazakhstan and China show again the highest improvement from 2010 to 2016, even in the economic sector, aside from the general sustainability improvement ranking. In the last places there are Myanmar and Thailand, which also show bad sustainability results and improvement in total, but also Brunei, which instead is in the first position for sustainability outcome.

Rank	2010		2011		2012		2013	
1	Qatar	17.45	Qatar	17.15	Qatar	16.82	Qatar	16.34
2	Kuwait	9.10	Kuwait	9.62	Kuwait	10.10	Kuwait	9.33
3	Brunei	8.24	UAE	8.14	UAE	8.48	UAE	8.25
27	Turkey	-6.16	Iraq	-5.81	Turkey	-5.78	Iraq	-6.19
28	Iran	-6.96	Iran	-7.05	Iran	-7.47	Iran	-7.61
29	Jordan	-7.78	Jordan	-8.13	Jordan	-8.47	Jordan	-8.98

Table 39: top 3 best and worst BRI countries for the results in economic assessment, from 2010 to 2013.

Rank	2014		2015		2016		2010-2016 improvement	
1	Qatar	16.26	Qatar	16.12	Qatar	16.19	Kazakhstan	5.00
2	Kuwait	9.19	UAE	8.76	UAE	9.01	China	4.55
3	UAE	8.54	Kuwait	8.70	Kuwait	8.64	Saudi Arabia	1.67
27	Pakistan	-6.10	Pakistan	-6.03	Pakistan	-6.13	Myanmar	-1.64
28	Iran	-7.71	Iran	-7.40	Iran	-6.99	Brunei	-1.87
29	Jordan	-9.01	Jordan	-8.92	Jordan	-9.20	Thailand	-1.91

Table 40: top 3 best and worst BRI countries for the results in economic assessment, from 2014 to 2016, and overall improvement from 2010 to 2016.

6.5 Energy sector

As far as the energy is concerned, the countries with the highest results are Singapore, Bahrain and Qatar, which are all small and wealthy countries with the main economic activities based on fossil fuels. Qatar holds the third position from 2010 to 2013 and then it is surpassed by Europe. In fact, after 2014 there is a rapid escalation of Europe until it reaches the first place in 2016. The last two results in the energy assessment are Pakistan and Bangladesh, which are also in the final places of the sustainability ranking in general. The third last country is alternately Mongolia, mainly in the first years considered, and Jordan. Concerning the improvements from 2010 to 2016 in the energy sector, the first two countries are again China and Kazakhstan, which constitute the main sustainability progresses on the whole, in the BRI region under consideration. The third highest improvement in energy sector is experienced by Europe, which in effect grows rapidly from 2014 onwards until reaching the top of the ranking. On the contrary, Qatar, which was in the third position for the outcome of energy assessment, before being surpassed by Europe, is also in the top 3 worst energy progress of the BRI countries. Finally, in the last two positions of the ranking for energy improvement there are Pakistan and Azerbaijan, which also show bad improvements for sustainability in general.

Rank	2010		2011		2012		2013	
1	Singapore	4.83	Singapore	4.96	Bahrain	4.66	Bahrain	4.92
2	Bahrain	4.70	Bahrain	4.75	Singapore	4.65	Singapore	4.44
3	Qatar	4.51	Qatar	4.70	Qatar	4.47	Qatar	4.04
27	Mongolia	-2.62	Mongolia	-3.78	Mongolia	-2.68	Mongolia	-3.25
28	Pakistan	-3.25	Pakistan	-4.67	Pakistan	-4.74	Pakistan	-5.08
29	Bangladesh	-7.84	Bangladesh	-7.72	Bangladesh	-7.91	Bangladesh	-8.18

Table 41: top 3 best and worst BRI countries for the results in energy assessment, from 2010 to 2013.

Rank	2014		2015		2016		2010-2016 improvement	
1	Bahrain	4.70	Bahrain	4.67	Europe	4.37	China	4.16
2	Singapore	4.12	Europe	4.57	Bahrain	4.08	Kazakhstan	3.05
3	Europe	4.11	Singapore	4.21	Singapore	3.81	Europe	1.34
27	Jordan	-3.01	Mongolia	-3.62	Jordan	-3.01	Qatar	-1.11
28	Pakistan	-4.10	Pakistan	-4.49	Pakistan	-4.81	Pakistan	-1.55
29	Bangladesh	-8.33	Bangladesh	-7.98	Bangladesh	-7.03	Azerbaijan	-2.26

Table 42: top 3 best and worst BRI countries for the results in energy assessment, from 2014 to 2016, and overall improvement from 2010 to 2016.

6.6 ENVIRONMENTAL SECTOR

Finally, the environmental assessment has been produced to complete the sectoral analysis on the 4 spheres of sustainability. In this category, Europe is the first classified in all the years considered, with a high result several units away from the rest of BRI countries. Another country at the top of the ranking is Brunei Darussalam, since it is a small country with limited environmental impacts. From 2010 to 2012 Malaysia has been ranked third in the environmental evaluation, but after 2013 it is outranked by Kazakhstan, which rapidly grows and conquers the second place of the classification. This rapid growth is probably due to the implementation of carbon pricing mechanism after 2013. Concerning the lowest results in the environmental sector, they are represented by Pakistan and Bangladesh, which in general have the worst sustainability results of all, and China, from 2010 to 2012. After 2013 also some jurisdiction in China decided to implement some forms of carbon pricing mechanisms, making China's result improve quite fast. In fact, from 2013 onwards, the third last outcome of the environmental assessment is represented by Uzbekistan and Saudi Arabia alternately. In the end, considering the improvement from 2010 to 2016 in the environmental sector, the greatest progresses are experienced again by China, Kazakhstan and Europe, as it happens for the energy field. On the contrary, the countries with the lowest improvements are Iran, Oman and United Arab Emirates.

Rank	2010		2011		2012		2013	
1	Europe	10.61	Europe	10.95	Europe	11.22	Europe	11.42
2	Brunei	7.41	Brunei	7.47	Brunei	7.17	Kazakhstan	6.95
3	Malaysia	5.04	Malaysia	5.16	Malaysia	4.93	Brunei	6.81
27	Pakistan	-6.85	China	-7.45	China	-6.48	Uzbekistan	-5.47
28	China	-7.09	Pakistan	-7.46	Pakistan	-6.84	Pakistan	-7.31
29	Bangladesh	-8.26	Bangladesh	-8.00	Bangladesh	-7.76	Bangladesh	-7.82

Table 43: top 3 best and worst BRI countries for the results in environmental assessment, from 2010 to 2013.

Rank	2014		2015		2016		2010-2016 improvement	
1	Europe	11.88	Europe	11.84	Europe	11.91	China	8.67
2	Kazakhstan	7.15	Kazakhstan	6.98	Kazakhstan	7.19	Kazakhstan	6.61
3	Brunei	6.90	Brunei	6.52	Brunei	6.59	Europe	1.30
27	Uzbekistan	-5.17	Saudi Arabia	-5.58	Saudi Arabia	-5.30	Iran	-1.33
28	Pakistan	-7.41	Pakistan	-6.64	Pakistan	-7.22	Oman	-1.37
29	Bangladesh	-8.55	Bangladesh	-7.72	Bangladesh	-7.58	UAE	-2.04

Table 44: top 3 best and worst BRI countries for the results in environmental assessment, from 2014 to 2016, and overall improvement from 2010 to 2016.

CONCLUSIONS

Sustainability is a very current theme, at the centre of political debates, local, national and international action plans, business objectives and it is even present in our everyday life. In our analysis, we have reported the main interpretations and applications of the concept of sustainability and we have developed our connotation of the word, based on 4 interconnected sectors, namely society, economy, energy and environment. We have decided to apply these considerations and assess the sustainability level of the countries, which are involved in the Belt and Road Initiative, abbreviated BRI. At the moment there are 130 countries involved in all continents and BRI also became an opportunity to boost sustainability and environmental protection all over the world. Given the vastness of the area under consideration, we have decided to focus on the Eurasian continent, and we have made a selection of the BRI countries, to represent the most important contributions to the energy TFC, Imports and Exports of the area. It has resulted in a list of 30 countries, which, at first, we have analysed to produce an overview of the energy sustainability along BRI. The main fields under investigation were energy and electricity supply and consumption, environmental impacts and carbon pricing policies. Considering the energy dimension of the BRI region,

- the 30 BRI countries have a TPES value equal to 297528 PJ and a total TFC equal to 201603 PJ, representing respectively about 50% of both TPES and TFC of the entire world.
- The countries which contribute the most to the total regional TPES are China (42% of the 30 BRI total), Europe (23%) and Russia (10%). Similar shares are shown for TFC.
- In addition to consume large quantities of energy, Europe and China are also the greatest energy importers of the area, while the most relevant energy exporters are Russia and Saudi Arabia.

Moving to electricity of the area under consideration,

- most of electricity is still generated using fossil fuels, which specifically cover the 67% of the total electricity generation in the 30 BRI countries and 36% of the total generation in the world.
- The countries which produce the greatest amounts of electricity, both from fossil and non-fossil resources, are in order China, Europe and Russia.
- The regions which relying the most on fossil fuels are Central Asia and Middle East, while the countries with the highest share of non-fossil resources in their electricity mix are Europe (50%), Myanmar (56%) and Vietnam (45%).

