HULT PRIZE 2018

2018 HULT PRIZE CHALLENGE

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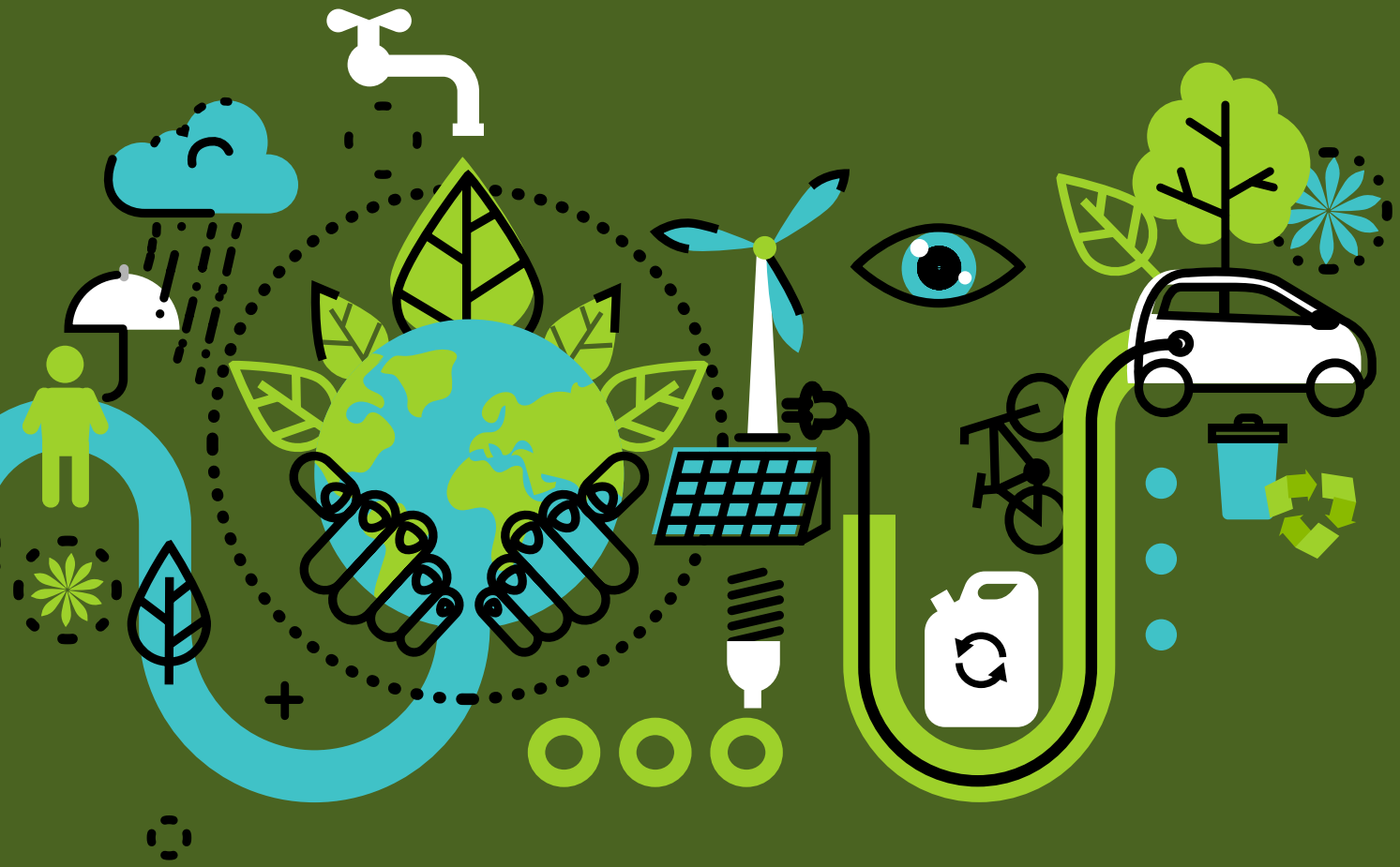


Transform

Harnessing the **Power of Energy** to Transform the Lives of **10 Million People**

TABLE OF CONTENTS

Energy is the lifeline of humanity.

When you harness the power of energy creatively, you can change the world.

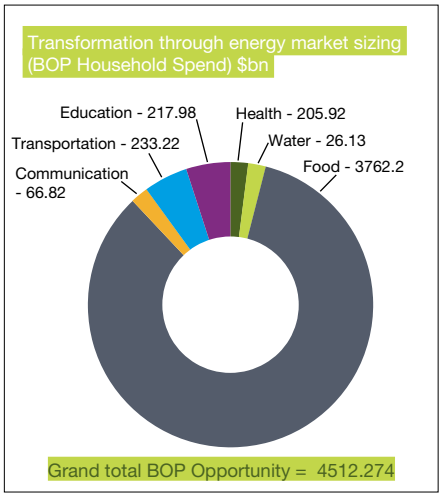
Thomas Edison invented the light bulb in 1878, but that's not when the light bulb changed the world. The change happened when people around world discovered ways to use the light bulb to transform their own lives and the lives of others.

The world has enough latent capacity for energy-powered innovation to shift the trajectory of global development.

The world needs more disruption that taps into those energy-powered innovations and transforms lives not only among the ultra-poor, but across every economic stratum in society.

This year we looked at six dimensions of energy use that affect all of humanity. We ask you to find and develop energy-powered innovations that can be scaled to improve the lives of millions.

1. Can you build a **scalable, sustainable social enterprise** that harnesses the power of energy to transform the lives of **10 million people by 2025?**



As this chart and those accompanying the other dimensions illustrate, energy transformation may have the greatest beneficial impacts among the poorest members of society--adding up the amounts in each of these charts, a more than $5 trillion total market opportunity. However, the potential for transformation certainly doesn't stop there. As we noted at the outset, energy-powered innovations can transform lives not only among the ultra-poor, but across every economic stratum in society. So the market-sizing estimates we have offered here are actually lower-bounds for the total transform opportunity globally.

Writer and futurist William Gibson had it right when he wrote, "The future is already here—it's just not very evenly distributed." The technology to transform energy use—and to transform human lives for the better—already exists in the form of tens of thousands of prototypes, patents, and pilot projects. This year's Hult Prize challenges student teams not to invent the energy systems of the future but to deploy them at scale by listening closely to customer needs, designing scalable business models, and executing plans that are capable of transforming the lives of 10 million people through the use of energy.

The greatest effort among energy-focused innovators today is going into either advancing the adoption of alternative forms of energy generation or increasing the efficiency of technologies for existing applications. Both are essential to shaping the global energy future, but this year's Hult Prize challenges teams to go further:

Given the array of technologies available today, what opportunities exist to harness the power of energy to transform the lives of 10 million people?

This year's Hult Prize Challenge walks you through six core areas affected by energy use that may form the basis of 2018 entries. The six dimensions ripe for transformation through energy-powered innovation include:

- **Connectivity**
- **Mobility**
- **Farming, food, and agriculture**
- **Water collection, storage and transport**
- **Health and the human experience**
- **Education**

This year's Hult Prize Challenge pushes you even further than previous Challenges, as it asks teams to do two things in parallel:

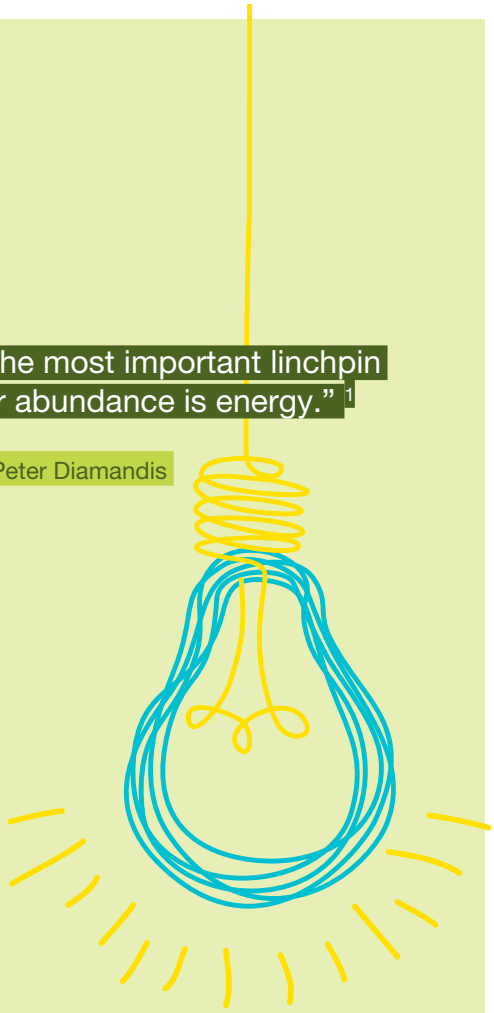
- **Extend your reach:** Search across campus, throughout town, and around the world to find the energy-driven technologies that are not realizing their potential to propel progress.

- **Get out of the building:** Find users and learn about their needs. Don't just imagine how you can use energy to enable new capabilities—prove it.

The Light Bulb as Example, Icon, and Inspiration

"The most important linchpin for abundance is energy."[1]

- Peter Diamandis



The light bulb is an iconic emblem of ideas and innovation. It is difficult to imagine the realities of daily living before its invention, but consider Thomas Edison's vantage point: he imagined an electrified world before it existed, and he brought that transformative vision to life.

For millennia, open flames from fires and torchlights were supplemented with expensive candles and oil lamps that exuded weak light and filled homes with smoke. The light bulb put electricity to use with revolutionary consequences: It transformed lives by decoupling humankind's work and rest schedules from the cycles of the sun. It made our environment safer at night and brightened our homes. It illuminated playgrounds for the human imagination.

When electricity became available as a form of power in the 1800s, an explosion of innovation began. This innovation was fueled in particular by the demand for better, more affordable light. Thomas Edison's famous bulb was just one of many light bulbs invented at that time, and it was not the first. But Edison's iteration made the light bulb practical, and his business acumen made it commercially viable. His vision spurred the creation of lighting systems for homes and entire cities, and his access to capital gave him the means to execute that vision.

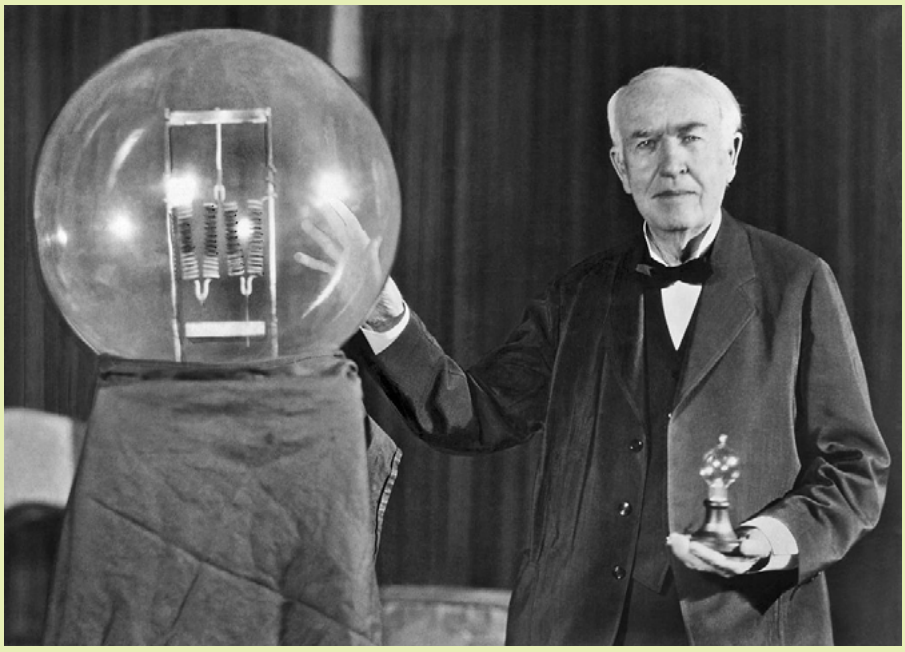
Edison's success created an entire ecosystem of innovations and businesses, including incremental improvements to the light bulb and the rapid electrification of homes and workplaces. The electrification of lighting in turn led the way for many other inventions that relied on this new system of grid-based energy.

The light bulb's evolution—from flame to incandescent, fluorescent to LED—is emblematic of the progression of energy-powered innovation. Successive innovations were built on each other and have continued to refine lighting technology in ways that harness energy more efficiently.

The lessons the light bulb offers to energy innovators are clear: Use promising energy systems as the basis for innovation. Focus on practical inventions. Capitalize on the potential ecosystem of business that exists around important new innovations. Create infrastructure if it does not already exist. Think boldly—imagine a transformed world, as Edison did, and work to bring your vision to reality.

"Energy is the only universal currency: one of its many forms must be transformed to get anything done."[2]

- Vaclav Smil



2. The future of energy cannot be limited by the successes and failures of the past

2.1. Energy is a key enabler of humanity's progress

"I skate to where the puck is going to be, not where it's been."

- Wayne Gretzky, hockey great

Over time, our energy-powered innovations have built on one another, thereby driving advancements and radically reshaping human civilization. This has led to:

1. Increased life expectancy: Increasing the availability of food to a level above mere subsistence and the provision of adequate healthcare has increased the human lifespan.

2. Higher incomes and the emergence of a middle class: Mechanization led to the worldwide trend toward increased urbanization, and the world's cities have provided unprecedented occupational and intellectual opportunities.

3. Global mobility of goods and people: New techniques have increased personal mobility to a level that was hard to imagine just a half-century ago, and have transformed international trade into a truly global, mass-scale affair.

4. Revolutionary communications and information infrastructure: Advances in electronics have multiplied the availability of information to such an extent that any owner of a PC or a smartphone can—instantly and inexpensively—access an amount of information equivalent to a library of millions of volumes.[3]

Gains resulting from energy-powered innovations have not been equally distributed: Many people still lack access to basic energy services. More than 1.2 billion people do not have access to electricity. An estimated 2.7 billion people live without adequate cooking facilities. As energy historian Vaclav Smil writes, "The technical advances made by high-energy fossil-fueled civilization have accentuated the gap between have and have-not nations, with access to information (through ownership of electronic devices, or purchases of printed matter) and opportunities to enjoy a high-quality life (rising life expectancy, choice of occupation) becoming even more unequal than average incomes."[4]

As you work toward scalable, sustainable solutions that have a social impact, you'll need to consider the differential energy landscape, including the potential of sizeable underserved markets.

2.2. The efficiency of both energy generation and energy consumption technologies have increased greatly in recent decades, yet too much of the world remains in darkness

Current Energy Landscape Trends

Generation:

- Plummeting costs for renewables will continue.
- Fossil fuels remain a key part of the energy mix, but are diminishing.
- There is growing consumer control over how and where energy is produced.
- Demand outstrips generation capacity in many developing markets.

Transmission:

- Distributed energy systems are emerging.

Storage:

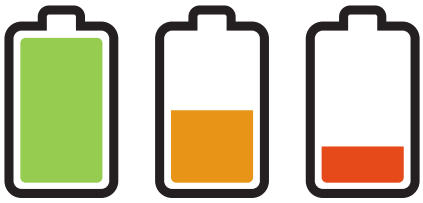
- Renewables drive demand for new, better storage solutions.
- Battery technologies are more important than ever.

Use:

- There is escalating demand for electrification.
- Opportunity exists to leverage further gains from improved energy efficiency.

Technological advances in the way we generate, transmit, store, and use energy are undergoing a dramatic transformation, with rapidly accelerating change in all four domains. While this year's Challenge is focused squarely on how innovations in the end use of energy—that is, the forms experienced directly by consumers—can transform millions of lives, a brief review of trends in energy generation, transmission, and storage can help forward-looking innovators understand how to capitalize on new opportunities in the ways we use energy.

