Beloved Coal:
The Living Comfort After Retirement of Coal Power Plants. Case studies of Coal Regions During Energy Transition in Poland and Bulgaria.

Xiaojie Jiang

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Supervisor: Stephan Hauser
TU Delft, Faculty of Architecture and the Built Environment

Content

Abstract

The transition of coal power plants has showed the struggles in overcoming coal energy in Europe, where its largest power plant, Bełchatów Power Station, in 2021 announced its fourteen-year closure plan. In the instances of Poland and Bulgaria, coal regions are hesitant to act for transitioning and their energy distribution systems still predominantly rely on coal. Therefore, alternatives for the transformation of coal-related infrastructure are critical for future urban planning strategies to enable a new adaptable way of living without carbon energy. In the first part, this paper will investigate how coal energy framed current architecture and infrastructure, which indicate why Poland and Bulgaria are reluctant to act due to their deep-rooted energy grids. The analysis of urban economic changes through satellite maps and archived photos in Poland and Bulgaria will demonstrate how their regional urban redevelopment gives urban planners directions for future transition. The last part explores new standards of living comfort for inhabitants to follow to propose new design schemes that architects and engineers should implement. This is supported by evaluations of building design strategies from existing projects. These strategies can suggest future redevelopment of coal-related industrial clusters and prepare a way of living without coal.

Chapter 1: Introduction

Coal has formed and existed on earth for millions of years. By the Industrial Evolution in Britain, its undeniable abundancy made it a new energy source for economic and domestic human activities. In the nineteenth century, the first coal-fired power plant was established in London, where the coal industry incorporated coal into domestic and industrial electricity use. Since then, it infused our existing urban landscape with carbon forms, a notion Elisa Iturbe refers to is the space, form and interventions in life that emerged because of fossil fuels (Iturbe 2019). The coal industry, as an example, is presented with carbon forms such as coal mines, machineries, cooling towers, transmission tower, substations, and power poles (Figure 1). It shows a flow of converting coal to a form that runs from industrial infrastructure to domestic scales and eventually become an intertwined urban grid system. As new architectural typologies like power plants and substations appear, inevitably, the growth of coal industries coincides with urban typologies from regional towns, suburbs to cities (Figure 1). Coal was a vital commodity for domestic use when households had replaced firing wood with coal long before its industry flourished. In houses, coal existed as appliances in kitchen stoves, home heaters and gaslight lamps that light coal to make gas. As a new experience of living, people grew more comfortably with bringing coal indoor. Moving away from heating with wood brought excitement, and likewise, carbon forms, into our home. These quotidian commodities unconsciously shifted our understanding of domestic comfort, similar to the shift of our society experienced from hunting and gathering to agricultural living. Subsequently, the reassurance of having abundant fresh food from refrigerator shelves and the expectations of having underfloor heating are the climate-controlled comfort that coal brought to us.

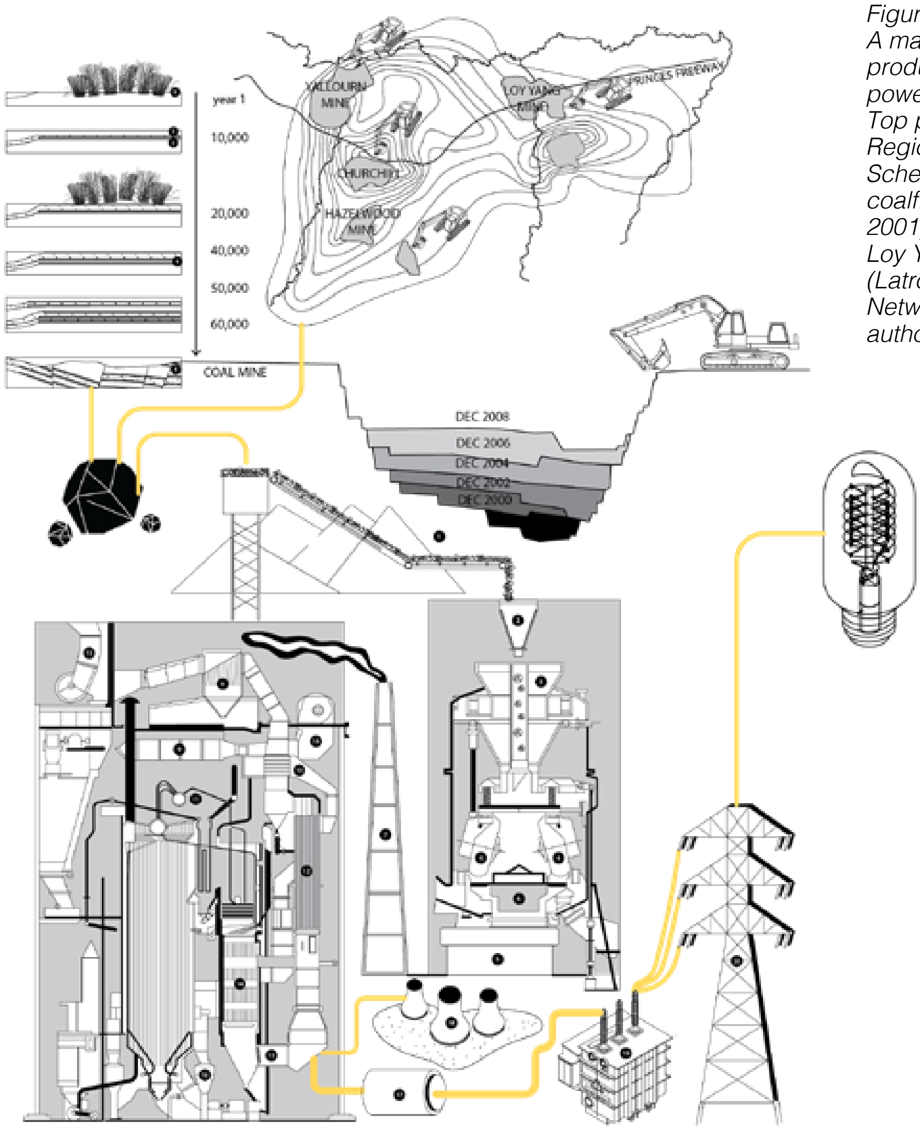

Figure 1
A mapping of coal energy electricity production and distribution of power plants in Victoria, Australia. Top plan and section referencing Regional Subsidence Contours and Schematic section of Yallourn east coalfield (Schaeffer, Laird, et al., 2001), bottom sections referencing Loy Yang B Power Station Schematic (Latrobe Valley Air Monitoring Network Inc, 2021). Courtesy of the author.

The previous energy phases have produced distinctive conditions of living standards that brought different understandings of comfort to us. However, in each energy shift, comfort has improved quality of life, efficiency, convenience, and many other aspects that individuals can perceive. Architecture and urban planning are the physical space framework where comfort may be designed, performed, and sensed. With an expected vision that the world will live without coal, this thesis examines the influences of retirement of coal power plants on architectural design, urban planning, as well as the understanding and experience of living comfort.

A system full of carbon forms that was once designed by architects and planners around big, centralised power plants is slowly phasing out because of its overwhelming influence on climate changes and a finite amount of coal. Upon the coal energy transition and power plants closures, the thesis envisions two scenarios: 1) the electricity network will rely on other sources of energy and hence there will be 2) a decreasing consumption of electricity, carbon, and waste. The effects of such scenarios will be analysed through the lens of comfort.

The retirement of coal power plants must lead architects, urban planners, and inhabitants to design collectively and redefine living comfort. Instead of introducing carbon forms and making carbon forms and carbon comfort readily available in each household like the previous modernists did, the climate crisis urges the adjustment to their progressive departure. It will introduce a new normal way of living with other forms of energy and induce a decrease in electricity consumption. The inclusive participation of these stakeholders in the retirement of ageing coal-fired power plants, implementing carbon policies and alternative planning and design methods need to be developed by public authorities to address changes in the system of comfort. These concepts will be explored in scales that follow the coal energy's flow: from power plants, energy grid, to public and domestic buildings (Figure 2).

Figure 2
Distribution of coal-powered electricity from Loy Yang coal mine to the authors apartment in Carlton, Melbourne. The energy flow is represented in the physical forms: coal power plants, energy grid and individual buildings. Courtesy of the author.

Specifically, this paper focuses on Poland and Bulgaria as energy transition representatives (Figure 3). These two countries have already shown ambitions for coal power plants decommissions and urban redevelopment strategies. Yet, the statistics prove they share the same reluctancy on transitioning and still heavily rely on coal energy as electricity source. In 2017, in Bulgaria, coal power plants accounted for 45.9% of the total electricity production, whereas in Poland, the percentage was 49.2% in 2018.

Primary energy production		2018
Total primary energy production*	Mtce	16.8
Brown coal and lignite (saleable)	Mt / Mtce	30.3 / 7.2

Primary energy consumption		2017
Total primary energy consumption*	Mtce	26.8
Coal consumption	Mtce	8.8

Bulgaria

Primary energy production		2018
Total primary energy production	Mtce	88.3
Hard coal (saleable output)	Mt / Mtce	63.4 / 51.7
Lignite (saleable output)	Mt / Mtce	58.6 / 16.6

Primary energy consumption		2018
Total primary energy consumption	Mtce	150.7
Hard coal consumption	Mtce	63.5
Lignite consumption	Mtce	16.6

Poland

Figure 3
Statistics of primary energy production and consumption, with reference to solid fossil fuels production and consumption in Bulgaria and Poland (Eurostat, 2020).