Considering the environmental impacts caused by the selected countries,

- the total amount of GHG of the area is equal to 26504 Mt of CO_2 equivalent, which account for 54% of the total GHG emissions in the world. Focusing on CO_2 emissions, the chosen BRI nations are responsible for 20118 Mt, which cover 62% of the CO_2 emitted worldwide.

- Once again, the countries with the greatest shares of both CO_2 and GHG emissions in the region are China (about 50% of the 30 BRI total), Europe (17%) and Russia (8%). These countries are also the most polluting ones for N_2O and HFC emissions.
- For the mean annual level of exposure to PM 2.5, it resulted that the most polluted countries are Qatar, Saudi Arabia and Bahrain.

To complete the overview on the sustainability status of the 30 BRI countries, we have also investigated the presence or absence of carbon pricing mechanisms.

- Unfortunately, most of the BRI countries do not have a carbon pricing mechanism and they are not even considering implementing it.
- In this framework, Europe is the area with the most advanced environmental policies, since it has introduced a regional ETS and in some countries even a carbon tax.
- Carbon tax is a measure implemented only in Europe and Singapore, but generally speaking it is the ETS the most common solution adopted or considered in the Eurasian region.
- Another important issue is that when carbon pricing mechanisms are implemented, their tax rates are usually too low to meet the goals on emission reduction.

Once we have finished to analyse the present state of the 30 BRI countries, we have decided to implement the actual sustainability assessment, in the period 2010-2016. Based on our definition of sustainability, we have selected 15 KPIs to represent the main characteristics of the 30 BRI countries in the fields of society, economy, energy and environment. To elaborate them all together and obtain the ranking of the countries according to their annual sustainability level, we have used the theories of Multi Criteria Decision Analysis MCDA and in particular the method PROMETHEE II. This algorithm has been implemented through a MATLAB code, which has produced the annual lists of the 30 BRI countries with their respective value of net flow, used as sustainability outcome. In summary, the achieved results have shown that

- small and wealthy countries, with stable economies based on fossil fuel production or refinement, are favoured and cover the highest positions in the ranking. This is the case for Brunei Darussalam, which is often ranked first, Singapore or other Middle East countries, like Qatar and Kuwait. However, their progress towards sustainability in time is among the lowest of the BRI region.
- In addition to these countries, also Europe is in the top places of the ranking, but not the first sustainable area until 2016. This is probably due to the fact that it has been considered as the average of a set of different countries. Europe is the best case possible, since not only has a high sustainability result, but it also presents one of the highest improvement of sustainability in time.
- Aside from Europe, the countries which experienced the highest progress in sustainability of all are China and Kazakhstan, thanks to their increasing performances of most of the KPIs and in particular thanks to the implementation of carbon pricing mechanisms.

- The countries with the lowest sustainability level are Pakistan and Bangladesh, which are always ranked last from 2010 to 2016. In addition, Pakistan shows very poor improvement towards sustainable development in time. On the contrary, Bangladesh is improving its sustainability score at high rates.

Sustainability assessment is a necessary tool to measure the actual results of implemented policies, in the present and in the future, and to optimize their effectiveness. Moreover, BRI is an active and important initiative of international cooperation, involving some of the global superpowers around the world. Some future prospects of improvement for this analysis might be

- Expand the area of focus to all the Eurasian countries of BRI or even to all the countries interested by the initiative worldwide.
- Find and include additional KPIs, more representative of the sustainability sectors, to better reflect the qualities and the criticalities of each country.
- Increase the length of the time period considered, in order to give a wider time perspective and better analyse how sustainability is evolving in these countries.
- Develop a model of how carbon pricing mechanisms affect and are affected by socio-economic indicators and by the level of pollution itself. In this way, it would be possible to produce some scenario analyses, to investigate the sustainability level and the possible consequences of implementing carbon pricing mechanisms along BRI.

Appendix I

Energy Along BRI parameters

Name	Symbol	Definition	Unit of measure
Total Primary Energy Supply	TPES	Overall internal energy needs of a given country or area, requested to satisfy its consumption. This is also referred to as Gross Inland Consumption. It represents domestic demand only and is broken down into power generation, other energy sector and total final consumption and it excludes international marine and aviation bunkers.	PJ
Total Final Consumption	TFC	Amount of primary and secondary energy commodities directly consumed in the end-use sectors in order to fulfil the so-called energy services demands (i.e. space heating and cooling, water heating production, lighting, cooking, use of electrical appliances for the residential and commercial sectors, industrial production, mobility of passengers and goods, etc.)	PJ
Net Energy Imports	I	Net imports comprise the total amount of Imports minus exports for total energy (<0 corresponds to an export).	PJ

Table 45: Parameters chosen to analyse the energy dimension of BRI countries.

Electricity production parameters

Name	Symbol	Definition	Unit of measure
Total electricity generation	EGEN	Total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.	TWh
Fossil Fuel electricity generation	$EGEN_{FF}$	Total amount of electricity generated using fossil fuels, so coal, oil and natural gas. Coal also includes peat and oil shale where relevant.	TWh
Non-Fossil electricity generation	$EGEN_{RES}$	Total amount of electricity generated using non fossil resources, such as hydroelectric, nuclear, photovoltaic and wind energy.	TWh
Total electricity consumption	EL	Electricity generation less power plants' own use and transmission, distribution, and transformation losses less export plus import.	TWh
Diversification of Electricity Generation	S	Measure of the diversification of electricity generation. Indicator obtained adapting Shannon diversity index. It takes into account the share of energy commodity *i*, p_i, in electricity generation. $$S = \frac{D}{D_{max}}$$ $$D = -\sum_i p_i \ln(p_i)$$ $$D_{max} = -\ln\left(\frac{1}{M}\right)$$ where M is the number of primary sources. The lower the value of this indicator, the lower is the diversification of the electricity generation, meaning that the country is significantly dependent on a specific energy source.	-

Table 46: Parameters chosen to analyse the electricity production of BRI countries.

Environmental Impacts parameters

Name	Symbol	Definition	Unit of measure
Total CO_2 emissions	$CO2_{TOT}$	Total amount of CO_2 emissions.	MtCO2
Total Greenhouse gas emissions	GHG	Annual amount of emissions of all the greenhouse gases, calculated as the amount of CO_2 that would have an equivalent global warming impact.	Mt CO2 eq
Total N_2O emissions	$N2O_{OT}$	Amount of N_2O emissions from N_2O usage, forest and peat fires and other vegetation fires, human sewage discharge and waste incineration (non-energy) and indirect N_2O from atmospheric deposition of NOx and NH_3 from non-agricultural sources (IPCC Source/Sink Categories 3, 5, 6 and 7).	Mt CO2 eq
HFC emissions from industrial processes	HFC	It comprises by-product emissions of HFC-23 from HCFC-22 manufacture and the use of HFCs (IPCC Source/Sink Categories 2E and 2F).	Mt CO2 eq
PM 2.5 air pollution, mean annual exposure	PM	Level of exposure of population to concentration of suspended particles measuring less than 2.5 microns in aerodynamic diameter, which can cause severe health damage to the respiratory system. Exposure is calculated as the annual average of concentration of PM 2.5 by population.	mg/m^3

Table 47: Parameters chosen to analyse the environmental impacts of BRI countries.

Energy and economics parameters

Name	Symbol	Definition	Unit of measure
Gross Domestic Product	GDP	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Dollar figures for GDP are converted from domestic currencies using single year official exchange rates.	Billion 2010 USD
Gross Domestic Product based on purchasing power parity	GDP PPP	GDP PPP is gross domestic product converted to international dollars using purchasing power parity rates (PPP) instead of market exchange rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States.	Billion 2011 UDS
Energy Intensity	ξ	Measure of the energy efficiency of a nation's economy, calculated as the Total Primary Energy Supply divided by the Gross Domestic Product PPP.	MJ/USD 2011
Carbon Intensity	$CO2_{\xi}$	It represents the tons of CO_2 per unit of value added, so it is calculated as the ratio between CO_2 emissions and GDP PPP of a country.	KgCO2/USD 2010 PPP

Table 48: Parameters chosen to analyse energy and economics of BRI countries

Carbon pricing parameters

Name	Symbol	Definition	Unit of measure
Value of carbon pricing	$CP	Total amount of money paid to compensate for emissions in countries where a carbon pricing mechanism is implemented.	Billion USD
Tax rate	TR	Price to which emissions are subjected to. ETS price is the mean value observed between April 2017 and April 2018. Carbon tax price is equal to the value observed on April 1, 2018.	USD/tCO2
Share of emissions covered	%CP	Percentage of emissions produced by a country which are subjected to carbon pricing mechanisms.	%

Table 49: Parameters chosen to analyse carbon pricing of BRI countries.

