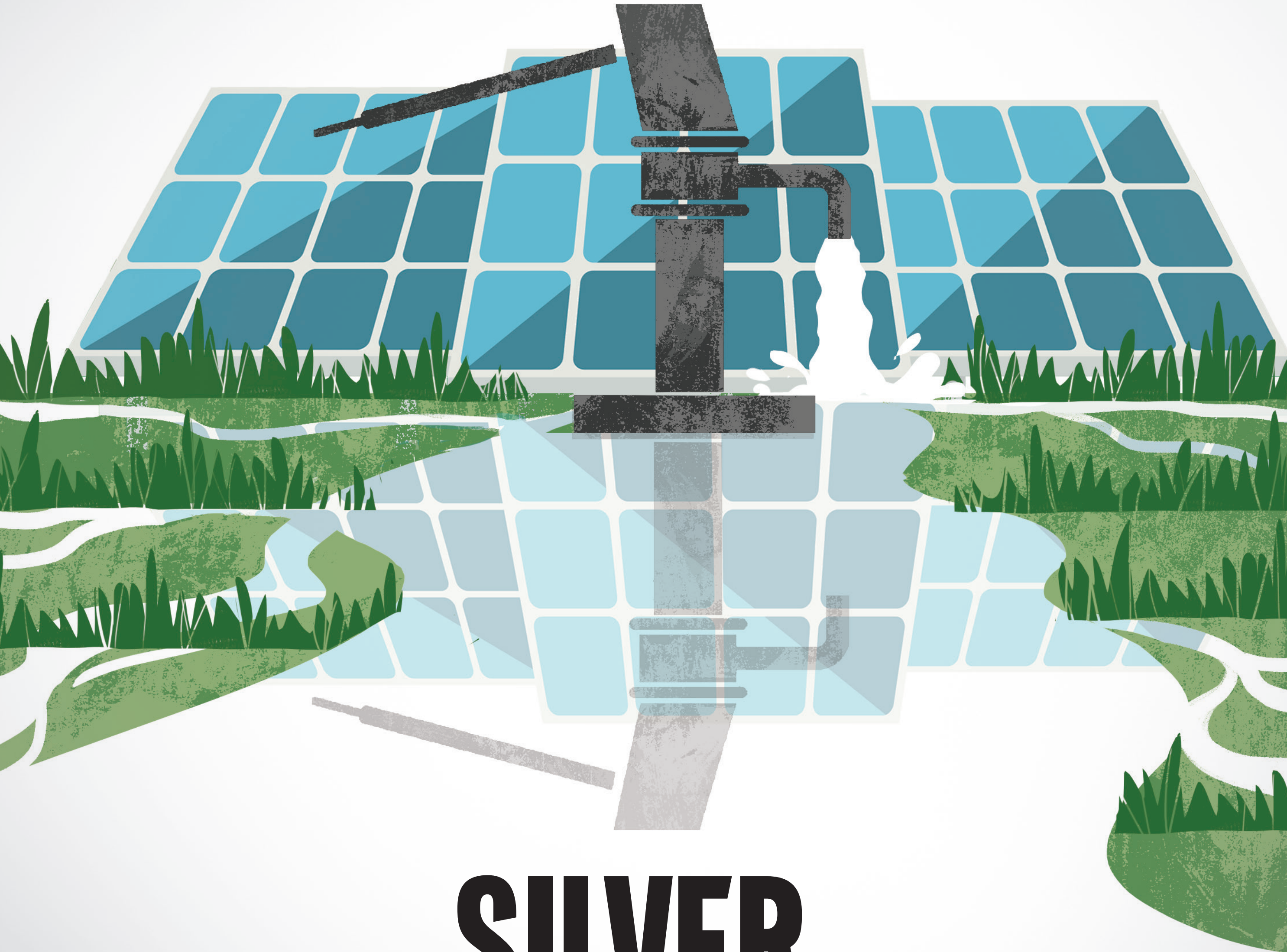

# SILVER BULLET

Redesigning Solar Pump Programme for Water and Energy Security

# SILVER BULLET

## Redesigning Solar Pump Programme for Water and Energy Security

Centre for Science and Environment

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## ABBREVIATIONS

| | |
|---|---|
| APEPDCL | Eastern Power Distribution Company of Andhra Pradesh Ltd |
| AT&C | Aggregate Technical and Commercial Loss |
| BCM | Billion cubic metre |
| BU | Billion unit |
| CAGR | Compound annual growth rate |
| CEA | Central Electricity Authority |
| CERC | Central Electricity Regulatory Commission |
| CFA | Central Financial Assistance |
| CGWB | Central Groundwater Board |
| CPSU | Central Public Sector Undertaking |
| CSE | Centre for Science and Environment |

| | |
|---|---|
| CWC | Central Water Commission |
| DCR | Domestic Content Requirement |
| DDUGJY | Deendayal Upadhyaya Gram Jyoti Yojana |
| Discom | Distribution company/utility |
| EESL | Energy Efficiency Services Limited |
| FiT | Feed-in tariff |
| GRACE | Gravity Recovery and Climate Experiment |
| HP | Horse power |
| ICT | Information Communication and Technology |
| JNNSM | Jawaharlal Nehru National Solar Mission |
| KUSUM | Kisan Urja Suraksha Evam Utthan Mahabhiyan |
| LCC | Life-cycle cost |
| LCoE | Levelized cost of electricity |
| MIC | Minor Irrigation Census |
| MNRE | Ministry of New and Renewable Energy |
| MSEDCL | Maharashtra State Electricity Distribution Company |
| MU | Million unit |
| MW | Megawatt |
| NABARD | National Bank for Agriculture and Rural Development |
| NASA | National Aeronautics and Space Administration |
| NCEF | National Clean Energy Fund |
| PIM | Participatory Irrigation Management |
| PM KUSUM | Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan |
| PPA | Purchase Power Agreement |
| PV | Photovoltaics |
| REC | Renewable Energy Certificate |
| RRB | Regional Rural Bank |
| SFA | State Financial Assistance |
| SGWB | State Groundwater Board |
| SKY | Surya Shakti Kisan Yojana |
| SNA | State nodal agency |
| SPAP | Solar-powered agricultural pump |
| T&D | Transmission and distribution |
| TERI | The Energy Research Institute |
| USPC | Universal solar pump controller |
| WUA | Water Users Association |

Increased irrigation needs are giving way to large-scale Solar pump installations

Chapter 1

# INTRODUCTION

Agriculture in India has become increasingly dependent on groundwater for irrigation, as pump-sets powered by electricity and diesel have gained popularity. Nearly 90 per cent of India's total groundwater draft during a given year is used to irrigate 70 per cent of the country's total irrigated land area. While this has helped increase productivity and farmer income, it has also led to over-exploitation of aquifers. The dependence has led to a crisis stage, with groundwater resources fast depleting at an alarming rate.

**90%**
**OF INDIA'S ANUAL GROUNDWATER DRAFT IS USED FOR AGRICULTURE**

The increased dependence on groundwater in recent decades has been catalysed by availability of cheap, often free, and mostly unmetred power for irrigation. As the number of electric pumps increased exponentially to reach over 21 million now, so has the agricultural subsidy burden on states. Accurate data on agricultural subsidy is not available, however, estimates suggest it to stand at around Rs 50,000 crore per annum contributing significantly to discom losses.

**0.24 MILLION SOLAR PUMPS INSTALLED IN INDIA, ACCOUNT FOR LESS THAN 1% OF TOTAL PUMPS**

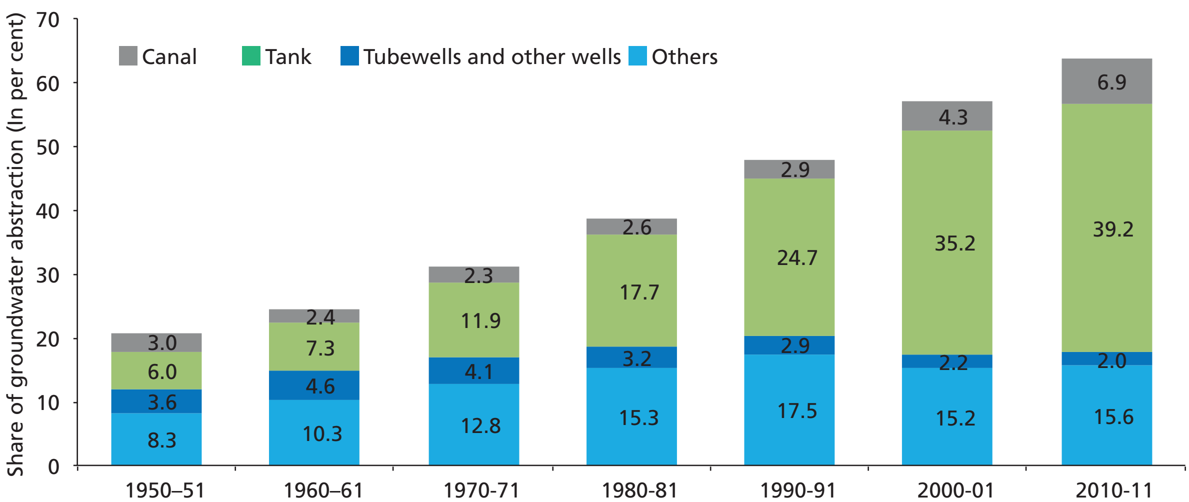
Central and state governments in India have been increasingly pitching for solar-powered agricultural pumps (SPAPs) to simultaneously provide farmers with access to assured irrigation, while reducing the electricity subsidy burden. The government sponsored solar pump programmes have existed for a while now, however, the ambition and scale of intervention has expanded in recent years, since agricultural subsidies become increasingly unsustainable. Several innovative models to harness solar power for irrigation are also being explored now to improve utilization of pumps as well as to augment the incomes of farmers.

Currently, there are only 0.24 million solar pumps installed in India, largely in off-grid mode. However, this is likely to increase manifold very soon as the central government's Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM KUSUM) scheme alone targets addition of 1.75 million off-grid pumps and 1 million on-grid pumps, in addition to installation of 10 GW of small solar power plants on agricultural feeders. Meanwhile, large targets have also been set under various state-level solar pump programmes.

In the wake of the expanding role of solar power in irrigation, Centre for Science and Environment (CSE) in this report analyses the extent and need of irrigation including the use of pumps, the potential impact on groundwater, and the economic benefits to the government/discom of a switch to solar water pumps. The analysis has been supplemented by a survey of farmers in three districts with high penetration of solar pumps—Buldhana in Maharashtra, Pilibhit in Uttar Pradesh, and Vizianagaram in Andhra Pradesh—to understand roadblocks in success of solar pump programmes in India. The report attempts to capture the key considerations for effective deployment of solar pumps keeping in mind on-ground issues and challenges.

**Graph 1.1: Source-wise area under irrigation in India**

Share of groundwater abstraction structures has increased to 70 per cent




*Source: Ministry of Statistics and Programme Implementation, Centre for Monitoring Indian Economy*

**Table 1.1: State-wise annual groundwater draft for irrigation**

Uttar Pradesh and Punjab account for 36 per cent of total groundwater draft for irrigation

| States | Annual groundwater draft for irrigation (BCM) |
|---|---|
| Uttar Pradesh | 48.3 |
| Punjab | 34.1 |
| Madhya Pradesh | 17.9 |
| Rajasthan | 13.8 |
| Haryana | 13.3 |
| Tamil Nadu | 13.0 |
| West Bengal | 10.8 |
| Karnataka | 8.8 |
| Andhra Pradesh | 7.3 |
| Others | 61.0 |
| Total | 228.3 |

*Source: Groundwater Year Book 2017*

## 1.1 GROUNDWATER FOR IRRIGATION

**70%**
**SHARE OF GROUNDWATER IN TOTAL IRRIGATION**

Despite the rapid economic growth over the past two decades, around 60 per cent of India's population continues to directly or indirectly depend on agriculture. Nearly half of the country's land area, or 182 million hectares is cultivated.[1] Of this, only 68 million hectares have assured irrigation.[2]

Canals, which dominated irrigation with a 40 per cent share in the irrigated area during the 1950s and 1960s, now account for only 23 per cent (see *Graph 1.1: Source-wise area under irrigation in India*). As canal networks in the country has not kept pace, private pumping systems powered by diesel and electricity to extract ground water steadily gained popularity. Also, the pumps' inherent merits of controllability and certainty, as well as low cost of operation, helped their growth.[3]

Groundwater thus emerged as the primary source of irrigation—its share increased steadily from 30 per cent of the area under irrigation in 1960–61 to 62 per cent in 2000–01 and further to 70 per cent now.[4]

Nearly 90 per cent of India's total annual ground water draft of 253 billion cubic metres (BCM) is used for irrigation. Nearly 36 per cent of this is drawn by Uttar Pradesh and Punjab; while another 47 per cent is drawn by Madhya Pradesh, Maharashtra, Rajasthan, Haryana, Tamil Nadu, Gujarat, West Bengal and Bihar (see *Table 1.1: State-wise annual groundwater draft for irrigation*).

Increased dependence on groundwater has resulted in improving agricultural yields. Studies show that between 1970 and 2004, rapid increase in groundwater-based irrigation accounted for 70–80 per cent increase in the value of agricultural production, as crop area remained relatively stable.[5]

But it has also led to over-exploitation of groundwater resources, which has reached crisis stage in several states. For instance, NASA's Gravity Recovery and Climate Experiment (GRACE) observed in 2009 that groundwater under

**6.7%**
**INCREASE IN GROUNDWATER EXTRACTION ASSOCIATED WITH 10% INCREASE IN ELECTRICITY SUBSIDY**

irrigated fields in Rajasthan, Punjab and Haryana has been declining by an average of one meter every three years (or one foot per year), and that over 109 cubic km of groundwater has disappeared in these areas between 2002 and 2008.[6]

India's Groundwater Year Book 2017 says 11 states—Punjab, Rajasthan, Haryana, Delhi, Tamil Nadu, Karnataka, Himachal Pradesh, Uttar Pradesh, Gujarat, Telangana and Andhra Pradesh—account for 94 per cent of groundwater blocks that were over-exploited or are critical (defined as blocks with over 90 per cent groundwater use, significant long-term decline pre- or post-monsoon, or both). The Planning Commission of India assessed that the number of over-exploited blocks in India increased from 4 per cent to 15 per cent between 1997 and 2004.[7] The World Bank predicts that around 60 per cent of aquifers in India will be in a critical state by 2032.[8]

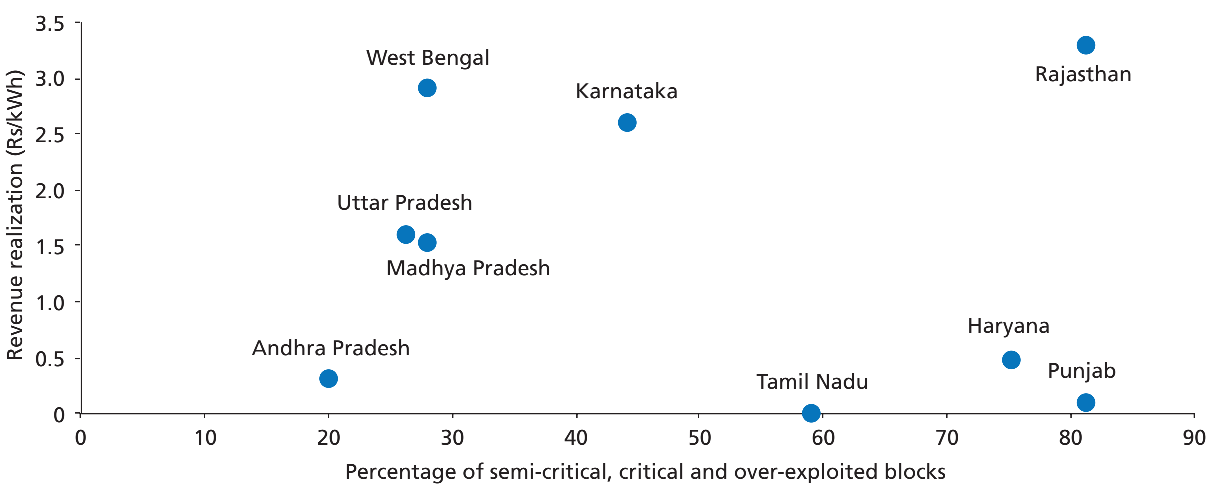
## Role of electricity tariff

The problem of groundwater over-exploitation in agriculture has been driven by the availability of subsidized, often free power for irrigation, which creates little incentives to use power or water efficiently. Indeed, states with very low tariff for agriculture tend to have high share of semi-critical, critical and over-exploited water blocks.[9]

While there are limited studies that assess the impact of free/subsidized electricity on groundwater exploitation and agricultural production, a paper from University of California, Davis concluded that a 10 per cent decrease in the average electricity subsidy leads to 6.7 per cent decrease in extraction of groundwater.[10] The conclusions seem clear from assessment of groundwater exploitation and average agricultural tariff (see *Graph 1.2: State-wise exploitation of groundwater and average agriculture tariff*). The north-western states of Haryana, Punjab

**Graph 1.2: State-wise exploitation of groundwater and average agriculture tariff**

States with low agriculture tariff tend to have greater exploitation of groundwater




*Source: Goundwater Year Book 2017; PFC Utilities report*

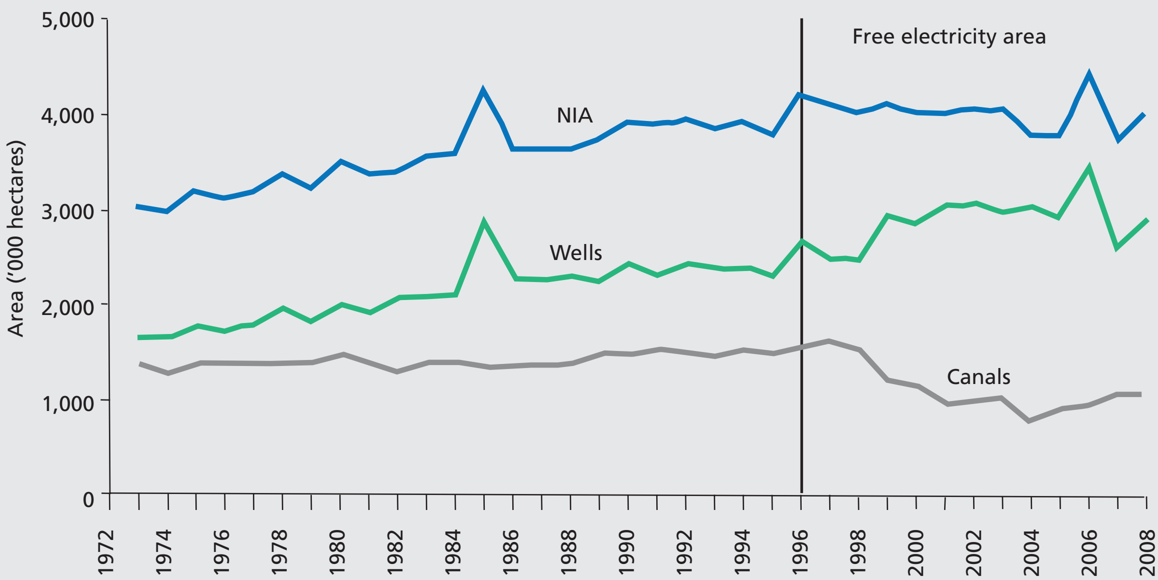
## BOX 1.1: IMPACT OF ELECTRIFICATION ON GROUNDWATER - EVIDENCE FROM PUNJAB

India's most prosperous agrarian state Punjab is facing a severe groundwater crisis–the average water table depth in the state declined from 7.32 metres in 1998 to 12.79 metres in 2012, registering an annual fall of 41.6 cm.[11] Of the 138 blocks assessed in Punjab, 76 per cent are over-exploited, 5 per cent are semi-critical or critical, while only 19 per cent are safe. Studies have attributed this to increased penetration of electric pumps and supply of free agricultural electricity.

