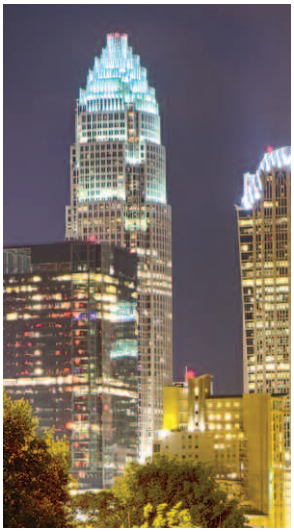
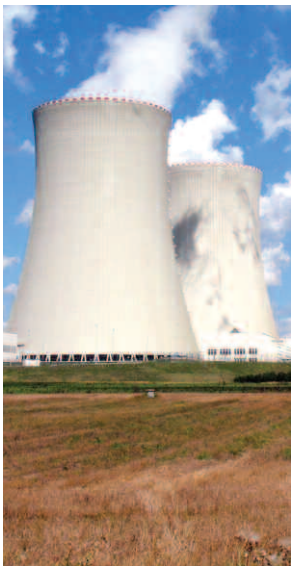
ENERGY FOR HUMAN DEVELOPMENT

BY TED NORDHAUS, SHAIYRA DEVI, AND ALEX TREMBATH








BREAKTHROUGH INSTITUTE

BY TED NORDHAUS, SHAIYRA DEVI, AND ALEX TREMBATH

ENERGY FOR HUMAN DEVELOPMENT

ABOUT

The Breakthrough Institute is a leading global research center that leverages high-quality scholarship to identify practical solutions to major environmental and human development challenges.

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EXECUTIVE SUMMARY

For over two centuries, an abundance of dense, fossil energy combined with modern agriculture, cities, governance, innovation, and knowledge has fueled a virtuous cycle of socio-economic development, enabling people in many parts of the world to live longer, healthier, and more prosperous lives. The discovery and conversion of modern fuels arguably enabled sustained economic growth for the first time in human history. These energy sources–principally coal and oil along with natural gas, hydroelectric power, and nuclear energy–have enabled rising living standards since the onset of the Industrial Revolution.[1]

Along with these material gains have come liberalizing social values, the ability to pursue more meaningful work, and environmental progress.[2 3] Billions of people around the planet are increasingly free to choose their own destiny.

In this report, we consider the relationships between energy systems, economic growth, human development, environmental protection, and climate change.

Understanding these relationships represents among the most pressing social and environmental questions facing the world today, as roughly three billion people have yet to make the transition to modern fuels and energy systems. These populations remain trapped in what we call the wood economy.

Living in the wood economy means relying upon wood, dung, and other basic bioenergy for primary energy consumption. For people who live in the wood economy, life choices are extremely limited, labor is menial and backbreaking, and poverty is endemic. There is little ability to produce wealth beyond what is necessary to grow enough food to meet minimal nutritional needs. For women especially, the wood economy is oppressive. Educational opportunities are limited, off-farm employment is rare, and social mobility is non-existent.[4]

While there is broad global agreement that everyone should have access to modern energy, there is no similar consensus about how best to achieve that outcome, how to mitigate climate change and other environmental impacts associated with energy development, or even what actually constitutes access.[5]

There is, however, a rich history to draw from. Over the last two hundred years, nations around the world have made concerted efforts to bring electricity and modern fuels to most or all of their populations. While the context and details have varied, there are a number of consistent features that have characterized successful efforts. Nations that have achieved universal electrification and access to modern transporta-

tion and fuels have uniformly moved the vast majority of their populations off of the farm and out of the agricultural sector. There is no nation on earth with universal electricity access that remains primarily agrarian. To date, urbanization and industrialization have been preconditions for universal access to modern energy systems.[6]

The relationship between rising incomes and rising energy consumption is bi-directional.[7] Modern energy infrastructure enables large-scale economic enterprise that

creates opportunities for off-farm employment, higher labor productivity, and rising incomes in the wage economy. Rising incomes allow people to afford modern fuels and electricity and the appliances that turn modern energy into useful energy services. Similarly, levels of energy consumed within households cannot be disentangled from energy consumed outside the household.[8] Unless there is energy and infrastructure to support large-scale employment outside of the household and the subsistence agricultural sector, there is little income available to purchase energy or appliances for household use.

Micro-finance, micro-enterprise, and micro-energy are no substitute for industry, infrastructure, and grid electricity.

Historically, rising household energy consumption, especially electricity consumption, has come as a side benefit of industrialization, urbanization, and agricultural modernization. Rural electrification has been the last step toward achieving universal electrification, after rural regions have depopulated, population has shifted to urban and suburban areas where economies of scale and population density allow electrification to be achieved at lower cost, and rising societal wealth in the urban and industrial core allow extension of electrical grids to the periphery, usually with some form of state subsidy.[9] Even in these contexts, rural electrification has only proved sustainable where it is targeted to raise agricultural and labor productivity, and hence produces incomes for rural populations consistent with rising consumption of energy.

Contemporary efforts to address energy poverty in developing nations that ignore this history are unlikely to succeed and will, at best, provide very limited development benefits. Programs that target household energy consumption without attending to broader economic factors are unlikely to significantly raise household energy consumption, even if they check the box marked "energy access," and risk, instead, confusing charity with development.[10]

Achieving modern levels of energy consumption for the three billion people who currently are locked out of the modern energy economy, consistent with achieving the human development goals with which energy consumption is highly correlated, can be achieved with more or less impact on the environment and the climate. But tradeoffs are inevitable and policies that condition development of energy infrastructure to a limited set of zero-carbon energy sources are unlikely to succeed at either their development or climate ambitions.[11]

Decentralized renewable and off-grid energy technologies can play an important role in some contexts, where they are targeted to increase agricultural productivity or otherwise support productive economic enterprises capable of raising incomes, particularly when they are deployed in ways that augment expanding centralized grid electricity. They cannot, however, substitute for energy and other infrastructure necessary to support industrial-scale economic enterprise. Micro-finance, micro-enterprise, and micro-energy are no substitute for industry, infrastructure, and grid electricity.

Developing economies do still have choices, however, and some of those choices might result in significantly lower carbon trajectories. Sub-Saharan Africa, for instance, is rich in both natural gas and undeveloped hydroelectric capacity, suggesting that African development might largely bypass coal.[12] China and India, both with large populations without access to modern levels of energy consumption, have both made significant commitments to both conventional and advanced nuclear energy and to utility-scale wind and solar development.

