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Foundational Research Report

SDG Push+

Accelerating universal electricity access and its effects on sustainable development indicators

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Executive Summary

Electricity access is critical to achieving the 2030 Agenda for Sustainable Development. It is necessary to power economic growth, improve education and employment opportunities, improve health outcomes, and reduce poverty. While significant progress has been made in the past decade, about 987 million people globally lack access to electricity today, with two-thirds concentrated in sub-Saharan Africa. This global figure masks considerable disparities in access geographically. As of 2022, only 78 percent of people in rural areas have access to electricity, compared to 95 percent in urban areas. Without transformative change, the world is not on track to meet the Sustainable Development Goal (SDG) 7 on affordable and clean energy for all in the coming decades.

Recognizing that there is potential trade-offs and synergies between different policy choices and their impacts on energy access, social policy, and poverty reduction, this study applies the Futures Modeling approach to advocate for investment in electricity access. It uses dynamic and integrated modeling and scenario analysis to explore pathways to achieving significant milestones in electrification.[1] These scenarios are the Current Path, Universal Access, and SDG Push+.

1. **The Current Path** scenario, a business-as-usual scenario, projects an improvement in access rates as countries develop and invest in building new infrastructure. Globally, 73 countries are not on track to meet SDG 7 on universal electricity access by 2030, and 58 will still not meet the target by 2050.
2. **The Universal Access** scenario simulates a rapid increase in access in all regions to better understand the cost and potential benefits of achieving universal electricity access globally. This scenario provides access to almost 1 billion people who would not have it otherwise by 2030. It also meets the UN Energy Pledge and UNDP's commitments to expand access to 500 million people by 2025, thus halving the population without electricity access, and continuing to expand it by 2030.
3. **The SDG Push+** scenario: These benefits are notable, but greater efforts are needed to fully harness the benefits of electrification. This scenario combines the SDG Push (concrete policy interventions in governance, social protection, green economy, and digitalization) with Universal Access to electricity – an ambitious, yet achievable option towards attainment of the SDGs.

This report estimates the benefits of these investments and presents options to compare them with costs associated with expansion in electricity access. The results show the following:

1. The Universal Access scenario increases economic productivity, resulting in cumulative GDP gains of nearly US$300 billion by 2030 and US$10.5 trillion by 2050, lifting more than 2 million people out of extreme poverty (US$1.90/day)[2] by 2030 and around 38 million people by 2050. In addition, with the transition from traditional cookstoves, around 2.16 million deaths

[1] IFs help users to understand dynamics within and across systems at a global, national and even sub-national scale. It integrates forecasts across different sub-models, including population, agriculture, education, economy, energy, socio-political, environment, technology, infrastructure and health. These sub-models are dynamically connected, so the model simulates how changes in one system leads to changes across all other systems. Consequently, IFs endogenizes more relationships from a broader range of key global systems than any other integrated assessment model (Hughes, 2016).

[2] The World Bank has recently revised the international poverty line from USUS1.90/day based on 2011 purchasing power parities (PPPs) to USUS2.15/day based on 2017 PPPs. However, the real value of the international poverty line remains virtually unchanged.

would be averted from respiratory diseases globally by 2030 and over 6.5 million deaths by 2050.

2. These benefits are most prominent in sub-Saharan Africa, where the current access deficit is the largest. In this region, Universal Access is associated with over US$5 trillion in cumulative GDP benefits, over 36 million people lifted out of extreme poverty, and a doubling in the use of modern fuel cookstoves by 2050.

3. The SDG Push+ scenario results in broad gains, including a cumulative US$16 trillion in GDP gains by 2030 and US$545 trillion by 2050, and lifts 110 million people out of extreme poverty by 2030 and an additional 163 million by 2050 – half of them being women and girls, indicating that gains in gender equality are also observed as a result of this integrated set of interventions. The benefits of the Universal Access scenario, when combined with other interventions in the SDG Push scenario, have a productivity effect seven times greater than the Universal Access scenario alone.

4. The benefits resulting from increased electricity access rates are associated with significant costs, especially in building new connections in rural areas. The analysis in this report shows that the cost of building and maintaining electricity infrastructure to achieve universal access is a cumulative US$785 billion between now and 2030. This is approximately US$200 billion more than the building and maintenance costs estimated under the Current Path scenario. Universal access to electricity will require a strong focus on investing in rural areas. Of these additional needed investments, more than US$166 billion must be directed towards the rural areas and urban areas demand an additional US$33 billion.

5. The report also explores trends in electricity access rates in 31 countries that benefit from two important UNDP efforts – the African Minigrids and the Action Opportunities programmes. These countries are characterized by low access rates and inequities, being home to more than 512 million people with no electricity access, of whom 421 million and 91 million live in rural and urban areas, respectively. By simulating the achievement of the UN-Energy Pledge and UNDP's commitments, we halve the population without electricity access by 2025 in these countries under the Universal Access scenario.

6. The results suggest that expanding access to these countries would be costly (approximately US$24 billion/year, or US$190 billion between 2022 and 2030, compared to US$60 billion under the Current Path scenario), and special attention will need to be paid to underserved rural areas to achieve universal access. Until 2030, a Universal Access scenario requires greater investment than expected returns when measured strictly by GDP gains. However, in just two decades, the productivity benefits surpass the cumulative investments and pay-off.

Introduction

Sustainable Development Goal (SDG) 7 aims to ensure access to "affordable, reliable, sustainable, and modern energy services" for all by 2030. SDG target 7.1.1 aims explicitly to expand electricity access universally in an energy-efficient, affordable way (UNEP, 2021; United Nations, 2022). After decades of impressive advancement, including increasing access to an additional 1.3 billion people between 2010 and 2020, progress has slowed in recent years (IEA et al., 2022). This slowdown is attributed not only to the COVID-19 pandemic, but also the difficulty of the 'last mile' – i.e. increased cost and challenges of reaching those still left without power, many of whom live in rural and remote areas. To date, one out of every eight persons still live without fully benefiting from electricity access due to reliability and quality issues (UNDP, 2022).

The COVID-19 pandemic emphasized the importance of access to technology and electricity, and brought inequalities within and between countries to the forefront, leaving millions in the dark. Technological advancement and the increased use of information and communication technologies transformed how many organizations and people connect and operate. However, access and ability to use these technologies is unequally distributed across society. The widespread movement toward digitalization threatens to leave some populations digitally marginalized and thus economically and socially marginalized. Moreover, delays in digitalization limit the potential for economic and human development. Particularly in many rural areas, the potential for digital inclusion remains constrained by, among other factors, limited access to electricity.

Energy, and specifically electricity are important enablers of sustainable development, even beyond their importance in enabling access to and use of digital technologies. SDG 7 is a critical enabler to achieving the 2030 Agenda for Sustainable Development, given that energy is necessary to power economic growth, improve education and employment opportunities, improve health and gender outcomes, and reduce poverty. Electricity access can increase labor productivity (Nerini et al., 2018), improve access to and the quality of education (UNDESA, 2014), enable the use of improved cookstoves, and reduce household air pollution and resultant adverse health effects (Barron & Torero, 2017).

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Recognizing the importance of these linkages for a more prosperous, equitable, inclusive and sustainable future for people and the planet, the UN-Energy Pledge has reinforced its support to Member States to provide access to 500 million more people by 2025 and by raising energy access annual investments to US$40 billion, of which 50 percent should be directed to the least developed countries. Aligned with these commitments, UNDP, as part of the 2021 High-Level Dialogue on Energy, has pledged to catalyse partnerships, knowledge, innovation and finance to increase energy access to half a billion more people by 2025, halving the deficit in specific countries (UN, 2021).

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This report uses integrated modeling techniques and a 'what-if' analysis to assess the future of electrification and the potential benefits from these commitments and efforts to expand electricity access. First, we explore the current state and likely future of global electricity access across the world. Then we simulate several scenarios where Universal Access is achieved by 2030. We use these scenarios to understand the costs of full electricity access, its economic and human development benefits. Likewise, given the interlinkages across many SDGs, the model also allows understanding the causal dynamics and synergies in pursuing SDG 7.1.1 and how its achievement can help in the pursuit of others. Our findings suggest that investments in increased access to electricity will result in substantial gains such as growth in GDP, a reduction in monetary poverty, and an improvement in health outcomes. However, electricity access alone is not as effective as pursuing electricity access together with an integrated policy push across the SDGs. The synergies associated with expanding electricity access in concert with other development interventions are substantially larger.

This report is structured as follows: the methodology section provides a brief overview of the International Futures (IFs) model with the different scenarios used in generating results. It is followed by a presentation of findings for each of the three global scenarios and for a smaller set of the UNDP focus countries. Finally, the conclusion highlights key takeaways from this analysis.

Methodology

This project uses the Ifs model to forecast the future of electricity access and the effects of expanded access on the economy and human development. IFs is an open-source integrated assessment model that simulates interactions within and across 186 countries and 12 core systems: agriculture, demographics, economics, education, energy, environment, finance, governance, health, infrastructure, international politics, and technology. These systems are dynamically connected, so changes in one system may lead to changes across all others, which can illuminate spillover effects, trade-offs, and synergies with different policy choices. Detailed information about the IFs infrastructure sub-model is available in Appendix 1, and a complete overview of the tool is provided by Hughes (2019). The overview covers the model in greater detail, including the infrastructure aspects within IFs and the estimation procedure involved in investment spending.

Building on the results of another flagship partnership between UNDP and the University of Michigan, this report incorporates the high-resolution energy access estimates generated based on satellite imagery and machine learning techniques.[3] National estimates for countries that are not covered by this dataset come from the latest data available at the World Bank Global Electrification Database (IEA et al., 2022).

This report examine results for three scenarios:

1. The Current Path scenario represents the 'most likely' course of development – a business-as-usual scenario. It forecasts the dynamic interaction and unfolding of development trajectories across systems as expected. It includes the economic effect of the COVID-19 pandemic but does not simulate major shocks and transformative policy changes in the future.

2. The Universal Access scenario simulates the achievement of SDG Target 7.1.1 by attaining universal electricity access in all countries by 2030 and by almost halving the electricity access gap by 2025 to reflect the UN-Energy Pledge and UNDP's commitments. To this end, we rapidly expand electricity access in IFs (the scenario assumption) and then explore how that expanded access affects economic and human development across countries and regions.

3. The SDG Push+ scenario combines the same expanded electricity access from the Universal Access scenario with an ambitious development programme across all SDGs – the SDG Push. The SDG Push is a set of interventions originally introduced in 2021 (Abidoye et al., 2021; Hughes, Hanna, McNeil, et al., 2021) and updated in 2022 to simulate a strong, integrated push toward improving development and SDG achievement globally. The SDG Push+ scenario includes interventions focused on improving governance and human development, boosting innovation, and moving toward a greener economy. Thus, it allows for exploration of how universal electrification with an integrated approach to development can lead to synergistic development gains across systems.

More information and the full list of scenario interventions for Universal Access and SDG Push+ is available in Appendix 2.

[3] For more details on the high-resolution electricity access data and methodology, access UNDP's Geohub Electricity Dashboard: https://geohub.data.undp.org/dashboards

Findings

The current path of electricity access

As of 2022, an estimated 987 million people (12.4 percent of the world's population) do not have access to electricity.[4] Under the Current Path scenario, we expect that access will grow to 89.3 percent of the global population by 2030 – a meaningful improvement, but one that still fails to meet the SDG target of universal access. 73 out[5] of 186 countries are not on course to provide universal electricity access by 2030, leaving nearly 916 million people worldwide without access. By 2050, it is projected that 58 countries will not fully attain their universal access SDG targets without targeted interventions, leaving close to 608 million people without access.

This global figure masks considerable geographic disparities in access. As of 2022, only 78 percent of people in rural areas have access to electricity, compared to 95 percent in urban areas. Despite a gradual trend toward convergence, this access gap persists until 2050 under the Current Path scenario, when urban access grows to nearly 97 percent while the rural access rate (88 percent) fails even to reach the current urban access level.

Persons without Electricity Access	2010	2022	2030	2050
OVERALL	1.16 Billion	986.9 Million	915.8 Million	608 Million
RURAL	848.7 Million	753.5 Million	668.5 Million	429.6 Million
URBAN	311.3 Million	233.4 Million	247.3 Million	178.4 Million

Figure 2. Global population without electricity access under the Current Path scenario, overall, rural and urban.
Source: IFs 7.87.

4 The IFs model and database are the most frequently used sources of data and forecasts in this report. If no external attribution is provided for an in-text statistical reference, the source is International Futures (IFs) modeling system, Version 7.87. Frederick S. Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver, Denver CO. The IFs historical database houses over 4,500 data series. Primary sources and metadata can be found by accessing the database.

5 Considering >97% as threshold given that in IFs we treat that as close to attaining full access.

There are even more significant regional disparities. By far, sub-Saharan Africa has the lowest electricity access rates globally. Today, just 46 percent of the population in sub-Saharan Africa has electricity, followed by Central and Southern Asia (90 percent), and North Africa and Western Asia (93 percent). Electrification in sub-Saharan Africa is even lower in rural areas, where the access rate is just 24 percent. Rural access in the region is expected to grow only to 32 percent by 2030 and 62 percent by 2050.

Although electricity access in sub-Saharan Africa would improve under the Current Path scenario, it will not be fast enough to catch up with other regions or with population growth. Even in 30 years, almost 25 percent of sub-Saharan Africans (or 483 million people) will still live in the dark in this scenario.

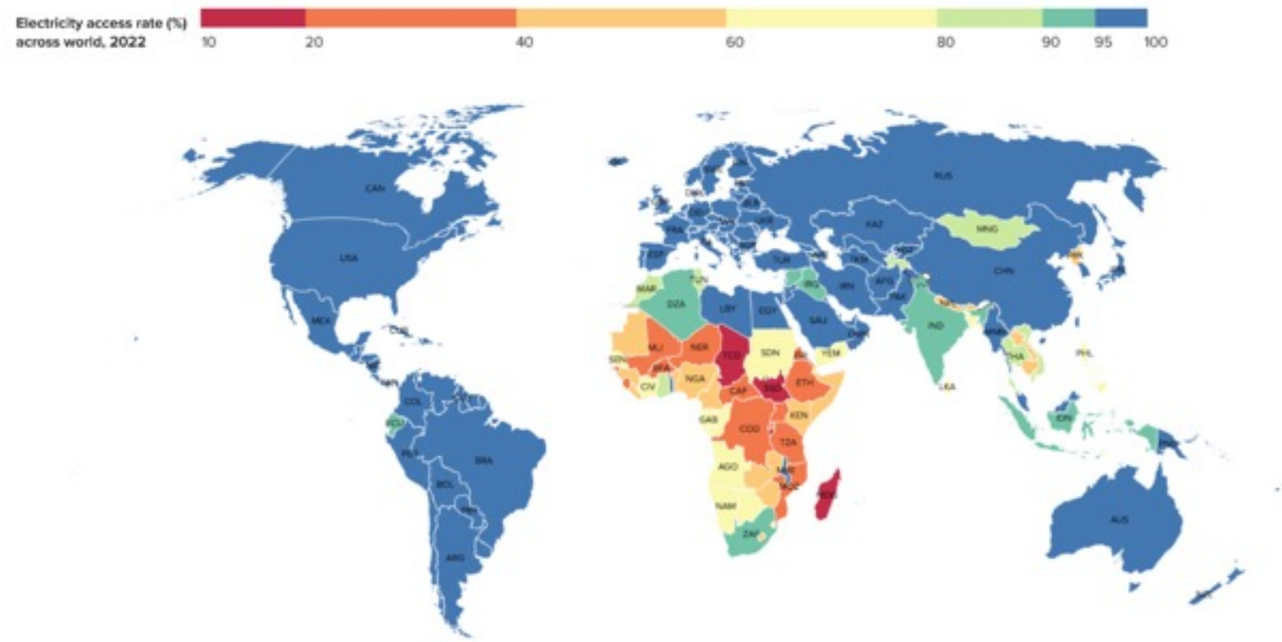

Figure 2: Estimated electricity access rates in 2022, by country (% of population).
Source: IFs 7.87.

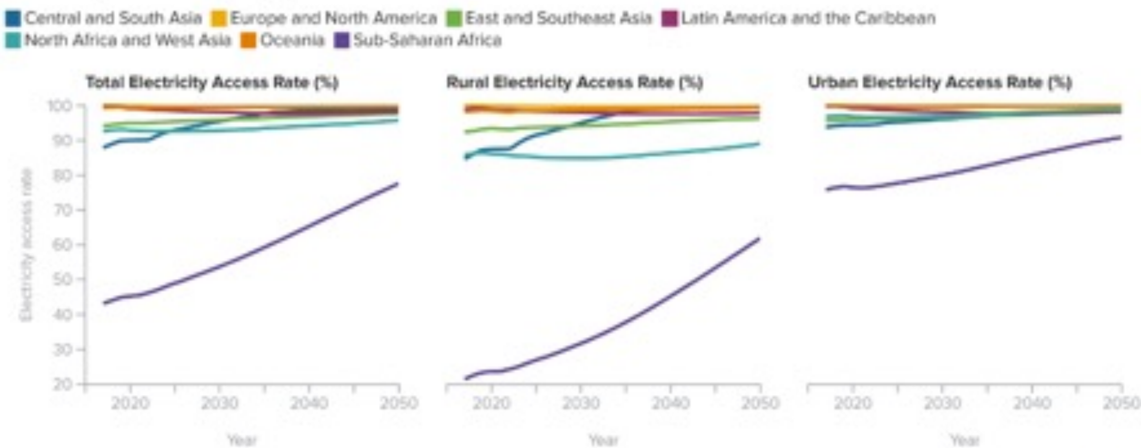

Figure 3: Electricity access rate by region under the Current Path scenario (% of the total population).
Source: IFs 7.87.

