Energy

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Glossary

Energy landscape A landscape whose physical, functional, and symbolic characteristics have been significantly altered by energy developments and infrastructures

Energy poverty A situation in which a person or household is unable to attain energy services at a socially- and materially-necessary level

Landscape The collection of material and cultural features characterizing a particular space

Place attachment A positive emotional connection with familiar locations such as the home or neighborhood

Energy is becoming a major topic in human geography. How energy is secured, supplied, and consumed is fundamental to the form and functioning of economies, political systems, built environments, social relations, and livelihoods. Many of our contemporary understandings of what constitutes a prosperous and decent society are dependent on the production and consumption of significant amounts of energy.

At the same time, major ecological and social challenges can be traced to energy generation, transmission, and use. Climate change results from greenhouse gas emissions generated by burning of fossil fuels for electricity, heat, or transport. Energy security, ensuring provision of the reliable and consistent supplies of energy, is a concern for many countries around the world. And there is a need to ensure that energy is available for households at an affordable price, a situation that is not the case for millions of people around the world. Yet attempting to address one of these problems can sometimes be in tension with resolving another. For example, shifting to a low-carbon system of energy production based on renewable energy in response to climate change can be in conflict with ensuring security of supply, due to the intermittent nature of renewable supply. The combination of these three challenges, and the tensions in reconciling them, is often termed the "energy trilemma." Nonetheless, it is widely accepted that a rapid and radical global change in the way energy is secured, supplied and consumed is necessary.

The centrality of energy to social and spatial relations, along with the significant difficulties posed by the energy trilemma, have popularized the study of energy within human geography in recent decades. The term "energy geography" is typically used to describe the application of geographical ideas, approaches, and methods to the study of energy systems. Its history dates back to at least the 1950s, with early work in energy geography having a predominantly descriptive focus, aiming to describe the distribution of energy production and consumption occurring on the Earth's surface. The field has evolved since then via the rise of more explanatory and critical studies. These seek to understand the underlying processes that give rise to energy-related patterns and dynamics, and their implications for social and environmental well-being. Within this broad remit, geographical research on energy is very diverse theoretically, methodologically and philosophically. This has led some to argue that the plural, "energy geographies," is a more appropriate label.

Despite this diversity, one key principle that holds together much contemporary geographical research on energy is the idea that energy systems and social and spatial relations are co-constituted. This idea describes a two-way relationship between energy and society. On the one hand, the organization and dynamics of energy systems are influenced by, and embedded within, the distinctive (political, economic, social, material) characteristics of a given spatial context. On the other, energy systems are deeply implicated in producing social life and the construction of space, giving rise to particular ways of living, working and moving around. From this perspective, to fully understand the organization of energy systems one must also developed a contextualized understanding of society, and vice-versa.

Geographies of Energy Production and Supply

Fig. 1 shows the proportion electricity generation coming from different sources, and compares the 39 high-income countries that comprise the Organisation for Economic Co-operation and Development (OECD) with the rest of the world. It shows that, on aggregate and in both the OECD and non-OECD areas, the majority of the world's electricity is generated using fossil fuels. Rates of fossil fuel use are higher in the non-OECD area, although this is largely due to higher rates of nuclear power generation in the OECD area. The proportion of electricity coming from renewable energy sources is very similar between the two areas.

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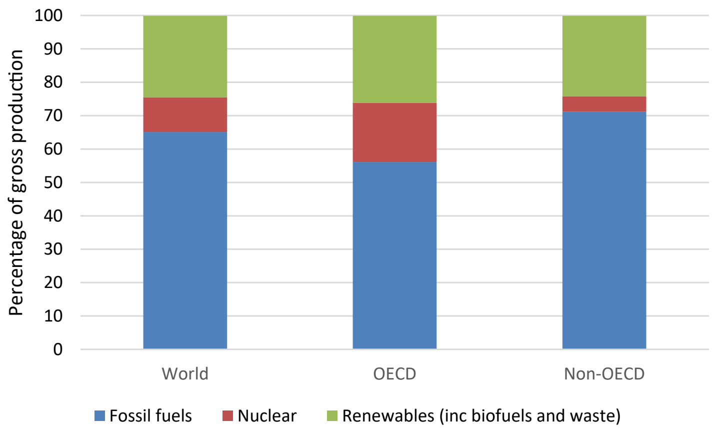

Figure 1 Percentage of gross electricity production by source, 2016. Based on IEA data from Electricity Information: Overview © OECD/IEA 2018, www.iea.org/statistics, License: www.iea.org/t&c; as modified by Neil Simcock.

This higher aggregate rate of fossil fuel production in the non-OECD countries is significant in terms of global carbon emissions, since in 2016 these country's share of electricity production reached approximately 56%, roughly double the share they held in 1974. This rise in percentage terms is because, in terms of absolute amounts, electricity generation has risen at a faster rate in non-OECD countries compared to the OECD. In 2016, approximately 14,000 TWh electricity was generated in non-OECD countries and 11,000 TWh in the OECD. It is also important to recognize that the non-OECD group comprises 154 countries, compared to 39 countries comprising the OECD. Therefore, on a per-country basis, the OECD countries are still, on average, far more energy-intensive and generate more electricity from fossil fuels.

At a finer scale of analysis, Table 1 compares the individual countries that comprise the European Union. It shows significant differences between nations in the amount of electricity they generate. The vast majority of EU electricity production occurs in

Table 1 Gross electricity generation in TWh for EU countries, 2015

Country	*Fossil fuels*	*Nuclear*	*Renewables (inc biofuels and waste)*
Austria	13.7	–	51.6
Belgium	27.3	26.1	16.8
Bulgaria	24.6	15.4	9.3
Croatia	3.7	–	7.7
Cyprus	4.1	–	0.4
Czech Republic	46.2	26.8	10.8
Denmark	9.2	–	19.7
Estonia	8.8	–	1.6
Finland	14.2	23.3	30.9
France	34.1	437.4	96.6
Germany	352.9	91.8	200.4
Greece	36.9	–	15.0
Hungary	11.1	15.8	3.4
Ireland	20.2	–	8.2
Italy	169.6	–	112.8
Latvia	2.8	–	2.8
Lithuania	2.3	–	2.4
Luxembourg	0.8	–	1.9
Malta	1.2	–	0.1
Netherlands	89.3	4.1	15.3
Poland	141.3	–	23.4
Portugal	26.6	–	25.8
Romania	28.1	11.6	26.6
Slovakia	5.3	15.2	6.3
Slovenia	4.8	5.7	4.7
Spain	122.4	57.3	101.1
Sweden	1.9	56.4	103.8
United Kingdom	178.9	70.4	89.9

European Commission, 2017. EU Statistical Pocketbook 2017. Brussels, EC.

a relatively few countries—Germany, France, Italy, Poland, Sweden, Spain, United Kingdom—while some nations are reliant almost entirely on imports (e.g., Latvia, Cyprus, and Croatia). Such dramatic variations will generate significantly different landscape impacts between countries, as well as shaping geopolitical relations within the EU space.