In the past five decades, increasing number of farmers in Punjab shifted from canal to groundwater irrigation. In addition, there was an enormous expansion of the area under water-intensive crops like rice.[12] Notably, the decline in canal-irrigated area and rise in pumps-irrigated area was more pronounced after 1997 when electricity was made free for agriculture (see *Graph 1.3: Irrigated area by various sources in Punjab*). Within pump irrigation, share of electric pumps increased to over 75 per cent now from 45 per cent in 1970.

### Graph 1.3: Irrigated area by various sources in Punjab

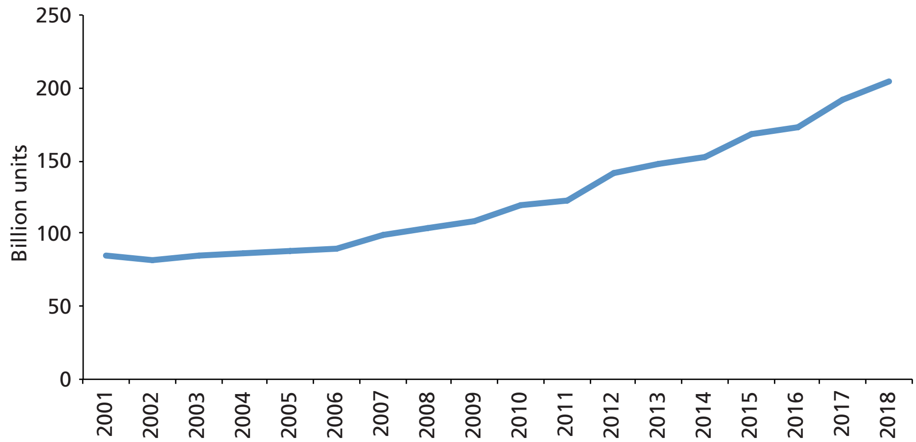
Increase in pumps-irrigated area more pronounced since introduction of free power




*Note: NIA-Net Irrigated Area; Source: Sarkar and Das (2014).*

**Graph 1.4: Electricity consumption of the agriculture sector**

Agriculture's electricity consumption has expanded rapidly in the past decade




*Source: Central Electricity Authority*

**6 MILLION ELECTRIC PUMPS ADDED IN 2010-18 AGAINST 2 MILLION DIESEL PUMPS**

and Tamil Nadu that have seen some of the lowest agricultural tariffs, as well as high penetration of pumps, have experienced most severe ground water crisis. On the other hand, states with moderate tariffs such as Madhya Pradesh, Uttar Pradesh, Karnataka and West Bengal have fewer over-exploited blocks. Despite free electricity, Andhra Pradesh has fewer number of over-exploited blocks since free electricity has been introduced relatively recently in 2004.

## 1.2 GROWTH OF ELECTRIC PUMPS

At present, nearly 30 million pumps are estimated to be operating in India, of which 20 million are electric and 10 million are diesel-based.[13] The electric pumps serve roughly 22.8 million land holdings while diesel pumps serve about 30 million land holdings.[14] Diesel pumps serve more landholdings due to their greater mobility.

Despite the flexibility offered by diesel pumps, electric pumps have become the preferred pumping source due to their low cost of operations. CSE estimates that the fuel cost of operating a 5 HP diesel pump could be as high as Rs 42,000 every year for 500 hours of operation. Thus, high reliance on diesel-based pumps is reported in only three states—Bihar, Uttar Pradesh and West Bengal—primarily due to erratic or non-existent agricultural power supply.

In vast areas of the country, electric pumps are preferred by farmers. Between 2010–11 and 2017–18, 6 million electric pumps were added across the country, against 2 million additional diesel pumps. The penetration is particularly high in the states of Punjab, Tamil Nadu, Andhra Pradesh and Haryana, supported by improved rural power supply and low to 'no' agricultural tariff—driven by the government's desire to improve rural household's income.

With the growing penetration of electric pumps, agricultural electricity consumption has doubled from 107 billion units (BU) in 2008–09 to 204 BU in 2017–18, registering a compound annual growth rate (CAGR) of 6.7 per cent during the decade (see *Graph 1.4: Electricity consumption of the agriculture sector*).[15] Compared to this, the growth in 1998–2008 was at a CAGR of about 2.3 per cent. The acceleration in demand growth primarily reflects increasing subsidy for agricultural supply. *

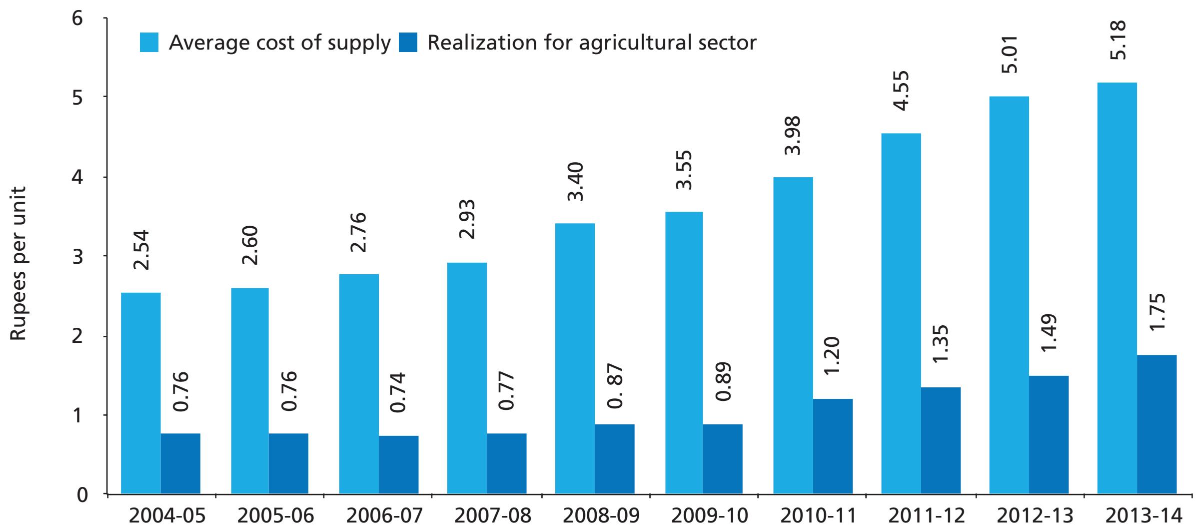
**6.7%**
**CAGR**
**OF AGRICULTURAL ELECTRICITY CONSUMPTION DURING 2008-2018**

The growth trends are likely to continue. A recent report from The Energy Resources Institute (TERI) projects the electricity demand of agriculture to increase to 238–307 BUs by 2030 due to increasing area under irrigation and falling water tables partly offset by the efficiency improvement of both pumps and irrigation.[16]

The increase in electricity demand has been driven by subsidized supply that is, in many cases, also unmetred. The erstwhile state electricity boards stopped metering electric pumps since the 1970s as the number of installed pumps expanded exponentially and the cost of metering individual pumps became prohibitive against revenues generated. Most states introduced flat tariffs and stopped recording consumption. The flat tariffs were initially intended to align electricity generation and supply costs, but eventually became highly subsidized.[17] In fact, a number of states including Punjab, Tamil Nadu and Andhra Pradesh supply free power for agriculture.

On an average, the realization from agriculture sector has been around 30 per cent of the cost of supply (see *Graph 1.5: Average cost of supply and realization for agriculture sector*).[18] The gap is either financed through higher tariffs charged from commercial and industrial consumers (cross-subsidy) or directly covered by state governments. The result is that against a 22 per cent share of agriculture in aggregate units of energy sold in 2015–16, the share in revenue generated was only 8 per cent.[19]

**Graph 1.5: Average cost of power supply and realization from agriculture sector**
Revenue realization is about 30 per cent of the cost of supply of agriculture supply




*Source: Central Electricity Authority*

**₹50,000 CRORE**

**ESTIMATED YEARLY AGRICULTURAL ELECTRICITY SUBSIDY BURDEN**

## Increasing subsidy burden

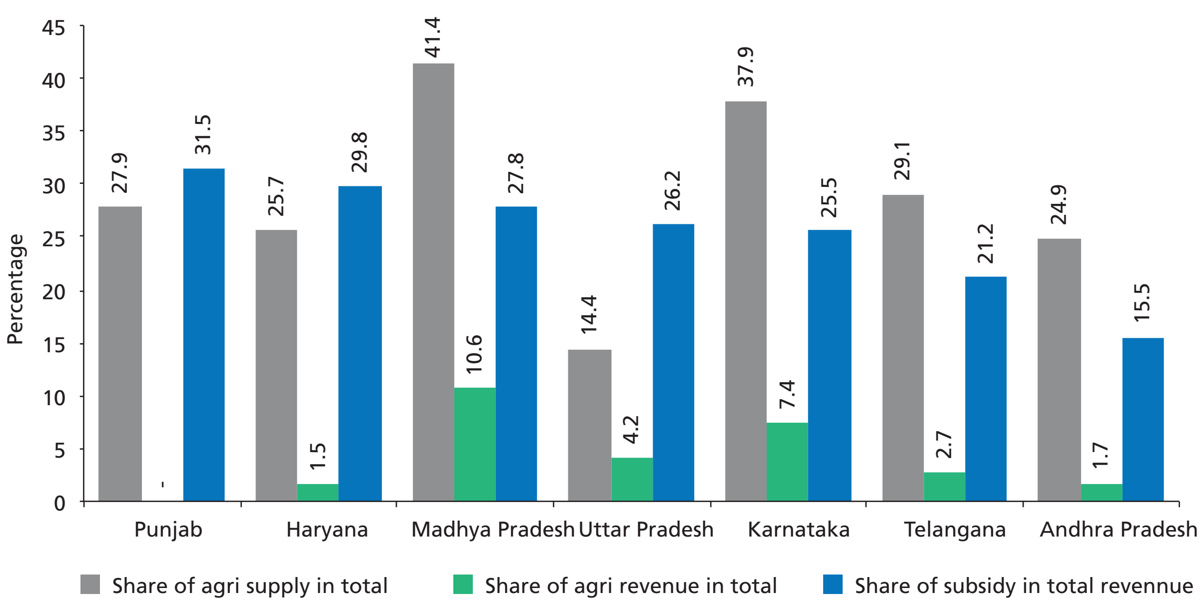
Most discoms in India face significant losses resulting in severe financial stress. Bulk of the revenue gap is on account of subsidized agricultural supply (household supply is responsible for most of the rest). This gap is partly covered by subsidies from the state governments which have been increasing; at the same time uncovered gap has been rising resulting in huge losses for discoms. Subsidy burden tends to be higher in states with a high share of agriculture in total power supplied but only a small share of revenue due to low agricultural tariff (see *Graph 1.6: Annual subsidy burden and revenues of discoms in major agricultural states*).

Accurate data on agricultural subsidies is not available due to several interlocking issues. First, agricultural supply itself is not correctly known due to a vast number of unmetred and flat-charge connections.* Second, promised subsidy may not be fully revealed, or paid in full, or paid in time. Finally, subsidy is not clearly broken up for agricultural consumers and other subsidized consumers. Estimates suggest the agricultural subsidy burden is currently around Rs 50,000 crore per annum.[20] States like Haryana and Punjab have accumulated huge losses largely due to subsidy levels of the order of Rs 7,000 crore per year.[21]

The problem of subsidized supply is worsened by thefts and poor collection. In Maharashtra, the outstanding electricity dues accumulated from the agricultural sector during 2013–17 were estimated to be Rs 15,000 crore.[22] In April 2018, the state government announced plans to waive off this outstanding due.[23] The

**Graph 1.6: Annual subsidy burden and revenues of discoms in major agricultural states (2015-16)**

Subsidy burden higher in states with a disproportionate share of agriculture in supply and revenue




*Source: Power Finance Corporation*

## BOX-1.2: NUMBER OF PUMPS INSTALLED IN INDIA

MNRE estimates 30 million pumps are operational in India, including 20 million electric and 10 million diesel pumps. However, reliable agricultural pumps data is unavailable, making it challenging to analyze their impact on agriculture, groundwater, cost to farmers, and electricity subsidies, and to design policies and scheme for irrigation and energy access. International Water Management Institute's (IWMI) study published in 2012, identified as much as 40 per cent differences in various data sources which raise questions about the veracity of the data[26]. Such discrepancies continue to exist by various government agencies (see *Table 1.2: Number of agricultural pumps in India*).

CEA reports that 22 million agricultural consumers at the end of 2017 (proxy for number of pumps), with an average contracted load of 6.4 HP. While the overall growth is reported to be at a CAGR of around 4 per cent, there was a sharp decline in 2014 possibly due to overestimation of consumers during previous years.

Similarly, in the Agricultural census (2010-11) and Input Survey (2011-12), there is a high contrast between the number of landholdings served by a diesel pump in Uttar Pradesh (17.41) which is almost five times higher than that in Bihar (3.65) while the average landholding size is twice in Uttar Pradesh as compared to Bihar. This reflects one diesel pump in Uttar Pradesh is serving almost 10 times the area one diesel pump serves in Bihar. In fact, the same ratio is 10 to 17 times higher than Bihar in states like Maharashtra, Madhya Pradesh, Andhra Pradesh. Therefore, the number of diesel pumps in Bihar might be overestimated, which accounts for almost half of the diesel pumps installed in India. These numbers suggest that the estimates of the number of pumps are largely based on anecdotal evidence or non-representative samples.

### Table 1.2: Number of agricultural pumps installed in India

Data mismatch exist between various government agencies

| Year | Number of electric pumps as per CEA (million) | Contracted load per consumer as per CEA (HP) | Other sources |
|---|---|---|---|
| 2006 | 13.8 | 5.40 | Agricultural Census, 2005-06: 10.1 million electric and 4.5 million diesel pumps |
| 2007 | 14.4 | 5.80 | 4th Minor Irrigation Census (MIC) , 2006-07: 11.4 million electric and 6.4 million diesel pumps |
| 2008 | 15.8 | 5.57 | |
| 2009 | 16.0 | 6.00 | |
| 2010 | 17.9 | 6.04 | |
| 2011 | 21.8 | 5.80 | Agricultural Census, 2010-11: 14.3 million electric and 6.2 million diesel pumps |
| 2012 | 23.6 | 6.30 | |
| 2013 | 24.6 | 6.43 | 5th MIC, 2013-14: 14.7 million pumps and 5.1 million diesel pumps |
| 2014 | 19.0 | 6.63 | Shakti-KPMG report, 2014: 19 million electric and 7 million diesel pumps |
| 2015 | 20.2 | 7.32 | |
| 2016 | 20.9 | 6.94 | |
| 2017 | 22.0 | 6.44 | |
| 2018 | - | - | |
| 2019 | - | - | KUSUM scheme 2019, 20 million electric and 10 million diesel pumps |

*Source: Agriculture Census, All India Report on Input Survey 2011–12*

**Table 1.3: Average hours of power supply per day to agriculture**

Hours of power supply have been declining in the past decade

| States | 2018–19 | | 2008–09 | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| Haryana | 7:09 | 9:50 | 5:00 | 14:00 |
| Punjab | 3:49 | 8:44 | 6:00 | 16:00 |
| Rajasthan | 6:30 | 6:30 | 10:00 | 12:00 |
| Gujarat | 8:05 | 8:05 | 8:00 | 8:00 |
| Madhya Pradesh | 9:33 | 9:55 | 4:00 | 16:00 |
| Maharashtra | 9:00 | 9:00 | 5:00 | 13:00 |
| Karnataka | 6:00 | 6:00 | 6:00 | 8:30 |
| Tamil Nadu | 9:00 | 9:00 | 10:00 | 20:00 |

*Source: Central Electricity Authority*

Gujarat government in December 2018 announced a waiver of Rs 625 crore in unpaid electricity bills, under its one-time settlement scheme for over 6 lakh people living in rural parts of the state.[24] Such waivers add to the financial burden on states.

## Poor quality of rural power supply

From the farmer's perspective, although power has been nearly free, electric pumps have not proved to be a good solution. Poor quantity and quality of rural power supply undermines their ability to carry out planned irrigation.

