Understanding the Electricity, Water & Agriculture Linkages

Volume 1 : Overview

Prayas (Energy Group)

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September 2018

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Prayas (Energy Group)

About Prayas

Prayas (Initiatives in Health, Energy, Learning and Parenthood) is a non-governmental, non-profit organization based in Pune, India. Members of Prayas are professionals working to protect and promote the public interest in general, and interests of the disadvantaged sections of the society, in particular. Prayas (Energy Group) works on theoretical, conceptual, regulatory and policy issues in the energy and electricity sectors. Our activities cover research and intervention in policy and regulatory areas, as well as training, awareness, and support to civil society groups. Prayas (Energy Group) has contributed in the energy sector policy development as part of several official committees constituted by ministries, erstwhile Planning Commission and NITI Aayog. Prayas is registered as SIRO (Scientific and Industrial Research Organization) with Department of Scientific and Industrial Research, Ministry of Science and Technology, Government of India.

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Acknowledgements
Interactions with farmers, farmer associations and researchers have greatly helped us to gain insights into this complex area, especially since it is relatively new for us. We would like to thank Aditi Mukherji, Chanda Nimbkar and Sathyanarayana Udupa for sharing their valuable inputs regarding various aspects of agriculture, irrigation and electricity. Our reviewers have given many valuable comments, which have enriched the paper. We are grateful to K J Joy, Milind Murugkar and Ashwini K Swain for reviewing Volume One of this discussion paper and to Ajit Pandit, M Palaniappan, M Thimma Reddy, Ashwini K Swain and DP Chirania for reviewing Volume Two of the discussion paper. We thank Neeta Dehpande, who has helped with language editing. Our colleagues, especially Shantanu Dixit, Ashwini Chitnis and Ann Josey have given many insightful inputs towards preparation of this paper. Shilpa Kelkar has helped with the production. As authors, we take sole responsibility for any errors or omissions.

Suggested citation: Prayas (Energy Group). (2018). Understanding the Electricity, Water, Agriculture Linkages - Volume 1

September 2018
For Private Circulation only

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Executive Summary

Electricity distribution companies (DISCOMs) have been reeling under massive financial losses for a long time. The central government has implemented three bailout packages in the last 15 years to relieve their financial stress. Thus, it is no surprise that electricity distribution is characterised as the weakest link in the power sector. This in turn is largely seen as a result of subsidised electricity supply to certain categories, major among them being agriculture. This subsidy is covered either by consumers of other categories who are charged higher tariffs (cross-subsidy), or by grants from the state governments (direct subsidy).

Since the 1970s, agriculture in many Indian states has been receiving electricity with low tariffs. In some cases, electricity is supplied for free. Much of this supply is unmetered. Subsidised supply has played a key role in the growth of groundwater irrigation and agricultural production in the country during the green revolution and after. But in recent years, studies have emphasised the negative impacts of subsidised electricity supply not only on DISCOMs, but also on state governments and cross-subsidising consumers who also finance this subsidy. Free or subsidised electricity supply is seen as the primary cause of unsustainable groundwater extraction as well as the poor quality of electricity supply to rural consumers. Unsurprisingly, a large part of the story of power sector reforms has been the push for the reduction of this subsidy. However, such reforms have been largely ineffective, and issues related to DISCOM finances have persisted or been aggravated. This problem thus requires deeper examination.

We reiterate that electricity based ground water irrigation has a crucial role in ensuring food security and rural livelihoods. We argue that this subject needs to be analysed in an integrated manner, covering the water and agriculture or food production aspects of electricity supply, as well as its linkages with farmers' livelihoods and welfare. This is because of the inextricable linkages between agricultural electricity supply and groundwater, food production and farmer livelihoods, and the far-reaching implications of reforms in the electricity sector on these issues. Only such an integrated analysis and joint efforts by all concerned actors can address the challenges in electricity based ground water irrigation.

This discussion paper on understanding the linkages between electricity, water, and agriculture is presented in two volumes. While Volume 1 provides an overview of the subject, Volume 2 addresses the challenges in electricity supply. Together, they tackle important questions like: How does unmetered subsidised electricity supply to agriculture affect DISCOM finances? How much is the subsidy responsible for over-extraction of groundwater? What is the impact of the subsidy on agricultural growth and farmers' livelihoods? What are the likely implications of cutting back on the subsidy for agricultural growth and farmers' livelihoods? What has been the efficacy of attempts undertaken to address the challenges so far? And what are the possible methods to address them?

The key findings of the study are:

1. **Subsidy to agriculture is overestimated:** The subsidy to agriculture is overestimated as electricity consumption in agriculture is overestimated, which has been a long-standing problem. When more accurate methods to estimate agricultural consumption are used,

many states have seen a downward revision in their agricultural electricity consumption and upward revision in distribution loss, some even multiple times over the years. Thus, it would appear that state governments and cross-subsiding consumers are financing theft and DISCOM inefficiencies under the guise of agricultural consumption. Feeder separation (separating agriculture feeders from village feeders) should have helped to improve the estimation of agriculture consumption. But this has not happened, since it is not completed in all states and in some cases where it is, feeder data is not used for estimation, for example in Gujarat.

2. **Financing of total subsidy is a problem:** Agriculture is not the only consumer category that receives subsidised electricity. Subsidy to other consumer categories, especially domestic consumers, is on the rise. State governments bear a higher share of the total subsidy. At the same time, subsidy from state governments is getting delayed or is falling short of their subsidy reimbursement obligations to the DISCOMs, leading to financial problems for the latter. This issue is only going to get worse due to the current trend of reduction in share of the cross-subsidy in the total subsidy.

3. **Subsidised electricity supply has facilitated agricultural growth:** The availability of electricity at cheap rates has been one of the important factors in the sharp rise in irrigation facilities, thus helping growth in agriculture. Groundwater is now the dominant source of irrigation in the country. As groundwater (or pumped) irrigation places control of the timing and quantity in the hands of the farmers, it has been the preferred mode of irrigation, and is likely to remain so in the future. Thus, groundwater, and in turn electricity will remain crucial for agricultural growth and by implication for livelihoods and food security in the country.

4. **Rationing hours of supply and connections has limited impacts:** Rationing of power supply by limiting hours of supply or restricting number of connections to agriculture does help impose some limits on its electricity consumption and subsidy requirements, but it has not led to the expected results. The limitations in hours of supply have often been met by farmers installing higher capacity pumps and/or more pumps. Restrictions on new connections have seen rise in unauthorised connections. Feeder separation has reduced the hours of supply to agricultural pump-sets and reportedly improved the quality of supply. But it has also adversely affected water markets in several cases. Thus, rationing hours of supply and connections alone cannot curtail electricity consumption and thereby significantly reduce subsidy. This is because electricity consumption is driven primarily by the need for pumped irrigation, which would in turn depend on the irrigation water requirement of the crops cultivated, i.e. on the cropping pattern.

5. **Raising agricultural electricity tariff is likely to have significantly impact on farmers' incomes:** Farmers' margins for their produce are already being squeezed, and a rise in electricity tariff will only make matters worse for them, even though electricity cost is a small portion of the total input cost.

6. **DISCOMs need to take the first step to address the issues of poor quality electricity supply and low levels of metering:** While low metering levels for pump-sets have been attributed to resistance from farmers to metering, poor supply and service quality to agriculture has been seen as a result of the low agricultural tariff. However, continued

issuance of unmetered connections by DISCOMs and the failure of DISCOMs to take regular meter readings has shown that DISCOMs have also been reluctant when it comes to metering. It is difficult to attribute poor supply quality to agriculture and rural areas to low tariffs, as subsidy has been largely addressing the issue of low tariff. But it is also to be noted that subsidy is not always fully covered by the state or cross-subsidy, or not covered by the state in a timely manner.

Farmers and DISCOMs have been caught in a low equilibrium because of low revenue from agriculture for DISCOMs and poor supply quality for farmers. It is a challenge to ensure quality supply and service to rural consumers thinly spread over a large area. One way suggested to break out of this low equilibrium is to raise agricultural tariff which will improve the DISCOM's ability to provide better quality supply. However, improvement in power and service quality through higher tariffs is uncertain, largely owing to the lack of accountability of the DISCOM in ensuring improvements in supply and service quality.

Further, owing to farmers' distrust of DISCOMs as well as the significant impact of higher tariffs on farmer economics, DISCOM revenue from agriculture will not improve if power quality and service is not improved prior to tariff increase. Therefore, it is the DISCOMs which should take the first step to improve the quality of service before raising tariffs. A separate regulatory process with public hearings can be initiated to monitor power supply and service quality.

7. **Electricity subsidy is an enabler, rather than driver for excessive groundwater extraction:** The link between excessive extraction of groundwater and electricity subsidy is not straightforward. Hence, whether metering and raising tariff will address groundwater over-extraction is questionable. Cropping patterns are a major driver for the demand for groundwater, with cheap electricity being an enabler. The extensive use of diesel to power pump-sets, even though expensive to run, testifies to this. Growing crops in areas that are not agro-climatically suitable leads to less efficient use of water, and the need for excessive water withdrawals from groundwater. Sugarcane in some parts of Maharashtra and rice in Punjab are examples of this phenomenon. Such skewed cropping patterns are a result of better prices and more assured procurement compared to those prevalent for less water-intensive crops or crops more suitable to the region. Thus, unless farmers get a remunerative price and assured markets for crops which consume less water and are suitable to the local agro-climatic characteristics, commercial pricing of electricity to agriculture may not lead to reduction in groundwater extraction.

8. **Reduction in electricity subsidy alone is not a solution:** All of the above show that a higher electricity tariff (even if the increase is modest and within the paying capacity of farmers) may not solve the problems, unless there are simultaneous measures in power supply, agricultural marketing and groundwater conservation and regulation. It is also doubtful that increases in tariff would reduce the financial losses of DISCOMs and agricultural electricity subsidy, unless there are reliable estimates of agricultural consumption.

9. **Existing data is inadequate, unreliable and inconsistent:** Right from agricultural electricity consumption estimates to data on the groundwater irrigated area, many data points and data-sets with respect to electricity, water and agriculture are unreliable. There

is no data for key parameters like groundwater irrigated area by crop, or for variables related to electricity supply in some states, and existing data has many gaps. There are inconsistencies in the same data published by different agencies involved in ground water, agriculture and electricity. All of these make it hard to analyse issues related to subsidised electricity supply to agriculture. However, available data has been used with care so that the broad lessons and observations drawn in this discussion paper are not undermined by the data limitations.

Following are the suggestions that follow from these observations:

1. **Integrated approach to electricity supply and subsidy is needed:** Agricultural supply, metering, and tariff revision should not be seen only from an electricity/ DISCOM perspective. These issues need to be seen from a larger social perspective, which includes the needs and situation of farmers, and incorporates an understanding of the agriculture as well as water sectors, as shown in the figure. The determination of subsidy should also be done in such an integrated manner at the state level (or lower levels like district, block or panchayat), and can be coordinated by state governments. The quantum of subsidy should be backed by a clear rationale arrived through research, studies and planning that addresses suitable cropping patterns, farmers' economics and groundwater regulation.

2. **Framework for estimation of agricultural electricity consumption is needed:** Past experience has shown that universal pump-set metering is difficult due to various reasons. Thus, feeder and distribution transformer (DT) metering, regular energy audits, third party audits, publication of data in the public domain, and a periodic census of pump-sets will be needed for more reliable estimates of agricultural electricity consumption.

3. **Ideas need to be tested through pilot projects:** Since tariff reform alone is not a solution for the problem, other ideas need to be tried out in the form of pilot projects after consultation with farmers. Pre and post implementation studies should be conducted to evaluate their effectiveness. Solar plants of 1-2 MW capacity at the feeder level catering exclusively to agriculture feeder is an excellent alternate supply option. Metering of a group of pump-sets where farmers have shown interest, DT metering, automatic feeder metering, census of pumps and third party energy audits will help to improve consumption estimation. Setting up distributor transformer associations on the line of water users associations, community driven regulation of ground water extraction and recharge, and improved power and service quality and grievance redressal are some other possible pilots. Ideas to improve efficiency include extending capital subsidy for new and efficient pumps in areas without groundwater stress, block level hours of supply or electricity tariff depending on the cropping pattern and groundwater status of the block and a procurement and price regime to encourage a shift towards an appropriate cropping pattern.

It is apparent that the mainstream discourse around the role of electricity supply to agriculture in the financial loss of DISCOMs and groundwater over extraction has severe limitations. It only addresses issues like low electricity tariffs and lacks the emphasis on many key systemic problems of the electricity distribution, water and agriculture sectors, and the interlinkages between these sectors. Given low incomes and high risks in agriculture, levying higher charges on farmers should not be the immediate priority. Before that, the system needs to be made more accountable, inefficiencies in the system need to be weeded out, and supply and service quality has to be improved. Without these measures, agriculture will continue to be an easy scapegoat for issues surrounding the electricity-groundwater-agriculture 'nexus', and effective solutions for these problems will continue to remain elusive.

Table of Contents

List of Figures

List of Tables

1. Introduction

In November 2015, the Government of India (GoI) launched the Ujjwal DISCOM Assurance Yojana (UDAY), a scheme for operational and financial turnaround of power Distribution Companies (DISCOMs). Documents pertaining to this scheme estimated the total accumulated losses of DISCOMs in March 2015 to be Rs 3.8 lakh crores (MoP, 2015)—3.3% of the country's Gross Domestic Product (GDP) for that year (MOSPI, 2017).

But these figures do not tell the whole story. The gravity of the problem is revealed further by the fact that UDAY is the third major bailout package for the distribution sector between 2001 and 2015 (PEG, 2018, p. 206).

That this problem has persisted over the years despite bailouts and reforms points to the important lacunae in identifying the fundamental reasons and addressing them.

From the early 1990s, a significant thread in the story of reforms related to the power sector and particularly the distribution sector in India is the financial unsustainability of the distribution sector. One of the reasons for this unsustainability has been the free or below-cost and subsidised supply of electricity to certain categories of consumers (PEG, 2018, p. 213). This has meant higher burden through cross-subsidies on other consumers, massive financial outgo from government coffers as direct subsidy, and breakdown in the financial stability of DISCOMs.

Agricultural supply has been singled out by many as the main cause of these developments (Department of Power, GoI, 1980; Planning Commission, 1994; AF-Mercados, 2014). Unsurprisingly, a major part of the reforms has been the push for the elimination of subsidies and increasing tariffs for agricultural consumers.

In the case of agricultural electricity supply, it has been argued that subsidised supply has also led to its poor quality. This is often described as a vicious cycle, with the DISCOM having little incentive to ensure quality and adequacy of supply to agricultural consumers as it loses money on every additional unit supplied due to tariffs that are below the cost of supply.[1] The farmers, on the other hand, have little incentive to pay higher tariffs as they receive electricity at odd times, of uncertain quality, and insufficient quantity. Thus, farmers and DISCOMs are locked in what is referred to as a low-level equilibrium. Subsidised or free supply of electricity is also said to lead to an overextraction of groundwater resulting in sharp falls in groundwater levels and related problems of higher pumping costs and deterioration in groundwater quality. Rationalisation of agricultural tariffs, which is another word for increasing the tariffs towards the cost of supply, is advocated as necessary to tackle these problems as well.

The contribution of groundwater and hence electricity to agriculture production and growth has been steadily increasing over the years, and now groundwater is the dominant source of irrigation. Considering the critical position that agriculture occupies in the country's economy, in ensuring

1. While DISCOMs are supposed to be compensated by the state governments for this loss, the payments by the state government are often delayed and may not cover the entire amount. Moreover, part of the loss due to tariffs below cost of supply is supposed to be covered by cross-subsidy, that is, charging other consumers higher tariffs than the cost of supply. This leads to resistance on part of consumers with high paying capacity.

food security for the population, providing livelihoods to the majority, and indeed as a way of life for most rural people, reforms, including tariff reforms, in agricultural electricity supply have far-reaching implications. Unfortunately, much of the analysis of the role of agricultural supply in the financial problems of DISCOMs, as well as suggestions to address these problems, have been narrowly focussed only on the power sector aspects. To appreciate all the dimensions of the problem, it is important to place it within the context of the linkages between agriculture, electricity and water. Barring a few exceptions, comprehensive and nuanced analysis bringing in insights from the agriculture and water sectors is missing. This is an important reason for our failure to effectively address agricultural supply related problems of the distribution sector. Also, solutions that can simultaneously address the problems of not only the DISCOMs but also the agriculture and water sectors have been difficult to come by for the same reason.

It is against this background of the persistent financial problems of DISCOMs, the onus placed on agricultural supply for these problems, and the far-reaching implications of reforms in agricultural electricity supply that we felt it important to examine this issue in a comprehensive manner. We have two key motivations. First, we would like to question the role of electricity supply to agriculture in the financial losses of DISCOMs. Second, we want to address the need for a comprehensive analysis of electricity supply to agriculture keeping in mind its linkages to the water and agriculture sectors.

The overall objective of this discussion paper is to bring out the linkages between electricity, water and agriculture, with the aim to inform policy and decision makers as well as other actors in the power sector about these linkages. We also highlight the need to take these linkages into consideration when planning agricultural electricity supply.

