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Navigating Energy-Only Markets: Regulatory Insights from the Recent Crisis

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***Summary*:** Energy-only markets offer a number of attractive features if normal conditions prevail in an electricity market. However, in the event of external disturbances, stemming from short-sighted government policies, interruption in forces of supply, etc., these markets can be marked by substantially high prices. The growing popularity and affordability of renewable energy-based electricity makes the margin of error even smaller. This paper explores the role of energy-only markets in the recent European energy crisis, while drawing a comparison with the US electricity crisis. It also delves into the role of renewables, and proposes the way forward for regulators and policymakers, to prevent similar crises in the future.

***Keywords*: decarbonization, energy crisis, energy-only market, energy poverty, market forces, quadrilemma**

I. INTRODUCTION

Scientifically speaking, electricity generation is a consequence of power conversion. In thermal power, fossil fuels cause thermal conversion, a hydroelectric power plant converts head pressure, while wind power plant converts mechanically. Electricity produced through any scientific process is transmitted through the electric grid to its end consumers. Electric grids work reliably when supply of electricity is balanced with the demand for electricity. This is eerily similar to the concept of equivalence between demand and supply of any good in an economic sphere to arrive at the equilibrium price. An electric grid that has surplus power compared to demand for power, is overloaded and if not rectified, critical infrastructure could be destroyed or damaged. Similarly, if demand exceeds supply, the result is blackouts and brownouts. This physical constraint is addressed through base-load generation and variable-load generation. A constant demand can be fulfilled by baseline generators running inexpensively and reliably. Alternatively, spikes in demand are met by variable generators. What could go wrong in this perfectly synchronous universe of electric demand and supply? Yet, the bony arms of reality paint another picture.

The European Green Deal trajectory is a commitment of Europe to become climate neutral by 2050. The EU commission has devoted its efforts to reduce greenhouse gas emissions up to 55 percent till 2030 compared to 1990. However, the energy crisis of 2021 is posing a threat to radical decarbonization in Europe. The EU must come up with a robust way forward that can allow green transition amid energy market volatility without compromising the climate neutrality commitments of Europe.

Popkostova [1] explains that the aggressive polices to reduce emissions have compounded the situation in Europe. According to him, the winter of 2020-21 was unprecedented in both Europe and Asia who happen to be major competitive players for liquefied natural gas (LNG). The cold weather in Texas resulted in a reduced volume of LNG laden cargoes to Asia and Europe. The temperatures in summers increased significantly thus causing demand for air conditioning across Europe, Asia and America to accelerate. Further, Latin America faced drought periods that reduced the hydropower generation while the Panama Canal met with transit issues. All of this resulted in decreased volumes of LNG cargoes to Europe. The post-COVID economic stimulus packages across the globe raised the demand for LNG and other fuels so the competition for these scarce resources became fierce. The market forces of demand and supply chipped in by increasing prices significantly. Further, the supply chain bottlenecks from Russia could not be replenished timely to match the ever-increasing demand. On the one hand, the global arena left Europe looking at higher energy prices. On the other hand, the sub-optimal wind conditions in the EU compromised the wind generation significantly in Germany and Netherlands who rely majorly on wind power generation specifically after the phasing-out of nuclear power generation in Germany. The higher demand had to be met with higher supply. The reduced output from wind generation was fulfilled through coal and gas. The problem here became two-pronged for EU. The Emissions Trading System (ETS) rules kicked in and caused carbon pricing to soar [2]. Higher carbon pricing meant that it had become expensive to shift from already costly gas-based generation (lower carbon emission) to coal-based power (higher carbon emission). The result was higher coal and gas prices. Since major generation in Europe is gas-based and the marginal pricing mechanism in Europe is linked to gas prices, the cost of electricity in Europe ballooned to unprecedented levels and gave birth to the energy crisis. The renewables are already subsidized sources of energy. If the higher energy prices are subsidized to cure energy poverty for residential consumers and provide relief to energy-intensive industries, the result will be additional burden on the fiscal budget. Consequently, Europe realized that RE-based output curtailment cannot be met through large-scale batteries or sufficient baseload when there are supply and demand shocks from both, internal and external, factors. This implies that the European future energy system appears to be lacking robustness.

