RENEWABLE ENERGY&HYDROGEN ECONOMY



The Sun: Goldmine of Green Energy

GLOBAL INSTITUTE OF SCIENCE & TECHNOLOGY

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Renewable Energy Solutions For India - Action Plan



The Sun: Goldmine of green energy

PREPARED FOR THE PRIME MINISTER OF INDIA NEW DELHI, INDIA

November 3, 2014

Prepared by: **Darshan Goswami, M.S., P.E.** *U.S. Department of Energy (Ret.) dlgoswami@hotmail.com Pittsburgh, Pennsylvania, USA*

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Purpose of this Presentation

For economic as well as environmental reasons India need to shift to Renewable non-polluting Energy. The aim of this presentation:

- ✓ Provide <u>Renewable Energy (RE) solutions ACTION</u>
 <u>PLAN</u> (for 5 and 10 Years) to meet India's Energy Needs
- ✓ Develop Favorable policies For RE development
 5 YEARS PLAN:
- Develop Solar Energy > 50,000 MW by 2020*
- Develop Wind Energy > 20,000 MW by 2020* 10 YEARS PLAN:
- Develop Solar Energy > 100,000 MW by 2025*
- Develop Wind Energy > 50,000 MW by 2025*

^{*}Assuming favorable Policy, Incentives, Tariffs, and Financing is provided

Challenges and Issues Facing India

- Demand far exceeds generation capacity
- Lack of transmission and distribution capacity
- **Remote locations too expensive** to provide electric service
- Lack of O&M for existing infrastructure
- Lack of financial resources for infrastructure development
- Lack of development of technologies for the generation of electricity from renewable energy sources
- Lack of regulations and technical standards to ensure renewable energy systems are reliable

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Present India's Renewable Energy Capacity (As of January 31, 2014)

- Wind 20,294 MW
- Solar Power 2,208 MW
- Small Hydropower 3,774 MW
- Biomass Power & Gasification 1,286 MW
- Bagasse Cogeneration 2,513 MW
- Waste to Power 99 MW

OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWEQ)

- Waste to Energy 120 MW
- Biomass(non-bagasse) Cogeneration 517 MW

(Source: Ministry of New and Renewable Energy, Government of India). 5

Case For Renewable Energy Solutions in India

Renewable energy is the only technology that offers India the theoretical potential to service all its long-term power requirements. The Indian subcontinent is blessed with abundant renewable energy resources. For instance, taking advantage of 300 to 330 sunny days a year, India could easily generate 5000 trillion kWh of solar energy, which is higher than India's total yearly energy consumption India could build 1,000 GW of solar on just 0.5% of its land (Approximately 4 times current capacity)

Case For Renewable Energy Solutions in India

- Domestic coal supply is limited and poor quality
- Foreign supply of hydrocarbons have serious impact on country's energy security
- Renewable Energy (RE) sources are not depleted
- RE is non-polluting
- Reinvestment can be used for many decades w/o affecting the environment

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PROPOSED ACTION PLAN SUMMARY

- 1. Invest in Renewable Energy (FE) and Energy Efficiency
- 2. Enact a National RE Standard of 20% by 2020
- 3. Deploy comprehensive RE policies, PPAs, FIT, etc.
- 4. Decentralized Energy; e.g., Roof-Top Solar Policy , etc.
- 5. Deploy large utility-scale solar generation Farms and cooperatives using PV, CSP and CPV technologies; & wind farms co-operatives
- 6. Proper Incentives to create exponential growth of RE
- 7. Phase out all conventional energy subsidies
- 8. Give birth to the "Green Revolution" in India
- 9. Invest in a smart & micro-grid; and smart meters
- **10. Develop large-scale manufacturing "Solar Hub in India**
- 11. Work towards a Hydrogen (H2) Economy and fuel cells 12. R&D facilities with IITs, Govt., industry for Tech. Dev.