We present our analysis in the form of this Discussion Paper "Understanding the Electricity, Water, Agriculture Linkages", in two volumes. Volume 1 (which is this document) focuses on an overview of the linkages between electricity, water and agriculture. It provides a brief overview of the electricity sector related issues of power supply to agriculture. It further discusses the role that electricity has played in agriculture and groundwater development, as well as key issues of concern. It examines the likely impacts of reforms in agricultural electricity supply including tariff reforms on water, agriculture and farmers. Based on this analysis and discussion, some ideas for the way forward are set out.

The companion Volume 2 provides a detailed analysis of the electricity sector related issues of the linkage. It critically examines the current power sector approach to agriculture with respect to consumption estimation, subsidy, power supply and service, load management, connections, and metering. First it looks at the estimation of electricity consumption in agriculture and the impact of its over-estimation. Second, it assesses the distribution of the subsidy among consumers and subsidy financing. Third, it examines the issues surrounding power supply and service quality to agriculture.

We hope that this study will bring forth insights that can offer more effective and well-rounded suggestions to address the relevant problems.

2. A Word about Data Issues

Before we get into the key issues and their analysis, a word about the availability and quality of data would be in order here. To understand issues related to electricity supply to agriculture, some of the key parameters we need to analyse include the quantum of electricity supplied to agriculture, losses in the course of this supply, total installed agriculture load, number of pump-sets, alternative sources of energy for pumping like diesel, area irrigated by groundwater, other areas irrigated by pumping like surface lift commands, and groundwater availability and draft. Unfortunately, the quality of the data available for almost each and every one of these parameters is problematic. Issues include wrong estimates, large differences in figures from different official sources, lack of adequate time-series data with data often being available at only large time intervals, and so on.

While these data limitations do create problems in analysing the issue, we would like to emphasise that there is enough data and information available, especially when used with reasonable assumptions and proper corroborations, to allow us to draw important inferences and insights, and offer recommendations that would help address the issue effectively. Some examples are provided below to indicate the extent of the problems with the available data.

2.1 Wrong Estimates of Electricity Consumed by Agricultural Consumers

The most basic parameter related to this issue—how much electricity is consumed by agricultural consumers—itself is often not known. Partly, this is because much of this consumption is unmetered. But in such cases, the DISCOM is supposed to use appropriate methodologies to estimate agricultural consumption. In many cases, the estimation methodologies used are inadequate, inaccurate and lacking in rigour. Many times, losses are conflated with and presented as power consumed by agricultural consumers. Because of these issues, in many cases Electricity Regulatory Commissions have disallowed the estimates submitted by DISCOMs, forced them to bring out better estimates using surveys and appropriate methodologies, and revised (almost always downwards) the estimates of agricultural consumption. In spite of several such attempts, reasonably accurate estimates of agricultural consumption remain elusive in most states. These developments are discussed in detail in Section 3.1.

A direct corollary of this situation is that the accuracy of figures of transmission and distribution losses, including both technical and commercial losses of electricity, is questionable.

2.2 Inaccuracies in Groundwater and Irrigation Data

The "Report of the Working Group on Water Database Development and Management" set up by the erstwhile Planning Commission to provide inputs to the 12th Five Year Plan is quite explicit about the dismal condition of data related to groundwater and irrigation (Planning Commission, 2011). To quote one instance:

> "There are considerable unexplained differences between the official estimates of land use and irrigated area at the State and National levels, and those generated by the National Sample Survey and the Planning Commission... (p. ix)

> Data currently being generated are inadequate to provide reliable estimates of groundwater potential and utilisation." (p. xi)

Another issue is that while the figures for areas irrigated by different sources (ground, surface, major, minor, etc) are available, these are for the net irrigated areas. Such source-wise breakup of irrigated areas is often not available for gross irrigated area.[2] There is the additional issue that significant sections of the irrigated areas in the county are under conjunctive irrigation, that is, they are partly irrigated by surface water and partly by groundwater. But the relevant numbers are not always available and conjunctively irrigated areas are clubbed with either surface or groundwater irrigated areas.

2.3 Problems with Data on Number of Pump-sets and Energy Sources of Pumping

There are large discrepancies in the data on the number of pump-sets put out by different official agencies, as well as in the data related to various energy sources powering pump-sets. This is particularly so for the state-level data. For example, see figures given by various agencies for the number of electric pump-sets in Haryana[3] in Table 1 below.

Table 1 Number of Electric Pump-sets, Wells/Tube-wells in Haryana

(Data from Various Official Agencies over the Years)

Year of Reference	No of Electric Pump-sets, as per Central Electricity Authority (CEA)	Other Official Data	
		Number of Electric Wells/Tube-wells	Data Source
2006-07	4,74,296	53,556	4th Minor Irrigation Census
2010-11	5,59,334	5,44,700	10th Agricultural Census
2013-14	5,85,589	3,15,176	5th Minor Irrigation Census

Source: (MoWR, 2014; MoAFW, 2015; MoWR, 2017)

Another example is that of Bihar, where the 4th Minor Irrigation (MI) Census for 2006-07 gives the number of wells/tube-wells using electricity as the power source as zero, and only 14 wells/tube-wells using diesel. More than 6.4 lakh wells/tube-wells are shown as powered by 'other' power sources.[4]

2. The Central Water Commission's Water Resources Information System (WRIS) of India defines net and gross irrigated area thus: Net irrigated area is the area irrigated during the year counting the area only once, even if two or more crops are irrigated in different seasons on the same piece of land. Gross irrigated area is the total irrigated area under various crops during the whole agricultural year, counting the area irrigated under more than one crop during the same year as many times as the number of crops grown. Inter-cultured or mixed crops are treated as one crop. (WRIS)

3. Note that while the CEA figures are for the number of pump-sets, the Agricultural and MI Census both give numbers for wells/tube-wells. These can be somewhat different considering the possibility of multiple pump-sets on the same well or multiple wells powered by the same pump-set. However, this is not enough to explain the large differences in the numbers in different years between these various agencies.

4. The 5th Minor Irrigation Census for reference year 2013-14, which has been released just as this report was being finalised, corrects this.

Similar discrepancies are observed for several other states like Uttar Pradesh (UP), Kerala, Madhya Pradesh (MP), West Bengal (WB), Andhra Pradesh (AP) and Bihar across data from the minor irrigation censuses (2006-07, 2013-14), the agricultural census (2010-11) and the CEA.

Another issue is that reliable data for how much diesel is used to power agricultural pump-sets is not directly available, and we have had to estimate it using various assumptions.

2.4 Disparity between Theoretical Estimations and Actual Agricultural Electricity Consumption

One important indicator of likely problems in the estimation of electricity consumption by agriculture is the wide gap between theoretical estimations for the required pumping energy, and actual agricultural consumption.

The official electricity consumption per unit of groundwater draft for irrigation in many states is considerably higher than the conservative theoretical estimation of the electricity requirement for groundwater pumping. For example, Maharashtra has a theoretical requirement[5] of 0.34 kWh/m^3 of groundwater draft for irrigation, whereas official electricity consumption in agriculture is close to 0.98 kWh/m^3 of draft of groundwater. Such high electricity consumption is justified only if the average groundwater depth in the state is more than 90 m, whereas as per the Central Ground Water Board (CGWB), a miniscule 1-2% of the wells in the state have depth of water more than 20 m (CGWB, 2015, pp. 12-15).

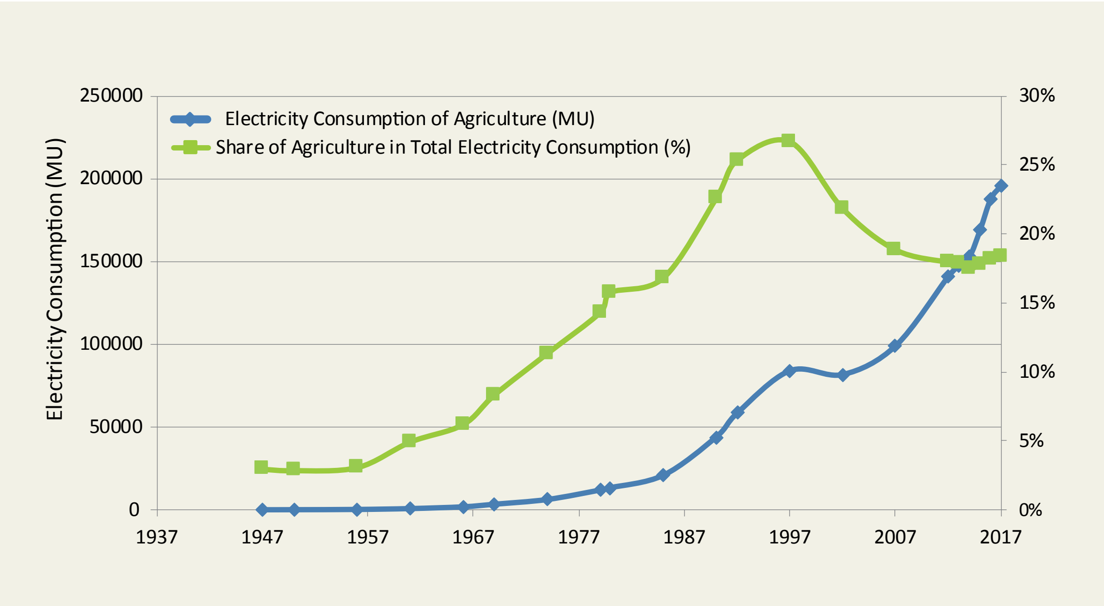
While these data issues do create problems, we would like to reiterate that there is enough data and information available, especially when used with reasonable assumptions and proper corroborations, to allow us to draw important and major inferences.

5. Assumptions used for these theoretical calculations are: (1) Depth/head of groundwater extraction is about 30 m. (2) Pump + motor efficiency is 24% (Indian Pump's Manufacturing Association, 2016).

3. Electricity Use in Agriculture

Due to the rapid growth in groundwater irrigated area, there has been a sharp growth in the electricity use in the agriculture sector, especially since the 1980s. Electricity consumption of agriculture rose from 3,465 Million Units (MU) in 1969 to 1,87,493 MU in 2016. At one time, agriculture use constituted almost 27% of the total electricity consumption, though the share has fallen considerably after that, even as it has increased in absolute value (See Figure 1).

Figure 1: Growth of Electricity Consumption for Agriculture



Source: (CEA, 2017, p. 43)

Since agricultural electricity consumption has been subsidised—either directly or through cross-subsidies—this has created demands on the finances of the power sector and the state governments. Further, in a large number of cases, agricultural connections are unmetered, leading to several problems in estimating the consumption, hiding of technical and commercial losses like theft behind agricultural consumption, lack of accountability in the system, etc.

Due to this situation, cheap or free and unmetered agricultural consumption is seen as a key culprit responsible for many of the long-standing problems of the power sector like the financial health of electricity distribution companies, poor power quality of supply to agricultural consumers, and the impact of cross-subsidies on other categories of consumers.

We examine below some important details of agricultural electricity consumption, and the issues and concerns mentioned above.

3.1 Is Agriculture the Trouble Maker for the Electricity Distribution Sector?

There is some truth in the idea that electricity supply to agriculture has put the sector under financial stress. However, our analysis shows that the responsibility for financial losses cannot be laid solely at its door. Despite the focus on tariff subsidies to agriculture, not much attention has been paid to whether the subsidy goes to subsidise agricultural electricity consumption or pay for distribution losses of DISCOMs. Subsidy support is provided to some non-agriculture consumers (like domestic consumers and a few other categories), and this subsidy component has been increasing in the past few years. Moreover, some part of the subsidy to agriculture is neither covered by the government nor by cross-subsidy, and it contributes to the financial loss of the DISCOM. The payment of subsidy owed to the DISCOM by the state government is often substantially delayed, not paid in full or not fully claimed from the government, which results in additional stress for the DISCOM. As a result, the extent of the sector's losses attributed to agriculture but actually due to factors other than agriculture has not been duly assessed. It is imperative to ascertain this to know if measures to reduce the subsidy are effective. In the following sections, we will examine the issues related to the estimation of agricultural electricity consumption, subsidy and the finances of the DISCOM. These issues are covered in greater detail in Volume 2 of this paper.

3.2 Estimation of Electricity Consumption for Agriculture

The level of metering of agricultural connections is quite low in many Indian states. Only 27% of electricity connections in agriculture were metered in 2012-13 in the major agricultural electricity consuming states: erstwhile undivided Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu (TN) and Uttar Pradesh.[6] This is despite repeated recommendations by government agencies (GoI, 2001; Planning Commission, 1994; GoI, 1993) and repeated directives by state electricity regulatory commissions (SERCs) to meter existing agricultural electricity connections and issue new ones that are metered. Hence the true level of electricity consumption in agriculture is unknown.

Some electricity is lost in the distribution system during transit before it reaches the end consumer. This is the distribution loss. It is lost because of a technical loss (due to losses in the electricity lines and transformers) and a commercial loss (due to unaccounted consumption).[7] Thus, the distribution loss is the difference between the total electricity input to the DISCOM and the total electricity sold by the DISCOM. When electricity sales to consumers are unmetered, one cannot determine how much electricity is reaching the consumer and how much is lost as distribution loss. As agriculture is the recipient of much of the unmetered sales in many states[8], the estimation of distribution loss is highly dependent on the estimation of unmetered agricultural consumption. Thus, overestimation of agricultural electricity consumption leads to underestimation of the distribution loss.

In order to understand how electricity consumption is overestimated, it is important to know how it is estimated.

6. Analysis by Prayas (Energy Group) based on various regulatory petitions and orders.

7. Some states like Tamil Nadu and Punjab don't report the distribution loss separately, but include it with the losses in the transmission lines (lines from generating stations up to distribution sub stations). This is reported as a transmission and distribution loss (T&D).

8. Except in Uttar Pradesh and Bihar that also have many unmetered domestic connections.

Figure 2: Agricultural Electricity Supply in the Electricity Distribution System

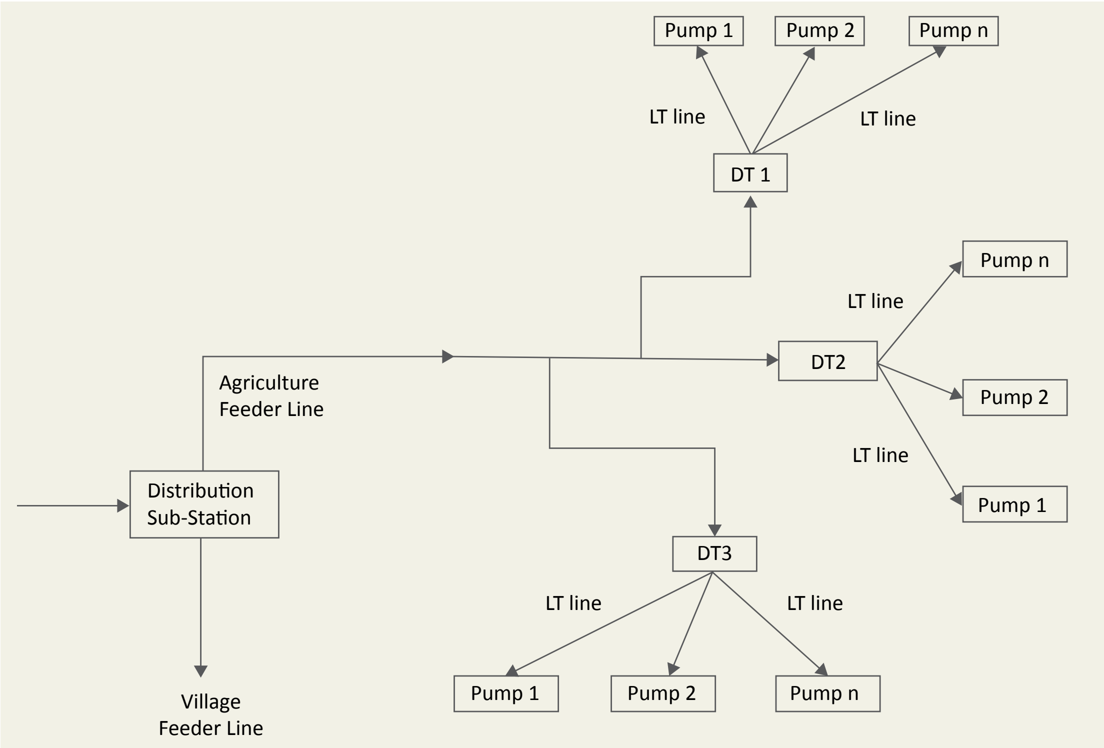


Figure 2 depicts the distribution system and how electricity is supplied to agricultural pump-sets. From a 33 kV distribution substation, typically there would be 3-4 agricultural feeders; on each feeder there would be 20 distribution transformers (DT); and on each DT, around 20 pump-sets.[9] This is the common layout in cases where physical feeder separation has been done. Alternatively, there are mixed feeders supplying to a common load of village and agricultural pumps. Electricity consumed by irrigation pump-sets can be measured at three stages in the distribution system: 11kV agricultural feeder, DT or pump-set. If consumption is measured at the feeder or DT level, the electricity loss (distribution loss) between the feeder/DT and the pump-set has to be deducted to arrive at the pump-set consumption. Thus, there are three main approaches to estimate electricity consumption by irrigation pump-sets:

- Agricultural consumption is calculated based on the average consumption of pump-sets fitted with meters. Average consumption is recorded through sample surveys, consumption by a set of metered pump-sets or based on assumptions about hours of operation of the pump. It is called the benchmark consumption norm of a pump-set, which is usually expressed as kWh per pump-set capacity in Horse Power (HP) or kilo-watt (kW) per annum. This benchmark consumption is then applied to all the pump-sets to arrive at the total agricultural electricity consumption under the DISCOM. Usually there is a single benchmark for pump-set consumption in a DISCOM, but sometimes there are separate benchmarks for different seasons, different DISCOM administrative zones, permanent and temporary connections, etc.