As a result of current access deficits and demographic projections, the lack of access to electricity will be increasingly concentrated in Africa. Today, more than half of the people who lack access to electricity globally live in sub-Saharan Africa (618 million); more than 20 percent live in Central and South Asia (202 million); and 119 million live in East and Southeast Asia.

By the mid-century, there is a reduction to 483 million but by 2030, the population without access in sub-Saharan Africa is projected to increase by 35 million people, while the number of people without access shrinks in all other regions. This is primarily because of expected population growth outpacing gains in electricity access rates in the region. Figure 4 illustrates these regional disparities over time under the Current Path scenario. By the mid-century, nearly 3 out of 4 people (74 percent) without access to electricity will live in sub-Saharan Africa.

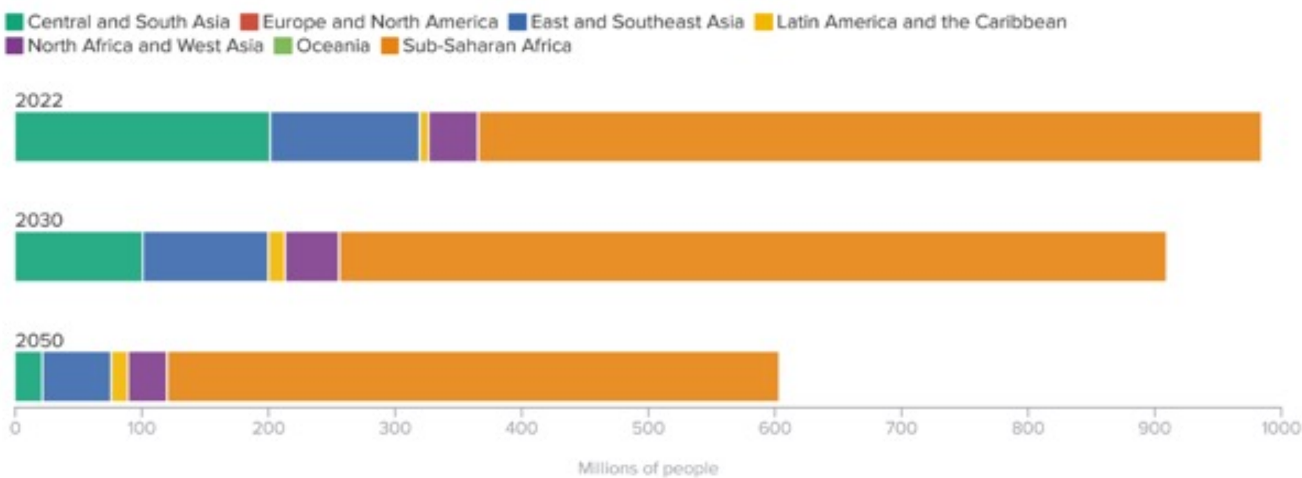

Figure 4: Total number of people without electricity access under the Current Path scenario in 2022, 2030 and 2050, by region.
Source: IFs 7.87.

At the country level, nine out of 15 countries with the largest number of people without access to electricity are situated in Africa, four in East and South East Asia, and two in South Asia (Figure 5). India has the highest number, with over 112 million people lacking access to electricity in rural areas and over 25 million in urban areas as of 2022.

In Africa, the urban-rural disparities to access are even more pronounced: in Niger, 18.9 million of its 20.4 million people without electricity live in rural areas; in Mozambique, around 19 million of its 21.5 million people do so. We observe similar disparities to access in Nigeria (80.5 million out of 104.5 million), United Republic of Tanzania (31.5 million out of 38.2 million), Uganda (28.8 million out of 35.3 million) and Kenya (24 million out of 29.4 million).

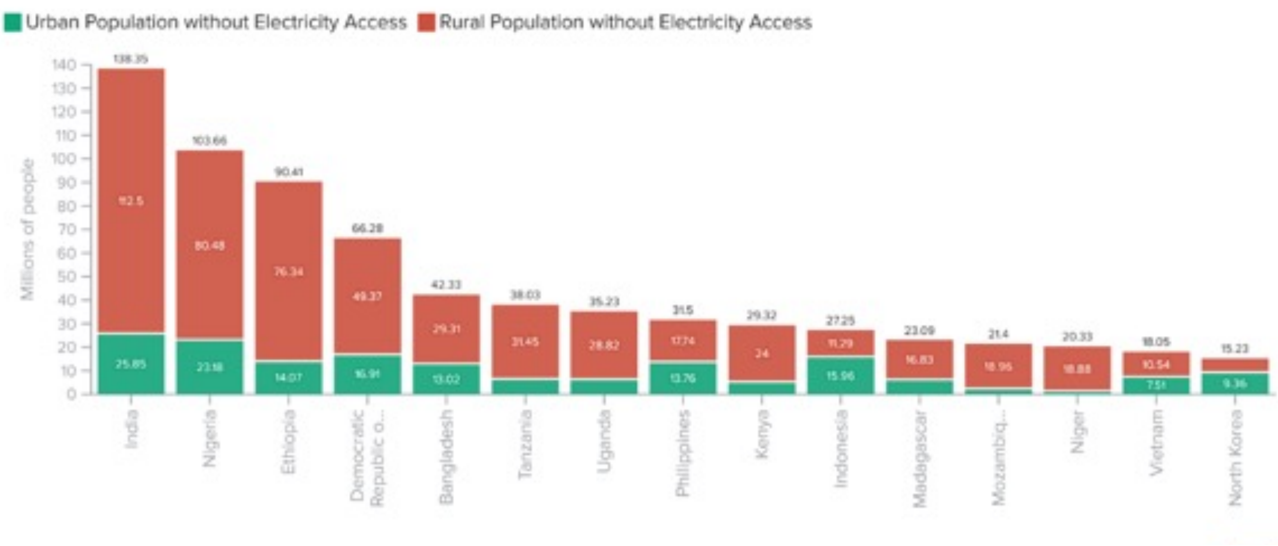

Figure 5: Top 15 countries with the largest urban and rural populations without electricity access in 2022..
Source: IFs 7.87.

Achieving universal access by 2030

The Universal Access scenario simulates a world in which the entire global population is provided access to electricity by 2030, per SDG Target 7.1. Under the Current Path scenario, 89 percent of the world will have electricity access in 2030. The Universal Access scenario brings global access close to 100 percent, thus providing electricity access to more than 900 million people who would not have it otherwise under the Current Path scenario. In doing so, this scenario simulates the pledge of the UN-Energy plan by providing electrification to more half a billion people by 2025.

Electricity access boosts economic productivity through multiple avenues, including enabling new businesses, extending operating hours, increasing efficiency and communication, encouraging investment, and improving education (Kanagawa & Nakata, 2008; Martínez & Ebenhack, 2008; Mazur, 2011; Niu et al., 2013). With Universal Access, cumulative GDP gains total nearly US$300 billion by 2030 and roughly US$10.5 trillion by 2050.[6] Regionally, the most powerful effects on GDP by2050 are observed in sub-Saharan Africa, which benefits from a cumulative gain of US$81 billion by 2030 and US$5.08 trillion by 2050, followed by East and Southeast Asia (US$53 billion by 2030 and US$1.6 trillion by 2050), Europe and North America (US$73 billion by 2030 and US$1.45 trillion by 2050), Latin America and the Caribbean (US$40 billion by 2030 and US$943 billion by 2050) and Central and South Asia (US$17 billion by 2030 and US$766 billion by 2050).

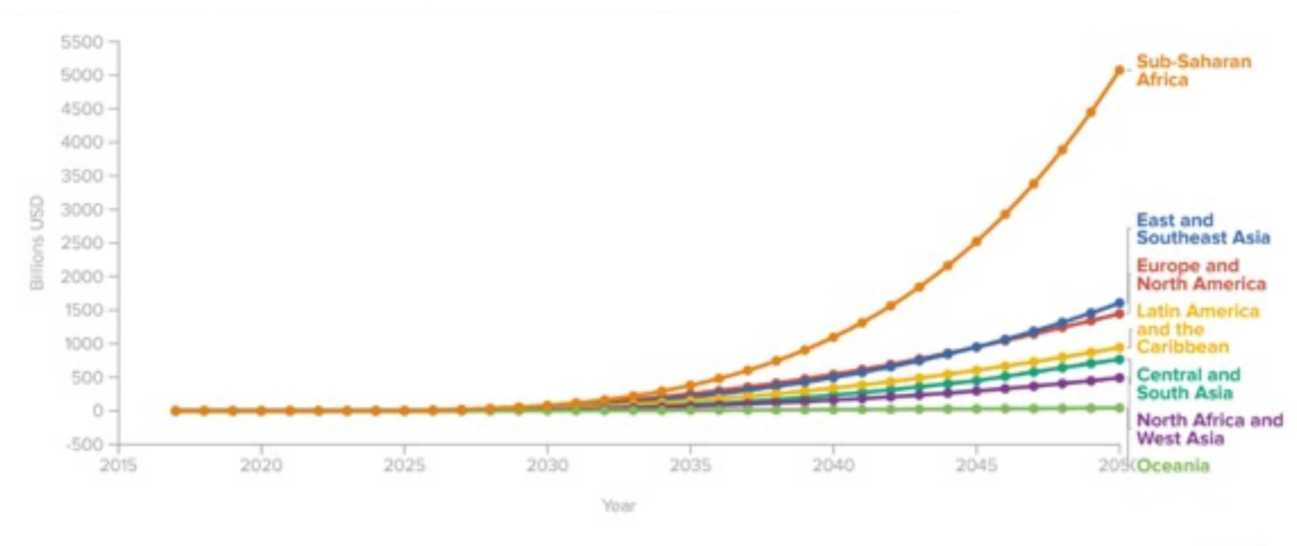

Figure 6: Cumulative gains in GDP (using market exchange rates) under the Universal Access scenario compared to the Current Path scenario, by region, by 2050.
Source: IFs 7.87.

6 Throughout this report, unless otherwise specified, GDP and all currency figures are measured in 2011 US dollars. There are two ways to measure GDP and/or per capita output. Market exchange rates (MER) measure the value of output in local currencies against prevailing market exchange rates for the 2011 US dollar. Purchasing power parity (PPP) is calculated for each country relative to its cost of living and inflation rates. It considers how much of one currency would have to be converted into that of another country in order to buy a comparable basket of goods and services in the latter country. GDP measurements in PPP tend to be higher, particularly for developing countries. Unless otherwise noted, GDP measurements from IFs are in MER and GDP per capita measurements from IFs are in PPP.

More importantly, under the Universal Access scenario, there are also gains in GDP per capita. As with GDP, sub-Saharan Africa enjoys the most significant relative benefit, where GDP per capita increases from US$3,529 to US$3,958 in 2030, and further to US$6,871 in 2050 due to a push towards universal electrification. In addition to the Current Path projections, Universal Access projects an increase in per capita GDP of US$27 by 2030 and US$354 by 2050. Figure 7 shows the net additions to GDP per capita across regions in 2030 and 2050 under the Universal Access scenario.

The GDP growth under the Universal Access scenario is significant but it takes time to meaningfully materialize. Physical electricity access is just one component of development, and additional interventions are needed to be able to fully realize its benefits. Moreover, expansion of access at this scale requires a massive upfront investment, which can lead to tradeoffs in spending as other areas (e.g. investments in health, education, and technology) are deprioritized. Later sections will explore how additional effort can unlock the development potential of Universal Access.

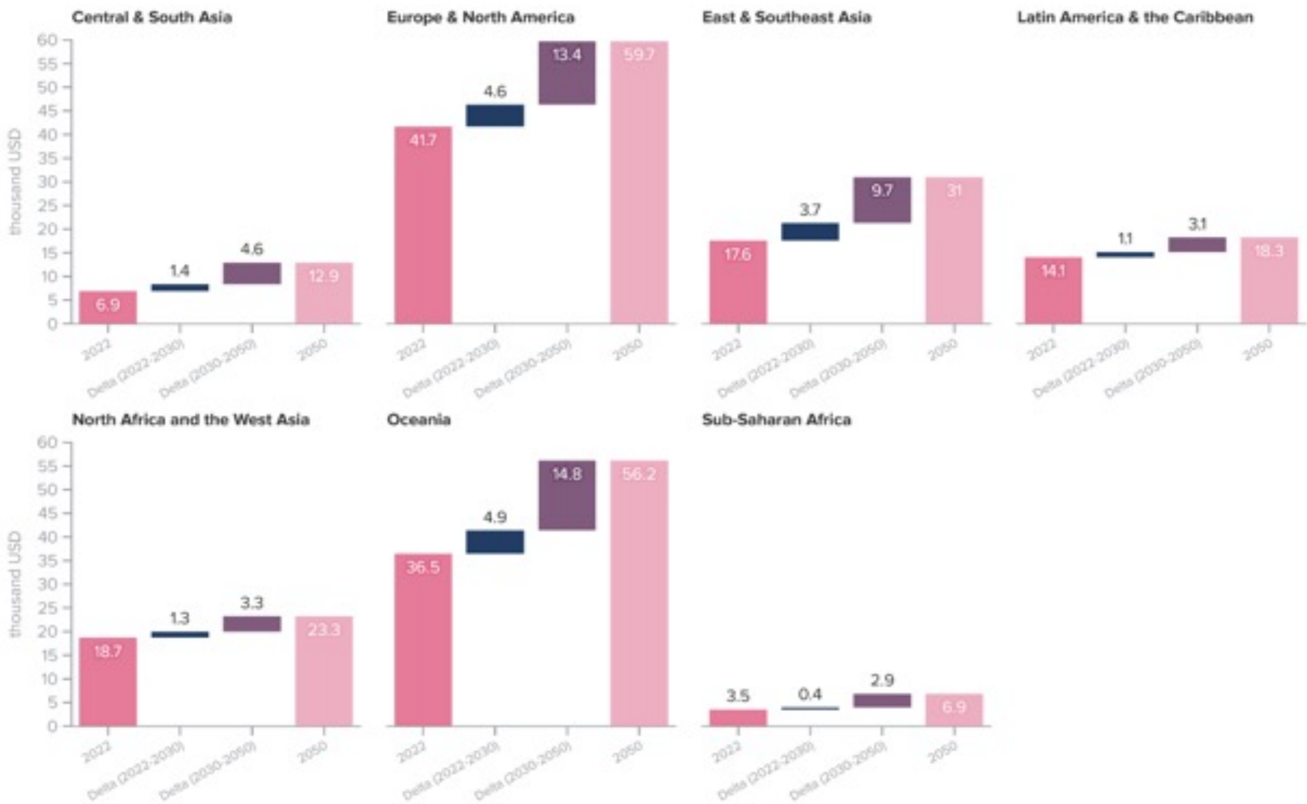

Figure 7: Additional GDP per capita (PPP) gains under the Universal Access scenario by 2030 and 2050, by region. Delta indicates the increment estimated for the indicated period.
Source: IFs 7.87.

Over time, this accelerated growth alleviates poverty (Cook, 2011). Ensuring the provision of universal electricity access has a moderate effect on poverty in the short term, lifting up to 2 million people out of extreme poverty (US$1.90/day) by 2030. By 2050, that figure grows to around 38 million. Majority of those lifted out of extreme poverty by 2050 under the Universal Access scenario live in sub-Saharan Africa.

The largest reductions in the population living in extreme poverty from Universal Access are estimated for the Democratic Republic of the Congo, Ethiopia, Uganda, Madagascar, United Republic of Tanzania, Niger, Burundi, Mozambique and Chad. Figure 8 shows the number of people lifted out of extreme poverty by 2050 for all regions under the Universal Access scenario compared to the Current Path scenario.

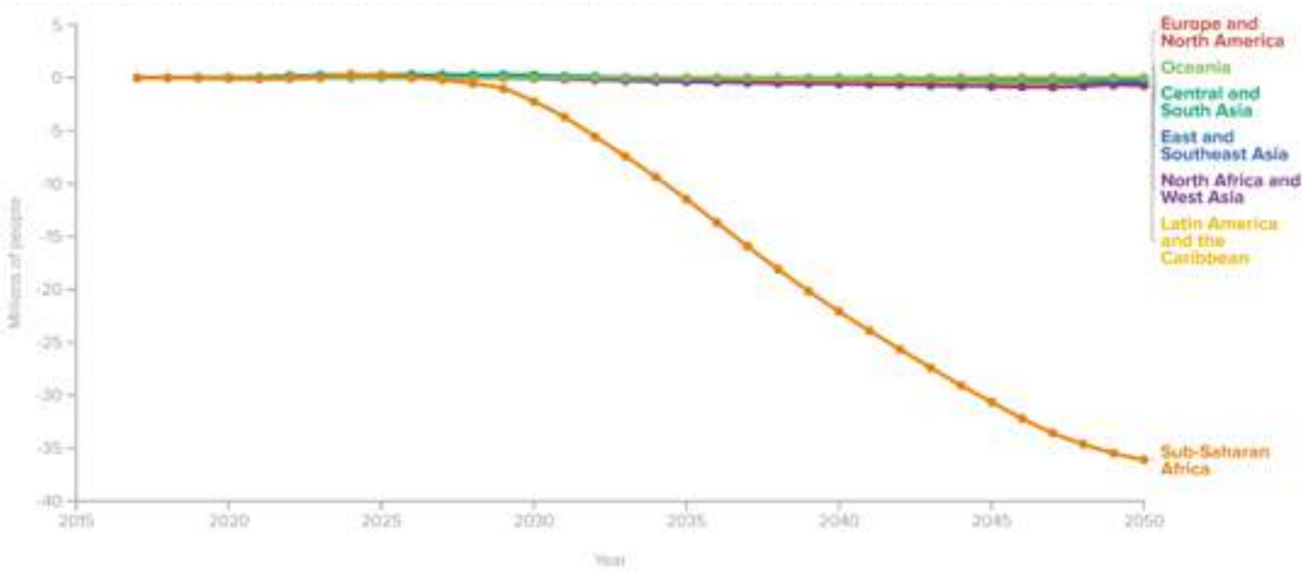

Figure 8: Change in the extreme poverty headcount (US$1.90/day threshold) under the Universal Access scenario compared to the Current Path scenario, by region, by 2050.
Source: IFs 7.87.