Interestingly, Popkostova [1] blames free markets for the European predicament. He maintains that laissez-faire framework should not be extended to energy markets because the balancing mechanism of demand and supply only works in case of temporary price fluctuations. This paper attempts to untwine the European energy crisis brain-teaser through argument based structure.

II. Body

1. DISSECTING THE EUROPEAN CRISIS BY DRAWING COMPARISON WITH THE US ELECTRICITY CRISIS

According to Adam Smith, the father of economics postulates, "The market price of every particular commodity is regulated by the proportion between the quantity which is actually brought to market and the demand of those who are willing to pay the natural price of the commodity, or the whole value of the rent, labour, and profit, which must be paid in order to bring it thither [to the market]."

Sennholz [3] explains that this supply-demand principle indicates three ways in which energy crisis could emerge. Firstly, in the event that legislators or regulators fix prices that do not allow for rent, labor and profit to bring electricity in the system. In this way, prices are set below the market prices and do not represent true costs. Secondly, when the legislators or regulators do not fix prices but prevent producers from meeting demand due to stringent emission rules that causes upward pressure on prices. Thirdly, legislators and regulators fix prices as well as prevent producers from entering the market through strict emission rules.

In California, the government restricted the entry of new nuclear, coal and oil power plants from 1980s. Only gas-based power plants were allowed to operate. This mandate of dismantling is akin to the phasing out of nuclear power plants in Germany. Furthermore, California faced inadequate pipeline capacity, causing supply chain issues. The next element that hopped on the bandwagon was the substantial increase in demand due to economic progress, population growth and unprecedented temperatures. Other things remaining equal, the surge in demand caused immediate shortage of power supply and prices faced inflationary pressure.

Under the government mandate, the utilities were provided lucrative incentives to sell fuel-based power plants. Consequently, they reduced self-generation from 72% to 20% while purchasing the imbalance from the market. The state law prevented long-term contracts due to the threat of collusion and created a spot market. Prices for the end-consumer were fixed at 12 cents but wholesale prices were negotiated from minute to minute at the power exchange which eventually exceeded 40 cents. The result was an electricity crisis that resulted in a whopping loss of $15 billion for utilities [3].

The underlying cause that brewed electricity crisis in California was majorly the imbalance between demand-supply due to limited expansion in generation and transmission capacity during the 1990s. There was a significant reduction in transmission infrastructure expansion as the demand growth from 1988 to 1998 was 30% compared to a growth rate of 15% in the transmission network. The problem escalated partly due to the market design where wholesale market was based on spot prices while retail price signals did not exist to respond to demand shocks. Nonetheless, California continues with its reliance on renewables. By 2020, the electricity prices in California were 50% higher than the national average for consumers [4].

The fundamental similarity between the European and California energy crises is the obvious disregard of the economic cost while formulating policies. Economic cost is not the price one pays for a good or service, but the reason or value one accords to that particular good or service. The cost of one unit of electricity from an RE-based source is the value an electric consumer could have gained from consuming another product or service. If a consumer has €1 and there is a choice of buying one unit of electricity and any other good or service at the same price of €1, the consumer will obviously choose the product that is more valuable than the other one. If consumer goes on to choose one unit of electricity at €1 then the cost of that one unit is not €1 which the consumer gave up to buy it rather it is the value of the other good which the consumer passed on. The other good is the true cost i.e. the economic cost of the consumer's action of buying one unit of electricity through renewable sources. Expanding it further, if a project is valued by an entrepreneur to be gaining higher return on investment to its consumers, the entrepreneur will pursue it despite higher initial investments because the project seems to be profitable. Simultaneously, other projects that are expected to reap lower returns on investment will not be adopted. Competition weeds out projects that entail lesser value. Such projects bound resources at the cost of projects having greater value to consumers. The end result is an economic loss to the whole society irrelevant to the meager short-term benefits such projects of lower value promise. The wasting of scarce resources at high economic cost (without sufficient expected value) usher in economic crises, which, if not bridled, cascade into social and welfare crises [5].