On an average, the duration of agriculture power supply is limited to six to nine hours a day, and this has been declining for the past decade in most states (see *Table 1.3: Average hours of power supply per day to agriculture*). Further, farmers are usually supplied power during off-peak hours, which is not only an inconvenience but often unsafe. For instance, farms in Tamil Nadu are supplied power six hours during the day and three hours during the night.[25] In Maharashtra, agricultural supply is mostly four days during the day and three days during the night in a week. Moreover, farmers often complain of voltage fluctuation, low voltage and frequent interruptions.

Popularity of solar pumps is increasing with decreasing photovoltaic prices

Chapter 2

# SOLAR PUMPS: AN ALTERNATIVE FOR IRRIGATION

In the backdrop of increasing demand for power supply for irrigation and increasing agricultural electricity subsidy burden, the government has been promoting solar-powered agricultural pumps (SPAPs) to meet the sector's energy requirement. In the past five years, deployment of SPAPs has increased from a mere 11,626 in March 2014 to around 0.24 million in March 2019 (see *Graph 2.1: Number of solar pumps installed in India*). This has been supported by capital subsidies of almost 90 per cent from the central and state governments (see Annexure 1: Central Government solar pump programmes and progress). The growth has also been helped by a sharp decline in solar pump price due to a fall in solar photovoltaics (PV) panel prices. A 5 Horse Power (HP) solar pump is Rs 56,000 per HP[27] as per MNRE benchmark costs for 2019–20 compared to over Rs 1.5 lakh per HP a decade ago.[28]

**₹56,000 PER HP**

**MNRE BENCHMARK COST FOR A 5 HP SOLAR PUMP**

**ONLY 11,000 SOLAR PUMPS INSTALLED IN INDIA TILL MARCH 2014 DESPITE SEVERAL DEDICATED PROGRAMMES**

The deployment of SPAPs has been concentrated in Chhattisgarh, Rajasthan, and Andhra Pradesh, collectively accounting for 60 per cent of the solar pumps in the country (see *Graph 2.2: State-wise cumulative solar pump installation over the years*).

The primary motivation in Chhattisgarh and Rajasthan for solar pump deployment was to improve rural access to water, while in Andhra Pradesh the key objective is to reduce the subsidy burden.

## 2.1 MAJOR MNRE SCHEMES

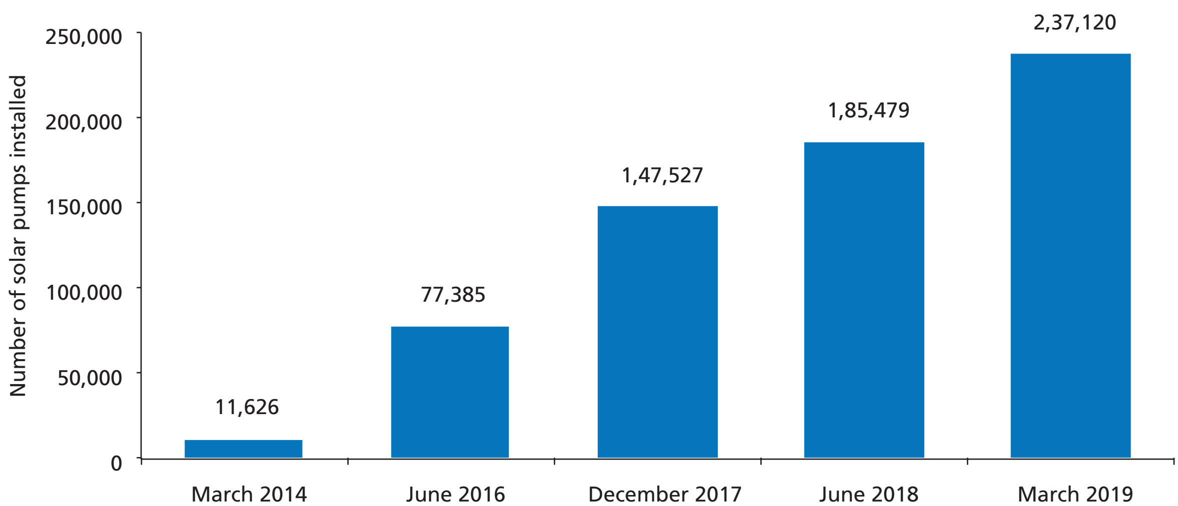
Ministry of New and Renewable Energy (MNRE) has been running a programme to install solar water pumping systems for irrigation and drinking water across India since 1992, providing a subsidy of up to 90% of the upfront capital cost. MNRE targeted 200 MW of solar-powered agricultural pumps (up to 5 kWp) under JNNSM Phase 1 (2010-2014). Till March 2014, only some 11,000 no. of solar pumps had been installed in the country reflecting very small scale of installation with a focus on decentralised off-grid application.

Between 2014-15 and 2019-20, MNRE implemented the Solar Pumping Programme for Irrigation and Drinking Water.[29] The scheme targeted to install 10 lakh pumps in five years through either of the state nodal agencies or National Bank for Agriculture and Rural Development (NABARD). But it had hardly made any progress and had to be discontinued in 2017. The scheme could not succeed despite its holistic approach.

Firstly, it gave states the option to choose from various modes of installation of solar pumping systems – off-grid or grid-connected, mini-grid based, for replacement of diesel pumps, community-based, water-as-a-service, micro solar

**Graph 2.1: Number of solar pumps installed in India**

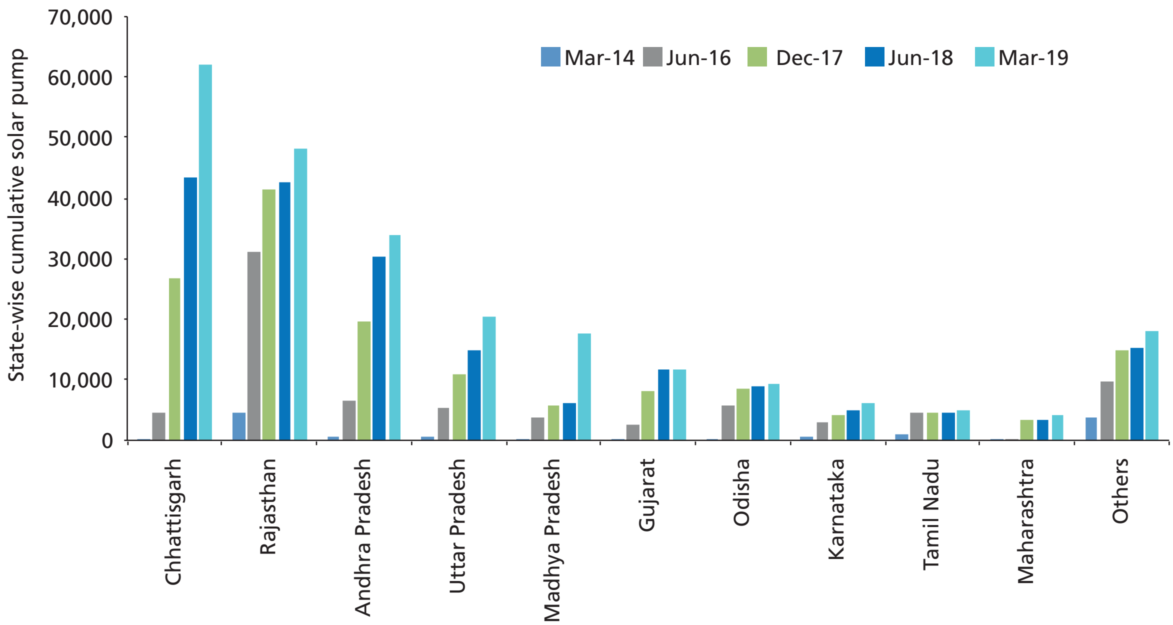
SPAP deployment has increased multi-fold, supported by capital subsidies and price decline




*Source: CSE, 2019 (compiled from various sources)*

**Graph 2.2: State-wise cumulative solar pump installation over the years**

Around 60 per cent of solar pumps are deployed in Chhattisgarh, Rajasthan and Andhra Pradesh




*Source: Ministry of New and Renewable Energy*

pumps. But states largely indulged in deployment off-grid solar pumps without a comprehensive impact assessment. Only a few states like Gujarat and Andhra Pradesh experimented with grid-connected model.

Secondly, states were given an option to decide the subsidy on solar pumps. States like Rajasthan and Maharashtra have offered subsidies up to 86 per cent and 95 per cent. This subsidy could be raised by state governments by arranging long-term loans which could be repaid by utilizing the savings owing to a reduction in the consumption of subsidized power. However, since off-grid pumps were installed mostly in the areas with little or no electricity connectivity, the scheme only added to the state exchequers.

Thirdly, state nodal agencies were given the responsibility of monitoring and evaluation of solar pumps installed in the field. However, data on performance and benefits of the programme is not available for any state, except for some independent projects carried out by private players. MNRE has done a report (including ground-level surveys) in association with Shakti Sambodhi but it does not give conclusive analysis. Some manufacturers (like Jain Irrigation Systems in Maharashtra) have put in monitors along with pumps but there is no assessment yet. Further, the scheme called for metering of solar pumps but the implementation is in vain.

The installation of solar pumps through NABARAD was a 'credit-linked capital subsidy' component of the scheme under which the share of beneficiary farmer was 20 per cent of the solar pump cost to be paid up-front, the government

**DATA ON PERFORMANCE AND BENEFITS OF MNRE PROGRAMMES ARE NOT AVAILABLE FOR ANY STATE**

was contributing 40 per cent as subsidy, while the remaining 40 per cent was made available to the farmer as debt from the banks, payable over 10 years. The scheme failed to reach even 15 per cent of its target of installing 30,000 solar pumps. The failure of the scheme can be attributed to parallel implementation of capital subsidy scheme by state nodal agencies where the farmer contribution was relatively smaller.

The government has now launched the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (KUSUM) scheme to scale up targets and subsidies for solar pumps to provide irrigation with an added aim to reduce electricity subsidy. Lately, another goal has been tacked on—to provide additional income to farmers through the sale of power. Under this, the government is moving beyond the conventional off-grid solar pump model and exploring other models—setting up small solar power plants to power electric pumps, solarization of existing electric pumps, and sale of surplus power backup to the grid.

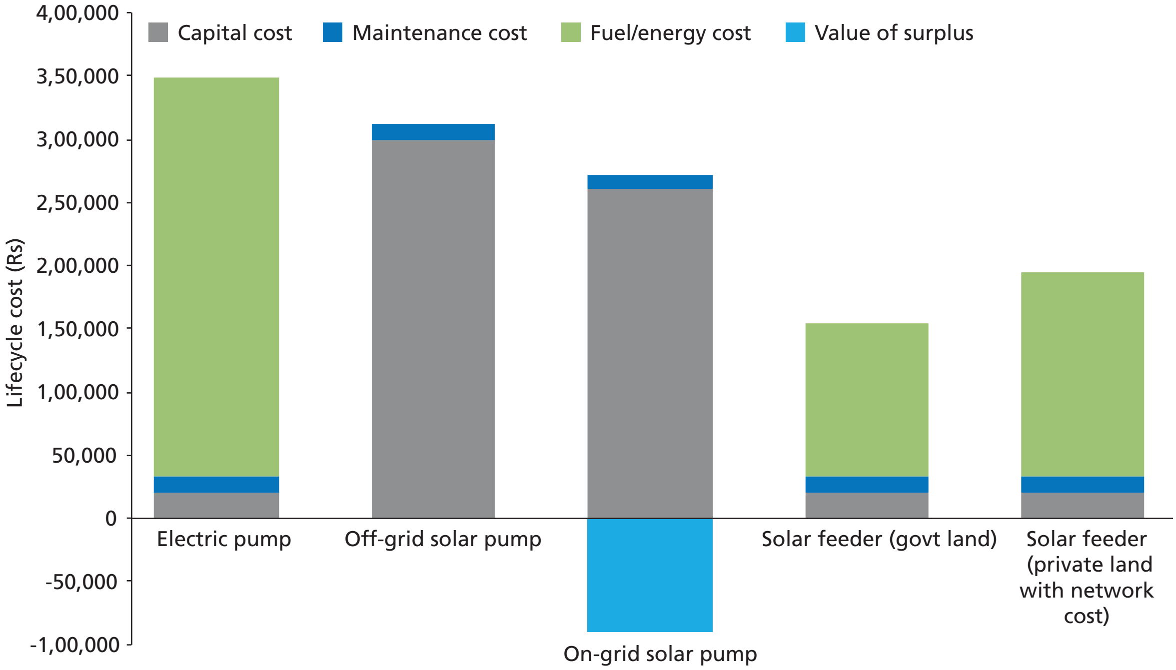
## 2.2 COMPARATIVE ECONOMICS OF PUMPS

There are multiple models through which solar power can be harnessed to pump groundwater for irrigation. Currently, most of the installed solar pumps are being operated off-grid since the main goal was to provide irrigation source where power was unavailable or infrequent. Solar pumps can also be connected to the grid to supply the surplus energy to the grid or to merely draw from it when needed. Another option is that of installation of PV panels at agricultural

Solarized agricultural feeders turn out to be the most economic of all the alternatives for irrigation

**Graph 2.3: Life-cycle cost of various modes of pumping in over 25 years of operation**

For a moderate pumping requirement of 800 hours, off-grid solutions are the most expensive




*Source: CSE estimate*

feeders—called solarizing—to supply power to agricultural pumps. All three models are being explored by the government under KUSUM. Each of these has varying economic benefit for farmers and the government, which has a bearing on the suitability for different areas.

**40:60**

**RATIO IN WHICH THE UPFRONT COST OF SOLAR PUMPS IS USUALLY SPLIT BETWEEN FARMER AND GOVERNMENT DUE TO AVAILABILITY OF CAPITAL SUBSIDY**

## Upfront costs versus life-cycle cost

Based on just upfront costs, electric pumps are the cheapest option costing about Rs 20,000 for a 5 HP pump against Rs 3 lakh for an off-grid solar pump and Rs 2.6 lakh for an on-grid solar pump of a similar size. The upfront cost of solar pumps is usually split between farmer and government in 40:60 ratio due to the availability of capital subsidy. While the upfront costs of solar pumps are higher, life-cycle costs reveal solar-based solutions to be more cost effective both for farmers and the government (see *Graph 2.3: Life-cycle cost of various modes of pumping for irrigation over 25 years of operation*).

To compare relative costs, CSE developed a financial model for a 5 HP pump powered by various sources, assuming it operates for 800 hours in a year and performs over 25 years (Refer to Annexure 2: Assumptions for Economic Analysis of Various Modes of Irrigation). Key conclusions drawn from the model are as follows:

- For an electric pump the lifecycle cost is nearly 17 times the upfront cost because of the cost of power over the operational life. Cost of power assumed at Rs 6 per unit, based on discoms' cost of power purchase and accounting for T&D losses up to the feeder level, escalating every year.

- While the upfront cost of a 5 HP off-grid solar pump is very high, it has minimal operating/maintenance cost. As a result, its life cycle costs are lower than the life-cycle cost of electric pumps for 800 hours of usage.
- The life-cycle cost of an on-grid solar pump is 13 per cent lower than that of off-grid pump. However, the on-grid pump offers significant income from the sale of surplus units, which is around one-third of the total life cycle costs in our model.
- The life-cycle cost is the lowest and the benefit highest for electric pumps based on solarized feeders.
  - If solar panels on the feeder are set up on government land, power can be supplied at a low and constant tariff of about Rs 3 per unit (as seen in Maharashtra tenders). The life cycle cost is the lowest in this case—it is nearly half of an off-grid system.
  - In case the cost of land and network to set up the solar plant is taken into account, power can be supplied at a relatively higher tariff of about Rs 4 per unit. Even in this case, the life-cycle cost is lower than the solar pump.
  - Assuming the panel at feeder is similar in size to a 5 HP pump, it will generate surplus energy that can be injected back which can be valued between Rs 1–1.5 lakh depending on whether we are considering government land or private land. This benefit would accrue to the government.

**8-9 YEARS**
**PAYBACK PERIOD FOR FARMER WHEN SHIFTING FROM ELECTRIC PUMP TO ON-GRID SOLAR PUMP (AT FIT OF ₹ 2/UNIT)**

## Cost sharing between farmer and government

Despite long-term economic benefits, SPAPs remain out of reach for most farmers due to the high upfront cost and limited access to financing. Transition to solar powered irrigation is not possible without significant subsidy support from the government. Choosing between various pumping options thus requires analysis of cost sharing between the government/discom and farmers.

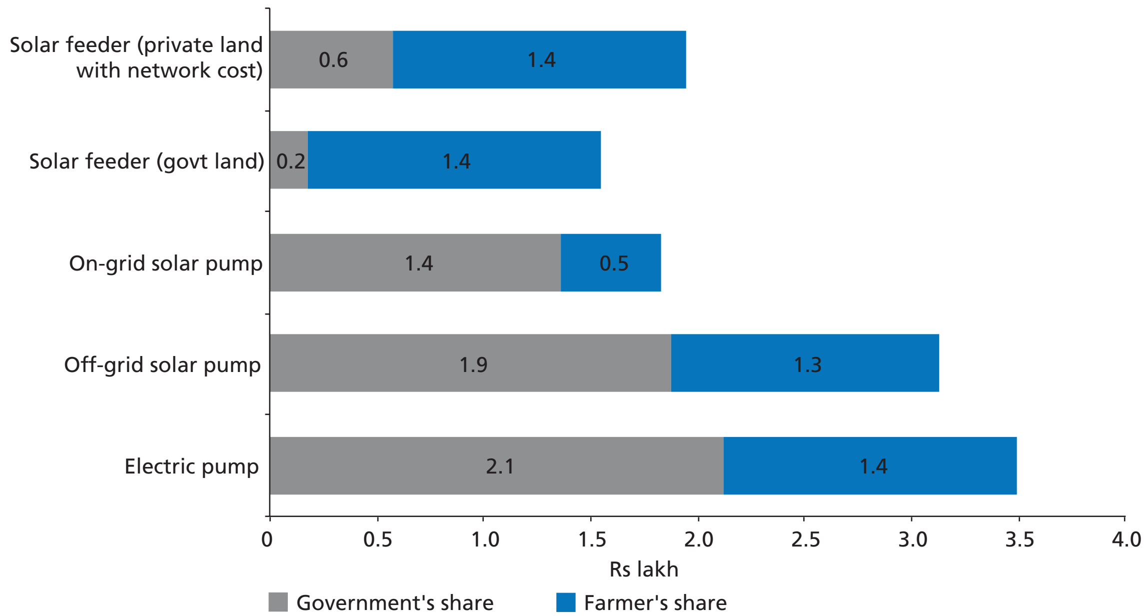
While the government has promoted off-grid solar pumps so far, its life-cycle cost burden is the highest among all solar options (see *Graph 2.4: Life-cycle cost sharing for various modes of pumping over a 25 year period)*. The costs are lowest in case feeders are solarized through plants set up on 'free' government- or discom-owned land. Even if the land and evacuation costs are included, the cost of solarized feeder is lower than the cost of off-grid and on-grid solar pumps.

