World Future Council

100% RENEWABLES

VOICE OF FUTURE GENERATIONS

RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT

Accounting for Impacts on the Path to 100% RE

IMPRINT

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1. INTRODUCTION

Societies around the world are on the verge of a profound and urgently necessary transformation in the way they produce and use energy. This shift is moving the world away from the consumption of fossil fuels (which cause climate change and other environmental and social challenges) toward cleaner, renewable forms of energy. Millions of people around the world already use renewable energy to generate electricity, heat and cool buildings, cook and provide mobility. Renewable energy is market-ready and price competitive with conventional sources in many jurisdictions, and met about 19% of the world's final energy demand in 2014.[1]

Around the world, communities, islands, and cities have found that making the transition to 100% renewable energy is largely a matter of political will and that the required technologies already are at hand.[2] An increasing number of governments at all levels and on all continents is setting ambitious targets for renewable energy, with an ever-growing number of jurisdictions aiming for 100% renewables. Local governments, in particular, are pioneering this movement and are becoming incubators of regionally appropriate best practices and policies.[3]

The rapid deployment of renewable energy has been driven mainly by a wide range of objectives (drivers), which include advancing economic development, improving energy security, enhancing energy access and mitigating climate change. Altogether, these drivers might be described as the pursuit of *sustainable development,* where economic prosperity is advanced around the world while negative impacts are minimized. While such presumed benefits are widely cited as key drivers in political and energy debates, specific, documented evidence of such benefits remains rather limited for reasons including a lack of adequate conceptual frameworks, methodological challenges, and limited access to relevant data.

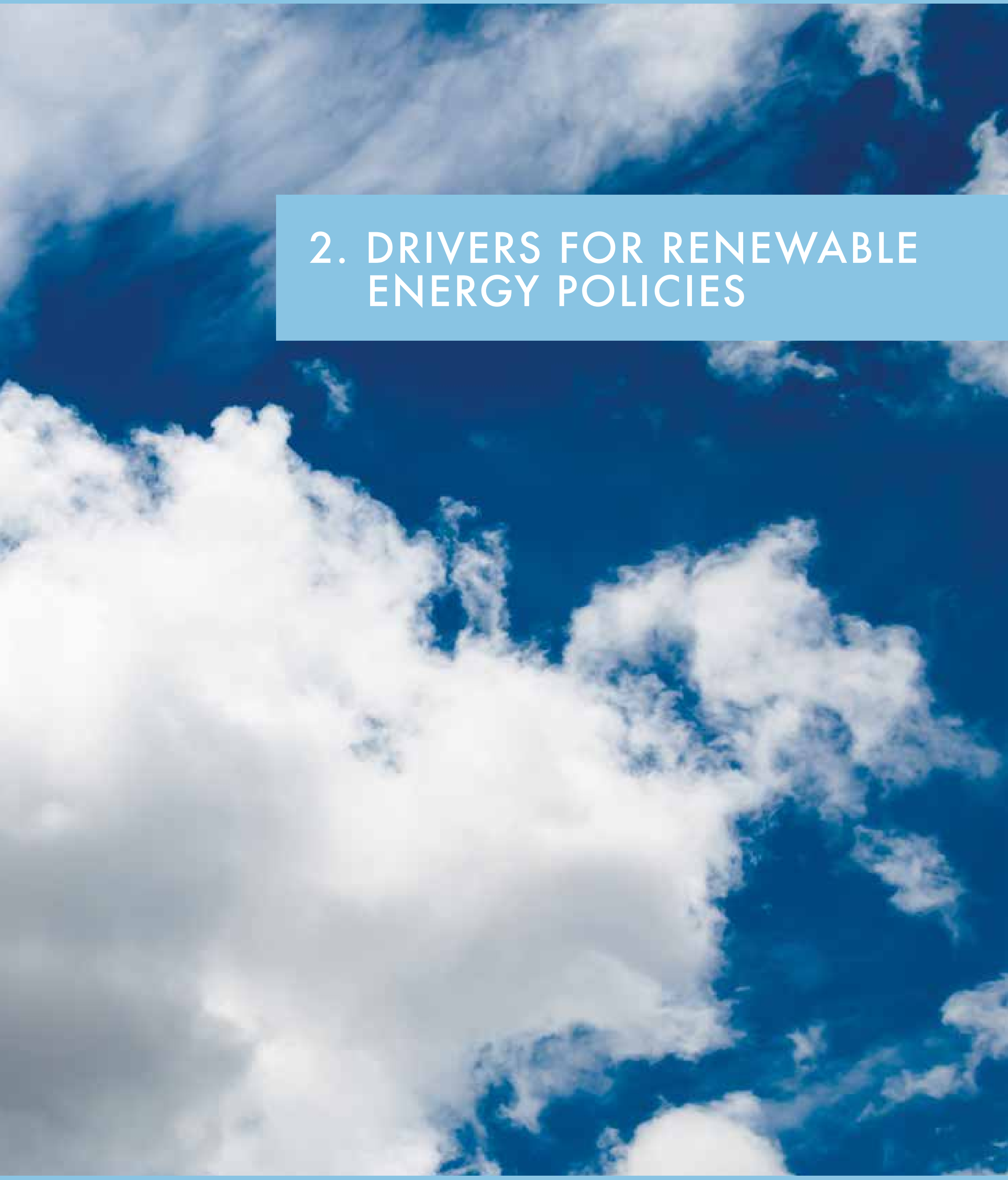
The purpose of this paper is threefold. First, to identify the various drivers behind the push for the renewable energy transition and to document some of the sustainable development benefits experienced around the world. Second, to review some of the recent attempts to measure, quantify or project past and future benefits of increased renewable energy deployment, and the methodologies applied. Finally, to identify some of the remaining questions relating to the implications of aiming for 100% renewable energy, with the aim to provide a basis for subsequent development of a conceptual framework for future work on this topic.

This paper conceives of the *drivers* behind renewable energy as being the many economic, social, political, and environmental imperatives that might motivate society to pursue this transition for a net positive outcome. The various expected *benefits* of the transition are the realized positive outcomes (positive impacts), which are presumed to be closely aligned with the drivers that motivated the transition. For example, one driver (and ultimate benefit) may be the imperative of reducing the incidence of respiratory illness, which can be realized through reduced air pollution, and which is achieved in part by substituting renewable power for fossil-fired power generation. Drivers and benefits are classified here by the three main categories of economic, environmental, and social/political, while acknowledging that many benefits do not fit any one category at the exclusion of others. The drivers (and benefits) of improved public health arguably may be all at once: economic, social, political, and environmental. Establishing a hierarchy of classification for any given benefit may not be as critical as correctly

identifying the impact, assigning it relative value and taking precautions against double-counting that value across different impact categories.

Beyond classification, the study of renewable energy benefits runs quickly into the problem of finding a common measure across different categories of observed benefits. Not all benefits can be easily monetized, nor do they always need to be. The paper suggests that aggregating impacts across categories into a single measure of net benefit from the renewable energy transition represents a significant challenge.

2. DRIVERS FOR RENEWABLE ENERGY POLICIES



2. DRIVERS FOR RENEWABLE ENERGY POLICIES

Renewable energy technologies provide energy services, including lighting and electricity, heating and cooling, mechanical energy and mobility. Further, relative to other types of energy (from fossil fuels, nuclear power, and traditional biomass), moderns renewables provide a variety of additional socio-economic benefits. In most jurisdictions, these socio-economic benefits are a major force driving policymakers to adopt renewable energy targets and support policies.

Renewable energy drivers (benefits) have been categorized in a variety of ways. For example, the United Nations Intergovernmental Panel on Climate Change (IPCC) *Special Report on Renewable Energy Sources and Climate Change Mitigation* (SRREN) categorized key drivers, opportunities and benefits of renewable energy into environmental (climate change mitigation and reduction of environmental and health impacts), energy access, energy security (e.g., diversity of fuel supply; fuel imports; balance of trade), and social and economic development (e.g., job creation, rural development).[4]

In 2012, research funded by the German government established three main categories: macro-economic effects (including macro-economic impulses such as investment and industry turnover; gross effects such as employment in the renewables industry; impact on current accounts from reduced fossil fuel imports; and net effects such as overall net change in GDP and employment from renewable energy technology deployment); system-related benefits such as avoided environmental damages; and distributional effects.[5] The International Renewable Energy Agency (IRENA) adopted the German framework, with some adjustments, focusing in its latest study on a sub-set of economic impacts (Gross Domestic Product, public welfare in the traditional context of public consumption but also in a broader sense of human well-being, employment, and trade balances).[6]

This section identifies some key drivers according to the main categories of environmental, economic, and political (social and security) criteria, acknowledging that many drivers can be classified by more than one category.

ENVIRONMENTAL DRIVERS

The extraction, transport, refining and use of fossil and nuclear fuels result in a host of significant environmental impacts, including damage to land from mining; pollution of air and water; consumption of vast amounts of fresh water, particularly for cooling at power plants; loss of biodiversity; risk of nuclear accidents; global climate change; and associated impacts on human health.[7]

For example, the World Health Organization estimates that outdoor air pollution – due largely to the burning of coal and road transport – killed 3.7 million people worldwide in 2012.[8] Another account estimates that 5.5 million people die prematurely each year due to household and outdoor air pollution; of that total, 1.6 million people die of air pollution in China and 1.4 million in India.[9] The single greatest contributor in China is pollution from coal burning (which causes an estimated 366,000 deaths annually), while in India the major contributor is burning of solid biomass for cooking and heating.[10]

Health problems, biodiversity loss, and other environmental challenges will only be exacerbated by climate change.[11] Renewable energy deployment has become an integral part of government strategies around the world to address these many challenges. Examples include:

Reduce pollution and improve public health. Around the world, governments at all levels have enacted policies to support renewables in order to reduce health impacts associated with energy production and use. In China, for example, the quest for cleaner air and water has become an important driver of renewable energy targets and policies, alongside carbon dioxide (CO2) emissions reductions, job creation and economic development.[12] Concerns about the impacts of traditional use of biomass, and burning of kerosene and other fossil fuels for cooking and heating on indoor air quality, as well as the need to reduce local deforestation, also have driven policies to promote modern renewables.[13]

Reduce fresh water use.

Many governments are turning to renewable energy to reduce water consumption associated with energy production.[14] For example, Georgetown, Texas, a US city of more than 50,000 inhabitants, aims to achieve 100 % renewables in the electricity sector by 2017, in part to reduce water consumption in the sector; other drivers include opportunities for local economic development and protection against volatile fossil fuel prices.[15]

Reduce reliance on nuclear power.

In the wake of the 2011 Fukushima Daiichi nuclear disaster, several Japanese cities and regions – including Hokkaido, Kyoto, and Osaka – have set targets and enacted policies to promote renewables and energy efficiency in order to reduce their reliance on nuclear power.[16] Germany reacted to the disaster in Japan by planning to phase out its own nuclear power facilities, to be replaced over time with renewable energy.[17]

Mitigate climate change.

Climate change mitigation is becoming increasingly the key environmental driver of renewable energy; in combination with energy efficiency improvements, renewables now represent a key pillar in many governments' efforts to decarbonize their energy sectors.[18] For the 21st Conference of the Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC), held in Paris in late 2015, 189 countries* (representing an estimated 95 % of global emissions and 98 % of population) submitted Intended Nationally Determined Contributions (INDCs).[19] The vast majority of countries prioritized the energy sector in their plans, with most of these relying primarily on deployment of renewable energy and energy efficiency technologies to achieve their stated emissions reduction targets.[20]

Prior to COP21, many countries and regions were increasing the deployment of renewables to address climate change. For example, the European Union 2020 target of 20 % energy consumption by renewables is intended (alongside an energy efficiency target) to assist Europe in reducing greenhouse gas (GHG) emissions (relative to 1990) by 20 %.[21] India's National Solar Mission, part of the National Action Plan on Climate Change, launched in 2008, aims to promote ecologically sustainable energy growth, constituting "a major contribution by India to the global effort to meet the challenges of climate change."[22]

Climate-driven action is certainly not limited to national governments. Renewables are playing an important role in the climate mitigation strategies of numerous state, city and local governments. The Compact of States and Regions, launched in 2014, committed to GHG reduction targets, with most members setting renewable energy targets to achieve them.[23] As of December 2015, membership included 44 supporting states and regions on almost every continent, representing 325 million people and one-eighth of the global economy.[24]

* There were 162 individual submissions that cover 189 countries, with the European Union submitting one INDC to cover all 28 Member States. A total 160 was submitted in 2015, with Nepal and Panama submitting their INDCs in early 2016.