Table 1 also allows comparison of the amount of electricity generated from different sources. In ten EU countries, electricity generated from renewable sources is greater than from fossil fuels, and in several others renewables are almost on parity with fossil fuels. This parity is reflective of the fact that renewable energy capacity in the EU increased by 71% between 2005 and 2015, although these figure represents only electricity generation and does not take into account energy utilized for heating or transport. When these are taken into account, energy production from fossil fuels still far outweighs renewables.

Energy Landscapes

A central concern for many geographers engaged in energy studies is the profound ways that energy systems shape and transform the Earth's landscapes. Indeed, it has been argued that the notion of "energy landscapes" is one of the most intriguing, challenging, and important issues in energy geographies. Some geographers have argued that the term energy landscapes should be used to describe those places whose physical, functional, and symbolic characteristics have been significantly altered by energy developments and infrastructures. Given the significance of energy for all human activity, it could be argued that it is now difficult to find a landscape that hasn't been altered in some way by energy systems. Instead, it may be more accurate to consider different degrees of impact.

Energy systems transform landscapes in a multitude of ways. Some of these can be indirect, relating to the ways that energy enables any aspects of human activity. Changes in the way energy is supplied and consumed have underpinned major social and geographical change throughout history. The "time–space compression" enabled by abundant and cheap energy sources has transformed economic activity, driving a rapid expansion in global trade and the emergence of international production networks and divisions of labor. Meanwhile, the spatial form and organization of cities have been dramatically altered by the advent of fossil fuel production and new types of energy transmission infrastructure. Whereas many older cities were founded in close proximity to energy resources or power generation facilities, as energy transmission infrastructure improved, cities were no longer required to be close to energy generation infrastructure. The widespread availability of electricity and motor cars has also enabled lower-density living, evident in the expansion and spread of city suburbs in many places. Changes in energy systems have also had a significant impact on landscapes in rural areas. For example, in Europe rural landscapes are no longer solely the dominion of farming and food production, as was the priority in the years following World War II. Increasingly, rural areas accommodate energy infrastructures into their landscapes and livelihoods, underpinned by narratives of (sustainable) rural development and self-determination.

Energy systems also transform landscapes in more direct and obvious ways, via the various infrastructures— mines, power stations, electricity cables, gas pipelines, oil refineries, waste disposal sites, and so on—associated with energy capture, production, transmission, and consumption. Some of this infrastructure is often invisible in everyday life, either physically hidden (such as submerged underground or within other built structures) or simply a taken-for-granted part of everyday spaces.

Technologies of energy generation are some of the most visible, and often contentious, ways that energy systems (re)shape the physical and cultural features of landscapes. These technologies are extremely varied in their material makeup and geographical characteristics. At least three material characteristics shape the geography and landscape implications of energy generation technologies: scale, site specificity, and spatial dispersion (Table 2). Across these tenets, a broad distinction can be observed between fossil fuel and nuclear energy generation, on the one hand, and renewable energy technologies (RETs) on the other.

Scale refers to the material size and areal extent of energy infrastructure. The scale at which an energy technology is deployed has important implications for its landscape impact in terms of physical presence, connection to other physical infrastructure (such as power lines and buildings), degree of mobility, and potential for environmental impact and disturbance. Fossil fuels (coal, oil, and

Table 2 Key geographical features of different energy generation technologies.

	Scale	*Site specificity*	*Spatial distribution*
Wind	Household, community and macroscale	High	Diffused
Solar	Household, community and macroscale	Medium	Diffused
Hydro	Household, community and macroscale	High	Macroscale projects—centralized Household and community scale projects—diffused
Coal	Predominantly macroscale when used to generate electricity. Household and community scale possible when used for localized heating.	Low	Centralized
Gas	Predominantly macroscale when used to generate electricity. Household and community scale possible when used for localized heating.	Low	Centralized
Nuclear	Macro	Low	Centralized

gas) and nuclear energy power stations are most often developed at a macroscale, with a single large facility typically able to generate large amounts of energy sufficient to sustain several thousand homes. In contrast, a core feature of most RETs it the affordance of much greater scalar flexibility, being capable of deployment at a wide variety of material sizes ranging from "microscale" developments deployed on an individual home, "meso scale" initiatives design to provide for communities or neighborhoods, and "macroscale initiatives," such as large wind or solar developments that generate megawatts of electricity.

In terms of site specificity, in order to function, the vast majority of RETs (biomass and waste being exceptions) must be spatially tied to sites where the fuel to be exploited is located. For example, geothermal power plants need to be sited in areas with underground aquifiers or hot rocks, and tidal power to places with sufficient tidal ranges. Wind energy and solar energy are more flexible, but to function efficiently they must still be sited in places with appropriate degrees of wind speed and sunlight, respectively. For wind turbines, this requirement has led to their siting in areas previously "untouched" by energy generation infrastructure, such as rural localities of high elevation, or offshore and coastal areas. The diffusion of solar energy, meanwhile, has seen the proliferation of new sites of energy production, from large solar farms in deserts and agricultural land to urban buildings. Because the capacity to take up different RETs is closely linked to geographical conditions, different RETs can exhibit very different spatial patterns of deployment.

By contrast, fossil fuel and nuclear power plants have far fewer locational constraints, because their respective fuels (e.g., coal, gas, oil, uranium) are able to be transported from site of extraction to site of production. One exception is the need to be close to a water source, as this is often essential for functioning but is typically expensive to transport—hence the tendency for nuclear power stations, for example, to be located in coastal areas.