Sustainability KPIs

Name	Symbol	Definition	Unit of measure	Source
Urbanization rate	URB	The percentage of population living in cities or area defines as urban, so with a greater population density than rural areas, with respect to the total population.	%	World Bank
Life expectancy at birth	LE	Number of years that a new-born infant would live if prevailing mortality patterns at its birth remained the same throughout its life.	Years	World Bank
Mortality Rate, infant	MR	The reported number of infants who died before the first year of age with respect to 1,000 live birth per year.	Deaths	World Bank
Access to electricity	α_{el}	Percentage of the total population in a given area that have relatively simple and stable access to electricity.	%	World Bank
Air pollution deaths	Ω	Number of deaths caused by air pollution with respect to 100,000 deaths per year.	Deaths	Institute for Health Metrics and Evaluation
PM 2.5 level of exposure	PM25	Level of exposure of population to concentration of suspended particles measuring less than 2.5 microns in aerodynamic diameter, which can cause severe health damage to the respiratory system. Exposure is calculated as the annual average of concentration of PM 2.5 by population.	mg/m^3	World Bank
GDP PPP per capita	$GDP_{P,c}$	GDP PPP per capita is gross domestic product based on purchasing power parity divided by midyear population.	International USD 2011/ per capita	World Bank
Employment to population ratio	EMP	The percentage of the total population employed. The condition of employment is given by a person in the working age, so aged 15 or older, who was occupied in producing goods or services for pay or profit, during a period of time.	%	World Bank
Carbon Pricing measures	CP	The actual implementation, scheduling or consideration of carbon pricing mechanisms in the whole nation or in smaller jurisdictions. The carbon pricing measures can be the Emission Trading System ETS or the carbon tax. They have been quantized as 1 if a carbon pricing measure is implemented at national level, 0.7 is a measures is implemented in some areas, 0.5 if a measure is under consideration.	-	World Bank and Institute for Climate Economics
TPES per square metres	$TPES_{m2}$	The Total Primary Energy Supply, TPES, which is total internal energy demand of a country, constituted of power generation, other energy sector and total final consumption, divided by the total area of the country under consideration.	TJ/m^2	IEA
% RES in electricity generation	RES	The percentage of the output of electricity produced by renewable energy sources, over the total output of electricity produced. It defines the penetration of renewables in the electricity mix in a given country.	%	IEA
Total Self Sufficiency	S_{TOT}	The ratio between the total domestic energy production and the total primary energy supply TPES.	%	IEA
Electricity consumption per capita	ε_c	The actual amount of electricity consumed by end-users, so the gross generation + imports – exports -losses, divided by population.	kWh per capita	IEA
Total CO_2 emissions	$CO2_{FUEL}$	Total amount of carbon dioxide emissions, caused by burning fossil fuels.	Mt	IEA
% Forest area	A_{FOR}	Percentage of land area under natural or planted trees for at least 5 meters in situ, excluding agricultural and green urban areas.	%	World Bank

Table 50: KPIs chosen to assess the sustainability level of BRI countries.

APPENDIX II

2010											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ
Brunei	8.37	Brunei	7.59	Brunei	6.74	Brunei	5.90	Qatar	5.26	Brunei	5.78
Qatar	7.11	Qatar	6.76	Qatar	6.35	Qatar	5.82	Brunei	5.10	Qatar	5.55
Singapore	6.48	Singapore	5.75	Europe	5.29	Europe	5.08	Europe	4.91	Europe	5.24
Kuwait	6.15	Kuwait	5.56	Singapore	5.04	Singapore	4.40	Singapore	3.83	Singapore	4.43
Europe	5.68	Europe	5.50	Kuwait	4.88	Kuwait	4.23	Kuwait	3.62	Kuwait	4.17
UAE	4.72	UAE	3.98	UAE	3.27	UAE	2.71	UAE	2.22	UAE	2.73
Bahrain	2.98	Bahrain	2.59	Bahrain	2.27	Bahrain	2.00	Bahrain	1.75	Bahrain	2.10
Israel	2.30	Azerbaijan	2.08	Azerbaijan	1.87	Azerbaijan	1.67	Azerbaijan	1.42	Azerbaijan	1.66
Azerbaijan	2.26	Israel	1.99	Israel	1.69	Israel	1.42	Israel	1.16	Israel	1.48
Oman	2.18	Oman	1.78	Russia	1.43	Malaysia	1.20	Malaysia	1.07	Malaysia	1.26
Russia	1.88	Russia	1.67	Oman	1.41	Russia	1.19	Russia	1.00	Russia	1.17
Malaysia	1.69	Malaysia	1.51	Malaysia	1.34	Oman	1.12	Oman	0.88	Oman	1.13
Kazakhstan	0.14	Kazakhstan	-0.01	Kazakhstan	-0.11	Kazakhstan	-0.16	Kazakhstan	-0.16	Kazakhstan	0.04
Vietnam	0.04	Vietnam	-0.07	Vietnam	-0.18	Indonesia	-0.20	Indonesia	-0.21	Indonesia	-0.28
Thailand	-0.32	Indonesia	-0.32	Indonesia	-0.21	Vietnam	-0.26	Vietnam	-0.31	Vietnam	-0.31
Saudi Arabia	-0.51	Thailand	-0.37	Thailand	-0.34	Thailand	-0.34	Thailand	-0.32	Thailand	-0.32
Indonesia	-0.51	Saudi Arabia	-0.66	Saudi Arabia	-0.74	Saudi Arabia	-0.77	Saudi Arabia	-0.74	Saudi Arabia	-0.65
Turkey	-1.29	Turkey	-1.17	Turkey	-1.06	Turkey	-0.94	Turkey	-0.82	Turkey	-0.92
Iran	-2.11	Iran	-1.85	Iran	-1.62	Iran	-1.36	Iran	-1.15	Iran	-1.38
Jordan	-2.56	Jordan	-2.11	Jordan	-1.74	Jordan	-1.44	Jordan	-1.25	Jordan	-1.66
Turkmenistan	-2.78	Turkmenistan	-2.40	Turkmenistan	-2.07	Turkmenistan	-1.74	Turkmenistan	-1.46	Turkmenistan	-1.75
Iraq	-3.29	Mongolia	-2.82	Mongolia	-2.34	Mongolia	-1.94	Mongolia	-1.60	Mongolia	-2.14
Mongolia	-3.45	Iraq	-2.93	Iraq	-2.57	Iraq	-2.22	Iraq	-1.89	Iraq	-2.19
Uzbekistan	-3.62	Philippines	-3.22	Philippines	-2.79	Philippines	-2.42	Philippines	-2.05	Uzbekistan	-2.39
Philippines	-3.68	Uzbekistan	-3.25	Uzbekistan	-2.85	Uzbekistan	-2.45	Uzbekistan	-2.07	Philippines	-2.45
Myanmar	-4.30	Myanmar	-3.93	Myanmar	-3.50	Myanmar	-3.14	Myanmar	-2.81	Myanmar	-3.16
China	-5.11	China	-4.88	China	-4.62	China	-4.30	China	-3.99	China	-4.11
Pakistan	-8.61	Pakistan	-7.89	Pakistan	-6.92	Pakistan	-6.03	Pakistan	-5.24	Pakistan	-6.00
Bangladesh	-9.86	Bangladesh	-8.90	Bangladesh	-7.91	Bangladesh	-7.01	Bangladesh	-6.13	Bangladesh	-7.01

Table 51: sustainability ranking of BRI countries in 2010, according to different values of preference and indifference indexes.

2011											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ
Brunei	8.15	Brunei	7.32	Brunei	6.41	Qatar	5.84	Qatar	5.26	Qatar	5.59
Qatar	7.22	Qatar	6.82	Qatar	6.39	Brunei	5.53	Europe	5.03	Brunei	5.44
Singapore	6.55	Kuwait	5.98	Europe	5.39	Europe	5.20	Brunei	4.74	Europe	5.35
Kuwait	6.54	Singapore	5.83	Kuwait	5.35	Kuwait	4.65	Kuwait	3.94	Kuwait	4.50
Europe	5.82	Europe	5.62	Singapore	5.10	Singapore	4.44	Singapore	3.89	Singapore	4.49
UAE	4.95	UAE	4.17	UAE	3.45	UAE	2.85	UAE	2.34	UAE	2.84
Bahrain	2.87	Bahrain	2.52	Bahrain	2.22	Bahrain	1.97	Bahrain	1.72	Bahrain	2.07