By early 2016, over 450 cities from all continents and regions, representing more than 391 million people, had committed to the Compact of Mayors since its launch by UN Secretary-General Ban Ki-moon in 2014.[25] This global coalition aims to position cities as climate leaders and to demonstrate the global impact of local action.[26] At COP21 in Paris, the Compact of Mayors announced a formal partnership with the Covenant of Mayors, which brings together thousands of local and regional authorities (mostly in Europe, but expanding globally) that commit voluntarily to implementing EU climate and energy objectives in their own territory.[27]

Alongside COP21, the Climate Summit for Local Leaders issued a declaration that was signed by 1,000 mayors from around the world, pledging to support a transition to 100 % renewable energy by 2050.[28] Other efforts to advance 100 % renewables include the 100 % RES Communities and RES Champions League in Europe, and the Global 100 % RE initiative.[29]

ECONOMIC DRIVERS

Renewable energy technologies can provide a number of economic benefits, particularly for energy importers. This is becoming increasingly true as renewable energy costs (especially costs of solar PV and wind power) continue their rapid decline. In addition, the use of renewable energy helps to avoid a number of indirect economic costs associated with fossil energy production and use, such as health care expenses. It also can help reduce the longer term costs associated with global climate change, such as the potential for sudden disruption and displacement of people and their economic activity (e.g., spread of disease, forced migration). Thus, investments in renewable energy systems and associated infrastructure can result in sustainable development in every sense of the term – sustained economic growth that is environmentally sustainable.[30]

Economic benefits associated with renewable energy that drive the adoption of support policies include:

Improve balance of trade and reduce price volatility. The majority of countries, states or communities must import most if not all of the fossil or nuclear fuels that they consume. Investment in renewables can improve a country's or region's trade balance and can reduce fuel price volatility and supply risk. Reduction of fossil fuel imports, and the associated economic savings (for consumers and for government budgets for related subsidies, etc.), is one of the key drivers for renewable energy policies, including 100 % renewables targets.[31]

Denmark, for example, expects that its strategy to move toward 100 % renewable energy (power and heat by 2035, and fossil fuel-free economy-wide by 2050), will result in reduced energy expenditures relative to business as usual.[32] The Danish city of Frederikshavn has set a more-ambitious target of 100 % renewable energy by 2030 in order to become energy self-reliant and to avoid impacts of fuel-price volatility, while also reviving and diversifying the region's economy.[33]

From Africa to the Pacific to the Caribbean, island nations are adopting policies and targets to promote renewable energy, driven by the need to reduce exposure to volatile market prices for fuel (as well as high shipping costs). The African island nation of Cape Verde chose to aim for 100 % renewable energy largely to eliminate its high dependence on imported fossil fuels. In addition to achieving huge cost savings, Cape Verde expects that its investments in renewable energy will result in new business sectors, environmental stewardship, and social responsibility, enabling the country to become a global model for zero emissions and a regional knowledge hub.[34]

Following a 2008 fuel price spike, the Marshall Islands, which depended heavily on imported fossil fuels, enacted the National Energy Policy and the Energy Action plan to improve the national economy and the lives of its inhabitants through renewable energy deployment.[35] The island nation of Grenada expects that national savings associated with transitioning to renewable energy will be on the order of USD 300 million annually, and that substituting renewables for fossil fuels will improve the balance of payments while also enhancing energy and food security.[36]

Create jobs and develop new industries and skills.
Studies suggest that while the renewable energy transition shifts jobs by sector and location, the net impact on job creation will be positive. In its Advanced Renewable Energy Scenario, an ambitious pathway towards a 100 % renewable and carbon-free global energy system for 2050, Greenpeace projects that there will be 48 million jobs in the energy sector in 2030, compared to 28 million jobs under the reference scenario.[37] IRENA estimates that solar PV deployment creates twice the number of jobs per unit of electricity generated as does coal or natural gas.[38] Skills required for manufacturing, selling, installing and maintaining renewable energy systems and associated infrastructure vary significantly, with a variety of medium- and high-skilled opportunities.[39] Job creation has been a driver of renewable energy policies that aim to help strengthen local economies, and to stem or reverse depopulation and brain drain.

In Morocco, for example, deployment of concentrating solar thermal power (CSP) is considered a means to multiple development objectives in local communities, including job creation, skills development and training, as well as social development, socio-cultural enhancement, and climate change mitigation.[40] The US state of Iowa has supported ethanol production and deployment of other renewable technologies to create good jobs that strengthen the state's middle class, increase in-state technology investment, reduce dependence on imported fuels, and provide cleaner air and water.[41] Drivers for renewable energy policies in Scotland have included diversification of rural employment and skills development.[42] In Tipperary, Ireland, a local renewable energy eco-village was planned to stem rural depopulation, to help develop skills and new enterprises, as well as to reduce CO2 emissions.[43] And the Chinese city of Dezhou enacted policies to support solar power demand and supply with the aim of transforming into "China's Solar City", creating jobs, building local capacity, fostering innovation, and attracting investment in the process.[44]

In 2011, when announcing Germany's decision to phase out nuclear power, Chancellor Angela Merkel called for electricity of the future to be "safer and at the same time reliable and affordable," and called for Germany to be "the first major industrialised country that achieves the transition to renewable energy with all the opportunities – for exports, development, technology, jobs – it carries with it."[45]

Meet rapidly rising energy demand.
The modularity of many renewable technologies and relative speed with which they can be implemented, alongside their rapidly falling costs (particularly for solar PV and wind power), have made them technologies of choice for meeting ever-growing demand for energy services across the Global South.

Brazil, which has been highly dependent on hydropower (historically meeting over 80 % of national electricity demand), has turned to other renewable technologies to meet rising electricity demand while reducing the country's vulnerability to supply shortages in drought years.[46] Chile has set a national target of 20 % renewable electricity (not including hydropower) by 2025 and plans to ease power shortages and resulting high prices in the central region (which increased 30 % over the period 2010-2015) by linking solar and wind power plants in the north to demand centers via a 3,000 kilometer transmission line.[47]

In Africa, Egypt is advancing deployment of renewables in the electricity sector to help meet surging power demand.[48] And South Africa plans to increase significantly its electricity production from renewable sources to help stabilize the power grid and to alleviate power shortages that have caused rolling blackouts throughout the country.[49]

Provide access to energy and alleviate poverty in the Global South.

More than a billion people still lack access to electricity while more than two in five people around the world depend on traditional biomass for heating and cooking.[50] In remote areas, electricity generated with renewable technologies is generally less costly than the alternatives, including imported diesel fuel and grid extension.[51] Indeed, in many areas it may be the only viable option, economically or otherwise, within any reasonable timeframe. Renewables also can provide heating, cooling, and mechanical energy for crop irrigation and other productive services. The modularity of many renewable technologies means that they can be installed rapidly and scaled up as needed. Many countries have established targets and enacted support policies to scale up renewable energy to provide access to modern energy services for people living in remote and rural areas.[52]

Increasingly, not only national but also regional and local governments are adopting renewable policies and targets to advance energy access. Sumba Island in Indonesia (population of 650,000) has adopted a local government plan that is supported by international donors and aims to achieve 100 % renewables by 2020; the plan is driven by the desire for a "just" transition that boosts energy access, improves local business and livelihoods, and safeguards public health.[53]

In Africa, the Ugandan district of Kasese (home to about 130,000 households) set a goal to achieve 100 % access to energy services to meet all domestic, productive and social needs with renewable energy by 2020. Drivers include advancing local development by eliminating poverty related to lack of access to energy, and reducing health impacts associated with traditional use of biomass and kerosene, while also reducing local deforestation and land degradation. When Kasese's target was set, only 7 % of households had access to the electricity grid; about 87 % used kerosene for lighting and 97 % relied on firewood and charcoal for cooking.[54] Also important to the community is the role they are playing in fighting climate change, which threatens nearby glaciers and thus their very sense of identity.[55]

Alleviate fuel poverty and advance rural economic development in industrialized countries.

In industrialized countries, where the vast majority of people have access to modern energy services, renewables can reduce fuel poverty and improve quality of life.

The aforementioned community project in Tipperary, Ireland, was established to invest in renewable energy combined with energy efficiency retrofits in order to reduce fuel poverty.[56] Policies in the United Kingdom also have aimed at reducing fuel poverty by supporting domestic renewable heat.[57]

In Japan's Nagasaki prefecture, Goto City developed an extensive renewable energy plan to cover more than 130 % of the region's total energy needs with renewables by 2030 in order to foster rural economic development.[58]

There also are numerous examples in the United States. For instance, Washington, D.C. has implemented policies to promote renewables combined with energy efficiency to advance local economic development and reduce energy costs for the city's low-income residents.[59] The Alaska Energy Authority is working toward a target of 50 % electricity from renewables by 2025, in great part to reduce energy costs for rural residents; in some communities, more than half of average household income is spent on electricity and home heating because fossil fuels must be imported by barge and distributed by air or boat, making them relatively costly.[60]

Keep energy revenue local.

When fuel imports are displaced with local renewables, whether at the national or sub-national level, energy expenditures can spur further economic activity in the local economy.

The US state of Hawaii adopted binding legislation in 2015 to aim for 70 % renewable electricity by 2030, and 100 % by 2045. Hawaii faces the highest electricity prices of any US state and an unsustainable dependence on imported fossil fuels. Renewable energy is expected to address both of these challenges, providing home-grown electricity at much lower cost.[61] In 2014, East Hampton in New York state decided to meet 100 % of the community's electricity needs with renewables by 2020; the switch was considered "the right thing to do, both for the environment and for keeping more money in the local economy and creating jobs [locally]."[62]

Similar motivations lay behind steps taken by the German district of Rhein-Hunsrück. In 2011, in an effort to retain the value added within the local economy, the district set out to displace its significant expenditure on fossil fuels through energy efficiency and local renewable energy production. By 2014, the district had become a significant net exporter of renewable electricity, mostly from wind power but also from solar PV and biomass power.[63]

Increase tax revenue.

Local governments collect income and property tax payments from renewable energy project owners; the additional revenue enables governments to reduce tax rates for inhabitants, such as low-income residents, or to support additional public services.[64] Renewable energy projects may also reduce government expenditures.

For instance, Washington, DC announced plans in December 2015 to install solar panels on roofs and parking lots of 34 government-owned facilities, where electricity would be purchased through a Power Purchase Agreement (PPA). City officials estimate that the plan will save taxpayers USD 25 million over the 20-year term of the PPA, while also spurring small business development and job creation.[65] A separate deal, to meet one-third of the government's annual electricity needs with wind power, will save the Washington, DC city government (and thus, the taxpayers) an estimated USD 45 million over 20 years.[66]

Reduce public health costs.

The burning of fossil fuels for energy production results in high economic costs for societies, in addition to tremendous physical suffering. By one estimate, the cost of health impacts associated with air pollution in OECD countries (deaths and illnesses) was USD 1.7 trillion in 2010; road transport accounted for about half of this total. Estimated costs associated with health impacts of air pollution in China and India during 2010 were about USD 1.4 trillion and USD 0.5 trillion, respectively.[67] A 2007 study found that environmental pollution costs the Chinese economy about 10 % of total GDP; more recently, pollution in cities such as Beijing is causing widespread public discontent and prompting brain drain and capital flight, leading to further economic and social losses for China.[68] In Europe as of 2012, air pollution and GHG emissions from industry, including power generation, cost the region at least EUR 59 (and possibly as much as 189 billion) – energy production and use accounted for 67 % of the total.[69]

It is the potential to reduce such costs through deployment of renewable energy that has helped to drive renewable energy policies in the European Union, China, Kasese District in Uganda, Vancouver in Canada, several US cities, and elsewhere.[70]

POLITICAL AND SECURITY DRIVERS

Energy is critical to a healthy economy and energy services can sustain or improve people's quality of life. Therefore, the uninterrupted physical availability of highly reliable and reasonably affordable energy products and services is critically important to economic and political security. By the same token, conditions of economic stability and polit-

ical security are the necessary foundation for the healthy development of energy infrastructure and reliable delivery of energy services. Increasing the share of energy from indigenous renewables offers the potential to reduce dependence on imported fuels, improving security of supply. Renewables can increase the diversity of energy supply, and contribute to flexibility and resilience of the energy system through local, distributed generation, both of which reduce the risk of disruption of energy services.[71] The risk of widespread technical failure of the energy system (system component malfunction) and risk of external physical disruption (natural disasters, terrorism and sabotage, and piracy) are potentially lessened by the use of distributed renewables. This is because each individual system component, (e.g., a wind turbine) becomes less critical to total system integrity.

Political and security drivers of renewable energy policies and targets include the following:

Improve energy security.