The combination of differences in spatial scale and locational constraints ultimately results in very different geographies of spatial dispersal. Fossil fuel and nuclear power stations have a relatively concentrated distribution, being focused on a few large-scale sites. RETs are far more widely dispersed across space via many generating sites of varying capacities, typically impacting upon a much greater number of places and landscape types (such as urban and marine environments).

These differences between technologies have important implications, especially in societies aiming to greatly increasing their low-carbon forms of energy generation in response to climate change. Such transitions will result in significant land-use changes and new geographies of energy production, with the spatially dispersed nature of RETs meaning that energy generation becomes a driver of landscape transformation across a wide range of spatial settings. Places that were for a time relatively distant or disconnected from energy generation, such as urban centers or isolated rural idylls, are now once again becoming sites for the production of energy.

Furthermore, it is also vital to recognize that the landscape impacts of energy systems are the not only the result of their physical characteristics. Human geographers taking a socio-technical approach emphasize that technologies and infrastructures are always simultaneously material and social. Energy generation technologies can be developed, owned, and governed via multiple types of social organization, including by nationalized utilities, private corporations, local municipalities, community enterprises, and individual households. Each of these different forms of social organization distributes decision-making power and project outcomes very differently, and consequently plays a central role in shaping the social meaning and identity of any particular energy development and also therefore its landscape implications. Depending on its mode of social organization, an energy generation development may be viewed as, for example, a tool of corporate profit, a symbol of community empowerment, or an external imposition on local democracy.

These complexities emphasize that the precise ways that energy generation produces and transforms landscapes are very diverse and hinge on many contingencies such as a technology type, scale, and mode of social organization and governance. These contingencies, and thus the landscape impact of energy generation, are not pre-ordained but arise from economic and political decisions about which technologies should be pursued and how energy systems ought to be organized. Looking to a future in which many countries aim for a much greater level of electricity production from RETs, there are important political decisions about which sorts of energy landscapes ought to be made. Nonetheless, the landscapes of any low-carbon society will be quite different to those reliant on fossil fuel and centralized energy technologies.

Energy and Landscape Conflicts

The development of energy infrastructures and the landscape transformations they produce are frequently a source of considerable contestation and debate. Plans for new energy developments can lead to substantial resistance, often pitting opposition groups and local publics against those supporting or proposing to build such infrastructures. Public attitudes can have a significant impact on what and where energy technology is developed, alongside projects' constituent features such as size and scale. Geographers have been at the forefront of research that seeks to understand and explain public attitudes toward and conflicts around, new energy infrastructures.

Interestingly, in many countries some energy technologies (such as wind and solar power) are supported by the majority of the public at the national level, but often encounter substantial local conflict and resistance. The 'Not In My Backyard' (NIMBY) theory is often used to explain such opposition and the apparent disjuncture between local views and national polls. This hypothesis suggests that those opposed to energy infrastructure are driven by irrational, ignorant, or selfish motivations because they accept the need for energy infrastructure in general but, for self-interested reasons, do not want it located near their own homes. The NIMBY account has been widely critiqued in academic literature as inaccurate and reductive, failing adequately to understand the causes of local opposition while acting as a catchall label that enables developers and project proponents to delegitimize all debate.

As an alternative to reductive narratives of NIMBYism, geographers have emphasized the importance of landscape perceptions in shaping public responses to new energy infrastructure. Landscape refers not only the physical features of a particular setting, but also the symbolic meanings and cultural imaginaries that shape how people value different locales. This point can apply broadly to general types of landscapes; for example, in many countries rural landscapes are often valued and represented as picturesque, scenic and tranquil. Alongside such general views, particular landscapes can be especially valued for their specific landscape qualities and characteristics, and such values can be formally embedded into planning regulations and land-use designations in ways that constrain the deployment of energy infrastructure. For example, the Lake District in the United Kingdom is often represented in British culture as being a unique and important landscape, and as a National Park new development within its boundaries is tightly monitored. Finally, individuals or groups may also develop emotional and affective bonds to a particular place that are not necessarily shared widely but instead reflect personal experiences of living or spending time in an area; for example, people may grow attached to the neighbourhood and landscape in which they grew up. This phenomenon is termed "place attachment."

Recognizing these symbolic dimensions, geographers have argued that public opposition to new energy infrastructure if often fueled by a perceived clash between the meanings and qualities of landscapes, on the one hand, and energy technologies, on the other. Like landscapes, as discussed earlier technologies of energy generation and their associated infrastructures are not simply anonymous or neutral artifacts but are instead replete with symbolic meaning. If energy infrastructure is considered to disrupt, degrade or otherwise not fit with the pre-existing qualities ascribed to a particular landscape by dominant cultural or place-based imaginaries, then this is can lead to public resistance and conflict. In this account, opposition to energy developments is a form of "place protective action," in which individuals and communities seek to preserve the distinctive qualities of particular landscapes. For example, an offshore wind energy project proposed near Cape Cod in the United States met local opposition because it was perceived as threatening to industrialize a special place of unique natural beauty. A wave energy development near Cornwall, UK, was opposed by some because it was seen as turning a public good (the ocean) into a corporate, profiteering space. Similar cases of symbolic clashes have been seen in relation to a wide array of other energy technologies, including solar, biomass, nuclear, shale gas, and tidal energy.

Landscapes and places do not have singular or fixed meanings, but rather multiple and contested ones that vary between cultures and individuals depending on, *inter alia*, values, experiences, and political perspectives. As noted, energy technologies also have multiple possible meanings and identities, depending in part on the characteristics of a particular development— its size, scale, and 'social' dimensions, such as its form of ownership and governance. Landscape and technology meanings can also change and shift over time; for example, it was only in the 17th Century that most Europeans began to see mountainous landscapes as places of spectacular beauty; prior to that time they were frequently interpreted as ugly and dangerous.

Such symbolic diversity explains how individuals can form different opinions about the impact of a particular energy development and therefore how conflict around its implementation can emerge. It also demonstrates that widespread local opposition to energy developments is not inevitable, but hinges on the social and material contingencies of the particular projects and the landscapes in which they are developed. For example, three community-owned wind turbines on the Isle of Gigha generated strong local support. They have been affectionately named the "Three Dancing Ladies," and are locally ascribed with positive symbolisms such as community empowerment and self-sufficiency. In this case, the project's relatively small physical scale (three small wind turbines) combined with its governance structure (community ownership that returns profits to the local area) generates a symbolic meaning very different from many other wind energy projects. In short, energy projects that are perceived as fitting with or positively enhancing the meaning, character, and identity of a particular landscape can garner greater levels of public support.