Germany increased the share of wind and solar energy in electricity generation significantly between 1999 and 2012. The share of energy from wind, solar and natural gas rose to 48% in Germany in 2020. On the other hand, the European Commission identified 49 shale formations in Europe at numerous locations in France, Poland, Romania, Portugal, Bulgaria, UK and Ukraine. Fennoscandian Shield is a shale formation stretching from Northern Europe to the Baltic States [6]. However, Europe decided against utilizing these resources and relied on intermittent RE and gas imports. When output from wind power plunged from historical levels in 2021, companies relied on gas power plants that already had limited stock and Europe witnessed the first indicator of an energy crisis when gas prices started increasing. The result is economic loss.

Similarly, Texas invested billions of US dollars into installing wind power plants across the state. To undertake the ambitious project of installing thousands of these plants, Texas needed hundreds of miles of transmission lines with price tags exceeding six billion US dollars. This dried up funds for the part of the grid that supplied reliable electricity to the consumers. As a result, routine maintenance on existing transmission lines was halted while emergency maintenance prevailed throughout the network. The winter storm of 2021 caused an unprecedented increase in demand for electricity and the same cycle of misallocation of scarce resources causing a demand-supply gap and consequently, crisis occurred all over again [7]. When solar and wind power generators ramp up supply during favorable conditions, the wholesale electricity prices plunge because of excessive supply. The coal and gas power plants lose money because of their inability to cover costs at lower prices. On the other hand, wind and solar power plants are protected by subsidies regardless of the wholesale prices. The result is, yet again, economic loss [8].

2. ENERGY-ONLY MARKETS AND RELIABLE SUPPLY OF ENERGY

Robert Bryce [9] regards electricity as one of the most important forms of energy upon which depends the human development and prosperity. In his book, "A Question of Power: Electricity and the Wealth of Nations" [9], he declares electricity to be the most important and most difficult form of energy to supply reliably. Undoubtedly, there is a significant relationship between energy consumption and human development. That is why access to reliable and sufficient supply of electricity can lift low-income countries out of poverty and maintain the living standard of high income countries.

The European markets trade electricity in energy-only form i.e. €/kWh. By design, energy-only markets motivate generators to produce more when the demand for energy is high because prices are high and consequently earn profits. During the macroeconomic crisis of 2008, the short-term profits of generators remained significantly below the fixed costs which caused the expected rate of return to shrink, discouraging new investments in the power plants.

What conspired in the current European crisis is that, in response to external and internal demand as well as supply shocks, the demand-supply gap widened causing scarcity of generation and putting upward pressure on energy prices [2]. These higher prices are actually "scarcity prices" that signal scarcity in the market. The signal of scarcity through higher prices encourages investments in new power plants. The prices may remain higher in the short run i.e. one to two years, however afterwards if new generation is not banned through any government mandate, the supply of energy will increase, causing downward pressure on "scarcity prices" thus curing inflationary pressures [10]. Yet the important factor remains that there should be no ban on new generation. Though the question of responsibly increasing the generation capacity remains, for environmental and climatic concerns.

3. INTEGRATING RENEWABLES: UNDERSTANDING THE UNAVOIDABLE CHALLENGES

The foremost question is the role of renewables in providing reliable energy supply. There are certain factors that explicitly and implicitly affect the cost of renewables. These costs, if ignored, can cause significant welfare and economic loss. The unreliability of renewables makes it challenging to integrate them into energy-only markets. Certain other factors make this even more challenging.