Israel	2.39	Israel	2.08	Israel	1.74	Israel	1.46	Israel	1.20	Israel	1.55
Russia	2.04	Russia	1.86	Russia	1.59	Russia	1.32	Malaysia	1.10	Malaysia	1.32
Oman	1.81	Malaysia	1.57	Malaysia	1.42	Malaysia	1.25	Russia	1.08	Russia	1.32
Malaysia	1.75	Azerbaijan	1.50	Azerbaijan	1.32	Azerbaijan	1.11	Azerbaijan	0.94	Azerbaijan	1.15
Azerbaijan	1.66	Oman	1.49	Oman	1.17	Oman	0.91	Oman	0.70	Oman	0.93
Vietnam	0.49	Vietnam	0.32	Vietnam	0.18	Vietnam	0.06	Vietnam	-0.02	Kazakhstan	0.00
Kazakhstan	0.01	Kazakhstan	-0.09	Kazakhstan	-0.16	Kazakhstan	-0.16	Kazakhstan	-0.14	Vietnam	-0.03
Saudi Arabia	0.00	Saudi Arabia	-0.22	Indonesia	-0.22	Indonesia	-0.21	Indonesia	-0.17	Thailand	-0.21
Thailand	-0.16	Thailand	-0.26	Thailand	-0.27	Thailand	-0.26	Thailand	-0.25	Indonesia	-0.30
Indonesia	-0.61	Indonesia	-0.35	Saudi Arabia	-0.36	Saudi Arabia	-0.44	Saudi Arabia	-0.47	Saudi Arabia	-0.39
Turkey	-1.19	Turkey	-1.05	Turkey	-0.99	Turkey	-0.88	Turkey	-0.76	Turkey	-0.82
Iran	-2.08	Iran	-1.79	Iran	-1.55	Iran	-1.31	Iran	-1.12	Iran	-1.33
Turkmenistan	-2.31	Turkmenistan	-1.98	Turkmenistan	-1.70	Turkmenistan	-1.44	Turkmenistan	-1.22	Turkmenistan	-1.48
Jordan	-2.56	Jordan	-2.11	Jordan	-1.75	Jordan	-1.46	Jordan	-1.26	Jordan	-1.66
Iraq	-3.31	Iraq	-2.87	Mongolia	-2.44	Mongolia	-2.06	Mongolia	-1.72	Iraq	-2.16
Mongolia	-3.39	Mongolia	-2.95	Iraq	-2.46	Iraq	-2.07	Iraq	-1.75	Mongolia	-2.17
Philippines	-3.63	Philippines	-3.20	Philippines	-2.80	Philippines	-2.42	Philippines	-2.06	Philippines	-2.44
Uzbekistan	-4.22	Uzbekistan	-3.73	Uzbekistan	-3.22	Uzbekistan	-2.75	Uzbekistan	-2.28	Uzbekistan	-2.72
Myanmar	-4.42	Myanmar	-4.00	Myanmar	-3.54	Myanmar	-3.14	Myanmar	-2.78	Myanmar	-3.16
China	-5.34	China	-5.11	China	-4.83	China	-4.46	China	-4.12	China	-4.24
Pakistan	-9.19	Pakistan	-8.54	Pakistan	-7.58	Pakistan	-6.61	Pakistan	-5.75	Pakistan	-6.48
Bangladesh	-9.82	Bangladesh	-8.84	Bangladesh	-7.85	Bangladesh	-6.94	Bangladesh	-6.06	Bangladesh	-6.95

Table 52: sustainability ranking of BRI countries in 2011, according to different values of preference and indifference indexes.

2012											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ
Brunei	8.14	Brunei	7.37	Brunei	6.53	Brunei	5.68	Europe	5.04	Brunei	5.57
Qatar	6.97	Qatar	6.49	Qatar	6.06	Qatar	5.56	Qatar	5.00	Europe	5.37
Kuwait	6.61	Kuwait	6.12	Kuwait	5.56	Europe	5.23	Brunei	4.89	Qatar	5.35
Singapore	6.36	Europe	5.71	Europe	5.44	Kuwait	4.92	Kuwait	4.24	Kuwait	4.76
Europe	5.97	Singapore	5.62	Singapore	4.91	Singapore	4.27	Singapore	3.72	Singapore	4.32
UAE	4.95	UAE	4.22	UAE	3.50	UAE	2.90	UAE	2.38	UAE	2.86
Bahrain	2.68	Bahrain	2.28	Bahrain	1.99	Bahrain	1.77	Bahrain	1.54	Bahrain	1.88
Israel	2.28	Russia	1.96	Russia	1.66	Russia	1.37	Russia	1.09	Israel	1.40
Russia	2.21	Israel	1.90	Israel	1.58	Israel	1.30	Israel	1.04	Russia	1.38
Oman	1.97	Oman	1.64	Oman	1.31	Malaysia	1.13	Malaysia	0.99	Malaysia	1.24
Malaysia	1.70	Malaysia	1.50	Malaysia	1.29	Oman	1.02	Azerbaijan	0.87	Oman	1.03
Azerbaijan	1.37	Azerbaijan	1.24	Azerbaijan	1.11	Azerbaijan	1.00	Oman	0.78	Azerbaijan	0.98
Vietnam	0.68	Vietnam	0.68	Vietnam	0.50	Vietnam	0.34	Vietnam	0.23	Vietnam	0.20
Kazakhstan	0.19	Kazakhstan	0.02	Kazakhstan	-0.07	Kazakhstan	-0.10	Kazakhstan	-0.10	Kazakhstan	0.07
Saudi Arabia	0.10	Saudi Arabia	-0.12	Saudi Arabia	-0.26	Indonesia	-0.30	Indonesia	-0.25	Saudi Arabia	-0.31
Thailand	-0.31	Indonesia	-0.40	Indonesia	-0.32	Saudi Arabia	-0.35	Saudi Arabia	-0.37	Thailand	-0.32
Indonesia	-0.63	Thailand	-0.43	Thailand	-0.43	Thailand	-0.42	Thailand	-0.39	Indonesia	-0.35

Turkey	-1.20	Turkey	-1.08	Turkey	-1.00	Turkey	-0.91	Turkey	-0.81	Turkey	-0.87
Turkmenistan	-2.19	Turkmenistan	-1.93	Turkmenistan	-1.66	Turkmenistan	-1.40	Turkmenistan	-1.19	Turkmenistan	-1.43
Iran	-2.42	Iran	-2.12	Iran	-1.82	Iran	-1.54	Iran	-1.31	Iran	-1.56
Jordan	-2.78	Jordan	-2.37	Jordan	-1.97	Mongolia	-1.63	Mongolia	-1.34	Jordan	-1.85
Iraq	-2.98	Mongolia	-2.47	Mongolia	-1.98	Jordan	-1.66	Jordan	-1.46	Mongolia	-1.86
Mongolia	-3.13	Iraq	-2.57	Iraq	-2.23	Iraq	-1.90	Iraq	-1.60	Iraq	-1.92
Philippines	-3.94	Philippines	-3.51	Philippines	-3.09	Philippines	-2.69	Philippines	-2.31	Philippines	-2.71
Uzbekistan	-4.17	Uzbekistan	-3.71	Uzbekistan	-3.25	Uzbekistan	-2.79	Uzbekistan	-2.36	Uzbekistan	-2.74
Myanmar	-4.58	Myanmar	-4.15	Myanmar	-3.70	Myanmar	-3.28	Myanmar	-2.91	Myanmar	-3.31
China	-4.90	China	-4.69	China	-4.41	China	-4.11	China	-3.82	China	-3.91
Pakistan	-9.04	Pakistan	-8.32	Pakistan	-7.41	Pakistan	-6.46	Pakistan	-5.61	Pakistan	-6.38
Bangladesh	-9.89	Bangladesh	-8.87	Bangladesh	-7.85	Bangladesh	-6.94	Bangladesh	-5.96	Bangladesh	-6.87

Table 53: sustainability ranking of BRI countries in 2012, according to different values of preference and indifference indexes.

