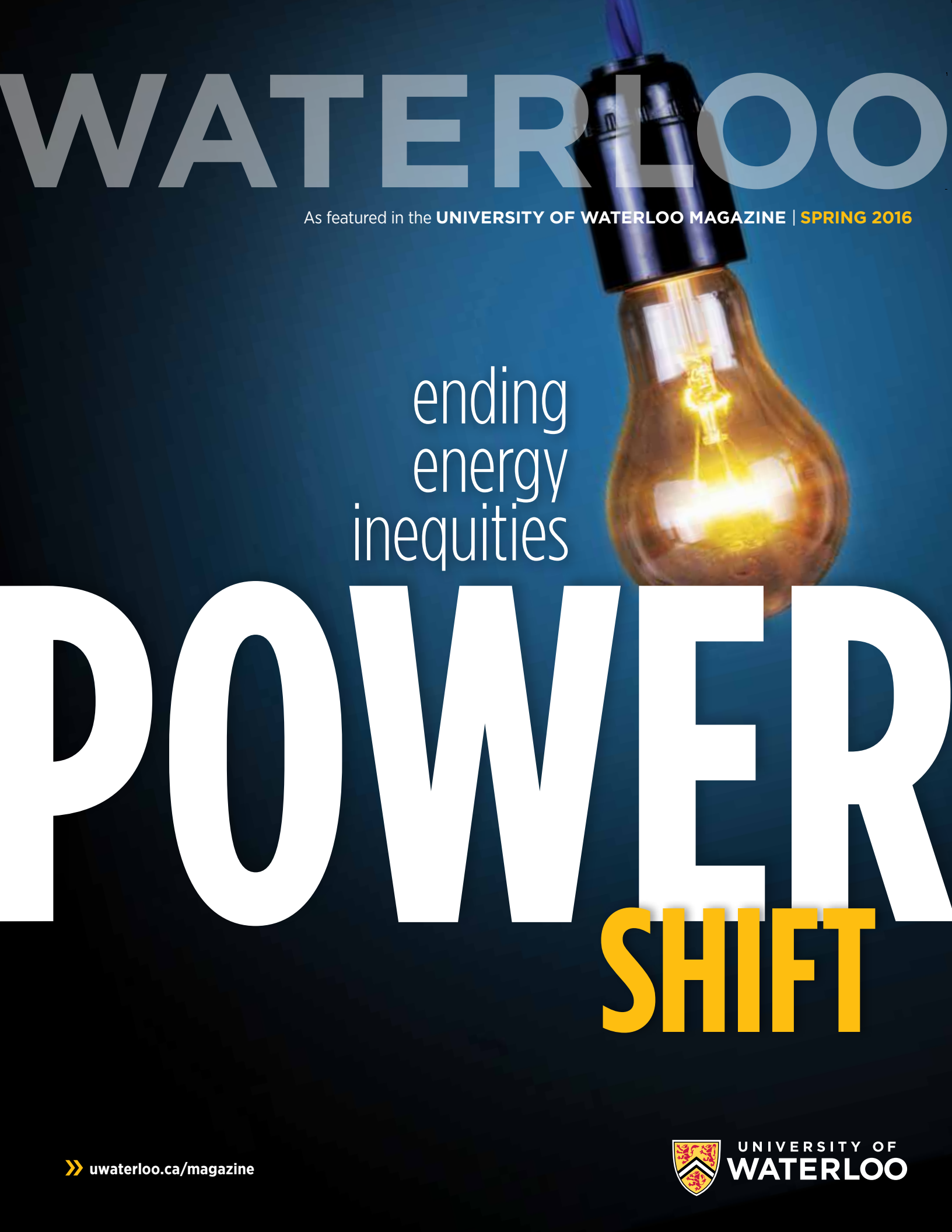

WATERLOO

As featured in the **UNIVERSITY OF WATERLOO MAGAZINE** | **SPRING 2016**

ending
energy
inequities

POWER SHIFT

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UNIVERSITY OF WATERLOO

DRIVING A REVOLUTION IN AFFORDABLE ENERGY FOR HUMANITY

More than a billion people with no access to modern electricity is a global injustice. Change will require a massive, co-ordinated investment of research, resources and resolve

power to the p

To truly grasp what it means to be energy poor — and to understand vast global disparities in access to electricity — consider this simple analogy.

