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للتنافسية والإحصاء
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Masdar: Powering UAE's Competitiveness with Clean Energy

Fast-Forwarding the Nation

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Masdar: Powering UAE's Competitiveness with Clean Energy

Executive Summary:

The rising global challenge of energy supply and security, and climate impact has created a complex and uncertain energy environment. The UAE has responded by establishing a unique initiative called Masdar, that acts as a cluster[1] to "advance renewable energy and sustainable technologies through education, research & development (R&D), investment, commercialization and adaptation."[2]

This ambitious multi-billion dollar renewable energy initiative of the Abu Dhabi government's Mubadala Development Company creates a system of innovation from which insights can be drawn for the wider Gulf region, as well as globally. Today, Masdar is frontrunner in the clean energy[3] and sustainability domain addressing issues of technology, human capacity building, and investment in renewable energy.

> *The economic progress of the past decades has seen hundreds of millions of people enjoy major improvements in their material well-being, particularly in emerging markets. Globalization and market liberalization have underpinned these developments, but we must not lose sight of the crucial enabling role played by the energy sector. Without heat, light and power you cannot build or run the factories and cities that provide the food, jobs and homes, nor enjoy the amenities that make life more comfortable and enjoyable. Energy is the 'oxygen' of the economy and the life-blood of growth.* *Adapted from Peter Voser, Energy for Economic Growth: Energy Vision Update 2012, World Economic Forum.*

As the world's seventh largest producer of petroleum,[4] the UAE's rich hydrocarbon resource base has given it tremendous advantage in a global economy driven by fossil fuels. With a per capita GDP of $38,389 and a national GDP of $362 billion (current dollars)[5] in 2012, it is among the richest countries in the world. Its entry into the volatile, dynamic and intensely competitive renewable energy arena is therefore a bold move.

Forward-looking policy-makers in recent years set the stage for economic diversification, and for the UAE to lead in the clean energy sector. Both the national strategic planning document UAE Vision 2021, and the emirate-level Abu Dhabi Economic Vision 2030, are blueprints that lay a clear path for the next stage of UAE's economic and social development as a knowledge-based higher value-added economy. Masdar is an important illustration of this endeavor.

Established in 2006, Masdar is a multifaceted business model through which the UAE is directing its innovation across the energy portfolio. Within a short span of time, it has successfully achieved global leadership in the clean energy sector. This case study explores how the UAE has achieved competitiveness through this unprecedented approach by:

1) **Investing in some of the world's most promising clean technology companies and developing large-scale renewable energy projects;**
2) **Taking an integrated approach to different value chains of the clean energy sector; and**
3) **Building a strong national knowledge-base and expertise for on-going leadership in the sector.**

The initiative is not only important for its business imperative, but for providing a valuable platform for international policy makers to address global challenges in the energy sector. Additionally, by creating fertile soil and planting the seeds for a new generation of green energy experts, it is ensuring its relevance well into the future for economic growth and prosperity based on knowledge and innovation.

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[1] A business or industrial cluster is a concentration of businesses and institutions in a particular sector that are closely interconnected. Typically these firms and institutions are physically located in close proximity, allowing networks to develop with opportunities to share knowledge and create value added goods and services. See Porter (1990).
[2] Masdar mission statement. Available from www.masdar.org.
[3] Clean energy can be defined as sources of energy that lead to lower carbon footprints than is possible with conventional fossil-fuels. The MIT Clean Energy Prize defines clean energy solutions as involving products or services which promote, enhance or advance diversity of supply sources/ transmission, efficiency in use, reduced negative environmental effects such as greenhouse gas emissions. This can include but is not limited to renewable sources (e.g. solar, wind, fuel cells, biofuels, geothermal and hydrotechnologies), conservation and demand response (e.g. grid management), enabling technologies (e.g. storage systems), more efficient and effective use of hydrocarbons (e.g. hybrid cars and carbon sequestration) and integrated systems (e.g. sustainable design). Clean technologies are those that make clean energy possible.
[4] International Energy Association. Available from http://www.eia.gov/countries.
[5] Emirates Competitiveness Council (ECC) estimates

Global Trends in the Energy Sector

INTRODUCTION

Global trends in the energy arena shed light on Masdar's significance in creating a competitive environment through which the UAE can meet long-term demands for energy. Today, clean energy is integral to addressing the challenges of global energy supply, security, and sustainability. We highlight some of these trends below:

- ***Policy dynamics:*** At least 118 countries had renewable energy targets in place by early 2012. Policymakers are increasingly aware of renewable energy's wide range of benefits including energy security, reduced import dependency, reduction of greenhouse gas (GHG) emissions, prevention of biodiversity loss, improved health, job creation, rural development, and energy access leading to closer integration in some countries of renewable energy with policies in other economic sectors. Globally there are more than 5 million jobs in renewable energy industries, and the potential for job creation continues to be a driver for renewable energy policies. Policy development and implementation were also stimulated in some countries by the Fukushima nuclear catastrophe in Japan and by the UN Secretary-General's announced goal to double the share of renewables in the energy mix by 2030.[6]

- ***Growth in Demand***: Global demand for energy continues to increase and is expected to reach more than 18,000 million tonnes of oil equivalents (Mtoe) by 2035 (**see Table 1**). The demand for clean energy has increased rapidly in recent years, driven by concerns of climate change and national economic policies to create jobs, against the backdrop of fluctuating, fossil-fuel prices. In the power sector, renewables accounted for almost half of the estimated 208 gigawatts (GW) of electric capacity added globally during 2011. Wind and solar photovoltaics (PV) accounted for almost 40% and 30% of new renewable capacity, respectively.[7]

- ***Investment***: Global new investment in renewable energy rose to a record US$257 billion in 2011. This was more than six times the figure for 2004 and almost twice the total investment in 2007, the last year before the acute phase of the recent global financial crisis.

  Some of the largest companies in the world are investing in renewable energy. Currently 23 companies for the Fortune 100 and Global Fortune 100 have set specific targets for buying and investing in renewable energy. Investment targets by some of the companies are:
  - Chevron: 2.2 billion between 2011 and 2013 (renewable energy and efficiency)
  - E.ON: €7 billion by 2017
  - BP: $8 billion between 2011 between 2005
  - Google: 100% renewable energy (long term).[8]

- ***Fierce competition***: Global competition is stimulating innovation as well as a sharp drop in the cost of clean technologies. Photovoltaic module prices, for instance, have fallen by almost 50% and onshore wind turbine prices by between 5% and 10%,[9] making competitive clean power and grid parity a realistic possibility.[10]

[6] REN21 (2012)
[7] REN21 (2012)
[8] David Gardiner & Associates, LLC
[9] Bloomberg (2012)
[10] Grid parity occurs when renewable energy sources are able to compete in price with conventional power utilities at rates that are equal to or less than conventional sources.