The farmer is indifferent between the power supplied by the conventional grid and the solarized feeder, as his life-cycle cost remains the same. The net cost for farmer is lowest in the case of on-grid pumps, as there is an additional income that the farmer can earn from the sale of surplus power.

Given the varying levels of costs accruing to the government and the farmer from each mode of pumping, the break-even also varies for the two (see *Table 2.1: Break-even period under various pump replacement scenarios*). Break-even period is calculated as the time required to recover the cost incurred for a particular solar pump model. These are crucial to assess as some of the options may not be viable, for e.g. if the break-even period is beyond 10 years.

## Graph 2.4: Cost sharing for various modes of pumping over a 25 year period

Cost of solarized feeder lowest for government, but farmer remains indifferent




Note: Life-cycle cost of on-grid pumps include benefits from sale of surplus

*Source: CSE estimate*

## Table 2.1: Break-even period under various pump replacement scenarios

Break-even for government shortest in case of solarized feeders, however, farmer is indifferent

| Replacement scenarios | Break-even for government | Break-even for beneficiary |
|---|---|---|
| Electric pump with off-grid solar pump | 20–21 years | Beyond 25 years |
| Electric pump with on-grid solar pump | 13–14 years | 8–9 years |
| Grid supply with supply from solarized feeder (on private land with network cost) | 5–6 years | No change |
| Grid supply with supply from solarized feeder (government land) | 3–4 years | No change |

*Source: CSE estimates*

- Shifting from electric pumps to off-grid solar pumps is not a feasible option with a break-even period of over 20 years for both the farmer and the government, assuming a 5 HP pump is being used for 800 hours annually.
- For the transition from electric pump to on-grid solar pump, the farmer has a break-even of eight to nine years at a FiT of Rs 2 per unit, while it is 13–14 years for the government.
- The transition to solarized feeders leaves the farmer indifferent since the tariff remains the same. For the government, break-even in case of transition to solarized feeders on private land is at about five to six years, while it is shortest at three to four years in case of solarized feeders on government land.

PRATHA JHAWAR/CSE

Mr V K Manda, District Manager NREDCAP with Solar Pump beneficiaries in Vizianagaram, Andhra Pradesh

Chapter 3

# SURVEY: EXPLORING ON-GROUND REALITIES AND EXPERIENCE

Solar pump deployment is a complicated policy decision, which requires careful consideration not just of economics but also of on-ground realities. CSE conducted surveys of farmers in three districts with high penetration of solar power pumps, one each in Maharashtra, Uttar Pradesh and Andhra Pradesh, and discussions with main agencies involved in solar pump deployment such as discoms, state RE development agencies, local equipment distributors) to understand the key issues:

- Beneficiary details (land holding, irrigation sources, pump size)
- Ground water scenario
- Utilization of electric/diesel and solar pumps, income benefit from solar pump
- Maintenance and service issues
- Impact of different solar models including implementation gaps

## 3.1 BULDHANA, MAHARASHTRA: OFF-GRID SOLAR PUMPS IN A WATER-SCARCE REGION

The Maharashtra government has been aggressively promoting off-grid solar pumps in the region with 90 to 95 per cent subsidy to improve irrigation in light of the poor state of rural electricity.

CSE surveyed 72 farmers in 22 villages of Buldhana district located in the drought-prone Vidarbha region of Maharashtra to understand the impact and utilization of solar water pumps in a water-scarce area. There are about 1,000 off-grid solar pumps installed in Buldhana, one of the largest numbers of solar pumps among districts in Maharashtra.

Of the 72 farmers surveyed by CSE, 90 per cent were using solar pumps. Of these farmers, 56 per cent were previously using diesel pumps, 35 per cent were dependent on rains, and the remaining 9 per cent were using electric pumps. Overall, transitioning to solar helped reduce the cost of irrigation and increased farmer incomes, however the assets were under-utilized partly due to the depleting water tables. The farmers showed a preference for solar pumps over diesel or electric pumps due to the following reasons:

- **Inability to invest in new electric connection:** Rain-fed and diesel-using farmers in the region are unable to invest in electric pumps due to high agriculture electricity connection charge of up to Rs 1,00,000. This includes Rs 11,000 for the connection, Rs 10,000 for cable, Rs 20,000 for the pipeline (in case of drip), Rs 20,000 for pump and the rest for other accessories or services.

- **High cost of irrigation:** The average irrigation expenditure for the surveyed farmers dependent on diesel was as high as Rs 9,800 for each acre per year (see *Graph 3.1: Cost of irrigation in Buldhana*). Given that farmers paid only Rs 27,000 to Rs 38,500 for 5 HP solar pumps, the payback period for a farmer with 5-acre land for buying subsidized solar pump was only one year.

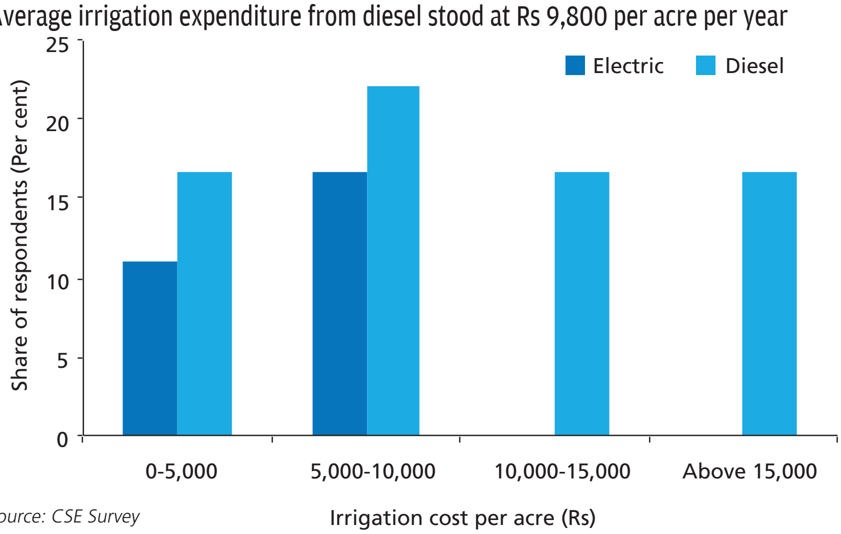
Similarly, the average irrigation expenditure for the electric pump was about

**90-95%**

**SUBSIDY PROVIDED BY MAHARASHTRA GOVERNMENT TO PROMOTE OFF-GRID SOLAR PUMPS**

**Graph 3.1: Cost of irrigation in Buldhana**

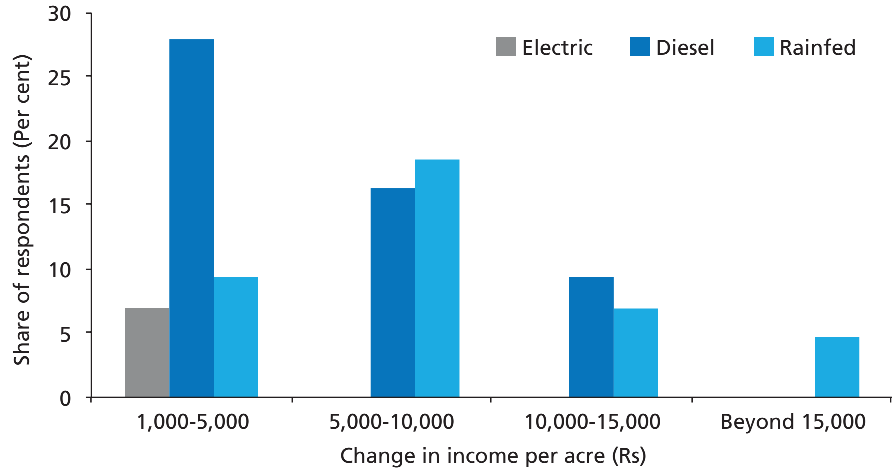
Average irrigation expenditure from diesel stood at Rs 9,800 per acre per year




*Source: CSE Survey*

## Graph 3.2: Income of farmers in Buldhana after transitioning to solar pumps

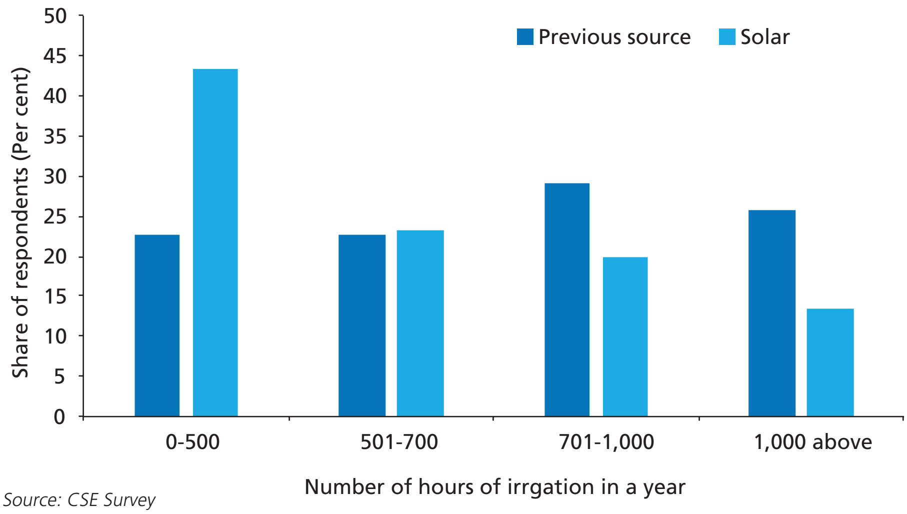
For previously rain-fed farmers, the average annual income increase is Rs 7,500 per acre




*Source: CSE Survey*

## Graph 3.3: Irrigation hours in Buldhana after transitioning to solar pumps

Irrigation declined from 800 hours to about 600 hours per year due to groundwater depletion




*Source: CSE Survey*

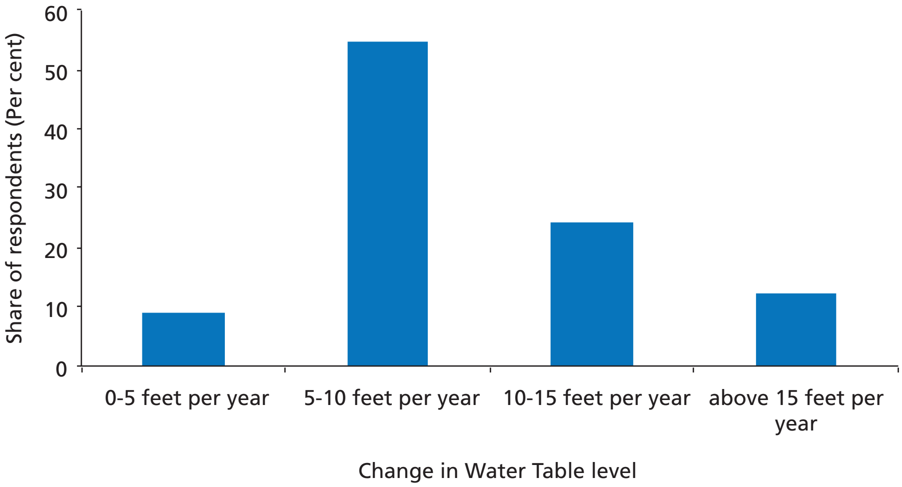
Rs 3,800 per annum for one acre of land, resulting in a payback of about two years.

The surveyed farmers who switched from electric to solar pumps also cited poor supply as one of the reasons:

- Agriculture power supply in the region is restricted to only 6 hours and supplied alternatively in the day and the night.
- Load shedding is very high during sowing time, forcing farmers to resort to alternative options.
- High voltage fluctuation results in frequent damage to the pump wiring and accessories that bring their maintenance bills to an exorbitant Rs 10,00–12,000 in a year.

**Graph 3.4: Long-term change in groundwater table in Buldhana**

Farmers on an average have experienced a dip of 8 feet per year in water table




*Source: CSE Survey*

- **Impact on agricultural income:** Transitioning to solar pumps increased farmers' income due to increase in productivity for the rain-fed farmers, and reduction in irrigation cost for the diesel and electric pump owners. The income increase was highest for the previously rain-fed farmers amounting to an average of Rs 7,500 per acre (see *Graph 3.2: Income of farmers in Buldhana after transitioning to solar pumps*). At this rate, the payback period for subsidized solar pumps for these farmers is under two years.
  Meanwhile, the average increase in income for previously diesel and electric pump owners is Rs 5,200 and Rs 3,400 per acre, respectively. The average increase in income is lower than the average decrease in irrigation costs since poor water availability meant both low solar pump use and reduced agricultural productivity.

**100-300 FEET**
**WATER LEVEL TABLE REPORTED AT PRESENT AGAINST 50-100 FEET 15-20 YEARS AGO**

Despite the positive impact of solar on farmer incomes, water-scarcity in Maharashtra restricts solar pump utility.

- **Decreased hours of irrigation:** The survey revealed that after transitioning to solar pumps, the hours for the irrigation decreased from an average of 795 hours per year to 627 hours per year (See *Graph 3.3: Irrigation hours in Buldhana after transitioning to solar pumps*). According to the surveyed farmers, the lack of groundwater is the prime reason for the lower solar pump use. Most solar pumps in the area have been installed in the past 3–4 years, during which time rainfall has been scarce, further depleting already low levels of water tables.

- **Depleting groundwater:** Over the last 15–20 years, the water table dipped from a level of 50–100 feet to 100–300 feet now (see *Graph 3.4: Long-term change in groundwater table in Buldhana*). This has constrained the farmers to grow cotton as the main crop in a year along with soya and some pulses. Farmers in only two of the total 22 villages surveyed were able to take a rabi crop (wheat) this year. Just one farmer of all the 72 responses, mentioned a change in cropping pattern by adding two new crops as a result of irrigation

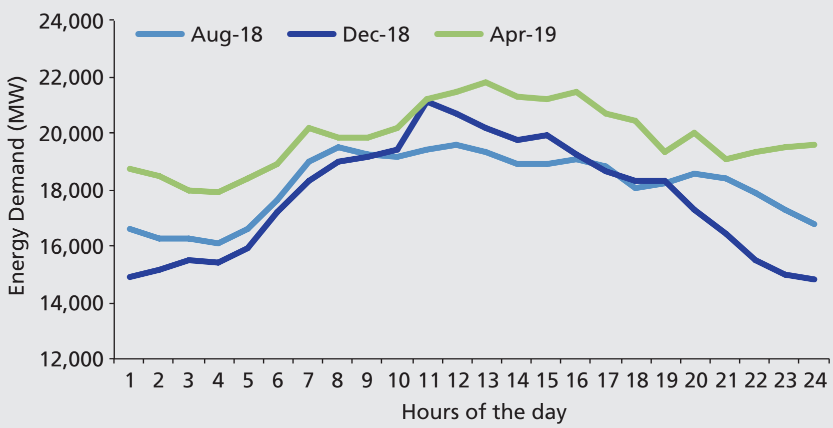
## BOX 3.1: MAHARASHTRA'S PEAK LOAD ANALYSIS

In 2017-18, 4.1 million agriculture consumers in Maharashtra accounted for 16 per cent of total consumer base and 18 per cent of the aggregate load. The agricultural consumer base is projected to increase to 4.4 million in 2019-20, and the agricultural sales from 29 BUs to 32 BUs.30 This will further increase the state's high subsidy burden given that the agricultural tariff is half of average supply cost. The state government thus plans to expand the deployment of solar pumps with 100,000 new pumps installed over the next three years. Further, under the Mukhya Mantri Saur Krishi Vahini Yojana, the government plans to solarize the agricultural feeders by installing solar power plants of 2 MW to 50 MW at substation-level through competitive bidding. Tenders have already been floated for 1,400 MW solar projects and another 3,200 MW is planned.

Investing in solar pumps to meet the 300 MUs of additional agriculture demand will help meet the peak demand in Maharashtra, which happens to coincide with daytime generation hours of solar plants, as the circadian load curve for Maharashtra peaks around noon (see *Graph 3.5: Maharashtra's circadian electricity load curve*).

### Graph 3.5: Maharashtra's circadian electricity load curve

Load curve peaks around noon, coinciding with daytime generation hours of solar plants




*Source: Maharashtra State Electricity Transmission Company Limited*

**DEPLETING WATER TABLES** HAVE COUNTER-ACTED AGAINST THE POSITIVES OF SOLAR PUMPS

from the solar pump. The rest could only partly offset the effects of drought with the solar pump irrigation. In fact, farmers of Hauda village in Nandura block rejected the idea of investing in solar pumps, which they believe would be ineffective in light of the water crisis.

### Implications and learnings

Solar pumps can reduce the cost of irrigation for farmers and the government's electricity subsidy burden; however, it isn't offering a solution to the more serious problem of water scarcity. In fact, it can exacerbate the problem.

Given that in water-scarce regions, the utilization of solar pumps is (and it should be) low, off-grid solar pump will be uneconomical. In such regions, at low utilization rate of solar pumps of around 33 per cent, the levelized cost of electricity increases from Rs 4.55 per unit (at 100 per cent utilization) to Rs 13.65 per unit.

