INSTITUTION OF AGRICULTURAL TECHNOLOGISTS,

BENGALURU

# EVALUATION OF RKVY PROJECTS

OF

## UNIVERSITY OF AGRICULTURAL SCIENCES,

RAICHUR

# “DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS”


INSTITUTION OF AGRICULTURAL TECHNOLOGISTS,

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# CONTENTS

# DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS

## EXECUTIVE SUMMARY

Energy is the lifeblood of technological and economic development. Energy is a vital component of any society playing a pivotal role in the national development. Although estimates vary, the world's proved, economically recoverable fossil fuel reserves include almost 1 trillion metric tons of coal, more than 1 trillion barrels of petroleum, and over 150 trillion cubic meters of natural gas. In addition to fossil fuels, mineral resources important to energy generation include over 3 million metric tons of uranium reserves. Global energy consumption draws from six primary sources: 44% petroleum, 26% natural gas, 25% coal, 2.5% hydroelectric power, 2.4% nuclear power, and 0.2% non-hydro renewable energy (Jeffrey Chow et al, 2003). A considerable amount of primary energy is converted to electricity either in the course of initial harvesting (as for hydroelectric, wind, and geothermal) or by combustion (as for fossil, biomass, and waste fuels).

Oil will remain the single largest fuel in the global primary energy mix, even though its share will fall marginally from 36% in 2002 to 35% in 2030 (Solangi et al, 2011). For the past 150 years or so, humans have relied heavily on coal, oil, and other fossil fuels to power everything from light bulbs to cars to factories. While a majority of the world's current electricity supply is generated from fossil fuels such as coal, oil and natural gas, these traditional energy sources face a number of challenges including rising prices, security concerns over dependence on imports from a limited number of countries which have significant fossil fuel supplies, and growing environmental concerns over the climate change risks associated with power generation using fossil fuels.

As a result of these and other challenges facing traditional energy sources, governments, businesses and consumers are increasingly supporting the development of alternative energy sources and new technologies for electricity generation. Renewable energy sources such as solar, biomass, geothermal, hydroelectric and wind power generation have emerged as potential alternatives which address some of these concerns. As opposed to fossil fuels, which draw on finite resources that may eventually become too expensive to retrieve, renewable energy sources are generally unlimited in availability.

Renewable energy is sustainable as it originates from sources that are inexhaustible (unlike fossil fuels). Sources of renewable energy include wind, solar, biomass, geothermal and hydro, all of which occur naturally. Renewable energy, generally speaking, is clean energy and non-polluting. Many forms do not emit any greenhouse gases or toxic waste in the process of producing electricity. It is a sustainable energy source that is reliable for

the long-term. Renewable energy is cost-effective and efficient. The challenge of climate change compels many nations to set a renewable energy target. Increasingly, governments around the world are turning to renewable energy to end our dependence on fossil fuels.

For centuries, people have harnessed the energy of river currents, using dams to control water flow. Hydropower is the world's biggest source of renewable energy by far, with China, Brazil, Canada, the U.S., and Russia the leading hydropower producers. While hydropower is theoretically a clean energy source replenished by rain and snow, it also has several drawbacks.

Harnessing the wind as a source of energy started more than 7,000 years ago. Now, electricity-generating wind turbines are proliferating around the globe, and China, the U.S., and Germany are the leading wind energy producers. From 2001 to 2017, cumulative wind capacity around the world increased to more than 539,000 megawatts from 23,900 mw—more than 22-fold increase (Christine Nunez, 2019).

Used for thousands of years in some countries for cooking and heating, geothermal energy is derived from the Earth's internal heat. On a large scale, underground reservoirs of steam and hot water can be tapped through wells that can go a mile deep or more to generate electricity.

Nuclear energy cannot really be termed renewable, since there is only a finite amount of uranium on this planet. The reactors also produce a by-product other than the power they generate. This is toxic harmful waste that must be stored indefinitely.

Solar energy is a renewable free source of energy that is sustainable and totally inexhaustible, unlike fossil fuels that are finite. It is also a non-polluting source of energy and it does not emit any greenhouse gases when producing electricity. Solar energy will never die of shining, since the Sun still has 6.5 billion years of life according to NASA. As the publication Renewable Energies Info estimates, the Earth's surface receives 120,000 Terawatts of solar irradiation, "which represents 20,000 times more power than the whole planet needs". As little as 18 days of solar irradiation on Earth contains as much energy as all the world's coal, oil and natural gas reserves put together. Solar radiation can satisfy our energy needs 4,000 times over (Acciona, 2020).

Solar energy can be a major source of power in the future. Its potential is 178 billion MW which is about 20,000 times the world's demand for power. Even if we can use only 5% of this energy source, it will be 50 times the demand for power in the world. Solar power generation has emerged as one of the most rapidly growing renewable sources of electricity. Solar power generation has several advantages over other forms of electricity generation, viz., reduced dependence on fossil fuels, environmental advantages, modularity and scalability, flexible locations, government incentives, avoids global warming, reduces energy imports, generates local wealth and jobs, contributes to sustainable development and can be applied alike for large-scale electricity generation and on a small scale in areas isolated from the network.

Karnataka receives solar radiation in the range of 5.1 to 6.4 kwh/ sq.m. during summer, 3.5 to 5.3 kwh/ sq.m. during monsoon and 3.8 to 5.9 kwh/ sq.m. during winter. Since Hyderabad Karnataka region is blessed with perennial solar energy that can help to meet the electricity shortage, it was proposed to develop/ establish, evaluate and demonstrate the technical soundness of various solar and other renewable energy systems to popularize the same among the people in the region.

Keeping this in view, the project, **"DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS"** was taken up by University of Agricultural Sciences, Raichur with Rashtriya Krishi Vikas Yojana funding. The project was implemented from 2013-14 to 2015-16. The details of the project are as under:

| | | | |
|---|---|---|---|
| 1. | **Title of Project** | **:** | **"DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS"** |
| 2. | **Nodal officer and Principal Investigator** | **:** | **Dr. M. Veeranagouda,**<br>Dean, College of Agricultural Engineering, University of Agricultural Sciences, Raichur |
| 3. | **Implementing Institution (S) and other collaborating Institution (s)** | **:** | Department of Farm Mechanization and Power Engineering |
| 4. | **Date of commencement of Project** | **:** | 2013-14 |
| 5. | **Approved date of completion** | **:** | 2015-16 |
| 6. | **Actual date of completion** | **:** | 2015-16 |
| 7. | **Project cost** | **:** | Rs. 175 lakhs |

The objectives of the project are as follows:

1. Establishment of Renewable Energy Park
2. Evaluation and Demonstration of Solar Pumping System
3. Testing and promotion of solar energy assisted cold storage unit for enhancing shelf life of horticultural produce

The focus of Evaluation is:

i. To evaluate the usefulness of establishment of renewable energy park in demonstrating the use of various equipment powered by renewable energy sources to the farmers.
ii. To evaluate the efficiency of solar pumping system developed in terms of energy saved.
iii. To evaluate the impact of solar cold storage unit for storage of horticultural produce.

University of Agricultural Sciences, Raichur has established a first of its kind Renewable Energy Park. Several equipment and machinery operated by renewable energy sources are on display in the park. The equipment on display include mini multi rack solar dryer, mini multi rack solar dryer with baffle plates, high capacity multi rack dryer, forced convection solar drying system, solar tunnel dryer, solar pumping system, cookstoves, inverted downdraft gasifier wood stove, solar powered knapsack sprayer, solar powered cycle mounted sprayer, solar cooker, parabolic solar cooker, solar water heaters, wind powered water lifting pump, hybrid water pumping system. While the efforts made by the University in establishing the renewable energy park is commendable, **there is need to maintain the equipment in good working condition so that visitors get a very fair idea of the uses of renewable sources of energy. Many equipment on display were not in working condition.**

While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.

With regard to the solar pumping system, studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted. It is generally believed that solar pumps are not efficient in pumping water from greater depths. Experiments done at Visvesvaraya National Institute of Technology, NAGPUR, INDIA have revealed that the discharge of water decreases as the head of pumping increases. However, with increase in solar radiation intensity the curve shifts upwards giving more discharge at the respective head (Arunendra Kumar Tiwari et al., 2015). Hence, it will be necessary to choose suitable pumping system depending on the depth of pumping.

The studies with solar assisted mini cold storage unit have revealed that they could be utilized for storing the horticultural produce. The results obtained by storing tomato in the cold storage unit revealed that the minimum and the maximum solar intensities were 340 $Wm^{-2}$ and 630 $Wm^{-2}$ with the panel efficiency of 79.95 % and 43.81 % on a clear sunny day during summer. In fruits stored at 5 °C, 90 % RH pH value, TSS value of fruits, microbial activity and colour loss was less, the fruits retained firmness longer.

## REFLECTIONS AND CONCLUSIONS

1. While the efforts made by the University in establishing the renewable energy park is commendable, there is need to maintain the equipment in good working condition so that visitors get a very fair idea of the uses of renewable sources of energy. Many equipment on display were not in working condition.
2. While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out.
3. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.
4. With regard to the solar pumping system, studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted to choose suitable pumping system depending on the depth of pumping.
5. Technical bulletin and publication have been brought out on the various uses of renewable sources of energy. There is need to organize field visits, training programmes and demonstration trainings involving farmers after giving wide publicity.
6. The economics of operation of equipment using renewable sources of energy need to be done systematically to establish their viability vis a vis traditional equipment.
7. There is need to commercialise manufacture of proven equipment under PPP model. Patents may be taken for the equipment designed and developed by the University.
8. There is need to maintain the equipment on display in the Renewable Energy Park in good working condition.

