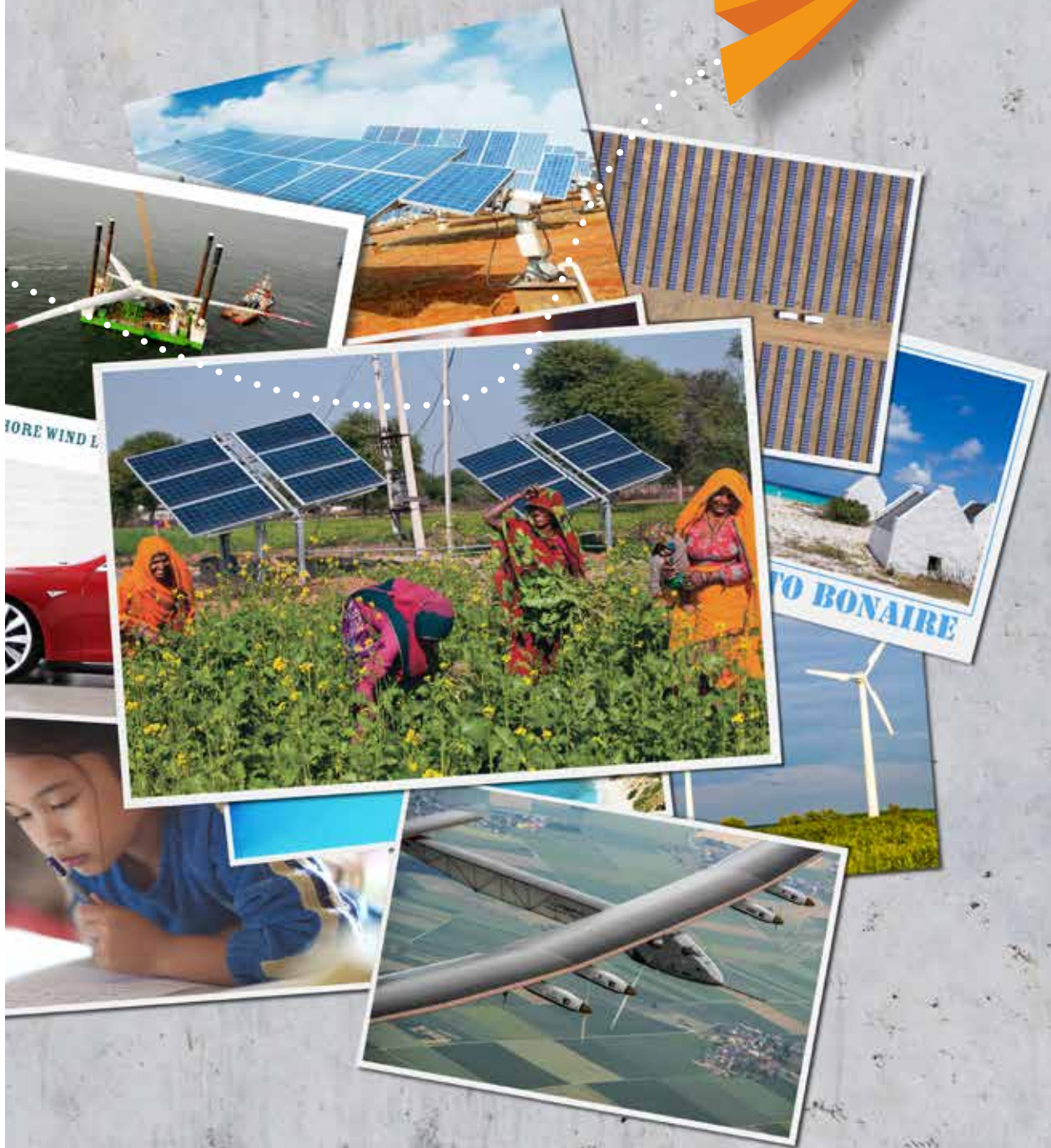




# THE CLEAN ENERGY VOYAGE 2

*Closer to the Destination*





# A REASON TO HOPE

At the start of the millennium, even the most optimistic predictions said that non-hydro renewable energy would account for just 3 per cent of global energy by 2020. Not only did we pass that target by 2008, but we already derive more than three times that amount from clean renewables and, by 2030, we could transform the lives of 500 million people thanks to solar power and innovative grid technology.

It is not surprising then, that such remarkable progress is attracting a growing response from investors. They are starting to appreciate the massive, mutually beneficial opportunities for people, planet and profits. That is why clean energy investment grew 17 per cent to US\$ 270 billion last year, funding almost half of all new power infrastructure.

The most recent *Global Trends in Renewable Energy Investment* report by UNEP, the Frankfurt School and Bloomberg New Energy Finance, shows that just under half of that investment was in developing countries, where wider access to clean energy is crucial for growing businesses, preserving biodiversity, promoting education and improving health, particularly for women and children.

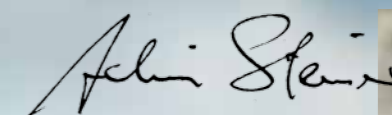
All of which puts the clean energy success story right at the heart of the much needed transition to a more inclusive, green economy and puts the necessary momentum behind the 17 goals of the 2030 Agenda for Sustainable Development.

Together, they could propel us away from a linear economy that extracts, consumes and discards, to one that is low-carbon, resource-efficient and equitable.

That transformation can be realized more quickly than most people imagine. Direct support for fossil fuels is estimated to be US\$ 550 billion annually and some US\$ 37 trillion is already earmarked for energy infrastructure and projects in the next two decades. Innovative policies and finance frameworks could redirect that investment, drive down costs and expand markets to accelerate the scaling up of clean, renewable energy.

Solar energy shows just how fast the switch can be made. It is already close to, even below, grid parity in many countries and the cost of solar cells has halved since 2010. In fact, last year, companies in Texas and Dubai successfully tendered to provide solar electricity at less than six cents a kilowatt-hour, which is cheaper than any other option.

From dirty to clean, from finite to renewable and from costly to profitable: the stakes are high, but people are inspired and clean energy is an idea whose time has come. As the world prepares to reach a historic agreement on climate change, this new report is an important and timely reminder of how far the world has already come and of how much further the Clean Energy Voyage can still take us.



**Achim Steiner**  
United Nations  
Under Secretary-General  
and Executive Director,  
United Nations Environment  
Programme



## THE CLEAN ENERGY VOYAGE 2

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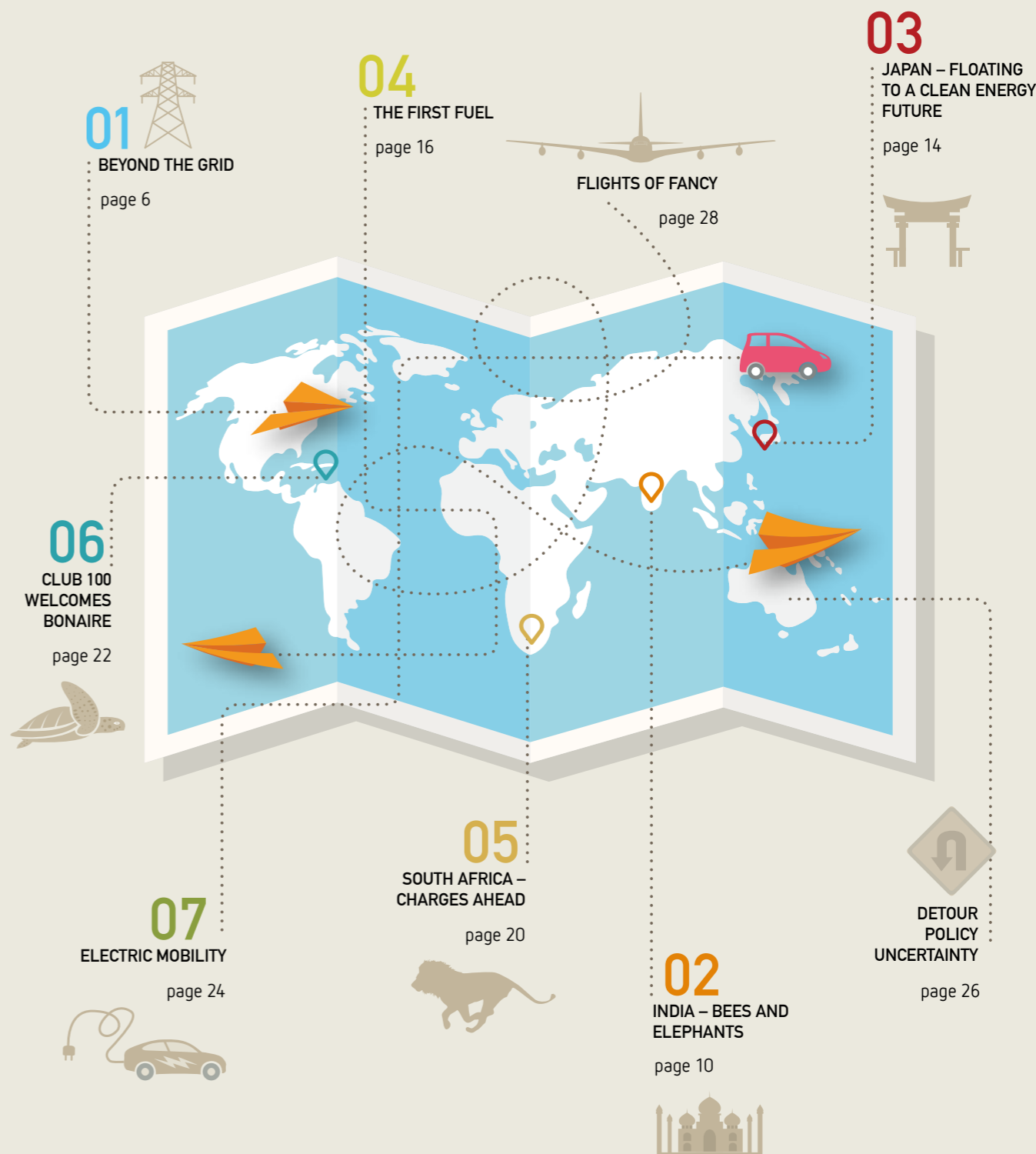
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Mongolia, © Chakto/Shutterstock.com