While theoretically, a community-model/water sale may increase utilization, it has its limits due to typically narrow irrigation windows for crops grown in water-scarce regions. For obvious reasons, push towards water-intensive crops to increase utilization of pump makes no sense.

Therefore, on-grid pumps or solarized feeders would be a better solution in this area. The two models offer different pros and cons. The feeder model has the advantage of limiting supply to the farmer to the existing level and thereby limiting water extraction. On the other hand, on-grid model can use FiT to create an alternative source of income for the distressed farmers, however, FiT may need to be high the ensure farmers sell excess electricity rather than increase their water withdrawal.

Solarization of feeders may solve the discom's subsidy problem but for assured irrigation it should be backed by improved power supply for agriculture—reliable and adequate day-time power supply, given that farmers' dissatisfaction with grid-based supply seem to be transitioning to off-grid solar pumps.

**SOLAR PUMPS**
**DO NOT REPLACE DIESEL OR ELECTRIC PUMPS FROM BEING PRIMARY IRRIGATION SOURCE, IN CASE OF STACKING**

## 3.2 PILIBHIT, UTTAR PRADESH: IMPLEMENTATION CHALLENGES AND GAPS IN TARGETING

Uttar Pradesh has the fourth highest deployment of solar pumps in India, with 20,000 pumps installed till March 2019 under the state's solar pump scheme. CSE surveyed farmers in Uttar Pradesh's Pilibhit district which has 2,000 solar pumps installed, to understand the challenges and gaps in solar scheme implementation. Pilibhit district is located in the Tarai region in the sub-Himalayan belt, where the average depth of the water table ranges 10–25 feet and farmers generally grow three crops (wheat, rice and often sugar cane). The survey included 58 solar pump beneficiaries in 23 villages across 4 blocks in the district.

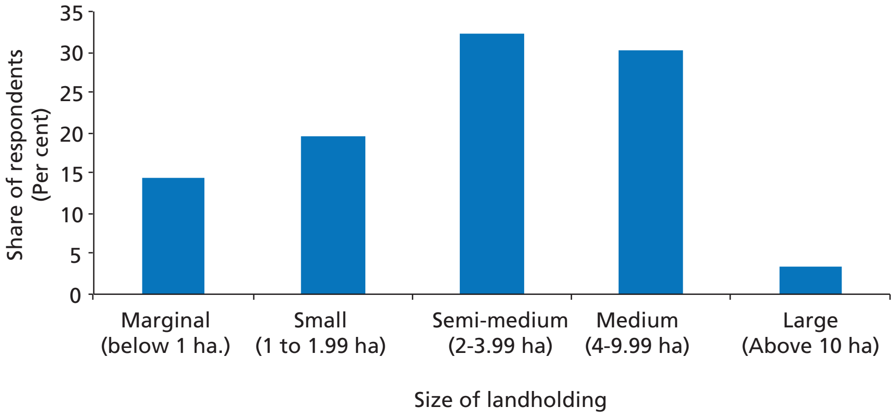
- **Inadequate solar pump capacity:** Uttar Pradesh's solar pump policy provides 70 per cent subsidy for installation of 2HP and 3HP pumps, and 40 per cent subsidy for larger pumps. The objective is to provide higher support to marginal and small farmers. However, poor implementation has resulted in large farmers taking subsidy for multiple small pumps.

  In CSE's survey, nearly 90 per cent of the farmers owned two HP solar pumps, and the remaining 10 per cent owned 3HP solar pumps. This has not meaningfully replaced/discouraged dependence on diesel/electric pumps.

  Two-thirds of the surveyed beneficiaries had relatively large farms with average landholding of 3.75 hectare or 9.35 acre based on their declared land ownership (see *Graph 3.6: Beneficiaries' landholding size in Pilibhit* ). The landholding size may even be higher as many farmers appeared to be understating their farm sizes. These farmers owned pumping capacity of an average of 9 HP (from single or multiple pumps) (see *Graph 3.7: Beneficiaries' pump size in Pilibhit*). Deployment of 2–3 HP solar pumps is not appropriate for these

## Graph 3.6: Beneficiaries' landholding size in Pilibhit

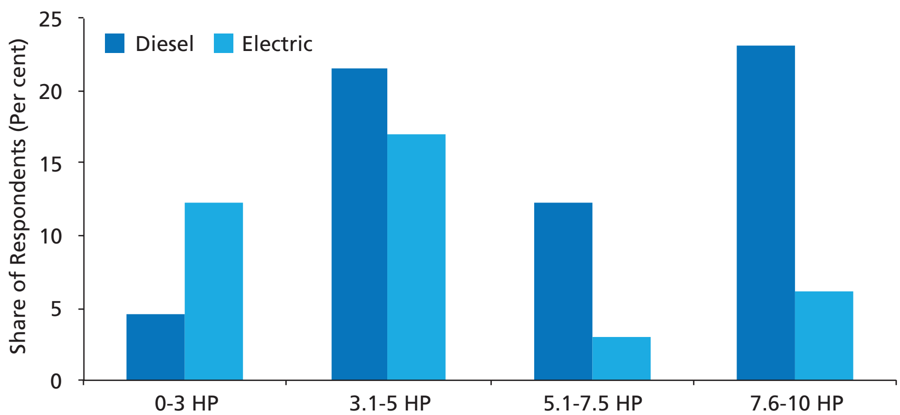
Only one-third of the surveyed beneficiaries were small and marginal farmers




*Source: CSE survey*

## Graph 3.7: Beneficiaries' pump size in Pilibhit

Average aggregate pumping capacity of farmers was 9 HP




*Source: CSE Survey*

farmers. While solar pumps have helped decrease diesel consumption by 150–200 litres per year, diesel and electric pumps remain the primary source.

- **Ineffective beneficiary targeting:** The average landholdings size of surveyed beneficiaries in Pilibhit is roughly five times higher than the state average (0.73 ha or 1.80 acres). Only 19 per cent of the surveyed beneficiaries were small and marginal. This indicates that the medium to large farmers are benefitting most from the solar pump subsidy in the district.

As per the state policy, the state nodal agency distributes pumps on the basis of the submission of a demand draft worth the entire upfront cost while applying for the pump. With limited access to funding sources, it becomes increasingly difficult for a small or marginal farmer to get a solar pump. Also, a vast number of these farmers still remain unaware of solar pumps or the government's subsidy policy. Small and marginal farmers rely primarily on renting of diesel pumps, paying Rs 100–150 per hour.

Meanwhile, instead of buying large pumps, some big farmers have taken multiple smaller pumps to avail higher subsidies. For instance, one single family in Bhaisaha village had five solar pumps in the name of different family members.

- **Pumps used for domestic needs:** Rural power supply in the district averages just over 15 hours (despite the government's promise to 24x7 quality power supply), with outages during the peak period. Given that the irrigation requirement in Pilibhit is mostly 100–120 days a year and the primary source of irrigation remains electric or diesel pumps, beneficiaries tend to utilize the associated solar panels for domestic use, animal husbandry and even house gardens. There is no incentive to farmers to reduce dependence on electric pumps given that they pay a flat tariff for the unmetred consumption.

  While the secondary use of the pumps has enhanced the utility of solar pumps, it also entails gross misuse of subsidy, which is meant for irrigation. Richer farmers are able to acquire the pumps at high subsidies and use the excess power generated for household consumption.

  A similar case of flawed beneficiary targeting was observed by IWMI in Bihar, where the high capital subsidy was benefiting medium and large farmers who already had irrigation access instead of making irrigation more accessible to small and marginal farmers. Solar pumps were stacked with other pumps and were routinely under-utilized.[31]

**SECONDARY USE**

**ENHANCES THE UTILITY OF SOLAR PUMPS, BUT ENTAILS GROSS MISUSE OF SUBSIDY**

- **Weak service market:** Nearly one-fifth of surveyed farmers in Pilibhit complained of maintenance or technical problems with solar pumps. Half of the complaints were addressed in two to five days, while the remaining were not addressed even after two to four months. Pumps belonging to 10 per cent of the beneficiary farmers were non-functional at the time of the survey. Since solar pumps were not the primary source of irrigation, some beneficiaries were not even eager to get them fixed. This indicates a serious gap in the development of a service market, which is crucial for long-term sustainability of the solar pumps.

  Nearly 15 per cent of the surveyed beneficiaries mentioned that the 2-inch tube provided with the solar pump for the water disposal does not deliver the required water throughput. Some also mentioned that 40 feet long pipe accompanied with solar pumps is inadequate due to the declining water tables. Nearly all AC solar pump owners (10 per cent of the surveyed beneficiaries) complained about sub-optimal functioning of the pumps, including long start time.

## Implication and learnings

- Providing solar pumps when power supply is free or flat rate is an ill-conceived policy. It will have little or no impact on agricultural power

Skills to be imparted to develop a service market for the maintenance of solar pumps

consumption. Solar pump will be underutilized or may be utilized for unintended purposes.

- Proper targeting of beneficiary is crucial. Targeting small and marginal farmers by providing higher subsidies for smaller pumps has led to large farmers installing multiple small pumps. Meanwhile, few small farmers have benefited.
- Poor farmers are not able to pay for solar pumps[32] (despite high subsidies). Given this, community-based solar pumps could be better suited for this category of farmers.
- A service market is required to be developed to ensure that the performance of the pumps is not compromised. This would also help to generate local employment.

## 3.3 VIZIANAGARAM, ANDHRA PRADESH: SOLARIZING ELECTRIC PUMPS

Andhra Pradesh is among the few states in India that have ensured daytime power supply of about seven hours to agriculture, mostly through segregated feeders. This supply to 2.5 lakh agricultural consumers is fully-subsidized and largely unmetred, leading to a high electricity subsidy burden on the state. Agriculture currently accounts for 22 per cent of state's aggregate power sale, and only 2 per cent of the revenue. According to APEPDCL, for each 5 HP electric pump installed in the district, the discom supplied an average of 6,000 units of free power during 2017–18, which is higher than the national average.

As a result, Andhra Pradesh has been aggressively promoting solar pumps for the past few years. With 13,000 solar pumps installed, Andhra Pradesh currently has the third highest share of solar pumps installed in India. The state plans to invest Rs 1,300 crore to increase solar pump base to 50,000 in the next five years. It is now exploring the option of solarizing electric pumps, through the on-grid model.

CSE visited Vizianagaram district, which had installed over 4,000 solar pumps till February 2019, and surveyed 47 farmers. Forty two farmers were using off-grid pumps and five were using on-grid pumps.

**Off-grid pumps:** A number of surveyed farmers in the district (around 35 per cent) had switched from electric pumps to off-grid solar pumps, even paying an upfront amount for the solar pump the sake of more reliable daytime power. Some of these farmers grow rice and maize as main crop, and coconut, banana, vegetables, cashew etc. as secondary crops. Their irrigation requirement was evenly distributed throughout the year, and so the utilization of the off-grid pump was high. In case of farmers growing only one or two crops, the solar assets and the developed network remained under-utilized.

**On-grid pumps:** The pilot project for solarizing electric pumps has been launched by Andhra Pradesh Electricity Power Distribution Company Limited (APEPDCL) at Bhogapuram, Svarnavelli feeder in the Vizianagaram district to reduce the discom's electricity subsidy burden and improve utilization of solar PV. The cost of the pilot project is being borne by APEPDCL through funds raised from sale of renewable energy certificates (RECs). Farmers do not pay any upfront cost for the transition, and are provided an incentive of Rs 1.50 per unit for the exported surplus. The pumps installed under the project are brush-less DC pumps that allow only one-way transfer (injection) of surplus power.

**100%**
**COST OF THE PILOT PROJECT OF SOLARIZING ELECTRIC PUMPS IS BEING BORNE BY APEPDCL**

So far, 216 electric pumps have been replaced by solar pumps of 3 and 5 HP capacity. Of these, only 20 pumps are being monitored (as of February 2019), which have collectively injected an average of 156 units of power into the grid per day.

At the time of the project launch, the government claimed that the on-grid systems will help farmers earn an additional income of Rs 15,000 per year.[33] But neither have the farmers experienced any change in cropping pattern and productivity, nor have they received a payback on the surplus electricity injected into the grid. In fact, given that each pump is injecting only 7–8 units per day, the expected benefit to farmer at an incentive of Rs 1.5 per unit would be about Rs 4,000 per annum. Further, only a small number of pumps are being currently monitored for power generation, making assessment of actual benefit difficult.

APEPDCL paid about Rs 300,000 for procuring and installing 5 HP solar pumps under the project, and estimates the payback period to be 11 years. While this itself is long, CSE expects it to be even longer at 13 years. The discom is now planning to expand the project in East and West Godavari districts for 10,000 solar pumps of 7.5 HP and 10 HP. In this case, the pay-back period is estimated to be 9 years (based on rates realized in the latest tender). The payback period would increase further as the FiT increases to Rs 3 per unit; however, it still remains lower than the off-grid pumps (13 years). These factors are restricting success of the project.

## BOX 3.2: GUJARAT'S ELECTRIC PUMP SOLARIZATION SCHEME

The Gujarat government announced the Surya Shakti Kisan Yojana (SKY) in June 2018, wherein farmers with existing electricity connections are being incentivized to install solar panels and sell surplus generation under a 25-year PPA. The scheme's objective is to augment farmers' income while reducing the state's agricultural subsidy burden. At present, agriculture power supply is highly subsidized in Gujarat with farmers paying Rs 0.60 per unit, against a cost of supply of Rs 6 per unit. So, while the sector consumes 27 per cent of the total power supplied in the state, it contributes only 3 per cent towards the revenue.[34]

Under the SKY scheme, farmers are allowed to install 1.25 kW of solar panel capacity per 1 HP of electric pumps, to ensure generation of surplus. The initial investment is supported by a joint subsidy from state and central governments amounting to 60 per cent of project cost, and low-interest loan (at 4.5-6 per cent) from the state government for 35 per cent of the cost. The farmer receives a FiT of Rs 3.50 per unit for generated surplus (equivalent to the average cost of power procurement in 2017-18, also in line with KUSUM guidelines), as well as an additional evaluation-based incentive of Rs 3.50 per unit for the first seven years to support debt repayment.

At the pilot stage, the target is to solarize 12,400 agricultural pumps with an aggregate load of 142,000 HP across 137 feeders in 33 districts. This will amount to installation of 175 MW of solar capacity at an estimated cost of Rs 900 crore.

Work under the SKY scheme has begun on about 50 feeders. It is picking up faster in central and southern Gujarat where the farmers on an average have relatively smaller pumps. Large farmers with higher rated existing electric pumps are finding it difficult to put in the upfront cost.

The payback from the scheme for the Gujarat government is estimated to be seven years. In theory, the model appears workable, albeit for a manageable scale. Concerted efforts are required to ensure that farmers have access to credit. The PPA with the farmers is respected for a period of 25 years.

**FREE SOLAR PUMPS WILL RESULT IN MISUSE LEADING TO EXCESS WATER DRAFT**

### IMPLICATIONS AND LEARNING

- Giving free solar pumps will result in its misuse, especially since grid power is reliable and cheap. Further, low FiT will not create incentives for judicious groundwater utilization. A better solution is to have some upfront payment required from the power combined with a higher FiT.
- Discoms have a central role in deployment of solar pumps, especially in the on-grid solar pumps or solarized feeder models. They must ensure proper metering, evacuation of power, and timely payment farmers for power injected into the grid.

  So far, discoms have shown limited interest to promote solar pumps. Discoms' lack of initiative is partly due to the poor design of the solar pump schemes itself. For instance, in Andhra Pradesh, the government has asked the discom to provide free pumps to the farmers, which is increasing their subsidy burden instead of reducing it.
- The transition from electric pumps to off-grid pumps as witnessed in Andhra Pradesh needs to discouraged, especially for farmers with low utilization. Even in cases of high utilization, such transition makes limited sense as pumps cannot be assumed to be operating for 10–12 hours daily throughout the year.

KUSUM scheme has enormous targets with potential to touch the lives of about 10 million farmers

Chapter 4

# KUSUM SCHEME

In February 2019, the Cabinet Committee on Economic Affairs approved the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (KUSUM) scheme that provides central aid of Rs 34,422 crores for installation of solar water pumps aggregating 25.75 GW capacity by 2022. The planned role out is massive and unprecedented for India, as the targeted capacity corresponds to about 11.5 million of 3 HP pumps or 7 million of 5 HP pumps. This implies that one-third to one-fourth of all irrigation pumps in the country could be converted into solar-powered pumps in about three years.

**₹34,422 CRORE**
**CENTRAL FINANCIAL AID FOR PM-KUSUSM BY 2022**

With this the government is targeting a host of objectives – expanding India's decentralized generation capacity, replacing diesel pumps with solar water pumps, solarizing electric pumps to reduce subsidy burden, and providing additional income to farmers. Thus, the scheme moves beyond the conventional model of off-grid solar pumps, to include grid-connected solar pumps (solarization of existing electric pumps) and solarization of rural feeders. While a few state governments in India have recently initiated programmes for these

## Table 4.1: Details of MNRE's KUSUM Scheme

Scheme will be implemented under three components

| Components | Details |
|---|---|
| Component A: Decentralized ground-mounted grid-connected solar plants | • 10,000 MW of solar capacity to be set up as 500 kW to 2 MW plants<br>• To be developed and owned by farmers, co-operatives, panchayats, or farmer producer organizations for sale of power to discoms at a feed-in-tariff determined by state electricity regulator<br>• Discoms to be provided performance-based incentives of Rs 0.40 per unit for five years<br>• 1,000 MW to be taken up on pilot basis first |
| Component B: Off-grid solar pumps | • 17.50 lakh off-grid solar pumps to be installed, of individual capacity of up to 7.5 HP<br>• Centre and state to share 30 per cent of pump cost each; farmer to provide the remaining 40 per cent (can access bank loan for up to 30 per cent of the cost)<br>• Tendering to be carried out by designated central public sector units (CPSUs) |
| Component C: Solarization of grid-connected electric pumps | • Solarization of 10 lakh grid-connected electric pumps of up to 7.5 HP each.<br>• Allowed solar PV capacity up to two times the pump capacity in kW terms, to enable sale of excess power to discoms.<br>• Procurement based incentive of Rs 0.60 per unit for discoms to purchase of surplus power<br>• Both net-metering and on-way transfer of power allowed<br>• Centre and state to share 30 per cent of pump cost each; farmer to provide the remaining 40 per cent (Can access bank loan for up to 30 per cent of the cost)<br>• Tendering to be carried out by designated CPSUs or state implementation agencies |

*Source: MNRE*

**PILOT MODE**

**COMPONENT A & COMPONENT C WILL FIRST BE IMPLEMENTED AS PILOT PROJECTS.**

(such as in Gujarat, Andhra Pradesh and Maharashtra), the MNRE for the first time included these models exclusively.