Under the Universal Access scenario, we expect a consistent reduction in the female population living in extreme poverty in all regions. By 2030, the most significant absolute decrease will be seen in Central and South Asia, where the number of women and girls in extreme poverty will drop from 81.7 million in 2022 to 45.1 million in 2030. By 2050, we estimate that sub-Saharan Africa will experience the most significant reduction in female poverty, from 241.6 in 2030 to 151.1 million in 2050.

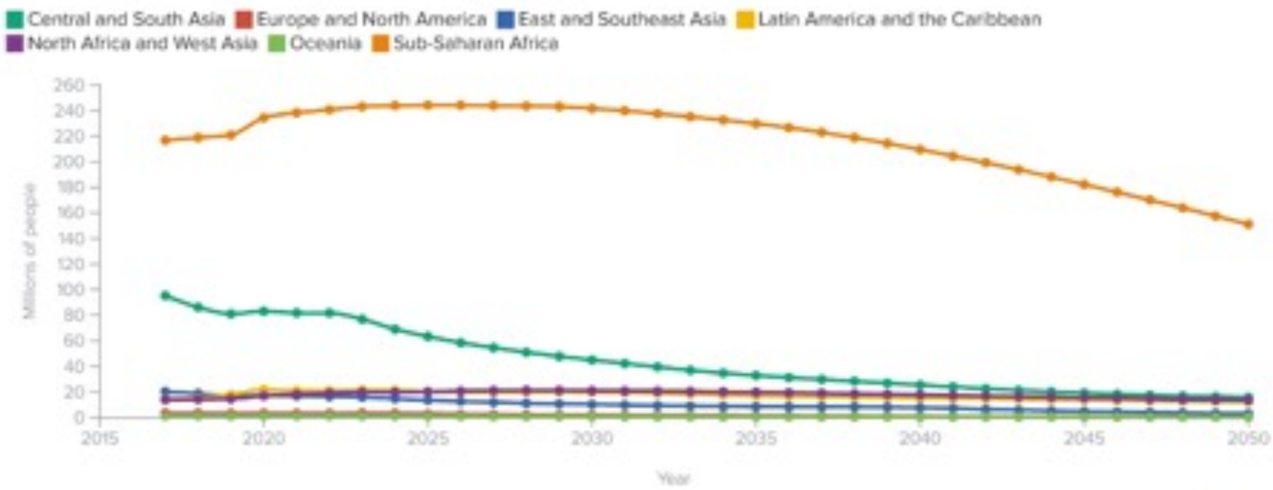

Figure 9: Female population living in extreme poverty under the Universal Access scenario, by region.
Source: IFs 7.87.

Electricity access is also directly linked with a reduction in the use of traditional cookstoves/indoor fuels for cooking, which is associated with household air pollution and ultimately to adverse health effects (Gordon et al., 2014; Lee et al., 2020). In the Universal Access scenario, the number of households using traditional cookstoves globally decreases from 433 million in 2022 to 266.2 million in 2030, and further decreases to 231.8 million in 2050 (compared to 409.4 million in 2030 and 322 million in 2050 under the Current Path scenario). We estimate that the percentage of households using traditional fuels will decrease from 23 percent in 2022 to 12.5 percent in 2030 and to 8.8 percent by 2050 under the Universal Access scenario.

Regionally, the greatest reduction in the use of traditional cookstoves compared to the Current Path scenario is found in sub-Saharan Africa, followed by East and Southeast Asia, and Central and South Asia. In the Universal Access scenario, the number of households using traditional cookstoves in sub-Saharan Africa reduces from 138.5 million (72.9 percent) in 2022 to 65.1 million (25.9 percent) in 2030. Due to population growth, this number increases to 80.2 million in 2050 while the proportion of households further reduces to 17.6 percent. For East and Southeast Asia, it decreases from 100.1 million (15.9 percent) in 2022 to 59 million (8.7 percent) in 2030 and further down to 38.7 million (5.2 percent) in 2050; while for Central and South Asia, it decreases from 169.6 million (47.4 percent) in 2022 to 121.1 million (28.7 percent) in 2030 and further decreases to 91.5 million (16.3 percent) in 2050.

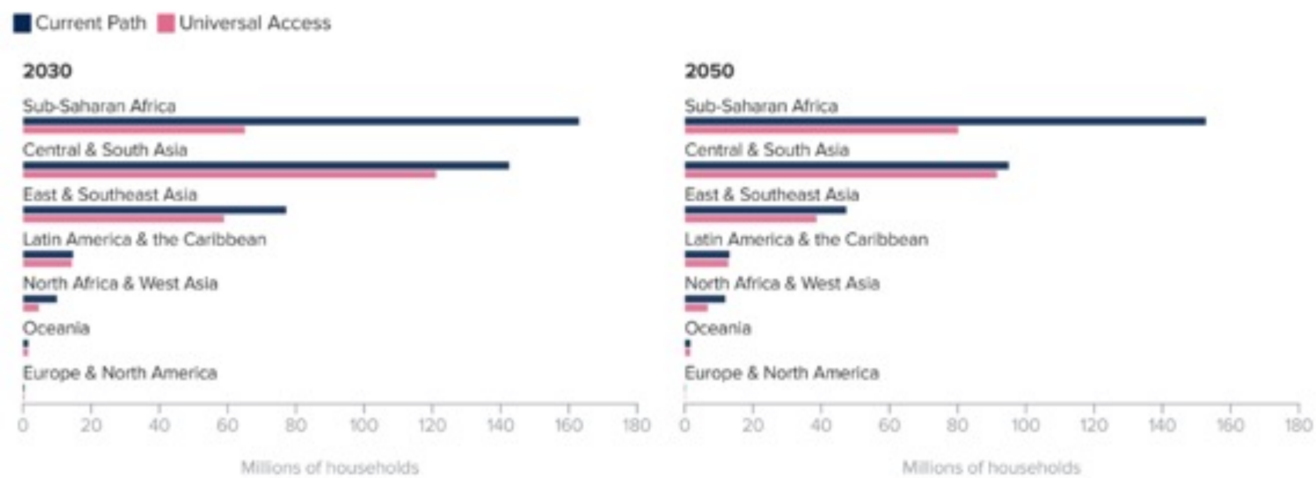

Figure 10: Number of households using traditional cookstoves under the Universal Access scenario compared to the Current Path scenario by region, by 2030 and 2050.
Source: IFs 7.87.

Non-communicable respiratory diseases (e.g. lung cancer) and communicable respiratory infections (e.g. acute lower and upper respiratory tract infections) are observed to rise with an increased use of traditional cookstoves (Faizan and Thakur, 2019; Pratiti et al., 2020). Based on this association, IFs estimates mortality-related indicators by different types of causes related to household air pollution caused by the use of these cookstoves.

Figure 11 illustrates the cumulative number of deaths from respiratory infections that can be averted by 2030 and 2050 across regions. Globally, we estimate that 944,000 cumulative deaths from respiratory infections can be averted by 2030 from universal access to electricity alone. This grows to around 2.7 million by 2050. Although respiratory infections are expected to be on the rise with an increased prevalence of pollution, the Universal Access scenario simulates a mitigated effect on deaths arising from these causes. Sub-Saharan Africa gains the largest benefits in the form of reduced mortality from such infections, cumulatively preventing around 851,000 and 2.5 million deaths from respiratory infections by 2030 and 2050, respectively.

For longer-term, adverse health effects in the form of non-communicable respiratory diseases such as lung cancer, we estimate a major improvement. By 2030, over 1.2 million cumulative deaths can be averted under the Universal Access scenario; by 2050 this grows to over 3.9 million deaths averted. Sub-Saharan Africa would prevent 338,700 and around 1.6 million deaths from non-communicable respiratory diseases by 2030 and 2050, respectively. The region is closely followed by Central and South Asia (546,900 cumulative deaths averted by 2030, and over 1.1 million by 2050) and East and Southeast Asia (299,500 cumulative deaths averted by 2030, and over 1.1 million by 2050) – regions that also closely follow sub-Saharan Africa in the number of households using traditional cookstoves.

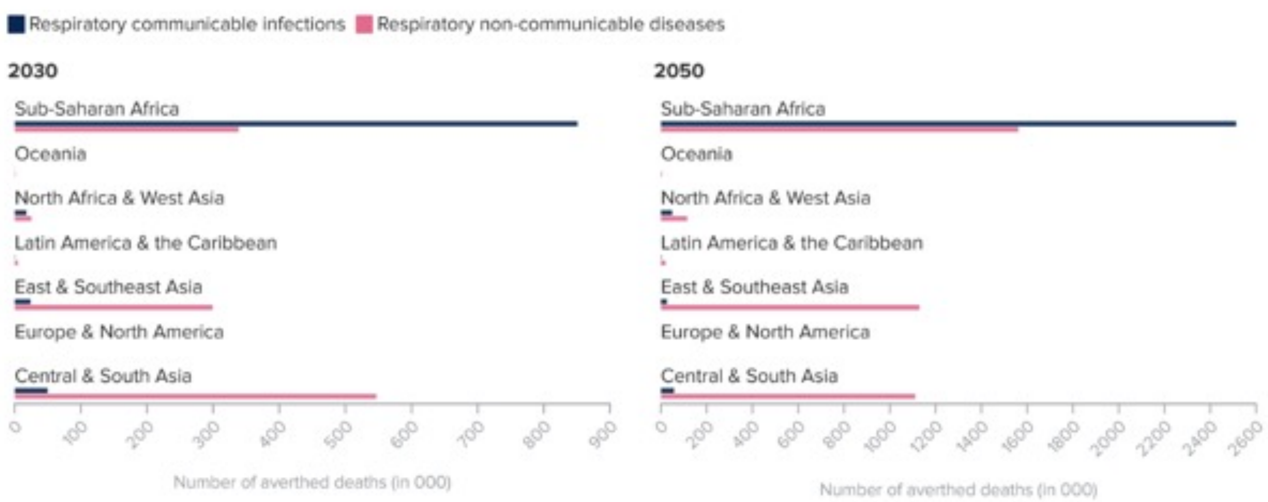

Figure 11: Cumulative number of averted deaths from communicable and non-communicable respiratory disease under the Universal Access scenario compared to the Current Path scenario.
Source: IFs 7.87.

The cost of universal access

The IFs model estimates the investment needed to expand and maintain levels of physical infrastructure, including electricity infrastructure. This cost is estimated as the cost of new construction and the cost of maintaining or renewing infrastructure. Like many other studies, IFs applies a universal cost to building and maintaining electricity connections that do not vary across time or country, although separate costs are applied to urban and rural connections. In IFs, all spending must be accounted for, so increases in spending by country may result in tradeoffs by reducing spending in other areas, or will require external aid, investment, or increased government revenues. As a result, IFs can provide a broad estimate for the cost of electricity access and generation, and how they may vary worldwide across time (as demand for electricity grows) and across scenarios. However, these cost estimates should not be taken as precise investment costs and do not reflect the real, dynamic cost context and challenges of expanding access in individual countries.

We estimate that the total cost of investment in electricity connections (including new construction and maintenance of existing connections) worldwide is over US$65 billion for 2022 (Figure 12). More than half (nearly US$36 billion) of which is directed toward urban areas. Even under the Current Path scenario, annual investment in electricity is expected to grow, together with rising populations and demand: by 2030, annual electricity investment globally is estimated at nearly US$75 billion, of which US$41 billion is urban. This is equivalent to cumulative spending of US$586 billion between now and 2030, mainly for urban electricity infrastructure (US$311 billion).

However, this investment under the Current Path scenario is not sufficient to expand access to all. Achieving universal access requires significant investments to fully develop new connections in under-served and rural areas, many of which are further challenged by limited government resources. In 2022 alone, estimated investment falls short by US$20 billion for rural areas and US$3 billion for urban areas.

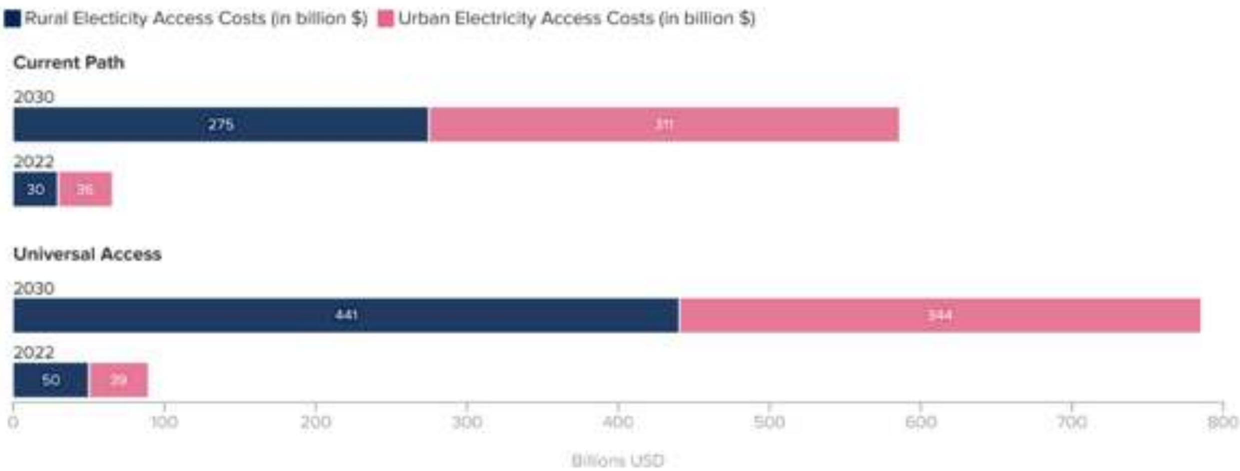

Figure 12: Estimated investment needs for electricity connections (including new construction and maintenance) in rural and urban areas, by scenario, by 2030.
Source: IFs 7.87.

We estimate investment needs from 2022 to 2030 for the Universal Access scenario will require a cumulative amount of more than US$785 billion between now and 2030, including more than US$441 billion on expanding rural access alone. Compared with the Current Path scenario, the Universal Access scenario requires over US$200 billion more in investment by 2030, with over 80 percent of which targeted toward rural areas. Not only will achieving universal electricity access require significant increases in investments, but it will also require a special focus on building out access in rural, access-deficit areas.

Other studies have made similar estimates of the cost of achieving universal access, ranging from US$65 to 86 billion per year or cumulative investments of US$480-970 billion by 2030. Further information on how electricity costs are estimated in IFs is provided in Appendix 1, and universal electrification cost estimates from other studies are highlighted in Appendix 3.

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SDG Push+

The Universal Access scenario demonstrates that expanding electricity access has real benefits, especially in regions with very low access rates. However, results also suggest that it is crucial to view electrification within an integrated strategy in order to fully reap the benefits from this expanded electricity access. Expanded electricity access can support improvements across systems, for example, by enabling new and expanded businesses, improving healthcare facilities and access, supporting education by making it possible study after dark, and so on. But in almost all cases, greater efforts are needed to effect transformative improvements. For example, real progress in education will require addressing: the lack of access to schools and materials and the cost of fees; the low number and lack of training of teachers; and socioeconomic challenges that keep children at home or at work. Electricity access is an important enabling factor but should be pursued in conjunction with other interventions to address country challenges and opportunities. Appendix 2 provides an overview of the full list of interventions employed under the SDG Push+ scenario.

The SDG Push+ scenario models universal access in addition to a set of interventions targeted to accelerating progress towards the 2030 Agenda. Appendix 2 provides an overview of the full list of interventions employed under the SDG Push+ scenario. This scenario results in broad gains across development indicators, in addition to those generated by Universal Access alone. Cumulative GDP gains above the Current Path globally reach US$16 trillion by 2030 and top US$540 trillion by mid-century. Annual global GDP per capita grows by nearly 5 percent by 2030 and more than 26 percent by 2050, compared to the Current Path scenario.