# BEYOND THE GRID



The Clean Energy Voyage has many paths to a clean energy economy, but they could all be converging on a new model for the generation and distribution of energy, particularly electricity.

In the 20<sup>th</sup> century, energy was provided almost exclusively by poles, wires and pipes running from large power stations and refineries to homes, offices and factories. These electricity and gas networks – or ‘grids’ – were the very symbol of progress itself, with increasing numbers of new customers a measure of economic and development success.

There were several limitations to this monolithic model, however. The grid provided for a one-way energy flow and was expensive to build and maintain. It had to have enough capacity to handle the highest ‘peak’ demand at any time, which meant that much of the grid’s expensive capacity was used for only a relatively short number of hours each year.

Grid extensions to sparsely populated areas also meant that a large part of the network was only servicing a small number of users. In the Australian state of South Australia, for example, the power network operator spends 70 per cent of its investment to meet the demand from just 30 per cent of its customer base. The Australian Energy Regulator says 30 per cent of electricity costs meet just one per cent of usage, which is the peak in demand<sup>4</sup>.

Throughout the globe, 1.3 billion people currently have no access to electricity. In Kenya, just five per cent of the population has grid access while India, one of the countries most affected by energy poverty, has around 400 million people without direct access to electricity. Even with access, the grid in many countries is often unreliable, with power cuts being a common and frustrating feature. The cost and difficulty of extending the grid to poor, rural areas of developing countries is always going to be difficult and expensive.

The advent of small solar photovoltaic (PV) power systems in the late 20th century, however, meant desirable energy services could be provided ‘without the wire’, but they had high upfront costs and reliability issues. People still clamoured for poles and wires that they believed would provide a more reliable and cheaper energy service.

Then things changed – rapidly.

In the first decade of the 21<sup>st</sup> century, solar power and other renewable energy technologies advanced to the point where they could provide reliable, modern energy services at a competitive cost and in places where the grid would never arrive.

At the same time, a curious thing was happening: in some regions where the grid was dominant, the price of electricity

from the grid became more expensive than electricity from off-grid systems.

In its 2014 *Solar Roadmap* publication, the International Energy Agency (IEA) notes that off-grid solar systems are now “the most suitable solution for minimum electrification” in sparsely populated rural areas<sup>5</sup>. With proper financing to manage high initial costs, the IEA report says that by 2030, about 500 million people with no access to electricity could enjoy the equivalent of 200 watts of solar PV capacity. This would be equivalent to a total capacity of 100 gigawatts (GW), the total solar PV deployment to date, and would be entirely in mini-grid and off-grid situations.

Using solar technology, the Government of India could very well reach its goal of delivering some form of power to all its citizens by 2020 (see “Club 100: India”). The Government has plenty of good examples to choose from, including the former UNEP Indian Solar Loan Programme<sup>6</sup>.

In other areas far from the conventional grid, renewable energy systems are also finding a ready market. A groundbreaking solar plus storage project could transform the way Australia’s remote mining industry sources power. The US\$ 30 million DeGrussa mine project will become Australia’s largest solar and battery storage system when completed in early 2016.

The 10.6 MW solar plant plus 6 MWh of battery storage is being installed at an existing copper and gold mine, 900 km north-east of Perth in Western Australia. The plant is expected to provide the majority of the mine’s daytime electricity requirements, offsetting about five million litres of diesel fuel used annually in an existing diesel-fired generator,



PV and Battery storage system at Pellworm Island (Photo: E.ON)



Aerial view of the De Grussa mine solar PV system (Photo: Sandfire Resources)



along with over 12,000 tonnes of CO<sub>2</sub> annually. The project is being watched closely by other miners that rely on diesel generators, which account for 30 per cent of operating costs.

The advent of cheaper storage is also propelling another company, Saft, to build a 9 MW solar PV power plant, incorporating a megawatt-scale storage using lithium-ion technology, on Réunion Island in the Indian Ocean. In June 2014, Saft signed a contract with French electricity supplier EDF to supply an initial energy storage system using a container of lithium-ion batteries that will also be tested on the EDF experimental "Concept Grid" south of Paris.

Saft also delivered a 20 MW lithium battery storage system for German utility E.ON on Pellworm Island, off the North Sea coast of Germany, and was awarded a multi-million-dollar contract by Kauai Island (Hawaii) Utility Co-operative (KIUC) to provide a 20 megawatt-hour Lithium Battery Energy Storage System (BESS) in eight containers to stabilize the Kauai island electrical grid. Saft's BESS will also be deployed for use as part of a new 12 MW solar energy park under construction in Anahola, Hawaii.

*Increased renewable penetration means that grid complexity has increased, requiring intelligent control of electricity supply and distribution. On the consumption side, "micro and nano grids" will become the reality.*

ABB CEO, Ulrich Spiesshofer

As other large multinational firms join these initial forays into energy storage, the grid, as it exists today, is being challenged. European engineering giant ABB, for example, has set a goal to focus on business growth priorities where storage, mini, micro and nano grids will play a central role<sup>7</sup>.

ABB's direction has been driven by a partnership with Chinese battery maker BYD to roll out an electric vehicle fast-charging network in China. The company believes the electric utility sector in general represents a market opportunity of US\$ 600 billion in 2014, and one that will grow to US\$ 750 billion through 2020.

A significant part of this market is the shift from simply transporting electrons to greater integration of intermittent sources and intelligent grid control. A key element of battery storage in established grids is their ability to react to demand in less than a second, making larger 'reserve' power stations redundant and ending the argument that renewable energy can only be used as an intermittent energy source.

Banker Citigroup estimates a 240 GW global market for energy storage worth more than US\$ 400 billion by 2030. Their report, *Energy Darwinism II*, states the global energy mix is shifting more rapidly than is widely appreciated, and this has major implications for generators, utilities and consumers, as well as exporters of fossil fuels.

It seems clear that the grid as we know it today is being transformed. In some regions the grid may expand to service large projects, while in other areas it may shrink to a fraction of its former size. With the power of the internet, the grid will gain significant intelligence that will turn business models on their heads.

These and other examples show that the Clean Energy Voyage will cross some turbulent waters before energy suppliers and their customers arrive at the destination of clean energy – on and off-the-grid – in every part of the globe.



Home battery storage and electric vehicles are transforming the domestic energy market. (Photo: Tesla Motors)

**Charging Up the Grid**

Current electricity systems are designed to have more generation capacity than needed to provide for spikes in demand and to regulate the power frequency. This 'spinning reserve' as it is called, requires keeping a number of turbine generators running on standby so that they can be brought on line quickly, usually within minutes. Meeting peak demand this way can be very expensive but grid operators claim it is also needed to support intermittent renewable energy sources, such as wind and solar.

A number of new companies are starting to challenge this paradigm, including Berlin-based Younicos<sup>8</sup>, whose company motto is "Let the fossils rest in peace."

