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MASTER THESIS

SUSTAINABLE ENERGY TECHNOLOGY

ENERGY TRANSITION IN GLOBAL NORTH-SOUTH DIMENSION: CASE OF OVERIJSSEL AND MATHURA

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List of Acronyms

ALPG	Artificial Load Profile Generator
BAU	Business-as-Usual
CHP	Combined Heat and Power
COP	Conference of the Parties
CEEP	Critical Excess Electricity Production
CNG	Compact Natural Gas
GDP	Gross Domestic Product
GJ	Giga Joule
HDI	Human Development Index
HEF	Hidden Energy Flow
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
LPG	Liquified Petroleum Gas
MSW	Municipal Solid Waste
MW	Megawatt
MT/ Mton	Mega Tonne
Mt	Metric Tonne
Mtoe	Mega Tonne of Oil Equivalent
MJ	Mega Joule
NIMBY	Not in my Backyard
PV	Photovoltaic
PVT	Photovoltaic Thermal
PNG	Pipeline Natural Gas
PJ	Peta Joule
RES	Renewable Energy Share
SDG	Sustainable Development Goals
TWh	Terawatt Hour

Abstract

In the present time, fossil fuels are the primary source of energy suppliers for electricity, transportation, cooking, industrial processes and thermal comfort. However, with global warming and changes in the eco-system, a transition to renewable energy is at the foremost. Energy transition has been a necessary initiative to mitigate climatic changes and reduce carbon emissions.

However, energy transition in the globalized world is challenged with diverse socio-economic and cultural factors. Global North and Global South signifying the developed and developing countries are distinct in terms of economic resilience, human wellbeing, public sector, state organization, industrial sector, social development and resource sharing. Furthermore, the bid to achieve sustainability also differs between the two parts of the world. The Global North countries are focussed on working on green agendas such as environment protection and resource degradation. Conversely, the Global South wants to mitigate brown agendas referring to food and energy security, poverty and health hazards. Moreover, this distinction in the globalized world is not only confined to nations but also at the transnational unit.

Furthermore, the impediment in the energy transition in the globalized world can be witnessed in terms of energy consumption and the definition of energy poverty. The Global North's with high energy consumption has an objective to promote energy efficiency and transition in the energy system by maintaining a secure and affordable energy supply. However, the focus of the Global South with low energy consumption is to acquire a secure energy supply through energy generation and infrastructure. Therefore, a sustainable energy transition must progress together with socio-economic resilience.

These implications in the energy transition in the Global North-South dimension are presented with a case study for the Overijssel part of Global North and Mathura, part of Global South. Both regions are similar in terms of area and economic activities. Moreover, established tourism, agriculture, and farming industries promote the utilization of bioresources for the future energy system in Overijssel and Mathura. These industries existed in Overijssel due to social and economic activities, while in Mathura due to religious beliefs.

However, the differences in social development and economic resilience also introduce a different scenario for the energy transition. The province of Overijssel has awareness regarding climate change, are making efforts to improve energy efficiency and has highly educated personal and research facilities formulating plans for energy transition with the support of local stakeholders. However, they are challenged with social issues such as NIMBY and political regulations to utilize resources from the region.

On the other hand, the region of Mathura is more focussed on having a reliable power supply to improve quality of life and reduce health hazards due to the unsustainable use of local bioresources. The transition in the region is amiable due to support from the government, weaker regulations and the need for reliable power. However, a lack of awareness, educated personal, investment, research facilities, and technical innovation restricts the transition in the energy system.

Moreover, the transition in the two separate regions will require different approaches. A region in the Global South due to low social development will be dependent on a top-down approach. On the other hand, the region from the Global North can implement top-down, bottom-up or social awareness and democratic approach based on the region due to higher awareness among people and regulations from the regional government.

For both regions, an energy transition plan is formulated based on economic activities, resource availability, social factors, land utilization and city planning to make them energy neutral by the year 2050. The energy transition plan is simulated on energyPLAN tool simulating energy system for the year 2018 (reference), 2030, 2040 and 2050. The scenarios formulated presented the path of transition, carbon emission and techno-economic cost. The results from the scenario are presented in Table I and Table II below,

Table- I: Carbon Emission for Different Scenarios in Overijssel and Mathura

Scenarios	Carbon Emission *(in Mton)*	
	Overijssel	Mathura
Reference	7.09	2.09
2030	5.32	2.6
2040	2.71	1.49
ET2050	0	0
BAU2050	6.27	8.43

Table- II: Techno-Economic Cost for Different Scenarios in Overijssel and Mathura

Scenarios	Techno-Economic Cost (in million ē)	
	Overijssel	Mathura
Reference	1540	168
2030	1654	447
2040	947	763
ET2050	887	1207
BAU2050	2257	1381

The results from the simulations present that in the reference scenario, Overijssel had higher carbon emission and techno-economic cost as compared to Mathura. However, during the process of transition in the energy system, both regions can acquire energy and carbon neutrality theoretically. Furthermore, the techno-economic cost for the reference scenario is presented to be higher for Overijssel as compared to Mathura. However, after the energy transition is concluded in the year 2050, the techno-economic cost of Mathura is higher due to growing electricity demand with a high population and economic resilience and unused waste heat due to climate conditions.

Moreover, the process of transition from the year 2018-2050 presents a dual transition in the transportation system. The transportation energy demand will initially be switched to bioenergy due to the presence of fossil fuel vehicles and then transformed to electric mobility in the future.

More importantly, the business-as-usual scenario presents the requisition for energy transition in both regions. During a low pace of transition, carbon emissions in Global South Mathura will be higher than the Global North Overijssel due to higher energy consumption. Nonetheless, the energy transition in the Global South from the societal perspective is viable, while technically and economically more feasible in the Global North

The two globalized world face inconsistency in economic resilience, technology availability and innovation. Therefore, to have a higher prospect of integration of renewable energy across the globalized world, different energy transition plans have to be formulated based on their present social and cultural values creating economic benefits with different targets. Moreover, the two parts of the world must congregate in terms of knowledge sharing and investment to formulate this transition and reduce the carbon emission to mitigate climate change.

Keywords: *Energy Transition, Global North, Global South*

Chapter 1

Introduction

To mitigate the climatic changes in the world, countries under the United Nations pledged to reduce carbon emission and signed the Paris Agreement at COP 21. Additionally, all states are also committed to progress towards 17 Sustainable Development Goals (SDG) set in the year 2015 to be achieved by the year 2030. Among those development goals, SDG 7 objective states that all citizens have access to affordable and clean energy. With that directive and the Paris agreement, the nations want to make a transition to renewable energy. The transition should contemplate and promote social, economic and cultural development. This development has to be achieved by improving standards of living, wellbeing and meeting the requirements of the present-day without comprising the needs of the future.

A considerable amount of greenhouse gases in the present day are emitted by the generation of energy for electricity, transportation and thermal comfort aggregated by fossil fuels. Moreover, there is an expected rise in energy demand in the future due to growing populations and income levels. Hence, there needs to be an energy transition from fossil fuels to decentralized low carbon energy generation technologies to reduce losses in energy transmission through a grid, maintenance cost and reduce the greenhouse gases in the environment

However, the countries are incapacitated with the transition targets as it does not take into the problems faced in the globalized world. Sustainable energy solutions implementation involves the replacement of fossil fuels with substantial investment in energy conservation through efficiency and renewable energy. It is essential to consider the consequences of such a change in the technologies, cost structure, society and industrial development. Therefore, the energy transition will only be possible through comprehensive analysis, technical innovation and socio-economic development in a region.

1.1 Problem Definition

The distinction between the globalized world can be observed on the basis of economic resilience, social development and state structure. These differences sought to introduce the terms developed and developing or the Global North and South countries. Impending climatic changes and the need to mitigate it, the world must reduce its carbon emission with the energy system at the forefront of that mission. Therefore, to make a transition to renewable energy and make them energy neutral, we must examine the development and social issues of the regions in the globalized world. There have been literature studies and research analyses on energy transition in the Global North. However, there is an absence of studies on possible energy transition plans in the Global South. Although, at present, the major emitting countries belong to the Global North, yet the impact of climate change affects both the worlds.

Furthermore, a futuristic prediction of growing population, economic and industrial development in Global South indicates a transition in the energy system vital as well. Therefore, a proposal for energy transition and carbon emission reduction should be made taking global realities into account for the globalized world. The sustainability discourse projected does not include the problems of the Global South, although it is effective and efficient in the Global North. An analysis of the origin of energy consumption, economic, social and cultural activities needs to be conducted to make an energy transition within a region.

1.2 Objective of the Research

The objective of the research is comparing the energy transition in Global North and South dimensions by analyzing solutions that are technically feasible, financially beneficial and socially acceptable. A smart energy system will be formulated that links the synergies between the usage of electricity, transportation, thermal comfort and cooking with a futuristic vision of the year 2050. The insights on the implementation of renewable energy are based on the regional capabilities and energy potential to be integrated into the existing energy system to reach energy neutrality.

However, energy transition in the globalized world is restricted through these socio-economic and cultural challenges. Moreover, both the globalized world differs in energy consumption and poverty based on their climatic condition and political and social scenario. For instance, the Global South lacks energy security currently and with growing populations and economic development in the future, its energy consumption is likely to rise, increasing its carbon emission. On the other hand, the Global North has a secure energy supply and efforts for energy efficiency are made, leading to a reduction in emissions. Nonetheless, a transition in the energy system in the globalized world is needed to reduce the carbon emissions to abide by the carbon budget presented by the Intergovernmental Panel on Climate Change. Therefore, a diverse energy transition approach needs to be followed for different part of the global world to reduce the carbon emissions and safeguard the socio-economic resilience.

1.3 Research Question

Through this thesis, I will infuse an understanding of the diverse energy technology, their implementation and technical, economic and social viability within two regions belonging to the two different part of the world.

The main research question will be,

What are the differences and similarities in the regional sustainable energy transition in the Global North and Global South?

1. What does the distinction between Global North and Global South conceptually and empirically mean?

   This research sub-question explains the origin of the terms of Global North and Global South and explain how they differ in terms of social and developmental issues. The section also specifies the presence of the Global South within a Global North country due to the uneven distribution of resources.

2. What implications could the distinction between the Global North and Global South have for the regional sustainable energy transition?

   This section of the research question focuses more on the implication of energy transition in the globalized world. It expresses that the challenges in both the regions concerning energy consumption, energy poverty and the sustainable transition in different regions, influenced by the socio-economic activities, cultural diversity and political scenario.

3. How will a regional sustainable energy transition in Overijssel and Mathura appear?

   This sub-question of the thesis is a case study for a region in Global North and South. The case study will discuss and simulate energy transition plan with the time frame of the year

2020 to 2050 along with a business-as-usual case for Overijssel and Mathura. The study is conducted for a long-term horizon, i.e., the year 2050 for the energy transition in both regions to attain energy neutrality.

4. What are the differences and similarities of the regional sustainable energy transition in the GN and GS?

   This part of the research question analyses and discusses the results from the simulation of both regions to identify the similarities and differences for a sustainable energy transition.

1.4 Method

1.4.1 Research Approach

The approach for the thesis research is initiated with the literature review. The research papers and articles formulate an understanding of the terms Global North and South and its origination. Furthermore, the study assists in comprehending sustainable development, energy consumption and energy poverty for the two globalized worlds.

Adding the knowledge of the Global North and South and its implication on the energy system, the literature review is examined by the case study on Overijssel and Mathura, indicating Global North and South. A review is conducted for both the region for their demography, geography, energy system, resource availability and energy potential based on climatic conditions, energy consumption pattern, economic activities, national and regional policies and societal perception. Based on the regional understanding, an energy transition plan is formulated for both the regions separately.

The transition plan, along with the data and distribution files acquired, is simulated on the energyPLAN tool. It is an energy analysis tool to formulate a model for a long-term energy transition. The software is available online for free with case studies about Denmark's energy transition plans and tutorials. EnergyPlan has been utilized in many pieces of research and a wide range of analyses with 100% renewable energy implementation. These studies include energy transition for European Union member states, national levels such as Denmark, Ireland and more and regional level like Aalborg, Denmark (Lund, 2010). The tool is suitable to create a smart energy system and includes simulation for electricity, heating/cooling and transportation on an hourly basis over one year. Additionally, it ensures long term transition with a transformation of the energy sector to 100% renewable energy by the year 2050.

The key principle stated below are used to define the methodology for this thesis,

1. Covering all energy sectors, which includes heating/cooling, electricity and transportation and forming synergies between the individual energy sector for optimization for domestic and commercial use.
2. Evaluate the impact of the integration of a low carbon smart energy system in the future.
3. The study conducted will take into consideration a long-term horizon, i.e., the year 2050, for both regions to be energy neutral.
4. The study will also consider the hourly fluctuations in energy production from renewables and demand. Therefore, suggesting a solution for reliable operation of the future smart energy systems.
5. The analysis is conducted from a perspective of carbon emissions and techno-economic cost to present the advantages of energy transition and used as a comparative parameter between the Global North and the Global South.

1.4.2 Brief Explanation on Case Study Regions

For the thesis, a case study is conducted to present a distinction between energy transition in the globalized world. From the Global North, the province of Overijssel and the Global South, Mathura is taken into considerations. Both the regions selected for the case study are approximately similar in land area, economic activities and resource availability and currently have a secure supply of electricity. However, for Overijssel, that supply is assisted with renewable share and the power transmitted does not leave other regions short of supply. While on the contrary, Mathura does not have a share of renewables and though the supply is secure, although it leaves the neighboring region short of energy supply.

On the other hand, both regions share similar economic activities. Agriculture and cattle farming are core activities in Overijssel, and Mathura and both the regions focus on tourism, where the former focuses on eco-tourism, while the latter receives religious tourism. Such similarities yet social differences are beneficial in indicating the distinction between Global North and South for the sustainable energy transition.

Additionally, for the time frame of the thesis, availability of data and understanding the societal and economic sector of the case study region is a challenge. It is easier to manage the data for Overijssel, while the social behavior and economic activities of the region were understood with my stay experience. On the other hand, the data availability for Mathura was challenging, but the connections in the region assisted in availing that data. Moreover, understanding the social behavior and economic activities of the region was more accessible with the native experience.

1.4.3 Energy Transition Scenario

The energy transition in the region is done stepwise to smoothly integrate renewable energy into the energy system, reducing the economic strain and maintaining the security of supply and grid stability. Moreover, it is also simulated to present the process of transition in the two regions. The transition of energy system in the Global North and South region is simulated for the year 2030, 2040 and the target year 2050 to achieve energy neutrality in the regions. These scenarios are created with the assistance of literature research and previous studies conducted for energy transition using energyPLAN software. The scenarios and the target for integration for renewable energy technology is mentioned below,

Scenario 2030: Integration of RES to 40%

Scenario 2040: Target of 75% for RES integration

Energy Transition 2050: Target to achieve 100% RES for energy neutrality.

The scenarios are based on a gradual transition from fossil-based energy resources to renewable resource-based energy supply, which will be compared with the business-as-usual scenario to ascertain the benefits of the transition.

1.5 Outline of the Thesis

The thesis report consists of eight chapters that explain and answers the main research question and sub-questions listed in section 1.3.

Chapter 1: Introduction

This chapter introduces the research topic with the problem definition, research objective, research questions and the methodology applied to answer those questions.

Chapter 2: Distinction between the Global North and Global South

This chapter will state the origin of the terms provide an understanding and explanation of the term Global North and Global South conceptually and empirically.

Chapter 3: Sustainable Energy Transition in Global North and Global South

This chapter will elaborate on the sustainable development and implications of energy transition in Global North and Global South regions and conclude with a hypothesis.

Chapter 4: EnergyPlan Methodology

The chapter elaborates on the software and explain the data collected that will be synthesized for the simulations.

Chapter 5: Energy Transition in Overijssel

This chapter of the thesis elaborates on the Global North region for sustainable energy transition. Moreover, an energy plan is formulated with predictive energy consumption in the year 2030 to 2050. Further, the transition plan is put to trial through simulation on the energyPLAN tool and the results are discussed by comparing it with the business-as-usual scenario.

Chapter 6: Energy Transition in Mathura

This chapter of the thesis elaborates on the Global South region for the sustainable energy transition. Moreover, an energy plan is formulated with predictive energy consumption in the year 2030 to 2050. Further, the transition plan is put to trial through simulation on the energyPLAN tool and the results are discussed by comparing it with the business-as-usual scenario.

Chapter 7: Implication of Sustainable Energy Transition in Overijssel and Mathura

This section will present the similarities and differences in the sustainable energy transition in Overijssel and Mathura.

Chapter 8: Conclusion, Discussions and Recommendations

This chapter concludes the thesis and discussions, indicating the assumptions and further recommendations are added.

Chapter 2

Global North and Global South Distinction

This chapter is designated to explain the origins of the terms Global North and Global South and present their definition empirically and conceptually. A literature review presents an explanation of the globalized world. Moreover, this chapter explains how these terms differ in social, economic and developmental issues.

2.1 Introduction

The focal point of this chapter is to present a distinction with the Global North and Global South conceptually and empirically. The term Global North and Global South are often used to signify wealthier and emerging countries. However, these terms hold a broader meaning than just economic resilience and cover social, cultural and political dimensions as well. The Global North is represented by countries in the northern hemisphere and Australia and New Zealand in the South due to their high quality of life enjoyed by the citizens and high Gross Domestic Production (GDP). These countries have a strong economy, the industrial sector, socially developed and dominant international relations.

On the other hand, Global South is represented by southern hemisphere countries due to the low quality of life, inequality in resource distribution, wealth and societal arena and low Gross Domestic Production. The Global South countries are recognized in the African, Asian and South American continent. (60 Second guide to the Global North/South Divide)

2.2 Historical Reference of Global North and South

Alfred Sauvy, a French demographer, anthropologist and historian on 14th August 1952, coined the term "third world" into the context of the division of the world during the cold war era. He distinguished the world into first world countries, i.e., the capitalistic NATO bloc or the industrialized western world, the second world countries under the Communist Soviet bloc and the Third World countries, which did not align with either the western or soviet bloc (Dirlik) (Eriksen). The third world countries were conceived with political non-alignment during the cold war and Alfred Sauvy addressed these countries as ignored, exploited and despised like the third estate. (Wikipedia, n.d.)

The third world countries were further distinguished as “third, fourth and fifth world” signifying as “developing, poor and under-developed countries” in that era and grouped as third world countries (Eriksen). However, a decade after the fall of the Soviet Union, the term was diminished by the scholars and took up the term developed and the developing countries to distinguish between economic superiority and development between countries. The industrialized countries, which were wealthy, powerful and prestigious, were placed as developed countries like the USA and Europe (Jackson, 2016), while poverty-stricken countries as developing countries (Aulette, 2012). Although, many scholars disagreed with the term as they believed that all countries on the planet are continually developing.

Another term used by the scholars after the collapse of the communist era called the World System model is "Core, Periphery and Semi-Periphery" countries. The Core countries were recognized to be well-financed and industrialized states with skilled labor, powerful international and trade relations, high-income level and socially developed. On the other hand, Periphery countries were defined as weak states with little power in trade and international relations and had poor productivity due to unskilled labors. These countries are categorized as countries whose industrial sector is less capital intensive and are crucial for the export of raw materials like minerals and agricultural products. Another term added to this was Semi-Periphery countries, which included states like China, South Africa, Russia and Korea. These countries were making progress towards economic development but not yet cross the threshold of Core countries. Although, the use of term semi-peripheral countries did not convince the scholars and they used them as peripheral countries only. Soon these terms were eluded widely by the academic world and the terms Core countries were recognized with Global North and Peripheral countries were recognized by Global South (Hall T. a.-D., 2006).

2.3 Conceptual Interpretation of Global North and South

Global North and Global South are divided in the context of globalization, development and global inequality. It should not be understood in terms of the equator or the political ideology as it was done during the cold war era and for that reason, "Global" is prefixed in defining the Global North and South (Jackson, 2016). The division of Global North and South is made based on the quality of health and education, nature of country's economy, society and industrial sector, trading policies and international relations (60 Second guide to the Global North/South Divide).

The segregation of the two worlds is strained on development. The development is often assessed in terms of Gross Domestic Production and the rise in income levels (Day, Walker, & Simcock, 2016). However, it is not the GDP alone, which separates the two distinct worlds. Many of the rich countries with high GDP are placed among the Global South countries (Magallanes) by the intellect minds. For instance, Brazil, India and China have a progressive GDP and steady states and yet are placed among the developing countries due to the lack of development in the social sections. Another parameter considered for segregation along with GDP is the Human Development Index (HDI). HDI ranks with the significance of income, health and education among countries, although even a country with high HDI and GDP are placed in Global South due to the presence of inequality, poverty, housing and lack of sanitation. For instance, UAE has a higher rank in HDI, and high GDP as compared to Portugal, yet Portugal is placed in the Global North for its economic superiority combined with higher quotient in balancing inequalities and wealth and resource distribution. Therefore, the actual development that divides the Global world into North and South evaluates the economic, social and cultural factors and exhibits by the quality of life (Schwarz).

The Global North refers to the industrialized world which has strong public sector, stable state organization, well-developed economy, dominant formal sector (Eriksen) and rates highly in the Human Development Index (HDI), while Global South refers to vice versa to these criteria. The revelation of the Global South term after the end of the cold war era has done a great benefit to the countries in the African, Asian and Latin American continent as it has reintroduced the studies in the academic field to analyze progress and constraints for progress (Kaltmeier). The development issues in the Global South are related to poverty, lack of food, education and healthcare, human and civil rights abuse, ethnic and religious violence (Ming'ate) and unequal distribution of resources and wealth. These issues cause low productivity due to mental and physical lethargy. These are developmental issues for the countries in the Global South, while for the Global North countries, these are rendered as social issues (Collins, 2000).

However, critics have linked these problems in the southern countries due to the historical exploitation and the current strength of the economic and political system of the Global North countries. The historical events and the present system render the Global South countries to lag in development (Rigg). It is found that the financial gap between the globalized world has even increased in the last century. E.g., the capitalistic countries' income was thrice the African countries in the year 1820, however by the 20th century, it has now increased to 2000 times (60 Second guide to the Global North/South Divide).

Nonetheless, the stated differences between the globalized world and the detractors placing the onus for these differences among the wealthier countries, the intellectuals and scholars have had difficulties in unifying the concept of the division of Global North and Global South (Jackson, 2016). There is a considerable disagreement between academician and politicians to place the nations among the right groups (Lawrence, 2010). Anthony Gidden, a sociology textbook writer, places China among the Global South countries. On the other hand, his colleague Ritzer places China among the global North countries. Ritzer states that China is a Global North state due to its economic strength and power among the world decision-making process, while Gidden adds that most of its citizens are living on $2/day, comparable to Global South countries (Jackson, 2016). Similarly, countries like Argentina and Malaysia have above average GDP and yet placed among emerging countries as compared to Ukraine, who sits as a Global North nation despite its social and economic issues (60 Second guide to the Global North/South Divide).

The concept of the Global North and Global South have varied regarding time as it contains geopolitical uncertainties. The meaning of these terms will change as it evolves with the perspective of the academicians and era it is being defined. However, the existence of these terms will always be closely related to socio-economic and political structures (Andrea Wolvers).

2.4 Global North and South Within A State

It has been analyzed that the Global North and Global South are found between and within the same country. The characteristics of the Global South are witnessed in the Global North countries and the characteristics of the Global North within a Global South country. For instance, India has the largest concentration of poor people around the world, yet they have a substantial number of middle class and wealthy people. In a metropolitan city like Mumbai, India has tall corporate building and housing in the city and contrastingly, it is adjoined with Dharavi slum, the largest in the Asian continent (60 Second guide to the Global North/South Divide). Similarly, the United States of America is an industrialized, powerful and wealthy country and rests among the Global North zone by academicians. However, Mississippi in America lies well within the zone of a Global South due to its high poverty rate in contrast to other parts of the USA (Jackson, 2016).

Macroeconomic instability has always been a concern for the developed country (Harvey, 2006). They present an array of geographical scales between countries to local regions with many spatial configurations (Duck). Mississippi is an ideal example of a Global South region within a Global North country representing macroeconomic instability with spatial configuration to the rest of America. The people living in Mississippi are living in similar social and economic conditions as people in developing countries or third world countries (Jackson, 2016). The region experiences racial exploitation, violence, financial struggles among citizens and inadequate healthcare and education (Duck). The life expectancy of people living in Mississippi averages 69 years, less than the Global South countries like Brazil or any African country (Jackson, 2016).

Citing above in section 2.3, the critics in the academic world placing the onus of poor development in Global South due to exploitation from Global North countries for economic benefit and this can also be reviewed regionally. The immigrants displaced the natives in Mississippi, Louisiana, Alabama and Georgia in the USA and initiated operations in the agricultural products, especially cotton in the 19th century. The immigrants who initiated this business and the industrialist in the Northern region of America and Europe reaped benefits from these operations. Thus, the Global North region exploited for the industrialized benefit the Global South regions for raw material and labor-intensive jobs (Jackson, 2016). However, sociologist Ritzer claims that we also need to pay attention to the complexities of living conditions present in the rich and the poor regions and states. There are numerous examples of an impoverished region in a wealthy country that are better off then issues of the developing countries (Ritzer, 2013).

In the end, the division of the globalized world needs to be redefined. Nation-state analysis is crucial to evaluate and identify the issue, but along with that, we should also move beyond nation-state centrism to the transnational unit for better and in-depth analysis (Robinson, 2004).

2.5 Empirical Indicator of Two Globalized World

The framework to observe the two globalized world is interconnected topic of inequalities, poverty, subalternity, uneven deployment of wealth and resources (Jackson, 2016). It covers both the local and global interdependence. An empirical indicator would present a pellucid picture to view multi-scalar to granular details of natural and global inequalities. A comparative analysis between Global North and Global South presents a more precise picture of segregation between the two.

a. Level of Productivity

There is a low quality of life and human development in the Global South. It affects the productivity level of the working force due to physical and emotional lethargy, making them unable to withstand the daily pressure of competitive work and environment. Moreover, the workforce of the Global South lags the technical engineering conception of production along with managerial competence. The lack of access to information and knowledge impacts worker motivation, followed by institutional inflexibility (Strauss, 1988).

This low productivity levels, in turn, creates a vicious circle that directs to lower-income to the workforce causing emotional and physical lethargy among them and thus yielding low productivity and obstructing development. (Dasgupta & Ray, 1987)

b. Population Growth

Population growth has been a big concern throughout the world in the sense of the shortage of resources, climate change and disruption of sustainable living. In 2004, it was recorded that there are 6.4 billion people on Earth and out of which only one-sixth of the population is present in Global North, while the rest lives in the Global South. Furthermore, the birth rate in a Global North country is 15-20 per 1000 population, while for Global South is 30-40 per 1000 population and rising. The increase in the population of the developing countries further adds pressure due to resource shortage and causes the high death rate and in a shorter life span in the emerging country and low death rate with longer life span in developed countries (Odeh, 2010).

c. Dependency Burdens

Dependency burden is defined as part of the population that is not working and does not contribute to economic progress. They are the non-productive member of society and classified as children and elders (Dasgupta & Ray, 1987). The children's population of a developing country is 40% of the total population, while it is less than 20% of the total population in a developed country. In total, 45% of the total population in the Global South falls into the dependency burden in comparison to one-third of the total population of the Global North (Odeh, 2010).

d. Agricultural Production

The agricultural sector is a crucial industry for sustainable livelihood and food resources. However, the living conditions have to upgrade in the rural areas where agricultural production takes place. It includes sanitation structure, global equality and just society. Global South witnesses more people working in the rural sector (Todaro & Smith, 2006). 65% of the people in developing countries are living in the rural areas and 58% of which are involved in agricultural activities, while 27% of the population in Global North countries are living in the rural areas and only 15% are working the agricultural sector (Odeh, 2010).

e. International Relations

Global North has always held a dominant position over the Global South for international trade and agreement on regulations. They are stronger due to economic, military and technical superiority. They are the one dictating the terms for the trade agreement, private capital transfer and aid, while they are the main culprits for the poor quality of life and under-development of Global South (Odeh, 2010). They push for a beneficial economic deal that impacts the working conditions, environmental degradation and income inequality by shifting the polluting industries or dumping of hazardous waste in the Global South.

2.6 Conclusion

The term Global North and Global South were introduced post cold war era to move from the distinction of three different worlds. The developed countries in the world were kept in the frame of Global North as they were majorly from the northern hemisphere but also had countries like Australia and New Zealand from the South. While the under-developed and developing countries were placed in the bracket of Global South.

The comparative analysis in the social, economic, political and technology sector presents an overview of the differences in the two globalized worlds. This distinction is not purely based on income, GDP or HDI. Instead, it shows a difference in the public sector, state organization, well-developed economy, dominant industrial sector, social development and an equal share of resources for a Global North as compared with Global South. Moreover, empirically, this distinction can be seen from the point of population growth, low level of productivity due to resource unequal distribution and subjugation in international relations for the Global South in comparison to Global North.

However, the distinction of the nations also needs to address the presence of the Global South in Global North country and a division further needs to be redefined. A nation-based division is simplistic, but an in-depth analysis presents the need to move from nation-centrism to transnational unit.

Chapter 3

Sustainable Energy Transition in Global North and South

This chapter of the thesis elaborates the implication of the distinction between Global North and South for the sustainable energy transition. The first part of the segment is literature research broadening the view on sustainable development and the role energy transition plays in the globalized world and its implication. Further, the chapter explores the differences in energy consumption, energy poverty and sustainable energy transition in the globalized world. It expresses the target of carbon emission reduction and development worldwide is uneven and a sustainable energy transition can be at the forefront of overall development and mitigate the climatic changes.

3.1 Introduction

The climatic changes have prompted a change from fossil fuels to renewable energy to reduce the carbon emission and make our energy system efficient. However, the change is bounded by the economic differences and social inequality between the globalized world, restricting the energy transition.

The Brandt Commission, established in 1977 by the head of the World Bank Robert McNamara and chaired by former Berlin and German Chancellor Willy Brandt, published a report on the impending climatic and economic catastrophe. This report primarily focussed on reviewing global developmental issues and presented a drastic economic development and standard of life difference between Global North and South. The commission report asserted that the development of the South in order to balance this segregation is required to avert the catastrophe to humankind and strongly suggested a transfer of technical knowledge, plans and other resources to the developing country (Brandt Report, n.d.).

3.2 Sustainable Development in the Globalized World

Defining the concept of sustainable development has been a difficult task over the years. Since 1987, there are more than 50 definitions of sustainable development stated by different academicians, politicians and organizations (Savage, 2006). The most famous and accepted definition among scholars for sustainable development is (Yazdani & Dola, 2013), "*Development that meets the need of the present without compromising the ability of the future generation to meet their needs*" (WCED, 1987). However, author and sustainable development consultant Robert Allen's definition added: "to improve the quality of life of the current generation under the circumstances that allow the utilized ecosystem and natural resources to keep renewing themselves" (Allen, 1980). Thus, focusing on human development and utilization of renewable sources to do so. On the other hand, scholar G.P. Hammond adds with his definition "to balance the social and economic development and protect the environment, i.e., people, planet and prosperity" (Hammond, 2000) or the "triple bottom line" (Parkin, 2000).

Among all the definitions, there has been a constant emphasis on the ecosystem. Following the understanding of sustainability, the United Nations formulated 17 Sustainable Development Goals. These goals focused on protecting the biodiversity and ecosystem, economic development, equality, human wellbeing and development, justice, people and business endeavour regularly to improve natural, built and cultural sections (Haughton & Hunter, 1994), provision of clean air, water and eco-friendly and affordable energy. However, post the development of these goals, there has been disagreement and difference to explain the "Needs of people and environment and are idealistic and impractical" (Hall T., 1998). The sustainability development ideas that are suitable and hold their characteristics to the Global North Countries are not suitable to Global South countries due to the social and cultural diversity and limitations (Myllyla & Kuvaja, 2005). The developed nations have their focus on sustainability (Kemmler & Spreng, 2007), i.e., the green agendas like environmental issues and its long-term impact, resource degradation and waste aggregation (Savage, 2006). On the other hand, the developing countries prioritize brown agendas, which include poverty, sanitation, waste hazard, pollutants in the air, water and soil, secure food resources, poor health conditions and necessary infrastructure (Savage, 2006). Therefore, it is believed that sustainable development is time and spatial dependent (Parkin, 2000).

Similar, assessment can be made about the energy system. The seventh sustainable development goals state that every person should have access to clean and affordable energy. However, the differences in the energy system and supply are witnessed in the globalized world. The Global North has a strong economy and provides secure access to energy. With the climatic changes and to reduce their emission, they have the technological advancement and organization of state to make a transition. Contrarily, the Global South does not have a similar simplification with the transition. The developing countries have a high poverty rate, a weaker economy, technologically inferior and shortage of energy supply. With these limitations, the goal of the Global South regions is to provide reliable energy at a cheaper cost, which is available with fossil fuels.

Moreover, the sustainability assessment in the globalized world is evaluated using indicators suitable to evaluate environmental issues in the Global North and not suitable for the Global South. For instance, carbon leakage is not assessed, which identifies the increase in carbon emission in one country as a result of decreasing carbon emission in another country (Yazdani & Dola, 2013), e.g., import of raw material and export of hazardous waste.

This universal inequality takes away the cooperative effort required by nations to achieve sustainable development goals as they casually ignore the problems of the Global South, creating a lack of trust and disrupts a platform to promote solutions (Timmons & Bradley, 2006).

3.3 Energy Consumption by Global North and South

History of human progression and development has been linked with the availability and consumption of energy. The industrial development in the last two centuries has witnessed the energy consumption increasing exponentially (Sørensen, 2012). This increase in consumption has been unequal among countries (Arto, Capellan-Perez, Lago, Bueno, & Bermejo, 2016) and between different social classes within the same state.

The consumption of power and the human development index (HDI) cease to co-exist (Akizu, et al., 2017). Countries with an HDI greater than 0.7 has an energy consumption higher than 4700 kWh per capita (Arto, Capellan-Perez, Lago, Bueno, & Bermejo, 2016). This assertion is relatable to Global North countries that rank high in the HDI. As seen in Figure 3.1, an average German or Danish person consumes 26,100 kWh/year and 40,200 kWh/year. It is way higher when compared with Global South countries like Cuba, where a person consumes 10,600 kWh/year and a Chinese person consumes 23,000 kWh/year. However, if hidden energy flows (HEF) are considered, then the energy consumption for Global South countries is even lower. Hidden energy flows are defined as energy debt on a developed country has been transferred to a developing country to reduce its energy consumption while maintaining its strong GDP, resource conservation and ecological balance. However, the production unit of energy and material is shifted to another country while a developed country indirectly consumes them. The ecological debt with these HEF impacts the society and environment in the Global South (Akizu, et al., 2017).

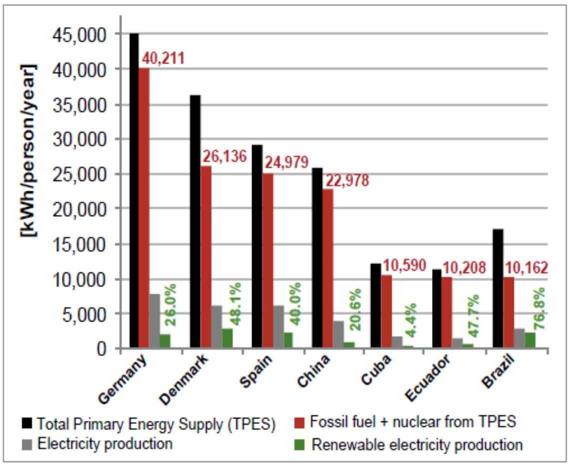

Figure 3.1 Variation in renewable energy share and fossil fuels in the primary energy supply for globalized countries.

For instance, Germany and Denmark are leading countries in the field of sustainable transition to renewable energy sources and the reduction of carbon emissions. As presented in figure 3.2, Germany, with their energy efficiency policies, have reduced their emissions by 21.94% since 1990 and similarly, Denmark has reduced it by 30.27% owing to HEF. While developing states like Brazil and Ecuador have increased their emission by 90.15% and 83.74%, yet the emission from Germany and Denmark per capita in 2013 is much higher than these countries (Akizu, et al., 2017). If the HEF is added to the industrial

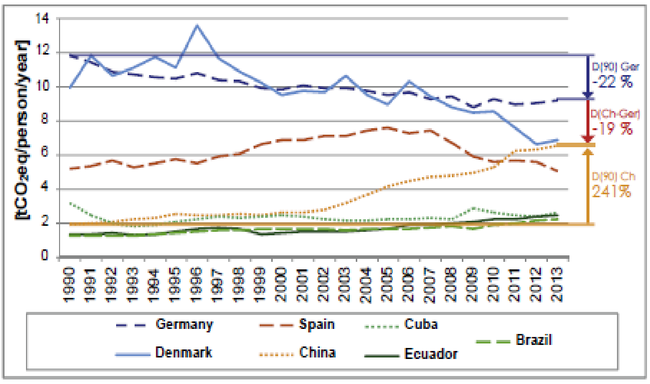

Figure 3.2: CO2eq emission from fuel consumption for the energy supply of globalized countries.

countries, then the energy consumption and the emission emitted by Global North will be higher. Thus, Global North nations are leading the emission and need to reduce their energy consumption significantly without formulating a hidden energy flow.

There are different studies, where a hypothesis is made that developed countries can reduce their energy consumption without causing any loss of quality of life or manage the natural resource depletion (Arto, Capellan-Perez, Lago, Bueno, & Bermejo, 2016). A similar trend can be witnessed in Overijssel in The Netherlands. The province has been able to reduce its energy consumption from 107.7 PJ to 100.7 PJ from the year 2013 to 2017, without any implication to quality of life (Reporting Energy Use- Overijssel, 2019).

On the contrary, the energy consumption for Mathura, India, a Global South region with similar land area and the larger population is estimated at 15.51PJ. The city receives energy round the clock but does not generate any energy. It will be unfair to set similar parameters for Global North and South to reduce energy consumption to protect the environment at the expense of economic growth, where a developed country is majorly responsible for ecological unbalance (Purvis & Grainger, 2005). However, a transformation of the growing energy consumption from fossil fuels to the sustainable system should be examined for Global South. While the Global North can further reduce their consumption and make a transition to renewables.

3.4 Energy Poverty in Global North and South

Energy plays a vital role in the day to day life of people. Humans utilize it for daily work, education, participation in social life and communications. Therefore, the energy transmitted should be reliable and affordable to attain social, economic, technical and cultural development. Energy poverty is a situation confronted by both the Global North and Global South that halts the overall development of society. It is defined as "*an inability to realize essential capabilities as a direct or indirect result of affordable, reliable and safe energy services and taking into account available alternatives of realizing these capabilities*." (Day, Walker, & Simcock, 2016)

The interpretation of energy poverty is different in the Global North and South. In the Global North, energy poverty is related to affordability and the implications of unable to afford the primary energy requirements. For the Global South, energy poverty holds a different explanation as the states are unable to provide reliable energy services by extending the energy infrastructure (Sen, 2014).

For nations belonging to the northern hemisphere of globalization like UK, USA, post-Soviet Europe, European Union have security of energy supply. The primary energy requirement and wellbeing for them is focussed on thermal comfort (Howden-Chapman, et al., 2012) (Thomson & Snell, 2013) (Petrova, Gentile, Mäkinen, & Bouzarovski, 2013), including hot water and spacing. The other energy services like electricity and transportation are acknowledged but are not strained concerning affordability and services. These countries are focussed on the affordability of heating due to under-rated energy efficiency in the houses leading to higher expenses for space heating. Heating issues due to poor efficiency leads to poor health or reduced expenses to meet other needs of a household (Day, Walker, & Simcock, 2016). In UK policy, fuel poverty in 2001 was defined for households spending more than 10% of their income to achieve suitable heating (Boardman, 1991). Additionally, unlike other EU countries, Austria was also focussing on lighting along with heating (Brunner, Spitzer, & Christanell, 2012), while Greece also investigated cooling during the summer months as significant energy demand (Santamouris, et al., 2007).

Moreover, the energy requirements for heating and lighting also depend on the inhabitants of a household. The energy poverty has a more significant impact on houses with elderly and children residing as they are home during daylight hours and their body endurance requires more comfortable environment (Executive, Scottish, 2002). The dependency burdens for a Global North is rising with the average age of the population is growing older. This situation would increase the energy consumption further for the Global North with little impact on economic development.

For the Global South countries, billions of people do not have access to energy, clean water, safety and food security and the focal point is to get access to electricity to provide these amenities (Day, Walker, & Simcock, 2016). The people in Global South are dependent on solid fuels like coal, raw biomass for cooking and electricity while oil for transportation, heating and lighting. The use of these resources causes air, water and soil pollution and has a more profound effect on the health of women and children (Bruce, Perez-Padilla, & Albalak, 2000). Additionally, collecting these resources at a personal level in the rural areas is time-consuming and does not result in knowledge, income and further reduces productivity level (Day, Walker, & Simcock, 2016).

3.5 Sustainable Energy Transition in Global North and South

Presently, energy transition to sustainable resources has been related mainly to the electricity sector in the globalized world (Akizu, et al., 2017), which accounts to 12.38% of the total energy utilized (Energy balances 2013, 2013). Although, the phenomenon of the energy transition is not only related to electricity but also involves the transition of energy for transportation, cooking and thermal comfort with a secure supply (Akizu, et al., 2017). Therefore, to implement 100% sustainable energy technology, efforts need to be made to develop a smart energy system that formulates a synergy between the energy systems. Furthermore, the energy transition in Global North and South must progress together with development in social, cultural and economic sectors. The current techniques and plans are made in following Global North (Rana, 2009), while there is a minimal study on energy transition in Global South.

Transition in the energy system is challenged by geographical locations, demography, economics, political, cultural and environmental conditions concerning historical traditions (Laurie, Andolina, & Radcliffe, 2005). Energy development is a wholly relative and context-dependent concept (Pike, Rodríguez-Pose, & Tomaney, 2014) and the ideas of sustainable development in the Global North will not work in the Global South (Rana, 2009).

Global South presents challenges to energy transition due to lack of studies and data availability for the researchers. In globalized South, there are no statistics on energy consumed or needed by households and the energy is often obtained from the grid by unlawful activities, i.e., black market (Day, Walker, & Simcock, 2016). Additionally, the implementation of renewable energy in the Global South is deterred by corporate greed. For example, the hydroelectricity plant in Brazil occupied the land from the locals and transferred it to the corporates. The wealth generated is kept by the plant owners, with no benefits are transferred to the displaced locals. Moreover, the prices of electricity remain high for increased profits to the owners, while the workers are exploited with low wages and poor working conditions.