The right mix of fossil and low-carbon energy technologies for any given economy will depend upon local resources, technological and institutional capabilities, geopolitical considerations, and a range of other factors. Given current technological options, however, no practical path to universal access to modern levels of energy consumption is likely to be consistent with limiting global atmospheric concentrations of carbon dioxide to 450 parts per million (ppm).

While this reality brings with it unquantifiable risks of dangerous climate change, insisting – either implicitly or explicitly – that the poorest people on earth forego basic economic development in order to mitigate climate change would seem to be, at the very least, a morally dubious proposition, particularly given that energy development generally increases societal resilience to climatic extremes and natural disasters.[13]

Moreover, even without eradicating energy poverty, most plausible projections of future emissions find stabilization at 450 ppm increasingly unlikely.[14]

However, climate mitigation and a world beyond 450 ppm do not represent a zero-sum proposition. A world of 500 or 550 ppm is one less likely to experience catastrophic impacts than one that stabilizes at 700 ppm. More importantly, there are plausible decarbonization pathways that could bring significant climate mitigation benefits that are consistent with a world in which every person consumes energy at modern levels.

Whether 450 ppm or beyond, any practical path to deep global decarbonization will likely require low-carbon energy systems capable of supporting a global population with fully modern standards of living. Key priorities for achieving modern levels of energy consumption for the global population as quickly as possible include the following:

1. **Prioritize energy development for productive, large-scale economic enterprises.** Economic opportunity at scales consistent with broad improvements to household incomes is not possible without significant growth in non-farm and non-household economic sectors.

2. **People to the power.** There is no pathway to significantly higher levels of energy consumption without moving most people out of subsistence agrarian poverty and into higher productivity off-farm employment and livelihoods in the formal knowledge, service, and manufacturing economies.

3. **Energy and electricity are not the same.** Efforts to address energy poverty must address needs for transportation fuels and infrastructure, and for fertilizer and mechanization of agriculture.

4. **Maximize bang for the buck.** Given the enormous population still lacking access to basic energy services and consuming energy at extremely low levels, national and international investments in new energy infrastructure must prioritize bringing the most energy to the most people.

5. **Off-grid investments must be an on-ramp, not a cul-de-sac.** Where off-grid technologies are the focus, they should be understood as transitional technologies to full grid access, not an alternative, and should be deployed in ways that hasten the arrival of grid electricity.

6. **Energy abundance is a public good.** Successful efforts to end energy poverty have and will continue to succeed when they are not pursued piecemeal but through strategic government industrial and agricultural policy, strong institutions, public utilities, and regulated monopolies.

None of the above assures decarbonization at levels consistent with meaningfully mitigating climate change. Building a high-energy, low-carbon planet demands accelerating the transition out of energy poverty for the world's poor while also making progress towards deep decarbonization by sometime later this century. These parallel social and environmental goals suggest several imperatives for policy and development:

1. **Focus on carbon intensity.** The key to mitigating emissions to the greatest extent possible while addressing energy poverty will be to accelerate the long-term trend toward higher-density, more efficient, lower-carbon fuels and technologies.

2. **Leapfrog dirty energy, not development.** In some cases, energy development may "leapfrog" some high-carbon fuels and technologies, but key steps in the development process such as urbanization, industrialization, and agricultural modernization cannot be leapfrogged.

3. **Innovate for a high-energy planet.** Current-generation low-carbon technologies cannot meet growing global energy demand at the necessary scale. Innovation must take center stage if all the world's inhabitants are to enjoy secure, free, prosperous, and fulfilling lives on a high-energy, low-carbon planet.

INTRODUCTION

This report is about the role energy plays in human development.

Human development is the process of expanding peoples' choices, including choices that allow them to lead long and healthy lives, to be educated, to enjoy a decent standard of living, and to decide what they will do and who they will be. Throughout human history most peoples' choices were limited to whatever it took to survive; education, material wealth and the choices these enabled were restricted to a privileged few. By current standards almost everyone living in the 19th century was poor and unhealthy; the average person lived only 30 years;[15] over 40% percent of children died before they reached their fifth birthday;[16] and even the most advanced economies had gross domestic products that would rank them among today's poorest countries.

Lifting all of humanity out of the wood economy represents the essential unfinished business of the modern project.

Modern energy – mostly fossil fuels – changed all of that. Abundant energy enabled the development of agriculture capable of providing cheap, abundant food to billions. It fueled industry that created jobs and material abundance. It made possible globe spanning transportation and communication systems that connected the world. Perhaps most importantly, it decoupled economic growth and wealth creation from the amount of labor that could be applied to arable land. In modern societies, energy coupled to technology has untethered human well-being from brute physical labor.[17]

Yet, amidst this new world of abundance and choice, there are still billions of people living without much choice about what they will be or do, who will get up every day of their lives hoping to grow enough food to feed their families. Billions of people live in what we call the wood economy. In these parts of the world, average per-capita

energy consumption is a small fraction of the amount consumed in developed countries. People still have to grow most of their own food, find, carry and burn enough wood, dung or crop waste to cook a meal, and haul water over distances. People who live in the wood economy live substantially shorter lives and have little access to education, infrastructure, markets, or off-farm employment. To live in the wood economy is to be poor; there is no affluent country in the world where people continue to rely on biomass for their primary energy.

Lifting all of humanity out of the wood economy represents the essential unfinished business of the modern project. In this report, we consider the role that energy plays in the process of modernization and human development, examine the opportunities to accelerate energy development in order to eliminate energy poverty, consider the implications of doing so for climate change, and examine the possibility that alternative energy and development pathways might better address global poverty with lower impacts upon the environment. Finally, we suggest a path toward universal access to modern levels of energy consumption that might best serve human development imperatives while mitigating climate risk.

PART I: CONTEXT

MODERNITY & ENERGY

Before the 1800s, economic growth was presumed to be limited by decreasing returns on the productivity of land, a fixed resource. But beginning in the 19th century, abundant and cheap energy, initially coal and later oil, began to replace biomass fuels and human and animal labor, decoupling economic growth from the availability of land, labor, and organic energy resources. This ignited a massive acceleration of growth far beyond what was believed possible by foundational economic philosophers like Smith, Ricardo, and Malthus.[18]

The fossil-fueled industrial revolution arguably kickstarted sustained, exponential economic growth for the first time in human history.[19] With abundant energy, mechanization, agricultural modernization, and labor specialization, productivity expanded enormously. The resultant economic growth fueled, and was in turn fueled by, unprecedented growth in the human population, from less than one billion in 1800, to two billion in 1930, to three billion in 1960, to over seven billion today.

