IWERM

Integrated Water Energy Resource Management

A study under CIPT

Centre for International Projects Trust

Columbia Water Centre

Columbia University

Funded by USAID

March 16, 2015

Based on a concept and technology from

Datamatrix Infotech Pvt. Ltd.

Executive Summary

This document explores the opportunities for improved productivity and sustainability, through Integrated Water Energy Resource Management using Smart Metering and Communication under the USAID funded CIPT grant, “Water-Agriculture-Livelihood Security in India”. The IWERM concept is based on the invention by Datamatrix under Patent No. 236496 that enables to derive all hydraulic parameters and dynamic performance of the pumping system from the energy signature of the prime mover. The major challenge addressed in the study was to decipher the water-energy- asset-performance nexus against agricultural productivity and sustainability.

The study was conducted at Asnapura Village at Mehsana, Gujarat. Asnapura village has a dedicated 11kV feeder with 28 deep borewells with pumps ranging from 50 to 100kW. There are around 10 to 15 farmers under each pump, irrigating their farms in rotation except for one farmer with a dedicated pump. All pumps were provided with smart energy meters. Nearly one in every four pumps in operation in the village was put under intensive monitoring with the dynamic energy, water, groundwater and efficiency parameters logged at an interval of five minutes.

The annual water and energy consumption of Asnapura village for 2014 was 3. 620 Million Cubic Meters against an energy use of 3.602 Million Units. The saving potential identified and analyzed under this experiment are as follows:

- 30% Improvement potential in Water Use Efficiency through equitable water distribution at a pump level and optimized irrigation at a farm level
- 44% Improvement potential in energy use efficiency through asset management, mainly due to the mismatch of the pumping assets and the deterioration of asset performance
- 25% improvement in the life expectancy of the well through better understanding of the aquifer with optimum well and pump design matching the head flow
- 20% Improvement in productivity by soil moisture management through optimized irrigation

This experiment establishes the preceding inter relationship to compute the saving opportunities. We have identified a road map for IWERM and set a practical target for energy saving of 35% and water savings to the extent of 20%. This has been found to have cascading effect on the sustainability with direct economic impact of Rs. 4.34 Crores per annum on the farming community of this village in comparison with their annual energy expenditure of Rs. 0.61 Crores. This is besides a huge energy subsidy and other social and environmental implications.

The following choices can be offered to the farmers for efficient energy and water use.

A. *Continue with the existing practice of energy based billing at the prevailing rates.*
B. *Use water as the basic commodity for billing in place of energy at a reduced cost; provided the energy and water efficiency meets a basic performance criteria*
C. *The energy and water efficient farmers will be provided with free electricity and free water, as and when the reduced subsidy exceeds the energy cost paid by the farmer.*

The experiment has provided compelling evidence that dynamic knowledge is the key to realizing the above opportunities and much of these savings can be achieved by knowledge management alone. For example improved water management improves energy efficiency and productivity. An Integrated Water Energy Resource Management Program as envisaged under this experiment will monitor the pump wise energy and water consumption and efficiencies and provide deep understanding on aquifer and the pumping assets to continuously optimize resources. This dynamic knowledge will help to break the vicious circle of inefficiency.

Contents

LIST OF FIGURES

LIST OF ABBREVATIONS

TERM	DESCRIPTION
BEP	Best Efficiency Point
DRMU	Datamatrix Remote Monitoring Unit
ESCO	Energy Service Company
IWERM	Integrated Water and Energy Resource Management
kW	Kilo-Watt
M &V	Measurement and Verification
O&M	Operation and Maintenance
UGVCL	Uttar Gujarat Vij Company Ltd (Utility)

1 Introduction

1.1 Background

Integrated Water Energy Resource Management (IWERM) through smart metering and communication is a project initiated by The Center for International Projects Trust (CIPT) and funded by USAID.

Datamatrix has an invention under Patent No 236496 whereby all the hydraulic parameters of a pumping system can be derived by the energy signature of the prime mover. This project leverages this invention to address the IWERM challenges. Asnapura Village in Mehsana District in North Gujarat has been identified for this program. The village was provided with a dedicated 11kV Agricultural feeder by the State Utility – UGVCL to provide power for 28 agricultural pumps located in the village ranging from 50 to 100 kW operating at a depth of 500 to 1000 feet below ground level.

1.2 Approach and Methodology

Datamatrix has carried out detailed tests on each pump capturing the Head vs Flow and Power vs Flow characteristics of each pump along with the other relevant information of the borewell and pumps. The Datamatrix system in a cloud computing environment has been configured with the test data. The technology is capable of mathematically modelling each pump with its behavior characteristics as at site to derive the hydraulic parameters based on the energy input to the pump, as depicted in the following figure.

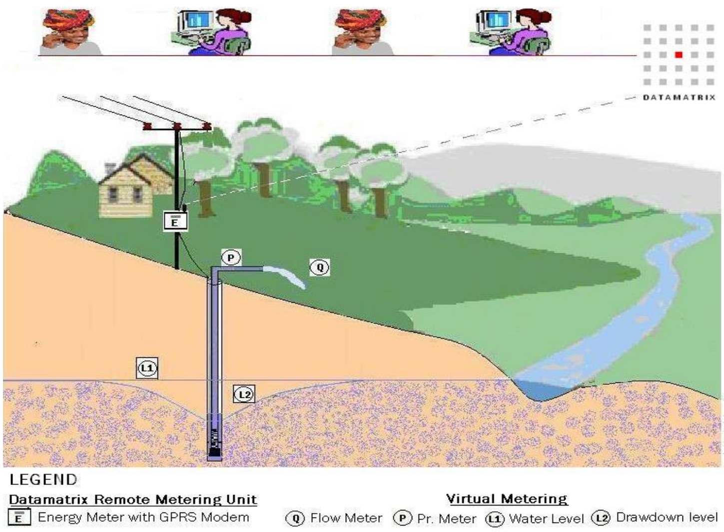


Figure 1: A schematic diagram of the Datamatrix Technology

Datamatrix has provided a dedicated energy meter with RS-485 communication facility for each pump, duly tested and calibrated by UGVCL.

The energy meters connected to a GPRS communication device transmits the energy data to a remote server at a minimum interval of 5 minutes. The near real time data communicated includes voltage, current, frequency, power factor, and power with the date time stamping for each data log. The Datamatrix system is capable of converting this information into hydraulic parameters computing the real-time water use, and the dynamic water levels and drawdown, against each pump. It will also compute the dynamic efficiency of the motor pumpset, and compute the energy losses in the motor, pump , and pipeline. The solution can be accessed using licensed software to create the Datamatrix Virtual Pumpstation on any remote PC with internet connectivity.

Using this solution, one can remotely monitor, analyze and optimize the performance of pumping systems. The following screen views represents the Performance Overview dashboard of the Asnapura Feeder, displaying the pumps that are online and the performance simulation of a pump, revealing its hydraulic performance and energy efficiency at a particular operating instant.

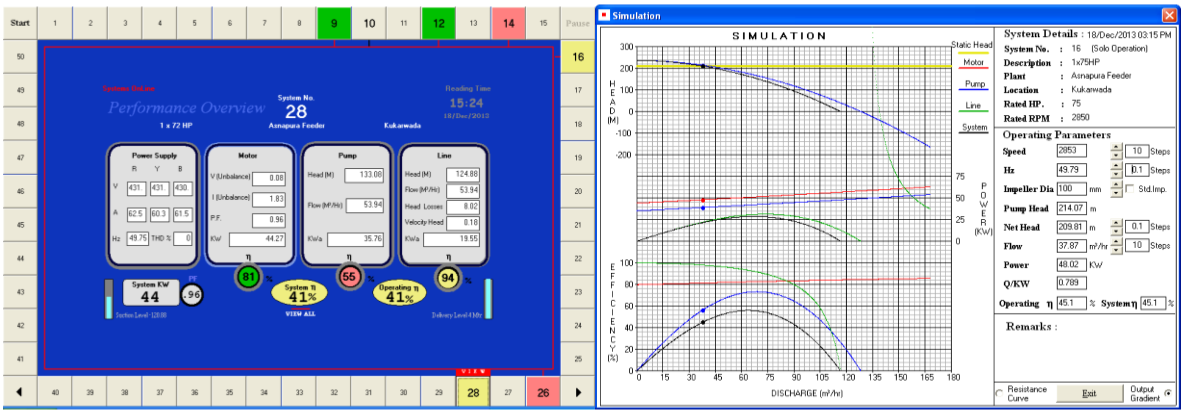


Figure 2: Performance Overview & Performance Simulation

Six pumps have been connected to the Datamatrix System for real time continuous monitoring of all the operating parameters of the pumping system as well as the dynamic suction and drawdown levels of pumps. The initial result of the study was discussed with the stake holders, viz. the farmers, engineers and the Managing Director of UGVCL and has garnered a positive response with the initial findings from the project.