- Invest in **Renewable Energy** and **Energy Efficiency**
- Enact a National Renewable **Energy Standard of 20% by** 2020 to create demand, new industries and innovation, and a new wave of millions of green iobs

• Accelerate the development and implement nation-wide user-friendly **comprehensive Renewable Energy** policies such as PPAs, FIT, depreciation; tax holidays; financing funds; international partnerships/collaboration, incentives for new technologies; HR development; zero import and excise duty on materials; and low interest rate loans. 10

 Decentralized Energy – Urgent need to develop a nationwide Comprehensive user-friendly Roof-Top Solar Policy to promote small-scale and decentralized solar power generation and to solve the energy crises by bridging demand-supply gap. Facilitate growth in large scale deployment by installing 100 million solar roofs, e.g., develop Solar Co-operatives like Solar Cities in CA and Wind Farm Co-operatives, etc.





 Aggressively expand large utility-scale solar generation, using Photovoltaic (PV), Concentrated Solar Power (CSP) and Concentrator Photovoltaic (CPV) technologies













• Develop, promote and establish **utility scale solar farms co-operatives, wind farms co-operatives, off shore wind farms and co-operatives**



- Develop favorable Renewable energy policies to ease the permitting process, and to provide start-up capital to promote the exponential growth of renewable energy.
- Phase out all conventional energy subsidies including coal, nuclear, petroleum products to compete with other fuels.





Give birth to the "Green Revolution" - Initiate a move to electrify automotive transportation or develop Electric Vehicles – plug-in hybrids – such as the Nissan Leaf, Tesla Model S, or Chevy Volt, etc. Develop and implement time-of-day pricing to encourage charging of cars at night. Adopt nationwide charging of electric cars from solar panels on roofs, and solar-powered Electric Vehicle charging stations around the country. Thousands of these solar-powered recharging stations could spread across India just like the present public call office (PCO). Deployed recharging connections at shopping malls, motels, restaurants, and public places where vehicles are usually parked for extended periods;





- Aggressively invest in a smart, two-way grid (and micro-grid) and smart meters
- Develop large-scale solar manufacturing in India (transforming India into a global "Solar Hub").



- Use all Renewable Energy options including solar, wind, hydro, biomass, and geothermal to ease the strain on the present transmission and distribution system .
- Develop waste-to-power Biofuel and Biogas power plants
- Engage States, industrial companies, utility companies, and other stakeholders to accelerate the Renewable Energy investment





• Establish R&D facilities within academia, research institutions, industry, government and private entities to guide technology development.







Work towards a Hydrogen (H2) Economy and fuel cells for generating heat and electricity — as well as for powering fuel cell vehicles. Produce H2 from renewable energy, e.g., solar and wind. H2 and electricity will eventually become society's primary energy carriers for the twenty-first century.



HYDROGEN (H2) ECONOMY APPLICATIONS













Work towards Energy Storage:

- ✓ Thermal energy storage Solar CSP and CPV (molten or liquid salt a mixture of sodium nitrate and potassium nitrate)
- ✓ Grid Battery Storage Lead acid, Li-ion, flow batteries, NaS
- ✓ Compressed air/Gas energy storage
- ✓ Vehicles-to-Grid/Home
- ✓ Pumped hydro
- ✓ Fuel Cells hydrogen-based power modules
- ✓ Flywheel Storage
- ✓ Superconducting magnetic energy storage
- ✓ Super capacitors

Estimated Cost Comparison Of Wind Energy In India (As of January 31, 2014)

COST COMPARISON OF WIND ENERGY ONSHORE WIND FARMS

- Investment of about \$1.5 million per MW
- Levelized cost of 6-7 cents per kWh
- O&M 1-3% of capital costs
- May be built in smaller units

OFFSHORE WIND FARMS

- Investment of \$2.3 million per MW
- Levelized cost of about 10-11 cents per kWh
- Higher O&M 40 per kW and 0.7 cents per kWh variable

Estimated Cost Comparison Of Solar Energy (As of August 23, 2011)