KUSUM's implementation guidelines, issued in July 2019, detail out the mechanism for installation of 17.50 lakh off-grid (Component B) and 10 lakh on-grid solar pumps (Component C), and 10 GW of solar capacity in rural areas through decentralized ground-mounted plants of 500 kW to 2 MW capacity (Component A) (see *Table 4.1: Details of MNRE's KUSUM scheme*). Both new components are initially planned to be taken up in pilot mode. Also, to ensure discom participation, the scheme provides procurement-based incentives to discoms of Rs 0.40 per unit and Rs 0.60 per unit for Component A and C respectively for the first five years.

No capital subsidy is planned for component A, while for Component B and C, the central and state governments will each provide 30 per cent subsidy on the pump cost. A farmer will be required to provide the remaining 40 per cent of the cost, of which he can access bank loan for up to 30 per cent of the cost.

In August 2019, MNRE announced the capacity to be rolled out in the first year of KUSUM – 526 MW of small RE plants, 173,700 off-grid pumps and 100,000 on-grid pumps – based on the demands projected by states. The total capacity allocated under Component A is about 50 per cent and component C is 100 per cent of the total to be installed under pilot mode.

**Table 4.2: State-wise capacity allocation under KUSUM during first implementation year**

Allocation is less than 10 per cent for first year of three years

| States | Allocation of capacities under | | |
|---|---|---|---|
| | Component A - Small RE Projects (MW) | Component B - Standalone Solar Pumps (Nos.) | Component C - Solarization of grid connected pumps (Nos.) |
| Andhra Pradesh | 75 | 25,000 | 22,000 |
| Assam | DNR | 700 | 100 |
| Bihar | DNR | 2,500 | 3,200 |
| Chhattisgarh | 30 | 15,000 | 4,000 |
| Gujarat | 75 | 4,000 | 18,500 |
| Haryana | DNR | 15,000 | DNR |
| Himachal Pradesh | 10 | 1,700 | DNR |
| Jammu and Kashmir | 6 | 1,000 | DNR |
| Jharkhand | DNR | 10,000 | 2,000 |
| Madhya Pradesh | DNR | 12,600 | 5,600 |
| Maharashtra | DNR | 9,000 | DNR |
| Meghalaya | DNR | 1,700 | DNR |
| Mizoram | DNR | 200 | DNR |
| Odisha | 30 | 2,500 | DNR |
| Punjab | 30 | 4,500 | 3,900 |
| Rajasthan | 75 | 25,000 | 12,500 |
| Tamil Nadu | 75 | 25,000 | 12,500 |
| Telangana | 75 | 1,000 | 6,000 |
| Tripura | 5 | 1,300 | 1,300 |
| Uttar Pradesh | 30 | 15,000 | 7,500 |
| Uttarakhand | 10 | 300 | 200 |
| West Bengal | DNR | 700 | 700 |
| Total | 526 | 1,73,700 | 1,00,000 |

*Note: DNR - Demand Not Received*

*Source: Mercom*

Overall, Andhra Pradesh has been allocated the highest capacities under all the categories followed by Rajasthan and Tamil Nadu (See Table 4.2: State-wise capacity allocation under KUSUM during first implementation year).

**HARYANA HAS NOT BEEN ALLOCATED CAPACITY UNDER SMALL SCALE RE PLANTS DESPITE ONE OF THE HIGHEST ELECTRIC PUMP DENSITY**

Highest capacities under Component A of 75 MW each are planned in Andhra Pradesh, Gujarat, Rajasthan, Tamil Nadu and Telangana. No capacity is planned under this category in Maharashtra and Haryana during the first year, despite very heavy agricultural electricity subsidies burden in both states.

As for component B, more than 10,000 off-grid pumps during the first year are planned to be set up each in Uttar Pradesh, Chhattisgarh, Haryana and Madhya Pradesh. Meanwhile, nominal addition is planned in Bihar and West Bengal, both of which are ideally suited for off-grid solutions (due to poor rural grid supply and good groundwater recharge). EESL has already released up a tender for 1,75,000 pumps for this component.

Andhra Pradesh and Gujarat lead in under Component C with 22,000 and 18,500 electric pumps to be solarized in the first year. Both states are already implementing this model under state projects. Punjab and Haryana have not been allocated significant capacity regardless of having the highest density of electric pumps in the country.

## 4.1 BENEFITS OF KUSUM

KUSUM scheme capitalizes on the falling cost of solar power pumps to enable generation of low-cost power near demand centers to empower farmers on one hand and reduce discom debts on the other. Some of the key benefits associated with the scheme for various stakeholders are as follows:

- **Assured day time irrigation and additional income for farmers:** Solar power pumps provide farmers with some obvious benefits. The income of rain-dependent farmers increases as they transition to solar pumps due to increased productivity. The transition from diesel pumps will adds

Benefits of solar pump could be long-lasting if promoted with caution for groundwater exploitation significantly to farmer income due to significant offsets in operation costs (which could be over Rs 40,000 per year for a 5 HP pump used for 500 hours). Offset in electric cost may be limited due to high subsidies in most states, however solar pumps are preferred as they are able to provide reliable day-time power supply of 6 to 8 hours. This is a significant advantage as power through grid is supplied usually during off-peak hours (night times) which creates a number of practical challenges for farmers. Further, quality of power supply in rural areas remains poor, with frequent interruptions and voltage fluctuations

Despite these advantages, adoption of solar pumps without government support remains is far-fetched in India. Even at a reduced price of Rs 54,000 per HP, these pumps remain unaffordable for the majority of farmers. KUSUM scheme makes buying pumps extremely affordable for medium-sized and large farmers – with 60 per cent subsidy and provision to take bank loans for 30 per cent of the cost, farmers have to shell out only 10 per cent of the cost to buy solar pumps.

The current targets imply that more and more farmers will be able to avail solar pump benefits. While the central and state government schemes implemented so far have collectively reached out to only about 2.4 lakh beneficiaries (approx. the number of pumps), the new scheme will target to reach out to 27.5 lakh farmers for off- and on-grid pumps only in a matter of three years.

**₹8,000**

**ADDITIONAL ANNUAL INCOME OF FARMER THROUGH SALE OF SURPLUS ENERGY GENERATED BY A 7.5HP ON-GRID SOLAR PUMP**

Further two components of KUSUM have been specifically designed to help farmers generate additional income. Under Component A, farmers either own and operate small solar plants to earn FiT or lease out space to developers for putting up such plants. A 1 MW plant can generate up to 1.5 million units in a year, which at a moderate FiT of Rs 3.5 per unit could lead to a revenue of about Rs 50 lakhs, of which about 12-14 per cent could be the return on investment.

Under Component C, the surplus power generated by on-grid pumps is sold back to the grid, creating additional income for farmers. For a 7.5 HP pump being used for a moderate 800 hours a year, additional annual income even at a low FiT of Rs 2 per unit could be over Rs 8,000 per year.

- **Reduced energy subsidy and discom losses:** One of the key motivations behind the implementation of solar pumps scheme on such a large scale is to reduce energy subsidies being rolled out for agriculture, estimated to be as high as Rs 50,000 crore annually. States of Punjab and Haryana which have less than 5 per cent of the total agricultural land share accounts for close to 28 per cent of the agricultural power subsidy.

  Component A and C of KUSUM will lead to a reduction in electricity subsidy, while Component B will help check their increase. The 10 GW of solar capacity planned as rural plants will reduce cost of supply by Rs 2 to 3 per unit, leading to a subsidy reduction of Rs 3,000 to 4,500 crore per annum. Similarly, solarization of 1 million electric pumps, would reduce grid consumption by roughly 4 BUs, leading to subsidy reduction of Rs 800 to 1,200 crore annually.

- **Impetus to solar pumps and PV market:** KUSUM mandates the use solar panel made from domestically manufactured solar cells. To ensure the quality and to assure post-installation services, only manufacturers of solar water pumps or solar modules will be allowed to participate in the bidding process[35] . This domestic content requirement will help solar manufacturing facilities to kick start production.

  As per the last official information available for July 2017, the installed solar cell and module production capacities is about 3 GW and 8.4 GW respectively of which only 50 per cent and 35 per cent were operational due to intense competition with cheap imports[36]. The KUSUM scheme will give a relief to under-utilized installed capacity of the indigenous solar cell production.

  Furthermore, the scheme provides an avenue to industry to set up new manufacturing plants which otherwise have been in a state of abeyance given the subdued interest of the industry in grid-connected Inter-state Transmission System Renewable Energy projects (the targets have already cut short from 10 GW of manufacturing to setting up 3 GW). KUSUM scheme has potential to boost production capacity additions as the industry could benefit from the increased demand for solar pumps.

**MANDATE**
**TO USE SOLAR PUMPS MADE FROM DOMESTICALLY MANUFACTURED SOLAR CELLS AND PANELS UNDER KUSUM**

## 4.2 DRAWBACKS OF KUSUM

The government's massive push for solar pumping systems certainly provides significant benefits to farmer's discoms and domestic solar industry. However, the scheme needs careful attention. Large-scale distribution of pumps could result in excessive water withdrawal and have a significant impact on the already depleting water tables. Second, various models of harnessing solar for irrigation differ in cost competitiveness and suitability across the country depending on a number of factors such as current irrigation choices, installed pump base, power supply, and electricity subsidy etc. Deployment strategies thus need to be carefully designed to ensure optimal utilization of resources.

Previously, MNRE's Solar Pumping Programme for Irrigation and Drinking Water, 2014-15 had called for the adoption of an integrated approach where the state nodal agencies could integrate the solar pump deployment with efficient irrigation and rural electrification programmes to ensure long-term benefit to farmers depending on regional requirements. In the KUSUM scheme, the focus seems to be on scaling up targets but such nuances have been lost which could make solar pumps an end-to-end sustainable solution for rural challenges around irrigation and energy access.

- **Inadequate attention to groundwater concerns:** It has already been established that the free/subsidized electricity often leads to over-exploitation of water. Therefore, KUSUM needs careful attention, as large-scale distribution of solar pumps could result in excessive water withdrawal and have a significant impact on the already depleting water tables. It fails to mandate or even suggest

## BOX 4.1: A TALE OF TWO STATES

Bihar and Punjab are two states where solar-based solutions for irrigation can be most beneficial, given the high penetration of diesel-based and electric pumps respectively. However, in the absence of specific measures to check groundwater exploitation, switching to solar will only exacerbate the groundwater situation in these states.

**Replacement of Diesel Pumps in Bihar:** As per Agricultural Census 2015-16, Bihar has 16.4 million operational landholdings, with an average size about 0.40 ha and about 50 per cent of the area is irrigated. Diesel pumps are a major source of irrigation, which has high operation cost. A farmer using diesel pump is mindful of the cost of diesel and is not likely to run the pump more than the required minimum. There is, therefore, an inbuilt mechanism that restricts wasteful water use.

Under KUSUM, these diesel pumps will be replaced by the far cheaper off-grid solar pumps, with no running expenses. There is, therefore, a high possibility of overuse of these pumps, leading to groundwater depletion. The KUSUM scheme has also not provided any provision to utilize surplus power from off-grid pumps to light rural homes and businesses. This means that these systems will only be used to pump water and hence the high probability of over-exploitation of groundwater.

**Solarization of feeders in Punjab:** Punjab has brought almost 100 per cent of its agricultural area under irrigation with nearly free electricity but at the expense of huge burden of agriculture power subsidy amounting to about Rs 7,000 crore per year and 80 per cent of the blocks in the critical and over-exploited category. Solarisation of agriculture feeders seems to be the most optimum solution for the state of Punjab. But the implications can be even more disastrous. With solar power predicted to be at least 30 per cent cheaper, the subsidy burden is likely to reduce significantly. This means that the state governments will have even less incentive to increase agriculture tariff to conserve water when the grid is solarised. Thus, the gross overexploitation of groundwater is likely to continue.

remote monitoring of pump use and groundwater withdrawal, particularly in states/regions with fast depleting aquifers. It also fails to promote efficient irrigation and incorporate explicit and strict measures against groundwater exploitation. The scheme only mentions exploring the possibility of its convergence with state-level schemes for promoting the micro-irrigation systems and energy-efficient pumps instead of mandating the same.

**50%**
**OR LESS IS THE WATER USE EFFICIENCY OF AGRICULTURE SECTOR**

KUSUM has adopted differential treatment of dark zones areas (with overexploited aquifers), where installing off-grid and on-grid solar pumps are not covered under the scheme. However, existing diesel or electric pumps should be converted to solar only if complemented with micro-irrigation techniques as India records less than 50 per cent water use efficiency in the field of agriculture.[37] Ensuring implementation of this will be a challenge.

- **Continued focus on off-grid pumps:** A massive investment is planned towards deployment of 1.75 million off-grid pumps, to replace diesel pumps where grid supply is unavailable. The plan is in contradiction with the country's goal of '100 per cent electrification of villages' under Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY).

  Further, KUSUM does not fully explore the option of utilizing surplus power generated by off-grid pumps through mini-grid type structures. It allows for installation of universal solar pump controller (USPC) for using the surplus solar power for alternative activities (operating agricultural equipment, floor mill, cold storage, battery charges, etc.), instead of mandating it. Also, it is left to the states to decide who bears the additional cost (farmer or the state), which is likely to limit the deployment of USPCs.

- **Weak on land use:** Component A of the scheme has the potential to convert the agricultural land into commercial land. 500 kW to 2 MW sized plants require 1 to 4 ha of the land, which is more than the average size of landholdings in most of the states. Therefore, putting up a solar plant will exhaust whole agricultural land of farmers. The provision of constructing stilt (raised panels) requires extra investment which might not be cost-effective for the kind of crops that can be grown under such solar plant.

- **Weak Beneficiary Targeting:** Off-grid and on-grid components of the KUSUM scheme call for priority being given to small and marginal farmers, however objective criteria for beneficiary selection is not defined. It is left to the state implementing agencies to select beneficiaries. While, the scheme makes buying pumps extremely affordable for medium-sized and large farmers. With 30% subsidy from the central and state government each and provision to take bank loans for 30% of the cost, farmers have to shell out only 10% of the cost to buy solar pumps.

**40%**
**FARMERS' CONTRIBUTION TO SOLAR PUMP AS UPFRONT. 30% CAN BE RAISED FROM LOAN**

  Past experience suggests that large farmers are primary beneficiaries of solar pump schemes implemented by various states, due to inability of poor farmers to pay even 10 per cent of the upfront cost, or due to lack of awareness, social exclusion or corruption. Meanwhile, the component A of the scheme pertaining to the setting up of small solar plants seems also exclusively designed for large and economically well-off farmers who can potentially shift from agricultural activities to putting up renewable/solar plants. This needs more serious attention than being given as instead of augmenting the income of farmers most in need, KUSUM could end up further increasing income divide in rural India.

- **Missing measures to ensure efficient discom participation:** The solar plant component of the scheme provides discoms with a procurement-based incentive of Rs 0.40 per unit for five years (or Rs 6.6 lakh per MW) to ensure efficient discom participation. The incentive is slightly higher at Rs 0.60 per unit in the case of on-grid pumps. However, while states are encouraged to have a policy for grid-connected solar pumps, there is no requirement mentioned for state electricity regulators to seek regular data from discoms on net metering, procurement and payments, which may be crucial for ensuring effective implementation.

Solutions for irrigation should encompass the effect of local characteristics

Chapter 5

# DISCUSSION & RECOMMENDATIONS

The government's solar pump schemes are simultaneously trying to solve too many things—providing assured irrigation to farmers and creating additional income source; reducing agricultural electricity subsidy burden; and meeting 100 GW solar power and distributed energy goals. Harnessing solar energy for meeting the energy needs of agriculture will go some way in providing cheap electricity to agriculture while reducing the subsidy burden on discoms. However, the government's plans have not been designed well to efficiently achieve any of these goals. Each associated objective is individually complicated, requires a comprehensive set of solutions.

Further, solutions cannot be generalized for the entire country and must take into consideration local characteristics such as groundwater availability, farmer demographics (landholding, income levels, cropping pattern and irrigation

# BOTTOM-UP APPROACH

## NEEDED FOR LARGE SCALE DEPLOYMENT OF SOLAR PUMPS

needs) and agricultural tariffs/subsidy. The existing plan of significant deployment of solar pumps thus needs to be revisited with a bottom-up approach. Some of the key questions/considerations in this context are such:

### Need for assured irrigation and groundwater concerns

In India, only 40 per cent of the aggregate agricultural landholdings of 182 million hectare being wholly or partly irrigated. The need for assured irrigation has increased even more in recent times as monsoons are becoming more and more erratic and the frequency of droughts is increasing. Only a handful of states such as Punjab, Haryana, Uttar Pradesh, West Bengal and Tamil Nadu have succeeded in providing irrigation to more than 50 per cent of the agricultural area within the state (see *Table 5.1: Share of irrigated agricultural area in different states*). The National Commission on Integrated Water Resources Development in 1999 projected the country's irrigation demand to reach 561 to 611 BCM by 2025, however, studies claim that this has already been reached. Given the past trends, the increased demand for assured irrigation will be met through groundwater exploitation.

KUSUM signals a transition in policy towards an increased reliance on solar energy for meeting existing and upcoming irrigation needs. However, it is vital to acknowledge that solar pumps can have far-reaching impact on groundwater exploitation similar to the impact of cheap/free electricity.