According to Figure 13, it is estimated that the largest additional gains in cumulative GDP from an electricity boost together with other development interventions are as follows:

1. East and Southeast Asia (US$4.5 trillion by 2030 and US$190 trillion by 2050);

2. Europe and North America (US$6.9 trillion by 2030 and US$158 trillion by 2050);

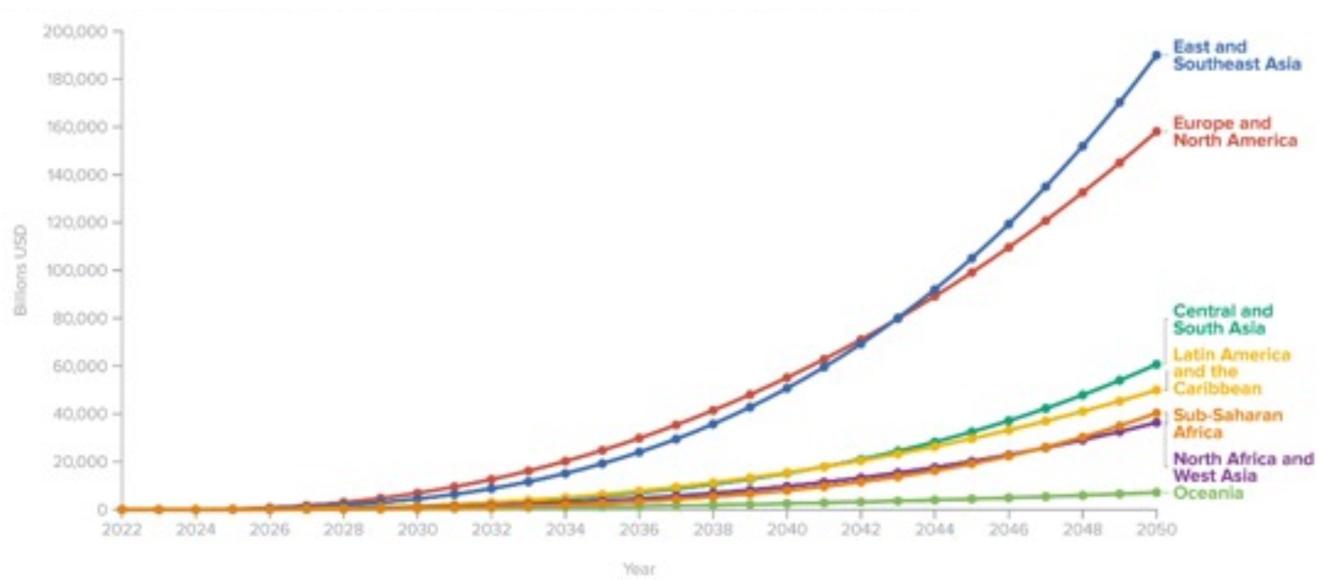

Figure 13: Additional GDP gains under the SDG Push+ scenario compared to the Current Path scenario.
Source: IFs 7.87.

3. Latin America (US$1.6 trillion by 2030 and US$50 trillion by 2050);

4. Central and South Asia (US$1.3 trillion by 2030 and US$60.7 trillion by 2050):

5. Sub-Saharan Africa's cumulative GDP gain from SDG Push+ reaches US$523 billion by 2030 and US$40 trillion by 2050 – a much greater benefit than from the Universal Access scenario alone.

In terms of GDP per capita (at PPP), Figure 14 illustrates the additional gains compared to the Current Path scenario. Global GDP per capita increases from US$16,130 in 2022 to US$18,570 in 2030 and increases further to US$28,840 in 2050 as a result of SDG Push+ interventions (compared to US$17,900 in 2030 and US$22,760 in 2050 under the Current Path scenario).

While these absolute gains are the smallest in sub-Saharan Africa compared to the other regions, the relative growth in the region is the highest. With respect to 2022, sub-Saharan Africa's GDP per capita almost triples to US$9,380 by 2050. This relative increase is closely followed by Central and South Asia (2.3 times the 2022 estimates), East and South East Asia (2.2 times), Oceania (1.8 times), Latin America and the Caribbean (1.7 times) and North Africa and West Asia (1.6 times).

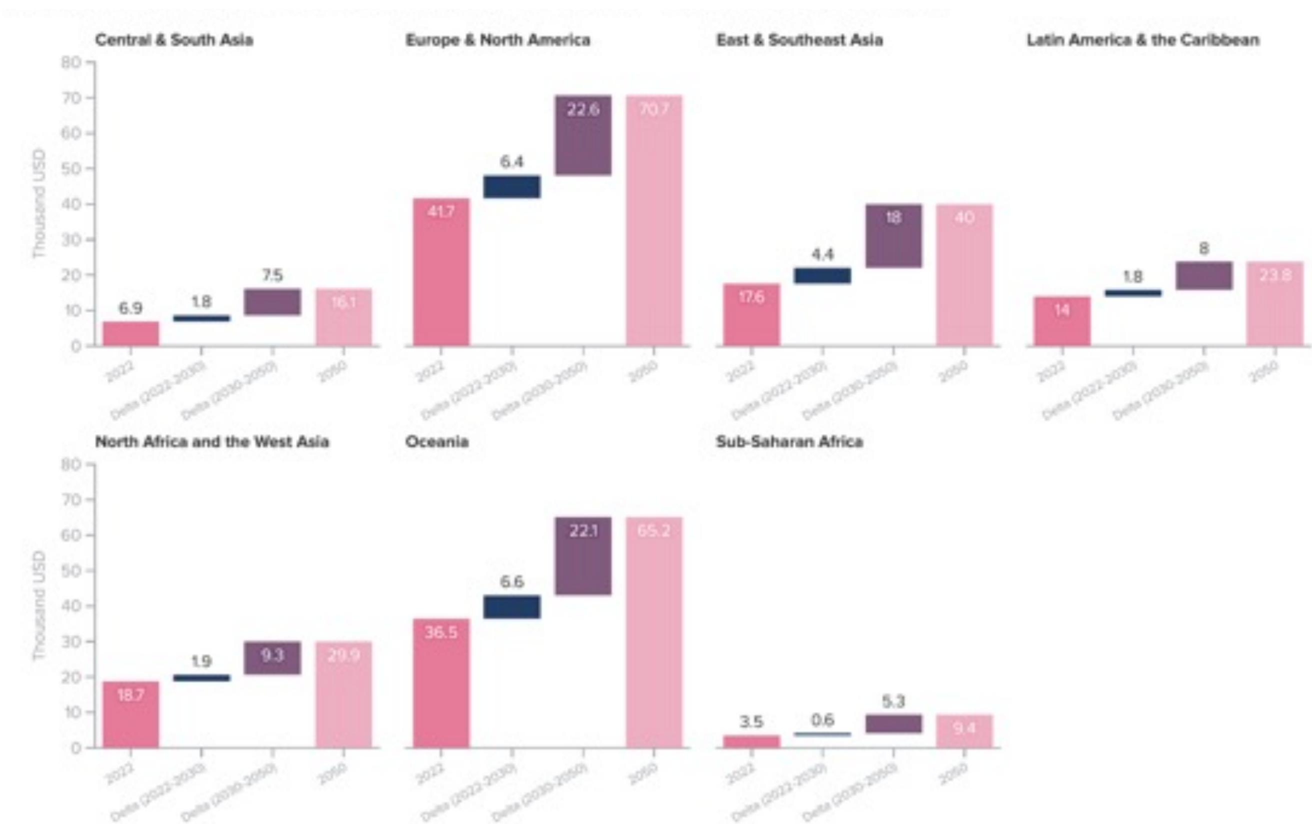

Figure 14: Additional GDP per capita (PPP) gains under the SDG Push+ scenario by 2030 and 2050, by region.
Source: IFs 7.87.

As a result of overall growth, improved development and targeted poverty reduction interventions, we estimate that globally over 110 million fewer people living in extreme poverty than expected under the Current Path scenario by 2030 and more than 270 million fewer people in 2050. The rate of extreme poverty is significantly reduced at a global level to below 3 percent by 2043. This poverty reduction is heavily concentrated in regions with both the highest extreme poverty levels and lowest levels of electricity access. Through 2030, half of the total poverty reduction as a result of the SDG Push+ scenario is in sub-Saharan Africa and 30 percent is in Central and Southern Asia. By 2050, 80 percent of the people pulled out of extreme poverty compared to the Current Path scenario live in sub-Saharan Africa.

Figure 15 shows the total population lifted out of extreme poverty by 2050 under the SDG Push+ scenario compared to the Current Path scenario. It also shows that the SDG Push ambition, together with achieving universal access, can effectively boost development outcomes.

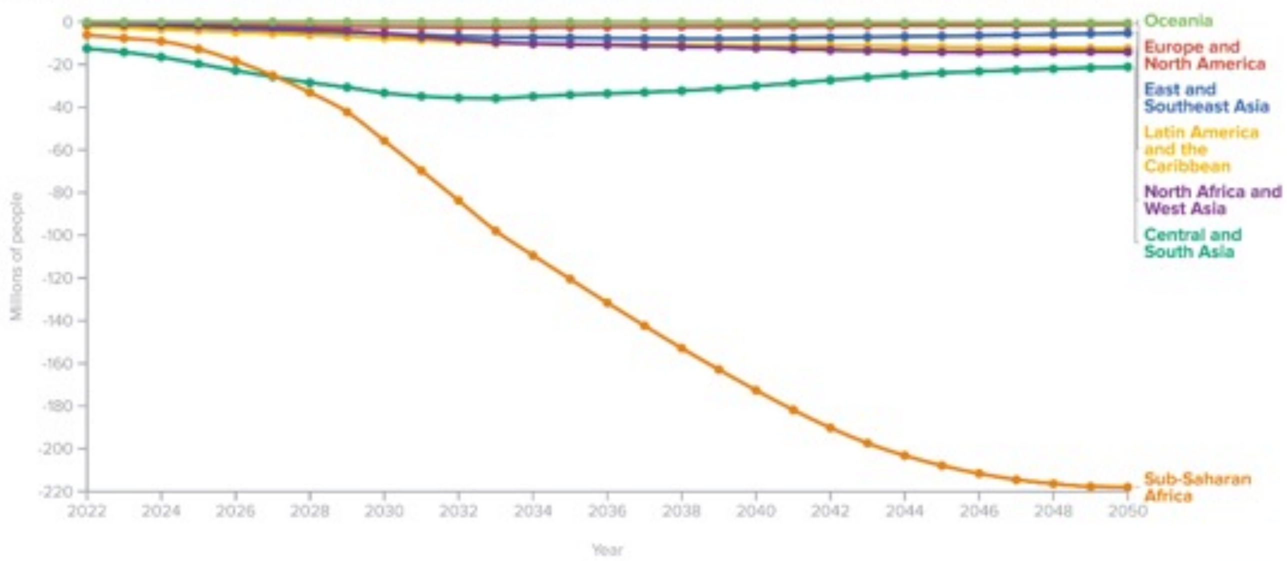

Figure 15: The difference in extreme poverty headcount between the Current Path and the SDG Push+ scenarios, by 2050, by region.
Source: IFs 7.87.

The SDG Push+ scenario includes interventions targeting increased gender equality. In this scenario, we estimate that the female population living in extreme poverty drops across all regions by 2030 and 2050. In sub-Saharan Africa particularly, the number of women and girls in extreme poverty drops from 237.5 million in 2022 to 214.7 million in 2030, and further down to 59.4 million in 2050. In Central and South Asia, with the second largest female population under poverty in 2022, the number of women and girls in extreme poverty drops from 75 million in 2022 to 26.5 million by 2030 and further to around 4 million in 2050.

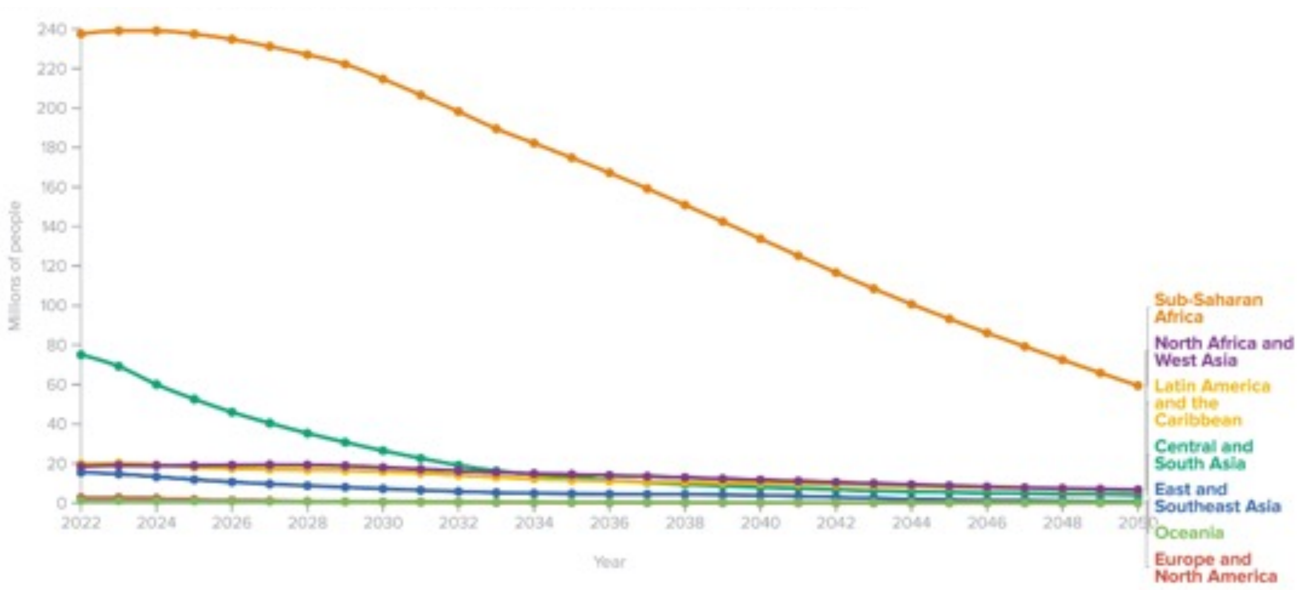

Figure 16: Female population living in extreme poverty under the SDG Push+ scenario.
Source: IFs 7.87.

Under the SDG Push+ scenario, the use of solid fuels in traditional cookstoves is drastically reduced. The scenario simulates a pattern shift to adopting modern, cleaner and sustainable cookstoves, thereby lowering the use of traditional cookstoves in countries and regions that excessively rely on them as the essential fuel for cooking. As shown in Figure 17, by 2030, all regions but two (Central and South Asia, and East and Southeast Asia) are projected to eliminate the use of traditional cookstoves in this scenario. By 2033, East and Southeast Asia will also eliminate its use. For Central and South Asia, the number of households using these forms of cooking fuels decreased drastically from 152 million (53 percent of total households) in 2022 to 74.5 million (18 percent) in 2030, and further down to 6 million (1.1 percent) in 2050.

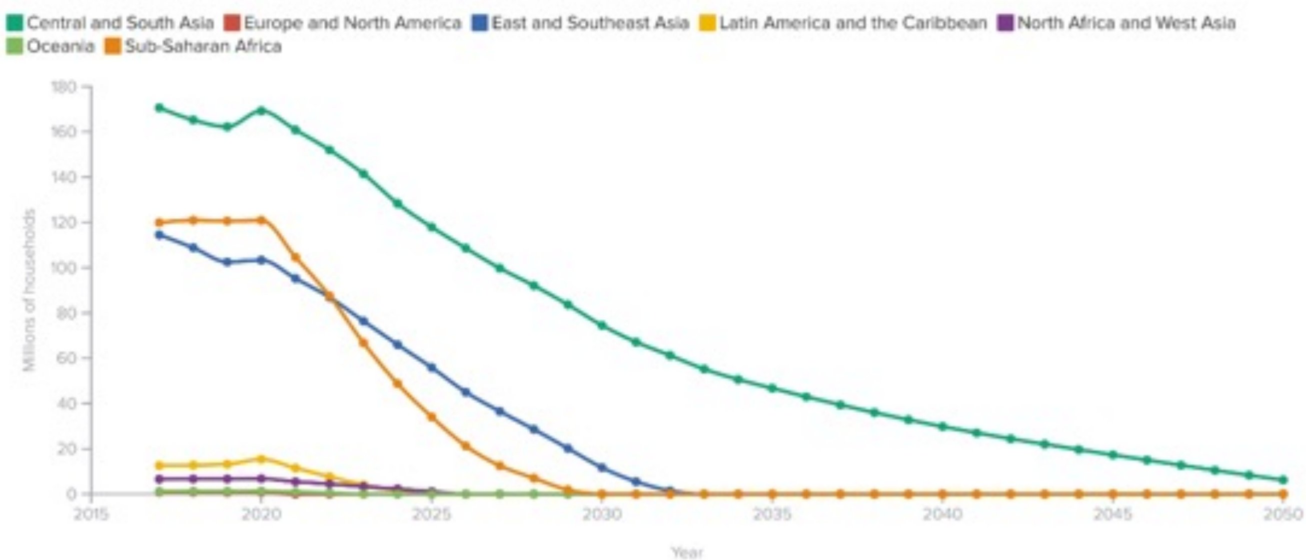

Figure 17: The use of traditional cookstoves under the SDG Push+ scenario.
Source: IFs 7.87.

Reducing the use of traditional cookstoves for cooking improves health outcomes and reduces deaths from causes related to household air pollution. In an SDG Push+ scenario, over 3.8 million cumulative deaths from respiratory infections and diseases can be averted by 2030. By 2050, this mortality burden is further reduced, with over 18.6 million averted deaths. We estimate that the largest burden of household air pollution is in Central and South Asia, sub-Saharan Africa, and East and Southeast Asia regions due to a higher proportional use of traditional fuels for cooking. In these three regions alone, over 3.4 million cumulative deaths from communicable and non-communicable respiratory diseases can be averted by 2030 (and over 15.9 million deaths by 2050).

Figure 18 shows the cumulative deaths averted from non-communicable as well as communicable respiratory diseases by 2030 and 2050 for each region under the SDG Push+ scenario compared to the Current Path scenario.

The 'SDG Push' interventions under the SDG Push+ scenario reduce poverty increase access to water and sanitation infrastructure, improve governance, and implement more efficient and environmentally sustainable agricultural practices. In addition to improving economic, human and environmental development, these measures contribute to greater economic growth and consequently higher government revenue. As a result, governments have more money to spend across policies, including on expanding electricity access.