Methodology

This research study is divided into four parts to propose a vision for the future of coal power plants, their energy grid transition and living comfort of inhabitants in Bulgaria and Poland. The first part investigates the framework of coal energy that has shaped how architecture is thought and built, which granted rise to necessary changes in architectural design paradigms for coal energy transition. The second chapter will look at coal power plants, where the energy is generated, and their transition strategies. This is followed by the analysis of urban economic changes in Bulgaria and Poland where innovative urban planning strategies show directional transition paths for their energy grid transition. The last part of the thesis explores the living comfort standards of urban residents in public and domestic buildings where the architect's work is designed, managed and desirable for the dwellers.

Case studies with innovative post-carbon designs will support the hypothesis of shifts in architectural design paradigms. By proposing planning methods indicated by case studies of power plant transformation in Bulgaria and Poland and cataloguing their energy grid systems from satellite maps and archive photos, this essay will focus on an approach to frame a new comfort system from the planners' and architects' angle. The analysis of building designs which are targeting innovative refrigeration, cooling, and heating designs will highlight ways for future living to change the current notion of comfort. These strategies suggest the redevelopment of urban clusters and the future way of living.

Chapter 2: The influence of energy on modern architecture in the 20th century

It is important to look at the basic structure of coal energy systems that sparked the modern movement and the ideology of postmodernism. In the early twentieth century, these systems had influenced modern space and adapted to proposed futures— the modern life. This process led to the creation of material realities of carbon forms that hinder their removal and modification. It is a system that expanded from coal infrastructure to our homes. This inclusion into the daily life of inhabitants' makes it now difficult to transform.

In his book, The New City: Principle of Planning, Hilberseimer identified that machines and industrialisation of the machineries were two components that contributed to a changed scene of social life (Hilberseimer, 1944). The Industrial Revolution marked transport and industrial machines that urged for more than sufficient sources of energy. As a result, excavations of coal mines and appearance of many coal power plants became the evidence of the society entering a new energy evolution in the early twentieth century. However, buildings that existed for centuries weren't prepared to deal with the space required for energy production machines and logistic systems. A design paradigm was then realised for the needs of new typologies of infrastructure.

As the current biggest producer of brown coal, Germany was profoundly influenced by the coal industry. Concerning the contemporary industrial building design, the 1909 AEG turbine factory produced turbine and generators to contribute to new power plants. In Berlin, the factory celebrated new technologies and electricity production that made mass production of machines possible. Through spatial planning, Peter Behrens illustrated how factories were initially thought and designed to accommodate new needs and set new architectural standards for industrial facilities. The assembly hall considers the scale of height for all machineries. In his cross section, slewing cranes and overhead cranes were accommodated to allow movements of both machines that operated production lines and turbines that were produced (Figure 4). With operational cranes, completed turbines and generators, the machines could be moved from the assembly line to a loading area.

The rigid dimensions designed for operation, storage and utility are proved amenable for other types of production too. In 1947, the main hall was adapted for the use of car production (Figure 5). It is no doubt that the influence AEG factory had on contemporary architects went beyond providing a factory model that engineers desired. Its materiality had framed symbolic impressions of modern industrial buildings. Unlike traditional factories, the assembly hall was visible to the outside as an exhibition for machines. These gestures are Behrens' attempts for "the new power of industrial civilization". (Bryant, 2000). By exposing its interior, AEG factory manifested the power of the energy industry visually to the public through its expressive glazing, concrete walls, and iron structure.

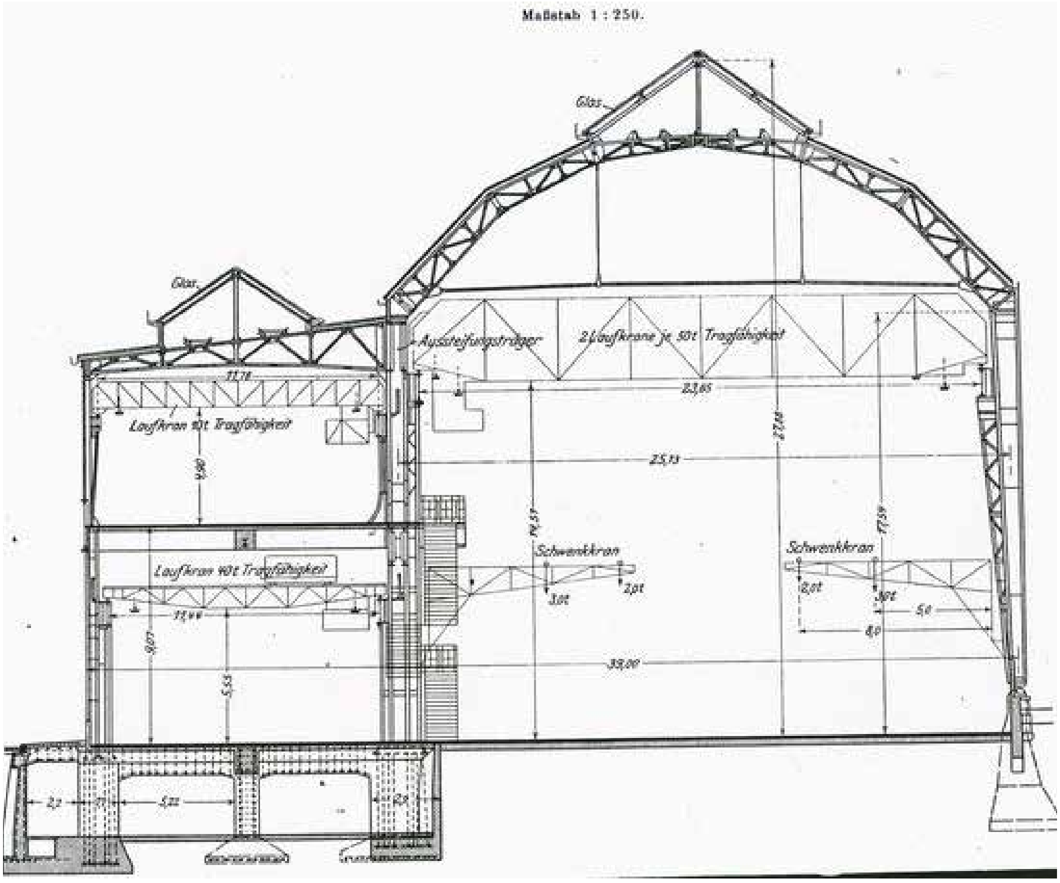

Figure 4
AEG turbine factory, transverse section (Behrens, 1909).

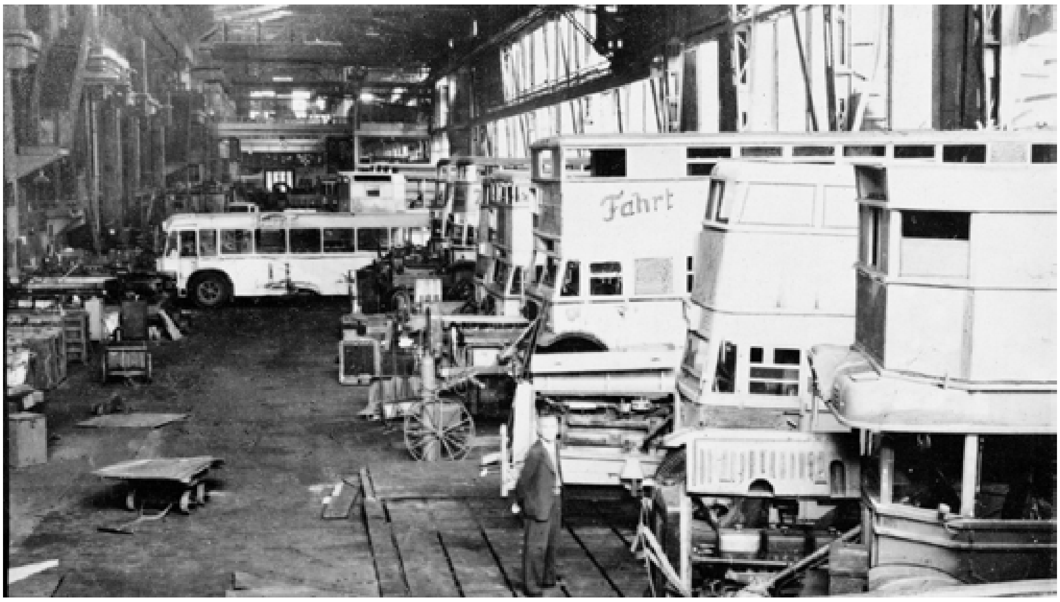

Figure 5
AEG turbine factory, assembly Hall for public transportation repair in 1947 (Siemens AG Company, 2017).