Since solar pump deployment is a relatively recent phenomenon in India, its impact on groundwater is not well understood through empirical studies. However, there is enough evidence of the disastrous consequences of highly subsidized electricity on groundwater withdrawal in states such as Punjab and Haryana. The stakes in case of off-grid solar pumps are higher, given that their usage cannot be easily controlled.

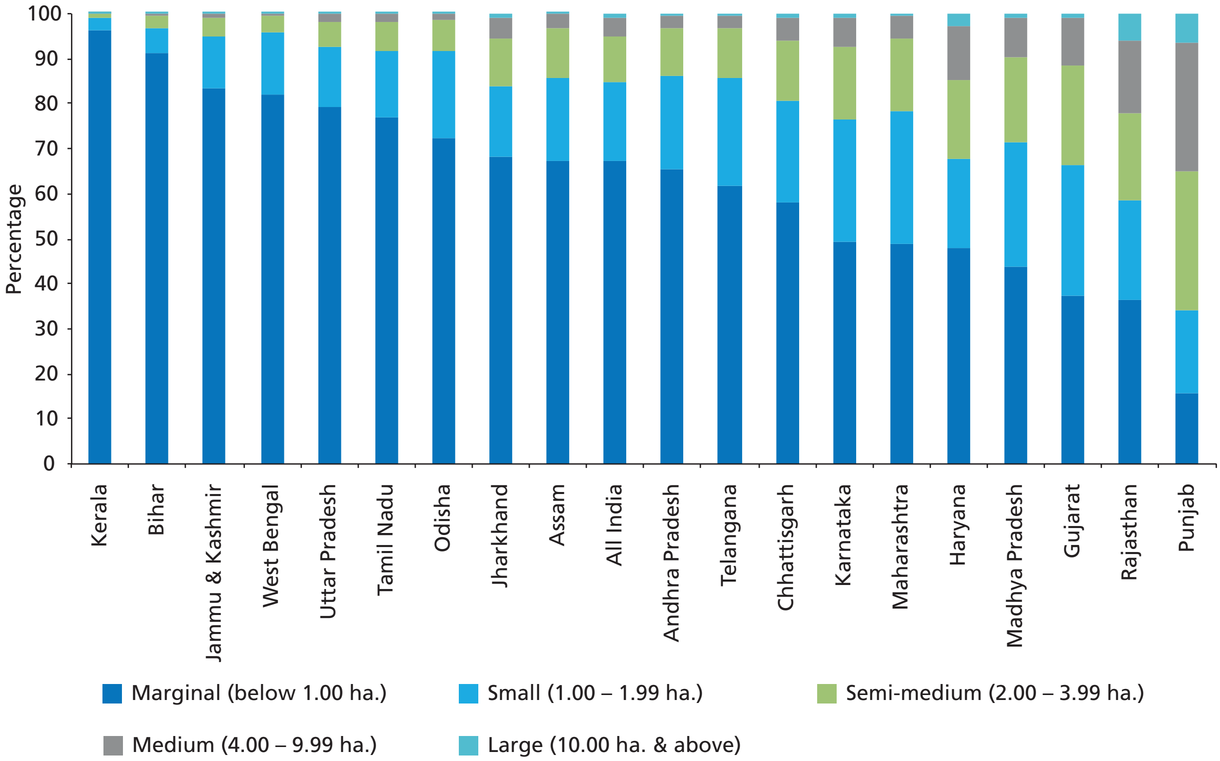
**Table 5.1: Share of irrigated agricultural area in different states**

Only a handful of states have succeeded in providing irrigation to 50 per cent of agricultural area

| Share of irrigated agricultural area (%) | States |
|---|---|
| Less than 10 | Jharkhand, Assam, Nagaland, Mizoram |
| 10–20 | Himachal Pradesh, Arunachal Pradesh, Sikkim, Maharashtra, Manipur |
| 20–30 | Meghalaya, Tripura, Kerala, Odisha, Chhattisgarh, Karnataka |
| 30–40 | Rajasthan, Andhra Pradesh, Jammu and Kashmir |
| 40–50 | Goa, Uttarakhand, Gujarat, Madhya Pradesh, Bihar |
| 50–60 | Tamil Nadu |
| 60–70 | West Bengal |
| 70–80 | Uttar Pradesh |
| 80–90 | - |
| 90–100 | Haryana, Punjab |

*Source: Agriculture Survey 2010–11*

**Graph 5.1: State-wise distribution of landholding according to size**
85% of the total landholdings in India fall under marginal or small size




*Source: Agricultural Census2015–16*

There are studies linking their deployment with changing cropping pattern and increased productivity, pointing to increased groundwater use. A working paper studying the Impact on Water Use, Energy Use and Cropping Patterns in Rajasthan suggests that access to solar pumps in the state enabled farmers to extract more groundwater and meet some amount of previously unmet irrigation water demand leading to an expansion in area under cultivation.[38] Widespread deployment of solar pumps in water-scarce regions could create more problems than they solve unless over-extraction of groundwater is prevented.

**SOLAR PUMPS CAN HAVE FAR-REACHING IMPACT ON GROUNDWATER EXPLOITATION SIMILAR TO THE IMPACT OF CHEAP/ FREE ELECTRICITY**

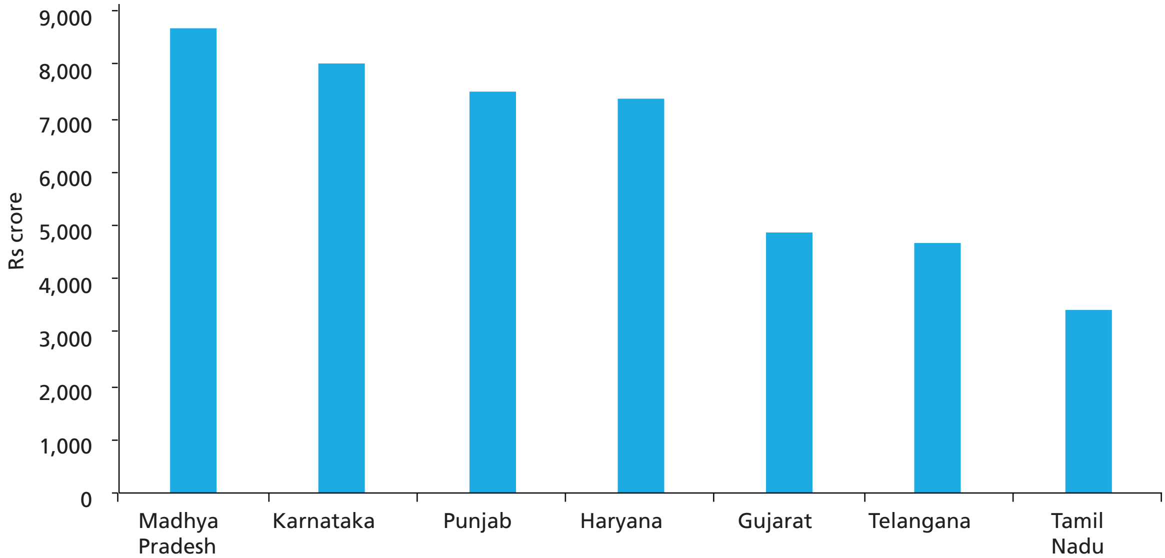
So far, groundwater concerns have been disregarded by the KUSUM scheme – it does not promote efficient irrigation or incorporate explicit and strict measures against groundwater exploitation. The scheme only mentions exploring the possibility of its convergence with state-level schemes for promoting the micro-irrigation systems and energy-efficient pumps instead of mandating the same. For this, KUSUM scheme will have to be redesigned and positioned as a water and agricultural scheme, and not merely as a renewable-energy scheme.

## Reducing farmer distress

Indian agriculture is characterized by small and marginal landholdings, which account for 85 per cent of the country's total land holdings [39] (see *Graph 5.1: State-wise distribution of landholding according to size*). These farmers are most vulnerable to financial distress due to lack of access to technological,

**Graph 5.2: Agricultural electricity subsidy burden in select states (2017-18)**

Agriculture subsidy in India is estimated at around Rs 50,000 crore per year




*Source: CSE (Compiled from various sources)*

## BENEFICIARY TARGETING

### A SERIOUS CONCERN AS KUSUM HAS NO TARGETS FOR SMALL & MEDIUM FARMERS AND NO DEFINED ECOSYSTEMS FOR FINANCIAL SUPPORT

financial and institutional support. These include limited access to formal credit, insurance, capacity-building programmes, irrigation scheme and marketing facilities. While large farmers also face similar challenges, the disparity in access is stark.[40]

One of the declared aims of the solar pump schemes is to provide more support to small and marginal farmers who are in deep distress. However, surveys in many states show that large farmers are the main beneficiaries of the existing schemes, as small farmers can't make even a small upfront payment and don't have access to financing.

Government's latest KUSUM scheme also fails to include specific targets for small and marginal farmers. While the scheme does improve the affordability of solar pumps, it does not define an ecosystem for lending support which will exclude most small and marginal farmers from benefiting from the scheme. Such farmers are likely to depend on high-cost informal loan sources, which could make matters worse.

Meanwhile, beneficiary targeting is a serious cause of concern under KUSUM as it is designed to provide farmers with additional income through the sale of surplus power through on-grid pumps and setting up of small plants. Component A of the scheme (solar power plants) will benefit large prosperous farmers almost exclusively, which is a serious shortcoming.

### Reducing electricity subsidy burden and discom distress

Discoms in India are grappling with the issue of high agricultural subsidy burden. Several states, including Punjab, Haryana, Karnataka and Madhya Pradesh have very high agriculture subsidy of Rs 8,000 to 6,000 crore (see *Graph 5.2: Agricultural Electricity Subsidy Burden in Select States*). While the average cost of power supply in these states varies from Rs 6-7 per unit, the revenue realized is close to nil. These may not reflect the actual agricultural power supply situation due to the lack of metering and transparency. Solar pumps can play a crucial role in reducing the agricultural subsidy, and thus should be prioritized in states with higher burden.

The 25,750 MW solar capacity planned to come up under KUSUM can potentially convert 25 per cent to 33 per cent of all irrigation pumps into solar-powered pumps in a short period of three years. This could potentially have a substantial impact on discom finances.

However, installation of solar pumps for the reduction in discom distress needs to be supplemented with a more comprehensive set of policy measures which includes reduction in overall electricity subsidy, 100 per cent metering of rural consumption and direct transfer of benefit.

**1/4th TO 1/3rd**

**OF ALL IRRIGATION PUMPS CAN POTENTIALLY BE CONVERTED INTO SOLAR-POWERED PUMPS UNDER KUSUM**

Further, the success of on-grid and feeder-based models depend heavily on efficient discom operations—evacuation, proper metering and billing and prompt payment. Discoms have so far not performed well on these fronts limiting benefits to the farmers. Additional responsibilities are being put on already struggling entities, while the net impact on reducing discom distress is unclear given the high cost of operations in rural areas and low expected benefits.

### Comparing various solar pump deployment models

While all three models of solar pump deployment – on-grid, off-grid and solarized feeders – provide farmers with access to assured irrigation, these have varied impact on crucial parameters of groundwater extraction, agricultural subsidy, additional farmer income etc. (see *Table 5.2: Comprehensive analysis of various solar-based models for irrigation*)

So far, the focus of various solar pump schemes has been on the off-grid pumps, an economically inefficient strategy due to their poor utilization. More importantly, off-grid pumps are difficult to monitor for usage, yet 17.50 lakh off-grid pumps are being planned under KUSUM. Given the government's large investment in rural electrification, investment in off-grid pumps is wasteful and should be minimized.

The government's plans to explore alternative models such as grid and feeder-based solar pumps under recent schemes may help improve utilization, however, their impact on subsidy burden and groundwater utilization would depend on policy design and details.

In case of solarized feeders, the economic benefits are clear – the payback period for required investment is shortest and the electricity subsidy burden certainly decreases. However, the model will not result in any reduction in groundwater

**Table 5.2: Comprehensive analysis of various solar-based models for irrigation**

All three models of solar pump deployment have varied impact on crucial parameters

| | Off-grid pumps | On-grid pumps | Solarized feeders |
|---|---|---|---|
| Irrigation | Access to day time reliable electricity to farmers | Access to day time reliable electricity to farmers | Access to day time reliable electricity to farmers |
| Additional income | Income increases due to assured irrigation, and reduction in the fuel/energy cost | Additional income due to sale of surplus power to discoms; benefit depends on the FiT | No change in income if existing electric pumps are solarized |
| Economics | Least economic with a breakeven period of 20-25 years; cheaper only than diesel pumps | Net benefit increases significantly due to higher utilization | Most economic option |
| Agriculture subsidy | Subsidy burden remains unchanged | Subsidy burden reduces, however unclear impact in case of net metered pumps | Subsidy burden reduced due to decrease in cost of supply |
| Groundwater | Exploitation and overuse may increase as there is no monitoring of use, and no incentive to restrict extraction | Extraction can be controlled if the FiT is sufficiently high | Extraction continues at the same rate, unless hours of supply is limited or the tariff is increased |

*Source: CSE analysis*

**MINIMIZE INVESTMENT IN OFF-GRID PUMPS, GIVEN THE GOVERNMENT'S LARGE INVESTMENT IN RURAL ELECTRIFICATION AND POSSIBLE IMPACT ON GROUNDWATER**

extraction unless agricultural tariffs are increased or the hours of supply are restricted. As for on-grid model, the expectation is that the FiT will act as an incentive to curtail groundwater use. However, this as well as meaningful augmentation of farmer income can only be achieved if the FiT is sufficiently high (see *Table 8: Comprehensive analysis of various solar-based models for irrigation*).

## RECOMMENDATIONS

Given that the solar pump policy purports to address a wide range of issues, it needs to pursue an integrated approach. The policy package should thus address issues of water as well as energy-efficient irrigation, support price for water-efficient crops, direct benefit transfer of subsidy, and an overall reduction in electricity subsidy. It should entail collaboration of various government agencies including the Ministry of Agriculture and Jal Shakti Ministry for the implementation of solar-based solution for sustainable agriculture.

### Managing groundwater extraction

Given the pressing need for groundwater conservation and the likely impact of free solar power on its overexploitation, it is crucial that solar pump schemes like KUSUM evolve into a comprehensive irrigation scheme. This is especially crucial for water-stressed regions of Maharashtra, Karnataka, Telangana, Rajasthan and Punjab. In fact, such schemes should be used by the central government as an opportunity to push massive irrigation reforms in states.

For instance, KUSUM should only be extended to states willing to take strong measures to improve irrigation efficiency and control exploitation of groundwater. The idea is also in line with the National Farmer Policy, 2007 which stated that all technology missions should also contribute to retain, renovate and restore water bodies that are linked to agriculture. As such, stringent regulations, incentives and disincentives, and awareness campaigns on water use and management should be included in the solar pump schemes. Central Water Commission (CWC) and Central & State Groundwater Boards (CGWB & SGWBs) should be given more responsibility within KUSUM for better utilization of water and proper assessment of groundwater resources.

Key elements to be included in the comprehensive solar pumps-based irrigation scheme are:

• **Earmark size of pumps and depth of well for each watershed based on water availability:** Solar pump schemes should include strict mandates of aquifer mapping through participatory approach for the quantitative and qualitative assessment of groundwater storage and transmission characteristics, based on which the size of pumps and depth of bore-well in a particular area should be decided. The wells should be registered to farmers, with water-draft limits and regulatory measures to restrict over-exploitation of groundwater.

• **Ban new installation in 'critical' areas identified by CGWB:** A complete ban should be imposed on the installation of new pumps in dark and grey zones. Further, replacement of old electric or diesel pumps with solar pumps in such areas should be accompanied by strict caps on pump usage, restrictions on sowing of water-intensive crops and mandatory groundwater restoration.

**FUNDS UNDER KUSUM SHOULD ONLY BE EXTENDED TO STATES WILLING TO TAKE STRONG MEASURES TO IMPROVE IRRIGATION EFFICIENCY AND CONTROL EXPLOITATION OF GROUNDWATER**

• **Provide solar pumps to farmers who are undertaking to plant water-efficient crops for 25 years:** Specifically, in water-scarce states, solar pump schemes should be used to promote cropping of less water-intensive but high-value crops such as pulses, millets, vegetables, legumes, oilseeds, medicinal plants etc. This may also require additional backing such as that of increased minimum support price. Crop rotation and diversification should be encouraged to improve the water holding capacity of the soil.

• **Mandate rainwater harvesting and development of irrigation structures:** Rainwater harvesting and recharge of the aquifer must be mandated for farmers deploying solar pumps to ensure the stability of supply. So far, rainwater harvesting regulations have focused primarily on urban areas, while in rural areas it has not yet taken off despite agriculture being the largest consumer of groundwater. Management and performance improvement of canal irrigation systems should also be made a part of the scheme.

• **Mandate use of efficient irrigation practice:** Efficient irrigation practices such as the use of sprinkler and drip irrigation must be mandated along with solar pump deployment. Such demand-side practices not only improve water efficiency but also help increase productivity. This is currently being promoted through the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) and should be integrated with KUSUM.

• **Periodical monitoring of groundwater extraction:** All installed solar pumps should be equipped with Information Communication Technology (ICT) enabled remote monitoring with water-metering systems to track their utilization and groundwater extraction. States like Maharashtra, Chhattisgarh

**GRADUAL INCREASE IN ELECTRICITY TARIFFS, ALONG WITH SOLARIZATION OF FEEDERS IS CRUCIAL TO CONTROL GROUNDWATER EXPLOITATION AND REDUCE AGRICULTURAL SUBSIDY BURDEN**

and Andhra Pradesh have already started experimenting with this. MNRE must define standard formats for data collection so that the data can be analyzed to identify trends. Necessary legislative measures to regulate and control groundwater extraction should be taken up simultaneously. Corrective measures should be put in place depending on the trends in water table levels.