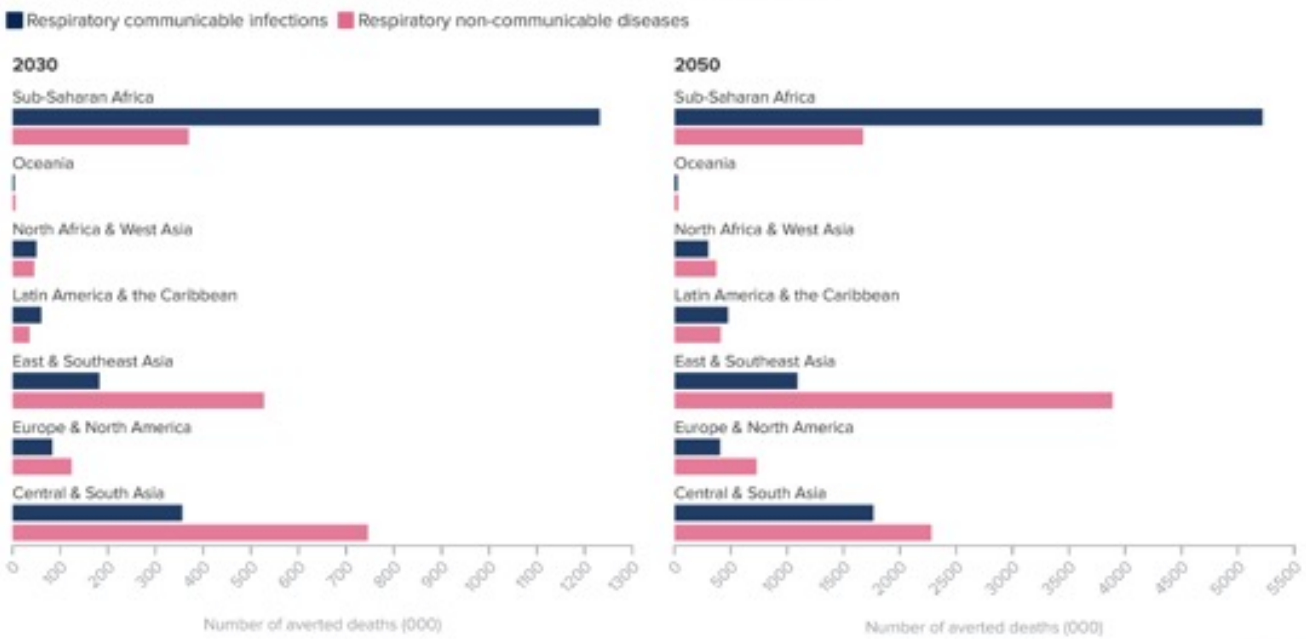

Figure 18: Cumulative number of averted deaths from communicable and non-communicable respiratory disease under the SDG Push+ scenario compared to the Current Path scenario.
Source: IFs 7.87.

Synergies associated with the Universal Access scenario

Energy is fundamental to all aspects of economic and human development, powering everything from schools and hospitals, to factories and water treatment plants. Electricity access is an important component and enabler across the 2030 Agenda for Sustainable Development. According to the ICSU (2017), Sustainable Development Goal (SDG) 7 is linked all of the SDGs, including with notable synergies with SDGs 1 (No Poverty), 3 (Good Health) and 8 (Productivity). Nerini et al. (2018) finds that SDG 7 is associated with twice as many synergies as it is with trade-offs. However, electricity access, which requires significant investment and careful planning, is also vulnerable to trade-offs, since financial resources may be pulled away from other investment areas (Moyer & Bohl, 2019).

In order to better understand the synergies associated with electricity access, we analysed the effects of the Universal Access interventions alone and then compared them with the effects of these same interventions under the SDG Push+ scenario. The Universal Access scenario alone resulted in a cumulative US$300 billion and US$10.5 trillion by 2030, respectively. The effect of electricity access when combined with a comprehensive development package is many times greater. Under the SDG Push+ scenario, electricity access results in a cumulative US$1.3 trillion in GDP gains by 2030; by 2050, this grows to US$71.7 trillion, or seven times greater than under the Universal Access scenario alone.

As discussed in the Universal Access section, in addition to providing benefits alone, electricity access provides even greater benefits when combined with other policy interventions. Improvements in other areas (education, healthcare, economic and agricultural production) are enhanced by accelerated electricity access. Moreover, the SDG Push+ scenario results in significantly increased government revenues (from accelerated growth and improvements in governance quality and efficiency), thereby opening the fiscal space to invest more in electricity access without the same trade-offs in spending in other areas.

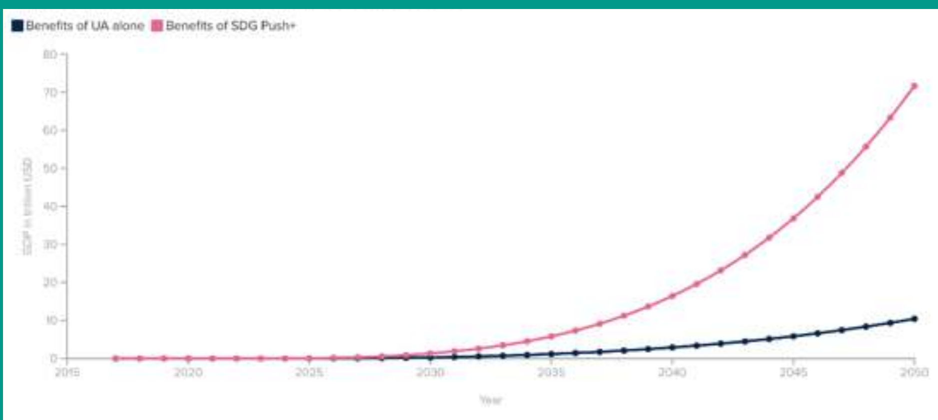

Figure 19: Cumulative increases in GDP with universal access (the difference between the Universal Access and the Current Path scenarios) and the benefits of synergies associated with Universal Access under the SDG Push scenario (the difference between SDG Push+ and SDG Push without the Universal Access scenario).
Source: IFs 7.87.

Focus on UNDP Programme countries

Building on the UN-Energy Plan of Action towards 2025, UNDP and partners have pledged to catalyse partnerships, knowledge, innovation and finance to increase energy access to 500 million more people by 2025, halving the energy access gap. As part of ongoing initiatives, a selected set of 31 countries (Algeria, Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Republic of the Congo, Democratic Republic of the Congo, Côte d'Ivoire, Djibouti, Eswatini, Ethiopia, Gambia, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Somalia, Sao Tome and Principe, Sudan, Zambia and Zimbabwe) is expected to benefit from two key interventions – the African Minigrids Program[7] and the Action Opportunities project.[8]

This group contains 7 of the 15 countries with the largest populations without electricity access today. Together, in these countries there are more than 512 million people without electricity access, of whom 421 million live in rural areas and 91 million live in urban areas. The 31 countries are characterized by both electricity access deficits and inequities: the average overall electricity access rate across the group is 46 percent, and the five countries with the lowest overall access rates – Burundi, Chad, Madagascar, Niger and Ethiopia – all have overall access rates below 25 percent; in five countries – Burkina Faso, Guinea, Somalia, Angola, and Republic of the Congo – the difference between rural and urban access rates exceeds 75 percentage points. Figure 20 illustrates access rates for these countries.

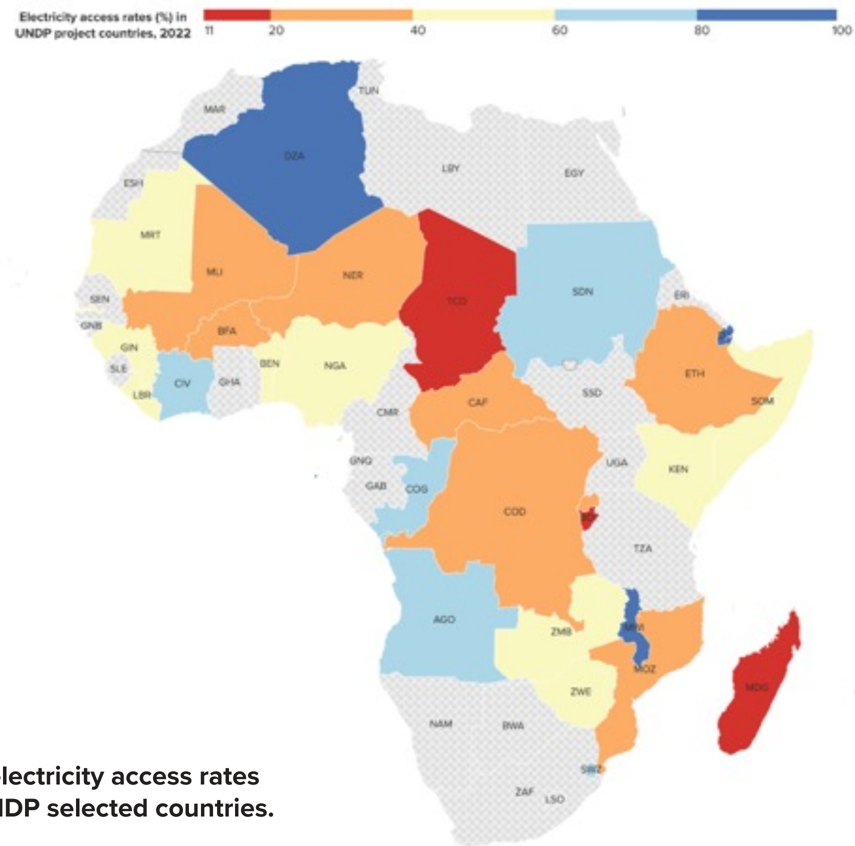

Figure 20: Total electricity access rates in 2022 for 31 UNDP selected countries.
Source: IFs 7.87.

[7] The African Minigrids Program aims at developing an enabling environment to increase the commercial viability of renewable energy minigrids and scale up investments in decentralized renewable energy solutions in the targeted African countries.

[8] As part of the Action Opportunities project, UNDP will conduct pre-feasibility assessments to identify country-level activities that can potentially boost electrification in several African countries. The results of these assessments will guide the selection of the most efficient activities, as well as specific levers, financial mechanisms and funding requirements that could drive both grant and concessional finance towards scaled-up clean energy access solutions across the region.

Under the Current Path scenario, the number of people in these countries without access to electricity is expected to increase by 7.2 percent in the next eight years, reaching 529 million by 2025 and 549 million by 2030. By 2030, eight out of ten people without electricity access will live in rural areas. Access is expected to improve to some extent under the Current Path scenario by 2050, but over 425 million (339 million in rural and 86 million in urban areas) will still live in the dark.

With a push towards Universal Access in the set of 31 countries, by 2025, we project that close to 219 million people will not have access to electricity, i.e. over 310 million fewer people living in the dark than in the 2025 estimates under the Current Path scenario. As a consequence, 293 million additional people will gain access to electricity in these countries – 243 million in rural areas and over 50 million in urban areas. This intervention effectively halves these countries' populations without electricity access by 2025.

With larger populations in Nigeria, Ethiopia and the Democratic Republic of the Congo, we also find the largest gains in the electricity access counts in these countries. For instance, 61.7 million additional people in Nigeria alone gain access to electricity by 2025 from the Universal Access scenario, relative to the Current Path scenario (51.2 million additional people for Ethiopia, and 38 million additional people for the Democratic Republic of the Congo).

The SDG Push+ scenario will bring the number of people without access down to 2.3 million by 2030. In particular, Burundi, Chad, Madagascar, Ethiopia and Niger – five of the world's countries with extreme deficit in electricity access whose access rates as low as 10 percent in 2022 – show marked improvements in this scenario. Compared to the Current Path scenario, 174 million people gain access to electricity by 2030 in these countries alone, followed by an additional 144 million people by 2050. To pursue these targets, a much larger focus must be placed on expanding access in the rural regions.

Figure 21 shows the number of people without electricity access under the Current Path, Universal Access and SDG Push+ scenarios by 2050.

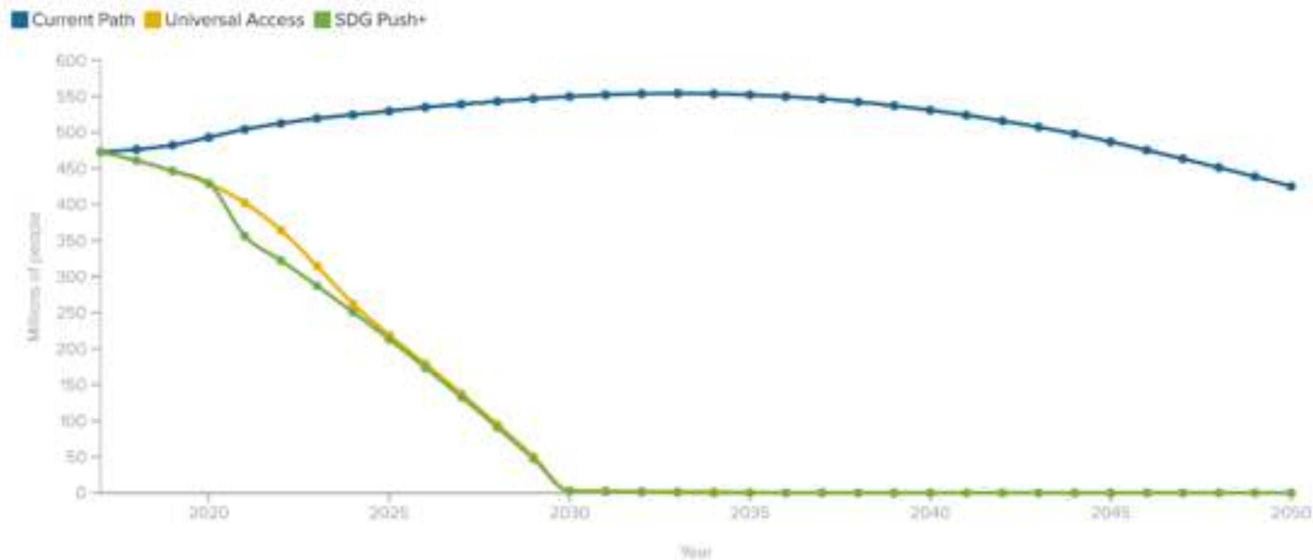

Figure 21: Population without electricity access in the UNDP programme countries under the Current Path, Universal Access and SDG Push+ scenarios.
Source: IFs 7.87.

The provision of universal access is associated with substantial long-term gains in cumulative GDP, with overall cumulative gains of approximately US$65 billion by 2030 and US$4.1 trillion by 2050. At a country level, small but significant gains of US$1 billion up to US$5 billion by 2030 are masked by substantial progress by 2050. Nigeria, Ethiopia, the Democratic Republic of the Congo, Angola and Kenya are projected to witness the largest benefits in terms of cumulative gains in GDP relative to the Current Path in 2030 and 2050.

The synergies associated with the SDG Push+ scenario further enhance the economic output among these countries due to other holistic development interventions. Relative to the Current Path, this scenario estimates a cumulative GDP gain of US$10.5 billion by 2025, climbing to approximately US$374 billion by 2030 and US$30.3 trillion by 2050, largely driven by an increase in economic output among countries such as Algeria, Angola, Democratic Republic of the Congo, Côte d'Ivoire, Ethiopia and Nigeria. Other countries with low electricity access rates such as Burundi, Chad, Burkina Faso, Mozambique and Niger are also projected to benefit through cumulative GDP gains compared to their current level of output in 2022.

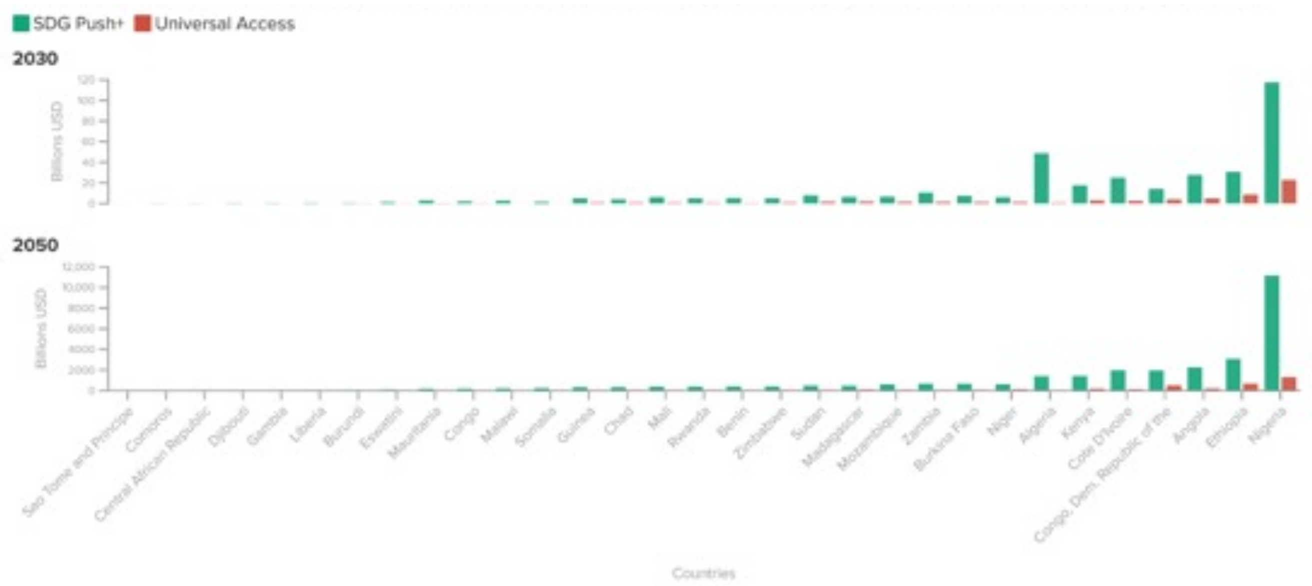

Figure 22: Cumulative gains in GDP for UNDP programme countries under the Universal Access and SDG Push+ scenarios.
Source: IFs 7.87.