With Le Corbusier's Weissenhof-Siedlung house 14 and 15, the architect's initiative for constructing a modern living experience can be found without effort. Realised in 1927, its ground floor came with a coal cellar, furnace room and utility room to address an envisioned lifestyle the house would support (Figure 6). Three years later, in his project Villa Savoye, the movement of automobiles is suggested on its ground floor plan within the garage (Figure 7). In the world Le Corbusier imagined, energy and new technology were provided in a physical environment to pass comfort to its inhabitants enjoying their daily routines. His proposition of "machine to live in" showed purposes of each spatial and formal decision in Villa Savoye. The continuity of garden view was achieved by pilotis, Open-air and natural light was carried out through the effect of open floor plan with horizontal windows, also the access to utility, cars, and maids was made possible through Corbusier's intended spatial arrangement. These new conditions of comfort living were put into practice. Stanford Anderson argued that in Le Corbusier's work, these seemingly fictional depictions of modern needs allowed inhabitants to live and think differently (Anderson, 1987). His early experimental and unprecedented proposals for future industry and living informed architects and engineers about a new design framework with a manifestation of coal energy in modern life.

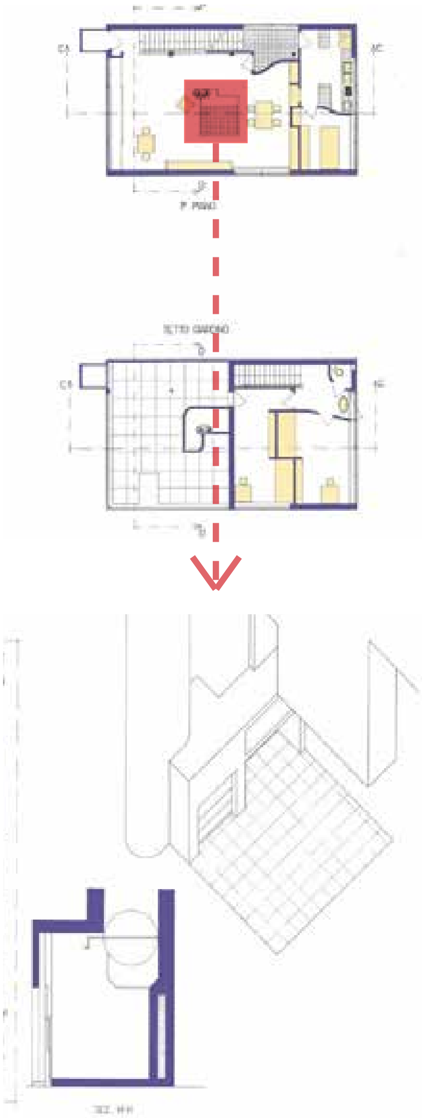

Figure 6
House 14 of Weissenhof Estate. Ground floor plan on top, Axonometric of coal cellar at the bottom (Perrot et al., 2017).

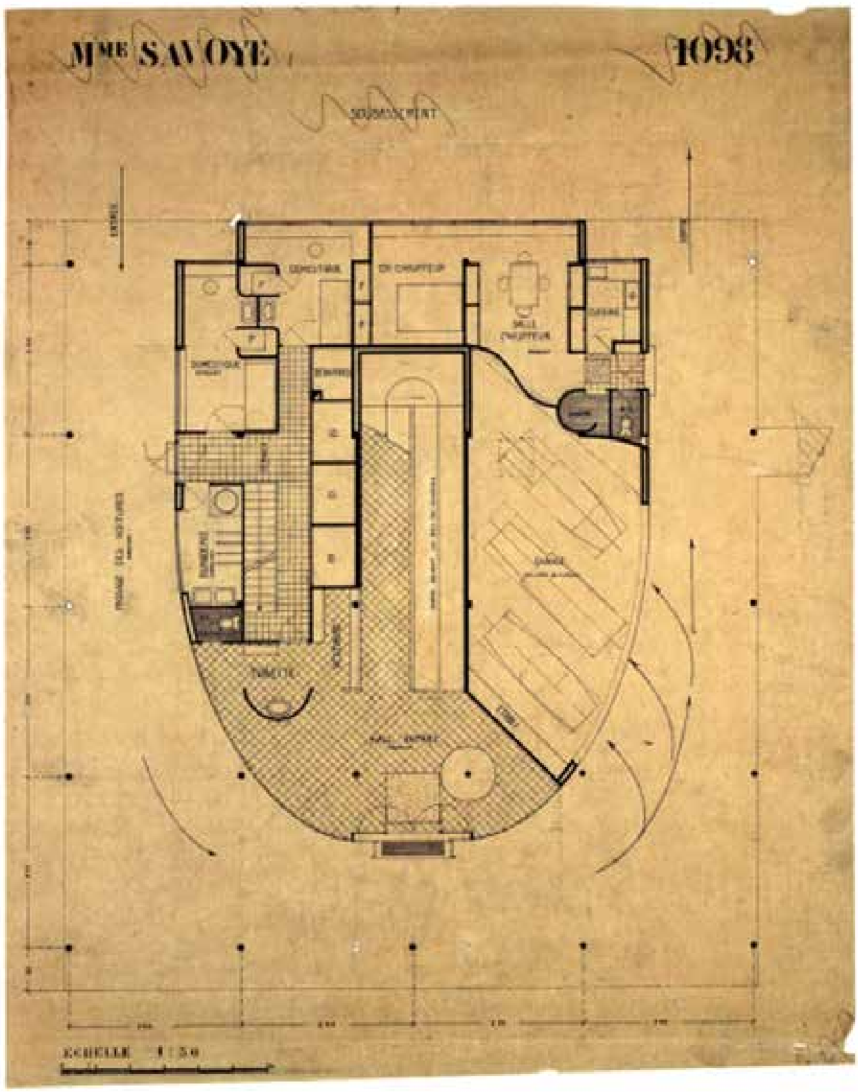

Figure 7
Villa Savoye ground floor plan (Jeanneret, 1928).

Over time, architects were exposed to the rising demands of modern life, specifically modern needs of households where people spend most of their time in. The readily available coal and energy allowed the mass production of cars, electronics, and climate-controlled interiors. Under such impact, individual households were calling for modern vehicle storage, full-time working electricity network and HVAC (Heating, Ventilation and Air Conditioning). These demands were recognised and translated by Wagner, as he described, “Modern life honours the virtues of comfort, cleanliness, and convenience.” (Wagner, 1996).

With Poland and Bulgaria, under the influence of modernists’ design framework, coal energy now represents nearly 50% of the overall energy production nowadays (Figure 2). For years, the promises of having enough coal to burn for electricity brought what people perceived as comfort to the economy and society in both countries. Besides the assurance of having enough coal energy never ended, the inhabitants still search for other forms of comfort through time.

The modernists during the 20th century in Poland and Bulgaria grew up in a period where their countries were politically troubled and economically behind. With a time-delayed modernisation, they promised the people to achieve radical social change with their new vision of architecture (Kohlrausch, 2019). While the other major European countries’ architects were developing light-filled factory with working space and fulfilling modern demands in houses and public buildings. These things stood differently for architects in Eastern and South-Eastern European countries. They wanted to do the same but also bring in social reform in the built environment. These desires are not coincidental. They respond to the callings of their societies. The people were searching for economic developments, clean home spaces, and sufficient hospitals over the ruins of destructions. For them, the notion of comfort was decided by having a well-being state of new life for themselves and the next generations. As a result, comfort is perceived differently and not always equally distributed, as Crowley(1999) pointed out, it varies from different individuals according to their age, countries or conditions.

Even though the realisation of modern life in architectural forms was postponed in Polish and Bulgarian societies, it also brought more space for opportunities, since the technological difficulties were solved by modernist forerunners. Overtime, Rapid population growth in urban areas emerged because of its successful economic and infrastructure developments (Figure 8). This is reflected particularly in Poland, in 1938, where there was an unprecedented crisis in the housing sector, involving a lack of affordable housing and excessive crowded apartments. According to Kohlrausch (2019), at the beginning of World War II, there were more than half of population in Poland who are living in one-bedroom apartments. Through time, cities were later expanded with large housing blocks providing more rooms for each household (Figure 9). By then, the concept of living comfort for the inhabitants shifted once again.

It is obvious from these early infrastructure and buildings that the system of comfort has always been hidden inside each social and technological transformations. The sensibilities of comfort in architectural forms represented an ideal state of living that gets rid of insecurity and ensures liveability as architectural forms.

Figure 8
Accident near Krakowskie Przedmieście street in Warsaw, 1931 (Narodowe Archiwum Cyfrowe, 1931).

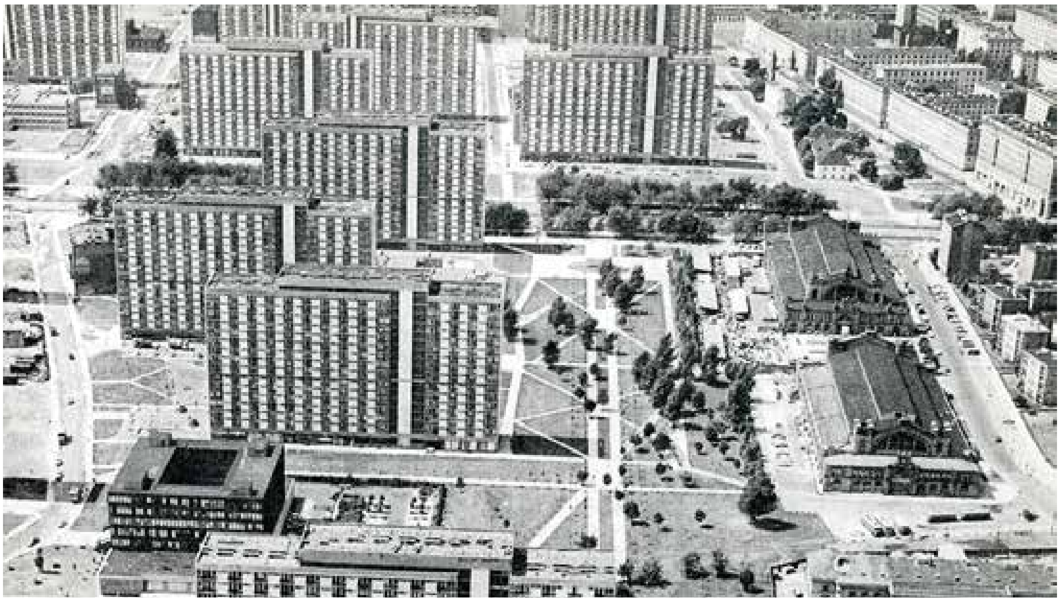

Figure 9
Aerial view of the Za Żelazną Bramą estate and the Lubomirski Palace after turning it over in the spring of 1970 (Śpiewak & Sternicka, 1970).