GLOBAL ENERGY DEMAND

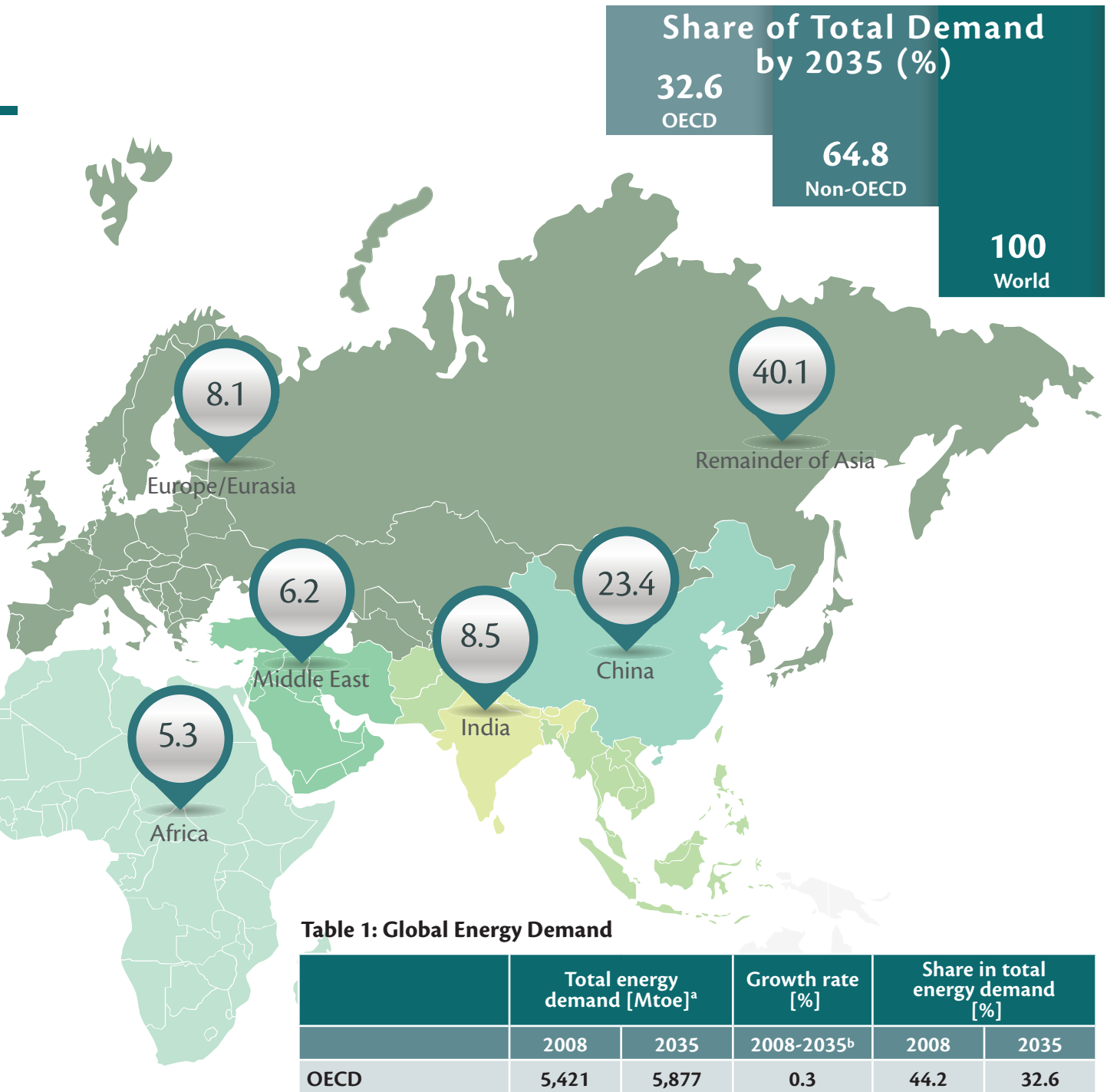


Table 1: Global Energy Demand

	Total energy demand [Mtoe][a]		Growth rate [%]	Share in total energy demand [%]	
	2008	2035	2008-2035[b]	2008	2035
OECD	**5,421**	**5,877**	**0.3**	**44.2**	**32.6**
Non-OECD	**6,516**	**11,696**	**2.2**	**53.1**	**64.8**
Europe/Eurasia	1,151	1,470	0.9	9.4	8.1
Remainder of Asia	3,545	7,240	2.7	28.9	40.1
China	2,131	4,215	2.6	17.4	23.4
India	620	1,535	3.4	5.1	8.5
Middle East	596	1,124	2.4	4.9	6.2
Africa	655	948	1.4	5.3	5.3
Latin America	569	914	1.8	4.6	5.1
World[c]	**12,271**	**18,048**	**1.4**	**100.0**	**100.0**

a. Million tons of oil equivalent. **b.** Compound average annual growth rate. **c.** World includes international marine and aviation bunkers (not included in regional totals), and some countries/regions excluded here.

Source: IEA (2010)

Masdar: Birth of a Clean Energy Initiative

Launched in 2006, Masdar ("*source*" in Arabic) is a sector-based approach to the clean energy industry. Structured as integrated business units (**see Box 1**), Masdar includes an investment arm (**Masdar Capital**), a renewable energy power generation and operation unit (**Masdar Clean Energy**), and an independent research-driven graduate university (**Masdar Institute**). Masdar's infrastructure also includes a cutting-edge urban complex (**Masdar City**, **see Box 2**) where innovative technologies can be tested and implemented in a real-life context of residences and workplaces. These integrated components allow Masdar to conduct a range of activities including innovation and R&D, investment, and utility-scale renewable energy projects. The coming together of different value chains including solar, wind and carbon capture, under a single umbrella creates a robust environment for knowledge sharing, collaboration, and commercialization to address today's energy challenges.

Driven by a strong spirit of stewardship, Masdar is in keeping with the vision of His Highness Sheikh Zayed Bin Sultan Al Nahyan, the late founder and President of the UAE, who championed environmental conservation in the region. Building on these principles, the current ruler, His Highness Sheikh Khalifa Bin Zayed Al Nahyan, President of the UAE and Ruler of Abu Dhabi, has provided the critical support for Masdar to gain a strong foothold in the global clean energy market.

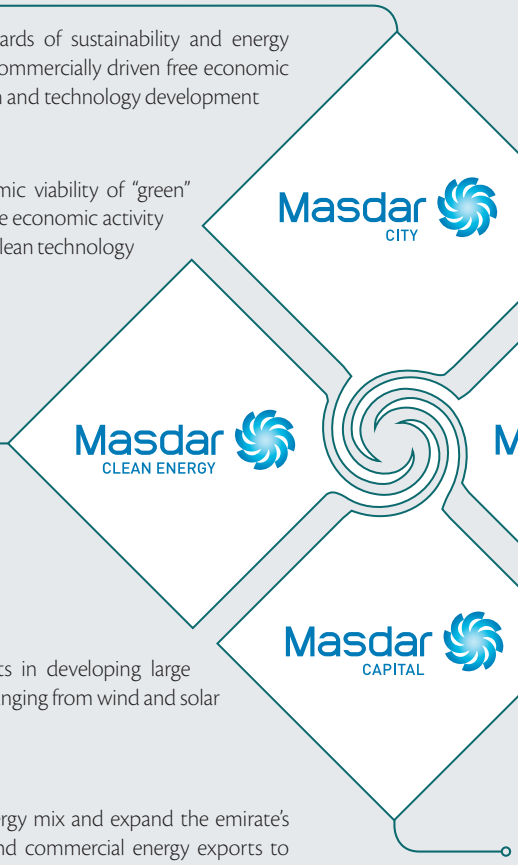
Box 1. What is Masdar

What?
Adhering to rigorous standards of sustainability and energy efficiency, Masdar City is a commercially driven free economic zone encouraging innovation and technology development

