Re-vitalizing Energy Transition
in Touristic Islands

ET ROADMAP IMPLEMENTATION-THE CHALLENGES

Prof. Constantinos S. Psomopoulos, UniWA

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Introduction

Analysis of the actual challenges that a municipality, especially in island territories can face during energy transition effort.

This unit includes scenarios of different challenges based on real case studies in mainland and island municipalities have faced during their energy transition.

The challenges coming from experiences collected by the GENERA team over 20 years in field of consulting and supporting municipalities in their efforts for renewables, energy efficiency measures and improvement of their environmental performance.

- It is helpful to first identify key concepts in the energy and policy sectors in order to comprehend the nature of energy transitions research.
- The necessity One often expressed viewpoint in today's debates highlights how the current environment—which differs from earlier eras—makes it necessary to change how society uses energy.
- This perspective is influenced by factors pertaining to energy security, dependability, accessibility, and sustainability. It's important to remember that there have previously been demands to change energy paths, especially during times of war and worldwide oil shocks.
- For example, nation-level programs that increased domestic energy self-sufficiency through efficiency, conservation, and/or scale of domestic businesses and sourcing were part of society's reactions to the oil shocks of the 1970s and early 1980s.

- Perhaps the biggest difference now is a greater understanding of the extent of energy-related issues, their effects across borders, and the potential actions required, depending on the issue.
- Social science may play its most important role in this area. Even the most brilliant technical and natural science solutions may go unexplored in a lab or field endeavour.
- Scholarship may help us understand how knowledge, attitudes, and practices are formed and affect one another; what markets and finance can and cannot achieve; and how a society's "social contract" either helps or hinders problem-solving.

Tradeoffs

- By 2035, the International Energy Agency projects that around $38 trillion in worldwide investment would be required to fulfil energy demand.
- Naturally, questions concerning who makes the decisions, who pays (consumers, taxpayers, business, etc.), and how this is resolved come up.
- Another question is whether strategic goals like employment, leadership in research and technology, pertinent deadlines, adaptability, and responsible stewardship are given priority. In a same vein, what is needed for underlying infrastructure, such as acceptance, dislocation, and land use and siting?

- Are decisions being made with short-term goals in mind, or are longer-term factors also being carefully considered?

- Such concerns are exacerbated by institutional considerations of how to navigate new routes when more drastically changed pathways are taken into account.
- Costs involve more than just finances, regardless of the route chosen. Unmonetized social consequences include those related to politics, the environment, security, and other areas.
- One of the most important areas for academic research is how to successfully handle the tradeoffs, which are a basic issue for decision-makers.

Innovation

- A new energy transition is frequently cited as requiring revolutionary advances in the sources, delivery, and use of energy, such as those made historically with the combustion engine or controlled nuclear fission.
- The idea of accelerating invention has been written about extensively in this school of thought.
- However, since discoveries do not occur spontaneously, innovation must be carefully developed.
- Furthermore, invention translation and scaling might involve more than only patent commercialisation. For instance, influences that come from sources other than a market may influence the popularisation of a new concept.

- When comparing the quick dissemination of an energy innovation against an energy transition, distinctions are also crucial. Although some occurrences may overlap, the underlying socio-technical factors might also be very different.
- Here, the conceptual and empirical understanding of the fundamental factors influencing change may be expanded by the work of experts in the fields of science history, science, technology, and society (STS), anthropology, political science, and policy.

Observing energy transitions

- Scale, structure, and quality of change are frequently analysed while looking at the field of energy transitions.
- In this instance, the change from a significant dependence on biomass, such as fuelwood, in the middle of the 1800s to a more diverse mix of inputs in the 1900s, including nuclear production, which was not commercially accessible in the 1800s, clearly illustrates the diversification of fuels.

- A more detailed study of the relative fuel shares in the global energy mix between 1971 and 2011 reveals that oil's dominance declined while natural gas, coal/peat, nuclear power, and some renewables increased.
- Numerous attributes, including as density, mobility, environmental or health impacts, efficiency, sustainability, and dependability, can be used to assess the quality of energy systems.
- The quantity of energy contained in a unit of mass or volume is known as its energy density. One significant movement towards higher energy densities is the historical transition from biomass to fossil fuels and nuclear power.

- As the usage of electricity and fossil fuels has grown, so too has energy mobility, or the capacity to transport energy easily. Due to the need for coordinated infrastructure investment, including that for pipelines, tankers, liquefaction plants, and/or power grid networks, such mobility is not totally inherent to the fuel type.
- With notable variations in local and global nature, other qualitative characteristics pertaining to environmental and health implications may concentrate on types of resource and material inputs, releases (such as emissions or trash), and affects on land and biodiversity.