Fertility rates over this period actually fell, as large populations moved from rural agrarian economies that required large families to work the land to urban economies in which wages and employment, not land and labor, determined economic well-being. With changing economic incentives came changing social arrangements and values. Girls were increasingly able to attend school and women to work outside the home, undermining traditional social mores and family structures and reinforcing the shift toward smaller families. But population increased nonetheless as falling infant mortality and rising life expectancy outpaced falling fertility rates.[20]

Improvements in health and welfare that enabled sustained population growth and rising living standards have been indivisible from other positive trends traced by the arc of industrial development.[21] As cities, commerce, and economies grew, so too did the size and sophistication of governments. Government regulation and investment created productive opportunities for private investment by building infrastructure, structuring markets, developing technologies and funding public education systems.[22] These in turn spurred innovation, improved products, lowered costs, enhanced services and led to greater knowledge that benefitted lives and livelihoods.[23]

Modern agriculture, cities, energy, governance, innovation, and knowledge have fueled a virtuous cycle of development. The growth of cities and the rise of market

economies created markets for cash crops and allowed farmers to invest in labor saving devices that allowed them to grow more food with less labor. The resulting agricultural surpluses helped to feed growing cities and allowed more people to leave the farm and seek opportunities in the cities.

Growing population and rising living standards associated with higher levels of material consumption also brought significant environmental impacts. Air pollution from coal burning plagued cities in the early phases of industrialization from the 19th century onwards. Rising automobile ownership and congestion created similar problems in the 20th century. Pollutants and toxins concentrated in urban areas before infrastructure and institutions evolved to mitigate them. Carbon emissions released through the burning of fossil fuels have warmed the atmosphere by about one degree Celsius since the onset of the industrial revolution.[24]

These trends – rising health, security, and prosperity along with increasing environmental impacts – increasingly describe the world where over half of humanity lives and are inseparable from the order-of-magnitude increase in energy consumption that comes with the shift from agrarian societies to modern living arrangements. Energy production and conversion technologies have seen exponential efficiency improvements over the last two hundred years. But the sheer scale of energy consumption that modern fuels and energy technologies have made possible still vastly outstrips the efficiencies that improving energy technologies have achieved.

THE WOOD ECONOMY

Despite these overall positive trends toward abundance and choice, about three billion people have yet to fully benefit from development, and remain locked out of the modern world. Most of that population lives in Asia – 400 million in South and Southeast Asia, 600 million in China, and 700 million in India. Most of the remainder – approximately 800 million people – live in sub-Saharan Africa.[25]

All told, about 40% of the global population still depends upon burning biomass such as wood or dung as their primary form of energy. People who live in the wood economy have to work hard to cook a meal, wash up, or heat their house. Finding enough fuel to burn can take a great deal of time, because in many places, residents of the wood economy have long ago found and carried away everything that was close at hand. Carrying fuel can be exhausting; biomass contains relatively little energy,[26] and so it takes a lot of it to create sufficient heat. People – mostly women and children – can spend hours a day in increasingly distant and frustrating searches, and hours more hauling it home.[27] [28]

The human cost in the wood economy is high.[29 30 31] The World Health Organization reports that every year over 4 million people die prematurely from illness attributable to household air pollution from cooking with solid fuels. That's more deaths than are attributable to HIV and malaria combined. Moreover, more than 50 percent of deaths among children under age five are due to pneumonia caused by particulate matter (soot) inhaled from household air pollution.[32] But the negative human impacts of the wood economy extend well beyond the direct health impacts associated with burning wood, dung, and other forms of biomass. Labor-intensive and time-consuming activity, such as gathering wood, hauling water, and tending to fields keep children out of schools, and prevent women from participating in the formal economy – which bring enormous costs to society, economically and socially.

Although the wood economy is a low-consumption, low-carbon economy, it can still have devastating environmental impacts. Due to its dependence on wood and charcoal for fuel, the wood economy can drive forest degradation, most prominently in Africa, where fuel wood collection and charcoal production have higher negative impacts than in any other forested regions.[33 34] Protein in subsistence diets comes disproportionately from bushmeat, which can drive defaunation of local forests and grasslands.[35] Subsistence agriculture is also characterized by low crop yields, which means more land is required to produce sufficient amounts of food, leading to soil erosion and deforestation.

Despite low per-capita carbon footprints, the wood economy contributes to global climate change in other significant ways. The conversion of forest to farmland, often driven, at least initially, by demand from smallholder farmers for additional land for low productivity crops and pasture, is currently responsible for about 13% of global greenhouse gas emissions.[36] Black carbon, or soot, produced by the burning of biomass is making a larger contribution to global warming than had previously been recognized. Researchers conclude that the role of black carbon ranks second only to carbon dioxide as the most important climate warming agent.[37]

There are thus ample human and environmental benefits to be achieved through the acceleration of the transition out of the wood economy through increased energy consumption. The movement away from the wood economy brings longer and healthier lives, creates greater opportunity for income generation and economic mobility, and allows far greater availability of life choices, especially for women.

HOW ENERGY POVERTY ENDS

Over a billion people living in the wood economy have some access to electricity – for lights, fans and cell-phone charging, and maybe even laptops, radios, and TVs.[38] But they still gather wood for heating and cooking, haul water for drinking and washing, and spend their days tending crops in order to feed themselves. They lack access to modern transportation fuels, and are isolated from modern infrastructure including roads, water, irrigation, sanitation systems, and grid electricity.

Energy consumption, not energy access, is the metric that is strongly correlated with better human development outcomes.