# ACTION POINTS

1. There is need for quantification of solar energy available for utilization in the region and its duration.
2. The solar pumping systems have failed in the State due free power available to farmers for emergising their traditional water pumps. However, this is a challenge to Agricultural Universities and there is need to develop a policy by converging the line departments on the benefits of solar energy and ecology and climate.
3. The economics of solar powered cold storage needs to be worked out besides total volume of storage needed in the region may be worked out with its economics.
4. There is greater scope of convergence of other line departments and focus on PPP model needs to be explored.
5. The wind energy turbines established by private sector needs to be evaluated in terms of their impact on climatic factors more so on aridity and soil moisture and impact on crop growth and yield in and around wind mills.
6. Human resources training on solar gadgets developed/ evaluated needs to be strengthened.
7. While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out.
8. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.
9. Technical bulletin and publication have been brought out on the various uses of renewable sources of energy. There is need to organize field visits, training programmes and demonstration trainings involving farmers after giving wide publicity through mass media (TV, Radio and newspapers).
10. There is need to commercialize manufacture of proven equipment under PPP model. Patents may be taken for the equipment designed and developed by the University.
11. Utilization of photovoltaic energy application in agricultural greenhouses for and water pumping.
12. Solar PV operated water lifting / pumping system.
13. Solar based processing of agricultural produces.
14. Establishment of Testing center for Solar Photovoltaic Water Pumping System and other solar gadgets as per MNRE (MINISTRY OF NEW AND RENEWABLE ENERGY) Guidelines.

# RESEARCHABLE ISSUES

1. Studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted to choose suitable pumping system depending on the depth of pumping.
2. The abundantly available solar power needs to be quantified and documented in different agro climatic zones coming under the jurisdiction of the University.
3. Develop protocols for solar energy usage in cold storages and value additions through PPP mode.
4. Need for developing mobile solar dryers and harvesters.

# DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS

## INTRODUCTION

Energy is the lifeblood of technological and economic development. Energy is a vital component of any society playing a pivotal role in the national development. Although estimates vary, the world's proved, economically recoverable fossil fuel reserves include almost 1 trillion metric tons of coal, more than 1 trillion barrels of petroleum, and over 150 trillion cubic meters of natural gas. In addition to fossil fuels, mineral resources important to energy generation include over 3 million metric tons of uranium reserves. To put this into proper perspective, consider that the world's annual 2000 consumption of coal was about 5 billion metric tons or 0.5% of reserves. Natural gas consumption was 1.6% of reserves, whereas oil was almost 3% of reserves, and nuclear electricity generation consumed the equivalent of 2% of uranium reserves. Reported recoverable reserves have tended to increase over time, keeping pace with consumption, and now are at or near all-time highs. In relation to current consumption, there remain vast reserves that are adequate for continued worldwide economic development, not even accounting for reserves that will become economically recoverable through continuing discovery and technological advance. Thus, it seems that the world is not running out of mineral fuels (Jeffrey Chow et al., 2003).

Total global energy use exceeds 370 exajoules (EJ) (350 quadrillion British thermal units (Btus)) per year, which is equivalent to over 170 million barrels of oil each day. Approximately 95% of this energy comes from fossil fuels. Global energy consumption draws from six primary sources: 44% petroleum, 26% natural gas, 25% coal, 2.5% hydroelectric power, 2.4% nuclear power, and 0.2% nonhydro renewable energy (Solangi et al, 2011). A considerable amount of primary energy is converted to electricity either in the course of initial harvesting (as for hydroelectric, wind, and geothermal) or by combustion (as for fossil, biomass, and waste fuels).

World primary energy demand is projected in the Reference Scenario to expand by almost 60% from 2002 to 2030, an average annual increase of 1.7% per year. Demand will reach 16.5 billion tons of oil equivalents (toe) compared to 10.3 billion toes in 2002. On the other hand, fossil fuels will continue to dominate global energy use (Solangi et al., 2011). They will account for around 85% of the increase in world primary demand over 2002–2030. And their share in total demand will increase slightly, from 80% in 2002 to 82% in 2030. The share of renewable energy sources will remain flat, at around 4%, while that of nuclear power will drop from 7% to 5% (IEA, 2004).

Oil will remain the single largest fuel in the global primary energy mix, even though its share will fall marginally from 36% in 2002 to 35% in 2030. Demand for oil is projected to grow by 1.6% per year, from 77 MBD in 2002 to 90 MBD in 2010 and 121 MBD in 2030 (IEA, 2004).

For the past 150 years or so, humans have relied heavily on coal, oil, and other fossil fuels to power everything from light bulbs to cars to factories. Fossil fuels are embedded in nearly everything we do, and as a result, the greenhouse gases released from the burning of those fuels have reached historically high levels. While a majority of the world's current electricity supply is generated from fossil fuels such as coal, oil and natural gas, these traditional energy sources face a number of challenges including rising prices, security concerns over dependence on imports from a limited number of countries which have significant fossil fuel supplies, and growing environmental concerns over the climate change risks associated with power generation using fossil fuels.

As greenhouse gases trap heat in the atmosphere that would otherwise escape into space, average temperatures on the surface are rising. Global warming is one symptom of climate change, the term scientists now prefer to describe the complex shifts affecting our planet’s weather and climate systems. Climate change encompasses not only rising average temperatures but also extreme weather events, shifting wildlife populations and habitats, rising seas, and a range of other impacts.

As a result of these and other challenges facing traditional energy sources, governments, businesses and consumers are increasingly supporting the development of alternative energy sources and new technologies for electricity generation. Renewable energy sources such as solar, biomass, geothermal, hydroelectric and wind power generation have emerged as potential alternatives which address some of these concerns. As opposed to fossil fuels, which draw on finite resources that may eventually become too expensive to retrieve, renewable energy sources are generally unlimited in availability.

Renewable energy is sustainable as it originates from sources that are inexhaustible (unlike fossil fuels). Sources of renewable energy include wind, solar, biomass, geothermal and hydro, all of which occur naturally. Renewable energy, generally speaking, is clean energy and non-polluting. Many forms do not emit any greenhouse gases or toxic waste in the process of producing electricity. It is a sustainable energy source that is reliable for the long-term. Renewable energy is cost-effective and efficient. The challenge of climate change compels many nations to set a renewable energy target. Increasingly, governments around the world are turning to renewable energy to end our dependence on fossil fuels.

In 2001, the Australian Government introduced a Mandatory Renewable Energy Target (MRET) program with the goal of increasing uptake of renewable energy in Australia's electricity supply. By 2007, the Government committed to ensuring that 20 per cent of Australia's electricity supply comes from renewable energy sources by 2020.

**Hydro systems**

For centuries, people have harnessed the energy of river currents, using dams to control water flow. Hydropower is the world's biggest source of renewable energy by far, with China, Brazil, Canada, the U.S., and Russia the leading hydropower producers. While hydropower is theoretically a clean energy source replenished by rain and snow, it also has several drawbacks.

Large dams can disrupt river ecosystems and surrounding communities, harming wildlife and displacing residents. Hydropower generation is vulnerable to silt buildup, which can compromise capacity and harm equipment. Drought can also cause problems. In the western U.S., carbon dioxide emissions over a 15-year period were 100 megatons higher than they normally would have been, according to a 2018 study, as utilities turned to coal and gas to replace hydropower lost to drought. Even hydropower at full capacity bears its own emissions problems, as decaying organic material in reservoirs releases methane.

Dams aren't the only way to use water for power: Tidal and wave energy projects around the world aim to capture the ocean's natural rhythms. Marine energy projects currently generate an estimated 500 megawatts of power—less than one percent of all renewables—but the potential is far greater. Programs like Scotland's Saltire Prize have encouraged innovation in this area (Christina Nunez, 2019).

Micro hydro systems convert the flow of water into electrical energy. A turbine can be fully immersed in water. The flowing water rotates the turbine's blades. The amount of energy created depends on the amount of water flowing on the turbine as well as the size of the turbine.

Micro hydro systems are generally used as standalone power systems which are not connected to the grid. They are recommended in remote areas where there is a continuous supply of water.

**Wind power**

Harnessing the wind as a source of energy started more than 7,000 years ago. Now, electricity-generating wind turbines are proliferating around the globe, and China, the U.S., and Germany are the leading wind energy producers. From 2001 to 2017, cumulative wind capacity around the world increased to more than 539,000 megawatts from 23,900 mw—more than 22-fold increase (Christine Nunez, 2019).

Some people may object to how wind turbines look on the horizon and to how they sound, but wind energy, whose prices are declining, is proving too valuable a resource to deny. While most wind power comes from onshore turbines, offshore projects are appearing too, with the most in the U.K. and Germany. The first U.S. offshore wind farm opened in 2016 in Rhode Island, and other offshore projects are gaining momentum. Another problem with wind turbines is that they're a danger for birds and bats, killing hundreds of thousands annually, not as many as from glass collisions and other threats like habitat loss and invasive species, but enough that engineers are working on solutions to make them safer for flying wildlife. The potential of wind energy in India is estimated to be 40,000 to 45,000 MW.

Wind power involves converting wind energy into electricity by using wind turbines. The wind comes from atmospheric changes. These include changes in temperature and pressure which make the air move around the surface of the earth. A wind turbine captures the wind to produce energy.

Wind power is a clean energy source that can be relied on for the long-term future. A wind turbine creates reliable, cost-effective, pollution free energy. It is affordable, clean and sustainable. One wind turbine can be sufficient to generate enough electrical energy for a household, assuming the location is suitable.

Because it is a renewable resource which is non-polluting and renewable, wind turbines create power without using fossil fuels, without producing greenhouse gases or radioactive or toxic waste. Wind power is one of the best ways to combat global warming.

**Hybrid systems**

Hybrid systems consist of combining different types of energy production systems into a single power supply system. The most common type of hybrid system is combining a solar system with a wind generator; however, hybrid energy systems can integrate solar panels, diesel generator, batteries, and an inverter into the same system.

Solar panels create electricity from sunlight. This electricity is then stored in batteries. The inverter converts the AC electricity into a DC current. The diesel generator automatically cuts in when the batteries are low. The generator when running supplies the load and charges the batteries. The key is to find the right mix of solar array, diesel generator and battery capacity.