- Benchmark consumption of a DT is calculated based on the average consumption of a sample of metered DTs with predominantly agricultural load. There can be separate benchmarks for different capacity DTs. Distribution loss below DT is deducted to arrive at the consumption by pump-sets.

9. Substation = 33 kV substation; Feeder = 11 kV feeder; DT = Distribution Transformer; LT = Low TensionW

- Consumption by agricultural feeders as recorded in feeder meters is used. Distribution loss below feeder is deducted to arrive at consumption by pump-sets.

Although these are the three broad approaches of estimation, the exact estimation method differs from state to state. The state and DISCOM level estimation methodologies are described in Volume 2 of this paper.

Over the years, better estimates for agricultural electricity consumption and hence distribution loss have been made available in many states. During such instances, estimates of electricity consumption by agriculture have been revised downwards and distribution loss has been revised upwards. There was a spate of revisions in various states between 1998 and 2001 when state electricity regulatory commissions (SERCs) were established. This was because the SERCs brought greater scrutiny over the process of agricultural consumption estimation. Studies on agricultural electricity consumption were conducted in many state electricity boards. Electricity consumption by agriculture and T&D losses were revised in Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, West Bengal, Haryana, Punjab and Maharashtra (Honnihal, 2004; PSERC, 2002), with revisions as large as a 53% reduction in agricultural consumption and increase in T&D losses from 25.5% to 42%[10] in Uttar Pradesh from 1998 to 2000 (Planning Commission, 2002). Agricultural consumption across the country actually declined from around 84,000 MU in 1996-97 to around 81,700 MU in 2001-02, which is quite uncommon, despite an increase in the number of electric pump-sets and an increase in overall sales of electricity. On the other hand, the T&D losses increased from 22.8% to 34% (CEA, 2015; Planning Commission, 2002; Planning Commission, 2001).

In recent times too, agricultural electricity consumption and distribution loss have undergone revision or 'restatement' when a more robust methodology has been adopted by a Regulatory Commission. This has happened for the year 2010-11 in Punjab, Haryana and Tamil Nadu, and for 2014-15 in Maharashtra. Again, the downward revision in agricultural consumption has been as large as 28% in Uttar Haryana Bijli Vitran Nigam Limited (UHBVNL), a Haryana DISCOM, which saw an increase in distribution loss from 24% to 33% (HERC, 2012). Electricity consumption in agriculture is overstated to such an extent that negative distribution losses have been reported on agricultural feeders in Punjab and Maharashtra, i.e. the curious phenomenon where electricity consumption by the agriculture pump-sets is more than the electricity input into the feeder (MERC, 2016; PSERC, 2016). Details of state-wise revisions in sales and losses are provided in Volume 2 of this paper.

Such restatement has multiple financial impacts on the distribution sector. First, the subsidy requirement from government and cross-subsidising consumers reduces. Second, DISCOMs have to bear a higher share of the financial loss. This is because distribution loss also results in financial loss to the DISCOM, as it is the energy that the DISCOM is purchasing but not getting revenue for. On the other hand, a DISCOM's loss in revenue because of subsidised power to agriculture is recovered from consumers in the form of higher tariffs. Thus, when the distribution loss is revealed to be higher, the DISCOM cannot fully pass the resultant financial loss onto others. Third, DISCOMs lose face when distribution losses are revealed to be greater, but get a better image (with lenders, the government, etc) by showing low distribution loss by conflating it with agricultural consumption. This shows that hiding distribution loss as agricultural consumption helps DISCOMs.

10. Distribution and T&D losses are usually expressed as a percentage of the energy input to the DISCOM. We have used the same approach here.

However, if loss is actually reduced, the DISCOM would get more revenue by selling that energy. Our analysis shows that UHBVNL would have received 12% more revenue in 2010-11 had it actually sold the restated distribution loss. The details are provided in Section 2.3 of Volume 2 of this paper.

Faulty estimation of agricultural consumption follows from the many problems in the estimation methodologies. Although SERCs have brought more transparency in the estimation process, it remains far from satisfactory. DISCOM estimates for agricultural consumption are often not in line with the rainfall, groundwater and agricultural situation. However, alternate estimates derived from rigorous studies that will counter DISCOM estimates are not available with the SERCs. DISCOMs often do not share key data regarding agricultural estimation unless pressured to do so. Crucial data regarding total number of pump-sets and connected load are not reliable as they do not account for permanently disconnected and illegal pump-sets and load. This produces discrepancies in DISCOM data and that of other government agencies as discussed before in Section 2.3. Often unsubstantiated assumptions are employed regarding hours of operation by pump-sets based on hours of supply to agriculture. The actual hours of pump-set operation can be significantly lower than the stipulated hours of supply. This is because the rural power supply availability and quality is poor and pump-sets are not in operation throughout the year. Benchmark consumption of pump-sets should be computed from regular representative surveys, but these are not carried out.

In instances where consumption is estimated using benchmark consumption of agricultural DTs, there are many issues with metering of DTs. A limited number of DTs are metered or a large portion of the available meter readings are unusable. Assumptions of losses from DTs to pump-sets are not periodically verified.

Metering existing unmetered pump-sets can be difficult, but DISCOMs are also issuing new unmetered connections, despite SERC directives to the contrary.

Past experience has shown that metering of all pump-sets is not practical in the medium term, except in a few situations, where agriculture connections are few, or where the farmers and DISCOM are ready to support metering. However, metering of all DTs and feeders is certainly possible and will go a long way in arriving at a better estimate of agricultural consumption. It is also important to conduct a periodic census of pump-sets and carry out third party verification of estimation.

3.3 Subsidy for Electricity Consumption

Electricity subsidy to agriculture is sourced through two sources: the state government and cross-subsidising consumers. Cross-subsidising consumers are often commercial and industrial consumers who pay tariffs that are higher than their cost of supply. This surplus is used to subsidise agriculture, domestic and other smaller consumers. The total subsidy requirement of agriculture is quite large, and it is the largest subsidised consumer. Total state government subsidy to the DISCOMs in the 10 states with the highest electricity consumption in agriculture was approximately Rs 50,000 crores in 2013-14, with majority of it availed for agricultural supply.[11]

11. Source: Analysis by PEG from Comptroller and Auditor General of India (CAG) Reports on Public Sector Undertakings (PSUs) of various states; State Regulatory Orders and Petitions; and (PFC, 2016). The 10 states with the highest electricity consumption in agriculture are erstwhile Andhra Pradesh (undivided), Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Agricultural consumption in these states formed 97% of the total agricultural electricity consumption in the country in 2013-14. See Section 3.2 of Volume 2 of this paper for details.

Total subsidy to agriculture has been increasing over the years for two reasons: increase in the subsidy level of agriculture (subsidy per unit of electricity supply to agriculture), and increase in electricity consumption in agriculture. As can be seen in Figure 1, electricity consumption in agriculture has been growing. The subsidy level of agriculture has been increasing with the increasing cost of supplying electricity to consumers. The cost of electricity supply is the cost to supply one unit of electricity to a consumer, including the cost of generation, transmission and distribution. Unlike tariffs for other non-subsidised consumers, agricultural tariffs have not been able to keep up with this increase. Based on indicative analysis, the average cost of supply (ACoS)[12] increased at an average rate of 8% per annum (pa) between 1979-80 and 2013-14, while agricultural subsidy level increased from 56% of the average cost of supply to around 90% in the same period. This means that the tariff for the agriculture supply was 44% of the ACoS in 1979-80 and 10% in 2013-14.[13]

However, agriculture is not the only category that is subsidised. Some domestic consumers and other consumers are also subsidised. Data from the Power Finance Corporation (PFC) on the electricity consumption in agriculture was analysed for 10 states which account for 97% of electricity consumption by agriculture in the country. The analysis shows that the subsidy requirement of the domestic category has grown from a quarter of the total subsidy requirement of all subsidised consumer categories in 2006-07, to around 30% in 2015-16. On the other hand, the share of agriculture in the total subsidy requirement has declined from 75% to around 61%. Some consumers in industrial categories are also subsidised in a few states. In 2006-07, such consumers were subsidised only in Rajasthan. But in 2015-16, they were subsidised in Haryana, Maharashtra and Tamil Nadu in addition to Rajasthan. Their subsidy is small compared to others, but has been on the rise. Recently, the governments of Punjab and Haryana announced subsidies for industrial consumers (PSERC, 2018a; PSERC, 2018b, p. 102; Industries and Commerce Department, GoH, 2018).

Share of agriculture in total subsidy requirement has declined because of two factors. Firstly, sales to agriculture have not grown as fast as other categories, because of rationing of power.[14] Secondly, tariffs of other subsidised categories have not increased with the cost of supply, or have seen additional subsidy (PFC, 2010; PFC, 2016). This analysis is indicative as PFC data has certain shortcomings. These shortcomings and results of an analysis using more reliable data from regulatory orders for the state of Punjab is discussed in Volume 2 of this paper.

State governments have been shouldering a greater proportion of the total subsidy requirement of DISCOMs than cross-subsidy. Their contributions have also been increasing over time. With limits on increase in cross-subsidy, additional subsidy requirements have been coming from them. In Karnataka, for example, in the case of DISCOMs of Bangalore and Hubli, the government contribution to the total subsidy has gone up from 2% in 2007-08 to more than 60% in 2014-15. In Punjab, the government subsidy of Rs 5900 Cr accounted for 88% of the total subsidy in 2014-15.[15]

12. Cost of supply can depend on the consumer category that is being supplied. ACoS is the average of the cost of supply to all consumers.
13. Sources: Analysis by PEG from (Department of Power, GoI, 1980; Planning Commission, 1994; PFC, 2016) as well as various regulatory orders and petitions.
14. Agricultural sales grew by 7% p.a. between 2006-07 and 2013-14, whereas sales to other subsidised categories like domestic, industrial Low Tension (LT) and other smaller categories have increased faster at 9%, 10% and 16% pa respectively.
15. Source: PEG analysis from various regulatory petitions and orders from Punjab and Haryana. See Section 3.2 of volume 2 of this paper for details.

As mentioned earlier, some part of the total subsidy required by the DISCOM is not covered by the government or cross-subsidy, which results in a financial loss to the DISCOM. The subsidy requirement that is uncovered is high in Tamil Nadu, ranging from 70% of the total subsidy requirement (around Rs 8,900 Cr) in 2011-12 to 46% (6,600 Cr) in 2013-14. Usually, the higher the uncovered subsidy, the higher is the overall financial loss of the DISCOM. Not surprisingly, TN was among the three highest loss making DISCOMs in 2014-15.

To make matters worse for the DISCOM, the government subsidy payments are delayed or not paid in full or do not make up for the full government subsidy requirement of the DISCOM. These shortfalls are not insignificant when cumulative shortfalls are considered. The percentage of subsidy booked that was actually received by the DISCOMs was as low as 47% from 2008-09 to 2012-13 in Uttar Pradesh. Some state governments have large subsidy obligations to the DISCOM, and though the subsidy received as a proportion of subsidy booked may not be low, the shortfall will be a significant proportion of the DISCOM's aggregate revenue requirement. If the cumulative subsidy shortfall were to be booked from the government in the year following the time period of shortfall (for example, in 2013-14 for Uttar Pradesh), then it would be as high as 42% of that year's aggregate revenue requirement (ARR) in Uttar Pradesh and 21 % in Haryana (HERC, 2016; UPERC, 2016).[16] In Punjab, this shortfall is 17%, thus also significant. Details of the analysis in this section are discussed in Volume 2 of this paper.

These uncovered subsidies and shortfalls in government subsidy payments lead to additional short term borrowings at high interest rates for the DISCOMs and ultimately feed into their financial losses. Cash flow shortages due to non-payment of subsidies were likely made up by cutting back on operation and maintenance expenditure of the distribution infrastructure. This must have led to further deterioration in supply and service quality to agriculture (and thereby rural) consumers, which is discussed in the next section.

3.4 Poor Supply and Service Quality to Agriculture

Power to agriculture is subsidised, but the hours of supply to agriculture, and hence rural supply hours are significantly lesser than that for urban consumers. Many states now have a system of rostering of supply, where power supply alternates between day time on a few days and night time on others. Agriculture does not receive more than 10 hours of electricity supply a day in a majority of the states.

Surveys show that farmers receive fewer than scheduled hours of supply which are often erratic and with frequent interruptions and voltage fluctuations, causing farmers to incur avoidable expenditure on pump repairs due to motor burnouts. Transformer burnouts[17] are a common occurrence, and there are long delays in getting the transformers repaired. Unreliability of supply makes farmers invest in higher capacity electric pumps as well as diesel pump-sets (Dossani & Ranganathan, 2004; World Bank, 2001).

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16. ARR that is annual revenue requirement of a DISCOM, is the amount that is to be recovered from consumers through tariff. Its figures are also obtained from various regulatory orders and petitions of the DISCOMs in these states.

17. Due to overloading because of transformer capacity being less than the cumulative load of pump-sets, poor maintenance, etc.

Recent evidence from the 5th Minor irrigation Census conducted by the Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR) for the year 2013-14 indicates that non-availability of adequate power is an important constraint responsible for the under-utilisation of wells and tube-wells (MoWR, 2017). 28% of the total wells and tube-wells are found by the census to be underutilised and within these, non-availability of adequate power accounts for the underutilisation of 33% of the under-utilized tube-wells, the second highest cause after 'less discharge of water' which accounts for the underutilisation of 37% of these under-utilized wells and tube-wells. This constraint of inadequate power can be overcome using diesel pumps or buying water from farmers with higher capacity pump-sets.

The fact that diesel pumps are used as a backup option in the event of erratic power supply to electric pumps has been brought to notice before (World Bank, 2001). This can still be seen in 2013-14, despite electricity replacing diesel in irrigation pumping over time (see Figure 4). Out of total electric powered wells and tube-wells in states where electricity is the dominant source of irrigation, 4% use electricity and diesel conjunctively, with it being highest in Telangana (10%), Punjab and Haryana (both 6%) (MoWR, 2017). Running diesel pumps is costlier than running electric pumps. Thus only a few farmers can afford operating both, which is why their numbers are low. In spite of being expensive, farmers continue to use diesel with electricity, and it is safe to say that this is because electricity supply is unreliable and inadequate.

Safety of farmers is also an important issue. Irrigating fields during the night can be risky and hazardous, especially for women and old farmers. This is so not only because of the danger due to creatures such as snakes but also electric shock accidents. Accidents during pump-set operation, while coming into contact with low hanging conductors, and while attempting to repair failed transformers are common. As per the data provided by the National Crime Records Bureau (NCRB), the number of deaths due to electricity accidents was nearly 10,000 in 2015, mostly occurring in rural areas, and this number has been increasing every year by 5-6% in the last two decades (NCRB, 2016).

During the public process of tariff determination in many states, farmer groups and representatives have raised issues with respect to long waiting times for agricultural electricity connections and the long delays in repairing transformers. Billing and collection of tariff from farmers are fraught with problems. Our interactions with farmers in Maharashtra revealed some instances of inflated bills received by farmers. Farmers complained that they spend a lot of time and money to get inflated metered bills corrected by the distantly located Maharashtra State Electricity Distribution Company Limited (MSEDCL) offices. In fact, consumer representatives have time and again pointed out that meter readings for metered pump-sets are not monitored on time or not monitored at all, which necessitates reassessment of bills issued (MERC, 2012, p. 29; Vernekar, 2018; Gadgil, 2018). In one such instance, almost all of the 4800 metered agricultural consumers under a sub-division in rural Maharashtra were issued bills with the same meter readings for 4 quarters in a row in 2011 (MSEDCL, 2012). Sometimes farmers have to pay for replacing failed meters and transformers without reimbursement. Existing grievance redressal mechanisms are inadequate and inaccessible to farmers.

It is evident that DISCOMs have their own issues in metering, billing and collection, and hence they also have some responsibility to shoulder for the slow progress in metering and low collection efficiency. It is easy to see why this situation has arisen. Cash-strapped DISCOMs do not invest in and maintain their rural distribution infrastructure to ensure quality supply and service because of low revenue from farmers, and farmers are the hardest hit because of the low quality of supply. Farmers try to overcome the problem with high capacity pump-sets or other methods, often worsening the situation. Thus power supply to agriculture is caught in a vicious cycle with no escape in sight, especially due to the growing trust deficit between the farmer and the DISCOM.