Battery technologies can help provide reliable and timely delivery of electricity for various end-uses.



Breakthroughs in energy generation are disrupting global markets and legacy energy systems. Since 2009, the cost of solar and wind energy have plummeted by 85% and 66%, respectively, and these drastic declines are forecast to continue. While coal and oil remain dominant primary energy sources, many studies suggest that demand will peak and then begin to decline as the world moves away from carbon-intensive fuels.

In developed markets, consumers are increasingly demanding a greater say in how and where their energy is produced. Advances in renewable energy technologies, energy policies, and cost breakthroughs mean that consumers can take advantage of distributed energy resources, such as rooftop solar and battery storage, to have more "behind-the-meter" control of their electricity procurement.

In developing markets, technological advances (including renewables and distributed solutions) may allow countries to "leapfrog" their energy infrastructure, which in many cases has been incompletely transitioned to fossil fuels. Poor reliability and power blackouts are frequent challenges, especially where high rates of urbanization and population growth have caused demand to grow faster than generation capacity.

Rapid adoption of renewable energy technologies is also changing how we transmit energy. More distributed energy systems are emerging as grid operators are challenged to provide flexible generation resources. Advanced metering infrastructure is likely to play an increasingly important role in the future of the electric grid. In developing markets, much attention is focused on distributing mini- and off-grid energy.

How we store energy from new energy sources is one of the leading frontiers of energy-powered innovation. Energy storage in global markets could grow by up to 40%, and thus reduce the need for major new transmission infrastructure.

Batteries will play a key and expanding role in energy storage. Battery technologies can help provide reliable and timely delivery of electricity for various end-uses. Advances in battery technologies now allow larger amounts of energy to be stored in a commercially viable manner, with battery costs falling by nearly 20% per year. Further cost declines are expected, as manufacturing capacity triples in the next four years and battery energy density doubles. New battery-powered electronics will disrupt markets and encourage fuel switching (i.e., from vehicles fueled by gasoline or diesel to battery-electric vehicles).

How we produce and consume energy is changing.

Advances in energy generation, transmission, and storage mean better decision making around where and how we use energy. Developments in smart-metering and low-power technologies mean that consumers can be smarter—and more efficient—in their energy use. Energy efficiency is sometimes referred to as the world's cheapest fuel. Across the globe, the efficiency of our energy use has improved, but there is great potential for further gains.

READ MORE

- How the World's Energy Use Is Changing
- Rethinking Energy—2017
- Key World Energy Statistics—2016

SUSTAINABLE DEVELOPMENT GOALS

"Energy is central to nearly every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential. Sustainable energy is opportunity – it transforms livs, economies and the planet."

– United Nations on the Sustainable Development Goals

The Sustainable Development Goals (SDGs) set by the United Nations are a universal call to action to improve the lives of people everywhere and to protect our shared planet. The 17 "Global Goals" —with 169 targets between them—constitute an ambitious set of markers of progress toward creating a better world in 2030..

The Hult Prize Challenge is deeply aligned with the framework for progress set by the SDGs. Each dimension area of the 2018 Challenge—connectivity, mobility, food, water, health, and education—is directly tied to one or more of the goals. Many other Goals are also deeply embedded within these priority areas. Ensuring access to affordable, reliable, sustainable and modern energy for all is the nexus which connects with, and enables, each of the six dimensions of this year's challenge.

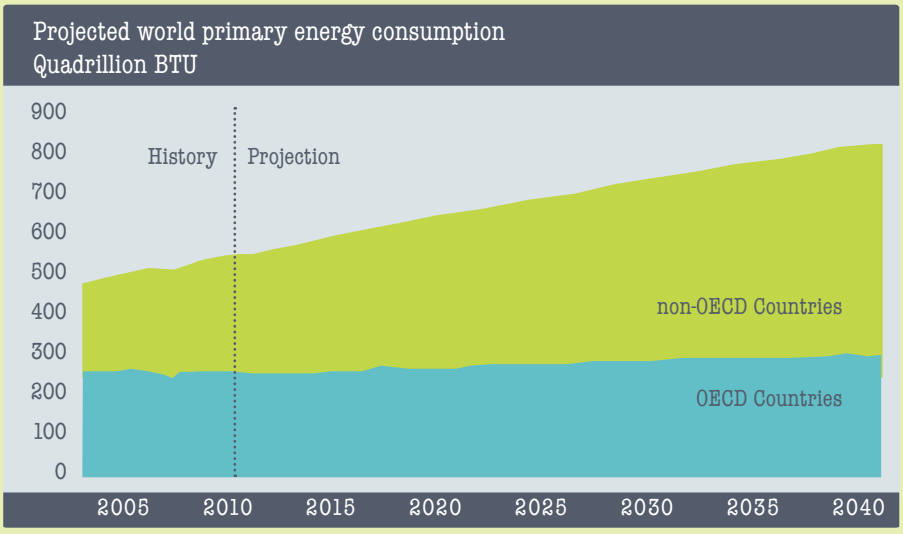
"The electricity sector is undergoing a transformation... These changes are creating an environment of genuine uncertainty in which many challenges arise, along with new opportunities."

— World Resources Institute

The International Energy Agency estimates that nearly two-thirds of the economic potential for energy efficiency has not yet been exploited, leaving many [as] yet untapped opportunities.

With the anticipated shift toward electrification for many end-uses, McKinsey estimates that future demand for electricity will be twice as high as that for other fuel sources.

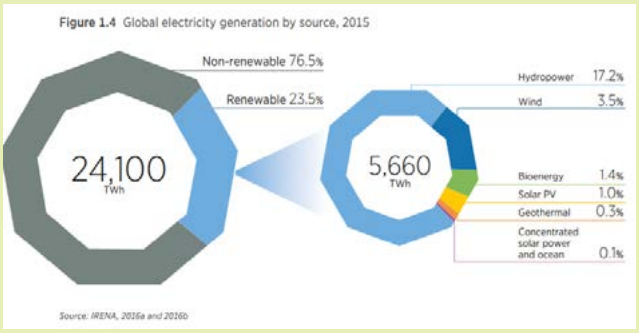
The energy shift now under way is as much geographical as it is technological. By 2040, the developing world will account for 65% of the world's energy consumption. That compares to 54% in 2010. Over the next three decades, energy use in non-OECD countries is expected to substantially outpace that of OECD members, like the European countries, the U.S., Canada, and Australia.



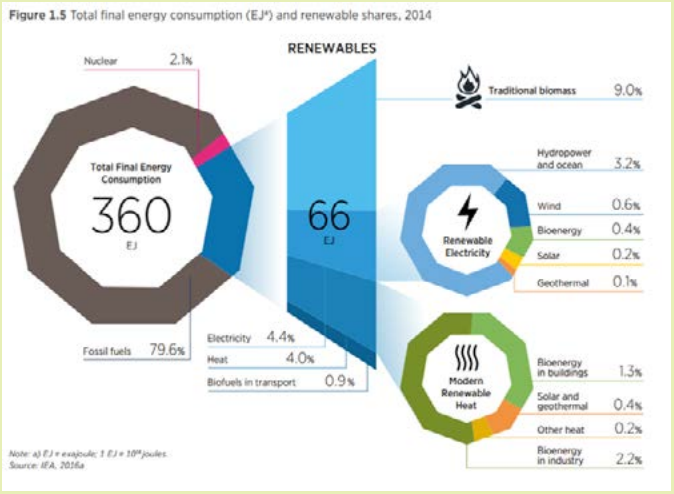
READ MORE

- The Sustainable Development Goals Report 2017

How does the world generate energy?

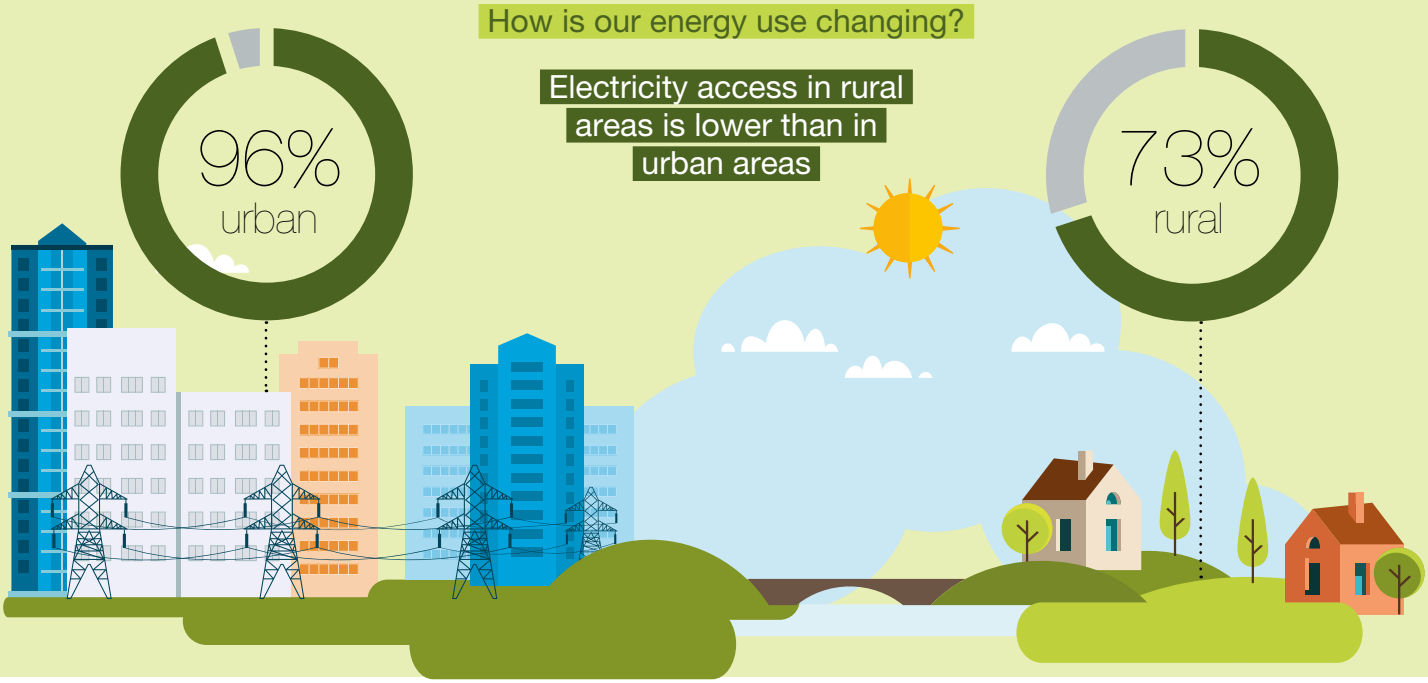


How does the world consume energy?



How is our energy use changing?

Electricity access in rural areas is lower than in urban areas



2.3. The key to harnessing the transformative power of energy lies in democratizing innovation, making it more accessible to all

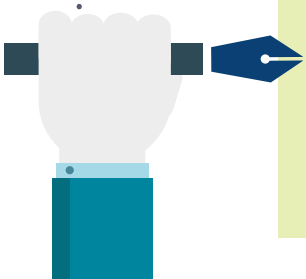
"At the end of any arc of innovation, when we have gone all the way from entrepreneur to automation, goods and services that used to be scarce and very expensive to acquire have now been made plentiful and cheap. That makes them a perfect platform upon which to build the next wave of innovation. Entrepreneurs are the ones who catch on to the implications of this new state the fastest. They kick off the next round of innovation, they launch the next arc."

—Geoffrey Moore, innovation expert

Visionary researchers have long sought radically better ways to harness the ambient energy around us. Significant scientific efforts have examined ways to capture the latent energy in our ionic atmosphere, unlock the power of magnets, or use vacuum power to propel our energy needs. They've even had (not so?) far-flung dreams of mining the moon or using an element called thorium to power molten-salt reactors. Researchers continue to investigate how, in the near future, we might derive power from ambient energy sources. This includes mechanical ways to use vibrational energy, thermal inventions to capture energy from temperature changes, radiant devices to take energy from light and radio waves, and electrochemical innovations to extract energy from biochemical reactions.

To reiterate: The 2018 Hult Prize challenges you to build sustainable businesses around existing technologies that have the potential to transform our world. We aren't asking you to uncover new major energy sources, but if you are to succeed in creating new, viable pathways for existing technologies, it is critical that you understand the current landscape, as well as the audacious horizons of energy generation and distribution. Wayne Gretzky, the greatest professional hockey player ever, attributed his uncanny talent to his ability to perceive and react to what was about to happen next. In thinking about scalable solutions, teams may want to evaluate whether their plans can be easily integrated with existing and future technologies—and whether solutions for today are future proof.

Your task now: be inspired and have the confidence to aim big, think unconventionally, and grab an ownership stake in the radical transformation of our world.



Case: GravityLight

Photo credit: Gravity Light

Not all energy-powered innovation requires a full-scale research lab to translate science fiction into reality.

GravityLight is a light source powered by gravity, much like a grandfather clock. Using the weight from a sack full of rocks or soil, it can produce electricity for indoor lighting. In just a few seconds it can generate 30 minutes of light from natural gravitational force—no battery or fuel required. It was developed for markets that are without reliable electricity and where indoor lighting after dark can mean that kids will have more time to study.

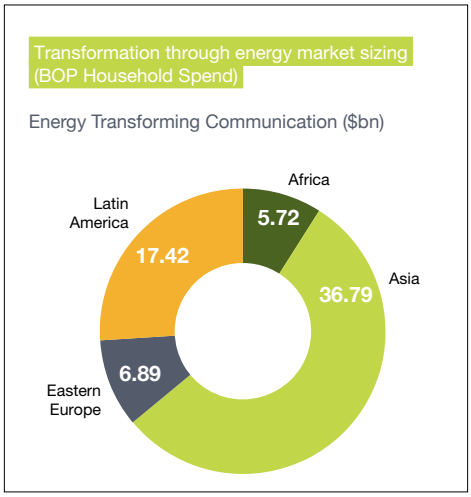
A crowdfunded invention that went on to win major innovation awards, GravityLight is now being distributed in Kenya and can be purchased from major retailers in the U.S., UK, and Canada.

3. Energy transformation can be mapped along **six principal dimensions**

This year's Hult Prize Challenge is focused on six dimensions of transformation that are poised for major disruptive innovation through the novel use of energy.

Each of these six areas can be tremendously impacted by social enterprises that develop and deliver solutions at scale. There are abundant opportunities to leverage underrealized innovations and help transform the lives of millions.

3.1. Energy enables connectivity, allowing us to communicate more rapidly and effectively on a global scale



8 DECENT WORK AND ECONOMIC GROWTH

Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

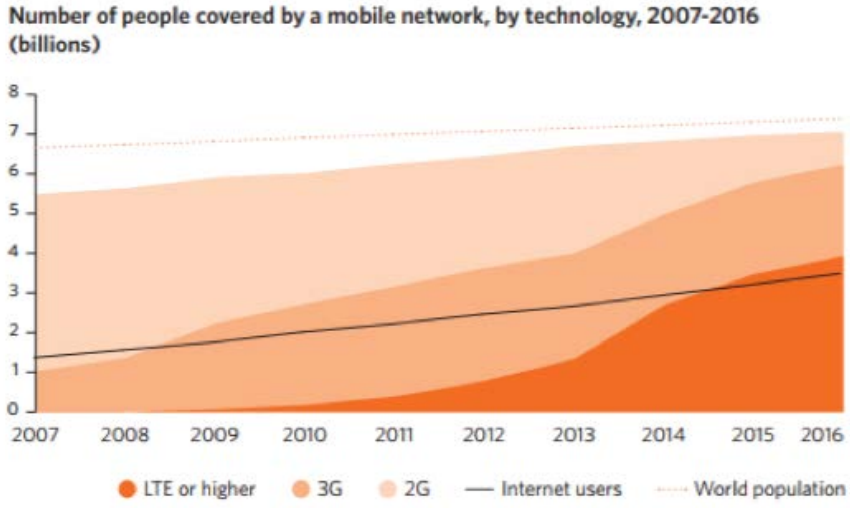
Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Perhaps no dimension has been more fundamentally transformed by energy over the past century than connectivity.