2013											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ
Brunei	8.10	Brunei	7.30	Brunei	6.47	Brunei	5.65	Europe	5.17	Brunei	5.56
Qatar	6.56	Qatar	6.06	Europe	5.61	Europe	5.38	Brunei	4.90	Europe	5.48
Europe	6.17	Europe	5.91	Qatar	5.61	Qatar	5.05	Qatar	4.49	Qatar	4.86
Kuwait	6.14	Kuwait	5.63	Kuwait	5.04	Kuwait	4.34	Kazakhstan	3.78	Kuwait	4.18
Singapore	6.13	Singapore	5.43	Singapore	4.73	Singapore	4.07	Kuwait	3.65	Singapore	4.11
UAE	4.51	Kazakhstan	3.89	Kazakhstan	3.79	Kazakhstan	3.77	Singapore	3.51	Kazakhstan	3.96
Kazakhstan	4.04	UAE	3.76	UAE	3.07	UAE	2.47	UAE	1.97	UAE	2.45
Bahrain	2.59	Bahrain	2.18	Bahrain	1.88	Bahrain	1.63	Bahrain	1.39	Bahrain	1.72
Russia	2.03	Russia	1.74	Russia	1.41	Russia	1.10	Russia	0.80	Israel	1.14
Israel	2.00	Israel	1.64	Israel	1.32	Israel	1.03	Malaysia	0.77	Russia	1.12
Oman	1.71	Malaysia	1.40	Malaysia	1.13	Malaysia	0.92	Israel	0.76	Malaysia	1.07
Malaysia	1.63	Oman	1.35	Oman	1.01	Oman	0.71	Azerbaijan	0.50	Oman	0.76
Azerbaijan	1.00	Azerbaijan	0.86	Azerbaijan	0.74	Azerbaijan	0.63	Oman	0.47	Azerbaijan	0.61
Vietnam	0.26	Vietnam	0.24	Vietnam	0.04	Vietnam	-0.10	China	0.16	China	0.08
Saudi Arabia	-0.13	Saudi Arabia	-0.34	China	-0.41	China	-0.12	Vietnam	-0.18	Vietnam	-0.21
Thailand	-0.82	Indonesia	-0.65	Saudi Arabia	-0.48	Indonesia	-0.55	Indonesia	-0.52	Saudi Arabia	-0.54
Indonesia	-0.84	China	-0.69	Indonesia	-0.58	Saudi Arabia	-0.57	Saudi Arabia	-0.59	Indonesia	-0.61
China	-0.88	Thailand	-0.88	Thailand	-0.85	Thailand	-0.82	Thailand	-0.77	Thailand	-0.73
Turkey	-1.37	Turkey	-1.23	Turkey	-1.15	Turkey	-1.07	Turkey	-0.98	Turkey	-1.05
Turkmenistan	-2.38	Turkmenistan	-2.17	Turkmenistan	-1.90	Turkmenistan	-1.65	Turkmenistan	-1.45	Turkmenistan	-1.67
Iran	-2.72	Iran	-2.40	Iran	-2.08	Iran	-1.80	Iran	-1.57	Iran	-1.83
Jordan	-3.21	Jordan	-2.76	Jordan	-2.32	Jordan	-1.98	Jordan	-1.77	Jordan	-2.18
Iraq	-3.43	Iraq	-3.00	Mongolia	-2.55	Mongolia	-2.15	Mongolia	-1.84	Iraq	-2.26
Mongolia	-3.65	Mongolia	-3.04	Iraq	-2.59	Iraq	-2.21	Iraq	-1.91	Mongolia	-2.34
Philippines	-4.42	Philippines	-3.94	Philippines	-3.50	Philippines	-3.08	Uzbekistan	-2.68	Philippines	-3.10

Uzbekistan	-4.61	Uzbekistan	-4.13	Uzbekistan	-3.64	Uzbekistan	-3.15	Philippines	-2.69	Uzbekistan	-3.11
Myanmar	-5.02	Myanmar	-4.55	Myanmar	-4.11	Myanmar	-3.68	Myanmar	-3.27	Myanmar	-3.69
Pakistan	-9.36	Pakistan	-8.62	Pakistan	-7.73	Pakistan	-6.78	Pakistan	-5.92	Pakistan	-6.71
Bangladesh	-10.03	Bangladesh	-8.98	Bangladesh	-7.95	Bangladesh	-7.04	Bangladesh	-6.17	Bangladesh	-7.09

Table 54: sustainability ranking of BRI countries in 2013, according to different values of preference and indifference indexes.

2014											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ	Country	Φ
Brunei	7.81	Brunei	6.99	Brunei	6.09	Europe	5.62	Europe	5.39	Europe	5.67
Europe	6.51	Europe	6.20	Europe	5.88	Brunei	5.25	Brunei	4.47	Brunei	5.16
Qatar	6.51	Qatar	6.04	Qatar	5.55	Qatar	4.98	Qatar	4.40	Qatar	4.79
Kuwait	6.17	Kuwait	5.64	Kuwait	5.03	Kuwait	4.37	Kazakhstan	3.92	Kuwait	4.27
Singapore	6.05	Singapore	5.36	Singapore	4.69	Singapore	4.04	Kuwait	3.73	Kazakhstan	4.15
UAE	4.44	Kazakhstan	4.14	Kazakhstan	4.01	Kazakhstan	3.95	Singapore	3.48	Singapore	4.08
Kazakhstan	4.35	UAE	3.73	UAE	3.02	UAE	2.43	UAE	1.93	UAE	2.40
Bahrain	2.53	Bahrain	2.12	Bahrain	1.80	Bahrain	1.57	Bahrain	1.32	Bahrain	1.66
Russia	2.10	Russia	1.82	Russia	1.50	Russia	1.18	Russia	0.86	Russia	1.17
Israel	1.84	Israel	1.50	Israel	1.18	Israel	0.90	Malaysia	0.74	Malaysia	1.09
Oman	1.83	Oman	1.45	Malaysia	1.13	Malaysia	0.90	Israel	0.64	Israel	1.03
Malaysia	1.65	Malaysia	1.40	Oman	1.07	Oman	0.76	Oman	0.51	Oman	0.82
Azerbaijan	0.99	Azerbaijan	0.86	Azerbaijan	0.75	Azerbaijan	0.64	Azerbaijan	0.50	Azerbaijan	0.62
Vietnam	0.22	Vietnam	0.30	Vietnam	0.25	China	0.11	China	0.35	China	0.27
Saudi Arabia	-0.13	Saudi Arabia	-0.34	China	-0.15	Vietnam	0.10	Vietnam	0.00	Vietnam	-0.08
China	-0.52	China	-0.39	Saudi Arabia	-0.49	Indonesia	-0.57	Indonesia	-0.53	Saudi Arabia	-0.56
Indonesia	-0.84	Indonesia	-0.70	Indonesia	-0.61	Saudi Arabia	-0.59	Saudi Arabia	-0.62	Indonesia	-0.60
Thailand	-0.97	Thailand	-1.01	Thailand	-1.00	Thailand	-0.94	Thailand	-0.87	Thailand	-0.82
Turkey	-1.96	Turkey	-1.75	Turkey	-1.60	Turkey	-1.47	Turkey	-1.33	Turkey	-1.41
Turkmenistan	-2.30	Turkmenistan	-2.07	Turkmenistan	-1.84	Turkmenistan	-1.60	Turkmenistan	-1.40	Turkmenistan	-1.62
Iran	-2.96	Iran	-2.64	Mongolia	-2.27	Mongolia	-1.90	Mongolia	-1.61	Iran	-1.99
Iraq	-3.32	Mongolia	-2.73	Iran	-2.29	Iran	-1.98	Iran	-1.74	Mongolia	-2.14
Mongolia	-3.33	Iraq	-2.80	Iraq	-2.38	Iraq	-2.03	Iraq	-1.76	Iraq	-2.17
Jordan	-3.46	Jordan	-2.99	Jordan	-2.54	Jordan	-2.16	Jordan	-1.91	Jordan	-2.36
Philippines	-4.00	Philippines	-3.57	Philippines	-3.16	Philippines	-2.77	Philippines	-2.41	Philippines	-2.85
Uzbekistan	-4.49	Uzbekistan	-4.02	Uzbekistan	-3.55	Uzbekistan	-3.08	Uzbekistan	-2.64	Uzbekistan	-3.01
Myanmar	-5.09	Myanmar	-4.64	Myanmar	-4.20	Myanmar	-3.75	Myanmar	-3.34	Myanmar	-3.75
Pakistan	-9.24	Pakistan	-8.58	Pakistan	-7.57	Pakistan	-6.64	Pakistan	-5.78	Pakistan	-6.59
Bangladesh	-10.39	Bangladesh	-9.33	Bangladesh	-8.32	Bangladesh	-7.33	Bangladesh	-6.26	Bangladesh	-7.23

Table 55: sustainability ranking of BRI countries in 2014, according to different values of preference and indifference indexes.