COST COMPARISON OF SOLAR VS. NUCLEAR



Sources 2011 readear price is the millipoint of the LDOE range given by Lazard, version 5.0. 2005 readear price is illustrative, calculated assuming 3.5% annual escalation; 2011 & 2016 PV Price Rown DOE. Advanced Research Projects Agency - Energy, 5138/art Photosolitaic Systems, May 2011, 2020 PV price Rown point development on distribution from 2016 Burther visibilities by price Burther visib

(Source: CleanTechnica)

Estimated Cost Comparison Of Solar Energy (As of August 23, 2011)

COST COMPARISON OF SOLAR VS. COAL



(Source: CleanTechnica)

Why Solar is the BEST Option to Meet India's Future Energy Needs

- Receives solar energy equivalent to nearly 5,000 trillion kWh/year
- Solar radiation of 4 to 7 Wh/sq.m in India
- Most parts of **India has 300~330 sunny days** in a year
- Power generation potential using solar PV technology is around 20MW/sqkm and using solar thermal generation around 35MW/sqkm.
- India could build 1,000 GW of solar on just 0.5% of its land.
- India's Present Total Generation Capacity is about 210 GW

Why Solar is the BEST Option to Meet Future Energy Needs

- Decentralized nature of generation
- Can be located close to demand
- Reliable and predictable performance > 25 years
- Low operational maintenance Requirements
- Domestic and freely available fuel source
- Zero human displacement
- No environmental impact
- Most States **Tariffs** already established
- Average Time to Build Solar is about 1 Year
 Vs. 13 Years for Nuclear

Jawaharlal Nehru National Solar Mission

- Under the National Action Plan on Climate Change 8 Missions were proposed. In the Prime Minister's words "Solar Mission was its centerpiece"
- National Solar Mission is one of the major global initiatives in promotion of solar energy technologies
- To deploy solar technologies on a large scale leading to cost reduction and aiming to achieve grid tariff parity by 2022
- Deployment of 20,000 MW of solar power by 2022
- Proposed Roadmap is not adequate
- Massive Power generation potential using solar technology (> 1000,000MW by 2050*)

*Assuming favorable Policy, Incentives, Tariffs, and Financing is provided

Present Tariff in Delhi

From 0 - 200 units 4.00 Rs per unit From 201 - 400 units 5.95 Rs per unit From 401 - 800 units 7.30 Rs per unit From 801-1200 units 8.10 Rs per unit Above 1200 units 8.75 Rs per unit

(Source: Zee Media Bureau)

Summary & Recommendations

- 1. National Policy 20% by 2020
- 2. Feed-in-Tariffs (FIT) & PPA for RE
- **3. Generation Based Incentive**
- 4. Make India Global "Solar Hub"
- 5. Establish Solar Parks & Solar Cities
- 6. Efficient Market Based Financial Mechanism
- 7. Establish R&D facilities at academic, research institutions, industry, Government and Civil Society to guide technology development
- 8. International Partnerships /Collaboration
- 9. HR Developments for Solar Revolution
- 10. Zero import duty on capital equipment

WHY RENEWABLES?

1. The Sun is the Goldmine of Green Energy

- 2. Long ago, scientists calculated that an hour's worth of sunlight bathing the planet held far more energy than humans worldwide could consume in a year.
- 3. <u>There are 7 countries already at, or very, near 100 %</u> <u>Renewable Power</u>
- 4. <u>Most of the world's countries could run on 100% renewable</u> <u>energy by 2050, it's already happening</u>
- 5. SOME LATEST NEWS HEADLINES
- <u>Cheap renewables could deliver 90pct clean grid in US by 2035,</u> <u>and cut costs</u>
- <u>Global wind and solar additions set new record in 2019, but more</u> <u>needed</u>
- <u>New York is trying to achieve 70% renewables by 2030</u> ³⁰

WHY RENEWABLES?

