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India

Rajasthan Water-Food-Energy Nexus

{Grow Solar, Save Water, Double Farmer Income}

{January 2020}

WAT



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GROW SOLAR, SAVE WATER, DOUBLE FARMER INCOME

An innovative approach to addressing
Water-Energy-Agriculture nexus in Rajasthan



Mohinder P. Gulati, Satya Priya, Edward W. Bresnayan

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FOREWORD

by Country Director, India



One of the most significant achievements in recent times has been the story of India's growth and development. Over the past decade or so, India has lifted more than 160 million people out of poverty. In the past twenty-five years or so, per capita incomes have quadrupled, illiteracy has plummeted, and health conditions have improved. And all this in an extraordinarily vast and complex federal democracy.

The country now stands at an inflection point. With people's aspirations soaring, India is ready to transition to a higher level of prosperity. So, what will India need to do differently to provide its people with the quality of life that they desire? As things stand today, India is the most resource-constrained country among the BRICS nations. It has less land and water per person than either China or Brazil. Yet its agriculture remains the world's largest irrigator, using way too much land and water, and engaging far too many people for too little output.

What's more with more than 27 million privately owned tube wells, India is the world's largest user of groundwater and, every year, withdraws more than twice the amount of water than China or the United States.

India's pattern of growth over the past few decades has led to significant exploitation of its scarce natural resources. Better management of water, energy, and agriculture are really at the heart of economic and social development. Persistently subsidized access to electricity for agricultural consumers has led to high usage of water by the agriculture sector, thereby, depleting water resources. This has created an adverse nexus between water-energy-agriculture that needs to be dealt with by finding solutions and engaging with different stakeholders.

In this study, the World Bank team has developed innovative approaches to provide financially and economically viable and politically acceptable business models to address the challenges posed by the adverse nexus.

The strength of this approach lies in its multi-sectoral and multi-stakeholder process. During consultations, the farmers showed a high level of awareness of the challenges and gave an encouraging response to the proposed approaches to addressing them.

Advancements in technology and falling prices, particularly of solar, have opened enormous opportunities of shifting the Water-Energy-Agriculture nexus into a virtuous cycle of conserving water, increasing farm income, and increasing energy efficiency of groundwater irrigation. In addition, the decentralized solar power generation could transform rural livelihoods.

The study was undertaken following a request from the Government of Rajasthan. I am thankful to the Chief Secretary, Government of Rajasthan and his team for extending their support to this initiative.

I am also pleased to note that the recommendations of this study have been taken on board by the Government of Rajasthan. The state is keen to leverage these models to address the challenges faced in the state. Among these are: depleting resources of groundwater and the deterioration of its quality, stagnating agricultural productivity, declining farmer income, and growing fiscal impact of power subsidies.

A learning-by-doing pilot is being planned in different agro-climatic zones of Rajasthan. We hope the pilot will lead to implementation of solutions on-the-ground to calibrate the business model, increase engagement and outreach to farmers, and demonstrate its viability for a scale up across the state. The model could also potentially be replicated in other Indian states that are facing similar challenges.

Junaid Kamal Ahmad



सत्यमेव जयते

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FOREWORD

I would like to congratulate the authors of the report, my staff in Departments of Agriculture, Power, Water, and Ajmer and Jaipur power distribution companies for a collaborative effort in producing this highly relevant Study for Rajasthan. This Study offers innovative solutions to a long-standing challenge of scarce and declining water resources, growing consumption of electricity for groundwater irrigation, and less than required growth in agriculture.

Rajasthan is one of the most water-stressed states in India. Successive governments in Rajasthan have given priority to, and have made impressive progress in, management of the state's water resources. But a lot more needs to be done. Dependence of our population and economy on agriculture is reflected in more than 85% of water resources and more than 40% electricity being consumed by agriculture. Groundwater in most blocks is over-extracted and less than 20% of blocks are considered safe. Climate change would likely aggravate these challenges and per capita water availability in Rajasthan is projected to fall below absolute water scarcity norm of 500 cubic meter by 2050. Without substantial increase in average agriculture household income in Rajasthan, which is currently at par with national average, we cannot achieve the target of doubling farm income. An adverse Water-Energy-Agriculture nexus is the binding constraint on Rajasthan's ambitions of double-digit economic growth and improvement in quality of life of its people.

This report appropriately titled "Grow Solar, Save Water, Double the Farm Income" offers a robust analysis and pragmatic suggestions for implementation. It is within the realm of possibility to achieve the trifecta of conserving water, doubling farm income, and conserving electricity. The suggestion of a "drought premium" is an innovative policy instrument to pay to the solar-farmers a scarcity premium on electricity they produce in times of drought. This premium would not be a charity and would respect the dignity of the farmers in distress.

The recommendations of the report are equally valid for many other states in India facing similar challenges. I hope to see field-testing of the recommendations of the report through a few pilots to help calibrate the scheme for scaling up across Rajasthan and potential replication in other states.


(D. B. Gupta)

FOREWORD

by Practice Manager, Water Global Practice, South Asia Region



At the request of the Government of Rajasthan, the World Bank carried out a diagnostic analysis of the water-energy-agriculture nexus in the state and explored practical ways to address what has hitherto remained an intractable challenge of managing these critical resources in a sustainable manner.

Two groundwater-stressed blocks – one each in Ajmer and Kota districts - were selected for the study. A cross-sectoral policy analysis, the experience of several initiatives and programs implemented by Rajasthan and other states in India, multi-stakeholder consultations, and detailed analysis of electricity and water consumption in agriculture underpin this study. The extensive experience gained through the Rajasthan Agriculture Competitiveness Project proved to be very helpful to furthering understanding of these complex issues.

Using locally contextualized institutional models for implementation, the study presents a framework for cross-sectoral policy analysis, business models and financial evaluation of the proposed business models from the perspective of three key stakeholders: farmers; power distribution companies; and the State government. The study points out the possibilities of achieving the triple benefits of saving water, doubling farmer income, and improving reliability of power supply and irrigation, through grid-connected solar irrigation system. A key concern of officials and the people of Rajasthan is water security. A methodology is presented to estimate the value of water in agriculture and evaluate the feed-in-tariff for solar electricity required to shift the trade-off towards conserving water. “Drought Premium”, an innovative policy instrument suggested in this study, can not only create awareness of scarcity value of electricity and water but also maintain the dignity of the farmer during a period of distress by offering relief as a payment for electricity instead of charity. The Government of Rajasthan has decided to field-test the suggested business and institutional models through a few learning-by-doing pilots.

I would like to thank the Chief Secretary, Government of Rajasthan and his staff in the departments of agriculture, groundwater, power, and the power distribution companies who provided unstinted support for carrying out this study. I look forward to the implementation of the pilots and sharing of the lessons learnt with other States.

Michael Haney

ACKNOWLEDGMENTS

This “Grow Solar, Save Water, Double Farmer Income - an innovative approach to addressing Water-Energy-Agriculture Nexus in Rajasthan” analytical study has been a collaborative effort amongst water, energy and agriculture departments of the Government of Rajasthan as well as within and among the World Bank global practices dealing with the water, energy, and agriculture sectors. The Study was launched at the request of the Government of Rajasthan in conjunction with the implementation of Rajasthan Agricultural Competitiveness Project. The Bank team would like to acknowledge and sincerely thank the Government of Rajasthan, which guided this Study at different stages and contributed in a substantive way toward its successful completion.

Special gratitude extends to Mr. Devendra Bhushan Gupta, Chief Secretary, Government of Rajasthan; Mr. Pawan K Goyal, the previous Additional Chief Secretary, Agriculture, Government of Rajasthan; Mr. N P Gangwar, now Principal Secretary, Department of Agriculture, who was previously Principal Secretary, Department of Power; Mr. K.L. Meena, Principal Secretary, Department of Power; Mr. Sandeep Verma, Principal Secretary, Department of Public Health Engineering Department and Groundwater; Chairman DisComs and Managing Directors, Jaipur and Ajmer Vidyut Vitran Nigam Limited, and the relevant officials of these departments for supporting and guiding the study.

We remain grateful to Dr. Om Prakash, Project Director of Rajasthan Agricultural Competitiveness Project (RACP) and his staff, in particular, Mr. V P Singh and Dr. P S Kalra for outstanding support and help extended during the Study to the Bank team without which it would not have been possible to complete the Study. The World Bank is grateful for the cooperation and help extended to the Study team by officials from several other Rajasthan Government departments and agencies, including field level officials of Departments of Water, Energy and Agriculture.

The Study was conceptualized and led by Satya Priya of the Global Water Practice; Mohinder Gulati

of the Global Energy Practice; and Edward W. Bresnyan of the Global Agriculture Practice of the World Bank. This report relied on the analytical and intellectual support of Shilp Verma and Neha Durga whose experience in this field with International Water Management Institute and TATA (IWMI-TATA) led work in the field of solarization of irrigation is greatly acknowledged. Special thanks to Prince Purohit, a local professional from Jaipur and his contribution to the study. Outstanding support from World Bank colleagues Lucy Lytton for guiding the groundwater management and administrative support from Roshni John is highly recognized. Special thanks are also due to World Bank consultants Anish Bansal, and R. P. S. Malik for their meticulous contributions to analysis of business models. Helpful comments and contributions were received from peer reviewers are IJsbrand H de Jong, Patrick Verissimo, Defne Gencer of the World Bank and one external reviewer, Tushaar Shah, IWMI-Tata Water Policy Program.

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Finally, we would like to express our sincere appreciation to Junaid Ahmed, India Country Director, World Bank, Michael Haney, South Asia Practice Manager, Water Global Practice, World Bank, for their overall guidance and support to this activity. Thanks are also due to Demetrios Papathanasiou, Practice Manager, Energy Global Practice and Mary Kathryn Hollifield, Practice Manager, Agriculture Global Practice for their support.

ABBREVIATIONS AND ACRONYMS

| | |
|--------|---|
| ABHY | Atal Bhujal Yojana |
| AIBP | Accelerated Irrigation Benefits Program |
| APPC | Average Purchase Power Cost |
| AVVNL | Ajmer Vidyut Vitran Nigam Limited |
| BCM | Billion Cubic Meters |
| CACP | Cluster Agriculture Competitiveness Plan |
| CAD | Command Area Development |
| CGWB | Central Groundwater Board |
| CCT | Continuous Contour Trenches |
| CFA | Central Finance Assistance |
| CLD | Causal Loop Diagram |
| DBTE | Direct Benefit Transfer |
| DDUGJY | Deen Dayal Upadhyaya Gram Jyoti Yojana |
| DISCOM | Distribution Company |
| DPL | Development Policy Loan |
| EBI | Evacuation Based Incentive |
| EU-SSP | European Union – State Partnership Program |
| FE | Farmers Enterprise |
| FLM | Farmer Led Model |
| FPC | Farmer’s Producer Company/Corporative |
| FRBM | Fiscal Responsibility and Budget Management |
| GSDP | Gross State Domestic Product |
| GoI | Govt. of India |
| GoR | Govt. of Rajasthan |
| HP | Horse Power |
| INR | Indian rupee |
| IRR | Investment Rate of Return |
| IWMI | International Water Management Institute |
| IWRM | Integrated Water Resources Management |
| JICA | Japan International Cooperation Agency |
| JPAL | Jameel Poverty Action Lab |
| JVVNL | Jaipur Vidyut Vitran Nigam Limited |
| JNNSM | Jawaharlal Nehru National Solar Mission |
| KUSUM | Kisan Urja Suraksha evam Utthan Mahabhiyan |

| | |
|-----------|--|
| kWp | Kilo Watt Power |
| MGNRES | Mahatma Gandhi National Rural Employment Guarantee Scheme |
| MIT | Massachusetts Institute of Technology |
| MJSA | Mukhyamantri Jal Sawavalamban Yojna |
| MSP | Minimum Support Price |
| MNRE | Ministry of New and Renewable Energy |
| MW | Mega Watt |
| NABARD | National Bank for Agriculture and Rural Development |
| NAFIS | NABARD All India Rural Financial Inclusion Survey |
| NDDB | National Dairy Development Board |
| NTPC | National Thermal Power Company |
| NVVNL | NTPC Vidyut Vyapar Nigam Limited |
| PPA | Power Purchase Agreement |
| PMKSY | Pradhan Mantri Krishi Sinchai Yojana |
| POS | Point of Sale |
| POD | Point of Delivery |
| POPI | Producer Organization Promotion Institutions |
| PRAYAS | Initiatives in Health, Energy, Learning and Parenthood - a NGO |
| PPP | Public Private Partnership |
| PV | Photo Volatic |
| RRVUN | Rajasthan Rajya Vidut Utapadan Nigam |
| RRVPN | Rajasthan Rajya Vidut Prasaran Nigam |
| RACP | Rajasthan Agriculture Competitiveness Project |
| RKVY | Rashtriya Krishi Vikas Yojana |
| RWSP | Rajasthan Water Sector Restructuring Project |
| SAUBHAGYA | Pradhan Mantri Sahaj Bijli Har Ghar Yojana |
| SAWI | South Asia Water Initiative |
| SCD | Systematic Country Diagnostic |
| SFA | State Finance Assistance |
| SFAC | State Farmers Agribusiness Consortium |
| SIP | Systematic Investment Plan |
| SKY | Suryashakti Kisan Yojana |
| SPV | Solar Photo Voltaic |
| UDAY | Ujwal DISCOM Assurance Yojana |

EXECUTIVE SUMMARY

1. The key objective of this Study is to explore practical, politically feasible, scalable and sustainable approaches to address the challenge of adverse water-energy-agriculture nexus in Rajasthan. A bold and contextually appropriate policy framework of rapid expansion of rural electrification for irrigation, power and water subsidies, focus on cereal crops, market support through pricing and procurement, and promoting inorganic fertilizers designed to address the acute food crisis of a growing population in the 1970s gradually started falling out of step with the changing ground realities. Food shortages have disappeared, and rural poverty has gone down but it has come at a high cost to the energy and water economy and finances of the state. Advancements in solar and communication technologies have opened new possibilities to take a fresh look at the nexus and realign the incentives and interests of the farmers, power utilities, the government and other stakeholders to create win-win opportunities. This Study presents alternatives that have the potential to achieve the trifecta of increased irrigation energy efficiency, water conservation and doubling farmer income.

Rajasthan's agriculture growth has come at a high cost to the water and electricity sectors, but poor quality of power supply inflicts substantial costs on the farm sector.

2. Three-fourth of Rajasthan's population lives in rural areas and more than 60% depend on agriculture. National Bank for Agriculture and Rural Development's 2017 rural financial inclusion

survey reports that farm income contributes about half of the income of agriculture households. Rajasthan has an average agriculture household income of Rs108,000 per annum that is close to the national average and about half — Rs 54,000 or about US\$900 — is generated by farm production.

3. **Rajasthan has limited surface water resources and its economy is highly dependent on groundwater. Agriculture consumes 86% of available water resources, 11% is used for services including drinking water, and 3% is utilized by the industry.** There is high dependence on groundwater for both irrigation and drinking needs, with statewide extraction being 140% of annual replenishable recharge. In terms of groundwater development, of its 248 development blocks, only 44 are safe, 28 are semi-critical; 9 are critical, 3 are saline and an overwhelming majority of 164 blocks are over-exploited. **The average per capita water availability is expected to drop below 450 cubic meters by 2050, which is below the international minimum of 500 cubic meters that defines absolute water scarcity.**

4. The electricity sector in Rajasthan has expanded and improved over time. However, it is facing serious financial challenges that threaten the sustainability of supply in the long run. A combination of high generation costs, inefficiencies in the distribution sector and an accumulation of long-delayed tariff adjustments, resulted in several years of continuing losses, requiring substantial financial support from the State. More than 40% of electricity is sold to agriculture and

the sector suffers an aggregate technical and commercial loss of more than 25% that is partly paid for by cross-subsidy but substantially by the state government. In FY 2018, subsidy of ₹ 86 billion represented more than 20% of revenue of the power sector (₹ 400 billion). Accumulated losses of ₹ 814 billion, partly funded by short-term loans of ₹ 477 billion, have been restructured and taken over by the state government over a period of two years starting 2016. Nevertheless, without sustained operational restructuring, cost reduction and cost recovery, and increasing efficiency and effectiveness of power subsidy, Rajasthan's power sector would run the risk of sliding back and the government having to bear the fiscal costs of accumulated losses of the sector.

5. Agriculture consumes more than 85% of water, 42% of electricity, and contributes about 30% of Gross State Domestic Product. Of late, cropping intensity has increased from 115% in 2005 to 140% in 2015. Surface irrigation in Rajasthan is limited, however, because the bulk of the cropped area is irrigated using groundwater, which has risen to almost 70% the total irrigated area. In fact, two-thirds of the additional area brought under irrigation was due to the expansion of groundwater irrigation, contributing to the overexploitation of groundwater in large parts of the state. Rajasthan has more than 10% of cattle population of India's cattle population and is the second largest producer of milk in the country. The continuous increase in the state's human and livestock population is adding pressure to already limited water resources. Though **Rajasthan ranks fourth in India's food and grain production, its agricultural growth has come at a high cost to the water and electricity sectors. While farmers are ostensibly the beneficiaries of subsidized electricity, the poor quality of the power supply imposes substantial economic costs on the farm-sector and has given rise to a complex political economy which perpetuates this unsustainable situation.**
6. A review of groundwater development and agricultural growth in Rajasthan shows two important and unsustainable trends. First, power supply for agriculture is heavily subsidized. Second, this incentivizes water-intensive behavior further compounded by minimum support prices that

have ultimately led to depletion of groundwater. The absence of any regulatory controls over the amount of groundwater extraction further distorts the incentives. Many sectoral policies and welfare programs do not consider adverse impacts on other sectors or ignore the opportunities for synergies between the sectors that could enhance the outcomes and positive impact on beneficiaries.

7. This Study was prepared at the request of Government of Rajasthan in conjunction with the implementation of the Rajasthan Agricultural Competitiveness Project. The Study is in five chapters. Chapter 1 lays out the objectives of the Study. Chapter 2 presents the sectoral and nexus context and an approach to review sectoral policies in a nexus framework. Chapter 3 presents alternatives for addressing the challenges posed by adverse nexus, and potential business models. Considerable experience gained through a variety of initiatives launched by Indian states (Andhra Pradesh, Gujarat, Karnataka, Punjab, Rajasthan) informed the choice of alternatives, business models and institutional models for implementation. Fortuitously, during the course of the Study, the Government of India announced a scheme (Kisan Urja Surkhasha evam Utthan Mahabhiyan- KUSUM, July 2019) to encourage the use of solar energy for improving power supply to agriculture that reinvigorated and reinforced the discussion and consultations with the stakeholders. Financial analysis of the business models is based on the financing structure and Central and State Financial Assistance offered in the KUSUM scheme. Chapter 4 examines the comparative advantages and disadvantages of three institutional models for implementation. Chapter 5 presents the Study's conclusions and recommendations.

Key Drivers of the Business Models

8. The energy-groundwater nexus has trapped farmers, power utilities, consumers, and governments in an inefficient low-level equilibrium. Any viable approach to change the status quo needs to acknowledge and work with four realities. First, farmers are reluctant to relinquish access to subsidized power, even when utilities promise supply-quality improvements. Second, political decision makers face difficulties implementing a rational

price regime for agricultural power supply because it is hugely unpopular. Third, rural prosperity is largely driven by an irrigation economy in which groundwater plays an increasingly important role through direct benefits to farmers and multiplier effects via local markets. And fourth, attempts to liberalize markets and diversify agriculture would be a slow process. However, before starting to evaluate the alternatives, it's important to ask what are the objectives sought to be achieved? This study has identified six key objectives, one or more of which drive the choice of business models. The objectives are to:

- (i) Provide reliable, affordable and adequate electricity supply for irrigation to increase agricultural production and reduce risk;
- (ii) Improve energy efficiency and conserve electricity;
- (iii) Improve water productivity and conserve water;
- (iv) Contribute to the target of doubling farmer income;
- (v) Increase use of renewable energy;
- (vi) Improve efficiency and effectiveness of the electricity subsidy to agriculture.

9. Several attempts at improving the power supply, community-based groundwater management, and encouraging farmers to shift away from water-intensive crops have had limited impact. This Study examined different business models for energy-driven interventions, including some recent pilots. Karnataka (USAID), Gujarat (Columbia Water Center), Rajasthan (Jameel Poverty Action Lab) and Punjab (World Bank) have piloted variants of direct benefit transfer of electricity (DBTE) to agriculture for the grid-connected agriculture consumers¹. Given the right incentives for saving energy (payment of ₹ 4/kWh) farmers enrolled in the pilot in Punjab have shown energy savings in the range of 10% to 30%. A major factor for energy savings has been the daytime and more reliable power supply. When implemented at scale, the power distribution companies, or DisComs cannot provide daytime electricity supply to all agricultural participants in DBTE programs. Metering, billing, collection, management of

agricultural supply and governance of feeder lines remain a challenge. But the ever-rising and recurring subsidy for agricultural power supply is an unsustainable fiscal burden.

10. Rapidly declining prices and improving solar generation have opened an enormous opportunity. Three business models of solar irrigation pumps have been attempted. The off-grid solar model is used in many states, including Rajasthan, that subsidize solar irrigation for customers who could not be given electricity supply from the grid. Off-grid solar has improved power supply reliability but it has also led to further over-extraction of groundwater because farmers have no incentive to stop pumping water. Another approach known as a sub-station level solar plant has been attempted in Maharashtra (PRAYAS) as a public-private partnership. The third model of solar power plant is a grid-connected, farmer-led system. In this approach, farmers connect their solar irrigation pumps to the grid to sell surplus electricity, gaining an additional source of income and a greater economic return on solar investments. This model has been amply demonstrated by the International Water Management Institute through a pilot project in Dhundi (Solar Power as a Remunerative Crop- SPaRC) and National Dairy Development Board's solar cooperative in Majkuva (Gujarat). This model is being scaled up by Government of Gujarat as Suryashakti Kisan Yojana (SKY). The Government of India has combined all the three solar irrigation models in a scheme called "Prime Minister Kisan Urja Suraksha evam Utthan Mahabhiyan" (KUSUM) announced in July 2019.
11. These experiences were shared with various departments of Government of Rajasthan (energy, agriculture, water, finance), power companies, field officials implementing the Rajasthan Agriculture Competitiveness Project and individual farmers. Farmers responded enthusiastically to the possibility of getting not reliable daytime electricity and an opportunity to earn income by selling to the grid excess power generated from solar irrigation. The KUSUM scheme has three components: sub-station level solar power plant (A), off-grid solar irrigation

¹. Two World Bank reports "Direct Delivery of Power Subsidy to Agriculture in India" (Chapter 4), and "Deep Wells and Common Prudence" provide a good description of these initiatives.

pumps (B) and grid-connected solar irrigation (C). Rajasthan has installed more than 40,000 off-grid solar irrigation pumps. Researchers have pointed out their adverse impact on groundwater, apart from low utilization and the high cost of irrigation from off-grid solar. This report focuses on component A and C of KUSUM scheme. The two business models, which are predominantly based on the KUSUM scheme with some additional elements proposed by this Study are described below:

- (a) Business Model-1 (BM1): Public-private-partnership (PPP) for implementing KUSUM-A based on the assumptions that electricity is sold to the DisCom at a feed-in-tariff² determined by the electricity regulator or at average power purchase cost of the DisCom. The DisCom continues to meter, bill, and collect from consumers.
- (b) Business Model 2 (BM2): “Prosumer³” farmers. Grid-connected, farmer-owned, Farmer Enterprise aggregated model for implementing KUSUM-C. Segregation of feeder lines for supply to agriculture pumps is a pre-requisite for this model. What is proposed in this Study is essentially an enhanced KUSUM-C scheme based on the following key assumptions:
 - (i) farmers install solar panels and the irrigation pump on their own land;
 - (ii) farmers are offered a capital cost buy-down of solar capacity in kWp 1.5 the size of their connected load in Horse Power up to a maximum of 15kWp;
 - (iii) DisCom (or renewable energy buyer) buys surplus power at average power purchase cost;
 - (iv) to be eligible, at least 70% of farmers (or connected load) are required to form a solar cooperative or a farmer producer company (collectively called a farmer enterprise);
 - (v) A power purchase agreement is signed between the DisCom and the farmer enterprise. Net

meters are installed on farm solar irrigation pumps and at the sub-station. Point-of-sale and point-of-delivery are the 11kV side of the sub-station; and

- (vi) feeder maintenance from outside the boundary of the sub-station is managed by the farmer enterprise.

Financial Viability of the Business Models

12. Four feeder lines — Nandswaipura and Ganaheda in Pisangan block of Ajmer (AVVNL), and Laxmipura and Dobadi in Sangod block of Kota (JVVNL) — were selected for deeper analysis taking into account landholding, groundwater depth, crops grown, yields, connected load, and energy consumption. Financial analysis is presented from the perspective of three key stakeholders — farmers, DisComs, and the state government. Because of additional capacity of solar panels, farmers would earn income from sale of surplus power. DisComs would benefit from the lower cost of decentralized, distributed solar generation and a reduction in losses. The Government would gain greater control over fiscal spending by replacing a recurring subsidy to a farmer with a one-time capital subsidy. This Study also recommends an innovative drought premium on power purchases during dry periods as a scarcity premium for water and electricity.

Business Model-1 (KUSUM-A) is good for augmenting power supply but may result in over-extraction of groundwater.

13. The Rajasthan Electricity Regulatory Commission issued a draft order on September 6, 2019 for public consultation on a proposed tariff for KUSUM-A and KUSUM-C. Assuming the tariff of ₹ 3.14/kWh proposed for KUSUM-A, solarizing the entire feeder of Laxmipura through a private developer at 1.5 times the current connected load of agriculture consumers, the internal rate of return of the developer does not seem very

². Feed-in-tariff: Rate paid to the renewable energy producer for all the electricity generation they can supply to the grid anytime of the day

³. Prosumer: Producers who, instead of buying from the market, produce a product for their own consumption and sell the balance for trade. (This is an abbreviation of “producer+consumer” and was coined by Alvin Tofler in his book “Future Shock”). We are using it in the case of grid-connected solar because farmers have always been consumers of electricity from grid would become producers for own consumption and for selling to the grid.

attractive. At a capital cost of ₹ 34,300 per kWp — financed through 30% equity and 70% debt of a seven-year tenor at 10% per annum accelerated depreciation and degradation of solar panels at 0.8% per year — the internal rate of return at the proposed tariff is calculated at 8%. Average debt service coverage ratio is 0.57. This is not an attractive investment, unless the tenor of debt is increased, and the cost of debt reduced.

14. If rapid augmentation of generation capacity, or providing daytime supply is the primary objective, then KUSUM-A would be an appropriate choice. However, one of the major pitfalls of KUSUM-A scheme (Business Model-1) may be an increase in energy consumption, and potentially of groundwater extraction, by the farmers because of daytime, reliable, continuous supply of electricity. In due course it may be difficult to ignore demand of the farmers for longer hours of daytime electricity supply from a locally situated power plant, built possibly with participation of farmers. With DisCom as the supplier, the farmer would have no, or very little, incentive to save electricity and groundwater and would be agnostic to the source of power.

Business Model-2 (enhanced KUSUM-C) has the potential to achieve the trifecta of energy efficiency, water conservation, and doubling farmer income.

15. Financial performance metrics across all four feeder lines selected in the study look attractive for different stakeholders i.e. farmers, state government, the DisComs, and the lenders. For three feeders (Dobadi, Laxmipura, and Nandswaipura), the internal rate of return for farmers equity is more than 18%, return on state government subsidy is in the range of 23% to 30%, debt coverage ratio is in excess of 1.4. Cash income for the farmers is estimated to be in the range of ₹ 13,300 to ₹ 19,500 during the debt repayment period of seven years and thereafter in the range of ₹ 45,000 to ₹ 57,000 per year. A DisCom's annual income is estimated in the range of ₹ 29,700 to

₹ 56,000 per farmer per year. The state government can save in the range of ₹ 34,600 to ₹ 56,500 per farmer per year. Though lower than in other feeders, even the outlier Ganaheda could provide an internal rate of return of 16% to the farmers, a reasonable debt service coverage of 1.06 to 1.15 and return on government subsidy of 43%.

16. Replacement of grid-supply by self-generated solar electricity would result in substitution of recurring subsidy from the state government by a one-time capital subsidy. The return on a subsidy of more than 30% means the state government could recover the capital subsidy in less than four years. For the two DisComs in Jaipur and Ajmer, a one-time capital subsidy of ₹ 10,700 crore can fully replace a recurring annual subsidy of ₹ 6,200 crore which would otherwise continue ad-infinitum. Under a business-as-usual situation, the government would pay a recurring subsidy of ₹ 31,376 Cr over a period of five years while with solarization over a period of five years when it will continue to pay recurring subsidy for non-solarized customers, it would pay only ₹ 23,477 Cr. Thus, even during the transition period, before the entire agriculture load is solarized, the government would save a whopping ₹ 10,000 cr. If we take 25 years as the economically useful life of a solar panel, a capital subsidy of ₹ 10,700 crore would yield a saving of ₹ 150,000 crore over a period of 25 years. Government could not make a better investment in infrastructure and rural livelihood.

17. Given the right incentives, it is possible to improve efficiency of use of electricity and groundwater. A recent pilot implemented by Punjab since June 2018 which pays an incentive of ₹ 4/kWh to farmers for saving electricity has demonstrated energy savings of about 30% and water savings of 20-30%. In a few demo farms adoption of new irrigation and agriculture practices have shown even higher savings. Though it is a small sample, it shows the potential behavioral response of farmers to right incentives.⁴

⁴. A study (Kumar, Scott, Singh, International Journal of Water Resources Development January 2013) demonstrated that price of energy led to better water-use efficiency and water productivity. The study built a proxy energy pricing through comparing 600 farmers under 10 categories of water users (flat tariff, owners of diesel pumps, buyers of water from both, in eastern UP and South Bihar and metered farm connections in Gujarat). The study found that in terms of efficiency of water use: water buyers are more efficient than water sellers, diesel water pump users are more efficient than electric pump owners, and that metered electricity connection owners are more efficient than flat-tariff consumers.

18. Key reasons for the attractiveness of Business Model-2 are: (a) the difference in the current average cost of supply (₹ 6.97/kWh) and the cost of decentralized solar generation (₹ 3.69/kWh), (b) substitution of recurring government subsidy with a one-time capital subsidy with a payback period of less than four years, (c) sale of surplus generation by the farmer at an attractive feed-in-tariff at 11kV level and reduction in network losses, (d) Central Financial Assistance of 30% of capital cost, and (e) potential efficiency improvement in water consumption by agriculture due to financial incentive of sale of electricity. The financial benefit to the farmer would look even more attractive if the value of free self-consumption was added.

Sensitivity analysis shows the Business Models are quite robust under different assumptions.

19. Sensitivity analysis was carried out for the base case of Laxmipura feeder on three parameters: (i) Impact of size of Solar Photovoltaic (SPV) on income of farmer, profit to DisCom, and recurring subsidy saving of the State Government (ii) Impact of self-consumption of generated electricity on farmer's income, (iii) Impact of participation rate of farmers on profit of DisCom, and (iv) Impact of feed-in tariff on the income of the farmer and the DisCom. The outcome of these analyses presented in Figures 3.2 to 3.4, and Table 3. 6 of the report is summarized below:

- (i) *Higher the SPV Size, higher the income of the farmer and the DisCom:* Farmer's annual income of ₹ 15,384 during the loan repayment period would increase, after the loan is paid off, to ₹ 50,629 which is nearly double the current farm income (₹ 54,000). ***The government can achieve its objective of doubling farm income by implementing Business Model-2, and simultaneously increase profitability of the DisCom.***
- (ii) *Lower the self-consumption of generated electricity, higher the income of the farmer.* At 70% of current consumption, the farmer gets a cash income of ₹ 15,384 (base case). With adoption of water savings techniques such as laser levelling, optimizing irrigation, and micro-irrigation, it is possible to go down to 50% of current electricity consumption. ***Solarization would***

likely encourage more efficient use of electricity and, by proxy, of water.

(iii) *Higher participation of farmers in the scheme is highly profitable for the DisCom.* The DisCom's annual profit from Laxmipura could go up from ₹ 32 lakh at 50% participation rate to ₹ 58 lakh at 100% participation. To evacuate power from participating farmers, the DisCom has to keep the feeder charged ("ON") during daylight hours. This could potentially lead to a free-loader problem and higher consumption by the non-participating farmers. It is therefore, in the interest of the DisCom to encourage as high a participation rate as possible. ***A "prosumer" agriculture sector, instead of being a subsidy burden on the sector and the state, can become a source of profit for the power sector.***

(iv) *Changes in the feed-in tariff has a higher than proportional impact on farmer's income and debt service during the loan repayment.* Farmer income during loan repayment period, and the debt service is highly sensitive to feed-in tariff. For a 6.8% decrease (from ₹ 3.69 to ₹ 3.44) farmer's income drops by 25.6% and the debt service coverage ratio drops by 7%. In comparison the income of the DisCom varies negatively but almost proportionately with the changes in the feed-in tariff

Drought Premium and Maintaining the Dignity of the Farmer During Natural Hazard

20. Payment of a drought premium (say ₹ 1/kWh) by the State Government, coupled with an increase in the sale of surplus power due to reduced consumption for agriculture, can add significant income (estimated ₹ 30,000 in Laxmipura) to the farmer during a period of distress. The farmer would earn from regular sale of power, drought premium on the baseline quantity of sale, and from higher quantity of sale of electricity due to reduced consumption for irrigation. This is not a charity but a payment for electricity purchased from the farmer. **Thus, a "natural hazard" need not become an "unnatural disaster" for the farmer.** In summary, the "Drought Premium" is:

- (a) a scarcity premium on water;
- (b) a scarcity premium on electricity since

- hydropower generation goes down during drought years;
- (c) an instrument of delivery of drought relief quickly and directly to the affected farmers;
 - (d) not a charity but a payment for goods sold by a farmer; and
 - (e) a measure of impact of drought, and choices made by a farmer, captured by the quantity of surplus electricity sold by the farmer.

Sell Electricity or Sell Water: What would the farmer choose?

21. The farmer has the option of using the self-generated power for using in her own agriculture activity, or sell water to the neighboring farms, or sell electricity. Feed-in-tariff and the value of water in agriculture, or more precisely the crops grown, would influence farmers' choices between selling electricity or selling water to her neighbors. The State Government and the regulatory commission should consider the following pricing approaches and choose what best meets the public policy objectives:

- (i) Cost of generation. Recovering cost of capital and cost of operation and maintenance is a minimum necessity to attract investment. Assuming 20% as a reasonable return on equity for the farmer, and a seven-year 10% loan for the 30% debt-financing, it is estimated at ₹ 3.7/kWh.
- (ii) The average power purchase cost is a reasonable reference price for the decentralized distributed generation. Depending on the proportion of surplus power that can be consumed at the load center, a DisCom saves a significant amount of network losses, which is an effective discount on the average power purchase cost.
- (iii) The average cost of supply is the highest at the far end of the extended low voltage rural network. By shifting the farm consumption to self-generation and serving other customers from the power purchased at the load center, a DisCom is effectively reducing the average cost of supply for each kWh of consumption met through grid-connected solar generation.

However, a price equal to the average cost of supply would be the upper bound that can be paid, which would mean no savings for the government.

(iv) The opportunity cost or the value of water for agriculture. A farmer potentially has three options: using self-generated power on the farm, selling irrigation water to neighboring farms, or selling surplus electricity to the grid. It is important to assess the likely impact on farmers' behavior towards groundwater extraction and find the price-point of power that would shift the trade-off in favor of selling electricity. Annex C of the report "Value of Water in Agriculture" provides a methodology for evaluating the trade-off.

- 22. The value of water (per kWh) differs significantly by crop. For example, with barley the economics of selling water is favorable but the difference between proceeds realized from sale of water and value realized from sale of power is not very large. In the case of wheat and groundnut crops, the differences are relatively more prominent. Given the significant risks involved in realizing on-time the sale proceeds of water from the buyer, who is usually a marginal or a small farmer, the farmer may opt to sell electricity to the grid and get assured timely payment rather than waiting to get money from the water buyer. The only crop where the value realized from sale of water is higher than the value of energy is groundnut. However, groundnut is not cultivated on a very large scale in the study area. Even if farmers extract groundwater to sell, it will be a small quantity.
- 23. Access to solar power at the currently prevailing prices and costs is unlikely to result in significantly increased sales of water and adversely impact groundwater extraction. Nevertheless, it is difficult to predict behavioral response of farmers to the dynamic interplay of hydrogeology; value of water in agriculture; production, market and price volatility risks of agriculture; and financial incentive of feed-in-tariff. Implementing a few pilots in different agro-climatic-groundwater zones would help in developing a better understanding of this interplay and recalibrate the program of solarization of irrigation at scale.

Incentives matter, but right institutional arrangements can make it better

24. Three implementation models for A and C components of KUSUM scheme were evaluated: (i) Public-Private Partnership (for KUSUM-A) and (ii) Individual Farmer, (iii) Farmer Enterprise Aggregator for KUSUM-C. Each of these is briefly described below:

- (i) Public-Private Partnership model is useful for a sub-station level solar power plant (KUSUM-A). the private sector can be invited by the DisCom through competitive bidding to install solar power plant of a capacity higher than the current connected load of the feeder. Entire generation would be sold to the DisCom or a renewable energy buyer. Farmers would be provided daytime supply and would continue to be the customers of the DisCom who will meter, bill, and collect from the farmers. To improve efficiency in consumption of electricity and water by agriculture, the government may include a DBTE scheme for the farmers by allocating a seasonally-adjusted fixed amount of electricity to each agriculture customer and provide them incentive for consumption below the allocation.
- (ii) Individual Farmer would be responsible for purchase, installation, operation and maintenance and financing of the solar system. Point of Sale (POS) and Point of Delivery (POD) are the farm gate but a portion of feeder losses, say 6% are borne by the farmer. DisCom would be obligated to keep the feeder “ON” during the daylight hours and based on net-meter pay the farmer directly into her bank account.
- (iii) Farmer Enterprise Aggregator (Farmer Producer Company/Cooperative) would be formed for each feeder with at least 70%

of the farmers (or the load) participating as members. Farmers would purchase, install, operate and maintain, and finance the solar systems installed on their farms. They would also share the costs of maintenance of common grid infrastructure up to the delivery meter of the feeder. Farms and the feeder would be net-metered, the difference between the two and the normative technical losses on the feeder is considered as consumption by the non-participating farmers who continue to be the customers of the DisCom. Farmer Enterprise (FE) would be responsible for aggregation of energy from the participating farmers and sign a power purchase agreement with the DisCom. Point of Sale and Point of Delivery would be the net-meter on 11 kV side of the substation. FE would also be responsible for maintenance of the feeder, and internal energy accounting of FE members. Private sector, retained by the government through competitive bidding process, can play a very important role in mobilizing farmers, creation of FE, facilitating borrowings from the banks, supply and installation of SIP systems⁵.