Figure 3: Discussions with UGVCL and Farmers

All the pumps in the village have been subjected to extensive testing; mapping the well details, energy consumption, discharge, water levels and operating efficiencies. Detailed H-Q & Q-KW tests were also conducted at each well, picking up performance characteristics of each pump set operating as at site. Further, performance simulations were carried out for all pumps using the Datamatrix Technology, with the site tested parameters of each pump.

The operating cycles of pumps which were not continuously monitored were derived from the pumps that were under intensive monitoring. It was observed that almost all pumps in service were working continuously for around 8 hours during the main pumping season, spanning across eight months. This approach enabled to have a holistic perspective, and was further validated against high resolution operational data of pumps under intensive monitoring and continuous analytics.

Dedicated energy meters have been provided for each pump under the Asnapura Feeder. We have further analyzed the scenario with the latest data logs from site, to have a comparison between 2014 and 2015 to ascertain the longer term implications, particularly in understanding and calibrating the aquifer characteristics. This has helped us to have a far better understanding of the ground water scenario at Asnapura.

2 Water Use and Efficiency

2.1 The water use scenario at Asnapura

The irrigation at Asnapura is entirely dependent on groundwater. The Asnapura village has 28 pumps connected on the Asnapura feeder from Kukarwada, Mehsana, Gujarat. The farmers operate each pump under a cooperative society jointly financed by the farmers, except one large scale farmer with independent ownership of a well. Each well supports 10-15 farmers with varied shareholding patterns. The farmers use a colloquial terminology of holding ten “paisa”, fifteen “paisa”, etc. that denotes the percentage of shares held by each farmer. Even though the power is available almost on an 8 hour basis daily, each farmer gets the water for irrigating the land in rotation, according to the shareholding pattern of their respective well. The main pumping season of eight months falls between November to June.

2.2 Water Usage

The following figure indicates the pump wise water consumption during the year 2014.

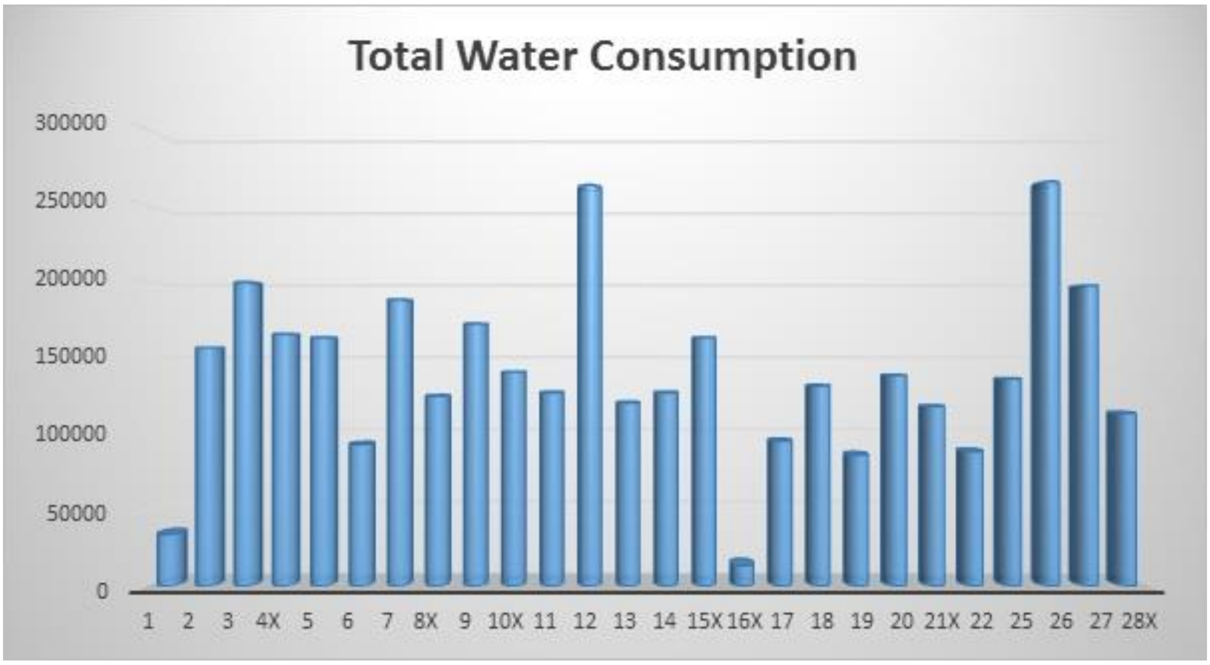


Figure 4: Pump-wise Annual Water Consumption

2.3 Cultivated area and water use

The crops under cultivation are jowar, bajara, castor, cotton, and wheat and the crop pattern is generally similar across the village. The following figure also highlights the variation on water use against different pump user groups. The following figure represents the cultivated area and its annual water use. The total irrigated area under Asnapura feeder is 1348 Bigha out of which, currently 1165.5 Bigha is cultivated.

Figure 5: Pump Wise Water Consumption against Cultivated Land

Based on the above study, we have computed the optimization potential for reduced water consumption at a pump level from the present annual consumption of 3620399 to 3081009 cubic meters per annum simply by restricting the excessive water consumption. This may lead to an opportunity for reducing 15% of the current water consumption, if we can measure the water use by each pump and create a community level water management program.

Further, it may be noted that the farmers have been using the pumps on rotation according to their shareholding pattern of their respective borewell. The well ownership and the sharing pattern are dependent on the ability of the farmer to bear the initial investment. This could further distort the equitable water use per cultivated land, especially when there is no mechanism to measure the water applied and the optimum irrigation as per the required moisture levels. There is a similar or even greater opportunity to optimize the water use per farm land of each farmer, if the water requirement and water use can be monitored at a farm level, with the active involvement of the farmers. This would have major impact on agricultural productivity as discussed under Section-4

2.4 The borewells at Asnapura.

The following diagram represents the bore well locations, depth and the water levels and the water withdrawals at Asnapura. The pumps put under the intensive monitoring are indicated in red letters and the draw down levels are highlighted in red.