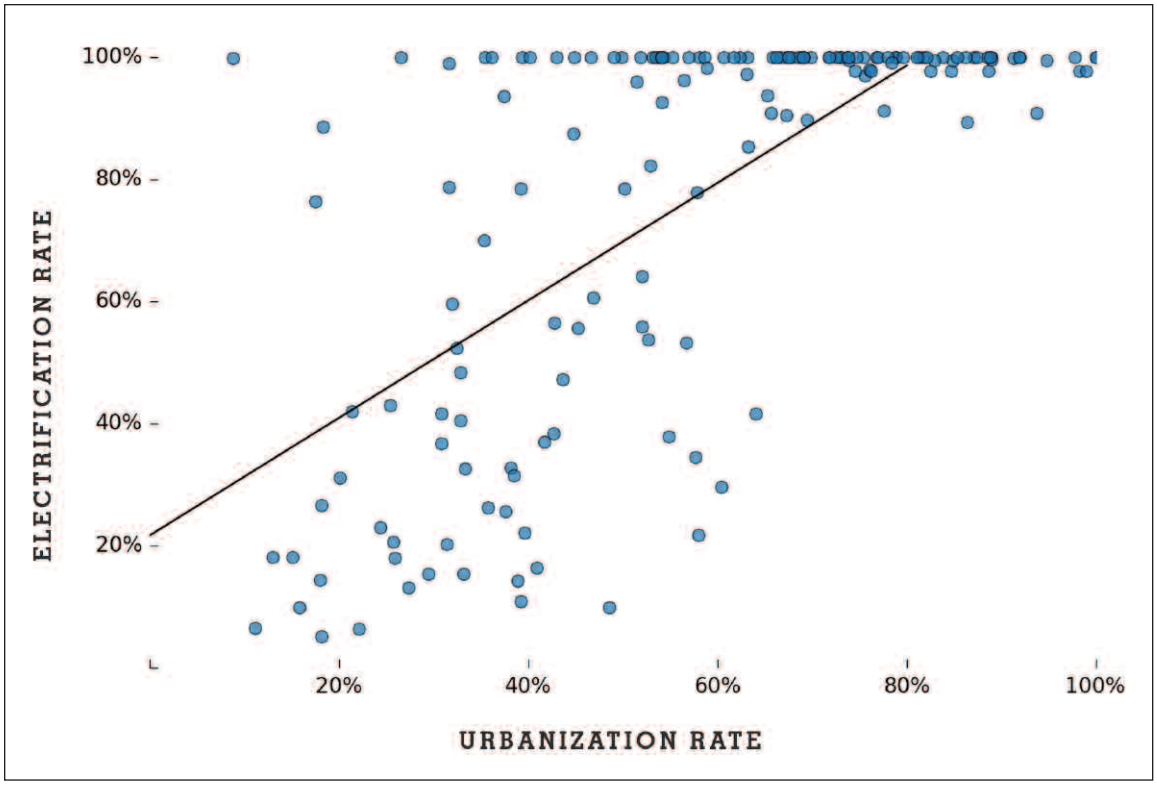
In this regard, the problem faced by the energy poor is not so much *access* to modern sources of energy as *insufficient consumption* of energy. Achieving modern levels of energy consumption is not simply a question of achieving access to a source of electricity, be it grid-based or off-grid. It requires sufficient incomes, infrastructure, and development such that households are capable of both affording significant amounts of energy and purchasing appliances, such as refrigerators, washing machines, water pumps, grain mills, and the like that allow them to use electricity and other forms of energy productively.[39]

Efforts that focus singularly on increasing the number of households with access to electricity are unlikely to significantly reduce energy poverty, close inequities in energy consumption, or even significantly reduce solid fuel use unless those efforts contribute in some meaningful way to increasing economic opportunity, labor productivity, and incomes. Energy consumption, not energy access, is the metric that is strongly correlated with better human development outcomes. There is little evidence

that access to modern sources of energy absent significantly higher levels of energy consumption improves public health, education, or other key social development indicators.[40 41 42] Energy access only contributes to human development, Shonali Pachauri and coauthors conclude in an assessment for the International Institute for Applied Systems Analysis, insofar as it supports "activities that are income generating and could empower growth and development."[43]

Importantly, modern household energy consumption has historically been achieved as a *side effect* of electrification for non-household purposes such as factories, electrified transportation, public lighting, and commercial-scale agriculture. Rising household incomes and low-cost generation and distribution of electricity were both made possible due to an initial focus on provision of energy services for productive economic activity, not household consumption.[44 45] The provision of productive energy services – especially in agricultural processing, mining, and factories – tends to create the load necessary for investment in large-scale, cost-effective power generation and distribution facilities. The large-scale economic enterprises those services enable create opportunities for off-farm employment, higher incomes for those who leave the farm, and higher labor productivity, and hence incomes, for those who stay behind.[46] Together, centralized generation and distribution of low-cost electricity and rising incomes due to the large-scale economic enterprises that infrastructure enables make possible rising household levels of energy consumption that simply providing household access to electricity cannot achieve.

ELECTRIFICATION RATES AND URBANIZATION RATES



Data Source: World Bank. *Urbanization rates and electrification.*

All countries with population greater than one million.

158 countries represented in total.

As a result, we would expect household energy consumption to increase as an indirect function of rising energy consumption in the industrial, transportation, and commercial sectors. The paradox of household energy consumption is that the wealthier a society is, the higher its household energy consumption is *and* the more of its economic output and energy consumption resides outside the household.[47] Italy's share of energy consumption in 2008, for instance, was only 17% residential, and similarly Norway's was only 21%. On the other hand, in 2008, Nigeria's residential share of total energy consumption was 65%.[48]

For these reasons, historically, most people around the world have achieved access to modern levels of energy consumption by moving to where electricity and economic opportunity already exist, not through the provision of electricity in rural, agrarian

contexts. While there is a long history of rural electrification efforts, those efforts have generally succeeded after most of a nation or region's population has already made the transition from rural agrarian to urban and industrial social and economic arrangements.[49] Rural electrification, where it has succeeded, has historically been the final step in achieving universal electrification, not the opening act.

Rural electrification, where it has succeeded, has historically been the final step in achieving universal electrification, not the opening act.

The empirical relationship between energy consumption and human development is clear, as is the history of efforts to assure universal access to modern levels of energy consumption. Modern living standards cannot be supported without modern levels of energy consumption. Modern levels of energy consumption are not possible without a shift of large populations from rural to urban settings and from subsistence agrarian economies to higher income, higher productivity off-farm employment. International efforts to reduce energy poverty and promote human development that do not prioritize these processes are unlikely to succeed in either significantly increasing energy consumption or living standards among the energy poor.

