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SOLAR ENERGY: INNOVATIVE PERCEPTION

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Abstract - Usage of Solar energy has gained high importance in last few years, for reducing environmental pollution and for conserving limited known source of fossil fuels (coal, petroleum products, natural gas, etc). Solar energy is the cleaner form of energy which can be converted to electrical energy easily by using Solar Thermal (ST) or Photovoltaic technologies and holds highest potential in most part of India. There is an inescapable need to tap this source of energy up to maximum possible extent. Diffusion of Innovation /adoption of solar energy depend on perception of all stake holders. This paper brings out the factors which are affecting utilisation of solar energy as replacement to fossil fuels based on innovative perception of all stakeholders. The aim of the paper is to analyse the theory of Diffusion of Innovation relevant to usage of Solar Energy in Indian context and bring out factors affecting replacement of conventional source of energy. This may help policy makers to make suitable changes in the existing Solar Policy and change perception of other stake holders to enable them to increase rate of solar energy usage and ultimately reduce carbon emissions and conserve fossil fuel resources.

Keyword – Renewable Energy, Solar Energy, Innovative Perception, Adoption of Innovation, Diffusion of Innovation (DOI), Consumer Choice, Consumer Behaviour.

INTRODUCTION

Fossil fuels (coal, petroleum, natural gas, etc) and other non-renewable energy sources are limited. Also, carbon /green house gases emission due to use of fossil fuel is a matter of concern, in view of increased environmental pollution and global warming up. Pollution in most Indian cities is touching/crossed specified dangerous level and all metropolitan cities are among the world's most polluted cities. Also, all known sources of the fossil fuels will get exhausted soon with the present rate of the consumption.

To overcome these problems, many countries are looking forward to replace these conventional sources of energy with alternative source of energy which is renewable and cleaner in usage, as a strategy to meet the increasing needs of consumers. Also, use of renewable energy will help in saving huge foreign currency in India which is being spent on importing petroleum products. Use of a cleaner alternate source of energy is very critical for India due to critical state of pollution in its cities.

There are several potential sources of energy that are considered renewable energy initiatives, including solar power, wind power, and biomass. Biomass refers to all renewable organic materials that are used to generate fuels from various natural sources such as ethanol, biodiesel, and switch grass products. Among the renewable energy sources, solar energy and wind energy has very high potential in India which can be converted to electrical energy (Solar Thermal, Photo Voltaic; ST systems use the available heat energy to warm a liquid that passes through a pipe system facing the sun, which is in turn passed through a heat exchange and the heat stored in a thermal store, whereas PV systems convert light energy into electrical current using a charged array), besides other usage like Space Heating, Water heating, Water pumps, etc.

There are number of stakeholders ie Government, industries, distributors/retailers, technicians, trainers, end users, researchers etc, those are responsible for replacing conventional sources of energy with renewable energy sources, especially with Solar Energy. These all stakeholders adopt Solar Energy as per their perception which is generally governed by theory of "Diffusion of Innovation". Keeping in view of Innovative Perception, it is examined how the desired rate of solar energy use can be achieved in India and to make recommendations accordingly.

Uses of solar energy for producing electricity and other uses are increasing with higher rate. But in-adequate knowledge, higher cost and other factors like aesthetic characteristics are making uses of solar energy unattractive to consumers.

OBJECTIVES OF STUDY

1. To understand the need for replacing conventional sources of energy with renewable energy.
2. To asses existing Govt of India policy on renewable energy and solar energy.
3. To conduct theoretically assessment of Solar power in India (Study where do India stand in adopting solar energy and present gap with respect to the potential for usage of solar energy).
4. To identify factors affecting the diffusion of innovation in field of solar energy.
5. To study factors of Innovative practices in Solar Sector.
6. To make recommendations to fill the gap.

DIFFUSION OF INNOVATION

The Adoption and Diffusion process:

The diffusion of an innovation is the process by which it is communicated through certain channels, over time and among members of a social system. The diffusion process has been modelled, and despite some weaknesses regarding the forecasting of adoption and an inherent pro-innovation bias, it has been favourably reviewed. Examples include the Bass model and the Roberts and Urban model (Mahajan 1990; Lynn and Gelb 1996; Sultan and Winer 1993). Diffusion of Innovations Theory (Rogers 1995) sets out a practical innovation adoption process. The speed at which an adopter passes along this process is influenced by the attributes of particular innovations, and the propensity of the adopter to accept innovation.