Chapter 3: Coal Power Plants in Poland and Bulgaria

3.1 Current Power Plant Transformation in Poland and Bulgaria

Tracing back to the power plants that manufacture coal energy in these two countries, they are only open to limited transformation strategies. The decisive factors behind it include considerable electricity demands during the Covid-19 pandemic, future economic conditions, as well as technologies advancement in production, storage, and distribution of energy.

In the context of Poland, officials announced every coal mines will cease to operate by 2049 (Karpa & Grginović, 2021). Bełchatów plant in Lodz region, the largest coal power plant in Europe, is expected to be retired, the last among all power plants. However, Figure 10 summarises Poland being the country with the largest number of plants without decommission vision (Europe beyond coal: Coal exit tracker, 2022). According to its geographic location and density of natural resources, the country had a large abundance of coal, which was a fundamental factor for the growth of coal culture. Its deep-rooted fortune on coal contributed to Poland's position on power plant retirement. Besides its heavy reliance on its coal abundancy, other sources of power are comparably neglected. This would explain why there is no infrastructure for nuclear energy (Figure 11) (Eurostat, 2020). The number of resources restricts Bulgaria's coal industry for energy production. According to Europe Beyond Coal, there are ten existing coal power plants in Bulgaria, yet, to date, the situation of future coal plants is undetermined with no retirement announcement (Figure 12) (Europe beyond coal: Coal plan database, 2022). The hesitancy in power plant closure is suggesting the country's dependence on its own coal energy system. The result of its energy self-sufficiency was also developed through its political history. Demonstrated by Tchalakov and Mitev, under the influence of communist industrialization from Soviet Union, Bulgaria could have a series of well-established policies that enabled the country to become energy self-sufficient (Tchalakov & Mitev, 2019). It can be assumed that with the same political history, Poland shares a similar reason for its affection over coal industry with Bulgaria. Despite geographical differences, their ways of dealing with transition challenges which originated from past strategies may be worth comparing.

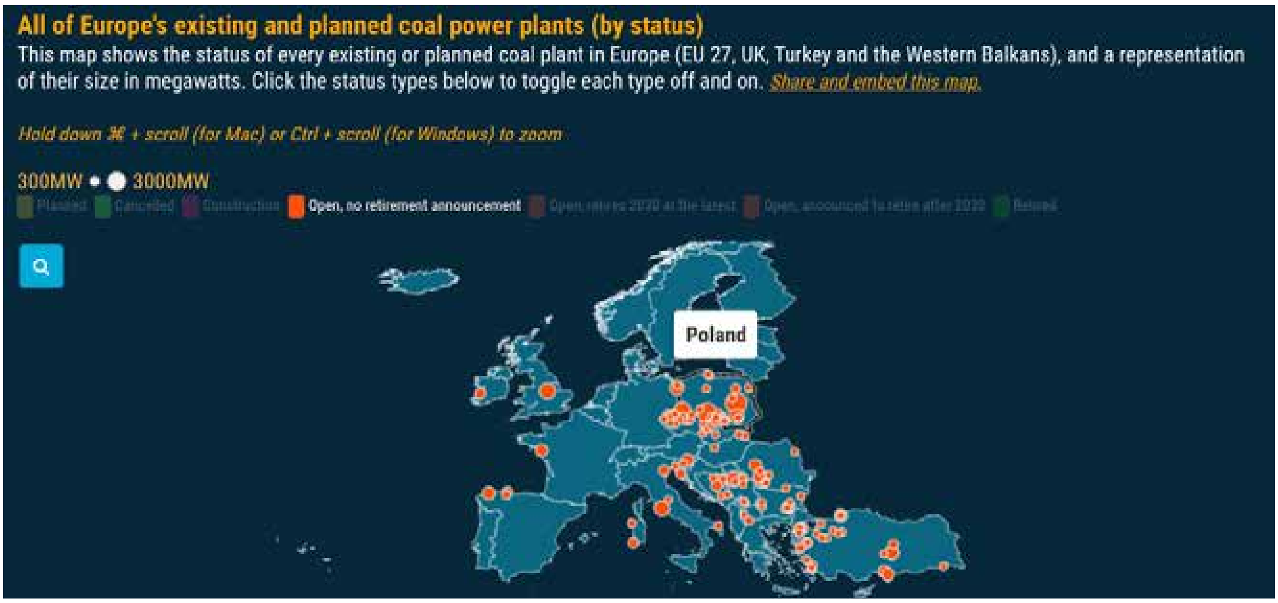

Figure 10
All of Europe's open coal power plants without retirement announcement (Europe Beyond Coal: Coal Exit Tracker, 2022)

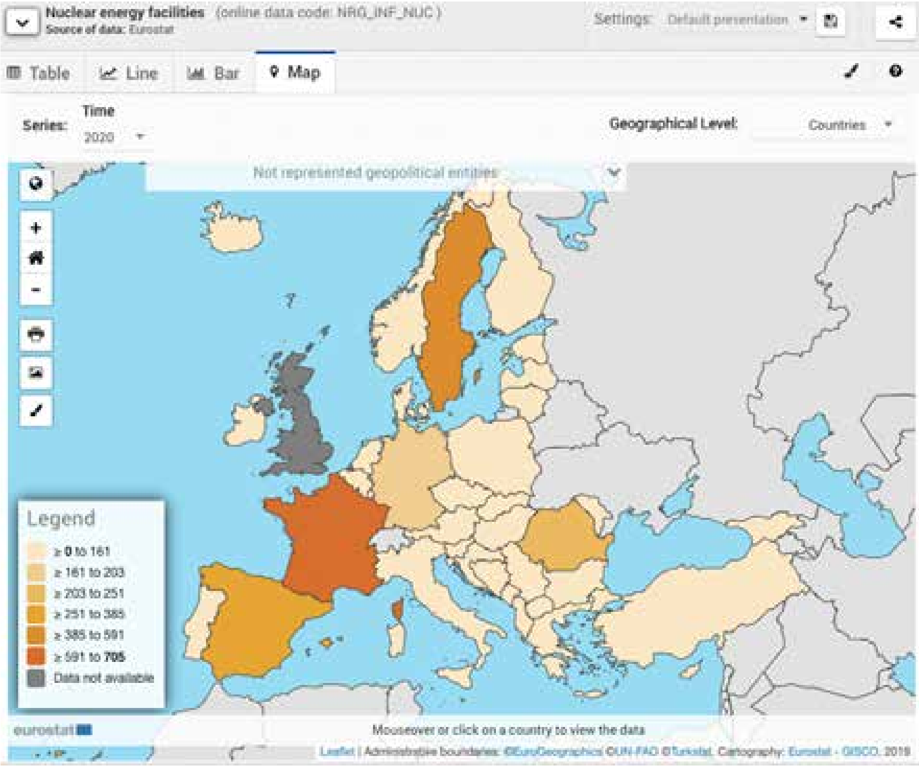

Figure 11
European nuclear energy production (Eurostat, 2020).

EUROPEAN COAL capacity/plants/uountry/company

Source: Europe Beyond Coal Database; status: 14 J

	Status @ 14 Jan 2022						
		Open				Retired or fuel switch	
	ion	Total	Lignite only	Hard Coal only	Open but announced to retire	Since 1 Jan 2016	Since 1 Jan 2005[1]
ALL Europe	,469	150,547	67,826	82,721	72,640	57,649	98,764
ALL Europe	3	248	101	147	105	77	140
ALL Europe	5	626	303	323	227	185	419
2. Split By Country							
EU Countries + UK							
Austria	-	-	-	-	-	3	6
Belgium	-	-	-	-	-	1	6
Bulgaria	-	10	8	2	-	-	1
Croatia	-	1	-	1	-	-	-
Czech Republic	-	31	23	8	5	3	4
Denmark	-	3	-	3	3	5	6
Finland	-	7	-	7	7	3	6
France	-	4	-	4	2	4	12
Germany	-	59	18	41	59	23	32
Greece	1	4	4	-	4	2	4
Hungary	-	2	1	1	1	-	3
Ireland	-	1	-	1	-	-	-
Italy	-	8	-	8	1	4	5
Netherlands	-	4	-	4	4	2	4
Poland	1	44	5	39	12	2	8
Portugal	-	-	-	-	-	2	2
Romania	-	8	5	3	-	2	8
Slovakia	-	4	2	2	1	1	1
Slovenia	-	2	1	1	-	1	1
Spain	-	6	-	6	3	10	16
Sweden	-	-	-	-	-	1	1
United Kingdom	-	4	-	4	3	8	14
Western Balkans							
Albania	-	-	-	-	-	-	-
Bosnia & Herzegovina	-	5	5	-	-	-	-
Kosovo	-	2	2	-	-	-	-
North Macedonia	-	2	2	-	-	-	-
Montenegro	-	1	1	-	-	-	-
Serbia	-	6	6	-	-	-	-
Turkey							
Turkey	1	30	18	12	-	-	-

Figure 12
Status of European coal plants by country (Europe Beyond Coal: European Coal Plant Database, 2022).