- World has a potential to meet its current power needs more than 10 times over with Solar Energy alone.
- World can go 100% Renewable by 2050.
- We must focus on Distributed Energy.
- Pollution, Climate Change and Global Warming is our single greatest Security threat
- India sets new record-low solar tariff of Rs 2.36/kWh
- The winning bid, for 300 MW of gen. capacity by Spanish developer Solarpack in a 2 GW auction is 3.3% lower than the last record of Rs 2.44.

REVOLUTIONARY CHANGES THAT TECHNOLOGY WILL BRING

- SOLAR ENERGY WITH STORAGE.....NO MORE POWER COMPANY BILLS (E. G., TESLA POWER WALL)
- WORLD CAN MEET ALL POWER NEEDS 10 TIMES THE PRESENT POWER GENERATION NEEDS – JUST FROM SOLAR ALONE
- SOLAR FUELS "EXPORTING SUNSHINE AROUND THE WORLD" - BOTTLING AND EXPORTING SUNSHINE AROUND THE WORLD (I have shared this plan with the Ministry of Power in Delhi)
- HOW WORLD CAN GO 100% RENEWABLE (Solar and Wind) BY 2050.
- ELIMINATE ALL COAL AND NUCLEAR POWER PLANTS, PATROL AND DIESEL CARS.
- SOLAR AND WIND WITH STORAGE CAN BEAT COAL³² AND NUCLEAR POWER NOW IN MANY COUNTRIES.

REVOLUTIONARY CHANGES THAT TECHNOLOGY WILL BRING

- SELF DRIVING CARS, BUSES, TAXIS, AIRPLANES -ARTIFICIAL INTELLIGENCE!!
- DRONES FIGHTING WARS TO AMAZON DELIVERING PACKAGES
- ALL ELECTRIC CARS BY 2030 INDIA'S
- FLYING ROCKETS INSTEAD OF PLANES
- Computers will be many 1000 times smarter than human brains -IBM Watson/ SuperbComputers
- Negative Effect Computer are replacing human job all over the world. For example, 80-90 of new cars are made by ROBOTS OR COMPUTERS.
- CLIMATE CHANGE AND GLOBAL WARMING ACTION PLAN : Already presented to the Ministry of Power (7/20/20³17)

RENEWABLE ENERGY IN INDIA - TODAY

- Total Installed Capacity of 370.106 GW (3/2020).
- 35.86% of India's installed electricity generation capacity is from renewable sources (3/2020).
- Present Installed RE Capacity = 86.75 GW (2/2020)
 - Solar = 34.40 GW
 - Wind = **37.66** GW
 - **Biomass = 9.80 GW**
 - Small Hydro = 4.6 GW
- Government plans to establish RE of 500 GW by 2030
- <u>100% renewable energy across all sectors possible by</u>
 <u>2050 with solar leading the way</u>.

Expected RE capacity addition in the next 5 years

Most players are expecting tariffs to come down over the years. Solar power is expected to maintain its cost advantage over wind power with a difference of about **RS 0.50/kWh**.

Courtesy: Bridge To India*



RENEWABLE FUTURE IN INDIA

- India to bid out 500 GW renewable energy capacity by 2028
- 350 GW would come from solar,
- 140 GW from wind, and
- 10 GW small hydro, biomass, etc.
- <u>40 % Electricity generation from</u> <u>Renewable Energy by 2030</u>
Conclusions

- RE is abundant, ready to harness & FREE
- RE is Non Polluting (Air, Water, & Soil)
- RE is a clean alternative to Fossil & Nuclear
- Solar (PV) power generation has emerged as a reliable and alternative source of clean energy
- PV market is showing robust growth world
- Solar cost down (10-20%/Year)
- Word is Developing large Utility Scale Solar Power Plants
- RE is in par with the fossil and Nuclear Power in many parts of the world today.
- Create million of jobs & Boost India's Economy

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How Concentrated Solar Power (CSP) Can Meet India's Future Power Needs

How Concentrated Solar Power (CSP) Can Meet India's

Future Power Needs - By Darshan Goswami, Dec. 27, 2016

http://www.triplepundit.com/2010/02/rajasthan-desert-solar/

The Sun: Goldmine of Green Energy



Solar energy is an enormous resource that is readily available in all countries throughout the world, and all the space above the earth. Long ago scientists calculated that an hour's worth of sunlight bathing the planet held far more genergy than humans worldwide could consume in a year.