Energy-related megatrends

- Urbanization

Since underlying decisions in infrastructure, land use, industry, electricity supply, and transportation have an impact on energy consumption, urbanisation also offers possibilities and difficulties for energy (and therefore, energy transitions) study.

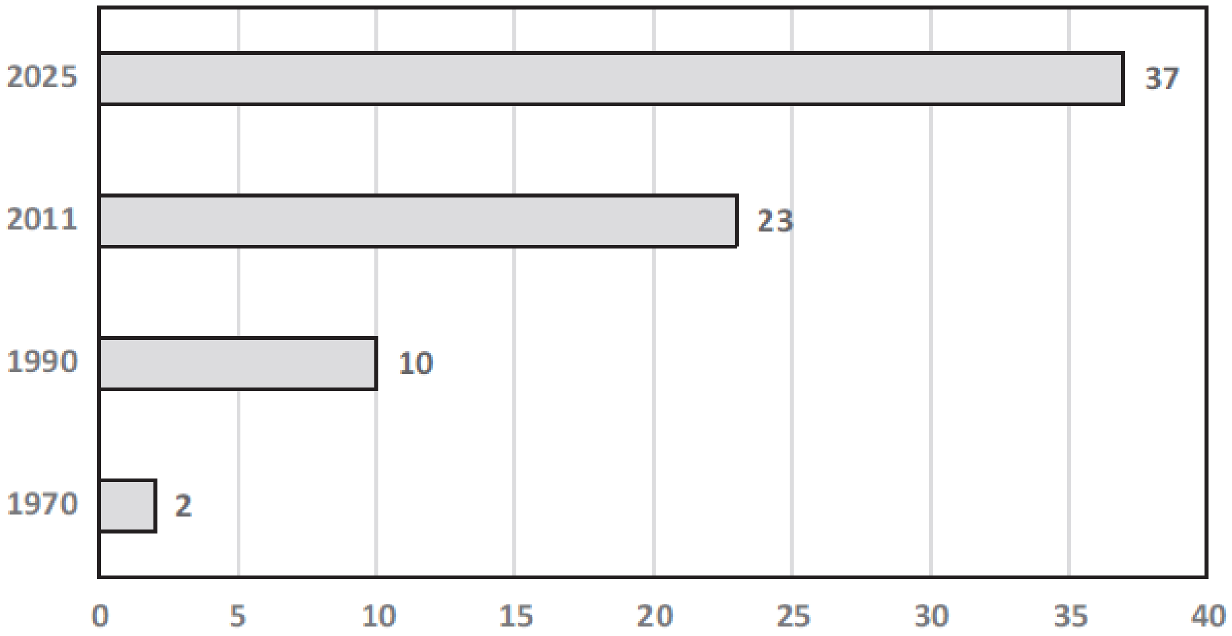
Approximately 2% of people on Earth resided in urban areas in 1800. Over half of the world's population currently does so. Megacities with tens of millions of inhabitants are indeed becoming more common.

Given that cities currently account for two thirds of energy use, these changes have implications for energy markets, efficiency potential, and health and environmental effects.

For example, energy demand centres are now considerably more concentrated, which might reduce losses from long-distance power delivery.

Energy-related megatrends

- Urbanisation can reduce the areas affected by land usage under these circumstances. However, because air and water pollution tend to be more concentrated around metropolitan centres, environmental effects may potentially worsen in some places. In this case, mitigation at the source site may be possible. Recognising the tactical alternatives of development choices remains a priority for urban planners, regulators, utilities, and community members.



United Nations Population Division. World population prospects, Revision;2013.

Energy-related megatrends

- Globalization

Another megatrend that is relevant to the transformation of the energy system is the escalation of cross-border commerce, information, and people movements.

Numerous sub-developments within this phenomena are important for the research of energy transitions.

The significant increase in cross-border energy commerce is one area of special significance.

For instance, if one looks at the world's natural gas supply, 31% of the gas used in 2011 came from imports, up from 5% in 1971.

To put this in perspective, throughout same time, global natural gas imports increased by more than a factor of 17.

When additional boundaries are involved, this change indicates a higher level of systemic complexity.

Energy-related megatrends

- They have specifically cited the growing global economic integration and degree of interconnectedness among nations as factors influencing energy consumption.
- The disruptive changes in the global economy and geopolitics linked to unconventional gas and oil are examples of this interconnectedness.
- Divergent opinions exist over whether this increased level of integration is a good thing since it offers chances to react quickly and dispersedly to novel circumstances, such as danger.
- But technology also brings problems from far-off places closer to home.