The innovation-decision process (Figure1) follows five phases that adopters will follow when deciding whether or not to procure an innovation. Firstly, adopters need to be knowledgeable of a product, and then be motivated to raise their awareness about it. At the 'awareness' stage, the adopter is concerned with the attributes of the innovation, particularly with advantages. The innovation must possess attributes that are perceived as attractive to adopters, although this level of attraction will vary between individuals as they all vary in their disposition to adopt the products. The awareness stage in the process is the optimal point at which to gain a full understanding of the product attributes and thus overcome any risk of post purchase dissonance. At the 'decision' stage, an adopter can choose to either adopt or reject the innovation, although if adopted, use of the innovation can be later discontinued. The actual implementation of the innovation follows the decision to adopt, after which an adopter will confirm that the product meets all expectations. (Rogers 1995).

The majority of the lay public is uninformed about the scientific and practical applications of renewable energy sources (Bang, Ellinger, Hadjimarcou, & Triachal, 2000; Sovacool, 2009), despite the fact these innovations have a very high significant social impacts. A study was carried out at Michigan State of USA to explore stakeholder perspectives and to examine different stakeholder responses to alternative energy resources when the state was developing the infrastructure to adopt several different types of alternative energy sources (Natural Resources Defence Council, 2014). This study provides how all stakeholders perceived the advantages and disadvantages related to alternative energy sources framed in diffusion of innovations (DOI). As our world's climate continues to change, greenhouse gases, pollution, and overuse of non-renewable resources have profound effects (Pimentel et al., 1994).

The DOI (Rogers, 2003) theory, which provides a framework through which the public's perceptions about attributes of renewable energy initiatives and provides insight about their likelihood of adoption, is discussed below.

1. **Adopter Categories**. Rogers (2003) suggests that individuals can be categorized into one of five adopter categories.

(i) Innovators are those who are on the forefront of the creation and adoption of the innovation and generally belong to elite social groups.
(ii) Early adopters consist of those who are among the first groups to adopt the innovation and are considered to have more "local" social status than innovators. Early adopters are often looked to as opinions leaders.
(iii) The early majority consists of those who wait to adopt the innovation until they have had a chance to observe the early adopters but who adopt the innovation before the "average" individual.
(iv) The late majority adopts the innovation after the "average" individual and tends to take time to carefully evaluate the innovation before adoption.
(v) Laggards are the last to adopt the innovation and are often considered to be on the outskirts of the social system. They tend to have fewer resources and are the most sceptical of the innovation.

The adopter category into which each person falls depends largely on the individual's evaluation of the innovation with regard to the following five attributes: Relative advantage: Relative advantage refers to the extent the innovation is perceived to be better than other related options and can be determined by a variety of factors. The relative advantage may be economic (i.e., innovations that can replace or supplement more expensive items), or it may be some other advantage, such as relative effectiveness. For example,
(i) If stakeholders perceive that it is more costly to pay for electricity generated by solar energy, they will not be as likely to support the innovation.
(ii) If stakeholders view elements of renewable energy to be an efficient way to produce clean energy, then initiatives may have the clear advantage over conventional methods.
(iii) Conversely, if renewable energy is perceived as inefficient or similarly efficient as current strategies, there would be no clear advantage to adopting the initiative.
(iv) Overall, the higher the relative advantage of the innovation, the more likely it is to be adopted.

2. **Compatibility:** Compatibility refers to the extent an innovation is consistent with the values, beliefs, needs, and experiences of the public. The public is more likely to feel comfortable with an innovation that is congruent with their pre-existing values, beliefs, and needs (Atwell, Schulte, &Westphal, 2009; Aubert & Hamel, 2001; Foy et al., 2002; Rogers, 2003; Tornatzky& Klein, 1982). For example, if current farming practices and technology are not compatible with the renewable energy sources, it may be difficult for farmers to adopt the innovation. Furthermore, if stakeholders do not value clean energy or do not believe that the renewable energy source is capable of reducing pollution and reliance of fossil fuels, adoption would be less likely to occur.

