



HOW COMPUTERS CAN HELP CREATE SOLAR-POWERED COMMUNITIES

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YOUNG REVIEWERS:



ALBERT

AGE: 11



PRATHISH

AGE: 12

Around 700 million people around the world do not have any electricity, and there are many more that only have access to electricity some of the time. Many of these people live in places that are hard to reach, and solar (photovoltaic) panels are a good way for them to get electricity. However, installing new solar panels can be expensive. Knowing how much electricity people need, and how much they might need in the future, is important to make sure that the right number of solar panels are installed, and in the right places, so that nobody goes without electricity. In this article, we discuss how openly available computer programs can help us to work out the best way for these communities to receive electricity.

NATIONAL GRID

A much larger network that connects people who need electricity to electricity sources.

Unlike a mini-grid, a national grid is large and connects together a whole country.

MINI-GRID

A network which connects a source of electricity (like solar power) to users (like houses, businesses and industries) using cables. Mini-grids usually generate all of their own electricity.

Figure 1

A schematic of a solar mini-grid. Photovoltaic panels (in the **middle** of the picture) generate electricity from the sun. Batteries store this electricity before distributing it when it's needed through a network of cables (shown in orange) throughout the community. Mini-grids can help power hospitals (on the **right**) and schools (on the **left**) to help with the United Nations' Sustainable Development Goals (SDGs) 3 and 4.

Mini-grids can provide electricity for people's homes (helping with SDG 7), and can provide the electricity farmers need for watering and storing their crops (helping with SDG 2) [2].

WHAT IS A SOLAR MINI-GRID?

You are likely reading this article on a screen. It might be on a tablet, phone, or laptop, but it is still a screen that needs electricity. This electricity either comes from a battery that you charged earlier, or from an outlet socket. But where does the electricity in your outlet socket come from? It is very likely that the electricity that's powering your screen was generated far away and traveled through a network of cables, known as a **national grid**, before reaching you. Over 99% of the world's population gets their electricity this way, but there are still over 670 million people without access to electricity throughout the world, with over 500 million of them living in Sub-Saharan Africa [1].

One way that people in remote places can access electricity is by using a **mini-grid**. A mini-grid is a small version of the national grid: it connects a source of electricity, like solar panels, to people who need it in houses, businesses, or public spaces like libraries or street lights. Whereas a national grid might supply a whole country, a mini-grid is a lot smaller and may supply around a few hundred people with electricity. Mini-grids can also operate in remote places that do not have a connection to the national grid. A schematic of a mini-grid network is shown in **Figure 1**. You can see potential users of electricity such as schools, farms, homes, and hospitals.

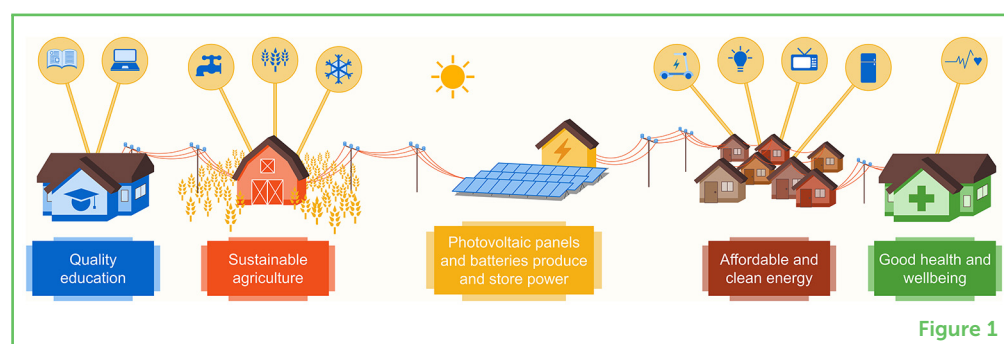


Figure 1

Many people without access to electricity live in very sunny places where using **solar panels** is often the cheapest way of producing electricity. Solar panels that produce electricity are called **photovoltaic** (PV): they take in energy from the sun (the "photo" part) and produce electricity (the "voltaic" part). Mini-grids can be powered by lots of different technologies. Mini-grids can use generators which burn fossil fuels (such as diesel) or can use renewable technologies like **solar panels**, **wind turbines**, or hydropower. A **solar mini-grid** is a mini-grid which is mostly powered through solar panels.