On the other hand, the energy transition in the Global North presents different challenges. The data availability and studies provide support to technological innovations and transition. However, there are limitations in the process through policies and the social sector, along with excessive consumption. For instance, the European Union regulates the use of land for the first-generation bioresource. The Dutch government imposes similar regulations on cattle farmers, where they have to export excess manure to their land area. Another example is the case of NIMBY (not in my backyard), a phrase used by the locals to avoid having wind turbines near their houses. Nonetheless, the awareness among people and the environment-friendly policies by the government have initiated the transition into low carbon technologies.

It has been witnessed that the Global North states like Germany and Denmark have progressed and leading to the integration of renewable energy systems in their electricity transmission. Although, as we analyze figure 3.1 and the arguments related to issues with the transition in Global South, states like Brazil and Ecuador have a higher share of renewable energy as compared to Germany and Denmark and the utilization of fossils is much lower than the Global North countries (Akizu, et al., 2017).

Additionally, the implementation of sustainable energy technology in the globalized world also presents a distinction. The regions in the Global North are more lenient towards a bottom-up approach or a democratic and social awareness approach. A bottom-up approach can be defined as an effort initiated by the participation of the community, while democratic and social awareness also includes the participation of the community but in a combined effort with the administration as a result of awareness regarding energy issues and implication of climatic change. The two above mentioned approaches are useful in the Global North due to a high rate of education and socio-economic equality.

Meanwhile, the transition approach for Global South would be more lenient toward the top-down approach. A top-down approach refers to an action by the government for the benefit of the people, where they do not intend to have a say but can review the results. This approach for Global South is beneficial due to poverty, low literacy rates and inequality. Although, more developed Global South states also have an option to imply a democratic and social awareness approach.

However, the approach to have a sustainable transition in the energy system is not related to Global North and Global South countries but rather region dependent. For instance, Feldheim in Germany prefers a top-down approach with the banks having the option to choose based on monetary benefits and not the citizens. On the other hand, in eco-village Sieben, Germany showcases a bottom-up approach, where people changed the way of life by minimizing material consumption, sharing communal areas of the house and placing a low carbon energy system.

Furthermore, it is hard to pick one method to implement sustainable energy transition in the Global North and South. Different regions have diverse regional capabilities to generate and maintain a secure supply of energy supported by social and cultural values creating economic benefits. For instance, Ontario in Canada generates a substantial amount of wind energy with its offshore wind turbines (Giannetta, 2018). Subsequently, Maharashtra and Gujrat states in India focuses more on bioenergy (Goyal, 2018) and solar energy as they are rich in bioresources due to their social and economic activities and geographical location. It is challenging to integrate a single model that also supports economic growth, as multiple social processes will have a different preview from diverse disciplines (De Paula & Dymski, 2005). All the regions in the globalized world share the spatial imbalances in geographical concentration related to economic growth (Pike, Rodríguez-Pose, & Tomaney, 2014).

3.6 Conclusion

To conclude this chapter, a sustainable energy transition in the Global North and South will have implications due to the diversity presented between the two states. Sustainable Development Goal 7, formulated by the United Nations, focuses on clean and affordable energy for all. However, the "Need" associated with sustainability differs in the globalized world. The Global North objective towards need is for green agendas like environmental protection and resource degradation. While, for the Global South, the need relates to brown agendas, that is food and energy security, poverty and health hazards.

On the other hand, while analyzing the energy consumption in the globalized world, it is found that the consumption of developed countries is way higher than the developing countries. The initial attempts to reduce the consumption and carbon emission in the Global North were assisted with hidden energy flows, as seen from the example of Germany, Denmark, Brazil and Ecuador.

Nonetheless, the consumption and carbon emission of the southern countries was examined to lower post hidden energy flows.

The analysis of energy poverty provides another distinction between the globalized world. The measures to define energy poverty is different in both Global North and South. The Global North energy poverty is more inclined to the affordability of energy and mainly heating for their general public. Inability to afford basic energy requirements would hinder the wellbeing of the local public in the developed world. Meanwhile, for the Global South energy, poverty has a much broader meaning associated with the reliability and secure supply of energy. The shortage of energy promotes the use of raw biogas or oil-filled candles for light leading to health effects and mental and physical lethargy, leading to lower productivity.

Moreover, sustainable energy transition must progress together with development in social, cultural and economic sectors by formulating a synergy between the energy systems. An energy transition in the Global North faces limitation with social welfare groups and policies yet is much simplified with the awareness among people and the ability to manage the cost related to secure supply. Although, it is not that simplified with the Global South facing energy shortage, lower economic development and illegal activities.

Lastly, there are diverse approaches like top-down, bottom-up and democratic and social welfare for energy transition. Nevertheless, these approaches are not confined to Global North and South countries but rather at the regional level. An energy transition in the Global South will be more inclined to a top-down approach, while the Global North region differs in accordance to the communities. To conclude, it is challenging to integrate a single model across the globalized world. Different regions have diverse regional capabilities to generate and maintain a secure supply of energy supported by social and cultural values creating economic benefits.

Chapter 4

Data and Method for Energy Transition Scenario Analysis

This chapter of the thesis explains the data availability and tool utilized for simulating the energy transition scenario and its analysis. At first, a brief introduction of the energyPLAN tool is presented along with the reasoning to use this software to answer the research question. Later a brief understanding of the smart energy system is conferred, followed by the inputs and data acquired for the tool. Lastly, the chapter ends with an explanation of the simulation strategy for the research.

4.1 EnergyPLAN Software

The energy transition model for the Global North and South are designed based on the theoretical framework of the smart energy system. The verification of the energy transition model for the case study is conducted through simulations on software to indicate the distinction between the globalized world for a sustainable energy transition.

Therefore, a literature review ushered a concise analysis of all 37 available energy planning tools and compared them with each other. The comparative analysis assisted in shortlisting four tools, namely EnergyPLAN, Homer, Compose and LEAP. The shortlisting was done based on availability of the software and tutorials online, training period, integration and analysis of diverse renewable energy technologies and smart energy systems. One vital criterion for shortlisting the software for this thesis was that the software could assist in developing and simulating scenarios annually with a futuristic vision.

Of the available tools for energy planning, energyPLAN software is selected. EnergyPLAN has a user-friendly interface, open-source, includes all energy balances and sectors and embraces the futuristic low carbon energy technologies. The energy system analysis model was developed in the year 1999 and since then has been upgraded continuously, most recently to version 15 in

September 2019. Moreover, the training period for the tool required from a few days to a month based on the complexity of the simulations (Connolly, Lund, Mathiesen, & Leahy, 2010).

The energyPLAN software presents a medium to the research community to validate their energy transition scenarios. It has been used in researches to design and simulate national and regional energy planning strategies by formulating a synergy among energy systems. The tool includes the fossil energy system, renewable energy technologies, thermal systems and energy storage systems across the domestic and industrial sector. It is a deterministic input-output model with the inputs are energy demands and generation capacity along with their distribution profile, regulation strategies for import and export of energy and costs (EnergyPLAN, 2017). Furthermore, the scenario timeframe required is one year with a one-hour time step and has the luxury to be combined and create a scenario for multiple years (Connolly, Lund, Mathiesen, & Leahy, 2010). The energy system analysis can be carried out with different technical simulation strategies and market economic simulation strategies (EnergyPLAN, 2017).

Technical Analysis

For the technical analysis and design of the energy system, an input of energy demand, production capacities, efficiencies, storage units and energy sources are required. The input presented along with the distribution profile for each energy use delivers the output in the form of fuel balance, carbon emissions and annual energy balances. This simulation strategy focuses on simulating energy system with penetration of a large number of renewable energy sources, reducing the import and export of electricity and minimizing the fuel balances (EnergyPLAN, 2017).

Market-Economic Analysis

Further, for market economic analysis, the trade of energy is based on the energy market prices. The alteration in the import and export of energy is dependent on those prices. This model works on the assumption to optimize the business economic profits by identifying the least cost solution along with taxes and cost of carbon dioxide emissions (EnergyPLAN, 2017).

4.2 Smart Energy System

EnergyPLAN tool emphasizes on formulating a smart energy system through synergies between electricity, thermal comfort and transportation demands and generation. It analyses the whole energy system and provides a medium for fluctuating energy production to be utilized among diverse energy balances during low demands. For instance, renewable energy sources like wind and solar energy are fluctuating and often face the issue, where the supply does not match the demand. This fluctuating energy is integrated using smart grids. The excess electrical energy generated is utilized for other purposes like heating, production of hydrogen for synthetic fuels, fuel cells and production of biofuels (EnergyPLAN, 2017). Such measures create a synergy and optimize the use of the energy system, thus replacing fossil fuels and improving fuel efficiency.

The energyPLAN tool calculates the hourly balance of energy demand and generation across all sectors. Further, it optimizes energy usage based on the regulation strategy set for the import and export of energy and the simulation strategy. The illustration of components in the energyPLAN model and the interaction with other energy balance is presented in figure 4.1.

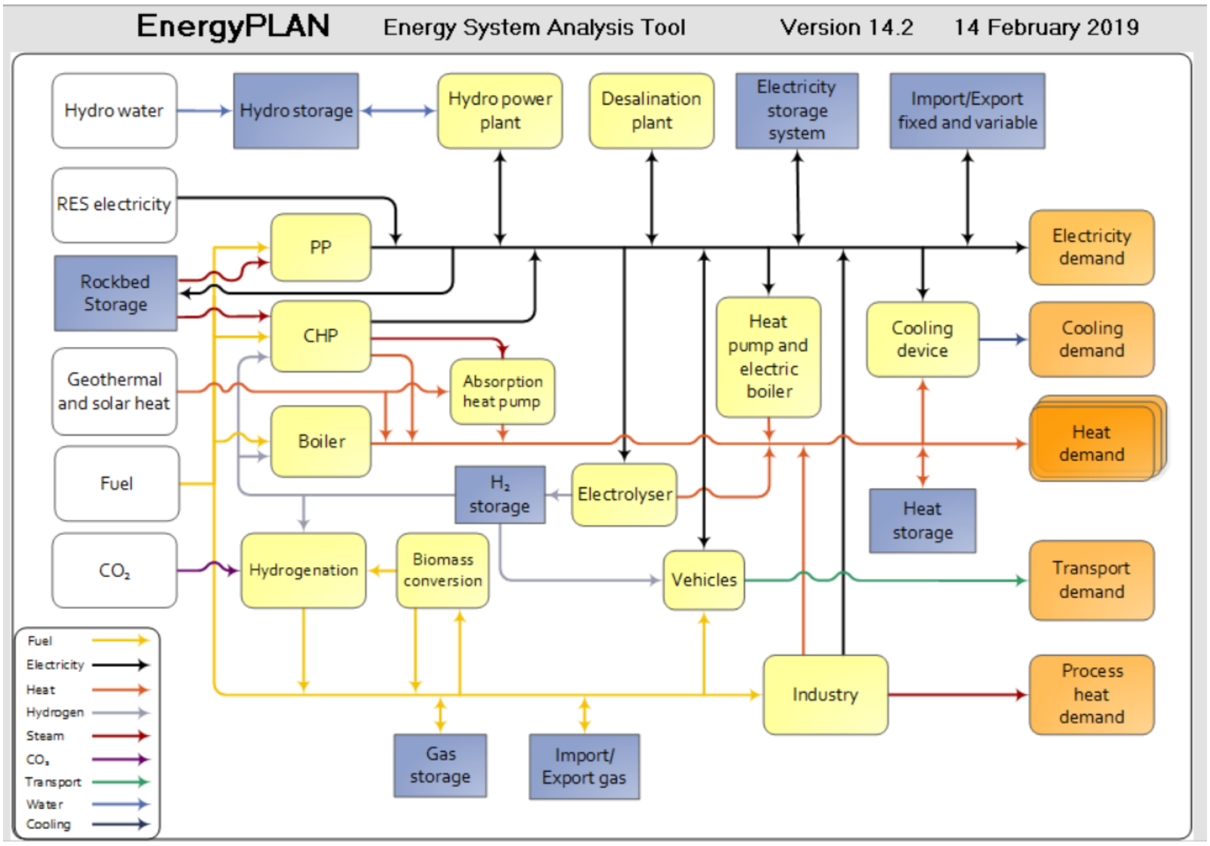

Figure 4.1: Energy flows in energyPLAN tool

4.3 Input Data in The Model

The input into the energyPLAN model for the thesis is described in this section in the following format.

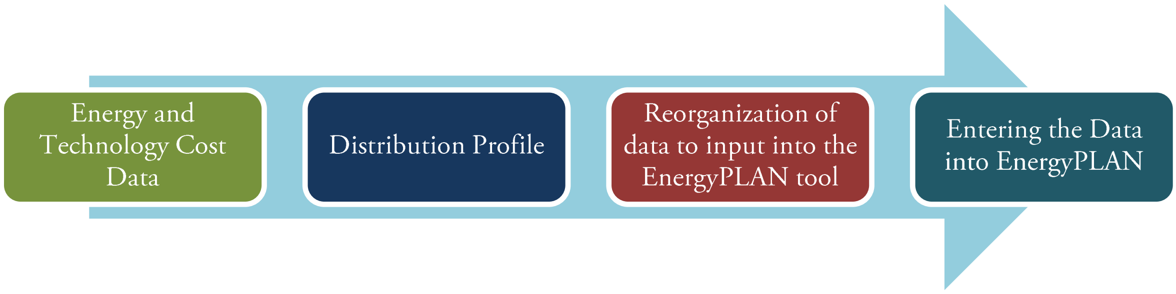

Figure 4.2: Process Flow for Data to be utilized in energyPLAN

Energy Data

The static data of the energy for the province of Overijssel is collected from the official website http://www.overijssel.nl and the previous year data for energy is collected from https://klimaatmonitor.databank.nl. The data collected includes energy consumption through electricity, heating and transportation across all sectors.

On the other hand, for the district of Mathura, the electricity data was collected by contacting the local authorities and was provided by Dakshinanchal Vidyut Vitran Nigam Limited (DNVVNL) *(See Appendix D)*. The transportation consumption data is not available with the local authorities. Therefore, an assumption is based on contact with local authority and owner of a fuel station and presumed to be the same for all registered fuel station in the district. While the cooking fuel data is acquired from the official Assessment report on LPG cooking fuel by CRISIL: An S&P Global Company in June 2016.

Technical Cost Data

The technical cost data includes the investment cost of the energy system divided over the operational lifecycle of the system. Moreover, the operation and maintenance cost of the system, fuel cost, fuel handling cost and cost incurred with carbon emission are also added to calculate the techno-economic cost. This data is acquired from the developers of energyPLAN software, who compiled the cost from diverse researches based on European standards. The technology and fuel valuation of the system is determined for the year 2020, 2030 and the year 2050 and utilized respectively for individual scenarios. *(See Appendix A)*

Obtaining Distribution Profile

The distribution profile is required to know the hourly energy demand. The hourly profile of climatic conditions and energy flow is also needed to determine the energy production by the renewable energy system. The energy consumption profile for electricity and gas for Overijssel is acquired from Liander. The distribution profile downloaded is a generic one from the year 2008 and assumed for the province. Additionally, the tool requires solar and wind data to evaluate the actual energy production from solar energy and wind energy systems. The hourly weather profile of Overijssel is downloaded from Meteorological Data Portal for TU Delft (https://www.tudelft.nl/). The dataset consisted of one year constructed from weather data averaged over a multitude of years, with a one-hour time resolution *(See Appendix C).*

Table 4.1: Distribution Profiles and Data Sources for Overijssel

Distribution	Timespan	Source
Solar irradiance	Average 1991- 2018	TU Delft
Wind speed	Average 1991- 2018	TU Delft
Electricity demand	2008	Liander
Gas/heat demand	2008	Liander
Transport BEV	Basic Data Profile	EnergyPLAN
Constant	Value 1 for all hours	EnergyPLAN

The distribution profile for the Mathura region is not available due to administrative regulations. Therefore, the profile is formulated by using the Artificial Load Profile Generator (ALPG). ALPG is an open-source software developed by the University of Twente and simulates load profile for electricity and heating with constraints from controllable domestic devices. However, for Mathura, these controllable domestic devices are not used, and a basic electricity profile is developed based on the demographics of the city. The weather profile for the district is downloaded from Solar Radiation Data (SoDa) website (http://www.soda-pro.com/web-services/meteo-data/merra) and are at a one-hour time step *(See Appendix D).*

Table 4.2 Distribution Profiles and Data Sources for Mathura

Distribution	Timespan	Source
Solar irradiance	2018	SoDa
Wind speed	2018	SoDa
Electricity demand	Monthly Average 2018	DNNVL
Gas/heat demand	Not Applicable	Not Applicable
Transport BEV	Basic Data Profile	EnergyPLAN
Constant	Value 1 for all hours	EnergyPLAN

Reorganization of Data

To input the data into the energyPLAN tool, the static energy consumption data must be altered to annual data in Terawatt Hours and the energy generation units in Megawatt. On the other hand, the distribution profile must have 8784 data points at a one-hour time step and are usually between the range 0-1, representing 0-100%. This is automatically adjusted by the energyPLAN tool once the data is placed in the required format and uploaded. Another method is to divide the data set with the maximum value to achieve a viable data set for the tool. Moreover, the profile must be uploaded as a text file and saved in the distribution profile folder of the tool. (EnergyPLAN, 2017).

Influence of data on Simulations

The results of the simulation are dependent on the data set and the distribution profile uploaded into the software. The energy distribution profile for Overijssel is from 2008, while the static data is current. An alteration in the results is expected if the current data set is used and applied for future scenarios. These alterations are due to changes in the behavior of consumers and the introduction of new and efficient appliances. Similarly, the data set for Mathura was not available with ease and needed to be extrapolated from one month, while the distribution profile is generated through ALPG. The software generates a comparable profile for the Netherlands. However, the societal differences between India and the Netherlands will generate a comparable difference in the manner of distribution.

Lastly, the simulations are influenced by selecting the regulations criteria to reduce CEEP and to maintain the grid stabilization. The CEEP strategy for both the regions is selected separately, while the grid stabilization share has been the same for both the regions to 0.3. *(See Appendix A)*

4.4 Conclusion

There are 37 energy planning tools that are available to simulate energy systems and were analyzed based on a review paper. Out of the list of software mentioned, the energyPLAN tool was the most suited among them as it involved simulations based on scenarios and integrated the current and the futuristic renewable energy technologies. Moreover, the scenario simulations are not restricted by timeframe and match the demand and supply on an hourly basis for the whole year. The results available from the simulation by utilizing the hourly distribution profile are realistic and has been utilized in several case studies throughout Europe.

Additionally, for the simulations, the software requires static annual energy data and distribution files with a timestep of one hour. The energy data and distribution files acquired for the respective region has to be reorganized before being uploaded into the software for simulations. Given the focus of the research for this thesis, the tool can provide relevant results that can be utilized to compare energy transition in the Global North-South dimension.

Chapter 5

Case Study: Energy Transition in Overijssel

5.1 Introduction

This chapter characterizes the sustainable energy transition in the Global North by utilizing the Province of Overijssel in the Netherlands as a case study. The objective of this part of the case study is to formulate energy transition in Overijssel to make it energy neutral by the year 2050. This planning for the energy transition is done considering the geography, demographics, economy, society, resource availability and the energy potential in the region.

The transition initiates by determining the current energy system in the province and energy targets in place by the provincial and the national government. The energy consumption targets are in place to reduce the carbon emission and are utilized to determine the energy consumption for the year 2030, 2040 and the year 2050. Based on the predicted consumption for electricity, heating, industries and transportation, the transition in the energy system is simulated on the energyPLAN tool for the year 2030, 2040 and 2050 utilizing diverse energy technologies. The results from the simulations are explained, followed by a comparison between the energy transition scenario and a business-as-usual scenario for the year 2050 is presented.

5.2 Province of Overijssel

5.2.1 Geography and Demography of Overijssel

The province of Overijssel is located on the eastern side of Netherlands with its capital city Zwolle, and Enschede as its largest city. The province covers a land area of 3,327 km^2, with a population of 1.15 million as of the year 2019. The gender ratio in the region is approximately equal and the average population age is 40 years (Province of Overijssel, 2019).

The region is administered at the intermediate level and focuses on regional development by keeping track of spatial and economic planning. The province is well connected to cities and villages and supports local companies and SMEs through diverse connecting programs and subsidies. They also take proper care of local landscapes that boost the opportunities for tourism (Province of Overijssel, 2019).

5.2.2 Socio-Economic Factors in Overijssel

The people in Netherlands are aware of the climatic changes and determined to transform into sustainable living while maintaining the security of energy supply. The province of Overijssel has half of its population living in urban cities, while the other half is living in rural areas. The region focuses on agriculture and eco-tourism and wants to maintain their pleasant surroundings. Furthermore, the agriculture and food industry in the province is supported as it recently received € 12 million for sustainable initiatives research and implementation (Province Overijssel, 2019). For this, the regional government plans to utilize the bioresources as the primary source of energy. However, there are doubts related to maintaining biodiversity and carbon reduction. The regional government supports local initiatives with bioresources through subsidies. However, in the year of 2015, these subsidies were suspended for biomass co-firing. Although, later, a limit of 25 PJ of biomass co-firing was approved (Zuidema, 2016).

The awareness has initiated efforts to reduce their carbon consumption in the Netherlands, but there are barriers from local regulations and procedures. For instance, NIMBY (Not in my Backyard) is referred to as a situation by locals to avoid having wind farm and biomass processing units in the locality. Wind turbines create visual and audio pollution, while there is a fear of nuisance due to transport and process of bioresources. Moreover, due to low potential in the inland region and authorities not much in favor of wind energy (Hoppe, Dijk, & Arentsen, 2011).

Additionally, spatial zoning is a pre-determined criterion for installing renewable energy in the region. It involves diverse stakeholders and dealt with the development of integrated environment vision documents. This document provides a list of sites approved by the local stakeholders and the government to diffuse the renewable energy systems (Hoppe, Dijk, & Arentsen, 2011).

On the other hand, the local solar energy system does not face much opposition from the people in the region and the solar panels can be applied to the household and building roofs. However, the systems face financial restriction due to low irradiation causing lower output with their operation and high initial costs (Hoppe, Dijk, & Arentsen, 2011).

5.3 Overview of Energy System

This section of the chapter previews the current energy system, energy consumption across all sectors, the resources available and the energy potential of those resources. The energy generation and consumption data are acquired for the year 2015.

5.3.1 Energy Supply in Overijssel

The energy supply in the Overijssel is accounted to be 102.8 PJ for domestic, commercial and transportation in the year 2015 (Beurskens, 2016). Among the energy delivered, only 9% of energy is generated from renewable energy sources that include wind, solar, geothermal, bioenergy and biofuels. The rest of the energy is generated by fossil fuels like coal and natural gas and imported from the neighboring regions. The details of the current energy system can be viewed in table 5.1 below.

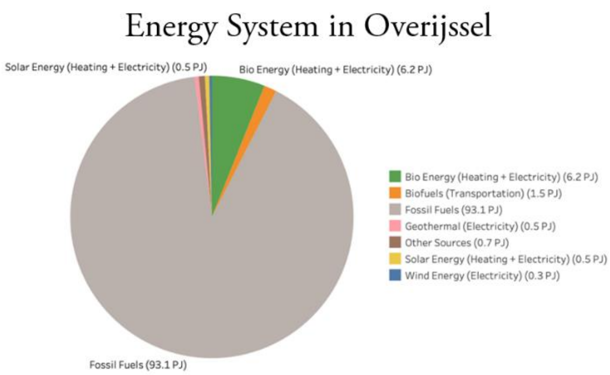

Figure 5.1: Energy System in Overijssel (2015)

Table 5.1: Energy Supply in Overijssel (2015)

Total Energy Required in Overijssel *(Year 2015)*	**102.8 PJ**
Energy derived from Fossil fuels or Imported	**93.1 PJ**
Total Renewable Energy Generated	**9.7 PJ**
Wind Energy (Electricity)	0.3 PJ
Solar Energy (Heating + Electricity)	0.5 PJ
BioEnergy (Heating + Electricity)	6.2 PJ
Geothermal (Electricity)	0.5 PJ
Biofuels (Transportation)	1.5 PJ
Other Sources	0.7 PJ

5.3.2 Energy Consumption in Overijssel

As stated above, the total energy consumption in Overijssel is 102.8 PJ for the year 2015 (Beurskens, Reffeltrath, & Menkveld, 2016). The energy consumed can be divided into consumption in domestic, commercial and transportation sectors. Furthermore, the energy consumption is these sectors are administered as electricity, heating and fuel. The consumption patterns of 2015 are listed in table 5.2.

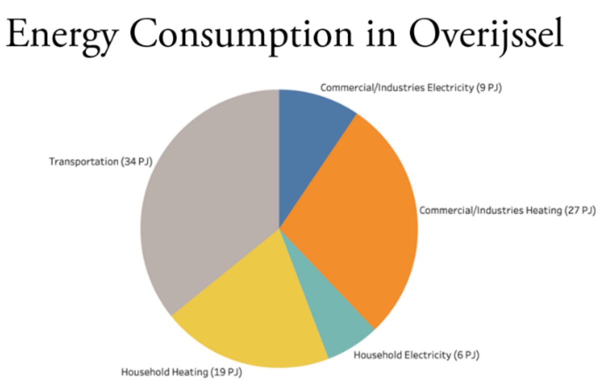

Figure 5.2: Energy Consumption Pattern in Overijssel

Table 5.2: Energy Consumption Pattern in Overijssel (2015)

Total Energy Consumed in Overijssel	**102.8 PJ**	
Household	27.8 PJ	
	6 PJ *(Electricity)*	19 PJ *(Heating)*
Commercial/ Industries	40 PJ	
	9 PJ *(Electricity)*	27 PJ *(Heating)*
Transportation	34 J	

5.3.3 Sustainable Resource Potential

In order to achieve the provincial targets on reducing carbon emission and integrating renewable energy technology, the province focuses on four sources of energy besides energy efficiency.

1. Bioenergy

The bioenergy to be generated and utilized in the region must be provided by the second, third and fourth generation biomass feedstock. The European and the national law restricts the use of first-generation feedstock for safeguarding food security. The standard type of waste and bioresources available in the region is pruning wood, animal waste, municipal solid waste (MSW) and agriculture waste. These wastes can be utilized to produce green gas upgraded from biogas and gasification processes, while the process of pyrolysis can produce the biofuel.

Pruning Wood

The forest land area can be utilized to acquire pruning woods. It has been assumed that we are not using the land to grow trees but utilizing the forest area sustainably for a constant source of pruning wood. The forest area in the province is estimated to be 33270 ha, while for the simplification oak tree has been assumed as the source for pruning wood with 10% pruning. The energy potential of pruning wood is estimated to be 6.6 TWh per year *(See Appendix B).*

Organic Feedstock

Dairy farming is a prominent industry for dairy products and meat in the Overijssel region and manure disposal is a big problem in the region due to regulations. These regulations content the dairy farm owners to process extra cost to transport the manure out of the region. The overall unused biomass potential in the region is about 200,000 GJ/ year, where most of it is the solid animal waste. The number of biomass process installation for biogas are expected to increase, with a theoretical raw biogas availability of 275^6 m^3, able to cover 6.6 PJ of energy requirement. This solid waste can be processed and utilized to generate green gas through anaerobic biodigester. (Hoppe, Dijk, & Arentsen, 2011)

Table 5.3: Animal manure production in Overijssel in 2009 (CBS, 2011).

Animal source	Amount (wet) (MT/yr)
Cattle	9.1
Pig	1.7
Poultry	0.1
Other	0.2
Total	11.2

Municipal Solid Waste

The municipal solid waste (MSW) is the garbage produced by the public in the cities and consists of discarded everyday items. The average MSW for the OECD countries is estimated to be 2.2 kg/capita/day (Hoornweg & Bhada-Tata, 2012). Provided the number of residents in the Overijssel and energy content in the MSW, i.e., 15 MJ/kg approximately (Akkaya & Demir, 2009), the estimated energy potential is 3.86 TWh every year *(See Appendix B).*

Agriculture Waste

The province supports the agriculture industry and has an agriculture land area of 202,620 ha (Utilized Agriculture Area in Netherlands, 2013). The agriculture residue from the crop production is estimated to be 84698 Mt per year, equivalent to approximately 0.35 TWh per year *(See Appendix B).*

2. Geothermal Energy

Geothermal energy for thermal comfort and electricity is another source of energy explored in the region. In 2015, the region was supplying 0.5PJ of energy with an expected increase to 1.7 PJ in 2030 (Beurskens P. R., 2016). The 'Energiepact 2008' of the province Overijssel mentions geothermal energy as one of the sources to reduce CO2 emission. To make use of the geothermic potential the province is committed to monitor and regulate the use of geothermic energy (Willigenburg, Nolten, Hazelhorst, Jacobs, & Hoek, 2013) (Bouwhuis, 2016).

3. Wind energy

From the hourly data extracted for wind at 10m height and the pressure within the region and compiled it from 1991 to approximately 2018, the potential wind energy per sq. meter (rotor) is estimated to be 240 kWh/m^2 annually *(See Appendix B)*. However, the wind energy potential will increase at a higher altitude due to low resistance from buildings and trees. The wind energy production is planned to expand in the coming five years and cooperation is requested from the municipality. The target is to increase wind energy production from 0.3 PJ to 1.1 PJ by 2030. (Beurskens, Reffeltrath, & Menkveld, 2016)

4. Solar Energy

Overijssel generates 0,5 PJ primary energy from solar power today and by 2023, the province targets to generate 1.5 PJ of solar energy for heating and electricity and 1.9 PJ by the year 2030 (Beurskens, Reffeltrath, & Menkveld, 2016). In order to achieve this target, the province plans to add solar energy in domestic and commercial roofs. Therefore, the province stimulates individuals and cooperates to include solar energy in new constructions through a sustainability loan, agreements, an energy fund and subsidies (Bouwhuis, 2016).

The region, on the whole, receives the power of approximately 182 kWh/m^2 from the sun annually if a PV panel with an efficiency of 18% is installed *(See Appendix B).* However, the power generation from the solar park or on the building/houses will be less due to aggregate placement and spacing between the panels according to their global location and tilt or to avoid shading.

5.4 Reference Scenario: Overijssel

This section of the chapter introduces the reference scenario for Overijssel simulated on energyPLAN tool. The year 2018 is taken as the reference year with approximately similar energy consumption as for the year 2015 expressed above. Therefore, the bifurcation on energy consumed is assumed to be similar. The regulation strategy selected in the tool for Overijssel is "Balancing the Heat Demand," as heating is significant energy consumption in the European Union. Additionally, the stabilization share needed for grid stability is 0.3 of the total energy generation.

As stated in the current energy system, Overijssel, a Global North's electricity demand is fulfilled by large coal/natural gas power plants, PV panels and wind turbines. On the other hand, the heat demand is assumed to be majorly sufficed by individual natural gas boilers in 2018 with a mixture of production through the individual heat pump and biomass boilers and the industrial fuel for process heating is determined to be 7.5 TWh by the province.

The transportation demand is divided among conventional sources like petrol, diesel and natural gas. It is assumed that each delivers 30% of the fuel for the demand. Furthermore, in a report by Centraal Bureau Voor de Statistiek, the Netherlands has 1.6% of electric vehicles on the road by 1st January 2019 and the share of 1.6% of electric vehicles is assumed for Overijssel as well. The total transportation demand sums up to 16 billion km in a year.

The results of the simulations for the reference year is present in the table 5.4 and 5.5below and the resource utilization for energy supply is presented in figure 5.3 and the energy flow chart is presented in figure 5.4,

Table 5.4: Annual Energy Demand for Reference Scenario in Overijssel

ENERGY DEMAND	Overijssel
Electricity Demand *(in TWh)*	**4.18**
Heating Demand *(in TWh)*	**5.28**
Individual Biomass Boiler	*0.69*
Individual Natural Gas Boiler	*4.29*
Individual Heat Pump	*0.3*
Industrial Fuel *(in TWh)*	**7.5**
Transportation Fuel Demand *(in TWh)*	**9.44**
Petroleum Fuel	*5.9*
Biofuel	*0.4*
Electric Vehicle (Dump Charge)	*0.44*
Natural Gas	*2.7*
Total Billion km/yr	**16**
Carbon Emission *(Mton)*	**7.09**

Table 5.5: Annual Energy Supply for Reference Scenario in Overijssel

ENERGY GENERATION	Efficiency	Overijssel
Condensing Power Plant *(in TWh)*	45%	3.33
Geothermal Power Plant *(in TWh)*	10%	0.13
Wind Energy *(in TWh)*		0.18
Solar Energy *(in TWh)*		0.23
Electricity from Waste *(in TWh)*	25%	0.86
Total Annual Cost *(in million €)*	-	**€ 1540 million**

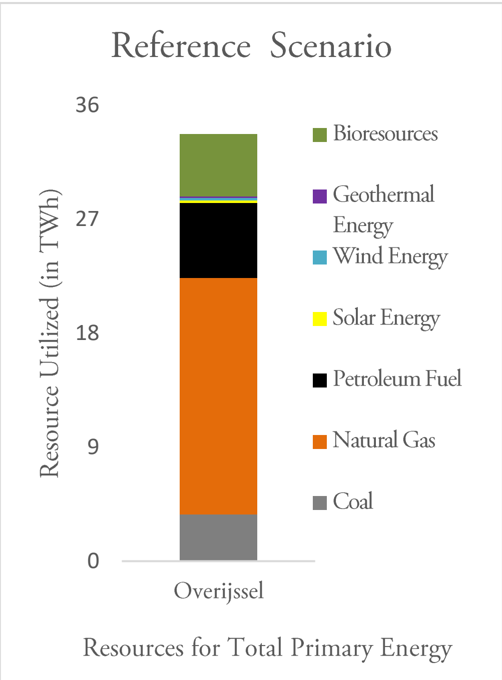

Figure 5.3: Resources Utilized for Energy Supply for Reference Scenario in Overijssel

As represented by the results, the Global North region Overijssel has a high energy consumption leading to excess and unsustainable resource usage, leading to a carbon emission of 7.09 Mton. Due to the climatic condition, the region requires the majority of its energy in the form of heating for thermal comfort and industrial processes. The synergy is present with the application of a heat pump that requires only 0.10 TWh to generate 0.30 TWh of heat demand, while 0.44 TWh electricity is utilized to suffice the transportation demand. The renewable energy share for the reference scenario is only 18.9% of the primary energy supply.

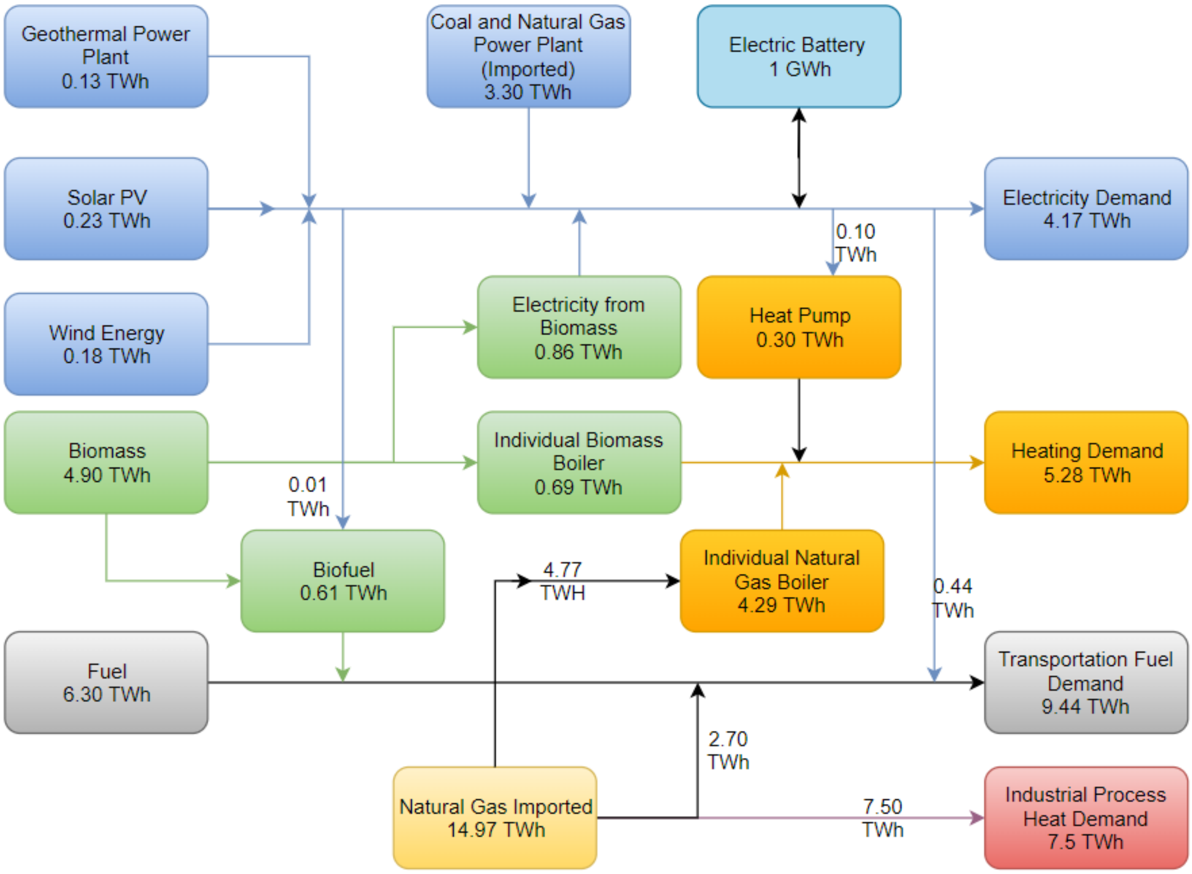

Figure 5.4: Energy Flow Chart for Reference Scenario in Overijssel

5.5 Energy Trends in Overijssel

The annual energy consumption for the province is reportedly between 100 PJ – 108 PJ over the last decade (Klimaat Monitor, 2019). The industrial sector consumes energy for its processes, while thermal comfort consumes a considerable amount of domestic energy, followed by transportation. The province of Overijssel initiated an energy transition by introducing the "New Energy Plan" in the year 2017. The regional government aims to integrate 20% renewable energy and reduce energy consumption by approximately 6% to 96.3 PJ by the year 2023. The target for the "New Energy Plan" is to make the province of Overijssel energy neutral by the year 2050 (Beurskens, Reffeltrath, & Menkveld, 2016). This objective falls in line with the pledge taken by The Netherlands to reduce their carbon emission and integrate renewable energy systems.

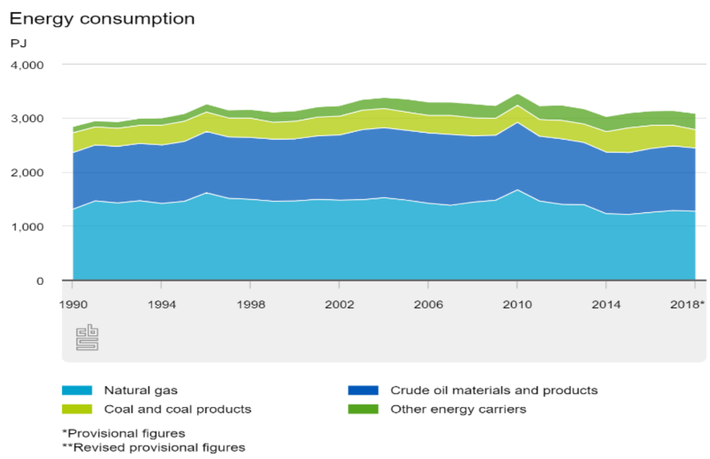

Figure 5.5: Total energy consumption in The Netherlands (Centraal Bureau Voor de Statistiek, 2019)

The historical trend of energy consumption for Overijssel and The Netherlands is provided in table 5.6 and the trend for The Netherlands is shown in figure 5.5. The energy trend between Overijssel and The Netherland exhibits that the province consumes approximately 3% of the total primary energy consumption of the country.

Table 5.6: Total energy consumption in Overijssel and The Netherlands from 2012-2018

Year	In Overijssel		In Netherlands	
	in PJ	*in TWh*	*in PJ*	*in TWh*
2012	101.16	28.09	3,250.90	900.49
2013	107.7	29.91	3,183.70	881.88
2014	100.98	28.04	3,039.70	841.99
2015	101.23	28.11	3,407.80	943.96
2016	103.57	28.76	3,144.30	870.97
2017	100.75	27.98	3,150.50	872.68
2018	102.8	28.55	3,098.50	858.28

The province developed a transition plan for the year 2023, although they have not conducted a study or estimated the energy consumption for the long term. On the other hand, there have been studies to estimate the energy consumption for the Netherlands, based on the policy plans, initiatives and targets set by the central government. Based on the historical trends, targets set by the government and research studies, the total energy consumption for Overijssel is predicted and elaborated below,

Year 2030

The estimated energy consumption in the Netherlands for the year 2020 is 2981 PJ and for the year 2030 is 2829 PJ (National Energy Outlook 2017 Summary). The government made an objective to reduce carbon emission by switching to sustainable energy resources to mitigate climate change. Currently, 55% of the energy generation for electricity and heating utilizes natural gas, where most of the gas is transmitted from Groningen. Adding to that, the Dutch government plans to close the Groningen plant by 2030 due to increased earthquakes in the region. Moreover, the administration targets to reduce the use of natural gas for power consumption to 30% while phasing out coal-based power plant by the year 2030. 60% of the excess energy is planned to be comprised of wind and solar energy systems (Power Technology, 2019).

The critical issue with this proposal is that it challenges the energy security in the country as the Dutch government plans to close the Groningen plant. Therefore, the country must become the net importer of natural gas to employ proper baseload capacity for uninterrupted power supply in case they are unable to switch to renewable energy or reduce their energy consumption.