3. **Complexity:** Complexity refers to the extent an innovation is easy to understand and use. Innovations that are difficult to comprehend or use are not as likely to be adopted (Rogers, 2003; Tornatzky& Klein, 1982). For example, Grilli and Lomas (1994) observed that highly complex resulted in low compliance rates. Given the complexity of solar energy and its related technologies, stakeholders may not feel comfortable adopting solar energy innovations.

4. **Trialability:** Trialability refers to the extent an innovation can be tested before permanent adoption. Innovations are more likely to be adopted if potential adopters have the ability to test the innovation. The ability to try the innovation before full-blown adoption reduces uncertainty surrounding the innovation, increasing the likelihood that individuals will adopt the innovation (Rogers, 2003). For example, Grilli and Lomas (1994) observed that recommendations that allowed trialability resulted in higher compliance. Trialability at the individual adoption level is difficult to implement based on the financial costs associated with adoption of

renewable energy initiatives. This lack of opportunity to test the innovation may decrease the likelihood of adoption.

5. **Observability:** Observability refers to the extent the innovation can be examined before it is adopted. Observability is primarily concerned with whether or not the results or outcomes of the innovation can be viewed before a decision to adopt is made. Observing the impact of the innovation can reduce uncertainty and facilitate adoption (Rogers, 2003). In the context of renewable energy, if stakeholders are able to observe a renewable energy innovation being used elsewhere, they may be more comfortable in adopting the innovation

These five characteristics are critical in assessing the likelihood of innovation adoption

EXISTING GOVT POLICY

The National Action Plan on Climate Change also points out: "India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting the decentralized distribution of energy, thereby empowering people at the grassroots level".

Based on this vision a National Solar Mission was launched under the brand name "Solar India".

Solar Renewable Purchase Obligations (RPO)

Among the various renewable energy resources, solar energy potential is the highest in the country. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual radiation varies from 1600 to 2200 kWh/m2, which is comparable with radiation received in the tropical and sub-tropical regions. The equivalent energy potential is about 6,000 million GWh of energy per year.

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With the objective to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible Government of India launched National Solar Mission.

The National Tariff Policy was amended in January 2011 to prescribe solar-specific RPO be increased from a minimum of 0.25 per cent in 2012 to 3 per cent by 2022. CERC and SERCs have issued various regulations including solar RPOs, REC framework, tariff, grid connectivity, forecasting etc. for promoting solar energy. Many States have come up with up their own Solar Policy.

In view of the ongoing efforts of Central and State Governments and various agencies for promoting solar energy, Ministry of New and Renewable Energy has undertaken an exercise to track and analyze the issues in fulfilment of Solar Power Purchase Obligation and implementation of Solar REC framework in India. This would help various stakeholders to understand the challenges and opportunities in the development of solar power. It would also include monitoring of Solar RPO Compliance; analyzing key issues related to the regulatory framework for solar in various states of India.

ASSESSMENT OF SOLAR POWER IN INDIA

Over the years India has successfully created a positive outlook necessary to promote supply of renewable energy. In addition to grid power, decentralized distributed electrification using renewable energy technologies provides economical options for meeting lighting, cooking and productive energy needs in rural areas.

In the year 2015, the Government of India announced a target for 175 GW cumulative renewable power installed capacity by the year 2022. A capacity of 62.84 GW has been set up by December 2017 and this constitutes 18 per cent of the total installed capacity. Now India has 6th global position solar power deployment.

Renewable energy has started playing an increasingly important role for augmentation of grid power, providing energy access, reducing consumption of fossil fuels and helping India pursue its low carbon developmental pathway. The INDC also commits to reduce India's GHG emissions intensity per unit GDP by 33 to 35percent below year 2005 levels by year 2030, and to create an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide through additional tree cover.