Energy-related megatrends

Globalisation offers opportunities for more in-depth attention from energy transition analysts, including:

- evolving models of energy self-sufficiency in global markets;
- the systemic interplay between long-term energy planning and global environmental and security concerns;
- the increased influence of international finance organisations and IGOs in regional energy investment;

and the ways that changing travel modalities impact cross-border energy tracking.

Challenges

- Discretion is required to guarantee that information limitations and compatibilities are comprehensible given the growing diversity of energy data and information sources.
- In order to correctly communicate national energy information, the United Nations, International Energy Agency, and World Energy Council rely on surveys of industry members or country authorities.
- Although this method may be effective, it is susceptible to differing respondent interpretations, various levels of accuracy in data collection and estimate, and even the politics of reporting.

For instance, various political goals and sets of assumptions are frequently used when reporting on energy reserves and resources, which can change technological and economic feasibility and result in wildly disparate totals.

By better harmonising cross-cultural data and using analytical techniques that are sensitive to regionally specific characteristics, social scientists and humanities specialists can enhance such resources.

The accounting technique used to create primary energy data is another factor to take into account for energy transitions study.

The use of high or low heat values in computations can result in a spread of 5–6% for solid and liquid fuels and 10% for petrol when using combustible fuels, namely fossil fuels and biomass.

In contrast, variations for non-combustibles may be significantly greater [37].

These sorts of distinctions are framed by conversion methods, which often include hybridised techniques, direct counterparts, or replacement.

There are also fundamental data deficiencies. Information at the national and international levels is rather complete from the 1970s to the present, although industrialising nations have less historical history accessible.

When non-commercial energy estimates are available, they often concentrate on biomass, such as waste and fuel wood, but leave out other non-commercial energy sources, such solar water heating, wind-powered ships, and classic water wheels and wind mills.

Here, disciplinary tools, methodologies, and insights may be applied by historians, sociologists, and international development experts to enhance and expand on current estimates.

Another difficulty in the study of energy transitions is the requirement for more distinct data.

Information on renewable energy sources, such as geothermal heat and power, solar thermal heat and power, wind power, biofuels, ocean power, etc., is sometimes combined into a single technology in a way that obscures their distinct energy paths.

This disparity in reporting, whether intentional or the result of an unintended effect, causes researchers to choose more data-rich subjects, such as historically commercialised energy, due to resource bias.

Additionally, sophisticated technological alternatives like efficiency, storage, and systems methods are overlooked by simplified reporting. Some progress has been made recently by groups like IRENA, REN21, and the IEA.

Governmental assistance from the Organisation for Economic Cooperation and Development (OECD) has mostly been represented in country-level data on spending for energy research and development.

Reports on research, development, and demonstration expenditures at a more global level, including significant industrialising nations and private sector investment, have also just recently started to be produced.

However, there is still much to learn, notably about state-owned businesses and national laboratories that are not part of the OECD.

Similar to the fundamental data gaps mentioned above, when access to specific information is limited, historians, sociologists, and maybe researchers with an industrial emphasis may be able to expand estimates.

The creation and reporting of energy information may be more thoroughly mapped at a theoretical level to uncover underlying factors on knowledge growth, an area in which specialists in STS and institutions naturally excel.

Challenges to the low-carbon energy transition

Creation of a framework of obstacles to the low-carbon energy transition. Division into five categories.

Below is an explanation of the proposed framework's five pillars. Each identified difficulty is then thoroughly described.

• **Social pillar**: issues that fall under this category either directly impact or are impacted by people. For example, public involvement is directly linked to public acceptability, which is a significant barrier to the low-carbon energy transition. As such, governments and other stakeholders should increase public engagement to increase public acceptance.

Additionally, every societal transformation, including the shift to low-carbon energy, is impacted by public understanding. Since education and public awareness are linked, raising awareness might result from bettering public education.

Social pillar

However, resistance to change is another hurdle to any social transition owing to the lack of knowledge and participation, which creates changes in consumer behavior.

Also, the low-carbon energy shift can harm the revenue of thosestakeholders who profit from the present system.

Moreover, employment loss and inventiveness are two key side-effects of each societal transformation, including the low-carbon energy transition. The low-carbon energy transition should be sufficiently filled by the employment produced in green sectors; if not, the transition may encounter significant opposition owing to the large number of job losses, particularly in businesses that rely heavily on fossil fuels.

Additionally, the shift to low-carbon energy should ensure inexpensive and safe energy.

Economic pillar

One of the worldwide issues facing the energy industry that has to be addressed is energy poverty.

The current study's inclusion of energy justice in the suggested framework is motivated by the fact that a fair energy transition is an essential remedy for energy poverty.

- **Economic pillar**: it includes obstacles to the low-carbon energy transition that impact energy sector investment, provide competitive advantages, and boost economic expansion. For example, in any socio-technical transition, such as the shift to low-carbon energy, all stakeholders should take investment risk into account.