The life of a renewable energy power plant starts from design, procurement, construction, operations, maintenance, and ends at

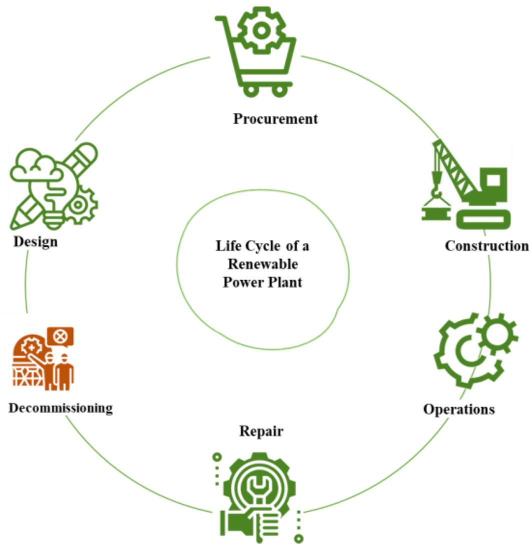

Figure 1: A Sustainable Lifecycle

decommission and disposal or recycling. Government subsidies extend to designing, procurement and construction while decommissioning and disposing is apparently still an unfamiliar subject. In the principle of fair treatment, the same standards of recycling, as are prevalent in decommissioning of mines and coal or nuclear power plants, should apply to renewables.

According to Jonathan Naughton, Director of the Wind Energy Research Center, a wind turbine is primarily made up of copper and steel that can easily be recycled, however, wind turbine blades, equal to the wing of a Boeing 747, are extremely challenging to recycle. There are certain efforts to repurpose these blades, but these are inadequate. It has been estimated that by 2050, the annual blade waste will reach to a staggering level of 43 million tons that is equivalent to 215,000 locomotives. [11].

The American civil society has been vibrantly vocal about the issue through movements like not-in-my-backyard (NIMBY), purely based on landscape destruction, high acreage requirements, noise and other environmental concerns. A total of 526 rejections have been recorded since 2015 in America regarding installation of wind (391 rejections) and solar power plants (135 rejections). Such sentiments can increase the economic cost of wind and solar power projects. Gathering public support to continue reliance on renewables and increase their share in the overall generation mix will become challenging in the near future. Europe has no wind corridor like US. The onshore wind farms are located in areas which rely on tourism for economic activities. There is growing public opinion against the installation of wind farms in such landscapes. Offshore wind farms have outperformed onshore wind farms in terms of stability. Yet issues related to requirement of huge investments in offshore grid interconnection and technological barriers have to be resolved to capitalise on these sources [12].

In addition, Sweden has shown its reluctance to pursue the green agenda aggressively. The Swedish Finance Minister, Elisabeth Svantesson has stressed upon the requirement of stable electric supply system to meet the energy needs of the country in comparison to intermittent renewable sources. [13]. Furthermore, the European Parliament has voted to classify nuclear and natural gas-based power projects as “environmentally sustainable”. In response, Netherlands, Italy, and Norway have accelerated gas exploration. By 2022, there were twenty-five additional LNG import terminals planned in Europe [6].

Bryce [9] has pointed out that renewable energy, on its own, cannot meet the electricity demand that is the “terawatt challenge” of world population over the course of time. He believes that four challenging factors obstruct renewables from securing the future energy systems which include, cost, storage, scale, and land use. The cost of relying on renewables is manifested through higher energy bills in California, Australia, Canada and Germany. With a price tag of $0.37 per kWh, the residential consumers of Germany, who majorly rely on renewable sources, pay the highest energy bills in Europe. Similarly, electricity prices for residential consumers have increased by 71% between 2008 and 2016 in Canada. [14]. Driessen [15], a senior policy advisor from US, reports that seven windless and sunless days powered by backup batteries to replace gas, nuclear, coal, internal combustion vehicles, and fuel for domestic and industrial consumption would need 8.5 billion MW of generation capacity. Fulfilling this much capacity translates to 75 billion solar panels or 4 million 1.8 MW onshore wind turbines, 3 million 12 MW offshore wind turbines or a combination of both, with additional 3.5 billion 100-kWh batteries, and new transmission lines stretching for hundreds of miles. Also, this will result in excessive mining to pump raw material for wind and solar power plants.