2015											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**
Brunei	7.62	Brunei	6.83	Brunei	6.03	Europe	5.71	Europe	5.48	Europe	5.75
Europe	6.69	Europe	6.32	Europe	5.98	Brunei	5.27	Brunei	4.58	Brunei	5.24
Qatar	6.29	Qatar	5.79	Qatar	5.29	Qatar	4.68	Qatar	4.07	Qatar	4.49
Singapore	5.94	Singapore	5.29	Singapore	4.65	Singapore	4.01	Kazakhstan	3.76	Singapore	4.07
Kuwait	5.75	Kuwait	5.18	Kuwait	4.55	Kuwait	3.81	Singapore	3.48	Kazakhstan	4.03
UAE	4.32	Kazakhstan	3.96	Kazakhstan	3.83	Kazakhstan	3.76	Kuwait	3.14	Kuwait	3.71
Kazakhstan	4.17	UAE	3.66	UAE	2.99	UAE	2.40	UAE	1.89	UAE	2.36
Bahrain	2.36	Bahrain	1.99	Bahrain	1.74	Bahrain	1.52	Bahrain	1.30	Bahrain	1.60
Israel	1.86	Russia	1.62	Russia	1.34	Russia	1.05	China	0.76	Malaysia	1.08
Russia	1.86	Israel	1.51	Israel	1.20	Israel	0.92	Russia	0.76	Israel	1.07
Oman	1.72	Malaysia	1.37	Malaysia	1.10	Malaysia	0.87	Malaysia	0.71	Russia	1.03
Malaysia	1.63	Oman	1.32	Oman	0.96	Oman	0.66	Israel	0.68	Oman	0.76
Azerbaijan	0.88	Azerbaijan	0.69	Azerbaijan	0.52	China	0.57	Oman	0.41	China	0.63
Vietnam	0.14	Vietnam	0.15	China	0.35	Azerbaijan	0.40	Azerbaijan	0.29	Azerbaijan	0.46
China	-0.03	China	0.13	Vietnam	0.01	Vietnam	-0.11	Vietnam	-0.20	Vietnam	-0.25
Saudi Arabia	-0.42	Saudi Arabia	-0.70	Turkey	-0.69	Turkey	-0.67	Turkey	-0.62	Thailand	-0.69
Thailand	-0.79	Turkey	-0.71	Saudi Arabia	-0.82	Indonesia	-0.76	Indonesia	-0.69	Turkey	-0.71
Turkey	-0.84	Thailand	-0.87	Indonesia	-0.83	Thailand	-0.82	Thailand	-0.77	Indonesia	-0.76
Indonesia	-1.10	Indonesia	-0.93	Thailand	-0.86	Saudi Arabia	-0.91	Saudi Arabia	-0.95	Saudi Arabia	-0.86
Turkmenist an	-2.59	Turkmenist an	-2.38	Turkmenist an	-2.08	Turkmenist an	-1.80	Turkmenist an	-1.58	Turkmenist an	-1.79
Iran	-2.89	Iran	-2.51	Iran	-2.13	Iran	-1.85	Iraq	-1.60	Iran	-1.89
Iraq	-3.12	Iraq	-2.57	Iraq	-2.16	Iraq	-1.85	Iran	-1.61	Iraq	-1.99
Jordan	-3.36	Jordan	-2.85	Jordan	-2.38	Jordan	-2.02	Jordan	-1.79	Jordan	-2.23
Mongolia	-3.79	Mongolia	-3.15	Mongolia	-2.62	Mongolia	-2.21	Mongolia	-1.90	Mongolia	-2.40
Philippines	-4.21	Philippines	-3.79	Philippines	-3.34	Philippines	-2.91	Philippines	-2.52	Uzbekistan	-2.93
Uzbekistan	-4.35	Uzbekistan	-3.91	Uzbekistan	-3.45	Uzbekistan	-3.01	Uzbekistan	-2.60	Philippines	-2.97
Myanmar	-4.88	Myanmar	-4.45	Myanmar	-4.04	Myanmar	-3.61	Myanmar	-3.22	Myanmar	-3.64
Pakistan	-8.88	Pakistan	-8.10	Pakistan	-7.37	Pakistan	-6.50	Bangladesh	-5.61	Pakistan	-6.50
Bangladesh	-9.99	Bangladesh	-8.88	Bangladesh	-7.76	Bangladesh	-6.62	Pakistan	-5.66	Bangladesh	-6.65

Table 56: sustainability ranking of BRI countries in 2015, according to different values of preference and indifference indexes.

2016											
p=50%, q=6%		p=60%, q=9%		p=70%, q=12%		p=80%, q=15%		p=90%, q=18%		p=90%, q=6%	
Country	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**	**Country**	**Φ**
Brunei	7.28	Brunei	6.51	Europe	5.96	Europe	5.68	Europe	5.44	Europe	5.72
Europe	6.70	Europe	6.34	Brunei	5.67	Brunei	4.93	Brunei	4.23	Brunei	4.90
Qatar	6.22	Qatar	5.76	Qatar	5.30	Qatar	4.76	Qatar	4.22	Qatar	4.61
Singapore	5.84	Singapore	5.16	Singapore	4.52	Singapore	3.89	Kazakhstan	3.71	Kazakhstan	4.01
Kuwait	5.56	Kuwait	5.04	Kuwait	4.46	Kuwait	3.82	Singapore	3.35	Singapore	3.94
UAE	4.28	Kazakhstan	3.93	Kazakhstan	3.80	Kazakhstan	3.73	Kuwait	3.18	Kuwait	3.71
Kazakhstan	4.16	UAE	3.66	UAE	3.00	UAE	2.42	UAE	1.92	UAE	2.35
Bahrain	2.04	Bahrain	1.67	Bahrain	1.40	Bahrain	1.21	Bahrain	1.01	Bahrain	1.34
Russia	1.93	Russia	1.66	Russia	1.38	Russia	1.08	China	0.78	Malaysia	1.14

Israel	1.86	Malaysia	1.49	Malaysia	1.17	Malaysia	0.91	Russia	0.78	Russia	1.05
Oman	1.84	Israel	1.45	Israel	1.09	Israel	0.82	Malaysia	0.72	Israel	0.99
Malaysia	1.82	Oman	1.43	Oman	1.05	Oman	0.74	Israel	0.58	Oman	0.83
Azerbaijan	0.91	Azerbaijan	0.77	Azerbaijan	0.61	China	0.61	Oman	0.50	China	0.69
China	0.18	China	0.26	China	0.43	Azerbaijan	0.47	Azerbaijan	0.36	Azerbaijan	0.51
Vietnam	-0.02	Vietnam	0.01	Vietnam	-0.06	Vietnam	-0.20	Vietnam	-0.27	Vietnam	-0.33
Saudi Arabia	-0.13	Saudi Arabia	-0.36	Saudi Arabia	-0.51	Saudi Arabia	-0.61	Saudi Arabia	-0.64	Thailand	-0.59
Thailand	-0.49	Thailand	-0.67	Thailand	-0.74	Turkey	-0.75	Turkey	-0.70	Saudi Arabia	-0.61
Turkey	-0.91	Turkey	-0.73	Turkey	-0.76	Thailand	-0.76	Indonesia	-0.70	Indonesia	-0.76
Indonesia	-1.06	Indonesia	-0.92	Indonesia	-0.83	Indonesia	-0.77	Thailand	-0.75	Turkey	-0.78
Iran	-2.78	Mongolia	-2.29	Mongolia	-1.75	Mongolia	-1.41	Mongolia	-1.18	Mongolia	-1.79
Turkmenistan	-2.78	Iran	-2.45	Iraq	-2.06	Iraq	-1.73	Iraq	-1.49	Iran	-1.84
Mongolia	-3.00	Turkmenistan	-2.53	Iran	-2.15	Iran	-1.87	Iran	-1.63	Iraq	-1.91
Iraq	-3.10	Iraq	-2.54	Turkmenistan	-2.24	Turkmenistan	-1.94	Turkmenistan	-1.69	Turkmenistan	-1.92
Jordan	-3.48	Jordan	-3.04	Jordan	-2.61	Jordan	-2.25	Jordan	-1.99	Jordan	-2.41
Philippines	-3.96	Philippines	-3.60	Philippines	-3.19	Philippines	-2.78	Philippines	-2.40	Philippines	-2.86
Uzbekistan	-4.34	Uzbekistan	-3.90	Uzbekistan	-3.47	Uzbekistan	-3.04	Uzbekistan	-2.62	Uzbekistan	-2.92
Myanmar	-5.21	Myanmar	-4.73	Myanmar	-4.31	Myanmar	-3.88	Myanmar	-3.48	Myanmar	-3.89
Pakistan	-9.39	Pakistan	-8.65	Bangladesh	-7.44	Bangladesh	-6.33	Bangladesh	-5.34	Bangladesh	-6.42
Bangladesh	-9.98	Bangladesh	-8.74	Pakistan	-7.72	Pakistan	-6.75	Pakistan	-5.89	Pakistan	-6.74

Table 57: sustainability ranking of BRI countries in 2016, according to different values of preference and indifference indexes.

APPENDIX III

Focus on European Countries

This additional analysis focuses on Europe, which so far has been considered all together as a macro area, but in reality, it is composed of a multitude of different countries. Surely, they share some features with respect to the rest of the Eurasian countries of BRI, but treating Europe like a single country might imply a significant degree of approximation. In fact, the contribution "Europe" in the analysis is just an average calculated on more than 35 countries, which perform quite differently on sustainability. That is the reason why we have decided to investigate in greater detail the European continent, by including some relevant countries and analyse how they rank with the PROMETHEE II algorithm. In particular, we have selected 11 countries, which are Bosnia and Herzegovina, Bulgaria, France, Germany, Italy, Norway, Poland, Spain, Sweden, Ukraine and United Kingdom UK. Norway and Sweden have been chosen since they have the reputation to be among the most sustainable countries in the world, for their stable economies and advanced policies in environmental protection. France, Germany, Italy and UK have been included because they are the main powers in Europe, often referred to as the Big Four or G4 of Europe. Spain has been added as another important country in Europe and Poland as a fast-growing country in the continent, still showing some criticalities but steadily improving. Finally, Bulgaria, Ukraine and Bosnia and Herzegovina have been inserted to represent European countries facing more difficulties in reaching the sustainable development. In this way, the considered BRI countries for the analysis have become 40, but the rest of the inputs for the MCDA algorithm has remained the same. In fact, we have adopted the first weighting method for the sake of coherence and for making comparisons with the original results. Thus, also the values of preference and indifference indexes have not changed, assuming the values p=70% and q=12% of the maximum difference. The following tables reports the most relevant values of the sustainability results and improvements. In fact, they include just the first 20 countries ranked according to the final net flow of the PROMETHEE method listed by year. For the sustainability improvements, it has been considered just the overall progress from 2010 to 2016.