Many countries import fossil (and nuclear) fuels, often from regions that are politically unstable or that might stop the flow of supply at any time. By contrast, renewable energy resources are diverse, they rely on natural flows (rather than exhaustible stock), are available locally (with type and amount of resource differing by location), and the technologies required for capturing and converting these resources into useful energy are available in the global market place.

Although the primary energy security focus of most countries revolves around maintaining access to fossil fuels, renewable energy is viewed increasingly as having a role in improving energy security.[72] Europe, for example, depends heavily on natural gas that comes from Russia via pipelines that cross other countries (including Ukraine); when gas flows to Ukraine were restricted in the winter of 2014, much of Europe experienced a drop in supply.[73] Thus, an important driver for EU renewable energy support policies has been to reduce the region's dependence on imported fossil fuels, including natural gas.[74]

In the Caribbean region, the high cost of imported fuel diverts resources away from economic development, reducing economic competitiveness and making these economies vulnerable to fuel supply shocks.[75] To address such concerns (and to advance energy security and access to energy, economic development, and environmental and climate goals), governments of the region, the Caribbean Community (CARICOM) Secretariat, and several other national governments and international agencies committed in early 2015 to support a transformation of the region's energy system through renewable energy and energy efficiency.[76]

Other countries promoting renewables to advance security include: South Africa, where policies are driven by the country's plentiful renewable energy resources, concerns about energy security, and the desire to reduce fuel imports; Fiji, where renewable energy support and deployment are rising as renewable technology costs decline with the aim of reducing heavy dependence on imported fossil fuels (which affects both energy security and prices); and Chile, which is promoting renewable energy to reduce dependence on energy imports, particularly from Argentina (which unilaterally cut off gas lines to Chile in 2008).[77]

Energy security has been a driver of renewable energy support policies in the United States as well. Shortly before advanced drilling technology triggered a dramatic rise in domestic oil and gas production, the US Renewable Fuel Standard (along with the strengthening of fuel efficiency standards) was part of 2007 legislation to improve national security by reducing dependence on imported petroleum.[78] Further, the country's military appears committed to improving energy security in their operations through deployment of renewable energy. The US Navy, for example, is pursing renewables to "improve our energy security, operational capability, strategic flexibility and resource availability."[79]

Increase reliability and resilience.

At the state and local levels, concerns about risk associated with fuel transport (e.g., rail or pipeline accidents), power outages, supply bottle-necks, and other factors are driving renewable energy policies. Distributed renewable energy systems are less prone to large-scale failure; can make the power grid and other energy systems more resilient to a variety of threats, including weather-related impacts of global climate change; and distributed power can be available locally (on rooftops, or from wind power projects in a city's harbor), so there is less concern about transporting power to demand areas.

In the wake of the tsunami and nuclear disaster following Japan's severe earthquake in 2011, Higashimatsushima, a city of 40,000 inhabitants, set a target for zero net energy by 2022. The city aims to transition to a safe, resilient, and sustainable energy system based on distributed renewable energy. As part of this effort, the city is building Japan's first micro-grid community (Higashimatsushima Disaster-Prepared, Smart Eco-Town) for evacuations in the event of future emergencies.[80]

While aiming to keep energy money at home and to create jobs was a motivation for East Hampton's 100 % renewables goal, as noted above, the city also was mindful of the impact of Hurricane Sandy in late 2012, and the need for reliable energy services during natural disasters.[81] The US state of Massachusetts also has adopted several programs to support renewable energy deployment (particularly solar PV plus storage) to make power more resilient for communities and critical services.[82] In addition, the US Army revealed plans in 2013 to deploy 1 GW of renewable projects by 2025 to help ensure that its "installations achieve high levels of energy security in the event of conventional grid outages."[83]

Ensure energy democracy. (See Box 1.)
The desire for energy democracy, including local control over energy production and distribution, is playing an increasingly important role in driving local targets and policies to support renewable energy, often in combination with energy efficiency improvements, particularly at the local level.

A growing number of municipalities in Germany, Japan, the United States and elsewhere has regained ownership of local utilities to achieve more democratic control, a trend often linked to the desire to advance local renewable energy.[84]

In Berlin, Germany, a large coalition of groups has worked for re-municipalization to address climate change and broader environmental sustainability goals, and to make the local energy system more democratic and socially equitable.[85] In 2013, Hamburg voters decided, by narrow majority, to reverse utility privatization and buy back local energy distribution networks.[86] In part, this outcome has been characterized as growing out of frustration over citizen's inability to stop the construction of a local coal-fired power plant three years earlier.[87]

In Japan, as of December 2015, about 14 cities had formed companies to generate renewable energy from local resources in order to reduce dependence on foreign energy sources.[88] One key catalyzer for this trend, in Japan in particular, is the development of market facilitation organizations (MFOs), which support the growth of community energy projects through a variety of factors, including: networking, information dissemination, market research, user education, partner matching, business-deal identification and facilitation, technical assistance, consulting services, financing, and policy advocacy or advice. MFOs are supported through private and public funds, and they play a significant role in several developing countries.[89]

In the United States, the city of Boulder in Colorado voted to municipalize its electricity system in order to advance energy efficiency and renewable energy to address climate change.[90] Following a tornado that hit in 2007 and damaged or destroyed most of its structures, Greensburg, Kansas, a US town of about 1,500 residents, set a goal of 100 % renewable electricity (already achieved). The small rural community of committed citizens aimed to overcome disaster and to build a common vision for a sustainable future.[91]

BOX 1: ENERGY DEMOCRACY

Energy democracy goes beyond national security of energy supply to bringing energy resources and infrastructure under public or community ownership or control. The term grew out of the climate justice movement, and is grounded on the basic understanding that "the decisions that shape our lives should be established jointly and without regard to the principle of profit."[94]

A growing number of experts and communities believe that de-carbonization of the energy economy is critical not only for mitigating climate change but also for achieving a more just, sustainable and resilient economy. In addition, some experts note that an equitable, ecologically-sound energy system should serve the needs of the world's peoples, and that an energy transition will be advanced by a shift to public and community control.[95] The distributed nature of renewable energy resources – which theoretically are public goods accessible to all – helps to facilitate this process.[96]

Elsewhere in the United States, the Navajo and Hopi Native American tribes jointly formed a group to retake control of their tribal lands – which they had leased for coal extraction – and develop a solar power project. Not only will they retain ownership of the project, they also hope to acquire the jobs, skills, training and economic development that result from it.[92]

Similarly, in the French region of Nord-Pas-de-Calais, the small town of Loos-en-Gohelle committed to 100 % renewable electricity by 2020 (also advancing energy efficiency) to break away from its industrial and mining past and achieve energy autonomy. The town also aims to reduce energy poverty and advance research and training with the region's engineering schools.[93]

In addition to the more-traditional political drivers, an increasing number of governments is advancing renewable energy for less-traditional reasons linked to a "moral imperative": namely, because it is deemed the right thing to do (e.g., San Diego, California, United States; Oxford County, Ontario, Canada), or driven by a desire to help others in the community (e.g., finance home efficiency improvements for poor families), or by the aspiration be first and to set an example for others to follow.[97] Reputation also is becoming a factor, as in Vancouver, which aims to become the greenest, most live-able city in the world.[98]

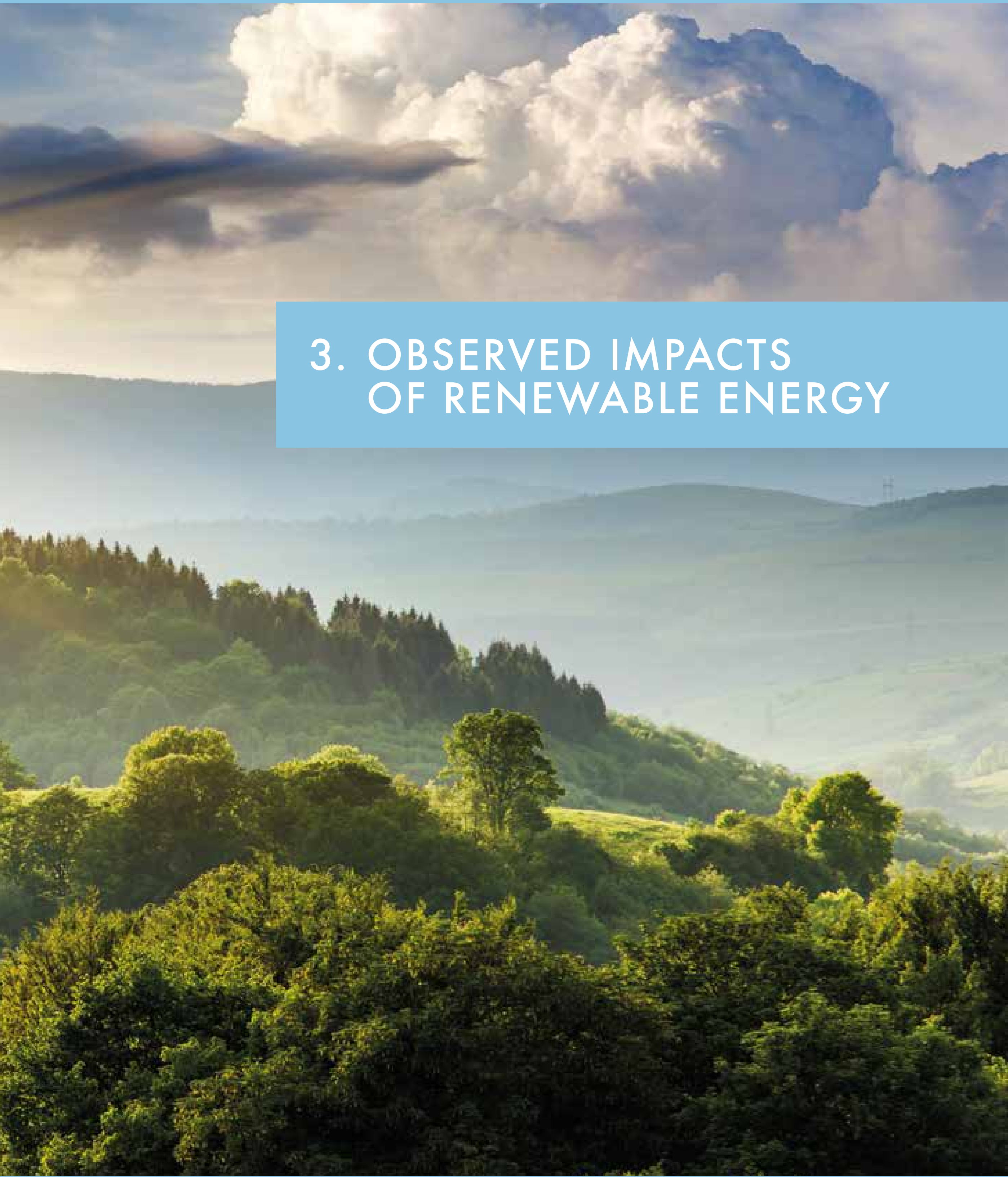
THE EVOLUTION OF DRIVERS

As seen from the examples above, the vast majority of jurisdictions acting to advance renewable energy does so for several reasons, crossing categories of drivers. The relative importance of drivers varies from place to place, and may change or evolve over time.[99] The IPCC SRREN (2011) determined that environmental factors and concerns about security of energy supply had played a more significant role in driving policies in industrialized countries, whereas economic opportunities had been the most important factor elsewhere.[100]

As of early 2016, however, the lines do not appear to be so clear-cut, reflecting either an increase in available information about drivers around the world or possible shifts in priorities. Global climate change and public health concerns – due to air pollution in urban areas and to heavy dependence on traditional biomass and kerosene in rural areas – are playing increasingly important roles in driving renewable energy policies across the Global South. And industrialized countries also are driven by economic factors. Local communities everywhere appear to be increasingly concerned about resilience, local choice and control, all of which can work together to empower citizens and strengthen communities, both socially and economically.

An increasing number of jurisdictions around the world aims for 100 % renewable energy, with most targeting the power sector specifically (either through on-site generation or the purchase of renewable power generated elsewhere), but some also are including heating and cooling, and even transport.[101] Most 100 % targets are at the local level, with towns and small cities at the forefront of this rapidly emerging movement. However, there is a growing number of large cities (e.g., Copenhagen, Frankfurt, San Diego, San Francisco, Stockholm, Sydney, and Vancouver) and even countries (e.g., Cape Verde; Denmark; Scotland; Sweden) joining their ranks.[102]

The municipal initiatives mentioned above have brought increased visibility to the 100 % movement. While the list of jurisdictions is largest and growing most rapidly in the industrialized world – including Europe and North America, as well as countries such as Australia and Japan – an increasing number of those committed to 100 % renewable energy includes small island nations and cities and towns in the Global South.[103] Drivers of the 100 % renewable energy movement are similar to those that have motivated more modest goals, and it remains unclear precisely which factors are most important in driving the goal of a 100 % transition to renewable energy.