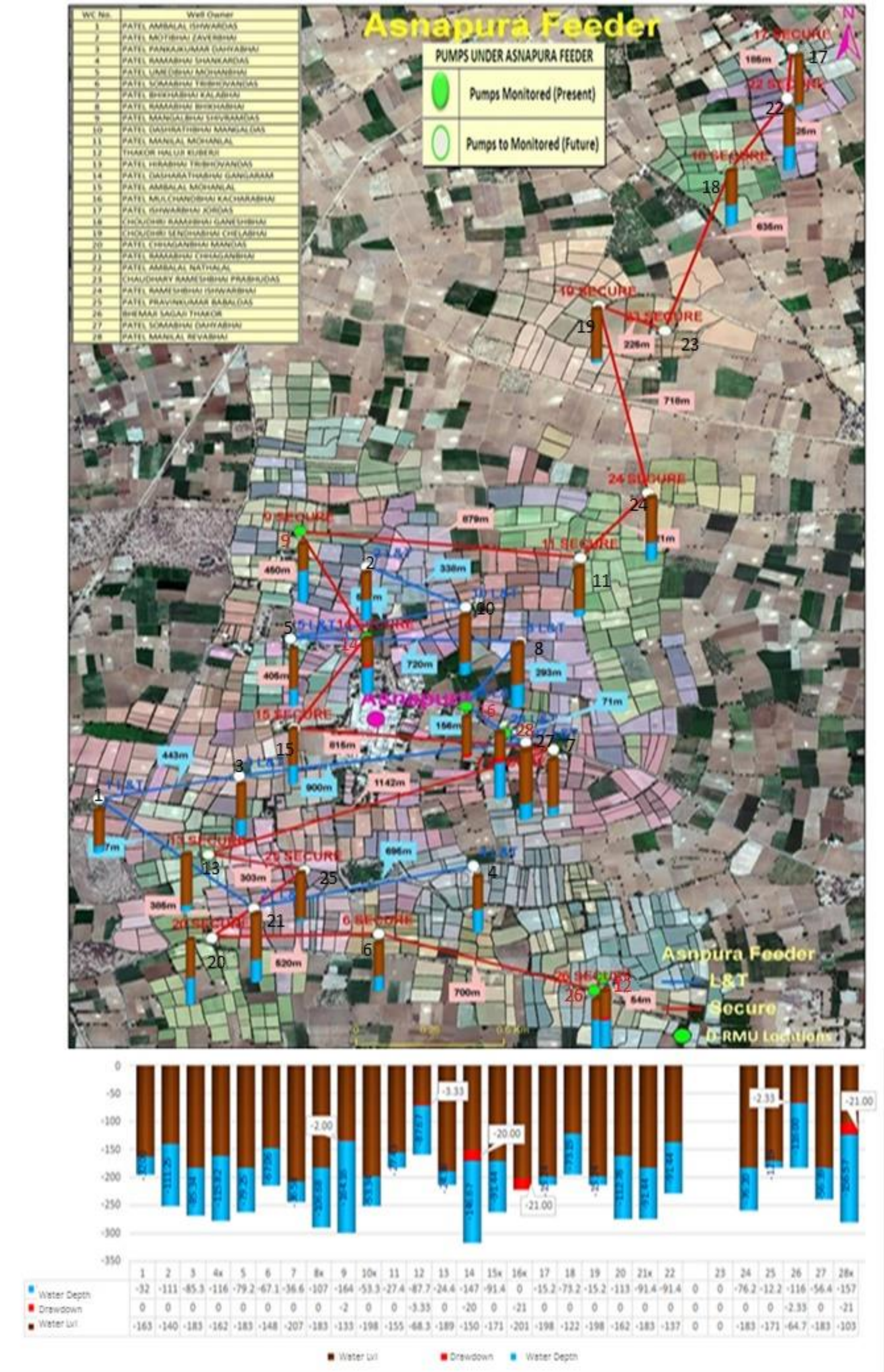


Figure 6: Borewells at Asnapura Village

2.5 Groundwater Scenario

The following figure represents the ground water level of 6 pumps put under intensive monitoring throughout the pumping season, logged at an interval of 5 to 10 minutes. Please note that the following figure represents around 3 Lakh records only on ground water levels of the pumps shown. The combined data base for energy, water, and asset performance of 6 pumps will exceed 15 million data points.

The following figure displays the water level of 6 pumps at the village located somewhat diagonally across the village (South East to North West). Please note that the width of the water level bands represent the daily drawdown level of the pump over an 8 hour pumping duration of the day.

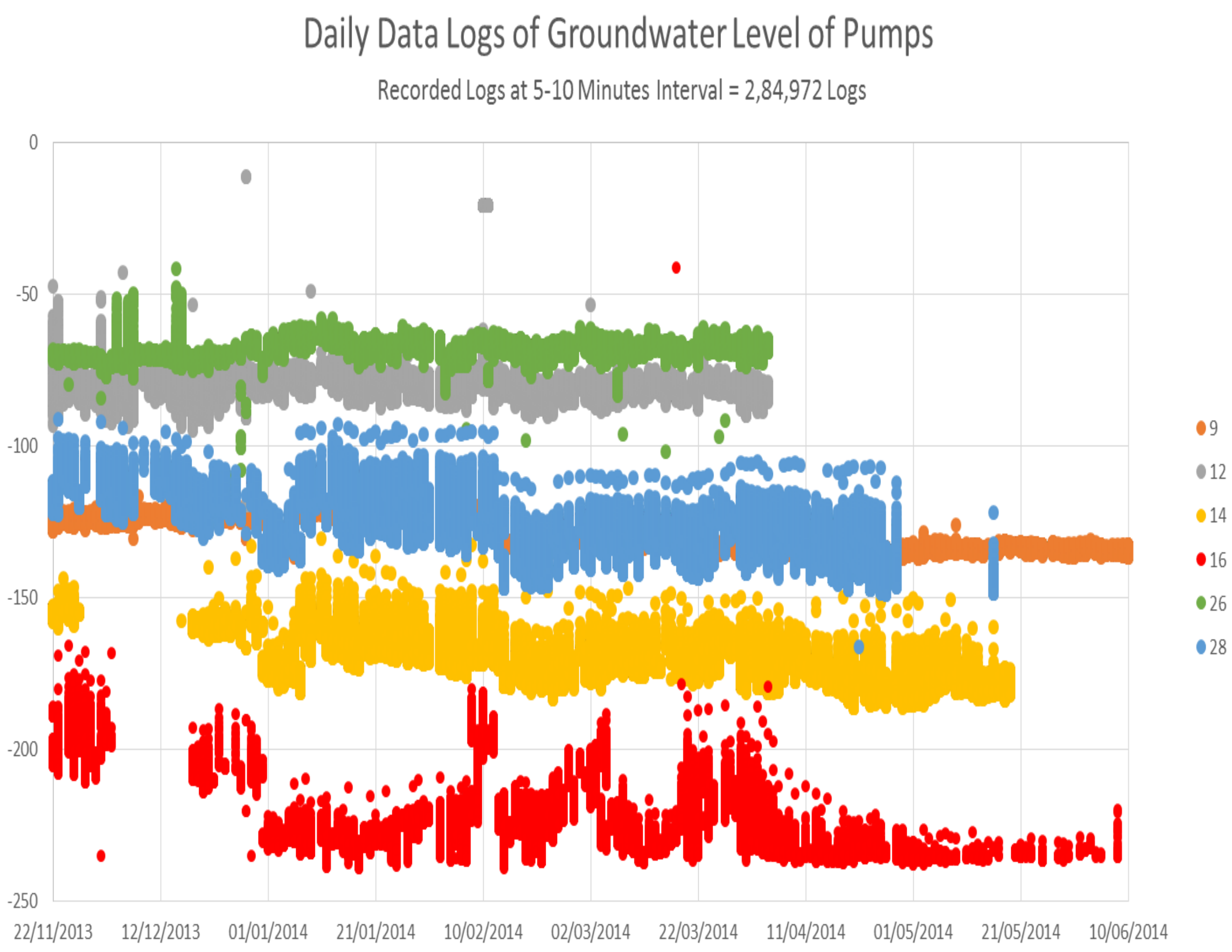


Figure 7: Daily Water Level Logs at 5-10 Minutes interval for 6 Pumps in meters

The water level of pump No. 16 represented in Red has reached the depth of the bore well and it has been observed that the water contains significant quantum of sand. The pump failed on 19th March 2014 and was replaced immediately. The events that led to the failure and the data during failure is highlighted in Section 3.5 along with the strategic insights for scientifically managing the wells.

The pumps, P9 and P28 seem to operate on a more stable aquifer regime under similar water levels. The water level over August 2013 – March 2015 of this pump is represented in the following figure that shows a significant variation of around 10 Meters over this period. The variation in the other pumps is more profound as evident from the earlier figure.

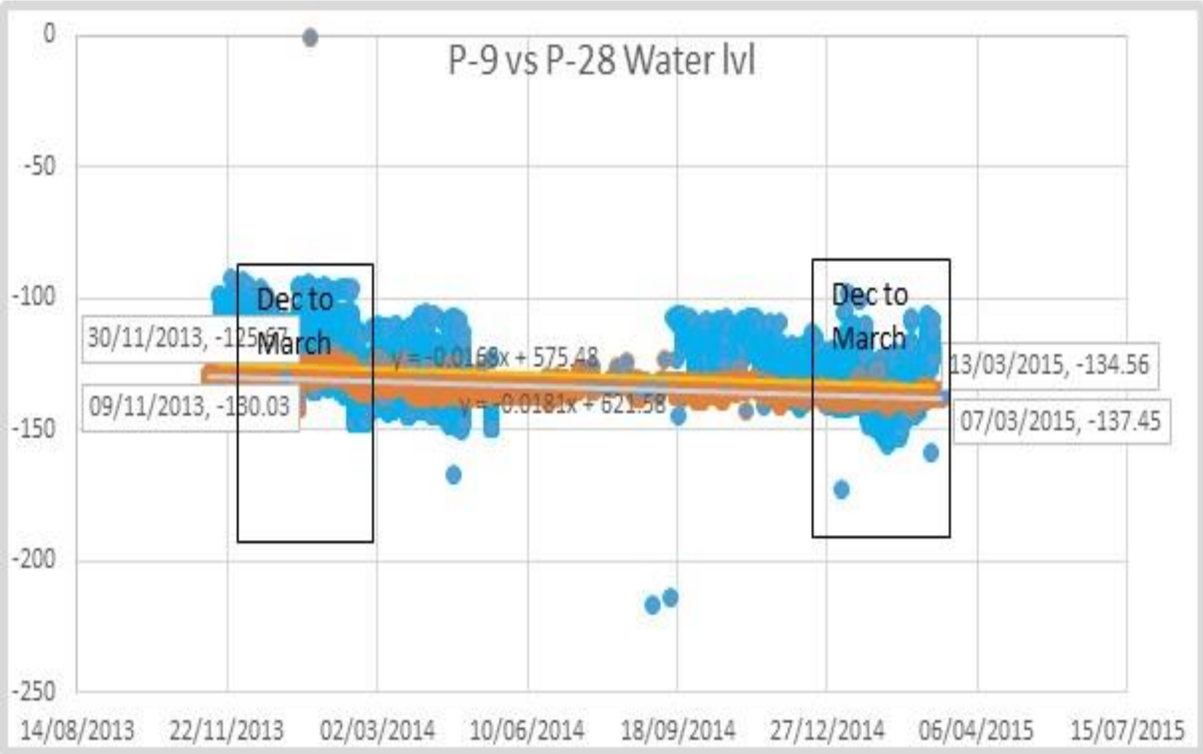


Figure 8: Yearly Water Level Trends for Pumps 9&28

As we need more technical expertise to interpret the aquifer and its behavior, the issue had been referred to Dr. Himanshu Kulkarni of ACWADAM. His observations on the hydrogeological aspects based on the initial data have been submitted to CIPT. His observations have helped us to added new dimensions to the data analyses. The insights derived from real time aquifer monitoring could help to evolve into a sustainable solution for aquifer management as well as making optimum choice of pumping assets.