1.5 billion people in the world have, say, a light bulb and a washing machine. Another 4 billion have only the light bulb. *And, 1.5 billion have neither.*

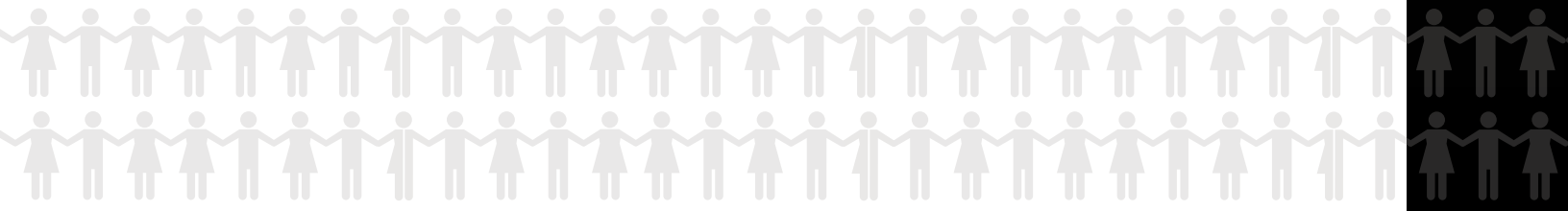
Factor in the lack of access to modern fuels such as gas, and fully a third of humanity — that's roughly 2.5 billion people — live on the margins of society.

It's an enormous global imbalance, and one that is not confined to the developing world. Many remote indigenous communities right here in Canada are also energy poor because they rely on diesel fuel that's trucked or flown in at exorbitant prices.

Experts say the absence of electricity has an enormous impact on economic productivity, health, education, and social and cultural development. It's one of the main obstacles to human development, touching lives in ways that we in the West can scarcely imagine.

To that end, Jatin Nathwani, executive director of the Waterloo Institute for Sustainable Energy (WISE), launched Affordable Energy for Humanity (AE4H), a global coalition of more than 100 people from 27 institutions in 12 countries — including Waterloo's counterpart in Germany, the Karlsruhe Institute for Technology, and leading researchers at institutions including Cambridge, Oxford and Berkeley.

AE4H harnesses global muscle and brainpower to transform the lives of those living without electricity. **»**



1 in **5**
people

have enough electricity to power a light bulb and a washing machine

eople

3 in **5**
people

have only enough electricity to power a light bulb

A question of balance

Wake up, flip on the lights, run the dishwasher, throw a load of laundry in the dryer. Just a normal day, right? Wrong. For much of the world, reliable electricity is — for now — just a pipe dream.

1 in 5 people have **NEITHER**

PHOTO: THINKSTOCK

> If you take the view that energy is a fundamental enabler of human betterment — one that is intricately linked to quality of life — access to it remains a very powerful driver for high levels of achievement.

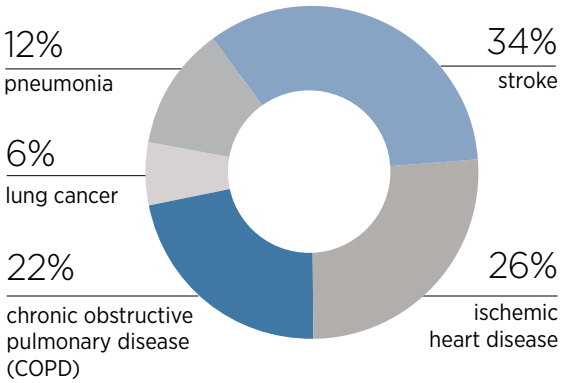
JATIN NATHWANI, executive director of the Waterloo Institute for Sustainable Energy, has built a global coalition known as Affordable Energy for Humanity (AE4H) to address energy poverty.

HOUSEHOLD AIR POLLUTION AND HEALTH

Energy poverty can have deadly consequences

Approximately **3 BILLION people** cook and heat their homes using open fires and simple stoves burning biomass (wood, animal dung, crop waste) and coal.

4.3 MILLION people die prematurely each year from illness attributable to household air pollution caused by use of solid fuels for cooking. These deaths include:



ENERGY POVERTY: DESTROYING PRODUCTIVITY AND POTENTIAL

"These people are essentially the poorest in the world, and when night falls, it is pretty harsh," says Nathwani, who is also a professor of civil and environmental engineering at Waterloo.