Why?
To demonstrate the economic viability of "green" developments and encourage economic activity for Abu Dhabi in the field of clean technology

What?
Established in partnership with MIT, the Masdar Institute of Science and Technology ("Masdar Institute") is a graduate–level research focused university advancing clean energy and sustainable technologies

Why?
Cultivating Abu Dhabi's human capital and R&D capabilities to enable the clean technology and sustainability industries to thrive in Abu Dhabi



What?
Masdar Clean Energy invests in developing large scale clean energy projects, ranging from wind and solar to energy efficiency and CCS

Why?
To diversify Abu Dhabi's energy mix and expand the emirate's range of energy expertise and commercial energy exports to include clean energy

What?
Masdar Capital, through its two clean technology funds of $540M under management, is investing in the commercialization of tomorrow's most promising technologies

Why?
To support the development of new technologies and generate financial returns and know-how for Abu Dhabi

Masdar is focused on making profitable and sound investments in the clean energy and sustainable technology sectors, creating value for the economy and maintaining Abu Dhabi's leadership in the evolving energy market

Box 2. Building the City of the Future

Masdar City is an emerging global hub for renewable energy and clean technology that puts companies and residents inside it at the heart of a fast-evolving industry.

The low-carbon development, 17 kilometres outside Abu Dhabi's city centre, relies almost entirely on solar and other renewable energy sources.

Its sustainable elements include narrow streets that encourage walking, unique shading created by buildings that are constructed next to each other, and solar panels extending from rooftops that both block sunlight from the ground and capture it for power.

Streets and buildings are aligned along a northeast-southwest axis, guaranteeing shade all day and capturing cooling breezes.

Educational spaces are mixed with recreational, residential housing, retail, manufacturing and office spaces, dramatically reducing the strain on transport systems. Commuters and residents can find everything they need, close at hand.

Buildings are low-rise and densely populated, allowing residents to live and work in the same location. This reduces the energy required for heating, cooling and internal transportation.

The Knowledge Centre at Masdar Institute


Driverless electrical pod shuttles people around Masdar Institute


Wind tower at Masdar Institute

Underscoring its leadership position in sustainable development, Masdar City will host the headquarters of the International Renewable Energy Agency (IRENA), and is home to the Masdar Institute of Science and Technology, a graduate-level research university that is dedicated to innovation in clean energy.

Residential units at Masdar Institute are monitored for minute-by-minute electricity consumption, cold-water and hot-water use, and residents are regularly reminded of their exact usage of resources, encouraging them to use less.

Smart grids at buildings make it possible for power to be distributed in two directions. Electricity can be fed into the grid from multiple points, and consumers can be suppliers if they have enough power to spare from solar panels. This allows them to generate more electricity than they use.

The smart-grid project is part of a collaboration with Siemens, the German technology company that is building its regional headquarter in Masdar City. Masdar City has taken a ground-up approach to ensure sustainable and enjoyable life, leveraging the desert's natural advantages to deliver sustainable energy and living.

Stimulating Innovation in the UAE and Internationally

A. MASDAR AS AN INNOVATION SYSTEM

Masdar represents an innovation system whose key elements include knowledge, technologies, actors (such as entrepreneurs, firms, government, and other organizations), networks, and institutions.[11] In an innovation system, the value creation process is systemic, the result of a complex set of interactions among actors. Innovation typically happens in systems as firms rarely innovate in isolation. An innovation system enables the creation of coalitions of firms, industry, associations and research communities that are integrated in networks, facilitating dynamic exchange of knowledge and creating possibilities for commercialization of new products and services.[12]

Clusters for Innovation

Currently the UAE ranks 27th out of 144 countries in the World Economic Forum's (WEF) Global Competitiveness Report (GCR), in the "innovation-driven" category. The country has maintained a place as "innovation-driven" for seven consecutive years — the only Arab country to have done so. This places the UAE alongside countries such as the United States, Singapore and Germany, indicating its ability to compete in the innovative sectors of the economy. Similarly, the INSEAD Global Innovation Index ranks the country 37th out of 141 countries for innovation across all sectors.[13]

The UAE hosts a number of dedicated economic clusters and free zones in addition to Masdar. These include TECOM's Dubai Media City, Dubai Internet City and Abu Dhabi's media zone twofour54. Clusters are generally considered an effective development strategy for promoting innovation. Co-located firms and entities in the same sector to allow for knowledge spillovers and provide a fertile environment for producing novel ideas, products and services. Critical components of a cluster are investment in R&D and high-quality scientific research institutions that foster collaboration between universities and industry. Protection of intellectual property, as well as access to financing. The UAE ranks highly in this benchmark as well: In the GCR 2012-2013 it ranks 4th out of 144 for its state of cluster development and 15th out of 144 in terms of "availability of scientists and engineers".

Masdar's model hinges on creating strategic partnerships, fostering collaborations, and building synergies with private sectors firms, government entities, financial institutions, and academia to advance the renewables industry, both nationally and internationally. Through its support of Masdar, the UAE is charting new territory and developing novel approaches for generating a highly skilled workforce, gaining expertise in a range of clean technologies and an developing understanding of finance for emerging area of renewable energy. Masdar provides a valuable model for an emerging sector-based approach to innovation and moving up the value chain towards high value activities from which policymakers may draw. Highlighting this system-based approach, Masdar was featured as a world best practice in developing the clean tech industry by *Harvard Business Review* (**see Box 3**).

Box 3. Case of Best Practice: Jump-Starting the Clean-Tech Economy

Harvard Business Review featured Masdar as a world best practice for its approach the clean-tech industry. The article argues that most of the world has approached clean technology by focusing on developing specific new technologies and applying those to existing systems. This piecemeal approach has been costly and has hampered the adoption of renewable technologies.

According to the authors, governments and businesses must balance four components: (1) an enabling technological system; (2) an innovative customized business model; (3) a market adoption strategy that ensures a foothold, and (4) favourable government policy. Masdar, it notes, is unique in its holistic approach to clean technologies as a sector-based approach.

As a government-owned entity, Masdar enjoys significant advantages, on a scale not possible in the private sector. Although independently managed, it was founded in 2006 with a $15 billion government investment, and a land grant as part of a larger Abu Dhabi economic development initiative. Masdar City is a "free zone" in which foreign companies can establish without a local partner and benefit from an entrepreneurial environment that promotes innovation.

As a result of its systemic, integrated, and "wisely measured approach to implementation," Masdar is discovering new ways to combine key elements into a whole, thereby accelerating the development of viable clean technologies. In the process, Masdar is reducing risks and costs while increasing efficiency—a model worthy for policymakers to study.[14]

[11] *Vidican et al. (2012)*
[12] *Ibid*
[13] *INSEAD, Global Innovation Index*
[14] *Johnson and Suskewicz (2009).*

B. MASDAR'S STRATEGIC APPROACHES

Through an institutional structure that reflects its mandate, Masdar is developing an indigenous renewable energy industry in the UAE and securing a foothold in established and upcoming technologies:. **Masdar Capital**, **Masdar Clean Energy**, and **Masdar Institute**; each embody specialized knowledge and capital streams that function synergistically to:

i. **Invest in promising renewable energy and clean technology companies;**
ii. **Position the UAE in the global renewable energy value chains; and**
iii. **Build a comprehensive knowledge-base that contributes to global leadership in sustainable development.**

We explore each of these strategic strands below.

i. MASDAR CAPITAL: INVESTING IN PROMISING CLEAN ENERGY COMPANIES

Despite positive growth in previous years, in the current environment of economic uncertainty countries are scaling back their support for green technologies. This is particularly so in OECD countries that have faced economic challenges since 2008.[15] In the private sector, the World Economic Forum's (WEF) report *Financing Green Growth* in a *Resource-constrained World*, reports that due to perceived risks and the relative novelty of the market, significant private investment is not being attracted to clean energy projects.[16] While many countries are retrenching in the dissemination of new technologies, and the private sector is circumspect, Masdar is at the forefront of incubating and investing in innovative technologies world-wide. Through its funding mechanisms, Masdar Capital is providing critical financial backing to the sector and creating precedents for financial vehicles in a volatile clean energy environment.