Year 2040

According to the National Inventory Report, to achieve the 2050 carbon emission reduction target set by The Netherlands at the Kyoto Protocol, the country must reduce its emission by 55% by the year 2040. Report by McKinsey & Company state that, The Netherlands can reduce its total energy consumption by 30% from the year 2014 to reduce its carbon emission by 55%. They estimated the energy consumption till the year 2040 should be 1760 PJ (Roelofsen, Pee, & Speelman, 2016). The estimated target compiled is very ambitious, although the plans and policies in place by the government can make it achievable. At first, the national government wants to implement only zero-emission vehicles from the year 2030. This step would increase the share of electric vehicles and vehicles run only from biofuels, thus virtually banning petrol and diesel. It is possible, as the country sells half a million cars annually and the market transition will be achievable with the implementation of fluctuating renewable energy systems (Lambert, 2017).

Additionally, the regulations for insulation of houses will strengthen, while heating opportunities from waste heat, green gas and electricity are proposed to be explored. Lastly, the expected energy efficiency of the domestic and industrial appliances will also improve.

Year 2050

The KIVI understands that energy consumption in the Netherlands will reduce by the year 2050. According to their report, the energy conversion losses will recede and changes in the industrial process will increase energy efficiency. Furthermore, the increase in the share of zero-emission transportation, efficient appliances and maturing of energy technologies will assist in the reduced consumption to 399 TWh (1436 PJ). Additionally, the KIVI report also mentions that if no changes to the renewable energy system, the energy consumption with the BAU case will result in 783 TWh (2819 PJ) more than the energy consumption for the year 2015. (Persoon, Luitjens, Boonstra, & Moerkerken., 2017).

EnergyNL2050	2015	BAU 2050	energy plan 2050
	TWh	TWh	TWh
Lighting + devices	119	120	127
Grid losses	4	4	19
Curtailment			2
Transport	155	170	70
Low T heat	200	211	43
Residual heat			(40)
High T heat	160	168	78
Heat loss at power stations	110	110	
Conversion and heat losses			60
Total	748	783	399

Figure 5.6: Energy Consumption in the year 2050 in the BAU case and energy transition case for Netherlands. Source: KIVI Engineering Society.

5.5.1 Estimated Energy Consumption in Overijssel

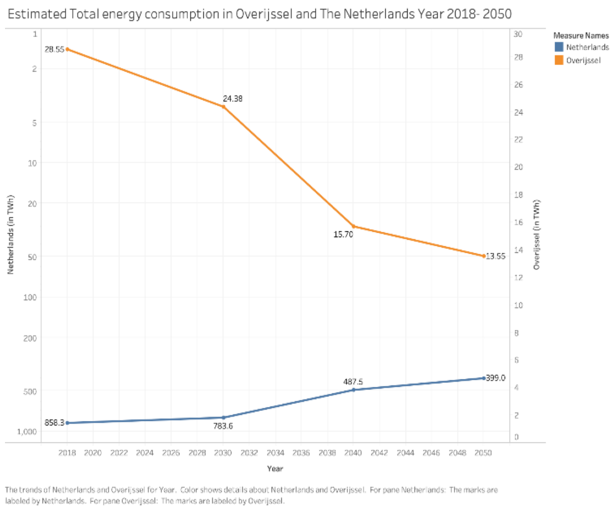

Figure 5.7: Estimated Energy Consumption Trend for Netherlands and Overijssel from Year 2018-2050

As stated above, no studies are estimating the energy consumption for Overijssel in the long term. However, there are studies conducted estimating the future energy consumption of the Netherlands based on the policies, social aspect and targets set by the Dutch government. The provincial government is proactive towards making the region energy neutral and wants to assist the central government in achieving the target to reduce carbon emission. Therefore, by analyzing the energy consumption trends between Overijssel and the Netherlands over the decade, it is assumed that the province consumes approximately between 3-3.5% of the total energy consumption of The Netherlands in the upcoming years for the simulation model. The expected energy consumption by Overijssel as compared with Netherlands is given in table 5.7 and presented in figure 5.7.

Table 5.7: Estimated Total energy consumption in Overijssel and The Netherlands Year 2018- 2050

Year	Netherlands		Overijssel	
	in PJ	*in TWh*	*in PJ*	*in TWh*
2018	3,098.50	858.28	102.8	28.55
2030	2,829.00	783.63	84.87	24.38
2040	1,760.00	487.52	52.8	15.7
2050	1,436.40	399	43.09	13.55

The bifurcation of energy consumption based on heating, electricity and transportation for domestic and industrial use are also assumed to be similar in proportion to the year 2015. On the other hand, transportation consumption is added based on the increase in transportation frequency with the increase in vehicles and quality of life. The number of vehicles increased from 10 million in 2017 to 10.1 million in 2018 within the Netherlands and the volume of vehicle traffic on Dutch roads increased by 1 percent from 2016 to 2017. Therefore, transportation traveling coverage is also assumed to increase from 16 billion km in 2018 to 20 billion km in 2050 (Trends in the Netherlands, 2018). Based on the trends, the bifurcation is given in table 5.8

Table 5.8: Estimated electricity, heating and transportation consumption in Overijssel for simulations.

Year	Electricity Consumption		Heating Consumption				Transport	
	PJ	*TWh*	*PJ (Home)*	*TWh (Home)*	*PJ (Industry)*	*TWh (Industry)*	*PJ*	*TWh*
2018	15	4.17	19	5.28	27	7.50	34	9.44
2030	14.4	4.03	17.56	4.88	24.84	6.90	30.96	8.60
2040	10.29	3.16	10.94	3.04	18	5	17.28	4.80
2050	8.17	2.27	9.50	2.64	16.56	4.60	14.54	4.04

5.5.2 Steps for Energy Transition in Overijssel, Netherlands

Thermal comfort consumes most of the domestic energy and is a priority in the Netherlands. The region plans to implement 20% renewable energy produced within the province, with bioresources producing half of that energy by 2023 (Beurskens, Reffeltrath, & Menkveld, 2016). Additionally, the houses in the region and the industrial process must be made energy-efficient to reduce energy consumption. By 2030, 40% renewable energy system should be integrated into the energy system. It is done with the implementation of solar panels on the roofs, wind turbines and production of green gas and 10% biofuel using the bioresources in the region.

Electric cars will be in the market due to the central government plan to make all vehicles zero carbon emission until the year 2030, for simulation, the complete transition to EV is kept post-2030. The matured renewable energy system can suffice the fluctuating energy requirement and push for the involvement of Electric cars. Additionally, a district heating system needs to be developed as the Groningen natural gas supply will reduce and eventually close. To suffice the heating requirement, the waste heat from industrial processes and CHP units can be utilized to provide thermal comfort. Thus, reducing consumption from fossil fuels and provide a smooth transition to RES in heating.

The next step would be to implement an alternative wind system and improve the efficiency in solar panels, seasonal heat and cooling. The final stage to make the region energy-neutral would be maturing of efficient batteries and new energy technologies. The stepwise transition is presented in figure 5.8 below.

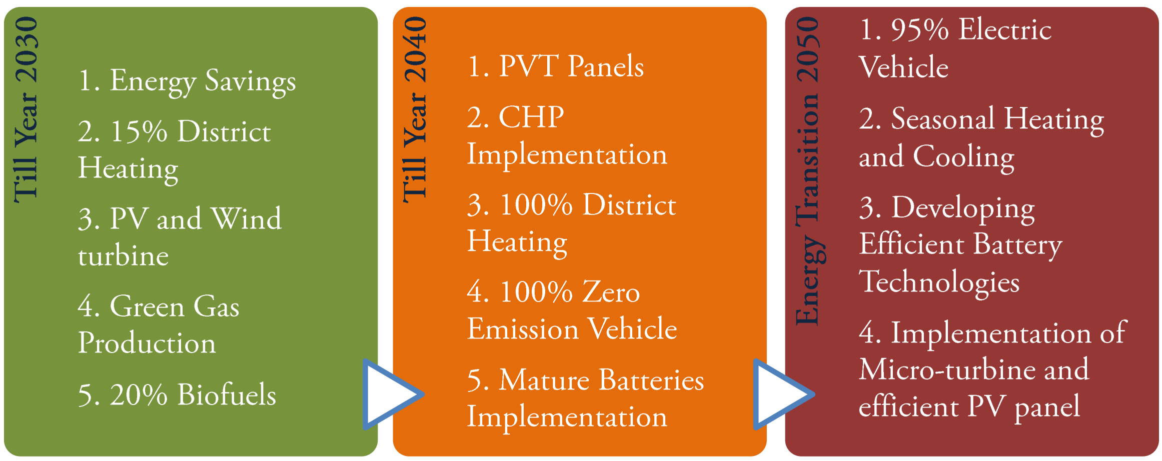

Figure 5.8: Energy Transition Plan for Overijssel

5.6 Energy Transition Scenario

This section of the chapter presents the results of the simulation for the energy transition in the province of Overijssel. The regulation strategy for the transition is "Balancing the heat demand," while the stabilization share is 0.3 for grid stability. The simulation for transition is conducted for the year 2030, the year 2040 and the year 2050, implementing the steps as explained in section 5.5.2.

5.6.1 Overijssel Scenario 2030

For this scenario, an assumption is taken that approximately 40% of the total primary energy supply should be renewable. This can be done by placing stringent policies to improve the energy efficiency of the houses and the industries to reduce energy consumption and meet their emission targets for the year 2050. This is indicated with the expected drop in energy consumption as predicted by the National Energy Outlook report for the Netherlands. Moreover, the reduction in energy consumption will assist higher integration of renewable energy share. A simulation for the Overijssel Scenario 2030 is carried out in the energyPLAN tool and the results of that simulation are added in table 5.9 and 5.10 below with resource utilization and energy flow in fig 5.9 and 5.10.

Table 5.9: Annual Energy Demand for Overijssel Scenario 2030

ENERGY DEMAND	Overijssel
Electricity Demand *(in TWh)*	**4.03**
Heating Demand *(in TWh)*	**4.88**
District Heating	*0.56*
Individual Natural Gas Boiler	*3.72*
Individual Heat Pump	*0.6*
Industrial Fuel *(in TWh)*	**6.9**
Transportation Fuel Demand *(in TWh)*	**8.6**
Petroleum Fuel	*2.65*
Biofuel	*1.65*
Electric Vehicle	*1.6*
Natural Gas	*2.7*
Total Billion km/yr	**18**
Carbon Emission *(Mton)*	**5.32**

Table 5.10: Annual Energy Generation for Overijssel Scenario 2030

ENERGY GENERATION	Efficiency	Overijssel
Condensing Power Plant *(in TWh)*	45%	3.74
Geothermal Power Plant *(in TWh)*	10%	0.72
Wind Energy *(in TWh)*		0.4
Solar Energy *(in TWh)*		0.63
Industrial CHP *(in TWh)*		0.4
Battery Technology *(in GWh)*	80%	2
Waste Heat *(in TWh)*	85%	**0.56**
from Gasification Plant (in TWh)		*0.2*
from Biopetrol (in TWh)		*0.46*
Total Annual Cost *(In million €)*		**€ 1654 million**

In the scenario 2030, 39.6 % of total primary energy has a renewable share. The carbon emission will reduce to 5.32 Mton from 7.09 Mton in 2018, while the fuel balances and the total investment is expected to rise. The focus in this scenario has been to introduce district heating and integrating more renewable energy electricity system.

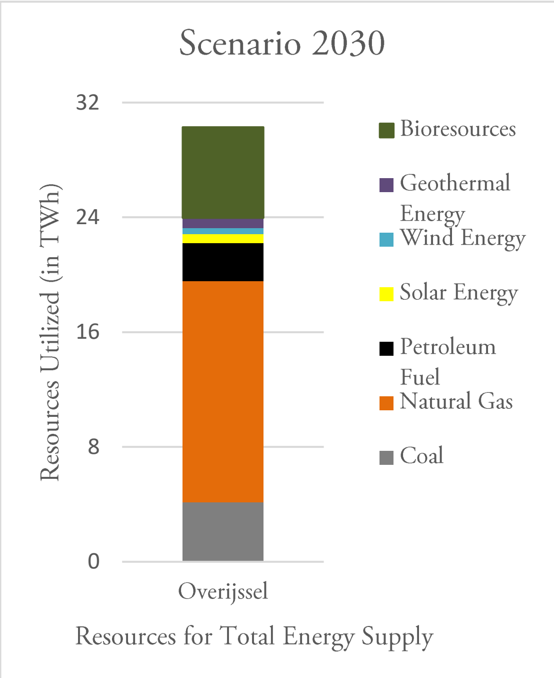

Figure 5.9: Resources utilized for Energy Supply in Overijssel Scenario 2030

The Dutch government intends to phase out coal from its energy system by the year 2030. However, for this simulation, coal is used due to lower fuel prices and investment costs. The energy supply from the power plant has further increased in this scenario to balance the integration of wind and solar energy along with electric vehicles while maintaining the security of supply. Moreover, the natural gas import is utilized for heating, industrial processes and electricity production, although it has reduced with the initiation of biomass conversion to green gas for individual boilers and transportation.

The average distance covered is assumed to increase based on the trends of a 1% raise every year to 18 billion km. However, the energy demand for transportation has reduced to 8.6 TWh as compared to the year 2018 due to the integration of electric vehicles.

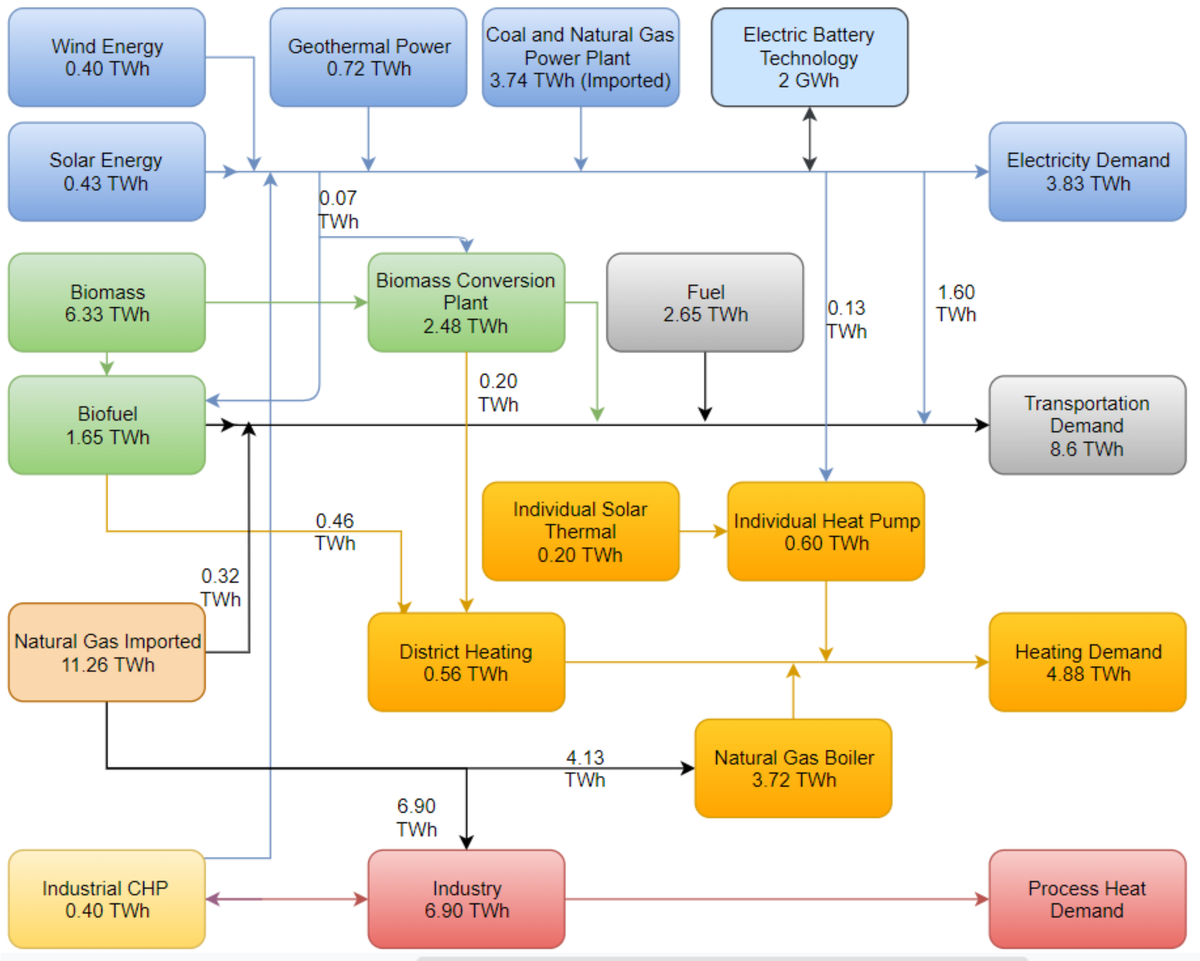

Figure 5.10: Energy Flow Chart for Overijssel Scenario 2030

5.6.2 Overijssel Scenario 2040

The target for this scenario is approximately 75% of renewable energy share of the total primary energy. This scenario encounters a drastic reduction in the energy consumption due to the complete integration of fluctuating energy technology, electric vehicle, battery technologies, combined heat and power units and district heating. Additionally, the energy management system is also expected to enter the energy market supporting smart grids and thus, adding flexible energy supply. The expected reduction of energy by the year 2040 is approximately 35% from the energy consumption in the year 2015. The results from the simulations of this scenario are presented in the table 5.11 and 5.12 below along with the resource utilization presented in figure 5.11 and the energy flow chart for Overijssel Scenario 2040 in figure 5.12. *(See Appendix C)*

Table 5.11: Annual Energy Demand for Overijssel Scenario 2040

ENERGY DEMAND	Overijssel
Electricity Demand *(in TWh)*	**3.16**
Heating Demand *(in TWh)*	**3.04**
District Heating	*2.44*
Individual Heat Pump	*0.6*
Industrial Fuel *(in TWh)*	**5**
Transportation Fuel Demand *(in TWh)*	**4.8**
Biofuel	*1.5*
Electric Vehicle	*3.3*
Total Billion km/yr	**19**
Carbon Emission *(Mton)*	**2.71**

Table 5.12: Annual Energy Generation for Overijssel Scenario 2040

ENERGY GENERATION	Efficiency	Overijssel
Condensing Power Plant *(in TWh)*	45%	2.83
Geothermal Power Plant *(in TWh)*	10%	0.81
Wind Energy *(in TWh)*		0.9
CHP *(in TWh)*		0.69
Solar Energy *(in TWh)*		1.39
Industrial CHP *(in TWh)*	40%	0.5
Battery Technology *(in GWh)*	80%	6
District Heat *(in TWh)*	85%	**2.44**
from Gasification Plant (in TWh)		*0.66*
from CHP (in TWh)		*0.86*
Solar Thermal (in TWh)		*1.12*
Heat Pump (in TWh)		*0.39*
from excess Industrial heat (in TWh)		*0.6*
Boiler (in TWh)		*0.08*
from Biopetrol (in TWh)		*0.41*
Total Annual Cost *(In million €)*		**€ 947million**

The results indicate that the renewable energy share has increased to 74.4% with the transition and formulation of synergy in the Overijssel Scenario 2040. Additionally, the carbon emission has further reduced to 2.71 Mton along with the total annual cost as compared to the scenario in 2030 and the reference scenario.

The import of natural gas is phased out in this scenario with the expected closing down on natural gas reserves within the country. Instead, the green gas powers the CHP and for industrial use,

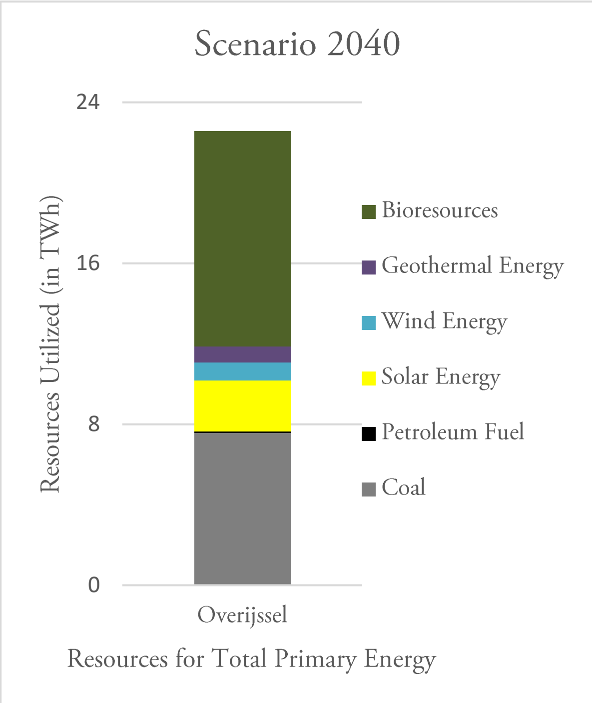

Figure 5.11: Resource utilization for Energy Supply for Overijssel Scenario 2040

generated by biomass conversion plants and fed to the gas grid. On the other hand, coal power plants are still not phased out to maintain the security of supply and lower fuel prices. The scenario also holds 10% of the electrical energy as flexible with an expected introduction of smart grids and domestic energy management system. The flexible electric supply improves the efficient use of energy and helps in increasing the share of renewables in the energy system.

Secondly, in this scenario, the province is simulated to have thermal comfort by utilizing the district heating system. The district heating system reduces the fuel balance by utilization of waste heat from industries process heat assumed to be 10-12% of the total energy supply to industries (Papapetrou, Kosmadakis, Cipollina, Commare, & Micale, 2018). Besides, boilers, heat pumps and solar thermal is used to match the demand during peak hours. Additionally, a heat storage system with 14 days of storage timeline is applied to manage peak demands in the winters. While the individualized heat pumps are still added assisted by solar thermal panels to reduce the consumption for individual households in the region.

Lastly, transportation in this scenario is approximately 70% transformed into electric vehicles and 30% to biofuels. This target falls in line with the objectives of the Dutch government of zero-emission vehicles. Moreover, provided the historical trend of an increasing number of vehicles and distance covered annually, the transport demand is taken as 19 billion km annually, which is sufficed by the efficient electric vehicles. The biofuels are used in the simulation for the transport of heavy vehicles and fossil vehicles within the region.

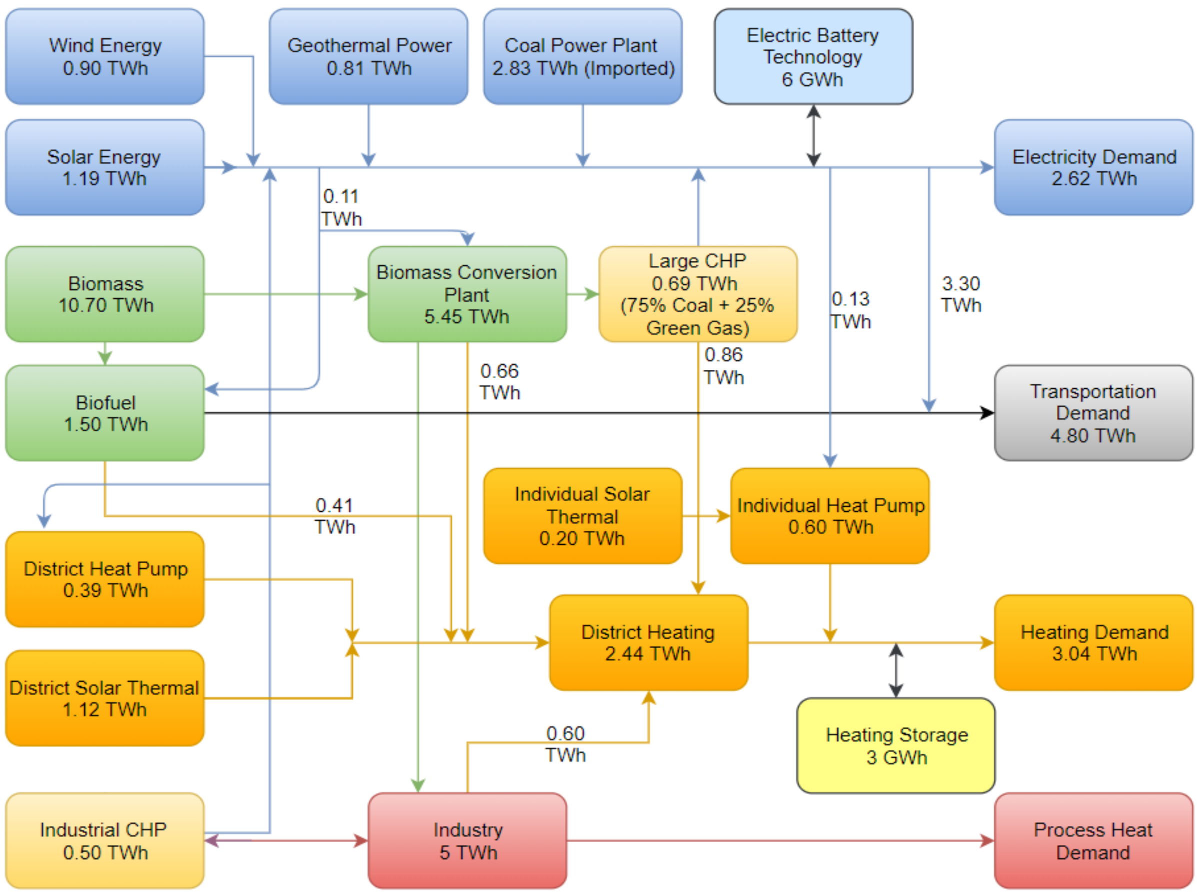

Figure 5.12: Energy Flow Chart for Overijssel Scenario 2040

5.6.3 Overijssel Energy Transition 2050

The energy transition scenario for Overijssel in the year 2050 is to simulate a neutral energy system. The results submitted with the simulation show that the energy consumed is generated with the resources from the region. The table 5.13 and 5.14 and the resource utilization and energy flow chart in figure 5.13 and 5.14 below present the results from the simulation. *(See Appendix C)*

Table 5.13: Annual Energy Demand for Energy Transition 2050 Overijssel

ENERGY DEMAND	Overijssel
Electricity Demand *(in TWh)*	2.27
Heating Demand *(in TWh)*	2.64
District Heating	*2.34*
Individual Heat Pump	*0.3*
Industrial Fuel *(in TWh)*	4.6
Transportation Fuel Demand *(in TWh)*	4.04
Methanol	*0.2*
Electric Vehicle	*3.84*
Total Billion km/yr	20
Carbon Emission *(Mton)*	0

Table 5.14: Annual Energy Generation for Overijssel Energy Transition 2050

ENERGY GENERATION	Efficiency	Overijssel
Condensing Power Plant *(in TWh)*	45%	1.64
Geothermal Power Plant *(in TWh)*	10%	0.88
Wind Energy *(in TWh)*		0.84
CHP *(in TWh)*		0.91
Solar Energy *(in TWh)*		1.74
Industrial CHP *(in TWh)*	40%	0.73
Battery Technology *(in GWh)*	80%	9
District Heat *(in TWh)*	90%	**2.34**
from Gasification Plant (in TWh)		*1.45*
from CHP (in TWh)		*1.14*
Solar Thermal (in TWh)		*0.97*
from Industrial excess heat (in TWh)		*0.5*
from Biopetrol (in TWh)		*0.2*
Total Annual Cost *(In million €)*		**€ 887 million**

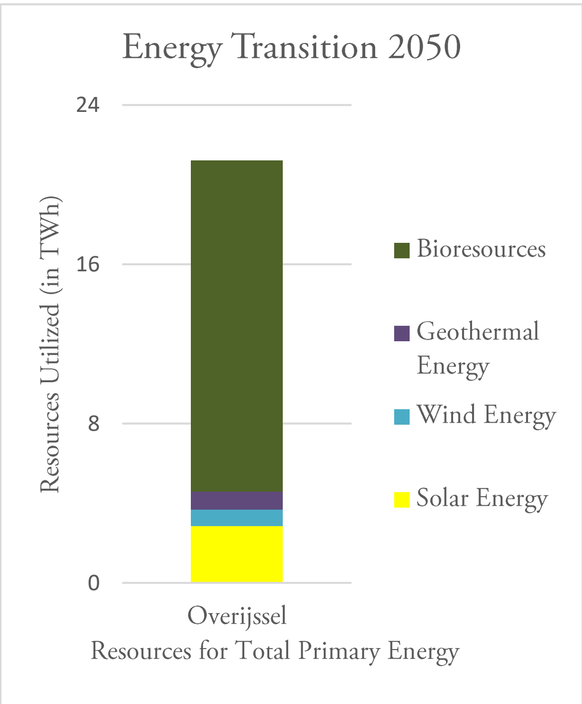

Figure 5.13: Resources utilized for Energy Supply in Overijssel Scenario 2050

The energy transition scenario for Overijssel presents the energy system to be neutral. Moreover, the simulation results show that if the resources within the region are utilized, then the region can obtain carbon neutrality in reference to energy system. Additionally, the techno-economic cost for this change is much lower than the reference scenario, i.e., € 887 million.

The utilization of bioresources like MSW, pruning wood, animal waste and agriculture waste except for the primary feedstock, assist in generating green gas and biofuel for the province. On the other hand, solar energy, geothermal energy and wind energy are used to provide electrical power for domestic, industrial and transportation use. The transport demand, in terms of distance covered, is assumed to be 20 billion km in the year 2050, provided the historical trend. However, energy demand is much lower due to the integration of electric vehicles, although 5% of the transport fuel is biofuel that could be utilized by the heavy transport vehicles.

Meanwhile, the domestic and process heat consumption is expected to drop with efficient houses and industrial processes. A synergy between the industrial waste heat and domestic thermal comfort could further reduce the strain on the energy supply and carbon emission. The additional heat for domestic use through solar thermal reduces the consumption for individual heat pumps. The solar thermal can work in conjunction with PV panels as PVT panels, which would improve the efficiency of PV panels and additional heat can be used for domestic heating or district heating. Thus, saving cost and land or roof utilization.

On the other hand, research to improve wind turbine efficiency and micro-wind turbine or alternative wind energy system would support the transition. The system designed for the transition has focussed explicitly on including the economic activities and social aspect. The idea presented here focuses on lowering the land utilization for renewable share and providing reliable energy with economic feasibility.

However, in the simulation for the year 2050, it is observed that the green gas generation require excess biomass of 16.63 TWh as compared to resource available of 12.58 TWh (including MSW, agriculture waste, animal waste and pruning wood) in the region. A replacement of bioenergy is considered for the simulation by using solar panels, but the grid stabilization was affected, given the stabilization share of 0.3 is taken for the simulation. While wind energy system was also not considered due to society barrier such as NIMBY. Moreover, the design is also challenged with the use of agriculture waste for energy, which can be used to feed the animal livestock in the region.

Another energy technology considered for this scenario was hydrogen energy (hydrogenation and electrolysis) as a medium for alternative fuels. However, during the simulations and addition of these systems, the overall electricity consumption and the requirement of green gas was further increased then the simulated scenario. Furthermore, the land utilization was also challenged with large capacity of electrolyser and hydrogen storage system. These conditions proved unsustainable for the scenario and the best available scenario with biomass conversion system was selected. Therefore, provided the estimated biomass energy available in the region, an energy-neutral system for the province will be challenging to achieve.

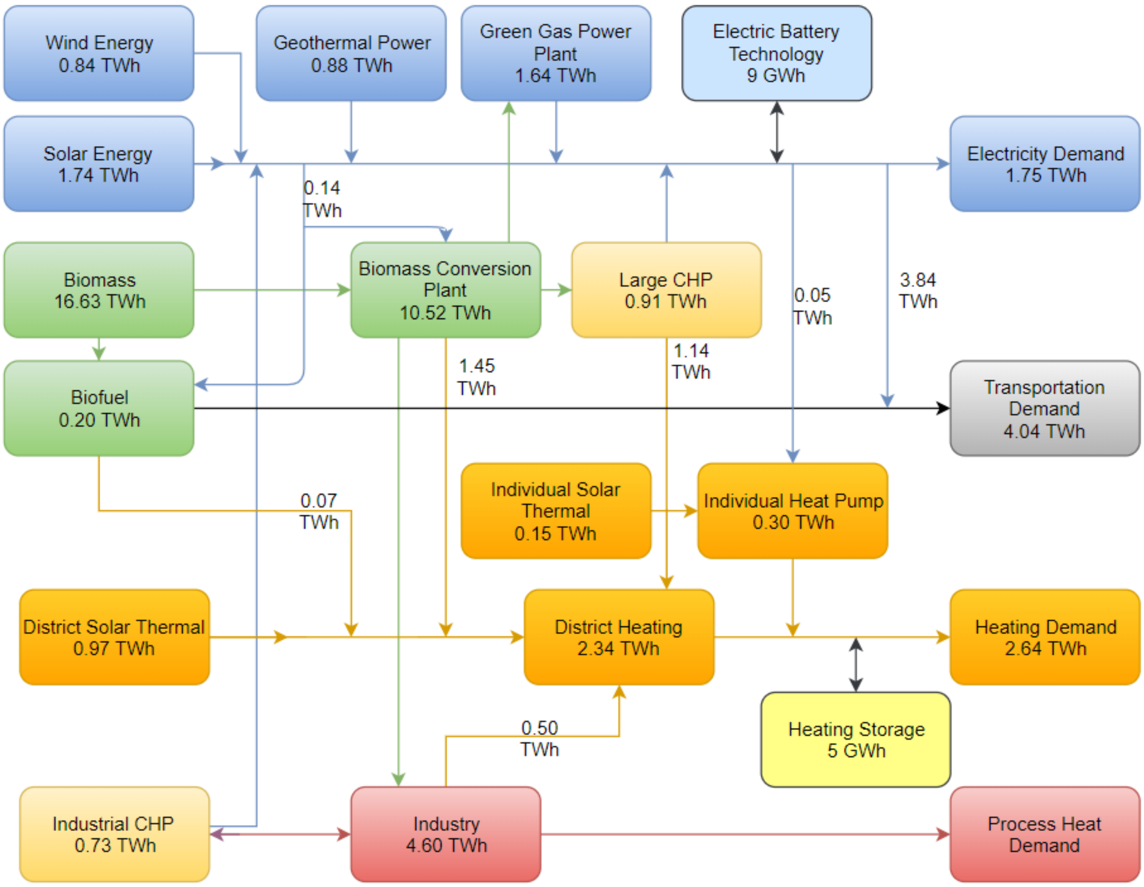

Figure 5.14: Energy Flow Chart for Overijssel Energy Transition Scenario 2050

5.7 Comparison of BAU And Energy Transition Scenario for Overijssel

This section will present a business-as-usual scenario and introduce a comparison between the BAU and the energy transition scenario of the province for the year 2050. The comparison will indicate the benefits of the energy transition in Overijssel. The comparing index will be limited to technology, technology cost and environmental benefits.

5.7.1 Business-As-Usual Scenario

The business-as-usual scenario, formulated for the year 2050 in Overijssel, demonstrate the energy system, consumption, fuel balances and carbon emission if the energy transition is not achieved. The Netherlands has initiated the process of the energy transition to reduce their carbon emission and meet the climate agreement. Therefore, in the BAU case for Overijssel, it is assumed that the pace of transition will be the same and not enhanced in transitioning the energy generation methods and energy efficiency. The electricity consumption for this scenario is expected to reduce to 3.94 TWh, while the heating demand is also expected to be almost the same as 5.21 TWh.

Similarly, industrial fuel consumption reduces with the implementation of efficient processes and systems installed as it presents economic benefits. However, the transportation fuel demand is not reduced due to the growing demand for automobiles and increasing total distance covered to 20 billion km annually.

Table 5.15: Annual Energy Demand for BAU Scenario in Overijssel

ENERGY DEMAND (BAU)	Overijssel
Electricity Demand *(in TWh)*	4.02
Heating Demand *(in TWh)*	5.21
Industrial Fuel *(in TWh)*	7
Transportation Fuel Demand *(in TWh)*	10.5

5.7.2 Comparing Reference, BAU and Energy Transition Scenario

The comparison between the two scenarios in the year 2050 is presented for energy demand and generation in table 5.16 and 5.17. The distinction can be viewed with respect to carbon emission, the annual cost and the difference in resource utilization is witnessed in fig 5.15. *(See Appendix C)*

Table 5.16: Annual Energy Demand between BAU and Energy Transition Scenario for Overijssel

ENERGY DEMAND	Overijssel	
	BAU	Energy Transition
Electricity Demand *(in TWh)*	**4.02**	**2.27**
Heating Demand *(in TWh)*	**5.21**	**2.64**
Individual Biomass Boiler	*0.79*	-
Individual Natural Gas Boiler	*3.42*	-
Individual Heat Pump	*1*	*0.3*
District Heating	-	*2.34*
Industrial Fuel *(in TWh)*	**7**	**4.6**
Transportation Fuel Demand *(in TWh)*	**10.5**	**4.04**
Petroleum Fuel	*5.7*	-
Biofuel	*1.2*	*0.2*
Electric Vehicle	*1.3*	*3.84*
Natural Gas	*2.3*	-
Total Billion km/yr	**20**	**20**
Carbon Emission *(Mton)*	**6.27**	**0**

Table 5.17: Annual Energy Generation for BAU and Energy Transition Scenario for Overijssel

ENERGY GENERATION	Efficiency	Overijssel	
		BAU	Energy Transition
Condensing Power Plant *(in TWh)*	45%	3.98	1.64
Geothermal Power Plant *(in TWh)*	10%	0.13	0.88
Wind Energy *(in TWh)*		0.2	0.84
CHP Electricity *(in TWh)*		-	0.91
Solar Energy *(in TWh)*		0.29	1.74
Electricity from Waste *(in TWh)*		0.95	-
Industrial CHP *(in TWh)*	40%	-	0.73
District Heat *(in TWh)*	90%	-	2.34
Total Annual Cost *(In million €)*		**€ 2257 mil.**	**€ 887 mil.**

The comparison between the energy transition scenario and the business-as-usual scenario shows a drastic difference in carbon emissions. The transition scenario formulates an energy-neutral region leading to carbon neutrality. Contrarily, the carbon emission for the BAU scenario is higher than the transition scenario aggravating climatic changes.

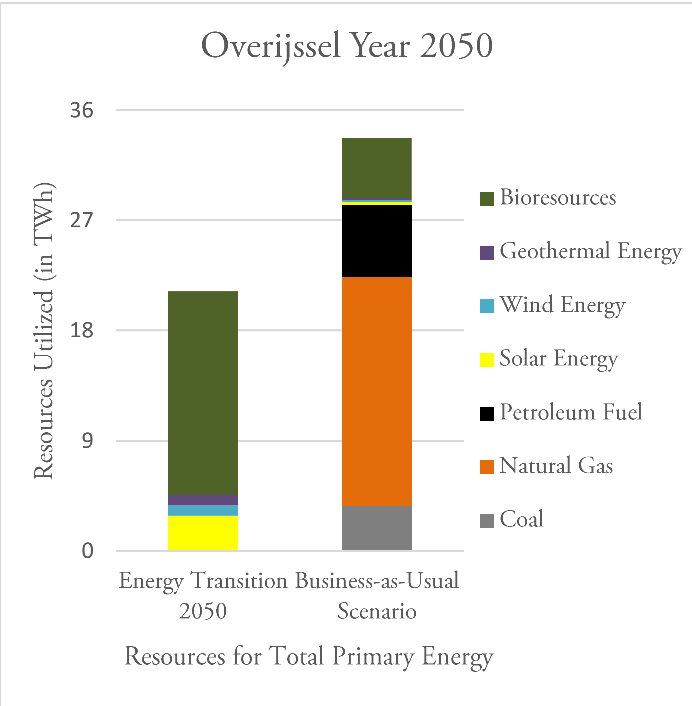

Figure 5.15: Resources Utilization for Energy Supply in Overijssel for BAU and Energy Transition Scenario

The distinction also stands with the energy demands as the demand for transition scenario is lower in comparison to BAU. The lower demand is enhanced due to the expected integration of energy efficient appliances, energy management system and smart grids for domestic and commercial sector. On the other hand, the improvement in efficiency in the industrial process also results in lower energy consumption and economic benefits. It accomplishes to attract the industry owners if the government implements long term financial benefits and policies. The energy demand for transport shows a comparative difference for the transition scenario due to the implementation of electric vehicles, while for the BAU scenario, it will be highly dependent on fossil fuels.

Further, the comparison in the energy supply section highlights the techno-economic cost. The techno-economic cost for a transition scenario is lower than the BAU scenario. This difference is inculcated with the transition to renewable energy sources and the formulation of synergy. A smart energy system reduces the waste energy and utilizes it for diverse needs, thus, reducing investment, operating and maintenance costs. Moreover, by exploiting the resources available in the region, fuel handling cost and transmission losses reduce, while increasing the job opportunities. Additionally, the cost incurred due to carbon emission aggravating climatic changes is further added to the difference in techno-economic cost. Therefore, the reasoning above attributes the energy transition to renewables would present a favorable outcome for the year 2050.

5.8 Conclusion

The chapter demonstrates the energy transition in the Global North by formulating a case study for Overijssel. A sustainable energy transition in Global North will tend to happen by maintaining an affordable and secure supply of energy. Moreover, the essential energy requirement must be prioritized. For instance, the energy transition in European cities will be focussing on balancing the heat demands and is the same for Overijssel as well. The energy transition plan for Overijssel is initiated by analyzing the current energy system, evaluating the resource availability and their energy potential, social behavior and economic and cultural activities.

For Overijssel, the economic factors are in favor of the utilization of bioresources due to eco-tourism, healthy agriculture and cattle industry and forest greenery. However, the region has to relax the regulations concerning the use of bioresources for energy generation, except for the primary feedstock. Furthermore, the region does present support for the solar energy system on the roofs and utilization of geothermal energy in the region. On the contrary, social factors dictate that the local public will not be in favor of wind turbines due to the belief of noise and visual pollution. However, the region has formulated spatial planning to set up sustainable energy technologies in the region by involving the local stakeholders.

The energy transition in Overijssel is presented and simulated for Scenario 2030, Scenario 2040 and Energy Transition 2050. The transition is made with essence to create synergy among all energy sources to achieve 100% renewable energy share by the year 2050. The transition simulation stepwise show that the carbon emission of the region reduces with increasing the share of renewables and the region achieve energy and carbon neutrality. Additionally, the techno-economic cost of increases in the year 2030 with the integration of renewable systems and biofuels but eventually reduces to € 887 million by the year 2050. Moreover, the transportation sector has to undergo transition twice, i.e., from fossil fuels to biofuels and from biofuels to electric mobility. This dual transition is requisite to adjust with the current transportation system and carbon reduction.