Pros and Cons of the three institutional models

25. If the scheme is offered on an individual farmer basis it could be deployed rapidly. Owning the assets and installing it on their own farms would create a strong incentive for them to maintain and protect the system. However, the farmers would have no incentive to maintain the shared feeder infrastructure. Low participation rate would make it technically and financially very costly for a DisCom to keep the feeder charged during the daytime and control the free-rider problem. Transaction cost of signing and sustaining a very large number of Power Purchase Agreements (PPA) would become prohibitive for a DisCom. Though participating farmers would have strong incentive to save electricity and water, it would

⁵. Farmer Enterprise (FE) can approach NABARD-created Small Farmers Agribusiness Consortium (SFAC) which operates a Credit Guarantee scheme to mitigate risk of financial institutions to lend to FEs and offers a matching equity grant of upto ₹ 10 lakh to capitalize an FE. NABARD-operated “Producers Organization Development Fund” can also finance share capital of members on a matching (1:1) basis up to a maximum of ₹ 25,000 per member of FE. This could enable farmers to put in equity of only 5% and obtain concessional financing for the remaining 5%. Annex F provides a comparative overview of the FPC and Cooperative. A practical option would be to create and register an FPO which is much quicker to create and easier to operationalize, and convert it into an FPC at a later stage

create perverse incentive for the non-participating farmers due to availability of daytime good quality electricity supply.

26. An FE would find it easier to operate and maintain and provide security for the shared infrastructure. Peer pressure on non-participating farmers against malfeasance would be high since any pilferage of electricity would be from their neighbors and not from the DisCom or the government. Since the PPA would be signed between a farmer enterprise and a DisCom, there would be fewer PPAs, and transaction costs would go down. With high participation rate, deployment of the scheme and implementation would be faster and because of the economies of scale the vendors would likely offer better prices for the supply and annual maintenance of the system. Insurance against theft of equipment could be cheaper due to broad-based ownership among the whole feeder community. **A major advantage of an Farmer Producer Company (FPC) model is that those farmers in the vicinity of the feeder who have been waiting in the queue for a long time to obtain electricity connection can be allowed to join the farmer enterprise.** Generally, these are small and marginal farmers who can benefit not only from assured electricity supply for irrigation but also earn an additional income. The flip side of this model is the intense effort needed to mobilize and organize farmers into a farmer enterprise, creating satisfactory standard operating procedures and rules of governance to avoid pitfalls of elite capture. However, a well-organized farmer enterprise is the most sustainable institutional model for solarization of agriculture feeders.
27. A private-public partnership model can be readily deployed at scale and obtain competitive rates for solar installation. The installations are likely to achieve high technical standards in equipment and maintenance. Availability of land and budget for state government subsidy for the recurring viability gap can be constraining factors. However, it does not create any additional income for farmers nor does it create any incentive for them to use electricity efficiently and conserve water. On the contrary, it may lead to further exploitation of groundwater resources and expansion of crop area creating additional pressure on water resources. Increase in malfeasance and challenges

of political economy of farm power supply are the most likely outcomes.

Any idea is only as good as its execution: Implementation arrangements

28. The state government and the DisCom are the two key players in rapid deployment of this scheme at scale. No less critical is the role of the producer organization promotion institutions that can be organizations like National Dairy Development Board which have enormous experience and expertise in creation of farmer organizations, civil society operating in rural areas, existing farmers cooperatives and other organizations, and private sector suppliers of solar systems. Role and responsibilities of each of these organizations is described below.
- (i) State government. For rapid scale up, a separate, fully funded and fully empowered “Mission” staffed by an inter-disciplinary team and led by a dynamic Mission Director should be created. Allocated state subsidy for the annual target should be placed in a separate budget head. The team should have experts with skills in solar energy, agriculture, electrical engineering, banking and credit appraisal, management of cooperatives and rural organizations, communication and farmer engagement, legal and commercial matters. Implementation could be rolled out in a few districts every year. Educated youth could be engaged as “Kisan Mitras” and placed in each block headquarters of the target districts to create awareness, provide accurate information, mobilize farmers and opinion leaders, and coordinate with the government agencies. It goes without saying that none of this would happen at the scale and speed at which it needs to happen without a strong political commitment to overcome the institutional constraints and to support the market transformation.
- (ii) DisCom. Its role of segregating the agriculture feeder, signing a PPA with the farmer enterprise, keeping the feeder charged during daylight hours, and maintaining or coordinating with the farmer enterprise to maintain the feeder to ensure surplus power can be evacuated,

are important pre-requisites for the proposed scheme to succeed and DisCom to earn an income. To mitigate payment risk of its power purchase, the DisCom should offer an appropriate risk mitigation instrument such as revolving letter of credit or an escrow account.

(iii) Producer organization promotion institution.

The primary responsibility of promotion institutions⁶ is to see that the farmer enterprise reaches a sustainable level of business and has the technical and managerial capability to run the business successfully when the promotion institution withdraws its support. The broad responsibilities of a promotion institution are: (a) mobilization of farmers and registration/incorporation of farmer enterprise, (b) business planning, (c) resource mobilization, (d) development of management systems and procedures, (e) training of farmer enterprise management, (f) business operations, (g) organizing compliance support for accounts and audit and finally prepare for its own exit and hand-over to the farmer enterprise management. POPI would need to be compensated by the government.

(iv) Farmer Enterprise/Farmer Producer Company. Led by a strong Board of Directors, the FE/FPC will ultimately be the “point of the spear” in the successful implementation of this scheme.

Holding all entities accountable for their contractual obligations: Commercial arrangements

29. Clearly formulated and enforceable commercial arrangements are necessary for a commercially viable, financeable, and sustainable business model. Several states have already procured MW scale solar electricity generation and implemented off-grid solar irrigation. Therefore, this report focuses on commercial arrangements needed for farmer enterprises. The state government would be well advised to develop standardized legal and commercial documents that would not only bring certainty of regulatory and commercial framework to the lenders and investors but also make the

process more efficient and less costly. These are briefly described below:

(i) Power purchase agreement would define some key elements of the sale of power by farmer enterprises: the point of sale, point of delivery, price, projected monthly generation and estimated sale, minimum volume of electricity sale, net metering, meter reading and billing schedule and protocol, determination of liability for interruption in evacuation due to feeder not being on or faults on the feeder, recording of consumption by non-participants if any, responsibility for billing and collection from non-participants, liability in case of faults at the sub-station, technical quality parameters (voltage, frequency) of electricity delivered, payment arrangements, and cost of payment delays. If the feeder infrastructure is to be maintained by the farmer enterprise, the boundary between the DisCom and farmer enterprise, and standards and protocols for maintenance may be included in the PPA.

(ii) Farmer Entity. Through implementation of Rajasthan Agriculture Competitiveness Project (RACP), the state has created the required institutional capacity to register and operate FEs and has basic legal documents such as memorandum of association and articles of association. These documents and learning can be easily adapted to create solar farmer enterprises. However, it would be important to prepare standard operating procedures of these farmer enterprises since the product, production and aggregation process, market and delivery process, and commercial arrangements for solar electricity are quite different from other agricultural produce. A standard operating procedure of farmer enterprises would inter-alia include: metering and meter reading of net meters of participating farmers, accounting of losses between the net meter at the point of sale and net meters of member farmers, rules regarding allocation of losses and operation and maintenance costs among members,

⁶. “Farmers Producer Organizations” NABARD 2015. https://www.nafpo.in/wp-content/uploads/2019/05/Nabard_FARMER-PRODUCER-ORGANISATIONS.pdf Downloaded on 3rd September 2019.

submission of invoices for power sale, and operation of the farmer enterprise bank account.

- (iii) Procurement, installation, and maintenance of solar irrigation systems. Wind conditions, incidence of flooding, soil conditions would influence the design, choice and strength of materials to be used for frames. Latitude of the location would inform the orientation and the benefit of fixed versus adjustable panels. Based on the climatic conditions and geography of the area, the government should prepare technical standards for the solar panels and installation. Farmer enterprises can aggregate demand for installation at the feeder and the government can aggregate the demand by district or a larger area for competitive bidding for supply, installation and annual maintenance and create a list of accredited vendors. The buyers would be individual farmers, but they can collectively select one of the accredited vendors to benefit from economies of scale.
- (iv) Feeder Maintenance Contract. Uninterrupted evacuation of power is critical for financial viability of the Business Model 2, The report recommends transferring the feeder and its maintenance to the farmer enterprise. A standard maintenance contract and qualifications of the maintenance contractor should be agreed to between farmer enterprise and the DisCom and enshrined either in the PPA or preferably a separate agreement.
- (v) Banking Agreements. A banking arrangement for flow of funds between the DisCom, FE, and the participating farmers would need to be put in place. FE would issue instructions to the bank to first distribute the payment received from the DisCom to the member farmers and the remaining amount left in the FEs account for operation and maintenance of the FE and the feeder.

Catalyzing Solar Energy Market.

- 30. Weak financial situation of DisComs, and stranded generation capacity in many states, including Rajasthan, may become a short-term constraint on

the ability of the DisComs to buy large quantities of surplus energy from solarization of agriculture feeders. Payment risk of DisComs may also affect the volume of commercial financing that can be raised for this scheme. To catalyze the market, Government of India could help kick-start the implementation in a few states by encouraging NTPC Vidyut Vyapar Nigam Ltd (NVTNL) to buy power from Farmer Enterprises. NVTNL has a mandate to buy solar bundled power. The transaction could be structured as power sale agreement between FE and NVTNL with back-to-back sale agreement between NVTNL and NTPC. Lenders may require a sale agreement for at least the duration of their loan. NVTNL can also provide credit enhancement to a PPA between a DisCom and a farmer enterprise by buying the PPA for the medium-term after which the PPA reverts to DisCom or other market players. In turn, NTPC could set it off against the central share of the state in NTPC generation. Once the market is primed, other aggregators trading in renewable energy and local large customers could emerge.

Job creation potential

- 31. In non-utility scale solar installations, about 65% of jobs are in installation and project development and less than 15% in manufacturing. Solar irrigation installation would generate jobs through the entire deployment cycle- business development, design and preconstruction, construction and commissioning, operation and maintenance. Based on a 2017 report, "Greening India's Workforce," (NRDC, CEEW, Skills for Green Jobs) it would be reasonable to assume a job-creation coefficient of 20 job-years per MW of solar irrigation pumps. This can translate into more than 275,000 job-years for converting about 14,000 MW of agriculture load of Rajasthan.

Next Steps: Learning-by-doing pilots to quickly recalibrate and scale up

- 32. There is very little experience of implementation of Business Model-2 (KUSUM-C) in any state. Because of practical difficulties, Gujarat has also moderated its targets under SKY scheme. As mentioned in Section 3.7 (Pricing of Power), it is difficult to the predict behavioral response of farmers to the dynamic interplay of hydrology;

value of water in agriculture; production, market and price volatility risk of agriculture; and capacity of the DisComs and the government to handle large scale retail transactions with farmers. Even the market players would face a steep learning curve. Therefore, this Study recommends implementing a few learning-by-doing pilots in different agro-climatic zones of Rajasthan and calibrate the design and implementation process of the scheme for replication and scaling up. A monitoring and evaluation system should be set up to closely monitor and evaluate the impact of the learning-by-doing pilots for implementation to access the pattern of electricity use, cropping pattern and cropping intensity, level of input use, employment of labor, farmer incomes, adequacy of institutional arrangements and their performance, and most importantly on the pattern of groundwater extraction and its use.

Conclusions

*Through grid-connected solar irrigation, Rajasthan can achieve the **triple objective of saving water, doubling the farmer income, and making the power sector financially viable, simultaneously and urgently.***

- Rajasthan has done some impressive work to increase water security of the state which is one of the most water-stressed states in India. However, depleting groundwater continues to push the water-energy-agriculture nexus into a downward spiral.
- Unless, demand-side measures and incentives to improve water productivity and conservation are put in place supply-side augmentation would remain inadequate.
- In the absence of major transformational disruptions in agriculture sector, electricity sector remains the most effective intervention to shift Rajasthan to a virtuous W-E-A nexus. Price increase for power supply to agriculture to moderate the demand for electricity, and consequently groundwater, is a non-starter in the current political economy, low rural incomes, and critical dependence of agriculture economy on water and electricity.
- The current policy of free/concessional power supply to agriculture is fiscally and environmentally unsustainable. However, falling prices of solar panels, and some successful experiences of grid-

connected solar energy, have opened-up huge opportunities for addressing the challenge of fiscal impact, unsustainable consumption of energy and water in agriculture, and agro-dependence of rural household income.

- Business Model 2 can add climate-resilient, acyclical, non-farm income to rural livelihood. In addition, it can help create local jobs through the supply chain of solar irrigation pumps.
- Economic analysis shows that a reasonable feed-in-tariff would influence farmers' decision in favor of selling electricity as against groundwater extraction. However, farmers' behavioral response to financial incentives for shifting to grid-connected solar irrigation is very difficult to predict due to complex and dynamic interaction between feed-in-tariff, value of water in agriculture, hydro-geology of the area, and seasonal and locally limited water market.
- Two major constraints in speed, scale, and sustainability in implementing KUSUM-C would be: (a) the inability of the State Government to finance the capital subsidy of 30% in the present context of limited headroom under FRBM Act, and (b) Government of India's requirement of sourcing solar panels and the other equipment from indigenous suppliers.

However, the potential of KUSUM-C scheme can be unlocked only through solarizing the feeders, mitigating the payment risk of the DisCom as buyers of surplus solar energy, and creating Farmer Enterprises as aggregators of power and for self-governance of the feeders.

Recommendations

It is important, in fact critical, to adopt a nexus approach to resolve conflicts and take advantage of synergies in cross-sectoral impacts of policies in energy, water, and agriculture sectors. Because of the complex political economy of agriculture, fiscal impacts of adverse nexus can be significant. Rajasthan, and many other states, have a huge opportunity to turn around the adverse nexus into a virtuous nexus.

- **Evaluate the multiple objectives** of saving water, doubling farmer income, and fiscal sustainability of energy sector **to decide the Business Model** and instruments of delivering subsidy and power supply to agriculture.

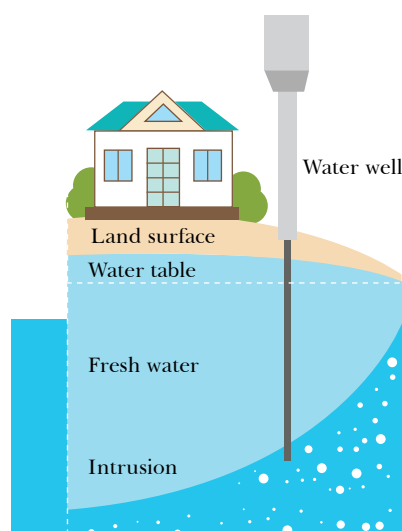
- **Expand the scope of KUSUM-C** (Business Model 2) to include farmers waiting for agriculture power connection if they are in the proximity (say one kilometer on either side of the electricity feeder) as eligible for grid-connected solar.
- **Choose an appropriate institutional model for implementation** that creates incentive for the farmers to use energy and water efficiently, strengthens the participation of farmers in management and operation of solar infrastructure, and creates an accountable feeder governance arrangement to ensure the scheme remains pro-poor and does not end up in elite capture. Farmer Entity as an implementing entity can have far reaching impacts on sustainability of benefits of grid-connected solar. Private sector should be involved to mobilize farmers to adopt grid-connected solar.
- **Explore Innovative financing mechanisms for funding state government's contribution** of 30%, through Deferred Subsidy Incentive (DESI) and blended finance to leverage limited budgetary resources of the state and rapidly scale up the investment.
- **Drought Premium** should be an integral part of the scheme to send strong signals on scarcity premium on water and deliver drought relief quickly and directly into the account of the farmers.
- **To catalyze the market, the capacity and resources of NVVNL** should be used by the Government of India. It would also help to mitigate the payment risk of DisComs in the short-term. State Government and the State Electricity Regulatory Commission should revisit the policy of transmission charges for purchase of surplus solar energy by renewable buyers other than DisComs to kick-start the market.
- **The requirement of indigenous component of solar panels and the balance of systems** should be reviewed by the Government of India to keep the capital cost low and enhance supply of solar systems for rapid scale up.
- **Launch a few learning-by-doing pilots** to demonstrate proof-of-concept and to better understand complex and dynamic interaction between feed-in-tariff, value of water in agriculture, and crop choices.



CHAPTER ONE

OBJECTIVES OF THE STUDY

The key objective of this Study is to explore practical, politically feasible, scalable and sustainable approaches to address the challenge of the perverse water-energy-agriculture nexus in Rajasthan.



Rajasthan's per capita availability of water is expected to fall under 450 cubic meters by 2050 – below the internationally accepted threshold of water security.

1. Rajasthan has limited surface water resources and its economy is highly dependent on groundwater. Agriculture consumes 86% of available water resources, 11% is consumed for services including drinking water, and 3% is utilized by the industry. The average per capita water availability is expected to drop below 450 cubic meters by 2050, which is below the international minimum of 500 cubic meters that defines absolute water scarcity (World Bank, 2017).
2. Rajasthan ranks fourth in India in food and grain production as well as its contribution to national agriculture. However, agricultural growth in Rajasthan has come at a high cost to the water and electricity sectors. While the farmers are ostensibly the beneficiaries of subsidized electricity, they suffer poor quality of power supply which imposes substantial economic costs on the farm-sector and has given rise to a complex political economy which perpetuates this unsustainable situation. The State Government is keen to address the challenge of groundwater and deterioration of its quantity and quality, stagnating agricultural productivity and declining farm income, and growing fiscal costs of power subsidies.
3. The development objective of the analytical work presented in this Study is to design an alternative and more efficient model of subsidy delivery to farmers in Rajasthan. The Study team consulted the farmers and other stakeholders⁷. Consultations with the farmers were carried out in two groundwater-stressed blocks Pisangan and Sangod in Ajmer and Kota districts, respectively.

⁷ This included several government departments such as Departments of Agriculture, Water, PHED/Groundwater, Energy and the Discoms such as JVVNL, AVNNL amongst others.

4. The analytical work underpinning this report has linkages to several sectors and was carried out in coordination with three World Bank-assisted projects: Rajasthan Agriculture Competitiveness Program (RACP), Rajasthan Programmatic Electricity Distribution Reform Development Policy Loan (DPL), and National Groundwater Management Improvement Project (Atal Bhujal Yojana)⁸. Lessons drawn from a small pilot of Direct Benefit Transfer for Electricity (DBTE)⁹ to agriculture being implemented by Jameel Poverty Action Lab (JPAL-South Asia) also informed the Study.
5. This Study is expected to be relevant not only to Rajasthan but also several other States in India. Many of the other South Asian countries are confronting similar challenges of groundwater management and use. This Study would, therefore, have much broader relevance in identifying measures that could be replicated with necessary modifications across the region. The Study has four interrelated activities aimed at devising effective groundwater management strategies:
 - a) Review of water, energy and agriculture sector policies, schemes and associated subsidies. The review identifies key areas of convergence and conflicts between sectoral policies to discover opportunities for tapping into synergies for a virtuous nexus.
 - b) Engage with the Government of Rajasthan's departments of energy, groundwater and agriculture, programs, projects and schemes in these sectors for planning and detailed design of subsidy delivery mechanisms in the State. The study is built on the detailed Cluster Agricultural Competitiveness Plans (CACPs) prepared under the World Bank-assisted Rajasthan Agricultural Competitiveness Program (RACP), ESMAP-funded "Direct Delivery of Power Subsidy to Agriculture in India" (2015), and lessons learnt from the State projects e.g., off-grid solar irrigation pump promotion scheme, Rajasthan Programmatic Development Policy Loan, and an upcoming project Atal Bhujal Yojana.
 - c) Propose options of subsidy delivery. The subsidy delivery models were consulted upon with the



⁸. The program already approved by the World Bank Board of Directors is awaiting the approval of Govt of India.

⁹. Instead of providing subsidy through concessional tariff, subsidy is paid directly to the farmers who pay for their consumption at regular tariff and retain the savings. However, there are variants of this approach as in Punjab which provides free power to agriculture and pays an incentive for saving electricity against a fixed allocation.

farmers and other stakeholders in selected clusters. The preliminary design options considered the current public policy choices of the State Government on concessional electricity tariff for agriculture. Government of Rajasthan's DBTE pilot on a few feeders started in 2017 which comprised of normative allocation of electricity instead of 'duration restricted' power supply, and monetization of energy savings from normative allocation to create incentives for the farmers to save both energy and groundwater, was reviewed¹⁰. The Study reviewed the experience of solar irrigation pilots of International Water Management Institute (IWMI) at Dhundi (Gujarat)^{11, 12}. The team conducted baseline survey to engage with farmers, communities and state level stakeholders to understand the intricacies of the nexus approach. Two groundwater-stressed blocks identified in RACP were selected for analysis and consultations. The focus of this component was to engage the farmers and other stakeholders in a meaningful consultation and participation to review and adapt the subsidy delivery model to the local context and, design "business models" that could be piloted

by the state for field-testing the concept before launching it at scale.

- d) Dissemination workshops. The Study conducted consultations and workshops to construct and disseminate findings/experience at different stages of the developments of the business model and obtain feedback to strengthen its design. This helped involve local stakeholders such as feeder level communities and local level institutions including Gram Panchayats. A couple of workshops were organized in coordination with the support of groundwater, energy, and agriculture departments of government of Rajasthan and the World Bank.
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¹⁰. "Direct Benefit Transfer for Electricity. A Practical Guide to the Design and Implementation of More Efficient Electricity Subsidies, July 2018, Ryan and Sudarshan.

¹¹. <https://www.epw.in/author/tushaar-shah>

¹². Solar Power as Remunerative Crop, IWMI-TATA Water Policy Program. http://www.iwmi.cgiar.org/iwmi-tata/PDFs/iwmi-tata_water_policy_research_highlight-issue_10_2016.pdf, Tushar, S, Neha, D, Shilp, V, Rahul R., 2016



CHAPTER TWO

WATER, ENERGY AND AGRICULTURE SECTOR INTERACTION

Case for ‘Nexus Approach’ to Public Policy in Rajasthan

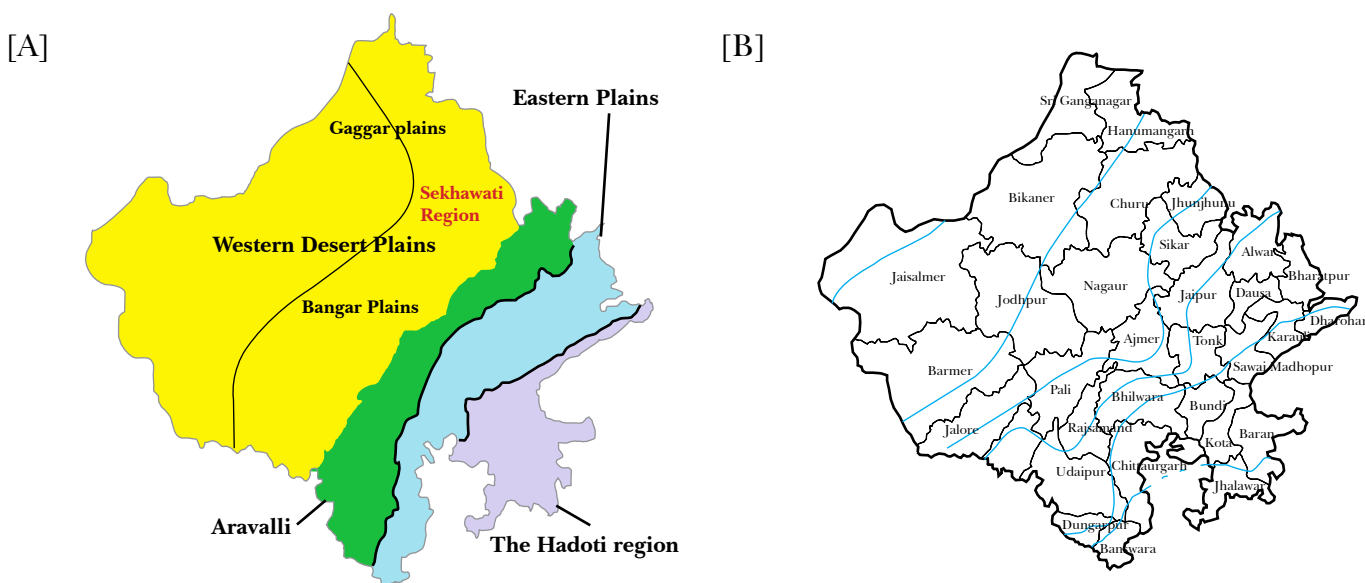
2.1 CONTEXT

1. Rajasthan is one of the most water-stressed states in India and faces acute water scarcity. The state is divided into four broad geographic regions: Western Desert Plains; Aravalli Range and Hilly Region; Eastern Plains; and South-eastern Hadoti Plateau (Figure 1 [A]). Rajasthan has only 1.2 and 1.7% of the country’s surface and groundwater

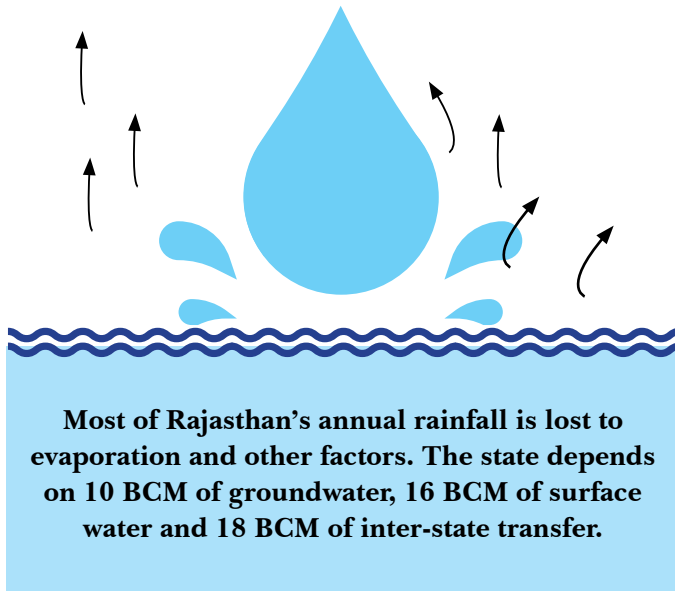
resources to meet the needs of 5.5% of the country’s population and 18.7% of livestock. Rainfall is highly erratic and unevenly distributed temporally and spatially; it ranges from 150 mm/year in the western desert to 900 mm/year in the eastern plains (Figure 1 [B]).

2. Overall, with a mean annual rainfall of 575 mm/year and a geographical area of 34.3 million

FIGURE - 1: [A] PHYSICAL DIVISIONS; AND [B] MEAN ANNUAL RAINFALL IN RAJASTHAN

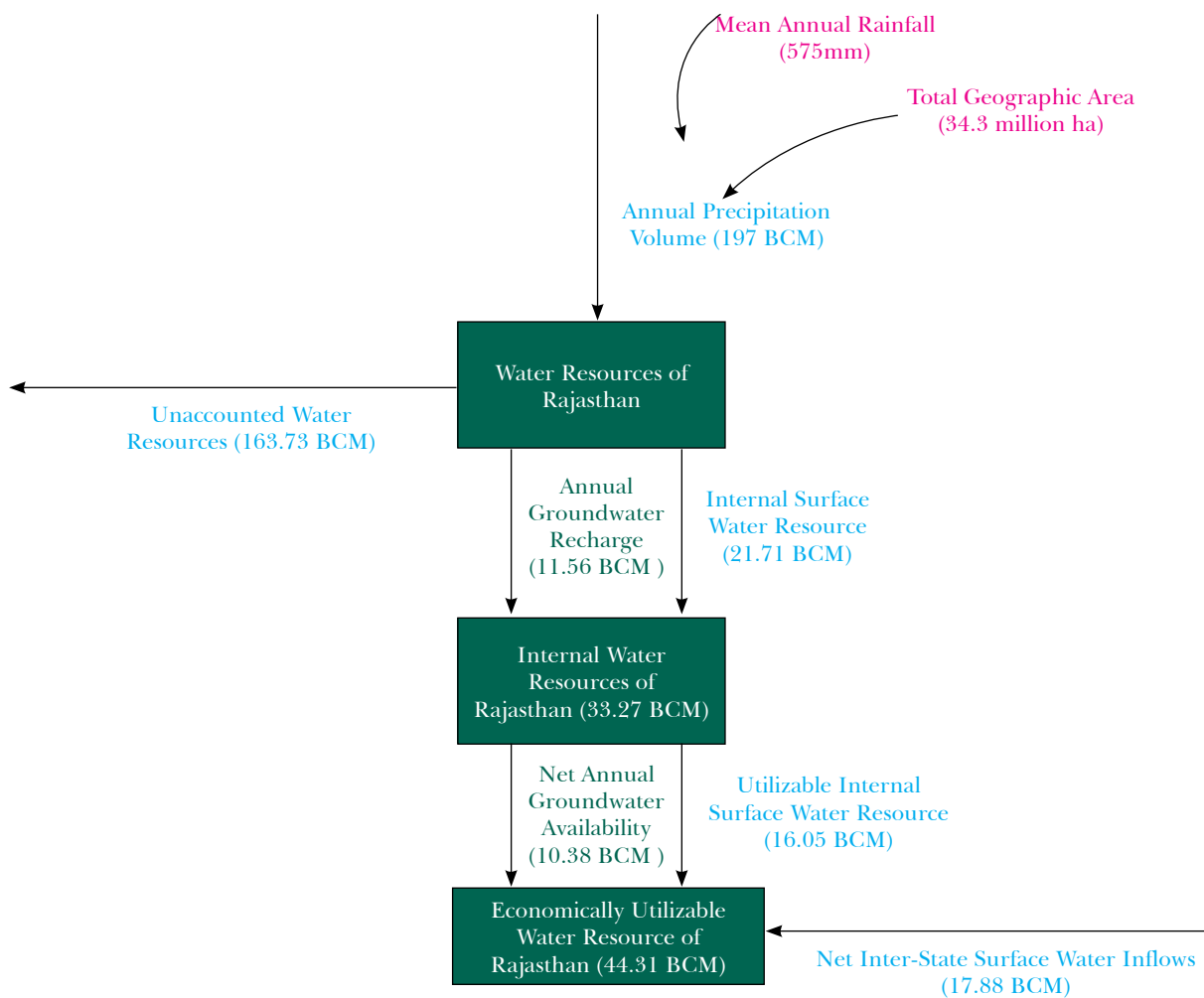


Source: : [A] <https://www.rajas.in/wp-content/uploads/2017/06/Physical-Divisions-of-Rajasthan.png>
 [B] <https://www.rajas.in/wp-content/uploads/2017/07/Annual-Normal-Rainfall-in-Rajasthan.png>



hectares, Rajasthan receives total precipitation of 197 billion cubic meters (BCM). However, of this, more than 160 BCM is “unaccounted” as it constitutes evaporation, rain-fed and non-crop evapo-transpiration, and deep percolation lost in deep aquifers and fossil groundwater (see Verma and Phansalkar 2007). Another significant part of the rainfall volume is “un-utilizable” due to temporal and spatial variability. In effect, the state’s annual replenishable groundwater resources are only 10.38 BCM and internal surface water resources are 16.05 BCM. Rajasthan also receives 17.88 BCM as net inter-state inflows. Thus, the annual economically utilizable water resources of the state (surface water and groundwater) amount to about 44.31 BCM (see Figure 2).

FIGURE - 2: WATER RESOURCES OF RAJASTHAN



Data Sources: Gupta et al. (2015); CGWB Website [http://cgwb.gov.in/gw_profiles/st_Rajasthan.htm]

3. There is high dependence on groundwater for both irrigation and drinking needs, with state-wide extraction being 140% of annual replenishable recharge (GoR 2016). CGWB has reported an average groundwater development¹³ of 125% in the state with over-exploitation of groundwater in 47% of the blocks. According to the Fifth Minor Irrigation Census 2013-14, Rajasthan is second only to Punjab in terms of number of deep tube-wells (GoI 2017; Rajan and Verma 2017). The high dependence in Punjab on groundwater sources such as deep tube-wells is indicative of the widespread decline in water table, high investment into tube wells, increased operation and maintenance cost, more power consumption, and deterioration of groundwater quality (Baweja 2017). To make matters worse, groundwater quality in the state is also deteriorating sharply. The aquifer conditions vary across the state with three distinct formations: a) alluvial aquifers of significant thickness occur in Hanumangarh, Jalor, Bikaner and Barmer districts; b) Pali, Dhaulpur, Rajsamand have significant thickness of weathered and fractured hardrock aquifers; and c) Bhilwara, Udaipur, Chittaurgarh, Jhalwar, Banswara, Rajsamand and Dungarpur districts do not have any significant alluvial aquifers and groundwater is mostly drawn from hard-rock aquifers. Evaporation losses, which range from 1,400 to 1,800 mm/year in most parts of India, are highest in Rajasthan (3,000 mm/year) (Guerra et al. 1990) due to high temperatures. Per capita and per hectare availability of water in the state is very low vis-à-vis national average. For instance, the average per capita water availability in Rajasthan is expected to drop below 450 m³ by 2050, below the internationally accepted minimum of 500 m³ per capita denoting absolute water scarcity [World Bank, 2017]. Continuous increase in human and livestock population is adding to the pressure on limited water resources of the state.
4. A review of groundwater development and agricultural growth in Rajasthan shows two important and unsustainable trends. First, power supply for agriculture is heavily subsidized.

Second, this incentivizes water-intensive behavior (crop choice, irrigation practices as referred in Table 1) further compounded by Minimum Support Prices (MSPs) that have ultimately led to depletion of groundwater. Absence of any legal controls over the amount of groundwater that can be extracted complicates the scenario still further. Therein lies the binding constraint on allocation of water and electricity for extraction of groundwater. Rajasthan agricultural growth has come at a high cost of water and electricity economy. Many of the sectoral policies and welfare programs do not take into account adverse impacts on other sectors or ignore the opportunities for synergies between the sectors that could enhance the outcomes and positive impact on beneficiaries.

TABLE 1: RAJASTHAN: CROPPING PATTERN AND % AREA IRRIGATED UNDER IMPORTANT CROPS 2013-14

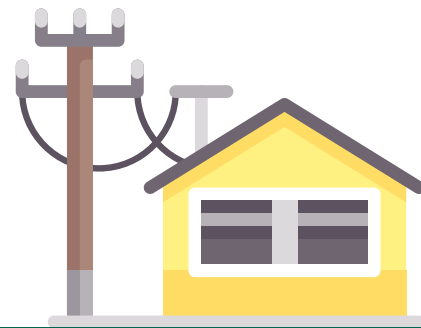
| Types of crop grown | Area (000ha) | % to GCA | % Crop area irrigated |
|----------------------|--------------|----------|-----------------------|
| Paddy | 1456 | 5.57 | 100 |
| Bajra | 4447 | 17.03 | 3.36 |
| Wheat | 3206 | 12.27 | 99.36 |
| Barley | 309 | 1.18 | 97.03 |
| Gram | 1924 | 7.36 | 35.70 |
| Soyabean | 1176 | 4.50 | 0.43 |
| Rapeseed and Mustard | 2783 | 10.65 | 87.57 |
| Guarseed | 5071 | 19.42 | 13.36 |
| Others | 5748 | 22.02 | |
| Gross cropped area | 26120 | 100 | 37.77 |

Source: GoR, 2016

5. The World Bank Systematic Country Diagnostic (SCD) findings emphasize the need to forge a resource-efficient growth path through more prudent use of groundwater resources. The SCD also calls for the need to correct distortions in groundwater, agriculture and energy nexus.

¹³. The Central Ground Water Board categorises groundwater development based on a ratio of groundwater draft to recharge, expressed as a percentage. A ratio >100 is categorized as “overexploited,” A ratio between 90-100 is “critical,” between 70 and 90 is “semi-critical,” and below 70 is “safe”.

The present Study was undertaken to better understand the 'Water- Energy-Agriculture' nexus in Rajasthan by reviewing existing analytical work (Verma, S. 2019; Nicholas, R. and Anant, S., 2018) and the prevailing policies of the state. A key focus of the Study has been the influence of subsidized farm power supply on groundwater irrigation and on agricultural practices and output (World Bank, 2018).