"If you take the view that energy is a fundamental enabler of human betterment — one that is intricately linked to quality of life — access to it remains a very powerful driver for high levels of achievement."

Zimbabwean Chiedza Mazaiwana agrees. As an advocacy officer for AE4H-founding partner Practical Action — a non-governmental organization based in the United Kingdom — she says the lack of affordable, accessible electricity destroys the productivity and potential of millions.

Rural African women, in particular, walk for hours each day — sometimes 10 kilometres or more — to collect firewood for cooking and washing. When darkness falls, chores are done by candlelight, kerosene lamp, or the dying embers of an indoor cooking fire.

Lack of electricity impacts all aspects of life. Women give birth in the dark. Fumes from cooking lead to health problems and premature death. Children can't study at night. There is no storage for vaccines or other medicines, no light or electrical equipment for health care workers. Crops must be watered by hand.

What precious electricity there is often goes only as far as to charge a cellphone or power a single light bulb. For billions of people, anything more than that — powering up a fridge, say, or a TV — is beyond comprehension.

SOURCE: WORLD HEALTH ORGANIZATION, FEBRUARY 2016

‘THE RATIONALE FOR ACTION NOW IS COMPELLING’

On the other hand, we in the West expect our power to be reliable, we expect it to be fast, and we certainly don’t expect it to disrupt our day. Nathwani describes the global energy that we rely on as a vast, interconnected system that extracts huge amounts of primary energy yet leaves millions to “scour the forests for twigs and branches for basic needs.

“Energy poverty remains a barrier to economic well-being for such a large proportion of humanity that the rationale for action now is compelling,” Nathwani says.

“The recognition of this issue has come full force to the highest level of discussion, almost at par with the challenges of climate change. It brings into focus the most formidable scientific challenges of this century: How do we get to a clean energy future that is essentially non-carbon?”

Renewable energy technologies such as solar panels, wind turbines and small-scale hydro plants can generate power on a smaller scale — and these technologies promise to bring power to rural, highly impoverished places without the need to invest in a huge central grid.

TECHNOLOGY ALONE WON’T WIN THE BATTLE

But Nathwani says technological innovations are not enough on their own — because solutions must ultimately be adopted in the cultural context of the way people live their lives.

The key is to have a deep supply chain of expertise to provide solutions at both a price point and performance point that are sustainable.

“I have absolutely zero doubt in our ability to succeed,” Nathwani says. “But let’s be realistic — this will take time. We sit on a bed of established technologies and solutions that we can begin to implement. And we can learn from those who are implementing them to actually understand what the barriers are: what’s not working in the field, why good intentions go awry.

“We can learn from that and feed into solutions that are already being implemented, and then the breakthrough technologies will improve things by an order of magnitude in terms of price and reliability.”

Many of the technologies themselves are still new. They need to be more durable, they must be simple, they have to meet people’s needs (because what works in Rwanda, say, won’t necessarily work in Zambia), and they must be more efficient.

Most of all, they must be affordable for the poorest people on the planet.

“Affordability” means that the cost of basic energy services is less than 10 per cent of disposable income. So, for someone who lives on less than $2 a day, their energy cost must not exceed 20 cents a day.

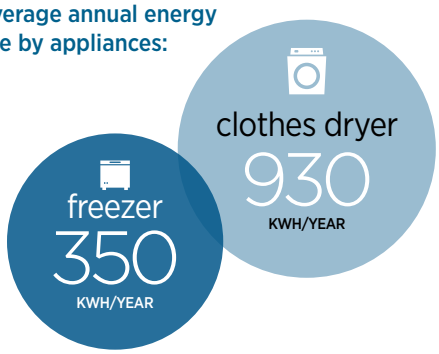
“One can’t just wait for this,” Nathwani says. “It has to have a mission and a clarity of purpose to deliver the fundamental physics and material-design breakthroughs that would influence the next set of devices.