However, it is essential to note that the energy transition scenario shows that the biomass energy potential available does not suffice the requirement for the energy transition in the year 2050. Thus, the natural gas has to be imported, or an alternative fuel source needs to be determined to make the region energy neutral.

At the end, when the energy transition scenario is compared with the business-as-usual scenario for the year 2050, it shows that the carbon emission will be negligible when a transition to 100% renewable energy takes place. Moreover, the resources utilized for generation and techno-economic cost will be much lower than the current energy system and the business-as-usual scenario. Thus, it highlights the lucrative prospects of transition to energy neutrality in Overijssel by the year 2050.

Chapter 6

Case Study: Energy Transition in Mathura

6.1 Introduction

This chapter characterizes the sustainable energy transition in the Global South with the Mathura district in India as a case study to make it energy neutral by the year 2050. The planning is conducted with a consideration of geography, demographics, economy, society, resource availability and the energy potential in the region. The current energy system in the region and energy targets of the national government is determined to initiate the planning for the energy transition in the future.

Further, the energy consumption for the year 2030, 2040 and the year 2050 is estimated based on researches, prospective emission targets and government reports. Based on the predicted consumption for energy, the transition is simulated on the energyPLAN tool utilizing diverse energy technologies. The results from the simulations are explained in this chapter. Towards the end, a comparison between the energy transition scenario and a business-as-usual scenario for the year 2050 is represented.

6.2 Mathura District

6.2.1 Geography and Demography of Mathur District

Mathura district is in the northern part of India, located in the Uttar Pradesh state. The district covers an area of 3,329.4 km^2, with a population of 2.54 million as recorded in the census in the year 2011. The region is famous for its religious heritage and attracts tourists throughout the year. The region is a combination of rural and urban cities connected with public transport.

The gender ratio in the region is unbalanced towards males and has a literacy rate of approximately 72%. The region has a strong base for agriculture and cattle farming. Approximately 75% of the land available in the region is utilized for agriculture and cattle farming *(See Appendix D).*

6.2.2 Socio-Economic Factors in Mathura

On the economic side, the district has a Mathura Refinery located in the city and is one of the biggest oil refineries of Asia with 8.0 MMTPA refining capacity. This oil refinery of the Indian Oil Corporation is a highly technologically advanced oil refinery and provides local employment opportunities. In addition to the oil refinery, the region also has a textile printing industry, water tap manufacturing units and small decorative household industries. However, the region prominently presents healthy agriculture and dairy farming sector. It is a hub for milk production and is renowned as the place where rivers of milk flow due to milk trading centers.

On the social front, the transition in the energy system or to reduce the carbon emission is not a vital concern among the general public of Mathura. Preferably a secure and affordable supply of electricity is prioritized among the people. However, the essence of climate change is realized by the locals of the region due to deteriorating health conditions, poor air quality and difficulties regarding receding water resources.

In 2014, the world wildlife federation conducted a People Perception Study with regards to renewable energy in India. The survey had a sample size of 901, with 50% of the respondents between the age of 22 years to 32 years. The survey was conducted to understand the perception of people towards renewable energy systems, their acceptance towards the technologies and source of energy, incentives and policies in India. The survey showed that 92.34% of the people agreed that renewable energy systems could replace the fossil-based system in the country, and they are willing to support the initiative to improve the biodiversity. Among the surveyors, 92% of them were inclined to the integration of solar energy, 60% of the people were interested in waste to energy and biogas followed by wind energy and hydropower. However, the people participating in the survey stated about lack of information about the targets, plans and subsidy policies from the government. They would prefer more information is readily provided to them through online and offline platforms (Jincy Joy; Divya Joy; T.S. Panwar, 2015).

Although, in the survey, the people indicated the willingness to be among the stakeholders to make a transition. However, the lack of awareness and reluctance to change in behavior acts as a barrier. The integration of the solar panel by the local public on the roof has been shallow throughout the country as they use the roofs for daily domestic activities. Nonetheless, solar rooftop energy systems have only been actively installed on government and industrial buildings.

Moreover, people want to avoid bureaucratic hassles and high investment upfront (DTE Staff, 2019). On the other hand, the investment for wind energy systems and bioenergy system can only be installed by corporates and government. People will not have problems with wind turbines near to their homes at present, while there can be a dilemma in having a bioenergy plant near a residential area. However, in the last five years, India transformed and produced approximately 38,000 kg of green gas daily (Goyal, 2018). The government plans to add more bioenergy plants in order to suffice the growing requirement of energy, reduce fuel import and increasing job opportunities (Biogas Technology Development Group, 2018).

6.3 Overview of Energy System

Irrespective of energy shortage in the country and Global South, the Mathura district at present receives 24-hour electricity with minor shortage, leaving the neighboring areas short of power. However, none of the energy is generated within the district. Instead, the electricity is imported from neighboring districts and states through the transmission system. The primary source of electricity generation in Uttar Pradesh is through thermal power plants along with few PV panels on government buildings.

6.3.1 Energy Consumption in Mathura

The estimated energy consumption in the Mathura district is approximately 14.75 PJ. 47% of the energy consumed is in the form of electricity, while the heating requirement is sufficed by electric power due to the average temperature. For cooking, liquified petroleum gas (LPG) cylinders are used, while pipeline natural gas (PNG) is in the development process. According to the data recorded in 2016, only 70% of the population had access to LPG cylinders and rest 30% of the household were suspected of using

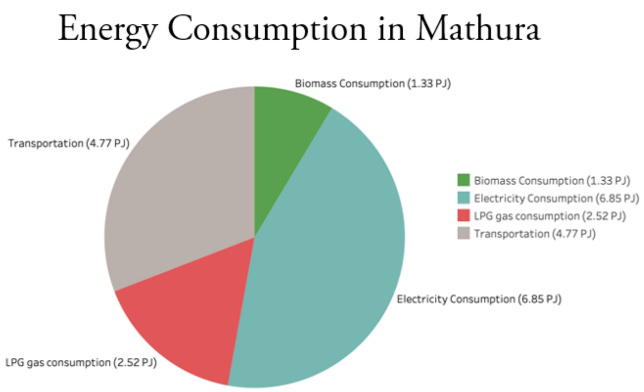

Figure 6.1: Estimated Energy Consumption in Mathura

biomass to generate heat for cooking. Additionally, gasoline (Petrol and Diesel) are the primary source of transportation fuel. Both LPG and petroleum are exported from foreign countries to fulfill the requirements in India and Mathura district.

The details of Energy Consumption within the Mathura district are listed in Table 6.1. The data for electricity is based on one month and extrapolated while the information for cooking gas and transportation is highly variable and based on statistical assumption *(See Appendix D).*

Table 6.1: Energy Consumption for Mathura (highly variable)

Energy Generated in Mathura District	**0 PJ**
Electricity Consumption	6.85 PJ
LPG consumption	2.52 PJ
Biomass Consumption for Cooking	1.37 PJ
Transportation	4.77 PJ
Estimated Energy Consumption in Mathura District	**15.51 J**

6.3.2 Sustainable Resource Potential

The following list presents the energy resources within the Mathura district. The resources available can assist the region in energy transition and formulating an energy-neutral territory.

1. Bioenergy

Mathura district has a strong farming sector, with 75% of the land used for agriculture and rich biodiversity. Bioenergy over here can be generated by using pruning wood, solid animal waste, municipal solid waste and agriculture waste. These wastes can be utilized to produce green gas upgraded from biogas and biofuels.

India is looking to produce 4.5 million liters of biofuels in the next four years, as it will reduce the fuel imports and create 150,000 jobs within the country (Verma, 218). The objective is to utilize the crop stubble, MSW and plant waste to generate the fuels. However, the plan looks very ambitious due to a lack of technical support and financial constraints (Thakur, 2019). The country will require 12 biorefineries to produce the above-said amount and an investment of 100 billion rupees (Verma, 218). However, the technical institutes within the country actively participate in researching efficient ways to improve the technical and financial constraints.

Pruning Wood

The forest cover in Mathura itself is 1528 ha with miscellaneous tree crops of 929 ha, according to the data census in 2011. The pruning wood from the forest and miscellaneous trees can be used to process biofuels. The assumption of same oak trees is taken as in section 4.3.3 and estimated energy pruning wood is determined to be 0.478 TWh *(See Appendix B).*

Organic Feedstock

The green gas plants have been flourishing in the western part of India and the central government is targeting setting up more green gas plants to suffice the need for cooking gas and transportation. From the census of 2011, it is found that the cattle population of cows and buffalos is 865,730, which are regularly milked and cradled by farmers with religious belief. The estimated energy content from the manure in terms of green gas is 1.43 TWh. *(See* Appendix B*)*

Municipal Solid Waste

The municipal solid waste (MSW) is the garbage produced by the public in the cities and consists of discarded everyday items. The average MSW for the Eastern Asian countries is estimated to be 1.1 kg/capita/day (Hoornweg & Bhada-Tata, 2012). Provided the number of residents in the Mathura and energy content in the MSW is 15 MJ/kg approximately (Akkaya & Demir, 2009), the estimated energy potential is 4.18 TWh. *(See Appendix B)*

Agriculture Waste

The crop yield for Mathura district in the year 2009-10 was reported to be 857,853 MT. However, the data does not include the crop residue collected. Therefore, it is calculated through research papers, which states that an average residue to crop ratio for wheat, barley and other crops is 1.2 with an energy content of 15 MJ/kg.

Utilizing that data and multiplying that with the crop yield annually, the energy content with agriculture waste is reportedly extremely high. Currently, the farmers prefer burning down the residue on the field itself to reduce the nutrient cost needed for the soil and labor cost to remove these residues, causing air pollution. Government initiatives to provide financial incentives for partly removal of the residue will reduce air pollution and provide energy for the region.

2. Wind energy

The district of Mathura does not have any wind turbine stationed. From the hourly data extracted for wind at 10m height and the pressure within the region in 2018, the potential wind energy per sq. meter (rotor) is estimated to be approximately 200 kWh/m^2 annually *(See Appendix B)*. The wind energy potential will increase at a higher altitude due to low resistance from buildings and trees. Moreover, the district is not surrounded by high rise buildings. The public acceptance of wind turbines should not be a problem. However, an excessive number of wind turbines can face barriers, as the region is known for religious tourists.

3. Solar Energy

Mathura does have some solar panels placed on governmental buildings. However, the placement of solar panels on the roof of households can be inefficient due to social factors and congestive town planning that will cause shading losses. On the other hand, Mathura has a large area of land that is utilized as "other fallows," approximately 3031 ha. Additionally, the panels can also be placed on the banks of the river Yamuna. The solar energy in this region is very high due to its geographical location and climate. The region, on the whole, receives the power of approximately 354.19 kWh/m^2 *(See Appendix B)* from the sun annually, if a PV panel with an efficiency of 18% is installed.

4. Hydro Energy

River Yamuna passes through the district of Mathura and is among the largest rivers in the country in terms of length and flow rate. The river records an average flow rate of 2,950 m^3/s. The flow rate does deviate and reduces during the summer months (April-June). However, it maintains a steady flow during the monsoon period (July-September) and the winter months. The high flow rate of the river can be utilized to install a run-off river hydropower plant, which can be used to provide base power to the region and an irrigation network for farms.

6.4 Reference Scenario: Mathura

Mathura, a Global South region, utilizes fossil fuel power plants to suffice electricity demands. While liquified petroleum gas (LPG) and liquid fossils like petrol and diesel are the only source of energy for cooking and transportation. The district itself does not have any power plants. Instead, it transmits the energy from the nearby regions. Therefore, the consumption is taken up as a hidden energy flow and the carbon emissions are added to the scenario.

The government buildings in Mathura and some of the commercial buildings have installed solar panels, but for the ease of calculations, this generation is not taken into consideration due to lack of data and minimal energy output. "Balancing heat and electricity" is the regulation strategy selected with a stabilization share of 0.3 to maintain grid stability.

On the other hand, the largest industry in Mathura district is the Oil Refinery, which utilizes natural gas for the process accounting to 56 MBN (MBTU/Bbl/NRGF) (Indian Oil Corporation Limited, 2015). Additionally, there are textile, cotton and decorative industries at a smaller scale, but their data is not available online. Therefore, the average industrial fuel, i.e., natural gas, is assumed to be 100 MBN, which is low when converted to Terawatt hour and is not considered for simulations. The reference scenario is simulated on the energyPLAN tool. The results of the simulation are presented in the table 6.2 and 6.3 below and the resource utilization is presented in figure 6.2, while an energy flow chart is added in the figure 6.3 *(See Appendix D)*,

Table 6.2: Annual Energy Demand for the Reference Scenario in Mathura

ENERGY DEMAND	Mathura
Electricity Demand *(in TWh)*	**1.9**
Cooking Fuel Demand *(in TWh)*	**0.98**
Liquified Petroleum Gas	*0.7*
Various	*0.38*
Industrial Fuel *(in TWh)*	Negligible
Transportation Fuel Demand *(in TWh)*	**1.32**
Petrol	*0.46*
Diesel	*0.86*
Total Billion km/yr	2
Carbon Emission *(Mton)*	**2.09**

Table 6.3: Annual Energy Generation for the Reference Scenario in Mathura

ENERGY GENERATION	Efficiency	Mathura
Condensing Power Plant *(in TWh)*	38%	1.9
Total Annual Cost *(In million €)*		**€ 168 million**

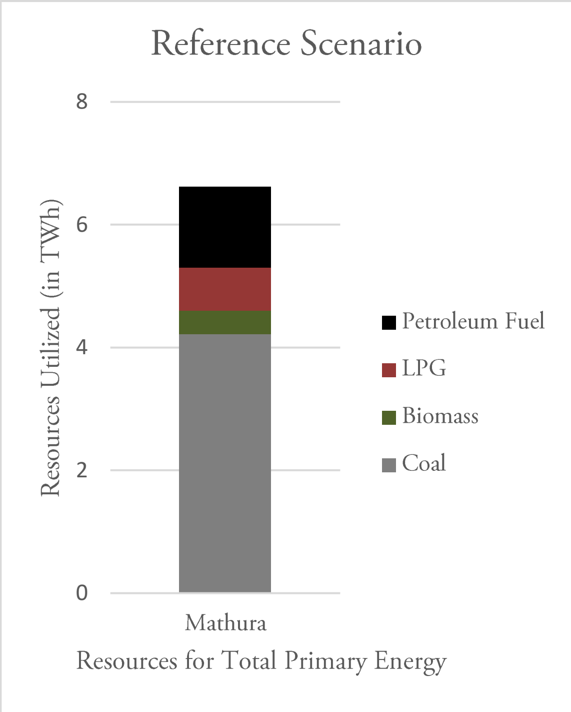

Figure 6.2: Resource utilization for Energy Supply for Mathura Reference Scenario

The district of Mathura has a low energy consumption, even with a dense population, which reduces the energy consumed per capita. It results in lower carbon emission of 2.09, and with a lack of secure supply and the utilization of coal power plants has a low techno-economic cost. The transportation demand assumed projects a total distance covered to be 2 billion km in a year. Moreover, partial cooking demand is fulfilled with raw biomass due to the shortage of LPG cylinders. It proves to be sustainable but unhealthy for domestic use and the government plans to provide low carbon cooking fuel to all the citizens in the future. The renewable energy share for the reference scenario is 3.2 percent.

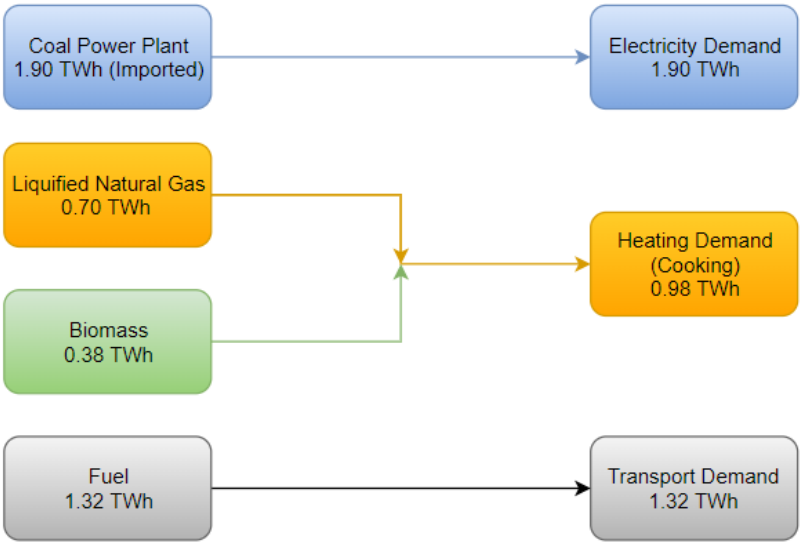

Figure 6.3: Energy Flow Chart for Matura Reference Scenario

6.5 Energy Trends in Mathura

The average monthly energy consumption data for Mathura for the year 2018 was obtained from the Dakshinanchal Vidhyut Vitran Nigam Ltd (DVVNL). It was challenging to obtain energy consumption data for previous years due to administrative regulations. Moreover, the district does not conduct studies on the expected energy consumption for the future. The study for expected energy consumption is conducted at the national level taking into consideration the central government plans. The changes in the energy consumption trends for the country are assumed to be in parallel to the energy consumption trends for Mathura district in the future.

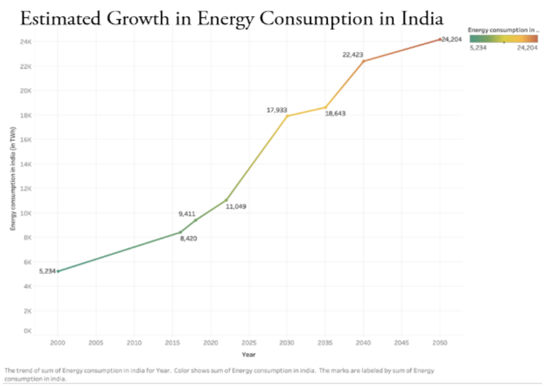

Figure 6.4: Estimated Energy Consumption in India from 2000-2050

The Energy consumption in India has been approximately doubled in the last two decades. The researches by academicians, corporate and the World energy annual report indicate the rise in energy consumption for India in the coming future, as presented in table 6.4 and figure 6.4. This rise in energy consumption is related to the high economic growth of the country, rise in population and improvement in the quality of life (Tiewsoh, Jirásek, & Sivek, 2019). Moreover, the central government of India were able to achieve approximately 100% electrification throughout the country (India, 2019) in the year 2019. Furthermore, now the futuristic aim is to maintain a secure supply all-round the year in all parts of the country.

Another factor that adds to the rise in energy consumption is the expected increase in the number of households in the urban region with infrastructure development in rural India and people moving from rural sector to urban sector due to better amenities and increasing income level (Tiewsoh, Jirásek, & Sivek, 2019). These trends are reportedly proliferating in developing countries. Lastly, the integration of technologies in manual labor jobs will also have an impact on energy consumption, e.g., the agricultural sector in India is usually managed by manual labor and in the future will switch to efficient methods.

Table 6.4: Assumed Energy Consumption for India based on various references

Year	Energy Consumption in India	
	in Mtoe	*in TWh*
2000	450	5,233.50
2016	724	8,420.12
2018	809.2	9,410.90
2022	950	11,048.50
2030	1.542	17,933.46
2035	1,603	18,642.89
2040	1,928	22,422.64
2050	2,081.20	24,204.35

Year 2030

The Energy and Research Institute (TERI), a government organization in India, published a report on National Energy Map for India: Technology Vision 2030. The report assesses the energy consumption for the country in correspondence to different policies related to the energy system by creating diverse scenarios. A business-as-usual case scenario represents a consumption of 2123 Mtoe in 2031. A plunge in the growth rate of the country would reduce the energy consumption to 1579 Mtoe, while a high growth rate would exponentially increase the consumption to 3351 Mtoe in 2031. However, a switch to renewable energy technology would slightly differ the energy consumption in 2031 from BAU to just 2097 Mtoe. Moreover, if clubbed with energy-efficient technologies, the consumption by 2031 can result in 1542 Mtoe (National Energy Map for India: Technology Vision 2030).

Year 2040

The Bharat Petroleum Energy Outlook, a public sector company, elaborated on the rise in energy consumption by the year 2040. The assessment considered the surge of integration of renewable energy technology in the Indian electricity supply. However, it stressed that coal would still be a significant source of power as 42% of the new energy demand is fulfilled by fossil fuels in 2017. The energy consumption by the end of the year 2040 is expected to be 1928 Mtoe, with 50% of the energy will be utilized for electricity (BP Energy Outlook – 2019, 2019). This surge in electricity consumption will also be supported by the integration of electric vehicles in India. The government is planning to sell only electric vehicles in the country by the year 2030.

Year 2050

According to the World Annual Energy report, India's economy is multiplying. India's primary energy consumption increased to 754 million tons of oil equivalent in 2017, i.e., 562 kilograms of oil equivalent per capita. The population of India is expected to rise to 1.72 billion by 2050 with the current trends. Provided the historical trend in GDP growth and continuously improving comfort and lifestyle, the per capita energy consumption is expected to rise 1.21 tons of oil equivalent by the year 2050, i.e., 2081.2 Mtoe overall (Li, 2018).

6.5.1 Energy Efficiency plans for India

In the Paris Agreement, India pledged to increase the integration of renewable energy systems into its energy sector to 40% and reduce its emission to 33-35% by the year 2030 (Timperley, 2019). The decision to integrate renewable energy is not only related to mitigation of climate change but also to enhance the economic growth by reducing the fuel imports and generating energy in the country, thus increasing job opportunities. To abide by the pledge, the central government placed regulatory mandate and defined standards and labels for energy-efficient appliances and building codes (Bhowmick & Aggarwal, 2018). Furthermore, India also initiated the development of smart cities with the assimilation of smart grids and energy systems. This effort is also signified with the schemes to promote the use of energy-efficient LED lights, solar appliances, transformation of city public transportation from fossil fuels to green gas produced within the country by upgrading biogas. Additionally, the interconnection of rivers to reduce the energy consumption by water pumps for irrigation is also a vital step to make the living standards energy efficient.

A vital step to reduce the energy consumption is the integration of Electric Vehicles in India. The government of India plans that the industries only sell Electric Vehicles by the year 2030 (Chao, 2017). The move was contemplated by economic benefits by reduced oil imports, more extensive integration of renewable energy and efficient fuel usage. A study by a research group at Berkley found that India can sell 10 million electric cars and 144 million electric two-wheelers annually by the year 2030. The research found a minor impact on the energy demand, i.e., adding 6% of projected peak load in 2030. Furthermore, the financial deficit faced by the electrical companies in India will improve and grid stability will be maintained even more (Chao, 2017). The other dominant energy requirement will come through electric cooling and can be maintained along with the electric vehicle.

6.5.2 Energy Consumption Trend for Mathura District

Mathura district is a vital location in India and Uttar Pradesh state, due to its religious significance. The district is receiving a secure supply of energy since 2017, while the supply is inefficient in other parts of the state. The assumption for the percentage increase in energy consumption in the future is taken in reference to Mathura district. Additionally, the energy consumption is region across all energy sectors (electricity, cooking and transportation) is bifurcated and assumed based on reference scenario. The cooking fuel is predicted to rise with the transformation from LPG to green gas. Further, the rise in population and the improvement in the quality of life with rising GDP would predictively increase the energy consumption. Based on the percentage increase in energy consumption between the respective years, the energy consumption of Mathura is predicted, and an assumed bifurcation is presented in table 6.5.

Table 6.5: Estimated Energy Consumption for Mathura for the year 2030,2040 and 2050

Year	Total Energy Consumption		Electricity Consumption		Cooking Fuel Consumption		Transport Fuel Consumption	
	PJ	*TWh*	*PJ*	*TWh*	*PJ*	*TWh*	*PJ*	*TWh*
2018	14.47	4.02	6.84	1.9	2.88	0.8	4.75	1.32
2030	28.08	7.8	13.96	3.88	3.96	1.1	10.15	2.82
2040	31.21	8.67	18.28	5.08	5.04	1.4	7.88	2.19
2050	43.3	11.54	26.35	7.32	5.76	1.6	11.23	2.62

6.5.3 Steps for Energy Transition in Mathura

Mathura, India, can become energy neutral with the resources around the region and assist India is reaching the goal of having 40% renewable energy share by the year 2030. The energy transition would initiate with transformation in electricity generation in the region.

By 2030, the implementation of high energy potential PV panels and biogas generation along with small run-off river hydropower and wind systems will reduce the pressure on the centralized grid, provide energy security and energy for cooking to reduce energy inequality. The provision to set up solar panels on the roof will face barriers among the local public. This situation arises due to financial constraints, unacceptance to behavior change for their roof usage and congested structural planning that would cause shading losses, making the system inefficient. On the other hand, the religious sentiments can help the region to set up a biogas system which can be upgraded to green gas and utilized for public transportation and cooking fuel.

The next step simulated for the scenario 2040 would be the implementation of matured batteries, electric cars and possibilities for hot water in winters. The central government expects to market only electric vehicles from the year 2030. However, the initial integration of electric vehicle would be witnessed in urban or metropolitan cities. Therefore, the integration of electric vehicles in the Mathura region will be simulated from post year 2030.

The third step, i.e., from the year 2040 onwards and for Energy Transition 2050, the region would have to investigate efficient energy technologies, improvement in existing renewable energy systems and a more efficient and sustainable battery system to support the 100% renewable energy system. It will be further progressed by seasonal storage and development of long-term new batteries. The Ministry of New and Renewable Energy has mentioned their eagerness to explore the possibilities of hydrogen, bio and synthetic fuels through research. The transition plan for the energy system in Mathura district is presented in figure 6.5.

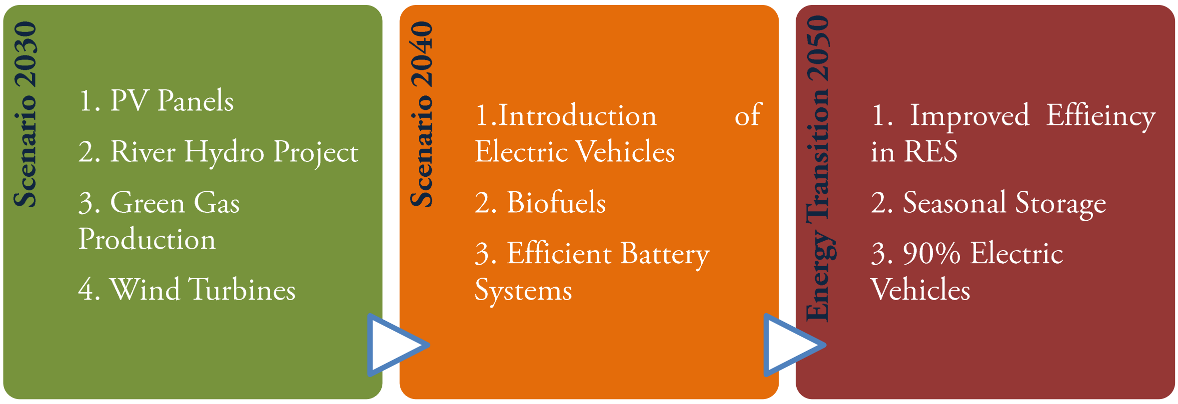

Figure 6.5: Energy Plan for Mathura District

6.6 Energy Transition Scenario

This section of the chapter presents the results of the simulation for the energy transition in the Mathura district. The regulation strategy for the transition is taken as "Balancing the heat and electricity demand," while the stabilization share is maintained at 0.3 to maintain grid stability. The simulation for transition is done for the year 2030, the year 2040 and the year 2050, implementing the steps as explained in section 6.5.3.

6.6.1 Mathura Scenario 2030

For the scenario of 2030 in the Mathura district, the renewable energy share target has been taken as 40%. As explained above, the predicted energy consumption for the region is expected to increase in the next decade across all consumption sectors. The central government has planned for sustainable energy transition and increase economic and job opportunities within the country. However, the state government or the district administration has not listed any target or plans over the transition but will intend to follow the targets in place by the central government to achieve their global targets. The simulation for the scenario 2030 is conducted on the energyPLAN tool and the results are published in the table 6.6 and 6.7 below along with resource utilization and the energy flow chart in figure 6.6 and 6.7 *(See Appendix D).*

Table 6.6: Annual Energy Demand for Mathura Scenario 2030

ENERGY DEMAND	Mathura
Electricity Demand *(in TWh)*	**3.88**
Cooking Demand *(in TWh)*	**1.1**
Green Gas	*1.1*
Industrial Fuel *(in TWh)*	Negligible
Transportation Fuel Demand *(in TWh)*	**2.82**
Petroleum Fuel	*2.4*
Green Gas	*0.42*
Total Billion km/yr	**4**
Carbon Emission *(Mton)*	**2.6**

Table 6.7: Annual Energy Generation for Mathura Scenario 2030

ENERGY GENERATION	Efficiency	Mathura
Condensing Power Plant *(in TWh)*	45%	2.33
Wind Energy System *(in TWh)*		0.22
Solar PV *(in TWh)*		1.44
Run-off River Hydro *(in TWh)*		0.18
Electric Battery *(in GWh)*	85%	5
Total Annual Cost *(In million €)*	-	**€ 447 million**

The results from the simulations for the Mathura scenario 2030 inculcates 38.7% renewable energy share. The carbon emission increased to 2.60 Mton and techno-economic costs to € 447 million in comparison to the reference scenario. This increase is due to the exponential rise in energy consumption, which procures a secure supply of energy. The renewable energy share is improved by the integration of solar PV, wind energy system and utilization of the run-off river hydro system. Moreover, the coal power plant is not phased out to maintain grid stability and cheaper fuel price.

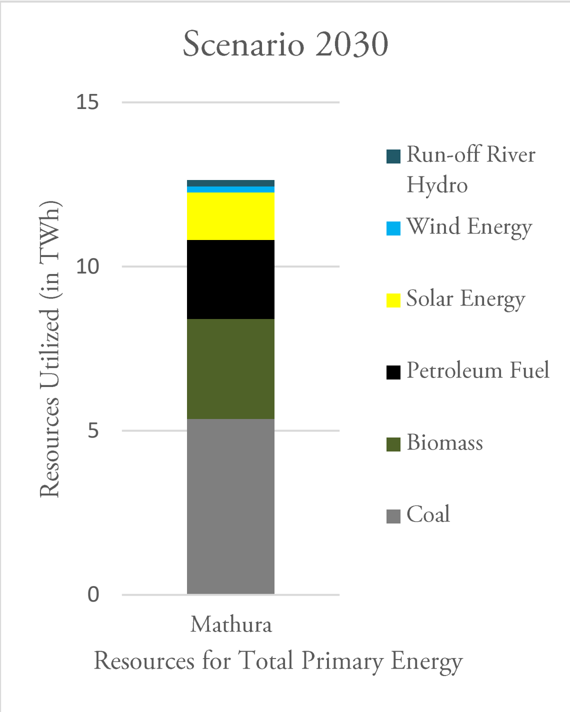

Figure 6.6: Resource Utilization for Energy Supply for Mathura Scenario 2030

Additionally, the wet biomass in the region is utilized along with an agriculture waste through biomass conversion plants to produce green gas. The green gas is used through the PNG system for cooking, phasing out LPG and partially suffice the demand for electricity and transportation. Meanwhile, the transportation fuel demand will increase due to the increase in the total distance covered to 4 billion km per year. The vehicular demand has the integration of biofuel and petroleum fuels, while natural gas is added for public transport and three-wheelers. The Indian government intends to convert the public busses and three-wheelers from fossil fuels to CNG.

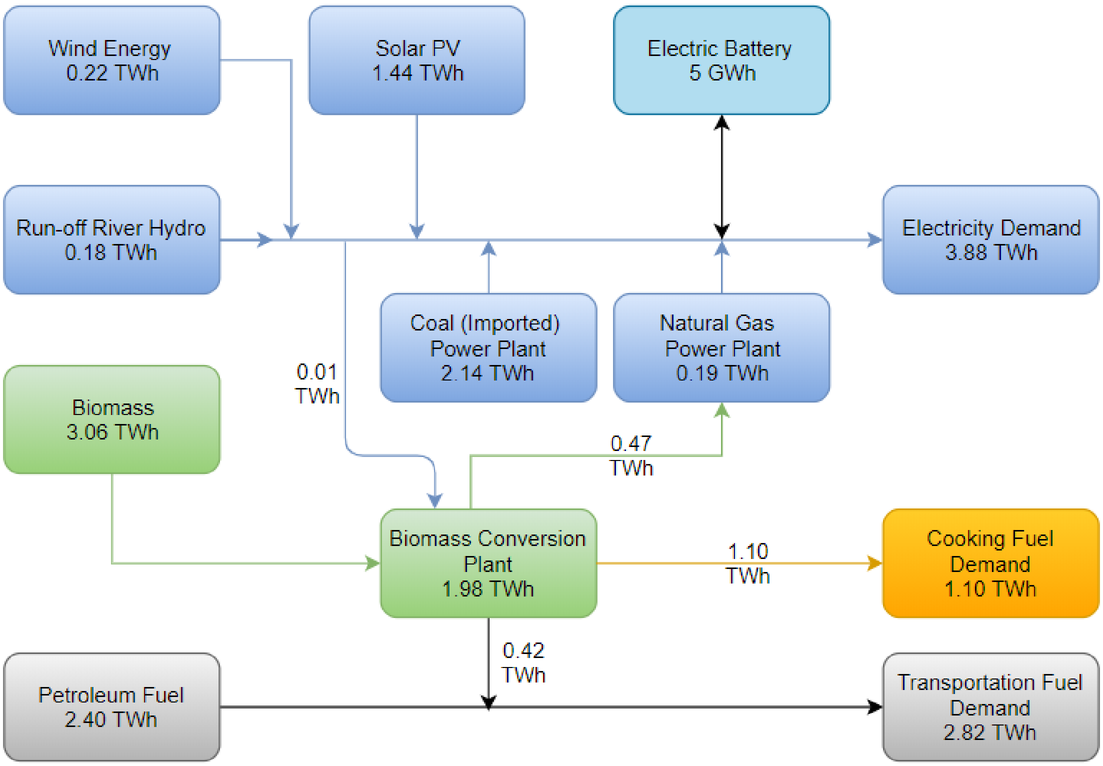

Figure 6.7: Energy Flow Chart for Mathura Scenario 2030

6.6.2 Mathura Scenario 2040

The scenario for the year 2040 will focus on integrating 75% of RES of the total primary energy in the region. The overall energy consumption for this scenario will further increase. However, the transportation demand should recede with the implementation of electric vehicles. The simulation results for the Mathura Scenario 2040 is presented in the table 6.8 and 6.9 below, along with the resource utilization and energy flow presented in figure 6.8 and 6.9 *(See Appendix D).*

Table 6.8: Annual Energy Demand for Mathura Scenario 2040

ENERGY DEMAND	Mathura
Electricity Demand *(in TWh)*	**5.09**
Cooking Demand *(in TWh)*	**1.4**
Green Gas	1.4
Industrial Fuel *(in TWh)*	Negligible
Transportation Fuel Demand *(in TWh)*	**2.19**
Petroleum Fuel	*0.2*
Biofuel	*0.22*
Electric Vehicle	*1.35*
Green Gas	*0.42*
Total Billion km/yr	**8**
Carbon Emission *(Mton)*	**1.49**

Table 6.9: Annual Energy Generation for Mathura Scenario 2040

ENERGY GENERATION	Efficiency	Mathura
Condensing Power Plant *(in TWh)*	45%	4.02
Wind Energy System *(in TWh)*		0.27
Solar PV *(in TWh)*		1.89
Concentrated Solar Power *(in TWh)*		0.57
Electric Battery *(in GWh)*	85%	8
Run-off River Hydro *(in TWh)*		0.22
Total Annual Cost *(In million €)*	-	**€ 763 million**

The renewable energy share for the Mathura Scenario 2040 is 76.7% of the total primary energy. Further increase in energy consumption in Mathura from the year 2030 onward will alleviate the techno-economic cost of the energy system. However, the simulation also presents carbon emission from the energy supply have receded from that of the year 2030 and 2018. Implementation of the biogas system and gasification systems will produce green gas which can be utilized for transportation, cooking fuel and electricity generation.

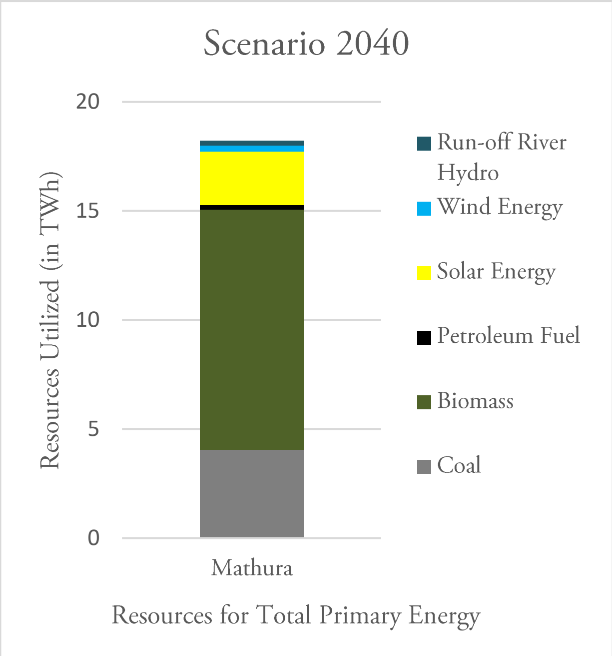

Figure 6.8: Resource utilization for Energy Supply in Mathura Scenario 2040

Additionally, the transport demand with the rising distance covered will increase to 8 billion km per year. However, the energy demand for transportation is much lower than the scenario 2030 due to the expected integration of electric vehicles. Moreover, the transport sector still supports natural gas, minimal petroleum and biofuels to suffice the demand for public transport, heavy vehicles and touristic transport, given the region is a touristic center.

The electricity share of the region has increased with renewable energy systems. Moreover, a synergy is formulated by utilizing access energy from fluctuating systems for charging electric automobile and generating bioenergy. Thus, optimizing the use of the resources.

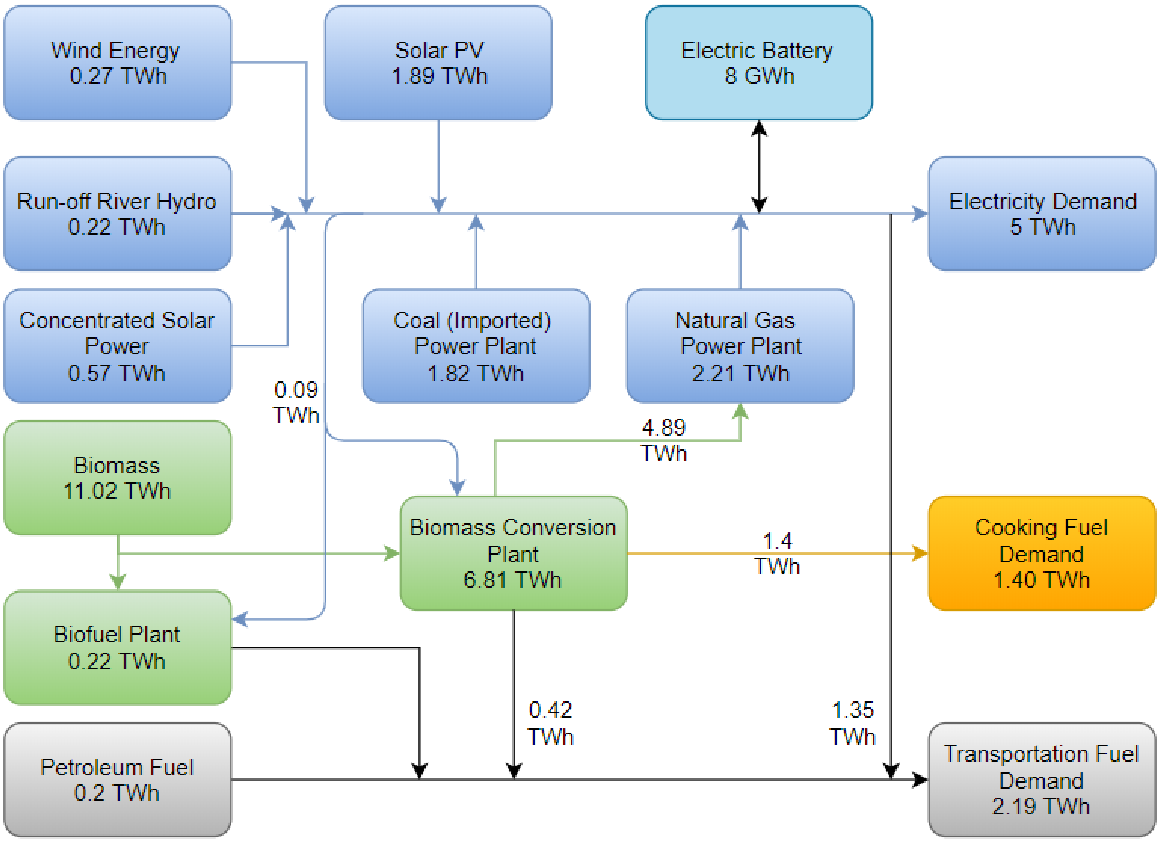

Figure 6.9: Energy Flow Chart for Mathura in Scenario 2040

6.6.3 Mathura Energy Transition 2050

The energy transition scenario for the Mathura district in the year 2050 focuses on making the region energy neutral. The growing population, GDP and improvement in the quality of life, leading to higher energy demands. However, this demand is shown to be met with sustainable means by utilizing the resources efficiently and procuring a synergy between energy demand and supply. The scenario is simulated on the energyPLAN tool and the results are published in the table 6.10 and 6.11 below with the resource utilization in figure 6.10 and energy flow chart in figure 6.11 *(See Appendix D).*

Table 6.10: Annual Energy Demand for Energy Transition 2050 in Mathura

ENERGY DEMAND	Mathura
Electricity Demand *(in TWh)*	**7.32**
Cooking Demand *(in TWh)*	**1.6**
Green Gas	1.6
Industrial Fuel *(in TWh)*	Negligible
Transportation Fuel Demand *(in TWh)*	**2.62**
Biofuel	0.22
Electric Vehicle	2.2
Green Gas	0.2
Total Billion km/yr	**12**
Carbon Emission *(Mton)*	**0**

Table 6.11: Annual Energy Generation for Energy Transition 2050 in Mathura

ENERGY GENERATION	Efficiency	Mathura
Condensing Power Plant *(in TWh)*	45%	5.94
Wind Energy System *(in TWh)*		0.4
Solar PV *(in TWh)*		2.84
Concentrated Solar Power *(in TWh)*		0.57
Electric Battery *(in GWh)*	85%	12
Run-off River Hydro *(in TWh)*		0.26
Total Annual Cost *(In million €)*	-	**€ 1207 millions**

The scenario simulated presents an energy-neutral region by utilizing the resources from the region. The results also represent that the region will be carbon neutral with the sustainable use of the resources by the formation of a synergy between the energy system.