3.1. THE QUADRILEMMA OF RENEWABLES

In his book, “Power Density: A Key to Understanding Energy Sources and Uses”, Vaclav Smil [16] emphasizes the importance of power density in explaining the nature and dynamics of energy systems to improve efficiency and minimize environmental impact of various sources of energy.

Power density, as explained by Smil, is the rate at which energy is generated or consumed per unit of area or volume. Smil [16] acknowledges the potential and crucial need of transitioning away from fossil fuel-based energy towards renewables. Yet Smil stresses upon both realistic and cautious outlooks towards renewables because they have significantly lower power densities compared to conventional fuels like coal, oil, gas and nuclear. Lower power densities have serious implications for environmental impact of land use on large-scale deployment which entails significant cost in terms of natural and agriculture land.

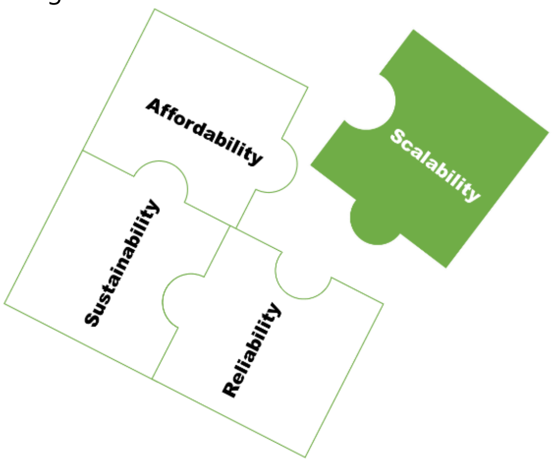

Figure 2: The Quadrilemma of Renewables

Layton [17] provided a mathematical framework for calculating energy densities of widespread energy sources. His results reveal that the energy density of oil is 35 to 45 gigajoules (10,000 kWh) per cubic meter. Scale-wise, one gigajoule equals one billion joules, and there are 3,600,000 joules in a kWh while a cubic meter is about half the volume of a kitchen refrigerator. Alternatively, his calculations found that solar energy has a density of 1.5 microjoules per cubic meter which is over twenty quadrillion times less than oil. He further calculated the energy densities of wind and tidal sources as 0.5 to 50 microjoules per cubic meter. This implies that the energy densities of renewables are significantly lower compared to conventional sources of energy.

He [17] goes on to calculate the true cost of energy. He explains that one human being throughout his life of fifty years consumes approximately 365 gigajoules of energy. This makes human energy to be valued as $1.37 per megajoule. From this calculation, he infers that human life is worth hundred times more than the fossil fuels. Using his calculation and assuming oil to be $79.9 per barrel, and that one barrel of oil contains 1.7 MWh or 6.1 gigajoules of energy, the cost of oil-based energy works out to be 1.2¢ per megajoule.

Layton [17] concludes that since quadrillionth is a millionth of a billion, it is extremely challenging to conceptualize the quadrillionth ratio between solar energy and petroleum density. He establishes that on the basis of energy density, the prevalent state of technological and economic advancement, as well as all of the world population combined with sources of solar, wind, lunar (tidal), earth (geothermal), cannot simply compete with ''black gold''.

Popkostova [1] establishes that the balance between the three dimensions of energy trilemma i.e. reliability, affordability and sustainability has been severely challenged to the point of worry. Based on the works of [9], [16] and [17], it can be inferred that one major dimension in the dilemma of energy has been grossly ignored: scalability. Hence, the energy sources face a quadrilemma comprising of four dimensions: reliability, affordability, sustainability, and scalability.