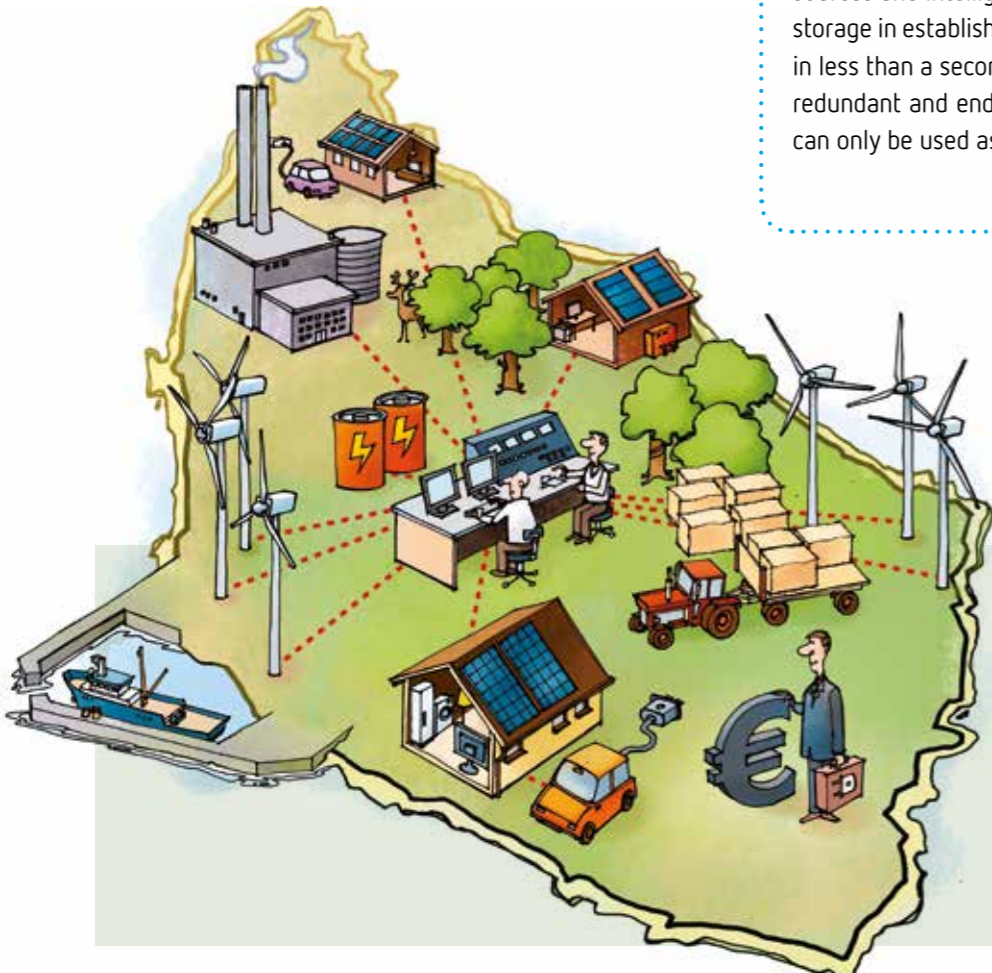
In September 2014, Younicos connected Europe's largest commercial battery power plant to the grid for WEMAG, a supplier of green electricity based in the northern German city of Schwerin, where currently 80 per cent of electricity comes from renewable sources. The commissioning of the company's fully automated five-megawatt unit marks the first time in Europe that a stand-alone battery is helping to stabilize grid frequency, while safely integrating wind and solar energy into the existing grid.

According to Younicos, the power grid in the past has been largely stabilized in Germany (and many other countries) by inflexible coal or gas-fired power plants that can only use a fraction of their output for control power. This blocks space in the grid,

increasingly forcing wind and solar generation to be taken offline.

But the Younicos battery system reacts to power fluctuations in milliseconds, making it much faster and more precise than spinning reserve from a thermal power station. The company says its five-megawatt battery in Schwerin provides the same control power as a conventional 50-megawatt turbine. The company is also working to provide battery systems that can provide important reactive power and black start capability<sup>9</sup>, thus offering further economic advantages.

Younicos designed and built the battery storage unit in just 12 months using 25,600 lithium-manganese oxide cells that are guaranteed for 20 years.



**Figure 1: Bornholm Grid**

Smart and distributed grids, such as the one on Bornholm island in the Baltic Sea, integrate many different clean energy technologies and storage, offering users different ways to buy and sell electricity.

Illustration: The EcoGrid Consortium





Photo: Tata Solar Power



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Kodalkanal, India



# INDIA: BEES AND ELEPHANTS

A report by Tata Power Solar and clean-tech analysts, Bridge to India, argues that India's solar potential is large enough to revolutionize the nation's energy mix, as long as decision-makers follow the best possible clean energy roadmap.

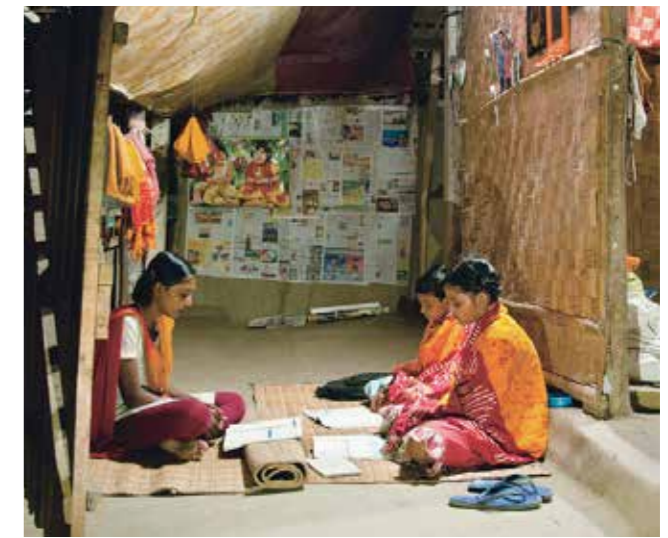
The innovative 2014 report, *How should India drive its solar transformation? Beehives or Elephants*, compares four different scenarios, each with a different solar focus – residential rooftops (solar bees); large rooftops (solar pigeons); utility-scale (solar horses); and ultra-mega projects (solar elephants). The scenarios evaluate the potential speed of deployment, implementation challenges and job-creation potential.



Residential rooftops    Large rooftops    Utility-scale    Ultra-mega projects

The report finds the realizable potential for solar power generation in India is between 110 GW to 145 GW across all four different scenarios, which could easily create more than 675,000 solar jobs in India by 2025.

The critical issue is to choose the best solar path for India, one that entails the optimum choice between millions of small systems ("bees") on one end of a spectrum, and a few very large systems ("elephants") on the other. The 'bees' scenario creates a consumer market, while the 'elephants' scenario creates an infrastructure market.



Education is greatly helped with solar lighting (Photo: Tata Solar Power)

The analysis compared each scenario in terms of landed cost of power (LCOP) – the cost to the consumer at the point of consumption – and the levelized cost of energy (LCOE)<sup>12</sup>, a more traditional gauge of generation costs. Analysts at Bridge to India and Tata argue that the LCOP, which can be as much as 30 per cent higher than LCOE, should become the new economic metric for measuring India's solar potential.

The report calculates that the LCOE for megawatt-sized plants in India at 6.6 rupees per kWh (US\$ 0.10/kWh), with a LCOP of 8.4 R/kWh (US\$ 0.14) – a figure that is already competitive with imported coal. Bloomberg New Energy Finance<sup>13</sup> has predicted that solar PV in India will beat both gas and coal on costs by 2020. Depending on the price of coal, the other three scenarios are likely to reach price parity during that time.

With almost 1.2 billion people, India has a large stake in the Clean Energy Voyage. Although many successful programmers have already delivered clean energy to thousands of citizens, the country has relied heavily on fossil fuels for development. In 2014, however, 400 million Indians are still without access to electricity.<sup>10</sup>

That could soon change, and substantially so.

In 2014, a newly elected Indian government pledged to bring power to all its citizens, but with one important difference from previous government commitments. Rather than relying on expensive and slow centralized grid extensions, the new government will take citizens to a clean energy future using distributed solar systems.

This could mean 145 GW of solar power installed across the sub-continent by 2025 – one-and-a-half times the total installed global solar capacity in 2014 – making India a world leader. By 2050, it is technically possible that India could be the largest member of Club 100, an economy based entirely on clean energy<sup>11</sup>.