Renewable electricity is not always available when people need it. For example, solar panels rely on the sun to generate electricity, and so they do not work at night! Because people may want electricity when it is not being generated, mini-grids normally have some way to

PHOTOVOLTAIC

Photovoltaic panels are solar panels that convert sunlight (photo-) into electricity (voltaic). This makes them different from solar panels that heat up water.

SOLAR MINI-GRID

A mini-grid which gets most of its electricity from **solar panels**. It may use batteries or a diesel generator as a backup source of electricity.

store electricity. Usually, mini-grids store electricity for later in electric batteries. This lets people use electricity when they want it, even when it is not being generated.

In some countries, people may already have access to electricity through their national grid. However, the grid may not always be able to supply everyone with as much electricity as they want. This can be for many reasons: sometimes old parts of the network break down, and sometimes there are simply more people who want electricity than the national grid can provide. Using batteries means that mini-grids can provide electricity around the clock (In places where the weather is less predictable, it might not be very sunny for several days in a row. In these places, a mini-grid might need more batteries so that it can store enough electricity to last for several days). Mini-grids can therefore provide communities with electricity in places where the national grid cannot provide enough electricity for everyone. This can ensure houses have all of the electricity that they need, help businesses to grow, and make sure that essential activities (like schools and hospitals) can function properly.

WHY DO SOLAR MINI-GRIDS MATTER?

Around the world, most people who do not have access to electricity live in rural areas. **Figure 2** shows a map of Sub-Saharan Africa (the region of Africa which is south of the Sahara Desert). The map on the left (**Figure 2A**) shows the extra people (some of whom have not been born yet) who will need access to electricity by 2035 (This is in addition to those who already do not have access today!). These rural areas are often remote, making it difficult for the national grid to reach them. In the map on the right (**Figure 2B**), the areas in blue are those where the cheapest way to provide electricity is through solar power. Areas that are close enough to the national grid for the grid to be the

Figure 2

Maps of Sub-Saharan Africa: **(A)** the additional number of people who will need access to electricity by 2035; and **(B)** the best way of supplying those people with electricity, whether using solar PV systems (in blue), diesel-powered systems (in pink) or extending the national grid (in purple). 25% of the new population's electricity is met by solar PV panels, 26% by diesel systems, and 49% by the national grid. Reproduced under CC-by 4.0 [3].

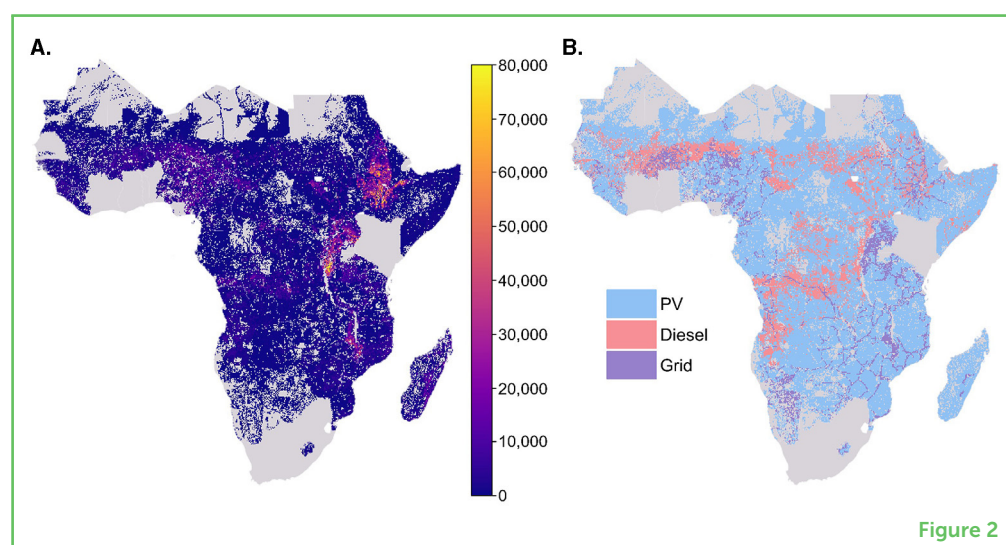


Figure 2

SDG

The “Sustainable Development Goals (SDGs)” are targets for improving people’s lives around the world by 2030 [2]. They cover things like eliminating poverty, supporting gender equality, and protecting natural habitats.

cheapest way to provide electricity are colored in purple, and areas where diesel generators are the cheapest are colored pink. Around half the people getting new access to electricity by 2035 live in the areas colored purple, and so will get connected to the national grid. In most of the remaining areas, solar mini-grids are the cheapest option.