National Solar Mission (NSM), launched on 11th January, 2010, had set a target for development and deployment of 20 GW solar power by the year 2022. The Cabinet in its meeting held on17/6/2015 had approved revision of target under NSM from 20 GW to100 GW. Using a three-phase approach, the mission's objective is to establish India as a global leader in solar energy, by creating the policy conditions for solar technology diffusion across the country as quickly as possible.

Solar water heaters and rooftop systems have been promoted in certain commercial and residential areas through regulatory intervention such as mandates under building by-laws and incorporation in the National Building Code. Off-grid and rooftop solar applications have been promoted through provision of subsidies from the central government. Research and development is also being encouraged through approvals of R&D projects and the establishment of Centres of Excellence by the Ministry. These measures led to decline in solar power prices in India much more than expectations. During the year, one of the major focus area of action was to address barriers confronting large-scale adoption of solar power, including available land, low-cost finance, domestic manufacturing capacity, and skilled manpower.

Various policy measures undertaken included guidelines for procurement of solar though tariff based competitive bidding process, standards for deployment of Solar Photovoltaic systems/ devices, identification of large government complexes/ buildings for rooftop projects; provision of roof top solar and 10 percent renewable energy as mandatory under Mission Statement and Guidelines for development of smart cities; amendments in building bye-laws for mandatory provision of roof top solar for new construction or higher Floor Area Ratio; infrastructure status for solar projects; raising tax free solar bonds; providing long tenure loans; incorporating measures in Integrated Power Development Scheme (IPDS) for encouraging distribution companies for net-metering.

Grid connected Projects: As on 31st December 2017, the total solar power capacity installed is 17052.37 MW. Based upon availability of land and solar radiation, the potential of solar power in the country has been assessed to be around 750 GWp. Against potential of 748.98 GWp, 17052.37 is the installed capacity of solar energy.

Scheme for Development of Solar Parks and Ultra Mega Solar Power Projects: The scheme for development of Solar Parks and Ultra Mega Solar Power Projects was rolled out by Ministry of New & Renewable Energy in December, 2014. The Scheme has been conceived on the lines of the "Charanka Solar Park" in Gujarat which is a first-of-its-kind large scale Solar Park in India with contiguous developed land and transmission connectivity. This scheme envisages supporting the States in setting up solar parks at various locations in the country with a view to create required infrastructure for setting up of Solar Power Projects. The solar parks will provide suitable developed land with all clearances, transmission system, water access, road connectivity, communication network, etc. This scheme facilitates and speeds up installation of grid connected solar power projects for electricity generation on a large scale. All the States and Union Territories are eligible for benefitting under the scheme.

Grid Connected Rooftop and Small Power Plants Programme: The Ministry is implementing "Grid Connected Rooftop and Small Solar Power Plants Programme" which is providing subsidy up to 30% of benchmark cost for the general category states and upto 70 % of benchmark cost for special category states. About 4200 MW is being targeted under this scheme (2100 MW with subsidy and 2100 MW without subsidy) by year2019-20. So far, 1810 MWp solar rooftop systems have been sanctioned/ approved under the scheme. Aggregate 982.30 MWp have been reported as installed in the country.

Union Budget and Solar Energy. The Union Budget 2018/19 was tabled on February 1, 2018 by the Finance Minister, Government of India. It has proposed a budget estimate of 4,895.60 crore for renewable energy. Of this, highest allocation of 2,045 crore has been proposed for achieving a capacity addition of 11 GW solar power. This translates into a financial support of 18 lakh for 1 MW solar power capacity addition. Emergence of renewables requires augmentation of grid infrastructure and for implementation of Green Energy Corridor project 600 crore has been allocated. In the off-grid and decentralized renewables, major allocations are for off-grid solar (848 crore)

Recent Achievements

Major highlights of recent achievements are given below.

1. Kurnool Solar Park in Andhra Pradesh with 1GW capacity was commissioned, this makes the Park the World's Largest Solar Park.

2. 650 MW capacity commissioned in Bhadla Phase-II Solar Park in Rajasthan.

3. 250 MW capacity commissioned in Phase –I of Neemuch-Mandsaur Solar Park (500 MW) in Madhya Pradesh.