India could generate up to 145 GW of clean electricity by 2025 and create 675,000 jobs. (Photo: TATA Solar Power)





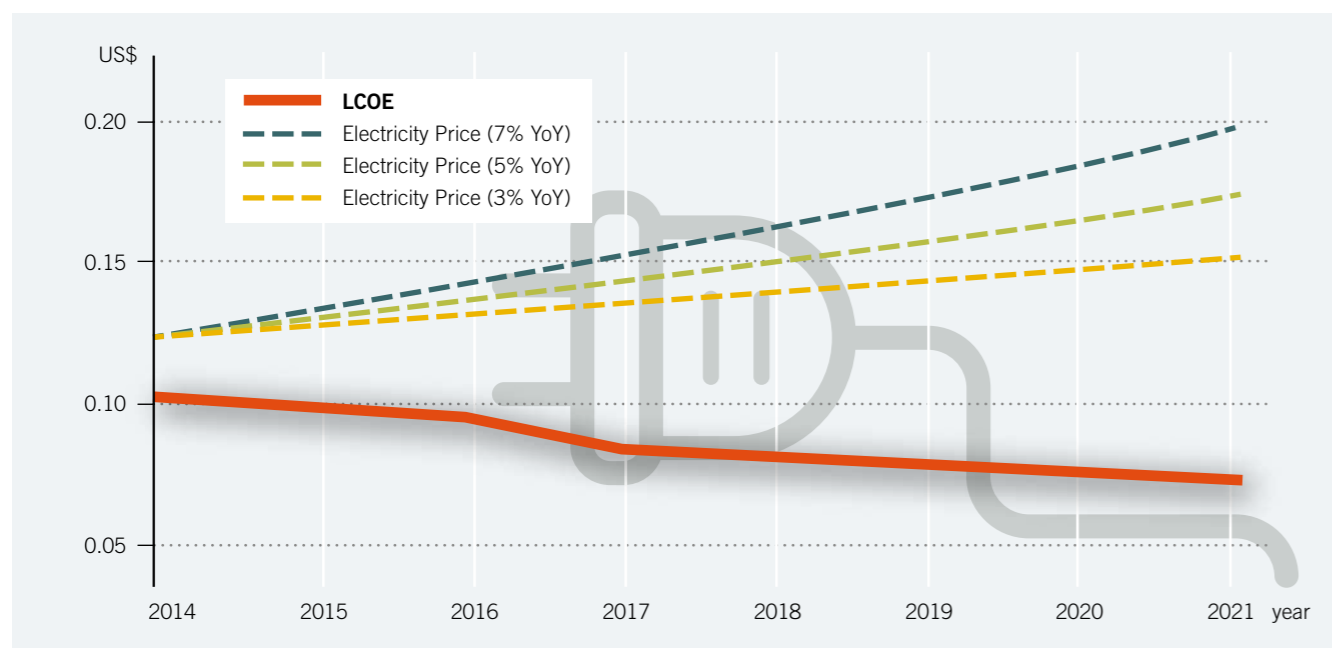
Photo: Tata Solar Power

This graph below shows the levelized cost of solar in India. The country's solar capacity has risen dramatically in the past few years, with a potential that is six times the previous National Solar Mission target for 22 GW by 2020.

The scenario analysis is particularly interesting because the scale of technology is analysed against the cost and benefits to find the right mixture of pathways that will provide both economic as well as social benefits.

In the longer-term, the Tata Power report suggests that large rooftop solar systems – the pigeons – will prove the cheapest option, achieving an LCOE of US\$ 0.10/kWh and an LCOP of just US\$ 0.11/kWh by 2024.

Figure 2: India Least Cost of Energy (LCOE) Analysis



Source: Deutsche Bank

The report also shows that the “solar bees” approach – with a focus on small rooftop projects – has the best outcome for India’s economy, offering the potential to add 325,000 jobs and 25 GW of PV capacity.

India may also take inspiration from neighboring Bangladesh where 2.9 million off-grid solar home systems are installed. In 2014, the country was installing 80,000 new installations each month, due primarily to a successful Infrastructure Development Company Limited (IDCOL) program. The IDCOL has led to a surging 60 per cent compound annual growth rate over the past decade, increasing the number of solar home systems installed from 25,000 in 2003 to 2.9 million in 2013.

India’s national goals are also supported in a number of states. The government of Madhya Pradesh has announced plans to install 1,200 MW of solar power using solar PV in 2015 – a move that would increase the state’s solar capacity to 1,400 MW. From just 2 MW in April 2012, Madhya Pradesh currently has 202 MW of installed PV power, with 145 MW added in the second quarter of 2013 alone.

The state’s wider renewable energy objectives are even loftier, with a projected 3.8 GW of clean power projects planned for 2015, 1.9 GW of which would come from wind power, plus 300 MW from biomass, and 200 MW from small hydro. If all this is achieved, the state’s renewable energy generation capacity would stand at 21 per cent of all power produced by 2015, up from five per cent in 2012.

*“Solar is unique in its limitless potential for power generation – from distributed to centralized generation, and residential kW to GW-scale solar plants, the permutations are endless.”*

Former Tata Power Solar CEO, Ajay Goel

India’s Clean Energy Voyage shows clearly how quickly the energy game can change, and the potential to re-energize an economy by creating millions of new jobs and reducing trade deficits. This presents India and other developing nations with a golden opportunity to address three huge problems simultaneously – energy poverty, energy security and climate change.

### A Blow for Coal, A Boom for Solar

In 2014, India’s Supreme Court cancelled 214 coal allocations made between 1993 and 2010 after the country’s comptroller and auditor-general found the allocations had been granted without competitive bidding.

The decision has shaken India’s coal sector, and may significantly affect any moves to offer the cancelled coal allocations up for re-allocation via competitive tender. Since the coal boom of the past decade, many of India’s debt-laden private power producers are under financial stress to deal with their day-to-day liabilities.

This comes at a time when a number of large public sector companies such as BHEL, Hindustan Salts, and India’s largest power company, NTPC, have all announced plans to diversify into large-scale renewable energy projects. These efforts are being driven by both policy and economics, including renewable energy targets and mandatory corporate rules that direct some company profits to investments that fulfill corporate social responsibility criteria. When bundled with renewable energy, for example, thermal power producers installing renewable energy projects can more easily sell their power.

Neyveli Lignite Corporation (NLC), for instance, is a large coal producer and power generator located in Southern India. The company is investing US\$ 82 million in 25 MW of solar photovoltaic and 55 MW of wind power capacity.

With several incentives on offer, and an implicit government directive, Indian public sector companies are looking to aggressively invest in renewable energy infrastructure, and likely to buy solar panels and other equipment from Indian companies rather than import them from other countries.



©Costas Anton Dumitrescu, India





# JAPAN – FLOATING TO A CLEAN ENERGY FUTURE

In June 2014, Japan unveiled the first offshore floating wind turbine in Asia. Ten private-sector companies and the University of Tokyo are part of the experimental project commissioned by the Ministry for Economy, Trade and Industry. The world's first floating power substation was installed near the two-megawatt floating turbine.

With no domestic fossil fuel reserves and a significant offshore wind resource, the Government has set a target of making floating offshore wind technology viable by 2018.

Another floating technology is also being pursued. Japanese electronics and ceramics manufacturer Kyocera announced it was beginning work on what will be the world's largest floating solar installation. Comprised of two large floating solar arrays, the 2.9 MW project is the first part of Kyocera's plan to develop around 30 floating two-megawatt power plants.

Kyocera's efforts are part of a broader development of the country's solar resource since the 1990s that has created the awareness and tools to rapidly expand.



This 2.9 MW floating solar power plant is part of Kyocera's plan to develop 30 such power plants. (Photo: Kyocera)

Consequently, solar PV has taken off across Japan in the past few years with new government incentives in the wake of the Fukushima disaster. Japan will have 100 GW of solar power generation capacity by 2030 according to recent estimates, and floating projects could play a significant role in this rapid growth.

In just two years after the country launched a feed-in tariff, more than 11 GW of renewable energy capacity have been installed across Japan<sup>14</sup>. Of that total figure, more than 10 GW was from solar energy projects.

In 2014, Japan had approved 72 GW of renewable energy projects, with solar representing 96 per cent of the approved capacity, a significant step to a clean energy future.



Installation of Japan's first offshore floating wind turbine. (Photo: NEDO, Japan)

The Clean Energy Voyage can sometimes accelerate due to unexpected events. The 2011 earthquake and tsunami that devastated Japan has had a lasting impact on the country's energy infrastructure and changed its long-term energy vision. The ensuing nuclear meltdown at the Fukushima Nuclear Power Plant resulted in all 48 of the country's nuclear reactors being taken offline. At a stroke, 30 per cent of Japan's electrical generation capacity became unavailable.