ENERGY ACCESS VERSUS ENERGY FOR DEVELOPMENT

Recent years have seen increasing focus among international development institutions on the role of energy in development. The United Nations declared 2012 the Year of Sustainable Energy for All, with the goal of ensuring universal access to modern energy services by 2030 and included energy access in its Sustainable Development Goals (SDG). In 2013, the Obama Administration launched the Power Africa initiative with the goal of doubling access to power in sub-Saharan Africa.

All of these efforts have been framed around the challenge of energy access, defined by the International Energy Agency (IEA) as "household access to electricity and clean cooking facilities." The IEA defines "modern energy access" as consumption of a mere 100 kilowatt-hours per person per year for urban areas and half that for rural areas – an amount that only allows for "a city dweller to power a single light bulb for five hours per day and charge a mobile phone."[50]

In its roadmap to universal energy access by 2030, the United Nations Sustainable Energy for All Initiative (SE4All) focuses on four key technological pathways: clean cookstoves, biomass-based mini- and micro-grids, decentralized solar generation technologies, and energy efficient solar lanterns and lighting. Consistent with that focus, other international aid groups, governments, and multilateral development agencies have distributed tens of millions of clean cook stoves to reduce the smoke from fires and make wood and dung burn more efficiently.[51] Millions more solar lanterns have been donated or sold to the energy poor as a replacement for candles and kerosene lamps. Agricultural modernization, industrialization and urbanization have not constituted a particularly central focus of any of these efforts. The resulting contrast, between contemporary energy access programs targeting household electrification in rural regions and the historic path by which large populations have achieved modern levels of energy consumption and, with that, modern living standards, could not be more distinct.

Where the traditional path to higher energy consumption and living standards has focused on centralized energy infrastructure to support large-scale economic enterprises in the production economy, these contemporary programs emphasize

small-scale, decentralized energy technologies to support modest increases in household energy consumption and, perhaps, small-scale community-based economic enterprises.

Where the traditional path has overwhelmingly involved rural populations migrating from subsistence agrarian economies to urban settings in which grid-based electricity could be provided cheaply and off-farm employment could support higher levels of consumption, current efforts focus on achieving modest increases in energy consumption within existing subsistence agrarian contexts.

And where successful provision of modern energy consumption to large populations has historically been state-led – usually through a combination of publicly-constructed infrastructure, publicly-owned utilities, publicly-regulated private monopolies, and public subsidies for low-income energy consumers – current efforts heavily emphasize private finance, private firms, and privately owned infrastructure as the means through which decentralized energy technologies will reach low income populations.

In all of these regards, the contemporary energy access agenda looks remarkably similar to the micro-finance effort. Like many current energy access efforts, micro-finance offers household-scale interventions as the solution to widespread poverty; celebrates self-help and the individual entrepreneur; and assumes that simply reaching the poor with a small benefit (microcredit in one case, lightbulbs and phone charging in the other) will establish a sustainable economic and social development trajectory.

In the case of micro-finance, the evidence for these assumptions was considered so weak that one major UK government-financed study concluded that the entire microcredit movement had effectively been constructed on "foundations of sand."[52 53] "The microfinance model may well generate some narrow positive short run outcomes for a few lucky individuals," write Ha-Joon Chang and Milford Bateman in their extensive review of the literature on micro-finance, but "positive outcomes are very limited in number and anyway swamped by much wider longer run downsides and opportunity costs at the community and national level."[54]

There is similarly little evidence or experience to suggest that micro-energy interventions are likely to move large populations out of deep agrarian poverty. The provision of small-scale, decentralized energy technologies at the village or neighborhood level

has yet to demonstrate much efficacy as a strategy to enable broad society-wide economic development or improvements in living standards.

Leading micro-grid proponents have suggested that the widespread deployment of solar powered microgrids might allow developing nations to "leapfrog" centralized electrical grids and electricity generating technologies. But there is little reason to think that leapfrogging of this sort can support heavy industry or provide fuels for modern cities, agriculture and transportation.[55]

What little evidence there is that microgrids can support sustained improvements in incomes and living standards finds that microgrids can in some cases promote small-scale milling and processing of agricultural products at the village level. But an extensive review for the World Bank in 2014 concluded that off-grid electrical systems "ultimately do not expand access beyond basic household needs."[56] These sorts of limitations are even more pronounced with regard to solar-powered microgrids, which are poorly suited for high voltage applications such as agricultural processing, irrigation, or manufacturing.[57] The benefits of low-energy, decentralized, and rural-focused development schemes promoted by the United Nations and other international development institutions and NGOs, therefore, appear to be limited to the village level and represent a short-term means of modestly ameliorating rural poverty, not a plausible pathway to modern living standards.[58] Micro-energy investments such as cleaner cook stoves, solar lanterns and household-scale solar systems may deliver modest benefits at the household level, but they do little to lift people out of subsistence economies. An end to the backbreaking work of plowing fields and hauling wood and water has come by moving to cities and joining the formal economy. That requires energy for fertilizer and the mechanization of agriculture, for transportation fuels and infrastructure, and for manufacturing and industrialization.

PART II: A FRAMEWORK FOR ENERGY DEVELOPMENT

ENERGY FOR DEVELOPMENT

The history of successful efforts to assure modern levels of energy consumption for large populations in nations around the world holds important lessons for global efforts to end energy poverty. So too do the more modest results that alternative, off-grid energy systems have demonstrated to date.

Strategies intended to alleviate energy poverty that do not align with and reinforce the long-standing drivers of rising energy consumption (namely urbanization, industrialization, and agricultural modernization) are unlikely to succeed. Successful efforts to address energy poverty will be consistent with a number of key concepts and principles.

1. **Prioritize energy development for productive, large-scale economic enterprises.**
   Higher levels of household consumption are not possible without higher incomes and higher incomes are not possible without economic opportunity. Economic opportunity at scales consistent with broad improvements to household incomes is not possible without significant growth in non-farm and non-household economic sectors. Growth in non-farm, non-household economic sectors is not possible without modern, large-scale energy infrastructure. Efforts to significantly increase household energy consumption will need to prioritize the provision of energy for industrialization, agricultural modernization, and economic growth.

2. **People to the power.**
   There is no pathway to significantly higher levels of energy consumption without moving most people out of subsistence agrarian poverty and into higher productivity off-farm employment and livelihoods in the formal knowledge, service, and manufacturing economies. Most countries around the world will need to urbanize to move their populations out of energy poverty, a great transformation that is already taking place at a historically unprecedented rate. As such, national and international efforts to accelerate energy development and eliminate energy poverty should prioritize resources toward large-scale energy development for cities and the infrastructure and economic enterprises that make them magnets of economic opportunity.