3.2. Aggressive Clean Energy Targets versus Considerate Clean Energy Targets

Without an iota of doubt, there must be a solution to arrive at the intended consequence of mitigating the disastrous effects of climatic rhythmicity without compromising the economic progression of human race. The focus should be on the intended outcomes rather than idealistic approaches to cure climatic and environmental woes.

Bryce [9] maintains that natural gas is both low carbon and low-cost source of energy. Between 1997 and 2017, a large number of reserves have been discovered in US, increasing global reserves by 50 percent, sufficient to last another 52 years. The natural gas can be transported to international markets as LNG, so there is no concern about storage. Comparatively, renewables face issues of storage, cost, and environment-friendly disposal of lithium-ion batteries which can cause serious impediments to the growth of renewables as integral part of the future electricity grid. Though there are future prospects of utilizing surplus seasonal energy from solar and wind for the production of synthetic fuels or hydrogen, which can be transformed back into electricity, or any other chemical form that can be stored cost effectively, the difficulties and costs associated with such transformations cannot be underestimated. Bryce [9] sternly establishes that there is no plausible way to cut carbon emission without increasing the portion of zero-carbon emission nuclear sources significantly. The International Energy Agency (IEA) also acknowledged this fact in its report [12] where it declared that without doubling nuclear energy, global carbon emissions by 2050 will increase so vigorously that controlling them will become much costlier. IEA [12] further warns that if the share of nuclear energy continues to decline, the electricity sector will require additional investments amounting to $1.6 trillion between 2018 and 2040, which will increase the supply costs to a staggering level of $80 billion in higher income countries. According to the IEA report, the European Union holds a substantial share of power sector investment hike in the Nuclear Fade Case, that is up to additional $560 billion between 2019 and 2040 [12].

The report supports installation of nuclear power projects which is consistent with the findings of Bryce in his book. [9] Bryce argues that the three major concerns with nuclear energy are radiation, waste and cost which are based on exaggerated empirical studies, inspired by political rhetoric rather than technological or scientific reasoning, and issues related to commercialization of plants and permissions. Bryce presents that the issue of cost associated with nuclear power plants can be resolved through installation of small modular reactors (SMR). His proposition is again consistent with the report of IEA. According to the report, light water-cooled SMRs are designed to enhance safety and reduce radioactive waste and they are at an advanced stage of development, while liquid-metal cooled, molten-salt cooled and gas-cooled SMRs are maturing technologies. The SMRs are comparatively less expensive because the components of plant can be fabricated in the factories rather than exclusively during on-site construction thus achieving economies of scale, and also additional capacity can be added flexibly to meet higher demand. A micro modular reactor (MMR), having a capacity of less than 10 MW, can provide electricity to remote areas with flexibility. US based NuScale is currently leading in SMR technology [12].

Overwhelming evidence suggests that since there is no tradeoff between human development and environmental sustainability, resources must be explored that do not hinder human development at the cost of afflicting irreparable loss to planet earth. Bryce [18] in his book, "Smaller Faster Lighter Denser Cheaper: How Innovation Keeps Proving the Catastrophists Wrong" believes that human ingenuity and innovation has been consistently solving problems. He relies on the power of innovation in bringing out new solutions to our current global challenges because the tools required to save humanity today cannot be found in the technologies or lifestyles of the past.

4. CAPACITY MECHANISMS: A RUNDOWN

Typically, the capacity payments in energy markets are designed to tone down the impact of market operations. Capacity mechanisms allow generating plants to make capacity available when needed. In exchange for this availability, 'capacity payments' are made to the generating plants. In energy-only markets, generating plants rely solely on the earnings from selling energy in the spot market. Under capacity mechanism, plants can earn additionally for making capacity available when required. Capacity mechanisms make resources available, yet caution is required in using this mechanism. If not handled carefully, the capacity mechanism can create a capacity payment trap that can increase the liability of the market tremendously. The power sector of Pakistan is engulfed by this capacity trap where the share of capacity charge in electricity cost has increased significantly (40%) [19] while energy charge is already high due to fuel inflation thus increasing electricity prices to unprecedentedly high levels.