The country has re-thought its energy future and is moving steadily towards systems based on renewable energy and energy efficiency. Ironically, the ocean that destroyed the Fukushima reactor may also provide at least part of its replacement with two new options.

One of those is offshore wind. Currently, Japan has a total of 45 MW of offshore wind capacity from 24 turbines at five locations (mostly near ports) with another 350 megawatts of commercial offshore wind projects in development.

## The Real Champion

While the solar and wind power are visible signs of Japan's Clean Energy Voyage, it is the country's energy efficiency that is the unseen champion. In the aftermath of the tsunami and the shutdown of nuclear capacity, Japan's population braced for blackouts. With few immediate options, the Government and the people turned to energy efficiency through a public

campaign called *setsuden* that means 'power saving'. Some of the measures were simple and social, such as relaxed dress standards at work. Other measures were technical – switching off high demand loads such as air-conditioners for short periods of time when grid demand was high. The campaign worked well in the short term, but could it also be a

long-term solution? In 2014, Japan has managed to replace half its missing nuclear power capacity through energy efficiency<sup>15</sup>, which offers the world a key lesson: coping with rapid loss of generation capacity requires fast, nimble and modular 21st-century solutions. That means efficiency and clean energy.



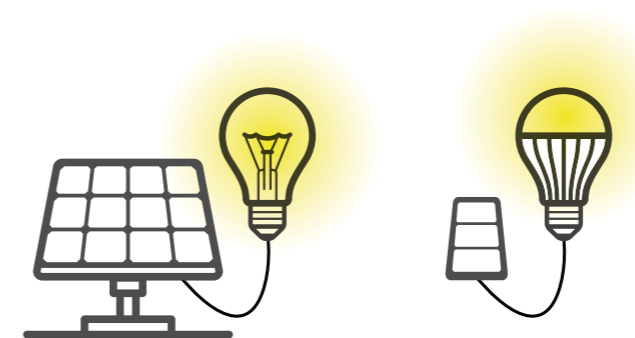


# THE FIRST FUEL



If such efficiency gains cascade through the global economy, the result can be staggering. Optimal use of LED lighting could reduce the world's electricity used for lighting from 20 per cent to just 4 per cent.<sup>16</sup>

In its 2014 report, *Capturing the Multiple Benefits of Energy Efficiency*,<sup>17</sup> the IEA has highlighted the growing importance and multiple benefits of energy efficiency to de-carbonize energy markets, reduce emissions, aid economic growth, and support energy and international security.



**2000** Cost of solar panel: US\$ 400      **2015** Cost of solar panel: US\$ 20

The growing importance of energy efficiency – also known as ‘negawatts’, or the measure of energy not used – can be gauged by an aggregated investment of more than US\$ 300 billion in 2011 – equal to all investments in coal, oil and gas power generation. According to the report, the resulting sav-

ings have been “larger than the energy provided from any other fuel, making energy efficiency the ‘first fuel’ for many IEA countries”. The IEA analysis has also shown that the uptake of economically viable energy efficiency investments has the potential to boost cumulative economic output through 2035 by US\$ 18 trillion – a figure larger than the combined 2014 economic output of the US, Canada and Mexico.

While energy efficiency may be a ‘first fuel’, the IEA also says it is a “hidden fuel... hiding in plain sight”, with a market that has barely realized its full potential. Despite the vital role that energy efficiency could play, IEA assessments suggest that under existing policies, two-thirds of the economically viable energy efficiency potential available between now and 2035 will remain unrealized.

To capture this potential, governments and policy makers need to invest time and resources to flush out the multiple benefits energy efficiency can provide. Further, the thinking that can reduce energy costs can be applied in other ways and with different compound benefits. According to the IEA, the value of productivity and operational benefits to industrial companies when integrated into their traditional internal rate of return calculations drops the typical payback period for energy efficiency measures from 4.2 to 1.9 years.

In the residential sector, energy efficiency measures can dramatically improve health and well-being by making homes warmer, drier and healthier. The resulting reduced cost of medical care, lost work time or child-care costs caused by illness can boost financial returns to as much as four dollars for every dollar invested.

The Clean Energy Voyage provokes a common and appropriate question: how much will it cost? Increasingly, the answer is ‘less than what was previously thought’. Of course, reducing costs for renewable energy technology and changing behaviour are important, but there is one essential and often ‘hidden’ fuel: energy efficiency.

**A simple example** shows how true this is. At the beginning of the 21<sup>st</sup> century, powering a single 40-watt incandescent light bulb for four hours a night by solar PV required a 40-watt solar system at a capital cost of US\$ 400 – a prohibitive sum for most families in developing countries. In 2015, however, the same amount of light from an LED lamp can now be obtained from a five-watt solar system at a cost of just US\$ 20-30, and the LED will last 20 times longer. The resulting lower capital costs makes the entire system affordable when it was previously prohibitive.



Investing in energy efficiency through such measures as energy labeling (right) and replacing inefficient models could boost global economic output through 2035 by US\$18 trillion – a figure larger than the combined 2014 economic output of the US, Canada and Mexico.



At the industry level, gains can be truly significant. Motor systems use almost half of the world's electricity, with pumps and fans driven by motors using half of that energy. Designing out friction that pumps and fans must overcome – in some cases a possible 90 per cent reduction – can yield staggering benefits across many energy-intensive industrial processes<sup>18</sup>.

For example, integrative design of a Texas Instruments chip fabrication plant saved significant energy and water while cutting total capital cost 30 per cent. A later design is expected to save about two-thirds of the energy and half the capital cost. Redesigning a Hewlett-Packard data centre in England tripled its computations per watt at no extra cost, but full adoption of its integrative-design potential could have saved an estimated 95 per cent of its energy and about half its capital cost<sup>19</sup>.

### UNEP Helps Drive Energy Efficiency in Latin America

In most developing countries and emerging economies, the demand for electricity is increasing rapidly. This is true in Latin America and the Caribbean due to a combination of a rapidly growing urban population and rising wealth. In Paraguay, for example, the stock of domestic refrigerators will double by 2030, while in Panama, the stock of air-conditioners is expected to increase by 400 per cent over the same period. This is part of a global trend of increasing electricity consumption, and consequently greenhouse gas emissions, when the electricity is supplied by fossil fuels.

In response, UNEP's Efficient Appliances and Equipment Partnership – called United for Efficiency – will help to accelerate the transition to more efficient appliances and equipment, including lighting, air-conditioners, refrigerators, electric motors, ceiling fans and distribution transformers<sup>21</sup>. Such a transition can reduce global electricity consumption by more than 10 per cent, saving US\$ 350 billion annually in electricity bills and reducing global CO<sub>2</sub> emissions by 1.25 billion tonnes a year.

United for Efficiency is a public-private effort that brings together inter-governmental and non-governmental organizations, appliance and

equipment manufacturers, utilities, and international development banks and financial institutions. The partnership provides tailored assistance to governments for the development and implementation of national and regional strategies that ease the permanent transition to energy-efficient products. Partners include the United Nations Development Programme, the International Copper Association, CLASP<sup>22</sup> and the Natural Resources Defense Council.

This partnership builds on UNEP's successful en.lighten<sup>23</sup> initiative, a public-private partnership that counts 65 countries globally as partners committed to phasing out inefficient incandescent lamps by the end of 2016.

In Latin America alone, en.lighten activities have reduced electricity consumption by 2.4 GWh and energy costs by more than US\$ 400 million. As important, this reduced demand means an extra US\$ 660 million does not have to be invested in new generation plants. The success is due to a combination of minimum energy performance standards, energy labeling, product certification and the enforcement of regulations.



### Energy Efficiency: The Catch

Improving energy efficiency is a desirable and economic goal – but there is a catch. As consumers become more efficient, they demand less electricity, which can substantially affect the bottom lines of incumbent generators.

In Australia, the combination of more efficient appliance standards and rooftop solar has reduced electricity demand by more than 10 per cent in some areas in 2013 alone, which is having a significant impact on the profits of coal-fired generators<sup>20</sup>. State and national governments have responded by moving to roll back or eliminate some of the most successful programmes, including a carbon price and renewable energy target. (See 'Detour: Australia').

In March 2014, for example, the government of the state of Victoria decided to cut back its Greener Government Buildings Program by eliminating US\$ 13 million in loans (in 2014) to government departments for energy efficiency upgrades that are estimated to save US\$ 2 billion in energy costs and more than US\$ 21 million a year in health costs. Ironically, the programme won the state's sustainability award in 2012, when the government said the scheme could save US\$ 2 billion in savings over 25 years, and cut the government's own greenhouse gas emissions by about 30 per cent.

A new government has reinstated the program, demonstrating clearly how politics can dramatically impact the Clean Energy Voyage.