In 2019 Rajasthan achieved 100% electrification for all 12.76 Million households

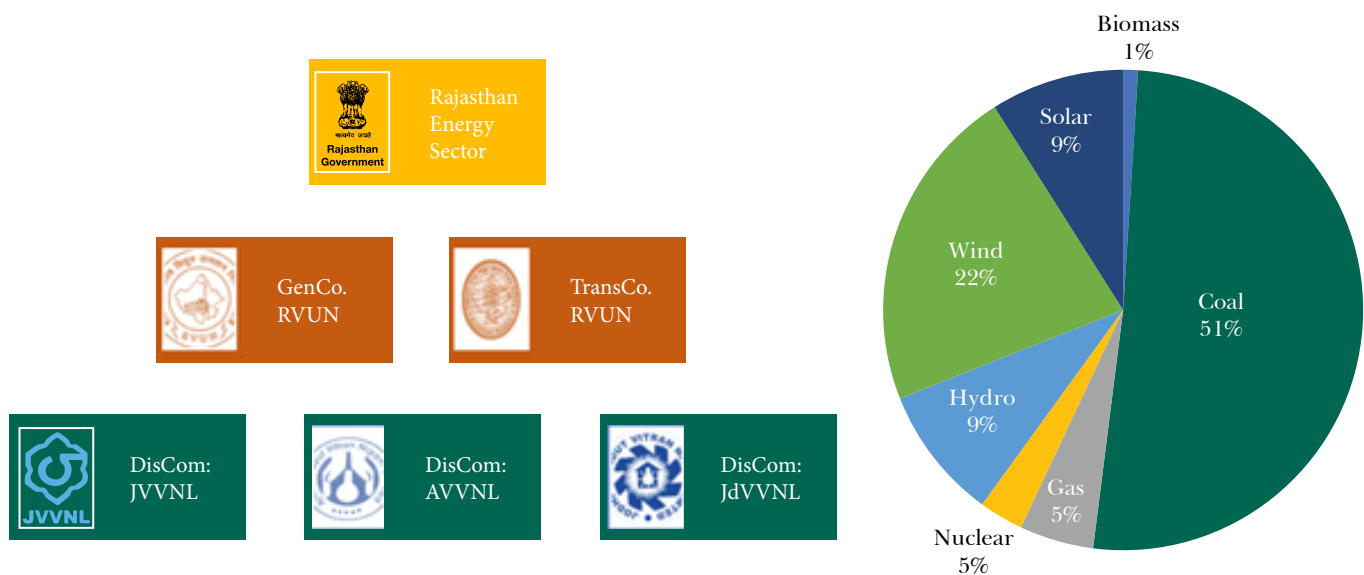
2.2 SECTORAL REVIEW

2.2.1 Energy and Renewable Energy

6. Rajasthan’s energy sector is organized around five entities – *Rajasthan Rajya Vidut Utpadan Nigam (RRVUN)*, the energy generation company; *Rajasthan Rajya Vidut Prasaran Nigam (RRVPN)*, the energy transmission company; and three distribution companies, Jaipur Vidyut Vitran Nigam Limited (JVVNL), Ajmer Vidyut Vitran Nigam Limited (AVVNL) and Jodhpur Vidyut Vitran Nigam Limited (JDVVNL) (Figure 3 [A]). In recent years, Rajasthan has taken some bold steps to improve its power sector and is attempting to improve its agriculture and water sector. The state’s

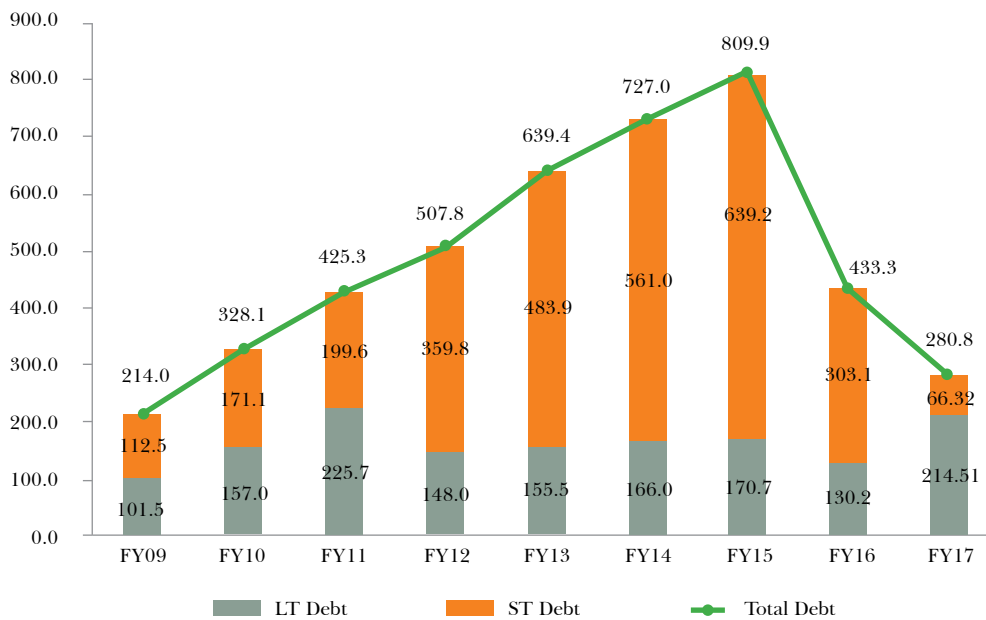
economic growth rate of about 7.9% is sought to be accelerated to 12%. While the goal is laudable, it may exacerbate pressure on natural resources and sharpen inter-sectoral competition for electricity and water. The state’s desire to increase household electrification from 67% to ‘electricity-for-all’ remained constrained for a long time due to severe financial stress faced by its power sector. It was only in 2019 – with support from the Government of India’s Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and Pradhan Mantri Sahaj Bijli Har

FIGURE - 3: ORGANIZATION OF RAJASTHAN’S ELECTRICITY SECTOR [A] AND RELATIVE SHARE OF DIFFERENT ENERGY SOURCES [B]



Source: <https://www.rajras.in/index.php/power-resources-of-rajasthan/>

FIGURE - 4: DEBT EXCLUDING THE INTEREST-FREE LOAN FROM THE GOR IN 2016 (INR BILLIONS)



Ghar Yojana (SAUBHAGYA) – that Rajasthan managed to achieve 100% electrification. Today, the state provides electricity to all its 12.76 million households, after connecting the last 1.86 million households post October 2017¹⁴. As of 2017, nearly 40% of Rajasthan’s 17 GW installed power capacity was attributable to renewable energy (22% wind; 9% solar; 9% hydro) while bulk of the remaining was from thermal power (Figure 3 [B]).

7. The electricity sector in Rajasthan has expanded and improved over time. However, it is facing serious financial challenges that threatens the sustainability of supply in a long run. A combination of high generation costs, inefficiencies in the distribution sector and an accumulation of long-delayed tariff adjustments, resulted in several years of continuing financial losses, requiring substantial financial support from the State (Figure 4). In FY 2018, subsidy of ₹ 86 billion represented more than 20% of revenue of power sector (₹ 400 billion). Accumulated losses of ₹ 814 billion, partly funded by short-term

loans of ₹ 477 billion, have been restructured and taken over by the State Government over a period of two years starting 2016.

8. Rajasthan signed up to a Government of India scheme titled “UDAY” to improve long-term financial sustainability of DISCOMs¹⁵. Nevertheless, without sustained operational restructuring, cost reduction and cost recovery, and increasing efficiency and effectiveness of power subsidy, Rajasthan power sector would run the risk of sliding back and the government having to bear the fiscal costs of accumulated losses of power sector.
9. Like in almost all other states in western and peninsular India, farmers in Rajasthan get farm power at highly subsidized tariffs; consumption up to an equivalent of ₹ 10,000 (about 11,100 kWh) per year is free. The low marginal cost and erratic, unreliable farm power supply leads to over-pumping of groundwater and inefficient water and energy use practices. With the cost of solar

¹⁴. <http://subhagya.gov.in>

¹⁵. The Ujjwal Discom Assurance Yojana (UDAY) scheme is centered around four initiatives: (a) improvement in operational efficiencies, including reduction of losses and revenue requirement adjustments; (b) reduction of power generation costs through the optimization of fuel logistics and pricing, as well as transparent competitive bidding; (c) reduction in interest cost of DisComs by requiring state governments to absorb and restructure about 75 percent of DisComs’ debt; and (d) enforcing fiscal discipline by converting the previously implicit liabilities to finance DisCom losses.

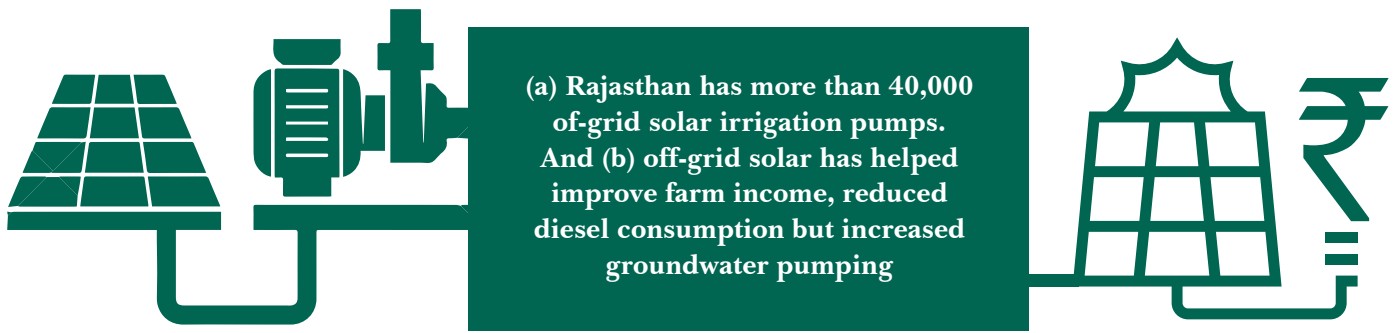
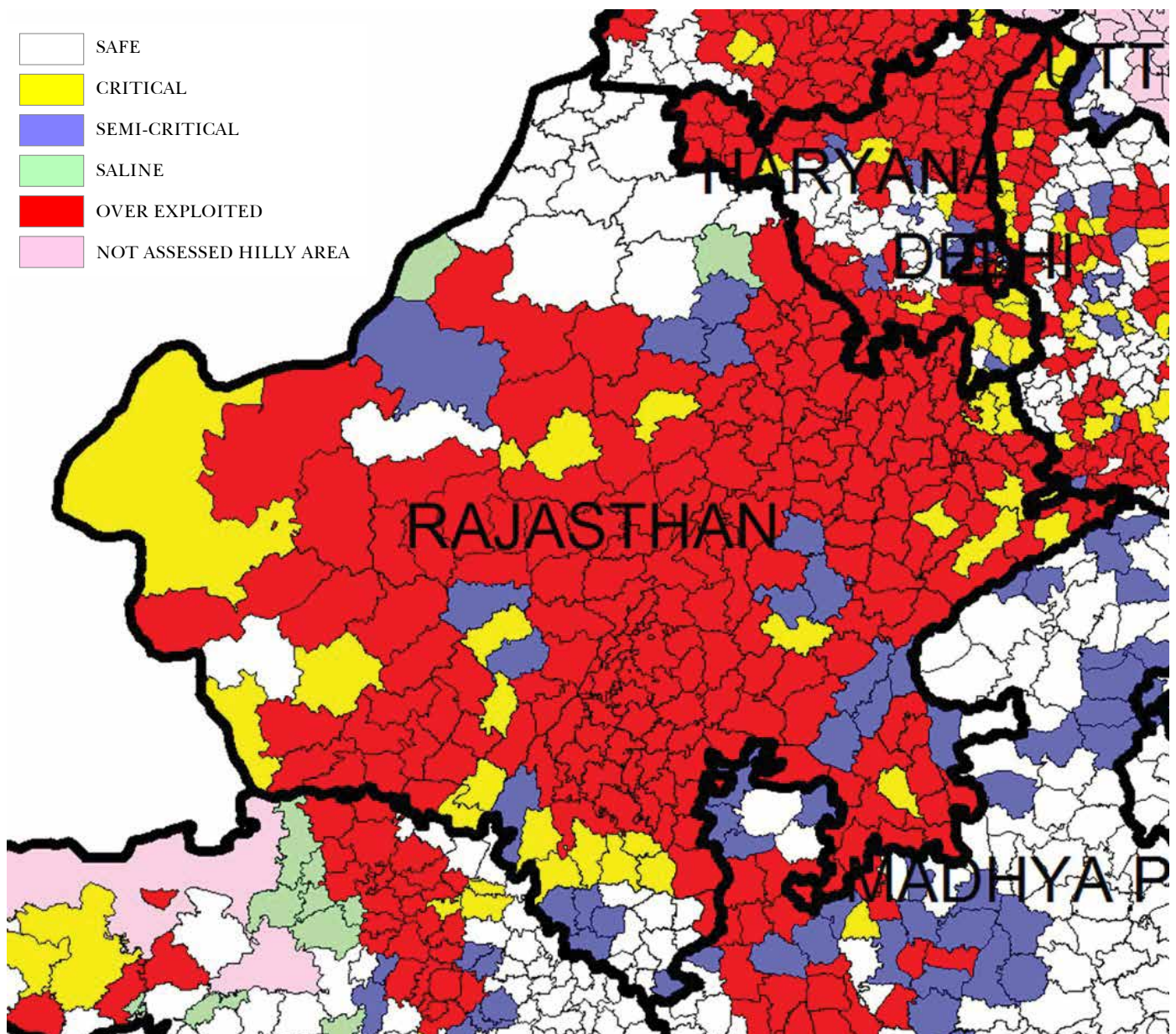


FIGURE - 5: STATUS OF GROUNDWATER RESOURCES IN RAJASTHAN (AS ON 31ST MARCH 2011)

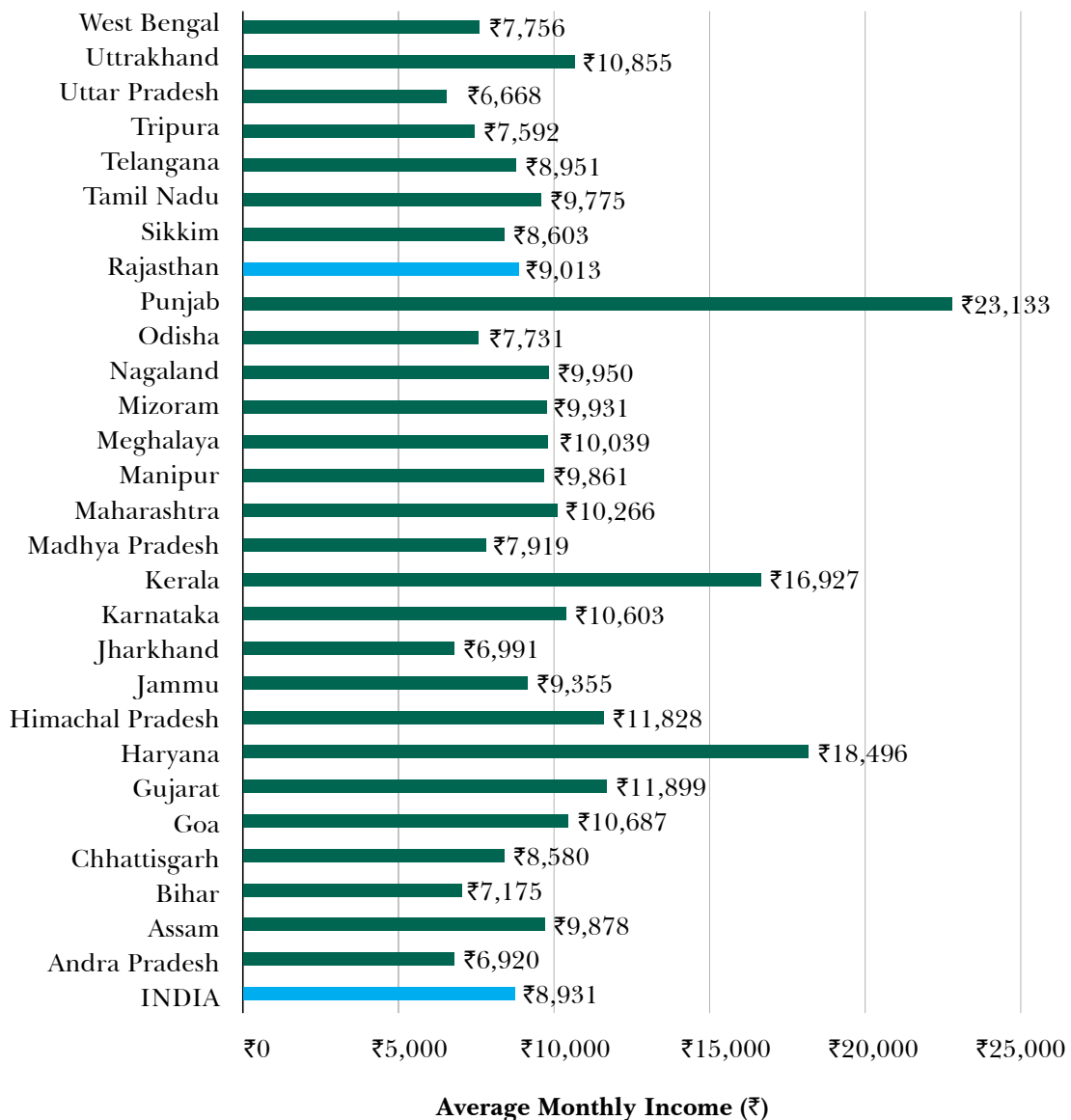


Source: <http://cgwb.gov.in/MAP/CATEGON%202011.jpg>

photo voltaic (PV) cells falling steadily and the price of diesel soaring, solar-powered pumping has emerged as an economically feasible idea in the last decade (Shah and Kishore 2012). Rajasthan was one of the early leaders in promotion and installation of solar irrigation pumps through an innovative convergence of federal schemes and state support (Kishore et al. 2014). With 30% support provided from Jawaharlal Nehru National Solar Mission (JNNSM) and another 56% from Rashtriya Krishi Vikas Yojana (RKVY), the capital investment required by farmers was significantly reduced to

around ₹ 80,000 and most farmers expected to recover their investments within a few years of operation via savings in electricity and/or diesel costs. Tewari (2012) also noted that farmers were viewing solar pumps both as a pumping as well as an energy solution. Since then, the state government has reduced the extent of capital subsidy to 70% while allowing larger capacity pumps, up to 10 kWp. By August 2018, the state had already installed 42,581 solar irrigation pumps (MNRE 2018). With an average estimated size of 3 kWp (equivalent to 4 HP), these solar pumps help farmers irrigate for up

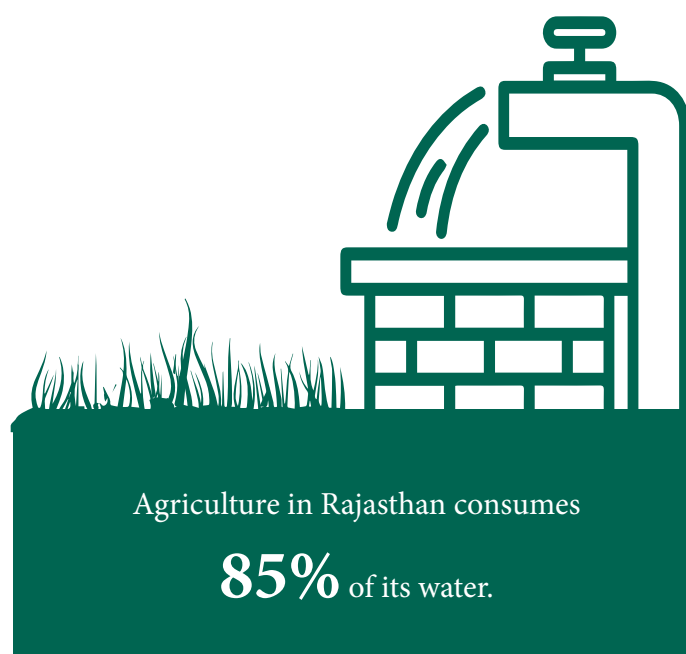
FIGURE - 6: STATE-WISE AVERAGE MONTHLY INCOME OF AGRICULTURAL HOUSEHOLDS (NAFIS 2017)



to 10 hours/day thereby bringing several thousand hectares under irrigation. Early assessments of solar pumps in Rajasthan (Tewari 2012; Kishore et al. 2015) reported that farmers were uniformly happy with the performance of these pumps. A recent field study on the impact of solar irrigation pump adoption on agricultural income, energy use and water in Rajasthan shows improvement in farm income, reduction in electricity and diesel use but also increased groundwater pumping (Gupta 2019). In the study region the solar power systems were however stand- alone systems and were not connected to the grid to enable farmers to sell surplus electricity to the utility and earn additional non-agricultural income.

2.2.2 Agriculture, Water Resources and Irrigation

10. Agriculture consumes more than 85% of water and contributes about 30% of Gross State Domestic Product (GSDP); in the 2018-19 state budget, an estimated outlay of US\$ 693 million was made for agriculture (IBEF 2019). Of late, cropping intensity has increased from 115% to 140% between 2005 and 2015 (GoR 2015a). Surface irrigation in Rajasthan



is limited, however, the bulk of the cropped area is irrigated using groundwater, which has risen to almost 70% of the total irrigated area. In fact, two-thirds of the additional area brought under irrigation was due to the expansion of groundwater irrigation (i.e., shallow tube wells), contributing to the overexploitation of groundwater in large parts of the state. Rajasthan has more than 10% of cattle population of India and is the second largest producer of milk in the country. Three-fourth of its population lives in rural areas and more than 60% depends on agriculture for livelihood (NITI Ayog *nd.*). In terms of groundwater development, of its 248 development blocks, only 44 are safe, 28 are semi-critical; 9 are critical, 3 are saline and an overwhelming majority (164) blocks are over-exploited (Figure 5). Rajasthan is among the leading states in implementation of *Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)*, with roughly 2/3rd of MGNREGS works focusing on water conservation and minor irrigation works.

11. With more than 5 million households still dependent on agriculture for their livelihood, in 2012, the Government of Rajasthan initiated the US\$ 160 million outlay Rajasthan Agricultural Competitiveness Project (RACP) with World Bank support. The project development objective of RACP is, “to sustainably increase agricultural productivity and farmer incomes in selected locations of Rajasthan”. According to the NABARD All India Rural Financial Inclusion Survey (NAFIS), the average income of rural agricultural households in Rajasthan was ₹ 9,013 per month in 2016; only slightly above the national average of ₹ 8,931 per month (NAFIS 2017; Figure 6). It is noteworthy that the NAFIS (2017) survey also reports that roughly half of this income comes from non-agricultural sources.
12. In 2010, with support from the European Union under an EUR 80 million ‘State Partnership Program’ (EU-SPP¹⁶), Rajasthan released its *Rajya Jal Niti (State Water Policy)*. The policy suggests, “a radical shift from predominantly engineering-based solutions to local community-based

¹⁶. See <http://water.rajasthan.gov.in/content/water/en/swrpdepartment/swrpd/euspp.html>

water management solutions” under the broad umbrella process of Integrated Water Resource Management (IWRM). The policy recognizes the following as critical issues in Rajasthan: [a] growing imbalance between demand and supply; [b] uncertainty in availability; [c] inequity in access; [d] low operational efficiency; [e] depleting groundwater and deteriorating water quality; [f] high cost of service, low cost recovery and low level of expenditure on O&M; and [g] lack of stakeholder ownership (GoR 2010). Further, in 2016, Government of Rajasthan launched the Mukhyamantri Jal Swavlamban Abhiyan (MJSA) (Chief Minister’s Water Self-Reliance Campaign) to help rural communities cope with water stress and droughts. The activities taken up under the program include construction of minor irrigation tanks, anicuts, check dams, field bunds, farm ponds, rooftop water harvesting structures, staggered trenches, continuous contour trenches (CCTs), deep CCTs and others to capture runoff. MJSA also focuses on tree plantation, afforestation of wastelands, pasture development, horticulture expansion and promotion of micro irrigation. The program thus brings together water-related investments by various line departments under one roof with the objective of creating a movement on water conservation with people’s participation. While the program focuses on increasing irrigated and cultivable areas, it has also given equal importance to drinking water. One of its objectives is to bring at least 40% rain-fed area under irrigation to increase production.

13. The Indira Gandhi Nahar Project, which imports water from Sutlej in Punjab to the dry desert of western Rajasthan led to vast expansion in area under crop production and improved the economic conditions of farmers in this region. Construction of local water storages (diggies), irrigation using sprinkler systems and choosing crops that are low water-intensive can enable farmers to take up crop production even in undulating land having saline groundwater, with low water application requirements. In the past, the Rajasthan Water Sector Restructuring Project (RWSRP) and JICA had taken up many projects on repair, renovation

and restoration (RRR) of old water bodies, environmental resources management, farm development and Command Area Development (CAD), for improvement of water use efficiency.

14. In addition to the above, Rajasthan is also an active participant and leading state in several central schemes. Extension of Narmada canal command area in south Rajasthan as well as modernization of Ganga canal are part of the Accelerated Irrigation Benefits Program (AIBP) component of Pradhan Mantri Krishi Sinchai Yojana (PMKSY). The Repair, Renovation and Restoration (RRR) component of PMKSY covers more than 13,000 ha of Cultivable Command Area (CCA).

2.3 SYSTEMS THINKING AND ANALYSIS OF WATER-ENERGY-AGRICULTURE NEXUS

15. In order to better understand the complex interactions and interlinkages between decision and outcome variables across the energy, water and agriculture sectors, it is important to take a “systems” approach. It is also important to keep in mind that behavior of interactive public policies changes over time since often the effect of public policies can be seen only with a time lag, and cross-sectoral impacts of public policies that are generally not self-evident are often ignored or are not well understood. Cross-sectoral impacts may be insignificant in the beginning but may get aggravated over time. Policies that are appropriate when enacted may fall out of step with the changing context. Energy-Water-Agriculture nexus is one such example. “System Dynamics” is an analytical tool to understanding the dynamic and non-linear behavior of complex systems using stocks, flows, causal (negative and positive) feedback loops¹⁷. However, system dynamic modelling is a data, resource and effort intensive activity but to present the interactive nature of cross-sectoral impacts we have used a simpler technique of causal loop diagrams in this report. Causal Loop Diagrams highlight the negative and positive feedback loops through which the water, energy and agriculture

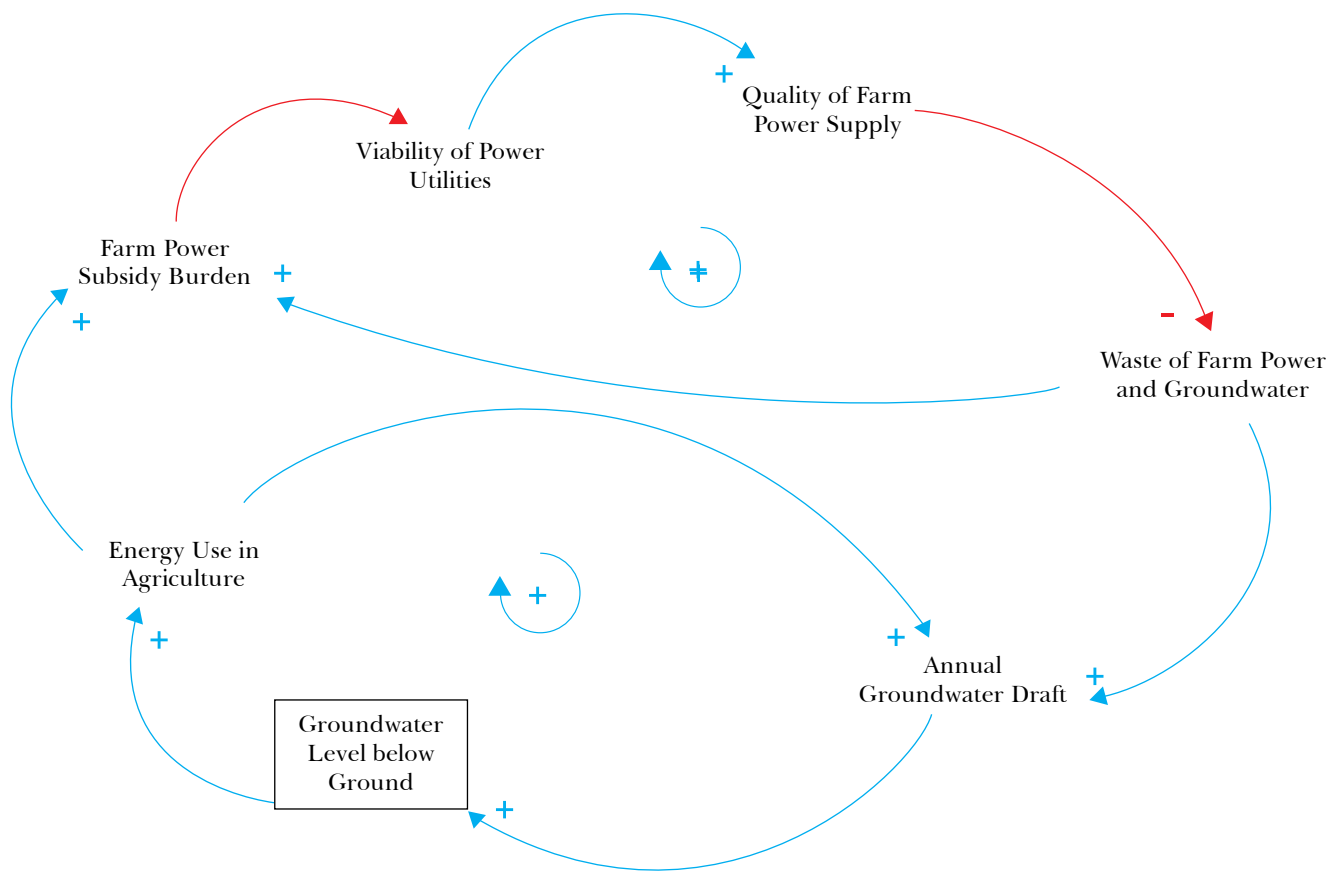
¹⁷. Some of the best known and most widely discussed early ‘System Dynamics’ work includes “Industrial Dynamics” (Forrester 1961), “Urban Dynamics” (Forrester 1969) and “The Limits to Growth” (Meadows et al. 1972).

sector influence each other. Through the Causal Loop Diagrams¹⁸, the reader can recognize how the complex decisions taken in one of these sectors can have intended, as well as sometimes unintended, consequences on the other sectors.

16. Figure 7 illustrates two positive feedback loops in India's (and Rajasthan's) *Energy-Groundwater-Agriculture Nexus*. Independent India inherited one of the world's largest surface irrigation systems and early governments made public investments in public irrigation a developmental priority. However, despite massive investments, the benefits of large, gravity-flow surface irrigation systems were confined to a small fraction of the country's geography

and population. Post-1970, with improvements in drilling and pumping technologies and public policy support, groundwater-based source of irrigation started becoming popular among Indian farmers. So rapid was the expansion of groundwater-based irrigation that almost all the new irrigated area added in India after 1980 may be attributed to groundwater. At 220-240 BCM groundwater withdrawal per year, India is the world's largest user of groundwater. Much of this use is in agriculture as millions of farmers rely on groundwater to intensify cultivation on small land holdings. At the heart of India's groundwater revolution is the highly subsidized and often free and unmetered power, thereby creating a perverse nexus between farm

FIGURE - 7: EXAMPLE OF A SIMPLE CAUSAL LOOP DIAGRAM APPLIED TO ENERGY-GROUNDWATER NEXUS



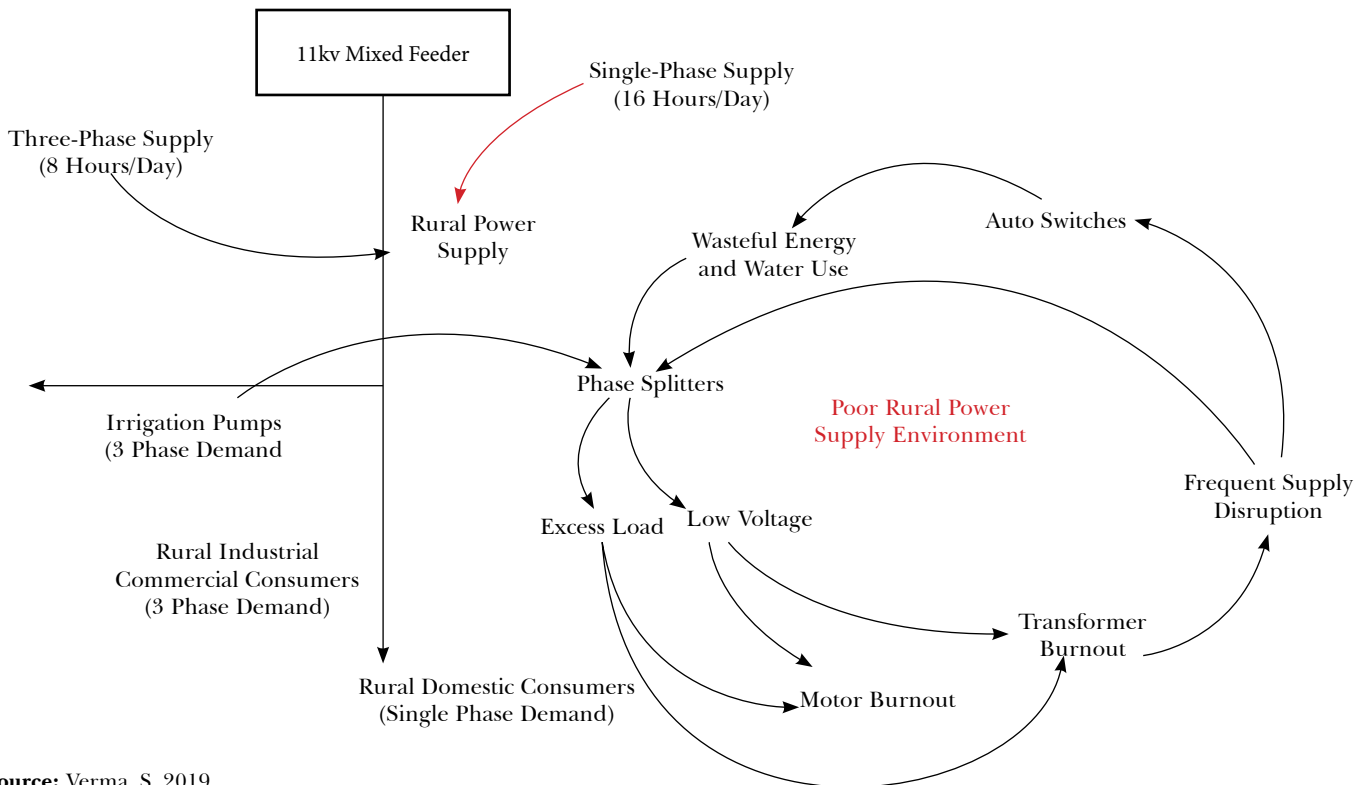
Source: Verma, S. 2019

¹⁸. CLDs are visual aids to explain the interactions between system variables; they consist of 'nodes' and 'edges'. Nodes represent the variables and edges are the links that represent a connection or a relation between the two variables. A link marked positive indicates a positive relation which means that the two nodes change in the same direction, i.e. if one increases, the other increases as well, and vice-versa. Similarly, a negative causal link means the two nodes change in opposite directions, i.e. if one increases, the other decreases.

power subsidies and groundwater over-exploitation. On the one hand, the 'groundwater boom' has undoubtedly provided succor to India's small holders; on the other, however, its collateral damage on India's energy sector has been massive. State's budgetary spend on power subsidy for agriculture has been rising rapidly. Electricity utilities in almost all key agricultural states in western and peninsular India lose money annually and are struggling to raise resources for infrastructure maintenance and improvements; the national farm power subsidy bill has crossed ₹ 100,000 crore (~US\$ 15 billion) and pockets of groundwater depletion are cropping up all over western and peninsular India. Thus, unreliable farm power supply will lead to inefficient use of energy and water, leading to groundwater depletion and further increase in demand for farm power and state subsidies. Effectively managing this nexus is critical for sustainability of groundwater and agriculture, as well as for maintaining the long-term viability of electricity utilities and fiscal health of the state.

17. One instrument that has been used to manage the 'energy-irrigation nexus' demonstrated above is feeder-segregation – implemented first through Gujarat's *Jyotigram Yojana* in 2005-06 (see Tushar Shah and Verma, S, 2007). Figure 8 shows how mixed rural feeders led to deterioration in rural power supply environment. Since utilities could not charge farmers for their energy use, utilities wanted to ration farm power supply to control their losses and maintain viability. To do this, utilities started supplying only 6–8 hours of three-phase supply for farmers to run their pumps, while only single-phase power was supplied during the remaining hours to serve non-agricultural customers. Unhappy with the rationing, particularly during peak irrigation season, farmers innovated and resorted to using locally-manufactured phase-splitters that would allow them to run their irrigation pumps even with single phase power supply. The use of phase-splitters became rampant even though they often led to motor or transformer burnout. Frequent transformer burnout led to frequent disruptions

FIGURE - 8: EXAMPLE OF A SIMPLE CAUSAL LOOP DIAGRAM APPLIED TO ENERGY-GROUNDWATER NEXUS



Source: Verma, S. 2019

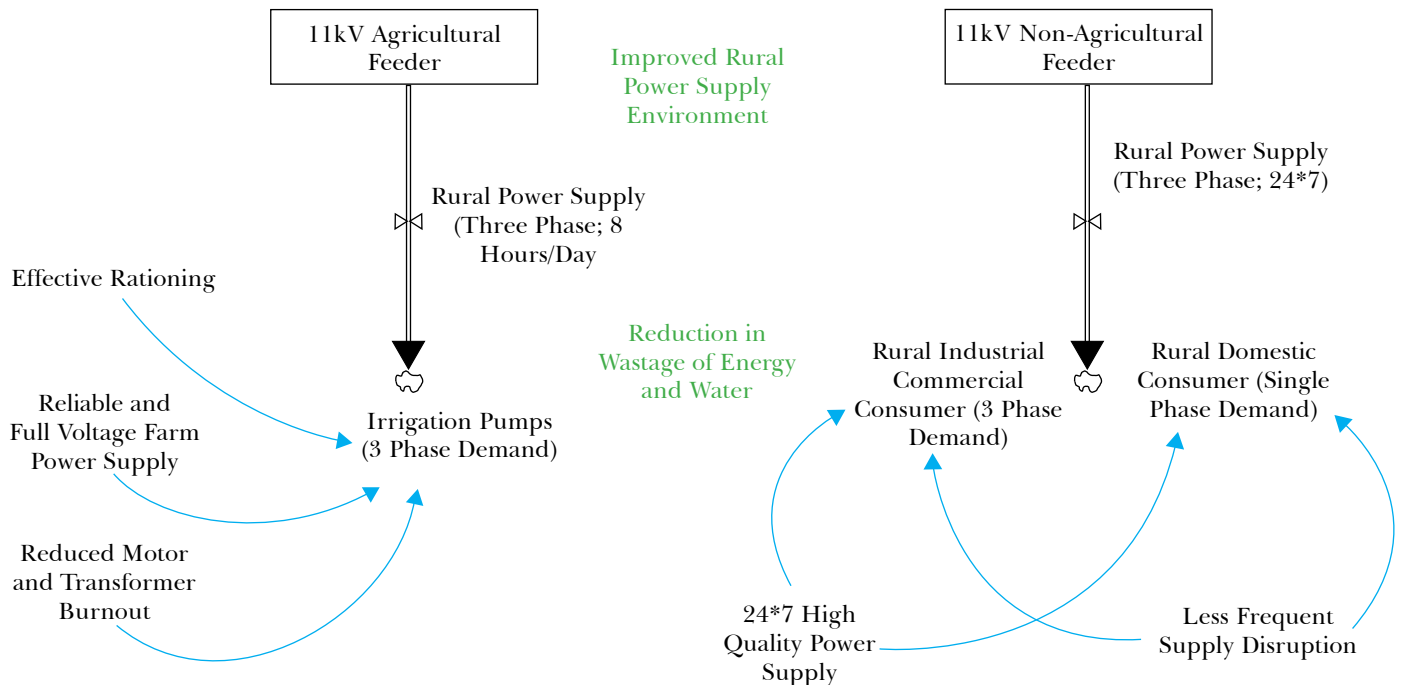
in power supply and increased the maintenance cost of rural feeders. As phase-splitters became common, the voltage regime on rural feeders also deteriorated and utilities tried to control farm power use by frequently resorting to load shedding and supplying farm power alternately during day and night hours, to manage load. In response, farmers installed auto-switches, so that their irrigation pumps could start pumping whenever power supply was available. All of this also meant that non-agricultural consumers, who paid commercial tariff without commensurate service, were held hostage by farmers as even their power supply environment deteriorated, for no fault of theirs. It also led to inefficient use of farm power and water, leading to wastage and groundwater depletion. With depletion and falling water tables, farmers needed more units of energy to pump the same amount of water and this further exacerbated the situation.