2.6 Optimizing Water

Based on the study on equitable water use per cultivated land area, we have estimated the optimization opportunities for reduced water consumption from the present annual consumption of 36,20,399 to 30, 81,009 cubic meters by restricting excessive water use as displayed in Fig.5 . The saving opportunities in water use have been computed below based on this study.

1. **Equitable water use at a pump level at each farmer's cooperative = 15% ;** assuming a potential opportunity of reduction of water use above the average water use of the village.
2. **Optimum water use at a farm level;** would be even more than the above and can be assumed at least at the above levels, considering various options of crop selection to managing the soil moisture levels based on the continuous simulation of predicted / monitored moisture levels.

A water saving target of 10% on both the above counts totaling to 20% saving can be targeted in 4 to 5 years' time. Since there is no direct economic value attached to the water, the implications on optimization can be understood only from its Sustainability implications. Better management of water will have radical economical social and environmental implications for all the stakeholders, analyzed in detail in Section 4.

2.7 Knowledge impact on Sustainability

The critical impact on Sustainability that can be optimally managed based on the knowledge on the aquifer are identified as follows and computed in the subsequent sections.

1. **Reduced energy consumption by optimizing the design of the well, matching the operating head of the pump with the optimum design head of the pump based on the water level and aquifer data captured and analyzed through the system:** Obviously, greater energy will be required for lifting water from a deeper well, as the water level falls. The energy use can significantly go up per unit discharge of water if the design is not optimized according to the falling water level.
2. **Increased Life of the well, by optimally designing the bore well taking into account the scientifically predicted water level, yield and sustainability:** The current average life of the well is 3.2 years as detailed in the next section and a more precise computation of the hydraulic parameters can extend the average well life by 25%, as detailed in the subsequent sections. This can make a major difference in the profitability of the farmers and the viability of agriculture in the region as this is a major capital expenditure.
3. **Improved productivity through Optimum Irrigation will make the biggest impact on sustainability**: The productivity gains and the additional incomes thus generated would far outweigh the other economic aspects.
4. **Climate change adaptation is another major aspect where this knowledge can play a critical role. This might have an indirect bearing on productivity.**

The imperative is to have a holistic perspective for sustainability. Various options for sustainability with stake holder engagements and dissemination of the requisite knowledge, exploring its economic viability have been discussed in Section 4.

2.8 Requirements for Optimization

The optimization opportunities discussed above can be realized with the help of the following:

- Metering water use at the farm level.
- A water audit for the target village, assessing the water availability, requirement and water balance at a pump / farm level and establishing a base line consumption.
- An integrated approach understanding the linkages in Water-Energy efficiency

The technology innovations have made it possible to cost effectively integrate and automate the above functions. The technology choices have also been discussed under Section-4.

3 Energy use and efficiency

3.1 Asnapura Feeder

The Asnapura feeder supplies power at 11 KV to the 28 pumps in Asnapura village. All pumps in use are submersible borewell pumps ranging from 50 HP to 100 HP. Each pump has a dedicated transformer which steps down the power to 433V 3-phase LT power supply. The power supply under this feeder is fairly stable with very minimal voltage variation. Power supply is available to all the pumps for 8 hours. A dedicated energy meter is provided under this program for each pump duly tested and calibrated by UGVCL.

3.2 Energy use & Efficiency

The total energy consumption of the 28 pumps connected in the feeder for the year for 2014 is 3.602263Million Units. The following figure represents the annual energy consumption by the pumps in use under the Asnapura feeder shown along with the energy use per unit cultivated land area (bigha).

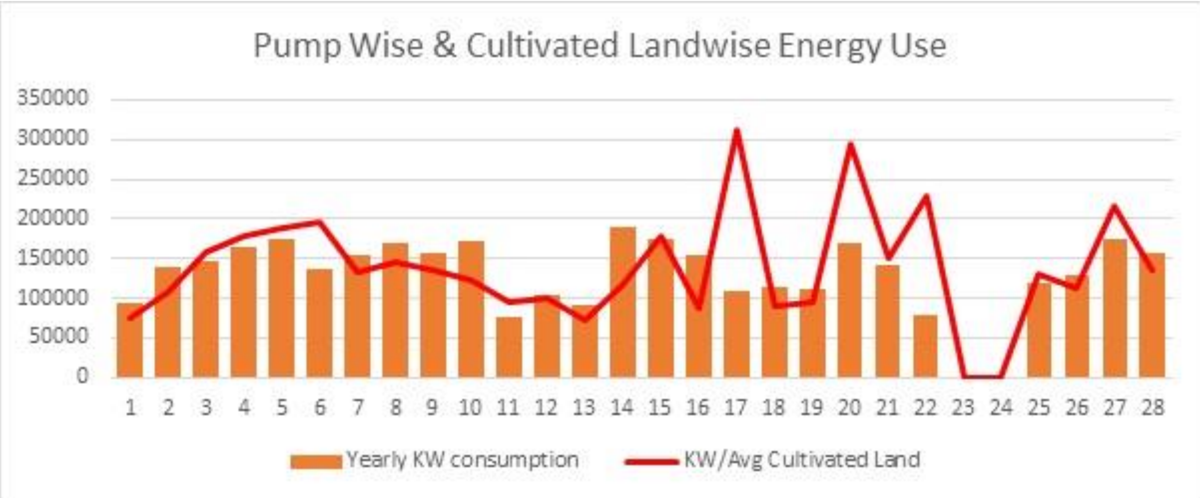


Figure 9: Pump-wise &Cultivated Land-wise Energy Use

3.3 Factors contributing to Energy Need

The comparison of energy use by the pumps during 2013 and 2014 shows that the energy use remained fairly stagnant despite the fall in the water level and reduced water withdrawal. This is due to the fact that the same pumps draw lesser energy as the head increases, but can draw more energy due to pump deterioration. Replacement by a higher capacity pump will be required to lift the same quantum of water, as the water level decline permanently. As such there is a need to look at the fundamental measurement for energy efficient agriculture from a perspective of sustainability, considering the measurable economic outcome of the energy usage, instead of going simply by the energy consumption of the feeder or the pump

The critical factors that contribute to the energy use per bigha land are outlined below.

1. Water applied per unit area
2. Pump Head / Water Level
3. Optimum Pump Selection
4. Operating Efficiency of the Pump

The water used per unit area may depend on the crop pattern and climatic conditions. The imperative for optimum irrigation is to measure the water used, or else the agricultural fields will be either under or over irrigated most of the time. As the overall crop pattern by a farmer group of 10 to 14 farmers per pump remains more or less similar, the water use per unit area by a pump can be directly compared. The pump head depends on the ground water level during the operation of the pump. The head and flow requirement is a critical aspect for optimum pump selection and it is essential to make the best match within the ever falling water level in the region. Most of the pumps in use in the area are branded pumps (Makes: Uneel=15; Duke=2, RSB=1, NSP=4, Jasco=2, Falcon=2, Unknown=2).

In the absence of scientific means to compute the precise pump capacity based on the water available and the head flow requirement, farmers have no alternative but to resort to vague assumptions, often with excessive margin distorting the optimum selection of the pump. These factors alone contribute to 18% of the energy losses in pumps which is easily avoidable with the help of accurate information on water levels and aquifers. Another casualty of the wrong pump selection, is the improper water use leading either to over irrigation or under irrigation, with major ramifications on sustainability.

3.4 Operating Efficiency of Pumps

Each pump in use at Asnapura Feeder has been subjected to extensive testing at site, mapping the behavior characteristics of each pump as at site. The manufacturer’s pump performance curves have been collected for computing the Head versus Flow. The Power versus Flow characteristics have been established based on site test as the manufacturers in India generally do not providing this data for agricultural pumps. The following figure represents the efficiency declared by the manufacturer as well as the operating efficiency and the BEP of the pump at site derived from the simulation using the test data with the help of the Datamatrix software. It has been observed that there is a significant variation from the manufacturers design efficiency and the operating BEP, even for the new pumps. This is a pointer to the fact that the pumps are not performing as expected based on the manufacturer’s design.