Energy allows us to communicate and collaborate on a global scale, with latencies as low as nanoseconds. Digital and mobile advancements have enabled breakthroughs in how we create and understand information and data – which in turn empowers to make better decisions, including how we can use resources most effectively and efficiently. The more granular the data, the more precise and tailored the recommended course of action.

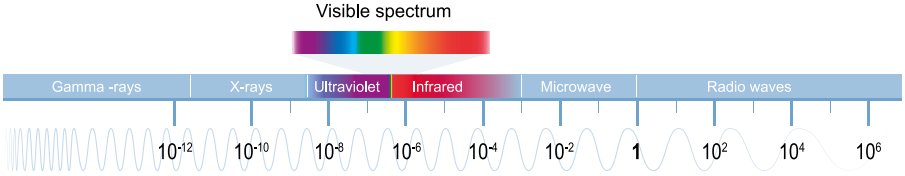
Yet with connectivity, as with the other domains in this year's Challenge, gains have not been evenly distributed, which raises several questions:

- **How can we expand Internet services to those who currently lack access?**
- **How can we harness new connectivity technologies to improve the delivery of other essential services?**
- **How will we build the next phase of connectivity so that it enables the next generation of human advance?**

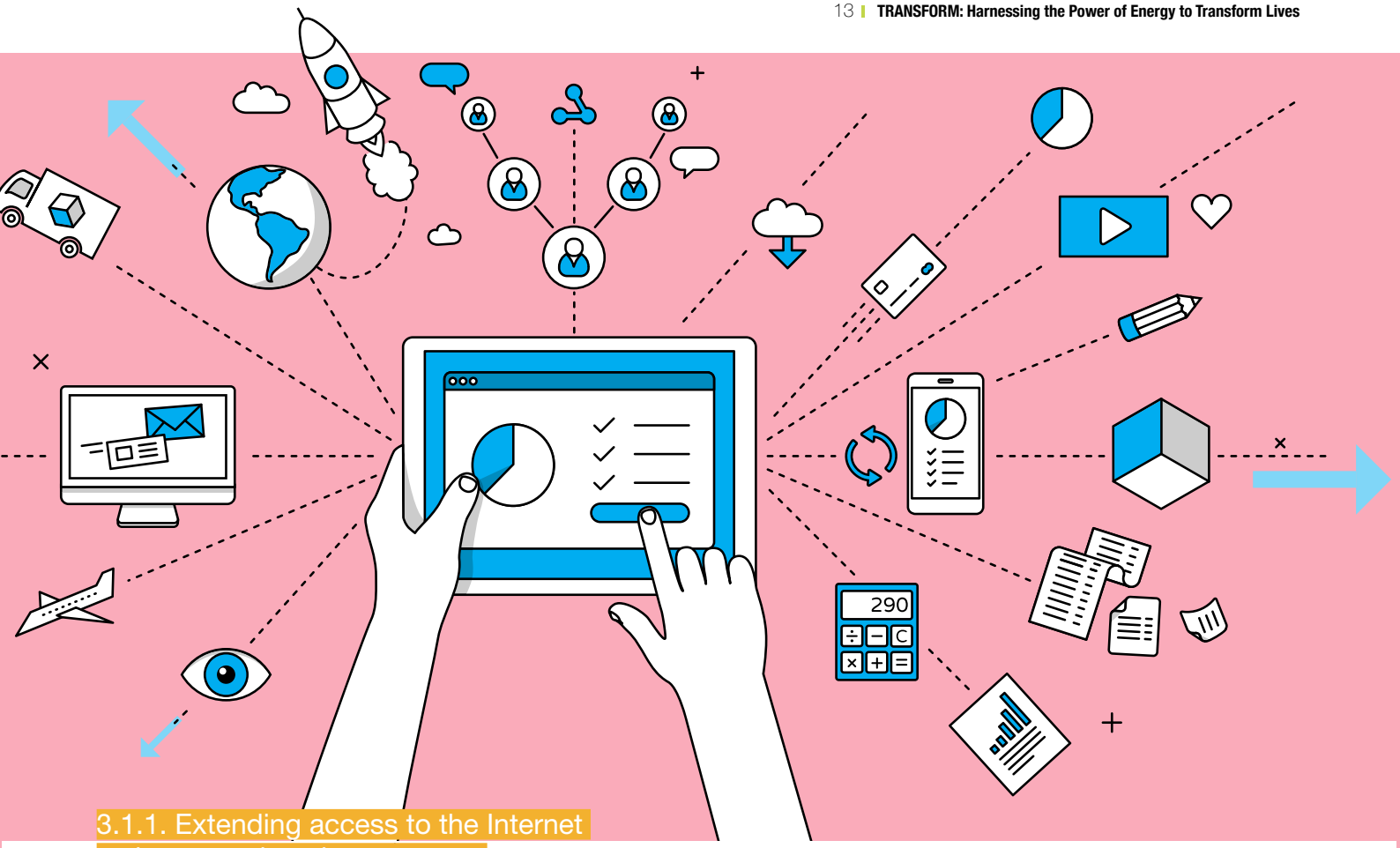


Note: LTE (Long-Term Evolution) is a standard for high-speed wireless communication that allows for faster speeds than 3G technologies but does not meet the technical criteria of a 4G wireless service.

Electromagnetic Spectrum:



All modern communication technologies mediate forms of energy: the wireless signals used by our cell phones are radio waves on an unseen part of the light spectrum.



3.1.1. Extending access to the Internet enhances education systems, healthcare delivery, and other services critical to human development

9.C SDG Target: Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries.

Nearly four billion people around the globe still lack Internet access.

Extending access to basic connectivity could enhance education systems, healthcare delivery, and other services critical to human development—and thus radically improve the lives of more than half the world's population.

Our rapidly digitizing world, with its ever-growing number of connected devices, poses a challenge for our mobile communications infrastructure. In geographic regions that already have basic or advanced Internet services, the connectivity opportunity lies in the ability to reimagine the ease and speed at which we can access vast troves of information and data on an unprecedented scale.

Creative solutions to expanding Internet access have been proposed by both tech behemoths and growing startups. Facebook has explored how solar-powered drones might fly above unserved areas (at a height above where commercial aircraft fly, and where weather conditions have no impact). Google's plans involve deploying helium balloons and high-capacity satellites that together could expand high-speed Internet access.

Expanding Internet access is also changing the way digital content is delivered. Millions of new-to-the-market, low-income consumers are now accessing the Internet directly using only voice and images, thus entirely bypassing the browser interface people in rich countries have become accustomed to since the launch of Netscape in 1993. Around the world, different solutions like UC Browser, SHAREit, MX Player, and Babajob are optimized for slow connections, minimal data storage, and voice commands. They've succeeded by finding new users where they are now, rather than expecting users to change their habits in order to conform.

Case: Jana—Building Business Models around Internet for All

While high-tech infrastructure efforts to expand access continue, so does work to develop commercially sustainable businesses that can enable that access.

Jana is one example of how an innovative business plan can fuel connectivity in new markets.

"Facebook is talking about lasers from space and Google [is] talking about giant blimps, which is great, but the real way to impact the lives of billions of people in terms of mobile—particularly in rural areas—is to reduce their price per megabyte," says Jana founder Nathan Eagle. "For example, more than half of the smartphones in Brazil don't have a data plan because it's just too expensive . . . And even though the price of megabytes is projected to halve by 2020, typical consumption is expected to go up 6x."

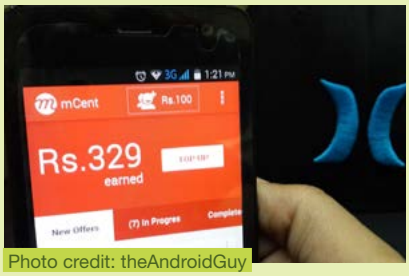


Photo credit: theAndroidGuy

Jana leverages advertising to provide free Internet service to more than 30 million people around the world. It offers basic Internet services in underserved and emerging markets by offsetting user costs through ad-sponsored but unrestricted Internet access. Jana's mCent browser is provided free to mobile users through partnerships with mobile operators. Jana monetizes its customer base with strategic mobile advertising campaigns to engage consumers in emerging markets. Billed as "subsidized Internet for the developing world," Jana demonstrates how business model innovations can create social impact at scale.

3.1.2. Expanding the range of services available will be the next phase of online innovation

8.2 SDG Target: Achieve higher levels of economic productivity through diversification, technological upgrading and innovation

The first generation of the Internet—the Internet we know today—is really a system for sharing information. As we all know, the Internet's impact on access to information has been astounding. To focus on just one example, Wikipedia, a venture with 200 full-time employees, engages a global network of 80,000 regular volunteers to create and curate a knowledge resource that reaches a half-million users a month in an astonishing 288 languages.

In the next phase of the Internet, the underlying architecture may manage transactions rather than information. The name for this adaptation is blockchain. This new architecture is already enabling the creation of an array of new business opportunities that bypass traditional intermediaries for transactions, such as banks, notaries, and various government agencies. It instead relies on peers to carry out detailed authentication protocols. From securing land claims to authenticating identity to ensuring that musicians are compensated for their work, blockchain-based systems have the potential to democratize the authentication of transactions in the same way the Internet has democratized the sharing of information.

Smart Devices, Smarter Energy Use

Smart devices and networks can manage energy use and provide a customizable user experience. This "democratization" of energy use could fundamentally alter how we interact with electronics. For example, users could remotely program their smart appliances to run during the time of day when electricity costs are lowest and the grid is not experiencing excess demand.

3.1.3. Realizing the full potential of innovation in Internet services will require building next-gen Internet access technologies that resolve supply side constraints

Building an interconnected world for all will require innovation in connectivity itself.

Numerous emerging technologies hold promise, including developments in wireless power and advances in next-gen wireless technologies.

Wireless power involves transferring energy directly into the end-use device, either through proximity to an energy source or via long-distance transmission.

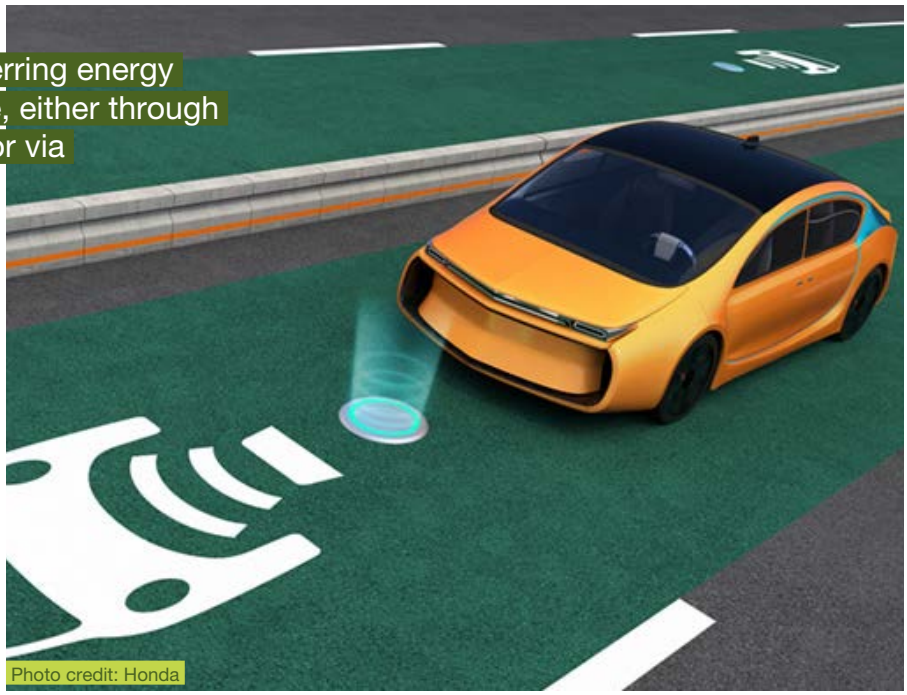


Photo credit: Honda

The energy that fuels our electronic devices is becoming less reliant on wires and cords. In the near future, electricity may be beamed directly into electronic devices, which will impact everything from how we charge our phones and computers to how we receive electricity in our homes. Early commercial efforts are continuing to mature; for example, Energous has debuted commercial technology that can power devices wirelessly across short distances.

Wireless power could revolutionize how electricity is transferred to various end uses. It may lead to the creation of "shared" public charging infrastructure rather than individual ownership of power cords and access to electrical outlets. It also could have major implications for issues involving land use for large-scale power delivery, as it could negate the reliance on thousands of miles of transmission and distribution systems to carry energy from remote generation sources to major load centers.

Other advances are concerned with the fundamental underlying architecture of our communications systems. There's been a lot of talk in recent years about "running out" of wireless spectrum. We can use only a fairly limited range of electromagnetic frequencies, and the number of signals we send and receive through cellular and Wi-Fi will continue to grow.

The deployment of 5G networks is expected to incorporate a number of new technologies that use the wireless spectrum more efficiently, such as millimeter waves, massive MIMO, small cells, and beamforming. Other efforts are entirely rethinking how we operate our wireless communications. For instance, Light Fidelity, or Li-Fi, is an emerging technology that conveys wireless communications at very high speeds. Discovered by Harald Haas in 2011, Li-Fi uses the visible light spectrum but at speeds so quick the light is not recognized by the human eye. Exponential growth in Li-FI is expected in the coming years, with early commercial efforts like NextLiFi attempting to realize Haas' vision of wireless data that emanates from every light bulb. The pCell technology from Artemis is another example of a potentially transformative new approach to enabling connectivity.

Photo credit: LextLiFi


Photo credit: Artemis

Case: pCell—Personal Connectivity Everywhere?

Current energy-powered innovations in connectivity may prove to be as revolutionary as the invention of the microprocessor.

pCell is one possible contender. This wireless innovation from Artemis appears to upend conventional understanding of the underlying architecture of connectivity.

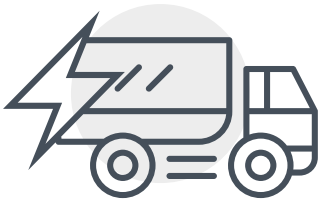
The ongoing rapid growth in the number of connected devices poses reliability and bandwidth challenges for the underlying communications architecture. Cellular networks are traditionally shared spaces with a cellular antenna that provides coverage with a single signal, or cell, shared by all who connect to it. This arrangement divvies up bandwidth into small increments to avoid interference.

Called an "elegant solution to a persistent problem," pCell's technology embraces interference; signals get stronger as interfering waves combine. By exploiting interfering radio waves, it creates an unshared "personal cell," or pCell, that follows each individual device and allows each user full access to the spectrum. pCell inverts the existing paradigm—a comparatively small number of large cellular towers—by building out a system that instead uses a large number of small cellular towers. With the latter approach, users in densely populated areas would not experience service disruptions from having to compete with others for access to the same network. Artemis claims that this results in a dramatic increase in the spectral efficiency of LTE and Wi-Fi systems, with signals up to 1,000 times faster. The innovation seems to break information theory—or, at least, to suggest that Shannon's Law was asking the wrong question. Beginning with a technological discovery in a university setting, pCell's path to commercialization has taken more than a decade. Artemis Technologies, founded in 2011 by QuickTime and WebTV creator Steve Perlman, has incubated its development.

pCell is a useful reminder that transformative technologies can follow a winding path to commercialization. Artemis' business model was first built on a notion of licensing pCell to wireless carriers and Internet service providers. Announcements of field testing in 2014 aroused significant media interest (and skepticism). Artemis signed a major agreement with Nokia Networks and licensed spectrum from DISH Networks in 2015, and the company has continued to innovate its business plan.