18. With separate feeders, high quality three-phase power can be supplied on agricultural feeders for

6-8 hours, as per a pre-announced schedule. This will allow farmers to adjust their demand to supply. It would also help if during peak agricultural seasons (usually 20-30 days in a year), power supply on agricultural feeders is increased to help farmers meet their increased demand. Non-agricultural feeders, on the other hand, can be supplied 24*7 power at commercial or near-commercial tariffs. This will lead to significant improvement in consumer satisfaction and boost rural power consumption, including for rural industries and commercial users. Figure 9 shows how feeder-segregation can improve the rural power supply environment by facilitating “intelligent rationing of farm power supply”.

19. Another example where the water-energy-agriculture nexus can lead to counter-intuitive outcomes is in the promotion of “water-saving” technologies such as drip irrigation. While adoption of drip irrigation improves water productivity as well as farmers’ income, global evidence indicates that it may not lead to a reduction in groundwater

FIGURE - 9: SEPARATION OF AGRICULTURAL AND NON-AGRICULTURAL FEEDERS



Source: Verma, S. 2019

over-exploitation. In fact, it may lead to an increase in annual groundwater extraction. The counter-intuitive increase in resource use with improvement in resource-use efficiency is also captured in the economic concept of Jevons Paradox¹⁹.

2.4 KEY FINDINGS: ADOPTING NEXUS APPROACH

20. With the above analyses, it is evident that the water, energy and agriculture economies in Rajasthan (and elsewhere) are closely inter-linked. **Decisions in one sector can strongly influence outcomes in another and sometimes, these outcomes can be counter-intuitive.** Often, adverse cross-sectoral impacts are not evident immediately and review of government policies lags behind changes in context, underlying assumptions, or objectives of policies until a crisis manifests itself. Impact of unmetered and free power supply on groundwater and agriculture is one such example. This counter-intuitive nature of the outcomes makes it difficult for policy makers to predict these outcomes, especially if they are operating in airtight sectoral silos.

21. We can summarize the key policy inferences and messages from our analyses presented in matrix in Table 2 as follows:

- The fates of the water, energy and agriculture sectors are closely inter-twined; this makes it imperative that a nexus approach²⁰ is adopted;
- Rather than decisions taken by water resource planners and irrigation engineers, the groundwater governance is likely to be influenced more by decisions taken in energy and agriculture sectors;

- Adopting the nexus approach to policy making will not only help develop more effective policies, it will also help avoid unintended negative inter-sectoral outcomes of seemingly benign and well-intentioned sectoral policies;
- The energy-water-agriculture nexus is particularly strong when it comes to management of groundwater; it would be futile to manage increased groundwater demand and over-exploitation – a common occurrence in many parts of Rajasthan – without understanding nexus implications;
- Even with the nexus approach, our analyses suggest that no one intervention is likely to be effective on its own;
- Investments in monitoring and understanding groundwater use – not merely measuring water levels – can help decision makers better understand the likely implications of their policy actions;
- Groundwater management, especially groundwater demand management, will need to deal with a strong and entrenched political economy around farm power subsidies; any proposed solution that ignores this is unlikely to succeed. Failure to manage demand will lead to a collapse in groundwater-based economic activities and absence of monitoring would just mean that no-one can predict when that collapse will occur;
- Sufficient resources are required to be invested in piloting “nexus ideas”, closely monitoring their impact on the ground; following on how resource users (farmers) respond and react to policy nudges; and appropriate scaling up will be required to transform the currently operating perverse incentives into a virtuous W-E-A nexus.

¹⁹. Jevons paradox occurs when “technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises due to increasing demand.” [https://en.wikipedia.org/wiki/Jevons_paradox]

²⁰. Advancing towards a more stable and sustainable future depends on the “nexus thinking” or “systems thinking” that, instead of just looking at individual components and short-term quantitative outcomes, recognizes feedbacks and connections, and promotes concerted action and cooperation on a global scale across sectors, time and space. Based on a better understanding of the interdependence of water, energy and food, this integrated approach identifies multilateral beneficial solutions to resource management and provide way to meet the needs of the present without compromising the ability of future generations to meet their own needs. In practical terms, the governments should review the policies in terms of their impacts on other sectors over a period of time, identify conflicts and synergies, establish inter-agency coordination for planning, plan and design interventions that would enhance synergies and reduce adverse impacts.

22. Specifically, for Rajasthan, our analysis suggests that:

- The politically sensitive issue of farm power tariffs needs a careful approach. The current regime keeps farmers unhappy while inflicting losses on the energy utilities and making groundwater irrigation unsustainable. It is an unsustainable proposition for Rajasthan's water, energy and agriculture sectors.
- Whether the State Government wants to continue offering farm power subsidies or not

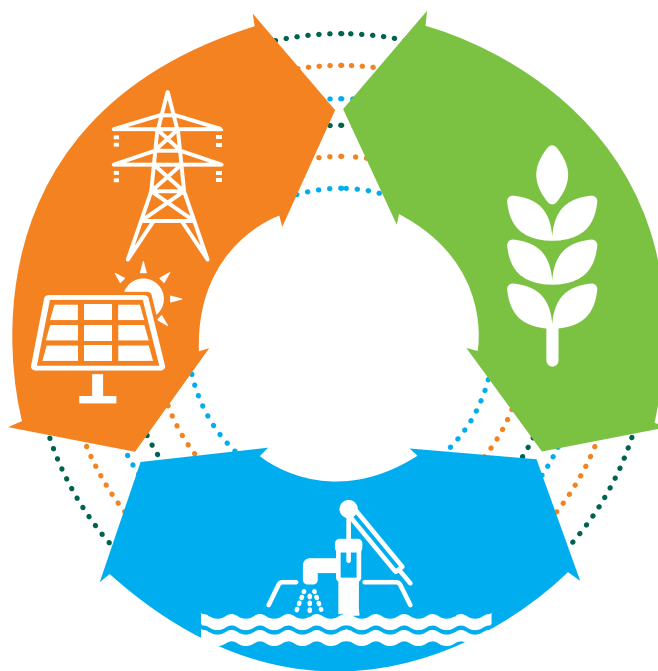
is a political decision, but the way in which these subsidies are delivered can be modified to improve outcomes for farmers, utilities as well as for groundwater sustainability.

- The State Government should revisit the current practice of *'virtual segregation'* and consider idea physically segregating agricultural feeders. Despite its seemingly high upfront cost, feeder segregation might offer significant long term financial, economic and institutional returns. In addition, it provides enabling conditions for rapid implementation of such innovative



solutions as Direct Benefit Transfer and grid-connected solar irrigation.

- Popular interventions such as the creation of decentralized water harvesting structures and water storages may, in some cases, have negative downstream consequences. Proper planning at the river basin or sub-basin scale is recommended while creating new water storage for agricultural use.
- Promotion of efficient irrigation technologies can lead to significant water saving at the farm level, and improve water productivity and farmer incomes. However, their impact on basin-level 'water saving' is subject to Jevon's Paradox.
- As the leader in promoting solar irrigation pumps, Rajasthan needs to account for the potentially negative consequences for groundwater sustainability. While SIPs need to be promoted, the State Government should develop a more groundwater-benign model of promotion through farmer-owned, grid-connected solar irrigation (discussed subsequently). Such a shift in approach is essential for the State Government to deliver a drought resilient and competitive agriculture economy in the state.



Groundwater management is about portfolio of approaches. No single policy, regulation or project can solve this alone

TABLE - 2: MATRIX OF WATER-ENERGY-AGRICULTURE NEXUS IN RAJASTHAN

| Policy | Description and Policy Intent | Policy translation into Field Action | NEXUS Impacts and Outcomes | | |
|--|--|---|--|--|--|
| | | | Energy Sector | Water Sector | Agriculture Sector |
| Rajasthan Water Policy 2010 (Rajya Jal Niti) | - Integrated and multi-sectoral water resources planning and execution | Energy, Water and Agriculture sectors work independently, without much coordination | [-] Continuation of mixed feeders, poor rationing of farm power supply and rising farm power subsidy | [-] GW wastage continues due to unreliable farm power [-] Unsustainable groundwater use [-] Inequitable GW access | [-] High coping costs of unreliable farm power supply [-] Low productivity and profitability of agriculture |
| | - Public participation in groundwater management and governance | Groundwater poorly managed, if at all | [-] No check on pumping behaviour | [-] Unsustainable groundwater use [-] Inequitable GW access | [-] Unreliable water and energy availability [-] High production risk of farmers |
| | - Legal framework for regulating groundwater abstraction and use | Water (and groundwater) rights not defined; GW Regulation Act not enforced | [-] No check on expansion of groundwater extraction and pumping behaviour | [-] Unsustainable groundwater use [-] Inequitable GW access | [-] Continuation of unreliable water and energy availability |
| - Better groundwater utilization through pressurized irrigation like drip and sprinklers | Government offers capital subsidies for drip and sprinkler adoption | [+] Increase in Energy Productivity (\$/kWh) | [+] Increased Gross Irrigated Area [+] Increased Water Productivity (\$/m ³) [-] More (ground)water use in agriculture | [+] Expanded Gross Cropped Area [+] Increased Land Productivity (\$/Ha) [+] Increased Labor (\$/person) Productivity | |

| Policy | Description and Policy Intent | Policy translation into Field Action | NEXUS Impacts and Outcomes | | |
|--|---|--|--|--|---|
| | | | Energy Sector | Water Sector | Agriculture Sector |
| Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) | - Assured work, close to home and with minimum wages and proper working conditions offered | Wage floor created by MGNREGS, improves bargaining power of laborers | | | [-] Cost of cultivation increases for farmers |
| | - Public assets created under MGNREGS contribute to rural water security | Durable public assets improve water security and boost agrarian economy | [-] More pumping and energy use in agriculture | [+] Improved rural water security | [+] Improved cropped and irrigated area; agricultural output; profitability |
| | - MGNREGS also supports private assets such as on-farm water ponds for small, marginal, SC and ST farmers | Durable private assets contribute to higher farm incomes | [+] Reduced energy consumption | [+] Improved rural water security | [+] Improved cropped and irrigated area; agricultural output; profitability |
| Rashtriya Krishi Vikas Yojana (RKVY) | - Equal wages for equal work to men and women under MGNREGS | Open market wage-gap between men and women is reduced over time | | | [-] Cost of cultivation increases for farmers |
| | - Creation of dug wells, farm ponds and small public reservoirs for protective irrigation | Improved water security, greater resilience of agriculture and farm incomes | [-] More pumping and energy use in agriculture | [+] Improved rural water security | [+] Improved cropped and irrigated area; agricultural output; profitability |
| | - Vermicomposting and Plastic Mulching Promotion | Improved water retention capacity and fertility; reduced non-productive evapotranspiration | [+] Reduction in energy demand for irrigation | [+] Improvement in soil moisture profile | [+] Improvement in soil fertility, agri incomes |

| Policy | Description and Policy Intent | Policy translation into Field Action | NEXUS Impacts and Outcomes | | |
|--|---|---|--|--|---|
| | | | Energy Sector | Water Sector | Agriculture Sector |
| Mukhyamantri Jal Swavlamban Abhiyan (MJSA) | - Construction of minor irrigation tanks and water bodies | Decentralized water harvesting and improved groundwater recharge; Improved resilience of agriculture and farm incomes | [+] Increase in Energy Productivity (\$/kWh) [–] More pumping and energy use in agriculture | [+] Improved local water security [–] Upstream-downstream conflicts | [+] Improved cropped and irrigated area; agricultural output; profitability |
| | - Construction of Anicuts, check dams and farm ponds | Decentralized water harvesting and improved groundwater recharge; Improved resilience of agriculture and farm incomes | [+] Increase in Energy Productivity (\$/kWh) [–] More pumping and energy use in agriculture | [+] Improved local water security [–] Upstream-downstream conflicts | [+] Improved cropped and irrigated area; agricultural output; profitability |
| | - Catchment treatment and afforestation | Improved resilience of agriculture and farm incomes | [+] Reduction in energy demand for irrigation | [+] Improved rural water security [–] Higher non-crop evapotranspiration | [+] Improved cropped and irrigated area; agricultural output; profitability |
| - Promotion of micro irrigation | Government offers capital subsidies for drip and sprinkler adoption | Government offers capital subsidies for drip and sprinkler adoption | [+] Increase in Energy Productivity (\$/kWh) [–] More (ground)water use in agriculture | [+] Increased gross irrigated area [+] Increased Water Productivity (\$/m ³) [–] More (ground)water use in agriculture | [+] Expanded gross cropped area [+] Increased Land (\$/Ha) [+] Increased Labor (\$/person) Productivity |

| Policy | Description and Policy Intent | Policy translation into Field Action | NEXUS Impacts and Outcomes | | |
|--|---|---|--|---|---|
| | | | Energy Sector | Water Sector | Agriculture Sector |
| Rajasthan (Subsidized) Farm Power Supply and Tariff Regime | - Power supply to farmers free or highly subsidized | upto 11,000 kWh free per farmer per year; remaining charged at ₹ 0.90/kWh | [-] Inefficient use of electricity [-] Ever growing farm power subsidy bill [-] Poor financial health of electricity utilities | [-] Incentivizes inefficient groundwater use | [+] Reduced unit cost of irrigation [-] Unreliable irrigation reduces agri productivity |
| | - Rationing of farm power supply | Virtual feeder segregation; farmers get farm power for 6-8 hours/day | [-] Ineffective rationing; high hooking; high AT&C losses [-] Frequent tripping, transformer burn-out | [-] Farmers unhappy with farm power supply regime | [-] Lac of reliable power/irrigation increases production risk [-] High cost of pump maintenance and repair |
| Rajasthan Solar Irrigation Pump (SIP) Promotion Scheme | - Farm power supply offered on rotational basis to flatten load curve | Unreliable and poor quality farm power supply | [-] Auto-switches; wastage of farm power | [-] Auto-switches; wastage of groundwater | [-] Auto-switches; sub-optimal farm output |
| | - 2010: 87% capital subsidy for adoption of 2-3 kWp SIPs | Replace dirty diesel and subsidized electric pumps with 'low-capacity', 'clean-energy' SIPs; - Reduce irrigation cost, especially for small and marginal farmers - Free farmers from unreliable and often poor-quality grid power supply; - Increase agricultural output | [+] Electricity utilities save (some) future farm power subsidies [-] Small SIPs complement diesel and electric pumps, rather than replacing them | [-] SIPs offer high-quality, day-time, zero marginal cost farm power to farmers, leading to inefficient water use and groundwater over-exploitation [-] High cost of irrigation due to low capacity utilization of off-grid SIPs | [+] Reduction in irrigation cost [+] Improved cropped and irrigated area; agricultural output; profitability |
| | - 2015: 70% capital subsidy for adoption of 2-5 kWp SIPs | | | | |
| | - 2018: 60% capital subsidy for adoption of 2-10 kWp SIPs | | | | |
| - 2019-20: More capital subsidy for even more off-grid SIPs under PM-KUSUM | | | | | |



CHAPTER THREE

BUSINESS MODELS

3.1 INTRODUCTION

1. The energy-water-agriculture nexus has trapped farmers, power utilities, consumers and governments in an inefficient low-level equilibrium. Despite significant efforts invested at research and policy levels to solve this, most of the solutions proposed in the past suggested removing incentive distortions by withdrawing power subsidies and reintroducing pricing for agricultural power and water. Conceptually, these approaches are the clearest, but they are destined to fail. Instead, any viable approach to change the status quo needs to acknowledge and work with four realities: first, that farmers are reluctant to relinquish access to subsidized power, even when utilities promise supply-quality improvements; second, that political decision makers face political difficulties in implementing a rational price regime for agricultural power supply because it is hugely unpopular; third, that rural prosperity is largely driven by the irrigation economy in which groundwater plays an increasingly important role both through the provision of direct benefits to farmers but also to multiplier effects via local markets; and four, the market liberalization and diversification of agriculture would be a slow process.
2. This Study examined different business models for energy-driven interventions, including some



recent pilots. Gujarat (Columbia Water Center), Rajasthan (Jameel Poverty Action Lab) and Punjab (World Bank) have piloted variants of Direct Benefit Transfer of Electricity to agriculture for the grid-connected agriculture consumers. Lessons learnt from several past initiatives to address the energy-water-agriculture nexus reviewed in a 2015 World Bank²¹ report were considered for this Study. Given the right incentives for saving energy (payment of ₹ 4/kWh) farmers enrolled in the pilot in Punjab have shown energy savings in the range of 10% to 30%. A major factor for energy savings has been the daytime and more reliable power supply. When implemented at scale, the DisComs cannot provide daytime electricity supply to all agriculture consumers participating in DBTE.

²¹. “Direct Delivery of Power Subsidy to Agriculture in India” (Chapter 4) and “Deep Wells and Prudence” (2010) provide a good review of several initiatives that have been tried over the last decade. <https://www.esmap.org/node/55823>; and <http://documents.worldbank.org/curated/en/272661468267911138/pdf/516760ESW0P0951round0Water129101110.pdf>

Metering, billing, collection, management of supply to agriculture and governance of feeders remains a challenge in the prevailing political economy context. Rising recurring subsidy for power supply to agriculture continues to pose an unsustainable fiscal burden. However, falling prices of solar panels have thrown up opportunities for its more extensive use in decentralized distributed generation mode and provide reliable daytime electricity supply.

3. In addition, the recurring subsidy can be replaced by a one-time capital subsidy. Three alternatives that have been tried are: (a) Sub-station size Solar Power Plant. Maharashtra (PRAYAS) have tried a sub-station size public private partnership model of solar power plant; (b) Off-grid Solar Irrigation. Many states, including Rajasthan had launched a scheme of subsidizing solar irrigation for those who could not be given electricity supply from the grid; and (c) Grid-connected Solar Irrigation. International Water Management Institute and, later, National Dairy Development Board, have piloted grid-connected solar irrigation that enables better capacity utilization of the solar panels by selling surplus electricity to the power distribution company which is being scaled up by Government of Gujarat as Suryashakti Kisan Yojana (SKY). The Government of India has combined all the three solar irrigation models into a scheme called “Prime Minister Kisan Urja Surakhsha evam Utthan Mahabhiyan” (KUSUM) announced in July 2019. These business models use a variety of institutional arrangements for implementation. These experiences led the authors to identify for analysis four business models that hold promise to achieve some of the key objectives of this report - Direct Benefit Transfer of Electricity, and three components of KUSUM scheme (Decentralized distributed solar power plants closer to rural feeders, Off-grid solar irrigation, and Grid-connected solar irrigation).
4. The KUSUM scheme has three components focusing on sub-station level solar plant (Component A), off-grid solar irrigation (Component B), and conversion of grid-

connected irrigation pumps to grid-connected solar irrigation (Component C)²². In brief, the key elements of these components are:

KUSUM-A

- (i) Farmer collective, or DisCom, or private sector can implement a 0.5 to 2 MW size solar power or other Renewable Energy power plant (Renewable Power Generator “RPG”) to meet the demand at an 11kV sub-station;
- (ii) DisCom is required to purchase power either at a competitively bid tariff or pre-determined feed-in-tariff under a 25-year duration PPA, and give a “must run” status to the power plant;
- (iii) DisCom to guarantee payment to the RPG through Letter of Credit or Escrow account;
- (iv) DisCom would get a performance-based incentive of ₹ 0.4/kWh or ₹ 0.66 million/MW from Government of India;
- (v) In case of investment by a private sector developer, lease rentals for land to be paid either based on land or on energy generated.

KUSUM-B

- (i) Eligibility threshold for the scheme is replacement of existing diesel agriculture pumps up to the capacity of 7.5 HP in areas where grid supply is not available;
- (ii) Solar panels capacity in kWp up to twice the size of connected load can be subsidized i.e. for a 7.5 HP connected load the farmer can get subsidy for solar panel up to a capacity of 15 kWp;
- (iii) Farmer is free to install solar panels of capacity higher than 15 kWp but the Government of India subsidy would be limited to 15 kWp
- (iv) Central Financial Assistance and State Financial Assistance of up to 30% of benchmark or tender cost would be provided to the farmer who must finance the remaining 40% from equity and loan.

KUSUM-C

- (v) Eligibility threshold for the scheme is grid-connected irrigation pumps up to the capacity of 7.5 HP;
- (vi) Solar panels capacity in kWp up to twice the size of connected load can be subsidized i.e. for a 7.5 HP connected load the farmer can get subsidy for solar panel up to a capacity of 15 kWp;

²² <https://mnre.gov.in/sites/default/files/webform/notices/KUSUMguidelines.pdf>

- (vii) Farmer is free to install solar panels of capacity higher than 15 kWp but the Government of India subsidy would be limited to 15 kWp;
 - (viii) Surplus power is to be sold to the DisCom at a tariff determined by the respective Electricity Regulatory Commission. *Though it is not clear whether selling surplus power to DisCom is a requirement or an option, but it stands to reason that until a vibrant market emerges for renewable power, DisComs should help buy the surplus and catalyze the market;*
 - (ix) Individual farmers, as well as farmers collectives are eligible to participate in the scheme;
 - (x) Central Financial Assistance (CFA) is offered up to 30% of benchmark or bid cost whichever is lower (CFA is 50% for North-East states, hill states and Island Union Territories);
 - (xi) States are expected to provide a subsidy (State Financial Assistance- SFA²³) of 30%;
 - (xii) Balance 40% (or 20% as the case may be) to be provided by the participating farmers as part equity and part borrowing from the banks.
- (iv) Contribute to the target of doubling farmer income;
 - (v) Increase use of renewable energy;
 - (vi) Improve efficiency and effectiveness of electricity subsidy to agriculture.
6. One of the major production risks faced by the farmers is inadequate and unreliable irrigation. Free or concessional power supply coupled with inability of the power companies to supply adequate, good quality and reliable power supply, synchronized with the needs of agriculture, has been a key reason for low water productivity and over-extraction of groundwater. Several attempts at improving power supply, community-based groundwater management, and encouraging farmers to shift away from water-intensive crops have had limited impact. Rapidly declining prices and improving productivity of solar generation has opened up an enormous opportunity. Though promotion of off-grid solar has helped alleviate the problem of reliable power supply, it has led to further over-extraction of groundwater since a stand-alone solar irrigation pump has no other utility except extracting water. Connecting the solar irrigation pump to the grid to sell surplus electricity provides an additional source of income for the farmer and increases economic return on the solar investment which has been amply demonstrated by IWMI through a pilot project in Dhundi (Solar Power as a Remunerative Crop-SPaRC) and NDDDB's solar cooperative in Majkuvu (Gujrat). These experiences were shared with various departments of Government of Rajasthan (energy, agriculture, water, finance), power companies, field officials implementing Rajasthan Agriculture Competitiveness Project and the farmers. Farmers response was very enthusiastic when they realized that not only would they get reliable day time power but also an opportunity to earn non-agriculture income. This Study therefore focuses on grid-connected solar irrigation.

It is mandatory to use indigenously manufactured solar panels with indigenous solar cells and modules. The balance of system also must be indigenously manufactured²⁴.

3.2 OBJECTIVES OF THE BUSINESS MODELS

5. The choice of business model depends on the objectives the government wants to achieve. The Study has identified six key objectives, one or more of which drive these business models:
- (i) Provide reliable, affordable and adequate electricity supply for irrigation to increase agricultural production and reduce its production risk;
 - (ii) Improve energy efficiency and conserve electricity;
 - (iii) Improve water productivity and conserve water;

²³. The term State Financial Assistance is not used in the government notification, but authors have introduced it as a parallel to CFA.

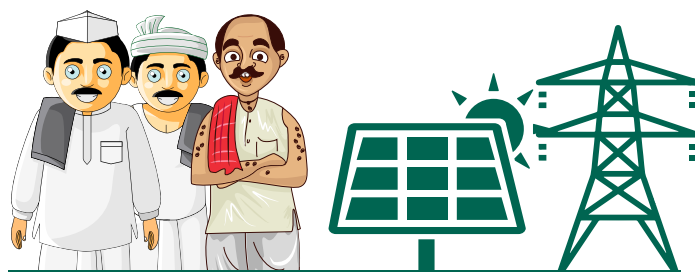
²⁴. Manufacturing of solar panels in India is limited, given the availability of inexpensive imports, mostly from China. The market share of domestic manufacturers decreased from 13% in 2015 to 7% in 2018. As of September 2017, the average price for imported module was US\$0.39/Watt compared with US\$1.44/W for domestic product and a large share of the existing manufacturing capacity stands idle. (IRENA: Renewable Energy and Jobs Annual Report 2018)

3.3 DESCRIPTION OF THE BUSINESS MODELS

7. Rajasthan has been a pioneer in off-grid solar irrigation that it launched in 2011-12. Some researchers (Bassi, 2015, Kishore et. al., 2014) have pointed out that off-grid solar investment is uneconomic due to low capacity utilization, and farmers do not consider the adverse impact on water since there is very little use, other than for water extraction, of surplus power generated by off-grid solar. Rajasthan has already piloted a DBTE scheme in three feeders with the assistance of Jameel Poverty Action Lab (JPAL) and their experience has been less than satisfactory for a combination of reasons and the government has not replicated or scaled up that scheme. Considering the learning from past initiatives of Rajasthan and positive outcomes of grid-connected solar irrigation in Gujarat which led to the Government of India's KUSUM scheme, this report has focused on components A and C of KUSUM scheme. KUSUM-A can achieve some of the objectives while KUSUM-C can potentially achieve most of the objectives enumerated in Table 3.1. Three implementation models for A and C components of KUSUM scheme were evaluated: (i) Public-Private Partnership (for KUSUM-A) and (ii) Individual Farmer, (iii) Farmer Enterprise Aggregator for KUSUM-C. Since Farmer Enterprise is a cumulative of individual farmer entrepreneurs, the financial analysis of (ii) and (iii) is combined into Business Model-2 for the purpose of presentation. The two business models, which are predominantly based on KUSUM scheme with some additional elements proposed by this Study are described below:

8. Business Model-1 (BM1): Public-private-partnership (PPP) for implementing KUSUM-A based on the following assumptions:

- (i) Electricity is sold to the DisCom at a feed-in-tariff equal to average power purchase cost (APPC) of the DisCom or Regulatory Commission determined tariff;



To be technically and financially sustainable, grid-connected solar power requires a majority of farmers served by that feeder (say 70 percent or more) to participate in the scheme

- (ii) Metering, billing, and collection from consumers continues to be carried out by the DisCom;
- (iii) Land for the solar plant is provided by the village Panchayat or at the DisCom sub-station free of cost for the economic life of the installation;
- (iv) To encourage efficiency in energy and water consumption and conserving water, the DisCom should offer a scheme of fixed allocation of electricity to farmers and benefit sharing for saving energy. The energy allocation could be based on preferably land holding or connected load.

9. Business Model 2 (BM2): Grid-connected, farmer-owned, FE aggregated model for implementing KUSUM-C through farmer cooperative or farmer producer company (collectively called Farmer Enterprise-FE). DisCom would segregate the feeder for supply to agriculture pumps. Farmers would have net meters installed for proper accounting. This is essentially an enhanced KUSUM-C scheme. The model is based on the following assumptions:

- (i) Farmers install solar panels and the irrigation pump on their own land;
- (ii) Farmers are offered a capital cost buydown of solar capacity in kWp 1.5²⁵ times the size of their connected load in HP up to a maximum of 15kWp

²⁵. Though KUSUM-C scheme offers replacement by 2 times the size of current load, the report has kept it at conservative 1.5 times keeping in mind the constraints of farmer contribution and state government subsidy. In Gujarat, farmer contribution at even 5% posed a challenge.

TABLE - 3.1: COMPARATIVE OVERVIEW OF THE BUSINESS MODELS

| Business Model/ Objectives | DBTE for Agriculture | KUSUM- Component A | KUSUM- Component B | KUSUM- Component C |
|---|---|---|---|--|
| | DisCom supply | DisCom supply through Sub-station size solar power plant owned by PPP/DisCom/FPO | Farmer-owned off-grid solar irrigation pump | Farmer-owned, FPO- aggregated, Grid-connected solar irrigation |
| Reliable Electricity for Irrigation | Low | High | High, production only for self- consumption | High, farmer becomes a “prosumer” |
| Save Electricity | High | Unlikely, on the contrary consumption of electricity and water extraction may increase | Unlikely, marginal cost of electricity is zero | High, Production is much higher than self-consumption; remunerative feed-in-tariff can encourage energy efficiency |
| Save Water | Moderate | Unlikely On the contrary groundwater extraction may increase due to reliable daytime electricity supply | Unlikely On the contrary groundwater extraction may increase to maximize return on investment | High If the feed-in- tariff is set at higher than value of water in agriculture |
| Doubling Farmer Income | No, only marginal impact | No, only marginal impact through increase in agriculture productivity due to daytime reliable electricity supply | No, only marginal impact through increase in agriculture productivity due to daytime reliable electricity supply | High Counter-cyclical, climate-resilient farm income from sale of power, increase in agriculture productivity due to day time reliable electricity supply |
| Increase use of Renewable Energy | Unlikely | High | High | High |
| Efficiency and Effectiveness of Electricity Subsidy | Moderately High if robust energy accounting and feeder governance improved | Unlikely no change in commercial relationship between farmer and DisCom | High a one-time capital subsidy in green investment but high economic cost due to low capacity utilization | Substantial recurring subsidy is replaced by a one-time capital subsidy, high return on subsidy for the government (exceeding 30%) |

Source: Authors

- (iii) DisCom (or Renewable Energy Buyer) would buy surplus power at average power purchase cost (APPC);
- (iv) To be eligible, at least 70% of the farmers (or connected load) are required to form a collective in the form of a Solar Cooperative or a Farmer Producer Company (collectively called Farmer Enterprise (FE) in this report);
- (v) Power Purchase Agreement is signed between the DisCom and the FE. Net meters are installed on farm SIP and at the sub-station. Point-of-sale and point-of-delivery are the 11kV side of the sub-station;
- (vi) Feeder maintenance from outside the boundary of the sub-station is managed by the FE; and
- (vii) Drought Premium. During a period of drought, the government may pay a “drought premium” on surplus power to encourage optimization of use of scarce water and quick delivery of drought relief. Farmers would be provided technical assistance to estimate how to maximize the value of water during drought through competing uses for saving crops, protecting fodder for the cattle, and drinking water for human and cattle consumption.

connection is replaced by 11.25 kWp solar system (a multiplier of 1.5 as against 2, allowed by the scheme).

- (ii) Cost of solar system (panels, controller, grid tie-inverter, submersible pump of 7.5 HP, net meter, miscellaneous at 7% of cost) is taken as ₹ 47,064/kWp for an 11.25 kWp system. If the size of the solar system is increased, the per kWp cost would come down.
- (iii) Average generation is assumed as 5.5 hours equivalent peak during an 8 hour of solar irradiance for 300 days of sunshine. Annual generation per kW is assumed to be 1650 kWh.
- (iv) Technical losses are taken at 6% of generation in the farm system and overall 10% for the feeder.
- (v) For Business Model-1, it is assumed that the PPP would be financed through 30% equity and 70% commercial loan for seven years at 10%.
- (vi) Business Model-2 assumes: (a) the financing structure envisaged in KUSUM-C, (b) net metering at farm and substation levels, (c) farmers are paid for net surplus energy sold.

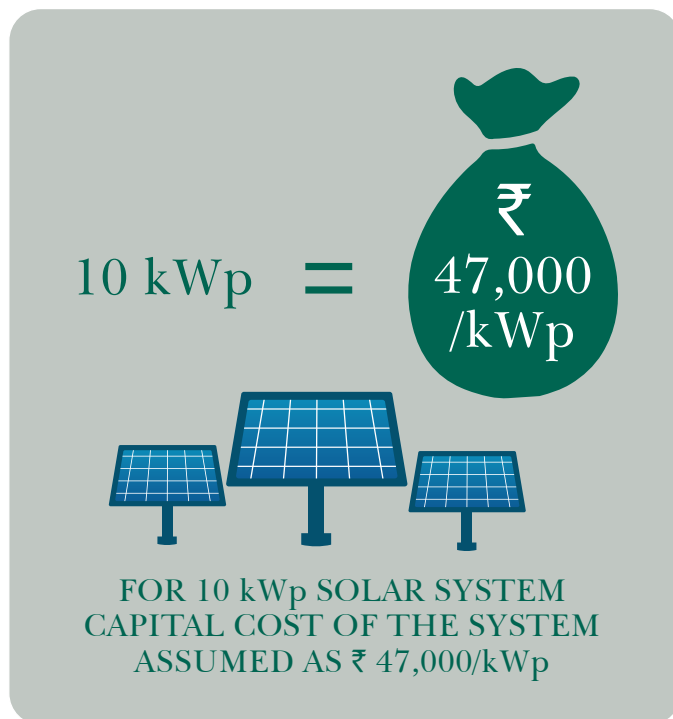
3.4 FINANCIAL VIABILITY OF THE MODELS: A TRIPLE WIN FOR FARMERS, GOVERNMENT AND THE DISCOM

3.4.1 Financial viability

10. Financial viability and environmental sustainability of solarizing irrigation critically depends on the quantity of surplus electricity available for sale and the feed-in-tariff. Therefore, it is important that the assumptions underlying the financial analysis of the investment are clearly understood by the investing farmers and the decision makers. Let us start with the assumptions:

11. Assumptions underpinning the two Business Models

- (i) Average connected load in HP is replaced by 1.5 times in kWp. For example, a 7.5 HP



3.4.2 Summary of Financial Analysis of Select Feeders

12. The RACP had prepared Cluster Agriculture Competitiveness Plans for 17 clusters. Two of these clusters dominated by groundwater irrigation - Sangod in Jaipur DisCom and Pisangan in Ajmer DisCom- were selected for the Study and an 11 kV rural feeder was taken as the unit of analysis. Financial analysis of four 11 kV feeders²⁶ - Dobadi, Laxmipura, Nandswaipura, and Ganaheda- was carried out. In terms of number of agriculture and non-agriculture connections and load, Dobadi is the smallest and Ganaheda the largest feeder. Groundwater level in Dobadi is about 50 meters while in the other three it ranges between 31 to 39 meters. Ganaheda has 400 agriculture connections while other feeders have less than 130 connections. Ganaheda has 45 unmetered consumers while on other feeders all agriculture connections are metered except Dobadi which has 5 flat tariff consumers. Ganaheda seems to be an outlier in the sample. Laxmipura feeder is the most representative feeder in the Study area.

3.4.3 Summary of Financial Analysis of Business Model-1

13. Rajasthan Electricity Regulatory Commission issued a draft order on 6th September 2019 for public consultation on proposed tariff for KUSUM-A and KUSUM-C. Assuming the tariff of ₹ 3.14/kWh proposed for KUSUM-A, solarizing the entire feeder of Laxmipura through a private

developer at 1.5 times the current connected load of agriculture consumers, the internal rate of return of the developer does not seem very attractive. At a capital cost of ₹ 34,300 per kWp, financed through 30% equity and 70% debt of a seven-year tenor at 10% per annum, accelerated depreciation and degradation of solar panels at 0.8% per year, the internal rate of return at the proposed tariff is calculated at 8%. Average debt service coverage ratio is 0.57. This is obviously not an attractive investment, unless the tenor of debt is increased, and the cost of debt reduced.