Providing electricity through a mini-grid can help improve a community’s quality of life beyond just providing electricity. The United Nations set out a series of goals to be achieved by 2030, called the **Sustainable Development Goals** (SDGs) [2], which set targets for human development such as climate action, reducing poverty, and improving education and healthcare. Electricity from a solar mini-grid can have impacts across some of these other SDGs beyond providing electricity (Figure 1). For example, providing electricity for schools helps with SDG 4, which focuses on “quality education” and “lifelong learning”; providing electricity for agriculture can help achieve “food security”, the aim of SDG 2; and providing electricity for hospitals and health centers helps with SDG 3, which focuses on “healthy lives” and “wellbeing”.

Replacing existing energy sources with a solar mini-grid can bring additional benefits. Communities that do not have electricity often use wood or charcoal fires for cooking. These fires produce harmful smoke which can damage people’s lungs. Some people in these communities could use electricity rather than firewood or charcoal to cook meals which can reduce pollution and help improve their health. Some people without electricity use kerosene for lighting (Kerosene is a fossil fuel used in old-fashioned lamps as well as airplanes). Burning kerosene releases dangerous fumes. A solar mini-grid can provide clean electricity for lighting homes to make people more comfortable, as well as make it easier to study, work, and spend time together.

HOW CAN COMPUTERS HELP?

Before installing a mini-grid, there are lots of questions that need answering. For example, should batteries or diesel generators be used to provide electricity through the night? Or how many of each component should be installed? Choosing the right technology can depend on lots of factors, such as how sunny a place is, how much electricity people need, and when they need it. Often, the best solution might even be a mix of different technologies to make sure that everyone has enough electricity when they need it.

Although solar electricity is becoming cheaper and cheaper, mini-grids are still expensive for the communities who need them. This is because the money needed for the equipment must be paid for over many years. It is important to design the mini-grid just right so that it meets the community’s needs, helps their economy to grow, and

COMPUTER MODEL

A piece of software that runs on a computer and which helps answer questions about something in the real world without needing to build anything or carry out experiments.

Figure 3

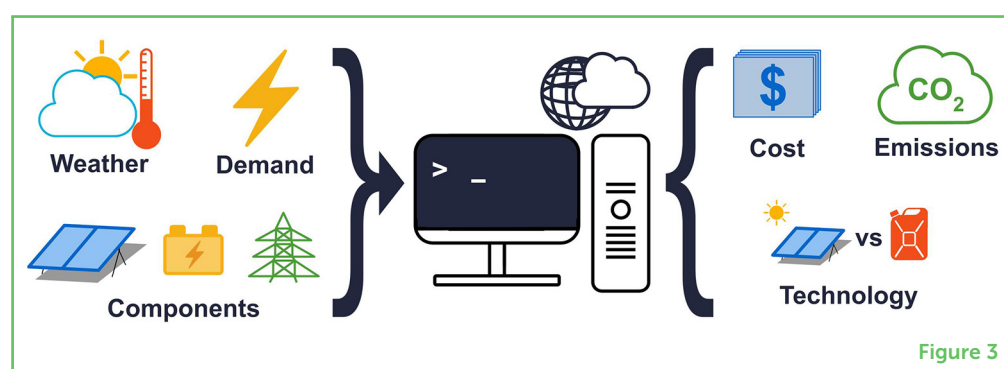
An infographic showing how computer models can help researchers and members of the public to answer questions about mini-grids. Computer models take in information about the community that needs investigating and output useful results. Information that goes into the models might include the weather (how sunny it is), the electricity needs (or “demands”) of the community, and information about the various pieces that will make up the mini-grid. Models can then calculate things like the costs and carbon footprint of mini-grids, as well as help answer questions like whether solar or diesel power is the best.

NGO

A “non-governmental organization” aims to help people first and make money second. You may have heard of: [WaterAid](#), [Greenpeace](#), or [Médecins Sans Frontières](#).

is financially sustainable. **Computer models** can help to design the right system.