Landscape conflicts are significant issues if and as societies aim to transform to low-carbon energy systems. It could be argued that as the proportion of renewable energy increases, this is likely to lead to more frequent and intense landscape conflicts, due to the inherently more disperse spatial distribution of most RETs. Yet the flexibility of such technology in terms of material scale and social organization also opens up the possibility of more harmonious relations between landscape and technology. As the Isle of Gigha example illustrates, there is evidence that energy projects developed and governed in a more localized and participatory manner can foster positive local attitudes and perceptions of landscape impact.

Geographies of Energy Consumption

Understanding the prevalence, patterning, and underlying drivers of energy consumption is a further important topic that has been addressed by geographers. The consumption of energy is a vital part of the functioning of contemporary, technologically driven societies, and is frequently seen as an indicator of progress and a necessary ingredient for human well-being. Yet at the same time, there is also widespread recognition of the importance of reducing aggregate energy consumption (globally, and in many cases nationally and individually) in response to pressures of the energy trilemma. Indeed, reducing consumption is sometimes framed as a way of addressing these problems in a manner that is less financially onerous than building substantial amounts of new low-carbon energy supply and associated infrastructure.

Measuring patterns of energy use is difficult, as the unit of measurement, choice of indicator and reliability of data all have an impact on results. Data, such as those shown in Table 3, inevitably miss out some energy consumption for which data collection is very difficult, such as from electricity systems not connected to formal grid networks or biomass fuel collected informally. There is

Table 3 Energy consumption in 2011 for selected countries.

Country name	*Energy consumption (2011, tonnes of oil equivalent)*	*GDP per capita (2011, USD PPP)*	*Population (2011, millions)*
Australia	5.5	41,588	22.3
Bangladesh	0.2	2252	152.9
Brazil	1.4	14,301	196.9
Canada	7.3	40,384	34.3
China	2	10,041	1344
Democratic Republic of Congo	0.4	433	63.9
Denmark	3.2	41,831	5.6
Finland	6.5	38,605	5.4
Germany	3.8	40,980	81.8
Haiti	0.3	1553	10
India	0.6	4883	1221.2
Italy	2.7	33,870	60.7
Japan	3.6	34,266	127.8
South Korea	5.2	29,035	49.8
Russian Federation	5.1	22,502	142.9
Sweden	5.2	41,763	9.4
Tanzania	0.5	1596	46.4
Turkey	1.5	17,998	73.1
United Kingdom	3	34,800	63.3
United States	7	49,854	311.6
World (average)	1.9	13,254	

European Environment Agency, 2016. https://www.eea.europa.eu/data-and-maps/figures/correlation-of-per-capita-energy#tab-used-in-briefings.

also the question of how to account for the "offshoring" of energy consumption, in which energy is consumed in the manufacture of goods and services that are then exported to another country. In such cases, should the energy consumed be attributed to the country in which the production takes place (as is the case in most energy consumption datasets), or in the country that actually demands and consumes the produced goods and services?

Despite these complexities, some broad trends and patterns are observable across a range of energy consumption statistics. Table 3 shows energy consumption levels in 2011 for a diversity of countries. An immediate observation is the glaring degree of inequality in consumption levels between countries, ranging from 7 tonnes of oil equivalent for the United States to just 0.2 in Bangladesh. The figures emphasize how a high proportion of global energy is consumed in the industrialized or "developed" nations of the Global North—although there are significant differences in consumption levels between these countries. The differences remain stark even when population is accounted for. It is also important to recognize that these types of aggregate figures mask substantial inequalities between citizens within particular countries. Studies in a number of settings have demonstrated those on higher incomes tend to consume significantly more energy than do those on low incomes. In low-income countries, a significant proportion of overall energy consumption can be the product of a minority of wealthy aspects of society that are able to live very energy-intensive lifestyles.

There are different ways to explain these uneven patterns of energy consumption and their temporal dynamics. This is important because the form, and effectiveness, of policies aiming to reduce energy consumption depends on how the causes of present consumption patterns are conceptualized. Broadly, three particular framings of energy consumption are often dominant in political and media discourse.

The first sees increased energy consumption as the unavoidable outcome of economic growth and development. This logic suggests that as countries and their citizens become richer, their economies become based on energy-intensive manufacturing and households increase their consumption of goods and services—including energy. Indeed, energy consumption is itself often seen to be a necessary part of maintaining economic growth and a major indicator of economic health. Such a perspective either takes demand reduction off the table completely when devising responses to the energy trilemma, putting the focus instead on new sources of low-carbon energy supply, or sees demand reduction as only feasible through improvements in energy efficiency (see below). While there is a general relationship between energy demand and economic output, the plausibility of this type of linear and deterministic logic is undermined by the fact that countries with relatively similar levels of GDP per capita can have substantially different energy levels of energy consumption—such as Germany, Sweden, and Canada (Table 3). Many geographers thus challenge the view that increases in energy consumption are a simple, inevitable, and unquestionable product of increased prosperity.

A second way of conceptualizing energy consumption, with roots in behavioral economics and psychology, sees energy consumption as the outcome of individual choice. From this perspective, people make choices about which behaviors to undertake depending on their preferences, values, and knowledge, and these choices have implications for the energy consumption of individuals and ultimately of collectives. This understanding legitimizes policy instruments that aim to reduce energy demand by attempting to encourage people into making different personal choices, such as information campaigns, marketing, financial rewards, and other forms of incentive. Many human geographers have critiqued this type of understanding and policy approach, for failing to account for the ways that individual actions are structured and constrained by wider social and spatial contexts. Furthermore, social and economic inequalities mean that individuals vary greatly in their capacity to reduce their energy consumption. Indeed, there is little evidence that such policies focused on individual choice have any significant or sustained impact on energy consumption.