3. **Energy and electricity are not the same.**
   Many efforts to address energy poverty focus on electrification. But many important energy services are not electrified, particularly within the transportation and farming

sectors. Of all the energy used globally in 2012, only 18.1%was consumed in the form of electricity, with less than half of all electricity going to residential use. Another 66% of final energy demand is satisfied directly by coal, oil, and natural gas. Most of this is for transportation and industry.[59] Efforts to address energy poverty must address needs for transportation fuels and infrastructure, and for fertilizer and mechanization of agriculture. The latter are critical to raising on-farm productivity and incomes, freeing up labor to move to higher productivity off-farm employment, and creating sufficient agricultural surpluses to feed large urban populations. The former are critical to providing farmers access to markets, urban populations access to food, and more generally creating opportunities for economic integration and the growth of the formal economy.

4. **Maximize bang for the buck.**
   Given the enormous population still lacking access to basic energy services and consuming energy at extremely low levels, national and international investments in new energy infrastructure must prioritize bringing the most energy to the most people. In general, grid electricity will serve more people at lower costs than any other investment. A recent analysis by the Center for Global Development estimated that a $10 billion investment by the Overseas Private Investment Corporation in natural gas generation in Africa would serve three times as many people as the same investment in renewable energy technologies.[60] Using geo-coded data from Western Kenya, UC Berkeley's Catherine Wolfram and colleagues have shown that many un-electrified homes are within 1,000 meters of an existing grid connection. Observing this, Wolfram et al. introduce the term "undergrid." Lack of connection for those undergrid results from a combination of costs, lack of access to credit, and inefficient government connection policies, suggesting that great progress on increasing energy access and energy consumption might be made at relatively low cost simply by prioritizing connecting those to the grid who already live within relatively close proximity.[61]

5. **Off-grid investments must be an on-ramp, not a cul-de-sac.**
   Solar lanterns and other decentralized energy technologies can represent a good first step in some locales. Where off-grid technologies are the focus, they should be understood as transitional technologies to full grid access, not an alternative, and should be deployed in ways that hasten the arrival of grid electricity. They will also need to target productive uses in the agricultural sector that can raise agricultural productivity, and hence on-farm incomes, such that higher levels of energy consumption can be supported.[62]

6. **Energy abundance is a public good.**
   Public policy and institutions are necessary to assure universal access to electricity and rising levels of energy consumption. Large-scale electrification has never been achieved without substantial involvement by the public sector. Whether through regulation of private monopoly utilities or the direct provision of energy services through public utilities, the build-out of large-scale energy generation and distribution infrastructure for both the production and household sectors has, in almost all cases, been led by public institutions. Once access to electricity has been achieved by most, if not all, sectors of society, privatization and deregulation of energy services can sometimes bring greater efficiencies and lower costs. But in the early stages of electrification, market-based policies to reform energy services have the potential to impede the growth of energy access and consumption. Successful efforts to end energy poverty have and will continue to succeed when they are not pursued piecemeal but through strategic government industrial and agricultural policy, strong institutions, public utilities, and regulated monopolies. This has been the consistent pattern in countries that have achieved universal electrification, and successful efforts in the future will likely require similar strategies.

ENERGY DEVELOPMENT AND CLIMATE MITIGATION

So long as fossil fuels remain the primary source of energy powering the global economy, energy development in poor countries around the world will bring with it significant risks associated with climate change. Despite close to three decades of international negotiations, commitments, and activism, global emissions and atmospheric concentrations of CO2 have continued to rise rapidly, with atmospheric concentrations of CO2 exceeding 400 part per million (ppm), up from 280 ppm prior to the industrial revolution.

These developments have reinforced one key principle at the heart of the United Nations Framework Convention on Climate Change – the clear mandate that poor nations have a right to develop – while deeply undermining two others: the notion that poor nations might develop in a significantly less energy- and carbon-intensive way, and the concomitant commitment to stabilize global temperatures at two degrees Celsius and global atmospheric carbon concentrations at 450 ppm. Given current global development trajectories and current energy technology, the prospect of stabilizing atmospheric carbon concentrations at 450 ppm is improbable.

As atmospheric concentrations move beyond 450 ppm, risks associated with climate change increase, most especially for the global poor, who lack the wealth, infrastructure, institutions, and social safety net that make wealthy societies highly resilient to climate-related disasters. Yet despite those risks, poor nations have consistently chosen to pursue fossil-energy-based development because, while energy- and carbon-intensive development in poor nations contributes to worsening climate risk, it also makes poor societies more resilient to climate change. Faced with a choice between improving living standards and with that, resilience to natural disasters (climate related or otherwise) today, or avoiding worsening climate impacts over the course of the next century, poor nations have chosen to pursue development and resilience in the present, and take their chances with climate change in the future.

Viewed in isolation, the wisdom of that choice is difficult to evaluate, due to uncertainties both about the severity and nature of future climate impacts and the capabilities of modern societies to adapt to them. But considered more broadly, in the context of the totality of ills and challenges that poor nations face, the choice is obvious

and understandable. Billions globally suffer from indoor air pollution, water borne illnesses, treatable diseases, and malnutrition today. Energy development and modernization solve or dramatically ameliorate all of those problems, and make societies more resilient to both present day natural disasters and future intensification of those disasters due to climate change.

While the prospects of stabilizing atmospheric carbon concentrations at 450 ppm are not good, stabilizing emissions at relatively lower levels, even if they exceed 450 ppm still might significantly mitigate climate risks, and are hence worth pursuing. As atmospheric concentrations of carbon rise, linear impacts associated with climate change increase and the probability of triggering non-linear impacts rises. Stabilizing atmospheric carbon concentrations at relatively lower levels results in less significant linear impacts and lower risks of crossing non-linear thresholds. Higher concentrations bring greater impacts and greater risks. This basic dynamic holds both below the 450 threshold and above it. As such, even if emissions result in atmospheric concentrations of carbon exceeding 450 ppm, stabilizing atmospheric carbon concentrations at 500 ppm still brings significant climate risk mitigation in relation to stabilizing at 550 ppm, 550 ppm brings lower risk than 600, and so on.