READ MORE

- **Internet for All: 2016 World Economic Forum Report**
- **#SystemTransformation: How Digital Solutions Will Drive Progress Towards The Sustainable Development Goals**
- **US Ignite supports next-gen applications and services built on advanced networking**



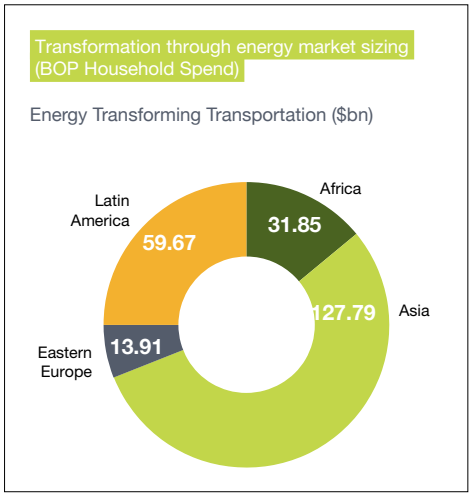
3.2. Energy enables greater mobility, fundamentally transforming the way we move goods and people

Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable

11.2 SDG Target: Provide access to safe, affordable, accessible and sustainable transport systems for all

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

9.2 SDG Target: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all



How we transport goods and people fundamentally touches every aspect of our existence.

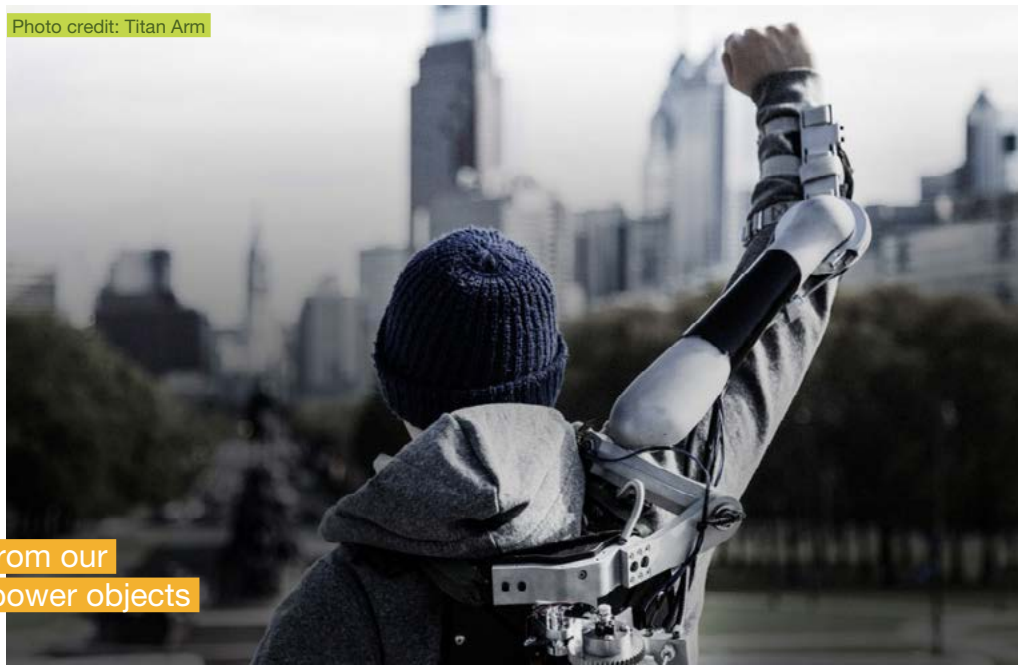
Like spokes in the wheels that propel us forward, the impact transportation has on our lives radiates out in many directions. Well-functioning transportation networks—for both goods and people—are essential to extending the human ability to flourish. Energy-driven technological gains have made transportation more accessible and cheaper than ever, but we still have more to do to extend the potential benefits to all—particularly those in impoverished rural areas.

Humans are more globally interdependent than ever, thanks to the mass transportation of goods and people, but the wide spectrum in mobility also highlights the sharp inequities in transportation technology between developed and developing markets. While rich countries with well-developed road networks turn their focus to the coming reality of driverless cars and other cutting-edge technologies that save time and fuel—including high-speed bullet trains, fast flights that (quietly) break the sound barrier, and even the specter of a hyperloop—many other countries still confront underdeveloped transportation networks that prevent access to basic services. According to the World Bank, one billion people in low-income countries still lack access to an all-weather road. The consequences can be dire: a sick child can't receive urgent medical care, crops rot before reaching the market, and education opportunities are out of reach. Finding new ways to extend transportation technologies to traditionally underserved markets not only can tap into strong demand from consumers, it can reap significant societal benefits.

Extending humanity's mobility has always been driven by energy-powered innovation, from the first seafarers who harnessed the wind to the innovators who made mass air travel possible in the 20th century. Today, the mobility sector is perhaps more deeply intertwined than any other with the systemic energy-powered innovations that are beginning to upend how we move through the world.

The transformation of transportation provides abundant openings for entrepreneurs in almost any setting. We now ask you to broadly consider how we can move goods and people inclusively and sustainably, while also getting back to basics. Consider that some of the most creative mobility innovations may be found not in flying cars or other futuristic technology but in the movement of our own bodies.

Photo credit: Titan Arm



3.2.1. We can harness energy from our bodies in motion to move and power objects

The human body is an energy powerhouse. It produces energy constantly, through chemical digestion and metabolism, mechanical locomotion, and heat generated by movement. Harnessing this abundant energy source is a potent "back-to-basics" approach for the 21st century.

Applying mechanical force to an object, like spinning a turbine, is one major method of energy production. Human locomotion refers to applying mechanical force from our musculoskeletal system to induce movement. Researchers have developed a chip that can capture the kinetic energy of human movement to fuel small electronic devices such as cell phones. Such technology could be inserted into the shoe soles to store energy created from movement, or it could be inserted into the body; for example, the natural movement of the lungs could power pacemakers continuously. Human energy might also be harnessed through thermoelectric generation, which captures heat energy from the body through temperature gradients within the ambient environment.

Photo credit: Pavegen

New innovations mean we can harvest energy from our bodies in motion. UK-based Pavegen has created tiles that convert kinetic energy into electricity using a mechanical system rather than more advanced piezoelectric technology. The tiles could be installed where there's high foot traffic, like at busy transit centers or in schools. At Riverdale Country School in New York, the tiles are already powering a phone-charging station entirely through the force generated by students' footsteps.

Energy-powered innovations in mechanistic assistance can also restore or enhance human movement through individual augmentation. For example, the Titan Arm is a bionic exoskeleton that can allow people to lift heavier objects than they otherwise would be able to handle. The opportunity to restore or enhance human movement through mechanical assistance could serve many applications throughout the medical and industrial sectors. In medicine, bionic devices could assist with physical therapy to rehabilitate patients. In industry, these devices could give manual laborers greater ability to lift heavy objects and reduce the strain on their bodies. This mechanical assist could help prevent acute or overuse injuries among manual laborers, thus enhancing their quality of life.

3.2.2. Meeting the needs of growing populations in increasingly urbanized settings will require rethinking how people and goods are moved

Transportation has traditionally required a huge infrastructure investment, as well as substantial energy consumption, to fuel mobility. Both elements are beginning to change.

In most places today, the mass transport of goods and people is dominated by four technologies that are more than a century old (trains, automobiles, trucks, bicycles) and one that is more than 50 years old (containerized shipping). In this decade, energy that's being harnessed in new ways is transforming each of these technologies. As new technologies create new options, norms and models for mobility are changing rapidly:

- Gains in solar-power technologies are beginning to fuel cars, bicycles—even our roadways. New varieties of electric-assisted bicycles are expanding the range of the world's most efficient form of transport. Private bicycle-sharing programs are growing rapidly, transforming transit in cities.

Photo credit: Shutterstock.com

- Dramatic improvements in battery technology have pushed back the boundaries of automotive transport, turning electric-powered vehicles (EVs) from the ugly ducklings of the automobile market to some of the most sought-after consumer goods. By so doing, EVs have helped shift the trajectory of the entire industry. (Although EVs currently comprise only 1% of all new vehicle sales globally, recent analyses suggest that EVs could account for 30% of all new light-duty vehicle sales by 2030 and 54% by 2040.)

- Autonomous transportation is an emerging trend that, as it matures, will continue to reshape transportation dramatically in urban and rural areas alike. Careem is already demonstrating how the efficiency gains of Uber-like ridesharing might be extended even further with driverless pods.

Finally, for the first time in decades, a fundamentally new mode of transportation entering into use has the potential to effect an even greater transformation: the autonomous drone. Dubai is the first city to approve a trial run for drone taxis. As we explore here in our fundamental building-block section, drones are already fundamentally impacting every domain and dimension.

Solar Roadways

As more populations reach new levels of prosperity, more vehicles are expected on the road, which creates an obvious question: How can we sustainably fuel an additional one billion cars by 2035? One potential solution is to power vehicles of the future through the electrification of the transportation sector.

Solar roadways are one idea being tested as a way to transmit power to vehicles and to the lights and signs that accompany roadways. Specially designed arrays of solar panels would be laid flat and provide energy to the vehicles and people traveling across them.

Solar roadways are one idea being tested as a way to transmit power to vehicles and to the lights and signs that accompany roadways.

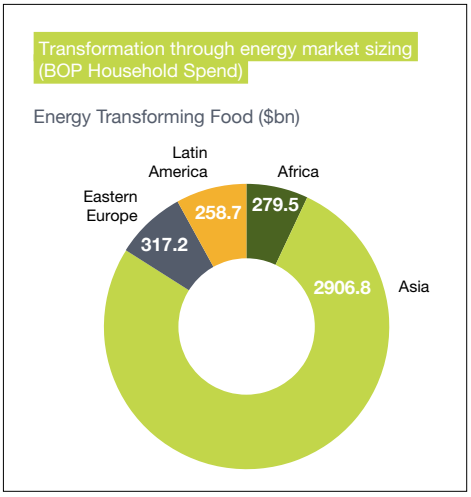
Though largely still in the R&D phase, the world's first solar-powered roadway was piloted in France in 2016. Other projects have explored different solar-powered transportation pathways; the SolaRoad, which was tested in the Netherlands in 2015 for use on bike paths, reportedly generated far more power than was anticipated.

Solar roadways face several cost, engineering, and maintenance challenges before they can achieve wide-scale deployment. The kilometer-long test bed in France cost $5.2 million; there are one million kilometers of roads in France and more than six million in the U.S. Even with a targeted deployment, the high upfront costs could mean an increased payback period for investors. Furthermore, laying the panels flat (rather than being angled toward the sun) seems to lessen their ability to generate energy. New technology breakthroughs may increase the product's attractiveness, such as the ability to prevent the accumulation of snow and ice, or including microprocessors in the panels to allow for communication between the panels, control hubs, and vehicles.

READ MORE

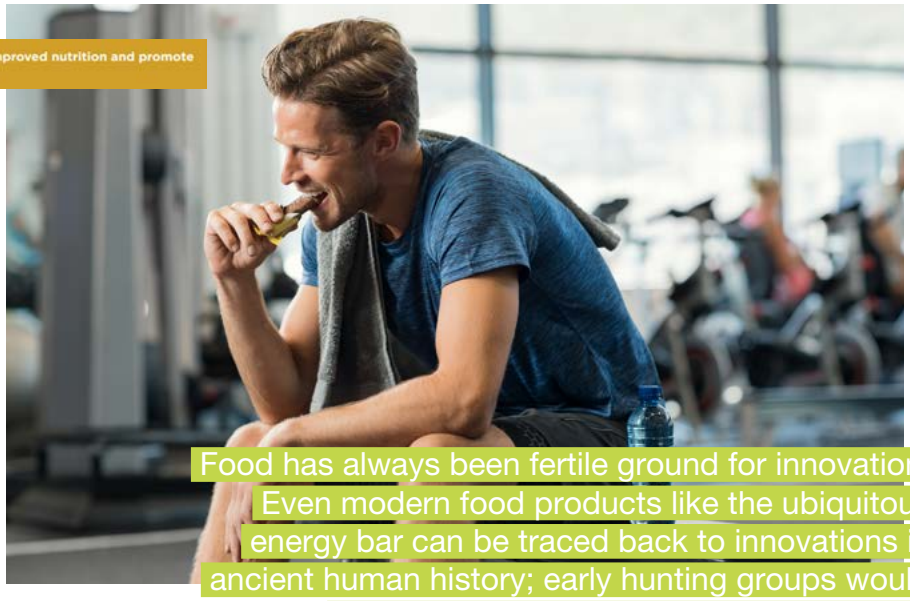
- **Sustainable Development Goal 11: Sustainable Cities and Communities**
- **Sustainable Mobility for All**
- **2016 Global Transport Sustainability Conference**

3.3. Energy enables efficiencies in farming, food production, and agriculture that can help reach many more people while transforming the way we produce and consume food



The food we consume to fuel our bodies is our primary personal energy source

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture



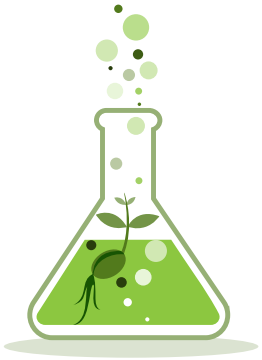
Food has always been fertile ground for innovation. Even modern food products like the ubiquitous energy bar can be traced back to innovations in ancient human history; early hunting groups would consume durable high-energy food called [illegible] from the rendered fat of big game, dried meat, and sometimes berries.[6]

Our modern food production systems hinge upon a variety of energy-driven technologies; fossil fuels, for example, power our tractors, and our fields are spread with nitrogen-based fertilizers. Today, the global supply of food energy requires significantly less land and human labor than it has for most of human history, but it does so with the expense of intensive energy investments in agricultural activities. The energy transformation in agriculture to date has had unequal results. The global harvest right now produces more than adequate calories per person, but 12% of the world's population remains undernourished; in rich countries the food supply is 75% higher than actual need, resulting in food waste and increasing incidence of obesity.[5]

Technology continues to redefine our mechanistic farming practices, but the coming decades will require a radical transformation of the sector: to meet the needs of the global population, we must grow 60% more food by 2050. We'll need energy-powered innovations that transform #Agtech and #Foodtech, which means rethinking how we produce and consume food. Teams are challenged to take a new perspective on:

- Redefining what food is
- Innovating how we grow food
- Changing how we process, store, and distribute food

Doubling our production of food, feed, and biofuel by 2050 is a steep challenge. Historically, we have been able to achieve even larger increases in our agricultural production over similar time periods, but efficiency increases are now slowing, in part due to climate change. Maintaining our past pace of yield increases will be difficult without new systemic innovations. Resource-conserving practices, such as conservation agriculture and climate-smart agriculture, are helping to increase agricultural productivity. A recent resurgence in both agricultural R&D and private investment makes it more likely than ever that these and other emergent innovations can achieve wider deployment.