We also observe a rise in GDP per capita from universal electrification, relative to the current levels of output among the UNDP focus countries. Figure 23 illustrates the percentage increase in GDP per capita among the countries that show the strongest effects from the Universal Access and the SDG Push+ scenarios in 2030 and 2050.

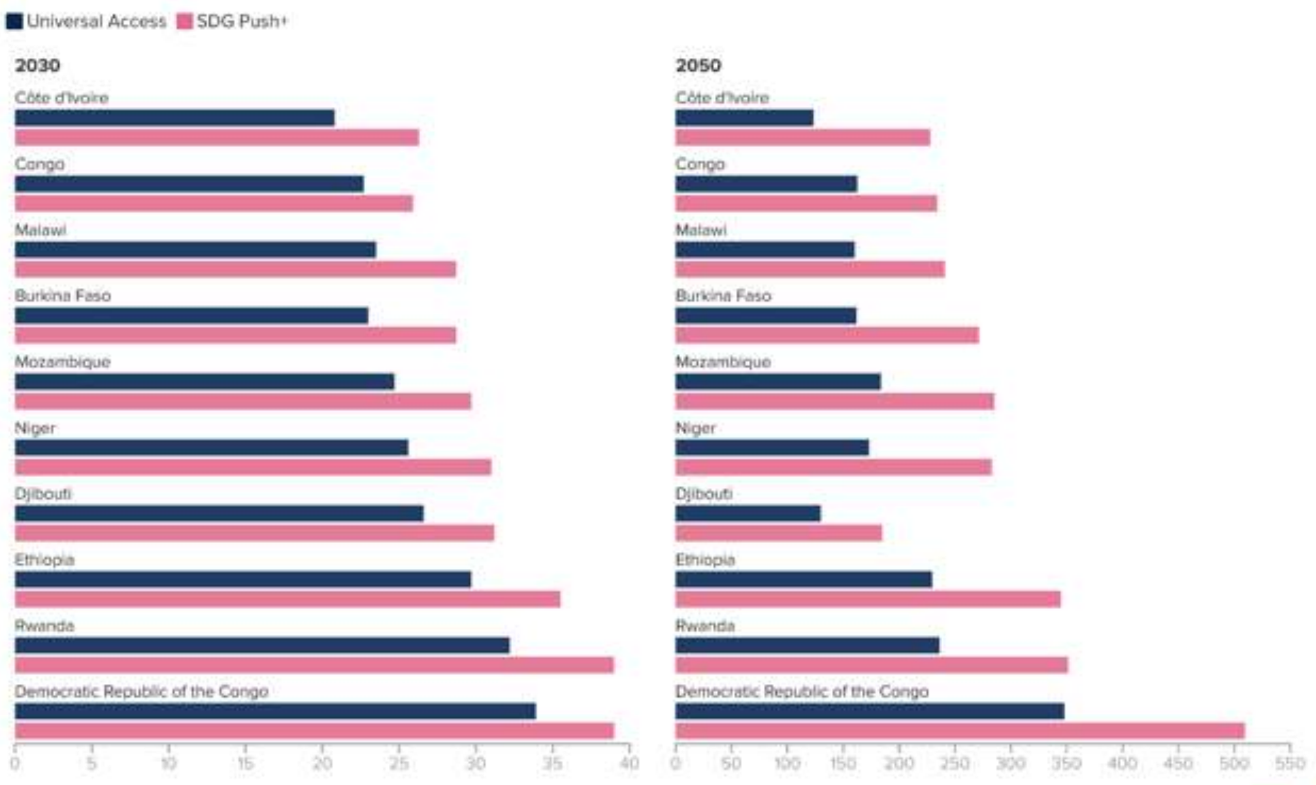

Figure 23: Percentage increase in GDP per capita under the Universal Access and the SDG Push+ scenario, by 2030 and 2050, compared to 2022.
Source: IFs 7.87.

It can be observed that in these countries, under the Universal Access scenario, around 1.8 million people will be lifted out of extreme poverty by 2030 and 31.0 million by 2050, relative to the Current Path, i.e. a reduction to 33.7 percent and 13.8 percent of the total population in extreme poverty in these countries in 2030 and 2050, respectively. The estimates for the SDG Push+ scenario suggest that 42.8 million and 183.5 million people more can be lifted out of extreme poverty by 2030 and 2050, respectively, than under the Current Path scenario. In addition, the extreme poverty rate could decrease to 30.2 percent and 5.4 percent by 2030 and 2050, respectively.

At the country level, the largest reductions in poverty count can be seen in the Democratic Republic of the Congo, where a push towards universal electrification without other development interventionsby 2030 lifts approximately 758,000 people out of poverty, followed by Ethiopia at 408,000, Madagascar at 170,000, Niger at 106,000, and Burundi at 98,000. In terms of proportion of people in extreme poverty, we estimate the greatest reduction in poverty rates relative to the Current Path for Madagascar, Burundi, Chad, Democratic Republic of the Congo and Niger – countries with Africa's highest poverty rates in 2022.

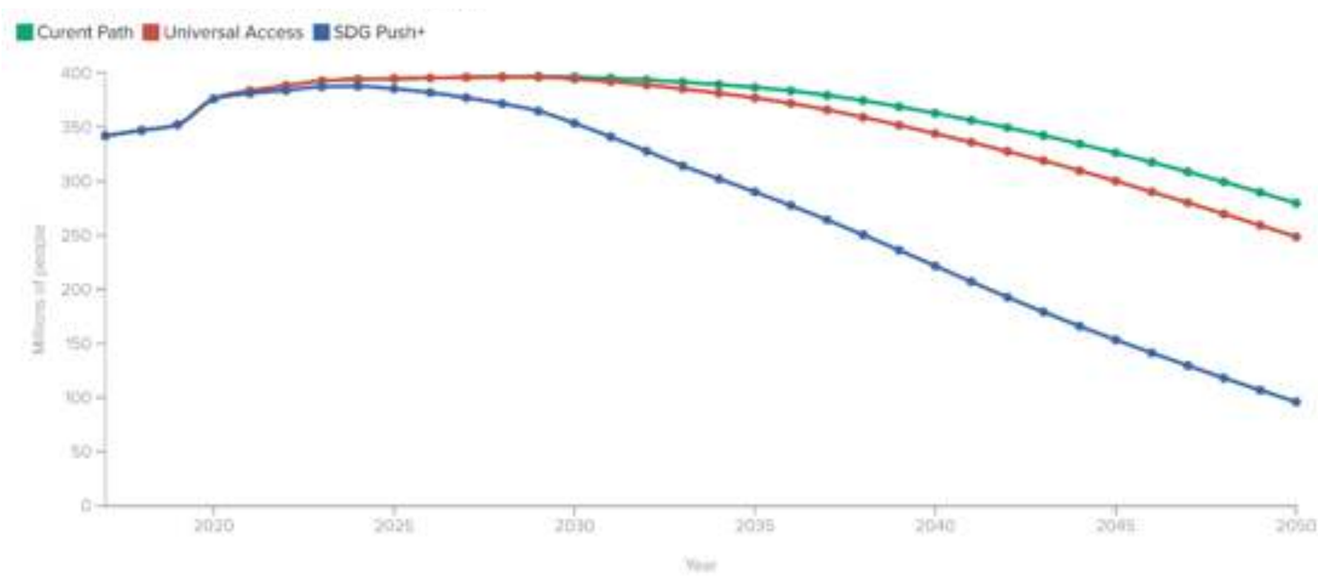

Figure 24: Number of people in extreme poverty in the UNDP programme countries under the Current Path, Universal Access and SDG Push+ scenarios.
Source: IFs 7.87.

By 2050, the estimated figures from the difference across Universal Access and Current Path scenarios suggest that Nigeria is projected to bring around 10 million people out of poverty, followed by Madagascar at 4.9 million, Democratic Republic of Congo at 4.4 million, Burundi at 1.6 million and Mozambique at 1.4 million. In contrast, Djibouti, Algeria, Sao Tome and Principe, Gambia, Eswatini, Republic of the Congo and Comoros show smaller reductions in poverty estimates either by 2030, or 2050 (Figure 25), which is primarily due to their having relatively lower population in poverty at the current level.

While the poverty headcount among these countries rises from 388.2 million in 2022 to 396.2 million in 2030, with a subsequent reduction in the following years under the Current Path scenario, the poverty rates are continually projected to drop from 41 percent of the total population in 2022 to 33.8 percent in 2030, to eventually 15.4 percent in 2050. The SDG Push+ scenario, in contrast, produces significantly positive outcomes, as 42.8 million (a 3.7 percentage point reduction) are lifted from extreme poverty by 2030 and a further 183.6 million (10 percentage points) by 2050, compared to the Current Path scenario. As under the Universal Access scenario, these reductions are driven by a drop in poverty rates across countries such as Madagascar, Burundi, Chad, Democratic Republic of the Congo and Niger.

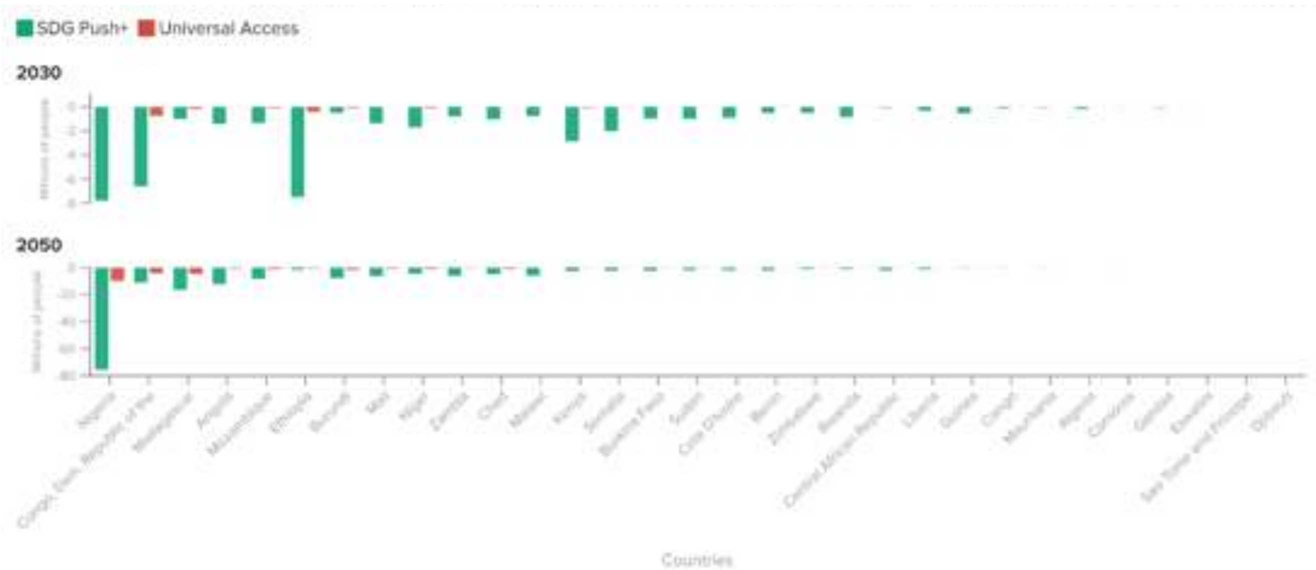

Figure 25: Reductions in poverty count for UNDP programme countries under the Universal Access and SDG Push+ scenarios.
Source: IFs 7.87.

Our estimates suggest that, in 2022, 111 million households in these UNDP Project countries use traditional cookstoves. By 2030, large reductions in the use of indoor fuels come from targeted investments in raising electricity access universally. We expect that the number of households using them reduces by over 81 million in 2030, albeit a lower reduction from Current Path estimates is seen by 2050 (65 million). While the SDG Push+ scenario simulates the elimination of the use of traditional fuels for cooking, the Universal Access scenario results in a rapid reduction in the proportion of households using them from 74.4 percent in 2022 to 26 percent in 2030, and 18.1 percent in 2050.

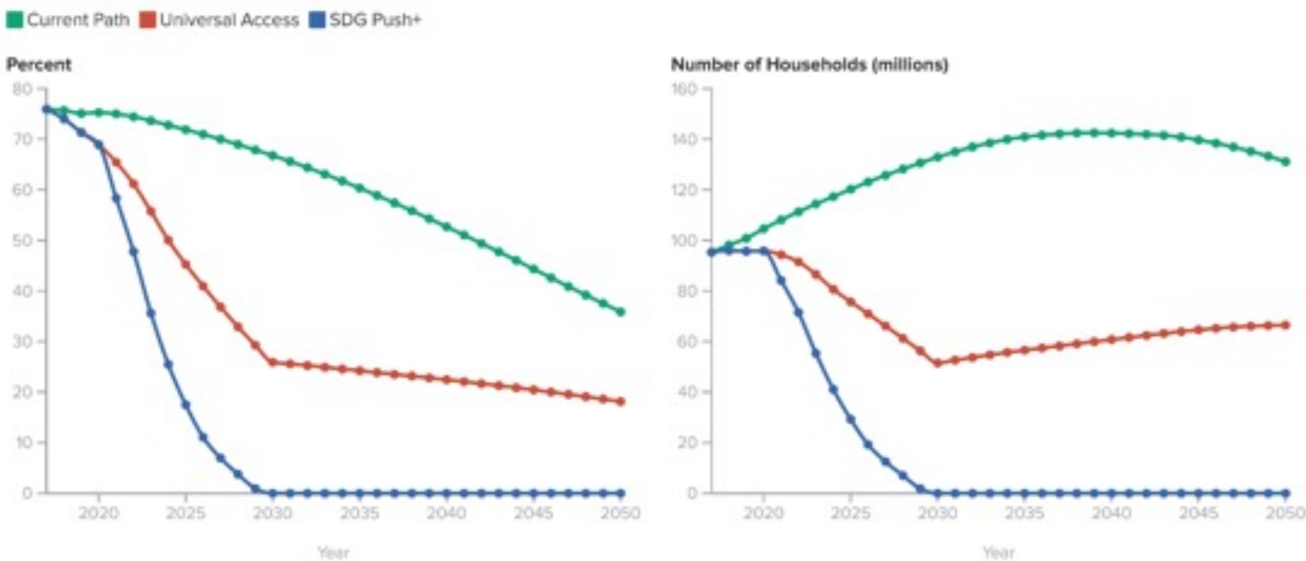

Figure 26: Total number of households using traditional cookstoves for UNDP programme countries under the Universal Access and SDG Push+ scenarios.
Source: IFs 7.87.

In this group, Nigeria is the country with the largest absolute reduction in number of households using traditional cookstoves, where under the Universal Access scenario, the number of people using these them is reduced by over 19 million by 2030. Following Nigeria, Ethiopia (14 million), Democratic Republic of the Congo (7.3 million), Kenya (5.2 million), Sudan (4.7 million) and Mozambique (4.4 million) show significant reductions in the number of people using traditional cookstoves. As seen in Figure 26, the SDG Push+ scenario eliminates traditional cookstove use after 2030.

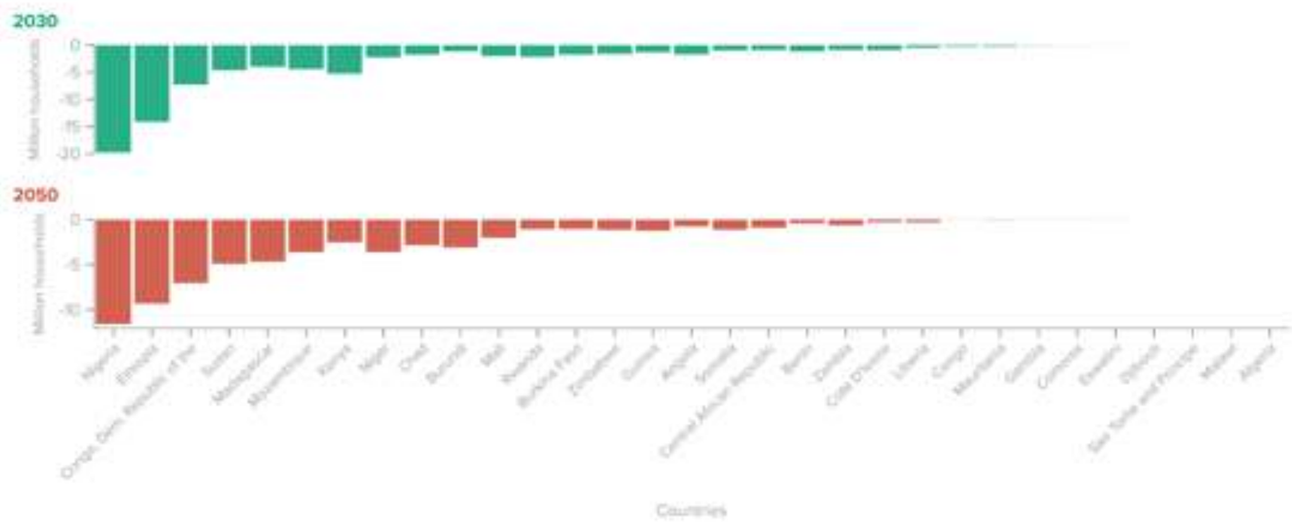

Figure 27: Reductions in the population using traditional cookstoves/indoor fuels for UNDP programme countries under the Universal Access scenario.
Source: IFs 7.87.