Figure 3: Electricity consumption in Australia from the National Electricity Market

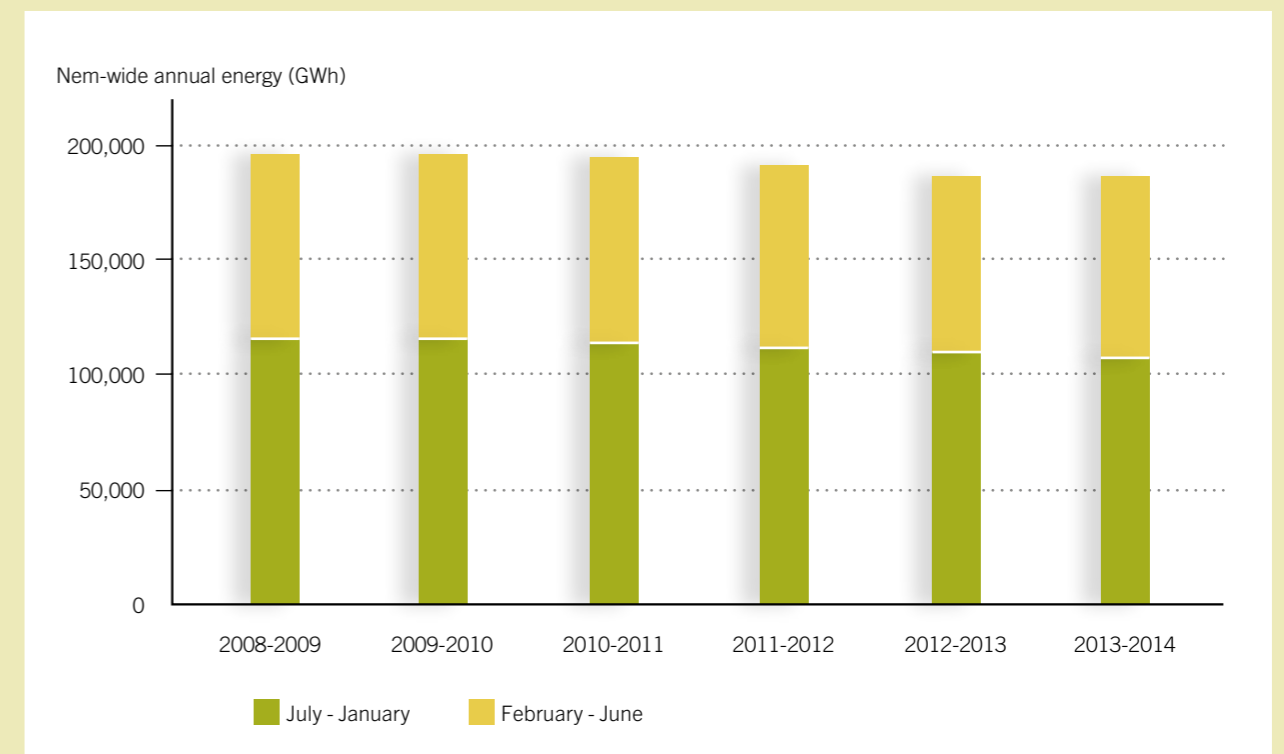






Photo: SolarReserve, LLC



# SOUTH AFRICA CHARGES AHEAD



**With its significant renewable energy resources, South Africa is emerging as a prominent destination on the Clean Energy Voyage. In 2010, after enduring years of rolling blackouts that were common throughout the continent, the country committed to a 34 per cent emissions reduction by 2020, while capping carbon emissions in new electricity infrastructure.**

**South Africa** also set the goal of installing 18 GW of renewable energy projects by 2030, more than 10 times the country's capacity in 2010, which then consisted mostly of large hydro installed in the 1970s and 1980s.

The Government's first action was to develop the Renewable Energy Independent Power Producers Procurement Programme (REIPPP), the most comprehensive private-sector-focused renewable energy policy on the African continent. The Programme included significant requirements for local economic benefits and job creation.

Through four successive auctions between 2011 and 2014, REIPPP was able to contract private developers to build nearly 5,250 MW of new wind and solar power generation, 10 per cent of existing installed generation. As a result, US\$ 14 billion was invested, with the majority from private sources and 87 per cent from domestic sources. Significantly, this investment was developed in just 30 months, and is greater than the US\$ 10 billion of *total* private investment made by all independent power producers across Africa during the past 20 years, including thermal and renewable energy projects.

The auction approach drove down prices, with wind tariffs decreasing between the three rounds by 42 per cent to just under US\$ 0.07/kWh and solar tariffs decreasing 68 per cent to US\$ 0.09/kWh<sup>24</sup>. In addition to reducing the country's carbon dioxide emissions by 500,000 tonnes each year, the projects will also create up to 2,000 jobs per annum in the construction phases. Based on such success, the Government announced a plan in April 2015 to add an additional 6,300 MW through further auctions.

With a range of new policies and the institutional capacity to make them happen, South Africa is also attracting major international companies. Google is making its first renewable energy investment in Africa through a stake in the US\$ 260 million Jasper Power Project, a 96 MW solar PV power plant near Kimberley in South Africa's Northern Cape. Completed in October 2014, the Jasper project is now powering up to 80,000 homes<sup>25</sup>. Two other 75 MW projects are also operating at Letsatsi and Lesedi.

At the beginning of 2015, South Africa had connected more than 500 MW of utility-scale solar power, becoming one of the world's top 10 countries for harnessing renewable energy from the sun<sup>26</sup>.

Solar thermal power is also part of South Africa's clean energy mix, including Khi Solar One, a 50 MW superheated steam solar tower with two hours of thermal storage. The project's centerpiece, a 205-metre tower, represents a significant advance in solar tower efficiency, possessing both the capacity for higher temperatures than previous designs, and also a new, innovative dry-cooling system.

In the country's Northern Cape district, the 100 MW parabolic trough power plant, KaXu Solar One, will be the first concentrating solar power plant in operation in South Africa. Both projects are scheduled to be online in 2015.

Solar water heating is also an important part of the mix, as water heating accounts for up to 50 per cent of residential

electricity bills. To support the national solar water heating programme, UNEP has helped the City of Cape Town initiate its own solar water heating programme in November 2013. Over 12,400 square metres of solar collectors have since been installed, contributing about US\$ 7.1 million to the solar industry and saving 12,600 MWh of electricity. Encouraged by the success of the programme, the city is expanding it to cover solar PV systems.

In total, South Africa's Clean Energy Voyage has managed to harness local and international capital and drive down costs, while growing a local supply chain. Their experience demonstrates that even in the most competitive of environments, costs can be reduced when developers and investors believe there is political support and reliable, long-term policy.



Photo: SolarReserve, LLC

The UNEP Seed Capital Assistance Facility and the Evolution One Fund (EV1) co-financed the development of the 80 MW Kouga wind farm in the REIPPP's first auction by underwriting the permitting costs. Once fully developed, the project raised US\$ 139 million, with the majority of the 32 turbines installed in 2014. When fully commissioned, the wind farm will generate enough electricity to power approximately 50,000 average households. In addition, the renewable energy from South Africa's first wind and solar projects last year delivered US\$ 70 million more in financial benefits for the country than they cost to build<sup>27</sup>.