"it's becoming easier to alter crop genes to improve disease resistance and drought tolerance"

3.3.1. Pioneering entrepreneurs are redefining what food is, creating game-changing opportunities to increase yields and improve nutrition

What we consider food continues to evolve with new innovations in how to use or alter various forms of energy input. With the advent of CRISPR, a new genetic engineering technology, it's becoming easier to alter crop genes to improve disease resistance and drought tolerance, or to increase yields and improve nutrition. New food products such as insect protein powders can make key nutrients more sustainable and accessible; others provide nutrition while cutting down on major sources of food waste. Advances in the laboratory are also making it possible to grow meat.

Case: Making Meat—Growing Protein in a Lab

Cultured meat production substitutes animal meat for lab-grown, plant-based products that can mimic the look, texture, and taste of actual meat. Meat production is a burden on the environment. The amount of energy invested in producing meat products is enormous in comparison to that required for producing the same number of calories from plant-based sources. It takes an average of roughly 1,800 gallons of water to produce a single pound of beef. Cattle grazing is a top contributor to global deforestation, and cows are a surprising key source of greenhouse gas emissions. The demand for meat around the world is projected to grow by two-thirds in coming decades. Meanwhile, many innovations are making meat production less energy intensive. Some of the most promising are going so far as to rethink what "meat" means.

Meat products made from plants have been around a long time, but soy burgers and meatless bacon rarely replace the true flavor and texture of meat. That is changing. Impossible Foods has created a burger using plant-derived "heme," which gives it the flavor and texture of meat. It is already being served at upscale food chains. Production of heme uses significantly less energy, consumes 95% less land, 74% less water, and produces 87% less greenhouse gas than traditional burgers.

Photo credit: Impossible Foods

Impossible Foods has created a burger using plant-derived "heme," which gives it the flavor and texture of meat.

Meatless meats of the near future will be lab-grown, or cultured. These meats are based on actual meat tissues and synthesized from cell cultures. Silicon Valley startup Hampton Creek has gotten off to a highly publicized start, as have Memphis Meats and Mosa Meats in the Netherlands. "Our goal is to entirely remove the animal from the meat production process," says Memphis Meats CEO Uma Valeti.

With only a handful of startups in this field, there are many possible business opportunities in building out the supply chain and bringing these kinds of products to new markets.

3.3.2. Innovations on the production side are set to alter how we grow food

Taking farming indoors, using hydroponic and aquaponics systems, and deploying robots to further automate the manual labor of agriculture are all altering how we grow our food.

VERTICAL AND INDOOR FARMING

Indoor farming is one response to the shrinking amount of farmland. With advances in solar energy, sensors, lighting, robotics, and artificial intelligence, indoor farms have become a viable alternative to traditional outdoor farms. Automated indoor farms use roughly one-tenth as much water and land as traditional farms, and localized production can cut down on transportation costs. Crops can be harvested many more times per year, without the same dependency on weather patterns or reliance on pesticide usage. Several startups, including Motorleaf, Plenty, Aerofarms, BrightFarms, Bowery Farming, and Freight Farms, are building "post-organic" indoor farming systems to grow fresh food locally, and they have raised considerable capital.

Farming can now be done without a field. In London, a hydroponic farm was built in the underground tunnels that once served as air-raid shelters.

AQUAPONICS

Aquaponics systems combine the farming of fish (aquaculture) with the cultivation of plants (hydroponics). In a "closed-loop" aquaculture system, fish are fed nutrients and their excrement is used as fertilizer for the plants. The water also can be filtered and reused for the fish. While promising, the challenges of large-scale deployment have limited implementation to date. The Food and Agriculture Organization of the United Nations has called aquaculture one of the fastest-growing food-producing sectors. With a handful of firms like Urban Organics and Blue Smart Farms developing plans for larger distribution, the sector has opportunities for further entrants.

AGBOTS

Mechanization was essential for the development of large-scale industrial farming. New technologies will further change how easily and quickly we can plant, maintain, and harvest food around the world. While some innovations look to harness nature—like using bees as delivery agents for direct pest management—others are looking to deploy robots to increase efficiency.

Agricultural robots, or "agbots," can complement emerging sensor and drone technologies to improve efficiency in the field. Prototype robots have been able to microtarget weeds with herbicides, using only 0.1% as much weed killer as is used in conventional blanket spraying. Introducing more automation into harvesting could decrease harmful monoculture practices, with small autonomous robots enabling mixed planting.

The field is ripe for the picking. The global market for agbots was estimated at $3 billion at the end of 2015, with forecasts suggesting growth to $17 billion by the end of 2020 and nearly $74 billion by 2024. There's still room for new ideas. "Big-machinery manufacturers are not putting their money into manufacturing agricultural robots because it goes against their current business models," says Simon Blackmore, an engineer at Harper Adams University in the UK.

3.3.3. Changing how we process, store, and distribute food will dramatically reduce food waste and enhance food security

12.3 SDG Target: By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses

1/3 OF ALL FOOD GROWN IS LOST OR WASTED EVERY YEAR THAT'S 1.3 BILLION TONS WORTH $750 BILLION

Safely processing, shipping, and distributing the food we produce is a significant logistics challenge. It's also a large market. Cold-chain services for perishable food distribution are valued at roughly $190 billion globally and are projected to grow by more than 40% by 2022. Improving how we store and distribute food is an essential component of ensuring food security. Problems with food distribution are one significant driver of global hunger: while great gains have been made in recent decades, an estimated 795 million people still lack access to adequate food.

Reducing food loss is a major vector for improving the efficiency of our global food production chain. It's estimated that 30% to 40% of all food grown is lost or wasted every year. In low-income countries, food loss and waste stem from challenges with harvesting, storing, and distributing food. In higher-income countries, lack of coordination between actors in the supply chain and consumer behavior drive the majority of food waste.

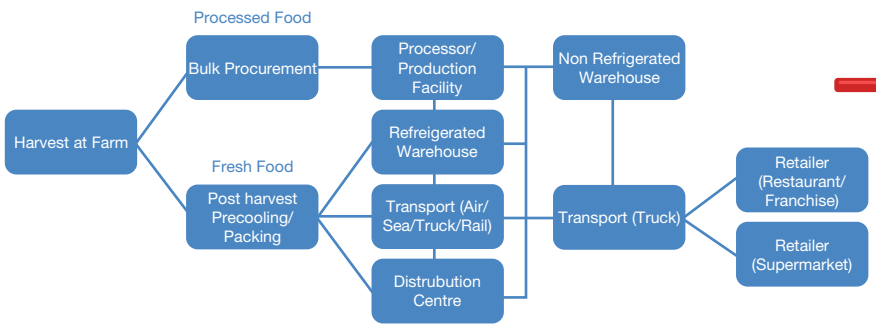
Building end-to-end cold-chain systems helps move perishable food safely to consumers. The maturation of proper cold-chain storage systems has yielded significant benefits in developed countries; the WHO identified refrigeration as a major factor in the reduction of stomach cancer by nearly 90% in the United States since 1930. But infrastructure challenges have limited the expansion of these systems in some developing countries. Creative solutions include using new energy technologies such as renewables to power modular cold-storage units. The East Africa Fruit and Farm Company, based in Tanzania, touts significant reductions in post-harvest losses (from 48% to 10%) through the use of cold storage driven by renewable energy. Hazel Technologies, a U.S.-based startup, focuses on providing growers and shippers along the supply chain with its small sachet inserts that can be slipped into shipments to inhibit ripening.

In addition to preserving what we grow, we also must ensure that food is safe to eat. New applications of energy can improve the safety of our food. RF Biocidics uses radio frequency to eliminate pathogens in food. By using electromagnetic waves instead of conventional thermal processing, food can be treated in packaging without the use of chemicals.

UN Food and Agriculture Organization:

"Given that many smallholder farmers in developing countries live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods."

Sample Cold Chain Diagram:



Case: ColdHubs—Preserving Harvests with Solar Power

In developing countries, nearly half the food harvested spoils due to lack of refrigeration. An estimated 470 million farmers in Africa, Southeast Asia, and Latin America lose up to one-quarter of their annual income from crop spoilage. ColdHubs, located in Nigeria, is leveraging renewable energies to tackle food-storage challenges in developing countries.

Photo credit: ColdHubs

Started by Nnaemeka Ikegwuonu, a farmer and entrepreneur, ColdHubs is styled as a "plug-and-play" solution to on-site food storage. Modular, solar-powered walk-in units allow for off-grid storage of perishable food. Solar panels mounted on the roof feed energy to high-capacity batteries that fuel a refrigerating unit.

The business model embraces microtransactions using a "pay-as-you-store" subscription model, which allows farmers to pay daily fees based on the amount of food they store. Rates currently are 100 Naira per day and per crate—about 50 U.S. cents. ColdHubs is designed for major food production and consumption centers, such as farms and outdoor markets, where sitting in the hot sun can scorch produce. ColdHubs' model extends its social impact by doubling as storage for refrigerated medications and vaccines.

Case: Farming Net Energy with Methane Digesters

Agricultural, industrial, and human digestion processes create an ongoing (and growing) stream of organic refuse.

Without thoughtful management, organic waste can emit fugitive methane gases as it decomposes. Methane creates a warming effect 34 times stronger than carbon dioxide over one hundred years.

One solution to this is to contain the decomposition of organic waste in sealed tanks called anaerobic digesters. The tanks harness the power of microbes to transform scraps and sludge into two main products: bio-gas, an energy source, and solids called digestate, a nutrient-rich fertilizer.

Brubaker Farms, a family-run dairy in Lancaster County, Pennsylvania, has developed an innovative agricultural system that's environmentally beneficial and economically successful. Using a digester, the farm captures methane produced by its 900 head of cattle and in turn produces electricity—enough to power the farm as well as another 200 homes. Waste heat from the generator is even reused to heat water for the farm, and digested solids find second life as hygienic bedding for the cows. This holistic, creative approach to resource management is good business for the farm—and good for the environment.

READ MORE

- **FutureAg: Current news in the future of sustainable agriculture**
- **FarmHack.net: An open-source community for farmer-driven agricultural innovations**
- **"How Big Data is going to help feed 9 billion people by 2050," Tech Republic**

3.4. Energy enables more efficient water collection, storage, and transport, helping humanity manage its most valuable resource

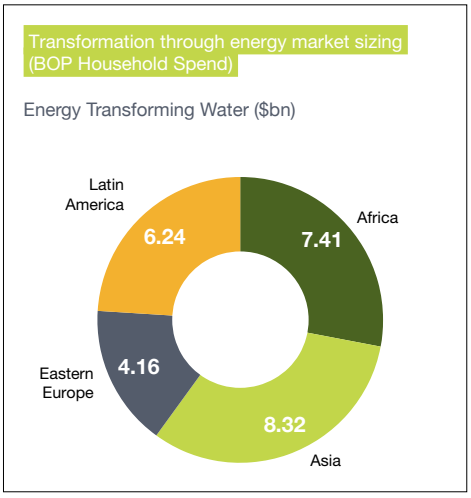
Energy and water are deeply intertwined. Some of our earliest innovations involved harnessing water's energy. Water is essential to human life in all phases of energy production, and energy-powered innovations are the critical underpinning of our water supply and treatment systems.

Discussions of water today are often focused on scarcity; by 2025, 1.8 billion people will live in water-scarce conditions. New energy-driven innovations are needed to transform how we collect, store, and transport water so that all people will have access to this vital resource. As new technologies help with clean water, water conservation, flood prevention, pollution control, data collection, and infrastructure planning, a holistic view of how water touches our lives is needed.

Teams are asked to consider how you might use energy to:

- **Create more clean water with new technologies**
- **Conserve water resources with improved stewardship**
- **Enable wider access to clean water resources**

Water is essential to human life in all phases of energy production, and energy-powered innovations are the critical underpinning of our water supply and treatment systems.



6 CLEAN WATER AND SANITATION

Goal 6: Ensure availability and sustainable management of water and sanitation for all

3.4.1. New technologies are producing more clean water from existing sources, allowing humanity to access a large untapped supply


Photo credit: Shutterstock.com

Water insecurity is a pressing global challenge, and declining water quality has become an issue in many population centers due to population growth, industrial and agricultural practices, and climate change.

Concerns over freshwater availability motivate the need for better ways to create clean water sources. Desalination and filtration technologies are two ways of creating more drinkable water.

DESALINATION

Desalination is one way to provide more fresh drinking water to the world's population. The process uses reverse osmosis to separate salt from seawater and produce drinkable water for human consumption. Years of development, cost breakthroughs, and gains in the technology's efficiency have made mega-desalination commercially viable. The world's largest desalination plant opened in California in 2015 after 20 years of planning. Part of a $1 billion public-private partnership, the plant is capable of producing 50 million gallons of freshwater per day.

Large-scale desalination has traditionally been costly as well as energy intensive. Over the next 25 years, the amount of energy used in the water sector is expected to more than double, mostly because of desalination projects. By 2040, these desalination projects will account for 20% of water-related electricity demand. Biomimicry (mimicking biological processes) are being explored as one way to transform seawater to fresh water using less energy. In Singapore, which built its first desalination plant in 2005, progress toward more energy-efficient desalination has come from learning to imitate the biological processes that allow mangrove plants and euryhaline fish to extract seawater. Aquaporin, a Danish company, is developing biomimicking membrane technology to use for desalination, and other plants around the world are using solar power to desalinate water more energy efficiently.

FILTRATION USING MEMBRANE AND OTHER NANOTECHNOLOGY

An estimated 1.3 million people die every year from diarrheal diseases caused by a lack of safe drinking water and basic sanitation. New energy-driven innovations can be infused into consumer technologies that help to create safe, drinkable water. Membranes can act as a sieve to filter impurities from water and produce consumable water. Some nanotechnology filtration uses nanoparticles that destroy harmful contaminants in water.

Many recent breakthroughs in membrane filtration have used graphene, which is 100,000 times thinner than a strand of human hair. The membrane tech could be adapted for the micro or macro scale—to fit either household faucets or be installed in large-scale industrial wastewater treatment systems. At least one startup, G2O, is exploring commercial applications for desalination, decontamination, and wastewater treatment, but there aren't yet many competitors actively commercializing this technology.

CASE: wAmrit —Using Nanotech to Create Clean Water

Photo credit: Thalappil Pradeep

Amrit—which stands for Arsenic and Metal Removal by Indian Technology—is a water filter that uses nanotechnology to filter arsenic from drinking water. Invented in 2012 by Indian chemistry professor Thalappil Pradeep, it can provide drinking water for a year for as little as $16. Its two-stage filtration process first removes impurities using ions from silver nanoparticles, and then removes chemical impurities such as arsenic using a variety of nanomaterials. Amrit's filtration system does not need electricity or running water, as it operates on gravity. The filtration process can be completed within minutes, thereby allowing arsenic to be removed from drinking water in a short period of time.

"Most countries have some water sources with dangerous levels of arsenic, but only now are we beginning to recognize the magnitude of the problem. It is the most dangerous contaminant of drinking water in terms of long-term health risks, and we must test all water sources worldwide as soon as possible."

—Allan Smith, University of California-Berkeley

The water purifier is offered in different sizes and at various price points, and the price includes installation. The $16 filter provides water for homes, while larger systems can be hooked up to schools or office buildings for $500; hooking up a whole village costs $1,200. The largest purifier is nine feet tall and "resembles a giant green coconut." It can produce nearly 80 gallons of clean water per hour.

With $18 million in venture funding from a U.S.-based nanotechnology company, Amrit has plans to deploy globally and to increase the range of their filtration to include other hazardous chemicals, including iron, lead, mercury, cadmium, and copper.

3.4.2. Improved stewardship conserves water resources by capturing a greater proportion for reuse

Photo credit: Accoustic Sensing Technology

New technologies are helping to conserve and reuse water resources through infrastructure monitoring and better wastewater management.