**Geothermal energy**

Used for thousands of years in some countries for cooking and heating, geothermal energy is derived from the Earth's internal heat. On a large scale, underground reservoirs of steam and hot water can be tapped through wells that can go a mile deep or more to generate electricity. On a smaller scale, some buildings have geothermal heat pumps that use temperature differences several feet below ground for heating and cooling. Unlike solar and wind energy, geothermal energy is always available, but it has side effects that need to be managed, such as the rotten egg smell that can accompany released hydrogen sulfide. This can be sources such as the shallow ground to hot water and hot rock found a few kilometers beneath the Earth's surface. It may go down even deeper to the extremely high temperatures of underground molten rock called magma. We usually only see this when it erupts to the surface in the form of lava.

**Nuclear energy**

Nuclear energy cannot really be termed renewable, since there is only a finite amount of uranium on this planet. The reactors also produce a by-product other than the power they generate. This is toxic harmful waste that must be stored indefinitely.

Nuclear energy comes from a nuclear reaction when the splitting or fusion of atoms occurs. Fusion energy is not available on an industrial scale yet. The splitting of atoms is fission. A typical example of fission energy is when an atomic nucleus of a high mass atom (such as uranium) splits into fragments inside a nuclear power reactor. This split then releases several hundred million electron volts of energy. The energy from the nuclear fission yields an amount of energy which is a million times greater than that from a chemical reaction.

Nuclear reactors emit no greenhouse gases, and are the closest thing to a nonpolluting energy source apart from renewable energy. Modern reactors are safer, and are more economic than what they used to be. The main issues with nuclear energy are the safety standards of a nuclear power plant and the storage of its radioactive waste. It is still a debated issue about whether or not nuclear power is a good alternative to limit our dependence on imported oil. France is the world leader in nuclear energy production, relying on nuclear power for 80% of its electricity.

**Solar power**

Solar power is clean green electricity sourced from sunlight. Or in some cases, from heat from the sun. Installing solar power systems in a residential setting generally means setting up a solar photovoltaic or a solar thermal system on the roof. Definition of photovoltaic: Photo = "light" and photons = energy particles coming from sunlight; voltaic = producing a voltage or volts. Abbreviation = PV.

Solar energy is a renewable free source of energy that is sustainable and totally inexhaustible, unlike fossil fuels that are finite. It is also a non-polluting source of energy and it does not emit any greenhouse gases when producing electricity. Solar energy will never die of shining, since the Sun still has 6.5 billion years of life according to NASA. As the publication Renewable Energies Info estimates, the Earth's surface receives 120,000 Terawatts of solar irradiation, "which represents 20,000 times more power than the whole planet needs". As little as 18 days of solar irradiation on Earth contains as much energy as all the world's coal, oil and natural gas reserves put together. Solar radiation can satisfy our energy needs 4,000 times over.

Solar energy can be a major source of power in the future. Its potential is 178 billion MW which is about 20,000 times the world's demand for power. Even if we can use only 5% of this energy source, it will be 50 times the demand for power in the world. Solar power generation has emerged as one of the most rapidly growing renewable sources of electricity. Solar power generation has several advantages over other forms of electricity generation:

**Reduced Dependence on Fossil Fuels**

Solar energy production does not require fossil fuels and is therefore less dependent on this limited and expensive natural resource. Although there is variability in the amount and timing of sunlight over the day, season and year, a properly sized and configured system can be designed to be highly reliable while providing long-term, fixed price electricity supply.

**Environmental Advantages**

Solar power production generates electricity with a limited impact on the environment as compared to other forms of electricity production.

**Matching Peak Time Output with Peak Time Demand**

Solar energy can effectively supplement electricity supply from an electricity transmission grid, such as when electricity demand peaks in the summer

**Modularity and Scalability**

As the size and generating capacity of a solar system are a function of the number of solar modules installed, applications of solar technology are readily scalable and versatile.

**Flexible Locations**

Solar power production facilities can be installed at the customer site which reduces required investments in production and transportation infrastructure.

**Government Incentives**

A growing number of countries have established incentive programs for the development of solar and other renewable energy sources, such as (i) net metering laws that allow on-grid end users to sell electricity back to the grid at retail prices, (ii) direct subsidies to end users to offset costs of photovoltaic equipment and installation charges, (iii) low interest loans for financing solar power systems and tax incentives; and (iv) government standards that mandate minimum usage levels of renewable energy sources.

Despite the cost, an advantage of photovoltaic systems is that they can be used in remote areas. Anywhere a diesel generator is the technology of choice, many times a photovoltaic system is a much better life-cycle cost option.

Stand-alone photovoltaic systems produce power independently of the utility grid. In some off-the-grid locations even one-half kilometer from power lines, stand-alone photovoltaic systems can be more cost-effective than extending power lines. They are especially appropriate for remote, environmentally sensitive areas, such as national parks, cabins, and remote homes.

To summarise, the benefits of solar energy are:

- Renewable
- Inexhaustible
- Non-polluting
- Avoids global warming
- Reduces use of fossil fuels
- Reduces energy imports
- Generates local wealth and jobs
- Contributes to sustainable development
- It is modular and very versatile, adaptable to different situations
- Can be applied alike for large-scale electricity generation and on a small scale in areas isolated from the network

The growing scarcity of fossil fuels has raised global interest in the harnessing of solar energy (Othman AK et al., 2006). Solar power is a type of energy with great future potential-even though at present it covers merely a minor portion of global energy demands (0.05% of the total primary energy supply); at the moment PV power generates less than 1% of total electricity supply. This is due to solar power still being considered the most expensive type of renewable energies. However, in remote regions of the earth it may very well constitute today's best solution for a decentralized energy supply (EREC, 2005).

The solar power market has grown significantly in the past decade. According to Solarbuzz, the global solar power market, as measured by annual solar power system installations, increased from 427 MW in 2002 to 1,744 MW in 2006, representing a CAGR of 42.2%, while solar power industry revenues grew to approximately US$10.6 billion in 2006. Despite the rapid growth, solar energy constitutes only a small fraction of the world's energy output and therefore may have significant growth potential. Solarbuzz projects in one of its forecasts that annual solar power industry revenue could reach US$31.5 billion by 2011.

Indeed, in rather less time, solar technology in some countries has evolved to compete with conventional sources of electricity generation. In just a few decades' time, it will become the major part of a sustainable energy system for the world.

Solar energy is that produced by the Sun's light – photovoltaic energy – and its warmth – solar thermal – for the generation of electricity or the production of heat. Inexhaustible and renewable, since it comes from the Sun, solar energy is harnessed using panels and mirrors.

Photovoltaic solar cells convert sunlight directly into electricity by the so-called photovoltaic effect, by which certain materials are able to absorb photons (light particles) and liberate electrons, generating an electric current. On the other hand, solar thermal collectors use panels or mirrors to absorb and concentrate the Sun's heat, transferring it to a fluid and conducting it through pipes to use it in buildings and installations, and also for electricity production (solar thermoelectric).

**Biomass**

Biomass energy includes biofuels such as ethanol and biodiesel, wood and wood waste, biogas from landfills, and municipal solid waste. Like solar power, biomass is a flexible energy source, able to fuel vehicles, heat buildings, and produce electricity. But biomass can raise thorny issues. Critics of corn-based ethanol, for example, say it competes with the food market for corn and supports the same harmful agricultural practices that have led to toxic algae blooms and other environmental hazards. Similarly, debates have erupted over whether it's a good idea to ship wood pellets from U.S. forests over to Europe so that it can be burned for electricity. Meanwhile, scientists and companies are working on ways to more efficiently convert corn stover, wastewater sludge, and other biomass sources into energy, aiming to extract value from material that would otherwise go to waste.

**Fuel cells**

Fuel cells create energy through chemical reactions. A fuel cell is an electrochemical cell which captures the electrical energy of a chemical reaction between fuels. It is an electrochemical conversion device which converts the chemical energy of fuel (i.e. hydrogen and oxygen) into water; and which produces electricity and hot air in the same process. Fuel cells have no moving parts and do not involve combustion or noise pollution.

A fuel cell is similar to a battery but does not need recharging. A battery recharges by using electricity which is then stored in a closed system. In comparison, fuel cell uses an external supply of fuel which needs to be continuously replenished. Fuel cells are not commercially available yet, and remain very expensive. They are used as power sources in remote areas. NASA uses fuel cells on space shuttles; they are also used for military applications, and in large public parks.

Fuel cells cannot store energy like batteries. Even if the energy from fuel cells goes into storage, their electrical efficiency is not nearly as high as a battery’s efficiency which also happens to be a much cheaper option.

Karnataka receives solar radiation in the range of 5.1 to 6.4 kwh/ sq.m. during summer, 3.5 to 5.3 kwh/ sq.m. during monsoon and 3.8 to 5.9 kwh/ sq.m. during winter. Since Hyderabad Karnataka region is blessed with perennial solar energy that can help to meet the electricity shortage, it was proposed to develop/ establish, evaluate and demonstrate the technical soundness of various solar and other renewable energy systems to popularize the same among the people in the region.