Labour productivity and GDP may temporarily decline as a result of the low-carbon transition, although the severity and length of these impacts will vary depending on the amount of investment. Since the low-carbon transition necessitates significant changes to existing technology, norms, and consumer behaviour, it demands a significant financial investment. Governments should thus encourage investors to boost their contributions by offering incentives like subsidies.

Economic pillar

- Governments continue to provide significant subsidies on fossil fuels to ensure energy accessibility, thus while energy subsidies may encourage the development of low-carbon energy, they may also act as a roadblock to the low-carbon energy transition.
- As significant obstacles to the low-carbon energy transition, energy transition costs—including adaptation and mitigation costs—should also be addressed.
- The expenses of lowering greenhouse gas emissions are referred to as mitigation costs, while the costs of creating a society that is more climate change adaptable are referred to as adaptation costs.

Environmental pillar

- The environmental pillar includes issues related to land usage, natural resource use, pollution, and climate change.
- The utilisation of resources, such as sand for green and energy-efficient building construction or lithium, selenium, gallium, cadmium, tellurium, and germanium for energy storage, poses a serious obstacle to the low-carbon energy transition and photovoltaic solar panels.

Environmental pillar

However, landfills for waste disposal and large-scale land use for wind and solar farm construction are major obstacles to the shift to low-carbon energy.

Green grabbing, for example, is a novel method of acquiring property in which natural resources and land are taken away in accordance with sustainable development objectives.

Lithium-ion battery recycling would also not be a pollution-free activity because pyrometallurgy is a high-energy process that releases toxic fumes and greenhouse gas emissions, and its hazardous waste has to be landfilled.

Institutional pillar

- **Institutional pillar**: This includes issues that either result from or have an impact on policies, plans, and choices. Similar to public opposition to change and investment risks, anti-innovation policies may impede the low-carbon energy transition, even if socio-technical transformations need for new supporting policies.

For example, the wind turbine sector needs assistance for research and development and local market demand, while export-oriented manufacturing policies are essential for the production of photovoltaics.

The shift to low-carbon energy is also hampered by short-term strategies. The rate of the low-carbon energy transition is impacted by low fossil fuel costs, although nations with abundant non-renewable resources typically provide greater energy subsidies to support their political parties.

Institutional pillar

- Additionally, reformation and transition are two sides of the same coin; reformation is necessary for a low-carbon energy transition to be effective, but it may also lead to disputes and, in turn, resistance to change.
- There may be ongoing disputes at every level of the policy-making process, such as when deciding on tariffs that impact investment returns.

Technical pillar

- **The technical pillar** includes issues that affect technological standards, technology advancement, and infrastructures.

In order to mitigate climate change, trap carbon emissions, and lower or stabilise the world average temperature, a technological shift in the low-carbon energy transition is unavoidable.

Consequently, standards, technology, and infrastructure are all being approached together by sustainable energy systems.

For example, implementing low-carbon technology to increase production-level energy efficiency and demand-side energy savings are examples of technical modifications that should be made.

However, in order to satisfy local and global criteria as stipulated by international accords, such as the Paris Agreement, a lack of technical standards may impede the development and adoption of new low-carbon technologies at the appropriate speed.

Social challenges - Public acceptance and engagement

- **The social challenges**—public participation and acceptance, public education and awareness, resistance and behaviour changes, energy justice, labour transformation, and energy security—are described in depth below.
- Many studies have ignored the crucial importance of public and democratic involvement in the low-carbon energy transition, and the role of states in boosting engagement transition processes has not been sufficiently addressed.
- Promoting an energy transition to a low-carbon system requires broad public support . Additionally, public involvement raises the acceptability of the low-carbon energy transition overall and the dependability of low-carbon technologies in particular.

Social challenges - Public acceptance and engagement

Changes in behaviour are necessary for public acceptability, encouraging participation in an energy system that is decentralised.

Additionally, cultural acceptability issues may arise for wind and solar energy, however boosting public involvement and engagement may not be the first step in energy planning.

Additionally, public networks encourage communication and collaboration across various sectors, which enhances decision-making and raises public participation.

Furthermore, consumers need to play a more reactive role in the present energy system by incorporating innovative low-carbon technology into their everyday routines.

Issues of social acceptability will vary depending on the sociocultural context. Social changes in every situation necessary to accomplish an equitable transition are part of the low-carbon transition [116].

Social challenges - Public education and awareness

Because it raises public awareness, public education is essential for the energy transition. From modest geographic scales, such as individual businesses and neighbourhoods, to cities and states, the energy transition data must cover both geographical and temporal dimensions.