Raising tariffs for agriculture has been suggested as a solution to break this vicious cycle. But mere tariff increase without addressing the systemic problems in the distribution sector may trap DISCOMs and farmers in an even lower equilibrium and worsen the trust deficit. In fact, if power quality and service are not improved immediately after a tariff increase, poor farmers will have to bear the adverse impacts of both higher tariffs and poor quality. Improvement in power and service quality through higher tariffs is uncertain, largely owing to the current poor distribution infrastructure in rural areas and the lack of accountability of the DISCOM in ensuring improvements in supply and service quality. Thus raising tariffs may not result in an increase in the DISCOM revenue from agriculture unless power quality and service is improved prior to tariff increase.

3.5 Summary: Electricity in Agriculture

The above discussion presents, from a power sector point of view, nuances and details of the issues of concern related to agricultural electricity supply including DISCOM finances. This understanding also offers insights into which solutions will work and which may be less effective.

Similarly, an understanding of the issues in agriculture, water and groundwater sectors related to agricultural electricity supply is also crucial in designing effective solutions. These issues include the role that electricity has played in agriculture growth, the extent to which low and subsidised tariffs have led to overextraction of groundwater, inequitable distribution of the subsidies as they appear to benefit large farmers more, and the likely impact on farmers of raising electricity tariffs.

We now explore these aspects in detail.

4. Agriculture

No discussion on agricultural electricity supply can be complete unless it includes an understanding of the critical role that electricity has played in agricultural growth in India, and therefore, in ensuring food security for the country and employment for a vast majority of our population.

Further, solutions to address the financial troubles of DISCOMs and other related power sector issues, particularly those that are being attributed to agricultural supply, are unlikely to be effective unless they factor in this role that electricity has played in agricultural growth.

Agriculture, and in particular food grain production, has shown significant growth over the years since independence. The total production of foodgrains increased by close to five times from 1950-51 to 2010-11, as shown in Table 2. The main contributors to this growth have been rice and wheat, whose production added up to close to 75% of total food grains in 2010-11 as against 53% in 1950-51, especially in Northern states like Punjab and Haryana. The country has also witnessed a shift in cropping patterns away from coarse cereals like jowar, bajra and maize.

Table 2: Food Production in India (Million Tons)

Year	Foodgrains	Pulses[18]	Oil Seeds
1950-51	50.82	8.41	5.16
1980-81	129.59	10.63	9.37
2010-11	244.49	18.24	32.48

Source: (MoA, 2013, p. 27)

The increase in production and productivity can be attributed to a combination of several factors like improved seeds, increased use of chemical fertilisers, better irrigation facilities, extension services, and procurement and price support.

Irrigation, largely driven by groundwater and electricity as we shall see, has played a very significant role in achieving this production. About 70% of the paddy and wheat production in India is from irrigated areas (MoA, 2016, p. 50; DES, MoA, 2016). Considering that the two crops constitute more than 75% of total foodgrain production in the country, we can see the significance of irrigation.

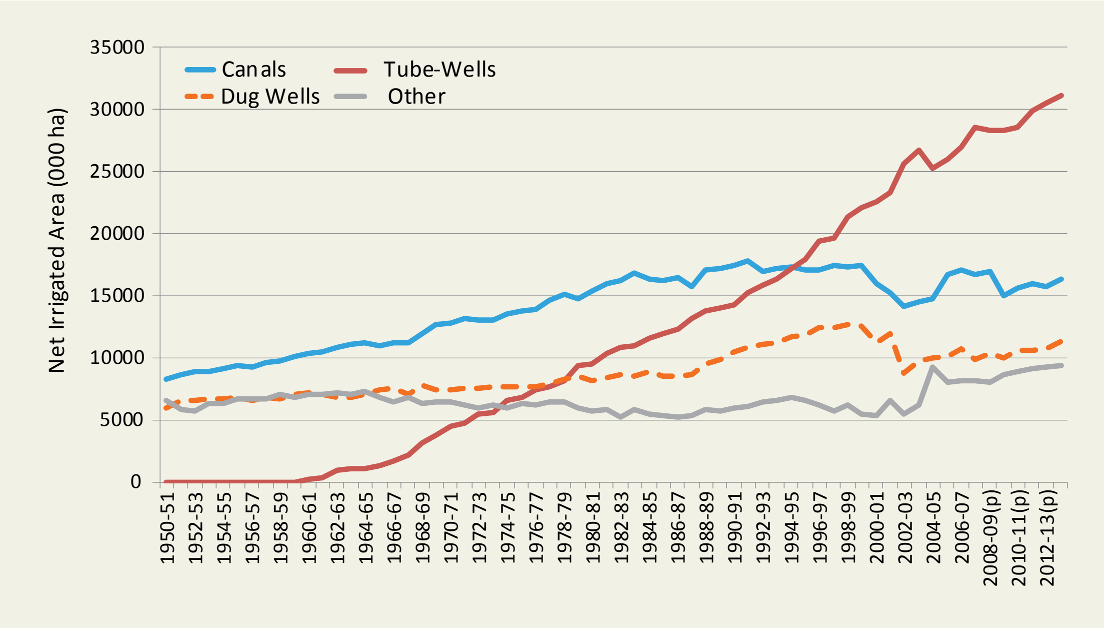
4.1 Shift in Irrigation Sources

Over the years, India's irrigation has been increasingly shifting towards groundwater. Groundwater's share in total net irrigated area has increased from about one-third in 1950s to almost two-thirds at present (DES, MoA, 2016) (Figure 3). In terms of area, while the net area irrigated by groundwater in

18. Note that pulses are included in foodgrains but we have presented the figures separately also to highlight the relatively slower growth in the production of pulses.

1950-51 was 5.98 million ha, in 2013-14, it had grown seven times to 42.44 million ha. Meanwhile, canal irrigated area has increased from 8.29 million ha in 1951 to a peak of 17.4 million ha in 2000 before falling to 16.28 million ha in 2013-14. The total number of pump-sets (electric pump-sets as reported by the CEA and diesel pump-sets as reported by the Ministry of Power (MoP)) in the country is now estimated to be around 2.6 crores (MoP, 2011; CEA, 2016).

Figure 3: Trend of Source-wise Net Irrigated Area in India



Source: (DES, MoA, 2016)

There are several reasons for this shift towards groundwater-based irrigation. One of the most important reasons is that groundwater based irrigation places much greater control in the hands of farmers especially in terms of the timing of irrigation. Greater control also allows optimal benefits of inputs like fertilisers, better seeds, etc, thus reducing the risk of spending on these inputs (Bhaduri, Amarasinghe, & Shah, 2006). Due to these and other reasons, the productivity of groundwater irrigated crops is significantly higher. Other reasons for the spread of groundwater irrigation include the difficulty of surface or canal irrigation reaching many areas, increasing costs of developing canal-based large surface irrigation systems, significant gaps between the potential created and utilised for many of the surface irrigation schemes, and the fact that groundwater irrigation systems are modular in nature and farmers can put them up individually making them easy to install. The advantages offered by groundwater are so significant that even in areas commanded by canals, farmers will often opt for groundwater-based irrigation, where part of the water drawn from the ground is the seepage of the surface schemes.

This extensive spread of groundwater irrigation has been facilitated by the spread of electrification as well as cheap, often free, supply of electricity to agricultural users. Sometimes the availability of such cheap electricity has been labelled as the driver of extensive groundwater use. But we would see it more as an enabler, whereas the several substantial advantages of groundwater use are really the drivers. One indication of this is the large number of farmers who, not being able to use electricity for pumping groundwater, have been using diesel driven pump-sets, even though these are significantly more costly to operate. We emphasise this distinction between a driver and an enabler, because it has important implications in the design of policy suggestions.

It is not a coincidence that some of the highest agricultural growth in the country has come through groundwater-based irrigation. Several studies have highlighted the crucial role played by groundwater (and reliable electricity supply and procurement support) in high agricultural growth, in regions and years as far apart as Punjab in the 1960s-70s (Dharmadhikary, 2005), Gujarat in the first decade of the millennium (Shah & Das Chowdhury, 2017), and Madhya Pradesh in the last few years (Gulati, Rajkhowa, & Sharma, 2017).

The growth in agriculture and especially foodgrains production, the implications for food security and employment in the country, and the role of groundwater and hence electricity in enabling these developments is the significant other aspect of the subsidies and support provided to electricity supply for agriculture. It is often ignored when discussing about tariff and other reforms related to electricity supply to agriculture. It is imperative to take all these developments into consideration while planning reforms in the electricity supply to agriculture.

5. Groundwater Use and Electricity

Almost all the electricity that is used in the agriculture sector is used for pumping.[19] Similarly, more than 85% of the total energy used for groundwater irrigation, or more accurately, pumped irrigation comes from electricity.[20] It should be noted that pumping can include pumping from dug wells, tube-wells, as well as in some cases from surface sources. In addition, a small amount of electricity is also used for large surface lift schemes.[21]

Table 3 shows the trend over the years in electricity used in agriculture and the amount of groundwater extracted.

Table 3: Groundwater Draft, Net Irrigated Area by Groundwater, and Electricity Consumption

Financial Year	Net Annual Groundwater Availability (Billion Cubic Meter) (BCM)	Annual Groundwater Draft—Irrigation (BCM)	Net Area Irrigated by Groundwater (000 ha)	Electricity Consumption by Agriculture (BU)
2004	398.7	212.4	36,385	88.9
2009	395.5	221.3	38,756	107.8
2011	397.6	222.2	39,172	126.4
2013	411.3	228.3	41,305	147.5
Decadal growth %	3.2%	7.5%	13.5%	65.9%

Source: (CGWB, Various years; DES, MoA, 2016; CEA, Various Years)

It can be seen that the relationship between agricultural electricity consumption and the extraction of groundwater is not straightforward, as between 2004 and 2013, the groundwater draft for irrigation and the net area irrigated by groundwater have grown by 7.5% and 13.5% respectively, whereas the official electricity consumption has increased considerably (by 66%) for the same period. The divergence between the growth rates of electricity consumption and groundwater extraction can be attributed to several factors. The first is the overestimate in the electricity supplied to the agriculture sector, which we have noted in the earlier sections. The second reason could be underestimation of the groundwater draft (GSDA, 2014). The third reason could be the

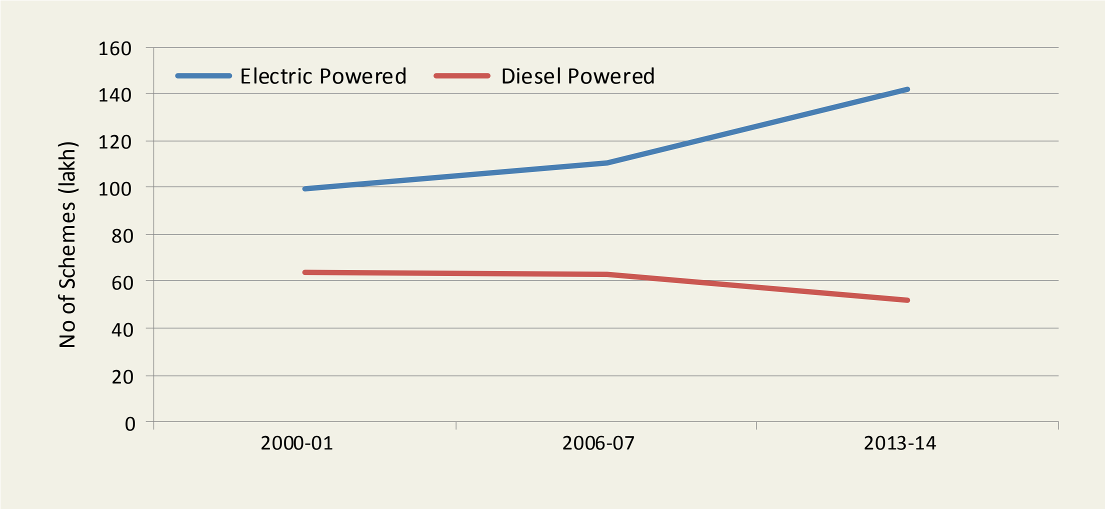
19. The total 'agricultural consumption' reported by the CEA is essentially the consumption of irrigation pump-sets (CEA, 2016).

20. Figures for the share of electricity in the total energy used to power irrigation pumps (diesel is the other major source) are not available in official statistics. Figures for the quantity of diesel used for irrigation pumping are also not directly available. We have estimated the diesel use in irrigation, and from this and the CEA figures for electricity used in agriculture, have estimated the shares of the two in pumping energy for the year 2009-10. As given in the main text, 85% of the pumping energy in the country is provided by electricity. However, in terms of the numbers of wells and tube-wells powered by various sources, electricity powers 70% of wells and tube-wells, whereas 26% are diesel powered wells and tube-wells. The remaining 4% depend on various sources like solar, wind, animal power and other sources. (MoWR, 2017).

21. For example, Maharashtra has almost 1.1 % of electricity sales for the High Tension(HT) Agriculture category which is mainly used for surface lift schemes (MERC, 2016, pp. 405,452).

falling groundwater levels in several areas, which imply the need for more energy to pump up the same amount of water. The use of electricity for increased lifting from surface sources could also be a factor, through the extent of this type of usage is not very high. Lastly, there is evidence of effective replacement of diesel by electricity in powering pump-sets especially since the mid-2000s (Figure 4), which would also have led to a growth in electricity use but not in groundwater extraction.

Figure 4: Trend of Diesel and Electric Powered Groundwater Irrigation Schemes in India



Source: (MoWR, 2001; MoWR, 2014; MoWR, 2017)

5.1 Falling Groundwater Levels and Subsidies

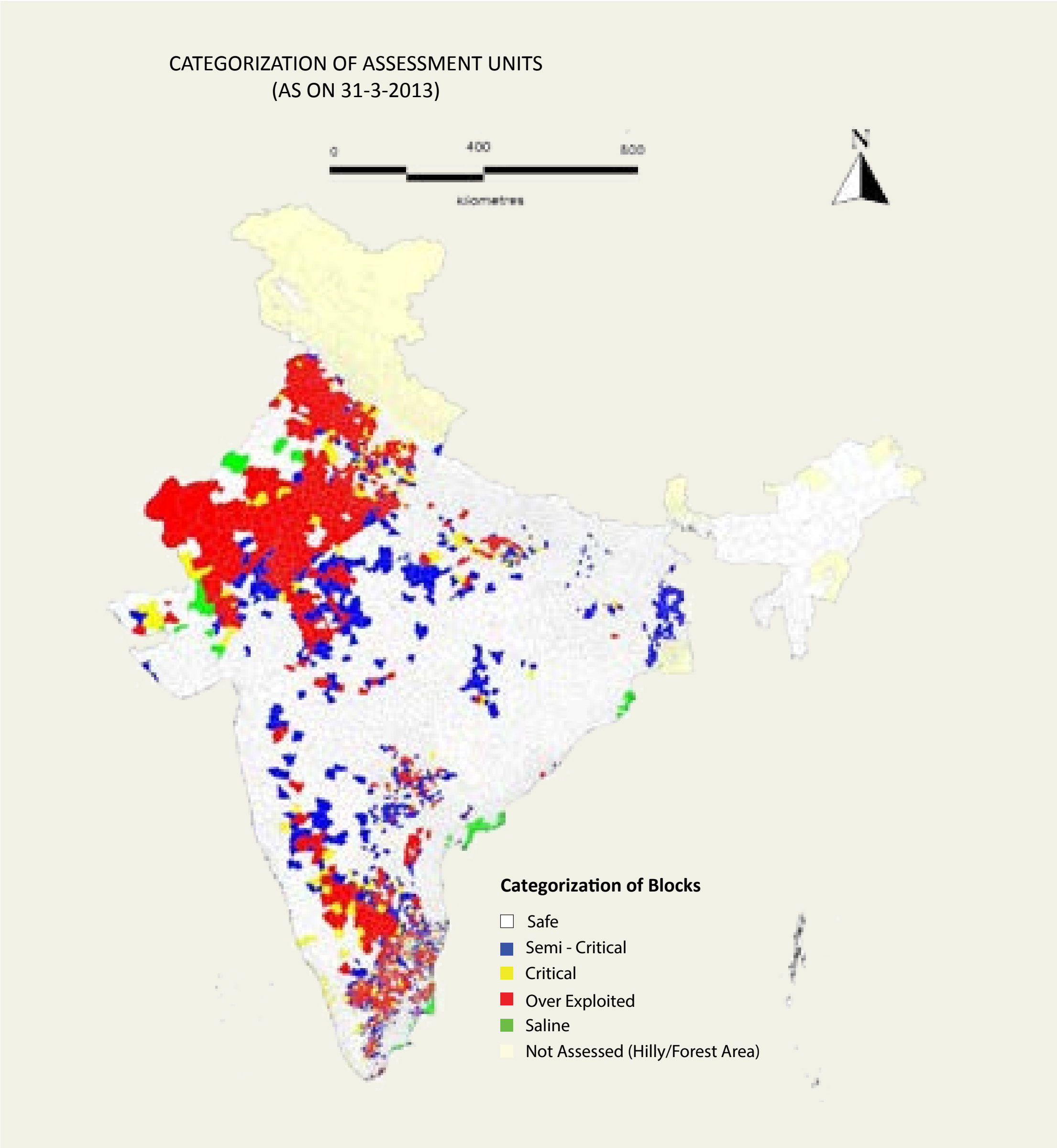
A major critique of subsidised electricity to agriculture is that it leads to unregulated pumping of groundwater as the marginal cost of pumping is very less, or zero. This leads to over-extraction of groundwater and falling groundwater levels.