Following consistent reductions in the use of indoor, traditional fuels, there are substantial improvements in health outcomes in the form of reduced mortality from communicable and non-communicable respiratory diseases. Relative to the Current Path scenario, by 2030, over 1.05 million cumulative deaths can be averted from the Universal Access scenario alone, which rises to 1.4 million averted deaths under the SDG Push+. By 2050, over 3.6 million cumulative deaths are averted under the Universal Access scenario, while over 5.9 million deaths are averted under the SDG Push+ scenario. A detailed summary of the effects on different development indicators across scenarios is presented in Appendix 4.

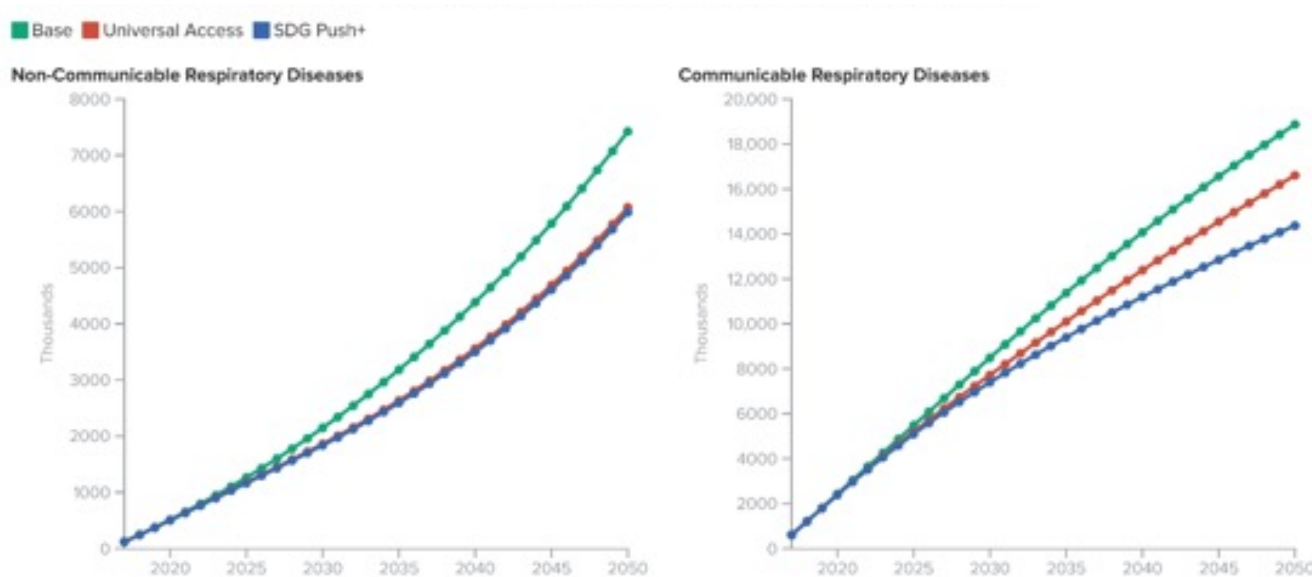

Figure 28: Cumulative deaths from non-communicable and communicable respiratory diseases in the UNDP programme countries.
Source: IFs 7.87.

The cost of universal access in UNDP programme countries

Today, the estimated annual cost for the maintenance and new construction of electricity connections in the set of 31 countries is approximately US$5 billion, split evenly across urban and rural areas. Under the Current Path scenario, annual costs are expected to rise to over US$8 billion per year - a cumulative cost of over US$60 billion between 2022 and 2030 (US$31 billion in rural areas and US$28 billion in urban areas).

Achieving Universal Access in these countries requires significant additional investment. Current levels of spending fall short of the amount needed by US$12 billion in 2022 (US$11 billion in rural areas and US$1 billion in urban areas). Under the Current Path scenario, investments could fall short by over US$130 billion cumulatively between 2022 and 2030; i.e. the universal access requires spending of over US$190 billion between 2022 and 2030 to expand electricity access to 100 percent, which would require annual investments of approximately US$24 billion.

In rural areas, the results from the Universal Access scenario suggest an additional demand for investments in electricity infrastructure expansion of approximately US$117 billion in addition to the Current Path estimates between 2022 and 2030. Urban areas, in contrast, show a cumulative requirement of over US$13 billion in addition to the Current Path scenario estimates.

However, while the requisite investment is large, so are the potential benefits. Figure 29 compares the additional cumulative investments needed in UNDP programme countries with the cumulative GDP benefits under a universal electrification scenario. Notably, expanding access to these countries is costly, and special attention will need to be paid to underserved rural areas in order to achieve universal access. Due to the lack of network effects, rural connections are more costly to build. By 2030, the Universal Access scenario requires much greater investment than it pays back, at least when measured strictly using GDP gains. However, in just two decades, the productivity benefits surpass the cumulative additional investments and pay off nearly three-fold.

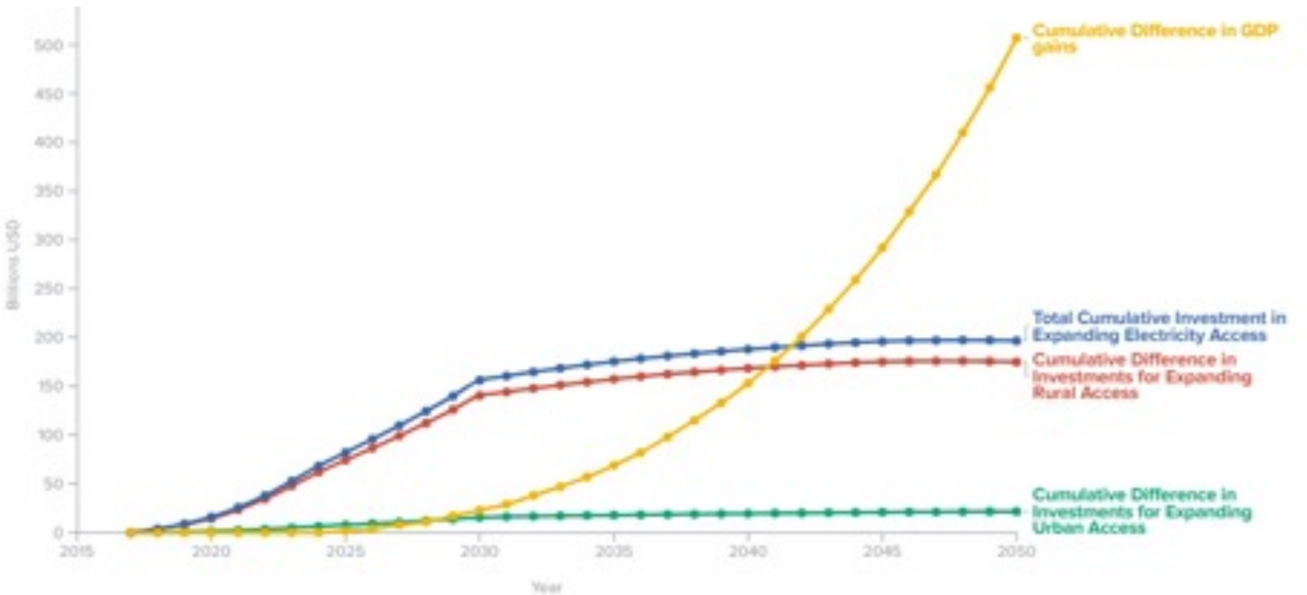

Figure 29: The cumulative additional cost of expanding electricity access in the UNDP Program countries in rural and urban areas, compared with the cumulative GDP benefits of Universal Access in that same group of countries.
Source: IFs 7.87.

How to use the report's findings for strategic and targeted investments

Development financing requires either an economic or financial appraisal to make a case for financing. The findings of this report provide critical inputs for governments and policymakers to make a case for investments in electricity access, such as fostering mini-grids and other sustainable sources of energy estimated as the least-cost option for a specific location.

UNDP has decades of experience in making case for such investments, including through "vertical funds" (funding mechanisms which address specific issues or themes, e.g., the Green Climate Fund). Economic cost-benefit analyses are carried out to assess the impact of a project (e.g., a mini-grid project aiming at increasing electricity access in a particular country) on society's welfare[9].

To carry out this appraisal, in addition to a detailed analysis of the technical feasibility, the estimates available in this report can be used as follows:

1. the estimated cost of providing access to electricity should be interpreted as financial costs and not economic costs. Therefore, these financial costs need to be adjusted to economic costs to reflect the real value or cost for the society (i.e., from market prices to economic (or shadow) prices);

2. discounted benefits from the investments can be calculated by downscaling the benefits estimates to country or project-level sites (e.g., combining estimates on electricity access and poverty alleviation gains/ mortality reduction from increasing access);

3. costs and benefits can be combined to estimate the economic return of an investment aiming at improving electricity access.

[9] In UNDP, the analysis of the projects are carried out in accordance with the Guidelines for the Economic Analysis of Projects of United Nations Development Program (UNDP, 2015). The economic desirability of the investments is determined by computing the economic internal rate of return (EIRR) and economic net present value (NPV) and comparing the EIRR with the assumed discount rate (typically 10% as recommended in UNDP 2015). This approach has been applied to all UNDP projects and secured more than one billion dollars as accredited entity for the Green Climate Fund.

Conclusions

This report applies a systems modeling approach to make a case for investments in areas deprived of electricity. Households in poorer and remote communities are likely going to be left behind from private sector provision of energy access. In this case, this report offers the rationale for public investments on electricity access, highlighting its societal gains such as poverty reduction, improvement in nutrition and several other co-benefits.

The findings demonstrate the benefits of improving and closing the deficit gaps to universal electricity access globally through a collection of intentional interventions and an integrated approach that accounts for synergies and tradeoffs of achieving SDG 7.1.1.

While a scenario focused solely on achieving universal access improves human development, it has even greater effects under the SDG Push+ scenario, which aims at eliminating the deficit in electricity access and improving other SDG outcomes.

Pushing for universal access through SDG interventions can have powerful multi-faceted effects across economic and human development.

The SDG Push+ scenario leads to gains in GDP, GDP per capita, reductions in poverty, and improved health outcomes as a result of reduced use of traditional cookstoves.

Achieving universal access requires significant investments to build out new connections in under-served and rural areas.

Although expanding electricity access has real benefits, it entails significant costs that may require trade-offs in fiscal choices. The study estimates substantial financial needs under both Universal Access and SDG Push+ scenarios, both of which require significant increased investments in rural areas in particular. The realization of universal access by 2030 under the Universal Access scenario will require a cumulative amount of more than US$785 billion, US$441 billion of which will be dedicated to expanding access in rural areas.

Targeting particularly low-access countries is necessary to ensure the no one is left behind.

UNDP is working with partners in a select set of 31 countries characterized by both electricity access deficits and inequities. This group of countries show immense benefits from increased access to electricity. By halving the population without access by 2025 and reaching full electricity access by 2030, GDP per capita in these countries increases between 26 and 39 percent by 2030, and from 185 to 510 percent by 2050. In addition, the population living in extreme poverty is projected to decrease to 33.7 percent and 13.8 percent by 2030 and 2050, respectively. However, major efforts on resources mobilization are needed in order to fulfill the US$24 billion of annual costs for maintenance and construction of electricity connections to provide universal access in these countries by 2030.

Policy dialogue is necessary to find an optimal mix of decisions by governments and other development organizations.

Although there are enormous synergies and benefits in ensuring universal access in electricity, there are also financial constraints in achieving this goal. Therefore, there is a need for engagement to determine the best policies that will fully ensure the realization of the benefits of access to electricity. This may require revisiting priority areas where trade-offs will be required regarding areas of spending.

Findings of this report can be further combined for strategic and targeted policy support.

Member States can jointly use the results of this report with other insights generated by UNDP and partners[10] on energy access, ability to pay and forecasts on electricity access to fully unleash the power of data and analytics. This can be leveraged to support advocacy for targeted support in the form of i) public financing, focusing those furthest behind including economic and financial appraisals, and ii) private financing, tailored to the ones with lower affordability constraints as critical inputs for financial appraisals.

[10] https://data.undp.org/achieving-universal-electricity-access/

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Appendix 1

International Futures and Infrastructure

International Futures (IFs) is a free, open-source quantitative modelling tool for thinking about long-term futures. IFs helps users to understand dynamics within and across systems at a global, national and even sub-national scale. It integrates forecasts across different sub-models, including population, agriculture, education, economy, energy, socio-political, environment, technology, infrastructure and health.

These sub-models are dynamically connected, so the model simulates how changes in one system leads to changes across all other systems. Consequently, IFs endogenizes more relationships from a broader range of key global systems than any other integrated assessment model (Hughes, 2016). Figure 30 illustrates a simplified representation of linkages within and across these sub-models.

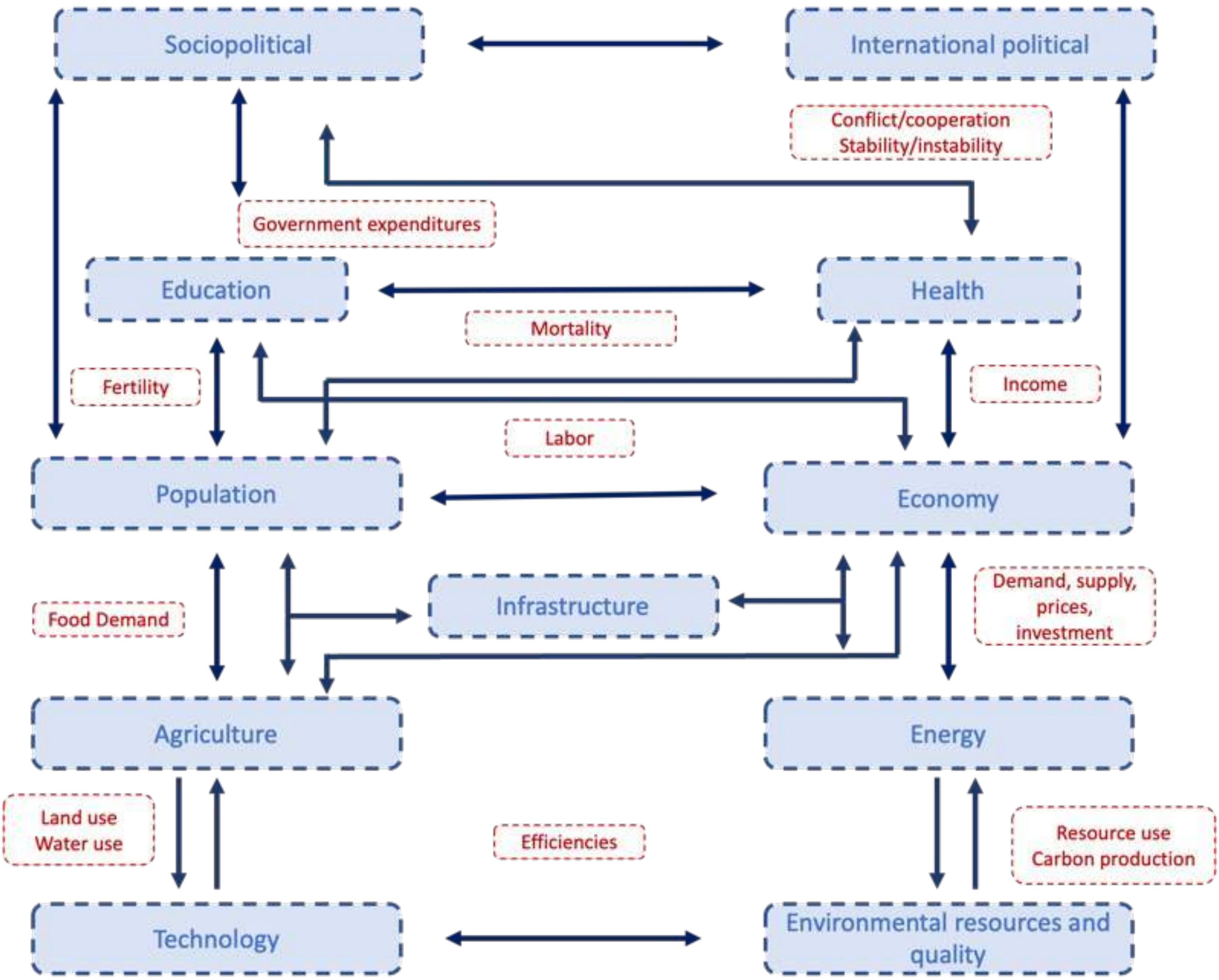

Figure 30: Stylized representation of the International Futures (IFs) modelling system.

IFs provides three main elements for analysis: historical data analysis (longitudinal and cross-sectional) of over 5,000 series; alternative scenario development (if-then statements about the future); and understanding the kinds of leverage various agent-classes may have in shaping the future.

While predicting human-centric systemic changes is a complex task, IFs forecasts rely on informed extensions of current trends built on our current knowledge of development patterns. Although the Current Path scenario generally demonstrates continuity with historical patterns, it provides a structure that generates a wide range of non-linear forecasts rather than simple linear extrapolation of historical data. It also assumes no major paradigm shifts, policy changes or low-probability, high-impact events.

Infrastructure in IFs

The IFs infrastructure model consists of two types of infrastructure: 'core' and 'other' infrastructure. While core infrastructure represents the explicit forms of infrastructure including roads, electricity, improved water and sanitation and ICT, the other forms of infrastructure represent those not explicitly modelled in IFs, which is a choice reflective of the availability of historical data. Below is a summary of how electricity access is estimated and forecast in IFs. See Rothman et al. (2014) for more detailed information on the infrastructure model.