With modern architecture design framework and long decommission plan, the policymakers in major countries are implementing strategies to create other/new values for existing industrial monuments and avoid demolition. For instance, major energy-intensive countries such as China, India and the United States conducted experiences on transforming coal power plants to natural gas and biomass power plants (Song, Mehedi et al., 2021).

One preferred transformation tendency is by converting coal power plant to a power plant using an alternative source of energy. This trend is confirmed to be tested on-site in Poland, at Adamów power station. Retired in early 2018, its owner, ZEPAK company, released a plan to employ solar PV panels on its coal mine area later in the same year. As expected, this pilot project will construct the largest solar farm in Poland (Bellini, 2021). Its intention to adopt renewable energy on an inactive coal land is favourably welcomed by the public sector. This is merely because the strategy gives the impression that such action will generate pollution less than traditional power plants. Aside from less pollution, it also allows the energy companies to escape its duty to clean up the pollution that was already there.

The energy company would retrofit and continue its operations in a former coal infrastructure area with an already established power grid. A system with solar PV panels does not engage the use of machines like the boiler or turbines from a coal power plant. Meanwhile, Bulgarian's coal power plants will transform into natural gas and hydro-power plants. Here, the action of changing fuel is missing interest for former coal industrial buildings. In the northeast, the private authority managing Varna plant is introducing steam-gas energy production to substitute its supposedly retired coal production units (Szoke, 2021). Unlike introducing solar panels on an unemployed coal industrial area, conversions of coal infrastructure make more sense for a circular and sustainable economy (Song, Mehedi et al., 2021). Through repurposing an existing power plant, the survival of the countries' coal heritage will be performed in a comparably fair scenario regarding its economic and environmental cost. This is because that the life cycle of building materials, energy production machines and energy grid in the existing power plant is being extended. Otherwise, new plants will eventually be built somewhere else because of the lack of energy supply. The major drawback would be the detrimental environmental effects it will bring, including exigent carbon emissions from its energy production process.

Even though the mandate to retrofit coal heritage is inevitable, these strategies are targeting current infrastructure that are forced to retire within a brief period to envision future energy infrastructure. Through the invention of the light bulb, which is still being used with little design changes, we can understand how limited the technological evolution of energy infrastructure is nowadays (Freese, 2003). This comparison shows that the transition needs an evolutionary step forward. By moving the focus beyond, we can ask alternatives for our current energy infrastructure and the production systems. What are the future forms of energy production and distribution that can play a role in reforming architectural design paradigm and our energy culture?

3.2 Precedents for Future Power Plants.

The culture of coal reflects the way we use energy, similarly, the way we produce and consume energy reflects our culture (Ferry, Laylin, et al., 2018). Coal's production showed a working culture with carbon forms infused in our built environment, along with a lifestyle of constantly consuming energy and producing carbon emissions into the air. Therefore, the energy transition will force our production and consumption culture to shift. Most importantly, the way we work, live and build.

Beyond solar panels, natural gas and hydro powered electricity, other novel forms of power generation are being considered outside of Poland and Bulgaria. In Australia, another model that delivered prosperity by coal, had shown such innovative projects. Through adapting the energy system with cultural infrastructure, they propose an expanding power distribution network, a new energy culture that future architecture need to adapt. On the ground level, the projects try to transform the built environment to run on local sources for energy production. Buildings in these projects, being closely used by consumers, would be the most powerful testing ground to convince people of a new way to produce and consume energy.

Started by the research lab Finding Infinity, WOWOWA Architecture proposes to turn swimming pools in Melbourne, Australia into future power plants. The urban interventions include towers that harvest energy from an embedded anaerobic digestion system. As a novel form of energy, the anaerobic digestors process food and beverages, converting them into biogas (Figure.13). The adopted system generates self-efficient energy for the building itself while dealing with the waste produced within the communities. The future swimming pools become compilations of energy production, storage, and social infrastructure (Figure 14). Such systematic change of a building's role has the potential to create a future for power industry where its occupants become energy producers instead of consumers.

Instead of promoting buildings to harvest energy, Hassell Studio depicts a "vehicle to grid" system that integrated energy storage with future urban infrastructure. In figure 15, the proposal indicates car parks as testing grounds for the energy storage use. Being able to charge and discharge, electrical cars are foolproof for returning electricity to its city. The infrastructure turns its inhabited electrical cars into power banks of the city's cultural events. Additionally, the cultural programs are scheduled to fill in emptied parking space (Figure 16). Other breakthrough forms of energy such as spray-on solar cells, green fluorescent protein, vibration energy and algae biofuels have also been discovered, it is just a matter of time for them to be efficient enough to offer domestic electricity.

"History, we know, is apt to repeat itself, and to foist ancient incidents upon us with only a slight change of costume." (Elliot, 1973). The emergence of carbon energy changed the way architects think and build in the past, so will the novel forms of energy. Yet, modern architectural design framework that was built upon coal energy system would still inherit carbon forms that require coal as an energy source for both production and consumption. Countries such as Poland and Bulgaria, with a great reliance on coal, continue to put faith in their long-established coal infrastructure. With limited visions for coal power plants' future, there are design initiatives beyond solar panel installations that can be a model for them. Future retirement of coal power plants is implying the need for shifts in how urban infrastructure and, in a greater sense, architecture, should be thought and built for future living.

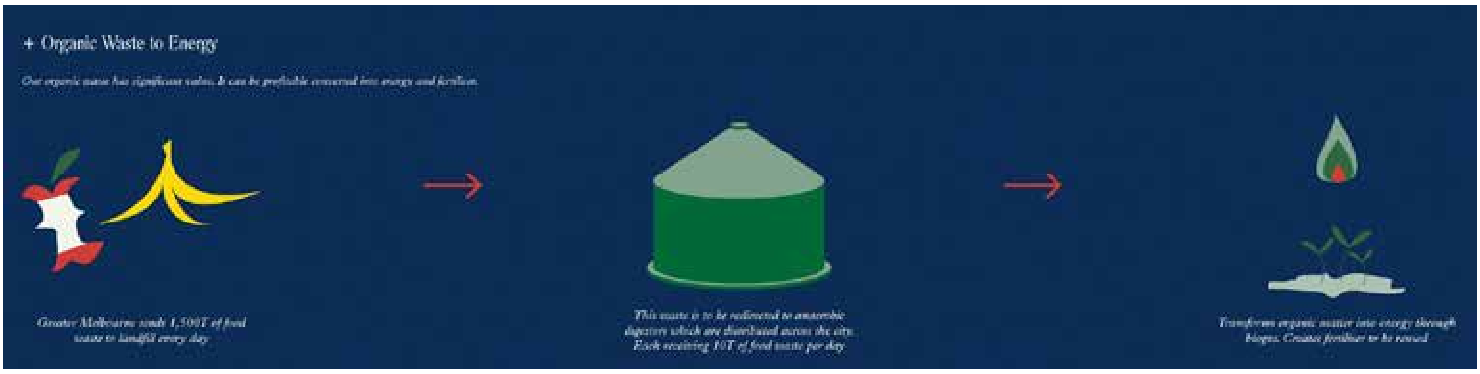

Figure 13
Diagram of an anaerobic digestion system that generates electricity (A New Normal, 2020).

Figure 14
Fitzroy swimming pool proposal (Wowowa Architecture, 2020).

Figure 15
Diagram of future energy storage grid integrated with carparks (A New Normal, 2020).

Figure 16
Little Collins Street carpark (Hassell Studio, 2020).

Chapter 4: Urban pattern and energy grid in Polish and Bulgarian coal regions

The needed shift in design paradigm applies at an urban scale too. Carbon forms in the urban model demonstrated significances in shaping our city's fabric. As mentioned earlier, it formed a mega-structure that expanded coal energy system into our living rooms. During the last decade of advocating coal exit, urban economic changes in Bulgaria and Poland have shown regional transformation pathways. These changes can be defined as urban growth - an urbanization phenomenon that is closely related to economic growth (Ioannides & Rossi-Hansberg, 2005).

There are traces that can be found in their coal regions, where postmodern urbanism gave rise to new ideas for conservative movements such as new urbanism. Instead of transforming landscapes of the modern city, the new urbanism focuses on its vernacular and community-scale approach, emphasises on the revitalization and preservation of the urban fabric (Marshall, 2003). This approach to postmodern ideas allowed for careful studies of current urban outcomes and an understanding to the spatial pattern and social representation of coal energy. Overall, it can be observed from the operated strategies and emerging local energy source studies that the transition models have potentials to become part of the future energy grid. These potentials will support future independence from the coal power grid, whose engagement is affecting the decision-making around the question of discomfort.