A third popular understanding sees energy consumption as a product of the relative energy efficiency of technology, buildings, and infrastructures. The focus here is on material devices and artifacts, and the amount of energy they use in order to produce a given service (such as lighting or heating a room, or powering machinery). From this perspective, the obvious way to reduce energy consumption is through improving the energy efficiency of various technologies and infrastructures. Many governing institutions at various scales, from the European Union and United Nations down to local municipalities, have developed policies with these aims. Examples include product standards, R&D investment, financial incentives, and the subsidized installation of more efficient devices. There are some links with the individual choice perspective, in that energy efficiency improvements are often seen to result from encouraging businesses and individuals to make different purchasing choices. The energy efficiency approach has also been criticized by some human geographers who argue it fails to engage with more fundamental questions about how energy is used and what energy is for, as well as often failing to reduce energy consumption by as much as initially suggested.

A popular alternative approach among geographers is to emphasize how energy consumption is deeply embedded in, and conditioned by, the social and material makeup of societies. Such an approach argues that, rather than being a matter of individual choice, energy consumption is often an obligatory requirement for participating in social life and undertaking everyday activities. From this perspective, spatial patterns and unevenness in energy demand are the result of differences in how energy consumption has become a necessary part of the functioning of societies. Various social and spatial contingencies are implicated in the making of energy demand and the need for energy.

One such contingency relates to climatic conditions, which clearly vary greatly across the globe. The need for space heating, for example, and the energy consumption this entails, is heightened in relatively cooler climates. In contrast, in hot, tropical climates the ability to keep sufficiently cool during the summer can be a more important issue than winter heating, leading to demand for air-conditioning and other cooling technologies. As well as temperature, patterns of daylight length and intensity also vary greatly across the globe and within countries, leading to very different requirements for artificial light. However, while climatic factors can play a role, these cannot fully explain differences in energy demand. For example, Table 3 shows that Finland has a higher level of aggregate energy consumption than Sweden, despite the two countries being similar climatically and Sweden having a significantly greater population. Therefore, geographers look to the role of additional social and material factors in building and sustaining energy demand.

The material characteristics of a place, such as the form of its built environment, play an important role in building and sustaining energy demand. An example can be seen in the adoption of air-conditioning systems for cooling, an increasingly common part of social life in many parts of the world with significant implications for escalating energy consumption. Studies in countries such as India, where air-conditioning use has risen rapidly in recent decades, have shown that dependency on this technology is in part the result of the increasing standardization of Western building designs and standards. Whereas homes and buildings in these countries traditionally made use of cool materials and natural ventilation in order to keep cool, the new "modern" homes have poor ventilation and are often made of materials that absorb heat. This change in the materiality of homes renders the use of air-conditioning (and the energy consumption this entails) an indispensable part of domestic life. Similarly, the necessity of heating is exacerbated in buildings that do not maximize passive heating from sunlight, or where inadequate thermal insulation means that much natural heat is lost through the walls and roof—a common problem in the United Kingdom and Eastern and Central Europe.

Infrastructures of energy supply are a further material factor that play a crucial role in structuring how energy is consumed and how the need for energy is built and sustained. A key idea in much critical geographical research on energy consumption is that supply infrastructures do not simply respond to pre-existing energy demands, but rather can be actively involved in creating such demand. For example, a central heating system fueled by a pipeline system that carries gas to the home eliminates the daily necessity of fuel-wood gathering, and shifts customs of indoor thermal comfort away from gathering around a single heat source toward the heating of multiple rooms. In doing so, patterns and levels of energy consumption are altered along with household expectations of what constitutes a comfortable living environment. A second example is in the way technological developments in motor cars have been aligned with major investment in supply infrastructures (e.g., petrol stations) along with roads and other changes in built form (e.g., suburbanization). Together, such changes have enabled and encouraged a situation where driving a car is normal, expected, and in many cases, a necessity for conducting everyday activities.

Alongside material conditions, geographers have also shown how institutional norms and rules can shape the necessity of energy services and their associated energy consumption. One example can be seen in the increasing prevalence of domestic internet and computer use in many societies and among different demographic groups. For example, research in the United Kingdom has shown that between 2008 and 2014 using these devices have become progressively more essential for the conduct of daily life. This need has been driven by the changing demands and design of larger organizations. Schools are increasingly expecting children to complete homework on a computer, and applying for jobs and accessing government services now often requires internet access. Such dynamics have made household computer and internet use increasingly necessary for the avoidance of disadvantage or exclusion.

The various examples presented here demonstrate a geographical approach to understanding energy consumption, focusing on how the underpinning demand for energy is embedded the social and spatial context of particular places. Energy consumption co-evolves with these social and spatial conditions as they change over time. In terms of strategies to reduce energy demand, geographers adopting this perspective would emphasize policies focused not on influencing individual choices or improving energy efficiency, but instead those seeking to minimize the underpinning need for energy.

Energy Inequality, Justice, and Democracy

Because energy systems are so central to social life, they can be both revealing and constitutive of social and spatial inequalities that have significant implication for people's well-being. Geographical research has examined how energy systems relate to, and help to produce and entrench, various forms of social disparity. Research of this kind almost inevitably touches upon moral questions of (in)justice and ethics. In this way, geographers have been central to the development of "energy justice," a field of study that examines the ethical implications of energy systems.

Research into energy inequalities usually considers at least two interconnected dimensions of justice. The first is often termed "distributional justice," and relates to how the outcomes of energy systems, both positive and negative, are unequally shared across society and space. These have been explored in relation to a number of different aspects of energy systems, including:

- Access inequalities, in terms of the unequal ability of people to attain the levels of energy required for a decent standard of living.
- Landscape inequalities, in relation to the landscape impacts and transformations resulting from energy developments.
- Health inequalities, in relation to the health consequences, both positive and negative, arising from the operation of energy systems.
- Economic inequalities, in terms of how the financial benefits and burdens of energy development are shared across society and space.

The second type of inequality relates to what is termed "procedural justice," and centers on issues of fairness and inequality in terms of energy system governance and decision-making.

Geographical research has utilized notions of distributional and procedural justice in two broad ways. One way has been as a tool to understand conflict and contestation in relation to the development of new energy infrastructures. Claims of inequality and injustice, relating to both distributional and procedural justice, have been shown to be a central part of resistance to energy developments by local publics, social movements, and non-governmental organizations. Issues of injustice and inequality thus offer an account of the underpinning reasons for energy system conflict and opposition, one that is additional to the theories of landscape and place attachment discussed earlier.