For all the constituent elements of the model, IFs follows a particular sequence of steps towards forecasting each year:

1. Estimating the expected levels of infrastructure;
2. Translating the expected levels of infrastructure into financial requirements;
3. Balancing the financial requirements with available resources;
4. Forecasting the actual levels of attainable infrastructure; and
5. Estimating the social, economic and environmental impacts of attainable infrastructure.

The dominant relations are those that determine the expected levels of infrastructure stocks and access, spending on infrastructure, and impacts of infrastructure on health and productivity. The expected levels of infrastructure stocks and access are influenced by socioeconomic factors related to population, economic activity, governance and educational attainment. There are also various path dependencies that supplement these basic relationships, reflecting the considerable inertia in infrastructure development.

Here, we focus on the energy/electricity sector of the model, which is fully integrated with the larger IFs system and provides forecasts of critical variables like energy demand, energy production by primary type, poverty, and governance character. The electricity sub-model comprises estimates of three components:

- Consumption
- Production
- Signaling that drives the demand for additional generation capacity in the case of a gap between consumption and production.

Figure 31 provides a stylized overview of the electricity sub-model. For the purpose of this project, we focus on the consumption component together with the forward effects along social, economic and health dimensions.

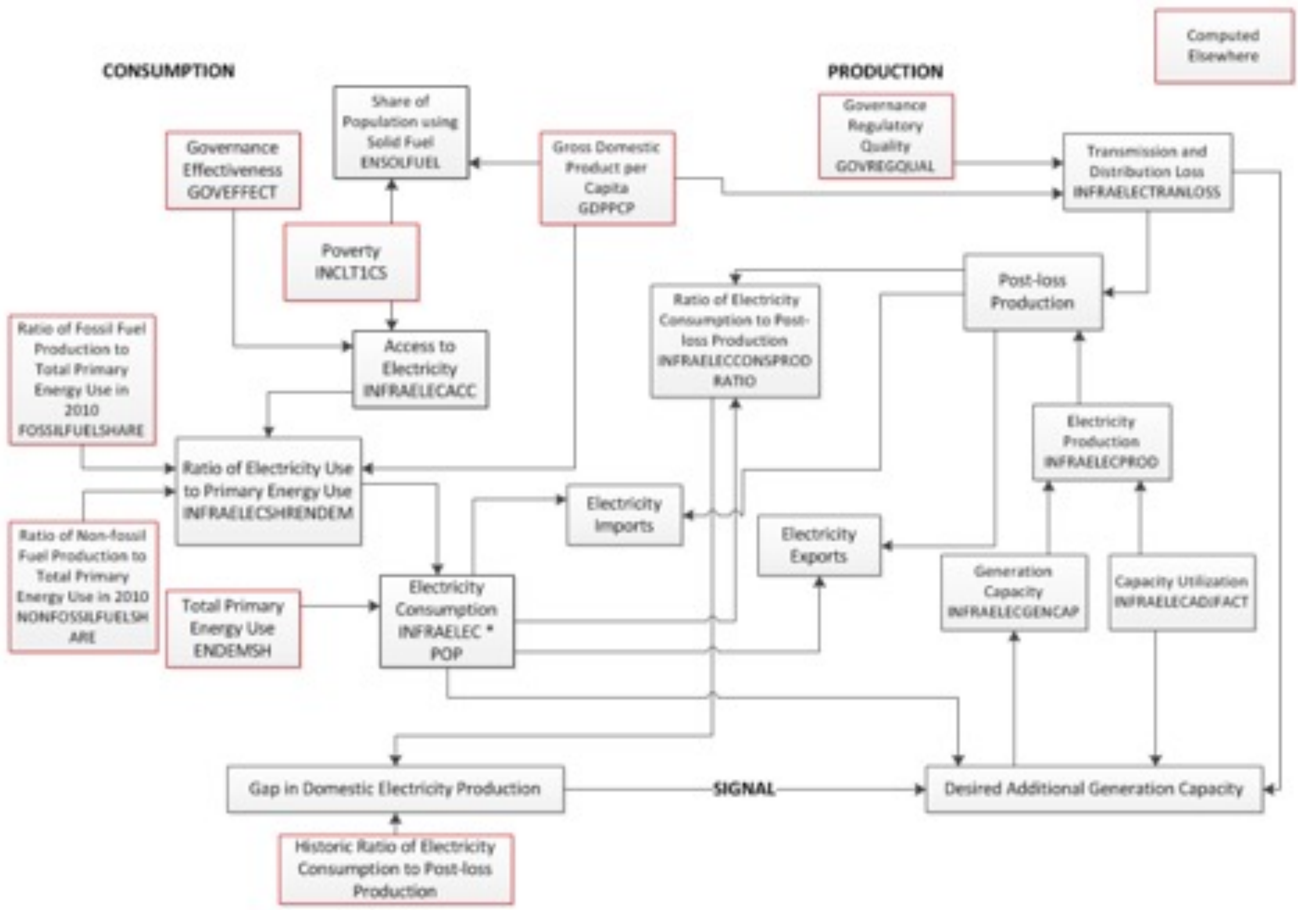

Figure 31: Stylized representation of the electricity sub-model in IFs.

Infrastructure spending in IFs

Like other infrastructure models within IFs, the cost of electricity access is calculated using estimates for costs of maintenance and for new construction, following the methodology used by Fay (2001) and Fay and Yepes (2003). Like many other studies, IFs holds unit costs constant across countries, and time, and for different levels of infrastructure. This is the approach used by most other modeling efforts (Rothman et al., 2014) and can help provide a broad understanding of costs at the global level and how different countries and geographies may face different financial challenges in expanding electricity access. However, it should not be used to identify country-specific investment needs.

First, the cost of maintenance or renewal of existing infrastructure is determined as a percentage of the 'dollar value' of the existing infrastructure at the start of the year multiplied by the infrastructure's unit cost. Second, the cost of new construction is calculated as the expected net change in the amount of physical infrastructure over the year multiplied by the same unit cost. Here, the annual maintenance/renewal percentages and unit costs are the key assumptions in the estimates of the financial requirements.

As noted, IFs assumes temporally fixed and geographically universal unit costs by infrastructure (one cost per infrastructure type) for reasons including lack of data needed to specify variable costs and the following complications in analysis over time. These unit costs that fall under the electricity infrastructure sub-module are summarized in Table 1.

Infrastructure type	Unit	Unit cost (US$)	Average lifetime (years)	Equivalent annual recurrent cost (% of stock value)	Public share
Electricity connection – rural	Per connection	1,750	40	1.73	80
Electricity connection – urban	Per connection	850	40	1.73	80
Electricity generation capacity	Per kilowatt of added capacity	1,900	40	1.73	80

Table 1: Unit costs, average lifetime, equivalent annual recurrent cost and public shares of funding for electricity infrastructure in IFs.

The following procedure is adopted for initializing variables associated with infrastructure spending. It is important to note that IFs does not use actual historical data on spending, but rather, estimates spending in the first year of the model based on data on the stocks and access to infrastructure.

- IFs assumes that the amount of infrastructure requiring maintenance in the base year is given by the level of infrastructure in the previous year times a factor based on the lifetime of the infrastructure. The amount of newly constructed infrastructure is the difference between the level of infrastructure in the base year and the previous year.
- Total spending on maintenance and new construction are represented by variables, 'INFRAINVESTMAINT' and 'INFRAINVESTNEW', respectively. If the amount of newly constructed infrastructure is less than or equal to zero, spending on that type of infrastructure is also set to zero.
- Given that real-world funding comes from both public and private sources for development of (electricity) infrastructure, IFs separates the funding requirement into public and private components.
- The sum of estimated public spending on maintenance and new construction, across all types of core infrastructure (including electricity) provides an initial estimate of government consumption for core infrastructure, represented by 'GDS' (Government spending, Infrastructure).
- If, in the first year of budgeting process, the total estimated government consumption on core infrastructure is reduced: 'INFRACOSTADJFAC', an infrastructure cost adjustment factor is calculated as the ratio of final to initial value of GDS (Infrastructure). Its value is also used to adjust infrastructure spending for future years.
- All variables pertinent to investment requirements for a particular form of infrastructure are multiplied with the cost adjustment factor to calculate their final values.

Detailed documentation on the working of the IFs infrastructure model is also available in Pardee's Wiki webpage[1] as well as the 'Patterns of Potential Human Progress'[2], which is Pardee's flagship publication wherein each volume considers a key aspect of human development from poverty, health, education and infrastructure to governance.

[1] https://pardeewiki.du.edu/index.php?title=Infrastructure
[2] https://korbel.du.edu/pardee/publications/pphp

Appendix 2

Interventions under the Universal Access and SDG Push+ scenarios

This appendix features the full list of scenario interventions made for the scenarios used in this report.

The Current Path scenario is the baseline case in International Futures (Ifs) and does not include any interventions or adjustments once the data from UNDP have been imported.

The Universal Access scenario models global achievement of universal access to electricity by the Sustainable Development Goal (SDG) horizon deadline of 2030. It includes no other interventions.

Finally, the SDG Push+ scenario combines the Universal Access scenario with elements of the SDG Push, a scenario created to assess the effects of a strong, global and integrated push toward achievement of the SDGs. It was first introduced in 2021 (Abidoye et al., 2021; Hughes, Hanna, Bohl, et al., 2021) and updated in 2022. The original interventions for the SDG Push scenario are categorized according to four pillars of COVID-19 recovery support outlined by the United Nations Development Programme (UNDP, 2020). For this report, we take the updated SDG Push scenario and add interventions, pushing the achievement of universal electricity access by 2030.

Note that the intervention descriptions specify the parameterizations used to construct the scenarios in the IFs model. These parameterized interventions do not override the values of variables, but rather affect underlying endogenous variable calculations within IFs. The actual change in the outcome variable may be greater than the parameterization, in cases where synergies occur across interventions, or it may be less than the parameterization, in the case of trade-offs.

Moreover, interventions are designed to simulate the successful implementation of policies designed to improve outcomes in a particular area. This is because the specific policy measures to improve outcomes differ significantly across and even within countries. For instance, the scenario does not model school vouchers, improved teacher training, or building new schools. Instead, it models an increase in school enrollment, which may result from any of those or other policies.

Intervention	Parameterization
UNIVERSAL ACCESS	
Electricity access target value and year	Targets a 100 percent electricity access rate for the world by 2030.
SDG PUSH: SOCIAL PROTECTION	
Calorie allocation	Improves diets via additional calorie allocation to those most in need.
Cookstoves	Increases numbers of improved modern cookstoves by 500 million units over a 12-year period.
Public health spending	A targeted doubling of the public health budget.
Welfare transfers	Globally increases welfare transfers from governments to households for unskilled workers by 50% in a 13-year period, and doubles government to household welfare transfers for unskilled workers in the WB low-income group over a 13-year period.
Safe water access	Increases percentage of population with access to piped water sources by 20% and increases percentage of population with access to other improved water sources by 20% over 10 years.
Sanitation access	Increases percentage of population with access to improved sanitation sources by 20% and increased percentage of population with access to shared sanitation sources by 20% over 10 years.
Gender wage parity	Ratio of female to male wages by country reaches 1 by 2050 (simulates all countries reaching wage parity over 30 years; ratio left alone if it already exceeds 1).
SDG PUSH: GOVERNANCE	
Government participation	The scenario simulates improved governance participation by 30% over a 13-year period via the polity project index.
Government effectiveness	Improves governance effectiveness (quality) by 30% over a 13-year period - World Bank's governance effectiveness index.
Government transparency	Reduces government corruption by 30% over 15-year period - Transparency International index.
SDG PUSH: GREEN ECONOMY	
Water demand	Is reduced by 30% over 32 years globally.
Electricity loss	Electricity transmission and distribution loss (as a percent of production) drops by 40% over 13 years globally.
Urban air pollution	Reduction of particulate matter in urban air (urban air pollution) of 30% over 35 years globally.
Reforestation	Increase in forested land area – simulating the impact of reforestation globally

Intervention	Parameterization
Carbon tax	Is introduced at $200 per tonne over 13 years for OECD countries and at $50 per tonne for non-OECD countries in a 13-year period.
Energy intensity	Energy demand per unit of GDP decreases by 1.4% annually, slowly declining to a rate of 1.3% by 2050, reducing the energy intensity of the economy. Energy demand in OECD countries drops a further 10% over 68 years, relative to endogenous calculation. Energy demand in non-OECD countries drops a further 38% over 78 years, relative to endogenous calculation.
Cleaner energy production	Simulates increased cleaner and more sustainable energy production sources by: • annual rate of energy production cost reduction for coal set to 0.002, reflecting recognition of the external costs of coal in its true total cost; • annual rate of energy production cost reduction for nuclear set at 0.0035, assuming new and safer nuclear technologies will continue to emerge; • annual rate of energy production cost reduction for other renewable energy set to 0.01 (continued encouragement of technological progress).
Agriculture loss	World agricultural production loss of crops, meat, ocean fish catch and aquaculture is reduced by 30% over 30 years. World agricultural transportation and processing loss is reduced by 30% over 30 years. World agricultural food loss at the consumption stage is reduced by 30% over 30 years.
Agricultural yields	High-income economies increase their agricultural yields by 20% over 15 years. Upper-middle-income economies increase their agricultural yields by 20% over 15 years. Lower-middle-income economies increase their agricultural yields by 50% over 50 years. Low-income economies double their agricultural yields over 50 years. This intervention results in yields that follow historical patterns. This, in combination with improved diets/calories intervention (incentive), results in yields that grow more rapidly.
Lowered fish catch	Countries currently catching more than 2 mmt of fish annually reduce their fish catch by 25% over 50 years.

Intervention	Parameterization
SDG PUSH: DIGITAL DISRUPTION/INNOVATION	
Lower secondary graduation	Lower secondary graduation rates are tripled in a 12-year period starting in 2021. Targets a 5% annual increase in lower secondary graduation starting in 2021.
Science and engineering graduates	The rate of science and engineering graduates is increased by 10 percentage points over a 13-year period.
Education spending	Targets a doubling of budgetary allocation to education.
Research and development spending	Targets a doubling of budgetary allocation to research and development.
Infrastructure spending	Targets a doubling of budgetary allocation to infrastructure.
Private research and development spending	Private research and development spending as a percent of GDP increases by 20% over a 13-year period.
Broadband access	Access to broadband grows by 50% over 19 years.
Mobile access	Access to mobile broadband grows by 50% over 19 years.
Informal employment	The informal share of the labour force decreases by 20% over 10 years.

Table 2: Full list of scenario interventions under the SDG Push+ scenario used in this report.

Appendix 3

Universal Electrification Cost Estimates from the Literature

Source	Region	Investment projections under the Universal Access scenario by 2030
Chirambo, 2018	Africa	Investment estimates of US$8 billion per year and additional US$41–51 billion per year
Narula, Nagai and Pachauri, 2012	South Asia (rural)	US$69.5 million in 2020, which increases to US$81 million in 2030; $60 billion in cumulative amount from 2012 to 2030
Pachauri et al., 2013	World	US$65–86 billion per year
Falchetta et al., 2020	East Africa	Cumulative Investment of US$57–110 billion; $5.6 billion per year on average between 2016 and 2030
Dagnachew et el., 2017	Sub-Saharan Africa	US$22–2,500 billion varying on the level of consumption
Lucas, Dagnachew and Hof, 2017	World	Cumulative 2010–2030 investment of US$480–970 billion, or US$24–49 billion per year
van Ruijven, Schers and van Vuuren, 2012	Developing countries (rural)	Cumulative investment of US$477–868 billion (additional US$238-400 billion in addition to the business-as-usual scenario between 2010 and 2030)
	Brazil	Business-as-usual scenario projects US$36–63 billion cumulatively and additional US$1–1.7 billion per year for universal access
	Latin America	Business-as-usual scenario projects US$37–67 billion cumulatively + additional US$3.3–5.4 billion per year for universal access
	India	Cumulative investment of US$96–105 billion
	Indonesia	Cumulative investment of US$30–59 billion
	Other Asian countries	Cumulative investment of US$66–126 billion.
	South Africa	Cumulative investment of US$12–19 billion
	Sub-Saharan Africa	Cumulative investment of US$131–226 billion

Source	Region	Investment projections under the Universal Access scenario by 2030
Cozzi et al., 2022	World	Annual investment between 2022 and 2030 of US$30 billion
	Sub-Saharan Africa	US$19.6 billion (2021, MER)
	Developing Asia	US$8 billion (2021, MER)
	Rest of the world	US$2.6 billion (2021, MER)
IEA, UNDP and IRENA, 2018	World	Annual investment of US$52 billion in electricity generation and infrastructure

Table 3: Estimated costs for universal electrification – the literature.

Appendix 4

Summary of the Effects on Development Indicators across Scenarios for UNDP Programme countries

	2030			2050		
Development indicator	CP	UA	SDG P+	CP	UA	SDG P+
Cumulative GDP (MER, in US$ billion)	22,988	23,053	23,361	101,391	105,506	131,651
Poverty head-count (at US$1.90/day, in million)	396.2	394.4	353.4	279.6	248.6	96.0
Poverty rate (at U$1.90/day, in %)	33.8	33.7	30.2	15.4	13.8	5.4
Female poverty headcount (at US$1.90/day, in million)	199	198.1	177.5	140.3	124.9	48.25
Households using traditional cookstoves (in million)	132.9	51.5	0.0	131.1	66.47	0
Households using traditional cookstoves (% of total)	66.8	25.9	0.0	35.87	18.13	0

Table 4: 31 UNDP Focus countries (effects on development indicators under the Current Path (CP), Universal Access (UA) and SDG Push+ (SDGP+) scenarios).
Source: IFs 7.87.

sdgintegration.undp.org