Through public campaigns, energy-related websites, and standards, it is essential to provide useful information and knowledge about the low-carbon energy transition.

Additionally, social movements have the ability to accelerate policy development, showing how new interests may increase public awareness and persuade businesses and decision-makers to adopt a low-carbon approach.

Sustainability has also emerged from a lack of common understanding of energy security brought on by the availability of fossil fuels.

One major obstacle to the adoption of offshore wind farms is a lack of understanding.

Furthermore, it is mentioned that adopting renewable energies is hampered by a lack of public awareness and insufficient training.

Additionally, societies with diversified professional and social networks and open, transparent, and participatory policymaking processes are better suited for social learning.

Furthermore, stakeholders' opinions on decarbonisation and the shift to low-carbon energy are incongruent, which calls on leaders and policymakers to raise awareness by enhancing public education.

- Additionally, those affected by low-carbon technology require better education and training.
- Therefore, in order to attain a low-carbon energy system, behaviour is changed through information sharing and raising awareness.
- Resistance and behaviour change. Low-carbon technologies have the potential to make infrastructure more responsive to social and environmental demands, but they also pose a danger to vital money from wealthy customers who cross-subsidize power for low-income
- A low-carbon energy system cannot be achieved just via technical improvement; energy consumption is necessary to reach a low-carbon energy future.

- Adopting low-carbon behaviours include reducing vehicle miles travelled (VMT), reducing the need for home heating, and switching to low-carbon forms of transportation. Important factors that complicate the low-carbon energy transition include the amount of change that must be made, the duration of the shift, and the energy uncertainty,
- However, when social institutions are progressively rebuilt in a low-carbon way, decades of policy development are required to implement the fundamental changes brought about by the low-carbon energy transition.
- A low-carbon energy transition should also take into account systemic changes in fundamental behaviours, practices, and regulations, as well as technological advancements, suitable legislation, and funding.

For instance, a change in consumer attitudes and technological advancements would be necessary to make the switch from gasoline-powered to electric automobiles.

However, both economic growth and human existence depend on fossil fuels. In the argument between those who believe that human behaviour must be changed immediately and others who want to maintain and improve the current socioeconomic structures, this point is frequently overlooked.

Additionally, the low-carbon energy transition requires regime change, which is accomplished through adjustments to institutions, infrastructure, and consumer behaviour.

However, because of regime opposition to the development of low-carbon energy systems, incumbent utilities may attempt to postpone or stop the low-carbon energy transition by forming a public discourse about the detrimental effects of low-carbon energy.

Social challenges - Energy justice

- It may be described as a global energy system where consumers equally share in the benefits and drawbacks of energy services.
- A standardised set of beliefs, values, abilities, passions, connections, and assets based on an understanding of the necessity of sustainable pathways are necessary for a successful low-carbon transition.
- If public interaction is not encouraged, policy decisions may be less responsive and representative, which might lead to societal conflict and animosity as well as increased inequality and exclusion.

Social challenges - Energy justice

Additionally, there are four types of justice:

- cosmopolitan (all people deserve just energy and are morally equal),
- recognition (the fair representation of those who are not physically threatened and are guaranteed full equality political rights),
- distributional (the balance of environmental advantages and disadvantages)
- procedural (participation in decision-making processes that promote equity).

Additionally, "just energy transition," which emphasises social justice as a key component of energy changes, is acknowledged by justice energy literature. Its objective is to prevent the impending energy transition period from creating new socioeconomic disparities or making preexisting ones worse.

When developing new energy technology, decision-makers can take energy justice into direct consideration.

It may be possible to "equalise" and "democratise" decarbonisation efforts by paying more attention to procedural, distributive, and energy justice details.

Energy justice is a space for creative discourses to promote more democratic energy systems and decision-making as well as alternative, participatory agendas.

- Reconversion: encouraging industrial redevelopment in affected areas;
- participation: encouraging increased involvement in the energy system; compensation: repairing harm done to individuals, society, investors, and the environment;
- distribution: bringing energy production closer to the point of consumption; transparency: assuming more transparent decision-making processes; plurality: encompassing a wide range of performers, viewpoints, and decision-making scenarios.

Social challenges - Labor transition

A major energy transition agreement that is signed by governments, unions, and labour might help to ease the move away from coal.

It will support the reformation of coal mines and prioritise retraining workers to enable a fair transition to socioeconomic factors.

The total impact on the labour force, however, depends on the possibility that individuals may leave the non-green sector in search of employment elsewhere, even though the low-carbon energy transition may result in a number of job vacancies in green businesses.

The transition's net inflationary effect would be a combination of job growth in green sectors, job loss in neutral industries, and employment loss in non-green industries, assuming that all new green industry positions were filled only by people quitting neutral industries.