Acoustic Sensing Technology, a UK startup, uses acoustic signals and analytics to provide more accurate, real-time monitoring of sewers and pipes. Better data generated faster means that infrastructure interventions can happen more quickly when problems arise.

The effective management of wastewater is important for both public health and water security reasons; wastewater is increasingly a reliable water source for food production, but it must be adequately treated for safe reuse. Pilus Energy has developed "bactobots"—genetically enhanced, highly metabolic bacteria that can simultaneously sanitize wastewater and generate electricity. Bactobots digest the pollutants in wastewater and convert them into electricity, which can be captured by an electrogenic bioreactor platform.

Photo credit: Wello

3.4.3. Innovations in water transport and access enable both traditional and modern practices to reach more people

Improving how we transport and provide access to clean water can take several forms. Mobile-enabled tools like Flowius facilitate pipeline design to develop new piped water infrastructure in rural areas.

Conversely, the Waterwheel from U.S. venture Wello is a low-tech innovation designed for rural environments where there is no piped infrastructure. Its deceptively simple design yields big benefits to women who are typically tasked with manual water collection. The 50-liter round container allows women to roll water from wells instead of carrying it on their heads, thus using kinetic energy in place of human labor. Building "water ATMs" to dispense affordable clean water is another solution that bypasses traditional pipeline infrastructure. Smaat India has created a sustainable business model for distributing low-cost water to 75 million customers in India through 2,800 water ATMs; the company also provides employment opportunities for the physically disabled.

Case: Learning from Earlier Innovation Attempts

Several end-use innovations in creating clean water have not been successful in reaching their hoped-for levels of impact. Your team may find useful lessons in their experience as you think about how to develop an effective solution that has a viable path to market.

The Watercone is a simple plastic cone that can filter 1.5 liters of fresh water from salt water each day using solar power. Invented in 2001, the Watercone, which was field tested by NGOs, has received wide acclaim and many innovation awards. It has not, however, been successfully commercialized at scale. One challenge may lie in the inherent limitations of the design; the area-to-water yielded ratio does not scale well for addressing community water needs. Another problem may lay in their focusing marketing efforts on NGOs instead of developing a demand-based path to market with end users.

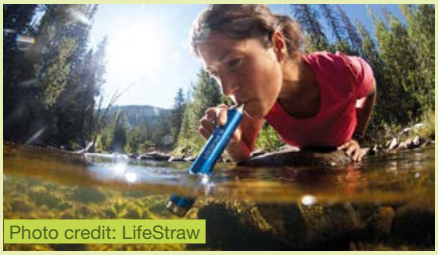


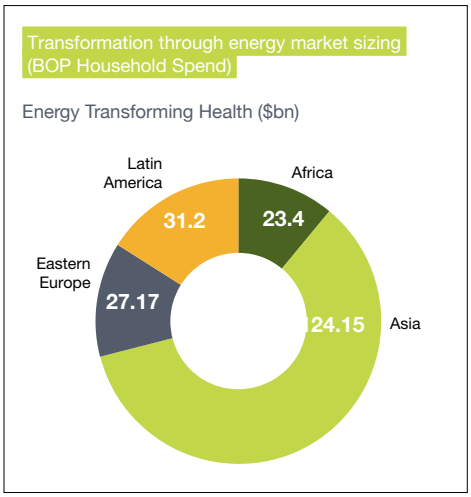
Photo credit: LifeStraw

The LifeStraw is another notable water innovation—though perhaps not for positive reasons. The hollow-membrane straw is small, lightweight, and portable, and can effectively filter out bacteria. While initially hailed as a game-changing innovation, the LifeStraw has since come to be viewed by some as a notable development failure. Critics charge that the solution doesn't scale to provide adequate amounts of water, doesn't provide adequate filtering (it can't filter out viruses), and wasn't offered at a viable price point for its market.

Both of these innovations were guided by good intentions. **How could their work be improved on? How could simple innovations be redesigned and better distributed to have a greater impact?**

READ MORE

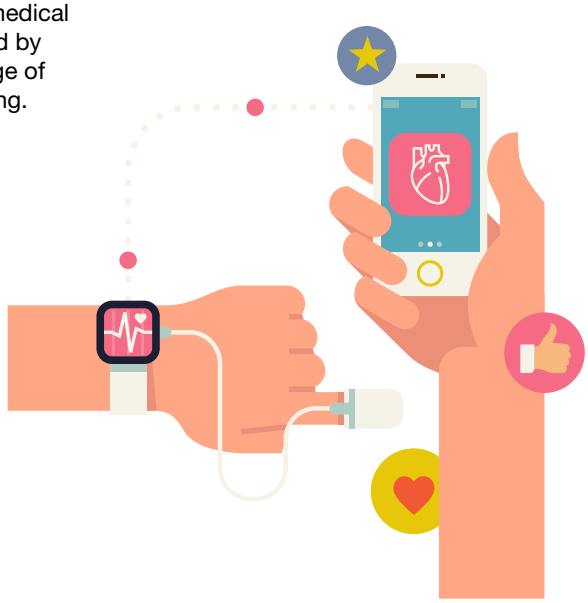
- **Sustainable Development Goal 6: Clean Water and Sanitation**
- **Innovation in the Water Sector: Reports from the U.S. Environmental Protection Agency highlight 10 market opportunities**
- **Explore more current trends in water innovation from the Global Water Summit**



3.5. Energy provides pathways to better human functioning, extending lives and improving quality of life

The health and human experience dimension of transformation encourages teams to think about how energy-powered innovations can drive advancements in diagnosis, treatment, rehabilitation, and quality-of-life medical applications. New frontiers of health knowledge enabled by energy-powered technologies are transforming the range of opportunities for extending human health and functioning.

Goal 3: Ensure healthy lives and promote well-being for all at all ages



3.5.1. Expanding medical care provision options and improving access across a greater variety of media promises to transform healthcare delivery

Connected medicine, which encompasses the telehealth, remote medicine, and mobile health domains, makes it possible to obtain quality medical care without regard to geography. Telehealth innovations mean that wellness promotion, disease prevention, diagnosis, and (when appropriate) treatment can be provided by qualified health professionals via digital channels (mobile phone, tablet, computer). At the other end of the spectrum, localized networks are enabling a return to healthcare in the home when possible. For instance, home visits by physicians in India and self-governing networks of home-care nurses in Holland demonstrate how advances in e-medicine are complemented by a return to medical house calls.

Not too long ago, most healthcare services anywhere in the world were provided in the home. The advent of modern medicine over the past century changed this. In the United States in 1930, house calls constituted 40% of physician encounters; by 1950 that number had dropped to 10%; by 1980 it was just 1%. In the past two to three decades, the advantages of hospital-based care have started to erode due to the high cost and increased prevalence of hospital-acquired infections, among other factors. At the same time, energy-enabled technologies and organizational innovations that enable the provision of healthcare both in the home and at a distance have improved radically in performance and cost.

Hospital and outpatient health-services systems are still unevenly developed in many developing countries, and quality healthcare is particularly inaccessible for millions of people in rural areas and in large urban slums. In these markets especially, innovations in energy-enabled healthcare provision are creating an opening for entrepreneurs literally everywhere to offer lower cost, equal, or more effective healthcare options for consumers.

Peer-to-peer health-service provision is another mode of healthcare made increasingly possible by energy connectivity. These as yet nascent efforts signal a market demand for institutional innovations that bypass the existing healthcare infrastructure to the extent possible. For example, Village Networks that have organized throughout the United States pool resources in their communities to enable the provision of healthcare services and other life services within the home.

Finally, advances in Big Data-enabled diagnostic and decisionmaking support are radically upending how we deliver healthcare. Combining Big Data analytics with the service models listed above creates especially acute opportunities for further disruption in healthcare. For instance, robotic surgery can offer improved access to advanced surgical options either in the home or at other locations far from formal care.

3.5.2. Broadening the spectrum of available and accessible medical treatment options is making better health outcomes possible

How can precision medicine be brought affordably into ascending markets?

New breakthroughs in neuroscience, genetic medicine, and domains of physical augmentation make it possible to treat and support our health in ways that would have been impossible only a few years ago.

Underlining each of these innovations are fascinating connections back to inventive ways of using energy to fuel better health outcomes. Finding ways to bring these advances to consumers would dramatically extend the collective flourishing of human capabilities.

NEUROPROSTHETICS AND NEURAL IMPLANTS

Advancements in prosthetics have led to the next generation of artificial limbs. Neuroprosthetics now allow the mind to control prosthetics just like regular limbs. These prosthetics are also modular, so healthcare practitioners and patients can tailor-fit designs according to the patient's needs. This technology could help people regain locomotor control of certain bodily processes, and hold promise to restore quality of life in a variety of medical applications. For example, the Argus II Retinal Prosthesis System is the first approved device to restore some functional vision for those living with blindness. It functions through a surgically implanted epiretinal prosthesis in and on the eye. Similarly, so-called neuro-bots are a growing field of brain-controlled prosthetic devices that allow paralyzed or other bodily disabled individuals to regain freedom and the ability to interact with their worlds.

As technology advances, neural implants grow closer to allowing the human brain to interface with an external computer system that facilitates the restoration of sensory performance, including vision and hearing. Neural implants have the potential to establish two-way communication flows between animate and inanimate objects, which could have profound implications for human health and learning ability. By linking electrochemical energy that powers the human brain with electricity that powers computer systems, these implantable technologies could help computers "talk" to the human brain and engage it in learning tasks that help restore deficits in human performance.

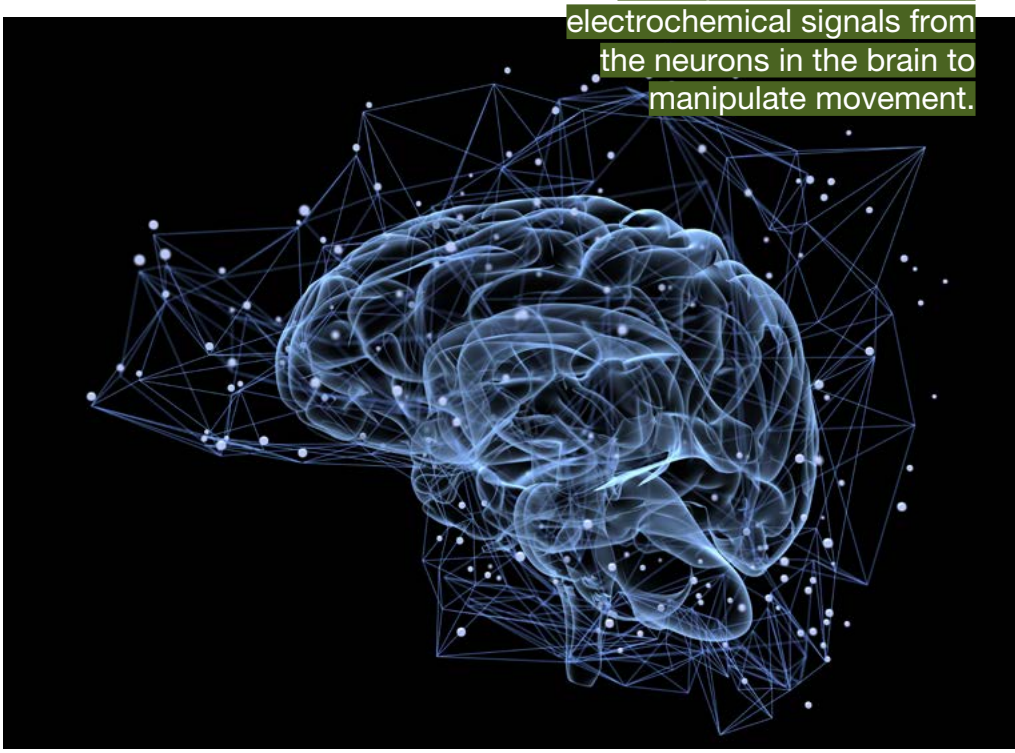
PRECISION MEDICINE

Precision medicine broadly refers to genetic and biomedicine.

Bioengineering (or genetic engineering) involves the study and manipulation of individual genes. Advances in bioengineering continue to help medical practitioners study diseases and offer novel treatments: We can grow human tissue on plant leaves. Creative immune engineering has reprogrammed cells to fight cancer and regenerate tissue growth. With gene editing, we can eliminate dangerous mutations in utero and maybe even transplant organs from other species.

As markets for genetic and biomedicine (and biopharma) accelerate their growth, serious ethical questions arise about how equally gains in medical treatment will be distributed. Genetic diseases have always been a shared vulnerability. With continued advances, parts of society may soon be able to opt out of these risks. So how will that affect how we provide support to those who remain vulnerable? The only

Neuroprosthetics receive electrochemical signals from the neurons in the brain to manipulate movement.



way to prevent genetic diseases from becoming diseases of poverty, says expert bioethicist Josephine Johnston, is to extend access to these services to more consumers.

At the risk of repetition, teams should not attempt to field new discoveries that require a professional lab and a multimillion-dollar R&D budget. However, there's considerable work to be done to take the existing breakthroughs in genetic and bioengineering and find ways to extend them to more consumers. "What's missing in the conversation is how we adopt all of these technologies to a society that considers well-being for all," says Eleonore Pauwels, a bioethicist at the Wilson Center. "There is already an access problem. But what about when we're editing out diseases? Who will pay for CRISPR? We are looking at much more disruption in the future."

Extending access to genetic knowledge is a start. Startup Genome Medical is one example of how a social enterprise can help empower more consumers with frontier medicine.

WEARABLES AND OTHER AUGMENTATION

Energy-based technological breakthroughs have broadly enabled us to overcome many sensory disabilities, but access to these empowering technologies has been unequally distributed because of cost barriers. One in 20 people have some level of disabling hearing loss, but of the 300 million people around the world who need hearing aids, each year only an estimated seven million—most of them living in the U.S. and Europe—are able to afford them.

A number of wearables are particularly promising, as they offer more affordable solutions to those with hearing impairments: Bone-conducting headphones can transmit sound in ways that bypass auditory deficits.

Bluetooth hearing aids are an example of a low-cost approach to deploying technology at scale, especially when integrated with smartphones that can be used as assistive listening devices.

Other creative wearable innovations translate various types of energy inputs into sensory outputs. The Sensory Substitution Vest translates audio captured by tiny embedded microphones into a grid of vibrational patterns. (Over time, a wearer's brain learns how to "hear" the vibrations from the interactive cloth.) LeChal Shoes translate haptic inputs for the blind; the shoe insoles, which connect to a mobile app integrated with Google Maps, vibrate to tell users when and where to turn in order to reach their destination.

"Somewhere between 600 million and 1 billion people need help with their hearing, depending on the degree of hearing loss. Contrast that need with the fact that the traditional hearing aid industry is selling only 10 million products per year."