3. OBSERVED IMPACTS OF RENEWABLE ENERGY

3. OBSERVED IMPACTS OF RENEWABLE ENERGY

Several jurisdictions have already achieved their 100 % renewable energy goals, including numerous towns and cities in Europe, three cities in the United States, and a few jurisdictions in Japan and the Pacific.[104] In late 2015, the Austrian state of Lower Austria achieved its target of generating 100 % of electricity with renewables.[105] Around the world, in all continents and regions, cities, states, provinces and countries have increased their shares of energy (particularly electricity) from renewables dramatically in response to renewable energy support policies. Some of these jurisdictions have assessed and reported on the domestic (local) impacts of renewable energy deployment, with examples noted below.

Even so, data on actual observed socio-economic impacts of renewable energy deployment are in short supply and are limited mostly to local case studies, each of which is subject to its own set of assumptions about how to measure the impacts. There is a great need to develop better methodologies and to increase the capacities to measure, compile, and share information on these impacts on a larger scale; at the same time, it is important to be mindful of the complexity involved and the fact that local conditions dictate varying outcomes from one community to the next.

ENVIRONMENTAL IMPACTS

According to IRENA, an estimated 3.1 gigatons (Gt) of CO2-equivalent (CO2-e) of emissions was avoided worldwide in 2012 through the use of renewable electricity (primarily hydropower); total global emissions would have been 20 % higher if not for renewable-based power generation.[106] At the end of 2015, renewable energy's share of global electricity production was an estimated 23.7 %, with hydropower accounting for about 16.6 %.[107]

In the European Union, renewables had achieved a 15 % share of total final energy consumption as of 2013, and an estimated 15.3 % share in 2014.[108] This deployment is credited with around 388 megatons (Mt) of gross avoided CO2 emissions in 2013, up from an estimated 326 Mt in 2012.[109] In 2014, Germany alone avoided an estimated 153.9 Mt of CO2-e through the use of renewable energy.[110]

In the United States, growth in solar and wind power generating capacity has been a key component in declining carbon intensity of the country's electricity supply, according to the US Energy Information Administration.[111] An analysis of the impacts of state Renewable Portfolio Standards estimates that new renewable power capacity (build after RPS enactment) reduced life-cycle GHG emissions by 59 million metric tons of CO2-e in 2013.[112] In addition, these renewables resulted in reductions of national emissions of sulfur dioxide (SO2) (down by 77,400 short tons), nitrogen oxides (NOx) (down 43,900 short tons), and particulate matter 2.5 (PM2.5) (down 4,800 short tons) in 2013. National water withdrawals and consumption were down 830 billion gallons and 27 billion gallons, respectively – amounting to 2 % of total power sector water withdrawals and consumption in 2013 – with the largest reductions in the water-stressed states of California and Texas.[113]

Renewable energy technologies (some more than others) do carry notable environmental costs of their own. Some of those costs are relatively localized, while associated benefits – particularly in the context of reduced GHG emissions – may not be. Environmental and associated social costs may include competition with wildlife and humans for available land and water, and GHG emissions and other air pollutants during manufacturing or operation of renewable energy technologies. Environmental costs of renewables are technology- and site-specific, and often can be mitigated to some extent.[114] Such costs need to be accounted for and in proper proportion to the environmental impacts of other energy sources.

ECONOMIC IMPACTS

When estimating economic benefits of renewable energy deployment, a distinction needs to be made between clear additional benefits (such as the economic benefits of reduced emissions of air pollutants , which result in lower overall health costs) and benefits that are not necessarily net additions (such as jobs created that may in whole or part come at the expense of jobs elsewhere in the economy). This latter category is sometimes referred to as a distributional effect, or resource transfer, without any specific characterization of net economic or societal benefit.

Increased use of renewable energy has helped to reduce costs associated with the consumption of fossil fuels, including fuel imports and environmental and health impacts. In the EU, for example, demand for fossil fuels was down by 116 million tonnes of oil equivalent (Mtoe) during 2013, thanks to renewable energy.[115] Avoided imported fuel costs due to increasing renewable energy production amount to an estimated EUR 30 billion annually.[116]

In South Africa, renewable energy generated an estimated R 0.8 billion net benefit to the economy in 2014, which rose to R4 billion in the first half of 2015, due to a combination of avoided fossil fuel costs and reduced load shedding (brown outs).[117]

The US Navy has found that long-term contracts for renewable power provide cost stability, freeing funds for use elsewhere.[118] In the US state of Alaska, the island town of Kodiak has virtually eliminated its use of diesel fuel, thereby saving an estimated USD 24 million since 2009, while also reducing local air pollution and GHG emissions.[119]

Environmental and human health benefits of incremental renewables in the United States that have been installed to comply with state RPS laws, are thought to be significant. Although there is a sizable degree of uncertainty, the US National Renewable Energy Laboratory (NREL) estimates that the benefits associated with reductions in GHGs and other air pollutants totaled approximately USD 7.5 billion in 2013* (or 7.5 cents/kWh of renewable electricity).[120] This compares with estimated net compliance costs** to utilities and other load-serving entities in the range of USD -0.004 to 0.048/kWh of renewable electricity, totaling an average USD 1 billion annually over the period 2010-2013.[121]

Renewables also have helped to create jobs worldwide, with global employment in the sector reaching an estimated 8.1 million in 2015 (excluding large-scale hydropower), according to IRENA, with large-scale hydro supporting an estimated 1.3 million additional direct jobs.[122] Most jobs to date have been created in the power sector (with the largest number in solar PV, at 2.8 million) and in biofuels (1.7 million), followed by wind energy (1.1 million) and the solar water heating and cooling sector (an estimated 940,000 in 2015).[123] The leading countries for renewable energy jobs in 2015 were China, Brazil, the United States, India, Japan, and Germany.[124]

* Note that the benefits associated with GHG reductions are global, whereas those associated with a reduction in air pollution emissions are more localized.

** RPS compliance costs represent the incremental cost to the utility or other load-serving entity with RPS obligations, net of avoided conventional generation costs. Negative RPS compliance costs may occur when renewable electricity procured to meet RPS obligations is less expensive than avoided conventional generation. Source: https://emp.lbl.gov/sites/all/files/lbnl-1003961.pdf.

China is the leading country for the manufacture and deployment of renewable energy technologies, and is by far the largest renewable job market with an estimated 3.5 million people (not including large-scale hydropower) employed in the industry in 2015, according to IRENA.[125] Rapid growth in China is reflected in cities such as Dezhou, which boasted over 120 solar energy enterprises as of 2010. Of the 66,000 new jobs created in Dezhou during 2010, nearly one-third were in the solar energy business, including the solar thermal heating and cooling and solar PV industries.[126]

The European Commission estimated in 2015 that Europe's renewable energy industry employed 1.15 million people.[127] Although employment levels for some technologies (such as solar PV) have been trending downward in some countries, they have continued to rise elsewhere.[128] Despite the fact that manufacturing of renewable technologies (such as solar PVs) has shifted to Asia, EU companies held 40 % of all patents for renewable energy technologies as of late 2015.[129]

In the United States, renewable energy jobs continue to rise at a rapid rate. According to one estimate, solar-related jobs accounted for almost 1.2 % of all jobs created nationally during 2015. With a growth rate of about 20 % (for the third consecutive year), solar jobs expanded nearly 12 times faster than the national employment growth rate of 1.7 %. In 2015 alone, the United States added more than 35,000 solar-related jobs, bringing the total to nearly 209,000. Wages are competitive with those in similar industries and average significantly higher than the median wage across all US occupations.[130]

Renewable energy-related employment remains low in Africa, except in a few countries such as Kenya, Morocco and South Africa.[131] However, targets and policies such as those in Uganda's Kasese district are creating new employment opportunities. Between 2012, when Kasese's 100 % renewables program was launched, and 2015, the number of "green" businesses (selling and building renewable energy projects as well as improved cookstoves) increased from 5 to 55, and at least 1,650 people in the district received relevant training.[132]

Across the Global South – in Kasese as well as Khulna District of Bangladesh, Sumba Island in Indonesia, villages of Andhra Pradesh in India, and elsewhere – renewables also are providing access to modern energy services, saving people money, and improving the quality of life.[133] In Kasese, Uganda, tens of thousands of people had acquired access to energy for the first time by late 2015, saving money on charcoal and kerosene that can, instead, be used to purchase food, clothing and education. Other benefits have included reduced indoor air pollution; fewer conflicts over firewood and time spent searching for it, meaning more time is available for productive work; and the opening of important lines of telecommunication through radio, television, cell phones, and computers with Internet access.[134]

In 2010, about the time that Indonesia's Sumba Island launched its 100 % renewable energy initiative, only 25 % of the local population had access to electricity; by 2014, the share had risen to 40 % and was still increasing.[135] Profits from electricity generation are reinvested in the community, and its citizens have become more willing to become involved in community programs.[136]

Renewable energy projects also have helped to improve standards of living in industrialized countries. In Zschadraß, Germany, for example, the revenue from community-owned renewable energy projects has been used to fund school meals and educational facilities. Investment in renewable energy under the German feed-in tariff enabled this relatively poor community to advance local living standards.[137] In Machynlleth in Wales, a third of the revenue from community-owned wind turbines goes into a fund to help poorer residents finance energy efficiency projects.[138] On the small island of Gigha in Scotland, revenue from a community-owned wind farm enabled residents to buy back the land on which they lived, to insulate old homes, and fund other projects. Between 2002 and 2013 the community's population nearly doubled, a positive development attributed at least in part to improvements in the standard of living due to re-municipalization of land and energy.[139]

While many energy experts and governments see citizen economic and political participation and the involvement of communities as necessary to ensure acceptance, experience shows that the benefits go well beyond this. Adopting a people-centered approach and empowering citizens, farmers and small businesses to invest in renewable energy projects can be a powerful tool for socio-economic development and local wealth creation.

POLITICAL AND SECURITY IMPACTS

Energy security on a local, national, or regional level may be enhanced with renewables through diversification and localization of energy supply. Energy security has both short-term and long-term aspects, where the former pertains to the capacity to cope with sudden imbalances in energy supply and demand, while the latter pertains to timely and appropriate investment in supply to meet long-term economic and environmental needs.[140]

As noted above, energy security fosters political and economic security, and vice versa. The conventional context for the study of this topic has been focused on fossil fuels. In that context, any mention of renewables has been largely limited to the vulnerabilities posed by variable output and the need to supplement renewable electricity with conventional electricity supplies, and the associated inherent risks.[141]