Masdar's financing mechanisms use targeted funds to address key risks and leverage capital flow into promising green technology projects. Masdar Capital is building a portfolio of the world's most promising renewable energy and clean technology companies. It identifies investments that have the greatest market potential globally, and for the UAE, with a focus on clean energy, environmental resources (including water and waste management), energy and efficiency (including developments in advanced materials and power-grid efficiency), and environmental services.

By providing capital for projects, targeted between $15 to $35 million (**see Box 4**), as well as management expertise, Masdar Capital enables individual companies with promising technologies to demonstrate and grow their technologies in the UAE and globally, accelerating their large-scale commercialization. Financial backing provides an important boost for these companies to break into volatile renewable energy markets.

Box 4. Masdar Clean Technology Funds: Investing in Green Technologies

Masdar Capital's investments in green technologies are made via two funds: the Masdar Clean Technology Fund (MCTF), and the DB Masdar Clean Tech Fund (DBMCTF). MCTF is a fully deployed $250 million fund that invested $45 million in three clean tech and $205 million in 12 direct investments in companies. MCTF was launched in conjunction with partners Credit Suisse and Siemens AG. DBMCTF is jointly managed with Deutsche Bank and raised US$290 million DBMCTF has an investor group comprised of Siemens, the Japan Bank for International Cooperation, Japan Oil Development Co. Ltd., Nippon Oil Corporation, Development Bank of Japan and General Electric (GE).

Through its investments and infrastructure to advance clean energy, Masdar is improving the country's competitiveness performance in a variety of ways: By taking calculated risks, investing in innovative technologies that hold promise for the world's future, it benefits from a first mover advantage in the green energy space. These investments in turn allow Masdar to tap into a deeper network of knowledge and innovation, and create a better educated workforce through its various exchange programs; additionally, it benefits from macro variables such as building the Masdar-UAE brand, and enhancing the country's base for sustainable, resilient pathways to economic growth.

[15] *UNEP/Bloomberg report*
[16] *World Economic Forum, Financing Green Growth in a Resource-constrained World*

ii. MASDAR CLEAN ENERGY: POSITIONING THE UAE COMPETITIVELY IN RENEWABLE ENERGY VALUE CHAINS

Masdar is making significant national and international contributions by competitively positioning the UAE in critical areas of the clean energy value chains through partnerships with international leaders. This includes manufacturing, energy generation and storage, power distribution, and the reduction of carbon output by means of efficiency and carbon capture and storage. Below we examine three key areas in which Masdar occupies a pivotal position in leading-edge technologies, along with international partners.

a) Manufacture of Photovoltaic Panels

Solar photovoltaic (PV) is a growing area of the solar energy market. Solar PV is a technology that converts sunlight directly into electric current using semiconductor material such as silicon. Thin-film cells are manufactured by applying very thin layers of the semiconductor material to a glass, metal or plastic backing. Masdar PV GmBH (Masdar PV), a wholly-owned subsidiary of Masdar, manufactures silicon-based thin-film photovoltaic modules for ground mounted and roof applications, as well as innovative building-integrated PV solutions.

Masdar PV is producing the world's largest and highest efficiency silicon-based thin film modules with optimized materials and innovative PV cell structures. It currently produces modules that are eight times larger and more powerful than the industry standards. For instance, it produces modules with up to 10% efficiency—an industry benchmark that implies a higher energy yield and profitability for the same surface area than competing products. It has been able to achieve this industry leadership through a corporate strategy centered on R&D and collaborations with world-leading research centers in photovoltaics, such as the Helmholtz Zentrum in Berlin, with which optimizes its current technology and works on developing the next generation of silicon thin film devices.

Reflecting its international competitiveness, Masdar PV has deployed its silicon-based modules in large-scale solar installations in Canada, India, Italy, South Africa, Germany and Mauritania. To promote greater adaptation of solar PV technology in the Middle East, Masdar Institute has collaborated on R&D with Siemens Energy. This collaborative effort focuses on advanced technology to develop coatings that counteract the effects of dust and require less water for cleaning than current high performance modules.

Masdar PV has the benefit of a secure financial backing and is able to offer long-term quality guarantees. These factors enhance Masdar PV's competitiveness as a player in the international photovoltaics market.

b) Carbon Capture and Storage Technology

Growing global emissions are intensifying pressure for policy makers to address the problem of climate change. Serious ecological problems including global warming, ozone depletion, loss of biodiversity, natural resource scarcity, air pollution, toxic wastes, and industrial accidents are increasing the costs of emissions. The UAE is among a handful of countries forging a path in the development of reduction technologies.

Masdar Clean Energy is a key developer of carbon abatement projects and technologies, making important strides in addressing greenhouse gasses (GHG). Capture & Storage (CCS) technology keeps carbon out of the atmosphere by capturing it and burying it underground. The technology holds the promise of reducing CO_2 and is an essential component in the global strategy to mitigate GHG emissions. Currently, however, CSS technologies and projects are costly, complex, and difficult to implement.[17] These carbon reduction projects are carried out through Masdar Clean Energy. The unit manages Masdar Clean Energy's projects to minimize carbon emissions include energy efficiency and waste heat/CO_2 recovery, as well as carbon capture and storage (CCS) schemes.

Masdar Clean Energy is developing one of the world's most ambitious large-scale CCS projects in partnership with the Abu Dhabi National Oil Company (ADNOC) and other players in the power and industrial sectors in the emirate. The plans are unique to this region and rare for a field in which only a handful of industrial carbon burial projects have been realized worldwide. When completed, the project will capture five million tonnes of carbon dioxide per year emitted from power plants and heavy industry, and transport it, via a national pipeline network, for injection into Abu Dhabi's oil and gas reservoirs for enhanced oil recovery (EOR). This carbon capture will contribute to Abu Dhabi's Vision 2030 to lower the emirate's carbon footprint.

In a transfer of technology to emerging markets Masdar is advancing trading schemes to counter high levels of CO_2 production. In a joint venture with E.ON Carbon, Masdar Clean Energy is investing in abatement projects in Africa, the Middle East, and Central and Southeast Asia in the oil and gas sector. Emission reductions from these projects have credits that can be traded under the Kyoto Protocol's Clean Development Mechanism (CDM). The CDM is the key international market-based tool to reduce GHG emissions from the developing world. It allows developing countries to offset their carbon emissions and achieve sustainable development goals while enabling industrialized countries meet their Kyoto emissions reductions commitments through trading schemes.