Provided the research added into the World Energy Report, the energy consumption for India is expected to be double by the year 2050 based on the trends and secure supply. This will result in the addition of power generation units to the existing ones, which will raise the investment cost and resource utilization. The techno-economic cost for the energy system in the simulated scenario also rises to €1207 million in 2050.

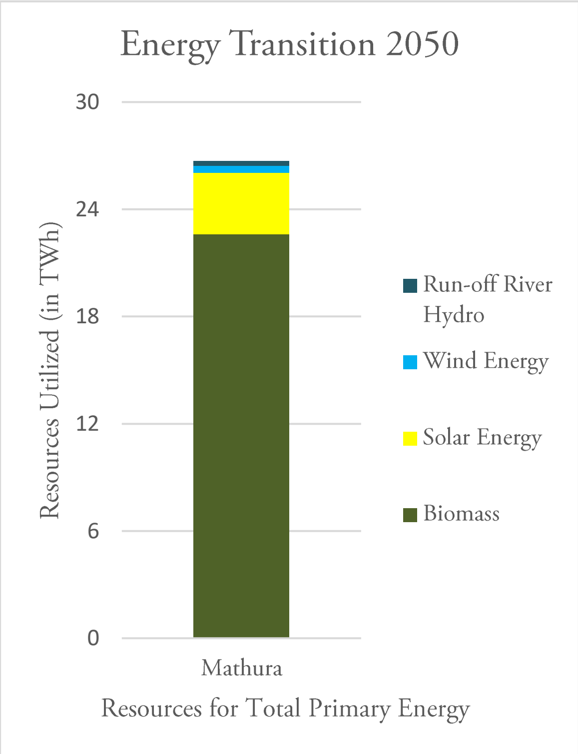

Figure 6.10: Resource utilization for Energy Supply for Mathura Energy Transition 2050

Renewables assist the electricity supply; however, the majority of the supply is provided by green gas power plants. The utilization of green gas for power generation in Matura is used due to excessive presence of bioresources in the form of animal waste and agriculture waste. 75% of the land in the region is utilized for agriculture producing extravagant residue, which is usually burned to avoid financial cost. The burning of crops is a wastage of energy that causes unbreathable air and health issues and can be preferably used to provide energy.

Additionally, the placement of solar panels on the roof in the region is not efficient due to densely built district as it will face shading losses and would not be the best solutions. Although solar panels on government buildings or houses in the farm regions might be beneficial. Nonetheless, commercial solar PV farm and concentrated solar energy system is suggested to be built and simulated for the region. The region has land availability in the form of other fallow lands with 3031 ha and a part of that land is assumed can be used for solar farms or along the river coast. This land usage should not be affecting the agriculture or other industries in the region.

The wind turbine is utilized to a minimum value as the onshore wind turbines are not that efficient. Moreover, provided the tourism industry, it will not be supported by the locals. On the other hand, Run-off River hydro system is utilized to a small value due to resource and land constraints. Moreover, the run-off river hydro system can be supported by the irrigation network for the farmland. The transportation demand is shown to be dependent on electricity with an expectation of a transition in the country, while 0.22 TWh of biofuels are still generated to support heavy vehicles.

In the simulation, the efficiency of wind and solar energy system is improved with the expected development in the domains with efficient designs and materials. Moreover, there could be further research into the utilization of waste heat from the small industrial processes and bioenergy generation. This heat can be used for heating during brief winters and cooling during summers with the utilization of absorption chiller. However, a heating and cooling gird would have to be placed and can add more cost, resulting in financial barriers. Additionally, the government is having further research into hydrogen energy and batteries. The introduction of the hydrogen-based system can be highly beneficial, although, for these simulations, hydrogen energy was not an efficient measure and has not been utilized.

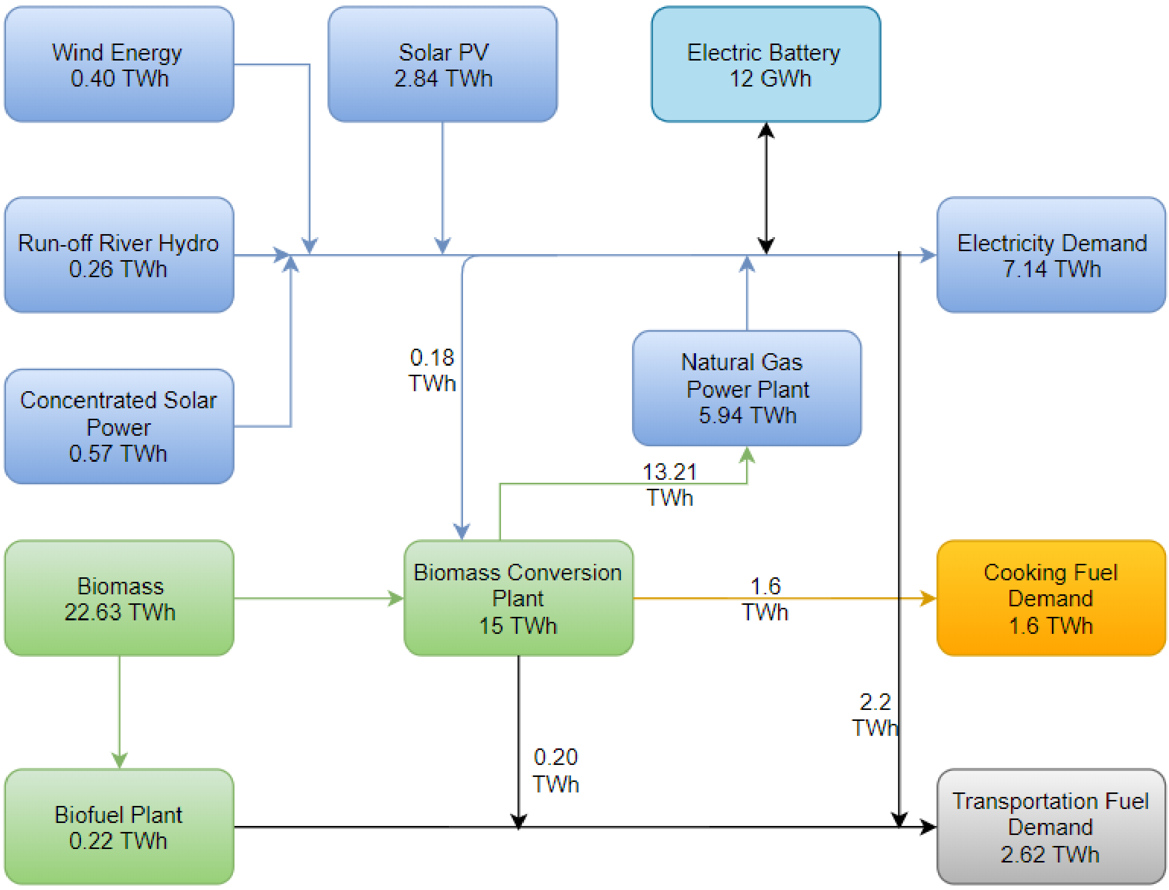

Figure 6.11: Energy Flow Chart of Mathura Energy Transition 2050 Scenario

6.7 Comparison of BAU and Energy Transition Scenario in Mathura

This section will present a business-as-usual scenario and introduce a comparison between the business-as-usual and the energy transition scenario of the region. The comparison will indicate the benefits of the energy transition in Mathura and the comparing index will be limited to technology, economics and the environmental benefits.

6.7.1 Business-As-Usual Scenario

The business-as-usual scenario is formulated for the year 2050 in Mathura, if the energy transition in the regio is not achieved. The Indian government has initiated the process of low carbon energy system by utilizing bioresource to produce green gas. Furthermore, the electricity consumption for this scenario is taken similarly as the energy transition scenario with an expected 100% electrification and secure supply matching the growing demands. Coal power plants will suffice the electricity demand for this scenario due to India's reliance on its coal reserves. Meanwhile, solar PV is a profitable alternative and will be utilized on the government building roofs only.

The transportation demand is estimated with the distance covered by vehicles over the year. For the year 2050, the estimated transportation demand is 12 billion km per year. This assumption is based on the trend indicating India's growing automobile industry. The fuel utilized will be petroleum fossil fuels, while the public transport and the three-wheelers will make a complete switch to CNG powered engines. The estimated annual energy demand for BAU scenario is given in table 6.12.

Table 6.12: Estimated Annual Energy Demand for Mathura in the BAU Scenario

ENERGY DEMAND (BAU)	Mathura
Electricity Demand *(in TWh)*	7.17
Cooking Demand *(in TWh)*	1.6
Transportation Fuel Demand *(in TWh)*	8

6.7.2 Comparing BAU and Energy Transition Scenario

The comparison between the BAU and energy transition scenarios in the Mathura district is presented with energy demand, energy generation and fuel balances. The distinction can be reviewed regarding resource utilization, carbon emission and techno-economic cost in table 6.13 and 6.14 and also on the basis of resource utilization in the figure 6.12.

Table 6.13: Annual Energy Demand between BAU and Energy Transition Scenario for Mathura

ENERGY DEMAND	Mathura	
	BAU	Energy Transition
Electricity Demand *(in TWh)*	**7.17**	**7.32**
Cooking Fuel Demand *(in TWh)*	**1.6**	**1.6**
Green Gas	*1.6*	*1.6*
Transportation Fuel Demand *(in TWh)*	**8**	**3.12**
Petroleum Fuel	*5.6*	-
Biofuel	-	*0.22*
Electric Vehicle	-	*2.2*
Natural Gas/ Green Gas	*2.4*	*0.2*
Total Billion km/yr	**12**	**12**
Carbon Emission *(Mton)*	**8.43**	**0**

Table 6.119: Annual Energy Generation between BAU and Energy Transition for Mathura

ENERGY GENERATION	Efficiency	Mathura	
		BAU	Energy Transition
Condensing Power Plant *(in TWh)*	38-45%	6.9	5.97
Wind Energy System *(in TWh)*	10%	-	0.4
Solar PV *(in TWh)*		0.28	2.84
Concentrated Solar Power *(in TWh)*		-	0.57
Electric Battery *(in GWh)*	85%	-	12
Run-off River Hydro *(in TWh)*	-	-	0.26
Total Annual Cost (in million €)		**€ 1381 million**	**€ 1207 million**

The distinction between the two scenarios indicates that a transition to a renewable energy system by the year 2050 will make the region energy and carbon neutral. The energy demand for BAU and transition scenarios is assumed approximately similar as the consumption is expected to rise. The growing energy consumption of the region is due to growing GDP, increasing population and improving quality of life while maintaining secure supply. Moreover, the energy-efficient appliances are expected to be part of both scenarios as the government already have policies in place. The electric automobiles have higher efficiency as compared to fossil fuel vehicles and thus lowered the energy demand for transportation for the transition scenario. More importantly, the research from the University of Berkley, show that the implementation of electric vehicles would not affect the grid much. They further state that the implementation of electric mobility will only increase the electricity demand by 6% while supporting the integration of renewable energy and financially benefitting the cash strapped electricity distribution companies.

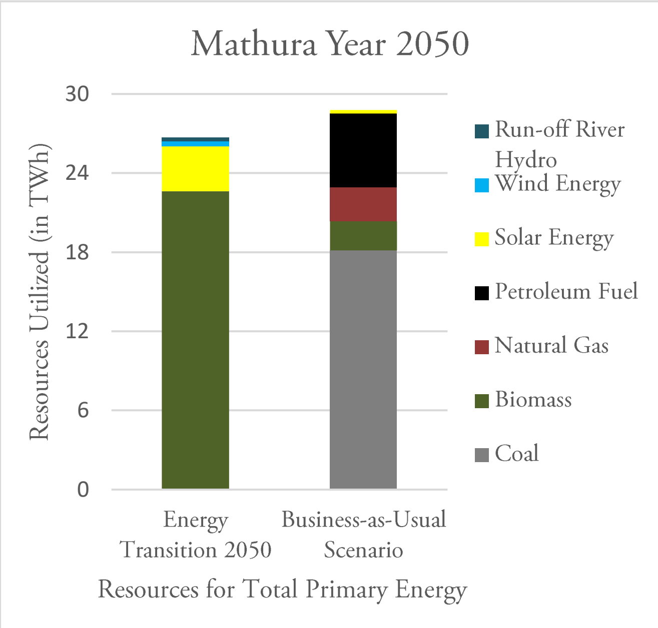

Figure 6.12: Resource utilization for Energy Supply in BAU and Energy Transition Scenario for Mathura

Further, the comparison in the energy supply section highlights the techno-economic cost. The techno-economic cost for a transition scenario is lower than BAU. The development of the energy system for reliable energy ought to increase the techno-economic cost. However, the cost related to technology for the energy transition scenario is compensated with the transition of the existing and new power generation units to non-conventional sources. Moreover, constant development in the renewable energy system reduces its investment, operating and maintenance costs. In the transition scenario, the focus is made on utilizing alternative energy sources and exploiting the resources available in the region. Thus, reducing the fuel handling cost, transmission losses and increasing the job opportunities. Additionally, the cost incurred due to carbon emission aggravating climatic changes is further added to the difference in techno-economic cost. The reason above attribute to the favorable outcome of the energy transition in the Mathura district by the year 2050.

6.8 Conclusion

The chapter demonstrates the energy transition in the Global South by formulating a case study for Mathura. A sustainable energy transition in the Global South will tend to happen by formulating an affordable and secure supply of energy. Moreover, the transition must prioritize the essential energy requirement. Electricity is the concern for the region or the Uttar Pradesh state due to climatic conditions and has a shortage of supply and social differences. Therefore, the regulation strategy has to be based on balancing the electricity demand, although, due to its unavailability in the software, it is set to "Balance heat and electricity demand." Additionally, the energy transition plan in the region is made by evaluating the resource availability and their energy potential, social, economic and cultural factors.

For Mathura, the economic factors are in favor of the utilization of bioresources due to 75% of land utilization for agriculture and a large population of cattle livestock due to religious beliefs. On the other hand, economic activities like religious tourism will produce societal barriers in the region. The tourism industry is well established in the region with the religious heritage, the locals and the government will not be in favor of wind turbines. However, due to shortage of power, it will be accepted to an extent. Conversely, the region has high solar irradiation and has support for the solar energy system. Although with dense population and city architecture, rooftop solar panels will be highly inefficient due to shading and poor maintenance.

The energy transition in Mathura is focused on making the region energy neutral by the year 2050. It is presented and simulated for Scenario 2030, Scenario 2040 and Energy Transition 2050. The energy consumption for the scenarios increases from the year 2018 to 2050 due to the growing population, GDP and quality of life. Moreover, the application of energy technologies is made regarding resource availability, energy potential and social factors. The process of energy transition through simulation in the energyPLAN software presented a rise in carbon emission until the year 2030. However, the emission reduces after the year 2030 to make the region carbon neutral.

On the other hand, the techno-economic cost steadily grew from the reference scenario to energy transition scenario. On the transportation front, the transition to green gas for transportation is already in process. However, the central government plans to make a transition to electric vehicles in the coming two decades, completing the lifecycle of the green gas vehicles.

At the end, when the energy transition scenario is compared with the business-as-usual case, the carbon emission showed drastic difference with BAU recording 8.43 Mton of CO_2 and higher techno-economic cost. On the contrary, the final energy transition scenario puts up an energy-neutral system by utilizing the resources from the region, making it carbon neutral with a lower techno-economic cost.

Chapter 7

Implications of Global North-South Dimension for Energy Transition

This chapter of the thesis presents the implication of energy transition in the Global North and South by referring to the empirical results of the case study. The segment is initiated with the explanation on requisite to have this distinction and later explains the implication on sustainable energy transition. The chapter concludes with a comparative analysis of the energy transition in Overijssel and Mathura.

7.1 Introduction

The distinction between the two worlds can be seen through differences in economic level, social development, culture and technology advancement. Overijssel, in the Global North, is technological more advance, socially developed and has a stronger industrial base as compared to Mathura in the Global South.

Moreover, the province of Overijssel is concerned about the green agendas that include environmental issues and resource degradation. These green agendas prompted them to initiate the "New Energy Plan" from 2017 to 2023 to make the province energy neutral by the year 2050. On the other hand, Mathura are entangled with brown agendas like food and energy security, poverty and health hazard. The region lacks planning for futuristic energy system and is more focussed on the reliable power supply with equal resource distribution.

7.2 Sustainable Energy Transition in Overijssel And Mathura

This section of the chapter presents the requisite and the implication of energy transition in Mathura and Overijssel representing the Global North and South.

7.2.1 Requisite of Energy Transition

The region of Overijssel, when compared with the Mathura district, has a higher energy consumption for the reference year 2018. The province has a stable industrial sector, socially developed and portrays economic resilience. Moreover, research facilities and state structure promote awareness and gather data trends for future planning. On the other hand, the region of Mathura has a higher population density in comparison to Overijssel and tackles social issues and weaker state structure. They do not have any data collection to assist in future planning and mostly done at the national level.

When the current energy system is analyzed for both the region, Overijssel has a higher renewable energy share. However, since the energy consumption of Mathura is lower than that of Overijssel, the carbon emission and the techno-economic cost is lower in the Global South region. A distinction between the two regions considering carbon emissions and techno-economic cost is presented in Table 7.1

Table 7.1: Distinction in Carbon Emission and Techno-Economic Cost for Reference Scenario between Overijssel and Mathura

Reference Scenario	Overijssel	Mathura
Carbon Emission *(Mton)*	7.09	2.37
Techno-Economic Cost *(in million €)*	€ 1540 million	€ 168 million

These disparities are noticed due to a lack of a secure supply of energy and unequal resource distribution in Mathura signified as energy poverty. Moreover, energy poverty is also distinct in the globalized world. The defined energy poverty in Mathura is social issues for Overijssel, which are rarely present. Energy Poverty in the Dutch region is related to the affordability of energy while maintaining energy security.

Furthermore, for the Global South region, the energy demand is expected to rise with development, rise in population and growing GDP. With the growing economic resilience, the standard of living in the Mathura will also improve and be comparable with the Global North region. Contrary, Overijssel maintains its economic strength, social evolution, while the growth in residents has minimal alternations. Thus, maintaining their energy demand as seen from the historical trends, while progressing towards sustainable means of energy.

Provided the energy efficiency and energy transition efforts from both the region, a business-as-usual case is developed for simulations. The results derived for carbon emissions and techno-economic costs between the two regions are presented in table 7.3.

Table 7. 2: Distinction in Carbon Emission and Techno-Economic Cost for BAU Scenario between Overijssel and Mathura

Business-s-Usual (Year 2050)	Overijssel	Mathura
Carbon Emission *(Mton)*	6.27	8.43
Total Annual Cost *(In million €)*	€ 2257 million	€ 1381 million

The results present that, if an energy transition is not processed at a quicker pace, the carbon emission of Mathura will be higher than Overijssel. Though the carbon emission of Overijssel will be lower than the reference year, but the techno-economic cost will be high, affecting the affordability of energy. Nonetheless, the carbon emissions generated for both regions for the year 2050 would impact climatic changes, as we would go over the estimated carbon budget set by the IPCC.

7.2.2 Implication of Sustainable Energy Transition

In the view of the sustainable development goal 7 for clean and affordable energy for everyone along with mitigating the climatic changes, the regions have to make a faster transition from fossil fuels to low carbon or renewable energy systems.

The energy transition in Overijssel, representing the Global North, is amiable due to awareness, economic resilience and technological innovation. The energy system in the region have to make a transition by maintaining a secure and reliable supply of energy. It has to be combined with a transition to energy-efficient industrial process and homes in the region. Contrarily, the energy transition in Mathura, the Global South, is amiable to eliminate the shortage of power and growing health issues due to using of unsustainable energy resources. The transition has to be implemented by satiating the growing need for energy along with a transformation of the current energy system in place, providing a secure and reliable supply of energy as it was absent in the previous years.

Additionally, the regulations and societal factors for energy generations are also different for the two regions and have implications on the implementation of sustainable energy technology. Overijssel is challenged by social factors like NIMBY (not in my backyard) and stringent policies on the usage of biomass from the region. The bioresources are limited to procure food security, and manure disposal is also regulated for cattle farmers. Similarly, the placement of bioenergy or wind energy system is dependent on social approval. Moreover, the lack of trust regarding policy longevity restricts the efficient process transition from the industries. However, the long-term targets by the national government and spatial planning through the involvement of local stakeholders motivate the region to transform their energy system, signifying democratic and social awareness approach.

On the other hand, for Mathura, the regulations by the government are not strict and the recent policies support the installation of PV panels and usage of bioresources by providing subsidies to the owners. However, the state and the central government do not promote the use of first-generation biomass to avoid further shortage of food. Nevertheless, lack of awareness, weaker economic structure, unavailability of technology innovation and illiteracy create barriers for the transition. Moreover, the region will regulate the use of wind turbines due to tourism, while the rooftop solar panels face shading losses affecting its efficiency due to dense city planning. Additionally, corporate greed tends to make energy unaffordable and a shortage is formulated with illegal activities of black-market electricity. A transition in the region is possible by taking a top-down approach. The unreliable power supply, religious inclination and economic activities can be utilized by the government to promote sustainable energy generation in the region.

On the transportation front, both the regions are initially planning to make a transition to vehicles using green gas and biofuels and later targeting to sell only electric vehicles by the year 2030 due to higher fuel efficiency. The integration of electric vehicle in the Netherlands has been initiated with the region also adding public vehicle charging stations. On the other hand, the plan of electric vehicles in India and Mathura is not yet initiated. The country and the region do not have any public charging stations, though the installation of charging stations is at the planning stage. Irrespective of the current situation, the transition to electric vehicles is expected as the central government has inclined its policies to electric automobiles and will take a longer time to integrate completely. Moreover, the move is warranted to reduce the import of petroleum to gain strength in international trade.

However, the integration of electric automobiles in the current time is barred by transmission grid issues. The transmission grid will face destabilization with a high volume of electric automobile charging at the same time, especially during the night hours. However, with the electric automobiles, the integration of the renewable energy system is supported. The renewable energy systems are highly fluctuating, and automobiles can be utilized as a storage unit forming a synergy. Further researches are analyzing the use of the vehicle to grid and grid to vehicle system to optimize the integration of non-conventional energy sources. Although, implementation of such a system is difficult to foresee in Mathura but possible for Overijssel by the year 2050.

The energy transition plan for Overijssel and Mathura is formulated based on the societal factors and economic activities and simulated on energyPLAN tool. The results presented in table 7.4 show that both regions to be energy and carbon neutral. However, the techno-economic cost of Mathura for energy transition will be more than the Overijssel.

Table 7. 3: Distinction in Carbon Emission and Techno-Economic Cost for Energy Transition Scenario between Overijssel and Mathura

ENERGY DEMAND	Overijssel	Mathura
Carbon Emission *(Mton)*	0	0
Techo-Economic Cost *(in million €)*	€ 887 million	€ 1207 million

The difference in the techno-economic cost is present due to the climate conditions in both the changes. The province of Overijssel requires heating primarily and the demand can be sufficed by utilization of waste heat from industries and bioconversion processes. On the other hand, Mathura needs electricity primarily and has a higher share as compared to Overijssel. The waste heat energy generation in Mathura is not utilized for heating due to warm climate. While the waste heat can be used for district cooling by the use of heat pump chillers or absorption chiller and reduce electricity consumption. Although the data on cooling was unavailable and setting up a district cooling system will be expensive and provided the average income group, it might not be affordable.

Lastly, the distinction between the two regions can be analyzed with technology innovation and acceptance. The region in the Global North procures advanced and affordable technologies with continuous researches. The research on the vehicle to grid system, PVT panels, micro-wind systems supports the transition to a low carbon energy system. On the other hand, Mathura or other parts of India are solely focusing on the implementation of technology more than technology research suitable for them. Contrarily, the application of new technologies is amiable in the Global South, with weaker regulation and interference by social groups as compared to Global North. Therefore, combined testing of systems and transfer of knowledge can support a sustainable energy transition in Overijssel, part of the Global North and Mathura, part of the Global South.

7.3 Conclusion

The chapter presents the implication on sustainable energy transition in Overijssel and Mathura representing Global North and Global South, respectively. The distinction is initially presented for the reference year and the business-as-usual scenario for the year 2050. The carbon emission of Mathura in the reference scenario is lower than Overijssel due to energy shortage. However, the region is expected to develop with growing GDP, though also indicating an increase in the population. It would increase the energy consumption and if the transition is not concluded and the rate of energy transition is low for the year 2050, then the carbon emission for Mathura will be higher than Overijssel.

On the other hand, Overijssel initiated an energy transition with "New Energy Plan" and is assisted with awareness and research facilities for technology innovation. However, if the transition is not concluded by the year 2050, the region will not witness much change in their carbon emission. The resulting carbon emissions from the simulations for BAU scenario indicate climatic changes and high techno-economic cost for both the regions.

To restrict the carbon emission and procure the carbon budget mentioned in the IPCC report, sustainable energy transition at a progressive rate is needed. However, the transition to sustainable energy is not solely dependent on resource availability and energy potential. The transition in the energy system can be formulated by considering the economic activities, social development, political scenarios leading to policies and cultural practices.

The economic activities of both the region are similar, which allows the distinct region to form a transition dependent on bioresources. Additionally, both regions provide support to solar energy systems, though distinctly in terms of land or space utilization.

Among the distinction between the two regions can be witnessed in terms of policies, development and societal behavior. The policies in Overijssel restrict the use of biomass, while societal issues like NIMBY slows down the process of transition rate. However, education, social development and research facilities assist the region is spatial planning and technical innovation to progress the transition. On the other hand, Mathura has the ease of transition due to growing consumption and amicable political and social scenario. However, the lack of literacy, awareness, stringent behavior and weaker economic resilience followed by corporate greed restricts the rate of transition.

When the energy transition scenarios are compared, both regions can achieve energy and carbon neutrality theoretically. Though while analyzing the availability of the resources, Overijssel presents a shortage in bioresources and have stricter policies regarding land use for energy generation. On comparing the techno-economic cost of transition, the costs are higher for Mathura. It is due to higher electricity consumption and waste of energy in the form of heat. Conversely, the electricity consumption in Overijssel is low, with lower population density and efficient appliances. Besides, the province of Overijssel requires heating and is provided with waste heat from the industrial process. Thus, optimizing the energy system in the region. The region of Mathura can also introspect the usage of waste heat for short winters or utilization of waste heat for cooling using absorption chillers. However, the system needs to be analyzed concerning economic viability.

To conclude, for a sustainable energy transition to progress at a quicker rate and reduce carbon emission globally, sharing of knowledge, testing new technology and technology transfer is equally required between the Global North and South.

Chapter 8

Conclusion, Discussions and Recommendations

This section of the thesis concludes the study on energy transition in the Global North and Global South and hold the findings from the case study. Post conclusion, this chapter will discuss the implications of the restriction with the study and present the influence of the assumptions and irregularities in the data. Finally, the chapter will be concluded with recommendations, explaining the further studies required and the improvement that can be made in the research topic.

8.1 Conclusion

The objective of the thesis is to identify the similarities and differences in the sustainable energy transition in the globalized world. Before recognizing and quantifying the distinction in the sustainable energy transition between the Global North and Global South, we address the emergence of the terms and their conceptual and empirical meaning.

The term Global North and Global South were introduced post-cold war era to signify developed and developing countries and move away from the distinction of three different worlds. Most of the developed countries were in the northern hemisphere and the developing countries except Australia and New Zealand in the southern hemisphere. Therefore, the developed countries were signified as Global North and the developing countries as Global South. The distinction is not only based on economic strength and location. Instead, the comparison includes wealth along with resilience in human wellbeing, public sector, state organization, industrial sector, social development and equal share of resources. The countries in the Global North have been identified as developed in the sections mentioned above as compared to Global South.

However, from the perspective of empirical distinction, the population growth in Global South is higher and five-sixths of the population currently resides there. Due to the unequal share in resources and below-average social development, the productivity level of these countries is lower and is subjugated in international trade relations. Moreover, the distinction is not limited to nations. Instead, there is a presence of Global South in the Global North countries unaddressed by the Global North countries. A division further needs to be redefined as a nation-based division is more simplistic. Preferably, an in-depth analysis presents the need to move from nation-centrism to transnational unit.

The United Nations formulated Sustainable Development Goals to resolve the distinction between the Global North and South. However, the "Need" associated with sustainability differs in the globalized world. The Global North objective towards "Need" is for green agendas like environmental protection and resource degradation. While, for the Global South, the "Need" is formulated to brown agendas, which relates to food and energy security, poverty and health hazards. Nonetheless, SDG 7 focuses on the availability of clean and affordable energy in both parts of the world. Though, the sustainable energy transition in the Global North and South will have implications due to the diversity presented between the two states.

When the energy consumption is analyzed in the globalized world, the consumption of developed countries is higher than the developing countries with the strong industrial sector and secure supply. The initial attempts to reduce the consumption and carbon emission in the Global North were assisted with HEF. Nevertheless, the consumption and carbon emission of the southern countries was examined to be lower.

Furthermore, the definition of energy poverty for the Global North and Global South are distinct. In the Global North, the energy poverty is defined in terms of affordability and its impact on the general public. Meanwhile, for the Global South, energy poverty has a much broader meaning associated with the reliability and secure supply of energy. The shortage of energy promotes the use of raw biogas or oil-filled candles for light in developing countries leading to health effects and mental and physical lethargy, leading to lower productivity.

Sustainable energy transition must progress together with development in social, cultural and economic sectors by formulating a synergy between the energy systems. An energy transition in the Global North faces limitation with social welfare groups and policies, yet it is also amiable with the awareness among people and the ability to manage the cost related to secure supply. Although, it is not that simplified with the Global South facing energy shortage, lower economic development and illegal activities. This situation for Global South to make their primary focus on satisfying the energy needs in the most affordable way possible. However, the transition in the energy system in the Global South can still be activated by sufficing the energy requirement in the coming years while slowly making a transition with their current system

Moreover, the approaches for transition in Global North and South are distinctive. These approaches are not confined to Global North and South countries but rather at the regional level. An energy transition in Global South will be more inclined to a top-down approach due to lower literacy rates, reliable power requirements and investment. On the other hand, the Global North region differs in accordance to the communities. Lastly, it is impossible to integrate a single model across the globalized world. Different regions have diverse regional capabilities to generate and maintain a secure supply of energy supported by social and cultural values creating economic benefits.

The distinction in the energy transition in the Global North and South is presented with a case study on energy transition in Overijssel from the Global North and Mathura part of the Global South. The case study entails on the implication of energy transition in both the regions. For both regions, the current energy system is analyzed along with the resources and their energy potential available in the region. Both the regions taken for the case study have a healthy agriculture and cattle farming sector. They present convincing economic factors to utilize bioresources for energy generation. Moreover, they both have an established tourism industry, Overijssel, based on ecology and Mathura based on religious heritage. The social factors and local stakeholders also have a vital role in energy planning and transition to renewable energy. An energy transition plan was formulated for both regions based on economic resilience, resource availability, policies in place, social factors, land utilization and city planning to make then energy neutral by the year 2050.

An energy transition plan is formulated to make the region energy-neutral until the year 2050. A smart energy system is formulated on the energyPLAN tool for the year 2030, 2040 and energy transition year 2050 with a stepwise renewable energy integration. Consequently, a reference scenario for the year 2018 and a business-as-usual scenario was also conducted to compare the benefits of the transition.

7.1.1 Energy Transition in Overijssel

The energy consumption and the carbon emission from the energy system in the province of Overijssel are high. The region plans to make a transition to sustainable energy by maintaining a secure supply of energy and affordability. The transition is supported by citizens with awareness regarding climate change and is inclined to reduce energy consumption and transform their energy supply to sustainable means. However, they face barriers socially, acknowledged with NIMBY (not in my backyard). The local citizens are displeased with the idea of wind turbines or bioenergy plants close to their houses as it creates exasperating experience. However, the solar panels on houses are widely accepted with financial benefits, although the region is not exposed to high solar irradiation. To overcome these issues, the province of Overijssel has dedicated spatial zoning for a renewable energy system with the association with local stakeholders.

Additionally, to reduce the carbon emission, the Netherlands wants to make a transition from fossil fuel transportation to efficient electric automobile or zero-emission vehicles from 2030 onwards. The transportation distance and usage of vehicles are expected to rise in the future as the standard of living improves.

The energy transition in Overijssel is simulated, presenting that the region can attain energy and carbon neutrality theoretically. However, it is essential to note that the energy transition scenario also presents that the biomass energy potential available, does not suffice the requirement for the energy transition in the year 2050. Thus, the natural gas has to be imported, or an alternative fuel source needs to be determined to make the region energy neutral.

At the end, when the energy transition scenario is compared with the business as usual scenario, it shows that the carbon emission will be negligible when a transition to 100% renewable energy takes place. Moreover, the techno-economic cost will be lower than the business-as-usual scenario indicating the benefits of the transition.

7.1.2 Energy Transition in Mathura

For Mathura, energy consumption and carbon emission are low due to the low quality of life and unequal resource distribution. However, with the ongoing development and growing GDP along with the population, the energy consumption of the region is expected to rise further. Therefore, an energy transition initiates with affordable and secure supply of energy prioritizing electricity.

The social problems related to energy systems in Mathura are less of an issue due to shortage of power. Climate change is not an urgency for the region, although access to reliable power and degrading health is the emergence issue in the region. The local public is open to the utilization of bio-resources (agriculture and cattle waste) due to religious belief and air pollution caused by the burning of agriculture residue. However, the utilization of bioresources has to be supported by financial incentives to the farmers.

Secondly, the region has plentiful solar irradiation, which makes the application of solar energy advantageous in energy generation. Although, the idea is not well supported on the roofs due to dense city planning leading to shading losses and unacceptance of local public to alter their use of the terrace. Therefore, the implementation of solar panels has to be an investment procured by the government and corporates, considering land utilization. Moreover, the local government and the tourism industry will not be in favor of wind turbines as it will repulse the tourism sector.

The transportation distance and usage of vehicles are expected to rise in the future as the standard of living improves in India. Furthermore, like the Netherlands, India also plans to have electric mobility along with biofuels supported vehicles from the year 2030 onwards. Consequently, the green gas-powered vehicles are being utilized in metropolitan cities for public and commercial transport and will enter the Mathura district with local green gas production. India is motivated to make this transition to reduce its fuel import, increase jobs in the country and gain power in international trade.

The energy transition in Mathura is simulated and the result for the year 2050 present an energy and carbon-neutral region and presents a drastic difference when compared with BAU scenario. Moreover, the techno-economic cost of the transition scenario is increases from the reference scenario due to the increase in the energy consumption. However, when the techno-economic cost of energy transition scenario is compared with the business-as-usual case, it shows that the technical cost of the BAU scenario is higher than the transition scenario, thus, indicating the advantage of the energy transition in the region.

7.1.3 Implication of Energy Transition between Overijssel and Mathura

On simulating the energy transition scenarios for Overijssel and Mathura, we witness similarities and differences between resource availability, economic activities, societal behavior, energy system and changes to techno-economic cost and carbon emissions.

A distinction is initially perceived from the reference year and the business-as-usual scenario for the year 2050. The carbon emission of Mathura in the reference scenario is lower than Overijssel due to energy shortage. However, with growing consumption in the year 2050, the carbon emission of Mathura is much higher than Overijssel. Nonetheless, to mitigate the climatic changes and high techno-economic cost in the future, energy transition at a progressive rate is essential for both the regions in Global North and South.

The energy transition scenario for both regions share similarities with the regional resource availability with their economic activities. Furthermore, they share their inclination to the solar energy system and represent their societal inconvenience at different levels with the wind energy system. However, both the regions from the globalized world present differences in terms of policies, development and social inclination to renewable energy systems.

The policies in Overijssel restrict the use of biomass and introduce social issues NIMBY over the bioenergy system and wind turbines. However, education, social development and research facilities assist the region is spatial planning and technical innovation to progress the transition. On the other hand, Mathura has the ease of transition due to the shortage of power and demand for a reliable supply of energy. However, the lack of literacy, awareness, stringent behavior and weaker economic resilience followed by corporate greed restricts the transition process. These attributes can be witnessed with the restriction to place solar panels on roofs in Mathura or unsustainable farming practices like burning agriculture waste on the field itself.

Moreover, the regions share a similar process for a sustainable transition in transport. The region of Mathura has initially increased the share of green gas vehicles, specifically for public transport, to reduce fuel import. While the province of Overijssel initially makes a partial transition to biofuels to assist the current transport vehicles and lower the carbon emission. However, both the regions intend to make a second transition post the lifecycle of the vehicles using green gas and biofuels to energy-efficient electric vehicles. This secondary transition in both regions is presented due to the time frame needed to integrate electric vehicle in the energy system. Although, the integration in Overijssel is already in the process, while Mathura is yet to pass the planning phase.

When the energy transition scenarios are compared, both regions can achieve energy and carbon neutrality theoretically. During the process of the energy transition, the carbon emission of Mathura peaks in the year 2030 to 2.60 Mton, lower than the emission from Overijssel's energy system from the scenario 2030 and 2040. On comparing the techno-economic cost, the cost incurred for transition is higher for Mathura. It is due to higher electricity consumption and waste of energy in the form of heat. Conversely, the electricity consumption in Overijssel is lower with lower population density and efficient appliances. Moreover, the province can utilize waste heat from the industrial process for domestic thermal comfort. Thus, optimizing the energy system in the region. The region of Mathura can also introspect the usage of waste heat for short winters or utilization of waste heat for cooling using absorption chillers. However, the system needs to be analyzed concerning economic viability.

The transition in the Global South from the above social factors presents a responsive approach for the energy transition in comparison to the Global North due to energy shortage and need for development. However, the two globalized world face inconsistency in technology availability and innovation. The Netherlands and Overijssel have a higher percentage of educated personal and is supported by research organization and investment that makes a transition amenable here. Conversely, India's technology sector is confided to implementation and lack research investment. Although the Global South regions will be inclined to the testing of safe and new technologies. A knowledge transfer and testing of technologies can assist both the worlds in making the transition to renewable energy efficiently.

At the end, impending the climatic changes, there is an urgency to make a transition to sustainable practices and energy system. A change from fossil fuels to renewable energy would reduce the carbon emission and make our energy system efficient. However, the change is bounded by the economic differences and societal inequality between the globalized world. The Global North is well positioned to procure energy transition in their region with their strong economy, security of energy supply, low poverty rates, research facilities and efficient use of resources through information technology.

On the other hand, the Global South suffers due to low productivity in their industries, growing population rates, unreliable power supply, social inequality, poverty, low human development index and technology deficiency. These drawbacks hold the Global South in making a transition as they aim is to resolve these issues. Nonetheless, it is essential for the Global South to switch to renewable energy as more that $5/6^{th}$ of the population is in these regions and constantly growing with the improving standard of living.

To conclude, it is challenging to integrate a single model across the globalized world. Different regions belonging to the two different parts of the world need to have separate transition plans based on their present social and cultural values while creating economic benefits with different emission targets. Moreover, the two parts of the world must congregate in terms of knowledge sharing and investment to formulate this transition and reduce the carbon emission to mitigate climate change.

8.2 Discussions

The master thesis research is conducted to highlight the difference and the similarities between the globalized world and its impact on sustainable energy transition. The boundary condition for this study is confined to techno-economic cost, carbon emission and integrating more renewable energy by curbing the import and export of energy. There are various aspects of the research that can alter the outcome of the proposed results of the thesis.

The techno-economic cost for this research is only limited to technology investment cost, carbon emission cost, fuel handling cost and operation and maintenance cost. This cost can vary between the Global North and South due to the difference in raw material availability and economic structure. However, for the ease of the study, it is assumed to be the same and acquired from the energyPLAN software developer's research.

Moreover, the planning of a sustainable energy transition in a region has to be supported by local stakeholders as the transition involves transformation from large grids to a distributed energy system. For India, there was a people perception study on renewable energy conducted by World

Wildlife Federation in India, including approximately 900 surveyors. This study is used as an outline to determine the social idea of Mathura as well. On the other hand, there is no survey related to sustainable energy transition conducted in the Netherlands recently or for Overijssel. The societal concerns and acceptance added for this study has been gathered from different studies and general perception of the regions.

Additionally, both the regions also have well equipped industrial sector. The industrial sector of the Overijssel has been discussed in the study, but the industrial sector in Mathura has not been included due to the unavailability of real data. Although the region has established Asia's largest oil refinery and cotton and textile printing industries.

Furthermore, the data assumed, or the period of data acquired for energy consumption and supply along with the bifurcation, influences the result for the case study. For Overijssel, the energy consumption data and the bifurcation for the consumption of the year 2015 was available with the recent "New Energy Plan" study. However, the distribution profile of the electricity and gas consumption was acquired from Liander, for the year 2008, while the data distribution profile for geothermal energy was assumed as constant for this study.

On the other hand, Mathura district did not have any consumption data available. It was through a contact to the official authorities, a monthly average electricity data for the year 2018 was acquired. Moreover, the cooking fuel data was acquired with a personal understanding of LPG cylinder usage in the country, while the transportation fuel data was assumed based on a query with fuel pump owner in Mathura. The data for all the three sectors were extrapolated to get an estimation. More importantly, it was difficult to assume or acquire the distribution profile due to government regulations. Therefore, the distribution profile was generated through Artificial Load Profile Generator for consumption. Moreover, due to the unavailability of river data, it was assumed to be constant due to the steady flow of the Yamuna river.

Moreover, the estimated energy data for Overijssel and Mathura for the year 2030, 2040 and 2050 were simulated based on the estimated energy consumption for Netherlands and India with the same distribution profiles. Moreover, the distribution profile for electric automobiles was assumed from the energyPLAN software due to data unavailability in both regions.