# CLUB 100 WELCOMES BONAIRE



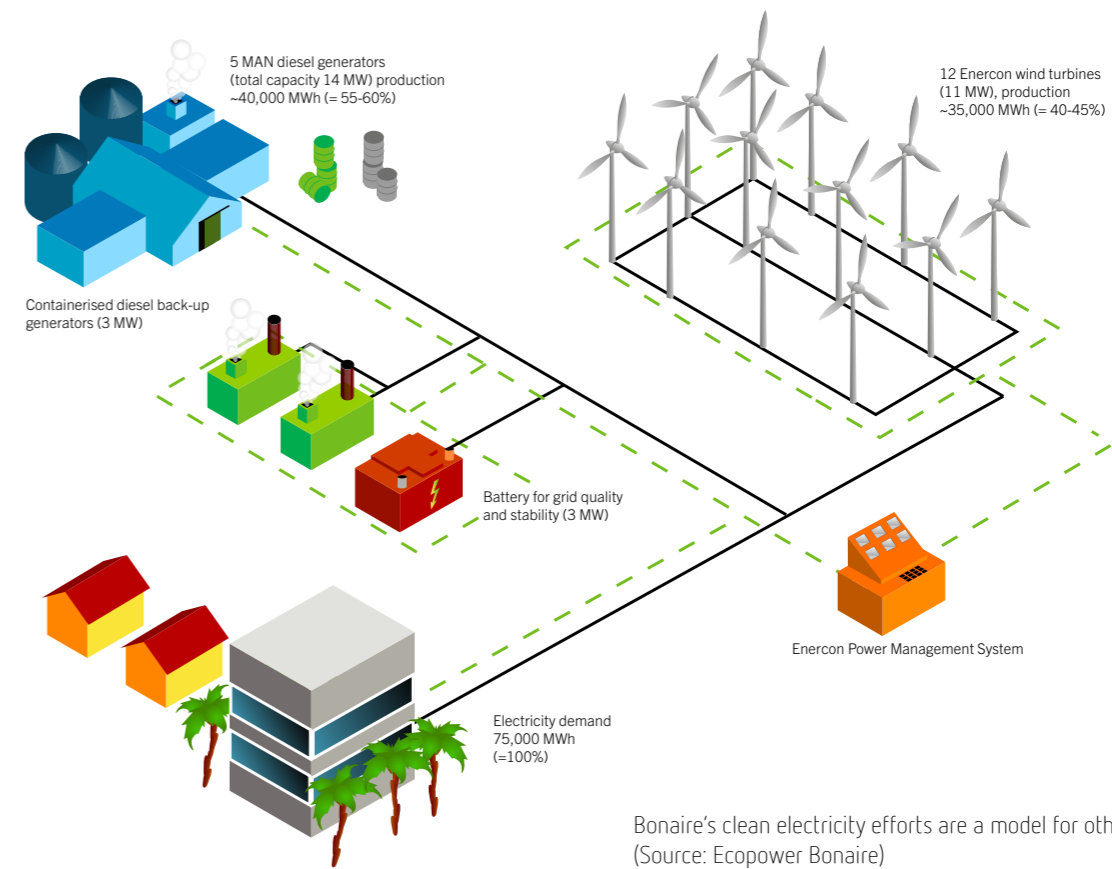
A small island off the coast of Venezuela is the newest member of Club 100. Bonaire (population 14,500), is famous for its beautiful marine reefs that are visited by 70,000 tourists every year. What many of the tourists don't realize is that the majority of the electricity powering their needs comes from renewable energy. Yet for the residents of Bonaire, the switch from fossil-fuelled to renewable energy systems has made a world of difference.

## With a peak demand

of 11 MW, Bonaire is typical of many Caribbean islands that rely on diesel generators using expensive, imported fuel. This creates high and uncertain electricity prices that reflect changing fuel costs.

Bonaire's path to Club 100 may have taken much longer but for a catastrophic event in 2004 when a fire destroyed the existing diesel power plant. The situation, however, provided an opportunity for Bonaire to consider what kind of new electricity system to build. Temporary diesel generators were rented to provide power for the short term.

Figure 4: Ecopower Bonaire, 100% renewable wind-(bio)diesel system



Bonaire's clean electricity efforts are a model for other islands. (Source: Ecopower Bonaire)

Meanwhile, the government and local utility began working together to create a plan that would allow Bonaire to reach a goal of generating 100 per cent of its electricity from renewable sources.

The result is a transformed electricity system that combines clean energy with energy storage. Twelve wind turbines on Bonaire supply up to 90 per cent of the island's electricity at times of peak wind, and 45 per cent of its average annual electricity. The six megawatt-hours of battery storage can provide energy in times of low wind, particularly when additional diesel generation needs be brought online when there is a sudden drop in wind.

The diesel generators are equipped to run on both conventional diesel as well as biodiesel. The next steps in the island's energy transformation involve using local algae resources, grown in the large salt flats on the island, to create biofuel for use in the existing generators. This will allow Bonaire to operate a 100 per cent renewable electricity system from a combination of wind and biodiesel technologies.

With their new electricity system, the citizens of Bonaire have access to reliable electricity, more employment opportunities, and reduced dependence on imported fossil fuels with their fluctuating prices.

It's also much cheaper.

Bonaire residents currently pay US\$ 0.22/kWh for electricity, much lower than other nearby islands where electricity prices are often US\$ 0.36/kWh and above. The new electricity system also created jobs for the construction and ongoing operation of the wind farm, and for research and development of biofuel from algae. Additional employment opportunities will be created for continuing algae production and operation of the biodiesel plant.

Bonaire's success provides an important example to other nearby islands of the significant opportunities afforded by a journey on the Clean Energy Voyage.



Photo: Ecopower Bonaire





# GETTING THERE: ELECTRIC MOBILITY



The most exciting “destination” in Clean Energy Voyage may be mobility itself. The advent of cost-effective energy storage options means electric vehicles (EVs) of all types and shapes are now on the path to becoming an economic choice over the internal combustion engine.

With the electric vehicle fleet doubling each year for the past three years, the transition to vehicles that run on batteries and fuel cells charged by renewable energy sources has well and truly begun. In the US state of California alone, there are now 100,000 EVs on the road and the state’s goal is for 1.5 million by 2020.

This evolution may also help conventional electric utilities avoid the revenue “death spiral”, where an increasing number of customers find it cheaper and easier to go off-grid with solar and battery storage. This pushes the cost of maintaining the grid on to fewer remaining customers who, in turn, are more likely to then leave the grid because of their escalating bills<sup>28</sup>. A strong and smart grid will be an essential element to service the growing fleet of electric vehicles.

One of the early innovators with pure electric vehicles, Tesla Motors, is now on a path to significantly reduce battery costs with the construction under way of their “Gigafactory”. The company believes the increasing penetration of electric vehicles, allied to a growing solar sector where more and more residences and businesses act as distributed generators, is likely to have a transformative impact on electricity demand.

But there are other factors.

Most EVs, for example, are driven on average only about 4 per cent of the time, and are charging about 10 per cent of the time. For the remaining 86 per cent of time, they are effectively untapped energy storage on wheels. With managed charging and the right tariff mechanisms and incentives, technology could be used to smooth electricity demand, manage spikes and shift loads, while reducing the need for costly network upgrades.

Utilities that fail to move on this opportunity could accelerate decreasing demand and profits. Households are already aware that energy storage and solar PV is a perfect match. What if people could use their electric vehicles to store excess solar power generated on their roofs throughout the day for consumption at night?

In 2011, Nissan unveiled a system that enables electricity stored in its LEAF lithium-ion batteries to be used in the household, effectively acting as home battery backup system with enough storage to run the average household in an OECD country for more than a day. The batteries being used in some of the latest model Teslas can store enough energy to power the average house for three days.

The increasing rate of innovation in smart technology, and of household self-generation and consumption systems, as well as the decreasing cost and increasing efficiency of batteries, means the use of EV batteries as household self-storage mechanisms could provide the last piece of the off-grid puzzle.



(Photo: zeromotorcycles.com)



New electric models with a range of 500 km are starting to enter the vehicle market. (Photo: Tesla Motors)



Electric cars and motorcycles (above) can be charged at home, the office, or shopping centre.





# DETOUR: POLICY UNCERTAINTY

The Clean Energy Voyage is full of twists, turns, diversions and even U-turns. Some of these are technical, some social, and some political. Good examples of this are Australia, featured in the original Clean Energy Voyage, and Spain.



DETOUR



With a carbon price effectively dropping emissions, and a renewable energy target that had encouraged 15 per cent of all households to generate a portion of their electricity from a rooftop solar array, **AUSTRALIA** boasted one of the best climates for clean energy investment. When the country's clean energy incentives started to reduce greenhouse gas emissions and customers were saving money on their electricity bills, the profits of conventional coal-fired generators also started to decline.

A new national government elected in September 2013 eliminated the carbon price and attempted to disband the country's Climate Change Authority, Clean Energy Finance Corporation, and Australian Renewable Energy Agency. The Government tried unsuccessfully to close the country's renewable energy target (RET) six years early, but managed to reduce the RET from 41,000 GWh to 33,000 GWh. The Prime Minister, Tony Abbott publicly declared wind turbines "visually awful" and intended to reduce the growth rate of the sector.<sup>29</sup>

Analysis has confirmed the success of the carbon price before its removal. During the five years to mid-2012, emissions from the electricity sector declined at an average annual rate of 0.56 per cent. In the two years the carbon price was in force, emissions declined at five per cent each year, some nine times faster than during the preceding five years. According to the Australian Energy Market Regulator, coal-fired generation increased after the removal of the carbon price along with CO<sub>2</sub> emissions that rose 3.2 million tonnes in just five months after removal of the carbon price compared to the same period one year earlier. These trends continued in 2015.