“You can’t be naïve about it because imposed solutions don’t work. You can’t say, ‘Here’s your big black box and isn’t it great?’ ” »

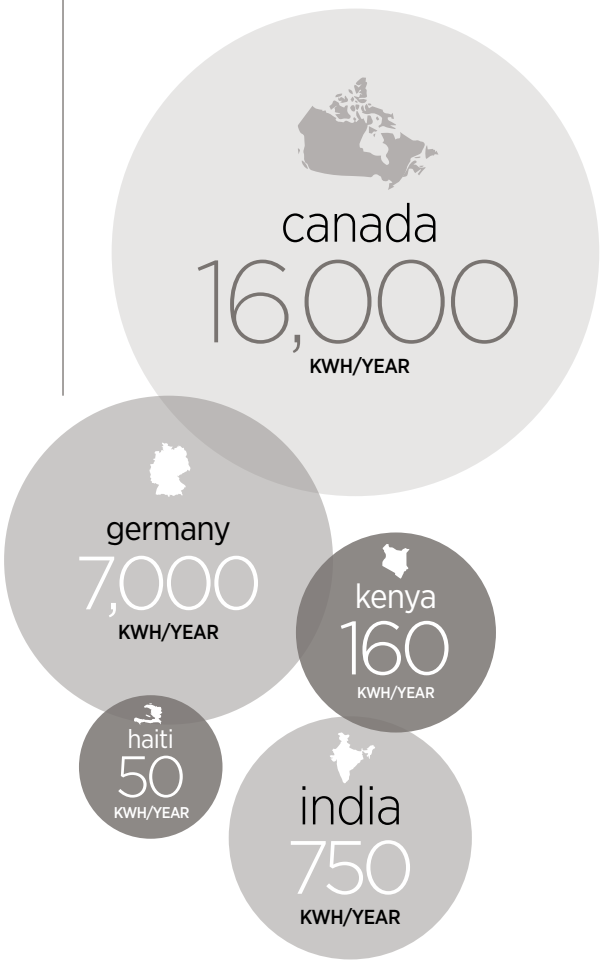
POWER IMBALANCE

Average annual power use varies greatly around the world. Single appliances many Canadians take for granted often use many times more electricity than people living in other countries use in an entire year.

Average annual energy use by appliances:



Average annual energy use per person:



4 WAYS TO OPEN ENERGY ACCESS

Waterloo research powering a global revolution

No magic bullet, no single solution will fix global energy inequities that leave billions with little or no access to electricity. Change will come from connecting the ideas, innovations and experience of some of the world's top minds. Affordable Energy for Humanity (AE4H) focuses on four high-impact research areas.

TAKING A SHOT AT SOMETHING BIG AND IMPORTANT

Along with its partners, the University of Waterloo is taking a shot at "doing something big and important," adds Nigel Moore, manager of global programs and initiatives at WISE.

"Now that we've got over 100 individual researchers and practitioners from 27 institutions in 12 countries around the world saying, 'I'd like to be a part of this initiative,' our job is to marshal this enthusiasm," Moore says.

"We want to engage in activities where there are tangible links between the things we're learning in the field in energy-poor communities and the innovation that's going on in the laboratories in places like the University of Waterloo. Because if we don't understand what the needs of these people are — but we're going ahead and trying to create technologies for them anyway — there's a good chance they won't work."

WHAT'S NEXT?

The wider mission for AE4H will come from a blueprint developed out of the Waterloo Global Science Initiative's (WGSI), OpenAccess Energy Summit, which took place April 24 to 27 in Waterloo.

A partnership between the University of Waterloo and the Perimeter Institute for Theoretical Physics, WGSI hosts bi-annual summits, bringing together researchers, policy makers and community leaders from around the world to develop and implement solutions to some of the world's most pressing challenges.

The summit's goal is to translate research into action, to foster connections between different organizations and disciplines, and to promote the development of strategic partnerships to meet the global energy access challenge.

RESEARCHER » Linda Nazar, Faculty of Science

RESEARCH AREA 1

GENERATION, DEVICES AND ADVANCED MATERIALS

Promise and potential: Next-generation batteries

Next-generation batteries are an emerging market with unlimited potential — and Waterloo chemistry professor Linda Nazar is eager to see her team's extraordinary labours pay off.