Another approach often adopted by geographers taking a critical perspective is to use research to understand the patterns, causes, and consequences of energy-related inequality. Such studies often aim to: (i) reveal energy-related inequalities, and understand their implications for the environment and the quality of people's lives; (ii) explain the processes through which such inequalities are produced. Research in this vein has shown how inequalities in energy system outcomes often reflect and reinforce existing axes of social disparity, such as class division, racial discrimination, and gender inequality. Moreover, already marginalized groups—racial and ethnic minorities, older people, women, or those on lower-incomes—often have little power or influence in decisions about how energy systems are operated and organized. Which of these axes of difference is most fundamental for energy-related inequalities depends on wider social context (for example, racial disparities in relation to energy systems occur more strongly in some places than others), as well as the energy system dimension or outcome in question (be they economic, health, or landscape impacts, for example).

There is an important recursive relationship between procedural and distributional forms of inequality. Choices about who wins and who loses from the operation of energy systems often reflect political and economic power. Those who are on the margins of the governance and decision-making procedures that determine the design of energy systems are subsequently often disadvantaged in the distribution of benefits and burdens. By the same token, those who lack or have precarious energy access, or bear the negative consequences of energy systems, often encounter additional challenges and constraints that severely limit their ability to participate in energy decision-making processes.

A range of different substantive forms of procedural and distributional inequality have been examined, unpacked, and confronted by critical geographers and citizen activists alike. In relation to procedural justice and energy system governance, activist groups, and local publics have critiqued a lack of democracy in relation to the planning and implementation of new energy developments. Research has shown that concerns that developments are being unjustly imposed on local communities by corporations and private companies is an important motivation for public opposition to the implementation of a range of energy infrastructures—including wind farms, solar parks, overhead power lines, and the storage of nuclear waste. Exactly what constitutes a 'procedurally just' decision process can be complex, particularly in situations when democratic support at one scale of governance (e.g., national) is in conflict with opposition at another scale (e.g., local). Research has also examined the power of incumbent interests and financially powerful corporations to influence the direction of energy policy and regulation in ways that protect vested interests. Recent controversies regarding shale gas reserves in England provide a particularly powerful recent example of how questions of democracy, legitimacy, and corporate power can become embroiled in energy debates.

In terms of distributional justice, inequalities related to health are perhaps the most important. In a range of contexts, critical geographers have analyzed how the harmful health impacts of energy developments most frequently and severely impact those who are politically and economically marginalized. Globally, for example, climate change imposes health risks (such as heat-waves and droughts) that are felt most extremely in lower-income societies, often among communities that do not enjoy many of the benefits of modern energy services and generate very little in terms of global carbon emissions. At local and regional scales, air pollution from fossil fuel power stations and transport infrastructure has been shown to be concentrated among more economically disadvantaged communities.

Claims of distributional unfairness and injustice have been expressed around the landscape impacts of energy infrastructures. For example, local communities and critical geographers have raised concerns that peripheral areas of rural Scotland are being exploited by government and private developers as sites for the large-scale expansion of wind energy, with the electricity produced then consumed predominantly in distant towns and cities. Such communities, it is argued, contribute relatively little to national energy demand, yet shoulder a disproportionate degree of landscape transformation in order to satisfy the behests of resource-hungry urban areas. These arguments are often entangled with injustice claims relating to the economic aspects of energy systems, namely that the financial profits of energy generation infrastructure are exported from areas bearing the landscape impacts while enriching distant company shareholders (an argument embroiled in conflicts around a wide range of energy technologies). Some energy developers have begun to respond to such concerns through the provision of local 'community benefit funds', in which a small proportion of revenue is redirected to a local group or trust. The extent to which these lead to fundamental and long-term forms of economic development for local communities has been questioned, with the revenue streams dwarfed, in quantitative terms, by those that could be generated through full community ownership.

Another form of economic inequality that has recently gained attention among critical geographers relates to the potential for regional job losses resulting from a transition to a renewables-based energy system, particularly in areas where the fossil fuel industry was a significant employer. Concerns have also been expressed regarding the potential for labor exploitation resulting from resource extraction and manufacturing associated with the making of renewable energy components. These issues have only begun to be examined, and offer a new avenue for future research on energy inequalities and justice.

Geographers would emphasize that the emergence and production of these multiple inequalities and claimed injustices is not inevitable, but rather is better understood as arising from political decisions regarding the organization of energy systems. There are important differences between energy technologies in terms of the impacts and distributional inequalities they produce. Health inequalities relating to climate change and air pollution are clearly connected to fossil fuel-based forms of energy production, for example. Likewise, the consequences of wind power take a different form and have a different social and geographical unevenness compared to those of nuclear energy, for example.

The particular ways that energy systems are socially organized, managed, and owned also plays a central role in constituting the form of energy-related inequalities. For example, many of the distributional and procedural injustices discussed are often the product of energy developments owned and controlled by private companies, whose interests and obligations lie, ultimately, in shareholder profit. In several countries in the world, grassroots activists are now arguing for a shift toward collective and cooperative-based forms of ownership of renewable energy development. It is argued that these offer an alternative to privatized and corporate forms of ownership by enabling more democratic governance structures and more widespread profit distribution. Community-led or -owned renewable energy projects are often seen as an example of such a vision put into action; however, research has shown that such projects can still encounter difficulties in harmonizing differing expectations, visions, and perspectives about what constitutes justice in project outcomes and decision-making. Justice, importantly, is a concept that is contested rather than given.

These issues all raise important questions regarding how energy systems will, and should be, arranged in the future—particularly given the need to shift to low-carbon forms of energy generation and consumption. How such a transition is pursued will have important implications for inequality and (in)justice. A range of different energy futures are possible, with each allocating costs and benefits (economic, social, and environmental) in quite different ways and implying varying governance mechanisms and power structures. Energy transitions, therefore, have the potential to produce new forms of inequality but also greater justice. The next stage of geographical research on energy is reflecting carefully and critically on what a "just transition" might involve and the complexities in achieving it.

Energy Poverty

One particular form of energy-related inequality that has been widely studied relates to disparities in people's ability to access energy, and the many benefits it can bring, in their home. "Energy poverty" refers to a situation in which a household is unable to attain adequate levels of energy use, leaving them unable to satisfy their basic needs. The consequences of energy poverty can be severe, including serious harms to physical health and mental well-being, social exclusion, stigmatization, and the impairment of social, political, and economic opportunities. Geographers have made key contributions to understanding the prevalence, distribution, causes, and consequences of this problem.