A. INSTALLED CAPACITY MECHANISMS

In installed capacity markets, a market operator or administrator pays generators to make available a certain amount of generation capacity above recent summer peak demand (15%-20%). The capacity price is arrived through auctions in which peak generation plants and demand reduction service providers bid to fulfil the stipulated peak demand. The price that clears the market for additional supply over peak demand is added to the price that clears the spot market. In the US, prices for capacity have been increasing without installation of additional generation. Since the demand for electricity is inelastic, a small increase in demand causes prices to move upward significantly if the supply is fixed in the short run [8].

B. CAPACITY BANK

Hirth and Ueckerdt [10] suggest that the dispatch decision in energy markets may be transferred to an independent institution just like a central bank. They called it a "capacity bank". A capacity bank must enjoy complete autonomy from the regulator, system operator, market operator and government. The dispatch decision should be based on one stringent rule that the capacity bank will dispatch emergency reserve only when the day-ahead and intraday market do not clear even when price is significantly higher. The capacity bank must assess the volume of capacity needed in the next, say fifteen years, and procure the reserves through auctions and bidding. They further recommend that these emergency reserves should not be utilised with the agenda of climate policy or renewable expansion. Absolute procurement should be made to provide supply security in the market.

4.1. CAPACITY CHASING ENERGY:

Capacity is the maximum potential of a generating plant to produce electricity while energy is the actual flow of electricity. Energy produced by a generating plant is the result of utilization of its capacity over time. It can be deduced that the capacity prices or charges or payments should also be solely based on the forces of demand and supply because energy and capacity are two different products traded in the different markets, yet both are mutually dependent products. The signals emitted by scarcity prices are received by both capacity and energy producers. In a market where there is no ban on installing capacity, the prices will always clear the market without leaving any shortage or surplus. The most expensive supplier sets the price in the market for all generators to meet the demand at a given time. Inframarginal generators, which have access to relatively cheap gas because of long-term contracts and operate efficiently, enter the market to sell energy and earn profits. Marginal generators, that are both inefficient and costlier do not have opportunities to earn profit compared to the inframarginal generators. It is beneficial for inframarginal generators to keep excess capacity available. The competition in the market weeds out inefficient and expensive generators [8].

III. CONCLUSIONS

The energy-only markets are based on the balance between demand and supply of energy, which determines the price. If forces of demand and supply are allowed to act freely, prices will always adjust to clear market and there will be no shortages or surpluses. In a market where prices are flexible to clear the market, there can never genuinely be any surplus or shortage because prices emit all the right signals to the forces of demand and supply. However, any interruption in the forces of supply, such as banning of certain resources without considering the actual costs and consequences, will prevent prices from clearing the market in an efficient way. As a result, shortages at higher prices will become a common phenomenon in energy-only markets. The capacity payments should also be solely based on uninterrupted forces of demand and supply because inframarginal generators will keep excess capacity to capitalize on price signals and earn higher profits while filling the gap between supply and demand.

The quadrilemma of renewables is a serious impediment in their future growth. Scalability has costs, which cannot be ignored while making aggressive policies in the wake of climate threats. The blame falls on the enterprise of free market, yet the real cause of massive contradictions comes from such policies that ignore crucial elements related to costs. If prices do not reflect true costs, the forces of demand and supply will never pick the correct price signals, thus blurring investment decisions. The result will be an energy crisis. A technology-neutral approach to allow energy resources that have low carbon emissions (gas and nuclear) to compete fairly in providing flexibility to the future electricity systems will prevent human beings from plunging into energy poverty and secure a sustainable future.

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