India's solar sunrise

- India's solar sunrise By Darshan Goswami
- 02 May 2012







Full version: India's solar sunrise
 <u>http://www.renewableenergyfocus.com/view/25555/full-version-india-s-solar-sunrise/</u>

Solar Energy has the potential to re-energize India's economy by creating millions of new jobs, achieve energy independence, reduce the trade deficit and propel India forward as a 'green nation'. In short, solar offers too many benefits for India to ignore or delay its development. 40

CAN INDIA GO 100% RENEWABLE BY 2050? By Darshan Goswami, M.S., P.E.; U.S. Department of Energy; Pittsburgh, PA; USA, May 6, 2014



http://www.solarpowerworldonline.com/2014/05/can-india-go-100-renewable-2050/

Renewable energy is the only technology that offers India the theoretical potential to service all its long-term power requirements. The Indian subcontinent is blessed with abundant renewable energy resources. For instance, taking advantage of 300 to 330 sunny days a year, India could easily generate 5000 trillion kWh of solar energy, which is higher than India's total yearly energy consumption.

ENDING INDIA'S MASSIVE POWER GRID OUTAGES – By Darshan Goswami, M.S., P.E.; U.S. Department of Energy; Pittsburgh, PA; USA, September 20, 2012



• TriplePundit.com

Solar energy is a game-changer for India: It has the potential to re-energize India's economy by creating millions of new jobs, achieve energy independence, reduce the trade deficit and propel India forward as a "Green Nation." Solar energy offers too many benefits for India to ignore or delay its development.

SOLAR FARMING POTENTIAL IN INDIA - By Darshan Goswami, M.S., P.E.; Project Manager; U.S. Department of Energy, July 31, 2011





http://www.triplepundit.com/2011/08/solar-farming-potential-india/

Imagine a crop that can be harvested daily on the most barren desert and arid land, with no fertilizer or tillage, and that produces no harmful emissions. Imagine an energy source so bountiful that it can provide many times more energy than we could ever expect to need or use. Imagine that an hour's worth of sunlight bathing the planet holds far more energy than humans worldwide could consume in a year. You don't have to imagine it -- it's real and it's here. Solar energy is an abundant enormous resource that is readily available to all countries throughout the world, and all the space above the earth. It is clean, no waste comes from it, and once a system is in place, it's ''free.''

SOLAR ENERGY FROM THE RAJASTHAN DESERT CAN MEET INDIA'S FUTURE POWER - By Darshan Goswami, M.S., P.E.; Project Manager; U.S. Department of Energy, April 5, 2010



http://www.eartheasy.com/blog/2010/04/solar-energy-from-the-rajasthan-desert-canmeet-india%E2%80%99s-future-power-needs/

The Government of India must take advantage of the vast amounts of energy available from the Rajasthan Desert sun (instead of oil from the Arab nations) to power its future energy needs. In addition, solar energy would not only create millions of jobs, but also sustain India's positive economic growth, help lift its massive population out of poverty and 44 combat climate change.

HOW TO EMPOWER INDIA WITH BIG SOLAR ENERGY PLANS - By Darshan Goswami, M.S., P.E.; Project Manager; U.S. Department of Energy, August 5, 2012



http://www.energypulse.net/centers/article/article_display.cfm?a_id=2525

Solar energy can be the source of many benefits for India and the environment. Solar energy has the potential to reenergize India's economy by creating millions of new jobs, achieve energy independence, reduce the trade deficit and propel India forward as a "Green Nation." Solar Energy offers too many benefits for India to ignore or delay its development.. 45