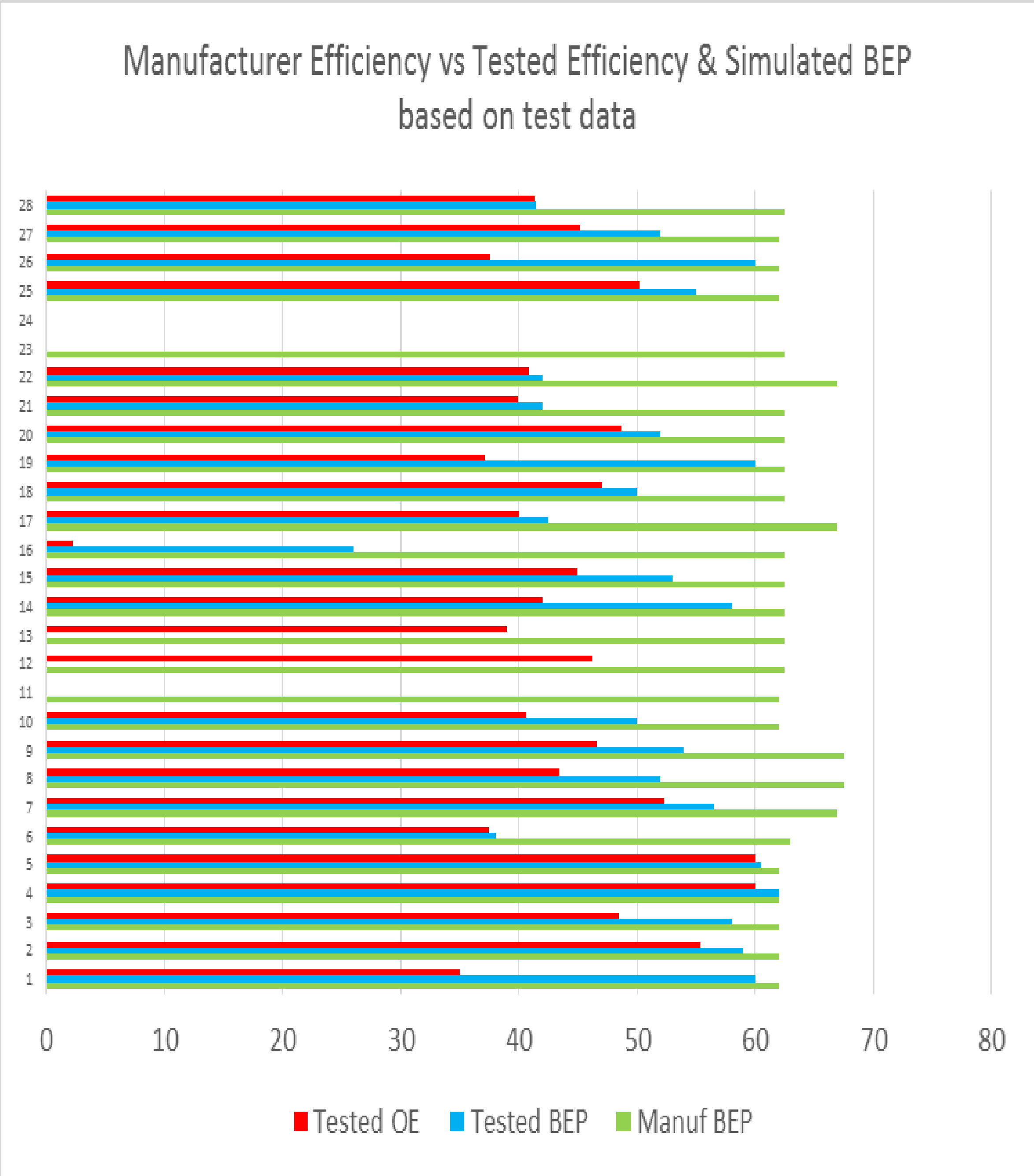


Figure 10: Manufacturer BEP vs Tested BEP (Simulated) & Operating Efficiency

3.5 Pump Efficiencies

Detailed performance tests have been carried out for each pump measuring the Head, Flow and Power as at site. Few of the pumps (indicated only with the manufacturers' efficiency/BEP) are completely sealed without any access to measure the actual head. The discharge and energy used by each pump in operation has been tested at site. The average efficiency of the pump based on the manufacturer's data is 63.2% while the BEP simulated from the test data is 51.48% while the average operating efficiency of the pump is observed as 43.26%.

The following figure indicates the borewells with the year of installation vis-à-vis their water levels.

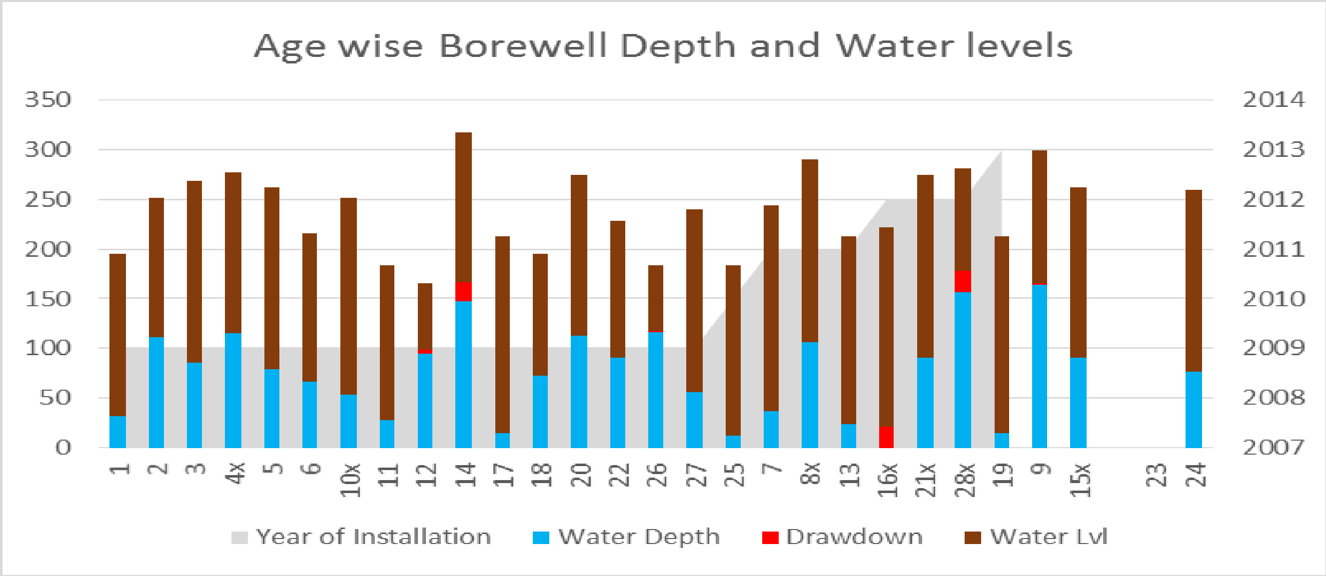


Figure 11: Age of the Borewells

Due to the steep decline in the water levels, the average life of the bore wells has come down to 3.2 years. Several direct and indirect factors contribute to this. It is obvious that the well may not yield sufficient water as the level has reached its bottom. The farmers now are increasingly adapting to a practice of making the well far deeper than the requirement, fearing that the levels may drop significantly. Since the pump can have only one BEP, the best efficiency can be designed either for today or at the declined water level. In the absence of a clear understanding of the aquifer the optimum pump selection is difficult. Often, the pump head and flow do not match with the requirement when the level is changed and the farmer will have to change the pump or dig a new well without having a clear understanding of the problem.

There is a compelling need to equip the farming community and other stakeholders on the water levels, availability and sustainability to efficiently manage both water and energy. Often, more energy is lost due to the poor design in appropriately estimating the head and flow requirements than selection of the star labelled energy efficient pump. Perhaps the dynamic water level may be one single factor that can help the optimum design and the optimum energy requirement and water delivery for pumps. The need of the hour is to have a better understanding of the aquifer. The aquifer being a common pool resource, the responsibility squarely rests with the government in making this information available. The government is ill equipped to address this challenge as the traditional methods are inadequate to monitor the dynamic aquifer behavior and arrive at an accurate and reliable understanding of the water level in the borewells on a large scale. The conventional approaches are prohibitively expensive and the need of the hour is to identify and engage technologies that can cost effectively address these challenges.

3.6 Operation & Maintenance

The Operation and Maintenance of the pump is a critical factor for the optimum water and energy use. The optimum selection of the pump will minimize the problems associated with O&M. Following is the case study presented on Pump No. 16. It was observed that this pump was operating with low water level and the discharge was intermittent. The following data log diagrams indicates the logs with discharge and zero discharge intermittently.

It has been observed that 25% of the logs indicate that the pump has been running with almost the same energy consumption even when no discharge was taking place. It is possible to save this energy either by intermittently switching on the pump after allowing the water to recoup or by using a pump of smaller capacity that matches the yield of the well.