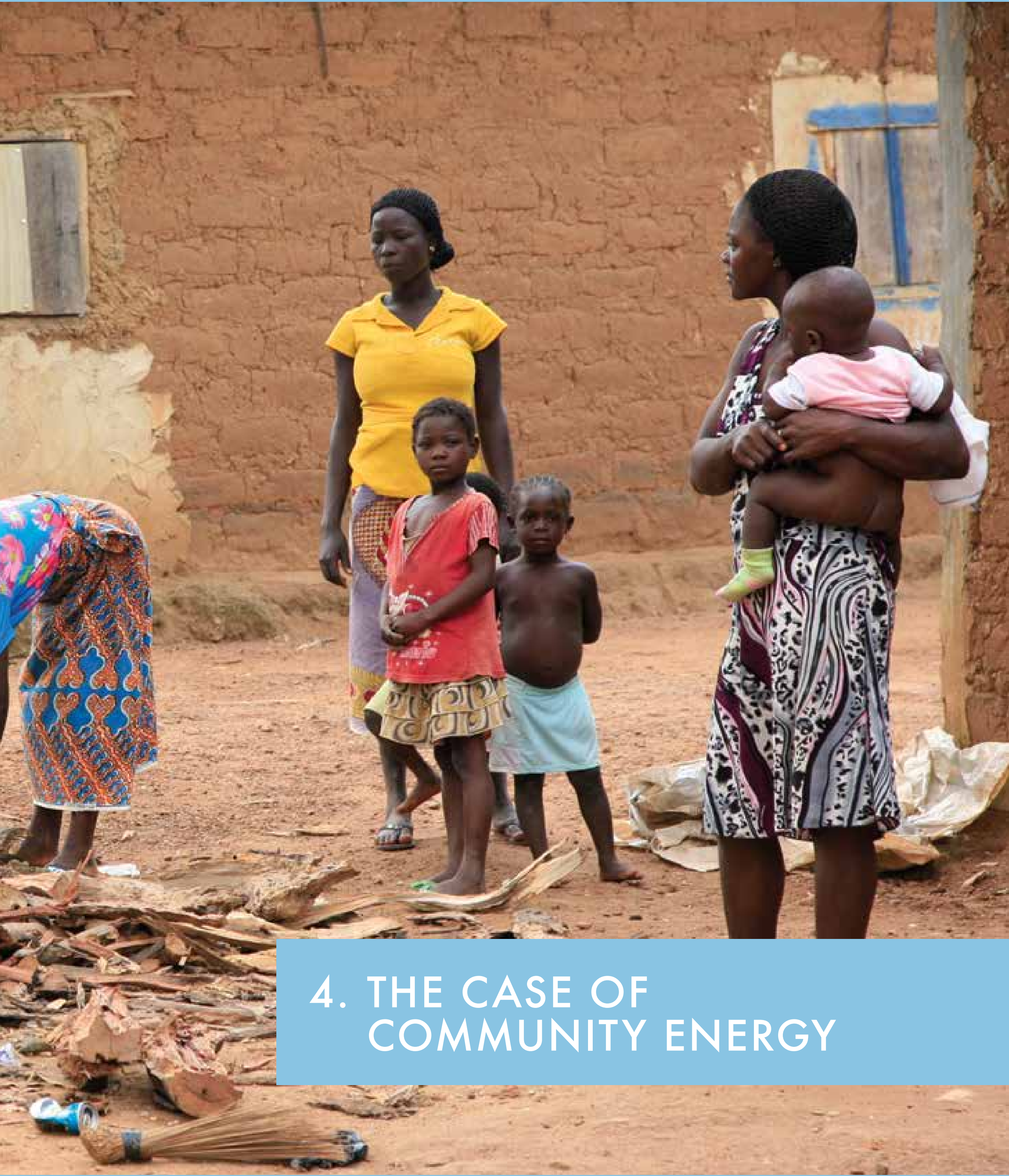
Indeed, increased renewable energy deployment is not unequivocally synonymous with improved energy security and reliability as variable renewables in high concentrations (notwithstanding the limitations of conventional energy supplies) may, in the short-term, adversely affect security and reliability of supply until such concerns are addressed through options such as expanded interconnection, use of non-variable renewables, and increased storage capability.

However, the attention to this security aspect of variable renewable energy output stands in contrast with the lack of concerted effort to measure and account for the actual beneficial role of renewable energy, and its further potential, in improving energy security, whether locally or globally, and subsequent benefits to political and economic stability.

Increased deployment of renewable energy has been shown to improve energy security in the EU, where renewable's substitution for natural gas accounted for 30 % of the estimated reduction in fossil fuel demand during 2013.[142]

In the United States, the Navy has deployed on-base micro-grids powered by renewable energy ensure that facilities can continue to function even in the event of a grid outage, increasing security of the naval bases and, by extension, contributing to US national security.[143]

At the sub-national level, the island of El Hierro, the smallest of the Canary Islands, claimed freedom from reliance on diesel-powered generation when, in 2014, the inhabitants married a 6 MW pumped storage plant to 11.5 MW of wind capacity, making the island self-sufficient in electricity.[144]



4. THE CASE OF COMMUNITY ENERGY

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The appeal of local ownership through energy cooperatives and municipalization of local energy utilities has grown significantly in recent years. While there is a long history of power cooperatives in Germany and elsewhere, going back over a century, there has been a notable resurgence in the model over the past several years. As of late 2013, more than 800 cooperatives had been established in Germany alone in the field of renewable energy, with the majority formed between early 2009 and end-2012.[145] According to one analysis, in 2012 citizen ownership accounted for 47 % of Germany's installed renewable power capacity and 43 % of its renewable power generation.[146]

While most renewable energy cooperatives focus on power generation, there also are new cooperative district heating networks that connect households to biogas plants, for example, bringing together farmers, citizens and the broader community to make decisions that affect all inhabitants directly and to promote local value.[147]

Research in Germany and beyond has found that citizen participation plays an important role in the public acceptance of renewable energy at all levels: this includes the general perception of renewable energy, as well as acceptance of specific projects. Even so, levels of acceptance vary by technology and location. There are many reasons for objections to concrete local projects, ranging from concerns about aesthetics to potential impacts on local traffic patterns (e.g., delivery of biomass feedstock to new plants).[148]

Concern about projects – as well as infrastructure, such as transmission and distribution lines – can be reduced by working to maximize individual benefits in relation to the creation of public goods through distributive and procedural justice. Distributive justice focuses on who pays and who benefits – a sense of equitable distribution of costs and benefits positively affects project acceptance. Procedural justice requires that all affected have a fair chance to participate in the planning process and to be heard, even if their views do not rule the day. Research has distinguished four basic levels of participation: information, consultation, cooperation, and self-determination.[149]

Many energy experts and policy makers have long considered citizen involvement to be critical for ensuring project acceptance.[150] In Germany, energy experts and the government have noted its importance for increasing acceptance of the Energiewende.[151] Social acceptance of renewable energy projects is considered by many to be critical for a successful energy transition because of the necessarily large increase in renewable energy capacity required, and because much of the energy production will occur closer to home.[152] The World Wind Energy Association notes that local community ownership appears to have generated significantly higher social acceptance of wind power in Austria, Germany, Scotland and the United States.[153]

A 2009 Scottish study followed wind energy projects in two communities, one where the project was operated by a national power company and the other (in a community with similar conditions) where the wind farm was citizen-owned. Acceptance for the project (and potential for its expansion) was found to be higher in the latter due to increased revenue for the municipality, the "green" image that emerged from the project, and broad consideration of the project as a local success story.[154]

In fact, the benefits go well beyond acceptance of renewable energy generally or of specific projects.[155] Several studies covering the importance of participation from local actors conclude that local ownership – as opposed to the typical land lease or other arrangements with traditional power producers – not only helps to advance the energy transition but also benefits society as a whole. Adopting a more people-centered approach to energy production and use empowers citizens, farmers and small businesses to invest in renewable energy projects, which helps keep profits in a community and can be an important tool for local socio-economic development.[156] Citizen participation also helps with community-building, while ownership and control over the means of energy production and consumption can lead to a reduction in total energy consumption.[157]

These studies[158] have found numerous beneficial effects beyond acceptance that are associated with local ownership and participation in renewable energy projects, including:

- More-engaged citizenry – general increase in willingness of community members to be engaged socially and politically, and development of greater competence in dealing with local government, thereby strengthening democracy;

- Increased awareness about energy issues and importance of energy efficiency improvements;

- Increased likelihood of project success due to local participation and transparency in planning and construction, especially if much of project design is in the hands of local citizens;

- Stronger communities as projects bring people together, creating a common identity, as well as pride in joint accomplishments and increased feeling of self-worth among people involved;

- Reduced dependence on a limited number of energy producers and broader distribution of assets and influence within the energy system;
- Reinvestment of energy money in the community rather than its migration into global financial flows (through imports of fuels, electricity, etc.);
- Realization of projects – such as local heating networks or wind farms – that might not be developed by major actors due to relatively high transaction costs and project risk;
- Local energy needs are more likely to be met;
- Local value creation through use of local services, tax revenue, and other returns for a total value-added that likely is greater than otherwise would be the case;
- Local job creation and skills acquisition, particularly for those projects that would not materialize if they were not citizen-owned. In many communities studied, new jobs have been created to manage or maintain installations and, depending on project size, organizers have sought to award contracts to local craftsmen.[159] Jobs can be created indirectly as well, through the value-added effect that results from reduced capital outflow.[160]
- Increased economic resilience of community members through diversified sources of income;
- Increased pool of funders – local ownership increases the number of people and available funds for investment in renewable energy projects as this opens doors for those who otherwise would not have the opportunity, interest, or sufficient funds to invest in renewables;
- Innovation stemming from volunteerism and free exchange of knowledge.

Although most such studies have examined what has occurred in industrialized countries, there exist similar benefits to local participation and ownership across the Global South, as well as similar challenges in many locations where these elements are lacking.

For example, in Morocco, despite efforts to ensure that the NOORo solar thermal power complex would contribute to socio-economic development of local communities, misunderstanding arose due to the shortcomings in citizen engagement. A lack of transparency and inclusive participation in project planning and development led to unrealistic expectations about jobs and other economic opportunities, distrust toward project developers and local authorities, and shortfalls in project siting and in implementation procedures. Subsequently, strategies for the project were being revised as of 2015.[161]

A study in China, examining the national “Township Electrification Program” found that, in spite of the beneficial impacts of the program, there were a number of challenges due to the centralized top-down approach and lack of local participation in decision making. The study concluded that, ultimately, the program pursued the conceptions of political leaders rather than meeting energy needs of the local people. In addition, program designers underestimated the financial implications (e.g., ability to pay the electricity fee) for people at the local level, and misjudged the available human resources and institutional capacity.[162]

While local ownership and control offer numerous advantages, few communities are literal islands, and there also are advantages to cooperating beyond the local area. IRENA has found that regional and international approaches and initiatives to renewable energy can reduce costs, produce economies of scale, attract investments, increase available financial capacity, stimulate trade across borders, and enable shared progress in accelerating global deployment of renewable energy technologies.[163] Also important (assuming they are available) are robust grid connections with neighboring districts, and beyond, to reduce the costs and technical challenges associated with system balancing, demand response, and storage. To this end, studies have found that strategies combining top-down as well as bottom-up elements, and collaboration with other regions and higher levels of government, all are important for success.[164]

5. MEASURING COSTS AND BENEFITS – EXAMINATION OF METHODOLOGIES

5. MEASURING COSTS AND BENEFITS – EXAMINATION OF METHODOLOGIES

As the global community tackles the challenge of meeting its sustainable development objectives, the imperative of the renewable energy transition must be backed up with solid assessments of how effectively renewables, and all supporting policies, can accomplish the task. Certainly, a transition to 100 % renewable energy in the not too distant future is a key component to stabilizing climate change, but the aggregate benefits go well beyond that. Yet, how can we know the sum of the benefits (and costs), which often defy a common measure?

The challenge is significant: To accurately identify and quantify the myriad benefits and costs of pursuing a policy for a complete transition to renewables; to predict and account for the scale of these variables individually and in relation to other variables; to do so on the appropriate geographic and temporal scales; and to find a common unit of measurement that allows proper proportional weighting of each variable in an aggregate frame of accounting (and without double-counting).

For example, consider the costs and benefits of reduced air pollution resulting from the deployment of renewable energy technologies. These can be counted under direct environmental benefits (reduced acid deposition), welfare (public health benefits of reduced mortality, improved human well-being), economic benefits (reduced health care expenditures, improved worker productivity), economic costs (any incremental system costs, reduced GDP on account of reduced health care consumption), and distributional effects (emissions reduced in one location but effect realized in down-wind areas, even across national borders, and jobs gained in one location or industry at the expense of another). Not all of these costs and benefits can be monetized easily for common measure and comparison. Some of the impacts are realized locally where the renewables are deployed while others are realized elsewhere or shared globally, creating an accounting challenge based on geographic scope. In addition, some benefits are immediate while others are realized over long time horizons, creating a temporal accounting challenge.

There also may be a risk of contextual bias, in which some costs and benefits are inappropriately weighted more heavily than others. This is particularly likely in the context of costs and benefits that have non-direct (or nuanced) economic dimensions, such as loss of coal mining jobs (somewhat direct economic cost) compared to aquatic mercury pollution (somewhat indirect economic cost). It is also important to be mindful of any tendencies to discount improperly costs relative to benefits. The ultimate value of any cost-benefit analysis of expanded renewables deployment hinges on its credibility, which in turn is the product of: robust and impartial methodology; reasonable and sound assumptions; unbiased relative assessments; as well as the absolute commitment to transparency, precision and accuracy.

There have been several recent studies of the relative costs and benefits of renewable energy deployment. All measure the impacts in several ways, but none has claimed to represent a comprehensive assessment of the subject.

This section examines a number of these studies, starting with a discussion of various assessments of the value of distributed solar PV in the United States, a more narrowly defined sub-category of the genre. Following are overviews of four broader studies, noting, the main characteristics of the conceptual approaches and methodologies, and, in some cases, highlighting some potential shortcomings. Two of these studies are retrospective assessments of achievements and two are projections of potential future outcomes.

Each study has a different objective, which accounts for the different approaches. These studies were chosen for review because they represent some of the most recent (and varied) efforts to assess the benefits of increased renewable energy deployment, and because they offer an opportunity to gauge which approaches and methods may work well, and also where the greatest challenges may lie. However, the task of proposing specific improvements or offering a comprehensive alternative approach is beyond the scope of this paper.