[17] *IEA, CCS Report*

[18] *CSS technologies are expected to become more feasible in diverse settings such as chanelling outputs from biomass and gas power plants, fuel transformation, and gas processing sectors, as well as in emission-intensive sectors such as cement, iron and steel, chemicals, and pulp and paper.*

As the environmental costs of output increase, it is becoming necessary to develop large-scale carbon capture and storage technologies.[18] The International Energy Agency suggests that mitigating GHGs to acceptable levels will require 100 CCS projects globally and 3000 projects by 2050, requiring an investment of $2.5-3 trillion by 2050. As a pioneer, and one of a small handful of countries implementing projects in the CCS field, Masdar has positioned UAE to bring valuable competencies and know-how for the global community to address climate change and sustainable development.

c) Utility-Scale Power Generation

Masdar Clean Energy seeks to provide cleaner energy through innovative technologies in renewables on a more cost effective and more reliable basis. The significance of these utility-scale projects is that they are operational and are already providing power to residences and enterprises. Masdar Clean Energy's portfolio of utility-scale projects consists of direct investments with a focus on photovoltaic (PV) solar energy, concentrated solar power (CSP), and Wind Technology. These technologies have relevance globally and for the UAE's long-term future of power generation. Each of the projects highlighted below is a major step forward in the global drive to transform the energy industry:

- #### Photovoltaic Solar Energy

  Masdar's earliest photovoltaic (PV) project in the UAE, the 10 megawatt (MW) PV Plant at Masdar City, operational since 2009, saves more than 25,000 tonnes of carbon annually. The solar power plant meets the energy needs of the Masdar Institute, Masdar site offices, and powers the on-going construction activities of Masdar City. The plant, consisting of 87,777 panels (50% thin film and 50% crystalline silicon) at a cost of $50 million was one of the most cost-efficient PV installations in the world in terms of its projected output.

  Currently, Masdar Clean Energy is developing one of the world's largest solar PV plants— Noor 1, a 100MW plant in Abu Dhabi.

- #### Concentrated Solar Power

  In the arena of concentrated solar power (CSP) Masdar has achieved several milestones and breakthroughs in its projects in the UAE and internationally, demonstrating the UAE government's commitment to competitiveness in the area of large-scale deployment of clean energy.

  In March 2013 in a joint venture with Total and Abengoa, Masdar Clean Energy launched the the 100MW Shams 1, a concentrated solar power (CSP) plant in the western region of Abu Dhabi. This installation is among the largest CSP plants in operation in the world. Using state-of-the-art parabolic trough technology, the installation covers an area of 2.5 km^2.

  Now fully operational, the plant is connected to the grid will generate clean energy to power 20,000 homes in the UAE.

  The development represents a major stride in introducing renewable energy in Abu Dhabi and the UAE. It will prevent approximately 175,000 tons of CO2 emissions each year--the equivalent to planting one and a half million trees or eliminating the use of 15,000 cars (**see Illustration 1**).[19]

  In the international arena, in partnership with Torresol and SENER, Masdar has invested in three CSP projects in the Andalucía region of southern Spain: Valle 1, Valle 2, and Gemasolar. Valle 1 and Valle 2 are parabolic trough plants with 7.5 hours of stored capacity, and are in commercial operation with a total installed power of over 100MW. Masdar's flagship CSP plant, Gemasolar, near Seville, is already providing electricity to over 27,000 residents. It's major innovation is being able to produce more than 15 hours of power without sunlight (**see Box 6**).

- #### Wind Technology

  Often clustered in farms, wind turbines convert wind energy into electricity and are a growing source of energy globally. Large wind farms consist of hundreds of individual wind turbines connected to the electric power transmission network. Despite the state of the global economy, wind power is becoming a favored source of renewable generation, with the global wind power market increasing.[20] Capitalizing on global demand, Madar Clean Energy is building wind energy sources in the UAE and internationally. The iconic 1,000 MW London Array offshore wind farm in the Thames Estuary, a joint venture with technology giants the Danish DONG Energy and the E.ON, is planned to be the world's largest (**see Box 5**).

Closer to home, Masdar Clean Energy is putting in place a wind farm on Sir Bani Yas Island, 250 km southwest of Abu Dhabi, with a targeted capacity of 28.8 MW for the first phase.

Transporting its expertise internationally, Masdar is also helping reduce dependence on fossil fuels. In other countries. In Seychelles, a wind power project is underway for a 6MW onshore wind farm; In Mauritania, a 15MW PV plant will generate 10% of the country's electricity capacity.

[19] *Abengoa Solar website, 12 December 2012*
[20] *Wind Power Market Rose to 41 Gigawatts in 2011, Led by China, Alex Morales - Bloomberg News, 07 February 2012*

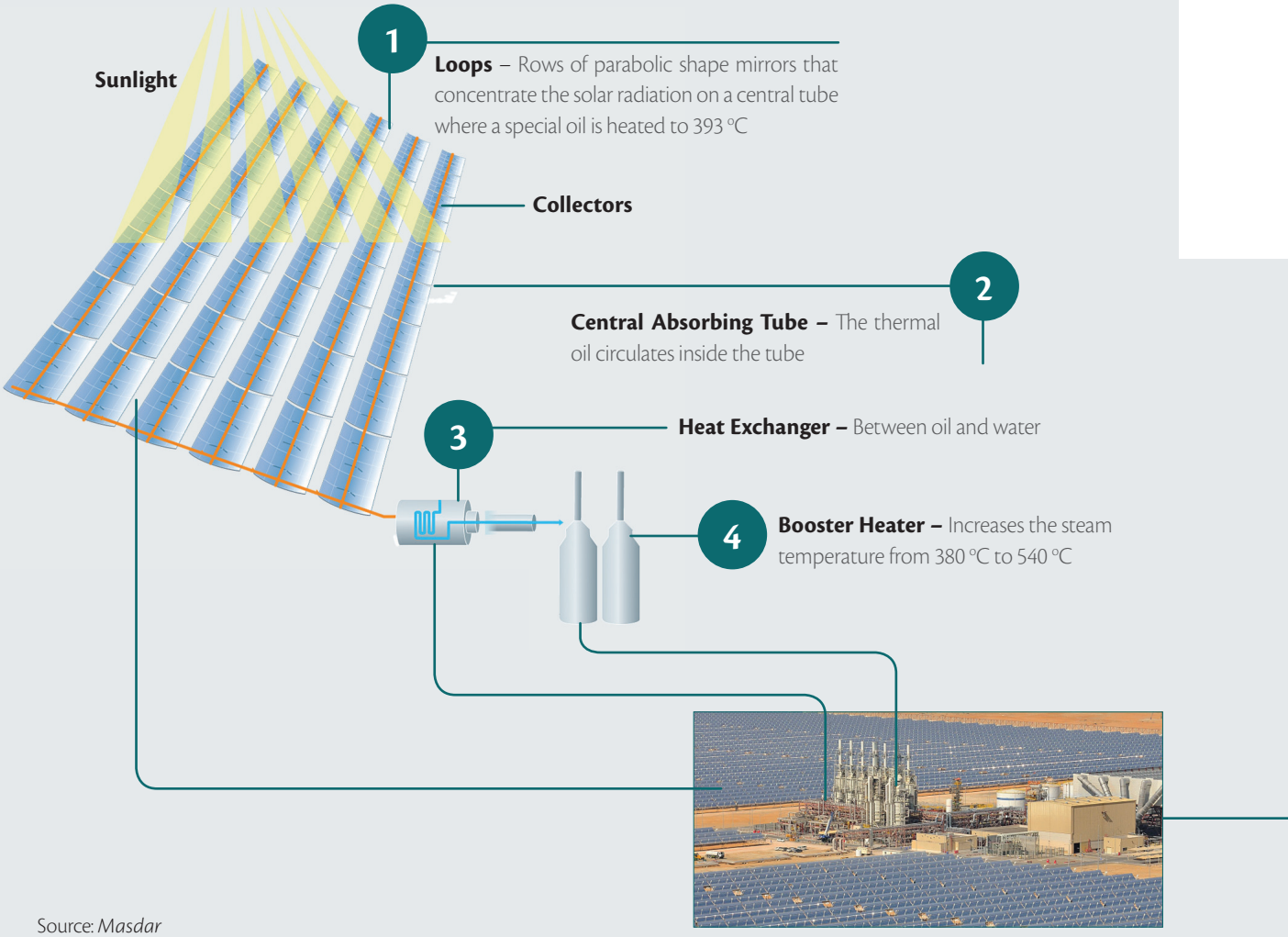
SHAMS 1 Concentrated Solar Thermal Using Parabolic Trough