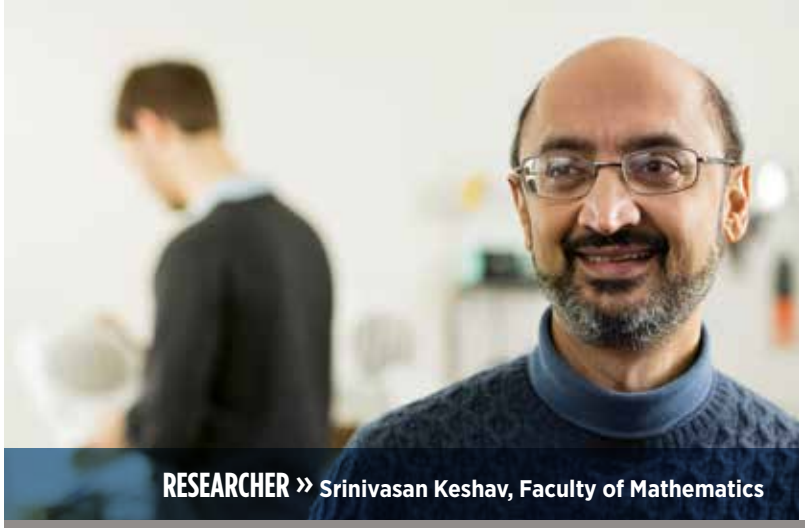
Nazar, who was recently named an Officer of the Order of Canada for her advancements in battery systems and clean-energy storage, is contributing to breakthroughs in the design of rechargeable batteries for grid storage, electric vehicles and other clean-energy technology.

"Our research team and others at the University of Waterloo are working on a lot of different battery technologies where we're starting to see the hard efforts that we've put in over the last decade really paying off in terms of making batteries that have higher energy density, that are safer and also have longer cycle life," says Nazar, who along with colleagues at the Waterloo Institute for Nanotechnology, Zhongwei Chen and Michel Pope, are planning to launch an Electrochemical Energy Research Centre at the University.

Their work could have huge ramifications for energy-poor developing countries.

"In impoverished countries where there's an abundance of sunshine, it's critical to be able to store renewable energy in affordable energy storage systems to allow for load leveling and also for storage at night or even off-season storage," Nazar says.

"That allows communities that are limited in their electrical resources to have a cheap, abundant source of energy to power activity in the evening and when the sun isn't shining."



RESEARCHER » Srinivasan Keshav, Faculty of Mathematics

RESEARCHER » Catherine Rosenberg, Faculty of Engineering

RESEARCH AREA 2

INFORMATION AND COMMUNICATIONS TECHNOLOGIES FOR ENERGY SYSTEM CONVERGENCE

Reducing the carbon footprint, improving energy efficiency

Energy poverty is one of the biggest challenges facing humanity, according to Waterloo computer science professor Srinivasan Keshav.

"More than one billion around the world don't have access to good forms of energy," Keshav says. "The only energy they have is their own human labour, so if they want to dig a trench they have to do it by hand. How much firewood they can carry determines what they're going to cook. That's really what it comes down to."

Keshav and his research team are focusing on greener, more efficient sources of energy that will ultimately help address these inequities.

"The work I'm doing in this lab is focused on two things," Keshav explains. "One is to reduce the carbon footprint. The other is to improve the energy efficiency of systems that generate, transmit and consume energy — everything from power plants to the solar panels on your roof.

"Solar efficiency is going up and the costs are coming down at the same rate as costs have gone down for electronics. The same thing is happening with lighting. The technology is now coming into place which allows us to put a panel on the roof, [add] storage and efficient lighting — and you have the ability to transform lives.

"At some level the changes come not just from technology but from policy, not from research but from imagination. We make it possible for somebody to imagine a different future — and that perhaps is the biggest thing we do."

A smart grid for smarter energy

Just as smartphone technology has come to dominate the way we communicate, the future of 21st-century electricity may well belong to the smart grid.

The smart grid is an intelligent infrastructure that uses information technology — sensors, communications, automation and computers — to improve the way electricity is delivered. It also allows for renewables such as wind and solar power to be part of the equation.

"A lot of people do not have access to the electrical grid the way we do," says Catherine Rosenberg, a professor of engineering and Canada Research Chair in the Future Internet at Waterloo. "There are two types of technologies that can have a major impact on the smart grid. The first technology is renewables — solar, wind. The second is energy storage."

Rosenberg, who is collaborating with computer science professor Srinivasan Keshav, says that having access to renewable energy — solar panels, for example — and some storage would allow communities without grid access or with poor grid access to be self-sufficient.

Just as importantly, access must be affordable, and Rosenberg is optimistic that storage will become cost-efficient in the near future.

"Because there are more and more needs for energy storage — for example for electric vehicles — the price of energy storage is going to decrease," she says. "We are in the business of designing systems by integrating many technologies and showing how those systems should be operated in a cost-efficient manner."