THE VALUE OF DISTRIBUTED SOLAR PV

The rapid growth of distributed solar PV generation in the United States, driven in large part by state net metering policies, has prompted many US jurisdictions to attempt to quantify the value of distributed solar energy to the grid. One such mechanism is the value of solar (VOS) rate, which is determined through a bottom-up calculation that considers the value of distributed solar PV generation to a utility company and its customers, as well as to society and the environment as a whole. The VOS has been adopted only by Austin Energy in Texas (in active use) and the State of Minnesota (not in use as of early 2016[165]); however, the methodologies and calculations are instructive for considering the broader costs and benefits associated with renewable electricity.

Several US institutions – including Minnesota's Department of Commerce (DOC), the National Renewable Energy Laboratory (NREL), Rocky Mountain Institute (RMI), and Interstate Renewable Energy Council – have set the foundations for performing VOS rate calculations. The main components of these methodologies include energy; emissions; T&D loss savings; generator capacity; T&D capacity; ancillary services; and other costs and benefits (e.g., other environmental impacts, fuel price hedging, diversity, market price suppression, operation and maintenance (O&M) costs, integration costs, grid support services, and resiliency).[166]

In most if not all model calculations based on various VOS methodologies, the largest VOS component has been avoided fuel cost, followed by avoided capacity and environmental cost (primarily the avoided cost of carbon). Minnesota's DOC example calculation resulted in a VOS of USD 0.127 (25-year levelized value). A separate estimate calculated by the utility Xcel using the DOC's methodology was a 25-year levelized value of USD 0.1208/kWh.[167] Three hypothetical VOS tariffs calculated by NREL, based on differing assumptions and across US states (excluding Alaska), ranged from USD 0.049/kWh to USD 0.11/kWh (with a mid-value of USD 0.075/kWh).[168]

Some costs and benefits are difficult to monetize, VOS rates vary considerably depending on methodology and assumptions as well as local context, and VOS rates will change over time with changing conditions. Even so, the numbers derived in these studies suggest that there is a positive value to utilities and society from distributed solar PV.

Beyond VOS, many studies have been carried out in the United States in recent years to determine the costs and benefits of distributed solar PV. RMI reviewed 16 cost-benefit studies on distributed solar PV (published 2005-2013) by utilities, national laboratories and other organizations: while there was a wide range of values, most studies found that benefits were at or above the average local retail rate of electricity.[169] In mid-2015, the NGO Environment America released a review of 11 recent analyses – including those by or for utilities and state utility commissions – all of which found that solar energy brought net benefits to the grid; eight of them concluded that the value of solar energy was worth more than the average residential retail electricity rate in the area at the time of study.[170]

Despite the apparently significant total net value of solar, the case has been made that the pure economic value of solar (and other variable sources) depends on its rate of penetration in the electricity market. A 2012 modeling study based on the future California power market in 2030 showed that without the benefit of energy storage, the capacity component of the value of solar might well decrease as its share of the energy mix increases. In other words, the economic market value of solar depends on its relative market penetration.[171]

GERMAN COST-BENEFIT STUDY OF 2012 (RETROSPECTIVE 2008-2011)

In 2012, a study funded by the German government sought to identify, isolate, and quantify some of the costs and benefits of growing use of renewable energy in the country.[172] From the outset, the study noted the need to account for the scale and system boundaries, as costs and benefits of renewable energy in Germany are not bound by national borders. The study devised a conceptual framework that classified costs and benefits as: a) system-related (all direct and indirect costs associated with increased use of renewables and displacement of other energy sources); b) distributional effects (assumed to be zero-sum reallocation within the system); or c) macro-economic effects (renewable energy industry turnover, investment in renewables, avoided energy imports, and gross change in employment associated with renewable energy deployment.

A major consideration noted was that costs and benefits can be aggregated and compared only if evaluated by a common measure (in monetary terms).[173] (This is in contrast with some aspects of the global cost-benefit analysis done by IRENA in early 2016 – see below.) Also, the study emphasized the importance of proper accounting of where externalities may have been partially internalized within the economic system through other environmental or energy policy instruments.[174]

Among system-related costs and benefits, the study identified EUR 10.9 billion in additional energy-related costs in 2011, most of which are incremental generating costs of renewables. This was balanced against EUR 10.1 billion in avoided environmental costs in the same year, but it was noted that the estimation of the monetary value of avoided environmental harm spanned a very wide range, subject to great uncertainty.[175] In addition, a significant portion of the avoided damage lies in avoided GHG emissions (the other part being air pollutants such as oxides of sulfur and nitrogen), and it is unclear whether the estimated benefit of reduced GHG emissions (or even other pollutants) was limited to the geographic scope of the study (Germany).

Distributional effects are defined as those impacts associated with increased renewable energy deployment that result in redistribution among affected parties, but that are net zero-sum – meaning that money (or value) is transferred in the course of bringing about growth in renewable power capacity.[176] The largest distributional effect is the EEG surcharge, the rate increment on electric power that partially funds the transition. Renewable energy plant operators are the beneficiaries, while rate payers bear the burden (excepting those industries and railways that are exempted from the related charges).

The second largest distributional impact is the "merit-order effect", in which the near-zero variable cost of renewable generation shifts the supply curve in the power spot market with the effect of lowering the marginal price of electricity. This reduces average wholesale prices, benefiting rate payers at the expense of electricity producers. While this is a "zero-sum" distributional effect, it does have secondary impacts in the economy as consumers' discretionary spending may increase while the power industry may incur stranded generating assets that are no longer able to recover operating costs in a changing power market. However, those impacts would be counted elsewhere under macro-economic effects.

Among macro-economic effects, the study noted EUR 25 billion in renewable energy industry turnover in 2011, EUR 23 billion in investment in new renewable plants, and EUR 6 billion in avoided energy imports.[177]

On employment, the study identified 381,600 renewable energy-related jobs in Germany in 2011: these included renewable energy production, operation and maintenance (O&M), fuel provision, and other related publicly-funded activities. There was no attempt to measure the net employment benefits in the German economy from renewable energy deployment (net of losses elsewhere in the economy), except to say that these jobs "often require higher skills than the industrial average."[178]

The overall conclusion of the study was that, despite the challenges of conducting a comprehensive cost-benefit analysis of the domestic transition to renewable energy sources, and considering that the study attempted only to measure some of the more important variables, the benefits thereof "more or less outweighed the costs, for the observed time span (2008-2011)."[179] However, this conclusion is limited to variables where "system boundaries coincide" in order to ensure that results are aggregated by a common measure, time frame, and geographic boundary. Other considerations such as impacts on energy security, nuclear risk mitigation, technology innovation, political considerations, and impacts on national security were noted but not quantified.

NREL/LBNL STUDY OF 2016 (RETROSPECTIVE 2013)

A study released in early 2016 by two US national laboratories (National Renewable Energy Laboratory, NREL, and Lawrence Berkeley National Laboratory, LBNL) aimed to provide the first national level assessment of the benefits and impacts of state Renewable Portfolio Standards (RPS) laws in the United States.[180] The study applied a simulation model to estimate the amount of fossil fuel generation that was displaced due to new renewable energy generation used for RPS compliance in 2013. Subsequently, the study estimated the associated benefits (reduced GHG emissions, other emissions and water use) and other impacts (gross job creation, economic development, wholesale electricity prices, and natural gas prices).[181]

The study makes a distinction between "benefits" and "impacts" in that no qualitative estimation is made for any net social benefits from impacts such as job creation, and reduction in energy prices, while reductions in air emissions and water use are quantified (and monetized if possible) as benefits. The rationale for this is the ambiguity of whether the impact is a benefit or a cost depending on who is affected.[182] For example, declining natural gas prices benefit energy consumers at the expense of natural gas suppliers, and jobs in the renewable energy sector may come at the expense of jobs in other sectors of the economy. Such impacts are thus referred to as "resource transfers" in a manner similar to the category of "distributional effects" under the German study of 2012 (see above).

Much as the German study does, the NREL/LBNL study acknowledges the wide range of estimates for the monetized global benefit of GHG reductions. With a projected 59 million metric tons of CO2-e reductions in 2013, a central value of USD 37 per metric ton yielded a global benefit of USD 2.2 billion, or USD 2.2 cents per kWh of additional renewable generation in 2013 to meet the year's RPS requirements. Given the inherent uncertainty in quantifying the value, the estimated range of benefits was noted to be USD 0.7 – 6.3 billion.

The (domestic) health and environmental benefits of reduced emissions of sulfur dioxide, oxides of nitrogen, and particulate matter were estimated at USD 5.2 billion in 2013, or the equivalent of USD 5.3 cents/kWh of additional renewable generation applied for 2013 RPS compliance. Again, the estimated range of global benefits was wide, at USD 2.6 – 9.9 billion during the year.

The study estimated that RPS requirements supported 200,000 jobs in 2013, with 15 % of those in O&M and the rest in construction. Construction jobs are concentrated in the solar PV market, whereas wind power demands more O&M jobs.

As with the German study, the NREL/LBNL study considered the effect of renewable power shifting the supply curve. This "merit-order effect" was estimated to result in savings to consumers in the range of USD 0 – 1.2 billion (USD 0 – 1.2 cents/kWh). The wide range resulted from uncertainty about the actual impact on wholesale spot market prices and about whether any savings actually accrue to consumers. The reduction in natural gas prices, due to reduced demand, was estimated at USD 1.3 – 3.7 billion. The study notes that these price reductions amount to "wealth transfer" from producers to consumers (a zero-sum distribution effect), and thus no net societal benefit is claimed.[183]

The authors of this study noted the limitations and boundaries of the analysis as context for the absolute projected benefits and impacts. While efforts were made to use the best available data and consistent methodology, the study's results depend on models and methodologies that introduce some uncertainty. Among noted caveats is that not all benefits and impacts are considered and that those considered were not compared against the costs of deploying renewables for the RPS programs. It also was noted that the study made no determination whether renewable energy is either the only or the least-cost alternative to bring about the estimated benefits.

SYNAPSE STUDY OF 2015 (PROJECTION TO 2050)

The 2015 "Clean Energy Future" report by Synapse Energy Economics attempts to project the cost and benefits of reducing US GHG emissions 80 % by the year 2050.[184] This modeling exercise focused on the employment benefits and economic costs of achieving this reduction in GHG emissions through both accelerated renewable energy deployment and energy efficiency improvements.

The report projects that a net annual average of 550,000 jobs would be added across the US economy through the study period at a slight cumulative cost savings relative to the reference case, with cost savings based, presumably, on energy cost differentials between the two cases.[185] The study projected these job increments, which result from increased renewable technology deployment and energy efficiency, net of job losses in fossil and nuclear industries. The projected incremental job creation in renewable energy and energy efficiency was greatest during the middle of the study period, while much of the incremental job creation in the latter part of the study period was projected to be in the automotive (EV) industry, as well as jobs induced by energy savings that are "spent on other purchases".[186]

The Synapse study notes that both renewable energy and energy efficiency typically create more jobs per unit of generation capacity relative to fossil fuels, but that "most of the cost of clean energy is spent on labor rather than on capital and fuel" and that the clean energy scenario leads to a shift from extractive industries to construction and manufacturing.[187] In other words, renewable energy makes up for its higher labor cost, at least in part, through lower operating costs (and possibly lower capital costs), while also changing the qualitative aspects of the jobs required.

Potential concerns about the study: Aside from the renewable energy sectors themselves, the two most significant incremental (gross) job-creating components were energy efficiency (501,100 jobs on average created each year through the period) and the automobile industry (287,000 jobs).[188] The latter component is driven by the assumed need to expand the electric vehicle (EV) fleet to almost fully displace gasoline light vehicles by 2050. It is unclear, however, how the projected new EV demand translates into such a large net incremental effect on vehicle manufacturing jobs, as opposed to merely displacing gasoline vehicle manufacturing. The projection shows that the direct job impact from renewable technology deployment and energy efficiency declines toward the end of the period, while EV manufacturing and stimulus from net energy cost savings make up more than half the job impact by 2050.[189]

IRENA STUDY OF 2016 (PROJECTION TO 2030)

In early 2016, IRENA published what it called the "first global quantification of macroeconomic impacts of renewable energy deployment," setting out to estimate the impact of doubling the share of renewables in the world's energy mix by 2030.[190] The study used macro-econometric modeling to project the effect of increased renewable technology deployment in four areas: global GDP, job creation, trade, and a composite proxy for human welfare, based on economic, social and environmental indicators.

The IRENA study is more ambitious and comprehensive than the other three discussed above. With projected outcomes across four areas, one being a complex composite for human welfare impacts, the study warrants careful examination of whether the chosen metrics can be measured reasonably well, and whether they serve well as indicators of the potential benefits of the renewable energy transition.