Illustration 1. SHAMS 1

MAIN FEATURES OF SHAMS 1

- Power output of 100 MW
- Uses solar thermal collectors to concentrate the heat from direct sunlight
- Uses sustainable and renewable energy to produce electricity
- Will save 175,000 tonnes of CO_2 every year, equivalent to planting 1.5 million trees of taking 15,000 cars off the road
- Power supplied will be enough for 20,000 UAE homes
- One of the largest Concentrated Solar Power (CSP) plants worldwide
- The size of the plant site is around 2.5 km^2
- The solar field consists of 768 units of Solar collector assemblies
- 192 parallel loops with four series connected collectors
- The Solar field includes 258,048 mirrors that take up a total mirror aperture of 627,840 m^2
- Collectors – high reliability, optical performance and state-of-the-art design that reduces production and assembly costs

OPERATIONS PROCESS



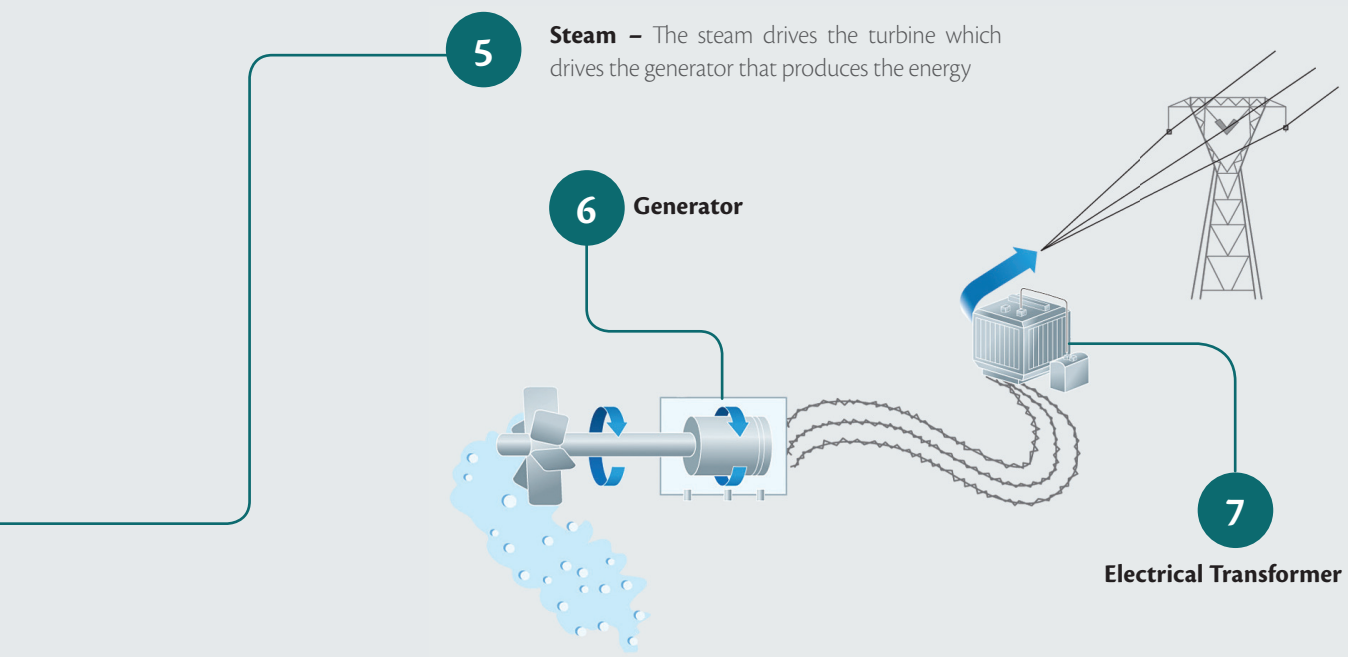
Source: *Masdar*

Box 5. Propelling the World Ahead

London Array offshore wind farm first turbine installation

Installation of the 175th and last turbine of phase 1

Set to become the world's largest offshore wind farm, the London Array project will consist of up to 278 wind turbines of 1,000MW, producing enough energy to power 750,000 homes—a quarter of Greater London homes, and displacing the emissions of 1.9 million tonnes of CO_2 per year. When fully operational, the London Array will make a substantial contribution to the UK government's target of providing more than 15% of all electricity supply from renewable sources by 2015—the London Array project would represent nearly 7% of this target.



Gemasolar: A Beacon of Light

Box 6. Gemasolar: A Beacon of Light for Utility Scale Power Generation

Gemasolar, a flagship CSP plant in Spain can store 15 hours of sunlight—a breakthrough in CSP technology that allows uninterrupted provision of power to the 27,000 homes it serves in Fuentes de Andalucía, Seville, Spain

A Breakthrough Technology

A stellar success in the international arena Masdar's flagship Gemasolar CSP plant located in Seville, Andalusia, is joint venture of Masdar and technology leader SENER, through Torresol Energy.

Gemasolar is a commercial-scale CSP, Initiated in 2011, plant with a central tower that produces more than 100 GWh annually. Currently, the plant supplies electricity to over 27,000 homes in the Andalusia region.

A key challenge of CSP in general is the ability to provide unimpeded electricity because of the technology's reliance on the availability of sunlight. When sunlight is impeded—such as on cloudy days and at night, the flow of electricity is affected. However, through a breakthrough in thermal transfer technology Gemasolar, has overcome this hurdle so that it provides uninterrupted electricity to the population it serves.

The installation can reach operating temperatures of well over 500°C—much higher than other types of conventional solar technologies that use parabolic troughs. The tower boasts a capacity to store up to 15 hours of sunlight. This capacity to store electricity in turn permits the plant to provide 24 hours of continuous electricity on most summer days, regardless of sun conditions.

How it Works - the details

In the Gemasolar plant, sunlight is focused and concentrated by mirrors onto a central tower receiver that contains molten salt. The salt is heated to a high temperature by the focused solar light. The molten salt then transfers heat to water, generating high-pressure steam that drives a conventional turbine. By using a particular cutting-edge thermal transfer technology developed by SENER, the Gemasolar installation enhances molten storage technology and the more efficient heat transfer enables it to store the energy of the sunlight for long periods of time.