4.1 Coal region communities and their urban planning pattern in Poland and Bulgaria

In modernism movement, CIAM group of European architects manifested that modern city as 'the functional city', should be recognised as distinguishable areas of life (Gold, 1998). These areas would develop into larger clusters of functional models that concentrated on modern living and economic growth. It is clear in the case study of Polish and Bulgarian coal communities; their urban grids are under the influence of modernists. This will be supported by analysing urban patterns of Katowice area in Poland and Dimitrovgrad area in Bulgaria through archive and satellite photos.

Due to the impact of World War II, the urban planning patterns, and social orders of these two areas were reconstructed to a certain extent. Hence, this section will mainly focus on the period after World War II. Gold (1998) also identified the keys elements of a functional city are dwellings, work, leisure, and circulations. To compare and analyse the urban pattern that influenced by coal energy economy in the case studies, the following paragraphs will pinpoint the observations through these four elements.

Located in Silesia region, "the most coal-dependent region", Katowice is the major city with four coal power plants (European Commission, 2020). Katowice's coal industry is close to city centre for less than 50 km radius. In relation to the influence of modernism in Polish cities, Kohlrausch recognised that modernism led architects to imagine utopian future moments in modern living conditions. These conditions are often combined with 'national aspirations' (Kohlrausch, 2019). With Katowice, the national aspiration would be coal. The most significant characteristic is that these national aspirations - coal mines and related infrastructure - are occupying locations near dwelling plots. For example, built in 1958, the Łagisza Power Station in the image was set as a dystopian backdrop for its neighbouring houses (Figure 17).

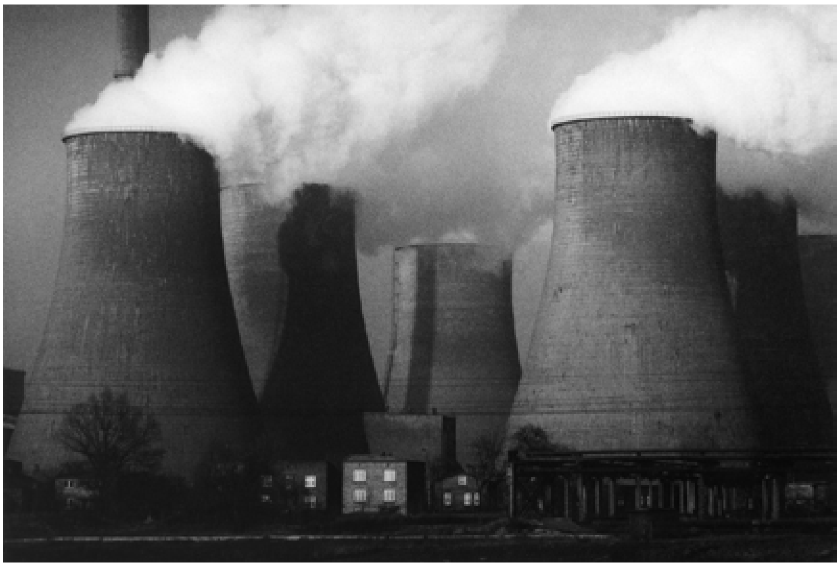

Figure 17
Lagisza Power Station,
taken in 1978 (Cala, 1978).

The large cooling towers were emitting steam to create a synthetic cloud that hovers above inhabitants. On the opposite side, the monumentality of these coal industrial infrastructures expressed easy accessibilities to energy for the occupants of the community around. From the recent satellite image, these single-family houses were kept until now (Figure 18). The incredible proximity of the community also can be found through its community church and cemetery on the north side of the cooling towers. The two northwest axes of the neighbourhood pass through these house plots, providing workers and homeowners with a circulation for access to public and private transport.

Figure 18
Satellite image of Lagisza Power Station in 2017. (Google Earth Pro 7.0, 2017).

Besides dwelling plots, several corporate offices and warehouses are at the northwest corner of Łagisza Power Station, adjacent to a rail track to leads to another coal field 8 kilometres away (Figure 19). The remote coal field shows a similar urban characteristic of the Lagisza Power Station neighbourhood, where the axis of its neighbourhood is shared between inhabitants, coal facilities, and other complementary industrial facilities. Being right next to coal fields - a national symbol of prosperity, the past and current urban pattern of the Lagisza's coal communities reflects that the living and working scenarios of occupants are intertwined with urban sceneries that shaped by coal through time.

Figure 19
Satellite image of Lagisza Power Station excavation land 2 in 2017 (Google Earth Pro 7.0, 2017).

In Dimitrovgrad, south-central Bulgaria, the city's Maritsa 3 power plant was built in 1951 after World War II. The unprecedented industrial expansion that came along with Maritsa 3's opening provided the city with infrastructural development in dwelling areas, as well as job positions in the coal industry (Dimitrovgrad Municipality, 2022). Compared with Lagisza power plant region, there is a more deliberate distinction of functional areas in Dimitrovgrad's urban pattern. For Bulgaria, the pattern of three distinctive urban articulations were built up on the communist's effect (Tonev & Tashev, 2018). During the early post-war period, the communist's governance substantially helped to build up these highly structured urban patterns that accompanied by large green areas that spread throughout the city central. (Figure 20) In the aerial photo of Dimitrovgrad, the city is being separated into three distinct parts through the public highway (Figure 21). On the outskirts of east Dimitrovgrad, two large public parks wrap around the dwelling clusters. In the coal infrastructure area, there are a few light industry companies that add on to the urban industrial clusters. These industrial clusters partake of the city's rail lines that permeate two main dwelling clusters. Public highway serves as a grid barrier and anchor point that isolates the coal infrastructure with residential areas.

The pattern of post-war urbanism in Katowice and Dimitrovgrad both showed the governments' visionary which was longing for modern living and economic growth for the whole society. Although with early intensive implementation of public and energy infrastructure in urban cities, the formed coal communities strengthened into contemporary industrial models. However, the economic changes in the contemporary are no longer depending on enterprises of heavy industry and coal energy.

Figure 20
Archive photo of Dimitrovgrad city central in Bulgaria (Dimitrovgrad municipality, 2022).

Figure 21
Satellite image of Maritsa 3 Power Plant in 2019 (Google Earth Pro 7.0, 2019).

4.2 Urban economic changes and Post-modern planning strategies in coal regions

“Some stated the pace of change in all aspects of our global society is sufficient for us to speak of revolution.” (Dear & Flusty, 1988). Regardless of the two governments’ reluctancy on coal infrastructure closure and the firmly implanted modernists’ planning, in Polish and Bulgaria, urban economic changes are parallel with the transformations to low-carbon models. By analysing the modernists’ urban pattern in the coal community models mentioned, there are complementary industrial facilities right in coal industrial clusters that had already shown potential for economic growth. The Polish and Bulgarian policy makers saw the tendency of urban economic change, thus provided similar planning strategies near the coal industrial clusters.

In late twentieth century, Katowice Special Economic Zone was established for the sake of revitalizing wasteland of former industrial and agricultural clusters (Medialab Katowice, 2012). The policy makers of the special economic zone tried to introduce innovative enterprises. The act of supporting new industry and investors to establish warehouses and offices in Katowice provides the local community a chance to gain new insights about job opportunities in alternative industry job markets. As stated by Katowice Special Economic Zone website, the incoming industry sectors were mainly taken over by the automotive sectors in 2012 (Figure 22). It is apparent to assume that before technological breakthrough in recent years, the special economic zone had a conflict of interests in creating a low-carbon post-industrial model. This is because of the unevenly distributed focus of industry on car manufacture – a major carbon emission contributor - hindered the objective of working towards a sustainable industrial cluster model.

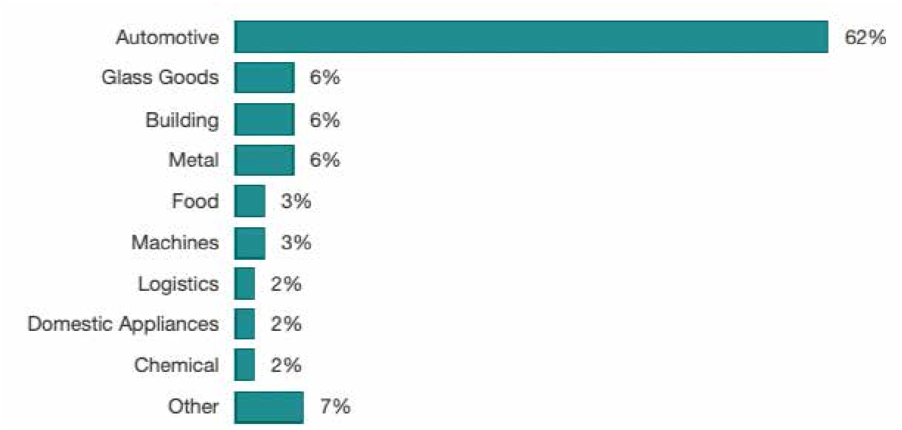

Figure 22
Total investment by industry sectors in Katowice Special Economic Zone, 2012 (Medialab Katowice, 2012).