Freed from the implausible two degree, 450 ppm target, the present zero-sum conflict between global energy development and climate mitigation becomes a good deal

more navigable. The long-term trend in the global economy toward decarbonization does offer some promise of reconciling energy development imperatives with climate mitigation efforts.

Most advanced developed economies have shifted from burning lignite to cleaner burning hard coals, to more efficient coal combustion technologies, and from coal to natural gas. In some instances, major economies have succeeded in decarbonizing faster still. This has primarily been accomplished through public policy and public sector driven shifts in energy technology. France, Sweden, and Belgium, largely in response to the oil price shocks of the 1970's and a lack of indigenous fossil fuel reserves, shifted much of their electrical systems to nuclear power. Norway, Sweden, and notably Brazil, blessed with enormous hydroelectric potential, decarbonized their electricity systems through hydro-electric power. In all of these cases, the build out of low carbon electricity systems was led by the public sector and featured low carbon technologies that could produce large volumes of centralized, on-demand, grid electricity to power industry and other productive, large scale economic enterprises as well as meeting growing residential demand for electricity.[63]

Opportunities to accelerate decarbonization and minimize emissions growth will vary widely, depending on both geography and socio-economic circumstances. Nuclear energy, for instance, represents a plausible and immediate large-scale source of zero-carbon energy in places like China, India, and Brazil. Sub-Saharan Africa, by contrast, is rich in natural gas and hydro resources, while India and many other parts of South Asia are not, suggesting that it might be possible for much of Africa to develop and modernize without the huge build out of coal-fired generation that has characterized that process across much of Asia in recent decades.

No matter the specific geo-political circumstances, what should be clear from the last three decades of international efforts to address climate change is that mitigation strategies that fail to address energy poverty will fail. Addressing energy poverty represents a basic boundary condition for successful climate mitigation. Carbon caps and similar measures to limit emissions are unlikely to place significant limits upon efforts to eradicate energy poverty through the burning of fossil fuels so long as fossil fuels represent the lowest cost means to move large populations out of poverty.

The history of decarbonization, then, suggests a number of principles for accelerating decarbonization in developing economies while also addressing energy poverty at

a scale and pace consistent with achieving modern living standards for everyone on Earth:

1. **Focus on the carbon intensity of energy systems.** The key to mitigating emissions to the greatest extent possible while addressing energy poverty will be to accelerate the long-term trend toward higher density, more efficient, lower carbon fuels and technologies. New fuels, energy technology, and energy infrastructure should be judged based upon what they replace. Where coal-fired power plants replace wood and dung, it is decarbonizing and positive; where it replaces nuclear energy, as in Germany and Japan in recent years, it constitutes recarbonization and is negative. What is most important is the direction of travel: always towards higher density, higher efficiency, and lower carbon intensity.

2. **Leapfrog dirty energy, not development.** In some cases, progress up the energy ladder may "leapfrog" steps along the way, skipping over some high carbon fuels and technologies. But while some fuels and technologies might be skipped, key steps in the development process cannot be leapfrogged. Modern living standards and modern levels of energy consumption and energy service provision simply cannot be achieved in subsistence agrarian economies. Urbanization, industrialization, and agricultural modernization are necessary to achieve modern living standards. Energy technologies that cannot support these processes, no matter what their carbon footprint, cannot significantly advance human development and well-being.

3. **Innovate for a high-energy planet.** The most important goal in securing a high-energy, low-carbon future is continuing innovation towards cheap, clean, and scalable alternatives to fossil fuels. Current-generation low-carbon technologies cannot meet growing global energy demand at the scale necessary. They provide neither the cost, abundance, nor versatility of energy that fossil fuels can. Large hydroelectric dams can provide abundant low-carbon energy and nuclear can replace coal and natural gas in rich and middle-income countries. Wind and solar can similarly displace fossil fuels, most readily natural gas, where that is an option. But for the most part, economic modernization still depends on fossil fuels. This is even truer in transportation and industry than in the electric power sector. Thus, innovation must take center stage if all the world's inhabitants are to enjoy secure, free, prosperous, and fulfilling lives on a high-energy, low-carbon planet.

PART III: CHALLENGES AND LIMITATIONS

Understood within the broader context of human development and modernization, ending energy poverty and mitigating climate change are entirely feasible and reconcilable. There are important challenges and limitations to such efforts that are important to acknowledge.

1. **Declining employment shares for manufacturing.** Urbanization and agricultural modernization are predicated upon industrialization and manufacturing. Without availability of higher productivity off-farm employment for large populations, there is little opportunity for agricultural productivity to rise without stranding large populations without incomes in either rural agrarian or urban contexts. And, as noted above, rising household energy consumption is not possible without rising household incomes.

   Manufacturing is not the only sector that can provide higher productivity off-farm employment for large populations. But it has historically been the primary way that large populations of poorly educated, low-skilled laborers have found higher productivity employment, capable of supporting rising wages, in emerging economies.

   Due to rising labor productivity and automation, increasing globalization of trade and supply chains, and economic liberalization, opportunities to grow employment in the manufacturing sector for late-developing economies may be significantly less than has been the case historically. Princeton economist Dani Rodrik has documented progressively falling levels of peak manufacturing employment for emerging economies the later they industrialize.[64]

   Rodrik does not see an alternate path to modern living standards for large agrarian populations. Nor does he suggest that lower peak manufacturing employment represents an insurmountable obstacle to modernization and development. But he does suggest that it may entail slower modernization and development for late-industrializing nations, a development that would likely significantly retard progress on energy modernization and development, and hence the eradication of energy poverty as well.

2. **Two degree Celsius target is infeasible.** The eradication of poverty, as noted above, is not compatible with stabilizing atmospheric carbon concentrations at 450 ppm given current development trajectories and energy technologies. It is important to note, however, that the world is on track to exceed those targets even if energy poverty persists for a large segment of the global population well into the latter half of the 21st

century. According to the central scenario of the International Energy Agency's *World Energy Outlook 2015*, 810 million people globally will still lack access to electricity in 2030 even as the world overshoots its climate goals.[65] It is also the case that efforts to establish, much less enforce a binding two degree target have not only failed but have corresponded with an acceleration of emissions growth. As noted above, there is no evidence to date that emerging economies are willing to sacrifice energy development to stay below the two degree target, nor that present day low and zero carbon technologies are capable of meeting rising global energy demand at sufficient scale to eliminate that trade-off.