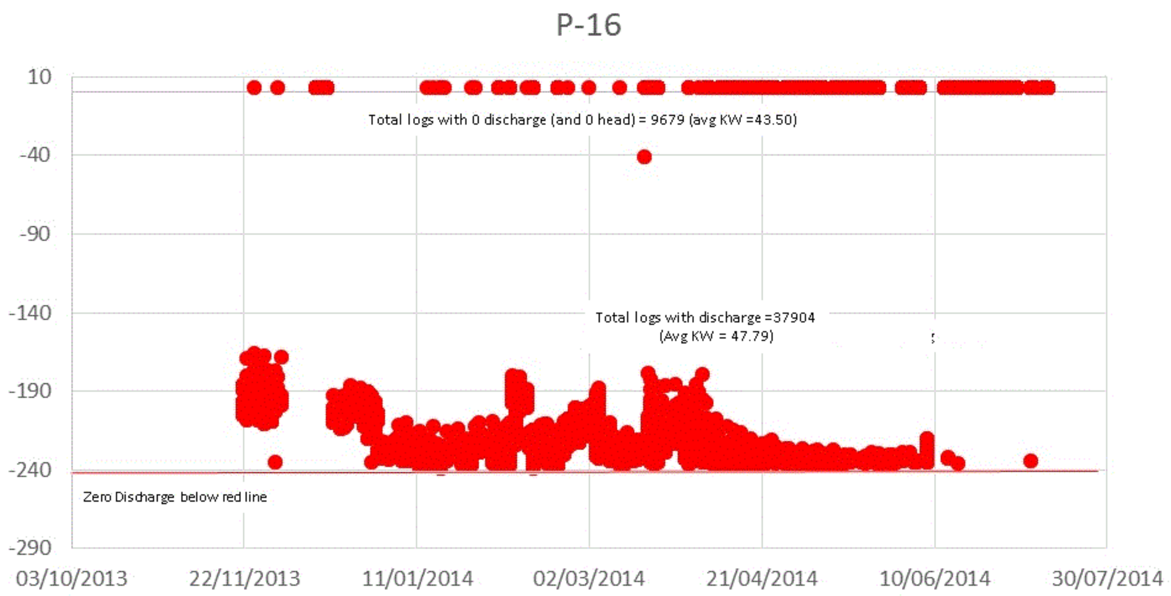


Figure 12: Pump No. 16 with intermittent discharge

The pump failed on 19th March 2014 and was replaced immediately by an identical pump, as captured in the following daily pump head variation reports. Though the discharge has temporarily improved for some time after replacement of pumps, the discharge dropped significantly within a months time as indicated in the daily pump head variation before and after the fault and after one month. The farmer has resorted to raising cattle reducing the cultivated land and need for water. Of late he is facing difficulties in getting the required drinking water for the cattle and this scenario if unchecked will raise serious livelihood issues, unless a minimum supply of water is assured for all.

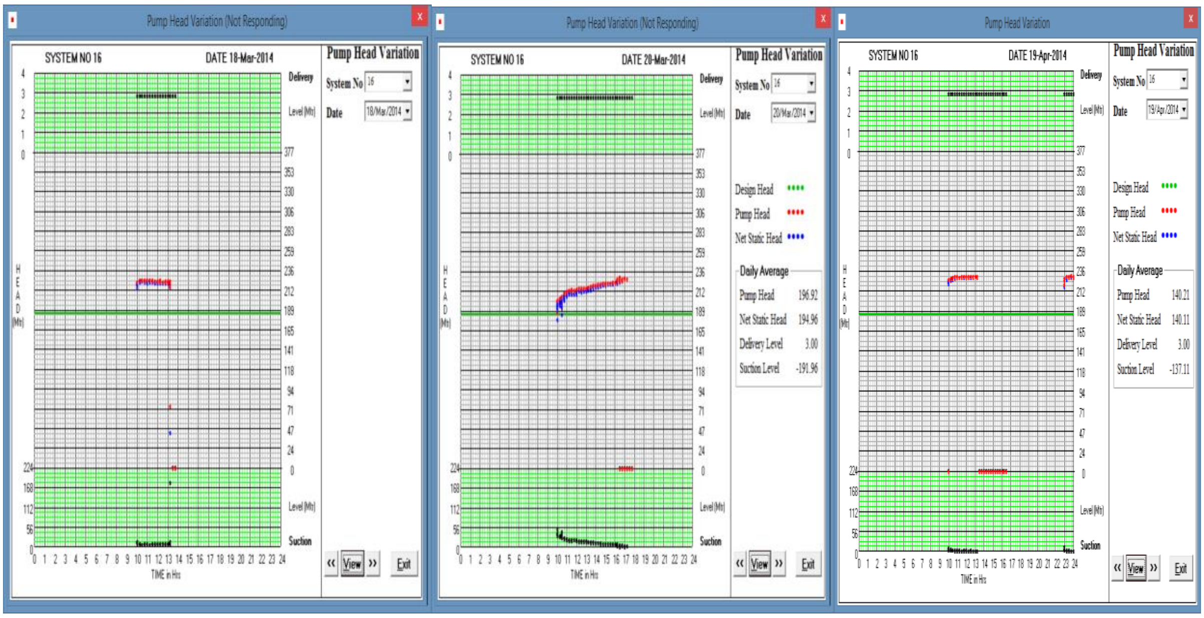


Figure 13: Daily Pump Head & Ground Water Level for P16

3.7 Energy Saving Potential

Based on the above study, the potential for energy savings are computed as follows:-

I. Energy Savings from Reduced Water Consumption (Refer to the previous section)

1. Equitable water distribution = 15%
2. Optimize water use and soil moisture management = 15%

II. Energy savings through Asset Management

1. Optimum Pump Selection = 15.28% (The difference between BEP & Op. Efficiency)
2. Matching the yield and pump capacity = 4.17% (Excessive Draw down/No discharge)
3. Pump Replacement = 24.35% (The difference between Manufacturers Eff. and BEP)

3.8 A new approach to energy efficiency

The critical resource needed to realize the above benefits is the measurement of energy and water at the point of withdrawal. It is necessary to further analyze this data to arrive at a clear understanding on the aquifer, yield and the operating head for each pump. This will help to precisely match the head and flow requirements for optimum pump design, with a potential saving opportunity of 19.45%.

The precise computation of water use per unit area on a real time basis will help to calibrate the water used, against water requirement to arrive at the optimum irrigation to have the desired level of soil moisture. This would also help to make better choices by the farming communities enabling a to better choice of crop based on the water availability and sustainability. The imperative is to have a holistic understanding of the energy and water scenario with precise understanding of aquifer, water availability and withdrawal by each user.

The efficiency gap between the manufacturers' declared efficiency and the operating BEP of the pump as at site (Derived from Datamatrix Simulation of Site test data of the pump) shows the extent of performance deterioration of the pump. Accordingly, the overall performance deterioration of the pumps at Asnapura is computed at 24.35%. It may be noted that the pumps are fairly new and this high percentage in deterioration may be due to the under performance of the machines as compared to the manufacturer's pump performance data due to various factors at site. This performance cannot be realized unless there is a better understanding of the pump operation. This is a costly intervention in comparison with the other knowledge based interventions suggested above, and there is a need for creating a knowledge base for better understanding of pumps for optimum replacements. It shall be borne in mind that all machines keep deteriorating over time. The effective savings in the long run based on optimum replacement is estimated to be half of this saving potential, arriving at a net saving potential of 12% through timely replacements and asset management. It is important to note that mere one time replacement of pumps, as commonly practiced as an energy efficiency measure is not a sustainable solution unless the well and pump dynamics are clearly understood, particularly on areas with significant fall in the water levels.

Based on the above facts and figures and potential saving opportunity, we would like to set a practical target (optimum) of 50% achievement of the total saving potential in 7 Years. This will work out to an improvement in the energy efficiency to the extent of 37.54%. **It will be practical to chase a target of 35% improvement in the energy efficiency in agriculture in 7 Years' time.** The saving target and the priorities shall be decided by each village / farmer group depending on the specific problems to be addressed in the village. A village water committee shall be constituted under the

Village Panchayat to manage the water resources of the village and govern this initiative, effectively addressing their needs and challenges. The representative from the village, Government and Academia along with NGO/Private sector can manage the sustainability. Other than the support for creating the Knowledge Infrastructure few successful pilots, the investments can be through the Farming Community/ NGO / Private Sector.

3.9 Standardization

The critical challenge will be to ensure a well-structured Metering, Monitoring, and Measurement & Verification process that can be easily replicated elsewhere. Over the last decade, the Energy Management Standard ISO 50001 and IPMVP - International Performance Measurement & Verification Protocol were developed. These can be effective tools that can be readily applied to this scenario for managing energy and water with continuous improvements. These standards will ensure data quality and a stringent management process for continuous performance optimization with measurable and verifiable cost reduction that can be easily replicated. Since energy is the basic measurement, this process will have vital significance in the overall quality and reliability of measurements, when the program is expanded to large areas. Careful selection of the technology that entails very high degree of domain knowledge and innovation to achieve this mammoth feat, cutting across many disciplines is the key to the success of IWERM

4 Exploring IWERM

4.1 IWERM & Sustainability

Integrated Water Energy Resource Management is a new approach experimented under this project to study and understand the water energy nexus and its implications on sustainability. The direct impact on improving the water use efficiency through water management and energy efficiency is mainly on account of the asset management as elaborated in the earlier sections. The economic impact on productivity and the asset carrying cost is even much larger. We have made an attempt to estimate the same in the following sub sections, to get an overall picture, even though this is not the major focus of this project.