Impact on global GDP.

IRENA found that doubling the shares of renewables in the global final energy mix (36 % by 2030) would increase global GDP in 2030 by 0.6 – 1.1 %, representing USD2005 0.7 – 1.3 trillion, compared to business as usual.[191] The higher end of the range represented IRENA's REmapE case, where end-use electrification for heating and transport was emphasized at the expense of biofuels.

While the GDP growth projection was the headline conclusion of the study, it hinged to a great extent on the assumption that the vast additional capital investment required to implement the outcome would not "crowd out" investment in other sectors of the economy to any extent.[192]

In a separate sensitivity analysis, the study acknowledged that the positive impact on global GDP might be significantly reduced, or even turn slightly negative, if financing of renewables were to compete fully with investment opportunities in other sectors.[193]

Potential concerns about IRENA's GDP projections:

IRENA's assumption that capital invested in renewable energy would not "crowd out" other investment in the economy is highly debatable, as it assumes that the entire capital required is sitting on the sidelines and would not be allocated elsewhere if the renewables deployment scenario were not to play out as modeled. In addition, the study acknowledges that the bulk of the needed capital would be private.[194] Private capital is subject to a wide range of competing opportunities in global markets. Therefore, it is questionable whether this assumption is a reasonable "middle of the road" expected value in this modeling exercise. This is significant because the strong positive global GDP growth projection due to a doubling of renewable energy shares by 2030, as modeled in this study, appears to be highly dependent on this assumption.

Another concern regarding the use of GDP growth as a measure of benefit is that many universally accepted "positives" of renewables, such as a reduction in health care expenditures associated with burning of fossil fuels, have a negative impact on GDP. In addition, the projected GDP growth is influenced particularly by the required investment and "capital-intensive nature of renewable energy technologies compared to alternative options."[195] This observation of the study suggests that the direct positive GDP impact depends on relatively high costs of renewables and that declining renewable energy costs in the future would actually reduce the economic benefit of high renewables shares (notably, the future cost of renewable energy technologies is an exogenous input from IRENA in this modeling exercise). Conversely, lower future technology costs would translate into lower energy prices which then boost disposable income, consumption, and thus the general welfare (economic utility) that accrues to the population. Based on these limitations of the projected impact on GDP, it may be reasonable to conclude that, at least in isolation, GDP is an imperfect indicator of the projected benefit of rising renewable energy shares.

Impact on employment.

The IRENA study projects jobs in renewable energy to grow from 9.2 million in 2014 to 24.4 million in 2030 under the REmap case, or 22.8 million jobs under the REmapE case (with a higher rate of end-use electrification). The lower value in the electrification case is explained by less biofuel production, which is relatively more labor-intensive. This is 9.3 – 10.9 million more jobs than expected under the reference (business as usual) case. Under REmap the fossil fuel industry was projected to lose 2.4 million jobs relative to the reference case; by comparison, it was projected to lose 0.9 million jobs under the electrification case (REmapE) due to the greater need for electric power generation from fossil fuels. The nuclear power industry was expected to show little or no change in job numbers under either scenario relative to business as usual. Overall, the net increase in jobs is in the range of 6 – 8 million relative to the reference (business as usual) case.[196]

The IRENA study referenced several national studies that project positive job creation associated with increased deployment of renewable energy technologies, with most showing net increases (more jobs created in renewable energy than lost in non-renewable energy sectors). This is explained in part by the fact that renewable technologies are more labor-intensive than are conventional energy systems.[197]

Potential concerns about IRENA's employment projections:

The reasonable presumption of the IRENA study is that job creation will continue to be a compelling policy driver for advancing renewable energy. Notwithstanding this major driver for policies to promote renewable energy growth, the study does not acknowledge the potential economic costs associated with relying on labor-intensive energy. All else being equal, increasing the required labor input per unit of output – constituting reduced economic productivity – is generally not considered by economists to be a positive economic outcome, except perhaps in the context of persistent under-employment. Again, all else being equal, higher labor costs per unit of energy raise energy prices and subsequently reduce the disposable income of consumers. If the reverse were true and renewable systems required fewer jobs than conventional energy systems, as may be the case in the future as the technologies evolve, one might argue that renewable energy technologies are a net contributor to economic productivity and thus economically beneficial relative to conventional energy.

For a modern economy operating at or near full employment, the incremental jobs created by renewable energy per unit of energy output relative to other sources may not be very significant or helpful; however, they may be far more so for less advanced economies lacking for jobs and economic stimulus. Therefore, much like the projected impact on global GDP, the labor requirement per unit of energy from renewable sources is an uneven measure of renewable energy value creation and warrants examination in a wider context.

Impact on trade.

The IRENA study projected somewhat insignificant net impact on global trade from doubling of renewable energy by 2030, with a reduction of USD 40 billion relative to global export value of all goods and services of USD 50 trillion in the reference case, excluding trade in bioenergy.[198] This relatively small net change is the result of significant reduction in fuel exports by oil and coal exporting countries,

balanced by an increase in trade of capital-intensive renewables, and by subsequent secondary impacts on demand for other goods and services. The net impact on trade balances would be negative for fossil fuel exporters in particular (with greatest overall impact on economies most reliant on the fossil fuel industry) but largely positive for traditional fuel importers.

Potential Concerns about IRENA's trade projections:
One might surmise that as renewable energy markets mature globally, it is likely that an increasing share of a growing demand for renewable energy goods and services will be met through domestic supply in each market and, therefore, that international trade would not grow in proportion with renewable energy deployment. The IRENA study concludes that growing global demand for renewable energy components and services would spur growth in trade due to the "capital-intensive nature of renewable energy technologies."[199] However, the modeling exercise appears to employ exogenous inputs for renewable energy manufacturing capacities around the world through 2030 (along with exogenous inputs for renewable energy technology costs), and it may not have accommodated what, in actuality, might be a gradual growth in domestic supply lines (through 2030) in tandem with growth in renewable energy deployment around the world. Growth in domestic manufacturing capacity worldwide, somewhat commensurate with global growth in renewable energy deployment, presumably would negate the need for steep growth in global trade in renewable energy goods and services.

Impact on welfare.
The IRENA study attempted to quantify the welfare benefits of renewable energy deployment in a context that goes beyond traditional measures of utility, i.e., those measured in consumption of goods and services. The analysis incorporates three dimensions of welfare: social, which encompasses

TABLE 1. REPRESENTATION OF AGGREGATE WELFARE CALCULATION RELATIVE TO REFERENCE CASE IN 2030 (IRENA 2016)

Dimension	Welfare Function Component	Weight	Projected Change (%)	Weighted Value
Economic	Consumption and Investment	1/3	+ 0.7	0.233
Social	Employment	1/6	+ 0.1	0.017
Social	Health and Education	1/6	+ 1.8	0.300
Environmental	GHG Emissions	1/6	- 11.2	1.867
Environmental	Material Consumption	1/6	- 1.6	0.267
Total implied percentage increase in aggregate global welfare (sum of weighted): 2.68 %				

Source: IRENA, Renewable Energy Benefits: Measuring the Economics (2016), based on Table 1, p. 34.

employment, health and education expenditures, and the cost of health impacts from local air pollution; environmental, which includes the avoided cost of GHG emissions and depletion of other natural resources; and economic, which is defined as consumption and investment.[200] The study noted that including investment in the economic dimension of welfare represented a departure from other analyses, which have based welfare on consumption only, and that this was done to incorporate "benefits resulting from a future more efficient and sustainable economy where investment is counted as future consumption."[201]

The study projected the percentage increase for each of these dimensions for both scenarios (REmap and REmapE), with and without full crowding out* of capital. Then, each dimension was allocated a one-third weighting, and each subcomponent was allocated equal weighting therein (e.g., employment gets weighting of 1/6th as it is considered to represent one-half of the social dimension). The composite projected percentage improvement in welfare was established as the weighted average of the percentage improvements of the constituent parts. (See Table 1)

For the REmap case without crowding-out, the study concluded that: "The impact of renewable energy deployment in global welfare is positive, increasing by 2.7 % (compared to 0.6 % GDP improvement) if the share of renewables doubled [by 2030]." It stated, subsequently, that "the benefits of renewable energy go beyond the traditional and limited measurements of economic performance."

Potential concerns about IRENA's welfare projections:

Even if all agree that the impact on human welfare must be positive, and probably far greater than can be measured by GDP projections alone (which is surely limited for the purpose at hand), this methodology for measuring aggregate welfare and, in particular the subsequent comparison to the GDP growth projections, raises concerns about the validity of the very specific quantitative conclusion of 2.7 % welfare improvement relative to the 0.6 % GDP increment. These concerns include the following:

* "Crowding out" means that available capital is invested elsewhere in the economy if it is not allocated to renewable energy as projected.

- The constituent parts of the aggregate welfare function are not presented by common measure (e.g., not monetized). The percentage reduction in GHG emissions is aggregated with the percentage increase in employment without any qualitative differentiation based on common measure of value except percentage change relative to the baseline scenario.

- The absolute weight of the constituent parts of the aggregate welfare function is arbitrarily determined by their projected relative change in these parts, and without qualification of their relative value. For example, an 11.2 % reduction in GHG emissions is weighted at 1/6th value alongside a 0.1 % increase in employment at the same 1/6th value. The implicit assumption is that an 11.2 % reduction in GHG emissions has equal qualitative impact on aggregate human welfare as a 0.1 % increase in global employment, and this is never defended by the analysis.

- The comparison of welfare and GDP projections in percentage terms is questionable because the two are not comparable (or at least not based on any common measure) and because the internal weighing of welfare variables is arbitrary.

- The inclusion of investments (as “future consumption”) appears to count future benefits as increased utility (welfare) in the present instead of doing so at the time the benefits accrue. If so, this may overestimate the current welfare of increased renewable energy deployment at the expense of future benefits.

The study concludes that because this conception of aggregate welfare is less sensitive to crowding out of capital (explained largely by the disproportionate absolute weighing of reduced GHG emissions), the “overall social welfare benefits are relatively independent from simple measures of economic growth such as GDP.”[202] It is almost certainly true that the complex social welfare benefits of renewables cannot easily be captured by economic criteria alone but that conclusion is probably not predicated on the somewhat arbitrary design of this specific welfare function.

Being the “first global quantification of macroeconomic impacts of renewable energy deployment,” the IRENA study is very ambitious and, therefore, in a different league from the other studies discussed here. It represents a solid foundation for further work that will face inherent methodological challenges, and that will defy any attempt to condense or simplify extremely complex relationships among the multitudes of impacts that are often positive, sometimes negative, and quite easily a bit of both, depending on the context.

If any definitive observation were to be drawn from the four broad studies detailed above, it is that any exercise designed to identify and quantify the costs of benefits of the renewable energy transition is difficult, and particularly so when one attempts to distill multiple complex relationships into simple conclusions.

6. REMAINING QUESTIONS REGARDING SUSTAINABLE DEVELOPMENT IMPACTS OF 100 % RENEWABLE ENERGY

6. REMAINING QUESTIONS REGARDING SUSTAINABLE DEVELOPMENT IMPACTS OF 100 % RENEWABLE ENERGY

The analyses in this paper confirm that socio-economic and sustainable development benefits increasingly are gaining importance in energy policy debates.

At the same time, this literature review also shows that there is a significant need to develop better and more-comprehensive conceptual frameworks to analyze, measure and assess the socio-economic and (more broadly) the sustainable development benefits of renewable energy.

As the momentum for 100 % renewable energy increases, there is an urgent need to fill the gap to help decision-makers strengthen the case for adopting 100 % renewable energy targets. Many political leaders aim to build the narratives and comprehensive policy plans for 100 % renewable energy and to convince their peers in city councils, national parliaments, and ministries. Among other things, these objectives require that they have the tools necessary to demonstrate quantifiable economic and social benefits.

Therefore, to continue building political will for 100 % renewable energy, further research and in-depth analyses are needed on a range of key questions. This final section attempts to explore some open questions and to provide preliminary answers, including the following:

1. Considering all of the benefits associated with renewable energy, which are of the greatest value (monetary or otherwise)? And is the monetary value of these benefits obvious enough to encourage mobilization of additional resources toward renewable energy deployment?

This is unknown and it appears that there is very little discussion of this in the available literature. One can presume that the area(s) of greatest benefit vary from place to place and depend on a number of factors, including starting point in economic and energy (including renewables) development, resource base, geographic scope, economic conditions (skilled labor force, economic capacity), etc. It may differ by economic sector as well.