Energy poverty scholarship derives from two relatively distinct academic traditions that have recently been brought into closer conversation. The original use of the term "energy poverty" arose from literature in development studies focusing on lower-income societies that lack widespread electricity infrastructure. Here, energy poverty is understood as inability to physically access to modern energy services, manifesting as either (i) a lack of electricity connection to the home; (ii) a reliance on solid-fuels such

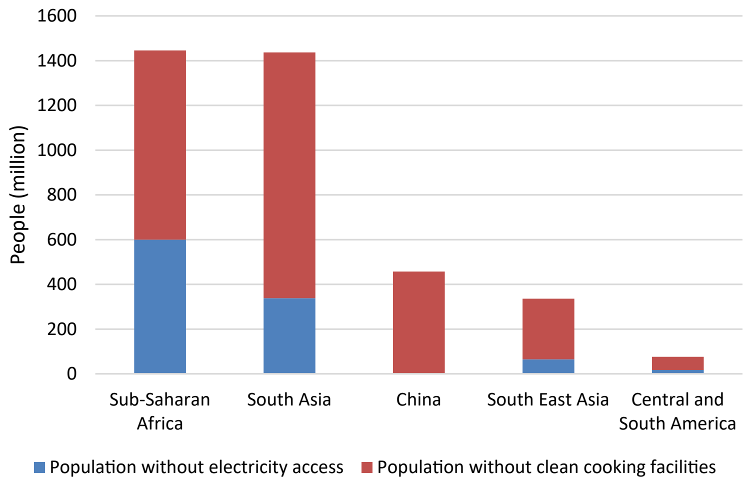

Figure 2 Number of people without electricity access and clean cooking facilities. Based on IEA data from Electricity Access Database © OECD/IEA 2017, http://www.iea.org/energyaccess/database, License: www.iea.org/t&c; as modified by Neil Simcock.

as wood, dung, or charcoal for cooking. Estimates made in 2017 suggested that around 1.1 billion people—approximately 14% of the current global population—live without access to electricity. The vast majority of these live in rural areas, predominantly in sub-Saharan Africa and South Asia (Fig. 2). An even more prevalent problem is the 2.8 billion people—38% of the world's population—relying on solid-fuels for cooking, often in poorly ventilated spaces, leaving them exposed to a number of harmful health consequences. Again, this problem is most frequent in South Asia and sub-Saharan Africa, but is also a significant issue in China and South East Asia (Fig. 2). Alongside these spatial disparities, there are also significant gender inequalities in exposure to the harmful impacts of inadequate energy access. The economic, health, and labor burdens tend to be borne most severely by women, and children, also, tend to be at heightened risk of exposure to energy poverty's detrimental effects.

A further body of energy poverty scholarship, taking place mostly in Europe and other higher income localities, has centered on situations in which a household cannot attain sufficient levels of energy services due to a lack of affordability—that is, they have physical access to an electricity supply and other modern energy carriers, but cannot afford the monetary cost of consuming energy at a required level. This can lead to the inability to keep homes sufficiently warm, cool or well lit, leading to consequent housing problems, such as indoor damp and mold, as well as deleterious impacts upon people's health and well-being. Attention to this problem first arose in the United Kingdom via the terminology of "fuel poverty," as a result of grassroots activism in the 1970s, before being fully established as an academic concept in the 1990s. In recent years, research focusing on a lack of energy affordability has expanded into many other geographic settings: the United States, New Zealand, Japan, South Korea, and many countries across Europe, among other places. Outside of the United Kingdom the principal terminology to describe this problem has been energy poverty, rather than fuel poverty.

Measuring the geographical patterning and extent of energy unaffordability is difficult. Reliable data are not available in many places, and differences in collection methods mean that data may not be directly comparable between countries. Furthermore, a number of different indicators can be utilized to measure the problem, with each producing different results.

Some of the most extensive and comparable available data on energy poverty as unaffordability relate to the European Union. Table 4 compares energy poverty rates for the EU 28 countries using four indicators: two "subjective" measures, relating to a household's perceived inability to keep adequately warm or cool, and two "objective" measures, relating to whether a household has arrears on their utility bills or has housing condition problems. Although these different measures do not perfectly correlate, some broad patterns can nonetheless be identified. It is clear that the prevalence of energy poverty is highly uneven geographically, with the problem particularly widespread in Eastern and Southern Europe (for reasons that shall be discussed shortly). Other recent research has highlighted extensive spatial disparities in energy poverty rates within individual countries, at a variety of scales.

Recent research has argued that the two distinct traditions of energy poverty research, as inadequate access and unaffordability, should be brought into closer conversation, for two primary reasons. First, the binary distinction between access and affordability is not clear-cut, with many households facing both issues simultaneously. For example, off-grid communities in the Global South frequently encounter exorbitant financial charges to connect to an electricity grid, while households in higher income nations can still lack access to networked energy infrastructure (such as a gas network) and be reliant on expensive fuels that subsequently create affordability problems. Second, inadequate energy access and lack of energy affordability ultimately result in the same underlying problem: a lack of sufficient domestic energy services, manifesting as homes that are, for example, poorly lit, or unable to keep sufficiently warm or cool.

Geographers have also made important contributions to understanding the underlying causes of energy poverty across the world. In the Global South context, energy poverty has traditionally been understood as caused by insufficient power line

Table 4 Percentage of people in energy poverty in EU countries based on four different indicators.

Country	*Unable to keep home adequately warm*	*Unable to keep home adequately cool*	*Poor housing conditions*[a]	*Arrears on utility bills*
Austria	2.7	15.0	11.2	5.0
Belgium	4.8	12.4	19.3	31.7
Bulgaria	39.2	49.5	12.3	3.0
Croatia	9.3	24.5	11.5	2.5
Cyprus	24.3	29.6	27.1	3.0
Czech Republic	3.8	21.8	8.2	7.9
Denmark	2.7	11.3	15.9	12.1
Estonia	2.7	23.3	13.9	42.2
Finland	1.7	25.2	4.7	7.8
France	5.0	18.9	14.0	6.1
Germany	3.7	13.6	13.1	25.3
Greece	29.1	34.0	14.7	8.9
Hungary	9.2	26.3	26.7	15.4
Ireland	5.8	4.0	13.4	13.2
Italy	16.1	26.0	21.0	9.7
Latvia	10.6	29.9	21.9	4.0
Lithuania	29.3	24.6	18.2	16.2
Luxembourg	1.7	10.2	18.7	9.0
Malta	6.8	35.4	8.9	2.0
Netherlands	2.6	17.7	16.3	4.2
Poland	7.1	25.3	11.6	9.5
Portugal	22.5	35.7	30.5	7.3
Romania	13.8	22.3	13.3	18.0
Slovakia	5.1	21.0	6.2	15.9
Slovenia	4.8	17.3	23.8	5.7
Spain	10.1	25.6	15.9	7.7
Sweden	2.6	7.6	7.4	2.6
United Kingdom	6.1	3.3	16.4	5.7
EU 28 average	8.7	19.1	15.4	8.1

[a]Leaking roof, damp walls, floors or foundation, or rot in window frames or floor.