Keeping this in view, the project, **“DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS”** was taken up by University of Agricultural Sciences, Raichur with Rashtriya Krishi Vikas Yojana funding. The project was implemented from 2013-14 to 2015-16. The details of the project are as under:

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|---|---|---|---|
| 1. | **Title of Project** | **:** | **“DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS”** |
| 2. | **Nodal officer and Principal Investigator** | **:** | **Dr. M. Veeranagouda,** Dean, College of Agricultural Engineering, University of Agricultural Sciences, Raichur |

| | | | |
|---|---|---|---|
| 3. | **Implementing Institution (S) and other collaborating Institution (s)** | : | Department of Farm Mechanization and Power Engineering |
| 4. | **Date of commencement of Project** | : | 2013-14 |
| 5. | **Approved date of completion** | : | 2015-16 |
| 6. | **Actual date of completion** | : | 2015-16 |
| 7. | **Project cost** | : | Rs. 175 lakhs |

The objectives of the project are as follows:

4. Establishment of Renewable Energy Park
5. Evaluation and Demonstration of Solar Pumping System
6. Testing and promotion of solar energy assisted cold storage unit for enhancing shelf life of horticultural produce

## HYPOTHESIS

The context of the evaluation arises from the following facts:

1. While a majority of the world's current electricity supply is generated from fossil fuels such as coal, oil and natural gas, these traditional energy sources face a number of challenges including rising prices, security concerns over dependence on imports from a limited number of countries which have significant fossil fuel supplies, and growing environmental concerns over the climate change risks associated with power generation using fossil fuels.
2. As a result of challenges facing traditional energy sources, governments, businesses and consumers are increasingly supporting the development of alternative energy sources and new technologies for electricity generation. Renewable energy sources such as solar, biomass, geothermal, hydroelectric and wind power generation have emerged as potential alternatives which address some of these concerns. As opposed to fossil fuels, which draw on finite resources that may eventually become too expensive to retrieve, renewable energy sources are generally unlimited in availability.
3. Renewable energy is sustainable as it originates from sources that are inexhaustible (unlike fossil fuels). Sources of renewable energy include wind, solar, biomass, geothermal and hydro, all of which occur naturally. Renewable energy, generally speaking, is clean energy and non-polluting. Many forms do not emit any greenhouse gases or toxic waste in the process of producing electricity. It is a sustainable energy source that is reliable for the long-term. Renewable energy is cost-effective and efficient. The challenge of climate change compels many nations

to set a renewable energy target. Increasingly, governments around the world are turning to renewable energy to end our dependence on fossil fuels.

4. Karnataka receives solar radiation in the range of 5.1 to 6.4 kwh/ sq.m. during summer, 3.5 to 5.3 kwh/ sq.m. during monsoon and 3.8 to 5.9 kwh/ sq.m. during winter. Since Hyderabad Karnataka region is blessed with perennial solar energy that can help to meet the electricity shortage.
5. There is need to educate the farmers on use of renewable sources of energy in their daily tasks so that dependence on fossil fuels is reduced.

## OBJECTIVES AND ISSUES FOR EVALUATION

The scope of evaluation is to study the impact of scheme, **"DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS" IMPLEMENTED** by University of Agricultural Sciences, Raichur from 2013-14 to 2015-16.

**1. Stake Holders**

a) University of Agricultural Sciences, Raichur – Sponsorer
b) Rashtriya Krishi Vikas Yojane – as Monitoring Authority
c) Institution of Agriculture Technologists – as Consultant
d) Farmers / beneficiaries as target group of evaluation

**2. Purpose of Evaluation**

**Evaluation Framework**

The focus of Evaluation is:

i. To evaluate the usefulness of establishment of renewable energy park in demonstrating the use of various equipment powered by renewable energy sources to the farmers.
ii. To evaluate the efficiency of solar pumping system developed in terms of energy saved.
iii. To evaluate the impact of solar cold storage unit for storage of horticultural produce.

**LOG FRAME/THEORY OF CHANGE/PROGRAM THEORY**

The intention of the project is to develop, evaluate and demonstrate the use of various renewable sources of energy in operation of equipment used in crop production. The various operations studied included pre-planting operations, sowing, irrigation, intercultural operations and post-harvest management.

# EVALUATION DESIGN

Evaluation design has a rationale of requirement of field level data (primary) that is required to study evaluation objective with respect to beneficiary farmers on one part and the projects taken up for study per se on the other part. The evaluation requires analysis of administration obligations under the two heads and hence a secondary data analysis becomes important and accordingly formats were designed to procure secondary data. The third obligation under evaluation is opinion of stake holders with respect to improvement of the schemes, which require group discussions and exchange of views both in the form of a format, as well as group discussions with the stake holders. The entire evaluation process required a central administration of all activities.

A core team of experts at the Institution level considered three methods to bring a meaningful evaluation of the subject, keeping in mind the scope, evaluation questions and sub-questions duly keeping its focus on the purpose of evaluation. The three methods are:

a. Accessing and analysis of secondary data from the implementing department.
b. Interaction with Principal Investigator and his team.
c. Actual visit to the project site to study and obtain necessary information to elicit answers to the evaluation questions.

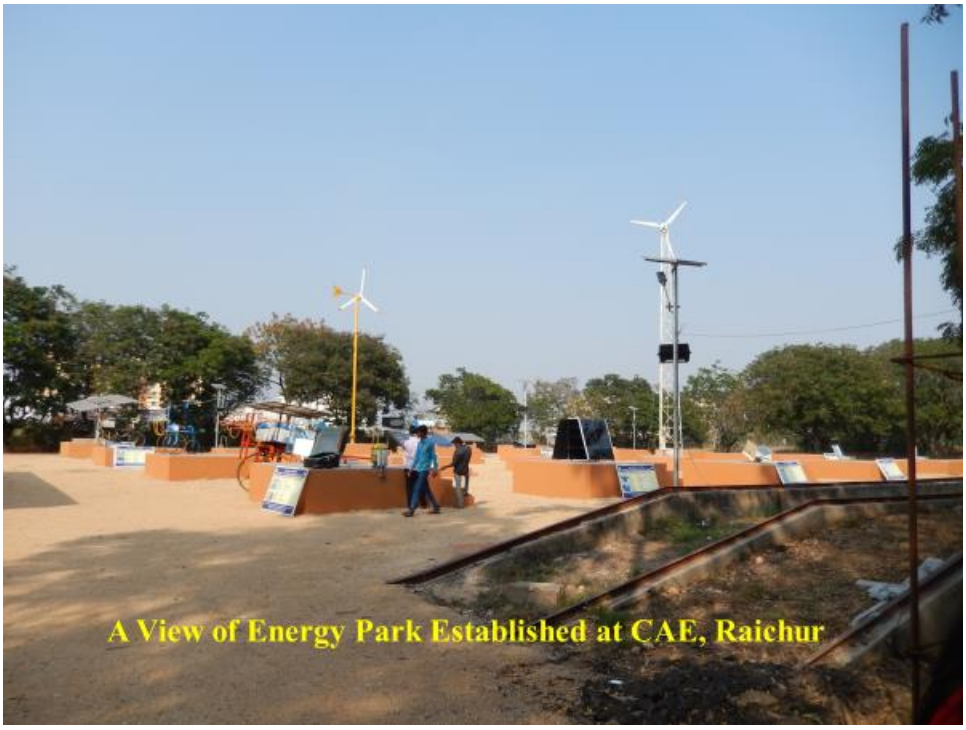
# DATA COLLECTION AND ANALYSIS

**Establishment of renewable energy park**

The survey of existing energy parks was carried out and the purchase of various solar, wind, biogas, biomass and other energy gadgets was done to ensure that the farmers are shown all types of energy sources and their use in farm production operations. The various renewable energy sourced equipment included solar water heater, solar cooker, solar still, solar dryer, solar air conditioner, wind aero-generator, wind mill pumping unit, biogas plant models, solar sprayers, biomass gasifier, improved cook stoves etc. The layout for establishment of renewable energy park was prepared and the construction of platforms for renewable energy gadgets / systems was carried out.

The performance of the gadgets was evaluated for assessment of their technical soundness.

Demonstration of a few energy gadgets has been conducted to create awareness among farmers, students and other stake holders regarding utilization of abundantly available solar and other renewable energy sources and also for popularizing the technologies and to motivate and encourage farmers, students of primary to graduation level to create awareness of the utility of renewable/non-conventional energy sources by conducting live demonstrations and arranging training/workshops/seminars.


A View of Energy Park Established at CAE, Raichur

Evaluation and demonstration of Parabolic type Solar cooker

Evaluation and demonstration of improved rice husk cook stove

Evaluation and demonstration of Evacuated Tube Collector (ETC) type Solar Water Heater

The established renewable energy park is the first of its kind in the state which has made a greater impact on educating the students, farmers and other stake holders in creating awareness and utilization of natural resources including solar, wind etc. which are freely and abundantly available, in day-to-day life among the domestic and farming community.

**Evaluation and Demonstration of Solar Pumping System**

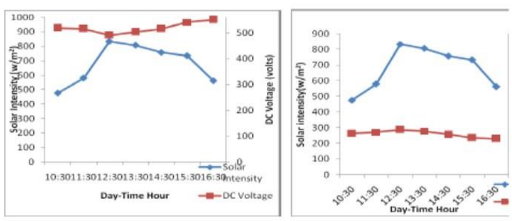
The merits and demerits of the pumping systems presently used by the farmers was studied. Different solar pumping systems were installed to evaluate their performance. Four units of solar pumping systems of 5 HP and 7.5 HP capacities with submersible and surface pumps were commissioned at the university farm for pumping of water for irrigation and as well as for demonstration purpose. One unit of solar pumping system of 5 HP capacity with submersible pump was installed in the farmer's field to study the practical utility of pumping of water for irrigation and as well as for demonstration and popularization among farmers.