Most of the major states have either free or low-priced electricity supply to agriculture, resulting in significant quantities of subsidies (direct state subsidy and cross-subsidies). Total annual state government subsidy to the sector was around Rs. 50,000 Cr in 2013-14 for 10 major states in terms of electricity consumption by agriculture, which gives us an idea of the extent of the subsidies, with most of them availed for agriculture supply.[22] The weighted average electricity tariff payable by farmers in 10 major states was only around Rs 0.5 per kWh whereas the Average Cost of Supply (ACoS) was more than Rs 6 per kWh for 2013-14.

Coming to the status of groundwater use, Figure 5 shows the groundwater status in the country in terms of overexploited (red coloured), critical (yellow) and semi-critical areas (blue). The white regions on the map indicate areas classified as safe, whereas green regions represent saline groundwater status. This categorisation is done as per criteria that combine the stage of groundwater development (gross draft as a percentage of net groundwater availability) as well as the long-term trend of decline in groundwater levels.

22. Source: Analysis by Prayas (Energy Group) from (RBI, 2016), CAG Reports on PSUs of various states, State Regulatory Orders and Petitions, and (PFC, 2016).

Figure 5: Groundwater Status of Blocks of India in 2013



Source: (CGWB, 2017)

This map shows that the overexploited areas are predominantly in the north and north-west part of the country, and also in the south-central areas. To understand the possible role of electricity tariffs, we compared the actual electricity tariffs[23] payable by farmers in some major groundwater using states where the share of critical and overexploited blocks is high (Haryana, Punjab, Rajasthan, Tamil Nadu and Karnataka) and relatively low (Andhra Pradesh and Gujarat). Table 4 shows the electricity tariffs payable by farmers in these states and the detailed status of groundwater blocks.

23. The electricity tariffs are as of 2013-14 or for the latest available year. Most of these states have been receiving almost free power for at least the last 10 years.

Table 4: Groundwater Situation in 2013 in Selected States

State	Electricity Tariffs (Payable by Farmers) (Rs/kWh) in 2013-14	Proportion of Blocks under Groundwater Stress				Safe blocks
		Overexploited	Critical	Semi-critical	Total	
Haryana	0.30	54%	12%	9%	75%	25%
Karnataka	0	24%	8%	12%	44%	56%
Punjab	0	76%	3%	2%	81%	19%
Rajasthan	0.9	66%	4%	11%	81%	18%
Tamil Nadu	0	31%	9%	19%	59%	38%
Andhra Pradesh	0	9%	3%	8%	20%	74%
Gujarat	0.4	10%	3%	4%	17%	78%
Uttar Pradesh	1.5	14%	7%	5%	26%	74%

Source: (CGWB, 2017), Various Tariff Orders by SERCs

It can be seen that a direct correlation between low electricity tariffs and over extraction of groundwater is not uniformly applicable across states. For example, states like Punjab and Haryana have low tariffs and a high percentage of overexploited units; Rajasthan has high tariffs and a high percentage of overexploited units, whereas Andhra Pradesh and Gujarat have low tariffs but have a much smaller percentage of overexploited units. In all these states, groundwater is a significant or dominant source of irrigation.

Thus, it is clear that while at the level of an individual farmer, low priced or free electricity offers an incentive for unchecked lifting of groundwater due to low or zero marginal cost, there are several factors other than the tariff that will influence whether groundwater is excessively drawn. These factors include the quality of power and hours of supply, the duration for which cheap or free power has been available, the hydrogeology of the region, groundwater conservation efforts, farmers' awareness, irrigation intensity and cropping patterns.

We examine some of these factors in the following sections. It is important to note here that while low tariffs can encourage or enable unchecked exploitation of groundwater, they can, and have facilitated institutions like water markets which help increase equity in access to the benefits of electricity and irrigation. We deal with this in Section 5.6 of this paper.

5.2 Cropping Pattern

The cropping pattern adopted by farmers is a major determinant of irrigation requirements and hence water withdrawals. One of the important considerations in this regard is the cultivation of crops that are unsuitable to the agro-climatic and eco-climatic characteristics of a region or season. Such crops often require very high inputs of water over and above rainfall, which is supplied by canal waters or groundwater. Some examples of this phenomenon are sugarcane farming in water-stressed areas of Maharashtra, or rice farming in Punjab.

Normally the cropping pattern is determined by agro-climatic considerations. However, because irrigation often enables overcoming some of the climatic limitations, market conditions become the major drivers of the crop choice for farmers. For example, Ashok Gulati, agricultural economist and a former chairman of the Commission for Agricultural Costs and Prices (CACP), points out that Punjab was not geographically suitable for paddy cultivation, and such cultivation, made possible by the Minimum Support Price (MSP) and procurement support, has had an impact on the environment and has become detrimental to the sustainability of agriculture (Gulati, Roy, & Hussain, 2017, p. 29).

The crop price support to farmers mainly through the MSP mechanism, along with the market availability for selling the agricultural produce especially through government procurement, influences the farmer's selection of crops and hence corresponding electricity consumption for irrigation.

Ideally, the MSP and procurement policies should be formulated such that they encourage agro-climatically suitable crops. This helps reduce the irrigation cost and the total cost of production through reduced use of inputs and more efficient use of inputs. At the same time, it assures better margins for farmers. For instance, arid and semi-arid regions should encourage crops which require less irrigation, which is however not the case.

For example, the National Institution for Transforming India (NITI) Aayog, in its recent report, notes:

> "Minimum Support Prices (MSPs) have distorted cropping patterns due to their use in certain commodities in selected regions. There has been an excessive focus on the procurement of wheat, rice and sugarcane at the expense of other crops such as pulses, oilseed and coarse grains. These distortions have led to the depletion of water resources, soil degradation and deterioration in water quality in the north-west. At the same time, eastern states, where procurement at the MSP is minimal or non-existent, have suffered." (NITI Aayog, 2017, p. 28)

Thus, market support in terms of MSP and procurement has emerged as one of the main drivers for the choice of cropping pattern, and in turn, the driver or determinant of groundwater extraction. In the case of Punjab, where a water-intensive cropping pattern prevails in spite of depleting groundwater levels, we see that around 19% of all wells and tube-wells are powered by diesel[24] (MoAFW, 2015, p. 180). This is despite the significantly higher operating costs due to the cost of fuel. Further, 6% of electricity powered wells and tube-wells in Punjab and Haryana had both electricity and diesel pumps for pumped irrigation in 2013-14, even though owning/renting and running both pumps can be significantly costlier. This indicates that the cost of energy to drive groundwater pumping is a lesser influence on groundwater extraction as compared to the factors that are pushing the prevailing cropping pattern. This factor becomes important in assessing whether agricultural electricity tariff reform will also help control excess withdrawal of groundwater.

The use of MSP and procurement policies to encourage a specific cropping pattern could require the use of different MSPs for different regions. This can have its own set of issues like farmers from other areas bringing their produce to sell into regions with higher MSPs, but these could be addressed by some other measures (like procurement only against land deed or proof of address). Undoubtedly, the aim of aligning cropping patterns to agro-climatic zones will need a regional focus including regional MSP and procurement policies, and solutions will have to be found for the obstacles to such policies. The CACP has suggested such an approach several times. For example, in its "Report on Price Policy for Kharif Crops of 2004-2005", it says:[25]

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24. Our estimates also indicate that for 2014-15, in energy terms, diesel in Punjab provided 18% of the pumping energy.

25. https://cacp.dacnet.nic.in/ViewReports.aspx?Input=2&PageId=39&KeyId=347

"...the central government, in consultation with state governments develop a strategic, albeit region specific plan for agricultural diversification along with appropriate technological, infrastructural and policy support. If necessary, a pilot scheme on agricultural diversification should be launched in selected districts ...".

Considering the importance of this issue, we have also suggested a similar pilot project in our recommendations.

5.3 Cost of Irrigation in the Cost of Cultivation

Market conditions and farmers' margins are among the key determinants of the cropping pattern. Farmers' margins are influenced by their costs of cultivation. It is important to understand the extent to which the cost of irrigation contributes to the cost of cultivation, as increases in electricity tariffs for farmers will influence the cost of irrigation for farmers dependent on groundwater.

Unfortunately, several shortcomings in the publicly available DES/CACP data on the cost of cultivation make it difficult to estimate the cost of irrigation in the total cost of cultivation. In the aggregate data for crop-wise cost of cultivation, there is no distinction between costs for irrigated and rainfed cultivation of the crop. Further, there is no distinction between costs of cultivation of crops irrigated by groundwater and surface water. In the disaggregated, raw data, some of these details are available, but the irrigation costs given do not separate fuel and electricity charges from capital costs, maintenance costs, etc, which could have helped to understand the role of electricity and the corresponding subsidy in the cost of cultivation for farmers.

To get around this data limitation, and since our main interest is in the cost of electricity needed to power groundwater irrigation, we have used another approach to estimate how an increase in tariffs would impact the cost of cultivation and in turn farmers' margins. The CEA regularly reports state-wise figures on the number of pump-sets in the country as well as the electricity used in agriculture which is essentially the electricity used for pumped irrigation. Based on these and the figures for the area irrigated by groundwater from the agricultural census, we estimate the electricity needed to irrigate one unit (hectare) of crop. Table 5 gives the relevant figures and the estimates of electricity needed to irrigate a hectare of crop in selected states[26], and therefore, the increase in pumping energy costs for farmers with every rupee increase in electricity tariff. The table highlights that an increase in tariff of electricity would have a significant impact on farmers' cost of cultivation. Note that electricity tariff is only one part of what the farmer has to pay for groundwater irrigation. In addition, he or she would also have to bear the capital cost of installing the well/tube-well and the pump-set, and other costs like maintenance and repairs.

26. These figures should be taken as indicative as there are several factors that introduce estimation errors. One, groundwater irrigated area would also include diesel driven irrigation, but in the absence of figures on diesel-driven groundwater irrigated area, and electricity being the dominant irrigation source in most states, we have assumed the entire irrigated area to be irrigated by electricity. The very low electricity use per hectare of irrigated area in Uttar Pradesh is due to this factor. In Uttar Pradesh, according to the 5th MI Census, diesel driven pump-sets constituted 85% of the total pump-sets in 2013-14. Thus, if the true area irrigated by electricity is taken, the impact of the rise in tariff on farmers' costs would be higher per ha, especially in states where diesel forms a significant source of pumping energy. Second, the groundwater irrigated area in the table is the net irrigated area whereas for proper estimation, we need to use the gross area irrigated by groundwater. Again, the figures for gross area irrigated by groundwater are not available. Last, while we have allocated all electricity use as driving groundwater irrigation, some of the pumping energy is used for surface lifts and hence will not be contributing to the groundwater irrigated area.

Table 5: Estimation of Electricity Tariff Impact on Cost for Water Pumping for Selected States in 2011

State	Number of Electric Pump-sets (lakh)	Electricity Consumption in Agriculture (MU)	Groundwater Irrigated Area (Net) (lakh ha)	Electricity Consumption per Net Groundwater Irrigated Area (kWh/ha)	Increase in per Hectare Pumping Energy Cost for Farmer pa, for Every 0.5 Rs/kWh Increase in Electricity Tariff (Rs/ha/year)
Madhya Pradesh	13.7	6,962	47.9	1,455	728
Maharashtra	34.9	15,765	16.7	9,450	4,725
Andhra Pradesh	29.1	17,319	25.3	6,854	3,427
Karnataka	18.2	12,659	19.0	6,678	3,340
Tamil Nadu	21.0	9,410	20.3	4,642	2,321
Punjab	11.4	9,656	31.3	3,090	1,545
Haryana	5.6	6,490	16.1	4,024	2,012
Uttar Pradesh	9.0	7,690	106.7	721	361

Source: (Various state electricity regulatory orders, CEA, 2012, p. 178; DES, MoA, 2016).

We also try to estimate the impact with respect to the farmers' incomes and/or margins[27] by estimating the average net income of farmers (income from a crop after deducting the cost of cultivating it) for the dominant irrigated crops[28] (mostly paddy and wheat) in a state. Table 6 shows that the impact of increase in tariffs is significant even when only paid out costs (A2)[29] are considered, except in Haryana and in the case of wheat in Punjab, as paddy and wheat in these two states have substantially higher productivities.[30] In Tamil Nadu, farmer income from paddy is not enough to cover the paid out cost for cultivation. When imputed costs[31] are also taken into consideration, farmer income does not cover the cost of cultivation in all states in Table 6 (except in the case of Haryana and wheat in Punjab). Thus, an increase in tariff incurs a greater loss for farmers than before.

27. Actual net incomes/margins might be even lower as many farmers do not sell everything they produce.

28. The crop for which the irrigated area is greater than 50% of the total irrigated area is chosen as the dominant irrigated crop. If no single crop has more than 50% of the total irrigated area, then multiple crops with large shares in irrigated area and whose total share is greater than 50% are chosen. Crop-wise irrigated area figures are from (MoAFW, 2015).

29. Transportation and insurance costs are not considered here.

30. A hectare of land may be cultivated multiple times in a year. To compare the electricity costs for a hectare of land, which are annual costs, to the cost of cultivation of and income from crops, which are seasonal values, we adjust the electricity costs downwards by a factor. This factor is the cropping intensity (ratio of gross cropped area to net sown area), which is a measure for the number of times a hectare of land is cultivated in a year.

31. Imputed costs include imputed costs of family labour, rent for own land, and interest on own capital. The sum of these imputed costs and the paid out costs is the C2 cost, which has been used by us when considering imputed costs.

Table 6: Impact of Rise in Electricity Tariff on Farmer Incomes (All Figures in Rs/ha) in 2010-11

State	Crop	Farmer Gross Income from Crop	Cost of Cultivation (A2) of Crop	Farmer Net Income	Increase in Pumping Electricity Cost per Crop with every 1 Rs/KWh Increase in Tariff (Derived from Table 4)	Increase in Electricity Cost as a % of Farmer Net Income
Madhya Pradesh	Wheat	20,487	12,589	7,898	1,009	13%
AP	Paddy	36,033	29,583	6,450	5,743	89%
Tamil Nadu	Paddy	29,383	31,775	-2,392	4,175	-175%
Punjab	Wheat	51,764	21,369	30,395	1,572	5%
	Paddy	41,802	27,518	14,284	1,572	11%
Haryana	Wheat	54,563	18,071	36,493	2,130	6%
	Paddy	57,900	22,884	35,015	2,130	6%

Source: PEG Analysis from MoAFW data. Farmer Income from a crop is estimated using crop-wise farm harvest prices (DES, MoAFW, 2013) and yields (DES, MoAFW, 2012a). Cost of cultivation is from (DES, MoAFW, 2012b).

5.4 Tariff Increase and Improvement in Quality of Service

While increase in power tariff for agriculture can have adverse impacts on the economics of the farmers, it is also argued that it can lead to improvement in the quality of power and service delivered to farmers (AF-Mercados, 2014, p. 17). It is said that the DISCOM will be motivated to provide better supply to farmers due to better revenue realisations, and also would have more resources for this purpose (World Bank, 2001). At the same time, it is argued that since farmers would be paying higher rates for electricity, they would demand better quality of supply, and this pressure from below would also lead to better quality of supply. Better quality of supply would also lead to lesser maintenance costs for transformers and motors and therefore lesser costs of irrigation.

However, given the trust deficit amongst farmers with regard to DISCOMs, and the fact that increasing tariffs would have significant impact on the farmers' economics, there is bound to be strong resistance to any such move. Hence, it is important to demonstrate improvement in quality first, before raising tariffs. Not only will this help build trust, but if improvements in the quality of power supply help farmers cut down motor maintenance and other costs, it would create more acceptability for raising tariffs. It is also important to make a commitment at the highest level on the trajectory of tariff increase, and also assure farmers that this trajectory would be linked to the quality of supply. Such a demonstrative effect can go a long way in gaining acceptance of farmers for any increase in tariffs.

For this purpose, measures to improve quality of supply should be put in place independent of tariff reforms, and indeed must precede them. This is particular so because an increase in tariff will not automatically lead to an increase in DISCOM revenue, especially if the quality of supply and service is not improved, and if such improvement is not demonstrated for some time, as people may not pay or will default.