RESEARCHER » Paul Parker, Faculty of Environment

RESEARCH AREA 3

ENVIRONMENTAL AND HUMAN DIMENSIONS OF ENERGY TRANSITIONS

Energy and sustainability: Lessons from the North

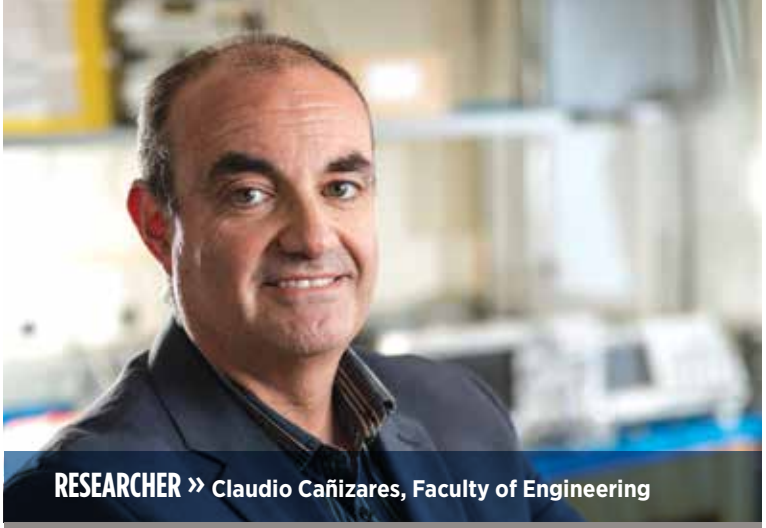
Energy poverty is not confined to the developing world. There are nearly 300 remote communities across northern Canada — about 170 of them First Nations — and most rely on diesel generators with fuel flown in or trucked in via ice road.

It's not only environmentally damaging, it's also incredibly expensive — up to $1 per kilowatt hour — so building capacity to get energy from renewable sources is the preferred option.

"In our First Nations communities, we see both huge need and huge opportunity," says Paul Parker, a professor in the Faculty of Environment. "We are here to work with communities to achieve what they want. The first question is, 'What future do you want?' And then it's, 'How do we design, evaluate and implement it?'

"The University of Waterloo is probably most famous for its technical capacity, but we also realize that technical capacity needs to have social context. We need the social scientists to work with our engineers and technicians in the North. Our students are fantastic. We've trained economic developers for communities across the North where they look and they see an opportunity and they say, 'Let's take those solutions to as many communities as possible,' " Parker says.

"We already have the technology to make these things happen, so [it's about] the implementation. And what we are learning in Canada has [global implications] in other parts of the world that experience energy poverty.



RESEARCHER » Claudio Cañizares, Faculty of Engineering

RESEARCH AREA 4

MICROGRIDS FOR DISPERSED POWER

Microgrids and the power of decentralization

As flaws in centralized power grids become apparent — their vulnerability to disruption and dependence on planet-warming fossil fuels — the time has come for renewable energy microgrids to take centre stage.

"Here at Waterloo we have a lot of expertise to provide in microgrids, not only to Canada but to the world, from simulation and modelling to hardware and social interactions with communities," says Claudio Cañizares, a professor of electrical and computer engineering at Waterloo.

Scientists are trying to transform microgrids — which can operate independently or in conjunction with main power grids — into renewable energy-based systems by introducing solar and wind power. Challenges being addressed by research at Waterloo include making the systems economically feasible, and learning to manage the variability inherent to renewable energy sources like wind and solar. Cañizares and his fellow researchers are doing both theoretical work — simulation, modeling, optimization — and applied science so they can understand how the controls work in different environments.

"One of the main motivations for our work here is to try to improve or facilitate the introduction of these renewable sources and to move away from diesel in the remote, mostly indigenous, communities in Canada," Cañizares says.

Ultimately, Cañizares believes the impact of affordable energy access will change lives.

His research partners in northern Chile, for example, are seeing young people who had left their communities return once affordable energy sources are introduced, and business opportunities cropping up that didn't exist before.

"We have come a long way," he says. "We believe Waterloo is particularly well-positioned ... people are paying attention."

» Read more about sustainable energy research in the spring 2016 issue of University of Waterloo Magazine: **uwaterloo.ca/magazine**

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