3. **Governance.** The history of energy modernization and development suggests that strong states and strong institutions are a precondition for universal modern energy consumption. Failing states, in which governments are unable to provide basic services due to corruption or civil discord, do not represent a particularly promising context in which energy poverty might be significantly eradicated. Efforts to end run these very basic necessities for development, by bringing small-scale, decentralized energy technologies directly to poor populations may provide some modest respite from the grinding poverty and insecurity that is especially prevalent in dysfunctional states. However, they cannot offer a plausible path toward the eradication of energy poverty unless those efforts in some way contribute to the establishment of civil society and accountable institutions.

   It is also the case that in the name of improved governance, international institutions have too often advocated policies that have made the effort to eradicate energy poverty more difficult. Economic liberalization has much to recommend it in many contexts. But the provision of modern energy services for large, impoverished populations is not among them. Efforts to improve governance in relation to the energy sector in developing economies will be well served to emphasize transparency, accountability and democratic governance while reserving economic liberalization for other sectors, contexts, and stages of development.

4. **Finance.** A number of factors have driven changes in the priorities of energy development efforts by international development and finance institutions, including: irrational exuberance about the capability of solar energy and other decentralized energy technologies to scale; growing concern about climate change; a lack of clarity about the basic building blocks of modernization, development, and prosperity; and skepticism about the capacities of governments in less developed countries.

Increasingly, many western institutions have deemphasized large-scale, centralized, grid-based energy infrastructure in favor of small-scale, decentralized, off-grid renewable energy technologies. The impact of this shift is not entirely clear. The accelerating pace of fossil energy development around the world, led by major emerging economies, suggests that changing finance priorities among western donor institutions have not much affected the overall picture in terms of large-scale, grid-based energy infrastructure. Where nations have resources, financial clout, and institutions to drive their own energy development trajectory, there has been no shortage of private finance available to underwrite energy development.

But for those nations least able to set the terms of their own development, struggling to set in motion the virtuous circle of modernization, growth, and development that creates resources that might be plowed back into further growth and development, the stakes are a good deal higher and the disposition of western donors matters more. In these contexts, donor institutions often leverage private finance at very high ratios, either by providing outright loan guarantees or simply by conducting due diligence and giving energy development projects a seal of approval from well-regarded Western institutions. In these contexts, formal and informal policies limiting investment in large-scale energy infrastructure such as hydro-electric dams, coal, or gas plants can have very significant impact upon the availability of finance, public and private, for energy infrastructure that is desperately needed to help jump start development, raise incomes, and support higher levels of energy consumption.[66]

CONCLUSION

How one orients towards the challenge of eradicating energy poverty depends, to some degree, upon whether one believes the global energy development glass to be half empty or half full. On the one hand, several billion people, depending upon what one counts as modern energy consumption, have yet to achieve access to modern energy. On the other, over little more than a century, 5 billion people or so have.

Our view is that the glass is half full. 150 years ago, modern energy didn't exist and virtually the entirety of a much smaller global population lived in deep agrarian poverty. Today the majority of a much larger population consumes levels of energy that were unimaginable to prior generations. With that consumption has come dramatic improvements in living standards.

It is true that several billion people still lack modern energy access. But it is also true that in recent decades people around the world have achieved access to modern energy faster than has occurred at any prior time in history, a byproduct of the accelerating pace of urbanization.

The challenge is not to reinvent the wheel but rather to make the wheel turn faster.

The key to achieving not only universal *access* to modern energy but also modern living standards and levels of energy consumption will be to sustain and accelerate the processes that have allowed 5 billion people to make that leap already. The challenge is not to reinvent the wheel but rather to make the wheel turn faster. The pace of modernization and urbanization has accelerated. To move billions of people from subsistence poverty to modern lives by the middle of this century will require those processes to move faster still.

To succeed in eradicating energy poverty as quickly as possible, international efforts to aid energy development must be centrally focused on providing fuels, energy tech-

nology, and infrastructure to support the key processes that have allowed for billions of people to live energy rich lives today. Universal access to modern energy is not an end to itself but a means to an end – to raise living standards and lift all of humanity out of poverty. There is no path to that end that does not involve urbanization, industrialization, and agricultural modernization.

Lifting all of humanity out of energy poverty does increase the risk of catastrophic climate impacts to some unknowable degree. But it is untenable morally and practically to insist that global climate targets be balanced upon the backs of the poorest people on earth. The apocalyptic climate outcomes that most developed world audiences fear when they consider climate risk – failed states and civil unrest, exposure to increasingly destructive natural disasters, droughts, famines, and limited access to fresh water – is the world that much of the energy poor inhabit today, not, primarily, due to anthropogenic climate change. It would be tragic if the international community, practically if not explicitly, insisted that they must continue to suffer so that we in the rich world might avoid their fate.

That choice is not one we need to make. Smart, practical policies, at both the national and international level, can help accelerate energy development and modernization while significantly mitigating climate risk. Those risks will never be eliminated. Already, we have pumped so much carbon into the atmosphere that we have already assured that significant levels of warming will continue through at least the end of this century, and in so doing, have already exposed ourselves to some unquantifiable level of catastrophic climate risk. But smart, well-considered energy development, some portion of that unavoidably for the time being from fossil fuels, can both rapidly improve living standards and resilience to climate impacts while limiting climate risk. The history of energy modernization and development, the failure of international efforts to limit emissions growth in the name of climate mitigation, and the rapid rate of global development, urbanization, and industrialization all suggest that the only plausible path to universal energy abundance and climate mitigation will a half-full approach.

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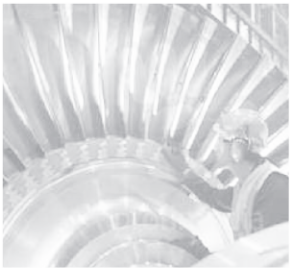

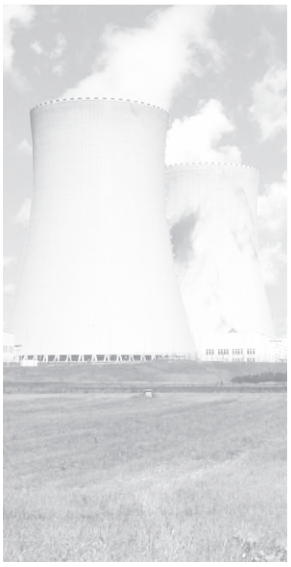

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