4.2 Sustainability linkage to Productivity

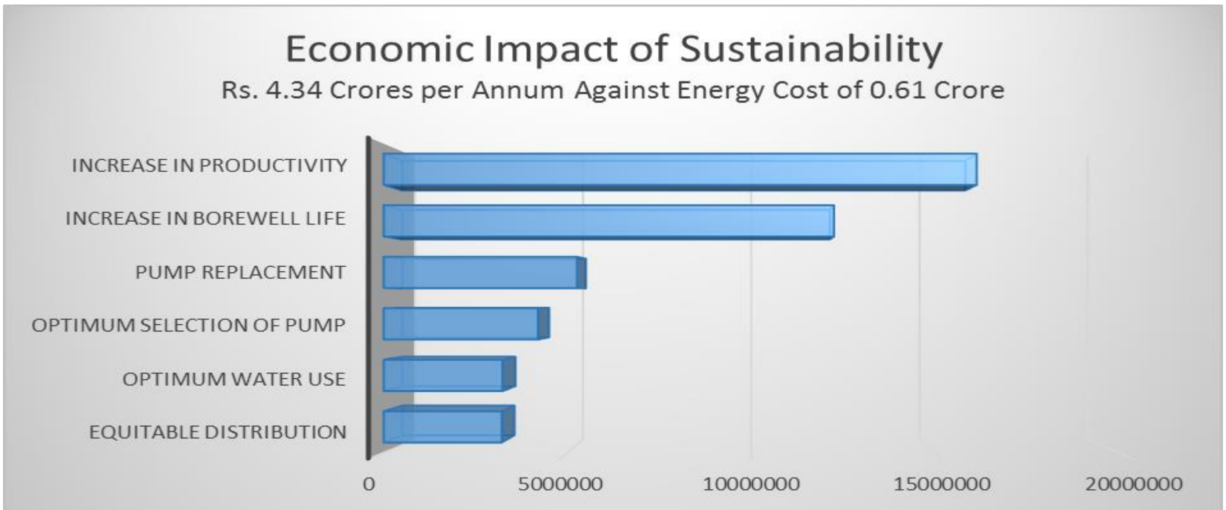
This study demonstrates that inefficient management of energy and water can make far greater sustainability implications with cascading economic impacts. In order to draw a hypothesis, we have worked out the value of the agricultural produce and its potential improvement in the yield based on the irrigation/soil-moisture management using real time data capture and analytics made available to each farmer and a community driven water management program. The dynamic knowledge on water and energy as detailed in the document becomes crucial for climate change adaptation as well. The potential improvement in productivity at a conservative estimate of 20% per annum by the end of the 5th year, would lead to a 40% rise in the income of the farmers leveraging the critical knowledge on water use and moisture management along with improved farming practices.

4.3 Extending the Life of the Borewell

At present, the prime difficulty facing the farming community at Asnapura and most of the areas in north Gujarat is the need to put up new borewells due to the ever falling water levels which is unpredictable and is less understood by the farming community from a scientific perspective. It has been observed that the age of the borewells in this village ranges from 1 to 5 years. We have observed that there is an opportunity to improve the life of the borewell by 25% or more through optimum borewell design and pump selection with a better understanding of the aquifer and its behavior. Considering the current head and yield mismatch with the pump design, and the rate at which the water level is declining, there is a huge scope to study and incorporate the dynamics into the design of the well to extend the life of the borewell. The cumulative effect of water management can also improve this scenario.

4.4 Economics of Sustainability

Consolidating the direct cost implications of water, energy and sustainability, we have illustrated a typical economic scenario for Asnapura village as highlighted in the following figure.



	Equitable Distribution	Optimum Water use	Optimum Selection of Pump	Pump Replacement	increase in borewell life	increase in productivity
Series1	3218261.764	3242036.7	4203840.9	5262976.2	12250000	16128000

Figure 14: Sustainability Impact & Economic Outcome

The preceding figure indicates the combined economic impact of water and energy savings, reduced asset carrying cost and productivity gains. Even though water has no direct economic value, the saving of water will reduce the energy need to a great extent. This is one of the most desirable forms of energy savings with maximum impact on sustainability. Please note that the projections are made for maximum achievable economic gains and it is necessary to prioritize and target the improvements to systematically achieve the optimum level of sustainability and economic benefits with the minimum resources. The carbon emission reduction by way of energy savings is estimated as 1299 tCO_2 per annum due to the annual energy savings of 1260MWH.

4.5 The Key Learnings from the Project

This study clearly establishes that there is a new knowledge centric approach required for sustainable gains. Piece meal solutions such as replacement of pumps as practiced today are not sustainable in the long run, unless a holistic approach is taken. It is also necessary to adequately compensate the utility for the energy saving rather than just managing the energy sale to make a paradigm shift in the approach. With their large pool of engineering skills at their command, utilities can undertake or supervise the critical Metering, Monitoring, and Measurement & Verification Process (3MVP). It will then be easy to fund the above sustainability improvements with measurable and verifiable performance matrices.

4.6 The Hard Learnings from this Project

This pilot project comprises dedicated energy meters for each pump, and establishing a communication network with the remote server for continuous transfer of energy data from various pumpsets connected in the field. The Datamatrix system has been configured with the test data of each pump that replicates a mathematical model of each pumpset in the remote server that will replicate the performance characteristics of the pumps in the field. The technology interprets the energy data into the hydraulics and performance parameters deriving the discharge, dynamic suction head, and machine efficiencies on a continuous basis.

The work at Asnapura started with a detailed site survey immediately after signing the contract, but the testing work was delayed for one month due to the unusual rains in 2013. The testing also took unusually long time (45 days) particularly for accurate measurement of the water levels in the deep bore well and to create the draw down effect for calibration of suction levels of the pump. The measurement using a precision air pressure gauge to calibrate the changing water levels against pumping was cumbersome for very deep wells. The sonic water level measuring instruments now available in India shall be tried for future projects with scale. Their accuracy levels shall be established to measure the drawdown levels. Along with a Flow meter with GPRS communication, this testing process can be a simple process, that can be undertaken by the villagers and the data can be remotely captured. This can immensely help in scaling up the program.

It was not possible to use the conventional smart grid solution for the energy data communication as the solutions available in the market communicate only few energy parameters on a daily basis. We require the complete energy signature/data on a much closer polling interval of 5 minutes to half an hour. Hence we decided to develop an appropriate hardware required for the data communication. In order to capture the required data, and carry out the basic analytics with high resolution data required for extrapolating the data to the other tested pumps, we had identified six pumps to be connected and analysed in detail. We used our fully developed high cost industrial hardware each pump capable of transmitting the data of 24 pumps simultaneously with all required energy parameters within one minute interval, along with the provision for several additional analog parameters such as temperature moisture sensors etc. Since the distance between the pumps was very large, we had to use one dedicated Industrial Unit for each pump, as against the general practice of connecting about 20 pumps to each unit.

We explored various technologies that can be used to scale up this program, and identified the RF based technology from Israel as the most suitable and cost effective for this application that would enable easy scale up of this program. The Israeli firm agreed to develop the product, capturing the Datamatrix requirements for telecommunication, after a visit to their office and detailed discussions at, Israel. The unique advantage in using this technology was that a simple antenna mounted at 8 feet height over any building in the village can pick up signals from the RTUs connected to the meter within a range of 10-20 KM. Considering the fact that the pumps in Gujarat are spread across a distance of 2-3 KM, this was the most desirable technical solution. Accordingly we imported a Base station and - Remote Terminal Units and carried out extensive trials at Pune.

Figure 15: Datamatrix GPRS Solution deployed at Asnapura (left) & the Israeli RF Based Communication Solution being Tested at our Lab for this project (right)

Unfortunately the management of this firm changed during the test run, and we faced problems for the technical support during the trials after the initial commissioning. This has forced us to put the deployment on hold to scale up the requirement, using this technology. The product is good and we would like to use them in future, if the support issues are sorted out. We have decided to develop a simpler GPRS based communication device for agriculture applications and this product is scheduled to be released in April 2015, which will be cost effective for large scale agriculture applications. Indian Smart Grid Manufacturers will be able to develop the Energy Meter with the required communication arrangement as per our requirement, provided there is an assurance for a minimum quantity to make it viable for development and manufacturing.