14. One of the major pitfalls of KUSUM-A scheme would be an increase in energy consumption, and potentially of groundwater extraction, by the farmers because of daytime, reliable, continuous supply of electricity. To the farmer, the power supplier continues to be the DisCom at subsidized tariff and the farmer is agnostic to the source of power. The farmer has no, or very little, incentive to save electricity and groundwater. To impede over-extraction of groundwater and contain electricity consumption and power subsidy, the power utility would need to continue the current system of rationing power supply. In the current political economy context, it may become difficult to ration power supply to farmers when it is being generated by a local solar power plant, for which the village community may even be asked to provide land. A benefit sharing scheme could potentially be grafted on KUSUM-A but the incentives for change in

TABLE - 3.2: KEY CHARACTERISTICS OF THE SELECTED FEEDERS

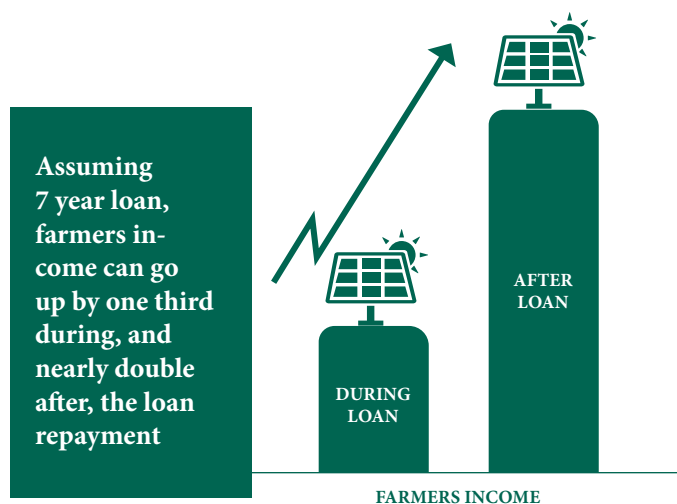
| DisCom | JVNL | | AVVNL | |
|--|--------|-----------|----------|--------------|
| Feeders | Dobadi | Laxmipura | Ganaheda | Nandswaipura |
| Agriculture load (HP) | 413 | 1,184 | 2,666 | 1,213 |
| Average Landholding (Ha) | 2.02 | 3.00 | 1.75 | 5.00 |
| Depth to groundwater (m) | 52.0 | 31.0 | 38.5 | 39.5 |
| No, of agriculture connections | 60 | 132 | 404 | 129 |
| Size of solar system (kW) at 70% participation | 433 | 1,243 | 2,799 | 1,274 |

Source: DisComs, Govt of Rajasthan

²⁶. These feeder are: Dobadi and Laxmipura in Sangod sub-division, District Kota, in Jaipur Vidyut Vitran Nigam Ltd (JVNL) and Nandswaipura and Ganaheda in Pisangan sub-division, District Ajmer, in Ajmer Vidyut Vitran Nigam Ltd (AVVNL)

behavior of farmers for resource use efficiency and potential for increasing farm income remain weak.

15. From the state government’s point of view, KUSUM-A can be implemented more rapidly than KUSUM-C for augmentation of power generation through other sources. If rapid augmentation of generation capacity and reducing upstream network losses, or providing daytime supply to agriculture is the primary objective, then KUSUM-A would be an appropriate choice. However, with large stranded thermal generation capacity²⁷ in the power sector, rapid and large augmentation of capacity would further increase the financial woes of the DisComs, and is not the key driver of policy choice of solarizing irrigation. Overarching objective of Rajasthan, and many other states in India, would be to increase reliability of irrigation to reduce farmers production risk, save water, and increase farm income. Enhanced KUSUM-C presented in Business Model-2 offers a very good opportunity to achieve all of these objectives.



3.4.4 Summary of Financial Analysis of Business Model-2

16. Table 3.3 presents a financial performance metrics of average farmers across all four feeders selected in the Study for analysis. All the performance metrics look attractive for different stakeholders i.e. farmers, state government, the DisComs, and the lenders. For Dobadi, Laxmipura, and Nandswaipura, the internal rate of return for farmers equity is more

TABLE - 3.3: FINANCIAL PERFORMANCE METRICS OF AVERAGE FARMER

| DisCom | JVNL | | AVVNL | |
|---|--------|-----------|----------|--------------|
| | Dobadi | Laxmipura | Ganaheda | Nandswaipura |
| Agriculture load (HP) | 7.5 | 10 | 7.5 | 10 |
| Solar System Size (kW) | 11.25 | 15 | 11.25 | 15 |
| MNRE Subsidy (₹ lakh) | 1.59 | 2.10 | 1.59 | 2.10 |
| State Subsidy (₹ lakh) | 1.59 | 2.10 | 1.59 | 2.10 |
| Farmer Loan (₹ lakh) | 1.59 | 2.10 | 1.59 | 2.10 |
| Farmer’s equity (₹ lakh) | 0.53 | 0.70 | 0.53 | 0.70 |
| RoE for Farmer (%) | 29% | 22% | 6% | 29% |
| Annual Income during loan repayment (₹) | 15,101 | 15,384 | 3,364 | 17,311 |
| Annual Income after loan repayment (₹) | 41,769 | 50,629 | 30,031 | 52,556 |
| Farmer’s IRR (%) | 22 | 18.8 | 16 | 21.1 |
| Annual profit for DisCom/farmer (₹) | 34,952 | 46,241 | 34,768 | 49,908 |
| Annual Saving for State Government/farmer (₹) | 34,620 | 56,526 | 66,466 | 55,170 |
| Return on State Subsidy (%) | 23.7 | 29.9 | 42.3 | 27.6 |

Source: World Bank calculations based on DisComs data.

²⁷. Rajasthan is estimated to have more than 1,700 MW of stranded capacity. <http://www.prayaspune.org/peg/publications/item/335-the-price-of-plenty-insights-from-surplus-power-in-indian-states.html>

than 18%, return on state government subsidy is in the range of 23% to 30%, debt coverage ratio is in excess of 1.4. Cash income for the farmers is estimated to be in the range of ₹ 13,300 to ₹ 19,500 during the debt repayment period of seven years and thereafter in the range of ₹ 45,000 to ₹ 57,000 per year. DisComs annual income is estimated to be in the range of ₹ 29,700 to ₹ 56,000 per farmer per year. The State Government can save in the range of ₹ 34,600 to ₹ 56,500 per farmer per year.

17. Similar figures for Ganaheda feeder are: farmer's internal rate of return on investment at 16%, debt service coverage of 1.06 to 1.15, return on government subsidy of 43%. Average annual cash income of farmer is ₹ 3,300 during debt repayment period and ₹ 30,000 thereafter. Annual income per farmer for the DisCom is estimated at ₹ 34,700 and savings for the state government at ₹ 66,400.
18. Key reasons for the attractiveness of BM-2 are: (a) the difference in the current average cost of supply (₹ 6.97/kWh) and the cost of decentralized solar generation (₹ 3.69/kWh), (b) substitution of recurring government subsidy with a one-time capital subsidy with a payback period of less than four years, (c) sale of surplus generation by the farmer at an attractive feed-in-tariff at 11kV level and reduction in network losses, (d) Central Financial Assistance of 30% of capital cost, and (e) potential efficiency improvement in water consumption by agriculture due to financial incentive of sale of electricity. The financial performance metrics (Table 3.3) would look even more attractive if the value of free self-consumption was added to the farmer's benefit. In the analysis the value of self-consumption of electricity has not been added to the benefits to keep it comparable to the current policy of free power up to an equivalent of ₹ 10,000 per year.

3.4.5 Financial Analysis: DisCom Perspective

19. For evacuation of surplus electricity generation, the DisCom would need to keep the feeder "ON" during day time. If only a small number of farmers participate in the scheme, DisCom may find it difficult to supply and control consumption by a large number of non-participating farmers. As long as the point of sale and point of delivery of

surplus power is the farm gate, any losses and pilferage on the feeder would be borne by the DisCom. However, if the point of sale and point of delivery by the farmer enterprise is the 11kV substation, the losses and pilferage on the feeder would be borne by the farmers. This may also bring down the chances of pilferage of electricity since the culprit would be stealing from his neighbors and not from the DisCom. Immorality of stealing from neighbors would be frowned upon by the community and would attract heavy social sanctions²⁸. The report suggests that the scheme be offered on a feeder only if 70% or more farmers (or load) become a part of the Farmers Enterprise (FE). To encourage higher participation, additional incentive be offered for early enrollment in FE.

20. To understand the financial performance of the FE, it was assumed that 70% of farmers participate, and a power purchase agreement is signed between FE and the DisCom for delivery of power at the 11 kV substation.
21. Table 3.4 presents financial performance metrics of DisComs across all four feeders selected in the study for analysis.

3.4.6 Financial Analysis: Government Perspective

22. The State Government's contribution to the scheme is not a subsidy but an exceptionally attractive investment in infrastructure since the state's contribution of 30% can be recovered in less than four years from the savings of recurring subsidy. However, two significant financial barriers to scaling up rapidly are the 10% equity contribution by the farmers, particularly small and marginal farmers who may find it difficult to provide upfront financing, and the initial commitment and high outlay required by the State Government. It would be desirable to reduce farmer's equity to 5% and increase the loan from commercial banks, which should count the 60% subsidy from the State Government as farmer's equity. Given the constraints imposed by FRBM Act and the shrinking headroom for State Government borrowing, the states may find it difficult to provide 30% upfront subsidy if a large number of farmers start enrolling. Therefore, the Study examined the possibilities of deferred subsidy payment.

²⁸. In one of the meetings with the farmers, they were quick to understand the dynamics and jocularly pointed out that it would stop hooking.

TABLE - 3.4: FINANCIAL PERFORMANCE METRICS OF DISCOMS

| DisCom | JVNL | | AVVNL | |
|---|--------|-----------|----------|--------------|
| | Dobadi | Laxmipura | Ganaheda | Nandswaipura |
| Agriculture load (HP) | 413 | 1184 | 2666 | 1213 |
| Solar System Size (kW)* | 433 | 1243 | 2799 | 1274 |
| MNRE Subsidy (₹ lakh) | 61.15 | 174.27 | 395.24 | 178.60 |
| State Subsidy (₹ lakh) | 61.15 | 174.27 | 395.24 | 178.60 |
| Farmer Loan (₹ lakh) | 61.15 | 174.27 | 395.24 | 178.60 |
| Farmer's equity (₹ lakh) | 20.38 | 59.09 | 131.74 | 59.53 |
| Annual profit for DisCom (₹ lakh) | 14.68 | 42.73 | 87.37 | 44.72 |
| Annual Saving for State Government (₹ lakh) | 14.5 | 52.2 | 167.0 | 49.4 |
| Return on State Subsidy (%) | 24 | 30 | 43 | 28 |

* assuming 70% participation rate.

Source: World Bank calculations based on DisComs data.

3.5 SCENARIO ANALYSIS

23. Three scenarios of financing of Business Model-2 are evaluated:

- (i) Base Case (Upfront subsidy): This is the base case following KUSUM-C scheme described above. In this scenario the cost of investment of each farmer would be financed through a Central Financial Assistance (CFA) of 30%, State Financial Assistance (SFA) of 30%, Commercial bank loan (CB) of 30% and farmer equity (F) of 10%. Commercial banks may finance more than 30% to reduce farmers equity contribution since central and state subsidy is a form of farmer equity in the investment.
- (ii) Scenario-1 (Partially deferred subsidy): This scenario assumes that State Government would provide subsidy equal to only 10% of the cost but facilitate the gap financing of 20% through guaranteeing commercial bank loan to the farmer. The State Government would provide repayment guarantee to the banks. This 20% loan to substitute State Government

subsidy would be paid through an additional tariff (deferred subsidy) labelled “Deferred Subsidy Incentive (DESI)” to be paid by the State Government. Linking the deferred subsidy payment to sale of power keeps the incentives of both the government and the farmer aligned and a stake for the government in ensuring the operation and maintenance of infrastructure and integrity of the PPA, payment risk of the DisCom, and debt service to the commercial banks.

- (iii) Scenario-2 (Fully deferred subsidy). This Scenario assumes 100% debt-financing of state subsidy guaranteed and to be paid through DESI.

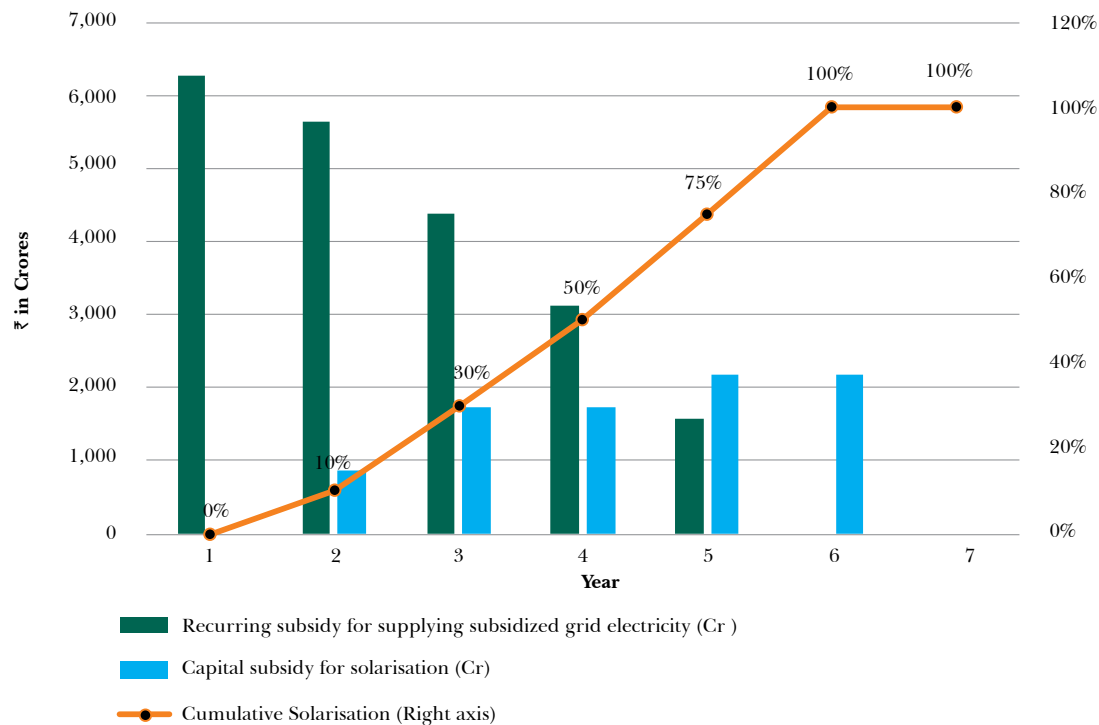
24. DESI is a compensation for servicing the additional debt taken by the farmer to substitute for upfront subsidy from the State Government. In both scenarios 1 and 2, DESI is calculated to keep the cash income of the farmer the same as in the base case. To keep the attention of the decision makers focused on the key issues and analysis, the Study has used Laxmipura in Table 3.5 as a representative feeder to present the scenario analysis.

TABLE - 3.5: LAXMIPURA FEEDER: COMPARISON OF THREE SCENARIOS

| Output Parameter | | Scenarios | | |
|--|-------|-------------------------------|--|---------------------------------------|
| Parameter | Units | Base Case- Upfront subsidy | Scenario 1- Partially deferred subsidy | Scenario 2- Fully deferred subsidy |
| Government of India Subsidy | % | 30 | 30 | 30 |
| State Government Subsidy | % | 30 | 10 | 0 |
| Farmer's Loan (commercial banks) | % | 30 | 30 | 30 |
| Farmer's equity | % | 10 | 10 | 10 |
| Farmer's additional loan for deferred subsidy | % | 0 | 20 | 30 |
| Deferred Subsidy Incentive | ₹/kWh | 0 | 1.88 | 2.82 |
| FARMER | | | | |
| Farmer's IRR | % | 20.31 | 18.36 | 17.70 |
| Debt Service Coverage Ratio, Year 1-7 average | Ratio | 1.36 | 1.23 | 1.20 |
| Annual Income for farmer, Average Year 1-7 | ₹ | 15,384 | 16,404 | 16,914 |
| Annual Income for farmer, Year 8-25 | ₹ | 50,629 | 50,629 | 50,629 |
| Annual Income for farmer, Year 1-25 | ₹ | 40,760 | 41,046 | 41,189 |
| DISCOM | | | | |
| Annual Profit to DisCom (25 Years Average) | ₹ | 42,72,661 | 42,72,661 | 42,72,661 |
| Annual Profit per farmer (25 years average) | ₹ | 46,241 | 46,241 | 46,241 |
| GOVERNMENT OF RAJASTHAN | | | | |
| State Govt Capital Subsidy | ₹ | 1,74,27,675 | 58,09,225 | 0 |
| State Govt Recurring Subsidy, Average Year 1-7 | ₹ | 52,22,973 | 52,22,973 | 52,22,973 |
| Net Benefit to GoR per farmer, INR Average Year 1-7 | ₹ | 56,526 | 49,038 | 45,294 |
| Return on Capital Subsidy by State Government | % | 29.93% | 29.14% | 15.08% |
| IRR (Return on Total Capital Subsidy (State+MNRE)) | % | 14.47% | 14.26% | 8.21% |

Source: World Bank calculations based on DisComs data.

FIGURE - 3.1: IMPACT OF SOLARIZATION ON STATE SUBSIDY



Source: World Bank calculations.

3.6 SOLAR CAPITAL SUBSIDY TO REPLACE RECURRING SUBSIDY IS SELF-FINANCING

25. Replacement of grid-supply by self-generated solar electricity would result in substitution of recurring subsidy from the state government by a one-time capital subsidy. The Return on Subsidy of more than 30% means the State Government could recover the capital subsidy in less than four years. Figure 3.1 shows the interaction between recurring and capital subsidy for Jaipur and Ajmer DisComs for an implementation period of five years to replace 100% of the agriculture load by solar electricity through Business Model 2. A one-time capital subsidy of ₹ 10,700 crore can fully replace a recurring annual subsidy of ₹ 6,200 crore which would continue ad-indefinitum under a business-as-usual approach. If we take 25 years as the economically useful life of a solar panel, a capital subsidy of ₹ 10,700 crore would yield a saving of ₹ 150,000 crore over a period of 25 years. Government could not make a better investment in infrastructure and rural livelihood.

26. Under a Business As Usual situation, the State Government would pay a recurring subsidy of ₹ 31,376 Cr over a period of five years while with solarization over a period of five years when it will continue to pay recurring subsidy for non-solarized customers, it would pay only ₹ 23,477 Cr. Thus, even during the transition period, before the entire agriculture load is solarized, the State Government would save ₹ 10,000 cr.

3.7 SENSITIVITY ANALYSIS

27. Sensitivity analysis was carried out for the base case of Laxmipura feeder on three parameters: (i) Impact of size of SPV on income of farmer, profit to DisCom, and recurring subsidy saving of the State Government (ii) Impact of self-consumption of generated electricity on farmer's income, (iii) Impact of participation rate of farmers on profit of DisCom, and (iv) Impact of feed-in-tariff on the income of the farmer and the DisCom. The outcome of these analyses presented in Figures 3.2 to 3.4, and Table 3. 6 is elaborated below:

3.7.1 Higher the SPV Size, higher the income of the farmer and the DisCom

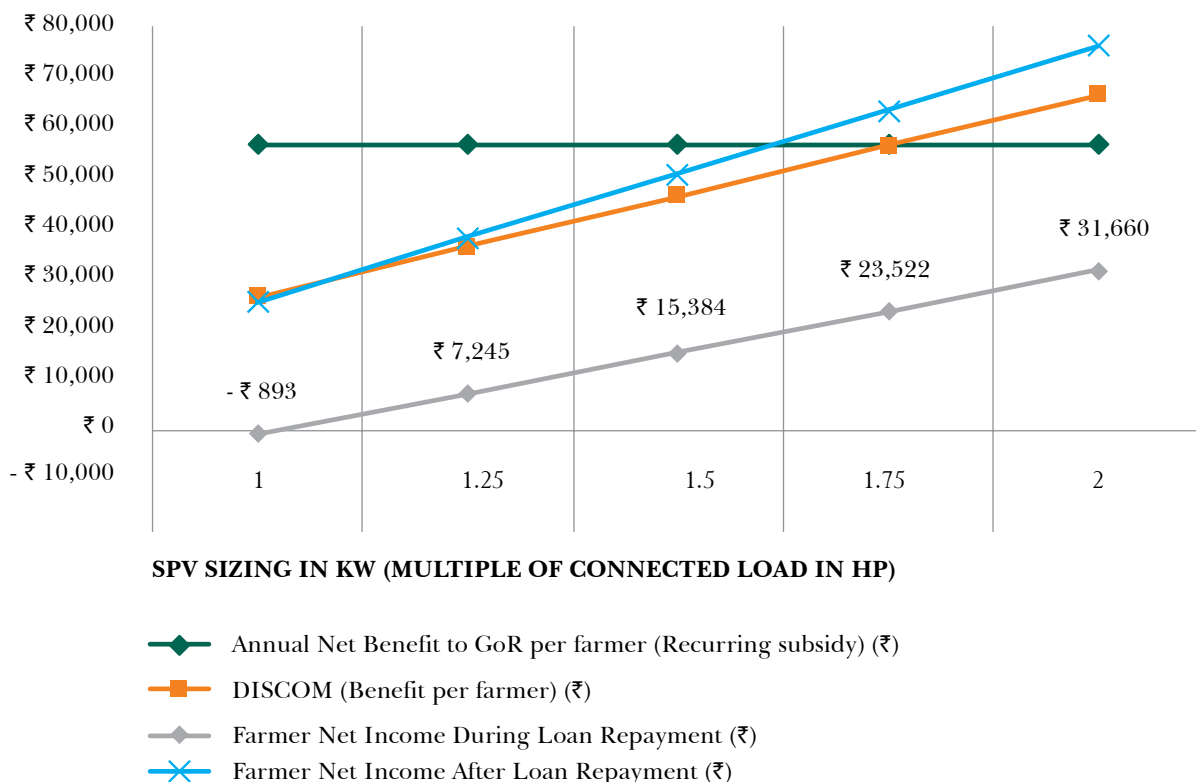
28. In Figure 3.2, the X-axis depicts the multiplier of connected load in HP to decide the size of the SPV and Y-axis the income/profit in Indian Rupees. A multiplier of 1 means that 7.5 HP load is replaced by 7.5 kW of SIP system. The base case scenario in Laxmipura is of 11.25 kW (multiplier of 1.5) that generates a cashflow of ₹ 15,384 for the farmer during the loan repayment period. However, after the loan is paid-off the farmer's income would be ₹ 50,629 which nearly doubles the current annual farm income of an average agriculture household in Rajasthan (₹ 54,000). Therefore, if the State Government follows KUSUM scheme and subsidizes twice the size of connected load, the farmer's income would be more than doubled. Income of the DisCom would also grow with higher size of SIP because of larger volume of cheaper solar energy available near the load center. Since the saving of recurring subsidy by the State Government is linked to current consumption of grid-supplied tubewell, it does not

vary with the size of the SIP. *The government can achieve its objective of doubling farmer income by implementing Business Model-2, and simultaneously increase profitability of the DisCom.*

3.7.2 Lower the self-consumption of generated electricity, higher the income of the farmer.

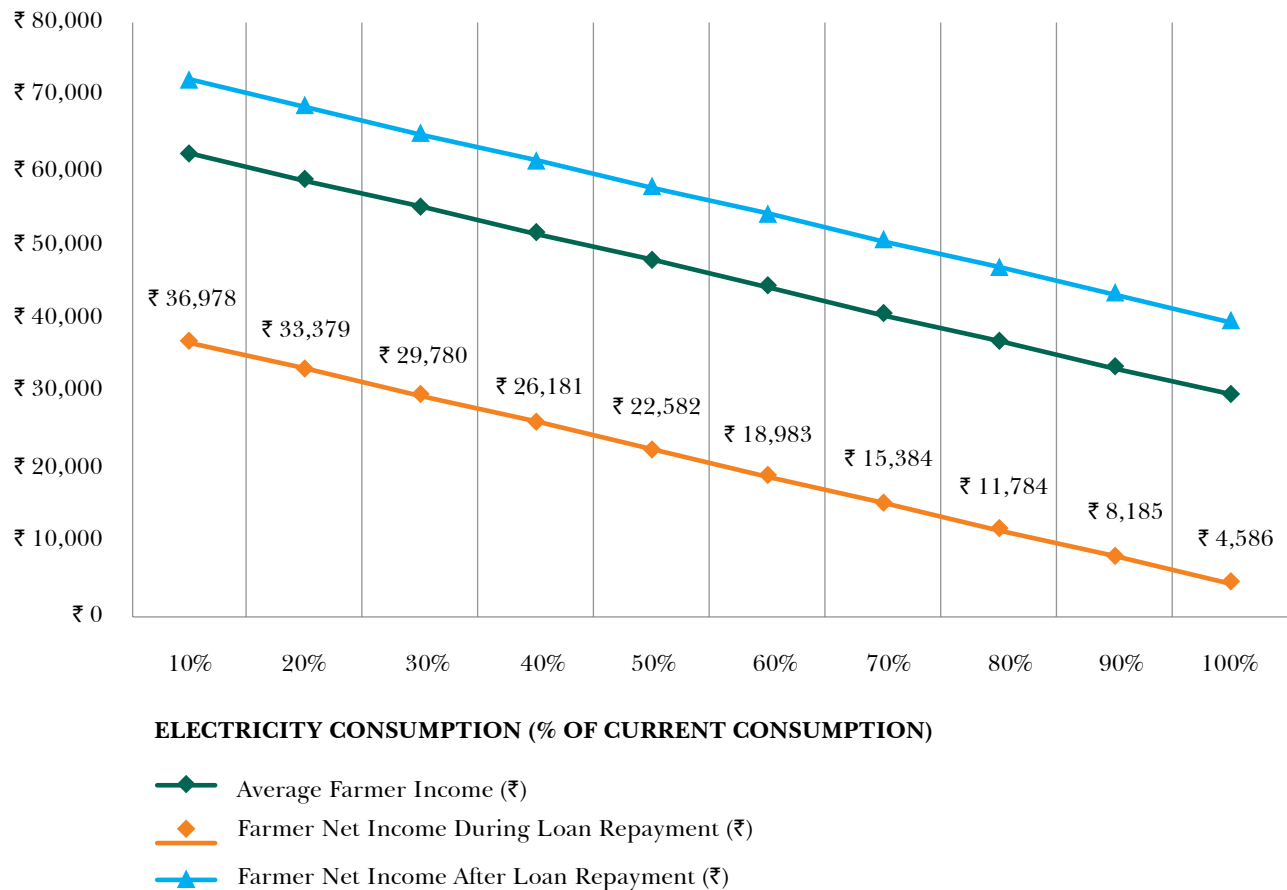
29. In Figure 3.3, the X-axis depicts the percentage of current consumption. 100% means the farmer continues to use electricity at her current level. The base case assumes a reduction of 30% due to efficient pumps, optimization of irrigation due to daytime supply of electricity, and financial incentive from sale of surplus electricity. At 70% of current consumption, the farmer gets a cash income of ₹ 15,384. With adoption of water savings techniques such as laser levelling, optimizing irrigation, micro-irrigation, it is possible to go down to 50% of current electricity consumption. The figure also shows a scenario of drought when the farmer may protect the crop on a small area only for self-consumption and fodder for the cattle. If the farmer reduces electricity consumption to 10% of current levels,

FIGURE - 3.2: SPV SIZING VS. FARM INCOME, DISCOM PROFIT, GOR BENEFIT (ILLUSTRATION: LAXMIPURA, SCENARIO BASE CASE)



Source: World Bank calculations.

FIGURE - 3.3: ELECTRICITY SELF-CONSUMPTION VS FARMER INCOME (LAXMIPURA FEEDER SCENARIO BASE CASE)



Source: World Bank calculations.

she could earn around ₹ 37,000 (as against about ₹ 15,000 in the base case) to partially compensate for the loss of crop. In addition, the government may pay a “drought premium” for the electricity sold. Impact of drought premium on the income of the farmer is shown in Figure 3.5. *Solarization is likely to encourage more efficient use of electricity and, by proxy, of water.*

3.7.3 Higher participation of farmers in the scheme is highly profitable for the DisCom

30. In Figure 3.4, the Y-axis shows the profit DisCom can earn from Laxmipura feeder by promoting SIP. X-axis depicts the participation rate of farmers. DisCom’s annual profit from Laxmipura could go up from ₹ 32 lakh at 50% participation rate to ₹ 58 lakh at 100% participation. To evacuate power from participating farmers, the DisCom

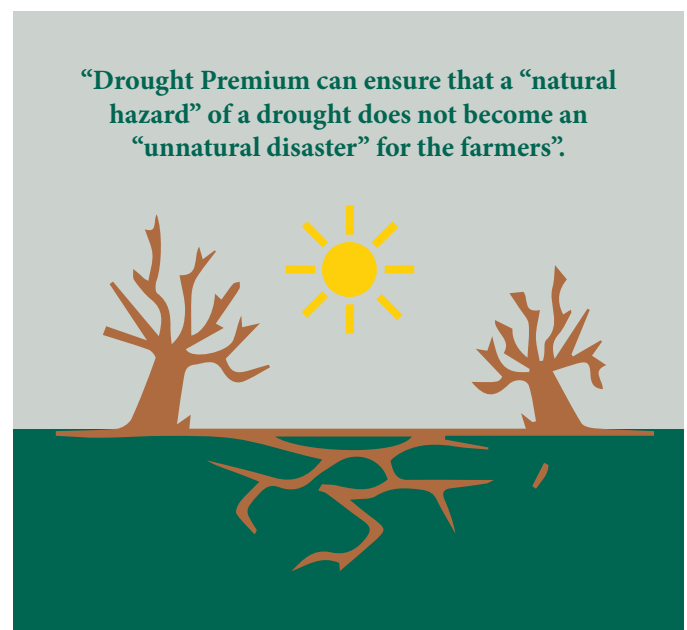
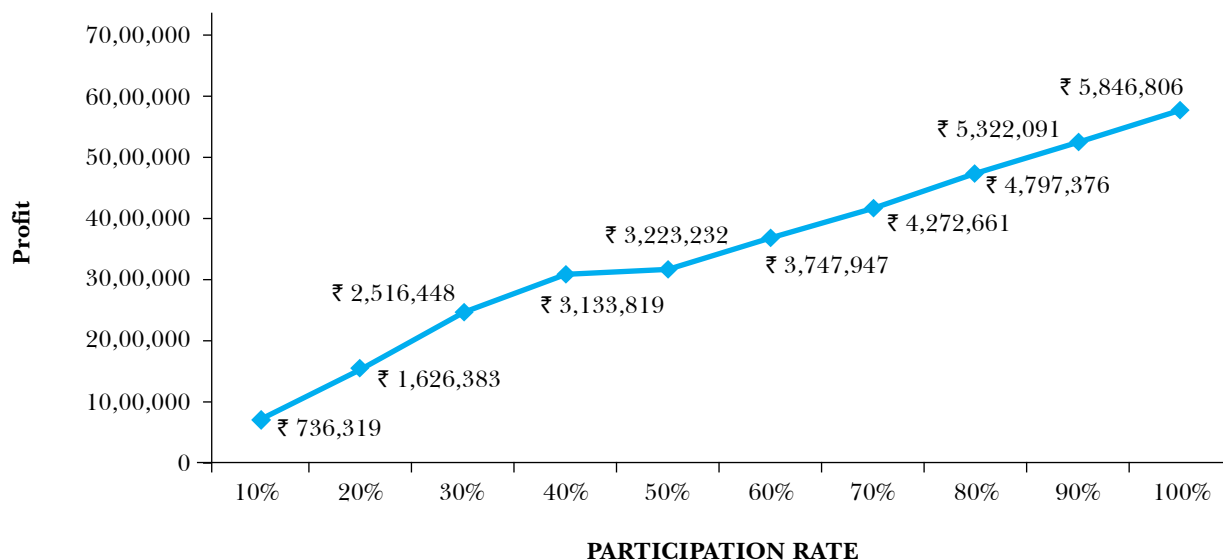


FIGURE - 3.4: DISCOM PROFIT PER FEEDER VS. PARTICIPATION RATE (LAXMIPURA FEEDER)



Source: World Bank calculations.

TABLE 3.6: IMPACT OF VARIATION IN FEED-IN-TARIFF ON INCOMES OF FARMER AND DISCOM

| Feeders | Unit | Lower Case FiT (RERC consultation draft ₹ 3.44/kWh) | Base Case FiT (₹ 3.69/kWh) | Higher Case (₹ 4/kWh) |
|--|------|---|----------------------------|-----------------------|
| Net Income for farmer, Average Year 1-7 | ₹ | 11,445 | 15,384 | 20,339 |
| Net Income for farmer, Average Year 8-25 | ₹ | 47,225 | 50,629 | 54,912 |
| Debt Service Coverage Ratio (average Year 1-7) | % | 1.26 | 1.36 | 1.47 |
| Net Profit to DisCom (25 Years Average) | ₹ | 45,25,662 | 42,72,661 | 39,54,370 |

Source: World Bank calculations.

has to keep the feeder charged (“ON”) during daylight hours. This could potentially lead to a free-loader problem and higher consumption by the non-participating farmers. It is therefore, in the interest of the DisCom to encourage as high a participation rate as possible. *A “prosumer” agriculture sector, instead of being a subsidy burden on the sector and the state, can become a source of profit for the power sector.*

3.7.4 Changes in feed-in-tariff has a higher than proportional impact on farmer’s income and debt service during the loan repayment

31. To estimate the impact of changes in feed-in-tariff, the base-case tariff of ₹ 3.69/kWh (DisCom’s average power purchase cost) was varied to ₹ 3.44 (tariff proposed in RERC’s draft order for public consultation) and increased to ₹ 4/kWh as



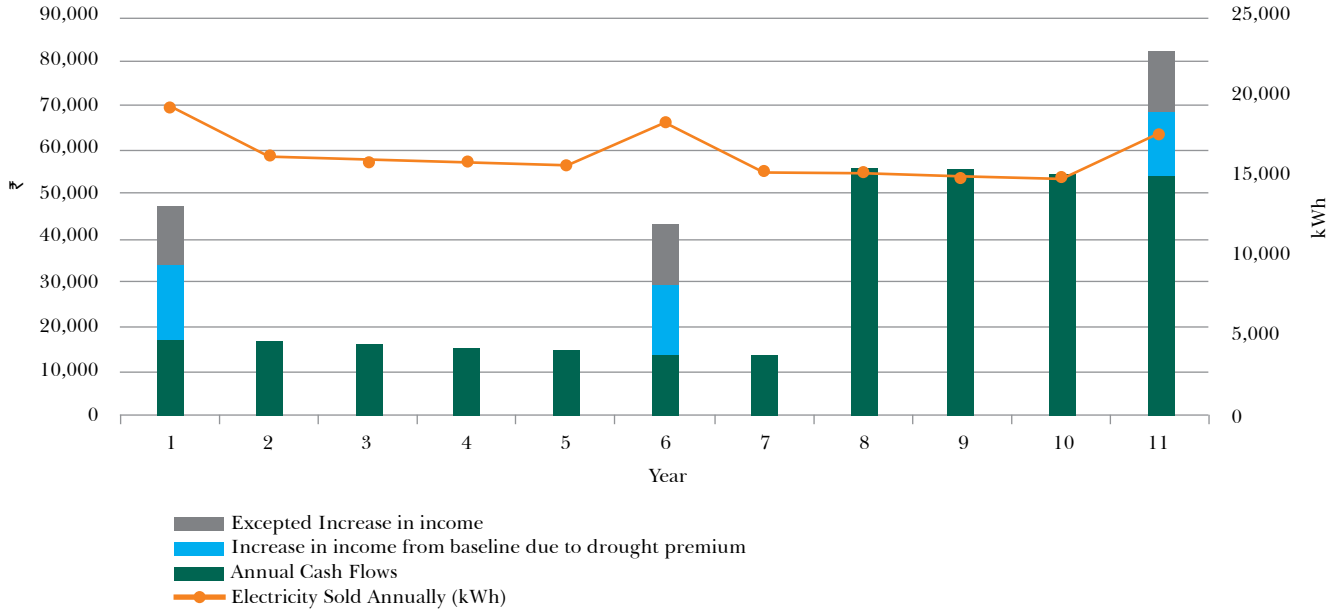
varies negatively but almost proportionately with the changes in the feed-in-tariff.

3.7.5 Drought Premium and Maintaining the Dignity of the Farmer During Natural Hazard

32. Payment of a drought premium of ₹ 1/kWh, coupled with increase in sale of surplus power due to reduced consumption for agriculture, can add significant income to the farmer during a period of distress. Impact of a drought every five years is shown in Figure 3.5. The lower section of the bar (yellow) is the annual income from sale of power in regular years, the middle section of the bar (blue) is the additional income from drought premium on the baseline quantity of surplus electricity, and the top section of the bar (green) is the additional income from higher quantity of sale of electricity (due to reduced consumption for irrigation). A drought premium of Rs 1/kWh can add upto ₹ 30,000 to the income of the farmer in times of distress and compensate for loss of crop. This is not a charity but a payment for goods purchased from the farmer. DisCom also benefits in reducing its demand and buying cheaper electricity during a period when hydro generation drops and stored water is more valuable. Sale of additional power by

the higher bound. Farmer’s income during loan repayment period, and the debt service is highly sensitive to feed-in-tariff. For a 6.8% decrease (from ₹ 3.69 to ₹ 3.44) farmer’s income drops by 25.6% and the debt service coverage ratio drops by 7%. In comparison the income of the DisCom

FIGURE - 3.5: IMPACT OF DROUGHT PREMIUM ON ENERGY SALE AND FARMER’S CASH FLOW



Source: World Bank calculations.

farmers would also be a validation of magnitude of drought in any area. Thus, a “natural hazard” need not become an “unnatural disaster” for the farmer. In summary, the “Drought Premium” is:

- (a) a scarcity premium on water;
- (b) a scarcity premium on electricity since hydropower generation goes down during drought years;
- (c) an instrument of delivery of drought relief quickly and directly to the affected farmers;
- (d) not a charity but a payment for goods sold by the farmer thereby protecting the dignity of the farmer; and
- (e) a measure of impact of drought, and choices made by the farmer, captured by the quantity of surplus electricity sold by the farmer.