Go solar - By Darshan Goswami

LifePositive

Go solar

- By Darshan Goswami

http://lifepositive.com/go-solar/

June 2014







Darshan Goswami makes a strong argument for India to harness concentrated solar power, a renewable, safe and clean resource, for its future energy needs.⁴⁶

WORLD'S FIRST SOLAR HIGHWAY

THIS 2 KM LONG HIGHWAY IS LOCATED IN JINAN, CHINA. IT WAS OPENED FOR PUBLIC DRIVING ON DECEMBER 28, 2017. IT CAN GENERATE ENOUGH ELECTRICTY TO POWER 800 HOMES (Solar roadways ready to power houses, and will be wirelessly charging our cars in the future).

https://www.youtube.com/watch?v=sYPzB1g5_5E

- Highway could sunlight into Electricity
- Transfer Power To Grid
- Road Surface is made of Special Material
- Melt Snow in Winter Make Road Safer
- Remote Charge Electric Car While
 Driving
- This Can Be End of the Road For Fossil Fuel Cars



2020 ELECTRIC VEHICLE (EV) REVOLUTION HAS JUST STARTED



WORLD'S LARGEST SOLAR PARK AT KARNATAKA'S PRAVAGADA IS NOW FULLY OPERTAIONAL



Wind turbines in Jaisalmer, Rajasthan, India



THE SOLAR ISLANDS

Courtesy: THE SOLAR ISLANDS



Renewable Energy Solutions For India (A Strategic Development Plan)



The Sun: Goldmine of green energy

Summit for US-India Trade & Economics (SUITE) 2012, May 23rd – 24th, 2012 The Mason Inn Conference Center & Hotel, Fairfax, Virginia, USA

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Solar Energy will Make India's Future Very Bright THANK YOU ENVISION INDIA POWERED ENTIRLY BY RENEWABLE S



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The Hydrogen Economy – The Future of Energy



Indian Institute of Technology (Banaras Hindu University), Varanasi, India November 6, 2012

Prepared by: Darshan Goswami, M.S., P.E. Project Manager U.S. Department of Energy darshan.goswami@netl.doe.gov Pittsburgh, Pennsylvania, USA

A Vision of a Hydrogen Future

- "I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. I believe then that when the deposits of coal are exhausted, we shall heat and warm ourselves with water. Water will be the coal of the future."
- -- Jules Vernes (1870) L'île mystérieuse 55

What Is Hydrogen Economy?

The hydrogen economy is a vision (**Hydrogen is clean energy choice Hydrogen is flexible**, **affordable**, **safe**, **domestically produced**, **used in all sectors of the economy, and in all regions of the country**).

It consists of an economic system in which energy is supplied by renewable resources.

In this **"Economy"** <u>hydrogen is the medium of</u> <u>energy storage and transport</u>.

In other words: Solar, Wind, Hydro, biogas, etc. National Vision to 2030 and Beyond*

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Where Do You Get Hydrogen?

Hydrogen can be extracted from fossil fuels, including gasoline, diesel, natural gas, propane or coal as needed, or **through electrolysis of water** using electricity from conventional power plants.

- Hydrogen can be made from renewable resources
 from water using electricity from solar,
 photovoltaic or wind or using direct processes.
- From methane gas, landfills, waste treatment or biomass processing.

Fuel Cell

BASIC FUEL CELL SCHEMATIC



- All fuel cells have the same basic configuration an electrolyte and two electrodes.
- <u>Fuel cells are classified by the kind of electrolyte used</u>.
 The type of electrolyte used determines the kind of chemical reactions that take place and the temperature range of operation.

Fuel Cell Type

PEMFC - Polymer Electrolyte Membrane Fuel Cells (or Proton Exchange Membrane Fuel Cells)

- **DMFC** Direct Methanol Fuel Cells
 - **AFC** Alkaline Fuel Cells
- **PAFC** Phosphoric Acid Fuel Cells
- MCFC Molten Carbonate Fuel CellsSOFC Solid Oxide Fuel Cells

How is Hydrogen Produced?