KUSUM should be seen as an opportunity under National Water Policy 2012 to help the agricultural sector evolve in a system which economizes the use of water and maximizes the value of irrigation with improved water application methods and deals with increased variability because of climate change. Groundwater management reform can be put forward through participatory approach to sustainable and equitable methods.

## Selecting the appropriate solar pump model

• **Prioritize solarization of feeders:** Solarization of agricultural feeders, also planned under KUSUM, should be the preferred solution, given that it is the most economical and provides additional income to farmers. However, this should be accompanied by a gradual increase in electricity tariffs, which is crucial to control groundwater exploitation and reduces the burden of agricultural subsidy.

• **Balance subsidy and FiT for solarized pumps:** On-grid pump deployment may be an alternative in water-scarce regions with high farmer distress as it can generate parallel income for farmers with adequate FiTs while dis-incentivizing water over-extraction. The schemes should focus on on-grid pumps that can inject power but cannot draw from the grid, to control groundwater extraction.

The Gujarat model of loan based financing of on-grid pumps clubbed with high FiT should be adopted as against Andhra's models of free pumps and low FiT, so as to incentivize groundwater conservation as well as meaningfully support farmer income.

• **Consider off-grid solar pumps only in exceptional cases:** Deployment of off-grid solar pumps should be planned only in areas where electricity supply is very poor and is unlikely to reach in coming years and moreover, where the water table is relatively high—for example in East Uttar Pradesh, Bihar and West Bengal. However, in the absence of any control over usage and alternate use, there is a serious risk of groundwater depletion. Therefore, the government must promote off-grid solar pumps for supplying electricity for household consumption and for broader economic development. Such a mini-grid system could have solar pumps or small business acting as anchor load, which could further be connected to the grid.
Community-based or entrepreneur-based water-sale models, ideally grid-connected, should be encouraged in areas with fragmented land holdings, i.e. high penetration of small and marginal farmers.

## Beneficiary targeting and financing

• Detailed assessment of beneficiaries: Beneficiary targeting should not be through limiting pump sizes but through a detailed assessment of the financial well-being of a farmer. Right now there is a misuse, hence, the government needs to ensure that benefits reach the intended beneficiaries. Clear targets must be set under schemes like KUSUM to include small and marginal farmers.

• **Cooperatives for small and marginal farmers:** Solar Farmer Cooperatives should be promoted to ensure inclusion of more number of small and marginal farmers under the scheme. These cooperatives can operate on on-grid/mini-grid solar pump model with a small contribution from each member-farmer for wide-range equity, sustainability impact with high utilization of asset. This will help develop participatory irrigation management (PIM) which will result in increased reliability and equitable water distribution.

• **Special funds under KUSUM:** Access to financing is a crucial determinant in ensuring that poor farmers benefit from solar pump deployment. Special funds can be created for supporting this through money raised by discoms from the sale of RECs or from NCEF.

## Capacity Building

• **Service market development and job creation:** Service market for solar pumps needs to be developed, as utilization of assets will depend on it. This can be catalyzed by state nodal agencies in coordination with the Ministry of Skill Development and Entrepreneurship leading to job creation.

• **Comprehensive awareness campaigns:** Solar-based irrigation scheme must also include a water literacy campaign for farmers to efficiently use and conserve groundwater drawn using solar pumps. Empowering of Farmer Water Users Associations (WUAs) should be done to ensure participatory irrigation management to reinforce bottoms-up approach for the implementation of KUSUM.

**SOLAR FARMER COOPERATIVES NEEDS TO BE DEVELOPED TO ENSURE SOCIAL EQUITY**

## Other key measures

• **Effective functioning of discoms:** Given the central role of discoms in grid-connected solar pump model, regulators need to ensure efficient discom operations by mandating regular reporting on installations, operations, evacuation, billing and payment to farmers.

• **Agricultural electricity tariff reforms:** Solar pump scheme should be complemented with overall electricity tariff reforms while taking into consideration the subsidy burden and the consumption levels. This will incentivize farmers to shift to solar-based solutions and energy-efficient irrigation practices.

• **Use of energy-efficient pumps:** Solarization of feeders should be accompanied by the replacement of regular electric pumps with energy-efficient pumps to reduce energy consumption and thus the agricultural subsidy.

• **Quality Control:** Large scale deployment of solar pumps will need a check on the quality of the pumps supplied to the farmers. The standards may vary regionally. Some government or private agencies should be designated to develop the test procedures to guarantee definite operation of solar pumps.

# ANNEXURES

## ANNEXURE 1: CENTRAL GOVERNMENT SOLAR PUMP PROGRAMMES AND PROGRESS

| Year | Programme | Target | Implementing agencies | Features | Progress |
|---|---|---|---|---|---|
| 1992–2010 | Solar Agriculture Pumps | 50,000 | IREDA and SNAs | CFA up to 90 per cent. Soft loan available for farmers | Negligible |
| 2010–14 | JNNSM Phase-1 Decentralized Off-grid Application | 200 MW (SPAPs up to 5kWp) | SNAs | SFA of 40 to 60 per cent over and above MNRE share | 11,626 SPAPs installed in the various parts of the country (till March 2014) |
| 2012–15 | Solar Pump Programme by Ministry of Drinking Water and Sanitation | 11,068 | 10 states | Financial assistance of Rs 221.2 crore provided to states under National Clean Energy Funded scheme (40 per cent), CFA (30 per cent) and SFA (30 per cent) | 8,967 pumps installed as of July 2016 |
| | | 15,400 | 17 states | With MNRE assistance | 5,004 pumps installed as of July 2016 |
| 2014–2022 | Solar Pumping Programme | 10 lakh pumps (1 lakh each year) | SNA and other central government ministries | 30 per cent by CFA, states have their own subsidy criteria, beneficiaries paying between 5 to 40 per cent | Total sanctioned—2.4 lakh (discontinued after December 2017)<br>Total installed—2.3 lakh as of March 2019 |
| | | 10,000 | NABARD and RRBs | 40 per cent CFA routed through NABARD, 40 per cent as loan, 20 per cent by the beneficiary | 4,000 |

*Source: MNRE, Lok Sabha Questions*

## ANNEXURE 2: ASSUMPTIONS FOR ECONOMIC ANALYSIS OF VARIOUS MODES OF IRRIGATION

| | Amount | Remarks unit |
|---|---|---|
| Pump size | 5 HP | Assumed average size |
| PV size | 4 kW | - |
| Capital cost of off-grid pump | Rs 60,000 per HP | Based on recent tenders |
| Capital cost of on-grid pump for 5 HP | Rs 52,000 per HP | Based on recent tenders |
| Capital cost of electric pump for 5 HP | Rs 20,000 | Market price |
| Average power procurement cost | Rs 3.6 per unit | CERC, 2019 |
| Average cost of supply | Rs 6.0 per unit | Estimated based on CERC data |
| Tariff rate escalation | 4 per cent | Estimated based on CEA |
| Discount rate (real) | 8 per cent | Assuming 4 per cent inflation |
| Hours of pumping | 800 hours | Assumed based on 8 hours of pumping for 100 days |
| Life cycle | 25 years | - |
| Rural AT&C loss | 40 per cent | Estimated based on CERC data |
| Realization rate | 33 per cent | PFC, 2017 |
| Rural feeder loss | 10 per cent | Estimated based on Gujarat experience in SKY |
| Solarized feeder (goverment land) | Rs 3.0 per unit | Based on tender awarded by Maharashtra to EESL |
| Solarized feeder (Pvt land) | Rs 4.0 per unit | Estimated based on developer inputs and other sources |

# REFERENCES


1. Ministry of Statistics and Program Implementation. (2018). Agriculture – Statistical Year Book India 2018. Retrieved July 1, 2019, from: http://mospi.nic.in/statistical-year-book-india/2018/177
2. Ministry of Statistics and Program Implementation. (2018). Irrigation – Statistical Year Book India 2018. Retrieved July 1, 2019, from: http://mospi.nic.in/statistical-year-book-india/2018/177
3. Narayanamoorthy, A. (2010). Development and composition of irrigation in India: Temporal trends and regional patterns. Irrigation and Drainage, 60(4), 431–445.doi:10.1002/ird.593
4. Gandhi, V.P., & Namboodiri , N.V. (2009). Groundwater Irrigation in India: Gains, Costs and Risks. Retrieved July 16, 2019, from: https://web.iima.ac.in/assets/snippets/workingpaperpdf/2009-03- 08Gandhi.pdf
5. Zaveri et. al. (2016). Invisible water, visible impact: groundwater use and Indian agriculture under climate change. Retrieved July 15, 2019, from: http://www.indiaenvironmentportal.org.in/files/file/groundwater%20use%20and%20agriculture%20India.pdf
6. National Aeronautics and Space Administration. (2009). NASA Satellites Unlock Secret to Northern India's Vanishing Water. Retrieved July 2, 2019, from: https://www.nasa.gov/topics/earth/features/india_water.html
7. Government of India. Planning Commission. (2007). Ground Water Management and Ownership. Report of Expert Group. Retrieved July 22, 2019, from: http://planningcommission.nic.in/reports/genrep/rep_grndwat.pdf
8. World Bank. (2010). Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India. Retrieved July 17, 2019, from: http://documents.worldbank.org/curated/en/272661468267911138/pdf/516760ESW0P0951round0Water129101110.pdf
9. Government of India. Planning Commission. (2007). Ground Water Management and Ownership. Report of Expert Group. Retrieved June 15, 2019, from: http://planningcommission.nic.in/reports/genrep/rep_grndwat.pdf
10. Badiani, R. & Jessoe, K. (n.d.). The Impact of Electricity Subsidies on Groundwater Extraction and Agricultural Production. Retrieved June 12, 2019, from: https://economics.ucdavis.edu/events/papers/Jessoe51.pdf
11. Ministry of New and Renewable Energy (2019). Guidelines for Implementation of Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan (PM KUSUM) Scheme. Retrieved on July 30, 2019, from: https://mnre.gov.in/sites/default/files/webform/notices/KUSUMguidelines.pdf
12. Ministry of Agriculture & Farmers Welfare. (2015). All India Report on Agriculture Census 2011-11. Retrieved August 1, 2019, from: http://agcensus.nic.in/document/ac1011/reports/air2010-11complete.pdf
13. Kaur, S., Aggarwal, R., & Brar, M. S. (2017). Groundwater Depletion in Punjab, India. 10.1081/E-ESS3-120052901.

14. Sarkar, A. & Das, A. (2014). Groundwater Irrigation-Electricity-Crop Diversification Nexus in Punjab. Retrieved July 15, 2019, from: https://www.indiawaterportal.org/sites/indiawaterportal.org/files/groundwater_irrigation-electricity-_crop_diversification_nexus_in_punjab_economic_and_political_weekly_2014.pdf

15. Central Electricity Authority. (June 2018). Growth of Electricity Sector in India from 1947-2018. Retrieved July 15, 2019, from: http://www.cea.nic.in/reports/others/planning/pdm/growth_2018.pdf

16. Spencer, T & Awasthy, A. (2019). Analysing and Projecting Indian Electricity Demand to 2030. Retrieved July 23, 2019, from: https://www.teriin.org/sites/default/files/2019-02/Analysing%20and%20Projecting%20Indian%20Electricity%20Demand%20to%202030.pdf

17. Gulati, M. & Pahuja, S. (n.d.). Direct Delivery of Power Subsidy to Agriculture in India. Retrieved July 25, 2019, from: https://www.seforall.org/sites/default/files/l/2015/08/SE4All-Direct_Delivery_of_Power_Subsidy_to_Agriculture_in_India.pdf

18. Central Electricity Authority. (2019). Executive Summary on Power Sector Mar-19. Retrieved August 1, 2019, from: http://www.cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-03.pdf

19. Power Finance Corporation Ltd. (n.d.). Report on "The Performance of State Power Utilities for the years 2013-14 to 2015-16". Retrieved July 5, 2019, from: http://www.pfcindia.com/DocumentRepository/ckfinder/files/Operations/Performance_Reports_of_State_Power_Utilities/1_Report%20on%20the%20Performance%20of%20State%20Power%20Utilities%202013-14%20to%202015-16.pdf

20. Prayas (Energy Group). (2018). Understanding the Electricity, Water, Agriculture Linkages - Volume 1. Retrieved July 5, 2019, from: http://www.indiaenvironmentportal.org.in/files/file/Understanding%20the%20Electricity,%20Water%20&%20Agriculture%20Linkages.pdf

21. Times of India. (May 21, 2019). Why give free power to rich farmers, asks HC. Retrieved July 1, 2019, from: http://timesofindia.indiatimes.com/articleshow/69420032.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

22. Gangan, S.P. Hindustan Times. (July 18, 2017). After loans, Maharashtra farmers now want state to waive Rs 22,000 crore electricity dues. Retrieved July 5, 2019, from: https://www.hindustantimes.com/mumbai-news/after-loans-maharashtra-farmers-now-want-state-to-waive-22-000-crore-electricity-dues/story-zse1hdxgBg9mlYuLxhOuaJ.html

23. Ganapatye, S. Asian Age. (April 12, 2018). State plans power bill waivers for farmers. Retrieved July 5, 2019, from: https://www.asianage.com/metros/mumbai/120418/state-plans-power-bill-waiver-for-farmers.html

24. The Economic Times. (December 18, 2018). Gujarat government waives Rs 625 crore energy bill dues of rural users. Retrieved July 5, 2019, from: https://economictimes.indiatimes.com/articleshow/67149423.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

25. Central Electricity Authority. (2019). Executive Summary on Power Sector Mar-19. Retrieved August 1, 2019, from: http://www.cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-03.pdf

26. Rawat, S. and Mukherji, A. (2012). Poor State of Irrigation Statistics in India The Case of Wells and Tube Wells. IWMI-TATA Water Policy Program. Retrieved on , from: http://www.iwmi.cgiar.org/iwmi-tata/PDFs/2012_Highlight-05.pdf

27. Ministry of New and Renewable Energy. (July 2019). Office Memorandum: Benchmark costs for Off-grid Solar PV Systems and Solarisation of Grid Connected Agricultural Pumps for the Year 2019-20. Retrieved July 29, 2019, from: https://mnre.gov.in/sites/default/files/webform/notices/Benchmark%20Order%20FY%202019-20.pdf

28. Ministry of New and Renewable Energy. (June 2010). Guidelines for off-grid and Decentralised Solar Application. Retrieved July 29, 2019, from: https://mnre.gov.in/sites/default/files/schemes/aa-mnre-jnnsm-2010-11.pdf

29. Ministry of New and Renewable Energy (2014). Solar Pumping Programme for Irrigation and Drinking Water. Retrieved on , from: https://mnre.gov.in/file-manager/UserFiles/Scheme-for-Solar-Pumping-Programme-for-Irrigation-and-Drinking-Water-under-Offgrid-and-Decentralised-Solar-applications.pdf

30. Maharashtra Energy Regulatory Commission. (2018). Retrieved April, 13, 2019, from: http://www.mercindia.org.in/pdf/Order%2058%2042/Order195%20of%202017-12092018.pdf

31. Durga et. al. IWMI-Tata Water Policy Program. (2016). Can Solar Pumps Energize Bihar's Agriculture? Retrieved June 15, 2019, from: http://www.iwmi.cgiar.org/iwmi-tata/PDFs/iwmi-tata_water_policy_research_highlight-issue_03_2016.pdf

32. Jain, A. & Shahidi, T. CEEW. (2018). Adopting Solar for Irrigation Farmers' Perspectives from Uttar Pradesh. Retrieved January 15, 2019, from: http://www.ceew.in/sites/default/files/CEEW-Adopting-Solar-for-Irrigation-Farmers-Perspectives-from-UP-Report-17Jan18.pdf

33. Indian Express. (May 30, 2018). AP government to back up farmers' income with solar power. Retrieved June 15, 2019, from: http://www.newindianexpress.com/states/andhra-pradesh/2018/ may/30/ap-government-to-backup-farmers-income-with-solar-power-1821209.html

34. Gujarat Electricity Regulatory Commission. (n.d.). Retrieved April 15, 2019, from: http://www.gercin.org/uploaded/document/da415e7b-2f4d-4a28-8834- 99b76d21cd32.pdf

35. Ministry of New and Renewable Energy (2019). Amendment in Guidelines for implementation of Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan Scheme. Retrieved on August 23, 2019, from: https://mnre.gov.in/sites/default/files/webform/notices/AmendmentKUSUMGUidelines.PDF

36. Ministry of New and Renewable Energy (2017). Concept Note on Solar PV Manufacturing Scheme. Retrieved on August 23, 2019, from: https://mnre.gov.in/file-manager/UserFiles/gspd-concept.pdf

37. Ministry of Water Resources (2014). Guidelines for Improving Water Use Efficiency in Irrigation, Domestic & Industrial Sectors. Retrieved on August 23, 2019, from: http://mowr.gov.in/sites/default/files/Guidelines_for_improving_water_use_efficiency_1.pdf

38. Gupta, E. (2017). Extending Solar Water Pump Subsidies: Impact on Water use, Energy use and Cropping Patterns in Rajasthan: Difference in Differences Analysis. Retrieved July 15, 2019, from: https://www.isid.ac.in/~epu/acegd2017/papers/EshitaGupta.pdf

39. Ministry of Agriculture & Farmers Welfare Government of India (2019). Agriculture Census 2015-16. Retrieved on August 23, 2019, from: http://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf

40. Bhogal, P. (2016). Policy Imperatives for India's Small Farmers. ORF Issue Brief. Retrieved on August 23, 2019, from: https://www.orfonline.org/wp-content/uploads/2016/12/ORF_Issue_Brief_167_Small_Farmers.pdf

Solar-powered irrigation is being aggressively promoted by the government as an affordable and sustainable solution for agriculture as well as the rising burden of electricity subsidy. But will solar pumps become a win-win situation for all stakeholders? Can they alleviate farmer distress when inclusion of small and marginal farmers is still doubtful? Can they assuage discom losses despite the continuing subsidy model? And, most importantly, are the groundwater concerns adequately addressed?

This report closely examines these issues to suggest ways to make solar-powered agricultural pumps a more comprehensive and holistic solution.

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