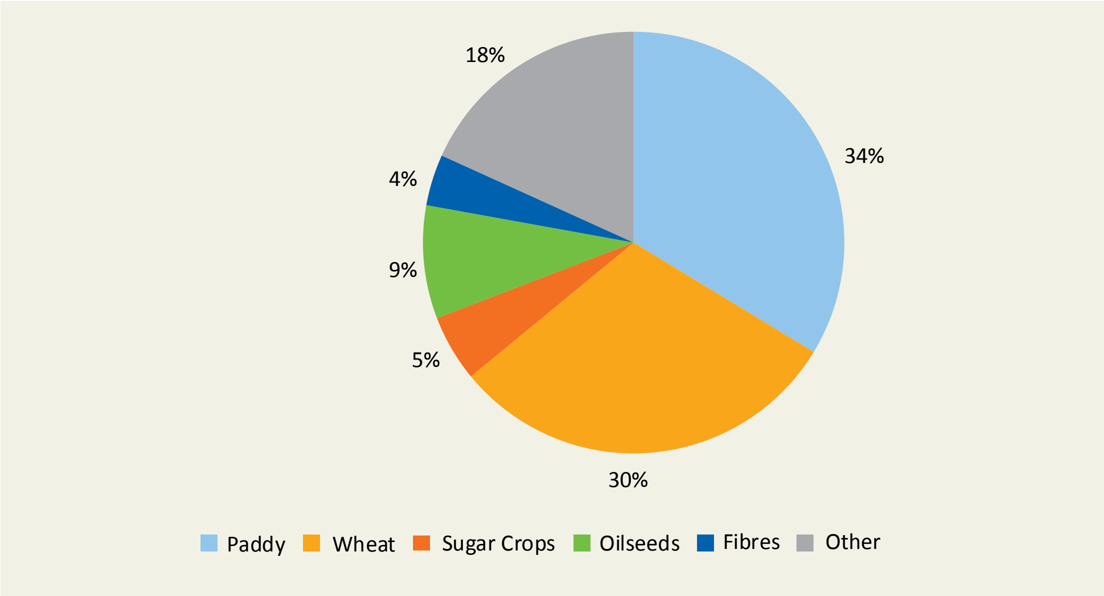
5.5 Equity Issues

Since electricity supply to agriculture is subsidised with a contribution from public resources, questions about which crops and farmers benefit from the subsidy are crucial.

Let us first look at what crops are supported by the electricity subsidy. There is no official data to identify the crops which are dependent on groundwater and hence on power subsidies. For example, the Agriculture Census reports the net irrigated area under different irrigation sources (including groundwater). It also reports total cultivated and irrigated area under different crops. But there is no reporting of crop-wise, irrigation source-wise irrigated areas. Other data sources like Land Use Statistics and district statistics report the data in a similar manner (DES, MoA, 2016; GoM, Various years).

However to get a broad idea, consider the fact that almost two-thirds of the net irrigated area is irrigated from groundwater and almost four-fifths of India's gross irrigated area is under five crops, namely paddy, wheat, sugar crops[32], fibres (mainly cotton) and oilseeds (Figure 6). Therefore we can safely conclude that most of the groundwater and hence electricity subsidy caters to these crops.

Figure 6: Share of Crops in Gross Irrigated Area in 2010-11



Source: (MoAFW, 2015, p. 67).

Let us also look at how the subsidy is being distributed among various sections of farmers in terms of landholding size.

Capital intensiveness of modern tube-well technology can favour large farmers disproportionately, who can afford the higher capital costs for irrigation equipment to extract groundwater from greater depths (Gandhi & Namboodiri, 2009, p. 18).

The Agricultural Census 2010-11 of the Government of India provides information about land held, irrigated, source-wise irrigation, wells and tube-wells held by farmers, etc. for various land-holding size categories. This allows us to draw information about the distribution of groundwater use, and hence electricity subsidy amongst various holding size groups.

32. The most widely prevalent sugar crop is sugarcane. Though area under sugarcane is small, considering its annual/1.5 year growth cycle and its need for frequent irrigation especially during no-rainfall period, its total water requirement is significantly higher especially in tropical belts (170–250 cm) and in Maharashtra (350 cm) (Kisan Suvidha). Similarly for cotton (8 months growth cycle), total water requirement is higher at around 80–90 cm than other crops (IIT Kanpur).

According to the Agricultural Census data, for the years 2010-11, there were almost 13.8 Cr total operational landholdings in India with around 15.96 Cr hectares of land. Out of these, around 42% of the total number of holdings did not receive any kind of irrigation. The proportion of area not receiving any irrigation is slightly higher at 48%.[33] This essentially means that 42% of all landholders in the country are out of the ambit of any irrigation subsidy or support—surface or groundwater (though they may be benefitting from other water related programmes like watershed management programmes.)

The Agricultural Census divides farmers into five groups based on the land-holding size. The groups are: marginal (less than 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (more than 10 ha). Table 7 gives the number of holdings in each class and the land area operated by each class.

Table 7: Number of Holdings and Area Operated for Various Size Classes

Size Class	Total Holdings (Number in lakh)	Total Area Held by the Size Class (lakh ha)	Holdings in the Class as % of Total Holdings	Area of the Class as a % of Total Area
Marginal	928	359	67.1%	22%
Small	248	352	17.9%	22%
Semi-medium	139	377	10.1%	24%
Medium	59	338	4.3%	21%
Large	10	169	0.7%	11%
All (Total)	1383	1596	100%	100%

Source: (MoAFW, 2015).

Table 8 shows the distribution of wholly unirrigated holdings across land-holding classes, as well as the percentage of land-holding area of each class that is unirrigated[34].

Table 8: Countrywide Distribution of Land Holdings across Size Groups without Irrigation in Terms of Number and Area

Size class	Number of Wholly Unirrigated Holdings as a Percentage of Total Number of Holdings of that Class	Unirrigated Area as a Percentage of Total Holdings Area of that Class
Marginal	40%	43%
Small	47%	50%
Semi-medium	46%	50%
Medium	43%	48%
Large	50%	51%
All (Total)	42%	48%

Source: (MoAFW, 2015)

33. It may be pointed out that this is different from the proportion of net cultivated area that is not receiving irrigation, because the total holdings area is more than the net cultivated area.

34. Note that each class will have some landholdings as wholly unirrigated, and some as partly irrigated. The unirrigated area is the sum of the areas of wholly unirrigated holdings, plus the unirrigated area of partially irrigated holdings.

The distribution of land is highly skewed across the holding categories. This means that any benefit that is distributed according to land size will reflect this inequity. Farmers in the Large landholding category have just 0.7% of the total number of landholdings, but they operate 10.59% of the total area. Similar, the Medium category has 4.25% of the total number of landholdings, but operates 21.2% of the total area of land. Given this, it is not surprising that together, the two categories constitute 4.95% of total number of landholders, but have 28.1% of the total groundwater irrigated area. If we take groundwater irrigated area as a proxy for the electricity subsidy[35], then these two categories of farmers take 28.1% of the total subsidy. Thus at one level, the distribution of electricity subsidy is skewed towards the large landholders, corelating with the inequity in land distribution.

However, for all the categories of farmers, the share in the total groundwater irrigated areas is on par with their share in the total area of landholdings.

Inequities are also seen in other ways. For example, while there are 66 wells (dug wells or tube-wells) for every 100 large landholders, the same ratio is only 15 for marginal landholders and 18 for small landholders. This likely reflects the high capital costs involved in putting in a well or tube-well, and the ability or lack of it to undertake such expenditure, which in turn is likely related to the landholding size. Similarly, almost 20% of all land held by large landholders is irrigated by tube-wells or wells, but only 10% of the marginal landholders' land is irrigated by tube-wells or wells.[36] Last but not the least, electricity powers only 45% of wells and tube-wells of marginal landholders, while it powers a higher percentage (between 72-79%) of wells and tube-wells of all other categories.

These various measures of inequity offer insights into how to structure agricultural electricity programmes including various subsidies so that the benefits reach the deserving in a more effective manner. For example, a capital subsidy to install wells/tube-wells for smaller farmers, who do not have access to any kind of irrigation, could help more of them get access to groundwater, and preferential electrification of pump-sets of this category of farmers would help them convert from diesel to electricity with less costly and more efficient pumping. Such an approach would need to be designed differently for each state or regions within states to reflect the region-wise differences. For example, states like Bihar, West Bengal and Uttar Pradesh, which have a higher number of marginal and small farmers who use diesel, could benefit from a preferential electrification programme. Incentivising solar pumps could also be an option for areas with large diesel use, and where groundwater is available at lower depths. Such an approach would need to also consider the groundwater status and stress in the area, and would be particularly useful in areas where groundwater is not stressed, or in areas with very little groundwater use, and in

35. This may not always be true as some DISCOMs have a tariff structure which differentiates tariffs for agricultural consumers based on certain criteria, which can differ from DISCOM to DISCOM. Some DISCOMs charge higher tariffs for agricultural consumers with higher pump capacities, while the DISCOMs in Andhra Pradesh do this for multiple connections per consumer or a larger size of landholding. This would result in larger farmers receiving less subsidy and vice-versa. However, in most states, the threshold for higher tariffs is quite high, and most agriculture consumers do not cross that threshold. Or the thresholds are not strongly enforced and most agricultural consumers fall in the category with the lowest tariff, like in Andhra Pradesh, rendering such tariff differentiation futile.

36. However, if we count all sources of irrigation including canals and other sources, 31% of all land held by marginal farmers is irrigated, which is the same as that for large farmers. This percentage for other categories ranges from 23% (semi-medium) to 28% (medium).

areas of high diesel use where such a scheme could be used to replace diesel pumps with electric pumps.[37]

5.6 Water Markets

Informal water markets, run at the level of individual farmers, are fairly common in various parts of the country. In such markets, typically, small farmers who do not have any irrigation facilities purchase water from nearby farmers who have groundwater extraction facilities, or Water Extraction Mechanisms (WEM), as they are often referred to. The payments can be monetary, or non-monetary, like a share in the crop produced.

Such water markets help to provide irrigation to resource-poor farmers who do not have access to irrigation, and thus are an important means to advance equity. Not only that, but such water markets can provide a better, more equitable distribution of subsidies that go towards groundwater extraction like electricity and diesel subsidies. Before proceeding with this line of argument, we would like to add some qualifiers here.

The term 'water markets' encompasses many different types of arrangements, with large variations in their nature, scope and extent. In the context of groundwater pumping and agricultural electricity supply, two types of water markets are important. One is a market where groundwater is pumped up in peri-urban areas and supplied through tankers to urban areas mainly for domestic use, but also for commercial use. A significant extent of such pumping could happen on agricultural land, using agricultural power supply. Our study does not cover this type of water market, and our remarks regarding the potential of water markets in advancing equity do not pertain to such markets.

The second type of water market is the one we have described at the beginning of this section, where a farmer with an agricultural electricity connection and a WEM supplies water to other farmers. Such markets can vary in their scale and the kind of arrangement for payment in cash or kind. Such markets that are run on a small scale can help better use of capital investment like pumps and motors, and help those without access to WEMs also get water, and thus further equity. However, we recognise that some of these arrangements can also be exploitative (for example, a large section of the produce as a payment for water) or can also lead to reverse land-leasing.

Recent estimates of the extent of the water markets in India are not easily available, but earlier estimates indicate that the practice is widespread (Saleth, 1998). One indication of the extent can be the number of landholdings receiving groundwater-based irrigation per an operating well or tube-well. Data from the Agricultural Census for year 2010-11 shows that one operating well/tube-well irrigates the land of 2.3 landholders who are using groundwater irrigation, though it varies widely from state to state. In other words, it can be said that only 45% of the ground-water irrigated landholders own an operating well or tube-well. The remaining 55% landholders must receive it from a government or private community lift scheme or from one of the holders who own such a water extraction mechanism, the latter arrangement in effect being a water trade or water market.

37. There are some important issues of debate here, which have implications for the electricity supply to agriculture, but which are beyond the scope of this paper. We have outlined them in the Additional Note.

Electricity reforms especially those dealing with tariffs, supply rationing, connection policies, etc can have significant impacts on water markets.

For example, the feeder separation programme in Gujarat implemented from 2006 that led to effective rationing of the hours of power supply is reported to have had a considerable adverse impact on water markets in Gujarat. Small farmers in Gujarat, who were mainly water buyers in the market, were found to be adversely affected due to the limiting of hours of supply of electricity to agriculture. The prices of water through water markets were increased by around 30-50% even though electricity tariffs did not increase to that extent. This could be due to apprehensions of the water sellers due to limited and metered electricity supply (Shah, Bhatt, Shah, & Talati, 2008). The details of feeder separation and its impacts are discussed in detail in Section 5.7 of this paper.

On the other hand, in West Bengal, in 2010-11, the tube-well permit system was abolished, the electricity connection process was simplified and its costs reduced, and the electricity tariff structure was modified from unmetered to metered, and from flat rate tariff to time-of-day (TOD). The change resulted in some improvement in the access to small farmers who were earlier not able to afford the connection or could not get it due to the licensing system for connections. However, at the same time, due to the change from flat to metered tariffs, water rates went up, and many water sellers preferred to lease in the lands from water buyers' lands rather than sell water (Shah & Das Chowdhury, 2017). In effect, it appears that the reforms made it easier for more farmers to get connections, but the change in tariff regime has adversely impacted water buyers. The details of the impact are discussed in detail in Section 5.8.

These examples indicate that electricity sector reforms, particularly those dealing with tariffs, connections or distribution, can have significant impacts on small and resource-poor farmers, and these impacts needs to be assessed before designing such reforms.

To be able to use water markets to address the challenge of inequity, some measures like increased hours of electricity supply (over the current 8 hours or less than that in many states) especially during peak irrigation demand periods, supply in two or more spells in a day especially in hard rock areas, common flat rate tariff for all consumers irrespective of the metering, etc have been suggested.

With this understanding of the complexities of the linkages between electricity, agriculture and water, let us look at some of the measures implemented to address the issues related to agricultural electricity supply.

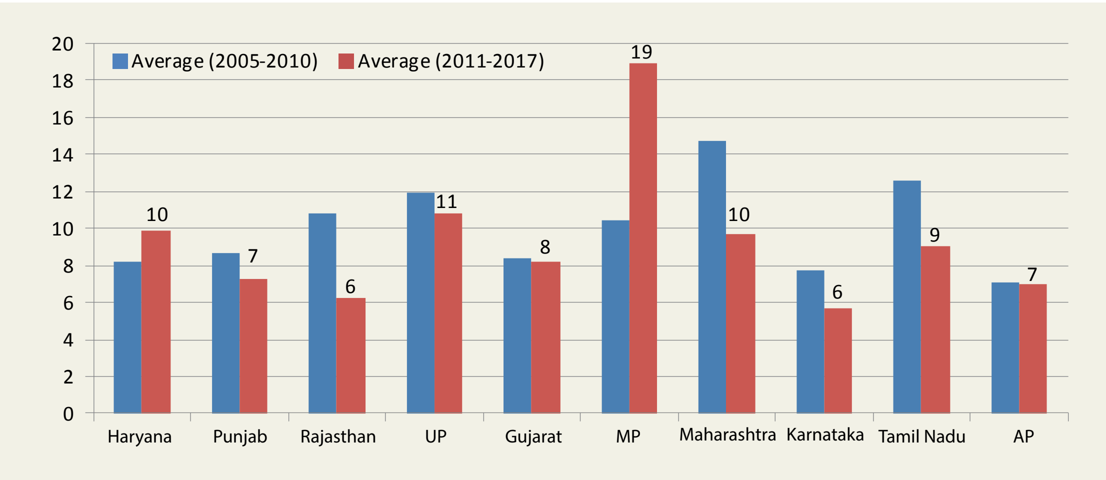
5.7 Agriculture Feeder Separation, Hours of Supply and Agricultural Consumption

A way to control the subsidy to agriculture consumers is to control the electricity consumption in agriculture. This can be done by curtailing or rationing the hours of electricity supply to agriculture. But rationing power to agriculture also means rationing power to other rural consumers because the rural power lines—or feeders, as they are called—on which pump-sets and agricultural consumers are located are the same. A way around this would be to physically separate rural power lines into two, one supplying to agricultural connections and the other supplying to the rest of the consumers in the village. This is called physical feeder separation. Another way would be to provide three-phase power for a limited number of hours, during which agricultural pump-sets can run, and single-phase power for the rest of the day. This curtails the hours for which pump-sets will operate, as irrigation pump-sets require three-phase power supply, whereas most rural consumers can do with single-phase supply. This is called virtual feeder separation. Although the core objective of feeder separation, physical or virtual, is to isolate non-agricultural rural consumers from the problems of agricultural power supply like low supply hours, high power cuts and low voltages, it effectively also controls the hours of supply to agriculture. Moreover, it enables the DISCOM to provide electricity to agriculture at off-peak hours when electricity demand from other consumers is low, which helps the DISCOM in load management. (For more, please see Volume 2 of this paper.)

While virtual separation was implemented to some extent in Rajasthan and erstwhile undivided Andhra Pradesh, Gujarat was the first state to complete physical feeder segregation of rural feeders in 2006 under the Jyotigram Yojana, followed by Haryana around 2010, and Punjab around 2013. Feeders are undergoing physical separation in many other states (World Bank, 2013; Forum of Regulators, 2014; MoP, 2017).[38]

DISCOMs have been rationing power to agriculture, sometimes by curtailing all rural power supply or through either modes of feeder separation, and there has been a gradual reduction in the hours of supply over time. In many states, agriculture now does not receive supply for more than 10 hours a day, as for example, in Andhra Pradesh, Gujarat and Karnataka (APEPDCL, 2017; DGVCL, 2017; KERC, 2016, p. 200). In fact, the recent 'Power for All' initiative of the central government promises 8-10 hours of power to agriculture and 24x7 power to all other consumers (Josey & Sreekumar, 2015). This can be seen in Figure 7, which shows the daily hours of supply to agriculture as an average of 2005-2010 and 2011-2017 in various states.[39] For Uttar Pradesh, the daily hours of supply shown are an average of those from 2011 to 2015 instead of 2011 to 2017. The hours of supply in Uttar Pradesh declined between 2005-10 and 2011-2015 before increasing again from 2016 onwards.