The heat transfer system makes the technology more efficient compared to conventional parabolic-trough technology, because the molten salts in the sunlight receiving tower of the plant are able to reach 565°C. These extremely high temperatures generate hotter steam at very high pressures, which significantly boosts its efficiency of the plant. This enhanced efficiency is what permits long storage time of the electricity and provide continuous sources of power.

Implications for the Industry

Globally there is increased interest in concentrating solar thermal power (CSP). The storage capacity is a major innovation of the technology, as it provides a backup of energy for periods with reduced sunlight. Rather than determined by the availability of sunlight, this technology is driven by demand.

Gemasolar's ability to generate uninterrupted electricity marks an important step toward demonstrating the reliability of solar technology and addressing one of the industry's biggest challenges. By overcoming fluctuations in the energy supply, the plant is able to manage the supply of electricity sent to the network and respond to spikes in demand. Control of the energy supply in this way makes solar energy comparable to conventional fossil-fuel power plants for reliability. The annual capacity factor of Gemasolar is higher than most baseload[21] plants such as nuclear power plants.

Environmental and Economic Benefits

On many days the plant's generation exceeds 400MWh/24 h, helping to prevent atmospheric CO_2 emissions by more than 30,000 tonnes a year.

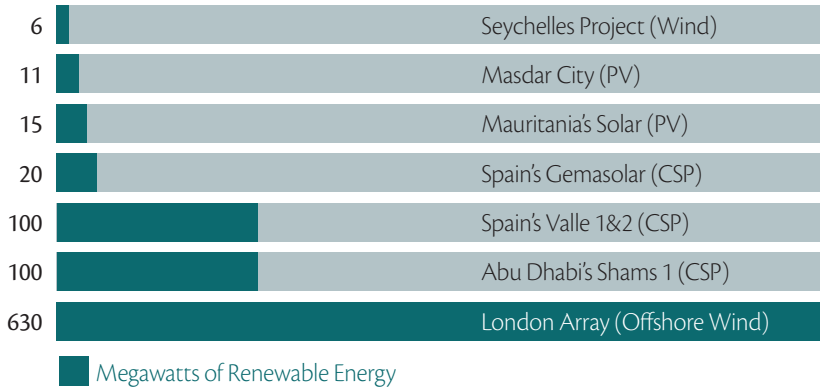
The plant also translates to significant savings for the Andalusia region when compared to traditional energy use. Currently Gemasolar allows the region to save the equivalent of 173,000 barrels of oil compared to conventional power generation using fossil fuels. Assuming a cost of US$100 per barrel of oil, this represents a hypothetical annual savings for the country of $17million.

Gemasolar official opening

[21] *Baseload is the minimum amount of power a utility company is required to make available for its customers.*

Global Competitiveness in Delivering Clean Energy

Masdar projects at a glance:



Delivering Clean Energy:

- Masdar's investments deliver nearly **1GW** of clean power
- Masdar has international wind and solar projects in Spain, UK, Mauritania, Seychelles and UAE
- Masdar is responsible for nearly **10%** of installed CSP capacity
- Masdar's projects represent an istimated **68%** of the Gulf's renewable energy capacity

iii. MASDAR INSTITUTE: LAYING THE FOUNDATIONS FOR A KNOWLEDGE ECONOMY

A talented, competitive workforce is at the heart of any country's ability to bring innovations to market, fueling a nation's competitiveness and productivity performance. Reflecting UAE's competitiveness objectives of developing talent at the individual level and the accumulation at the national level of human capital, this is a central feature of Masdar's model of knowledge transfer and fostering innovations.

Mohamed Al Sharhan, student of Engineering Systems and Management program, is working on 'Public Transportation for Abu Dhabi: Potential for a Sustainable Public Transportation System'.

Aysha Alnuaimi, conducting advanced research at the Microsystems Engineering program's 'Cleanroom' facility at Masdar Institute.

Through Masdar Institute, its academic and R&D arm, Masdar is creating a cadre of future-oriented specialists with premium knowledge for the green economy. Developed in collaboration with Massachusetts Institute of Technology (MIT), Masdar Institute's rich R&D environment is a magnet for some of the brightest minds to come to the UAE. Offering graduate degrees—Masters and PhD programs—the institute has an explicit focus on sustainable energy studies—the first of its kind in the region. By playing a dynamic role in contributing to the UAE's long-term strategy for knowledge creation and human capital development, the Institute serves as a source competitive advantage in the transition to a green economy.

[22] *EU-GCC Network*

Dr. Fred Moavenzadeh, President of Masdar Institute, at the launch ceremony in Abu Dhabi for the 100% renewable energy micro-grid project— a collaboration between the Global Green Growth Institute (GGGI), Masdar Institute and the Research Institute for Industrial Science and Technology (RIST), Pohang of South Korea

Students learn in a stimulating academic environment taught by sixty leading faculty and top-tier researchers recruited globally. Faculty and students devote approximately 60% of their time on R&D—an unusually high proportion of time by international standards—focused on seeking solutions to challenges of clean energy and climate. Students receive training as specialists in renewable energy; integrating theory and practice, with a strong industry and entrepreneurship emphasis (**see Box 7**). Increasingly, students and faculty raise their R&D grants from industry, giving the program a strong industrial, demand-driven focus.

Currently 337 students conduct research on the following areas in specialized labs: water, health and environment, energy systems, micro-systems and advanced materials. Project areas include: biomass-derived fuels, smart grid applications; salt water desalination and energy efficient technologies. By 2018, the Institute aspires to host up to 800 graduate students, mostly UAE nationals, and 200 academic staff.

Masdar Institute catalyzed the University Leadership Council in the UAE, in cooperation with five universities. The council provides a platform to share knowledge and spearhead new ideas for entrepreneurial innovations, and transfer technology in the region.

Box 7. An Environment of R&D Excellence

Similar to MIT, whose alumni have founded more than 6,900 companies with worldwide sales of approximately $164 billion representing 26% of the sales of all Massachusetts companies, Masdar Institute aspires to generate benefits for Abu Dhabi and the region. In its first five years, the Masdar Institute has been recognized many times for the quality of its R&D, for its patent applications, and for its publications and citations by professors and students at various global forums and renowned journals. Several local and international firms have entered into R&D contracts with Masdar Institute. The research-based institution in Abu Dhabi aims to achieve this through its academic and research focus on R&D, innovation and entrepreneurship, and more broadly by helping grow the region's human capital and knowledge base.

PARTNERSHIPS FOR INNOVATION

Masdar Institute's strategic collaborations include several agreements that join industry, government and academia together to address the challenges of a clean energy future. The Institute has joined hands with Abu Dhabi Company for Onshore Oil Operations, Petroleum Institute, and Massachusetts Institute of Technology to conduct research on carbon sequestration. It is also working in conjunction with the aerospace corporation Boeing, along with Abu Dhabi's flagship carrier, Etihad, and specialty materials company, Honeywell UOP, on a major research program and demonstration project in Abu Dhabi dedicated to the development of sustainable biofuels for aviation, using integrated saltwater agricultural systems.