Rank	2010		2011		2012		2013	
1	Norway	**18.46**	Norway	**18.54**	Norway	**18.64**	Norway	**18.35**
2	Sweden	**13.01**	Sweden	**13.10**	Sweden	**13.18**	Sweden	**12.56**
3	Brunei	6.76	Germany	6.60	Germany	6.61	UK	7.22
4	Spain	6.62	Spain	6.26	Europe	6.12	Brunei	6.21
5	Germany	6.46	France	6.15	France	6.11	Germany	6.07
6	France	6.35	Europe	6.05	Spain	5.97	Europe	6.06
7	Qatar	6.11	Qatar	5.93	Brunei	5.85	Spain	5.78
8	UK	5.92	Brunei	5.91	UK	5.73	France	5.59
9	Europe	5.69	UK	5.80	Qatar	5.41	Qatar	5.12
10	Italy	5.24	Italy	5.13	Italy	5.15	Italy	4.82

11	Poland	4.83	Poland	4.93	Poland	4.92	Poland	4.66
12	Singapore	4.61	Singapore	4.65	Singapore	4.59	Singapore	4.35
13	Kuwait	4.00	Kuwait	4.26	Kuwait	4.39	Kuwait	4.05
14	Bulgaria	3.40	Bulgaria	3.09	Bulgaria	3.11	Bulgaria	2.74
15	UAE	1.93	Ukraine	2.03	Ukraine	1.92	Kazakhstan	2.58
16	Bahrain	0.54	UAE	1.91	UAE	1.86	UAE	1.60
17	Azerbaijan	0.34	Bahrain	0.39	Bahrain	0.15	Ukraine	1.43
18	Israel	0.13	Israel	0.13	Israel	0.09	Bahrain	0.13
19	Malaysia	-0.14	Malaysia	-0.15	Malaysia	-0.19	Israel	-0.28
20	Oman	-0.28	Russia	-0.40	Russia	-0.31	Malaysia	-0.42

Table 58: rank of the first 20 BRI countries for sustainability result from 2010 to 2013, with a focus on European countries.

Rank	**2014**		**2015**		**2016**	
1	Norway	**18.17**	Norway	**17.86**	Norway	**17.72**
2	Sweden	**12.53**	Sweden	**12.85**	Sweden	**12.52**
3	France	7.46	UK	7.50	UK	7.49
4	UK	7.34	France	7.35	France	7.46
5	Europe	6.17	Europe	6.13	Europe	6.19
6	Germany	6.12	Germany	6.10	Germany	6.11
7	Spain	5.76	Brunei	5.84	Spain	5.83
8	Brunei	5.55	Spain	5.52	Brunei	5.03
9	Qatar	5.03	Qatar	4.87	Poland	4.83
10	Italy	4.86	Poland	4.73	Qatar	4.75
11	Poland	4.70	Italy	4.62	Italy	4.70
12	Singapore	4.58	Singapore	4.50	Singapore	4.56
13	Kuwait	4.14	Kuwait	3.54	Kuwait	3.19
14	Kazakhstan	2.68	Bulgaria	2.80	Bulgaria	2.79
15	Bulgaria	2.60	Kazakhstan	2.48	Kazakhstan	2.42
16	UAE	1.56	UAE	1.71	UAE	1.59
17	Ukraine	1.11	Ukraine	0.65	Ukraine	0.69
18	Bahrain	0.23	Bahrain	0.21	Bahrain	-0.13
19	Israel	-0.23	Israel	-0.24	Israel	-0.13
20	Malaysia	-0.35	Malaysia	-0.43	Malaysia	-0.30

Table 59: rank of the first 20 BRI countries for sustainability result from 2014 to 2016, with a focus on European countries.

The peculiarity of this focus on European countries are the first two countries of the classification, which are always Norway and Sweden with a very high value of sustainability outcome. In fact, these two countries show a final result which is quite distant from the rest of the ranking and it is even the double of the third ranked country. This is accordance with the high level of sustainability, quality of life and environmental protection obtained in Scandinavian countries. After them, France, Germany, UK and Spain hold the highest positions of the ranking. France and Spain maintain approximately their result over the years, while Germany and UK experience some changes. On one hand, Germany decreases its level of sustainability from 2010 to 2016 and on the other hand, UK improves it until reaching the third highest result. Poland and Italy are close in the ranking to number 10. At first, Italy has a higher sustainability result than Poland, but after 2015 it is outranked by Poland. Moreover, Ukraine and Bulgaria are some positions below in the classification. As it is possible to notice in table 58 and 59, the majority of the European countries considered is included in the first 20 BRI countries for sustainability result, in every year from 2010 to 2016.The only exception is for Bosnia and Herzegovina which is in the position 30 for most of the time, near Turkmenistan and Iran. Another particular case is Ukraine which in year 2010 is ranked 28th, even after Bosnia and Herzegovina, but from 2011 onwards rapidly improves and enters the group of the first 20 countries for sustainability result. This is probably due to the fact that Ukraine has implemented a carbon tax in 2011, which has a great importance in our evaluation. In fact, as shown in table 60, Ukraine experience the third highest improvement from 2010 to 2016, after China and Kazakhstan, as in the original analysis. Other big improvements involve UK and France, but there is a wide gap of several units between them and the first three in the ranking. Finally, considering the ranking of the sustainability progress, the rest of European countries is spread from the 10th position downwards, until Bosnia and Herzegovina almost at the end. In effect, not only it has a low sustainability result, but it is not even improving its status, highlighting some difficulties in growing in a sustainable way.

Rank	2010-2016	
1	China	6.12
2	Kazakhstan	4.70
3	Ukraine	4.07
4	UK	1.58
5	France	1.10
6	Bangladesh	1.01
7	Europe	0.51
8	Mongolia	0.33
9	Iraq	0.23
10	Saudi Arabia	0.09
12	Poland	0.00
20	Germany	-0.35
23	Sweden	-0.49
24	Italy	-0.54
26	Bulgaria	-0.62
30	Norway	-0.74
32	Spain	-0.79
37	Bosnia	-1.43

Table 60: BRI countries ranked for sustainability improvement from 2010 to 2016 with a focus on European countries.

BIBLIOGRAPHY

[1] IEA, “World Energy Outlook WEO”, 2019.

[2] World Energy Council WEC, “World Energy Scenarios”, 2019.

[3] BP, “Statistical Review of World Energy”, 2019.

[4] U.S. Energy Information Administration EIA, “World oil transit chokepoints”, 2017.

[5] Allen M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M.Wairiu, and K. Zickfeld,
“2018: Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty”
[Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

[6] IEA, "Global Energy & CO_2 Status Report 2019", IEA, Paris, [online]
Available : https://www.iea.org/reports/global-energy-co2-status-report-2019.

[7] United Nations, “Transforming our world: the 2030 Agenda for Sustainable Development”, 2015, [online]
Available : https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

[8] “Working Together to Deliver a Brighter Future for Belt and Road Cooperation: Keynote Speech by H.E. Xi Jinping President of the People's Republic of China at the Opening Ceremony of the Second Belt and Road Forum for International Cooperation”, April 26th 2019, [online]. Available: http://www.beltandroadforum.org/english/.

[9] History.com Editors, "Silk Road", 2017, [online],
Available : https://www.history.com/topics/ancient-middle-east/silk-road.

[10] United Nations Educational, Scientific and Cultural Organization UNESCO, “The Silk Roads Project: Integral study of the Silk Roads: Roads of Dialogue, 1988-1997”, 2002, [online], available: https://unesdoc.unesco.org/ark:/48223/pf0000159189.

[11] The Ministry of Foreign Affairs of the People’s Republic of China, “President Xi Jinping Delivers Important Speech and Proposes to Build a Silk Road Economic Belt with Central Asian Countries”, September 2013, [online], available:
https://www.fmprc.gov.cn/mfa_eng/topics_665678/xjpfwzysiesgjtfhshzzfh_665686/t1076334.shtml.