Additionally, there are limitations on dynamic labour markets since they prevent workers from switching from the existing energy system to a low-carbon energy system because of demographic concerns, regional relocation difficulties, and skill shortages or mismatches.

The influence on labour market rules may aid in the low-carbon transition by reorienting the structural workforce towards low-carbon sectors.

According to this viewpoint, it is essential to look at whether REs technologies need more workers to produce the same amount of energy as fossil fuels since employment in related industries like fuel supply, installation, equipment manufacturing, and operation and maintenance (O&M) are included.

Skills

It is predicted that significant linkages would exist between employment growth and the requirement for various skill levels.

Additionally, it is clear that companywide skill demands – both direct and indirect impacts the economy – can alter the labor market' need, which has consequences for labor market strategy in the low carbon transition.

It should be noted that labor unions have worked to affect the allocation of advantages and disadvantages within energy systems by lobbying for and obtaining equitable distribution, recognition, and involvement primarily within current energy systems.

Social challenges - Energy security

Making sure nations transition to energy while taking energy security and fairness into account is a major challenge.

The reliability of the infrastructure and the efficiency of the main energy mix from both domestic and foreign sources are the two main components of energy security.

The affordability and accessibility of energy supplies for all communities is another definition of energy equity. However, energy security, resilience, availability, and governance already encompass sustainability and cost.

In order to identify and quickly determine what constitutes energy security, proposed four "Rs":

- **REVIEWING** available energy sources and suppliers, energy services and infrastructure, secure energy supplies and intensities;
- **REDUCING** energy demand through conservation and energy efficiency;
- **REPLACING** vulnerable energy supplies through diversification and infrastructure changes;
- **RESTRICTING** new demand to secured sources.

The four "Rs" state that managing energy supply and demand, advancing technology, and boosting the local and global economy are all necessary to achieve energy security with sustainability and equality.

Separating supply and demand security into two categories for energy security.

Supply security guarantees a sufficient, reliable energy supply at affordable prices without endangering important national interests and goals.

Demand security includes energy flow security, fair price, and customer availability.

Incentives and investment risk

More money is needed to meet the needs for climate change adaptation and mitigation since there is a large disparity between the amount needed to transition to low-carbon technologies and the amount that is now available.

Disruptive advances, however, have the potential to lower the cost of adopting RE technology while raising the cost of maintaining the electricity grid as of right now.

Off-grid renewable technologies are also reasonably priced for providing rural families with modern energy sources and might lead to better development, but they demand a large investment.

While the development of REs technologies may result in a short-term decline in GDP and labour productivity, the length of time and severity of this decline would depend on the expenditures needed for REs technologies.

Incentives and investment risk

In market-based countries, the municipal energy sector needs additional financial incentives to be motivated.

In order to overcome legislative reluctance and demonstrate a strong commitment to decarbonisation, authorities should also offer sufficient incentives for low-carbon technology.

Additionally, a number of obstacles to the development of low-carbon energy still exist in the absence of private investment and international collaboration.

Nonprofit investors and people, however, lack sufficient incentives to engage in renewable energy; in fact, their participation in renewable power is occasionally actively discouraged.

Indirect or direct disincentives include, for example, the low feed-in tariffs, the state-set meagre energy unit price, and the environmental tax on solar panels due to the carbon integrated into the production system.

Incentives and investment risk

As governments must show their contributions to the development of low-carbon energy when it comes to public money investment, they should offer economic incentives to investors in order to lower investment risk.

Furthermore, it is widely accepted that, in order to achieve such a massive increase in private investment, conservative mitigation measures must be put in place, and that the majority of these investment projects must be financed by private funds.

This implies a consistent shift in private investment from the current energy system to a low-carbon system.

Mitigation and adaptation costs.

"Mitigation costs" are the policy expenditures related to achieving climate objectives. Determining a practical and affordable low-carbon energy transition is therefore essential to averting the worst consequences of global warming.

Additionally, nations' ability to lead efforts to mitigate and adapt to climate change has been negatively impacted by financial limitations and infrastructure privatisation.

Furthermore, technological innovation and socio-technical transformation include a wide range of topics, including how to improve performance and reduce costs across technologies and deploy them in various settings.

Additionally, it is noted that the expenses of the energy shift include maintenance, different fuel types, building, operation, and the societal cost of carbon emissions.

Furthermore, new generations of biofuels are desperately needed to help combat climate change, but the greater price of advanced biofuels might make mitigation more expensive for society as a whole.

Due to the complexity of energy systems, which are defined by innovative technologies, carriers, spatial-temporal aspects, and infrastructure that requires a significant investment, the low-carbon transition will come with significant energy system transition costs.