The use of photovoltaic (PV) array for pumping water is one of the most promising techniques in solar energy applications. The solar pumping system installed in the University consisted 32 modules of 255.8 watts each and 7.5 HP DC centrifugal mono block pump. The various accessories installed included photovoltaic controller, pump cable and ground wire, safety disconnects, pv array and a DC ammeter. The photovoltaic (PV) powered solar controller uses solar electricity produced on-site to run the pump. The primary function of a controller is to prevent the battery from being overcharged by the array. Some PV controllers also protect a battery from being overly discharged by the DC load. It balances entire system voltage and optimises system performance. Power wiring in conduit was installed from the solar array to the controller. Control wiring in conduit was installed from the controller to the float switch in the tank. Electrical wiring was installed from the pump in the well up to the controller. It was used to connect the pump to the solar array. Mathematical switches were installed to manually shut off electricity in case of an emergency or maintenance. These switches are usually installed between the solar panels and the controllers and between the controller and the pump. Orientation of the PV array is one of the most important aspects of the site assessment. The PV array is positioned in such a way that the sunlight is utilized to its maximum that is true south direction. The tilt angle was selected in accordance with the latitude of the location. Latitude of Raichur is 16º15' N, therefore solar PV array was tilted at this angle. The current I (A) and Voltage (V) generated by the PV array under both tracked and nontracked condition was recorded every hour of the sunny day from 10:30 am to 04:30 pm using DC ammeter. The power outputs from the solar photovoltaic panel on a typical sunny day in the month December 2014 were recorded. Volume of water delivered by pump per unit time $m^3/h$ or $m^3/sec$. The discharge of the DC pump used in the test was measured by volumetric method by collecting the water in 25 liters container and the subsequent time taken to fill the container was recorded using stopwatch. The same was repeated for five trails and the average of five trails was considered.

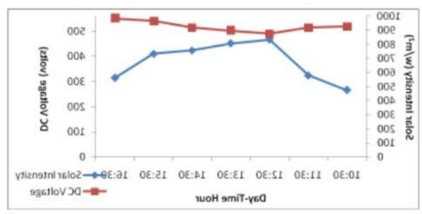
The system was tested for its performance in terms of variation in discharge due to change in solar testing. It was observed that during normal climatic conditions the PV array produced power in the range of 7051.40 watts to 7848.22 watts from 10:30 am to 4:30 pm in the month of December 2014. It was observed that reduction in power generation in the range of 10.16 % during noon conditions. PV array produced maximum power of 7848.22 watts (12:30 pm) while, Vmp and Imp of 490.82 volts and 15.99 amps respective. The pump delivered discharge of 33.40 $m^3/h$ (10.30 am-11:30 am) with a head of 22.8 m. During noon conditions pump delivered discharge of 41.82 $m^3/h$ (12:30 pm) with a head of 22.8 m and the pumping efficiency was measured at 66.06 %. It was observed that, power output from the solar array increases as solar intensity increases. Increase in the power output was in the range from 7051.40 to 7848.22 watts.

Hegazi et al., (2010) fabricated and evaluated solar powered irrigation pump. They found that pump efficiency decreases as head increases. They observed that pump efficiency was below 40% when head is at 4m. Abu-Aligah (2010) designed photovoltaic water pumping system and compared it with diesel powered pump. They observed that output of solar pump is mainly depend on correct design of solar panel system. Pawan Kumar et al., (2013) observed the performance analysis of photovoltaic based submersible water pump. In their study, they found that maximum discharge was obtained at noon for 2HP DC motor operated by 10 panels of each 225 W and power output of 75 to 85 $W/m^2$. Shiv Lal et al., (2013) analysed techno economic feasibility of solar photovoltaic based submersible water pumping system for rural areas of Rajasthan. In this study, they found that solar photo voltaic water pumping system can replace fossil fuels 100%. They

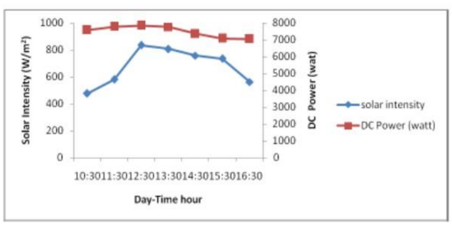
Variation of voltage and current



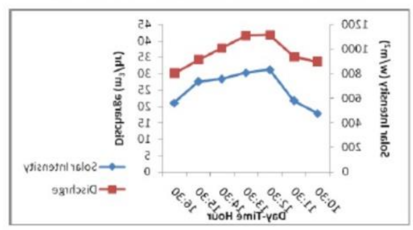

Variation of Dc power output with respect to temparature



Variation of Dc power output with respect to input solar radiation




Variation of discharge with respect to solar intensity



mentioned saving of $CO_2$ emission by 14977.57 kg/year.

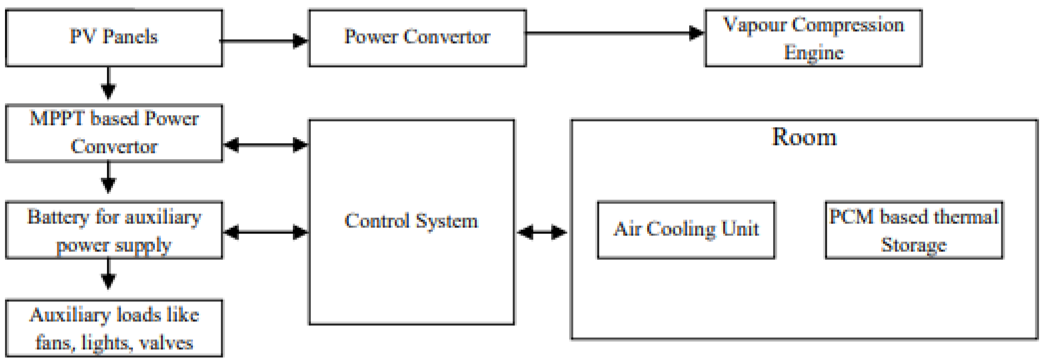
**Testing and promotion of solar energy assisted cold storage unit for enhancing shelf life of horticultural produce**

India's farmlands suffer from large volumes of crop and produce wastage. Lack of proper storage facilities is a major reason why farmers lose about 25 per cent of fruits and vegetables due to spoilage. Total annual food wastage in India is approximately Rs. 44,000 crores. Electric- or diesel-driven cold storage are available options, but collateral factors of exhaustible fuel usage and high running costs make these non-viable to most farmers. In addition, heat and carbon emission by these setups are harmful for the environment. About 10 million tons of cold storage capacity is required to prevent the over 30 percent wastage of perishable produce. Lack of high-quality cold storage facilities and lack of refrigerated transport for food manufacturers and food sellers are said to be two of the biggest contributors to food losses.

A micro cold storage was installed in the University to study its efficacy in storing horticultural produce. The cold storage harnesses solar energy from PV panels which is fed directly to the compressor via a drive that works on algorithm developed by us and ensures maximum utilization of solar power generated while accounting for variations in solar insulation, variations in load inside the cold storage (depending on time of day, amount of produce loaded, location etc.) and user's set points. Cooling is generated due to compressor's operation which is used to cold the room and create back-up in the form of thermal storage system.

The thermal storage system and the room cooling system works in tandem to maintain the setpoint at all points of time and ensure that the system has enough back-up to run for the maximum time possible when any power is not available. A part of the solar power generated also charges a small battery which is meant for control system operation and running auxiliary loads.

The pictorial representation of the working principle of the cold storage will be as




under:


The specifications of the cold storage unit were as under:

**Specifications of the photo voltaic model**

| Particulars | Details |
|---|---|
| Module type | SS40P |
| Module area | 0.25 $m^2$ |
| Rated peak power | 40 W |
| Rated voltage | 17.78 V |
| Rated current | 2.29 A |
| Open circuit voltage | 21.82 A |
| Short circuit current | 2.46 A |

**Specifications of vapour compression cold storage unit**

| Particulars | Details |
|---|---|
| Compressor | A type of reciprocating sealed compressor AE7 ZA7, 1/6 hp, 230 V, 1.4 A, 50Hz, R134a. Suction pressure 33.096 kN.$m^2$<br>Discharge pressure 1241.1 kN.$m^2$ |
| Condenser | Total 24 no. of tubes each having 0.30 mm thickness and 6.0 mm diameter. Total length of tube 17.90 m and area 0.3374 $m^2$. |
| Evaporator | 6 copper tubes of 10 mm diameter. Area of tube is 0.2230 $m^2$. Area and circumference of each tube is 0.0223 $m^2$ and 1.25 m, respectively. Total length of evaporator tube is 7.10 m. The tubes arranged in a rectangular shaped box. |
| Refrigerant | R134a |
| Expansion device | A capillary tube of 0.003 m diameter and 2.0 m length. |
| Thermostat | Mechanical thermostat |

The solar cold room is basically a container with five-ton storage capacity, running on solar energy captured and generated by solar panels. The system's proprietary algorithms harness the solar energy in the most efficient manner. This not only helps run the system but also charges the thermal plates installed inside, which can provide backup up to 30 hours. These thermal batteries have at least twice the life compared to conventional solar batteries and lower replacement costs—reducing running costs significantly. Interestingly, the system is portable and can be easily shifted from one place to other. Set up and installation are simple and quick. As backup, the system can be operated using grid or alternative power supply from a generator set. It has the capability to charge itself completely with just six to seven hours of grid power. During cloudy weather, the system automatically switches to the available alternative power supply, notifying the operator. The overall dimensions of solar operated cold storage unit were 1524.0 mm in length, 1066.8 mm in width and 1219.2 mm in height.

The results obtained by storing tomato in the cold storage unit revealed that the minimum and the maximum solar intensities were 340 $Wm^{-2}$ and 630 $Wm^{-2}$ with the panel efficiency of 79.95 % and 43.81 % on a clear sunny day during summer. The COP of the system varied from 4.4 to 8.5 at different load performance of solar operated cold storage system. The TSS content was high for untreated fruits as compared to other treatment. The pH value observed was less in fruits stored at 5 °C, 90 % RH as compared to other treatments. The weight loss observed was also less. The colour change was less observed in fruits stored at 5 °C, 90 % RH as compared to other treatments. The fruits were firmer with less firmness, L* value and b* value when stored at 5 °C, 90 % RH compared to other treatments. Microbial analysis of tomato during storage showed that, the minimum microbial growth after 22 days was of storage 8.69 × 103 cfu\ml for fruits stored at 5 °C, 90 % RH and maximum recorded after 22 days was 36.49 × 103 cfu\ml for fruits stored at 10 °C, 80 % RH. Total cost of operation was Rs. 8.09 per hour for 250 kg with a B-C Ratio = 1.48. The efficiency was found to be decrease with the ambient temperature due to decreases in corresponding open circuit Voltage. The results were similar to the earlier report work of Chander et al. (2015)

The Indian Institute of Technology (IIT), Madras has developed a portable solar-powered cold storage device with a 500 kg capacity for storing vegetables and fruits, among other items. The unit uses thermal energy storage. The photovoltaic-powered refrigeration system is used to charge the indoor thermal battery in the form of latent heat during day time and used to maintain temperature ($10^0$C) for 20-24 hours (Chander Mohan, 2018).