3.8 SELL ELECTRICITY OR SELL WATER: WHAT WOULD THE FARMER CHOOSE? PRICING THE POWER

33. In case of KUSUM-A, the price would be discovered through competitive bidding within the ceiling set by the regulatory commission. However, for setting the price of grid-connected solar irrigation (KUSUM-C), the State Government and the regulatory commission must consider the overarching objectives of the government to promote this scheme. As mentioned in Section 3.2, the State Government may have several complementary objectives. Adding decentralized distributed generation capacity, increasing renewable energy generation capacity, improving reliability of power supply to agriculture/rural consumers focus only on energy dimensions of the potential benefits. Emission reduction would be a co-benefit, though this report has not included the value of emission reduction in the feed-in-tariff. KUSUM-C can be a very potent instrument for conserving water and for increasing farm income. Therefore, the State Government and the regulatory commission should consider the following approaches and choose what best meets the policy objectives:

- (i) Cost of generation. Recovering cost of capital and cost of operation and maintenance is

a minimum necessity to attract farmers to accept the scheme and make these investments financeable. Assuming 20% as a reasonable return on equity for the farmer, and a seven-year 10% loan for the 30% debt-financing, it is estimated at ₹ 3.7/kWh.

- (ii) Average Power Purchase Cost (APPC) is a reasonable reference price for substituting other sources of power with decentralized distributed generation. Depending on the proportion of surplus power that can be consumed at the load center, DisCom saves significant amount of network losses (about 20% less losses at the feeder) which is an effective discount on the APPC.
- (iii) Average Cost of Supply is the highest at low voltage at the far end of the extended rural network. By shifting the farm consumption to self-generation and serving other customers from the power purchased at the load center, the DisCom is effectively reducing the average cost of supply for each kWh of consumption met through grid-connected solar generation. However, a price equal to the average cost of supply would be the upper bound that can be paid with no benefit-sharing between the government and the farmer since the entire benefit would accrue to the farmer.
- (iv) Opportunity Cost i.e. Value of Water for Agriculture. The farmer has the option of using the self-generated power for using in her own agriculture activity, or sell water to the neighboring farms, or sell electricity to the renewable energy buyer. It is important to assess the likely impact of the changes from grid to solar power on farmers’ behavior towards groundwater extraction and find the price-point of power that would shift the trade-off in favor of selling electricity instead of extracting more water for agriculture. Annex C, “Value of Water in Agriculture”, provides a methodology for evaluating the trade-off.

34. Annex C shows that the value of water (value of water per cum and per kWh expended on extraction) differ significantly across different crops. Based on



the estimated economics of extracting groundwater, under varying hydrological conditions²⁹, for sale vs selling the solar power spent in extracting this groundwater suggest that it is not economic to extract groundwater for sale in the case of several crops. For one of the three crops, namely barley, for which economics of selling water is favorable, the difference between proceeds realized from sale of water and value realized from sale of power is not very large. In the case of two other crops e.g., wheat and groundnut, the differences are relatively more prominent. Given the significant risks involved in realizing on-time the sale proceeds of water from the buyer, who is usually a marginal or a small farmer, the farmer may opt to sell electricity to the grid and get assured timely payment rather than waiting to get money from the water buyer. The only crop where the value

realized from sale is higher than the value of energy is groundnut. However, groundnut is not cultivated on a very large scale in the study area. Even if farmers extract groundwater to sell, it will be a small quantity.

35. Studies based on empirical evidence have demonstrated that price of energy led to better water-use efficiency and water productivity. One of the studies (Kumar, Scott, Singh, International Journal of Water Resources Development January 2013) built a proxy energy pricing through comparing 600 farmers under 10 categories of water users (flat tariff, owners of diesel pumps, buyers of water from both, in eastern UP and South Bihar and metered farm connections in Gujarat). The study found that in terms of efficiency of water use: water buyers are more efficient than water

²⁹. To illustrate, in the study area in Pisangan cluster, the main water bearing formation is Alluvium followed by Schist. In Sangod cluster, the main water bearing formation is Shale of Vindhyan Super Group. In general, the shale in the cluster is lying below alluvium. Thickness of the alluvium varies between 5 meters to 10 meters.

sellers, diesel water pump users are more efficient than electric pump owners, and that metered electricity connection owners are more efficient than flat-tariff consumers.

36. The data for north Gujarat shows that the pump owners with metered connections, use much less water per hectare of land (304 hours per year) as compared to their flat-rate counterparts (more than 440 hours per year). This represents a 30% reduction in pumpage per unit area. The difference in aggregate pumping is much greater between farmers with meters and those without meters. Such a high reduction in water usage per unit of cultivated land, which is disproportionately higher than the reduction in net return per unit of land, is made possible through high improvements in water productivity in economic terms (Kumar et al., 2011). In spite of the slight reduction in pumping, the net return from unit area of land was found to be higher for water buyers in eastern UP and the south Bihar plains. For instance, in the case of water buyers of electric well commands in eastern UP, the net income was INR27,570/ha, while it was INR24,880/ha for well owners. Similarly, in the case of water buyers in diesel well commands, the net return was INR18,075/ha against INR14,528/ha for diesel well owners. This is achieved through high improvement in water productivity through selection of less water-consuming and higher-valued crops (Kumar et al., 2011). This
- indicates that introducing a marginal cost for water and electricity promotes not only efficient use of water, as manifested by higher farm-level water productivity, but also more sustainable use of water.
37. A recent pilot implemented by Punjab since June 2018 which pays an incentive of Rs 4/kWh to farmers for saving electricity has demonstrated energy savings of about 30% and water savings of 20-30%. In a few demo farms adoption of new irrigation and agriculture practices have shown even higher savings. Though it is a small sample, it shows the potential behavioral response of farmers to right incentives. Given the right incentives, it is possible to improve efficiency of use of electricity and groundwater.
38. Access to solar power at the currently prevailing prices and costs is unlikely to result in significantly increased sales of water even through informal water market transactions and adversely impact groundwater extraction. Nevertheless, it is difficult to predict behavioral response of farmers to the dynamic interplay of hydrogeology; value of water in agriculture; production, market and price volatility risks of agriculture; and financial incentive of feed-in-tariff. Implementing a few pilots in different agro-climatic-groundwater zones would help in developing a better understanding of this interplay and recalibrate the program of solarization of irrigation at scale.



CHAPTER FOUR

INSTITUTIONAL MODELS AND IMPLEMENTATION ARRANGEMENTS

1. The design of any program is as good as its execution. A fit-for-purpose implementation arrangement and institutional mechanism should be able to achieve speed, scalability, and sustainability of the scheme. Since farmer engagement and mobilization is the bedrock of this program, the state government would be well advised to put in place the necessary institutional capacity and skill-set. For Business Model 2, involvement of private sector to mobilize and create a Farmer Enterprise (FE), and supply, install, and maintain solar systems could be a good option to rapidly roll out the scheme. However, civil society organizations working actively in rural areas could also be engaged to create awareness, mobilize farmers, and assist in formation and registration of an FE. A robust monitoring and evaluation mechanism should be put in place to assess the impact on underlying key variables to enable the government to re-calibrate the scheme as it is rolled out in a phased manner. Incentives matter but right institutions make it better.

4.1. INSTITUTIONAL MODELS

2. Three implementation models were evaluated: (i) Individual Farmer, (ii) Farmer Enterprise Aggregator, and (iii) Public-Private Partnership. Each of these is briefly described below:

(i) Individual Farmer would be responsible for purchase, installation, operation and maintenance and financing of the solar system. Point of Sale (POS) and Point of Delivery

(POD) are the farm gate but a portion of feeder losses, say 6% are borne by the farmer. DisCom would be obligated to keep the feeder “ON” during the daylight hours and based on net-meter pay the farmer directly into her bank account. Farmers may need to be given training to operate and carry out routine maintenance of the system.

(ii) Farmer Enterprise Aggregator (Farmer Producer Company/Cooperative) would be formed with at least 70% of the farmers (or the load) served by a feeder participating as members. Farmers would purchase, install, operate and maintain, and finance the solar systems installed on their farms. They would also share the costs of maintenance of common grid infrastructure up to the delivery meter of the feeder. Farms and the feeder would be net-metered, the difference between the two and the normative technical losses on the feeder is considered as consumption by the non-participating farmers who continue to be the customers of the DisCom. FE would be responsible for aggregation of energy from the participating farmers and sign a power purchase agreement with the DisCom. Point of Sale and Point of Delivery would be the net-meter on 11 kV side of the substation. FE would also be responsible for maintenance of the feeder, and internal energy accounting of FE members. Standardized contractual documents for registration of FE, standard operating procedures, power purchase agreement, feeder maintenance contract,

should be made available by the government. Private sector, retained by the government through competitive bidding process, can play a very important role in mobilizing farmers, creation of FE, facilitating borrowings from the banks, supply and installation of SIP systems. Licensed contractors can be engaged by the FE to maintain the feeder. FE can approach NABARD-created Small Farmers Agribusiness Consortium (SFAC) which operates a Credit Guarantee scheme to mitigate risk of financial institutions to lend to FEs and offers a matching equity grant of upto ₹ 10 lakh to capitalize an FE. NABARD-operated “Producers Organization Development Fund” can also finance share capital of members on a matching (1:1) basis up to a maximum of ₹ 25,000 per member of FE. This could enable farmers to put in equity of only 5% and obtain concessional financing for the remaining 5%. Annex F provides a comparative overview of the FPC and Cooperative. A practical option would be to create and register an FPO which is much quicker to create and easier to operationalize and convert it into an FPC at a later stage.

- (iii) Public-Private Partnership model is useful for sub-station level solar power plant. Private/Public sector can be invited by the DisCom through competitive bidding to install solar power plant of a capacity higher than the current connected load of the feeder. Land may be provided free of cost, for the duration of the techno-economic life of the plant, either at the sub-station or made available by the Gram Panchayat/Gram Sabha as appropriate. Entire generation would be sold to the DisCom or a renewable energy buyer. Farmers would be provided daytime supply and would continue to be the customers of the DisCom who will meter, bill, and collect from the farmers. To improve efficiency in consumption of electricity and water by agriculture, the government may include a DBTE scheme for the farmers by allocating a seasonally-adjusted fixed amount of electricity to each agriculture customer and provide them incentive for consumption below the allocation.

4.2 COMPARATIVE EVALUATION OF INSTITUTIONAL MODELS

3. This Section presents the pros and cons of the three institutional models. Many variants are possible within these three e.g. PPP could be with the private sector, a central or state public undertaking, farmer enterprise, or even DisCom could invest in a solar power plant on its own and claim the subsidy from the central government. Similarly, in case of a FE model, the off-taker could be a RPO buyer or a private sector aggregator who may buy the surplus for its own consumption at a different location by using the transmission network. Those variants are not discussed in this report, but many such innovations would emerge once the governments are able to demonstrate the technical and commercial viability of grid-connected solar irrigation. Possibilities of converting millions of farmers into non-agriculture entrepreneurs (power producers) are endless.
4. If the scheme is offered on an individual farmer basis it could be deployed rapidly. Owning the assets and installing it on their own farms would create a strong incentive for them to maintain and protect the system. However, the farmers would have no incentive to maintain the shared feeder infrastructure. Low participation rate would make it technically and financially very costly for the DisCom to keep the feeder charged during the daytime and control the free-rider problem. Transaction cost of signing and sustaining a very large number of PPAs would become prohibitive for the DisCom. Though participating farmers would have strong incentive to save electricity and water, it would create perverse incentive for the non-participating farmers due to availability of daytime good quality electricity supply.
5. An FE would find it easier to operate and maintain and provide security for the shared infrastructure. Peer pressure on non-participating farmers against malfeasance would be high since any pilferage of electricity would be from their neighbors and not from the DisCom or the government. Since the PPA would be signed between the FE and the DisCom, there would be fewer PPAs, and transaction costs would go down. With high participation rate,

INSTITUTIONAL MODELS FOR IMPLEMENTATION



Individual Farmer

- Responsible for purchase, installation, operation and maintenance, and financing
- Minimal Network Losses; to be borne by the farmers
- Net metering at farm level
- Point-of-sale at farmgate;
- Payments directly to participating farmers



FPC/ Cooperative

- Farmers; finance purchase, install, operate and maintain solar installation; shared costs of maintenance of common grid infrastructure
- Net metering at farm and feeder levels
- FPC: responsible for aggregation of power from farmer and point-of-sale at substation, aggregation of energy accounts of members, maintenance of feeder infrastructure; network losses borne by FPC, shared by farmers
- DisCom: responsible for billing and collection from non-participants, payments directly to participating farmers



[Public] Private Partnership

- Feeder scale investment is made by the PPP
- PPPs bid for tariff
- Power sold to farmers at regulated tariff, tariff gap funded by the government as operating subsidy
- Bills collected by PPP?
- DBTE offered to the farmers for saving electricity/water and benefit sharing?

COMPARING ALTERNATE INSTITUTIONAL MODELS



Individual Farmer

Advantages

- Strong incentive to maintain farm solar system
- Participating farmers will have strong incentive to use electricity and water efficiently
- Rapid deployment

Disadvantages

- No incentive to maintain shared feeder infrastructure
- Low participation will make implementation very difficult
- Free rider incentive for electricity as well as water
- High transaction cost for DISCOM as well as farmers
- Aggregation for RPO not feasible
- Network losses and cost of theft to be borne by DISCOM



FE

Advantages

- Easy to organize, operate and maintain feeder infrastructure
- Better security and protection for panels and shared feeder infrastructure
- Peer pressure on non-participating farmers against malfeasance
- Mutual learning to improve water and energy efficiency to maximize earnings
- Low transaction costs for DISCOM and FPC
- Easier deployment and implementation with higher participation rate
- Better prices for SIP due to scale

Disadvantages

- Organizing farmers and building capacity of FPC/Cooperative requires efforts
- FPC/Coop governance mechanisms will need to be established to keep it accountable and avoid elite capture
- Slower implementation but likely to be more sustainable



[Public] Private Partnership

Advantages

- Competitive power purchase price
- Better technical skills for operations and maintenance
- Lower transaction costs for DISCOM
- Rapid implementation, assuming keen private sector

Disadvantages

- Unless combined with other incentives like DBTE, no incentive for farmers to use electricity and water efficiently
- No incentive for farmers to maintain on-farm SIPs and shared feeder infrastructure
- Strong incentives for farmer malfeasance; high monitoring and vigilance costs
- Political economy of farm power supply remains problematic

deployment of the scheme and implementation would be faster and because of the economies of scale the vendors would likely offer better prices for the supply and annual maintenance of the system, and insurance against theft of equipment could be cheaper due to broad-based ownership among the whole feeder community. The State Government would find it more cost effective to provide extension services for improving efficiency of electricity and water use and agriculture diversification. **A major advantage of an FPC model is that those farmers in the vicinity of the feeder who have been waiting in the queue for a long time to obtain electricity connection can be allowed to join the FE.** Generally, these are small and marginal farmers who can benefit not only from assured electricity supply for irrigation but also earn an additional income. The flip side of this model is the intense effort needed to mobilize and organize farmers into an FE, creating satisfactory standard operating procedures and rules of governance to avoid pitfalls of elite capture. However, a well-organized FE is the most sustainable institutional model for solarization of agriculture feeders.

6. A PPP model can be readily deployed at scale and obtain competitive rates for solar installation. The installations are likely to achieve high technical standards in equipment and maintenance. Availability of land and budget for state government subsidy for the recurring viability gap can be constraining factors. However, it does not create any additional income for the farmers nor does it create any incentive for them to use electricity efficiently and conserve water. On the contrary, it may lead to further exploitation of groundwater resources and expansion of crop area creating additional pressure on water resources. Increase in malfeasance and challenges of political economy of farm power supply are the most likely outcomes.

4.3 IMPLEMENTATION ARRANGEMENTS

7. The State Government and the DisCom are the two key players in rapid deployment of this scheme

at scale. No less critical is the role of the Producer Organization Promotion Institutions (POPI) which can be organizations like NDDDB which have enormous experience and expertise in creation of farmer organizations, civil society operating in rural areas, existing farmers cooperatives and other organizations, and private sector suppliers of solar systems. Role and responsibilities of each of these organizations is described below.

- (i) State Government. For rapid scale up, a separate, fully funded and fully empowered “Mission” staffed by an inter-disciplinary team and led by a dynamic Mission Director should be created. Allocated state subsidy for the annual target should be placed in a separate budget head. The team should have experts with skills in solar energy, agriculture, electrical engineering, banking and credit appraisal, management of cooperatives and rural organizations, communication and farmer engagement, legal and commercial matters. Implementation could be rolled out in a few districts every year. Educated youth could be engaged as “Kisan Mitras” and placed in each block headquarters of the target districts to create awareness, provide accurate information, mobilize farmers and opinion leaders, and coordinate with the government agencies. It goes without saying that none of this would happen at the scale and speed at which it needs to happen without a strong political commitment to overcome the institutional constraints and to support the market transformation.
- (ii) DisCom. Its role of segregating the agriculture feeder, signing a PPA with the FE, keeping the feeder charged during daylight hours, and maintaining or coordinating with the FE for maintenance of feeder to ensure surplus power can be evacuated, are important pre-requisites for the proposed scheme to succeed and DisCom to earn an income. To mitigate payment risk of its power purchase, the DisCom should offer an appropriate risk mitigation instrument such as Revolving Letter of Credit or an Escrow account.



(iii) **Producer Organization Promotion Institution.**

The primary responsibility of the POPI³⁰ is to see that the FE reaches sustainable level of business and the staff of the FE acquire technical and managerial capability to run the business successfully when the POPI withdraws its support. The principal role of the POPI is, therefore, to build the capabilities of the Staff and Management of the FE through training and continuous hand-holding. The broad responsibilities of a POPI are: (a) mobilization of farmers and registration/incorporation of FE, (b) business planning, (c) resource mobilization, (d) development of management systems and procedures, (e) training of FE management, (f) business operations, (g) organizing compliance support for accounts and audit and finally prepare for its own exit and hand-over to the FE management. POPI would need to be compensated by the state government for its efforts and costs.

(iv) **Farmer Enterprise/Farmer Producer Company.** Led by a strong Board of Directors, the FE/FPC will ultimately be the “point of the spear” in the successful implementation of this scheme.

4.4 COMMERCIAL ARRANGEMENTS

8. Clearly formulated and enforceable commercial arrangements are necessary for a financially viable and sustainable business model. Several states have already procured MW scale solar electricity generation and implemented off-grid solar irrigation. Therefore, this Study focuses on commercial arrangements needed for Farmer Enterprises. The State Government would be well advised to develop standardized legal and commercial documents that would not only bring certainty of regulatory and commercial framework to the lenders and investors but also make the process more efficient and less costly. These are briefly described below:

- (i) **Power Purchase Agreement.** A PPA between the DisCom and the Farmer Enterprise (as the aggregator of surplus power) would define some key elements of the sale of power by the FE. The solar generators would have a must-run status. The PPA would define, the point of sale, point of delivery, price, projected monthly generation and estimated sale, minimum volume of electricity sale, net metering, meter

³⁰. “Farmers Producer Organizations” NABARD 2015. https://www.nafpo.in/wp-content/uploads/2019/05/Nabard_FARMER-PRODUCER-ORGANISATIONS.pdf Downloaded on 3rd September 2019.

reading and billing schedule and protocol, determination of liability for interruption in evacuation due to feeder not being on or faults on the feeder, recording of consumption by non-participants if any, responsibility for billing and collection from non-participants, liability in case of faults at the sub-station, technical quality parameters (voltage, frequency) of electricity delivered, payment arrangements, and cost of payment delays. If the feeder infrastructure is to be maintained by the FE, the boundary between the DisCom and FE, and standards and protocols for maintenance may be included in the PPA.

- (ii) Farmer Entity. Having created about 32 FPCs as part of implementation of the RACP, Rajasthan has the required institutional capacity to register and operate FEs and has basic legal documents such as Memorandum of Association, Articles of Association. These documents and learning can be easily adapted to create Solar Farmer Enterprises. However, it would be important to prepare standard operating procedures of these FEs since the product, production and aggregation process, market and delivery process, and commercial arrangements for solar electricity are quite different from other agricultural produce. A Standard Operating Procedure (SOP) of FE would inter-alia include: metering and meter reading of net meters of participating farmers, accounting of losses between the net meter at the point of sale and net meters of member farmers, rules regarding allocation of losses and operation and maintenance costs among members, submission of invoices for power sale and operation of FE bank account.
- (iii) Procurement, installation, and maintenance of solar irrigation systems. Wind conditions, incidence of flooding, soil conditions would influence the design, choice and strength of materials to be used for frames. Latitude of the location would inform the orientation and the benefit of fixed versus adjustable panels. Based on the climatic conditions and geography of the area, the government should prepare technical standards for the solar panels and installation. FEs can aggregate demand for

installation at the feeder and the government can aggregate the demand by District or a larger area for competitive bidding of supply, installation and annual maintenance and create a list of accredited vendors. The buyers would be individual farmers, but they can collectively select one of the accredited vendors to benefit from economies of scale.

- (iv) Feeder Maintenance Contract. Uninterrupted evacuation of power is critical for financial viability of the Business Model 2, The report recommends transferring the feeder and its maintenance to the FE. A standard maintenance contract and qualifications of the maintenance contractor should be agreed to between FE and the DisCom and enshrined either in the PPA or preferably a separate agreement.
- (v) Banking Agreements. A banking arrangement for flow of funds between the DisCom, FE, and the participating farmers would need to be put in place. Invoice of electricity supplied during a billing period would be delivered by the FE to the DisCom, with an itemized list of quantity supplied by each participating farmer and shared with the bank with whom the FE and the participating farmers have bank accounts. FE would issue instructions to the bank to distribute the payment received from the DisCom to the farmer account holders as per the itemized list attached to the invoice in whose favor an escrow would be created to first make payments to the participating farmers and the remaining amount left in the FEs account for operation and maintenance of the FE and the feeder.

4.5 CATALYSING SOLAR ENERGY MARKET

- 9. Catalyzing Solar Energy Market. Weak financial situation of DisComs, and stranded generation capacity in many states, including Rajasthan, may become a short-term constraint on the ability of the DisComs to buy large quantities of surplus energy from solarization of agriculture feeders. Payment risk of DisComs may also affect the volume of commercial financing that can be raised for this scheme. To catalyze the market,

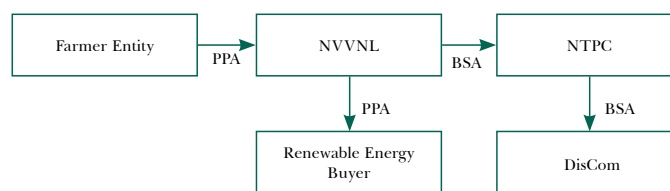
Government of India could help kick-start the implementation in a few states by encouraging NTPC Vidyut Vyapar Nigam Ltd (NVVNL) to buy power from Farmer Enterprises. NVVNL has a mandate to buy solar bundled power. The transaction could be structured as power sale agreement between FE and NVVNL with back-to-back sale agreement between NVVNL and NTPC. Lenders may require a sale agreement for at least the duration of their loan. NVVNL can also provide credit enhancement to a PPA between DisCom and FE by buying the PPA for the medium-term after which the PPA reverts to DisCom. In turn, NTPC could set it off against the central share of the state in NTPC generation (Figure 4.1). Once the market is primed, other aggregators trading in renewable energy and local large customers could emerge.

4.6 JOB CREATION POTENTIAL

10. In non-Utility scale solar installations, about 65% of the jobs are in installation and project development and less than 15% in manufacturing³¹. Solar Irrigation installation would generate jobs through the deployment cycle- business development, design and preconstruction, construction and commissioning, operation and maintenance. A 2017 report “Greening India’s Workforce” (NRDC, CEEW, Skills for Green Jobs) has calculated job-years per MW of solar PV manufacturing at 2.6, for rooftop installations at 24.72, and utility scale ground mounted solar at 3.45. Job-years per MW is the ratio of the time spent by an employee on a particular project/task in a given year to the standard total working hours in that particular year. The FTE formula translates short-term or one-time employment into a full-time equivalent or job-year. SIP development, design, construction and installation, and operation and maintenance would be similar to the rooftop solar though it would require some additional technical skills for grid-connectivity, feeder maintenance, and energy accounting. It would be reasonable to assume a job-creation coefficient of 20 job-years per MW of SIP. This can translate into more than 275,000 job-years for converting about 14,000 MW of agriculture load of Rajasthan.

³¹. National Solar Job Census, 2018, The Solar Foundation, USA

FIGURE - 4.1: CATALYZING SOLAR ENERGY MARKET



PPA – Power Purchase Agreement
BSA – Bulk Supply Agreement

4.7 LEARNING-BY-DOING PILOTS

11. There is very little experience of implementation of Business Model-2 (KUSUM-C) in any state. Because of practical difficulties, Gujarat has also moderated its targets under SKY scheme. As mentioned in Section 3.7 (Pricing of Power), it is difficult to predict behavioral response of farmers to the dynamic interplay of hydrology; value of water in agriculture; production, market and price volatility risk of agriculture; and capacity of the DisComs and the State Government to handle large scale retail transactions with farmers. Even the market players would face a steep learning curve. Therefore, this Study recommends implementing a few learning-by-doing pilots in different agro-climatic zones of Rajasthan and calibrate the design and implementation process of the scheme for replication and scaling up.
12. A monitoring and evaluation system is proposed to be set up to closely monitor and evaluate the impact of the learning-by-doing pilots for implementation to access the pattern of electricity use, cropping pattern and cropping intensity, level of input use, employment of labor, farmer incomes, adequacy of institutional arrangements and their performance, and most importantly on the pattern of groundwater extraction and its use. All such relevant parameters will be evaluated both before the start of the pilot (baseline) as well as at pilot completion (ex-post) stage with the stakeholders involved in devising modalities of generation and collection of data used. It is proposed that monitoring and evaluation system be put in place well in advance of the commencement of the pilot.



CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSIONS

1. *Through grid-connected solar irrigation, Rajasthan has the potential to achieve the **triple objective of saving water, doubling the farmer income, and making power sector financially viable, simultaneously and urgently.***

- Rajasthan has done some impressive work to increase water security of the state which is one of the most water-stressed states in India. However, depleting groundwater continues to push the water-energy-agriculture nexus into a downward spiral.
- Unless, demand-side measures and incentives to improve water productivity and conservation are put in place supply-side augmentation would remain inadequate.
- In the absence of major transformational disruptions in agriculture sector, electricity sector remains the most effective intervention to shift Rajasthan to a virtuous W-E-A nexus. Price increase for power supply to agriculture to moderate the demand for electricity, and consequently groundwater, is a non-starter in the current political economy, low rural incomes, and critical dependence of agriculture economy on water and electricity.
- The current policy of free/concessional power supply to agriculture is fiscally and environmentally unsustainable. However, falling prices of solar panels, and some

successful experiences of grid-connected solar energy, have opened-up huge opportunities for addressing the challenge of fiscal impact, unsustainable consumption of energy and water in agriculture, and agro-dependence of rural household income.

- Business Model 2 can add climate-resilient, counter-cyclical, non-farm income to rural livelihood. In addition, it can help create local jobs through the supply chain of solar irrigation pumps.
- Economic analysis shows that a reasonable feed-in-tariff would influence farmers' decision in favor of selling electricity as against groundwater extraction. However, farmers' behavioral response to financial incentives for shifting to grid-connected solar irrigation is very difficult to predict due to complex and dynamic interaction between feed-in-tariff, value of water in agriculture, hydro-geology of the area, and seasonal and locally limited water market.
- Two major constraints in speed, scale, and sustainability in implementing KUSUM-C would be: (a) the inability of the State Government to finance the capital subsidy of 30% in the present context of limited headroom under FRBM Act, and (b) Government of India's requirement of sourcing solar panels and the other equipment from indigenous suppliers.

2. However, the potential of KUSUM-C scheme can be unlocked only through solarizing the feeders, mitigating the payment risk of the DisCom as buyers of surplus solar energy, and creating Farmer Enterprises as aggregators of power and for self-governance of the feeders.

5.2. RECOMMENDATIONS

3. *It is important, in fact critical, to adopt a nexus approach to resolve conflicts and take advantage of synergies in cross-sectoral impacts of policies in energy, water, and agriculture sectors. Because of the complex political economy of agriculture, fiscal impacts of adverse nexus can be significant. Rajasthan, and many other states, have a huge opportunity to turn around the adverse nexus into a virtuous nexus. The State Government should consider the following while designing and planning implementation of the solarization of irrigation:*

- **Evaluate the multiple objectives** of saving water, doubling farmer income, and fiscal sustainability of energy sector to decide the Business Model and instruments of delivering subsidy and power supply to agriculture.
- **Expand the scope of KUSUM-C** (Business Model 2) to include farmers waiting for agriculture power connection if they are in the proximity (say one kilometer on either side of the electricity feeder) as eligible for grid-connected solar.
- **Choose an appropriate institutional model for implementation** that creates incentive for the farmers to use energy and water efficiently, strengthens the participation of farmers in management and operation of solar infrastructure, and creates an accountable

feeder governance arrangement to ensure the scheme remains pro-poor and does not end up in elite capture. Farmer Entity as an implementing entity can have far reaching impacts on sustainability of benefits of grid-connected solar. Private sector should be involved to mobilize farmers to adopt grid-connected solar.

- **Explore Innovative financing mechanisms for funding state government's contribution** of 30%, through Deferred Subsidy Incentive (DESI) and blended finance to leverage limited budgetary resources of the state and rapidly scale up the investment.
- **Drought Premium** should be an integral part of the scheme to send strong signals on scarcity premium on water and deliver drought relief quickly and directly into the account of the farmers.
- **To catalyze the market, the capacity and resources of NRVNL** should be used by the Government of India. It would also help to mitigate the payment risk of DisComs in the short-term. State Government and the State Electricity Regulatory Commission should re-visit the policy of transmission charges for purchase of surplus solar energy by renewable buyers other than DisComs to kick-start the market.
- **The requirement of indigenous component of solar panels and the balance of systems** should be reviewed by the Government of India to keep the capital cost low and enhance supply of solar systems for rapid scale up.
- **Launch a few learning-by-doing pilots** to demonstrate proof-of-concept and to better understand complex and dynamic interaction between feed-in-tariff, value of water in agriculture, and crop choices.

ANNEX A

POTENTIAL OF SOLAR ENERGY IN RAJASTHAN

SOLAR IRRADIATION IN AJMER AND KOTA DISTRICTS

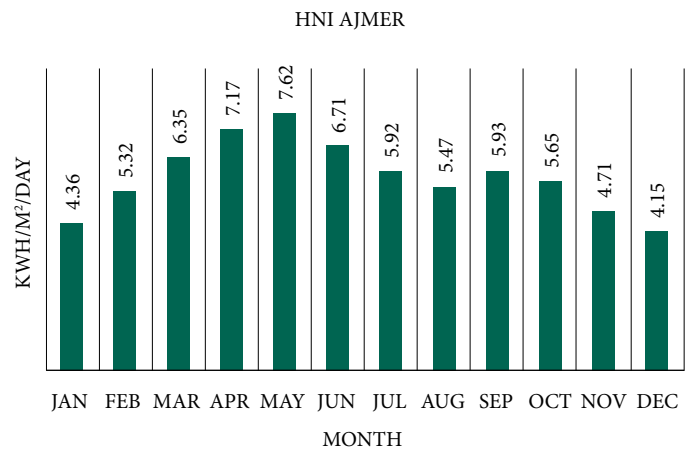
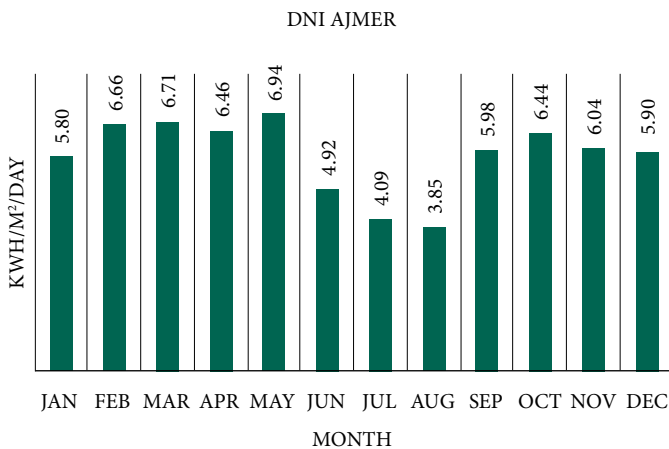
- Average Direct Normal Irradiance**
 This data provides monthly average and annual average daily total solar resource kilowatt hours per square meter per day. The insolation values represent the resource available to concentrating systems that track the sun throughout the day.
- Average Global Horizontal Irradiance**
 This data provides monthly average and annual average daily total solar resource kilowatt hours

per square meter per day. The insolation values represent the global horizontal resource - the geometric sum of direct normal and diffuse irradiance components, representing total energy available on a planar surface.

Ajmer District (Latitude: 26.45 Longitude: 74.65)

Annual Average Direct Normal Irradiance (DNI) - 5.78 kWh/m²/day

Annual Average Horizontal Normal Irradiance (HNI)- 5.78 kWh/m²/day



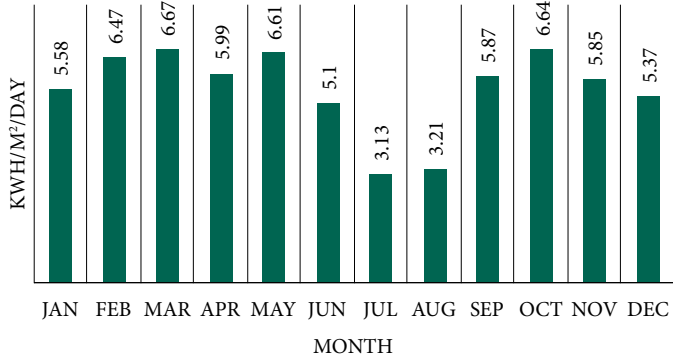
Source: NREL

Kota District (Latitude: 25.25 Longitude: 75.85)

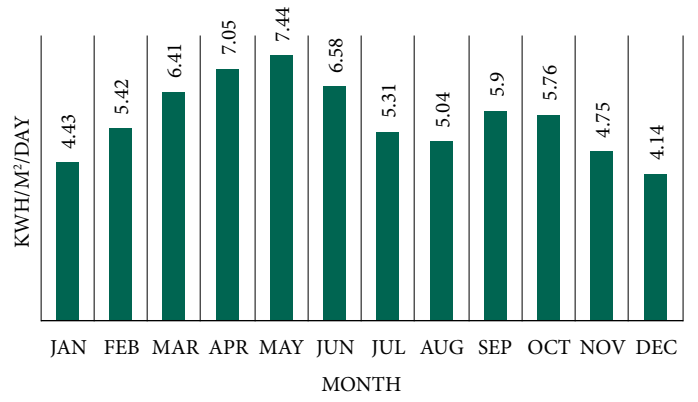
Annual Average Direct Normal Irradiance (DNI) - 5.53 kWh/m²/day

Annual Average Horizontal Normal Irradiance (HNI)- 5.68 kWh/m²/day

DNI KOTA



HNI KOTA



ANNEX B

SOLAR IRRIGATION PUMPS – A PRIMER

DEFINITIONS OF TERMS

1. **Array:** A photovoltaic (PV) array (or solar array) is a linked collection of solar panels. The modules in a PV array are usually first connected in series to obtain the desired voltage. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can power lights, motors, and other loads.
2. **Angle of Incidence:** An angle of incidence is an angle made by the light ray or wave hitting a surface and the line perpendicular to that surface. The intensity of solar radiation is largely a function of angle of incidence. As the angle of incidence decreases the intensity of solar radiation increases.
3. **Array Rated Power:** The peak wattage of a solar module is the number of watts it will produce under Standard Test Conditions.
4. **Balance of System:** All the parts of a PV system excluding the solar module. BoS comprises the complete PV operating system, including the inverter, mounting structures, cables, and connectors. Off-grid systems include charge controllers and batteries for electricity storage.
5. **Capacity Utilization Factor (CUF):** It is the ratio of the actual output from a solar plant over the year to the maximum possible output from it for a year under ideal conditions. The energy generation of a plant primarily depends on two key parameters; solar radiation received, and the number of clear sunny days experienced by the plant's location. These two factors affect the capacity utilization factor as well. Capacity utilization factor is usually expressed in percentage.

$$\text{Capacity Utilization Factor (C.U.F)} = \frac{\text{Actual energy from the plant (kWh)}}{\text{(Plant Capacity (kWp) x 24 x 365)}}$$
6. **Degradation Factors:** Energy generation from SPVRT modules degrades over its life cycle @ 0.7% to 1% per year and this is called Degradation Factors.
7. **Discharge:** Quantity of a fluid flowing through a section of pipe or channel per unit time. For incompressible fluid, such as water, it is defined as the ratio of volume of fluid flowing through the section and time.
8. **DNI (Direct Normal Irradiance):** DNI at a location is the amount of solar energy falling per square meter per day at that location. The higher the DNI, the higher the electricity produced by a solar cell. DNI is usually measured by a pyrheliometer mounted on a solar tracker.
9. **Feed-in-Tariff:** Feed-in-tariff (FiT) is a special price paid by the electricity utility to power generators for the power that the solar power projects feed into the grid. The FiT prices are usually higher than what a typical power generator (say from a conventional thermal power plant) will get for supplying power to the grid. The FiT is used as a financial incentive to encourage investment in renewable power, so that renewable energy capacity can be scaled up rapidly.
10. **Fixed/adjustable mounts:** Fixed Tilt Arrays are arrays of Solar Panels placed at a fixed angle which is usually the optimum tilt. To obtain maximum efficiency from the solar panels they need to be pointed in the direction that captures the most sun. Fixed tilt arrays, being immobile, are simple in construction, easy to design and maintain. Normally two to four adjustments are configured in the design for seasonal adjustment.
11. **Flow:** Flow is the amount of liquid that passes through a pump within a certain period of time. It is measurement of the liquid volume capacity of

a pump. Often given in liters per minute (l/min), liters per second (l/sec) and cubic meter per hour (m³/hr).