Figure 7: Three-Phase Average Daily Hours of Supply to Agriculture



Source: (CEA, Various Years).

38. In Andhra Pradesh, Telangana, Haryana, Punjab, Karnataka, Maharashtra, Madhya Pradesh and Rajasthan.

39. CEA reports average hours of supply per day for every month. We have taken the average of these over the entire time period.

Except Haryana and MP, all states have seen a decline in their hours of supply to agriculture. MP has been seeing a substantial growth in agricultural production driven by groundwater irrigation for the last few years, and the hours of supply seem to reflect this. These are the hours of supply as reported by the CEA, which reports the figures as submitted to it by the state governments and the DISCOMs.

The daily hours of supply to agriculture in Maharashtra declined from 14 hours to 10 hours in 2012 after the feeder separation scheme was implemented. It was decided that power supply would alternate between day time and night time. Electricity would be supplied for 10 hours at night and 8 hours during the day in rotation (MSEDCL, 2013).

In Haryana, the daily hours of supply to agriculture reduced from 14 hours in 2009 to 6.5 hours in 2010 when feeders were physically separated, before climbing back to 12 hours in 2013. The connected load of irrigation pump-sets, that is the sum of all pump capacities, and average pump-set size grew faster after feeder separation. Between 2005-06 and 2008-09, load grew by an average rate of 7% pa (supply hours also grew from 7 to 14), while between 2010-11 and 2013-14 it grew by 25% pa. Similarly, average pump-set size increased by 4% pa before and 8% pa after feeder separation (CEA, Various Years). Although growth in connected load and average pump-sizes can also be a response to the declining groundwater levels, it is possible that reduced hours of supply led to farmers digging multiple wells and tube-wells and installing pumps of higher capacities.[40]

Gujarat's villages, and hence irrigation pumps, were receiving 10-12 hours of three-phase power every day at the start of the millennium, which declined to 8 hours a day after the Jyotigram Yojana. (Shah, Bhatt, Shah, & Talati, 2008). In other states however, it is difficult to determine the change in the hours of supply to agriculture due to physical feeder separation based on available government data, as it is likely that power to agriculture was already being rationed. In Punjab, there is no prominent change in the hours of supply to agriculture. It was being supplied power for less than 9 hours before and after physical separation, indicating that agricultural supply was already limited in Punjab.

Some reports indicate that in Gujarat and Rajasthan, farmers faced lesser power interruptions and voltage fluctuations after feeder separation (World Bank, 2013). However at the same time, the feeder separation was also accompanied by a shrinkage of once thriving informal water markets in Gujarat. The power quality for farmers improved after the Jyotigram Yojana, thus benefitting pump-owners. But landless share croppers and water buyers, who are often poor marginal farmers, were pushed out of groundwater irrigation because of power rationing, reducing water availability in the water markets, and rising water prices (Shah & Das Chowdhury, 2017).

Similarly, no direct conclusions can be drawn regarding the impact of feeder separation on groundwater extraction, as there are several factors that affect groundwater use and withdrawal. However, there are some observations to be made regarding fall in hours of supply, growth in agricultural electricity consumption, connected load, pump size and groundwater withdrawal. Table 9 provides some important parameters related to electricity used in agriculture and groundwater for the states of Maharashtra, Rajasthan, Punjab and Uttar Pradesh for 2003-04 and

40. The growth in electricity consumption cannot be compared before and after separation as it was restated in 2010-11, due to a change in the estimation of electricity consumption in agriculture.

2012-13. These states have seen a fall in their hours of supply to agriculture between 2003-04 and 2012-13.[41]

Table 9 Electricity and Groundwater Related Parameters for Selected States

State	Year for Data	Electricity				Ground water		
		Number of Pumpsets (lakhs)	Connect-ed Load (MW)	Consump-tion (MU)	Average Pumpset Size (kW)	Annual Ground Water Availability (BCM)	Draft for Irrigation (BCM)	Groundwater Development (%)
Maharashtra	2003-04	25	7,187	10,572	2.9	31.2	14.24	48%
	2012-13	39	14,518	20,069	3.7	31.5	15.93	54%
	Increase over period (%)	**56%**	**102%**	**90%**	**28%**	**1%**	**12%**	**13%**
Rajasthan	2003-04	7	2,631	4,274	3.8	10.38	11.6	125%
	2012-13	11	9,091	18,325	8.1	11.26	13.79	140%
	Increase over period (%)	**57%**	**246%**	**329%**	**113%**	**8%**	**19%**	**12%**
Punjab	2003-04	9	3,482	5,745	4.1	21.5	30.34	145%
	2012-13	12	8,116	9,886	6.9	23.4	34.05	149%
	Increase over period (%)	**33%**	**133%**	**72%**	**68%**	**9%**	**12%**	**3%**
UP	2003-04	8	3,581	4,952	4.3	70.18	45.36	70%
	2012-13	10	9,656	9,215	9.7	71.58	48.35	74%
	Increase over period (%)	**25%**	**170%**	**86%**	**126%**	**2%**	**7%**	**6%**
Karnataka	2003-04	14	5546	8992	3.9	15.3	9.75	70%
	2012-13	19	15413	16803	8.2	14.83	8.76	66%
	Increase over period (%)	**36%**	**178%**	**87%**	**110%**	**-3%**	**-10%**	**-6%**
TN	2003-04	18	6666	9582	3.7	20.76	16.77	85%
	2012-13	21	8282	10206	3.9	18.59	12.98	77%
	Increase over period (%)	**17%**	**24%**	**7%**	**5%**	**-10%**	**-23%**	**-9%**

Source: Electricity related data from the CEA except consumption figures which are from state regulatory data wherever available. Groundwater related data from the CGWB.

41. Some of these states were facing power shortages during the latter part of these seven years, with power availability picking up after 2012-13. Thus it is possible that the overall hours of supply were lower, and not just to agriculture. However, the fact remains that on an average the hours of supply to agriculture are lower than the last decade even after improved power availability. Thus, this can be attributed to rationing.

In all these states except Tamil Nadu, it can be seen that despite reduction in the hours of supply, connected load and electricity consumption have grown substantially. One likely reason for the increase in pump-set size is the declining groundwater levels. The other very likely reason is that farmers seem to have compensated for the reduction in the supply hours by increasing their pump-set size. Overestimation of electricity consumption could also be a factor in the increase in the reported figures of agricultural consumption.

In comparison, increases in groundwater extraction have been modest. There could be several reasons for this mismatch apart from a fall in groundwater tables and overestimation of electricity consumption. As described before in Section 2.3, one possibility is that some of the pumping (and hence part of the increase in electricity consumption) was used to pump from surface water sources. Another reason could be that diesel-based pumping was replaced by electricity-based pumping as indicated by the 5th MI census. Clearly this would imply an increase in electricity consumption without a rise in groundwater extraction. Underestimation of groundwater extraction could also be a contributing factor.

But all in all, this means that it is very likely that power rationing alone cannot curtail electricity consumption to the extent that electricity subsidy is significantly brought down. Farmers find a way around the lower duration of power supply. This is because farmers greatly need pumped irrigation. Hence electricity consumption is driven primarily by the need for pumped irrigation, which would in turn depend on the irrigation water requirement of the crops cultivated.

5.8 Metering and Groundwater Permit Liberalisation in West Bengal

Unlike other states where electricity consumption in agriculture is significant, West Bengal successfully moved from a flat tariff regime to a use-based tariff by installing meters on all its electric irrigation pump-sets. This was possible because the number of electric pumps is much lower than other states and electricity-based pumping is still catching on in West Bengal. Further, farmers are charged a high metered tariff depending on when the electricity is used during the day (time-of-day tariffs). The tariff ranges from 2 to 4 Rs/kWh during off peak hours, and is as high as 7.5 Rs/kWh during peak hours. (WBERC, 2016). This tariff is significantly higher than the tariffs in other states, most of which are below 1 Rs/kWh. Therefore, this is seen as an important tariff reform.

In 2011, West Bengal's Water Resources Investigation and Development Department abolished the permit system which required tube-well owners to obtain groundwater permits. The permits were necessary for getting an electricity connection. At the same time, the DISCOM West Bengal State Electricity Distribution Company Limited (WBSEDL) also streamlined the process of getting an electricity connection, made it more transparent and reduced its cost from Rs 21,000[42] to Rs 8,100. This liberalisation of permits and electricity connections has facilitated the growth of tube-wells with electric pumps. However, the shift from flat to metered tariffs has affected water buyers adversely. Not only have the water prices increased by 30–50%, metering has also reduced the bargaining power of water buyers who have to lease their land to pump-owners at paltry rentals in exchange of irrigation water (Mukherji, A et al, 2009; Shah & Das Chowdhury, 2017).

42. In addition, significant "unofficial" payments are reported.

6. Need for a Different Approach

From the above discussions, it is clear that the picture of a DISCOM ailing financially due to below-cost supply to agriculture, with a large burden on the state and other consumers which can be addressed by metering all agricultural connections and increasing tariffs close to cost of supply levels, is a linear picture that does not capture the complexities of the situation or the interlinkages between the electricity, agriculture and water sectors. It is a picture that does not take into consideration the other aspect of the subsidy, that is, the role played by this electricity in agricultural growth, food security, livelihood support, and employment generation. It is a picture that ignores that DISCOM's themselves have often shown reluctance to fully meter the agricultural supply. It is a picture that disregards the likely impacts of tariff hikes on farmers. It does not take cognisance of the fact that the increase in tariffs does not automatically lead to better quality of service for farmers or even higher revenue and a reduction in electricity subsidy. In sum, it is a problematic formulation because it assumes that electricity supply to agriculture is primarily a power sector or a DISCOM level issue, whereas the reality is that it is an issue that has linkages with several other sectors, and needs to be seen from a larger social perspective.

Given this, we need a different approach to address this issue. First of all, agricultural supply, tariff revision and subsidies should not be seen only from the electricity/DISCOM standpoint. These aspects of agricultural electricity supply need to be seen from a lager social perspective, which takes into consideration the needs and situation of farmers. Further, it needs to bring in an understanding of the agriculture as well as water sectors.

Second, important initiatives in the water and agriculture sectors should be undertaken that would have a direct bearing on the use of groundwater and the electricity needed for this purpose. One such initiative that would be imperative to address the problems is to undertake large-scale, decentralised rainwater harvesting, soil and water conservation work. Such a programme can help raise the groundwater level and save pumping energy.[43] With regard to agriculture, aligning cropping patterns to the eco-climatic characteristics of the area, using organics fertilisers, etc would be important initiatives. Given the focus of this paper on the electricity aspect of this issue, we will not go into details of these water and agricultural programmes, but instead, explore the initiatives with regard to the power sector.

An important starting point would be to work out the subsidy needed for electricity supply to agriculture based on a desired agricultural development plan. Such an estimation of subsidies should be carried out by the state government at the state or sub-state level. Such an estimation process should encompass the following key elements.

- All the important stakeholders such as representatives from ministries/departments of power, water resources and irrigation, agriculture, groundwater, DISCOMs, consumer and farmer representatives should be actively involved in the process of subsidy estimation.

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43. At the same time, such programs resulting in increased groundwater storage can also lead to an increase in the number of wells and pumps, as there can be a race to tap the increased availability of groundwater. This can raise demand for electricity. Such programmes therefore need to be accompanied by an appropriate groundwater regulatory regime, like community wells (Ralegaon Siddhi) or no tube-wells for water intensive crops (Hivre Bazaar).

- The process should be carried out with a larger social perspective to improve the effectiveness and equity of the subsidy, keeping in mind the situation of different regions and different farmer size classes. Issues like the impact of the subsidy burden on state finances and DISCOMs should be considered, along with the impact of subsidy on ensuring food security, livelihood security, employment, agricultural growth, and sustainable use of groundwater.
- Since one of the central considerations, one which influences how much water and electricity is used, is the cropping pattern, such agricultural plans must propose cropping patterns aligned to the agro-climatic characteristics of each region, including surface and groundwater resources. The actualisation of a shift towards such cropping patterns can be achieved through a mix of measures including market and procurement support, value addition avenues, restructuring of the irrigation system, etc. For example, Ashok Gulati and his co-authors recommend that in Punjab "the government should facilitate diversification away from rice towards maize and horticulture by creating ... value chain development" (Gulati, Roy, & Hussain, 2017, p. 34).

Such an exercise may lead to different plans for different regions of the state. The Tariff Policy, notified by the Ministry of Power on 28th January 2016, in some ways anticipates such regional differentiation. It recommends that in fixing agricultural tariffs, the need to use groundwater sustainably should be kept in mind, and that different levels of tariffs and subsidies could be set for different parts of a state depending on the state of groundwater table to prevent excessive depletion of groundwater. It also suggests higher subsidy for poorer farmers of regions where adverse groundwater conditions require higher quantity of electricity for irrigation. (MoP, 2016, p. section 8.3(3)).

Such a planning process can help work out the optimal groundwater needs for irrigation and hence the optimal and most efficient levels of subsidies for electricity. Apart from helping optimise subsidies, such planning will also put the justification of subsidies on a more rational and stronger footing, leading to greater acceptability.

7. The Way Forward

To be able to adopt such an approach, it would be necessary to also address some of the gaps in the current knowledge and understanding of the agriculture-electricity-water linkage. It would also be of utmost importance to have accurate and more reliable data. Further, it would be advisable to try out some of the measures that can address these issues at a smaller scale before extending them at the state or regional level. Thus, the way forward should include

1. Additional research and studies
2. Efforts to improve data availability and quality
3. High level efforts to break the vicious cycle
4. Pilot scale projects to test and demonstrate solutions

7.1 Additional Research and Studies

Some of the areas which require more studies and development of a better understanding include

- How the use of water and electricity is influenced by different kinds of electricity tariffs— flat, metered, unmetered, free, etc.
- Which crops are being grown on pumped water, driven by electricity.
- Testing of pump-set efficiencies under field conditions. The electric pump-set's pumping efficiency / performance varies greatly depending on the field situation. Better estimates of efficiencies under field conditions will also aid verification of officially reported electricity consumption based on the groundwater usage and depths.
- The economics of farmers for different crops and different landholding classes.
- The impacts of tariff changes on farmers' economics.
- Distribution of electricity subsidy among farmers for a better understanding of who benefits from the electricity subsidy.
- Water markets, and whether and how these help benefits of electricity and electricity subsidy reach more people. Equity aspects of water markets. Impacts of tariff increase on water markets.
- Comprehensive assessment of earlier measures like feeder separation on farmers' economics, water markets, ground water depletion, DISCOM finances, etc.

These are only some important suggestions. Most of these aspects would need to be studied in the context of different crops, different farmer landholding classes, and different agro-climatic regions.

7.2 Efforts to Improve Data Availability and Quality

We have already highlighted the parameters where issues of data availability and quality are a concern. Some of these include better estimates and measurements of electricity use in agriculture, of extent of areas irrigated by ground and surface water and through conjunctive use, of groundwater extraction, etc. Here we mention only some of the ways to improve data availability and quality as this has been dealt with by several other agencies, for example, the Working Group on Water Database Development and Management for the 12th Five Year Plan.

First of all, there is a need to recognise data as a critical concern and accord it the due space in planning, budgets and implementation of programmes of various ministries, departments and agencies. For example, in spite of feeder separation having been implemented, this data is not used in Gujarat to estimate agricultural electricity consumption.

Second, better coordination amongst the various agencies who are gathering data would help cross-checking and corroboration leading to more accurate data. For example, some irrigation and pumping related data is gathered and recorded by multiple agencies and programmes like the Agricultural Census, Minor Irrigation Census, Agriculture and Water Resources Departments of state governments, etc. These agencies could coordinate with one another. Further, better integration of the data gathered by different agencies can go a long way in addressing many of the data issues. For example, DISCOMs or SERCs can coordinate with the Minor Irrigation or Agriculture Census agencies to carry out a census of pump-sets. Similarly, they can coordinate with the CACP to collect state-wise data on electricity consumption by different crops in agriculture as has been done by the Punjab Electricity Regulatory Commission in 2002-03.

Another very important measure would be to strengthen new sources of data collection and interpretation like satellite imagery and crowd sourcing along with their calibration using ground-level data and integration with data from other sources like various censuses. Such efforts will not only open up new sources of data but also provide synergies with existing data sources.

7.3 High Level Efforts to Break the Vicious Cycle

We have discussed earlier the vicious cycle with respect to agricultural electricity tariffs and farmers' willingness to pay, and how the initiative to break this low-level equilibrium has to come from the DISCOMs for various reasons, including the trust deficit. Given the stubbornness of the problem and its widespread prevalence, there is a need for concerted effort coming from the highest level with the highest priority. This would have to be a program with similar commitment and resource allocation as in the rural electrification program that was rolled out in 2005. This programme would also need to take into consideration the linkages with groundwater and agriculture as have been discussed in this report.

7.4 Pilot Scale Projects to Test and Demonstrate Solutions

We suggest some measures which can be tried out as pilots. Such testing will help refine the design of these measures, provide insights about their efficacy, demonstrate to what extent they can fit into the larger plans, and help upscale them.