4. Solar tariff has declined to lowest level of Rs 2.44 /kWh.

5. In order to ensure quality of material/ equipment being used in solar PV projects, MNRE, on 05.09.2017, has brought out a Quality Control Order titled "Solar Photovoltaics, Systems, Devices and Components Goods (Requirement for Compulsory Registration) Order 2017".

6. 982.30 MWp solar roof top power projects commissioned.

7. Concessional loans of around 1375 million US dollars from World Bank (WB), Asian Development Bank (ADB) and New Development Bank (NDB) have been made available to State Bank of India (SBI), Punjab National Bank (PNB) and Canara Bank for solar rooftop projects.

8. Under the Suryamitra program, total of 72 nos. of programs with 2208 Suryamitras have been organized in FY 2017-18(till 31.12.2017).

9. Research and Development continued to remain major focus area. Major programmes were supported in the area of Solar Photovoltaic, Solar Thermal, fuel cells and wind solar hybrid systems. In solar, high efficiency crystalline silicon solar cells of 18% efficiency was achieved in lab scale under a project at IIT, Bombay. Support for developing solar cells using other materials, storage and power electronic system was provided to R&D/academic institutions. Support for developing solar thermal system and component was provided for technology development and demonstration for utilizing solar energy for thermal and power generation applications. One such project, 1MWe Solar Thermal Power Plant with 16 hours thermal storage has set up at Mount Abu by World Renewable Spiritual Trust (WRST), Mumbai. Research and Development in hydrogen and fuel cells focused on technology development and demonstration for hydrogen production and storage for stationary and transport applications. Under National Solar Mission, the target for setting up solar capacity increased from 20 GW to 100 GW by 2021/22. Target of 10,000 MW, set for 2017/18 which will take the cumulative capacity over 20 GW till March 31, 2018.

10. Development of Solar Parks and Ultra Mega Solar Power Projects' has been enhanced from 20,000 MW to 40,000 MW.

11. 35 solar parks of aggregate capacity 20,514 MW have been approved in 21 States.

12. The Ministry is implementing Grid-Connected Rooftop and Small Solar

Power Plants Programme which provides for installation of 2,100 MW Capacity in the residential, social, Government/PSU, and institutional sectors. Measures for purchasing surplus solar power from solar pumps in farmers' fields.

13. Reduction of customs duty on solar tempered glass or solar tempered (anti-reflective coated) glass for manufacture of solar cells/panels/modules from 5% to zero.

14. Solar Power capacity addition of 5,525.98 MW in 2017/18.During 2017-18, a total 5602.65 MW capacity has been added till 31.12.2017. (Table 2)

15. So far, 1.42 lakh solar pumps have been installed in the country as on November 30, 2017 including 1.31 lakh during the last three and half years.

It can be seen the following.

1. There is huge gap between potential and installed capacity of solar energy.
2. Rate of installed capacity, in recent years has increased considerably high, but is far behind the possible rate. This may be attributed to mainly lake of info to community besides other factors.
3. Effective information is not available to end users.
4. Implementation of policy is to be effective.

INNOVATIVE PRACTICES IN SOLAR SECTOR

An **innovative practice** to effectively make use of the solar power is with transportation **powered** by photovoltaic (PV) **energy**. railways, auto, buses, planes, cars and even roads can all be **powered** by **solar**, and **solar** transit is becoming a popular offering in the **renewable energy** sector.

Electricity has become the preferred form of energy for almost all of our needs, a major emphasis in research has been on increasing the efficiency of conversion to electricity and reducing the costs. There are two main methods of converting solar energy to electricity – Photovoltaics (PV) and solar thermal power (commonly known as CSP, acronym for Concentrating Solar Power).

The present trend in research in PV is focused on using earth abundant materials, since some of the materials in today's PV panels, such as, Cadmium, Tellurium, Gallium, indium, selenium etc. are not abundant and also become hazardous waste at the end of panel life. Silicon, which is still the major material used in solar cells is, available abundantly on earth. Solar cells using earth abundant materials that are being researched include, Dye Sensitized Solar Cells (DSSC), polymer solar cells and Perovskite solar cells (PSC). The areas of research in these cells include improving their efficiency and stability over time.