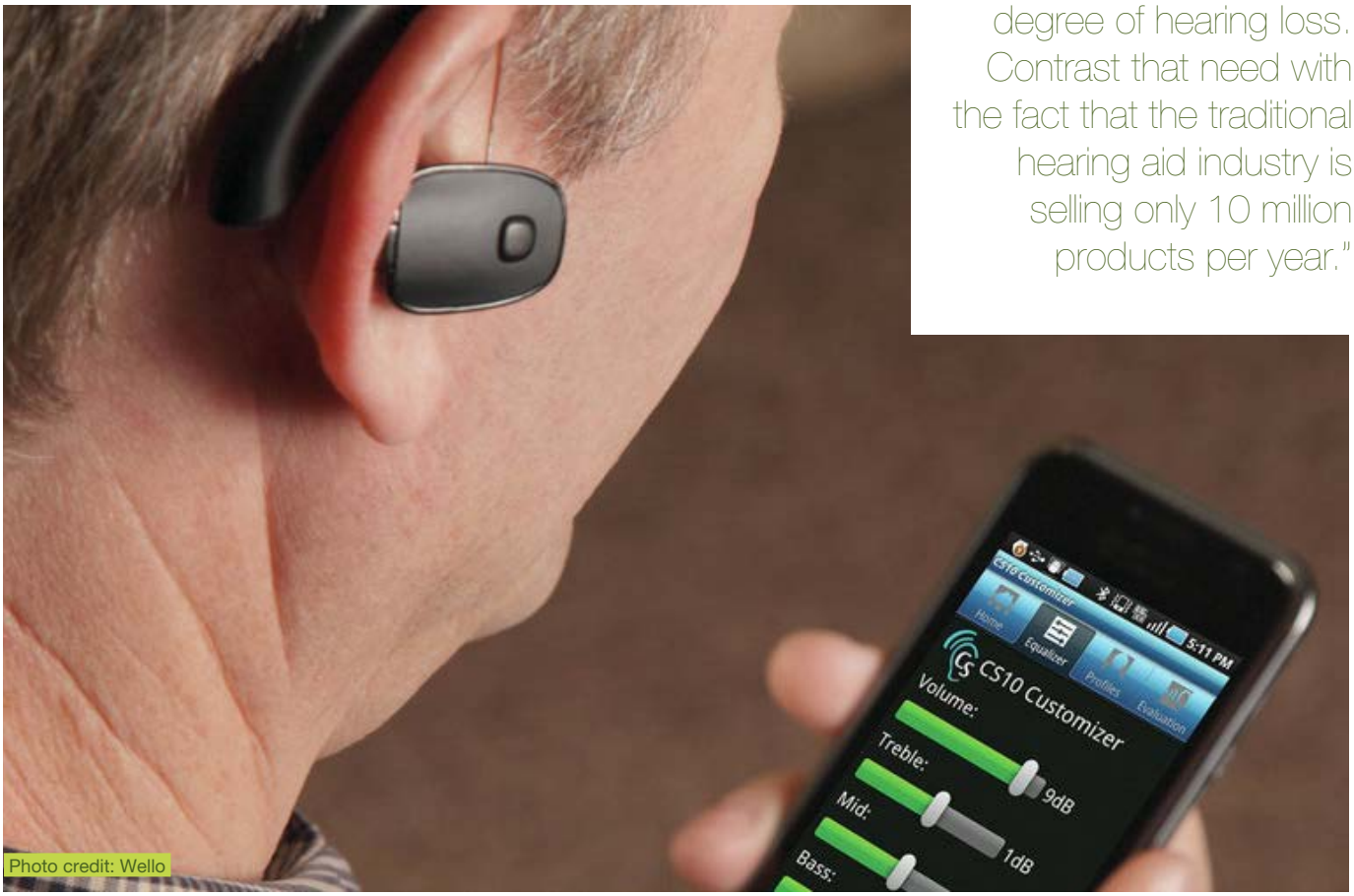


Photo credit: Wello

Case:
Smart Contact Lenses

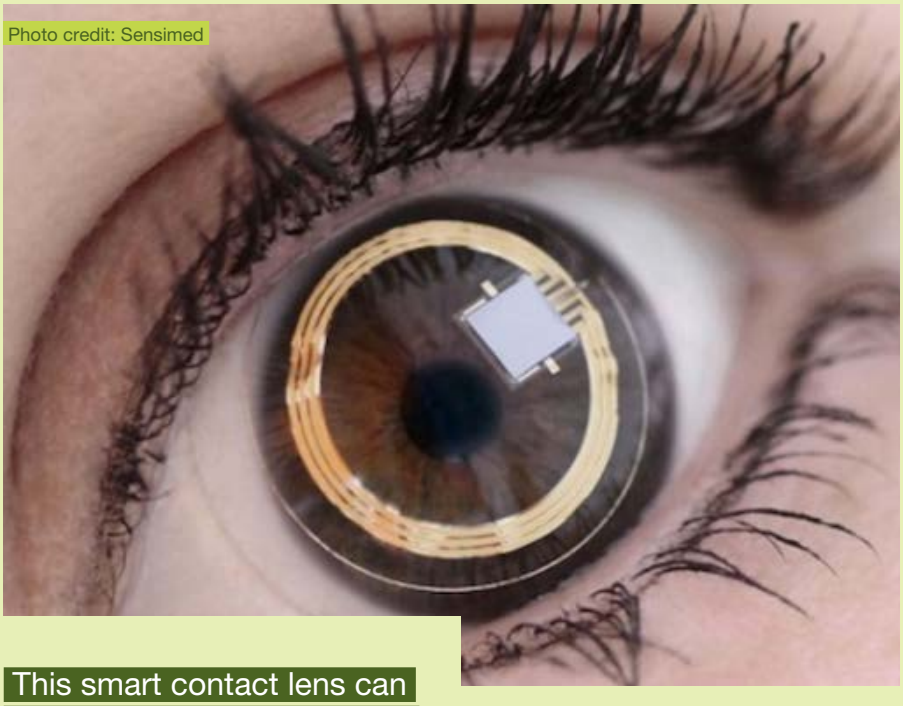


Photo credit: Sensimed

Every time we blink, we bathe our eyes in a lubricating fluid. That fluid, it turns out, contains many of the health biomarkers measured by standard blood tests.

Smart contact lens technologies demonstrate how a common mass-market item is being reconceptualized as a way to provide energy-driven health benefits to millions of people. Smart lenses hold the promise for a new way to non-invasively test and monitor health conditions. Distinct from the retinal prostheses described above, an active or smart contact lens can be applied to the eye just like a regular contact lens. Microchips and sensors no larger than flecks of glitter are embedded in the contact lens, which enables them to monitor health markers. The lenses are powered either by harnessing kinetic energy generated by eye blinks, or by near-field wireless charging. Transmitting the data wirelessly enables real-time monitoring by medical professionals.

This smart contact lens can monitor glaucoma, using an antenna made of gold to receive power and transmit data.

Over 100 million people wear contacts daily for vision correction; the range of applications for smart lenses—and the potential consumer market—is even larger. A smart contact that can automatically monitor glucose levels would be life-changing for the 420 million people around the world who must frequently monitor their blood sugar as part of ongoing treatment for diabetes. Other uses to date include measuring ocular pressure to monitor glaucoma (which affects 60-70 million people) and sleep apnea (100 million).

As the technology matures, the range of applications continues to expand. Other lens technologies have been able to correct color blindness. Researchers at the University of Washington have developed a smart contact lens with biosensors that can continuously monitor temperature, heart rate, and chemical levels in the eye fluid. Using an embedded micro-antenna, the lens reports health information over radio frequency. Samsung and Google also have patented lenses under development, while Swiss company Sensimed has released its Triggerfish lens in 33 countries. Future iterations might offer monitoring of cholesterol, sodium, potassium, and other biomarker levels, potentially allowing medical professionals to monitor chronic conditions remotely.

Smart lenses are an apt reminder that everyday items can become powerful vectors for improving millions of lives. How else might energy-driven advances like sensors be applied to common objects and improve health for millions?

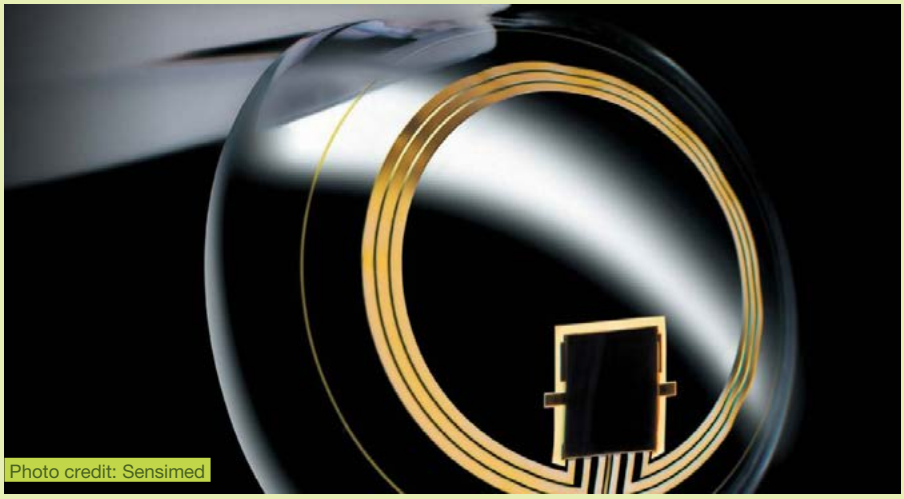


Photo credit: Sensimed

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- **Sustainable Development Goal 3: Good Health and Wellbeing**
- **The Digital Transformation of the Healthcare Industry**
- **Center for Health Market Innovations**

Solar Toilet

Photo credit: Caltech

Some 2.3 billion people still lack access to basic toilet facilities.

- World Health Organization

It's possible to address multiple dimensions of transformation in innovative and creative ways. One example of a cross-cutting solution is the Solar Toilet, invented by a team of students at Caltech in 2012.

The solar toilet, which is powered by solar energy, converts human waste into hydrogen gas for various uses and into fertilizer for food production. This approach epitomizes energy-powered innovation: it harnesses sustainable energy to provide sanitation while generating further useful energy inputs. The toilet system is completely self-contained and can run off-grid. It requires no sewer connection and can treat wastewater in just a few hours. This has marked implications for improved public health and sanitation systems, particularly in regions without access to electricity.

The Solar Toilet demonstrates how winning ideas from startup competitions can make their way to market. It's one of many innovations to come out of the Gates Foundation's annual Reinvent the Toilet Challenge, which calls for new sanitation solutions that are safe and sustainable. Since the competition, the team has continued to refine its design and has field-tested prototypes in India, China, and South Africa. It also has partnered with Kohler to explore scaling manufacturing and distribution.

The potential market is large and the social benefits of reaching this market enormous: 2.3 billion people still lack access to basic toilet facilities, which has dire consequences for public health. "Look at the promise of delivering proper sanitation to parts of the world that will, let's face it, never have water or sewage infrastructure," says Rob Zimmerman, Kohler's senior channel manager for sustainability. "If that can be demonstrated, it's going to be one of the most significant breakthroughs of the 21st century."

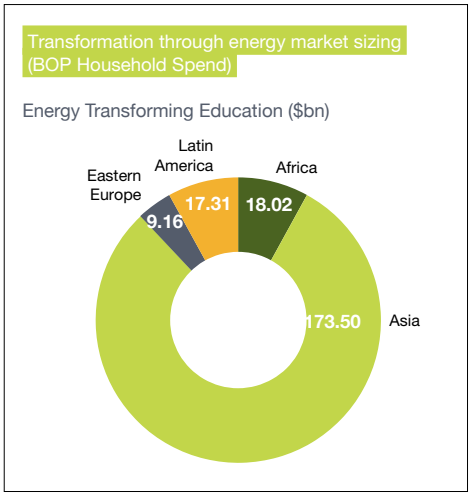
Incorporating on-the-ground-learning and capitalizing on advances in digital technology have been integral to the Solar Toilet's continued development. "It has become increasingly clear that solutions like ours to the sanitation problem are only going to work if there is an easy plan in place for maintenance," said Cody Finke, a graduate student on the Caltech team. The team is now embedding sensor technology in the units to respond to maintenance needs and streamline operations, which will be essential to deploying the technology at scale.

"We feel that our new self-diagnosing technology will enable what has been kind of a Band-Aid fix to become an actual sustainable fix to the sanitation problem," Finke adds.

"The world needs one billion toilets. That's a big market."

—Jack Sim (a.k.a. "Mr. Toilet"), founder of World Toilet Organization

3.6. Energy is allowing more people to access educational and knowledge resources, opening new gateways of opportunity



Participating fully in our world requires knowledge and basic education skills, but access to such opportunities is unequally distributed. Global literacy rates have risen dramatically in the last 100 years as educational inequality gaps have narrowed, but we have much more to do. An estimated one billion adults around the globe lack literacy skills. Although youth literacy rates have risen substantially, young women still lag behind, especially in sub-Saharan Africa.

It's easier than ever to extend education opportunities to more people and help them prepare for their future. With new interfaces and new ways to access information, we've continued to evolve our way of learning, from oral history traditions passed around the campfire to erudite scholars poring over the written word of the printing press to absorbing words that exist only as pixels on a screen.

As knowledge generation and dissemination is fundamentally transformed by digital disruption, we have access to more information than ever before. Wikipedia alone now comprises 45.6 million crowdsourced articles in 288 languages, but this growth is dwarfed by our thirst for knowledge. We collectively ask at least two trillion questions online each year. As access to information grows, we have even more questions. Using energy-driven technologies,

- **How can we extend learning to more people?**
- **How will we connect to and leverage the full range of human intellect?**
- **How can we further expand the frontiers of our collective knowledge?**

Though sometimes implicit in the digital developments that fuel new modes of education, energy has been an omnipresent catalyst for transforming how we learn and know.

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

3.6.1 New ways of learning that disrupt traditional schooling models are extending educational opportunities to more people

The way we typically approach education is based on a traditional schooling model that has not evolved significantly since it was first developed in 18th-century Prussia.

For most of the world's 1.5 billion schoolchildren, education models still revolve primarily around classrooms that are organized according to age and characterized by fixed duration and standard curricula. This limits the ability of many children to reach their full potential; in developing and developed countries alike, 25%-30% of children leave school without basic proficiency in at least one area of math, reading, or science.

Disruption of traditional learning has begun, with virtual classrooms and massive open online courses (MOOCs). Industry leaders like EdX and Coursera have opened up access to some of the world's leading higher education instruction, while Khan Academy and others offer accessible lessons aimed at younger learners. These sites have opened access to education resources to millions, but there's rich opportunity to extend these benefits to all. Connectivity issues, teachers' lack of tech savvy, and problems integrating some students into existing education structures have made it difficult for many schools in low-income countries to take advantage of these advances. As the global edtech market continues to grow at a wild pace, there's an increasing need for new sustainable pathways that spread and scale the low-cost interventions that help teachers do more with the resources they have and help them empower students to focus on learning.

EDTECH

We can further harness technology in the service of learning and teaching, and enable teachers to do more with the resources they have while improving education quality for learners around the world. New education technology, or edtech, marries technological advances with sound instructional methods.

Personalized, adaptive learning platforms in particular have substantial potential to improve educational outcomes in developing contexts. In low-income countries, there's often a large degree of difference in how prepared children are when they enter school, but research indicates that remedial interventions targeting those furthest behind can have a big impact on learning. "Adaptive" software, like Mindspark, can assess a learner's knowledge level and tailor content in response. Another interesting model of note is Zaya, which has deployed an affordable "blended learning" model for the low-income Indian market.

Education around the world is a $4.4 trillion annual market—and growing. The edtech field is crowded and diverse, with an estimated 500+ vendors in 42 distinct market segments for higher education alone. The market continues to grow and is projected to reach $250 billion by 2020.

How could #edtech address the intergenerational literacy gap?

VIRTUAL CLASSROOMS AND AUGMENTED REALITY

Virtual reality (VR) and AR are beginning to revolutionize the way we experience and conceptualize information through experiential learning.

"Today's virtual and augmented reality technology has created a virtual classroom, where students from around the world can meet and learn together," notes futurist Charlie Fink. He adds: "In this virtual space, these global students experience history, science and mathematics as three-dimensional concepts. They can visit the outer reaches of the solar system, travel to Antarctica or take a journey inside the human heart. This is not science fiction. This is real and is happening now."

Virtual classrooms or virtual worlds can also foster collaborative learning environments and enable human connections among geographically dispersed learners. Virtual labs can provide hands-on experiential learning for students who otherwise wouldn't have the chance to participate. Research suggests that VR/AR in education can increase student motivation, improve collaboration, and even enhance classroom management practices.