7.4.1 Distribution Transformer and Feeder Metering with Census of Pump-sets

One major issue is that the agricultural consumption measurement process is not trustworthy, mainly because of unmetered supply to the sector. Therefore, implementing feeder-level or DT-level metering can help to provide data for supply at least up to the feeder/DT level. This would improve the estimation of agricultural supply. In addition, it is also observed that the number of pump-sets and connected load per pump-set is not verified regularly and hence often results in outdated data. Non-working/disconnected pump-sets, changed capacities after rewinding of the pump-sets, or change in the pump-set are also not taken into account. It would be useful to carry out such verification in a census mode in select locations as pilot projects along with the feeder/DT level metering. Together, these measures would help improve the estimation of agriculture supply as well as make it more accountable.

7.4.2 Metering Individual Pump-sets for a Group of Farmers

Some groups of farmers (like those in the Udupi district) are willing to have metering of their electricity consumption for irrigation and are ready to pay tariffs based on the actual use. Such areas can be identified for group level metering—that is, metering of each individual connection for the entire group of farmers. Such group level metering can help provide calibration for a larger estimation of agricultural consumption. Such voluntary group-level metering can be incentivised through improvement in quality of supply and service after the metering, and the provision of additional facilities like a visit by a DISCOM representative to the area at a mutually agreed time for the collection of bills.

A Direct Benefit Transfer (DBT) arrangement can also be tested in such a situation for the delivery of subsidy, in order to understand the challenges in implementation. Each farmer will have a specific quota for the electricity consumption at the subsidised rate, and additional consumption will be charged at the ACoS without any subsidy. This can help in the conservation of electricity and groundwater. The decided subsidy based on the quota will be deposited in the bank accounts of farmers. Such an arrangement can also incentivise farmers if they use electricity less than their quota. The CACP (2016) has also made a similar recommendation of a per hectare quota of water and electricity, with farmers being incentivised "by cash rewards equivalent to unused units of water/power at the rates of their domestic resource costs."

7.4.3 Distribution Transformer Associations

Distribution Transformer Associations should be formed on the lines of Water User Associations. The main objectives would be to reduce power theft in the high theft areas, thereby controlling losses, increasing accountability and improving the power quality. Bringing in more equity in the distribution would be another important objective. This would help provide overall better service to the farmers in the association. Improvement of billing and collection efficiency in such areas can be useful for the power distribution companies. The association can have the powers to determine tariffs internally,[44] to collect electricity charges, and supervise maintenance of the electricity distribution system. Such an arrangement, apart from improving distribution efficiency, has the potential to bring in more equity and help shift cropping patterns, though the latter would also depend on many factors external to the association like marketing, price and procurement support.

7.4.4 Capital Subsidy for Purchase of Energy Efficient Pumps for Small Farmers

High capital cost of wells/tube-wells and pump-sets is often an obstacle especially for poorer and small farmers to access groundwater based irrigation. A subsidy to meet part of these initial or

44. The electricity tariffs at the DT level can be decided by the ERCs as part of their tariff process. The association members can decide internally about the tariffs applicable based on the area irrigated, use of water, crops grown, farmers' ability to pay, etc. Such tariffs could also be telescopic in nature. They could also introduce criteria to prevent misuse of subsidies, for example, by "farm houses" of the rich.

upfront expenses can help such farmers access groundwater irrigation. This would be particularly useful in areas with few and sparse electric pumps, such as certain areas in Bihar, Uttar Pradesh, Odisha and other eastern and north-eastern states. Such schemes are already present in some states. We suggest that such schemes be linked to the purchase/installation of energy-efficient pump-sets, thus creating long-term benefits for both, the farmer and the DISCOM. Moreover, in areas where the electricity network is poor or inadequate and groundwater is available at lower depths, such schemes can promote solar pumps. This can help ensure more equity in electricity access and groundwater usage especially for the farmers who currently do not have access or have limited access to electricity and irrigation facilities. Attention should be paid to the level of groundwater exploitation in the area when designing such schemes. Another option of procurement through an UJALA like model with mass procurement of pumps through competitive bidding and performance guarantee can be explored to ensure lower costs and higher quality of the pump-sets.[45]

7.4.5 Safety Measures

The rural distribution network is often not maintained well, with low hanging wires, DTs without fences, and poor quality pump-set switch-boards. This is often on top of a lack of adequate grievance redressal mechanisms. A pilot project for rolling out enhanced safety measures for the electricity infrastructure and good grievance redressal can help improve the confidence of farmers in the distribution companies and bridge the trust gap.

7.4.6 Hours of Power Supply Based on Cropping Pattern and State of Groundwater Aquifers

The power supply duration can be adjusted in order to help to grow particular, agro-climatically suitable crops in an area. In addition, the duration can also be decided considering the state of ground water aquifers in the region and seasonal variations in irrigation requirements. It should be ensured that the power supply be good in terms of quality and sufficient in quantity to enable the farmers to fulfil the planned irrigation requirement. However, this would need to take into consideration impacts on water markets and impact on water buyers. One way to address it may be to provide capital subsidy so that those without access to water extraction mechanisms (WEMs or pump-sets) can acquire such WEMs and thus would not remain dependent on water markets. Another issue to be considered would be that a major determinant of cropping pattern choice is often the market, price and procurement support. So these aspects may also need to be built into the pilot project.

7.4.7 Block/DT/Feeder Level Electricity Tariffs Based on Cropping Pattern and State of Aquifer

Additionally, or alternatively, the electricity tariffs and hence corresponding power subsidy can be decided based on the status of ground water aquifer in a block or a feeder/DT area, and an appropriate cropping pattern. As mentioned earlier, the tariff policy also suggests this. The caution with respect to cropping pattern mentioned in the previous suggestion (7.4.6) should also be kept in mind here.

45. At present, Energy Efficiency Services Limited (EESL) has initiated some steps in this direction (EESL).

7.4.8 A Procurement and Price Regime to Encourage Shift Towards Appropriate Cropping Pattern

The public procurement of region-suitable crops grown by farmers should be strengthened at the selected area at a fair price. This can help dissuade farmers from water-intensive crops (especially in water-stressed area) and help them recover their cost of cultivation and make an appropriate profit as well. However, such a policy itself may have some implications for subsidy, an aspect which should be examined. Pilot projects would help identify such issues.

7.4.9 Community-driven Regulation of Groundwater Extraction and Recharge

Several initiatives are attempting to put in place Aquifer Based Participatory Groundwater Management at small geographic levels as an alternative model of groundwater management (ACWADAM). This is based on mapping the aquifer at a local level. Such initiatives can also be paired with some of the pilots mentioned earlier that deal with electricity distribution so as to develop a model for a sustainable and equitable management of groundwater.

7.5 Drawing Lessons for Areas Covered by New Groundwater Based Programmes

There are several regions where the government has plans to implement programmes on the lines of the "green revolution", driven mainly by the development of groundwater resources. It is critical that these programmes be informed by lessons drawn from the experiences so far of the linkages between groundwater, electricity and agriculture development. For example, one such programme is the Bringing Green Revolution to Eastern India (BGREI).

The BGREI was "… initiated in 2010-11 to address the constraints limiting the productivity of 'rice based cropping systems' in eastern India comprising of seven (7) states, namely Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, Eastern Uttar Pradesh and West Bengal" (Department of Agriculture & Cooperation, 2015, p. 1). The goal of the programme is "to harness the water potential for enhancing rice production in eastern India which was hitherto underutilised."

Clearly, there is a lot of water potential in these seven states, particularly groundwater potential. Data from the CGWB for 2013 shows that these seven states had a total of 206 BCM of annual replenishable groundwater, that is, 46% of the country's total of 445 BCM (CGWB, 2017).[46] Out of this, water available for future irrigation development (that is, total available water minus water already being extracted and water reserved for future domestic and industrial use) in these seven states is 98 BCM, or 60% of the 162 BCM available in the country. Thus, there is excellent potential to base agricultural development on this available groundwater. However, there is a need to avoid the serious problems that have arisen in the electricity, water and agriculture sectors where similar groundwater-based development has taken place. This needs to be emphasised because the BGREI currently seems to be going along the same path.

46. It should be noted that these estimates pertain to the seven states including the entire state of Uttar Pradesh, whereas in this state the BGREI programme extends only to the eastern part. However, even leaving out Uttar Pradesh, the remaining six states have 29% of the annual replenishable groundwater of the country, and 48% of the total groundwater remaining for future use.

The very first objective of the BGREI is "to increase production and productivity of rice and wheat by adopting latest crop production technologies." That is, other crops seem to be relegated to a secondary position, whereas elsewhere, crop diversification is being seen as the need of the hour. In terms of the proposed interventions, "BGREI comprises of three broad categories of interventions: (i) block demonstrations; (ii) asset building activities such as construction of shallow tube-wells/bore-wells/dug wells, pump-sets, seed drills, etc; and (iii) site-specific activities for facilitating petty works such as construction/renovation of irrigation channels/electricity for agricultural purposes in a cluster approach for convenience and cost effectiveness" (Department of Agriculture & Cooperation, 2015, p. 1). Given the very similar approaches to earlier interventions, it is crucial that lessons learnt from elsewhere be used to inform the design of the BGREI and similar interventions.

8. Conclusion

Groundwater has emerged as the lifeline of India. It is the dominant source of irrigation in the country. This is because groundwater has significant advantages in terms of control in the hands of farmers, in terms of productivity, in terms of modularity and also in furthering equity. For all these reasons, it is certain that groundwater's dominance will continue and its extent increase. Therefore, it is important to address the several serious issues that have emerged around groundwater, electricity and agriculture, all of which are interrelated.

There are strong and complex interlinkages between the agriculture, water and electricity sectors. It is practically impossible to address the issues of one without addressing holistically the other sectors and the interlinkages. This is partly the reason why the problems are intractable even after several efforts to address them. We have tried to explore and lay out various facets of these interlinkages, attempted to look at the sectors in an integrated manner, and proposed certain approaches to address the issues of concern.

The mainstream discourse around agriculture's role in the financial loss of DISCOMs is limited to low electricity tariffs and lacks the emphasis on many key systemic problems of the distribution sector. Agricultural electricity consumption is overestimated and so is subsidy. DISCOMs benefit at the expense of the state governments and electricity consumers and it is agriculture that gets attributed with losses that are not its own. Many DISCOMs and state governments are caught in an unhealthy cycle where DISCOMs subsidise their inefficiencies under the guise of agricultural consumption, and governments do not fulfil their subsidy obligations. Deteriorating DISCOM finances and distribution infrastructure result in poor power supply and service which imposes substantial financial costs on farmers. These systemic problems have to be resolved before asking poor and indebted farmers to pay higher tariffs. This is because raising tariffs will not increase DISCOM revenue if power quality and service is not improved prior to tariff increase. The subsidy burden cannot be addressed unless more reliable estimates of agricultural electricity consumption are available. That being said, a new, integrated approach to subsidy is required to bring DISCOM finances in order without burdening farmers who are saddled with low incomes and high debt.

Our analysis shows that it would be important to first reduce the inefficiencies in the sectors, address the trust deficit to gain confidence of farmers and the users of electricity and groundwater, and increase accountability of the power sector. Only after these steps should measures like electricity tariff rise, higher water charges, and full metering at the farmer level be implemented based on requirements. This is because such measures are unsustainable and ineffective in an environment where there is a trust deficit and lack of proper accountability.

At the same time, there is a need to address the crucial issue of cropping patterns, which is one of the most important drivers of the groundwater and electricity used. A shift towards crops that are suitable to the local eco-climatic characteristics, and putting in place proper marketing and price support to ensure decent returns to farmers from such crops, is essential to address the problems of excessive withdrawals of ground (and surface) water, as well as achieve moderation or optimality in electricity use. In areas where extensive use of groundwater is not yet taking place, there is opportunity to incorporate these approaches from the beginning. These measures need to be combined with extensive, decentralised land-water conservation and rainwater harvesting to help sustainable use of groundwater, to ensure that groundwater levels do not fall, and in turn to help keep electricity use in check. Introduction of solar-based pumping in appropriate schemes can also help cut down subsidies while ensuring that irrigation needs are being met.

It is certain that only an integrated and comprehensive approach will be able to address the serious issues that currently plague the electricity sector in terms of subsidies, DISCOM finances and quality of supply to agricultural consumers, as well as related issues regarding groundwater use and agriculture. While this is no doubt a challenge, it is equally a source of hope and optimism. We believe that the understanding of the issues and problems presented by us, as well as our recommendations, will play a useful role in realising this hope.

9. Additional Note: A Few Words on Groundwater Resource Use and Equity

When we talk about equity and sustainability in the context of groundwater use, there are some important issues of debate which have implications for the electricity supply to agriculture, but which are beyond the scope of this paper. For one, would helping more and more farmers in an area to get access to their own pumping equipment lead to higher groundwater withdrawals and depletion? Or would it help farmers shift from being water buyers in a water market to being independent of the water market, thus giving them more control, without affecting the effective groundwater withdrawals? Another issue is if farmers, especially small and marginal farmers in an already groundwater stressed area, are discouraged, or even banned from getting their own pump-sets, would it be privileging those who were early installers of groundwater pumping machinery, most likely to be bigger farmers? This is linked to the question of who, if anyone, owns groundwater. Today, in practice, groundwater is treated as the private property of the owner of the land, who assumes a right to pump up as much groundwater as he desires. Since groundwater is a unified resource, this has implications for other users, and ultimately, on equitable use of the resources, apart from environmental consequences of resource depletion. These issues can be addressed only by recognising that groundwater is a common pool resource and a public resource, and by bringing in a regulatory regime that ensures sustainable use as well as equitable distribution. Some elements of such a regime would be participatory groundwater management which treats groundwater as a common property resource, prioritising the use of groundwater for basic needs, food security and sustenance agriculture (all of which are recognised as a priority in the National Water Policy 2012), and for livelihood security, encouraging appropriate cropping patterns, and putting in place public groundwater infrastructure as against private pump-sets.

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11. List of Abbreviations

ACoS	Average Cost of Supply
AP	Andhra Pradesh
ARR	Aggregate Revenue Requirement
AT&C Losses	Aggregate Technical and Commercial Losses
BCM	Billion Cubic Metre
BU	Billion Units
CACP	Commission for Agricultural Costs and Prices
CAG	Comptroller and Auditor General of India
CEA	Central Electricity Authority
CGWB	Central Groundwater Board
Cr	Crore
DHBVNL	Dakshin Haryana Bijli Vitran Nigam Limited
DISCOM	Distribution Company
DT	Distribution Transformer
EESL	Energy Efficiency Services Limited
FY	Financial Year
GDP	Gross Domestic Product
GoH	Government of Haryana
GoI	Government of India
Ha	Hectare
HERC	Haryana Electricity Regulatory Commission
HT	High Tension
KERC	Karnataka Electricity Regulatory Commission
kW	Kilo-Watt
kWh	Kilo-watt hour
LT	Low Tension
MP	Madhya Pradesh
MERC	Maharashtra Electricity Regulatory Commission
MI	Minor Irrigation
MoAFW	Ministry of Agriculture & Farmers' Welfare
MoP	Ministry of Power
MoSPI	Ministry of Statistics and Programme Implementation
MoWR	Ministry of Water Resources, River Development & Ganga Rejuvenation
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MT	Million Tonnes
MU	Million Units
MW	Mega Watt
PEG	Prayas (Energy Group)
PFC	Power Finance Corporation
PSERC	Punjab State Electricity Regulatory Commission
PSPCL	Punjab State Power Corporation Limited
PSU	Public Sector Undertakings
RBI	Reserve Bank of India
SERC	State Electricity Regulatory Commission
ToD	Time of Day
T&D	Transmission and Distribution
UDAY	Ujwal Discom Assurance Yojana
UHBVNL	Uttar Haryana Bijli Vitran Nigam Limited
UP	Uttar Pradesh
UPERC	Uttar Pradesh Electricity Regulatory Commission
WEM	Water Extraction Mechanism
WES	Water Extraction Mechanisms
WB	West Bengal
WRIS	Water Resources Information System

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Agriculture occupies a critical position in the country's economy, ensuring food security, providing livelihoods, and indeed as a way of life for most rural people. Due to many reasons, growth in agriculture has been largely driven by groundwater based irrigation, powered by electricity. It is also certain that the dominance of groundwater will continue in the coming years.

From the early 1990s, a significant thread in the story of reforms in electricity sector has been the financial unsustainability of the distribution sector. One of the reasons cited has been the subsidised supply of electricity to agriculture. Subsidised supply has also been held responsible for poor quality of supply and excessive use of groundwater. Increasing the agriculture electricity tariffs has been a major suggestion for improving distribution sector finances.

In spite of several decades of this approach, the problems persist. An important reason for this is the failure to acknowledge the strong and complex linkages between the electricity, water and agriculture sectors, and to recognise that it is practically impossible to address the issues of one without comprehensively addressing challenges in all the other sectors.

With this in mind, this discussion paper in two volumes brings out the linkages between electricity, water and agriculture sectors. It also highlights the need to take these linkages into consideration when planning agricultural electricity supply. Volume 1 of the paper focuses on an overview of the linkages and Volume 2 provides a detailed analysis of the electricity sector related issues of the linkage.

It is our hope that this discussion paper would catalyse a healthy discussion among actors in electricity, water and agriculture sectors, towards a better understanding of the challenges and evolving sustainable solutions.

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