12. **GHI:** Global Horizontal Irradiance (GHI) is the total solar radiation incident on a horizontal surface. It is the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance, and ground-reflected radiation.

13. **Head:** The head of a pump is an expression of how high the pump can lift a liquid. Head is measured in meter (m). It can be calculated by subtracting the suction head from the discharge head. Also referred to as Total Dynamic Head.

14. **Horsepower:** Horsepower (HP) is a unit of measurement of power, or the rate at which work is done. There are many different standards and types of horsepower. Two common definitions being used today are the mechanical horsepower, which is about 745.7 watts, and the metric horsepower, which is approximately 735.5 watts

15. **Inverter:** A solar inverter is the brain for a solar power plant. An inverter's core function is to convert Direct Current (DC) generated by the solar PV panels into Alternating Current (AC) required by our electrical loads. In addition, it integrates solar with other sources such as grid power or backup diesel generators. It is also known as a Power Conditioning Unit (PCU).

16. **kilowatt hour (kWh):** It is a measure of energy and is also called as "Unit". Indicates the amount a PV system produces in one hour or what is used over a period of time. Often written as kWh. A 100-Watt electric lamp used for 10 hours would consume 1 kWh.

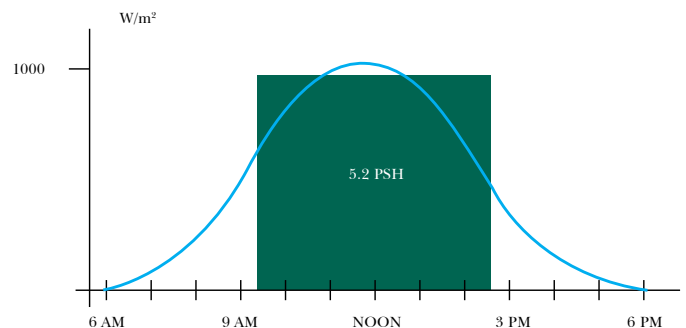
17. **Monocrystalline Silicon:** Photo Voltaic cells use crystalline silicon (c-Si), a light absorbing semiconductor. Mono-crystalline technology uses thin wafers sliced from a single, pure crystal silicon ingot. Mono-crystalline solar panels have the highest efficiency rates since they are made from the highest-grade silicon. The efficiency rates of mono-crystalline solar panels are typically 15-20%. Mono-crystalline solar panels perform better than similarly rated polycrystalline solar panels at low-light conditions. The

Mono-crystalline solar panels are more expensive than the poly-crystalline solar panels.

18. **Net Metering:** Net metering is a metering mechanism in which the utility meters the amount of "excess" electricity that the consumer exports to the grid. Net Metering is measured with a bi-directional meter, recording the export and import of electricity from the grid.

19. **Orientation:** Orientation refers to the placement with respect to the cardinal directions, N, S, E, W. To get the most from position-fixed (or seasonally adjusted) solar photovoltaic panels, they need to be pointed in the direction that captures the most sun.

20. **Peak Sun Hours:** Solar energy available in a given location is expressed as kWh/m²/day. This is commonly referred to as Peak Sun Hours (PSH). For example, if solar radiation for a particular location is 5.2 kWh/m²/day then PSH for that location will be 5.2 hours.



Since intensity of sunshine varies during the day reaching peak during mid-day, solar generation follows a parabolic curve. If capacity of the solar panel is 1 kWp and average solar day is 8 hours, a thumb rule for calculating total generation (sum of the area under parabolic curve) during the day is $\frac{2}{3} * 8 * 1$ i.e. 5.5 kWh.

21. **Polycrystalline Silicon:** Polycrystalline silicon, also called polysilicon or poly-Si, is a high purity, polycrystalline form of silicon, used as a raw material by the solar photovoltaic and electronics industry. Polysilicon is produced from metallurgical grade silicon by a chemical purification process.

22. **Solar panel efficiency:** Defines the amount of sunlight that can be converted by the panel into usable electricity.

Solar panel efficiencies for a panel depends on the cell type, manufacturer and size of the panel. A list of solar panel efficiencies of top panel manufacturers based on cell type is given as follows:

| Type of solar panel | Panel efficiency (%)* |
|---------------------|-----------------------|
| Monocrystalline | 17 – 21 |
| Polycrystalline | 14-16 |
| Thin Film | 7-14 |

Solar panel efficiencies are provided under standard Testing Conditions (STC) of incoming solar radiation of 1000 W/m² and Air Mass Ratio of 1.5 at 25° C

23. **Solar Panel Cleaning:** An unclean PV panel leads to loss of efficiency. PV panel cleaning is a necessity to maintain the desired energy generation performance. Technically speaking, dust, debris, bird droppings or dead insects, all of these ultimately act as obstructions to sunlight falling on the photovoltaic cells. Keeping the panel clean will allow the installation to deliver its expected performance along with improving its total lifespan and longevity. Solar Panel Cleaning could be done using cleaning apparatus made of materials like micro-fiber, soft sponge and even the right brushes. De-ionized water is recommended for cleaning where particulate matter is less than 75 ppm that prevent scale buildup of any form. Water jet spray can be used with nozzle pressure not more than 35 bars to avoid any structural or surface damages

24. **Solar Days:** The time required for a single rotation of the earth on its axis with respect to the sun, varying slightly throughout the year due to variations in the earth's orbit and other factors. The number of solar days is used for estimating the total energy generated in a year.

25. **System Efficiency:** The efficiency of a solar power plant after considering the losses due to various

factors viz., temperature, dirt, inverter, shading, manufacturer's tolerance, orientation, tilt angle, loss due to irradiance level and transformer and AC transmission is called system efficiency. Or total efficiency of the system after considering all the losses expressed as total derating factor.

26. **Thin Film Solar Cell:** A thin-film solar cell is a solar cell that is made by depositing one or more thin layers, or thin film (TF) of photo voltaic material on a substrate, such as glass, plastic or metal. A typical crystalline solar cell is made from silicon and contains an active semiconductor material layer that is about 300-micrometers (micrometer is a millionth of a meter) thick. In addition to amorphous silicon, thin film solar cells of today also made from CdTe (Cadmium Telluride), CIGS (Copper-Indium-Gallium-Selenide) or CIS (Copper-Indium-Selenide). The thin film efficiency lies between in the range 7-13%. High temperatures and shading have less impact on solar panel performance of thin film.

27. **Tracker:** A PV array that follows the path of the sun to maximize the solar radiation incident on the PV surface.

28. **Variable Frequency Drive for Motors:** is a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor. Other names for a VFD are variable speed drive, adjustable speed drive, adjustable frequency drive, AC drive, microdrive, and inverter. If the frequency applied to the motor is changed, the motor speed changes in direct proportion to the frequency change. The VSD's basic principle of operation is to convert the electrical system frequency and voltage to the frequency and voltage required to drive a motor at a speed other than its rated speed. The two most basic functions of a VSD are to provide power conversion from one frequency to another, and to enable control of the output frequency.

29. **Watt:** A measure of power, often written as W. Indicates how much power is produced a PV module or PV System. A kilowatt is 1,000 Watts, often written as kW.

ENERGY GENERATION ESTIMATION FROM A PV SYSTEM:

30. The amount of energy delivered by the PV system depends on a number of factors, but the primary factors are:

- Rated capacity or size of the PV array (Wp or kWp)
- Amount of solar irradiation it receives (expressed as peak sun hour)
- The total efficiency of the system after considering all the losses
- Performance degradation over life cycle



Working Example of Energy generation Estimation

31. On a clear and a sunny day, a 10 kWp PV array received 5 Peak sun hours (hours). Total loss (derating factor) in the system is estimated as 0.73 (73%)

Expected output can be determined as follows:

$$\begin{aligned}\text{Expected Output} &= \text{Peak Sun Hours} \times \text{Peak Power} \\ &\text{Output} \times \text{Total Derating Factor} \\ &= 10 \text{ kWp} \times 5 \text{ hour/day} \times 0.73 \\ &= 36.50 \text{ kWh per day (1st year)} \\ &= 32.85 \text{ kWh per day (on 10th year)} \\ &= 29.56 \text{ kWh per day (on 25th year)}\end{aligned}$$

ANNEX C

VALUE OF WATER IN AGRICULTURE

INTRODUCTION

1. Groundwater is an invisible common natural resource and therefore its scarcity determines its value in a region. However, the resource scarcity does not attach a price to it but the cost to access the resource determines the price. Therefore, the cost of groundwater abstraction invariably becomes the minimum price of groundwater. This price increases depending upon the value generated by the groundwater.
2. Groundwater abstraction cost depends on hydrogeology, depth of water, energy prices, installation costs and operation and maintenance costs of the water extraction mechanism (WEM). The cost per m³ of pumping groundwater depends primarily on pumping depth, energy source (electricity, diesel, solar), and the current price of energy, whereas costs per hectare for groundwater varies also with the volume of groundwater used during the season (Fraiture & Wichelns 2010).
3. To move away from the conventional grid connected irrigation pumping systems, the Government of Rajasthan is planning to undertake large scale pilots on installation of grid connected solar power systems on individual farmer fields. The likely impact of switching over from present system of providing restricted hours of grid power for irrigation to farmer owned and controlled solar power systems providing long hours of day time uninterrupted power supply for irrigation on groundwater extraction are however not known. This note attempts an assessment of the likely impact of the changes from grid to solar power on farmers behavior towards groundwater extraction. The scope of the analysis in this note is restricted to two of the proposed pilot sites in Rajasthan- Pisangan cluster in Ajmer District and Sangod cluster in Kota district. The two selected clusters differ in terms of size of the cultivated land available, average size of holding, cropping pattern practiced, proportion of

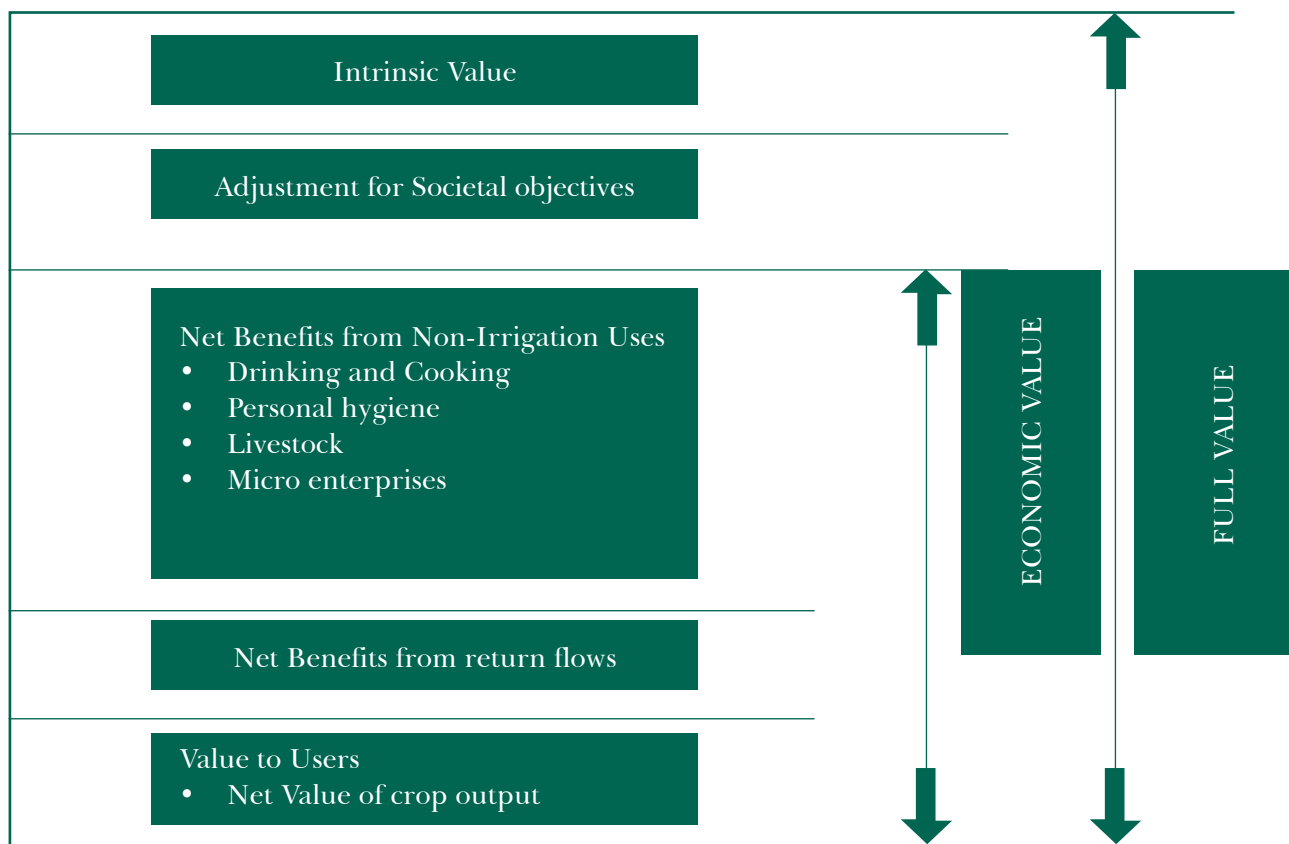
crop area irrigated, groundwater availability and stage of groundwater development. In both the clusters, farmers practice a diversified cropping pattern and cultivate a variety of crops.

4. In general, a tube well owning farmer would extract groundwater for irrigating his crop if the value addition from use of groundwater is higher than the cost of groundwater extraction. This is irrespective of the source of energy used- grid or solar.

ESTIMATING VALUE OF WATER IN IRRIGATED AGRICULTURE

5. For assessing the economic value of water in its various uses, several general principles are involved. For a given quantity of water, the value and opportunity cost of water in alternative uses is determined simultaneously when water supplies match water demands for user sub-sectors over time and space. Water markets, if functioning will perform these functions of matching water demands (both for quantity and quality) with supplies if appropriate policies (regulatory and economic incentives) are used to take care of externalities. Such markets for groundwater irrigation are however hard to find. In the absence of such well-functioning water markets, efficient water allocations (and resulting values and costs) can be obtained by using multi-period, multi-location systems analysis models. Where such systems analysis models are not available, for practical purposes of estimating values, costs and tariffs, a partial equilibrium approach can be followed (Rogers et al: 1998).
6. Estimation of the economic value of water in irrigated agriculture involves computing the three components of value as illustrated in Figure 1. The monetary returns from water forms one of the important components of the economic value.

FIGURE - C.1: ESTIMATION OF ECONOMIC VALUE OF WATER IN AGRICULTURE



The monetary returns from water in irrigated agriculture, however, could vary tremendously across crops and agro-climatic regions, and they depend critically on the timing of application of water and the level and efficiency of use of inputs other than water. In the absence of well-functioning water markets for irrigation, the value of water in irrigated agriculture can be derived as the Net Value of Output attributed to the use of water diverted for irrigating crops. It is defined from the Value of Water in Agriculture, as follows:

$$\text{Value of water in agriculture} = \frac{(\text{Net Value of Output with irrigation} - \text{Net Value of Output without Irrigation})}{(\text{Volume of water diverted for irrigation})}$$

7. The Net Value of Output is estimated as the gross value of output minus the cost of cultivation. The volume of water in the denominator refers to the quantities diverted for irrigation and not to the volume of water used by the crops or the evapotranspiration needs of the crops. This is because the costs of supply of water are determined

by the volumes of water diverted for irrigation, and not by the volume of water used by crops. Rainfall is not included in the volume of water in the denominator, but it is accounted for when net value of output without irrigation is quantified.

EMPIRICAL ESTIMATION OF THE VALUE OF WATER:

8. Detailed data on required variables for different study sites is difficult to obtain. The estimated values of water for different crops cultivated in the two study sites have been derived on the basis of data for above defined variables collected from various published and unpublished sources. The data on cost of cultivation and returns from different crops relevant to Rajasthan have been estimated based on data from various sources, principally from the data provided in the Annual Reports on Price Policy for different crops for various years (GoI, 2018, 2017, GoI, 2017a, GoR, 2017). The Net Value of Output (NVO) for a given crop has

been estimated by deducting from the Gross Value of Output (GVO) the cost of cultivation (Cost A2+FL)³².

9. The estimated value of water per cu m of water extracted for cultivation of some of the relevant crops of the study region and the estimated value of water per kWh of energy used in extracting this water are presented in Table 1. The values of water per cu m of water as also the value of water per kWh of energy vary significantly across different crops (Table 1). The estimated value of water per cu m for wheat crop at ₹ 2.24 in Sangod is much higher than the value of water for paddy at ₹ 1.36. Similarly, the estimated values of the two crops per kWh of energy used are respectively ₹ 21.63 and ₹ 13.17.

ECONOMICS OF SELLING WATER: DETERMINING THE MARKET PRICE OF WATER

10. Formal markets for sale of groundwater are rare though farmers occasionally sell and buy water from each other through an informal arrangement

at a price mutually agreed upon between the buyer and seller. There is no information available on the volume of water transacted, the frequency of such sales, quantum of water sold, for which crops the irrigation water is transacted, and the price charged. These water sales are often between neighboring farmers since transporting small quantities of water over long distances is generally not feasible. Given the precarious groundwater situation in the study region, we believe even such informal transactions are infrequent and few in number and quantity transacted on each occasion is limited. In the absence of any relevant information on the water markets, for assessing the economics of selling water we make certain assumptions.

11. A solar power operated tube well owning farmer, with sufficient spare energy available, would extract groundwater, on the margin, for sale if there is a demand for water and the price at which he can sell the water is higher than his cost of extracting groundwater. If it is not economic for the farmer to do so he has the option of selling the equivalent solar energy to the grid and make money from these sales. From a buyer's perspective, the price which a buyer would be willing to pay should be

TABLE - C.1: ESTIMATED VALUE OF WATER (IN ₹) PER CUM AND PER KWH

| Crop | Pisangan Cluster | | Sangod Cluster | |
|---------------------|------------------|---------|----------------|---------|
| | Per cu m | Per kWh | Per cu m | Per kWh |
| Kharif Crops | | | | |
| Jowar | 1.18 | 9.46 | | |
| Bajra | 0.29 | 2.30 | | |
| Groundnut | 3.80 | 25.43 | | |
| Paddy | | | 1.36 | 13.17 |
| Soyabean | | | 0.64 | 6.17 |
| Rabi Crops | | | | |
| Mustard | | | 0.06 | 0.63 |
| Wheat | 1.90 | 15.28 | 2.24 | 21.63 |
| Barley | 2.41 | 19.29 | | |

³². Includes: value of hired human labor; value of hired/owned bullock labor, hired machinery charges and value of own machinery labor; value of seeds insecticides and pesticides, value of manure and fertilizers, irrigation charges, depreciation of farm equipment and farm buildings, land and other taxes, interest on working capital, family labor, and misc. expenses.

TABLE - C.2: ESTIMATED MARKET PRICE OF WATER AND THE ECONOMICS OF SELLING WATER

| Crop | Cost of water extraction ₹/cu m | Value of water ₹/cu m | Market price of water ₹/cu m | Profit/Loss to seller ₹/cu m | Profit/Loss to seller ₹/kuh |
|-----------------|------------------------------------|--------------------------|---------------------------------|---------------------------------|--------------------------------|
| Pisangan | | | | | |
| Jowar | 0.95 | 1.18 | 1.07 | 0.11 | 0.91 |
| Bajra | 0.95 | 0.29 | 0.62 | -0.33 | -2.65 |
| Groundnut | 0.95 | 3.8 | 2.38 | 1.42 | 11.39 |
| Wheat | 0.95 | 1.90 | 1.43 | 0.47 | 3.79 |
| Barley | 0.95 | 2.41 | 1.68 | 0.73 | 5.83 |
| Sangod | | | | | |
| Soyabean | 0.79 | 0.64 | 0.71 | -0.07 | -0.71 |
| Paddy | 0.79 | 1.36 | 1.07 | 0.29 | 2.77 |
| Mustard | 0.79 | 0.06 | 0.42 | -0.36 | -3.52 |
| Wheat | 0.79 | 2.24 | 1.51 | 0.73 | 7.02 |

lower than the net value addition that the buyer can derive from the use of the bought water on his farm. Given the differences in value of water and water requirements of different crops, the market price of water would be linked to the crop. In the absence of any information on the water prices, we assume that the market price would be close to the average of the cost of water extraction by the seller and the value the buyer can derive from use of that water. This is a win-win situation for both – the seller and the buyer- because both gain almost equally from such a transaction.

12. Based on the above, we estimate the price of water per cum for different crops, and the profit / loss per KWH for different crops that the seller can derive at this price. If the profit of the seller from sale of water per kWH of energy used is higher than the value he can otherwise realize from selling the unused energy to the grid (₹ 3.69/kWH) it is rational for the farmer to extract water for selling. The results are presented in Table 2 and Figures 2 and 3. In Pisangan, in the case of such crops as jowar and bajra, it is economic for the farmer to sell the energy to the grid rather than use that energy for extracting groundwater for selling. For wheat the selling price of water

and the value of feed-in tariff are almost equal. In the case of groundnut and barley, however the marginal returns from selling water are higher than selling equivalent amount of energy to the grid. Similarly, in the case of Sangod cluster it is profitable to sell water for wheat crop only while in the case of the other three crops – soyabean, mustard and paddy the returns are higher from sale of energy. While in the case of the two of the three crops in the two study regions where selling water is profitable compared to selling energy to the grid, the differences are relatively moderate in the case of barley while in the case of other two crops groundnut and wheat the differences are relatively more prominent.

13. Two additional factors that could influence farmer’s behavior are:

- (i) Risk-adjusted return: different risk profiles of the two options i.e. selling electricity and selling water. Water market for agriculture is spatially and temporally constrained. Generally, payment for water is made by the buyer either by sharing the output as a barter or in cash only after the crop is harvested and sold. The seller of water thus shares the risk of yield, market and price

volatility and gets paid after a period of three to four months. In comparison, sale of electricity bears no price or market risk and payment is more frequent. Therefore, the potential profit from sale of water has to be adjusted for the risks. Experience of Dhundi shows that the farmers quickly learn this and have adopted a “portfolio” approach of self-consumption, small quantity of water sale to increase their profit and for relationship reasons, and most of the electricity generated is sold to the grid.

(ii) Coincidental and seasonal demand of electricity and groundwater i.e. farmer’s own need and demand in the water market. Because of seasonal nature of agriculture, and farmers in the proximity in an agro-climatic zone tending to grow similar crops, water and electricity demand tends to be coincidental. The local water market for irrigation is constrained by rationed supply of grid electricity and availability of groundwater. Even if constraint of electricity is removed by solar power, the water market would be limited by availability of groundwater and value of water in agriculture.

If there is no constraint on availability of water, value of water would tend towards cost of extraction plus a small margin. Thus feed-in-tariff has the potential to reflect scarcity value of water and it is unlikely that grid-connected solar with adequate feed-in-tariff would lead to over-extraction of groundwater.

SUMMING UP

14. With switch over to the grid connected solar energy supply, the farmers have innumerable opportunities to access larger amounts of groundwater, bring shifts in cropping pattern towards water intensive crops, substantially increase their farm incomes, besides earning considerable extra income from sale of water and sale of surplus solar power to the utility. In practice, however, given the precarious groundwater situation in the study region, major shifts in groundwater extraction behavior is unlikely in the short run. The farm level decision making involving which crop to produce, how much area to allocate to different crops, what production

FIGURE - C.2: ECONOMICS OF SELLING WATER-PISSANGAN

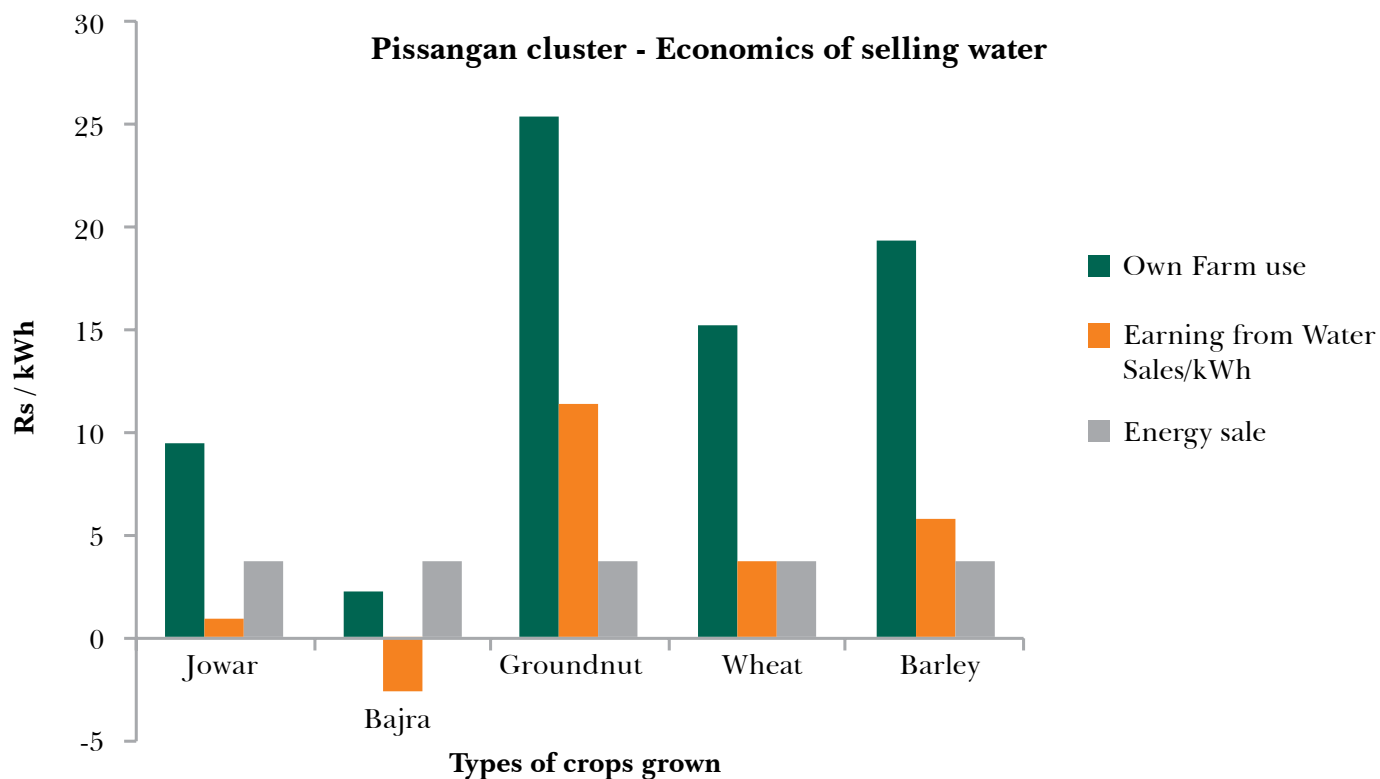
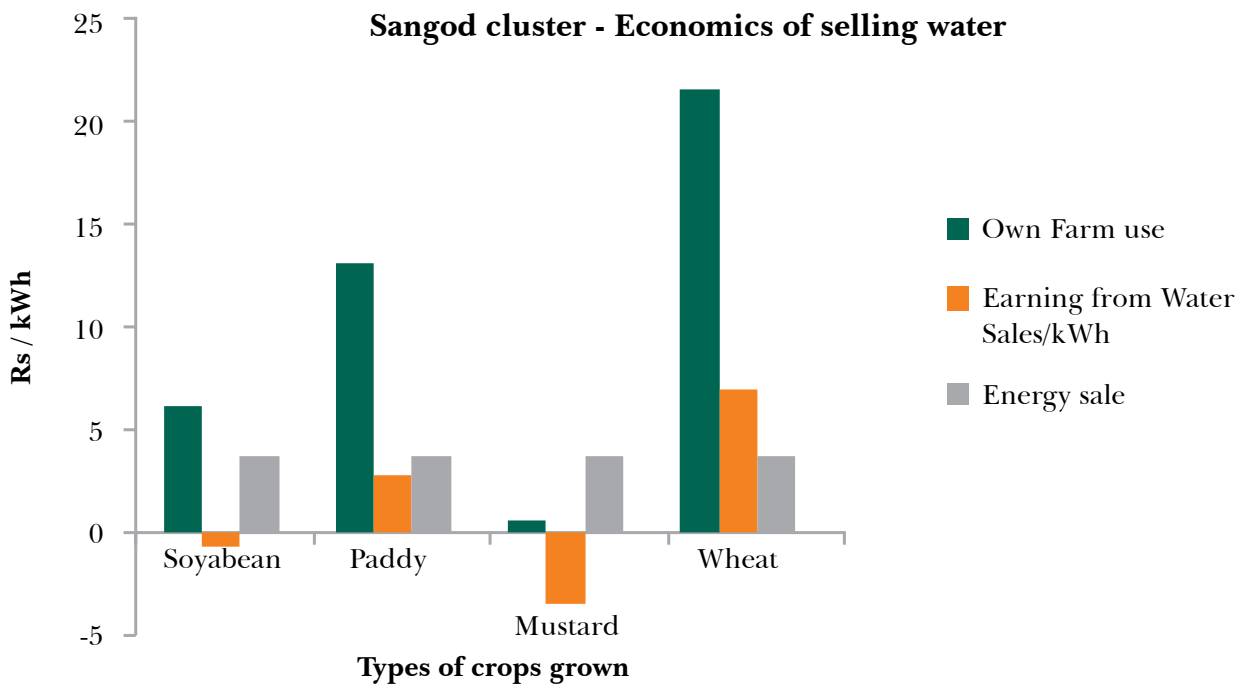


FIGURE - C.3: ECONOMICS OF SELLING WATER – SANGOD CLUSTER



technology to use is a complex process dependent on a large number of intertwined factors including agro-climatic factors, access to resources, cost of production, availability of assured markets etc. Access to additional water, if available, though important, may not per se ominously change the prevailing farm scenario at least in the short run. Even if no changes take place on the on –farm cropping scenario, the farmers’ incomes are likely to increase substantially due to assured evacuation of surplus solar power by the utility at a fair price.

risks involved in realizing on time, the sale proceeds of water from the buyer, who is usually a marginal or a small farmer, the farmer may opt to sell electricity to the grid and get assured payment on time rather than waiting to get money from the water buyer. The only crop where the value realized from sale is higher than the value of energy is groundnut. However, groundnut is not cultivated on a very large scale in the study area. Even if farmers extract groundwater to sell it will be a small quantity.

15. The results on value of water for different crops show that the value of water per m³ and per kWh expended differ significantly across different crops. Based on the estimated economics of extracting groundwater for sale vs selling the solar power spent in extracting this groundwater suggest that it is not economic to extract groundwater for sale in the case of a number of crops. For one of the three crops, namely barley, for which economics of selling water is favorable the difference between proceeds realized from sale of water and value realized from sale of power- is not very large. In the case of two other crops viz wheat and groundnut the differences are relatively more prominent. Given the significant

16. In conclusion, the access to solar power at the currently prevailing prices and costs is unlikely to result in significantly increased sales of water even through informal water market transactions and adversely impact groundwater extraction. Nevertheless, it is difficult to predict behavioral response of farmers to the dynamic interplay of hydrogeology; value of water in agriculture; production, market and price volatility risks of agriculture; and financial incentive of feed-in-tariff. Implementing a few pilots in different agro-climatic-groundwater zones would help in developing a better understanding of this interplay and recalibrate the program of solarization of irrigation at scale.

FINANCIAL ANALYSIS: FOUR CASE STUDIES

1. Two feeders from Kota block and two feeders from Sangod block serviced by Jaipur Vidyut Vitaran Nigam Ltd (JVNL) and Ajmer Vidyut Vitaran Nigam Ltd (AVNL) respectively were selected for analyzing the financial implications of solarizing feeders for farmers, DisComs and Government of Rajasthan. Three capital structuring scenarios discussed in section 5 (Business Models, Section 3.4) presented in Table D.1 anchor the analysis for the selected feeders. Also, the financial analysis discussed here is for farmer-led institutional model. However, the performance metrics do not change

significantly if institutional model is changed from Farmer-led to FPO. The performance metrics used to compare different scenarios of different feeders are income (*net cash in hand of the farmer after debt service, indicates additional income generated by selling solar electricity*), Debt Service Coverage Ratio (*indicates the financial ability of the farmer to service debt*), Return on Investment, RoI (*for farmer*), Return on Equity, RoE (*attractiveness of the proposition for the farmer to contribute equity*) and Return on Subsidy, RoS (*attractiveness of the proposal for the state government to provide capital subsidy to the farmers*).

TABLE - D.1: THREE CAPITAL STRUCTURING SCENARIOS

| Crop Scenario/ Stakeholders | Financing Solar Pump (% of capital cost) | | | |
|--|---|-----------------------|---------------|-----------------|
| | MNRE Subsidy | Upfront State Subsidy | Farmer's Loan | Farmer's Equity |
| Scenario Base Case | 30% | 30% | 30% | 10% |
| | This capital structuring has also been adopted in KUSUM scheme by GoI. Primarily, it entails raising capital through up-front subsidy (central and state), farmer's equity and debt (from NABARD) for solarizing existing grid connected pumps. The debt is assumed to be taken by the farmer at 10% rate of interest for 7 years. | | | |
| Scenario 1 (Partially Deferred Subsidy) | 30% | 10% | 50% | 10% |
| | This capital structuring entails converting part of the state capital subsidy into surplus electricity evacuation-based incentive to be given to farmer (DESI, ₹/kWh evacuated). Hence, in this scenario, state only gives 10% upfront subsidy and staggers 20% subsidy. The subsidy by MNRE remains the same (30%) but the farmer's loan increases to 50%. His equity contribution remains at 10%. Other debt conditions remain the same as in the earlier scenario. | | | |
| Scenario 2 (Fully Deferred Subsidy) | 30% | 0% | 60% | 10% |
| | This capital structuring entails converting the full state capital subsidy into surplus electricity evacuation-based incentive to be given to farmer (DESI, ₹/kWh evacuated). Hence, in this scenario, state is not burdened with any upfront subsidy and staggers the full 30% subsidy. The subsidy by MNRE remains the same (30%) but the farmer's loan increases to 60%. His equity contribution remains at 10%. Other debt conditions remain the same as in the earlier scenario. | | | |

³³. This annexure has been summarised in Section 3.4 (Summary of Financial Analysis, Page 30)

D.1 FEEDERS UNDER JAIPUR VIDYUT VITRAN NIGAM LIMITED (JVNL)

D.1.1 Dobadi Feeder in Sangod Block of Kota District

Overview and Baseline

- Dabodi feeder is an 8 km long feeder supplying electricity to Dobri and Dobra villages in Sangod block

of Kota district. As on September 2018, it had a total of 144 connections and total connected load of 503 kW consuming 0.443 million kWh (Oct'17- Sept'18) annually. It is a mixed load feeder with 60 out of 144 connection being metered agriculture connections with a total load of 412.5 HP consuming 0.342 million kWh annually, which is around 77.2% of the total annual consumption on the feeder. Fig D.1 and D.2 show the location of the Sangod block in Rajasthan and the location of Dobri and Dobra villages in Sangod block respectively. Table D.2 summarizes the defining parameters for Dabodi feeder.

TABLE - D.2: DOBADI FEEDER: KEY FEATURES

| Parameter | Value | Parameter | Value |
|--|----------|--|-------|
| Total No. of Connections | 144 | T & D loss | 22% |
| Total Connected Load (kW) | 503 | Average Cost of Supply (₹/kWh) | 6.97 |
| Total Consumption(kWh) | 4,43,040 | Electricity Tariff for Agriculture (metered) (₹/kWh) | 0.9 |
| No. of Agriculture Connections (metered) | 60 | Average DisCom Tariff (₹/kWh) | 6.86 |
| Agriculture Load (metered) (HP) | 412.5 | Subsidy per unit of agriculture supply (₹/kWh) | 6.07 |
| Average Pump Size (HP) | 7.5 | Annual Power Purchase Cost (₹/kWh) | 3.69 |

FIGURE - D.7, D.2: LOCATION MAP



Location Map of Sangod Block, Kota, Rajasthan



Location Map of Digod (Dobari) Feeder JVVNL in Sangod Ground Water Cluster Boundary, Kota

SUMMARY OF FINANCIAL ANALYSIS

3. The three business scenarios mentioned in Table D.1 were simulated for Dobadi to analyze the financial impact of different capital structures. It is assumed that solar panel capacity in kWp per HP connected load will be 1.5. Table D.3 summarizes the results of three scenarios and Fig D.3, D.4 and D.5 show the change in performance matrices across first 10 years for scenarios base case, scenario 1 and scenario 2 respectively.