Since costs of PV in the last ten years have come down so drastically, CSP has not been able to compete commercially. However, CSP has two big advantages over PV:

1. It uses the same thermal power conversion as the conventional thermal power (fossil fuel or nuclear based) and can therefore be integrated with the existing power infra-structure easily.

2. It uses thermal energy storage which is about one tenth the cost of battery storage.

In order for CSP to become cost competitive, the conversion efficiencies must increase and the cost must decrease. Since thermal power conversion efficiencies increase with an increase in the temperature (second law of thermodynamics), the trend in research is to improve the central receiver tower (power tower) technology to increase the conversion temperatures to around 700C-800C. Since it is not practical to use steam at such high temperatures, present research is to find a replacement for steam. Supercritical CO_2(sCO_2) is a very attractive fluid for this replacement. Simulation has shown that operating a sCO_2 Brayton Power Cycle at about 750 C can give a conversion efficiency of more than 50%, something you could expect only in a combined cycle plant operating at more than 1100 C before. So, most of the present research are directed toward making sCO_2 power conversion technology practical.

There is a lot of research going on in other solar energy applications also, such as, solar desalination, solar refrigeration and cooling, solar photo catalytic environmental clean-up, day lighting and passive solar uses.

Solar skin design

One major barrier for the solar industry is the fact that a high percentage of homeowners consider solar panels to be an unsightly home addition. Sistine Solar, a Boston-based design firm, is making major strides with the concept of aesthetic enhancement that allow solar panels to have a customized look. The MIT startup has created a “solar skin” product that makes it possible for solar panels to match the appearance of a roof without interfering with panel efficiency or production. Sistine Solar’s skin product is expected to hit U.S. markets by next year and will help to rebrand solar panels as a luxury product, not just a home efficiency upgrade.

Solar powered roads

Last summer paved the way for tests of an exciting new PV technology – solar powered roads. The sidewalks along Route 66, America’s historic interstate highway, were chosen as the testing location for solar-powered pavement tech. These roadways are heralded for their ability to generate clean energy, but they also include LED bulbs that can light roads at night and have the thermal heating capacity to melt snow during winter weather.

Wearable solar

Though wearable solar devices are nothing new (solar-powered watches and other gadgets have been on the market for several years), 2017 saw an innovation in solar textiles: tiny solar panels can now be stitched into the fabric of clothing. The wearable solar products of the past, like solar-powered watches, have typically been made with hard plastic material. This new textile concept makes it possible for solar to expand into home products like window curtains and dynamic consumer clean tech like heated car seats. This emerging solar technology is credited to textile designer Marianne Fairbanks and chemist Trisha Andrew.

Solar batteries: innovation in solar storage

An essential part of increased and complete use of solar energy is storage during the time sunlight is available, so that it can be used during the times sunlight is not available. There are many ways of storing solar energy, including batteries, thermal energy storage, pumped hydro, compressed air etc. The main research trend is to reduce the cost of battery storage and thermal energy storage (TES). Thermal energy storage is the cheapest way to store energy (Rs 700-2800/kWh for TES vs Rs1400-3500/kWh for batteries). The trend in electrochemical energy storage (battery is electrochemical storage) at the present time is in improving Supercapacitor storage. Supercapacitors can give very fast discharge but have very low storage capacity. Another way to store solar energy is to use it to produce hydrogen from water and use hydrogen to produce electricity in a Fuel Cell when you need it. Research is also going on this area.

The concepts of off-grid solar and solar plus storage have gained popularity in U.S. markets, and solar manufacturers have taken notice. The industry-famous Tesla Powerwall, a rechargeable lithium ion battery product launched in 2015, continues to lead the pack with regard to market share and brand recognition for solar batteries. Tesla offers two storage products, the Powerwall for residential use and the Powerpack for commercial use, and the clean auto behemoth is expected to launch its Powerwall 2.0 product in weeks to come. Solar storage is still a fairly expensive product in 2016, but a surge in demand from solar shoppers is expected to bring significantly more efficient and affordable batteries to market in 2018-2019.