- 1. Reforming fossil fuels
 - Heat hydrocarbons with steam
 - Produce H2 and CO
- 2. Electrolysis of water
 - Use electricity to split water into O2 and H2
- 3. High Temperature Electrolysis
 - Experimental
- 4. Biological processes
 - Very common in nature
 - Experimental in laboratories

Advantages of a Hydrogen Economy

- Waste product of burning H2 is water
- 2. Elimination of fossil fuel pollution
- 3. Elimination of greenhouse gases
- 4. Elimination of economic dependence
- 5. Distributed production

Technological Questions

- Where does hydrogen come from?
- How is it transported?
- How is it distributed?
- How is it stored?
- What are the issues with Hydrogen
- Transporting Hydrogen
- Hydrogen-Powered Autos
- Application of Fuel Cell Technology

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Hydrogen-Powered Autos



Figure 1. A conceptual fuel cell vehicle fueled with 5,000 psi hydrogen stored in carbon fiber- 63 wrapped tanks

How can Fuel Cell Technology be used?

Transportation

- All major automakers are working to commercialize a fuel cell car.

fuel cell buses are currently in use in North and South America, Europe, Asia and Australia

- Trains, planes, boats, scooters, and even bicycles are utilizing fuel cell technology as well







Hydrogen Fueling Station

Courtesy: Honda solar hydrogen station (FCX Clarity Car)



Fuel cell SUV

Courtesy: Honda Introduces Solar Hydrogen Station on Saitama Prefectural Office Grounds



Fuel cell BUS

Hydrogen fuel cell buses in London



Hydrogen-Powered Trucks



Fuel Cell Technology for Planes

Boeing Flies First Ever Hydrogen Fuel Cell Plane: The experimental airplane climbed to an altitude of 1,000 m above sea level using a combination of lithium-ion battery power and power generated by hydrogen fuel cells.

 After reaching the cruise altitude, batteries were disconnected, and the plane flew straight and level at a cruising speed of 100 km/h for about 20 min on power solely generated by the fuel cells.



Fuel Cell Technology Aircrafts

First Commercial Fuel Cell Powered Aircraft:

Airbus and the German Aerospace Center (DLR) presented the first commercial aircraft powered by fuel cells at the ILA Berlin Air Show 2008. <u>The fuel cells cannot replace the plane's jet engines for powering the heavy plane through the air.</u>

Fuel cells replace the auxiliary power units which meet the plane's power demands when the plane is on the ground.



Hydrogen-Powered Aircraft





Hydrogen powered passenger aircraft with cryogenic tanks along spine of fuselage. Hydrogen fuel requires about 4 times the volume of standard jet fuel (kerosene).

Fuel Cell Technology For Powered Trains


Hydrogen-Powered Rockets



Nanotechnology in Fuel Cells

- The researchers believe that the improvement is due to a more efficient transfer of electrons than in standard catalysts.

- Increasing catalyst surface area and efficiency by depositing platinum on porous alumina

- Allowing the use of lower purity, and therefore less expensive, hydrogen with an anode made of platinum nanoparticles deposited on titanium oxide.

"HYDROGEN – The New Source of Power"

- Hydrogen = "Currency of the Future"
- **HYDROGEN** Revolution
- Roadmap to the Hydrogen Economy
- Why Hydrogen as a Transportation Fuel
- Will Hydrogen be an alternative fuel or the mainstream fuel ?
- Short term and Long term Infrastructure
- Speculation on Timescales

HOW INDIA CAN EXPORT SUNSHINE AROUND THE WORLD

Solar energy is a free source of non-polluting renewable energy which is sustainable and inexhaustible. Most people are aware of photovoltaics (PV), and that solar panels can be used to generate electricity and produce hot water. Now experts have developed techniques to convert sunlight into 'Solar Fuels'. This can make a huge step toward overcoming the two major obstacles in shifting from fossil fuels to renewable energy: namely, storing large amounts of energy for later use, and powering forms of transportation that cannot easily run on batteries.

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Hydrogen Economy Schematic