The studies have revealed that solar assisted cold storage units could be utilized for storing the horticultural produce on custom-hiring basis which would reduce the post-harvest losses and enhance the profitability. The farmers and small-scale entrepreneurs have been trained to utilize the solar energy for safe storage of fruits, vegetables and other perishable produce through establishment of solar assisted cold storage units which can reduce the post-harvest losses and enhance the profitability.

## FINDINGS AND DISCUSSION

University of Agricultural Sciences, Raichur has established a first of its kind Renewable Energy Park. Several equipment and machinery operated by renewable energy sources are on display in the park. The equipment on display include mini multi rack solar dryer, mini multi rack solar dryer with baffle plates, high capacity multi rack dryer, forced convection solar drying system, solar tunnel dryer, solar pumping system, cookstoves, inverted downdraft gasifier wood stove, solar powered knapsack sprayer, solar powered cycle mounted sprayer, solar cooker, parabolic solar cooker, solar water heaters, wind powered water lifting pump, hybrid water pumping system. While the efforts made by the University in establishing the renewable energy park is commendable, there is need to maintain the equipment in good working condition so that visitors get a very fair idea of the uses of renewable sources of energy. Many equipment on display were not in working condition.

While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.

With regard to the solar pumping system, studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted. It is generally believed that solar pumps are not efficient in pumping water from greater depths. Experiments done at Visvesvaraya National Institute of Technology, NAGPUR, INDIA have revealed that the discharge of water decreases as the head of pumping increases. However, with increase in solar radiation intensity the curve shifts upwards giving more discharge at the respective head (Arunendra Kumar Tiwari et al., 2015). Hence, it will be necessary to choose suitable pumping system depending on the depth of pumping.

The studies with solar assisted mini cold storage unit have revealed that they could be utilized for storing the horticultural produce. The results obtained by storing tomato in the cold storage unit revealed that the minimum and the maximum solar intensities were

340 $Wm^{-2}$ and 630 $Wm^{-2}$ with the panel efficiency of 79.95 % and 43.81 % on a clear sunny day during summer. In fruits stored at 5 °C, 90 % RH pH value, TSS value of fruits, microbial activity and colour loss was less, the fruits retained firmness longer.

# REFLECTIONS AND CONCLUSIONS

1. While the efforts made by the University in establishing the renewable energy park is commendable, there is need to maintain the equipment in good working condition so that visitors get a very fair idea of the uses of renewable sources of energy. Many equipment on display were not in working condition.
2. While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out.
3. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.
4. With regard to the solar pumping system, studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted to choose suitable pumping system depending on the depth of pumping.
5. Technical bulletin and publication have been brought out on the various uses of renewable sources of energy. There is need to organize field visits, training programmes and demonstration trainings involving farmers after giving wide publicity.
6. The economics of operation of equipment using renewable sources of energy need to be done systematically to establish their viability vis a vis traditional equipment.
7. There is need to commercialise manufacture of proven equipment under PPP model. Patents may be taken for the equipment designed and developed by the University.
8. There is need to maintain the equipment on display in the Renewable Energy Park in good working condition.

# ACTION POINTS

1. There is need for quantification of solar energy available for utilization in the region and its duration.
2. The solar pumping systems have failed in the State due free power available to farmers for energizing their traditional water pumps. However, this is a challenge to Agricultural Universities and there is need to develop a policy by converging the line departments on the benefits of solar energy and ecology and climate.
3. The economics of solar powered cold storage needs to be worked out besides total volume of storage needed in the region may be worked out with its economics.
4. There is greater scope of convergence of other line departments and focus on PPP model needs to be explored.
5. The wind energy turbines established by private sector needs to be evaluated in terms of their impact on climatic factors more so on aridity and soil moisture and impact on crop growth and yield in and around wind mills.
6. Human resources training on solar gadgets developed/ evaluated needs to be strengthened.
7. While the University has established the Renewable Energy Park, systematic programmes to enlighten the farmers, students and general public about the equipment on display have not been chalked out.
8. Description of each equipment and its performance efficiency should be displayed in front of each equipment in local language as well as in English. Well trained guides should be available to escort the visitors and explain the equipment and other details. Sufficient publicity should be given about the Renewable Energy Park. The experience of Vishwesvaraya Industrial and Technological Museum, Bengaluru is worth emulating.
9. Technical bulletin and publication have been brought out on the various uses of renewable sources of energy. There is need to organize field visits, training programmes and demonstration trainings involving farmers after giving wide publicity.
10. There is need to commercialise manufacture of proven equipment under PPP model. Patents may be taken for the equipment designed and developed by the University.
11. Utilization of photovoltaic energy application in agricultural greenhouses for and water pumping.
12. Solar PV operated water lifting / pumping system.
13. Solar based processing of agricultural produces.
14. Establishment of Testing center for Solar Photovoltaic Water Pumping System and other solar gadgets as per MNRE (MINISTRY OF NEW AND RENEWABLE ENERGY) Guidelines.

# RESEARCHABLE ISSUES

1. Studies regarding the efficiency of solar pumping units at different heads of pumping may be conducted to choose suitable pumping system depending on the depth of pumping.
2. The abundantly available solar power needs to be quantified and documented in different agro climatic zones coming under the jurisdiction of the University.
3. Develop protocols for solar energy usage in cold storages and value additions through PPP mode.
4. Need for developing mobile solar dryers and harvesters.

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# TERMS OF REFERENCE
# FOR THE EVALUATION OF THE PROJECT ENTITLED "DEVELOPMENT, EVALUATION AND DEMONSTRATION OF SOLAR AND OTHER RENEWABLE ENERGY SYSTEMS" IMPLEMENTED DURING THE PERIOD 2013-14 AT THE UNIVERSITY OF AGRICULTURAL SCIENCES, RAICHUR

1. **Title of the study**
   Development, Evaluation and Demonstration of Solar and Other Renewable Energy Systems

2. **Department/ Agency implementing the scheme**
   College of Agricultural Engineering, University of Agricultural Sciences, Raichur

3. **Project Approval No.(Sector) : KA/RKVY-OTHR/2013/449**

4. **Year of Start / Year of Completion :2013-14 to 2015-16**

5. **Total Budget of the Project : 175 lakhs**

6. **Background and the context**

Energy is a vital component of any society playing a pivotal role in the national development. Post oil crisis shifted the focus of energy planners towards renewable resources and energy conservation. Renewable energy is energy which comes from natural resources such as sunlight, biomass, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). About 16% of global final energy consumption comes from renewables, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly. The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables.

Solar is a major power source and could be utilized for thermal applications through solar collectors and for electricity generation through photo-voltaic cell. The global solar energy sector has been growing at a rapid pace over the past few years. Amid climate change concern and desires for energy security, favorable policy supports has been witnessed from the government, coupled with rising cost competitiveness on technology advances. The Solar Industry in India is growing exponentially. The Government is striving hard to push the solar power industry to make India a global leader.

Biomass is another renewable source of energy in the form of wood, agricultural residues etc. The potential of agricultural residues alone is estimated to be 480 mt with residues from food grains contributing about 100 mt. These can be burnt directly to generate steam for use in steam turbines for power generation or they can be gasified so that the gas can be used in for running internal combustion engines for agricultural pumping or power generation. Another way of using biomass for energy generation is anaerobic digestion of biomass to produce biogas, which can be used for thermal applications in households, running internal combustion engines for pumping water or for power generation.

The use of wind power is increasing at an annual rate of 20%, with a worldwide installed capacity of 238,000 megawatts (MW) at the end of 2011, and is widely used in Europe, Asia, and the United States. Airflows can be used to run wind turbines. Modern utility-scale wind turbines range from around 600 kW to 5 MW of rated power, although turbines with rated output of 1.5–3 MW have become the most common for commercial use.

Karnataka receives global solar radiation in the range of 5.1–6.4 kWh/sq.m during summer, 3.5-5.3 kWh/sq.m during monsoon, and 3.8–5.9 kWh/sq.m during winter. This is very predominant and accounts to be high in Northern part of Karnataka. Solar as an energy source also has massive employments opportunities for all segments.

Because of inadequate supply of electricity, there is a frequent power cut and this situation is worse in the rural areas. The two main features of solar energy which makes it feasible for water pumping application are; i) The availability of solar energy intensity is very high during summer during which the water requirement of the crop is also high and ii) the availability of solar intensity is intermittent which matches with the irrigation intervals of the crop. Hence, there is a greater scope for utilization of solar energy for generation of electricity using solar photovoltaic cells and to further utilize the same for water pumping.

Since Hyderabad-Karnataka region is blessed with perennial solar energy, can help to meet the electricity shortage using abundantly available renewable energy that is best suited for rural/decentralized deployment and this region is bestowed with two major rivers which has led to the cultivation of many commercial crops like Papaya, guava, orange, fig, mango, tomato, amla etc. However, the earnings from the agriculture are often uncertain and very low as the unfavourable climatic conditions and pests and diseases adversely affect the quantum of production. The farmers are often victims of steep fall in the prices of their perishable commodities especially during the peak season. The traditional marketing methods and the price fluctuation often make it hard for the farmers even to meet their production cost. The farmers of this region are unable to get proper returns to their produce as they are forced to sell them immediately after the harvest. This may be due to inadequate processing and storage facilities available near the production catchment or due to the lack of awareness of the farmers to the appropriate storage facilities. This problem can be addressed by imparting the technical know-how to the farmers and by conducting the training programmes. The scientists of the UAS, Raichur can extend their technical support to enable the farmers to protect their produce till from the production catchments to the market.