On considering the energy potential of resources, there is a considerable variation in its availability. The estimated energy potential from bioresources is debatable. The estimation of bioenergy is done based on the research studies and then implemented for the respective regions. However, the energy potential for solar and wind was calculated through the updated distribution profiles of solar irradiation and wind speed at 10m for both regions.

These variations and uncertainty to the data and distribution profiles are acquired for both the regions. Some of the data was created and assumed, while some of the data input into the tool was outdated. Moreover, the energy potential calculated has assumptions, though generalized efficiency for the system is utilized in the simulations. The data trends and energy potential from resources assist in formulating efficient energy planning and variations in data can alter the results from simulations and for the study.

On advancing to simulation strategy for the scenarios, the simulations are conducted for technical analysis, i.e., larger integration of renewable energy technology and reducing the import and export by minimizing fuel balances. This strategy was utilized to make the regions energy neutral. However, being a part of nation-state lying in the Global North and South and vying of producing access energy for nearby regions. Sustainable energy transition should also be conducted with the strategy of market analysis, i.e., improving the business economic profits and further proceeding to conduct a socio-economic analysis.

Moreover, for both the regions, the stabilization share was framed as 0.3 to maintain the grid stability. Although, for a different region, the stabilization share will be different depending on the transmission grid. Additionally, the tool, by default, uses CHP and power plants to maintain the grid stabilization, though other sources of renewable energy could also assist in the future. However, for this case study of energy transition in 2050, Overijssel stabilization share was provided by CHP, while power plants provided Mathura's stabilization

In the end, the hydrogenation process for syngas and electrofuel is not used in this study as the overall energy consumption increased, increasing the need of biomass, which is limited. However, in the future energy system, hydrogen energy is recommended, and its efficient application can support the energy transition but requires further study.

8.3 Recommendation

There have been various studies regarding energy transition in the Global North, although energy transition research in the Global South has been scarce. However, currently, the majority of the world's population is placed in the Global South and the futuristic trend shows further population rise along with energy consumption. The objective of this thesis research was the distinction in the sustainable energy transition between the Global North and South. Moreover, present that the energy transition is dependent on the socio-economic and cultural factors.

The case study to present a distinction in energy transition utilizes Overijssel and Mathura. However, if a warmer region from the Global North is compared with Mathura, then the energy or a colder region from the Global South is compared with Overijssel, it would alter the techno-economic cost needed for transition. Similarly, when different regions are compared as part of the Global North and South, the outcome of carbon emission and energy neutrality will differ. The objective of the research was to present that separate parts of the world require different energy transition plans by considering economic stability, social development and cultural activities.

Further inquest into the data availability or data recording should be possessed in the respective regions or regions taken up for case study. The behavior aspect of energy consumers changes regularly with changes in the quality of life. Moreover, further research is needed in the energy data trends as the alteration in the data of the research can provide more accurate results and analysis. Moreover, regular studies regarding people's perception, societal behavior and economic resilience have to be conducted at the regional level. The perception of people is an essential factor in energy planning and support the local authorities to execute those plans. More importantly, an in-depth analysis of the resource availability, energy potential and land utilization are required as it should not coincide with food security or affect the economic activities in a region.

To conclude, the technical analysis has to be followed up by a market economic analysis in the energyPLAN tool. It would provide input for the business-economic profit required for setting up a renewable energy system in the region. The technical feasibility is essential, although to achieve an optimized system and investment returns, economic profits also play a vital role. In the end, a socio-economic study would evaluate the energy transition scenario and present a comprehensive assessment of the job allocation, environmental benefits and economic progress.

Appendix A

Techno-Economic Cost

The techno-economic cost consists of the investment cost of the technology over its lifecycle, operation and maintenance cost, cost incurred due to carbon emission, fuel cost and fuel handling cost. These cost data are acquired from energyPLAN cost data sheet compiled for the years 2020, 2030 and 2050 from different resources.

Fuel Cost

The fuel cost in the database is only presented for the year 2015 under the three different categories of low, medium and high which are assumed as the fuel cost for the reference scenario, year 2030 and year 2040 and 2050. The fuel cost taken for the simulation is presented in Table A1.

Table A1: Estimated Fuel Cost applied in energyPLAN Simulations

€/GJ	Coal	Diesel	Petrol	Natural Gas	LPG	Biomass	Dry Biomass	Wet Biomass
Low (2018)	2.2	11	11.9	6.3	6.3	4.6	10	**0**
Medium (2030)	2.8	16	16.4	8.3	8.3	6	10.9	0
High (2040 & 2050)	3.5	20.9	20.8	10.4	10.4	7.3	11.9	0

Fuel Handling Cost

The fuel handling cost in the energyPLAN cost database is only present for the year 2020 and has been utilized in the simulations for the scenarios of the year 2030, 2040 and 2050 as well. The fuel handling cost for the energyPLAN simulations are presented in table A2,

Table A2: Estimated Fuel Cost applied in energyPLAN Simulations

€/GJ / *Fuel*	Biomass conversion	Centralised Power Plants	Decentralised Power Plants & Industry	Households	Transport
Coal	-	0.05	0.05	-	-
Diesel	-	-	-	3.85	3.85
Petrol	-	-	-	-	4.67
Natural Gas	-	0.21	0.94	4.04	4.04
LPG	-	-	-	4.04	-
Biomass	1.186	0.68	0.55	4.34	-
Dry Biomass	1.186	-	-	-	-
Wet biomass	1.186	-	-	-	-

Technical Cost

The technical cost involves investment cost, operation and maintenance cost and lifecycle time frame. The technical cost utilized in the simulation for Overijssel and Mathura are presented in table A1 and A2,

Table A3: Technical Cost for the year 2018 and 2030 utilized in Simulations on energyPLAN tool

Technology	Units	2018			2030		
		Investment	Lifetime	Fixed O&M	Investment	Lifetime	Fixed O&M
Large Power Plant	*MWe*	1.93	40.00	1.63	1.90	40.00	1.63
CHP Plant	*MWe*	1.93	40.00	1.63	1.90	40.00	1.63
Heat Storage CHP	*GWh*	3.00	20.00	0.70	3.00	20.00	0.70
Electric Storage	*GWh*	7.50	50.00	1.50	7.50	50.00	1.50
Waste CHP	*TWh/yr*	246.42	20.00	1.00	215.62	20.00	1.00
Industrial CHP	*TWh/yr*	66.60	31.00	2.14	65.80	31.00	2.13
DH Boiler	*MWth*	0.06	25.00	3.33	0.06	25.00	3.25
Decentral DH HP	*MWe*	2.45	25.00	0.29	2.64	25.00	0.30
Onshore Wind Turbine	*MWe*	1.07	25.00	3.21	0.99	27.00	3.20
Commercial Solar PV	*MWe*	1.46	30.00	0.88	0.83	35.00	1.31
Domestic Solar PV	*MWe*	1.47	30.00	1.00	1.25	35.00	1.00
CSP solar power	*MWe*	5.60	30.00	4.00	4.50	30.00	4.00
River hydro	*MWe*	5.50	60.00	1.50	5.60	60.00	1.50
Geothermal Electricity	*MWe*	5.53	30.00	1.40	4.97	30.00	1.60
Solar thermal DH	*TWh/yr*	425.00	20.00	0.13	386.00	30.00	0.13
Industrial excess heat	*TWh/yr*	30.00	30.00	1.00	30.00	30.00	1.00
Biogas plant	*TWh/yr*	205.30	20.00	11.00	195.64	20.00	11.00
Gasification plant	*MW-Syngas*	1.89	20.00	2.20	1.73	20.00	2.30
Biogas upgrade	*MW-CH4*	0.34	15.00	2.50	0.30	15.00	2.50
Gasification upgrade	*MW-CH4*	2.26	20.00	1.70	1.32	20.00	1.50
Biodiesel Plant	*MW-Bio*	3.56	20.00	3.01	3.45	20.00	3.01
Biopetrol Plant	*MW-Bio*	2.18	20.00	7.68	2.11	20.00	7.68
Individual boilers	*1000 Units*	3.20	20.00	6.53	3.10	20.00	6.61
Individual Heat Pumps	*1000 units*	1.20	10.00	16.66	1.10	10.00	17.09
Individual solar thermal	*TWh/yr*	1700.00	25.00	1.22	1700.00	25.00	1.22

Table A4: Technical Cost for the year 2040 and 2050 utilized in Simulations on energyPLAN tool

Technology	Units	2040			2050		
		Investment	Lifetime	Fixed O&M	Investment	Lifetime	Fixed O&M
Large Power Plant	*MWe*	1.86	40.00	1.63	1.78	40.00	1.64
CHP Plant	*MWe*	1.86	40.00	1.63	1.78	40.00	1.64
Heat Storage CHP	*GWh*	3.00	20.00	0.70	3.00	20.00	0.70
Electric Storage	*GWh*	7.50	50.00	1.50	7.50	50.00	1.50
Waste CHP	*TWh/yr*	215.62	20.00	1.00	215.62	20.00	1.00
Industrial CHP	*TWh/yr*	63.50	31.00	2.14	60.60	31.00	2.15
DH Boiler	*MWth*	0.05	25.00	3.80	0.05	25.00	3.40
Decentral DH HP	*MWe*	3.18	25.00	0.30	2.45	25.00	0.29
Onshore Wind Turbine	*MWe*	0.91	30.00	3.27	0.93	30.00	3.40
Commercial Solar PV	*MWe*	0.69	40.00	1.28	0.56	40.00	1.32
Domestic Solar PV	*MWe*	1.00	40.00	1.00	0.85	40.00	1.00
CSP solar power	*MWe*	3.80	30.00	4.00	3.40	30.00	4.00
River hydro	*MWe*	5.62	60.00	1.50	5.62	60.00	1.50
Geothermal Electricity	*MWe*	4.47	30.00	1.80	3.61	30.00	2.20
Solar thermal DH	*TWh/yr*	307.00	30.00	0.15	307.00	30.00	0.15
Industrial excess heat	*TWh/yr*	30.00	30.00	1.00	30.00	30.00	1.00
Biogas plant	*TWh/yr*	176.19	20.00	13.00	159.03	20.00	14.00
Gasification plant	*MW-Syngas*	1.56	20.00	2.30	1.33	20.00	2.40
Biogas upgrade	*MW-CH4*	0.27	15.00	2.50	0.25	15.00	2.50
Gasification upgrade	*MW-CH4*	0.80	20.00	1.40	0.68	20.00	1.70
Biodiesel Plant	*MW-Bio*	3.03	20.00	4.52	2.75	20.00	6.02
Biopetrol Plant	*MW-Bio*	1.85	20.00	11.52	1.68	20.00	15.36
Individual boilers	*1000 Units*	3.00	20.00	6.63	2.70	20.00	6.70
Individual Heat Pumps	*1000 units*	1.80	10.00	9.83	1.70	10.00	9.76
Individual solar thermal	*MWe*	1533.33	30.00	1.35	1233.33	30.00	1.68

Carbon dioxide costs and emissions

These carbon emission factors are utilized to estimate the total carbon emission from the resources used to generate energy. Provided the climatic changes, carbon emission will result in additional cost. The carbon emission factors for different fuels are presented in table A5.

Table A5: Carbon dioxide emission factors for different fuels in the EnergyPLAN Cost Database

Fuel	Coal	Oil	Natural Gas	Waste	LPG
Emission Factor (kg/GJ)	98.5	72.9	56.9	32.5	59.64

Moreover, the carbon dioxide price in the energyPLAN database is based on three years and three different sensitivities from the Danish Energy Agency, 2014. However, for this research, the prices are assumed in Euros and applied for a specific year for simulations.

Table A6: Carbon dioxide Prices

Fuel	2018	2030	2040	2050
CO2 Price (€/Ton)	5	11	24	42

Simulation Strategy

The transmission line capacity is assumed to adequate for the year 2018 to be delivering no critical excess energy. However, for the simulations, a balancing strategy must be defined to reduce the critical excess electricity production (CEEP) and the grid stabilization. CEEP and stabilization issues are involved with the implementation of renewable energy technologies due to fluctuating production (EnergyPLAN, 2017). This could result in varying of the grid frequency and reactive power. Therefore, the model must be defined with a CEEP regulation and Grid stabilisation requirements.

CEEP Regulation: An order to reduce the energy production system is designated in order to reduce CEEP.

Grid Stabilization Requirements: Designates the minimum grid stabilization share and systems contributing to this share.

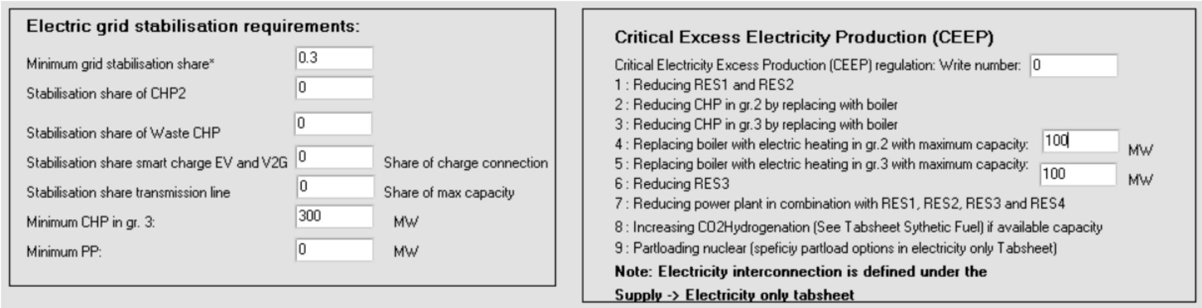

Figure A1: CEEP Regulation and Electric Grid Stabilization requirements in energyPLAN tool

EnergyPLAN Output

Each scenario simulation will deliver a .txt file will all the input information and an output sheet can be printed in PDF or XML format or simulation can simply run on screen to notify the results. The results will show us the monthly energy production and demand, import/export of energy, fuel balances and carbon dioxide emissions. The purpose of these simulations in different years is to develop a scenario to integrate maximum renewable energy system stepwise into the energy mix, match the demand, reduce the emissions and make the regions energy neutral.

Appendix B

Bioresources Potential

This section estimates the energy potential of bioresources from pruning wood, municipal solid waste, organic feedstock and agriculture waste for Overijssel and Mathura.

Pruning Wood Calculation

The most common tree found in Netherland is an oak tree and is taken as an assumption for Mathura and Overijssel(Tree species that are common in the Dutch woods., n.d.) to simplify the calculations for availability of pruning wood. To have an assumption on total number of trees in one hectare of land, we use an online tree calculator with an average distance between each oak tree to be 10 feet (Tree Spacing Calculator, 2000). The assumed average number of trees per hectare were evaluated by the calculator as 1100 oak trees.

The weight of an oak tree with 16 inches of DBH and 60 feet height is around 1 ton (David W. Patterson). A young tree can be pruned 25% and middle-aged tree can be pruned 20% while an old and mature tree can be pruned 10-15%. The pruning of wood is based on the photosynthesizing foliage to remain healthy and the tree can withstand the pruning based on its age as the photosynthesis foliage is much better and easy in a young tree and drops as it ages. (Purcell, 2015)

Over here, we take the pruning of the wood to be 5% as both the region includes various other types of trees, which will vary in their pruning percentage and the weight of the wood. Therefore, the wood pruned from one tree is 5% of 1 ton = 0.05 ton with an average lower heating value of wood is 4.00 kWh /kg (Bisaglia, et al., 2018)

Therefore, for 1 hectare of forest land, the total weight of pruned wood will be,

*0.05 ton/tree x 1100 trees/ha = **55 ton of pruning wood/ha***

Overijssel

According to David Mohren (Vodde, 2006), Netherlands has around 360,000 ha of forest area, which is about of 10% of the total land area in Netherlands. It further mentions that the Eastern side of Netherlands has a forest cover ranging from 10% to 20%. Since the pruning waste wood must be collected from the local regions of Overijssel. We assume that Overijssel has a forest cover of at least 10% of its total land area.

Land area of Overijssel Province = 332700 ha

Forest cover (10% of land area) = 33270 ha

Therefore, the estimated energy present in Overijssel from pruning wood

*Pruning wood /ha * Lower heating Value * Tree land cover =* ***6.6 TWh***

Mathura

Similarly, for Mathura the forest land is estimated as 1592 ha and land under miscellaneous tree crops is 929 ha, therefore, the energy from pruning wood in Mathura region will be,

*Pruning wood /ha * Lower heating Value * Tree land cover =* ***0.478 TWh***

Municipal Solid Waste

The estimated energy content in MSW is 15 MJ/kg (Akkaya & Demir, 2009) with an average MSW of 2.2 kg/capita/day for European countries and 1.1 for South Asian Countries(Hoornweg & Bhada-Tata, 2012).

The province of Overijssel belonging to the European continent has a population of 1.15 million people in January 2019. Therefore, the energy potential available within the region every year from municipal solid waste is **3.86 TWh** annually.

Similarly, for Mathura, belonging to the South Asian region, has a population of 2.5 million people in year 2011. Therefore, the energy content from MSW will be **4.18 TWh**

*Energy Potential from MSW = Energy Content MJ/kg) * Average MSW (kg/capita/day) * Population * 365*

Agriculture Waste

The total available land for agriculture in Overijssel is 202,620 ha. The average crop yield and the residue data is not available on the internet. Therefore, an alternative approach was used by determining the average agriculture residue in Europe i.e. 74.89 MT/year (Iqbal, et al., 2016) with an agriculture land area of 179 million ha (Land cover and land use, 2018). From this it is determined that 418 kg of agriculture waste is generated per ha per year and has an energy content of approximately 15 MJ/kg (Gravalos, et al., 2016) . The estimate energy content is 0.35 TWh.

*Energy Content in Agriculture Waste = Agriculture Land Area Overijssel(ha) * Energy Content(MJ/kg)) * Average agriculture residue (kg/ha)*

Organic Feedstock

It is assumed that 1 cow or buffalo produces 10 kg of wet biomass daily (Biogas, 2019), which can produce 0.062 m^3 of biogas (Kuria & Maringa, 2008). Provided that the Mathura district holds a population of 867,630 cattle (cows and buffalos) which can be used to generate biogas with 65% methane content. Therefore, the region has a green gas potential of 1.43 TWh annually.

*Energy Content from Organic Feedstock = Cattle Population * Manure Annually * 0.062 m^3/kg * Upgradation % * Energy Content of green gas (MJ/m^3)*

Solar Energy Potential

The energy potential from solar irradiation in Overijssel and Mathura is estimated by evaluating the hourly solar irradiation at one square meter for a solar panel with an assumed efficiency of 18%.

*Annual Energy Potential with a PV Panel (kWh/m^2) = ∑ [18% * Solar Irradiation (W/m^2)] /1000*

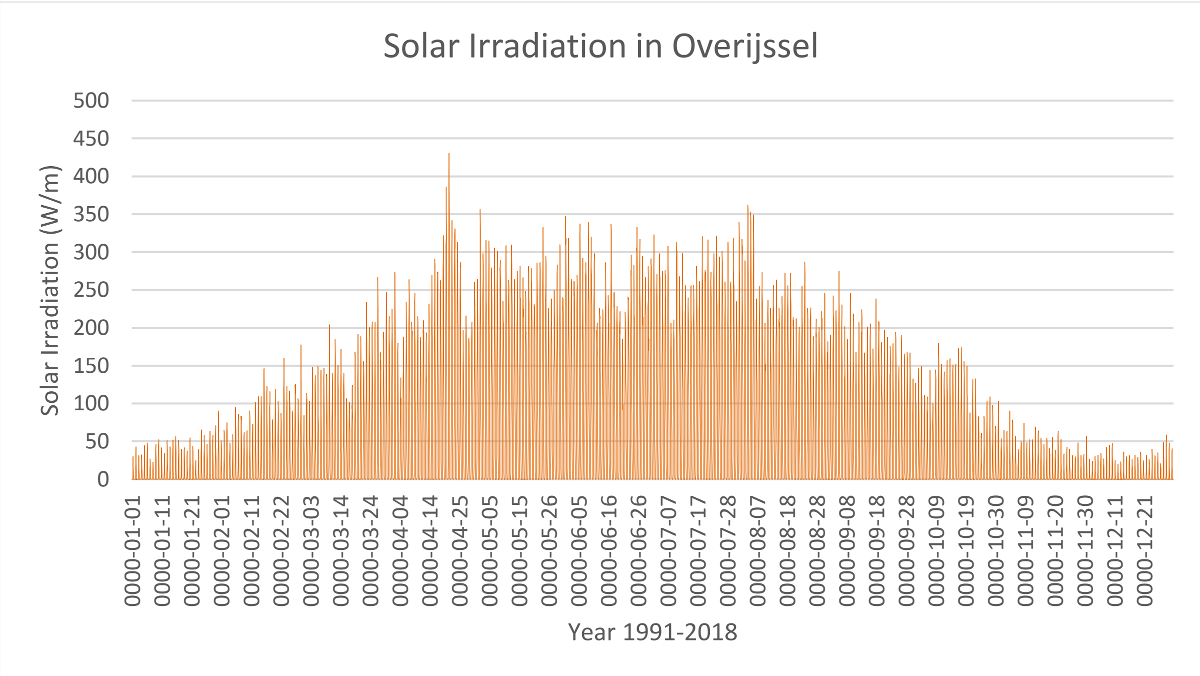

Figure B1: Distribution Profile for Annual Solar Irradiation for Overijssel from the year 1991-2018

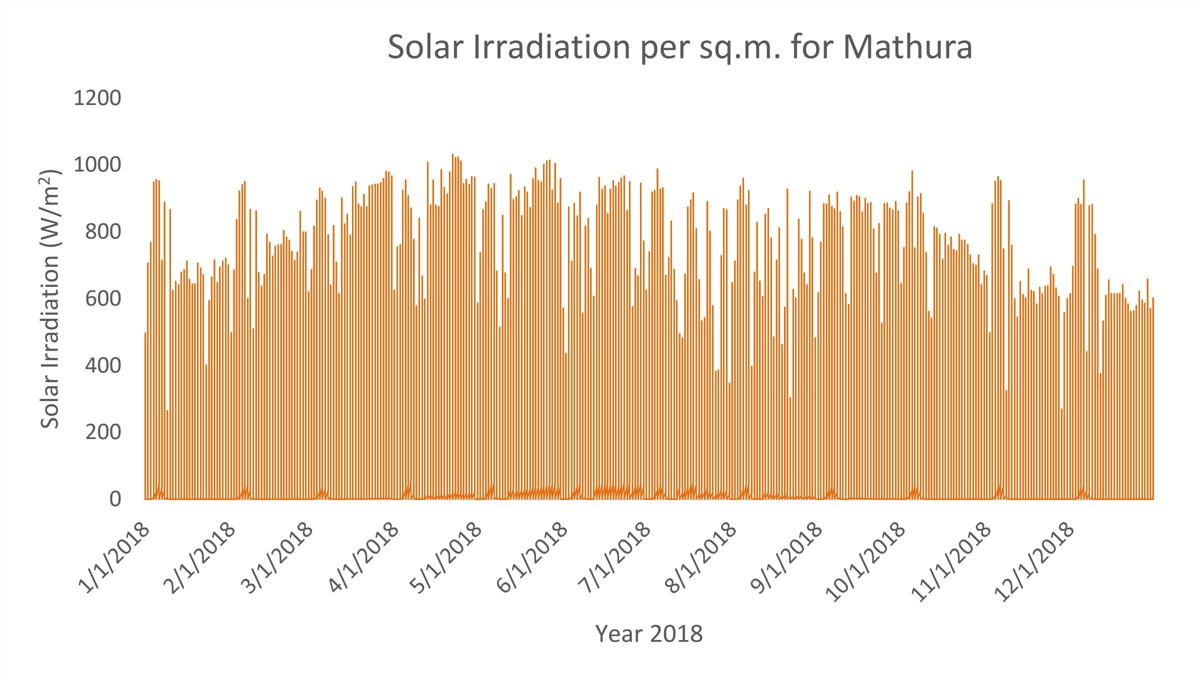

Figure B2: Distribution Profile for Annual Solar Irradiaton for Mathura in the year 2018

Wind Energy Potential

The wind energy potential in Overijssel and Mathura is estimated by evaluating the hourly wind speed at 10m height recorded by TU Delft for Overijssel and SoDa for Mathura at one square meter of the turbine.

Annual Wind Energy Potential (kWh/m²) = ∑ [0.5 Hourly Air Density * (Wind Speed) ^3 (m/s)]*

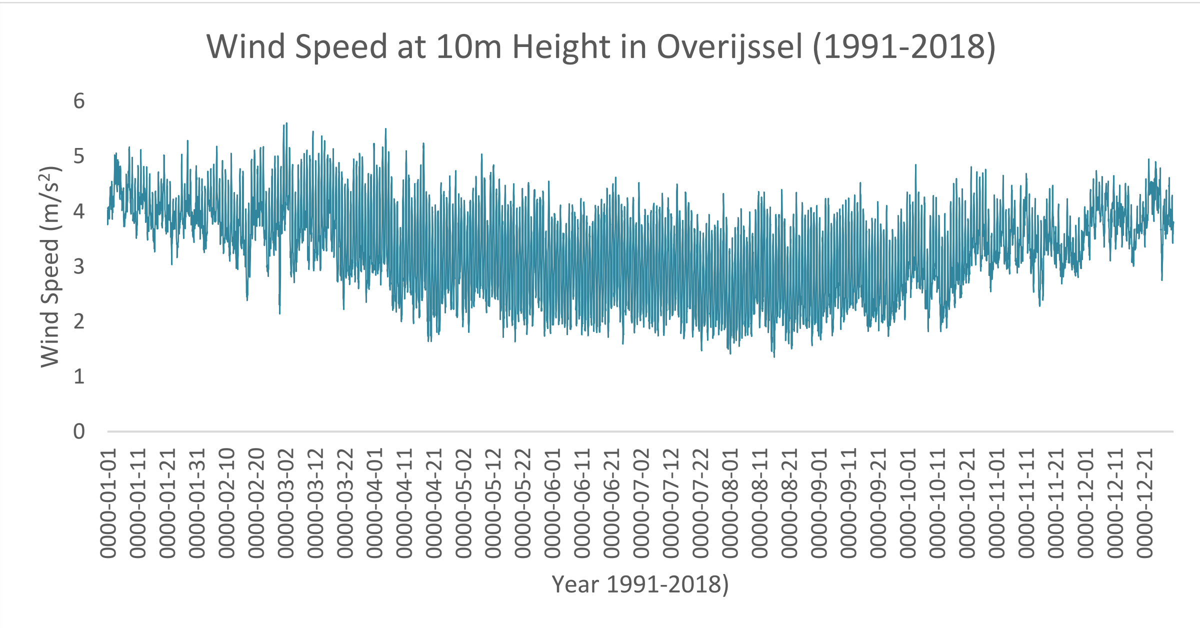

Figure B3: Distribution Profile for Annual Wind Speed for Overijssel from the year 1991-2018

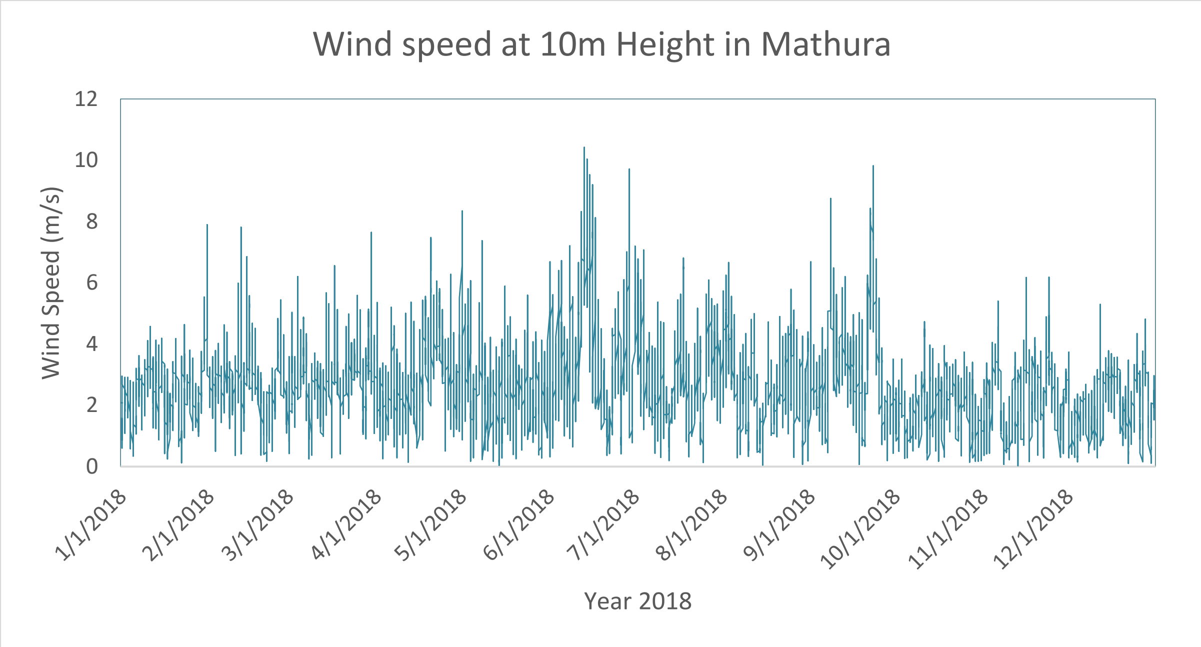

Figure B4: Distribution Profile for Annual Wind Speed in Mathura in the year 2018.

Appendix C

Distribution Profile for Overijssel

The distribution profile for electricity and gas consumption for Overijssel are acquired from Liander for the year 2008.

The hourly electricity distribution profile fraction acquired from Liander is presented in figure C1.

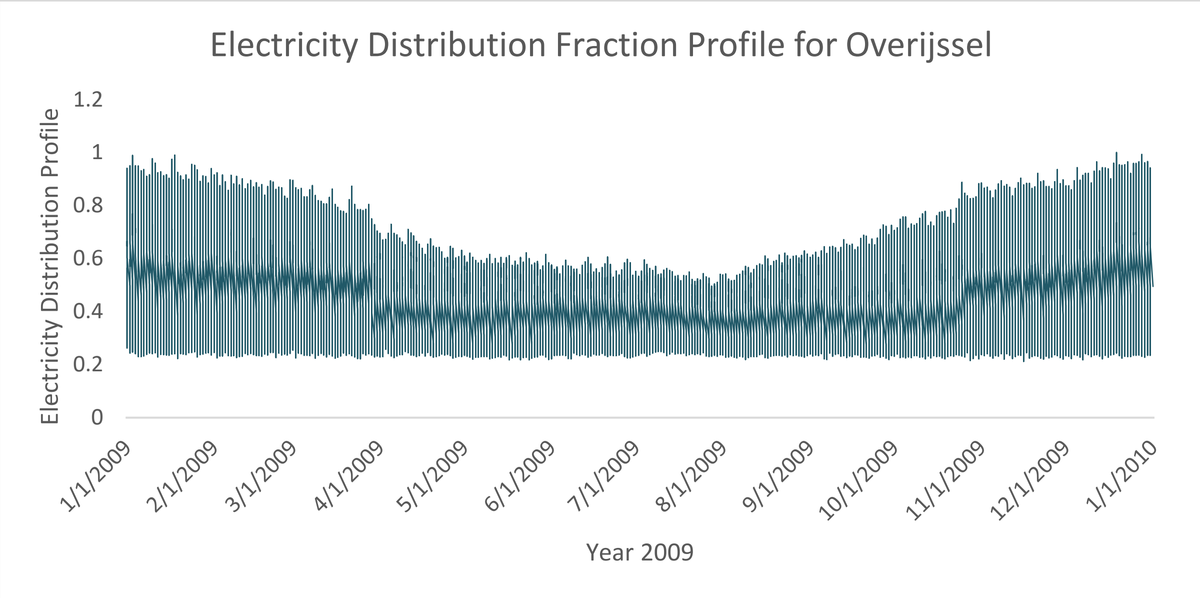

Figure C1: Electricity Distribution Profile from Liander for the year 2008.

While, the hourly gas distribution profile fraction acquired from Liander is presented in figure C2.

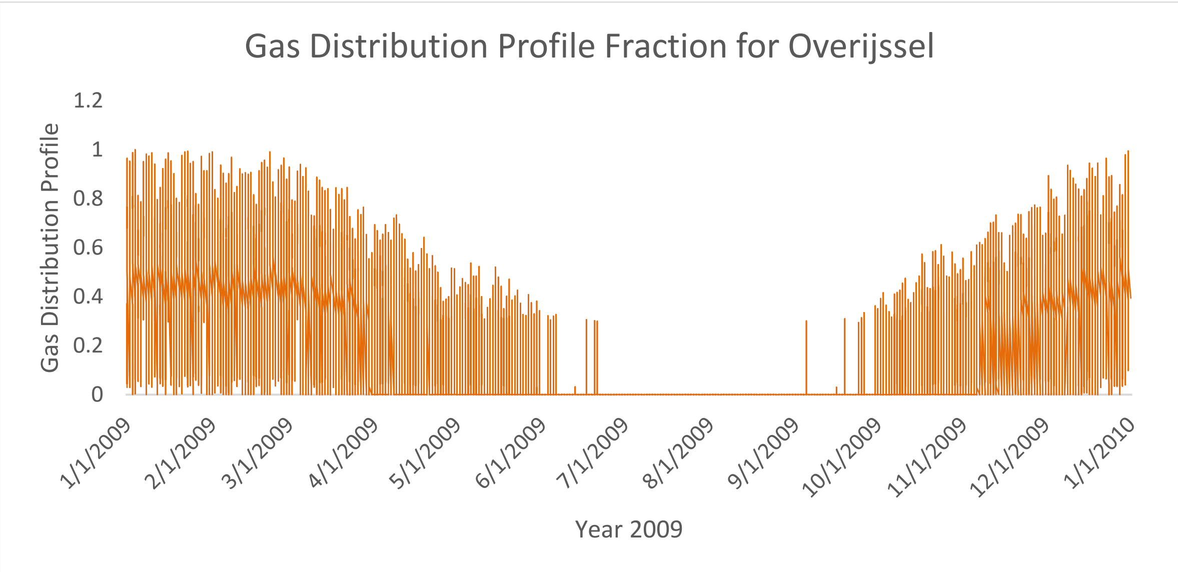

Figure C2: Gas Distribution Profile Fraction from Liander for the year 2008.

Results from energyPLAN Simulations

The scenarios for energy transition in Overijssel are simulated on energyPLAN software and the results are published in PDF format and presented in this section.

Reference Scenario

Input Overijssel_2018reference.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	4.18	Fixed imp/exp.	0.00
Electric heating + HP	0.10	Transportation	0.44
Electric cooling	0.00	Total	4.72

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

Wind	35	MW	0.18	TWh/year	0.00	Grid
Photo Voltaic	146	MW	0.23	TWh/year	0.00	stabili-
Wave Power	0	MW	0	TWh/year	0.00	sation
River Hydro	0	MW	0	TWh/year	0.00	share
Hydro Power	0	MW	0	TWh/year		
Geothermal/Nuclear	62	MW	0.13	TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	918		0.45		

Heatstorage: gr.2: 0 GWh gr.30 GWh
Fixed Boiler: gr.2:0.0 Per cent gr.0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.86
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy	Technical regulation no. 1	
CEEP regulation	984523176	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	212	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	EUR/MWh
Multiplication factor	2.00	
Dependency factor	0.00	EUR/MWh pr. MW
Average Market Price	227	EUR/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:		0.000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	5.90	2.70	0.00
Household	0.00	0.00	4.77	0.86
Industry	0.00	0.00	7.50	0.00
Various	0.00	0.00	0.00	0.00

Output WARNING!!: (3) PP/Import problem

	District Heating										Electricity																				Exchange	
	Demand	Production									Consumption						Production							Balance					Payment	
	Distr. heating MW	Solar MW	Waste CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW	Elec. demand MW	Flex.& Transp MW	HP MW	Electrolyser MW	EH MW	Hydro Pump MW	Turbine MW	RES MW	Hydro MW	Geothermal MW	Waste CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million EUR	Exp Million EUR
January	0	0	13	0	0	0	0	0	0	-13	553	50	26	0	0	0	0	32	0	20	98	0	481	258	0	0	0	0	0	0
February	0	0	13	0	0	0	0	0	0	-13	528	50	25	0	0	0	0	36	0	19	98	0	452	253	0	0	0	0	0	0
March	0	0	13	0	0	0	0	0	0	-13	495	50	21	0	0	0	0	45	0	15	98	0	408	243	0	0	0	0	0	0
April	0	0	13	0	0	0	0	0	0	-13	455	50	12	0	0	0	0	56	0	14	98	0	350	230	0	0	0	0	0	0
May	0	0	13	0	0	0	0	0	0	-13	431	50	5	0	0	0	0	64	0	14	98	0	312	220	0	0	0	0	0	0
June	0	0	13	0	0	0	0	0	0	-13	422	50	0	0	0	0	0	66	0	12	98	0	298	216	0	0	0	0	0	0
July	0	0	13	0	0	0	0	0	0	-13	409	50	0	0	0	0	0	64	0	9	98	0	289	215	0	0	0	0	0	0
August	0	0	13	0	0	0	0	0	0	-13	414	50	0	0	0	0	0	56	0	10	98	0	302	221	0	0	0	0	0	0
September	0	0	13	0	0	0	0	0	0	-13	443	50	0	0	0	0	0	45	0	13	98	0	338	233	0	0	0	0	0	0
October	0	0	13	0	0	0	0	0	0	-13	483	50	8	0	0	0	0	35	0	13	98	0	395	246	0	0	0	0	0	0
November	0	0	13	0	0	0	0	0	0	-13	521	50	16	0	0	0	0	28	0	19	98	0	443	255	0	0	0	0	0	0
December	0	0	13	0	0	0	0	0	0	-13	558	50	23	0	0	0	0	29	0	20	98	0	486	260	0	0	0	0	0	0
Average	0	0	13	0	0	0	0	0	0	-13	476	50	11	0	0	0	0	46	0	15	98	0	379	238	0	0	0	0	Average price	
Maximum	0	0	13	0	0	0	0	0	0	-13	993	100	46	0	0	0	0	170	0	61	98	0	918	295	0	0	0	0	(EUR/MWh)	
Minimum	0	0	13	0	0	0	0	0	0	-13	212	0	0	0	0	0	0	8	0	0	98	0	212	152	0	0	0	0	220	245
TWh/year	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	-0.11	4.18	0.44	0.10	0.00	0.00	0.00	0.00	0.41	0.00	0.13	0.86	0.00	3.33		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	3.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.70	0.00	3.70	1.31	1.31
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.90	-	-	5.90	0.00	5.90	1.55	1.55
N.Gas	-	-	-	-	-	3.70	-	-	-	-	-	-	-	-	-	-	-	2.70	4.77	7.50	18.67	0.00	18.67	3.82	3.82
Biomass	-	-	-	-	-	-	-	-	3.43	-	0.61	-	-	-	-	-	-	-	0.86	-	4.90	0.00	4.90	0.40	0.40
Renewable	-	-	-	-	-	-	1.29	-	-	-	-	-	0.18	0.23	-	-	-	-	-	-	1.69	0.00	1.69	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-0.40	-	-	-	-	-	-	0.40	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	7.40	1.29	-	3.43	-	0.21	-	0.18	0.23	-	-	-	9.00	5.63	7.50	34.86	0.00	34.86	7.09	7.09

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Output specifications Overijssel_2018reference.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1				Gr.2										Gr.3										RES specification				
	District heating MW	Solar MW	CSHP MW	DHP MW	District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Storage MW	Balance MW	District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Storage MW	Balance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	26	6	0	0	32
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	24	12	0	0	36
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	24	22	0	0	45
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	20	36	0	0	56
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	20	44	0	0	64
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	18	47	0	0	66
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	18	46	0	0	64
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	17	39	0	0	56
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	17	27	0	0	45
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	20	16	0	0	35
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	21	7	0	0	28
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	24	4	0	0	29
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	21	26	0	0	46
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	35	146	0	0	170
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	-13	8	0	0	0	8
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00		-0.11	0.18	0.23	0.00	0.00	0.41

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million EUR)	
Total Fuel ex Ngas exchange =	558
Uranium =	0
Coal =	30
FuelOil =	0
Gasoil/Diesel=	155
Petrol/JP =	186
Gas handling =	137
Biomass =	51
Food income =	0
Waste =	0
Total Ngas Exchange costs =	423
Marginal operation costs =	21
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	78
Total variable costs =	1080
Fixed operation costs =	0
Annual Investment costs =	460
TOTAL ANNUAL COSTS =	1540

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Individual MW	Transport MW	Indu. Var. MW	Demand Sum MW	Biogas MW	Syngas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Storage MW	Sum MW	Import MW	Export MW
January	0	0	534	1258	307	854	2953	0	0	0	0	0	0	2953	2953	0
February	0	0	502	1212	307	854	2875	0	0	0	0	0	0	2875	2875	0
March	0	0	453	1004	307	854	2618	0	0	0	0	0	0	2618	2618	0
April	0	0	389	574	307	854	2124	0	0	0	0	0	0	2124	2124	0
May	0	0	346	233	307	854	1740	0	0	0	0	0	0	1740	1740	0
June	0	0	331	10	307	854	1502	0	0	0	0	0	0	1502	1502	0
July	0	0	321	0	307	854	1483	0	0	0	0	0	0	1483	1483	0
August	0	0	336	0	307	854	1497	0	0	0	0	0	0	1497	1497	0
September	0	0	376	11	307	854	1548	0	0	0	0	0	0	1548	1548	0
October	0	0	439	367	307	854	1967	0	0	0	0	0	0	1967	1967	0
November	0	0	492	744	307	854	2397	0	0	0	0	0	0	2397	2397	0
December	0	0	540	1121	307	854	2822	0	0	0	0	0	0	2822	2822	0
Average	0	0	421	543	307	854	2126	0	0	0	0	0	0	2126	2126	0
Maximum	0	0	1020	2206	307	854	3913	0	0	0	0	0	0	3913	3913	0
Minimum	0	0	236	0	307	854	1397	0	0	0	0	0	0	1397	1397	0
Total for the whole year TWh/year	0.00	0.00	3.70	4.77	2.70	7.50	18.67	0.00	0.00	0.00	0.00	0.00	0.00	18.67	18.67	0.00

RES Share: 18.9 Percent of Primary Energy 30.2 Percent of Electricity 1.4 TWh electricity from RES