2. What are the incremental benefits of aiming for 100 % renewable energy as compared to a less ambitious target?

The definition of 100 % renewable energy (sectors) and how the target is to be met (geographic scope), may affect the incremental benefit. That said, a target of 100 % may provide a number of additional benefits relative to a less-ambitious target. For instance, there is evidence that 100 % renewable energy targets help to engage a wide range of stakeholders. Experience in Europe and elsewhere demonstrates that identification and communication of such targets help to build awareness – both locally and beyond the target area – which is essential to building the public support needed to achieve the goal. In addition, 100 % targets might ensure a more-efficient use of both technical and administrative resources, reducing the risks of duplication and of competing policy agendas.[203]

An important implication is the clear message it sends that all future investment in the energy sector is headed for renewables and efficiency – and infrastructure that supports them – providing greater certainty for investors. This “self-fulfilling prophesy” might stifle investment in fossil fuels as their uncertainties and risks are amplified. As a result, key stakeholders have confidence that is required to make large investments, whether in power plants or transmission and distribution grids. Increased certainty also can attract investment from new sources, domestic and international, ultimately making the target easier to achieve.[204]

When the end outcome is to be 100 % renewable energy across all sectors, heating, power, and transport, it may be worth asking what specific implications this has for the shape and nature of the future energy economy. Greenpeace notes that: "High targets for renewable energy – across all sectors – trigger innovation. A complete transition towards renewable energy requires the development of new policies to support business models in an ever changing energy market design. Setting ambitious long-term renewable energy targets will help to organize the energy transition across all three sectors."[205]

3. Is the increase in benefits proportional (linear) to rising renewable energy shares? If not, does 100 % renewables substitution deliver disproportional additional benefits over partial substitution? In other words, do benefits "accelerate" as we approach 100 % of energy from renewable sources? Conversely, might we expect "diminishing returns" for the cost-benefit ratio as we approach 100 % renewable energy?

Presumably, 100 % renewable energy eliminates some redundancy in energy systems because there is no longer need for extraction, shipping/pipelines, refining, and delivery of fossil and nuclear fuels for energy purposes*. As the renewable shares rise, the per-unit cost of maintaining fossil energy systems likely will rise. For example, as the renewably-powered fleet of electric vehicles grows at the cost of gasoline vehicles, the per-unit cost of maintaining the infrastructure for gasoline delivery rises. If so, this might give an additional push for completing a 100 % renewable energy transition. However, there also is the possibility that relative costs of renewables might rise with ever-increasing demand, if specific material shortages arise or if other capacity constraints push product prices upward. Conversely, technology advances, energy efficiency improvements, and economies of scale likely will continue to alleviate those pressures. Some drivers might become less acute with rising renewables shares as the perceived negative condition (such as impact on public health from poor air quality) gradually improves, possibly lessening the perceived benefit from further advances to the 100 % target.

4. Might the advent of 100 % renewables cause disruption, positive or negative?

A rapid growth in renewable energy deployment requires significant new construction activity for the duration of the build-up. Then, at a point of relative capacity saturation, it is possible that there might be a fall-off in manufacturing and construction jobs. While the build-up of renewable capacity will proceed at different rates in various regions, and peak at different times, it is plausible that some socio-economic disruption will be experienced along the way.

It is also conceivable that the transition to 100 % renewables will disrupt development paths based on conventional energy systems if the transition allows national or local economies to leapfrog some stages of infrastructure development made redundant in a transformed energy economy. To the extent that conventional production, procurement, and distribution systems are in place, the transition to 100 % renewable energy undoubtedly will be disruptive (as past energy transitions have been), with a mix of positive and negative outcomes to various parties over varying timeframes. The amount of disruption (positive or negative) likely will depend on speed of transition, type and size of economy, and geographic scope.

* Fossil fuels still might be required as feedstock in other sectors, including agriculture (e.g., fertilizer), chemical and metals industries.

The concern has been raised that an "emergency switchover" to a low-carbon economy to drive deep reductions in GHG emissions might itself cause economic disruption – including turmoil in financial markets – and could even trigger a global economic crisis.[206] This underscores the potential value of a steady and orderly build-up of renewable energy capacity over the coming decades relative to a back-loaded approach.

5. How important is the issue of ownership, political participation and general inclusivity for achieving increased value? How do social and economic impacts differ when ownership and energy production are dispersed and local rather than centralized and remote?

Jurisdictions around the world have shown that only by ensuring wide participating and sharing ownership of the energy system among diverse stakeholders can the transition away from fossil resources be successful. In fact, 100 % renewable energy supply might not be achievable without wide stakeholder participation and ownership, or at least without tangible sharing of benefits. And yet, 100 % renewables may not be feasible in some locations if people are to rely solely on local initiative and investment. There needs to be a marrying of higher-level policy impetus with local buy-in, and with the involvement of commercial entities and banks that operate on a national or even international level. This ties into the nature of existing energy regulations and systems: No community is an island, no city is an island, either by law or by physical (energy) conditions.

Significant local socio-economic benefits identified to date include: more jobs created locally; money stays in local economy; drop off in brain drain, where applicable, and a possibility of in-migration; greater sense of community and positive view of future; local empowerment – control over energy production and use; reduced energy consumption because of awareness of one's own stake in the process; reduced opposition to and increased support for local renewable energy projects.

But what are the impacts more broadly? Does this change much on a national or global level? The history of renewable energy deployment in Germany and Denmark provides some insight: much of the existing renewable energy capacity is citizen-owned (rather than owned by large utilities); at the same time, renewable energy historically has scaled up relatively quickly and also has received greater public acceptance in these countries than in many others.

6. How does one account for geographic, social, and even temporal shifts in benefits versus costs, and how important are these for driving or hindering renewable energy investment? Does geographic and social re-distribution of costs and benefits matter (e.g., job gained here for one lost there)? In other words, in what way does the allocation of costs and benefits among citizens and other stakeholders matter? Similarly, do time-lags matter, especially between realization of costs (acquisition, current) and benefits (returns, future)?

Among the four broad studies reviewed above, these questions were tackled in different ways, reflecting or at least acknowledging these challenges. To the extent that a transition to 100 % renewables incurs additional economic costs, the individuals and businesses that bear those costs presumably would wish to be reassured that they also would reap the bulk of the benefits that accrue. This cannot always be: some jobs will be gained in one area and lost in another; some businesses will rise while others succumb to changing energy portfolios; some countries will benefit from the markets and jobs created by early investment, while other countries will make (or have made) a disproportional investment in the advancement of renewables; and so on. In addition, the benefits of displaced air pollution are never fully bound to the region where the investments in clean energy are made; and some benefits will be realized in the future, while the expenditures must be made in the present.

7. How might impacts differ if a 100 % target covers the power sector only or if it also covers heating, cooling, and transport? How does

renewable energy offer opportunities to substitute renewable electricity for non-renewable heat and transport, and how does this affect motivations and impacts?

In the context of achieving 100 % renewables, the three sectors may be ultimately interwoven. The growing electrification of heating and transport, through advancing heat pump technology and electric propulsion, allows renewable power to serve all three sectors. Notwithstanding the role of biofuels and perhaps renewably generated hydrogen, the substitution of renewable electricity for liquid or gaseous fuels may facilitate the transformation of heating, cooling, and transportation as well. The impetus for using renewables to power electric heating and transport is in no small part derived from the desire to displace non-renewable grid power and its associated conversion losses from primary energy sources. Also, as noted above, declining demand for fossil fuels eventually will lead to higher per-unit cost for delivered fuels. Therefore, it is reasonable to suggest that certain synergies may lie in a comprehensive transition to 100 % renewable energy where a common carrier (electricity) may successfully kill two (or even three) birds with one stone.

8. Does energy efficiency provide both substitution and synergy for increased renewable energy shares? If so, should energy efficiency be an integral part of any study regarding how to reach higher renewable shares?

Just as synergies may be realized in a comprehensive (across all sectors) transition to 100 % renewables (see above), there also are important synergies between renewable energy and energy efficiency. Synergy occurs when the benefits exceed the sum of the parts. Not only does improved end-use energy efficiency reduce the amount of renewable energy needed to meet any given demand, but it may allow renewable energy sources to provide certain services more easily and affordably. For example, a well-insulated house in a cold climate that is well-designed for passive solar heating can be heated with on-site renewable sources. Further, many renewable energy technologies bypass many conversion processes that lead to tremendous energy losses, in the use of fossil fuels in particular. The effort to improve further efficiency – of both distribution and end-use – will be a critical component of a 100 % renewable energy future.

9. Do local impacts (costs and benefits) depend on local conditions and resources, local needs, and energy technologies deployed?

Local resources, needs and conditions (both energy-related and not) largely will determine the path to 100 % renewable energy, and the benefits derived. Many renewable energy technologies can be implemented in a way that fits local conditions, which includes proper scale. Renewable energy that is implemented locally, and with consideration for the needs of the people it is to serve, may well reduce wasteful expenditure and unintended outcomes while improving the chances of positive outcomes. Yet, what constitutes "local" is not carved in stone and one would not presume that each community must implement its own renewable energy future.

10. Renewable energy share targets have geographic boundaries while associated benefits likely are not confined to the target boundary. Does this matter? Why are those pursuing ambitious renewable energy targets willing to pay for non-exclusive (non-local) benefits? At what point do geographic boundaries become irrelevant on the trajectory to 100 % renewables?

At some point, when the reality of a global 100 % renewable energy draws near, these questions become less important. But for now, it may be important to acknowledge that no one is an island in this context. Neither costs nor benefits are borne perfectly evenly, as noted above. This is of some consequence in the context of global climate change politics, particularly when perceived local costs of the renewable energy transition are significant relative to perceived local benefits. Therefore, it is worth asking how and why that calculation gets reversed as cities and nations decide to transition toward renewables, perhaps without immediate concern over what their neighbors are doing at that moment.

11. What are the principles that need to be considered in a policy framework in order to ensure that the transition to 100 % renewables boosts community-level social and economic development?

Case studies mentioned in this review suggest some key characteristics of policies that enable and catalyze the benefits of renewable energy deployment and help to boost community-level development.

For example, ambitious, long-term renewable energy targets can communicate political commitment and provide official mandates for action. Policies to support such targets that are stable and predictable can help to inspire confidence among investors, provide security for new investment, and maximize efficient allocation of economic resources. At the same time, it is important that policies be flexible enough to adapt to changing circumstances without causing disruption for market participants.

Regardless of which policy tools are employed, policy design should account for broad stakeholder participation and ownership. There is evidence that stakeholder participation – including people from different levels of government, across sectors, and interested citizens and cooperatives at the local level – ensures widespread acceptance of renewable energy and provides numerous social and economic benefits to local communities. Policies and regulations that are transparent, easily accessible and accommodating of citizens and community groups can both encourage and enable participation.

Local economic and social development also can be advanced by policies that support a more decentralized, distributed infrastructure, and that encourage local investment and ownership in renewable energy projects. When energy is owned and generated locally, the socio-economic benefits accrue locally. Moreover, harnessing local renewable energy strengthens political security and relative energy independence, providing some of the stability needed to create new local businesses and advance economic prosperity. Experiences in communities across the world have proven that citizen engagement have resulted in sustainable development and socio-economic value creation at the local and regional levels. By providing market access to a wide range of stakeholders, policy makers can help build positive synergies between the imperatives of the evolving renewable energy transformation and various local development goals.

12. How can a transition to 100 % renewable energy be a tool to achieve the sustainable development goals (SDGs)?

The 17 SDGs read almost like a list of the many observed or projected benefits of the energy transition. In fact, there are only two SDGs that might not align perfectly with expected benefits of the energy transition, depending on how it is implemented.

One area of potential conflict lies in SDG 2, which focuses on ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture. This objective would not be well served by renewable energy development that resulted in competition for productive agricultural land, either by crop displacement (production of energy crops in place of food crops, or use of land for direct energy production to the exclusion of food production) or by flooding of agricultural land (a potential outcome of hydropower development).

Similar areas of concern arise with SDG 15, which focuses on protecting, restoring and promoting sustainable use of terrestrial ecosystems, sustainably forest management, combating desertification, and halting and reversing land degradation and halting biodiversity loss. It is not a foregone conclusion that the transition to 100 % renewable energy will occur in harmony with these priorities.

Other areas where SDGs may or may not be furthered directly by the renewable energy transition include, perhaps, equitable learning opportunities and sustainable use of marine resource (beyond ocean energy systems), but those objectives are certainly not at odds with the 100 % renewable energy transition.

It should be noted that costs and benefits depend largely on government policies (including stability and predictability) and regulations (whether they enable or impede renewable energy deployment) and on how projects are developed (whether or not renewables are deployed such that projects maximize benefits and minimize negative impacts).

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