The Big Data architecture is another area we have initiated during the course of the project as the originally designed data management solution at the Columbia University, NY was not adept to handle the large amount of data regularly polled into the system on a real time basis. The matter was discussed with the concerned professors at Columbia University and we have diverted the data to our cloud with the requisite architecture to capture and analyse the big data to draw clear inferences for our sustainability studies. The data logs still continue as of date beyond the expiry of the contract period of one year. This has enabled us to carry out the critical studies on ground water depletion over the last year and this year. This project and with its data captured and analysed continuously established that 'Big Smart Data' is at the heart of the road ahead to address the Water Energy Food (W-E-F) challenges facing the world, and the academia across the world may have a leading role in structuring this knowledge as this knowledge is yet to be formulated studied and structured.

4.7 Road Ahead

A big Smart Data Platform established in the cloud environment is to be provided for the selected Villages in India for implementing IWERM. We will connect the pumps to our system for Integrated Water-Energy Resource Management. An additional weather station and few soil moisture sensors at select locations for calibration shall be provided for each Village. This data will be integrated to our system. A Knowledge Dissemination Centre for Sustainability shall be established for each village or a group of villages to help use the information for improving the agricultural practices leading to productivity gains and sustainability. It may be even a single person carrying the training and knowledge interface with the farmer.

The center will disseminate the following information provided to the farmers through a Smart Phone App.

1) Daily water Use by each Farmer.
2) Real Time Moisture Levels (Directly measured /Simulated based on water applied)
3) Daily Energy Use and Efficiency and Automated Condition Monitoring of Pumps
4) Aquifer Mapping Water Forecasts & Water Balance Studies
5) Weather forecast and records

The solution provided will be fully integrated to decipher the water-energy nexus and will cost only a fraction of the conventional solutions, as all key parameters are derived from the energy inputs. The program can be easily scaled up through a 'Rural Smart Grid' Initiative. The Smart Phone App for Agriculture cost effectively predicting the moisture, water and energy and performance at farm level is already under development at Datamatrix, and is expected to be released shortly.

The human resources required for project management may comprise the following teams.

1) On site project management team
2) Remote Monitoring & Analysis Team

3) Expert Advisory (Aquifer, Pumps, Energy etc)

4) Best Practices Standardization through ISO 50001 Implementation

Datamatrix uses Energy as the basic measurement as it is more stable, reliable and cost effective in comparison with cumbersome measurement of hydraulic parameters. The Datamatrix System can derive hydraulic parameters from the energy data. The soil moisture levels are derived from the calibrated water use per unit cultivated land with corrections of the weather conditions. More over 10 to 50 energy parameters can be measured with a single energy meter as against the need of several costly instruments for the measurement of various hydraulic parameters of water. Creating a robust energy management practice linking energy and water will help the implementation of 'Plan Do, Check, Act', for continuous improvements for water applications as well, in the absence of such standards for water use efficiency.

The strategic intent is a continuous reduction on energy subsidies by linking energy price to efficiency, within the prevailing energy tariff, using dynamic knowledge for improved agriculture practices.

5 IWERM Business Model

5.1 The Customer Needs

Farmers use Water, utilities provide them energy and their need is the right soil moisture!

There is a total misalignment of the Water-Energy-Agriculture management paradigm in terms of fulfilling this user requirement. During the discussions with the Managing Director of UGVCL, Mr. Srivastav, it was pointed out by the CIPT-Datamatrix team that most of the energy distributed by UGVCL (more than 50%) is supplied for Agriculture. The utility is mainly engaged in the business of Supplying Power for Supplying Water. With a positive acknowledgement from Mr. Srivastav and his team on the need to look at the energy from a different angle, we started working on redefining the role of the stakeholders to meet the requirements of the end customer, the Farmer. Mr. Srivastav has also requested to give a proposal in this regard.

The missing link was the knowledge on Water-Energy-Agriculture nexus. We have restructured the knowledge derived from the project to address this challenge. The knowledge was converted onto a set of actionable performance indicators having a direct bearing on the economic outcome for Water Efficiency, Energy Efficiency and Sustainability.

5.2 The Scheme

The IWERM vision is to significantly improve the productivity and sustainability of farming, leveraging knowledge on common pool resources (Water-Energy Resources) as a key input for sustainable agriculture. The villages facing difficulties in managing water resources and those villages where there is a total agreement by all farmers to join the scheme will be preferred for piloting this program. The financial model currently built on energy sale, will be gradually shifted to water sale, at a reduced cost to the farmers with the improving efficiency. The farmers will be happy to embrace this model as their requirement is water and not energy and the total price will be less than the current bill for the farmers, depending on the improvement in energy efficiency. The program will entail better water management ensuring improved water availability for the farmers based on the technology driven water management program. All the pumps in the village will be metered for water and energy using the Datamatrix Integrated Metering Solution or separate energy and water meters will be provided for each pump.

5.3 Business Model & Pricing Strategy

The farmers will be free to opt for a billing scheme against the water utilization instead of energy use as in the practice today. The farmer will be able to choose any one of the following three options:

A. *Continue with the existing practice of energy based billing as in the practice today.*

B. *Use water as the basic commodity for billing in place of energy; provided the energy and water efficiency meets a basic performance criteria.*

C. *The most energy and water efficient farmers (5 to 10%) will be provided with free electricity and water.*

The overall billing within any farming community coming under the program shall not exceed the total energy cost of this community at the prevailing tariff.

The reduction in the energy subsidy to the extent of improved water-energy efficiency shall be ploughed back to bring more and more farmers operating under energy and water efficient regime, encouraging more and more farmers to subscribe to the free electricity and water scheme. It may be noted that the Government spends more on energy subsidy to agriculture than the electricity charges paid by the farmer. This scenario provides enough cushions to bring more farmers under Free Electricity & Water by tying up the loose ends of knowledge for sustainable agriculture. In future other subsidy schemes of the government aimed at Farmers such as fertilizers subsidy etc. or even agricultural loans will be delivered only if the farmer qualifies himself as a green / sustainable farmer under category B or C.

Soft Loans can be offered to the farmers for pump replacement, subject to the approval of the Auditors confirming economic viability and performance criteria. The extent margin to be provided by the farmer will be based on the subsidy reduction that can be recovered directly by the bank minimizing the risk. The bore wells in general should not be funded by the Government as it is risky and it will not add to the water-energy efficiency, unless it a compelling case with lesser head and water availability. The annual audit team shall recommend the sustainability category of the farmer to make it easy for accessing funds for sustainable farming.

5.4 Managing the Program

The farmer group supported by a service provider will be responsible for Integrated Water-Energy Resource Management. The service provider or an expert group shall provide remote monitoring and specialized advisory services for water-energy and agriculture efficiency. The expert group may carry out detailed aquifer mapping and analysis based on the data captured for sustainable water management. The farmers under the scheme will be provided with water-energy-agriculture knowledge management and support services including remote monitoring control and automation facility of pumps through Datamatrix or similar systems. The scheme will assist farmers with critical knowledge for optimizing productivity and attaining sustainability. The farmers under the scheme can access the data and control the pumps through a mobile app. made available to the participating farmers.

The basic knowledge infrastructure may be provided by the Government, taking advantage of the large scale and standardization. The smart metering / Smart Grid shall be provided by the Utility. The Knowledge Management & Audit Cost shall be initially borne by the Government / Utility and subsequently borne by the farming community.

5.5 Implementation

The schemes can be rolled out on the areas that are facing the crisis, where the farmers are more likely to engage with a wholehearted support. The proposed scheme can be implemented within the prevailing energy tariff of the Utility supplying power to the farmers. This scheme can be started as an option given to the farmer. He may choose this scheme or the present basis of energy billing. All energy and water use must be metered in the locations where the scheme is to be implemented. The scheme if implemented correctly can make the farming sustainable and would be politically correct, as our goal is to provide Free Electricity & Water to more and more farmers, making constructive use of the subsidy.

It is also possible to remotely control the pumping systems with the technology brought under this scheme and this feature can be used for Demand Response Program. This can be a major attraction for the Energy Utilities in future, considering the ability to shift to load in Agriculture to manage the peak demand of the Utility. The cost of the technology can significantly come down with the scale. It may be possible to make the technology available on a SaaS model while the Smart Grid & Audit Services can be routed through the routine tendering process of the Government, once the program reaches a particular scale. This program can be linked to the smart grid and smart metering program of the Government, for an accelerated implementation maximizing the return on these investments.

5.6 IWERM Differentiation & Debate

A preliminary study comparing Precision Farming and IWERM reveals that the dynamic knowledge is the critical input to augment productivity gains in both cases. The instrumentation cost of precision farming would be out of reach for most of the Indian farmers in the foreseeable future. The IWERM program aims at attaining sustainability by providing unique knowledge input to the stake holders for optimum irrigation, under an ever changing operating environment. Several scholars argue that 'Green Reveloution-2.0' for India would be entirely knowledge driven. India has the requisite technology, knowledge, infrastructure and institutions to manage this and quickly scale up at a National Level. The debate we need to continue is what are those critical knowledge and its linkages and how we can create and manage this knowledge, particularly addressing the common pool resources of Water & Energy.