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Overijssel Scenario 2030

Input Overijssel_2030Scenario.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	3.90	Fixed imp/exp.	0.00
Electric heating + HP	0.13	Transportation	1.60
Electric cooling	0.00	Total	5.63

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.66	0.00	0.66
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.66	0.00	0.66

				Grid stabilisation share
Wind	78 MW	0.40	TWh/year	0.00
Photo Voltaic	276 MW	0.43	TWh/year	0.00
Wave Power	0 MW	0	TWh/year	0.00
River Hydro	0 MW	0	TWh/year	0.00
Hydro Power	0 MW	0	TWh/year	
Geothermal/Nuclear	82 MW	0.72	TWh/year	

	Capacities		Efficiencies		
	MW-e	MJ/s	elec.	Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	1100		0.45		

Heatstorage: gr.2: 0 GWh gr.3 0 GWh
Fixed Boiler: gr.2: 0.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.40	0.00
Gr.3:	0.00	0.00

Regulation Strategy:	Technical regulation no. 1	
CEEP regulation	984523176	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	212	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	EUR/MWh
Multiplication factor	2.00	
Dependency factor	0.00	EUR/MWh pr. MW
Average Market Price	227	EUR/MWh
Gas Storage	0	GWh
Syngas capacity	184	MW
Biogas max to grid	135	MW

Fuel Price level:

	Capacities	Storage	Efficiencies	
	MW-e	GWh	elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	2.65	2.70	0.00
Household	0.00	0.00	4.13	0.00
Industry	0.00	0.00	6.90	0.00
Various	0.00	0.00	0.00	0.00

Output

	District Heating: Demand	Production								Balance	Electricity: Consumption						Production							Balance					Exchange	
	Distr. heating	Solar	Waste+CSHP	DHP	CHP	HP	ELT	Boiler	EH	Ba-lance	Elec. demand	Flex.& Transp	HP	Elec-trolyser	EH	Hydro Pump	Tur-bine	RES	Hy-dro	Geo-thermal	Waste+CSHP	CHP	PP	Stab-Load	Imp	Exp	CEEP	EEP	Payment Imp	Exp
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	%	MW	MW	MW	MW	Million EUR	
January	127	0	75	0	0	0	0	0	0	53	514	182	45	0	0	0	0	68	0	82	46	0	545	278	0	0	0	0	0	0
February	120	0	75	0	0	0	0	0	0	46	491	182	35	0	0	0	0	76	0	82	46	0	505	269	0	0	0	0	0	0
March	104	0	75	0	0	0	0	0	0	29	461	182	22	0	0	0	0	94	0	82	46	0	447	256	0	0	0	0	0	0
April	77	0	75	0	0	0	0	0	0	3	425	182	7	0	0	0	0	113	0	82	46	0	383	245	0	0	0	0	0	0
May	51	0	75	0	0	0	0	0	0	-24	402	182	1	0	0	0	0	127	0	82	46	0	345	238	0	0	0	0	0	0
June	37	0	75	0	0	0	0	0	0	-38	394	182	0	0	0	0	0	130	0	82	46	0	334	236	0	0	0	0	0	0
July	30	0	75	0	0	0	0	0	0	-45	382	182	0	0	0	0	0	126	0	82	46	0	327	237	0	0	0	0	0	0
August	31	0	75	0	0	0	0	0	0	-44	387	182	0	0	0	0	0	110	0	82	46	0	346	244	0	0	0	0	0	0
September	44	0	75	0	0	0	0	0	0	-31	413	182	0	0	0	0	0	90	0	82	46	0	386	254	0	0	0	0	0	0
October	68	0	75	0	0	0	0	0	0	-6	450	182	7	0	0	0	0	74	0	82	46	0	440	264	0	0	0	0	0	0
November	96	0	75	0	0	0	0	0	0	22	485	182	22	0	0	0	0	61	0	82	46	0	501	276	0	0	0	0	0	0
December	117	0	75	0	0	0	0	0	0	42	519	182	41	0	0	0	0	63	0	82	46	0	552	281	0	0	0	0	0	0
Average	75	0	75	0	0	0	0	0	0	0	443	182	15	0	0	0	0	94	0	82	46	0	426	256	0	0	0	0	Average price	
Maximum	134	0	75	0	0	0	0	0	0	59	918	364	92	0	0	0	0	319	0	82	46	0	1097	310	0	0	0	0	(EUR/MWh)	
Minimum	27	0	75	0	0	0	0	0	0	-48	201	0	0	0	0	0	0	18	0	82	46	0	212	149	0	0	0	0	224	214
TWh/year	0.66	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.90	1.60	0.13	0.00	0.00	0.00	0.00	0.83	0.00	0.72	0.40	0.00	3.74		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	Elc.ly	CAES	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp	househ.	Industry	Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	4.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.15	0.00	4.15	1.47	1.47
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.65	-	-	-	2.65	0.00	2.65	0.70	0.70
N.Gas	-	-	-	-	-	4.15	-	-	-	-	-	-2.48	-	-	-	-	-	-	2.70	4.13	6.90	-	15.41	0.00	15.41	3.16	3.16
Biomass	-	-	-	-	-	-	-	-	-	-	-	6.33	-	-	-	-	-	-	-	-	-	-	6.33	0.00	6.33	0.00	0.00
Renewable	-	-	-	-	-	-	7.20	-	-	-	-	-	-	0.40	0.43	-	-	0.20	-	-	-	-	8.24	0.00	8.24	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-1.65	-	-	-	-	-	-	1.65	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	8.31	7.20	-	-	-	-	2.20	-	0.40	0.43	-	-	0.20	7.00	4.13	6.90	-	36.78	0.00	36.78	5.32	5.32

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Output specifications Overijssel_2030Scenario.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating	Gr.1 Solar	Gr.1 CSHP	Gr.1 DHP	Gr.2 District heating	Gr.2 Solar	Gr.2 CSHP	Gr.2 CHP	Gr.2 HP	Gr.2 ELT	Gr.2 Boiler	Gr.2 EH	Gr.2 Stor-age	Gr.2 Ba-lance	Gr.3 District heating	Gr.3 Solar	Gr.3 CSHP	Gr.3 CHP	Gr.3 HP	Gr.3 ELT	Gr.3 Boiler	Gr.3 EH	Gr.3 Stor-age	Gr.3 Ba-lance	RES1 Wind	RES2 Photo	RES3 Wave	RES 4-7	Total
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
January	0	0	0	0	127	0	0	0	0	0	0	0	0	127	0	0	75	0	0	0	0	0	0	-75	57	11	0	0	68
February	0	0	0	0	120	0	0	0	0	0	0	0	0	120	0	0	75	0	0	0	0	0	0	-75	53	23	0	0	76
March	0	0	0	0	104	0	0	0	0	0	0	0	0	104	0	0	75	0	0	0	0	0	0	-75	53	41	0	0	94
April	0	0	0	0	77	0	0	0	0	0	0	0	0	77	0	0	75	0	0	0	0	0	0	-75	45	68	0	0	113
May	0	0	0	0	51	0	0	0	0	0	0	0	0	51	0	0	75	0	0	0	0	0	0	-75	43	84	0	0	127
June	0	0	0	0	37	0	0	0	0	0	0	0	0	37	0	0	75	0	0	0	0	0	0	-75	40	90	0	0	130
July	0	0	0	0	30	0	0	0	0	0	0	0	0	30	0	0	75	0	0	0	0	0	0	-75	39	88	0	0	126
August	0	0	0	0	31	0	0	0	0	0	0	0	0	31	0	0	75	0	0	0	0	0	0	-75	37	73	0	0	110
September	0	0	0	0	44	0	0	0	0	0	0	0	0	44	0	0	75	0	0	0	0	0	0	-75	39	52	0	0	90
October	0	0	0	0	68	0	0	0	0	0	0	0	0	68	0	0	75	0	0	0	0	0	0	-75	44	30	0	0	74
November	0	0	0	0	96	0	0	0	0	0	0	0	0	96	0	0	75	0	0	0	0	0	0	-75	47	13	0	0	61
December	0	0	0	0	117	0	0	0	0	0	0	0	0	117	0	0	75	0	0	0	0	0	0	-75	54	8	0	0	63
Average	0	0	0	0	75	0	0	0	0	0	0	0	0	75	0	0	75	0	0	0	0	0	0	-75	46	48	0	0	94
Maximum	0	0	0	0	134	0	0	0	0	0	0	0	0	134	0	0	75	0	0	0	0	0	0	-75	78	276	0	0	319
Minimum	0	0	0	0	27	0	0	0	0	0	0	0	0	27	0	0	75	0	0	0	0	0	0	-75	0	0	0	0	18
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.66	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00		-0.66	0.40	0.43	0.00	0.00	0.83

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million EUR)	
Total Fuel ex Ngas exchange =	624
Uranium =	0
Coal =	43
FuelOil =	0
Gasoil/Diesel=	121
Petrol/JP =	100
Gas handling =	126
Biomass =	235
Food income =	0
Waste =	0
Total Ngas Exchange costs =	460
Marginal operation costs =	29
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	85
Total variable costs =	1199
Fixed operation costs =	0
Annual Investment costs =	455
TOTAL ANNUAL COSTS =	1654

NATURAL GAS EXCHANGE

	DHP & Boilers	CHP2 CHP3	PP CAES	Indi-vidual	Trans port	Indu. Var.	Demand Sum	Bio-gas	Syn-gas	CO2Hy gas	SynHy gas	SynHy gas	Stor-age	Sum	Im-port	Ex-port
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
January	0	0	606	1089	307	786	2788	135	147	0	0	0	0	2505	2505	0
February	0	0	561	1050	307	786	2704	135	147	0	0	0	0	2422	2422	0
March	0	0	497	869	307	786	2459	135	147	0	0	0	0	2176	2176	0
April	0	0	426	497	307	786	2015	135	147	0	0	0	0	1733	1733	0
May	0	0	383	202	307	786	1677	135	147	0	0	0	0	1395	1395	0
June	0	0	371	8	307	786	1472	135	147	0	0	0	0	1190	1190	0
July	0	0	363	0	307	786	1456	135	147	0	0	0	0	1173	1173	0
August	0	0	384	0	307	786	1477	135	147	0	0	0	0	1195	1195	0
September	0	0	428	9	307	786	1531	135	147	0	0	0	0	1249	1249	0
October	0	0	489	318	307	786	1900	135	147	0	0	0	0	1618	1618	0
November	0	0	557	644	307	786	2294	135	147	0	0	0	0	2011	2011	0
December	0	0	613	970	307	786	2677	135	147	0	0	0	0	2395	2395	0
Average	0	0	473	470	307	786	2036	135	147	0	0	0	0	1754	1754	0
Maximum	0	0	1219	1910	307	786	3681	135	147	0	0	0	0	3398	3398	0
Minimum	0	0	236	0	307	786	1328	135	147	0	0	0	0	1046	1046	0
Total for the whole year TWh/year	0.00	0.00	4.15	4.13	2.70	6.90	17.88	1.19	1.29	0.00	0.00	0.00	0.00	15.41	15.41	0.00

RES Share: 39.6 Percent of Primary Energy 28.2 Percent of Electricity 1.5 TWh electricity from RES

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Overijssel Scenario 2040

Input Overijssel_2040Scenario.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year): Flexible demand 0.30
Fixed demand 2.73 Fixed imp/exp. 0.00
Electric heating + HP 0.13 Transportation 3.30
Electric cooling 0.00 Total 6.46

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	2.87	0.00	2.87
Solar Thermal	0.00	1.15	0.00	1.15
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	1.72	0.00	1.72

Wind	170 MW	0.90 TWh/year	0.00	Grid
Photo Voltaic	700 MW	1.19 TWh/year	0.00	stabili-
Wave Power	0 MW	0 TWh/year	0.00	sation
River Hydro	0 MW	0 TWh/year	0.00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	92 MW	0.81 TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	300	375	0.40	0.50	
Heat Pump	50	150			3.00
Boiler		30		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	1000		0.45		

Heatstorage: gr.2: 3 GWh gr.3 0 GWh
Fixed Boiler: gr.2: 10.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.50	0.00
Gr.3:	0.00	0.00

Regulation Strategy: Technical regulation no. 1
CEEP regulation 984532176
Minimum Stabilisation share 0.30
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 0 MW
Minimum PP 142 MW
Heat Pump maximum share 0.50
Maximum import/export 0 MW
Distr. Name : Hour_nordpool.txt
Addition factor 0.00 EUR/MWh
Multiplication factor 2.00
Dependency factor 0.00 EUR/MWh pr. MW
Average Market Price 227 EUR/MWh
Gas Storage 0 GWh
Syngas capacity 606 MW
Biogas max to grid 135 MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	0.00	0.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	5.00	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating (Demand: Distr. heating; Production: Solar … Ba-lance), Electricity (Consumption: Elec. demand … EH; Production: Hydro Pump … PP; Balance: Stab-Load … EEP), Exchange (Payment Imp, Exp)

	Distr. heating MW	Solar MW	Waste CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp. MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Payment Imp Million EUR	Exp Million EUR
January	757	117	191	0	292	120	0	37	0	0	359	410	85	0	0	0	0	162	0	92	57	233	320	154	0	0	0	0	0	0
February	729	238	191	0	241	104	0	17	0	-60	343	410	70	0	0	0	0	187	0	92	57	193	309	158	0	0	0	0	0	0
March	604	353	191	0	134	69	0	5	0	-147	322	410	45	0	0	0	0	237	0	92	57	107	314	175	0	0	0	0	0	0
April	345	290	191	0	25	24	0	1	0	-185	298	410	15	0	0	0	0	289	0	92	57	20	319	194	0	0	0	0	0	0
May	140	130	191	0	0	10	0	0	0	-191	282	410	4	0	0	0	0	324	0	92	57	0	290	193	0	0	0	0	0	0
June	6	5	191	0	0	0	0	0	0	-191	276	410	0	0	0	0	0	328	0	92	57	0	278	192	0	0	0	0	0	0
July	0	0	191	0	0	0	0	0	0	-191	268	410	0	0	0	0	0	320	0	92	57	0	278	194	0	0	0	0	0	0
August	0	0	191	0	0	0	0	0	0	-191	272	410	0	0	0	0	0	285	0	92	57	0	306	200	0	0	0	0	0	0
September	7	6	191	0	0	1	0	0	0	-191	290	410	0	0	0	0	0	234	0	92	57	0	357	209	0	0	0	0	0	0
October	221	169	191	0	22	22	0	1	0	-183	315	410	15	0	0	0	0	187	0	92	57	18	406	213	0	0	0	0	0	0
November	448	141	191	0	177	66	0	9	0	-136	339	410	44	0	0	0	0	148	0	92	57	141	363	183	0	0	0	0	0	0
December	674	88	191	0	285	114	0	33	0	-36	362	410	79	0	0	0	0	148	0	92	57	228	332	158	0	0	0	0	0	0
Average	327	128	191	0	98	44	0	9	0	-142	311	410	30	0	0	0	0	238	0	92	57	78	323	185	0	0	0	0	Average price	
Maximum	1327	1069	191	0	375	150	0	63	0	736	635	751	142	0	0	0	0	739	0	92	57	300	981	303	0	0	0	0	(EUR/MWh)	
Minimum	0	0	191	0	0	0	0	0	0	-566	144	0	0	0	0	0	0	43	0	92	57	0	142	100	0	0	0	0	204	209
TWh/year	2.87	1.12	1.67	0.00	0.86	0.39	0.00	0.08	0.00	-1.25	2.73	3.60	0.26	0.00	0.00	0.00	0.00	2.09	0.00	0.81	0.50	0.69	2.83		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp	Corrected Imp/Exp Net	CO2 emission (Mt): Total	Net
Coal	-	1.28	-	-	-	6.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.58	0.00	7.58	2.69	2.69
Oil	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.00	0.08	0.02	0.02
N.Gas	-	0.44	-	-	-	-	-	-	-	-	-5.45	-	-	-	-	-	-	-	-	5.00	-0.01	0.00	-0.01	0.00	0.00
Biomass	-	-	-	-	-	-	-	-	-	-	10.70	-	-	-	-	-	-	-	-	-	10.70	0.00	10.70	0.00	0.00
Renewable	-	-	-	-	-	-	8.08	-	-	-	-	-	0.90	1.19	-	-	1.32	-	-	-	11.49	0.00	11.49	0.00	0.00
H2 etc.	-	-	-	0.00	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-1.50	-	-	-	-	-	-	1.50	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	1.71	-	0.08	-	6.30	8.08	-	-	-	3.76	-	0.90	1.19	-	-	1.32	1.50	-	5.00	29.85	0.00	29.85	2.71	2.71

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Output specifications Overijssel_2040Scenario.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Stor-age MW	Gr.2 Ba-lance MW	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Stor-age MW	Gr.3 Ba-lance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total MW
January	0	0	0	0	757	117	68	292	120	0	37	0	1426	122	0	0	122	0	0	0	0	0	0	-122	128	34	0	0	162
February	0	0	0	0	729	238	68	241	104	0	17	0	1536	62	0	0	122	0	0	0	0	0	0	-122	120	67	0	0	187
March	0	0	0	0	604	353	68	134	69	0	5	0	1479	-25	0	0	122	0	0	0	0	0	0	-122	118	118	0	0	237
April	0	0	0	0	345	290	68	25	24	0	1	0	2617	-63	0	0	122	0	0	0	0	0	0	-122	100	189	0	0	289
May	0	0	0	0	140	130	68	0	10	0	0	0	2813	-68	0	0	122	0	0	0	0	0	0	-122	94	230	0	0	324
June	0	0	0	0	6	5	68	0	0	0	0	0	2813	-68	0	0	122	0	0	0	0	0	0	-122	83	245	0	0	328
July	0	0	0	0	0	0	68	0	0	0	0	0	2813	-68	0	0	122	0	0	0	0	0	0	-122	80	240	0	0	320
August	0	0	0	0	0	0	68	0	0	0	0	0	2813	-68	0	0	122	0	0	0	0	0	0	-122	82	202	0	0	285
September	0	0	0	0	7	6	68	0	1	0	0	0	2813	-68	0	0	122	0	0	0	0	0	0	-122	88	146	0	0	234
October	0	0	0	0	221	169	68	22	22	0	1	0	2582	-61	0	0	122	0	0	0	0	0	0	-122	100	87	0	0	187
November	0	0	0	0	448	141	68	177	66	0	9	0	1620	-14	0	0	122	0	0	0	0	0	0	-122	108	41	0	0	148
December	0	0	0	0	674	88	68	285	114	0	33	0	1535	87	0	0	122	0	0	0	0	0	0	-122	122	26	0	0	148
Average	0	0	0	0	327	128	68	98	44	0	9	0	2240	-19	0	0	122	0	0	0	0	0	0	-122	102	136	0	0	238
Maximum	0	0	0	0	1327	1069	68	375	150	0	63	0	3000	858	0	0	122	0	0	0	0	0	0	-122	170	699	0	0	739
Minimum	0	0	0	0	0	0	68	0	0	0	0	0	0	-443	0	0	122	0	0	0	0	0	0	-122	0	0	0	0	43
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	2.87	1.12	0.60	0.86	0.39	0.00	0.08	0.00		-0.17	0.00	0.00	1.07	0.00	0.00	0.00	0.00	0.00		-1.07	0.90	1.19	0.00	0.00	2.09

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million EUR)
Total Fuel ex Ngas exchange = 543
Uranium = 0
Coal = 97
FuelOil = 6
Gasoil/Diesel= 0
Petrol/JP = 25
Gas handling = 18
Biomass = 397
Food income = 0
Waste = 0

Total Ngas Exchange costs = 0

Marginal operation costs = 25

Total Electricity exchange = 0
Import = 0
Export = 0
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 65

Total variable costs = 632
Fixed operation costs = 0

Annual Investment costs = 315

TOTAL ANNUAL COSTS = 947

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	149	0	0	0	569	718	135	485	0	0	0	0	98	99	1
February	0	123	0	0	0	569	692	135	485	0	0	0	0	72	81	10
March	0	68	0	0	0	569	637	135	485	0	0	0	0	17	46	29
April	0	13	0	0	0	569	582	135	485	0	0	0	0	-38	9	47
May	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	51
June	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	51
July	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	51
August	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	51
September	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	51
October	0	11	0	0	0	569	581	135	485	0	0	0	0	-40	7	47
November	0	90	0	0	0	569	659	135	485	0	0	0	0	39	56	17
December	0	145	0	0	0	569	714	135	485	0	0	0	0	94	97	3
Average	0	50	0	0	0	569	619	135	485	0	0	0	0	-1	33	34
Maximum	0	191	0	0	0	569	760	135	485	0	0	0	0	140	140	51
Minimum	0	0	0	0	0	569	569	135	485	0	0	0	0	-51	0	0
Total for the whole year TWh/year	0.00	0.44	0.00	0.00	0.00	5.00	5.44	1.19	4.26	0.00	0.00	0.00	0.00	-0.01	0.29	0.30

RES Share: 74.4 Percent of Primary Energy 44.8 Percent of Electricity 2.9 TWh electricity from RES

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Overijssel Energy Transition 2050

Input Overijssel_2050_Energy Transition.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year): Flexible demanc0.25
Fixed demand 1.89 | Fixed imp/exp. 0.00
Electric heating + HP 0.05 | Transportation 3.84
Electric cooling 0.00 | Total 6.04

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	2.60	2.60
Solar Thermal	0.00	0.00	0.97	0.97
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	1.63	1.63

Wind	170 MW	0.84	TWh/year	0.00	Grid
Photo Voltaic	1000 MW	1.74	TWh/year	0.00	stabili-
Wave Power	0 MW	0	TWh/year	0.00	sation
River Hydro	0 MW	0	TWh/year	0.00	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	100 MW	0.88	TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	700	875	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	875		0.45		

Heatstorage: gr.2: 5 GWh gr.30 GWh
Fixed Boiler: gr.2:0.0 Per cent gr.0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.70	0.00
Gr.3:	0.00	0.00

Regulation Strate(Technical regulation no. 1
CEEP regulation 984532176
Minimum Stabilisation share 0.30
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 20 MW
Minimum PP 0 MW
Heat Pump maximum share 0.50
Maximum import/export 0 MW

Distr. Name : Hour_nordpool.txt
Addition factor 0.00 EUR/MWh
Multiplication factor 2.00
Dependency factor 0.00 EUR/MWh pr. MW
Average Market Price227 EUR/MWh
Gas Storage 0 GWh
Syngas capacity 1327 MW
Biogas max to grid 135 MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficienc elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomas
Transport	0.00	0.00	0.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	4.60	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating

	Demand Distr. heating MW	Production Solar MW	Waste CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW
January	686	91	229	0	389	0	0	0	0	-24
February	661	186	229	0	297	0	0	0	0	-52
March	547	308	229	0	147	0	0	0	0	-138
April	313	276	229	0	39	0	0	0	0	-231
May	127	127	229	0	25	0	0	0	0	-254
June	5	5	229	0	25	0	0	0	0	-254
July	0	0	229	0	25	0	0	0	0	-254
August	0	0	229	0	25	0	0	0	0	-254
September	6	6	229	0	25	0	0	0	0	-254
October	200	151	229	0	43	0	0	0	0	-224
November	405	110	229	0	170	0	0	0	0	-104
December	611	68	229	0	352	0	0	0	0	-38
Average	296	110	229	0	130	0	0	0	0	-174
Maximum	1202	981	229	0	875	0	0	0	0	89
Minimum	0	0	229	0	25	0	0	0	0	-254
TWh/year	2.60	0.97	2.01	0.00	1.14	0.00	0.00	0.00	0.00	-1.53

Electricity

	Consumption Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Production Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Balance Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Exchange Payment Imp	Exp Million EUR
January	248	466	17	0	0	0	0	185	0	100	84	311	113	230	0	0	0	0	0	0
February	238	466	14	0	0	0	0	229	0	100	84	238	133	215	0	0	0	0	0	0
March	224	466	8	0	0	0	0	303	0	100	84	118	172	195	0	0	0	0	0	0
April	207	466	3	0	0	0	0	366	0	100	84	31	198	188	0	0	0	0	0	0
May	197	466	0	0	0	0	0	394	0	100	84	20	179	185	0	0	0	0	0	0
June	193	466	0	0	0	0	0	403	0	100	84	20	168	184	0	0	0	0	0	0
July	187	466	0	0	0	0	0	392	0	100	84	20	172	186	0	0	0	0	0	0
August	190	466	0	0	0	0	0	363	0	100	84	20	194	189	0	0	0	0	0	0
September	202	466	0	0	0	0	0	313	0	100	84	20	232	192	0	0	0	0	0	0
October	219	466	3	0	0	0	0	240	0	100	84	35	282	196	0	0	0	0	0	0
November	235	466	9	0	0	0	0	176	0	100	84	136	251	214	0	0	0	0	0	0
December	250	466	16	0	0	0	0	167	0	100	84	281	154	232	0	0	0	0	0	0
Average	216	466	6	0	0	0	0	294	0	100	84	104	187	200	0	0	0	0	Average price (EUR/MWh)	
Maximum	433	874	46	0	0	0	0	882	0	100	84	700	821	294	0	0	0	0		
Minimum	105	0	0	0	0	0	0	47	0	100	84	20	0	100	0	0	0	0	223	251
TWh/year	1.89	4.09	0.05	0.00	0.00	0.00	0.00	2.59	0.00	0.88	0.73	0.91	1.64		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Oil	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
N.Gas	-	-	2.28	-	0.00	3.66	-	-	-	-	-10.52	-	-	-	-	-	-	-	-	4.60	0.02	0.00	0.02	0.00	0.00
Biomass	-	-	-	-	0.00	-	-	-	0.34	-	16.29	-	-	-	-	-	-	-	-	-	16.63	0.00	16.63	0.00	0.00
Renewable	-	-	-	-	-	-	8.78	-	-	-	-	-	0.84	1.74	-	-	1.12	-	-	-	12.49	0.00	12.49	0.00	0.00
H2 etc.	-	-	-	-	0.00	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-0.20	-	-	-	-	-	-	-	-	0.20	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	2.28	-	0.00	3.66	8.78	-	0.14	-	5.77	-	0.84	1.74	-	-	1.12	0.20	-	4.60	29.14	0.00	29.14	0.00	0.00

01-November-2019 [09:56]

Output specifications Overijssel_2050_Energy Transition.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Solar MW	CSHP MW	DHP MW	Gr.2 District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00

	Gr.3 District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW	RES specification RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total er MW
January	686	91	229	389	0	0	0	0	0	-24	132	54	0	0	185
February	661	186	229	297	0	0	0	0	0	-52	124	105	0	0	229
March	547	308	229	147	0	0	0	0	0	-138	121	181	0	0	303
April	313	276	229	39	0	0	0	0	0	-231	89	277	0	0	366
May	127	127	229	25	0	0	0	0	0	-254	66	328	0	0	394
June	5	5	229	25	0	0	0	0	0	-254	61	342	0	0	403
July	0	0	229	25	0	0	0	0	0	-254	59	333	0	0	392
August	0	0	229	25	0	0	0	0	0	-254	69	295	0	0	363
September	6	6	229	25	0	0	0	0	0	-254	91	222	0	0	313
October	200	151	229	43	0	0	0	0	0	-224	105	135	0	0	240
November	405	110	229	170	0	0	0	0	0	-104	112	64	0	0	176
December	611	68	229	352	0	0	0	0	0	-38	126	41	0	0	167
Average	296	110	229	130	0	0	0	0	0	-174	96	198	0	0	294
Maximum	1202	981	229	875	0	0	0	0	0	89	170	829	0	0	882
Minimum	0	0	229	25	0	0	0	0	0	-254	0	0	0	0	47
Total for the whole year TWh/year	2.60	0.97	2.01	1.14	0.00	0.00	0.00	0.00		-1.53	0.84	1.74	0.00	0.00	2.59

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million EUR)

Total Fuel ex Ngas exchange =	493
Uranium =	0
Coal =	0
FuelOil =	0
Gasoil/Diesel=	0
Petrol/JP =	0
Gas handling =	20
Biomass =	473
Food income =	0
Waste =	0
Total Ngas Exchange costs =	1
Marginal operation costs =	26
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	0
Total variable costs =	520
Fixed operation costs =	0
Annual Investment costs =	367
TOTAL ANNUAL COSTS =	887

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	779	250	0	0	524	1553	135	1062	0	0	0	0	355	451	96
February	0	595	295	0	0	524	1413	135	1062	0	0	0	0	216	358	142
March	0	295	382	0	0	524	1200	135	1062	0	0	0	0	3	220	217
April	0	77	440	0	0	524	1041	135	1062	0	0	0	0	-157	136	293
May	0	50	397	0	0	524	970	135	1062	0	0	0	0	-227	74	301
June	0	50	373	0	0	524	947	135	1062	0	0	0	0	-251	49	300
July	0	50	382	0	0	524	956	135	1062	0	0	0	0	-241	60	302
August	0	50	430	0	0	524	1004	135	1062	0	0	0	0	-193	110	304
September	0	50	516	0	0	524	1090	135	1062	0	0	0	0	-107	199	307
October	0	87	626	0	0	524	1236	135	1062	0	0	0	0	39	321	282
November	0	341	559	0	0	524	1423	135	1062	0	0	0	0	225	380	155
December	0	703	342	0	0	524	1569	135	1062	0	0	0	0	372	453	81
Average	0	260	416	0	0	524	1200	135	1062	0	0	0	0	2	234	232
Maximum	0	1750	1824	0	0	524	2507	135	1062	0	0	0	0	1310	1310	624
Minimum	0	50	0	0	0	524	574	135	1062	0	0	0	0	-624	0	0
Total for the whole year TWh/year	0.00	2.28	3.66	0.00	0.00	4.60	10.54	1.19	9.33	0.00	0.00	0.00	0.00	0.02	2.06	2.03

RES Share: 99.9 Percent of Primary Energy 57.9 Percent of Electricity 3.5 TWh electricity from RES

01-November-2019 [09:56]

Overijssel Business-as-Usual Scenario

Input Overijssel2050BAU.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	3.97	Fixed imp/exp.	0.00
Electric heating + HP	0.22	Transportation	1.30
Electric cooling	0.00	Total	5.50

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

					Grid stabilisation share
Wind	39 MW	0.20	TWh/year	0.00	Grid
Photo Voltaic	190 MW	0.29	TWh/year	0.00	stabili-
River Hydro	0 MW	0	TWh/year	0.00	sation
River Hydro	0 MW	0	TWh/year	0.00	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	15 MW	0.13	TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	1080		0.45		

Heatstorage: gr.2: 0 GWh gr.30 GWh
Fixed Boiler: gr.2:0.0 Per cent gr0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.95
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strate(	Technical regulation no. 1	
CEEP regulation	984567123	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	300	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	DKK/MWh
Multiplication factor	2.00	
Dependency factor	0.00	DKK/MWh pr. MW
Average Market Price	227	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level: Basic

	Capacities MW-e	Storage GWh	Efficiencie elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:		0.000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	5.70	2.30	0.00
Household	0.00	0.00	3.80	0.99
Industry	0.00	0.00	7.00	0.00
Various	0.00	0.00	0.00	0.00

Output

	District Heating										Electricity																		Exchange	
	Demand	Production									Consumption						Production							Balance					Payment	
	Distr. heating MW	Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million DKK	Exp Million DKK
January	0	0	19	0	0	0	0	0	0	-19	525	148	56	0	0	0	0	36	0	15	108	0	569	263	0	0	0	0	0	0
February	0	0	19	0	0	0	0	0	0	-19	502	148	45	0	0	0	0	42	0	15	108	0	529	255	0	0	0	0	0	0
March	0	0	19	0	0	0	0	0	0	-19	470	148	32	0	0	0	0	55	0	15	108	0	476	245	0	0	0	0	0	0
April	0	0	19	0	0	0	0	0	0	-19	433	148	20	0	0	0	0	70	0	15	108	0	417	235	0	0	0	0	0	0
May	0	0	19	0	0	0	0	0	0	-19	410	148	11	0	0	0	0	80	0	15	108	0	379	228	0	0	0	0	0	0
June	0	0	19	0	0	0	0	0	0	-19	401	148	7	0	0	0	0	82	0	15	108	0	365	226	0	0	0	0	0	0
July	0	0	19	0	0	0	0	0	0	-19	389	148	6	0	0	0	0	80	0	15	108	0	355	226	0	0	0	0	0	0
August	0	0	19	0	0	0	0	0	0	-19	394	148	7	0	0	0	0	69	0	15	108	0	371	231	0	0	0	0	0	0
September	0	0	19	0	0	0	0	0	0	-19	421	148	12	0	0	0	0	55	0	15	108	0	411	240	0	0	0	0	0	0
October	0	0	19	0	0	0	0	0	0	-19	459	148	22	0	0	0	0	42	0	15	108	0	466	249	0	0	0	0	0	0
November	0	0	19	0	0	0	0	0	0	-19	495	148	39	0	0	0	0	33	0	15	108	0	526	259	0	0	0	0	0	0
December	0	0	19	0	0	0	0	0	0	-19	530	148	52	0	0	0	0	33	0	15	108	0	575	265	0	0	0	0	0	0
Average	0	0	19	0	0	0	0	0	0	-19	452	148	26	0	0	0	0	56	0	15	108	0	453	244	0	0	0	0	Average price	
Maximum	0	0	19	0	0	0	0	0	0	-19	941	296	67	0	0	0	0	217	0	15	108	0	1079	297	0	0	0	0	(DKK/MWh)	
Minimum	0	0	19	0	0	0	0	0	0	-19	203	0	0	0	0	0	0	9	0	15	108	0	290	164	0	0	0	0	235	216
TWh/year	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	-0.17	3.97	1.30	0.22	0.00	0.00	0.00	0.00	0.50	0.00	0.13	0.95	0.00	3.98		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	2.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.95	0.00	2.95	1.05	1.05
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.70	-	-	5.70	0.00	5.70	1.50	1.50
N.Gas	-	-	-	-	-	2.95	-	-	-	-	-	-	-	-	-	-	-	2.30	3.80	7.00	16.05	0.00	16.05	3.29	3.29
Biomass	-	-	-	-	-	2.95	-	-	3.80	-	2.53	-	-	-	-	-	-	-	0.99	-	10.27	0.00	10.27	0.44	0.44
Renewable	-	-	-	-	-	-	1.32	-	-	-	-	-	0.20	0.29	-	-	0.33	-	-	-	2.14	0.00	2.14	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-1.20	-	-	-	-	-	-	1.20	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	8.85	1.32	-	3.80	-	1.33	-	0.20	0.29	-	-	0.33	9.20	4.79	7.00	37.11	0.00	37.11	6.27	6.27

18-October-2019 [20:38]

Output specifications Overijssel2050BAU.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1				Gr.2										Gr.3										RES specification				
	District heating MW	Solar MW	CSHP MW	DHP MW	District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW	District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW	RES1 Wind MW	RES2 Photo MW	RES3 River MW	RES 4-7 MW	Total MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	29	8	0	0	36
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	27	16	0	0	42
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	26	28	0	0	55
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	23	47	0	0	70
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	22	58	0	0	80
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	20	62	0	0	82
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	20	60	0	0	80
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	19	50	0	0	69
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	19	35	0	0	55
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	22	21	0	0	42
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	24	9	0	0	33
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	27	6	0	0	33
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	23	33	0	0	56
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	39	190	0	0	217
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	-19	5	0	0	0	9
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00		-0.17	0.20	0.29	0.00	0.00	0.50

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million DKK)	
Total Fuel ex Ngas exchange =	939
Uranium =	0
Coal =	38
FuelOil =	0
Gasoil/Diesel=	267
Petrol/JP =	267
Gas handling =	115
Biomass =	253
Food income =	0
Waste =	0
Total Ngas Exchange costs =	601
Marginal operation costs =	22
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	263
Total variable costs =	1825
Fixed operation costs =	0
Annual Investment costs =	432
TOTAL ANNUAL COSTS =	2257

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	0	422	733	262	797	2213	0	0	0	0	0	0	2213	2213	0
February	0	0	392	692	262	797	2143	0	0	0	0	0	0	2143	2143	0
March	0	0	353	597	262	797	2008	0	0	0	0	0	0	2008	2008	0
April	0	0	309	446	262	797	1813	0	0	0	0	0	0	1813	1813	0
May	0	0	280	292	262	797	1631	0	0	0	0	0	0	1631	1631	0
June	0	0	270	214	262	797	1543	0	0	0	0	0	0	1543	1543	0
July	0	0	263	173	262	797	1495	0	0	0	0	0	0	1495	1495	0
August	0	0	275	180	262	797	1513	0	0	0	0	0	0	1513	1513	0
September	0	0	305	253	262	797	1617	0	0	0	0	0	0	1617	1617	0
October	0	0	346	394	262	797	1798	0	0	0	0	0	0	1798	1798	0
November	0	0	389	555	262	797	2004	0	0	0	0	0	0	2004	2004	0
December	0	0	426	671	262	797	2156	0	0	0	0	0	0	2156	2156	0
Average	0	0	336	433	262	797	1827	0	0	0	0	0	0	1827	1827	0
Maximum	0	0	799	769	262	797	2618	0	0	0	0	0	0	2618	2618	0
Minimum	0	0	215	156	262	797	1430	0	0	0	0	0	0	1430	1430	0
Total for the whole year TWh/year	0.00	0.00	2.95	3.80	2.30	7.00	16.05	0.00	0.00	0.00	0.00	0.00	0.00	16.05	16.05	0.00

RES Share: 33.4 Percent of Primary Energy 55.1 Percent of Electricity 2.9 TWh electricity from RES

18-October-2019 [20:38]

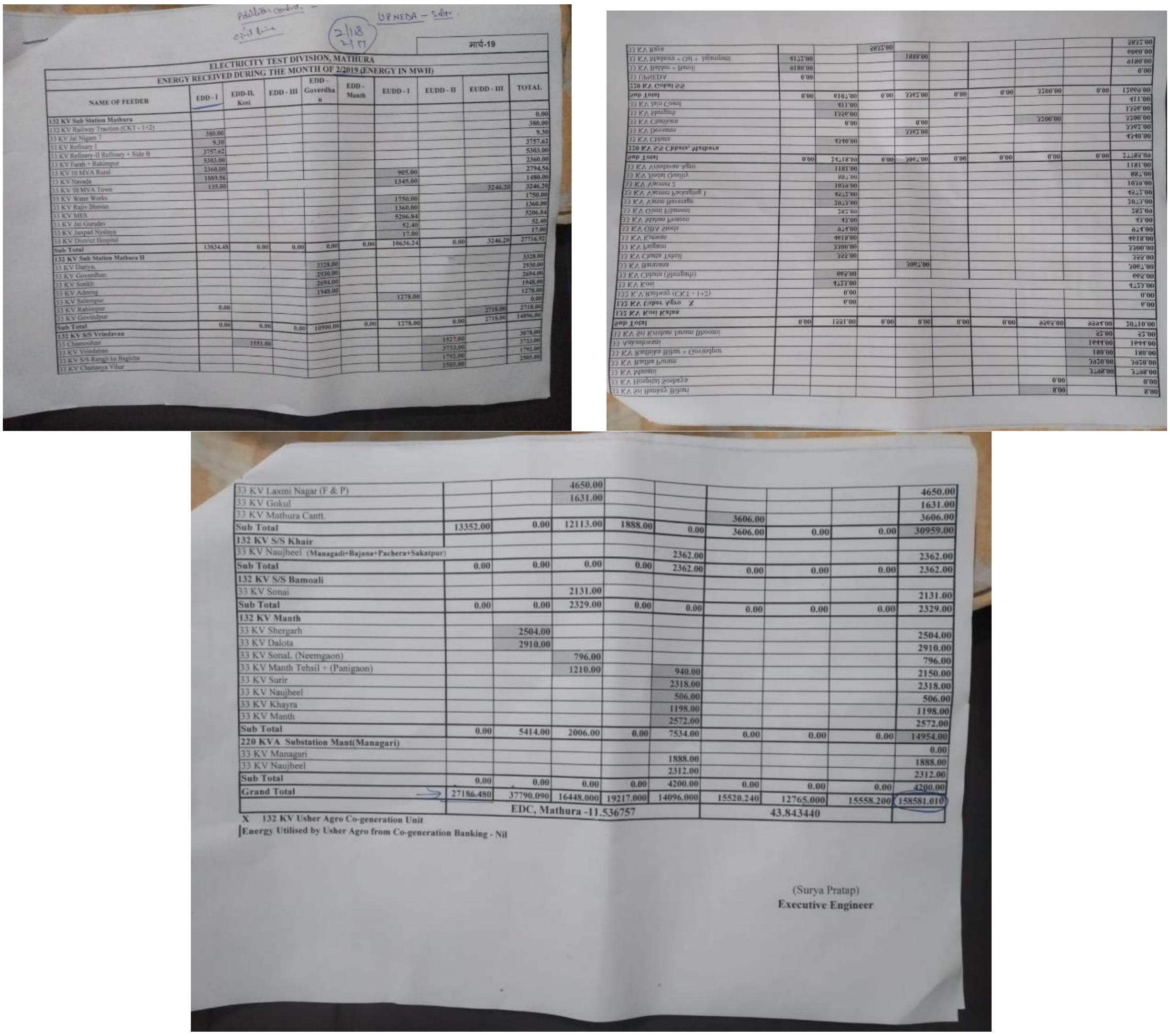
Appendix D

Demography Statistics for Mathura

The demographic statistics, land utilization and cattle population data for Mathura District is acquired from https://www.nabard.org/xls/uttardist/mathura%20-Dist_profile.xls

Electricity Demand for Mathura

The annual electricity demand for Mathura district is not available due to regulation, however a monthly energy consumption for February 2019 was acquired from Electricity Test Division, Mathura from the Executive Engineer. The data received from the centre is presented in figure D1 and is recorded in MWh.