Because of the substantial expansion of renewable energy, infrastructure investment is therefore essential. Additionally, system transition costs may arise from the phase-out of fossil fuels.

Therefore, as there is no one approach to accomplish a low-carbon energy system transition, cost reduction is desired yet challenging.

Although all approaches have the same objective, they differ in timing and pace, resulting in a wide range of transition strategies that impact transition costs.

Subsidies

Fossil fuel subsidies significantly affect the environment by promoting the low carbon transition, the adoption of renewables, and the labour shift.

Reducing subsidies is necessary to reduce greenhouse gas emissions and energy use.

It is generally accepted that subsidies for fossil fuels promote excessive energy usage; their removal would lower CO2 emissions associated with energy.

It is a fact that the cheap cost of coal and subsidies, which make the market for more sustainable alternatives uncompetitive, are among the factors preventing the expansion of renewable energy.

Nonetheless, government assistance and subsidies can help with the low-carbon energy transition; as a result, tax credits and subsidies successfully balance the market costs and profitability of different businesses.

Furthermore, it is thought that the price of fossil fuels is unpredictable and will likely keep growing, which will eventually make sustainable low-carbon energy more alluring.

Reducing subsidies will thereby reduce the demand for fossil fuels, increasing the viability of low-carbon energy.

A revival of fossil fuel energy subsidies for energy goods must also be prevented, and the government must keep reforming the energy market.

Land acquisition

One characteristic of the present global land rush is the requirement for large-scale land acquisition for the renewable energy transition.

Thousands of acres are needed for ultra-mega solar parks.

Suitable lands are scarce despite these large financial expenditures since they need to be available, the right size, and situated in regions with strong energy demand.

The aforementioned criteria could only be met by government-controlled areas, such as "wastelands" or "marginal" lands.

The worldwide land rush for a low-carbon transition depends heavily on land grabs.

The practice of enclosing vast tracts of land is known as "land grabbing" .

Furthermore, another type of land grab known as "green grabbing" involves taking natural resources and land in the name of sustainable development.

Land-use limitations may be necessary to safeguard high-biodiversity areas or locations at risk of losing carbon pools, often with financial compensation for landowners who lose out on revenue prospects.

Additional sustainability issues related to biofuels in general, like biodiversity, water management, and land-use change, are anticipated to be raised by the European Commission's plan for a low-carbon economy by 2050, which highlights the significance of developing biofuels technologies to fight climate change.

Particularly in the EU, like the Netherlands, land scarcity is a hindrance to the shift to a low-carbon economy because of the comparatively intense and growing conflict between land-use objectives.

Waste and pollution

Nuclear energy waste—public worries about radioactive waste—is the primary obstacle in waste and pollution management.

Additionally, through photosynthesis, biomass and biofuels—which are regarded as fossil fuel substitutes—may release pollutants like carbon monoxide.

However, the same amount of CO2 generated by fossil fuels might be collected by biomass-producing plants.

Lithium-ion batteries (LIBs) for electric cars and other energy storage devices that support renewable energy sources are also seeing growth in the industry. It would not be pollution-free to recycle LIBs.

Additionally, pyrometallurgy is a high-energy process that produces hazardous waste that needs to be landfilled, as well as greenhouse gas emissions and toxic fumes.

However, leachate formation—which is caused by a variety of biological and chemical degradation processes as well as rain soaking through garbage—is one of the most serious concerns associated with landfilling and illegal processing.

Natural resource consumption

Reliance on mineral resources serves as an illustration of the challenges associated with the global energy transition.

Studies have revealed a lack of variety in raw material supplies, including lithium, cobalt, and copper. The anticipated increase in the world's copper consumption will put further strain on the capacity for copper production.

Furthermore, it is thought that major risks are mostly caused by the increasing significance of storage, which raises the demand for natural resources and has inevitable environmental consequences, such as the use of mountainous regions for hydro storage, lithium extraction, and sand for building.

Additionally, integrating carbon capture and storage (CCS) would present risks, and the supply of renewable energy might be impacted by climate change. Furthermore, establishing biomass power plants requires long-term yet inexpensive supplies, and a lack of biomass resources prevents the widespread use of low-carbon energy.

Institutional challenges

The following provides a detailed presentation of institutional difficulties, such as anti-innovation, short-termism, disputes, and reformations.

- short-term thinking. Governments enacting short-term strategies to maintain political and economic viability are one of the obstacles to the development of low-carbon energy.

  For instance, guaranteeing short-term revenue is essential for political positions in petrostates with high budgetary break-even points (BEP), such as Iran, Kuwait, and Iraq. Furthermore, short-termism limits the options for combining short-term choices with long-term objectives by limiting the creation and implementation of public policies. Rather than providing a temporary private benefit, government involvement in the energy transition is more likely to address the long-term external cost of energy consumption.