Advances in solar energy: the latest solar technology breakthroughs

Solar tracking mounts

Ground mounted solar is becoming a viable clean energy option, along with the tracking mount technology. Trackers allow solar panels to maximize electricity production by following the sun. PV tracking systems tilt and shift the angle of a solar array as the day goes by to best match the location of the sun. GTM Research recently unveiled a recent report that shows a major upward trend in the popularity of tracking systems. GTM projects a 254 percent year-over-year increase for the PV tracking market this year. The report stated that by 2021, almost half of all ground mount arrays will include solar tracking capability.

Advances in solar panel efficiency

The past few years in the solar industry have been a race to the top in terms of solar cell efficiency, and 2016 was no different. A number of achievements by various panel manufacturers have brought us to today's current record for solar panel efficiency: 23.5 percent, held by premium panel manufacturer SunPower.

The solar cell types used in mainstream markets could also see major improvements in cost per watt. Due to efforts by Swiss and American researchers, Perovskite solar cells have seen major breakthroughs in the past two years. The result will be a solar panel that can generate 20+ percent efficiency with the lowest cost options in market.

A MIT researchers announced new technology that could *double* the overall efficiency of solar cells. The MIT lab team revealed a new tech concept that captures and utilizes the waste heat that is usually emitted by solar panels. This typically released thermal energy is an opportunity for improvement for solar technology. This innovation could help in reducing the cost of solar further.

Solar thermal fuel (STF)

There is little debate when it comes to solar power's ultimate drawback as an energy source: storage. MIT Professor Jeffrey Grossman and his team of researchers have developed alternative storage solutions for solar, solar thermal fuels (STFs).

The technology and process behind STFs is comparable to a typical battery. The STF can harness sunlight energy, store it as a charge and then release when require. The issue with storing solar as heat, is that heat will always dissipate over time, which is why it is crucial that solar storage tech can charge energy rather than capture heat. For Grossman's team, the latest STF prototype is simply an improvement of a prior design that allowed solar power to be stored as a liquid substance. 2016 saw the invention of a solid state STF application that could be implemented in windows, windshields, car tops, and other surfaces exposed to sunlight.

Solar water purifiers

Stanford University researchers collaborated with the Department of Energy to develop a new solar device that can purify water when exposed to sunlight. The minuscule tablet (roughly half the size of a postage stamp) is not the first solar device to filter water, but it has made major strides in efficiency compared to past inventions. Prior purifier designs needed to harness UV rays and required hours of sun exposure to fully purify water. By contrast, Stanford's new product can access *visible* light and only requires a few minutes to produce reliable drinking water. As the technology behind solar purifiers continues to improve, expect these chiclet-sized devices to come to market with hikers and campers in mind.

Factors restricting use of Solar Energy

1. Cost: The initial cost of purchasing a solar system is fairly high.

2. Weather Dependent: Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops.

3. Solar Energy Storage is expensive.

4. Uses a lot of space.

5. Associated with Pollution.

RECOMMENDATIONS

It is recommended Government policies should target for the following for effective Diffusion of Innovation.

1. To minimise Carbon/ Green House Gases emission reduction (Environmentally sensitive behaviour) .
2. To achieve high energy conversion efficiency.
3. To achieve high energy storage efficiency.
4. Social learning : adequate knowledge to the following:

(a) End users
(b) Technician involved in installation (Adequate manpower with required skill)
(c) Distributor and retailers
(d) Training institutes/trainers
(e) Innovation/research institutes
(f) Manufacturers
(g) Policymakers and media

5. All latest innovations are reached to all stakeholders at the earliest.
6. Latest technology is available to manufacturers.
7. All required facilities are made available to manufacturers.
8. Solar parks are planned in all different regional areas.

CONCLUSION

India may achieve its target of use of solar energy successfully, by following diffusion of Innovation theory. The theory may help in overcoming the perceptual barrier of all stakeholders, especially end users. It is found that mainly the gap exists due to inadequate dissemination of information till end users, poor implementation of policy, and non-availability of skilled manpower for execution of the policy. In view of this, it is important, Govt of India addresses these issues to ensure target of solar energy is achieved as well as enable her to set higher target for Solar energy. These steps will help not only in conserving fossil fuel reserve but also in reducing environment pollution.

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