[12] Kuo Lily, Kommenda Niko. "What is China's Belt and Road Initiative?", The Guardian, September 2015, [online], available:

https://www.theguardian.com/cities/ng-interactive/2018/jul/30/what-china-belt-road-initiative-silk-road-explainer.
[13] J. Wu, “President Xi gives speech to Indonesia's parliament,” Chinadaily, 2 October 2013, [Online], Available:
http://www.chinadaily.com.cn/china/2013xiapec/2013-10/02/content_17007915.htm.
[14] U. A. Bērziņa-Čerenkova, “BRI Instead of OBOR – China Edits the English Name of its Most Ambitious International Project,” Latvijas Ārpolitikas Institūts, 28 July 2016. [Online]. Available: http://www.lai.lv/viedokli/bri-instead-of-obor-china-edits-the-english-name-of-its-most-ambitious-international-project-532.
[15] OECD, "The Belt and Road Initiative in the global trade, investment and finance landscape", in OECD Business and Finance Outlook 2018, OECD Publishing, Paris, 2018 [online], available: https://doi.org/10.1787/bus_fin_out-2018-6-en.
[16] National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce of the People's Republic of China, “Vision and actions on jointly building Silk Road Economic Belt And 21st-Century Maritime Silk Road”, Belt and Road Portal, March 2015, [online], available:
https://eng.yidaiyilu.gov.cn/qwyw/qwfb/1084.htm.
[17] “The Belt and Road Ecological and Environmental Cooperation Plan”, Belt and Road Portal, May 2017, [online], available:
https://eng.yidaiyilu.gov.cn/zchj/qwfb/13392.htm.
[18] S. Tiezzi, “What did China accomplish at the Belt and Road Forum?”, The Diplomat, May 2017, [online], available: https://thediplomat.com/2017/05/what-did-china-accomplish-at-the-belt-and-road-forum/.
[19] M. P. Goodman, J. E. Hillman, “China’s Second Belt and Road Forum”, Center for Strategic & International Studies CSIS, April 2019, [online], available:
https://www.csis.org/analysis/chinas-second-belt-and-road-forum
[20] Zhou Jin, “China says Belt and Road will not get involved in territorial disputes”, Chinadaily, April 2019, [online], available:
https://global.chinadaily.com.cn/a/201904/16/WS5cb51601a3104842260b6584.html.
[21] 已同中国签订共建“一带一路”合作文件的国家一览, 中国一带一路网, April 2019, [“List of countries that have signed cooperation documents with China for the Belt and Road Initiative”, Belt and Road Portal], [online], available:
https://www.yidaiyilu.gov.cn/info/iList.jsp?tm_id=126&cat_id=10122&info_id=77298.
[22] V. De Decker, “To BRI or not to BRI? Europe’s warring member states”, Italian Institute for International Political Studies ISPI, April 2019, [online], available:
https://www.ispionline.it/en/pubblicazione/bri-or-not-bri-europes-warring-member-states-22786.

[23] European Commission, Joint Communication to the European Parliament, European Council and the Council, "EU-China, A strategic outlook", March 2019, [online], available: https://ec.europa.eu/commission/sites/beta-political/files/communication-eu-china-a-strategic-outlook.pdf.
[24] Bansari Kamdar, "What to Make of India's Absence from the Second Belt and Road Forum?", The Diplomat, May 2019, [online], available: https://thediplomat.com/2019/05/what-to-make-of-indias-absence-from-the-second-belt-and-road-forum/.
[25] The World Bank, "Open Data," [online]. Available: https://data.worldbank.org/.
[26] IEA, "Statistics & Data," [online]. Available: https://www.iea.org/statistics/.
[27] F. Umbach, China's Belt and Road Initiative and its energy-security dimensions, RSIS Working Paper, no. 320, 2019.
[28] United Nations, Economic and Social Council, Report of the Secretary-General, "Special edition: progress towards the sustainable development goals", May 2019, [online], available: https://undocs.org/E/2019/68.
[29] United Nations, General assembly resolution 43/53, "Protection of global climate for present and future generations of mankind", A/RES/43/53 (6 December 1988), [online] Available: https://www.ipcc.ch/site/assets/uploads/2019/02/UNGA43-53.pdf.
[30] United Nations, "Paris Agreement", 2015.
[31] IPCC, 2014: Climate Change 2014: Synthesis Report, contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp, [online], available:
https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf.
[32] F. Moricci (ISPRA), G. Rago (ISPRA), B. Gonella (ISPRA), A. Gagna (ISPRA), R. De Lauretis (ISPRA), Studio sulle alternative agli idrofluorocarburi (HFC) in Italia, 286/2018, [online], available:
http://www.isprambiente.gov.it/files2018/pubblicazioni/rapporti/R_286_18.pdf.
[33] Health Effects Institute, 2018 State of Global Air, 2018, Special Report, Boston, MA, Health Effects Institute.
[34] World Economic Forum, Energy for Economic Growth: energy vision update 2012, [online], available:
http://www3.weforum.org/docs/WEF_EN_EnergyEconomicGrowth_IndustryAgenda_2012.pdf.
[35] K. Yeager, F. Dayo, B. Fisher, R. Fouquet, A. Gilau and H.-H. Rogner, Chapter 6 - Energy and Economy, May 2014, [online], available:
https://www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-EnergyAssessment/GEA_Chapter6_economy_hires.pdf.
[36] O. Fontana, Il filo diretto tra finanza e carbon pricing, Centro Studi sul Federalismo.

[37] A. Majocchi, Carbon Tax, un'imposta da premio Nobel, Centro Studi sul Federalismo.
[38] S. Morgan, Eu's 'Just Transition Fund' gesture muddies budget waters, in Euractive.org.
[39] Lise Kingo (Executive Director, UN Global Compact), Executive Update: Setting a $100 price on carbon, Huffington Post Blog on 22 April 2016.
[40] World Commission on Environment and Development WCED, "Our Common Future: report of the World Commission on Environment and Development", 1987, [online], Available: https://sustainabledevelopment.un.org/content/documents/5987ourcommonfuture.pdf.
[41] R. Solow, "An Almost Practical Step Towards Sustainability", 1993, [online], available: https://www.nap.edu/read/4844/chapter/3#29.
[42] D. Gunn MacRae, "Thomas Malthus, English economist and demographer", Encyclopaedia Britannica, December 2019, [online], available:
https://www.britannica.com/biography/Thomas-Malthus.
[43] K. E. Portney, "Sustainability", the MIT press essential knowledge series, the MIT press, Massachusetts Institute of Technology, Cambridge, Massachusetts, 2015.
[44] Gan Lin, "Implementing China's Agenda 21: from national strategy to local action", Impact Assessment and Project Appraisal, 16:4, 277-287, [online], available:
https://www.tandfonline.com/doi/abs/10.1080/14615517.1998.10600138.
[45] Feng Hao, "China releases 2020 action plan for air pollution", Chinadialogue, July 2018, [online], available: https://www.chinadialogue.net/article/show/single/en/10711-China-releases-2-2-action-plan-for-air-pollution
[46] "Green Finance", The Green Belt and Road Initiative Research Center, International Institute of Green Finance IIGF, Central University of Finance and Economics, Beijing, [online], available: https://green-bri.org/green-finance
[47] B. Purvis, Y. Mao, D. Robinson, "Three pillars of sustainability: in search of conceptual origin", Sustainability Science, September 2018, [online], available:
https://www.researchgate.net/publication/327404334_Three_pillars_of_sustainability_in_search_of_conceptual_origins.
[48] S. Campbell, "Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development", Journal of the American Planning Association JAPA, 1996, published online November 2007, [online], available:
https://doi.org/10.1080/01944369608975696.
[49] B. Brown, M. E. Hanson, D. M. Liverman, R. W. Merideth, "Global Sustainability: Toward Definition", Environmental Management, January 1987, [online], available:
https://www.researchgate.net/publication/226879595_Global_Sustainability_Toward_Definition.
[50] C. Kidd, "The evolution of sustainability", Journal of Agriculture and Environmental Ethics, 1992, [online], available:
https://link.springer.com/article/10.1007%2FBF01965413

[51] B. Ness, E. Urbel-Piirsalu, S. Anderberg, L. Olsson, "Categorising tools for sustainability assessment", Ecological Economics, September 2006, [online], available: https://www.sciencedirect.com/science/article/abs/pii/S0921800906003636.

[52] M. Koksalan, J. Wallenius, S. Zionts, "Multiple Criteria Decision Making, from early history to 21st century", World Scientific, Singapore, 2011

[53] S. Greco, "Multiple Criteria Decision Analysis: state of the art survey", Springer Science & Business Media, January 2006

[54] I. B. Huang, J. Keisler, I. Linkov, "Multi criteria decision analysis in environmental sciences: ten years of applications and trends", Science of the Total Environment, 2011, [online], available: https://www.sciencedirect.com/science/article/pii/S0048969711006462.

[55] Jiang-Jiang Wang, You-Yin Jing, Chun-Fa Zhang, Jun-Hong Zhao, "Review on multi-criteria decision analysis aid in sustainable energy decision-making", Renewable and Sustainable Energy Reviews, December 2009, [online], available: https://www-sciencedirect-com.ezproxy.biblio.polito.it/science/article/pii/S1364032109001166.

[56] M. Cinelli, S. R. Coles, K. Kirwan, "Analysis of the potentials of multi criteria decision analysis methods to conduct sustainability assessment", Ecological Indicators, November 2014, [online], available: https://www.sciencedirect.com/science/article/pii/S1470160X14002647.

[57] J. Figueira, S. Greco, M. Ehrogott, "Multiple Criteria Decision Analysis: State of the Art Surveys", Springer Science + Business Media, Springer, New York, NY, 2005, [online], available: https://link-springer-com.ezproxy.biblio.polito.it/book/10.1007%2Fb100605#toc

[58] D. Antanasijević, V. Pocajt, M. Ristić, A. Perić-Grujić, "A differential multi-criteria analysis for the assessment of sustainability performance of European countries: Beyond country ranking", Cleaner Production, November 2017, [online], available: https://www.sciencedirect.com/science/article/pii/S0959652617315780.

[59] EIA, Brunei Analysis, updated March 2017, [online], available: https://www.eia.gov/international/analysis/country/BRN