In Bulgaria, Plovdiv’s special economic zone was also set as an example for alternative industrial restructure in areas near coal communities. Situated in south-central Bulgaria, Plovdiv is close to the Dimitrovgrad coal region. Even though Plovdiv is not under the influence of heavy coal industry, the special economic zone was set as a testing ground for its close by coal region transformations. The special economic zone, namely Plovdiv industrial park, becomes a zero-carbon industrial cluster (Kustova, Egenhofer et al., 2021). Opposed to Katowice, Plovdiv special zone selects investment sectors with satisfactory sustainable visions. According to the special zone, the investors include enterprises that are specializing in highly skilled services, such as engineering, electronics, and chemistry industries (Plovdiv Municipality, 2019).

The redevelopment of industrial clusters and planning principles of these community-building clusters that close to their coal regions promotes independence from coal energy system. This aim of using architecture and planning to invoke the new 'national prosperities' in Katowice and Plovdiv coincides with the ideology of new urbanism. As Talen pointed out, the new urbanists are concerned with the sense of community that the build environment should achieve (Talen, 1999). In the new urbanism agenda, planners are always designing for the liveability of communities by promoting diversities of working and living communities for greater social integration. The design manifestations claimed to provide solutions for reconstructing social sustainability, economic vitality that supported by architecture and urban planning (Shiebley, 1998). With coal regions in Katowice and Plovdiv, it reshaped the social expectation for coal community's living comfort while transforming the economic dependency.

The new urbanism ideas in these two regions showcased an interest in preserving the landscape of coal heritage while creating diversified communities in both residential and industrial clusters. On one hand, the paradox of new urbanism approach in city and regional reconstruction left a challenge for future energy grid transition. This post-modern approach identified in Poland and Bulgaria is only urban infill strategies. Like the modernists' architectural design paradigm, it did not include a synoptic transformation of urban grids that targets energy industry in the long run. It is understandable since the responsible technologies for energy transition have not occurred yet, whereas the modernists experienced energy transition before announcing their manifestation in modern architecture (Iturbe, 2019).

4.3 Emerging pathways for future power grids

Despite the limits of current strategies on the redevelopment of coal industrial clusters, in the Polish and Bulgarian models, there is academic research that implies alternative energy sources found onsite are creating possibilities for the transformation of the coal energy grid.

Underneath the land of Nowa Ruda, lower Silesian Coal region in Poland, the former coal mines have an underlying capacity to provide renewable sources of geothermal energy (Chudy, 2022). Due to intensive deep-mining operations throughout the development of coal industry in Poland, the closer of former coal mines accumulated underground water reservoirs. When the excavation work was ceased by local authorities in 2006 (Chudy, 2022), these reservoirs were flooded inside the mine works, along with waste materials that were left below the mining shafts. As studies suggested by Farr that these mining reservoirs of water, even though kept at a low temperature underground, can generate geothermal energy (Limb, 2022). In the diagram, mining shafts are being reused for water extraction (Figure 23). By applying heat pumps, the mining water is being heated to a satisfied temperature that can generate thermal energy.

The energy generation process includes consideration for dead coal mines and the renewable resources that were lost during the mine closure, the flooded mines in the heavy industrial clusters will be given a reliable treatment through proper actions. Studies have shown the potential resilience towards old coal mines in the Bulgarian models by coal gasification (Sheng, Green, et al., 2012). Through processing and generating an energy source under the surface of the coalfield, the production of coal gasification reuses coal industrial facilities while leaving the surface of the coalfield unharmed (Figure 24). These two approaches to transform abandoned coal mines into a new sustainable energy grid are also a retrofit for current coal regions. The geothermal and gas production of energy will then compensate the coal region communities a secure supply of electricity while getting rid of the unnecessary air pollution, waste, and toxic water that would been produced from coal energy production process.

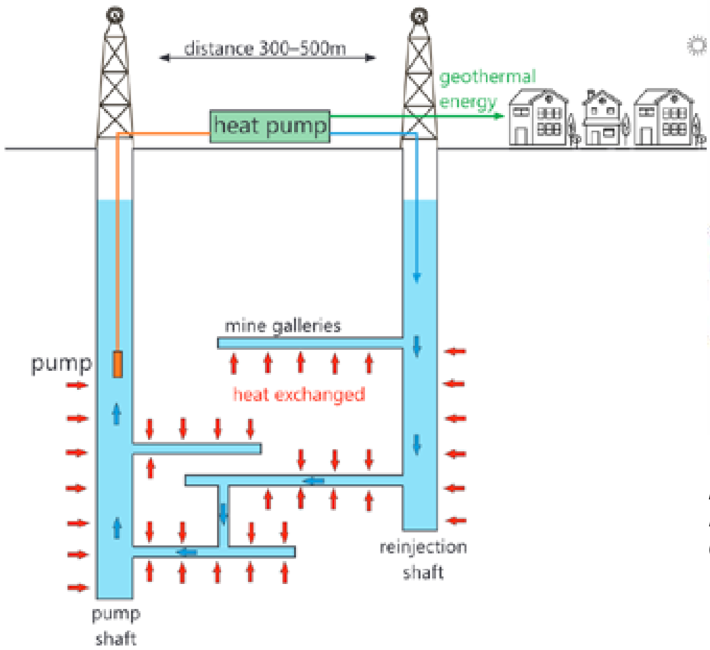

Figure 23
Electricity generation from coal mine water through a series of heat pumps and extractors (Chudy, 2022).

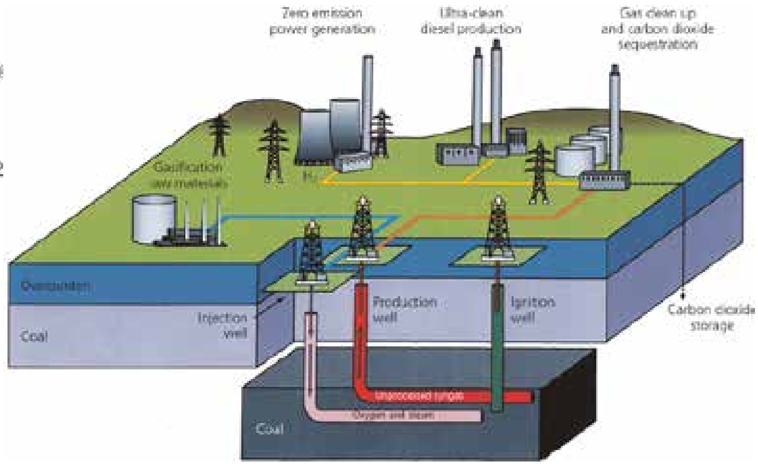

Figure 24
Electricity generation from coal gasification (Sheng, Green, et al., 2012).

Apart from adapting and integrating former coal mines into part of the future power grids, the architecture firm OMA's vision for 2050 European energy grid merge expanded and diversified research on new pathways for energy grid transformation. On the research road map 2050, OMA proposed an integrated energy network between European countries that is embedded with diverse sources of renewable energy. In the Map of Eneropa, the research recommended each country to be assigned to a specific energy production (Figure 25). These novel forms of power were decided and allocated in different countries depending on the geographic abundance of a certain energy source. For instance, Poland was named after Carbon Capture & Storage Republic and Bulgaria went by the name of East Hydropia. In OMA'S envisioned energy grid, each country would have decentralised and specialised source of power that would also be interchangeable between all the EU neighbours.

These two emerging pathways together visualise a secure supply of decentralised energy grid and they hint that the Polish and Bulgarian transition models have the potential to become a part of the future energy grid. Regarding the Polish and Bulgarian coal regions as analytical models, this chapter ushers in prospective the urban planning regime for these two countries that share reliance on coal energy grid. Through the methods of reflecting on the current urban patterns and gather collective visions for proposed urban grid, future cities with a history of coal would then introduce social and economic transformations that energy technological process would bring. For the next step, tracing from the flow of energy distribution, these visionary grid changes would then bring changes in our homes, which profoundly impact energy consumers' living standards and understanding of comfort.