Mobile apps have been the main distribution channel so far, with apps like FETCH! Lunch Rush allowing students to use their math skills and visualize problems in real-world scenarios. Building on early forays into the field such as Second Life, gains in interactivity and realism are driving rapid uptake in VR and in AR technologies in particular. (AR alone is expected to be a $120 billion market by 2020.) There is tremendous opportunity to develop new solutions applied to new markets.

WHAT IS AUGMENTED REALITY?

Augmented Reality (AR) is the digital modification and enhancement of real life. With mobile apps, your device's camera can register your current environment, and AR can then generate and superimpose 3D animations or video over the screen, enhancing what you can see and experience.

SCREENLESS DISPLAYS + INTERACTIVE PROJECTORS

Just as the light bulb can illuminate our nights and extend our ability to study, other new technologies are helping transform our environments into constant learning platforms. Using "screenless displays" and interactive projects, we can put words and images on any flat surface anywhere, which opens a whole new dimension for sharing knowledge.

Screenless displays, as 3D images projected into space, can convey information that a 2D image presented on a screen cannot. Similarly, interactive projectors can change any flat surface into a touch-screen whiteboard, and users (e.g., students) can have a hands-on learning experience by dynamically manipulating the underlying visual.

These relatively new technologies are rapidly gaining market share, but they have not achieved wide deployment in learning settings. **How could they brought to scale for those would benefit most?**

3.6.2 Advances in connectivity and machine learning are creating the potential to extend human cognitive capacity

9.5 SDG target: Encourage innovation and substantially increase the number of research and development workers

Energy-fueled gains in connectivity increase the range of opportunities for making full and effective use of the spectrum of human intellectual capabilities. This can take a variety of forms, including building business models that leverage the complementarities between human and machine learning, creating new ways to collaborate, and instrumentalizing the ways that the full continuum of neurodiversity can contribute to the betterment of all.

BALANCE HUMAN AND MACHINE INTELLIGENCE

Computers can increasingly do more of what was regarded as the domain of human intelligence. From gains in information processing, pattern recognition, and prediction, advanced computing has moved into areas requiring language comprehension and intuition, and even creative expression. Energy-powered innovation has underpinned these advancements in digital; it's time to think about how we can leverage complementary energy applications in the new balance between machine and human learning.

As technology advances, high-level social intelligence skills may become even more important than advanced quantitative knowledge. Computers can't (yet) understand the human condition, making social intelligence—skills such as empathy, leadership, and collaborative teamwork—increasingly essential.

COLLABORATE MORE CLOSELY ON KNOWLEDGE PRODUCTION

Increasingly, impressive gains in the frontiers of our knowledge about the human condition have been driven by a consortium of actors working collaboratively. The cell atlas is an ongoing attempt to comprehensively map the 37.2 trillion cells in the human body. This ambitious effort could lead to more sophisticated models of human biology and striking advances in pharmaceutical development. Similarly, the BRAIN Initiative—a public-private "Grand Challenge" collaboration between foundations, researchers, and governments to coordinate scientific efforts—has yielded significant findings as to how the brain processes and encodes information.

Leveraging the full range of human intellectual capacities will require continued improvement of how we coordinate research efforts. For example, administrative drudgery is one barrier that often keeps researchers from maximizing their contributions to scientific progress, and the current system for matching research talent with research needs is inefficient. Faculty members often manually search, screen, and select candidates in low-tech and low-yield ways, like posting to limited distribution listservs.

New platforms enabled by digital innovations make it possible to imagine designing more efficient solutions and even more efficient business arrangements. For instance, cloud-networked research laboratories allow virtual biotech startups to dramatically cut fixed overhead costs like full-time employees and lab space. This enables ventures to be more nimble and flexible about how they spend R&D dollars to achieve new breakthroughs. Other technological breakthroughs, such as efforts to provide real-time translation devices, will continue to break down traditional barriers to collaboration.

Case: Transcending Language Barriers with Real-Time Translation

It's the Tower of Babel come to life: the ability to translate spoken language in real time could facilitate cross-cultural communication and collaboration like never before.

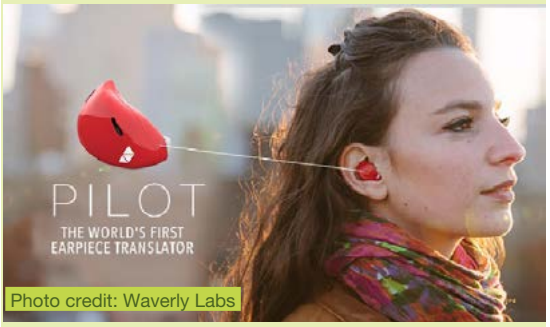


Photo credit: Waverly Labs

After several years of buzz, Waverly Labs will soon launch its Pilot earbud, which aims to provide real-time translation in 15 different languages. With $5 million in pre-order crowdfunding, the Pilot is scheduled to ship in fall 2017. Other incarnations are already here: Bragi recently debuted the Dash Pro earphone with similar real-time translation, and Google Translate continues to offer near-real-time translation powered by advances in Artificial Intelligence.

These developments are thrilling, but they prompt even more questions. Many consumers—even in wealthy countries—will find the roughly $300 price point out of reach. **How can we marry technological innovation with low-cost paths to reach more people? How else might we collapse invisible but persistent obstacles and unleash greater collaboration?**

Could new platforms encourage more efficient knowledge sharing and collaboration in other professional domains?

MAKE USE OF THE FULL SPECTRUM OF HUMAN INTELLIGENCE

About 1% of the world's population is thought to have some form of autism spectrum disorder; that seemingly small number translates into tens of millions of people. People with autism have always been part of humanity, but many have been excluded from mainstream daily life. One study found that a third of young adults with autism did not have a job or receive an education after high school. In recent years, a broader movement to recognize and appreciate neurological differences has emerged.

What was once viewed as an intellectual disability is increasingly understood as a potential key source of diversity—and a competitive advantage in the workplace. While corporate programs so far have focused on those with autism, it may be possible to reach out to other types of neurodiverse individuals, including those with ADHD, dyslexia, dyspraxia, social anxiety, and other mental health conditions. Doing so effectively requires rethinking work arrangements, finding suitable accommodations, and creating innovative business models.

How could those with different mental health backgrounds be connected to economic opportunities that capitalize on their unique skills?

Case: Specialisterne—Intelligence Inclusivity Is Smart Business

In 2013, German multinational software giant SAP AG announced it would hire hundreds of people diagnosed with autism.

Today the company continues to work toward the goal of having people with autism comprise 1% of its workforce by 2020. But this isn't a new corporate social responsibility initiative—it's a sound business decision.

The innovation economy means that different skillsets are increasingly valuable, and companies have begun to reorganize operations accordingly. Those with autism often possess skills well-suited to certain types of knowledge work, like excellent memory or pattern recognition, or an ability to focus deeply on a repetitive task. These skills mean those on the autism spectrum can be valuable employees.

A leading innovator in helping companies leverage the unique skills of neuro-atypical individuals is Specialisterne, a Danish company founded by Thorkil Sonne in 2004. Specialisterne sees hiring individuals with autism not as a charitable gesture but as a savvy move that provides companies with a strategic advantage. The company trains and places "specialist people"—"specialists with a business potential that can be realized through special understanding and management"—with companies to perform IT tasks such as software testing or data and quality control.

Photo credit: Specialisterne

Building inclusive models extends full participation to those who think differently—and it's smart business. The challenge now is to continue leveraging energy-driven innovations that enable greater collaboration and extend opportunities to other under-included groups of people. As Specialisterne's partnerships demonstrate, the results benefit everyone

3.6.3. Managing information along the ever-expanding frontier of collective knowledge holds opportunities to connect people with their learning needs more effectively

Knowledge and information flows are exploding so rapidly that they are difficult to quantify. Several years ago, Eric Schmidt, the chairman of Google's parent Alphabet, observed that we create as much information in two days as we did from the dawn of human history through 2003. The pace has since only accelerated.

The number of scientific articles published annually has been rising rapidly for decades, and over the last 100 years, the growth in annual global patent applications has been exponential.[8] Old ideas about doubling the rate of knowledge production are dwarfed by the output enabled by digital connectivity. We now collectively create at least 8 million new songs each year, 2 million new books, 16,000 new films, 30 billion blog posts, 182 billion tweets, and 400,000 new products.[9]

As the availability of information and data explodes, we need better ways to help people connect with and access what's most valuable to them. The attention economy is a complex, multisided market with unique value propositions. Decades ago, it would have seemed improbable that an $82 billion industry would revolve around answering questions for free. New approaches that can triage and filter these information flows will further expand the limits of what it is possible to know and address an ever-growing market of consumers thirsty for better information.

> "The gap between questions and answers is our ignorance, and it is growing exponentially."[7]
>
> —Kevin Kelly, founder of Wired

READ MORE

- **Sustainable Development Goal 4: Quality education**
- **Center for Education Innovations**
- **Journeys to Scale: Report on Education Innovations**

5. Energy-powered innovations are augmenting our ability to lead meaningful lives

"The best way to predict the future is to invent it."

—Alan Kay, computer scientist

Energy-powered innovations can augment our ability to lead meaningful lives. Throughout human history, and especially for the past two centuries, humanity has advanced by harnessing energy to extend human capabilities. Steam power made our hands do more and extended the reach of our bodies. Electrification gave entire cities the power to see at night. The internal combustion engine and then the jet engine have allowed us to move our bodies through space in previously unimaginable ways.

Each of these technologies used energy-powered innovations to help humans prosper and reach their full potential. The inventors deployed their innovations in creative ways using business endeavors and public-private partnerships. Thomas Edison, one of the most famous energy innovators, succeeded in spreading light throughout the United States as much because of his business acumen and vision as because of his inventiveness.

We're now on the precipice of even more astounding transformations, but this progress is not inevitable. Vision and hard work are required to realize this new world and to build social enterprises that can deliver solutions to broad markets. Cheaper, more affordable, and cleaner energy sources could radically transform the lives of millions—but only if the products and services are developed and made available to extend people's capabilities and move their lives forward.

Although energy-powered innovations have propelled the human race forward, not all gains have been shared equally. By rethinking how to use energy, we can create breakthrough enterprises that reimagine our world, collapse traditional barriers such as distance, and break traditional divides between the poor and rich, urban and rural, neurotypical and neurodivergent, conventionally abled and differently abled, the educated and those without access to educational opportunities.

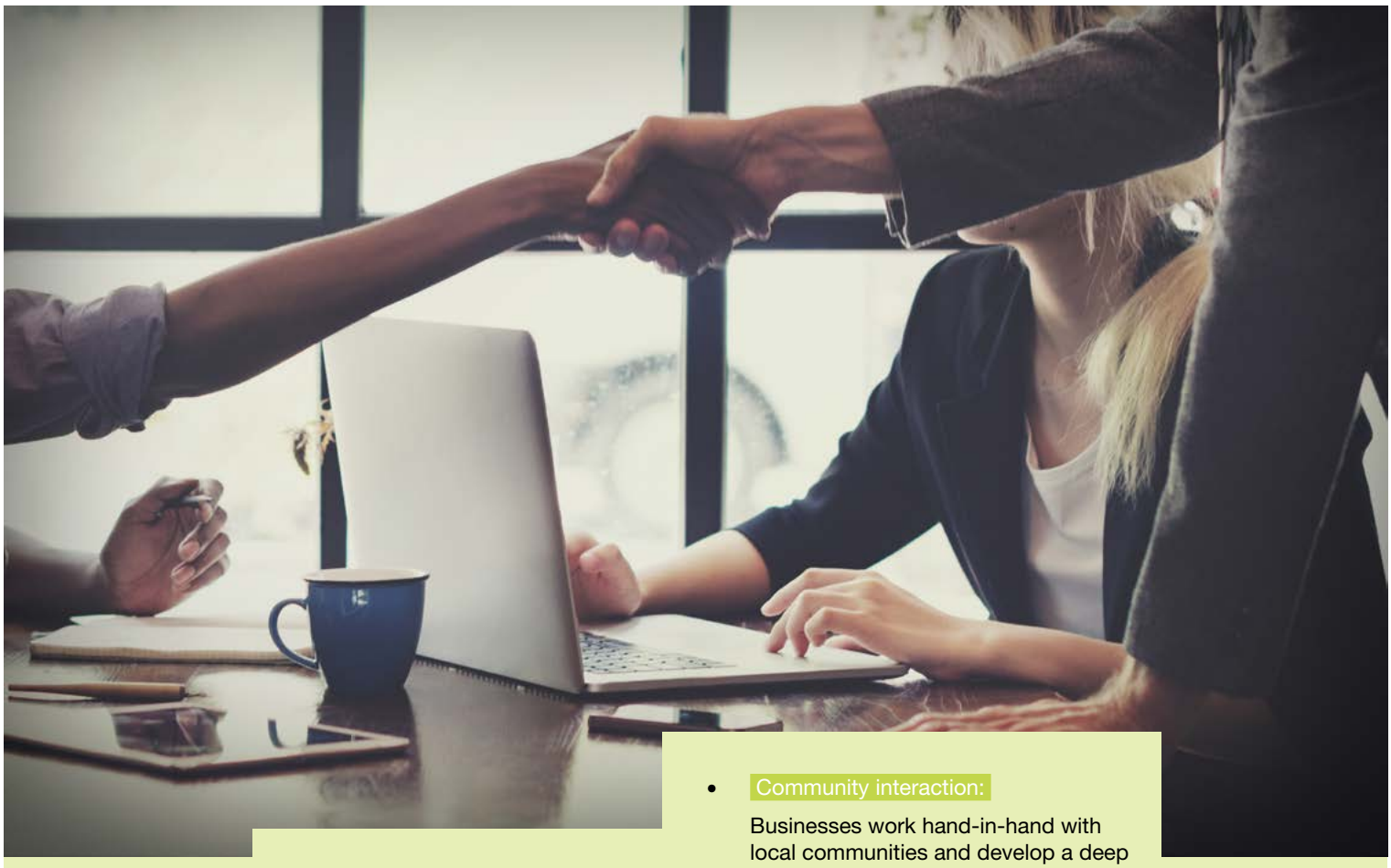
As the pace of change accelerates, there will be unprecedented opportunities to create and contribute solutions that can broadly benefit humanity.

Take a nascent industry **and formalize it**

Find a technology **and bring it to scale**

Connect with a neglected market **and serve it**

Look into the future **and shape it**



Business Models for Developing Markets

Surviving and growing in [developing markets] is very different than in a typical commercial enterprise. There are a lot of people working . . . on the small scale, but the problem becomes how they can scale the programs up and make them profitable," notes Inara Scott, an Oregon researcher with expertise in off-grid solar business models.

When it comes to working with renewable energy technologies in base-of-the-pyramid markets, Scott finds that successful enterprises frequently have four core pillars:

- Community interaction:

  Businesses work hand-in-hand with local communities and develop a deep understanding of local norms, culture, and social issues.

- Partnerships:

  Companies collaborate with other businesses, government organizations, or nonprofit groups to garner support and share ideas and resources.

- Local capacity-building:

  A community may not have typical distribution channels, while the people in the community may lack product knowledge and have little experience with technology. Consider potential customers as both producers and consumers, train local entrepreneurs as distributors, marketers, and equipment installation/repair technicians.

- Address unique barriers:

  Depending on the sector and solution, businesses need to address obstacles faced by consumers, such as providing financing for upfront costs, and to think creatively about how to develop multiple distribution networks that work for local contexts.

Goal 10: Reduce inequality within and among countries

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