In this context, it was proposed to develop/establish, evaluate and demonstrate the technical soundness of the various solar and other renewable energy systems to popularize the renewable energy technology involving the following major activities.

7. **The Objectives:**
    1. Establishment of Renewable Energy Park
    2. Evaluation and Demonstration of Solar Pumping System
    3. Testing and promotion of solar energy assisted cold storage unit for enhancing shelf life of horticultural produce

8. **Present Status of the Project**

**Establishment of Renewable Energy Park**

The survey of existing energy parks has been carried out. The purchase of various solar, wind, biogas, biomass and other energy gadgets is completed. The layout for establishment of renewable energy park has been prepared and the construction of platforms for renewable energy gadgets / systems is also completed.

The various renewable energy systems / gadgets viz., solar water heater, solar cooker, solar still, solar dryer, solar sprayer, solar air conditioner, wind aero-generator, wind mill pumping unit, biogas plant models, solar sprayers, biomass gasifier, improved cook stoves etc. have been installed. The performance of the gadgets is being evaluated and their technical soundness will be demonstrated. Demonstration of a few energy gadgets has been conducted to create awareness among farmers students and other stake holders regarding utilization of abundantly available solar and other renewable energy sources and also for popularizing the technologies and to motivate and encourage farmers, students of primary to graduation level to create awareness of the utility of renewable/non-conventional energy sources by conducting live demonstrations and arranging training/workshops/seminars.

**Evaluation and demonstration of Flat Plate Collector (FPC) type Solar Water Heater**


**Evaluation and demonstration of Evacuated Tube Collector (ETC) type Solar Water Heater**

**Evaluation and demonstration of Box type Solar cooker**

**Evaluation and demonstration of Parabolic type Solar cooker**

**Evaluation and demonstration of improved rice husk cookstove**

**A view of the windmill established in the energy park**

**Evaluation and Demonstration of Solar Pumping System**

The merits and demerits of the pumping systems presently used by the farmers has been studied. The purchase of different solar pumping systems is completed. The installation and evaluation of the solar pumping systems is under progress.

Solar system of suitable capacity to match 5 hp pumpset have been designed, installed and demonstrated in the UAS Raichur campus for pumping water. Later on, four units of solar pumping systems have been commissioned at the university farm for pumping of water for irrigation as demonstration units.

The performance of the solar pumping systems is being evaluated and their technical soundness will be demonstrated. Demonstration of the pumping units will be conducted to create awareness among farmers and other stake holders to overcome the power scarcity and crop loss due to shortage of electricity, which is very common in villages and also for popularizing the technology and to motivate and encourage farmers, to create awareness of the utility of renewable/non-conventional energy sources by conducting live demonstrations and arranging training/workshops/seminars.

**A view of the solar pumping unit established at UAS campus**

**Evaluation of the solar pumping unit established at UAS campus**

**Testing and promotion of solar energy assisted cold storage unit for enhancing shelf life of horticultural produce**

The survey on the existing cold storage units revealed that, the cold storages units of Raichur region have been built primarily for preservation of few fruits and grains only. Most of the cold storages are of big size and generally located in a city centre, therefore, small sized cold storages should be of portable in nature. This will reduce transportation cost and as a result more farmers will be encouraged to use this facility.

Post harvest losses of horticulture produce vary between 5-30 per cent of total production. The lack of quality consciousness on the part of horticulture producers increase post harvest losses, on the other hand, lack of the same, saves many produce from complete wastage because consumers purchase them on a relatively lower price. Thus, though it reduces quantitative loss of horticulture produce, it is hazardous for human health.

During the survey about cold storage facility, some of the farmers were not even aware of the very few existing cold storage facilities. But some of the farmers who were aware of it, were not willing to use this facility because the distance between the available cold storage units and the village (production centre of the horticulture produce), given the bad transportation facilities, actually made it unattractive for the horticulture producers to keep their produce in cold storage. Even farmers of Raichur district, on average will have to carry their produce from 10 to 40 kilometers to keep their horticulture produce in that cold storage. If farmers of the neighborhood districts decide to use the same facilities, on average they will have to carry it from 50 to 150 kilometers. And all this will only add to the cost of their produce and that will ultimately result in either low profit or no profit at all. The biggest obstacle in the proper functioning and development of cold storages is poor power supply.

The main horticulture produce of these regions are Onion, Dry chillies, Tomato, Papaya, Lemon, Brinjal, Mango, Pomegranate, Guava, Banana, Sapota etc. The combined data of horticultural produce and the extent of wastage is given in the table below.

**Table. 1. Combined data of five taluks of Raichur district**

| Name of Fruits & Vegetables | Total Estimated Production (in ton) | Total Estimated Wastage (in Per cent) | Total Estimated Wastage (Rs in lakh) |
|---|---|---|---|
| Onion | 50327 | 29 | 210 |
| Dry chillies | 43368 | 05 | 280 |
| Tomato | 22692 | 38 | 150 |
| Papaya | 15680 | 15 | 18 |
| Citrus | 10686 | 10 | 15 |

| | | | |
|---|---|---|---|
| Brinjol | 8019 | 11 | 12 |
| Mango | 7326 | 35 | 85 |
| Pomegranate | 5580 | 15 | 20 |
| Banana | 5115 | 18 | 55 |
| Guava | 3916 | 19 | 16 |
| Sapota | 3641 | 21 | 18 |
| **Total Estimated Post-Harvest Wastage** | | **878** | |

**Table. 2. Combined data of six taluks of Gulbarga district**

| Name of Fruits & Vegetables | Total Estimated Production (in ton) | Total Estimated Wastage (in Per cent) | Total Estimated Wastage (Rs in lakh) |
|---|---|---|---|
| Banana | 56570 | 18 | 538 |
| Brinjal | 32910 | 11 | 52 |
| Citrus | 32910 | 10 | 35 |
| Onion | 23725 | 29 | 103 |
| Tomato | 23167 | 38 | 172 |
| Mango | 17124 | 35 | 247 |
| Green Chilli | 13200 | 15 | 39 |
| Grapes | 4825 | 15 | 64 |
| Dry Chilli | 4046 | 05 | 34 |
| Turmeric | 3841 | 05 | 08 |
| Tamarind | 2923 | 10 | 13 |
| **Total Estimated Post-Harvest Wastage** | | **1305** | |

By taking the above factors into consideration, a cold storage unit has been designed to provide a better storage facility for perishable food stuff in the community and to promote the living standard of the people. This cold storage uses the solar energy thereby reducing the energy cost. The solar power system is also designed according to the design specification of the cold room. It is an adaptive design aimed at designing the cold room to suit the prevailing factors of Hyderabad-Karnataka region with reference to design calculations. This is timely, and a first of its kind within the locality. The design complies with all standard refrigeration principles and theory to best suit the prevalent climatic condition in Hyderabad-Karnataka region. The cold room if erected as designed inevitably will enhance the living standard of the community by providing them the access to fresh foods. It will also improve the local economy of the community by increasing the gross domestic product through better preservation.

Also by considering these facts, a portable solar powered cold storage unit for fruits and vegetables has also been designed and installed to provide a better storage facility for perishable food stuffs in the community and to promote the living standard of both rural and urban people. The cold storage was designed to suit the prevailing factors of Hyderabad Karnataka region with reference to adaptive design calculations. This is timely and a first of its kind within the locality. It will also improve the local economy of the community by increasing the gross domestic product through better preservation. The established solar assisted cold storage units could be utilized for storing the horticultural produce on custom hiring basis which would reduce the post harvest losses and enhance the profitability.


**A view of portable cold storage unit**

9. **Outcome of the project**

- The establishment of renewable energy park would not only help to promote the renewable energy technologies/gadgets among the farmers but also serve as a model for conducting R & D programmes on non-conventional energy sources and to interact with industries and other R & D institutions.
- The harnessing of abundantly and freely available solar energy for pumping water for irrigation would result in solving the problem of acute shortage of power supply in rural areas thus reduce the dependency on the electrical grid and improving the standard of living of the farming community.
- The establishment of solar assisted cold storage units could be utilized for storing the horticultural produce on custom-hiring basis which would reduce the post harvest losses and enhance the profitability.