Institutional challenges

Consequently, technological uncertainty and short deadlines that are incompatible with long-term system change must be dealt with by decision-makers. On the other hand, it moves from small-scale fixes to significant structural transformation within sociopolitical constraints.

Long-term collaboration and partnerships offer significant opportunities for accelerating technological and system innovation, scaling up collaboration, and increasing financial availability, as cooperation between governments and parties will be crucial to establishing a path towards a low-carbon energy transition.

Institutional challenges

Anti-innovation policies

To assist the low-carbon energy transition and change the existing state of the energy sectors, innovative policies are needed. Similar to public opposition and investment concerns, anti-innovation regulations may impede inventions.

In order to significantly reduce emissions on the demand side, mining, transportation, and industry sectors must implement suitable renewable energy legislation with international assistance.

Furthermore, although though carbon pricing is typically seen as the cornerstone of sustainable climate mitigation policies, creative policies like subsidies, rules, and information sharing are also required to spur innovation and remove obstacles to low-carbon pathways.

In order to enable the shift to a low-carbon economy, policy must also include measures that support renewable energy technology. To put it another way, government initiatives should be maintained throughout time, and all policies should be integrated to achieve the goals of the low-carbon energy transition.

New regulations are required to assist electricity storage systems (ESS) in the northern region of Italy, and it was also affirmed that central government organisations play a crucial role in solar PV in China. Werner and Lazaro (2023) also came to the conclusion that public support and political will are necessary for the implementation of climate and sustainable energy policy.

Institutional challenges

Conflicts and reformations

Systemic transformations of socio-technical systems towards sustainability are made possible by transition governance, a multifaceted, multi-actor, multi-level, and multi-phase governing process.

Thus, it is necessary to implement reforms gradually, particularly in authoritarian nations that tend to enforce regulations, which might lead to disputes while transitioning to low-carbon energy systems.

Throughout the several phases of policy formation, ongoing disputes may be seen, such as the political struggle over tariffs, which have a direct impact on investment returns.

In transition governance, which is commonly defined in its democratic form as the triangle of executive, legislative, and judicial authority, states usually play a major role.

Regulation, coordination, provision, introduction, management, and protection are among the responsibilities of the state in the transition governance process.

Clearly defining the extent of flexibility with which laws may be (re)designed highlights the limitations on maintaining policy credibility, especially when such modifications go counter to institutionalised projections of future policy changes in important areas of the policy mix.

Furthermore, as policy improvements may increase public knowledge and impact consumer choices, there may be a mutually reinforcing relationship between public awareness, the macroeconomic environment, and policy channels.

Technical challenges-Lack of technical standards

Novel technologies, laws, and policies, such carbon pricing schemes and regulatory requirements, or perhaps even less stringent rules pertaining to the growth of renewable energy, will need to be widely adopted in order to achieve the low-carbon energy transition.

An extensive system of rules and guidelines forces the energy supply to go in a certain direction. Furthermore, numerous stakeholders had attested to the absence of standards impeding the low-carbon energy transition, and came to the conclusion that the necessary regulatory frameworks are inadequate, preventing the adoption of innovative technologies in the energy sector, such as information technology, distributed electric energy, and renewable energy.

Furthermore, legal waste generation is made possible by legislation and decision-making processes that fail to take into account all potentially impacting operations and harmful pollutants.

Furthermore, although gaseous emissions are the focus of environmental regulations, businesses might potentially alter their operations to leak poisons into the air or groundwater, among many other sources.

Technical challenges- Lack of infrastructure

A fundamental shift in politics, infrastructures, and consumer behaviour is necessary for system transformation.

For instance, a change in automotive innovation and technology as well as a whole new infrastructure with electric charging stations would be necessary to make the switch from gasoline-powered cars to electric vehicles.

The grid's stability and adaptability are at danger due to the shifting demand for renewable energy as the energy transition appears to require an innovative energy infrastructure, which comes with a number of implementation hazards.

Technical challenges- Lack of infrastructure

The states' ability to oversee mitigation and adaptation efforts for climate change had been diminished by the privatisation of infrastructure; however, short-term emissions reduction necessitates both technical changes, such as new infrastructure, and social changes, such as overcoming fragmentation to provide new infrastructure.

A lack of infrastructure, particularly outdated and underdeveloped national grid networks, is another barrier to the adoption of renewable energy.

Nevertheless, choices about which resources to prioritise and where to build new infrastructure could lead to uneven regional economic development and energy poverty at the local and household levels.

Re-vitalizing Energy Transition in Touristic Islands

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