33 KV Laxmi Nagar (F & P)			4650.00						4650.00
33 KV Gokul			1631.00						1631.00
33 KV Mathura Cantt.						3606.00			3606.00
Sub Total	13352.00	0.00	12113.00	1888.00	0.00	3606.00	0.00	0.00	30959.00
132 KV S/S Khair									
33 KV Naujheel (Managadi+Bajana+Pachera+Sakatpur)					2362.00				2362.00
Sub Total	0.00	0.00	0.00	0.00	2362.00	0.00	0.00	0.00	2362.00
132 KV S/S Bamoali									
33 KV Sonai			2131.00						2131.00
Sub Total	0.00	0.00	2329.00	0.00	0.00	0.00	0.00	0.00	2329.00
132 KV Manth									
33 KV Shergarh		2504.00							2504.00
33 KV Dalota		2910.00							2910.00
33 KV SonaL (Neemgaon)			796.00						796.00
33 KV Manth Tehsil + (Panigaon)			1210.00		940.00				2150.00
33 KV Surir					2318.00				2318.00
33 KV Naujheel					506.00				506.00
33 KV Khayra					1198.00				1198.00
33 KV Manth					2572.00				2572.00
Sub Total	0.00	5414.00	2006.00	0.00	7534.00	0.00	0.00	0.00	14954.00
220 KVA Substation Mant(Managari)									
33 KV Managari									0.00
33 KV Naujheel					1888.00				1888.00
					2312.00				2312.00
Sub Total	0.00	0.00	0.00	0.00	4200.00	0.00	0.00	0.00	4200.00
Grand Total	27186.480	37790.090	16448.000	19217.000	14096.000	15520.240	12765.000	15558.200	158581.010
	EDC, Mathura -11.536757					43.843440			

X 132 KV Usher Agro Co-generation Unit

Energy Utilised by Usher Agro from Co-generation Banking - Nil

(Surya Pratap)
Executive Engineer

Figure D1: Energy Consumption for Mathura in February 2019

The total energy consumed in Mathura district in February 2019 was 158,581 MWh. Assuming the energy consumption for each month is the same, therefore the energy demand for the year will 1.9 TWh.

Distribution Profile

The region of Mathura only consumes energy for electricity, cooking and transportation. Due to the climatic condition, heating is brief needed in the December and January, while cooling is prominent requisite in the region. However, being part of the Global South, thermal comfort in the region is maintained by electric heating and cooling by affluent people.

The distribution profile for cooking fuel is used constant from the energyPLAN software due to unavailability of data and the dependence on liquified petroleum gas. However, the distribution profile for electricity is generated from Artificial Load Profile Generator by utilizing basic house appliances. The distribution profile of electricity for the region uploaded on energyPLAN software is presented in figure D2.

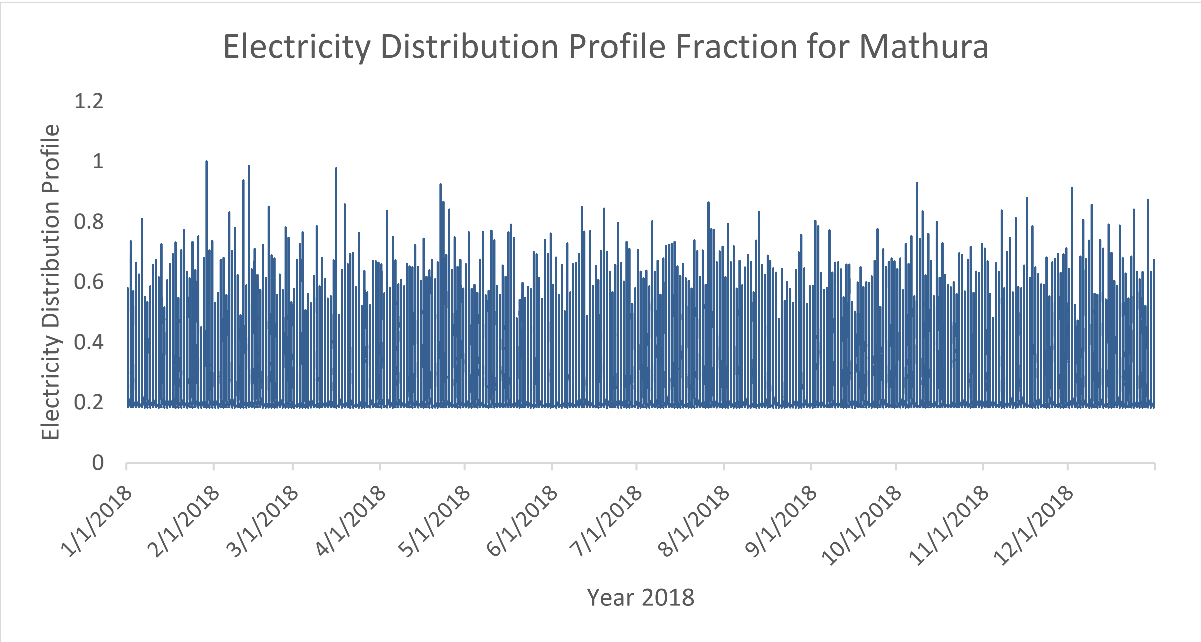


Figure D2: Electricity Distribution Profile Fraction for Mathura generated from ALPG

Analysis of Cooking Fuel Demand and Transportation Demand for Mathura

This section presents an analysis on determining the annual cooking fuel demand and the transportation demand for Mathura.

Annual Cooking Fuel Demand

India's cooking fuel demand is fulfilled by liquified petroleum gas cylinders and are subsidized by the central government. The subsidy provided on an LPG cylinder is limited to 12 cylinders each family or connection in a year based on the estimated average consumption (Post, 2014). The quantity of LPG provided in the cylinder is 14.2 kg with a heating value of 46-51 MJ/kg (Heat Values of Various Fuels, 2018) i.e. approximately 13.6 kWh/kg. Therefore, the energy content in one LPG cylinder is 193.12 kWh. Moreover, based on the estimated average demand per family or connection, the approximate energy consumed by one family for cooking will be 2,317.44 kWh.

The consensus in 2011 estimated the population of the region to be 2.54 million people and 4,23,125 households (Mathura District Population, Uttar Pradesh - Census India 2011, 2011). Assuming that every household has only one connection the estimated cooking fuel demand for the region will be **0.98 TWh**.

Annual Transportation Fuel Demand

The annual transportation fuel demand is not available in the official record. However, the main source of transportation fuel utilized in Mathura is petrol and diesel. Therefore, to estimate the energy demand for transportation, a local contact with a Mathura based petrol pump was made. The petrol pump provided an approximate figure of ₹ 1.11 million revenue per day from sales. Given, the current price of petrol and diesel of approximately ₹70 per litre, the total petroleum consumed in a day from one petrol pump in Mathura was estimated to be 15 thousand litres and annual 5.8 million litres.

The region was 25 registered petrol pumps (Petrol Pumps in Mathura, 2018)and it was assumed that each enterprise has similar revenue leading to similar amount of consumption. The energy content in petroleum fuel is 9.1 kWh (Energy related conversion factors, 2012) and therefore, when calculated, the yearly petroleum demand was estimated to be **1.32 TWh**.

Results from Simulations

The scenarios for energy transition in Mathura are simulated on energyPLAN software and the results are published in PDF format and presented in this section.

Reference Scenario

Input Mathura2018Reference.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	1.90	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	1.90

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

Wind	0 MW	0.00 TWh/year	0.00	Grid
Photo Voltaic	0 MW	0 TWh/year	0.00	stabili-
Wave Power	0 MW	0 TWh/year	0.00	sation
River Hydro	0 MW	0 TWh/year	0.00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	0 MW	0 TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	0		0.45		

Heatstorage: gr.2: 0 GWh gr.30 GWh
Fixed Boiler: gr.2:0.0 Per cent gr0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strate(Technical regulation no. 2
CEEP regulation 945238710
Minimum Stabilisation share 0.30
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 0 MW
Minimum PP 126 MW
Heat Pump maximum share 0.50
Maximum import/export 1000 MW

Distr. Name : Hour_nordpool.txt
Addition factor 0.00 EUR/MWh
Multiplication factor 2.00
Dependency factor 0.00 EUR/MWh pr. MW
Average Market Price227 EUR/MWh
Gas Storage 0 GWh
Syngas capacity 0 MW
Biogas max to grid 0 MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	1.32	0.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.38

Output

	District Heating: Demand Distr. heating MW	Production Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW	Electricity Consumption: Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Production: Turbine MW	RES MW	Hydro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Balance: Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Exchange Payment Imp Million EUR	Exp Million EUR
January	0	0	0	0	0	0	0	0	0	0	218	0	0	0	0	0	0	0	0	0	0	0	218	333	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	218	0	0	0	0	0	0	0	0	0	0	0	218	333	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	214	0	0	0	0	0	0	0	0	0	0	0	214	333	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	218	0	0	0	0	0	0	0	0	0	0	0	218	333	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	213	0	0	0	0	0	0	0	0	0	0	0	213	333	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	217	0	0	0	0	0	0	0	0	0	0	0	217	333	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	215	0	0	0	0	0	0	0	0	0	0	0	215	333	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	211	0	0	0	0	0	0	0	0	0	0	0	211	333	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	214	0	0	0	0	0	0	0	0	0	0	0	214	333	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	219	0	0	0	0	0	0	0	0	0	0	0	219	333	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	217	0	0	0	0	0	0	0	0	0	0	0	217	333	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	221	0	0	0	0	0	0	0	0	0	0	0	221	333	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	216	0	0	0	0	0	0	0	0	0	0	0	216	333	0	0	0	0	Average price	
Maximum	0	0	0	0	0	0	0	0	0	0	689	0	0	0	0	0	0	0	0	0	0	0	689	333	0	0	0	0	(EUR/MWh)	
Minimum	0	0	0	0	0	0	0	0	0	0	126	0	0	0	0	0	0	0	0	0	0	0	126	333	0	0	0	0	-	160
TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	4.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.22	0.00	4.22	1.44	1.44
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.32	-	-	1.32	0.00	1.32	0.35	0.35
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70	-	-	0.70	0.00	0.70	0.15	0.29
Biomass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.38	0.38	0.00	0.38	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
H2 etc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	4.22	-	-	-	-	-	-	-	-	-	-	-	2.02	-	0.38	6.63	0.00	6.63	1.95	2.09

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Output specifications Mathura2018Reference.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Solar MW	CSHP MW	DHP MW	Gr.2 District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW	Gr.3 District heating MW	Solar MW	CSHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Stor-age MW	Ba-lance MW	RES specification RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total er MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00

Own use of heat from industrial CH0.00 TWh/year

ANNUAL COSTS (Million EUR)
Total Fuel ex Ngas exchange = 0
Uranium = 0
Coal = 0
FuelOil = 0
Gasoil/Diesel= 0
Petrol/JP = 0
Gas handling = 0
Biomass = 0
Food income = 0
Waste = 0

Total Ngas Exchange costs = 0

Marginal operation costs = 0

Total Electricity exchange = 0
Import = 0
Export = 0
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 0

Total variable costs = 0
Fixed operation costs = 0

Annual Investment costs = 0

TOTAL ANNUAL COSTS = 0

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

RES Share: 5.7 Percent of Primary Energy 0.0 Percent of Electricity 0.0 TWh electricity from RES

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Mathura Scenario 2030

Input   Mathura_2030Scenario.txt   The EnergyPLAN model 14.1

Electricity demand (TWh/year): Flexible demand 0.00
Fixed demand 3.89 · Fixed imp/exp. 0.00
Electric heating + HP 0.00 · Transportation 0.00
Electric cooling 0.00 · Total 3.89

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

	Capacity		Production		Grid stabilisation share
Wind	100	MW	0.22	TWh/year	0.00
Photo Voltaic	850	MW	1.44	TWh/year	0.00
Wave Power	0	MW	0	TWh/year	0.00
River Hydro	20	MW	0.18	TWh/year	0.90
Hydro Power	0	MW	0	TWh/year	
Geothermal/Nuclear	0	MW	0	TWh/year	

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	1175		0.40		

Heatstorage: gr.2: 0 GWh · gr.3 0 GWh
Fixed Boiler: gr.2: 0.0 Per cent · gr 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy: Technical regulation no. 2
CEEP regulation 985432176
Minimum Stabilisation share 0.30
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 0 MW
Minimum PP 243 MW
Heat Pump maximum share 0.50
Maximum import/export 0 MW

Distr. Name : Hour_nordpool.txt
Addition factor 0.00 EUR/MWh
Multiplication factor 2.00
Dependency factor 0.00 EUR/MWh pr. MW
Average Market Price 227 EUR/MWh
Gas Storage 0 GWh
Syngas capacity 79 MW
Biogas max to grid 163 MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	2.40	1.20	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating (Demand / Production / Balance)

	Distr. heating MW	Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW
January	0	0	10	0	0	0	0	0	0	-10
February	0	0	10	0	0	0	0	0	0	-10
March	0	0	10	0	0	0	0	0	0	-10
April	0	0	10	0	0	0	0	0	0	-10
May	0	0	10	0	0	0	0	0	0	-10
June	0	0	10	0	0	0	0	0	0	-10
July	0	0	10	0	0	0	0	0	0	-10
August	0	0	10	0	0	0	0	0	0	-10
September	0	0	10	0	0	0	0	0	0	-10
October	0	0	10	0	0	0	0	0	0	-10
November	0	0	10	0	0	0	0	0	0	-10
December	0	0	10	0	0	0	0	0	0	-10
Average	0	0	10	0	0	0	0	0	0	-10
Maximum	0	0	10	0	0	0	0	0	0	-10
Minimum	0	0	10	0	0	0	0	0	0	-10
TWh/year	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	-0.09

Electricity (Consumption / Production / Balance) and Exchange

	Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Payment Imp Million EUR	Payment Exp Million EUR
January	446	0	0	0	0	0	0	184	0	0	0	0	286	247	0	0	0	0	0	0
February	446	0	0	0	0	0	0	210	0	0	0	0	266	240	0	0	0	0	0	0
March	439	0	0	0	0	0	0	227	0	0	0	0	251	237	0	0	0	0	0	0
April	446	0	0	0	0	0	0	230	0	0	0	0	253	235	0	0	0	0	0	0
May	437	0	0	0	0	0	0	219	0	0	0	0	252	237	0	0	0	0	0	0
June	443	0	0	0	0	0	0	225	0	0	0	0	250	230	0	0	0	0	0	0
July	440	0	0	0	0	0	0	217	0	0	0	0	255	233	0	0	0	0	0	0
August	432	0	0	0	0	0	0	211	0	0	0	0	252	236	0	0	0	0	0	0
September	438	0	0	0	0	0	0	221	0	0	0	0	254	234	0	0	0	0	0	0
October	447	0	0	0	0	0	0	215	0	0	0	0	262	242	0	0	0	0	0	0
November	444	0	0	0	0	0	0	178	0	0	0	0	289	249	0	0	0	0	0	0
December	453	0	0	0	0	0	0	165	0	0	0	0	306	254	0	0	0	0	0	0
Average	443	0	0	0	0	0	0	209	0	0	0	0	265	240	0	0	0	0	Average price	
Maximum	1408	0	0	0	0	0	0	885	0	0	0	0	1168	332	0	0	0	0	(EUR/MWh)	
Minimum	257	0	0	0	0	0	0	10	0	0	0	0	224	100	0	0	0	0	261	264
TWh/year	3.89	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00	0.00	0.00	2.33		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	5.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.35	0.00	5.35	1.90	1.90
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.40	-	-	2.40	0.00	2.40	0.63	0.63
N.Gas	-	-	-	-	-	0.47	-	-	-	-	-1.98	-	-	-	-	-	-	1.52	-	-	0.00	0.00	0.00	0.00	0.07
Biomass	-	-	-	-	-	-	-	-	-	-	3.06	-	-	-	-	-	-	-	-	-	3.06	0.00	3.06	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	0.22	1.44	-	0.18	-	-	-	-	1.83	0.00	1.83	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	5.81	-	-	-	-	1.08	-	0.22	1.44	-	0.18	-	3.92	-	-	12.64	0.00	12.64	2.53	2.60

02-November-2019 [15:43]

Output specifications   Mathura_2030Scenario.txt   The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Storage MW	Gr.2 Balance MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00

	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Storage MW	Gr.3 Balance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total er MW
January	0	0	10	0	0	0	0	0	0	-10	25	139	0	20	184
February	0	0	10	0	0	0	0	0	0	-10	26	164	0	20	210
March	0	0	10	0	0	0	0	0	0	-10	26	181	0	20	227
April	0	0	10	0	0	0	0	0	0	-10	24	185	0	20	230
May	0	0	10	0	0	0	0	0	0	-10	20	179	0	20	219
June	0	0	10	0	0	0	0	0	0	-10	32	174	0	20	225
July	0	0	10	0	0	0	0	0	0	-10	27	170	0	20	217
August	0	0	10	0	0	0	0	0	0	-10	25	166	0	20	211
September	0	0	10	0	0	0	0	0	0	-10	30	172	0	20	221
October	0	0	10	0	0	0	0	0	0	-10	19	176	0	20	215
November	0	0	10	0	0	0	0	0	0	-10	22	135	0	20	178
December	0	0	10	0	0	0	0	0	0	-10	20	125	0	20	165
Average	0	0	10	0	0	0	0	0	0	-10	25	164	0	20	209
Maximum	0	0	10	0	0	0	0	0	0	-10	100	835	0	20	885
Minimum	0	0	10	0	0	0	0	0	0	-10	0	0	0	10	10
Total for the whole year TWh/year	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00		-0.09	0.22	1.44	0.00	0.18	1.83

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million EUR)
Total Fuel ex Ngas exchange = 279
Uranium = 0
Coal = 43
FuelOil = 0
Gasoil/Diesel= 86
Petrol/JP = 48
Gas handling = 22
Biomass = 80
Food income = 0
Waste = 0

Total Ngas Exchange costs = -7

Marginal operation costs = 9

Total Electricity exchange = 0
Import = 0
Export = 0
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 28

Total variable costs = 308
Fixed operation costs = 0

Annual Investment costs = 139

TOTAL ANNUAL COSTS = 447

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	0	57	0	137	0	194	163	63	0	0	0	0	-32	3	35
February	0	0	53	0	137	0	190	163	63	0	0	0	0	-36	1	37
March	0	0	50	0	137	0	187	163	63	0	0	0	0	-39	0	39
April	0	0	51	0	137	0	187	163	63	0	0	0	0	-39	0	39
May	0	0	50	0	137	0	187	163	63	0	0	0	0	-39	0	39
June	0	0	50	0	137	0	187	163	63	0	0	0	0	-39	0	39
July	0	0	51	0	137	0	188	163	63	0	0	0	0	-38	1	39
August	0	0	50	0	137	0	187	163	63	0	0	0	0	-39	0	39
September	0	0	51	0	137	0	187	163	63	0	0	0	0	-39	0	39
October	0	0	52	0	137	0	189	163	63	0	0	0	0	-37	1	38
November	0	0	58	0	137	0	194	163	63	0	0	0	0	-31	3	35
December	0	0	61	0	137	0	198	163	63	0	0	0	0	-28	5	33
Average	0	0	53	0	137	0	190	163	63	0	0	0	0	-36	1	38
Maximum	0	0	234	0	137	0	370	163	63	0	0	0	0	144	144	45
Minimum	0	0	45	0	137	0	181	163	63	0	0	0	0	-45	0	0
Total for the whole year TWh/year	0.00	0.00	0.47	0.00	1.20	0.00	1.67	1.43	0.55	0.00	0.00	0.00	0.00	-0.32	0.01	0.33

RES Share: 38.7 Percent of Primary Energy 47.1 Percent of Electricity   1.8 TWh electricity from RES   02-November-2019 [15:43]

Mathura Scenario 2040

Input — Mathura_2040Scenario.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	5.09	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	1.35
Electric cooling	0.00	Total	6.44

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

	Capacity		Production		Grid stabilisation share
Wind	110	MW	0.27	TWh/year	0.00
Photo Voltaic	950	MW	1.89	TWh/year	0.00
Wave Power	0	MW	0	TWh/year	0.00
River Hydro	25	MW	0.79	TWh/year	0.90
Hydro Power	0	MW	0	TWh/year	
Geothermal/Nuclear	0	MW	0	TWh/year	

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	1518		0.45		

Heatstorage: gr.2: 0 GWh gr.3 0 GWh
Fixed Boiler: gr.2: 0.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy	Technical regulation no. 2	
CEEP regulation	985432176	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	390	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	EUR/MWh
Multiplication factor	2.00	
Dependency factor	0.00	EUR/MWh pr. MW
Average Market Price	227	EUR/MWh
Gas Storage	0	GWh
Syngas capacity	766	MW
Biogas max to grid	163	MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	400	3	0.80	
Hydro Turbine:	400		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	0.20	1.92	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

District Heating (Demand; Production; Balance) — Electricity (Consumption; Production; Balance) — Exchange

	Distr. heating MW	Solar MW	Waste CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Balance MW	Elec. demand MW	Flex.& Transp MW	HP MW	Electrolyser MW	EH MW	Hydro Pump MW	Turbine MW	RES MW	Hydro MW	Geothermal MW	Waste CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Payment Imp Million EUR	Payment Exp Million EUR
January	0	0	98	0	0	0	0	0	0	-98	584	154	0	0	0	118	85	272	0	0	0	0	511	252	0	0	0	0	0	0
February	0	0	98	0	0	0	0	0	0	-98	584	154	0	0	0	125	90	311	0	0	0	0	481	245	0	0	0	0	0	0
March	0	0	98	0	0	0	0	0	0	-98	575	154	0	0	0	148	106	389	0	0	0	0	421	234	0	0	0	0	0	0
April	0	0	98	0	0	0	0	0	0	-98	584	154	0	0	0	150	108	408	0	0	0	0	411	231	0	0	0	0	0	0
May	0	0	98	0	0	0	0	0	0	-98	572	154	0	0	0	154	110	406	0	0	0	0	402	230	0	0	0	0	0	0
June	0	0	98	0	0	0	0	0	0	-98	580	154	0	0	0	151	110	399	0	0	0	0	404	227	0	0	0	0	0	0
July	0	0	98	0	0	0	0	0	0	-98	576	154	0	0	0	140	100	351	0	0	0	0	445	235	0	0	0	0	0	0
August	0	0	98	0	0	0	0	0	0	-98	566	154	0	0	0	131	94	315	0	0	0	0	459	241	0	0	0	0	0	0
September	0	0	98	0	0	0	0	0	0	-98	573	154	0	0	0	141	102	360	0	0	0	0	435	235	0	0	0	0	0	0
October	0	0	98	0	0	0	0	0	0	-98	586	154	0	0	0	131	94	321	0	0	0	0	477	245	0	0	0	0	0	0
November	0	0	98	0	0	0	0	0	0	-98	582	154	0	0	0	115	83	263	0	0	0	0	515	254	0	0	0	0	0	0
December	0	0	98	0	0	0	0	0	0	-98	592	154	0	0	0	109	78	246	0	0	0	0	538	258	0	0	0	0	0	0
Average	0	0	98	0	0	0	0	0	0	-98	579	154	0	0	0	134	97	337	0	0	0	0	458	241	0	0	0	0	Average price (EUR/MWh)	
Maximum	0	0	98	0	0	0	0	0	0	-98	1823	307	0	0	0	400	400	1319	0	0	0	0	1517	333	0	0	0	0		
Minimum	0	0	98	0	0	0	0	0	0	-98	340	0	0	0	0	0	0	25	0	0	0	0	390	100	0	0	0	0	228	224
TWh/year	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	-0.86	5.09	1.35	0.00	0.00	0.00	1.18	0.85	2.96	0.00	0.00	0.00	0.00	4.03		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th.	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	4.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.05	0.00	4.05	1.44	1.44
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-	-	0.20	0.00	0.20	0.05	0.05
N.Gas	-	-	-	-	-	4.89	-	-	-	-	-6.81	-	-	-	-	-	-	1.92	-	-	0.00	0.00	0.00	0.00	0.00
Biomass	-	-	-	-	-	-	-	-	-	-	11.02	-	-	-	-	-	-	-	-	-	11.02	0.00	11.02	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	0.27	2.47	-	0.22	-	-	-	-	2.96	0.00	2.96	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-0.22	-	-	-	-	-	-	0.22	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	8.95	-	-	-	-	3.99	-	0.27	2.47	-	0.22	-	2.34	-	-	18.23	0.00	18.23	1.49	1.49

02-November-2019 [20:05]

Output specifications — Mathura_2040Scenario.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Storage MW	Gr.2 Balance MW	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Storage MW	Gr.3 Balance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	29	169	0	74	272
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	31	197	0	83	311
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	34	253	0	102	389
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	33	267	0	108	408
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	27	267	0	112	406
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	40	253	0	106	399
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	34	225	0	92	351
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	30	201	0	84	315
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	37	230	0	93	360
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	23	211	0	87	321
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	27	164	0	73	263
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	24	153	0	69	246
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	31	216	0	90	337
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	110	950	0	325	1319
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	98	0	0	0	0	0	0	-98	0	0	0	25	25
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00		-0.86	0.27	1.89	0.00	0.79	2.96

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million EUR)	
Total Fuel ex Ngas exchange =	460
Uranium =	0
Coal =	52
FuelOil =	0
Gasoil/Diesel=	11
Petrol/JP =	11
Gas handling =	32
Biomass =	356
Food income =	0
Waste =	0
Total Ngas Exchange costs =	0
Marginal operation costs =	16
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	36
Total variable costs =	512
Fixed operation costs =	0
Annual Investment costs =	259
TOTAL ANNUAL COSTS =	771

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Individual MW	Transport MW	Indu. Var. MW	Demand Sum MW	Biogas MW	Syngas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Storage MW	Sum MW	Import MW	Export MW
January	0	0	621	0	219	0	839	163	613	0	0	0	0	64	105	41
February	0	0	584	0	219	0	803	163	613	0	0	0	0	28	76	49
March	0	0	511	0	219	0	730	163	613	0	0	0	0	-45	19	64
April	0	0	499	0	219	0	718	163	613	0	0	0	0	-58	10	68
May	0	0	489	0	219	0	707	163	613	0	0	0	0	-68	3	71
June	0	0	492	0	219	0	710	163	613	0	0	0	0	-65	5	70
July	0	0	541	0	219	0	760	163	613	0	0	0	0	-15	44	59
August	0	0	558	0	219	0	777	163	613	0	0	0	0	2	57	55
September	0	0	529	0	219	0	747	163	613	0	0	0	0	-28	33	61
October	0	0	580	0	219	0	798	163	613	0	0	0	0	23	72	49
November	0	0	626	0	219	0	844	163	613	0	0	0	0	69	111	41
December	0	0	654	0	219	0	872	163	613	0	0	0	0	97	136	39
Average	0	0	557	0	219	0	776	163	613	0	0	0	0	0	56	56
Maximum	0	0	1844	0	219	0	2062	163	613	0	0	0	0	1287	1287	83
Minimum	0	0	474	0	219	0	693	163	613	0	0	0	0	-83	0	0
Total for the whole year TWh/year	0.00	0.00	4.89	0.00	1.92	0.00	6.81	1.43	5.38	0.00	0.00	0.00	0.00	0.00	0.49	0.49

RES Share: 76.7 Percent of Primary Energy 38.8 Percent of Electricity 3.0 TWh electricity from RES

02-November-2019 [20:05]

Mathura Energy Transition 2050

Input — Mathura2050_Energy Transition.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year): Flexible demand 0.55

Fixed demand	6.77	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	2.20
Electric cooling	0.00	Total	9.52

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

Wind	150 MW	0.40	TWh/year	0.00	Grid
Photo Voltaic	1300 MW	2.84	TWh/year	0.00	stabili-
Wave Power	0 MW	0	TWh/year	0.00	sation
River Hydro	30 MW	0.92	TWh/year	0.90	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	0 MW	0	TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	2413		0.45		

Heatstorage: gr.2: 0 GWh gr.3 0 GWh
Fixed Boiler: gr.2: 0.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy	Technical regulation no. 2	
CEEP regulation	985432716	
Minimum Stabilisation share	0.30	
Stabilisation share of CHP	0.00	
Minimum CHP gr 3 load	0	MW
Minimum PP	460	MW
Heat Pump maximum share	0.50	
Maximum import/export	0	MW
Distr. Name :	Hour_nordpool.txt	
Addition factor	0.00	EUR/MWh
Multiplication factor	2.00	
Dependency factor	0.00	EUR/MWh pr. MW
Average Market Price	227	EUR/MWh
Gas Storage	0	GWh
Syngas capacity	1561	MW
Biogas max to grid	381	MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiency elec.	Efficiency Ther
Hydro Pump:	500	4	0.80	
Hydro Turbine:	500		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	
CAES fuel ratio:	0.000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	0.00	1.80	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

	District Heating Demand Distr. heating MW	DH Production Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Electricity Consumption Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Electricity Production Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Balance Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Exchange Payment Imp (Million EUR)	Exp (Million EUR)
January	0	0	197	0	0	0	0	0	0	-197	777	313	0	0	0	139	100	384	0	0	0	0	748	246	0	0	0	0	0	0
February	0	0	197	0	0	0	0	0	0	-197	776	313	0	0	0	153	110	434	0	0	0	0	710	240	0	0	0	0	0	0
March	0	0	197	0	0	0	0	0	0	-197	764	313	0	0	0	186	134	539	0	0	0	0	625	230	0	0	0	0	0	0
April	0	0	197	0	0	0	0	0	0	-197	776	313	0	0	0	190	137	569	0	0	0	0	614	226	0	0	0	0	0	0
May	0	0	197	0	0	0	0	0	0	-197	760	313	0	0	0	195	140	586	0	0	0	0	587	223	0	0	0	0	0	0
June	0	0	197	0	0	0	0	0	0	-197	771	313	0	0	0	193	140	576	0	0	0	0	597	220	0	0	0	0	0	0
July	0	0	197	0	0	0	0	0	0	-197	766	313	0	0	0	168	121	489	0	0	0	0	659	229	0	0	0	0	0	0
August	0	0	197	0	0	0	0	0	0	-197	752	313	0	0	0	153	110	441	0	0	0	0	682	235	0	0	0	0	0	0
September	0	0	197	0	0	0	0	0	0	-197	762	313	0	0	0	175	126	498	0	0	0	0	650	231	0	0	0	0	0	0
October	0	0	197	0	0	0	0	0	0	-197	778	313	0	0	0	164	118	445	0	0	0	0	707	240	0	0	0	0	0	0
November	0	0	197	0	0	0	0	0	0	-197	773	313	0	0	0	130	94	372	0	0	0	0	754	248	0	0	0	0	0	0
December	0	0	197	0	0	0	0	0	0	-197	787	313	0	0	0	113	81	348	0	0	0	0	784	251	0	0	0	0	0	0
Average	0	0	197	0	0	0	0	0	0	-197	770	313	0	0	0	163	117	473	0	0	0	0	676	235	0	0	0	0	Average price	(EUR/MWh)
Maximum	0	0	197	0	0	0	0	0	0	-197	2409	551	0	0	0	500	500	1695	0	0	0	0	2403	333	0	0	0	0		
Minimum	0	0	197	0	0	0	0	0	0	-197	455	0	0	0	0	0	0	31	0	0	0	0	460	100	0	0	0	0	228	219
TWh/year	0.00	0.00	1.73	0.00	0.00	0.00	0.00	0.00	0.00	-1.73	6.77	2.75	0.00	0.00	0.00	1.43	1.03	4.16	0.00	0.00	0.00	0.00	5.94		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
N.Gas	-	-	-	-	-	13.21	-	-	-	-	-15.00	-	-	-	-	-	-	1.80	-	-	0.01	0.00	0.01	0.00	0.00
Biomass	-	-	-	-	-	-	-	-	-	-	22.63	-	-	-	-	-	-	-	-	-	22.63	0.00	22.63	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	0.40	3.49	-	0.26	-	-	-	-	4.16	0.00	4.16	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-0.22	-	-	-	-	-	-	0.22	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	13.21	-	-	-	-	7.41	-	0.40	3.49	-	0.26	-	2.02	-	-	26.79	0.00	26.79	0.00	0.00

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Output specifications — Mathura2050_Energy Transition.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Stor-age MW	Gr.2 Ba-lance MW	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Stor-age MW	Gr.3 Ba-lance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 MW	Total MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	43	252	0	88	384
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	46	291	0	97	434
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	51	373	0	116	539
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	50	398	0	122	569
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	43	417	0	126	586
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	62	394	0	121	576
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	50	333	0	107	489
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	44	298	0	99	441
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	54	337	0	108	498
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	34	310	0	102	445
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	39	246	0	87	372
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	36	230	0	83	348
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	46	323	0	105	473
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	150	1300	0	330	1695
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	197	0	0	0	0	0	0	-197	1	0	0	30	31
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	1.73	0.00	0.00	0.00	0.00	0.00		-1.73	0.40	2.84	0.00	0.92	4.16

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million EUR)	
Total Fuel ex Ngas exchange =	767
Uranium =	0
Coal =	0
FuelOil =	0
Gasoil/Diesel=	2
Petrol/JP =	2
Gas handling =	36
Biomass =	727
Food income =	0
Waste =	0
Total Ngas Exchange costs =	0
Marginal operation costs =	22
Total Electricity exchange =	0
Import =	0
Export =	0
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	0
Total variable costs =	788
Fixed operation costs =	0
Annual Investment costs =	418
TOTAL ANNUAL COSTS =	1207

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	0	1662	0	205	0	1867	381	1327	0	0	0	0	159	368	209
February	0	0	1579	0	205	0	1784	381	1327	0	0	0	0	76	293	217
March	0	0	1389	0	205	0	1594	381	1327	0	0	0	0	-114	147	261
April	0	0	1364	0	205	0	1569	381	1327	0	0	0	0	-138	130	268
May	0	0	1305	0	205	0	1510	381	1327	0	0	0	0	-197	97	294
June	0	0	1326	0	205	0	1531	381	1327	0	0	0	0	-177	114	290
July	0	0	1464	0	205	0	1669	381	1327	0	0	0	0	-38	218	256
August	0	0	1516	0	205	0	1720	381	1327	0	0	0	0	13	254	241
September	0	0	1445	0	205	0	1650	381	1327	0	0	0	0	-58	194	252
October	0	0	1571	0	205	0	1776	381	1327	0	0	0	0	68	286	218
November	0	0	1675	0	205	0	1880	381	1327	0	0	0	0	172	379	207
December	0	0	1742	0	205	0	1947	381	1327	0	0	0	0	239	445	206
Average	0	0	1503	0	205	0	1708	381	1327	0	0	0	0	1	244	243
Maximum	0	0	5340	0	205	0	5545	381	1327	0	0	0	0	3837	3837	481
Minimum	0	0	1022	0	205	0	1227	381	1327	0	0	0	0	-481	0	0
Total for the whole year TWh/year	0.00	0.00	13.21	0.00	1.80	0.00	15.01	3.35	11.65	0.00	0.00	0.00	0.00	0.01	2.14	2.14

RES Share: 100.0 Percent of Primary Energy 38.0 Percent of Electricity 4.2 TWh electricity from RES

02-November-2019 [20:46]

Mathura Business-as-Usual Scenario

Input Mathura2050BAU.txt — The EnergyPLAN model 14.1

Electricity demand (TWh/year):		Flexible demand	0.00
Fixed demand	7.17	Fixed imp/exp.	0.00
Electric heating + HP	0.00	Transportation	0.00
Electric cooling	0.00	Total	7.17

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0.00	0.00	0.00	0.00
Solar Thermal	0.00	0.00	0.00	0.00
Industrial CHP (CSHP)	0.00	0.00	0.00	0.00
Demand after solar and CSHP	0.00	0.00	0.00	0.00

Wind	0 MW	0.00	TWh/year	0.00	Grid
Photo Voltaic	145 MW	0.28	TWh/year	0.00	stabili-
Wave Power	0 MW	0	TWh/year	0.00	sation
River Hydro	0 MW	0	TWh/year	0.00	share
Hydro Power	0 MW	0	TWh/year		
Geothermal/Nuclear	0 MW	0	TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Group 3:					
CHP	0	0	0.40	0.50	
Heat Pump	0	0			3.00
Boiler		0		0.90	
Condensing	2600		0.38		

Heatstorage: gr.2: 0 GWh gr.3 0 GWh
Fixed Boiler: gr.2: 0.0 Per cent gr.3: 0.0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0.00	0.00
Gr.2:	0.00	0.00
Gr.3:	0.00	0.00

Regulation Strategy: Technical regulation no. 1
CEEP regulation 000000000
Minimum Stabilisation share 0.00
Stabilisation share of CHP 0.00
Minimum CHP gr 3 load 0 MW
Minimum PP 0 MW
Heat Pump maximum share 0.50
Maximum import/export 0 MW

Distr. Name : Hour_nordpool.txt
Addition factor 0.00 EUR/MWh
Multiplication factor 2.00
Dependency factor 0.00 EUR/MWh pr. MW
Average Market Price 227 EUR/MWh
Gas Storage 0 GWh
Syngas capacity 0 MW
Biogas max to grid 163 MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0.80	
Hydro Turbine:	0		0.90	
Electrol. Gr.2:	0	0	0.80	0.10
Electrol. Gr.3:	0	0	0.80	0.10
Electrol. trans.:	0	0	0.80	
Ely. MicroCHP:	0	0	0.80	

CAES fuel ratio: 0.000

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0.00	5.60	4.00	0.00
Household	0.00	0.00	0.00	0.00
Industry	0.00	0.00	0.00	0.00
Various	0.00	0.00	0.00	0.00

Output

	District Heating: Demand	Production									Electricity: Consumption						Production							Balance					Exchange: Payment	
	Distr. heating MW	Solar MW	Waste-CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste-CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million EUR	Exp Million EUR
January	0	0	0	0	0	0	0	0	0	0	823	0	0	0	0	0	0	24	0	0	0	0	799	100	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	823	0	0	0	0	0	0	28	0	0	0	0	795	100	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	809	0	0	0	0	0	0	37	0	0	0	0	772	100	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	823	0	0	0	0	0	0	40	0	0	0	0	783	100	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	806	0	0	0	0	0	0	42	0	0	0	0	763	100	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	817	0	0	0	0	0	0	39	0	0	0	0	778	100	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	811	0	0	0	0	0	0	32	0	0	0	0	779	100	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	797	0	0	0	0	0	0	29	0	0	0	0	768	100	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	808	0	0	0	0	0	0	33	0	0	0	0	775	100	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	825	0	0	0	0	0	0	30	0	0	0	0	795	100	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	819	0	0	0	0	0	0	23	0	0	0	0	796	100	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	835	0	0	0	0	0	0	21	0	0	0	0	813	100	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	816	0	0	0	0	0	0	32	0	0	0	0	785	100	0	0	0	0	Average price	
Maximum	0	0	0	0	0	0	0	0	0	0	2600	0	0	0	0	0	0	145	0	0	0	0	2599	100	0	0	0	0	(EUR/MWh)	
Minimum	0	0	0	0	0	0	0	0	0	0	474	0	0	0	0	0	0	0	0	0	0	0	440	100	0	0	0	0	-	-
TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	6.89		0.00	0.00	0.00	0.00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu	Hydro	Waste	CAES Elc.ly.	BioCon-version	Electro-Fuel	Wind	PV and CSP	Wind off Wave	Hydro	Solar.Th	Transp	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Net	CO2 emission (Mt): Total	Net
Coal	-	-	-	-	-	18.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.14	0.00	18.14	6.43	6.43
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.60	-	-	5.60	0.00	5.60	1.47	1.47
N.Gas	-	-	-	-	-	-	-	-	-	-	-1.43	-	-	-	-	-	-	4.00	-	0.00	2.57	0.00	2.57	0.53	0.53
Biomass	-	-	-	-	-	-	-	-	-	-	2.20	-	-	-	-	-	-	-	-	-	2.20	0.00	2.20	0.00	0.00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28	-	-	-	-	-	-	0.28	0.00	0.28	0.00	0.00
H2 etc.	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Total	-	-	-	-	-	18.14	-	-	-	-	0.77	-	-	0.28	-	-	-	9.60	-	0.00	28.79	0.00	28.79	8.43	8.43

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Output specifications Mathura2050BAU.txt — The EnergyPLAN model 14.1

District Heating Production

	Gr.1 District heating MW	Gr.1 Solar MW	Gr.1 CSHP MW	Gr.1 DHP MW	Gr.2 District heating MW	Gr.2 Solar MW	Gr.2 CSHP MW	Gr.2 CHP MW	Gr.2 HP MW	Gr.2 ELT MW	Gr.2 Boiler MW	Gr.2 EH MW	Gr.2 Stor-age MW	Gr.2 Ba-lance MW	Gr.3 District heating MW	Gr.3 Solar MW	Gr.3 CSHP MW	Gr.3 CHP MW	Gr.3 HP MW	Gr.3 ELT MW	Gr.3 Boiler MW	Gr.3 EH MW	Gr.3 Stor-age MW	Gr.3 Ba-lance MW	RES1 Wind MW	RES2 Photo MW	RES3 Wave MW	RES 4-7 er MW	Total MW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	24
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	28
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	37
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	40
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	0	0	42
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	0	0	39
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	32
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	29
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	33
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	30
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	23
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	21
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	32
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145	0	0	145
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.28	0.00	0.00	0.28

Own use of heat from industrial CHP 0.00 TWh/year

ANNUAL COSTS (Million EUR)		
Total Fuel ex Ngas exchange =		776
Uranium =	0	
Coal =	232	
FuelOil =	0	
Gasoil/Diesel=	226	
Petrol/JP =	195	
Gas handling =	0	
Biomass =	124	
Food income =	0	
Waste =	0	
Total Ngas Exchange costs =		96
Marginal operation costs =		20
Total Electricity exchange =		0
Import =	0	
Export =	0	
Bottleneck =	0	
Fixed imp/ex=	0	
Total CO2 emission costs =		354
Total variable costs =		1247
Fixed operation costs =		0
Annual Investment costs =		134
TOTAL ANNUAL COSTS =		1381

NATURAL GAS EXCHANGE

	DHP & Boilers MW	CHP2 CHP3 MW	PP CAES MW	Indi-vidual MW	Trans port MW	Indu. Var. MW	Demand Sum MW	Bio-gas MW	Syn-gas MW	CO2Hy gas MW	SynHy gas MW	SynHy gas MW	Stor-age MW	Sum MW	Im-port MW	Ex-port MW
January	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
February	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
March	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
April	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
May	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
June	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
July	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
August	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
September	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
October	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
November	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
December	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
Average	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
Maximum	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
Minimum	0	0	0	0	455	0	455	163	0	0	0	0	0	293	293	0
Total for the whole year TWh/year	0.00	0.00	0.00	0.00	4.00	0.00	4.00	1.43	0.00	0.00	0.00	0.00	0.00	2.57	2.57	0.00

RES Share: 8.6 Percent of Primary Energy 3.9 Percent of Electricity 0.3 TWh electricity from RES

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