Governments, **NGOs**, companies, and anyone else who might be interested in building a mini-grid will want answers to these questions before they start building. Computers with specialist software can help us answer these questions because they can let us explore lots of technical questions quickly (like estimating how much electricity will be generated by a solar panel). **Figure 3** shows some of the input information needed to run these computer models and some of the information that comes out.



Mini-grids are not the best choice to get power to everyone in the world. Some countries have more sun than others and may have lots of people living in rural places without power. In these countries, a solar mini-grid is a good solution. In other countries, a different type of renewable energy might be cheaper, like wind power. Using a computer model can help us to work out whether a solar mini-grid is likely to work well in a given place, or whether something else might work better, like a wind turbine.

FINAL THOUGHTS

Solar mini-grids can benefit communities by providing clean and affordable electricity (one of the United Nations’ SDGs) as well as other benefits like powering water pumps for drinking water or irrigating crops. By providing people with electricity, mini-grids can help improve people’s quality of life, power schools and hospitals, and reduce pollution released by burning fossil fuels. Computer models are a useful tool in determining whether mini-grids are the right solution for communities and how best to go about installing them.

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YOUNG REVIEWERS

ALBERT, AGE: 11

My name is Albert, and I am 11 years old. I recently graduated from elementary school with the President's Award for Academic Excellence. I love learning, especially science and math, and earned straight A's. In my free time, I enjoy reading, playing volleyball, tennis, and soccer, and staying active with team sports. I also love music and play both the drums and piano. I am excited for middle school and look forward to new challenges and opportunities to grow and learn.

PRATHISH, AGE: 12

Meet Prathish, the guy who is practically glued to his tablet, constantly bingeing fun and science videos. When he is not deep-diving into digital worlds, he is lost in an adventurous book or, more likely, out on the cricket field – he is a fantastic athlete! This science lover dreams of traveling the world, but do not let his worldly ambitions fool you; just show him a vending machine, and he will instantly become a gleeful kid again!

AUTHORS

BENEDICT WINCHESTER

I was born in America but grew up in the United Kingdom. I really enjoy using computers to find the best way to use technologies like solar panels to help improve people lives. I like to look at how solar energy can help with problems like providing clean drinking water and helping farmers with their crops. When I am not at work, I spend my time driving my home (a boat!) around London.
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HAMISH BEATH

I am from the UK and have always been interested in computers and how they work. While at university, I became interested in how energy is important for so many other things and decided I wanted to work on this in my job. My research looks at how we can expand access to green energy, and it considers things like how we could change the way we live to reduce our impacts on climate change. In my free time I like to swim (ideally in the sea) and go cycling.



**PALOMA ORTEGA-ARRIAGA**

I completed my PhD at Imperial College London, specializing in improving energy access with solar energy in rural houses, schools, and clinics. I have been interested in solar energy since I wrote my master's thesis on the potential of meeting the household power demand of my sunny hometown, La Paz, BCS, in Mexico, using solar and battery systems. In my free time, I love to spend time with my friends and family, go swimming or diving, or read a book by the beach!

**PHILIP SANDWELL**

I am interested in how we can use sustainable energy to help improve people's lives, especially in developing countries and where people did not have access to electricity sustainable energy before. I want to make sure it is affordable and as environmentally friendly as possible, so that everyone can benefit and we can help to tackle climate change. I completed my PhD at Imperial College London and now research how to provide sustainable energy to displaced people such as refugees. In my spare time I like to read and play a sport called Ultimate Frisbee!

**CHRISTOS N. MARKIDES**

I am a professor of clean energy technologies. For over 20 years, I have had an interest in technologies that can harness the energy of the sun and have worked on technologies that produce electricity, heat, or cooling for people or businesses, as well as clean drinking water and solar fuels for vehicles. Solar energy is spread out across the world, which can be challenging but also means that everyone can have access with the right technologies. The transition that is taking place toward renewable energy is really impressive and I hope it continues!

**JENNY NELSON**

I am a professor of physics and have worked on solar energy conversion for more than 30 years. I am interested in understanding new materials and designs of solar cells as well as the application of solar cells to provide electricity where it is needed without increasing greenhouse gas emissions. I think that tackling the causes and consequences of climate change is the greatest priority facing scientists today. When not worrying about that, I go swimming. *jenny.nelson@imperial.ac.uk