European Union Statistics on Income and Living Conditions, http://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions.

networks to distribute energy from large-scale, centralized energy generation facilities across a country's population. The expansion of large-scale grid infrastructures and generation technologies has therefore been pursued in many different nations; however, such macroscale and supply-orientated logics have been critiqued in recent years for being extremely expensive while having questionable effectiveness in improving energy access, as well as leading to harmful social and environmental impacts for local communities. In light of such criticisms, scientific and policy attention has increasingly focused on investment in community and microscale energy generation as a way to alleviate energy poverty. Here, renewable energy technologies (typically solar) provide electricity to nearby homes, businesses, and public facilities using localized, rather than nationalized, distribution networks.

In scholarship on fuel/energy poverty in the Global North, the dominant understanding is that a lack of energy affordability results from the interaction between three factors: a household's income, the price they pay for energy, and the energy efficiency of their homes. This conceptualization was originally developed by Brenda Boardman in the early 1990s, and has remained influential since. If a household is on a low income, and/or pays a high price for energy relative to their income, this increases their risk of being unable to financially sustain sufficient levels of energy consumption. However, while incomes and energy prices are recognised as important, it is the energy efficiency of the built fabric of the home—encompassing its walls, roofs, windows, appliances, and heating and/or cooling systems—that is frequently seen as the crucial determinant of a household's risk of experiencing energy poverty. Low-levels of energy efficiency mean that a household must consume a greater amount of energy in order to achieve the same standard of "energy service"—for example, a poorly insulated home must consume more energy to maintain an indoor temperature of 20 °C compared to a tightly insulated one, as more heat will be lost through the walls and roof. In such circumstances, households can be forced to choose between unaffordable energy bills or an inadequately heated home. The significance of energy efficiency is useful in demonstrating that energy poverty is a problem distinct from income poverty (although there are overlaps between them), because a household can suffer energy poverty even if they have an income that is above the official income poverty threshold.

Energy prices, incomes, and energy efficiency are unevenly distributed across space, and this geographical variance helps to explain the unequal prevalence of energy poverty in different parts of the world. For example, in relation to the European Union,

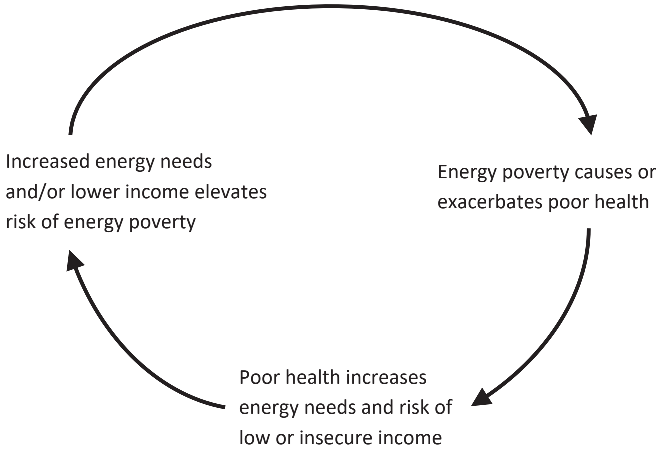

Figure 3 The "vicious circle" of poor health and energy poverty.

the higher rates of energy poverty in Southern and Eastern Europe have been attributed to the relatively low-levels of energy efficiency in the region, along with heating infrastructure that is either limited or in poor condition.

Recent years have seen these two classic frameworks expanded upon through the notion of "energy vulnerability." This concept particularly highlights a household's energy needs as a potential driving factor of energy poverty. Those households that are, for social or physiological reasons, reliant on relatively high amounts of energy consumption can find themselves more vulnerable to energy poverty. For example, those with a long-term illness or disability may require the use of medical equipment that consumes electricity, or need to heat their home for longer periods and to relatively higher temperatures. Such increased consumption needs can raise the risk of unaffordable energy bills, or increase a household's susceptibility to harm from inadequate electricity access. Such situations can lead to a vicious circle, in which inadequate energy services due to energy poverty cause or exacerbate health problems, which in turn increases a household's energy requirements and puts upward pressure on energy bills (Fig. 3).

While useful, all of these above approaches are also limited in that they focus predominantly on the domestic-scale factors that underpin energy poverty. Geographers have been central in demonstrating that the emergence and persistence of energy poverty is embedded within broader-scale economic, political, and social relations. For example, among other factors the price of household energy is determined by how energy utilities and markets are regulated within a particular geographical setting, as well as the form of energy supply infrastructure. Moreover, the prevalence and severity of energy poverty has also been shown to be unequal along the axes of age, gender, race, and social class, illustrating how the condition is embedded in deeper forms of social exclusion. Across the world, women are often more likely to be exposed to energy poverty due to patriarchal conventions and power relations operating in the home, economy, and wider society. Research in South Africa and the United States has also demonstrated how legacies of racial segregation continue to play a significant role in the highly unequal social and spatial patterning of energy poverty. Geographers have thus argued that to addressing energy poverty requires policy strategies and measures focused on addressing and reconfiguring broader social structures. Often, this will mean acting beyond energy policy, per se, in order to intervene in deeper relations of exclusion (such as racist ideologies, policies, and practices). Additionally, these need to be tailored to the social, economic, and political context of a particular geographical setting.

See Also: Climate Change; Consumption; Ecosystem Services; Environment; Environmentalism; Environmental Geography; Environmental Hazards; Environmental Justice; Environmental Regulation; Green Economy; Natural Resources; Resource and Environmental Economics; Sustainability; Waste Management.

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