## 10. Assets (Including building, equipment etc.)

| Sl. No. | Name of the Purchased Asset | Year of purchase | Qty (Nos.) | Cost (Rs. in lakhs) | Purpose of purchase |
|---|---|---|---|---|---|
| | **EQUIPMENT** | | | | |
| 1 | Solar photovoltaic power generation kit | 2013-14 | 1 | 0.92 | Gadgets for energy park |
| 2 | solar refrigeration system | 2013-14 | 1 | 0.95 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 3 | Refrigeration System | 2013-14 | 1 | 0.89 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 4 | solar colour T.V | 2013-14 | 1 | 0.99 | Gadgets for energy park |
| 5 | H.P colour printer | 2013-14 | 1 | 0.24 | Gadgets for energy park |
| 6 | Biogas Plant | 2013-14 | 1 | 0.53 | Gadgets for energy park |
| 7 | Solar sprayer | 2013-14 | 1 | 0.34 | Gadgets for energy park |
| 8 | solar Education K.i.t | 2013-14 | 1 | 0.25 | Gadgets for energy park |
| 9 | Paddy husk based improved chulla | 2013-14 | 1 | 0.27 | Gadgets for energy park |
| 10 | Fixed firewood chulla | 2013-14 | 1 | 0.21 | Gadgets for energy park |
| 11 | portable charcoai box chulla | 2013-14 | 1 | 0.068 | Gadgets for energy park |
| 12 | Metallic based improved chulla | 2013-14 | 1 | 0.057 | Gadgets for energy park |
| 13 | Solar torch | 2013-14 | 1 | 0.019 | Gadgets for energy park |
| 14 | Solar bag | 2013-14 | 1 | 0.09 | Gadgets for energy park |
| 15 | Mini solar lighting system | 2013-14 | 1 | 0.21 | Gadgets for energy park |
| 16 | Solar power bank | 2013-14 | 1 | 0.11 | Gadgets for energy park |
| 17 | Asus vltra book laptop | 2013-14 | 1 | 0.47 | Gadgets for energy park |
| 18 | Nikon digital camera | 2013-14 | 1 | 0.19 | Gadgets for energy park |
| 19 | Lenovo all in one desktop | 2013-14 | 1 | 0.50 | Gadgets for energy park |
| 20 | P.U.F panels | 2013-14 | 1 | 0.47 | Gadgets for energy park |
| 21 | Control system | 2013-14 | 1 | 0.18 | Gadgets for energy park |
| 22 | Digital manometer | 2013-14 | 1 | 0.22 | Gadgets for energy park |
| 23 | Solar still | 2013-14 | 1 | 0.48 | Gadgets for energy park |
| 24 | Solar dryer | 2013-14 | 1 | 0.41 | Gadgets for energy park |
| 25 | Parabolic cooker | 2013-14 | 1 | 0.13 | Gadgets for energy park |
| 26 | Box type solar cooker | 2013-14 | 1 | 0.06 | Gadgets for energy park |
| 27 | Box type solar cooker (with coil) | 2013-14 | 1 | 0.07 | Gadgets for energy park |
| 28 | Solar water heater (flat plate) | 2013-14 | 1 | 0.23 | Gadgets for energy park |
| 29 | Solar water heater(ETC tube) | 2013-14 | 1 | 0.14 | Gadgets for energy park |
| 30 | SPV LED light | 2013-14 | 1 | 0.21 | Gadgets for energy park |
| 31 | SPV lantern | 2013-14 | 2 | 0.09 | Gadgets for energy park |
| 32 | Kyocera copier | 2014-15 | 1 | 0.72 | Gadgets for energy park |
| 33 | Power system of cold storage | 2014-15 | 1 | 0.87 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |

| | | | | | |
|---|---|---|---|---|---|
| 34 | Solar p.v module 1kw with ups | 2013-14 | 1 | 0.97 | Gadgets for energy park |
| 35 | Solar AC unit 1T with battery and charge controller | 2014-15 | 1 | 0.98 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 36 | Vacuum pump | 2013-14 | 1 | 0.37 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 37 | magnetic stirrur | 2013-14 | 1 | 0.15 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 38 | Vacuum pump(Rackvac) | 2014-15 | 1 | 0.26 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 39 | Vacuum tray dryer | 2014-15 | 1 | 0.96 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 40 | vertical axis wind mill | 2013-14 | 1 | 0.98 | Gadgets for energy park |
| 41 | thermal backup | 2014-15 | 3 | 0.49 | Gadgets for energy park |
| 42 | solar fencing system | 2014-15 | 1 | 0.97 | Gadgets for energy park |
| 43 | Portable biogas for kitchen waste | 2013-14 | 1 | 0.80 | Gadgets for energy park |
| 44 | Solar pumping system(5.5 hp pump capacity-Surface pump) | 2013-14 | 1 | 6.60 | Promotion of solar pumping systems among farmers |
| 45 | Solar pumping system(5.5 hp pump capacity-Submersible pump) | 2013-14 | 1 | 6.50 | Promotion of solar pumping systems among farmers |
| 46 | Solar pumping system(7.5 hp pump capacity-Surface pump) | 2013-14 | 1 | 8.40 | Promotion of solar pumping systems among farmers |
| 47 | Solar pumping system(7.5 hp pump capacity-Submersible pump) | 2013-14 | 1 | 8.30 | Promotion of solar pumping systems among farmers |
| 48 | Solar street lights | 2013-14 | 06 | 1.08 | |
| 49 | Wind-Solar hybrid power plant for water pumping(Electrical) | 2013-14 | 01 | 4.30 | Promotion of solar pumping systems among farmers |
| 50 | Solar pumping system | 2013-14 | 01 | 4.99 | Promotion of solar pumping systems among farmers |
| 51 | Wind mill model (Stand alone) for water lifting (Mechanical) | 2013-14 | 01 | 2.22 | Promotion of solar pumping systems among farmers |
| 52 | Biomass Gasifier for thermal applications | 2013-14 | 01 | 4.80 | Gadgets for energy park |
| 53 | Solar Cold storage unit | 2014-15 | 01 | 20.00 | Promotion of solar energy assisted cold storage to reduce the post harvest losses |
| 54 | Solar street lights | 2014-15 | 25 | 0.18 | Lighting of energy park |
| | **CIVIL WORKS** | | | | |
| 1 | Construction of energy park layout | 2013-14 | 01 | 28.87 | Establishment of energy park |
| 2 | Compound wall | 2014-15 | 01 | 3.67 | Establishment of energy park |

**11. Where the project is undertaken**

Place to visit to evaluate the project

College of Agricultural Engineering
University of Agricultural Sciences
Raichur-584104, Karnataka

**12. Evaluation Questions and minimum expectations**

1. Weather the required equipments have been procured under the project.
2. Weather extension work is carried out for popularization of the technologies.
3. Weather the centre is having training facilities for farmers, line department officials, students and other stake holders.
4. Any live demonstration of the technologies carried out at the centre.
5. How is the work carried out after completion of the project?

**13. Evaluation methodology**

1. Interaction with the coordinator, principal investigators and other scientists to seek information.
2. Visit to the established solar energy park.
3. Visit to solar powered water pumping units.
4. Inspection of training facilities available at the centre.

**14. Deliverables**

Detailed report on the impact of the works/ research undertaken under the project for cretion of awareness among farmers and other stake holders.

**15. Contact Persons :**

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# EVALUATION TEAM MEMBERS

| Sl. No. | Name | Designation |
|---|---|---|
| 1 | Dr. M. A. Shankar | Principal Investigator |
| 2 | Dr. B. C. Suryanarayana | Associate Investigator |
| 3 | Sri. Siddaraju | Associate Investigator |
| 4 | Dr. M. Ananthachar | Subject Matter Specialist |

**Dr. M. A. Shankar** is a doctorate in Agriculture with specialization in Agronomy. He is former Director of Research, University of Agricultural Sciences, Bengaluru and presently the Executive Member of Institution of Agricultural Technologists, Bengaluru and Co-Chairman of Agribusiness Consultancy Subcommittee. He has implemented 51 research projects for the University funded by International organizations, Central and State governments, Private firms. He has guided 6 Ph. D. students and 15 M. Sc., (Agri) students. As Dean of College of Agriculture, Hassan, he has, with his administrative skills, streamlined accounting, financial, academic and administrative issues. He has been involved in review and evaluation of Technical Reports of 32 All India Co-ordinated Research Projects (AICRP) spread all over India. He has also evaluated 11 operational research projects for the technical feasibility and implementation. He has published 173 peer reviewed research papers. He has also penned 54 booklets and books for the University. He has vast experience in evaluation studies of projects.

**Dr.Suryanarayana, B.C.** is a doctorate in Agriculture with specialization in Agronomy and is a Certified Associate of Indian Institute of Banking (CAIIB), Fellow of Indian Institute of Valuers. He worked in State Bank of India from the year 1981 to 2014 as a Technical Officer and retired as Asst. General Manager (Rural Development). He is a practicing consultant in the field of Agriculture, Horticulture, poultry, dairy, fisheries and plant tissue culture and covered cultivation. He has about 35 years of experience in the field and has prepared several project reports for financial institution, written books in vanilla cultivation, anthurium, medicinal and aromatic crops, minor irrigation, poultry and dairy farming. He has appraised more than 6,000 proposals in agriculture and related fields for funding by the Bank and has also been involved in many studies relating to development of Agriculture and allied activities. He has served as a General Manager in a bio-fertilizer, bio-pesticides and organic manures manufacturing company and is also a Technical Director in a company involved in manufacture of agricultural implements and equipment.

**Sri. Siddaraju** is a Graduate in Agriculture with more than 35 experience in the field of Agriculture. He has served in the Karnataka State Department of Agriculture (KSDA) as Asst. Agricultural Officer in Farmers' Training and Education Centre, Soil Testing laboratory and as Subject Matter Specialist. He was Deputy Director of Agriculture (Commercial Crops) for 6 years, District Watershed Development Officer for 2 years. He has also been Joint Director of Agriculture (Inputs) for 5 years. He was involved in preparation of Annual Programme Planning booklets pertaining to Agricultural Inputs in Department of Agriculture. After retirement, he is serving as Chairman, Agriculture Consultancy Subcommittee, Institution of Agricultural Technologists, Bengaluru and has been actively involved in evaluation studies of projects.

**Dr. M. Anantachar** has a mechanical engineering degree from Karnataka University, Dharwad, a post graduate degree in Farm Power and Machinery from Tamilnadu Agricultural University and a Ph. D. in Mechanical Engineering Sciences from Vishveshwaraya Technological University, Belgaum. He is a Fellow of Institution of Engineers (India) and a life member of Indian Society of Agricultural Engineers. He has over 35 years' experience in teaching and research in Farm Machinery and Power. He has authored four books and published 23 research papers on Farm Power and Machinery is International and National research journals. He has also published 12 international papers, 42 national papers, 52 papers in other research journals and conducted/ participated in 72 national level seminars. He also has 98 popular articles and 37 teaching manuals/ extension bulletins and e-resources to his credit. He has been a Technical Committee member in Mechanization Scheme of Department of Agriculture, Govt of Karnataka from 2006 to 2017, Krishi Yantra Dhare Scheme in Raichur district, SMAM Meeting from 2013 to 2017, for establishment of RFMSC (Rural Farm Machinery Service Centres) in Karnataka during 2016-17 and a member for preparation of technical specification for Farm Machinery Tender document from 2008 to 2017. He was also Principal Investigator of Farm Implements and Machinery (Mechanization scheme of ICAR) project from 1996 to 2017.