The removal of the carbon price and uncertainty around the RET has significantly affected Australia's investment in clean energy. A report by Intelligent Energy Systems Advisory Services (IES) says that changes to the RET could cost billions in clean energy projects and increase coal-fired generation by 9 per cent.

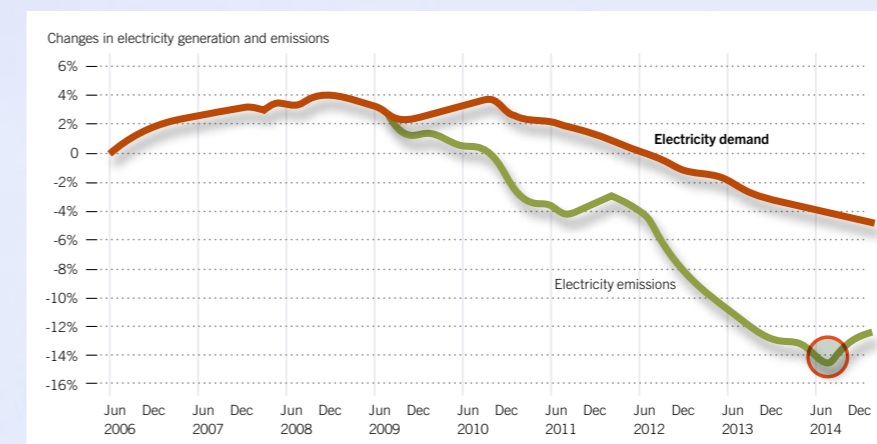
Support for renewable energy has also been slashed in **SPAIN**, a country that generated 47% of its electricity from renewable sources in March. The government, however, approved a clean energy bill in 2014 that capped the earnings of all existing renewable power plants. The move was retrospective, which caught the industry by surprise and led to a number of legal challenges.

In August 2015, the government introduced draft legislation that proposes a hefty fee for the use of batteries for residential solar self-consumption – and even more hefty fines for households that don't comply. The fee – which has been labeled by some as "a tax on the sun" – could increase the payback time for a solar plus storage system from around 16 years to 31 years.

Additional fines for infringement of the self-generation legislation, capped at € 60 million (US\$ 67.7 million), have also been proposed – an amount that is double the fine for leaking radioactive nuclear waste.<sup>30</sup>

**These policy detours present a conundrum for governments, utilities, suppliers and customers. In Australia, policy uncertainty over the RET effectively stopped investment in the clean energy sector for more than a year. Without the certainty of policies, the Clean Energy Voyage will take much longer that is needed and cost substantially more.**

Figure 5: Impact of removing the carbon price in Australia, June 2014



Source: Australian National Electricity Market Operator





# FLIGHTS OF FANCY

Humans are by their very nature explorers, and the Clean Energy Voyage is no exception. For some, the greatest motivation is simply being told 'it can't be done'. Even when pioneers have proved it can be done, all too often they are met with the disclaimer that their achievement, however notable, is "simply not practical".



In 1987, an Australian adventurer named Hans Tholstrup organized the first triennial World Solar Challenge, an inaugural event where 14 lightweight cars covered in solar cells raced across the continent's 3000 km 'outback' from Darwin to Adelaide.

The US\$ 14 million<sup>31</sup> General Motors Sunraycer won that event with an average speed of 67 km/h and fired more than just the imagination of engineers around the world. The GM effort generated an estimated US\$ 200 million in free publicity, and was up to that time, the most successful promotion in the company's history.

"Inspiring," said many observers, but cars covered in very expensive solar cells were simply "not practical".

In the ninth World Solar Challenge held in 2014, however, the cars had advanced to the point where they were faster than the road speed limits and the rules were changed<sup>30</sup> to encourage practical solar vehicles, which has resulted in a number of pre-production prototypes<sup>33</sup>.

As those cars were finishing their race, another group of explorer's were preparing an even more ambitious voyage – to circumnavigate the world in an aircraft powered only by solar cells.



Photo: <http://bosolarcar.de>, 2015



World Solar Challenge

The idea for the Solar Impulse 2<sup>34</sup> began after Bertrand Piccard completed the first ever round-the-world balloon flight in 1999 with Brian Jones. Although they started with 3.7 tonnes of propane, they arrived with just 40 kg, and the pilots realized their attempt could have failed for lack of fuel. Piccard promised himself to fly around the world again, but without using any fossil fuels.

"This was a big idea," explained Piccard, and embraced by many people because Solar Impulse was a very concrete way to demonstrate the power of renewable energy. "The excitement allowed us to raise the money from private companies and donations, but all aviation specialists told us this project was impossible".

The team faced formidable hurdles, with no clear benchmarks. They had to start from scratch.

"To fly day and night powered by solar energy alone, and to accomplish a round-the-world tour without fuel, we knew that the plane would require a large wingspan to reduce drag, and a large surface of enough solar cells to produce the energy we need. These had to fit on an ultra-light structure to maximize our energy efficiency, which could then enable us to fly through the night on battery power".

The team pushed the limits of many technologies and succeeded in developing an aircraft that is as elegant as it is breathtaking. Solar Impulse has a wingspan wider than a Boeing 747 (72 m), the weight of an empty family car (2,300 kg) and the average 24-hour power of a small motorbike (12 kW) fed by the electricity from 17,000 solar cells. When no aviation company could make the aircraft, the team turned to Decision One, a Swiss boat building company specializing in composite and carbon fibre constructions.

Solar Impulse 2 also has a number of practical spinoffs in energy efficiency, aerodynamic performance, and light-

weight materials. Better insulation materials, for example, can be used in all homes and household appliances, and the improved motors in electric cars. The team has also progressed the use of advanced batteries.

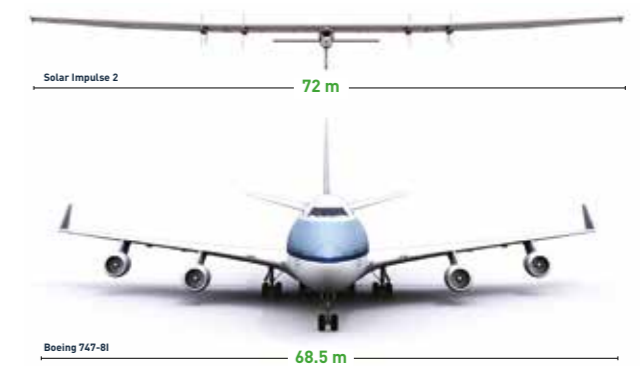
"All these technologies are used in our daily lives for lifts, cars, boats, and airplanes," says Piccard. The team's aim is not to revolutionize the photovoltaic industry but to revolutionize the mindset of people about renewable and efficient energy. "Solar Impulse aims to show that clean energy combined with energy efficiency can allow us to accomplish things that were previously considered impossible," he says.

Solar Impulse has become a symbol of the pioneering and innovative spirit that can be applied to successfully power our communities by clean energy .

The team is also part of [www.FutureIsClean.org](http://www.FutureIsClean.org) to petition governments at the 2015 UN Climate Conference (COP21) in Paris.

As with many inventions before, it's not practical yet, but it won't be long. Manufacturers such as Airbus and General Electric have already developed electric prototypes, with plans for commercial release as early as 2017.

At the same time, the Clean Energy Voyage shows clearly that such innovations can travel from the imagination to the market quickly when they are accepted simply as an idea whose time has come.



After flying for five days and nights, Solar Impulse prepares to land in Hawaii after the record-breaking flight from Japan during the project's round-the-world Clean Energy Voyage. (Photo: Solar Impulse)



Pilots Andre Borchberg (left) Bertrand Piccard with students in Chongqing, China during their epic round-the-world flight. (Photo: Solar Impulse)



## ENDNOTES

- 1 Unless otherwise stated, all monetary amounts are in US dollars.
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- 6 <http://www.unep.org/climatechange/finance/LoanProgrammes/IndianSolarLoanProgramme/tabid/29561/Default.aspx>
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# THE CLEAN ENERGY VOYAGE 2





(Photo: zeromotorcycles.com)

[www.unep.org](http://www.unep.org)

United Nations Environment Programme  
P.O. Box 30552 Nairobi, Kenya  
Tel: ++254-(0)20-762 1234  
Fax: ++254-(0)20-762 3927  
E-mail: [unep@unep.org](mailto:unep@unep.org)



For more information, contact:

**UNEP DTIE  
Energy, Climate  
and Technology Branch**

15 rue de Milan  
75441 Paris Cedex 09, France  
Tel: + 33 1 44 37 14 50  
Fax: + 33 1 44 37 14 74  
E-mail: [unep.tie@unep.org](mailto:unep.tie@unep.org)  
[www.unep.org/energy](http://www.unep.org/energy)

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