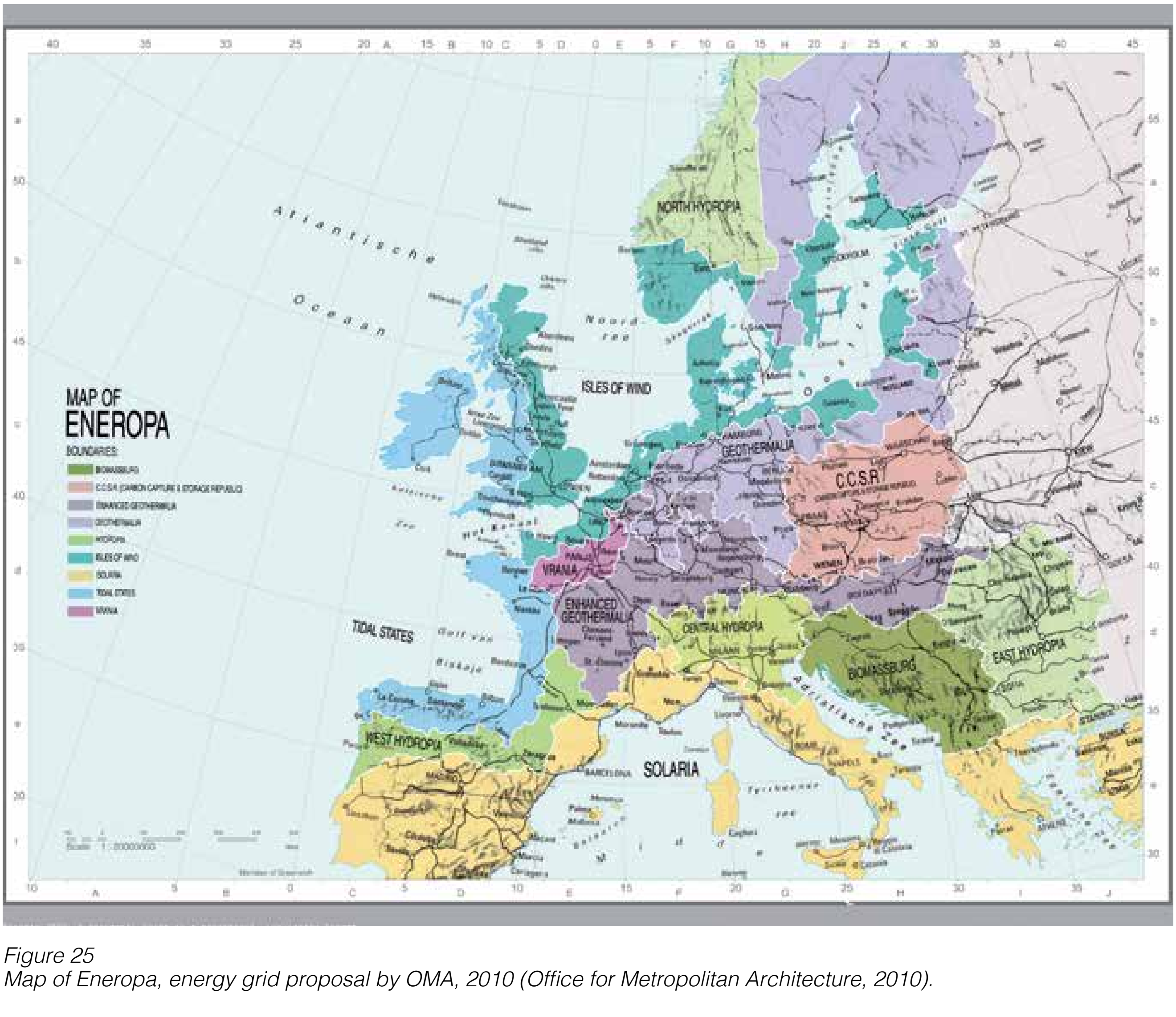

Figure 25
Map of Eneropa, energy grid proposal by OMA, 2010 (Office for Metropolitan Architecture, 2010).

Chapter 5: Living comfort

Comforts are the rungs on the ladder to luxury (Barber, 2019). With increasing requests for comfort, it leads to luxury. However, in the future scenario of decreasing electricity supply and more renewable energy because of the phase-out of coal, the understanding of comfort and luxury would then shift to a certain extent. For example, as a main coal exporter, the decreasing coal production in Australia, as well as China's ban on Australian coal have forced policymakers in northern China to limit individual households' electricity consumption in 2021 by cutting off power supply for a limited period a day in residential areas (Choudhury, 2021).

Since designing for comfort has produced a lifestyle where thermal interiors and exteriors within most modern architecture plans were poorly conceived because of the abundance of coal. This shift in living comfort standard for coal communities, as a collective event, will formulate new design schemes for the architects and engineers at a building scale. The desire for seeking a comfort living condition determined our how we consume energy (Crowley, 1999). Through the way architects and engineers design future homes, the new living comfort will the way we value space, creating a condition that requires less impact on the environment.

5 .1 Design schemes for a new standard of comfort

At a building scale, the interior is the signifier of living comfort for domestic life. Now that the structural and spatial representation of comfort is embedded in buildings, perceptions of living comfort are controlled by the designed interior conditions for inhabitants. Due to the lack of design frameworks for a new standard of comfort in a life without coal, architecture should construct scenarios to question design aspects that will be erased or preconceived for comfort design schemes of the future. It should be acknowledged by architects and engineers that there are a few fundamental conditions of designed interiors which can shape the perception of comfort in our homes. Essentially, the physical performance of a building interior can manipulate the experience of comfort in living conditions.

The most recognisable aspect of this physical perception would be the defined as thermal comfort. The thermal interiors of heating, cooling and ventilation make up the HVAC system, which is the main source of buildings energy consumption (Bienvenido-Huertas, Rubio-Bellido, 2021). Other aspects of interior comfort also include the sheltering provided by the roof and façade, as well as abundant natural life. Because of different climate conditions in different geographic locations, as well as the non-stop energy supply, the thermal interior system has been widely embraced as a general requirement of comfort. Beyond a secure supply of thermal interiors comfort, there are other aspects in living that can provide better living conditions. Recognised by Barber (2019), the higher rungs on the ladder are decided by precisions of designs such as filtered water system, filtered air, as well as acoustic insulation. These precisions of designs are supposed to optimise occupants' living comfort to a higher level.

Since the current system of comfort has been divided into two aspects that influence inhabitants: physical perception and precise sensation, these two aspects should be confronted with a hypothesis that coal will no longer provide energy for indoor use. Therefore, regulating the interiors in design schemes can help to decrease inhabitants' reliance on HVAC system.

Designed by DesignInc, the Council House 2 utilises the building itself to reduce energy required for cooling the interior. The embeded HVAC system coincides with its prefabricated double facade panel, creating a moderating thermal mass. On the outside, the chilled beams that attached to its double facade cools down the interior, as well as moderdate its exterior climate by storing cool water that were harvested from the rain (Figure 26).

However, in dealing with thermal interior, building policies in France took initiatives to confront cooling systems (Hales, 2017). Instead of reducing energy required by embedded cooling systems, the French building policies demand for direct design schemes that would understand heat stress during summer. Similarly, In the case of St Mary's Primary School, the Gymnasium was designed as a single mass that allows fully natural ventilation system and maximized insulation at the same time. In a sense, the project tries to deal with heat stress without the help of any cooling system. As an educational building, the sports activity takes place in a fully passive interior where the next generations will be trained to practice sports without refrigeration systems (Figure 27). This decision is trying to design a way of living which is current seen as a discomfort, yet a living comfort in a future scenario.

Compared to other urban areas, coal regions are more inescapable to act since they were more exposed and used to coal energy earlier during the intensive development of coal industry. The coal region communities will operate beyond as standard urban neighborhoods, and to act as a forerunner to reject and react on the architecture of carbon form, through the confrontations of comfort in living and accepting the routines of discomfort living. The current built environment celebrates the existing carbon forms which are shaped by the modernists' design schemes, at the same time, it articulated a living experience and consumerism culture in our society. Even though there are limited technology to completely change our living pattern to a zero-carbon pattern, there is work that should be carried out during this transition for architects to inform inhabitants that it's time to make a difference.

Figure 26
Exterior details of Council House 2, Melbourne, Australia (Snape, 2006).

Figure 27
New School Hall/Gymnasium/ Theatre for St Mary's Primary School in Bairnsdale, Australia.

Chapter 6: Conclusion

This thesis investigated the architecture and urban planning patterns that were shaped by coal energy, as well as addressing potentials for the current built environment to transform after the retirement of coal power plants. It looked closely at the Polish and Bulgarian coal community models through the scales of coal power plants, coal energy grid and the underlying influence of phasing out on living experiences at a building scale. The architecture modern movement reacted to a new way of living that determined by the efficiency and technological advancement in the 20th century. Through the emerging modern demands, modernists produced a design paradigm which later encouraged the use of coal energy in every individual's home.

While architecture and technological advancement encouraged new architectural typologies and housing designs, it introduced an understanding of comfortable homes that regards the previous accepted living standards as discomfort. This research continued to explore the shifts in the notion of comfort in the Polish and Bulgarian models by focusing on three signifier of coal energy: coal power plants, energy grid, and buildings.

Countries such as Poland and Bulgaria that rely on coal greatly make use of long-established coal infrastructure which therefore limits the visions of coal power plants' future designs and initiatives. Thus, policymakers ought to encourage energy companies not to hesitate when dealing with retired power plants and their underlying pollution, whilst investing time on the research of other novel forms of energy and localizing energy generation facilities.

The needed shift also involves changes in urban growth in relation to economic growth through analyzing Katowice and Plovdiv. There are significant motivations for energy transitions in the case of Poland and Bulgaria because of their success in the redevelopment of industrial clusters. These redevelopments enlightened these two countries with ways to make first move for urban growth by changing the focus of economic growth. The two cases both coincide design livability of communities by promoting diversities of working and living communities to increase social integration. These ideas help preserve the landscape of coal heritage as well as create diversified communities in residential and industrial clusters. Yet, for the next stage, Polish and Bulgarian government should also try to look at suggestions made by researchers on how to prepare the current energy grid for future adaptation on a urban scale.

Lastly, due to the lack of design frameworks for comfort without coal, it is important to question the design aspects for comfort design schemes of the future. During the energy transition, architects and engineers will redefine the notion of living comfort for urban residents in current coal regions, with designed, managed, and desirable interiors through architectural practice. Moreover, adapting current architecture of carbon forms into buildings that are not in favour of carbon forms can help reshape our culture of consumers into a culture of producers. Specifically, the architects' imperative job is to use physical designs to lead occupants lower their everyday energy and consumption expectations, educate future energy production methods, as well as

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