In 2011, Masdar Institute was selected to lead the Gulf region in establishing a clean energy research network in collaboration with the European Union, the EU-GCC clean energy co-operation, supported by the European Commission.[22]

A rich internship program allows students at Masdar Institute to transfer of skills and technology from its leading edge international investments in clean energy companies to its students in the UAE. Students apply their technical training to research at the cutting-edge of clean technology. Internships immerse them in experimentation, product design and addressing industry challenges. Students also get a close-up view of entrepreneurship, which is strongly encouraged (**see Box 8**).

Recently, Masdar Institute has established a multi-entity taskforce that will focus on new demand-side technologies and strategies for reducing energy demand for cooling. Coordinated by the Executive Affairs Authority of Abu Dhabi (EAA) the initiative will include participation and support from the Abu Dhabi Water and Electricity Authority, the Regulation and Supervision Bureau, the Department of the Municipal Affairs, and the Urban Planning Council. Commenting on the initiative, HE Dr. Sultan Ahmed Al Jaber, Managing Director and Chief Executive Officer of Masdar, noted:

Dr. Sultan Al Jaber and Abdulla Saif Al Nuaimi

Box 8. Internships Fuelling a Knowledge Economy

Masdar Institute's internship programs allow students to build hands-on skills with its partners-leading enterprise in the UAE and internationally. The students in turn bring to the institutions the latest in academia at:

- ### Abu Dhabi Water and Electricity Authority (ADWEA)
  ADWEA researches and develops ways to more efficiently produce, distribute and consume water and electricity. Masdar Institute recently signed an agreement with ADWEA to identify areas for exchange of scientific and technological information through research collaborations, covering sustainable energy, water and environmental issues.

- ### Global Green Growth Institute (GGGI)
  GGGI is dedicated to pioneering and diffusing a new model of economic growth, known as "green growth" that simultaneously targets key aspects of economic performance, such as poverty reduction, job creation, and environmental sustainability. GGGI has joined hands with Masdar Institute and the Research Institute for Industrial Science and Technology (RIST) in Pohang, South Korea, to design a robust and cost-efficient micro-grid operating on 100% renewable energy.

- ### GLOBALFOUNDRIES
  The world's second largest semiconductor foundry, GLOBALFOUNDRIES recently granted a number of students and professors from Masdar Institute privileged access to the company's technology development platform from its Abu Dhabi office. The laboratory-like environment includes powerful production servers, engineering work stations and a high-speed data network enabling remote access to one of the world's most advanced nanotechnology engineering systems based at GLOBALFOUNDRIES' leading-edge Fab 1 fabrication facility in Dresden, Germany. The environment will provide university researchers and students with wide access to process design kits (PDKs) for advanced semiconductor technology nodes, including the latest High-K Metal Gate (HKMG) 28nm nanometer transistor technology.

- ### Emirates Aluminum (EMAL)
  EMAL is a state-of-the-art aluminum smelter complex that produces high quality metal for the global market. The advanced smelter in Al Taweelah currently uses DX Reduction Cell Technology to produce 750,000 tonnes of aluminum annually. Masdar Institute has been working in close cooperation with EMAL on a research program to improve the efficiency and overall environmental performance of aluminum ore smelting and production. The two parties are currently creating skills development programs (ditto) for a national workforce capable of meeting future needs of the industry.

- ### Masdar
  Masdar PV hosts senior students at its high tech PV module fabrication plant in Germany. Dr. Harald Bloess, Head of Technology at Masdar PV, notes that interns in the 'MicroSystems Technology" are directly involved in the development of PV modules with advanced materials and "[they] get the opportunity to apply theoretical research directly at the production of modules and by that gain valuable practical experience."

- ### Siemens
  Siemens occupies leading market and technology positions worldwide with its business activities in the Energy, Healthcare, Industry, and Infrastructure & Cities Sectors. Masdar Institute is collaborating with Siemens on a long-term R&D program for Smart Grids, Smart Buildings (SGSB), and Carbon Capture & Storage (CSS) in the form of scholarships and R&D funding.

Through these various partnerships and networks Masdar is putting in place solid assets on which to build its intellectual capital base for UAE's prosperity performance: Skilled people, affiliations with world-leading educational institutions and a network of specialized businesses in the clean energy space.

[23] *Masdar Press Release 11 November, 2012*

"Air conditioning accounts for over 60% of Abu Dhabi's electricity demand, making it the most costly source of electricity in the emirate. Masdar has been a regional leader in the deployment of advanced cooling technologies with investment in geothermal cooling, absorption chillers, and district cooling. The new research program that Masdar Institute has undertaken with EAA demonstrates the Institute's ongoing commitment to providing research that will help address the region's most significant technological challenges. This research program is aligned with Masdar City's technology roadmap and will benefit from having Masdar City as a test bed for innovative cooling solutions that follow from the research." [23]

CONCLUSION

The UAE's national strategic plan Vision 2021 calls for the country to be among the most competitive, knowledge-based innovation-driven economies. To achieve this it must innovate continuously to upgrade productivity as the key to international competitiveness and prosperity in the modern economy. As it prepares itself to be a leading economy of the 21st century, it is putting in place several policies, procedures and institutions towards its long-term growth and prosperity.

It has effectively placed the UAE on the world map for long-term leadership in the clean energy sector. By creating a network driven by innovation and R&D; through its partnerships with strategic, top-tier clean energy companies internationally; through its investments in promising technologies and through the the creation of a cadre of green energy experts it is anchoring and rooting knowledge from its investments to develop the UAE for its long-term social and economic development. At the global level, Masdar is advancing the renewable energy agenda at a time when many other countries face austerity measures and are scaling back on their renewable energy programs.

Through its $4 million Zayed Future Energy Prize, the world's largest prize for future energy solutions, Masdar provides important incentives for addressing renewable energy challenges. The forum it provides for policymakers, scientists, and business leaders incentives to tackle the urgent energy and sustainable development issues. Other large-scale policy platforms include the Abu Dhabi Sustainability Week, anchored by events such as the World Future Energy Summit which draws heads of state and high level delegations from over 100 countries to discuss clean and secure energy, and the International Water Summit. In 2009, the UAE won the vote of 158 countries to host the International Renewable Energy Agency (IRENA) in Masdar City—a dramatic endorsement of the international community's confidence in the UAE as a fitting venue for this intergovernmental organization whose objective it is to promote the use of renewable energy. Such platforms facilitate dialogue, foster relationships, promote knowledge sharing and stimulate the development of new technology solutions for global energy security, climate change and sustainable human development.

Arguably, through its success in the clean energy arena, Masdar has sparked similar large-scale investments, initiatives and forums in the Gulf region. This move is fortifying the Gulf region as a clean energy hub that addresses the world's most pressing energy challenges. By creating a precedent and for unleashing the potential of clean energies at an industrial scale, it demonstrated the feasibility of green growth initiatives in the resource-rich Gulf countries.

Masdar is playing a vital role promoting innovations that are socially beneficial, and make efficient uses of resources to promote sustainable development that is central to the UAE's competitiveness strategy. As the price of fossil-fuel energy increases and energy from renewable sources becomes more economically viable, Masdar will continue to benefit from a first-mover advantage in the rapidly growing clean energy market. Its advantages will include an expert knowledge base from its R&D progress, lessons learned from its utility-scale initiatives and investments, and business intelligence from improving technologies and economies of scale. Through its strategic, integrated approach Masdar has propelled itself to world leadership in the clean energy sector and laid the groundwork for powering UAE's competitiveness and prosperity for future generations through clean energy.

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