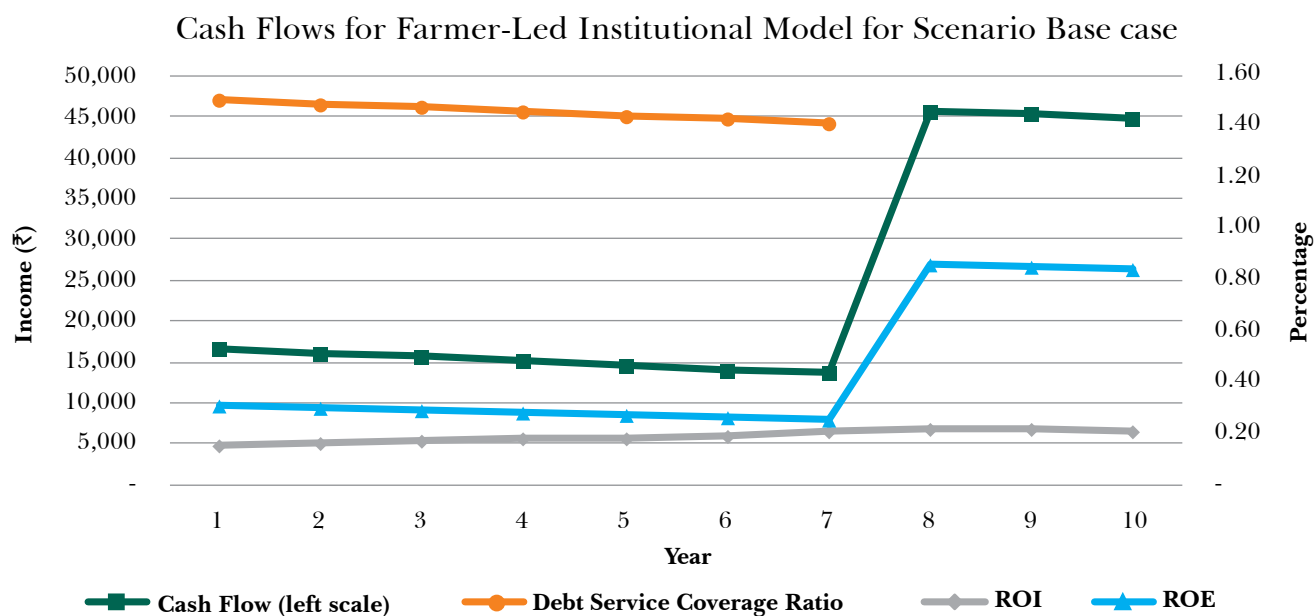
SCENARIO BASE CASE

4. All the performance metrics look attractive for different stakeholders i.e. farmer being able to generate an IRR of 22% and state government being able to generate a return on capital subsidy at 23.6%. The average income of farmer during the debt repayment period (initial 7 years) is ₹ 15,101 which increases to ₹ 41,769 post debt service. Hence, the proposition looks attractive for both the farmer and the government. The debt service coverage ratio is

TABLE - D.3: PERFORMANCE METRICS FOR DOBADI FEEDER ACROSS THREE SCENARIOS

| | Scenario Base case | Scenario 1 | Scenario 2 |
|--|--------------------|------------|------------|
| DESI (₹/kWh) | - | 1.74 | 2.60 |
| Farmer's Annual Income (₹) during loan repayment | 15,101 | 15,809 | 16,163 |
| Farmer's Annual Income (₹) after loan repayment | 41,769 | 41,769 | 41,769 |
| Debt Service Coverage Ratio | 1.46 | 1.29 | 1.25 |
| IRR (%) | 22.08% | 19.68% | 18.88% |
| RoE (%) | 29 | 30 | 31 |

FIGURE D.3: PERFORMANCE METRICS FOR SCENARIO BASE CASE FOR DOBADI FEEDER



more than 1.45 making it attractive for lender to extend loan to the farmer. A small decline in farmer income and debt service coverage seen in the Figure D3 is due to slight deterioration of solar panels every year. Even though, all the performance metrics look satisfactory in the scenario, the initial commitment and outlay required by the state government is substantially high, which may lead to slow speed of implementation or delays.

for the lender. The average cash flow for the farmer during the debt repayment period increases to ₹ 15,809 making the proposition more attractive for farmers because of significant income addition. The income post debt service remains the same as in Scenario 1 i.e. ₹ 41,769. The conversion of a part of state upfront subsidy to a staggered form will reduce the upfront commitment by the state government, therefore improving the scalability of the model.

SCENARIO 1 (PARTIALLY DEFERRED SUBSIDY)

5. In this scenario, the subsidy from the Central Government (MNRE) remains the same (30% upfront capital subsidy) but the state subsidy is split in to 10% upfront and 20% staggered form i.e. additional tariff to repay the debt taken by the farmer to finance the gap in upfront subsidy. To align the interests of both the farmer and the government, an evacuation-based incentive of ₹ 1.74 /kWh is paid to the farmer. Farmers debt increases to 50% as the state upfront subsidy reduces but the equity contribution by farmer remains at 10%. The debt service coverage ratio remains at comfortable 1.29 making it acceptable

SCENARIO 2 (FULLY DEFERRED SUBSIDY)

6. In this scenario, the 30% state subsidy is fully staggered through DESI of ₹ 2.60 /kWh and farmers takes 60% debt apart from contributing 10% equity. The DESI enables the farmer to pay the loan and also augment his cash income. The cash flow further increases to ₹ 16,163 in the debt repayment period making it attractive for farmers. But because they will be required to take a higher debt compared to scenario base case and Scenario-1, there may be skepticism among farmer community about this proposition. All other performance metrics remain attractive as in other cases.

FIGURE D.4: PERFORMANCE METRICS FOR DOBADI FEEDER FOR SCENARIO 1 (PDS)

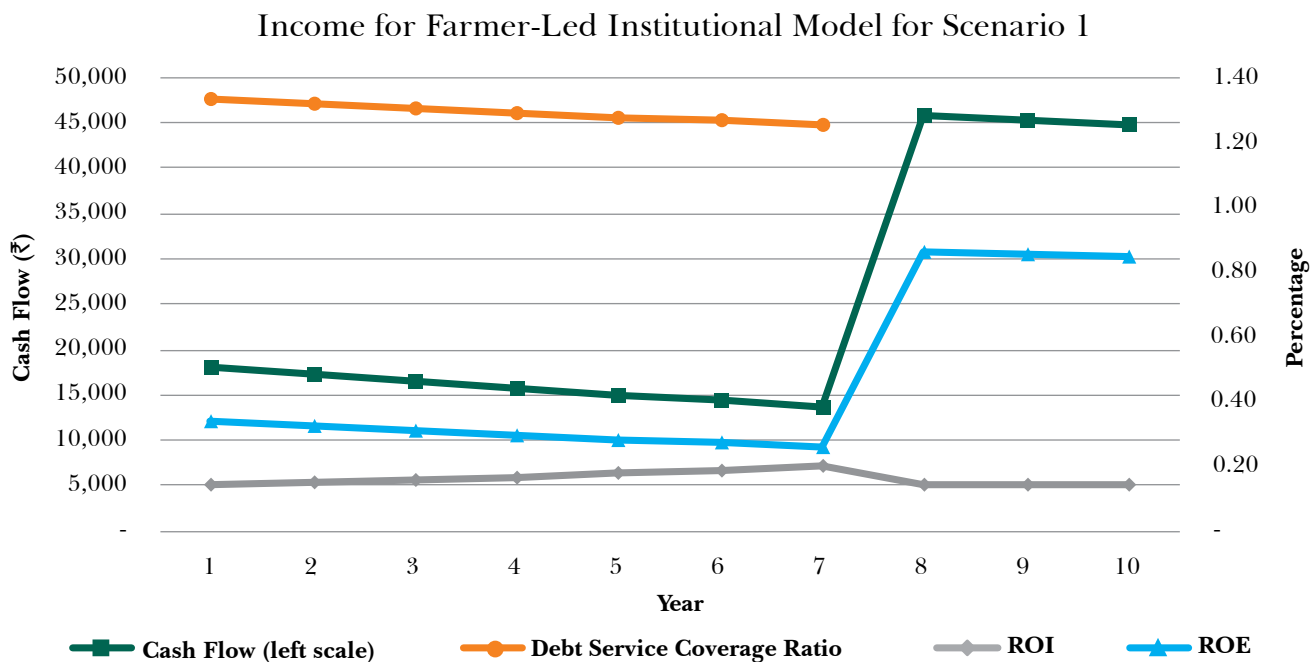
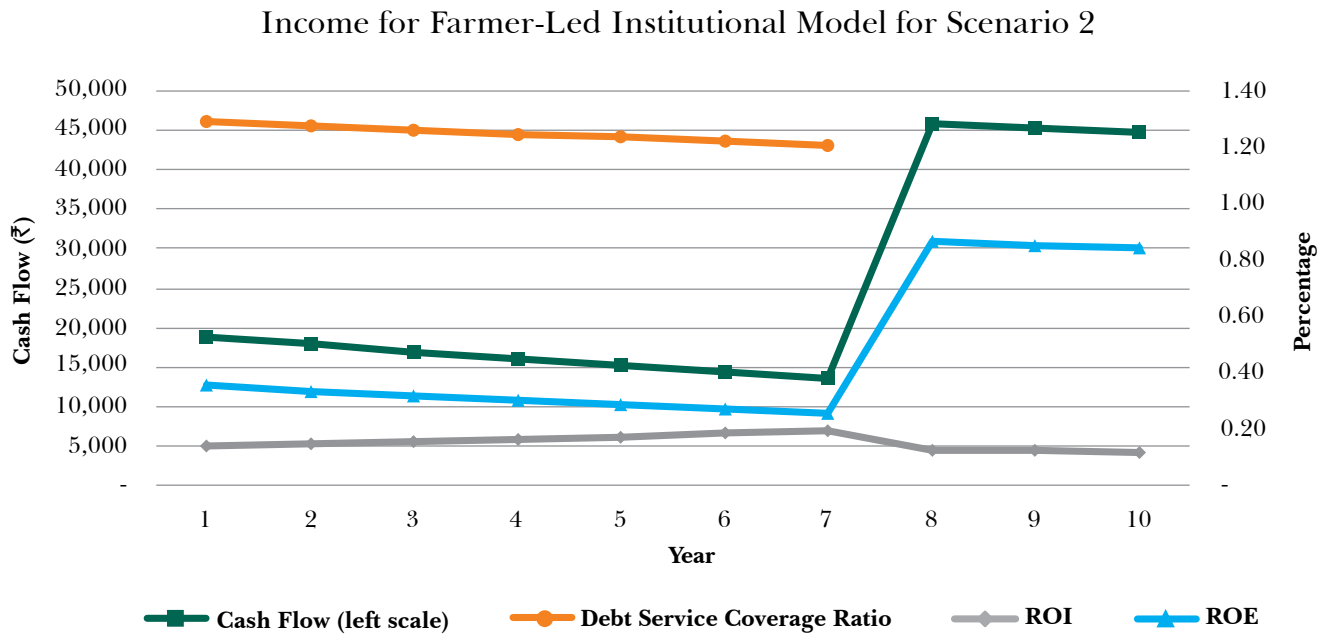


FIGURE D.5: PERFORMANCE METRICS FOR DOBADI FEEDER FOR SCENARIO 2



D.1.2 GANAHEDE FEEDER IN SANGOD BLOCK OF KOTA DISTRICT

Overview and Baseline

7. Ganaheda feeder is in Sangod block of Kota district. As on September 2018, it had a total of 1,039 connections and total connected load of

2,505 kW consuming 3.58 million kWh (Oct'17-Sept'18) annually. It is a mixed load feeder with 359 out of 1039 connection being metered agriculture connections with a total load of 2,423 HP consuming 3.57 million kWh annually, which is around 99% of the total annual consumption on the feeder. Table D.6 summarizes the defining parameters for Ganaheda feeder.

TABLE - D.4: GANAHEDE FEEDER: KEY FEATURES

| Parameter | Value | Parameter | Value |
|--|-----------|--|-------|
| Total No. of Connections | 1039 | T & D loss | 22% |
| Total Connected Load (kW) | 2505 | Average Cost of Supply (₹/kWh) | 6.97 |
| Total Consumption(kWh) | 35,84,196 | Electricity Tariff for Agriculture (metered) (₹/kWh) | 0.9 |
| No. of Agriculture Connections (metered) | 359 | Average DisCom Tariff (₹/kWh) | 6.86 |
| Agriculture Load (metered) (HP) | 2423 | Subsidy per unit of agriculture supply (₹/kWh) | 6.07 |
| Average Pump Size (HP) | 7.5 | Annual Power Purchase Cost (₹/ kWh) | 3.69 |

TABLE - D.5: PERFORMANCE METRICS FOR GANAHEDE FEEDER ACROSS THREE SCENARIOS

| | Scenario Base case | Scenario 1 | Scenario 2 |
|--|--------------------|------------|------------|
| DESI(₹/kWh) | - | 2.33 | 3.49 |
| Farmer's Annual Income (₹) during loan repayment | 3,364 | 4,312 | 4,787 |
| Farmer's Annual Income (₹) after loan repayment | 30,031 | 30,031 | 30,031 |
| Debt Service Coverage Ratio | 1.10 | 1.08 | 1.07 |
| IRR (%) | 16.00% | 15.08% | 14.75% |
| RoE (%) | 6 | 8 | 9 |

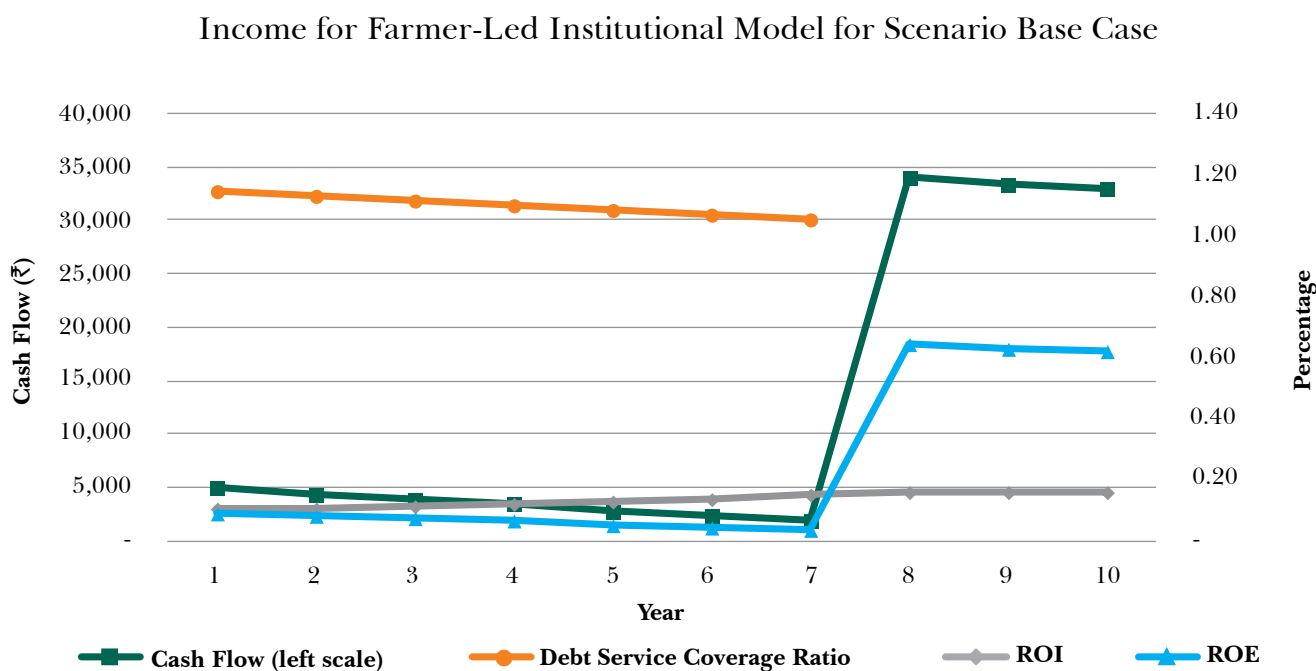
SUMMARY OF FINANCIAL ANALYSIS

8. Performance metrics of Ganaheda feeder are quite unattractive with annual income of farmer before debt repayment is a meager ₹ 3,364 and about ₹ 30,000 after debt repayment. A low return on equity at less than 10% indicates it is unlikely that farmers would invest in the scheme. One of the reasons is the higher consumption per HP by the farmers leaving little surplus to sell. There may be similar feeders in Rajasthan where one would need to explore other options.

SCENARIO BASE CASE

9. All the performance metrics look attractive for different stakeholders i.e. farmer being able to generate an IRR of 16% and state government being able to generate a return on capital subsidy at 42.25%. The income of farmer during the debt repayment period (initial 7 years) is quite low at ₹ 3,364. However, it increases to ₹ 30,031 post debt service. The proposition looks very attractive for the government because of the high farm power subsidy delivered in the feeder, which will be saved.

FIGURE D.6: PERFORMANCE METRICS FOR SCENARIO BASE CASE FOR GANAHEDE FEEDER



But given the lower surplus available with the farmers, the income is not significant for making the proposition attractive for them. Also, the debt service coverage ratio is low at around 1.1 making it unattractive for the lender to extend loan to the farmer under the assumed scenario.

The cash flow for the farmer during the debt repayment period increases to ₹ 4,312 making the proposition slightly better but still not attractive enough for farmers because of insignificant income addition. However, the income post debt service is attractive as discussed in Scenario base case i.e. ₹ 30,031.

SCENARIO 1 (PARTIALLY DEFERRED SUBSIDY)

10. In this scenario, the subsidy by center remains the same (30% upfront capital subsidy) but the state subsidy is split in to 10% upfront and 20% staggered form i.e. additional tariff to repay the debt taken by the farmer to finance gap in subsidy. To align the interests of both the farmer and the government, an evacuation-based incentive (DESI) of ₹ 2.33/kWh is paid to the farmer. Farmers debt increases to 50% as the state upfront subsidy reduces but the equity contribution by farmer remains at 10%. The debt service coverage ratio decreases slightly to 1.08 and remains unattractive for the lender.

SCENARIO 2 (FULLY DEFERRED SUBSIDY)

11. In this scenario, the 30% state subsidy is fully staggered through DESI of ₹ 3.49 /kWh and farmers takes 60% debt apart from contributing 10% equity. The farmer income increases slightly further to ₹ 4,787 in the debt repayment period because of the higher DESI but still is not substantial compared to farmer potential income in Dobadi feeder. Also, since farmers will be required to take a higher debt compared to scenario base case and 1, there may be skepticism among farmer community about this proposition.

FIGURE D.7: PERFORMANCE METRICS FOR GANAHEDE FEEDER FOR SCENARIO 1

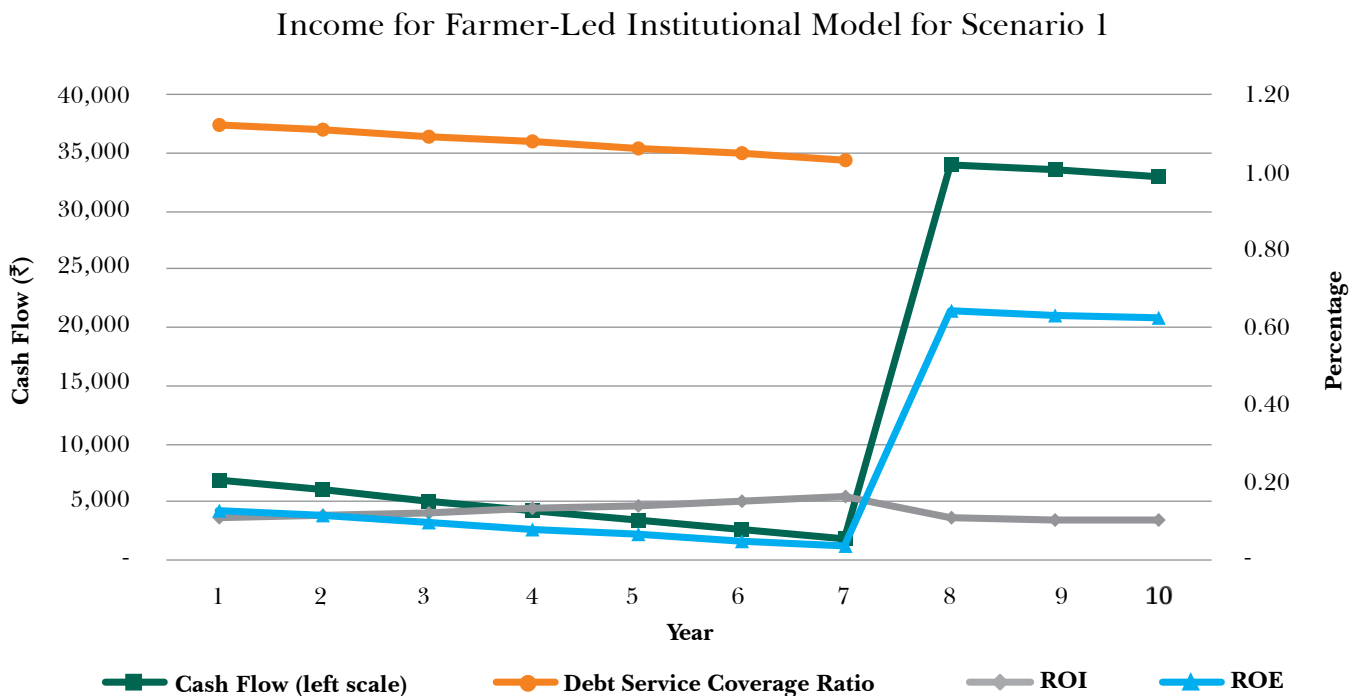


FIGURE D.8: PERFORMANCE METRICS FOR GANAHEDE FEEDER FOR SCENARIO 2

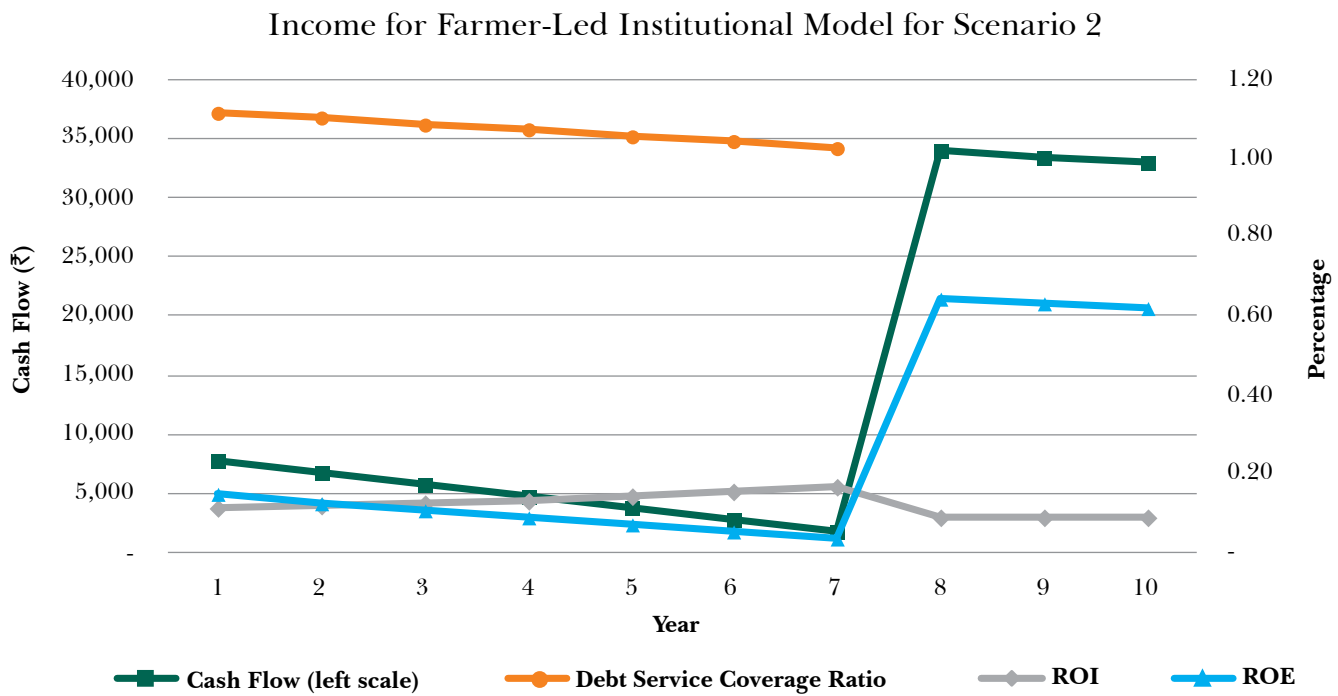


TABLE - D.6: LAXMIPURA FEEDER: KEY FEATURES

| Parameter | Value | Parameter | Value |
|--|-----------|--|-------|
| Total No. of Connections | 167 | T & D loss | 22% |
| Total Connected Load (kW) | 915 | Average Cost of Supply (₹/kWh) | 6.97 |
| Total Consumption(kWh) | 13,07,685 | Electricity Tariff for Agriculture (metered) (₹/kWh) | 0.9 |
| No. of Agriculture Connections (metered) | 132 | Average DisCom Tariff (₹/kWh) | 6.86 |
| Agriculture Load (metered) (HP) | 1184 | Subsidy per unit of agriculture supply (₹/kWh) | 6.07 |
| Average Pump Size (HP) | 10 | Annual Power Purchase Cost (₹/kWh) | 3.69 |

D.2 FEEDERS UNDER AJMER VIDYUT VITARAN NIGAM LIMITED (AVVNL)

D.2.1 Laxmipura Feeder in Pisangan Block of Ajmer District

Overview and Baseline

12. Laxmipura feeder is situated in Pisangan block of Ajmer district. As on September 2018, it had a total

of 167 connections and total connected load of 915 kW consuming 1.3 million kWh (Oct'17- Sept'18) annually. It is a mixed load feeder with 132 out of 167 connections being metered agriculture connections with a total load of 1184 HP consuming 1.22 million kWh annually, which is around 94% of the total annual consumption on the feeder. Table D.6 summarizes the defining parameters for Laxmipura feeder.

TABLE - D.7: PERFORMANCE METRICS FOR LAXMIPURA FEEDER ACROSS THREE SCENARIOS

| | Scenario Base case | Scenario 1 | Scenario 2 |
|--|--------------------|------------|------------|
| DESI (₹/kWh) | - | 1.88 | 2.82 |
| Farmer's Annual Income (₹) during loan repayment | 15,384 | 16,404 | 16,914 |
| Farmer's Annual Income (₹) after loan repayment | 50,629 | 50,629 | 50,629 |
| Debt Service Coverage Ratio | 1.36 | 1.23 | 1.20 |
| IRR (%) | 20.31% | 18.36% | 17.70% |
| RoE (%) | 22 | 23 | 24 |

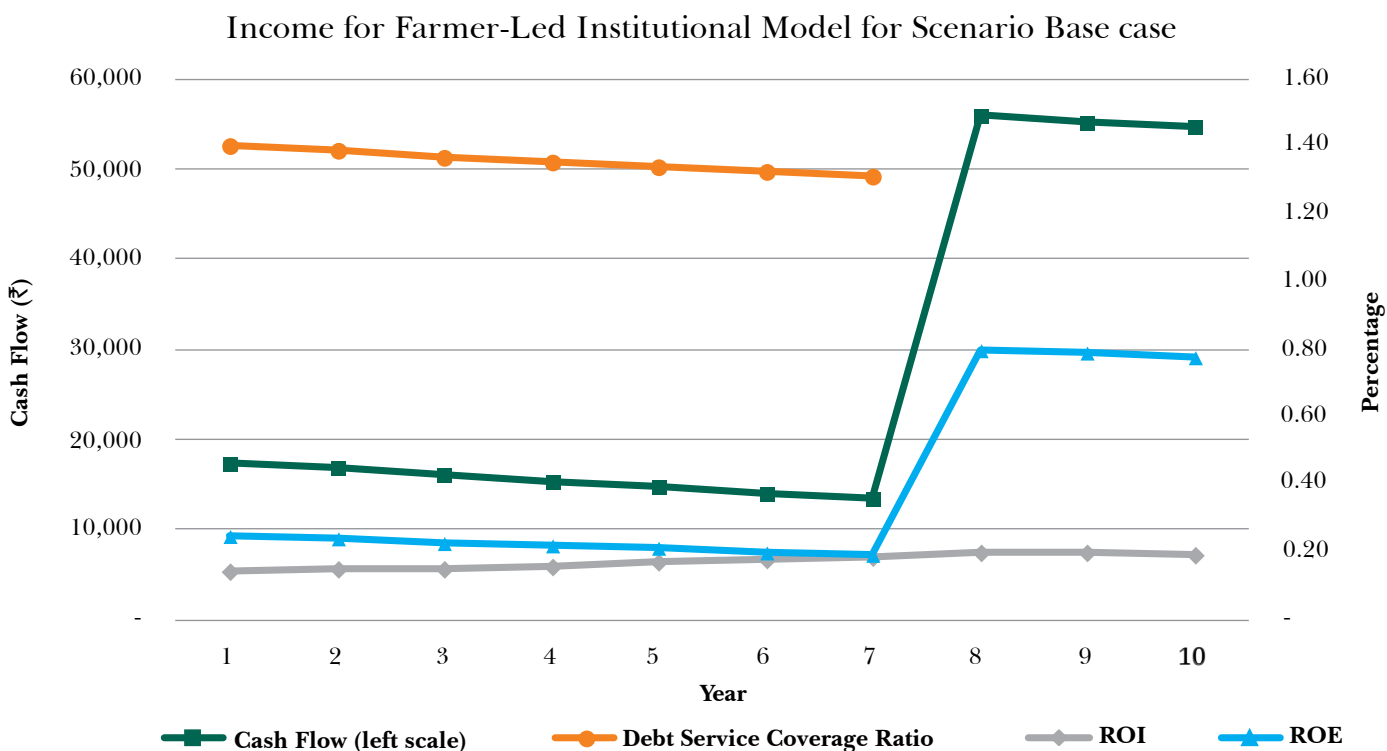
FINANCIAL ANALYSIS

13. The three business scenarios mentioned in Table D.7 were simulated for Laxmipura feeder to analyze the financial impact of different capital structures. It is assumed that kWp:HP will be 1.5 (1.5 kWp for a HP will be deployed). Table D.7 summarizes the results of three scenarios and Fig D.9, D.10 and D.11 show the change in performance matrices across initial 10 years for scenario base case, 1 and 2 respectively.

SCENARIO BASE CASE

14. This scenario is capital subsidy heavy with 60% upfront subsidy cumulatively, to be put in by central (MNRE) and state government. Farmer contributes 10% equity and takes 30% debt from NABARD for 7 years at 10% interest rate. All the performance metrics look attractive for different stakeholders i.e. farmer being able to generate an IRR of 20.3% and state government being able to generate a return on

FIGURE D.9: PERFORMANCE METRICS FOR SCENARIO BASE CASE FOR LAXMIPURA FEEDER



capital subsidy at 29.9%. The average cash flows of farmer during the debt repayment period (initial 7 years) is ₹ 15,384 which shoots up to ₹ 50,629 post debt service. Hence, the proposition looks attractive for both farmer and the government. The debt service coverage ratio is more than 1.3 making it acceptable for lender to extend loan to the farmer under the assumed scenario. Even though, all the performance metrics look acceptable in the scenario, the initial commitment and outlay required by the state government is substantially high, which may lead to slow speed of implementation or unspecified delays.

paid to the farmer. Farmers debt increases to 50% as the state upfront subsidy reduces but the equity contribution by farmer remains at 10%. The debt service coverage ratio remains close to 1.23 making it acceptable for the lender. The average cash flow for the farmer during the debt repayment period increases to ₹ 16,404 making the proposition more attractive for farmers because of significant income addition. The income post debt service remains the same as in Scenario 1 i.e. ₹ 50,629. The conversion of a part of state upfront subsidy to a staggered form will reduce the upfront commitment by the state government, therefore improving the scalability of the model.

SCENARIO 1 (PARTIALLY DEFERRED SUBSIDY)

15. In this scenario, the subsidy by center remains the same (30% upfront capital subsidy) but the state subsidy is split in to 10% upfront and 20% staggered form i.e. additional tariff to repay the debt taken by the farmer to finance gap in subsidy. To align the interests of both the farmer and the government, an evacuation-based incentive of ₹ 1.88 /kWh is

SCENARIO 2 (FULLY DEFERRED SUBSIDY)

16. In this scenario, the 30% state subsidy is fully staggered through EBI of ₹ 2.82/kWh and farmers takes 60% debt apart from contributing 10% equity. The remaining is the subsidy by central government (MNRE, 30%). The DESI enables the farmer to pay the loan and also augment his cash income.

FIGURE D.10: PERFORMANCE METRICS FOR LAXMPIPURA FEEDER FOR SCENARIO 1

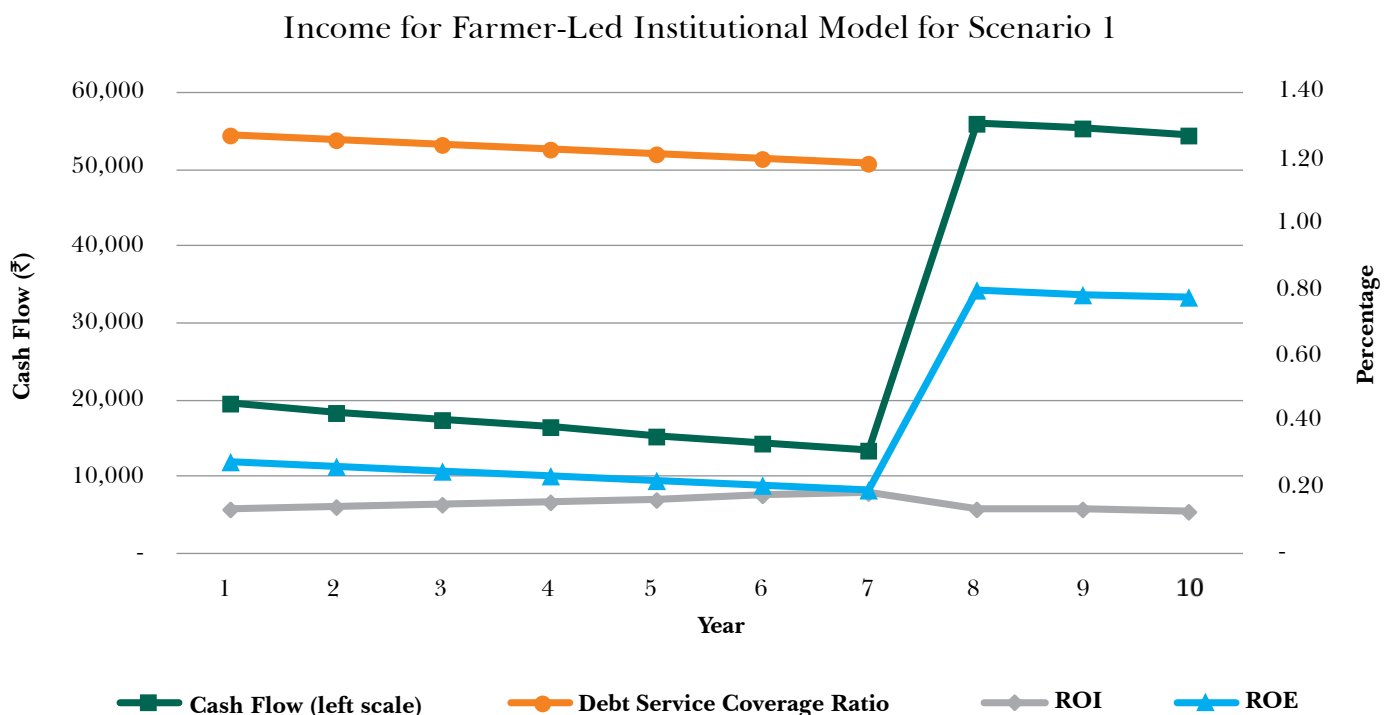
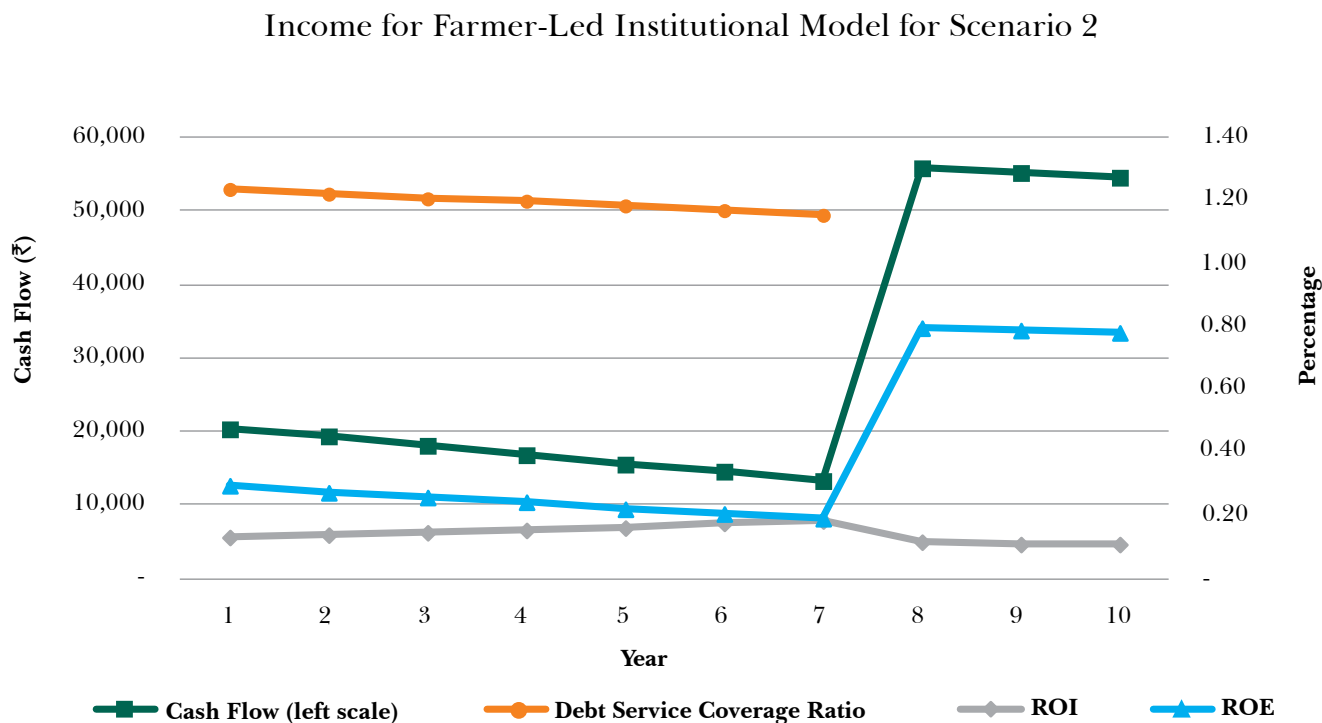


FIGURE D.11: PERFORMANCE METRICS FOR LAXMPIPURA FEEDER FOR SCENARIO 2



The cash flow further increases to ₹ 16,914 in the debt repayment period making it attractive for farmers from one point. But because they will be required to take a higher debt compared to scenario base case and 1, there may be skepticism among farmer community about this proposition. All other performance metrics remain attractive as in other cases.

D.2.2 NAND SAWAIPURA FEEDER IN PISANGAN BLOCK OF AJMER DISTRICT

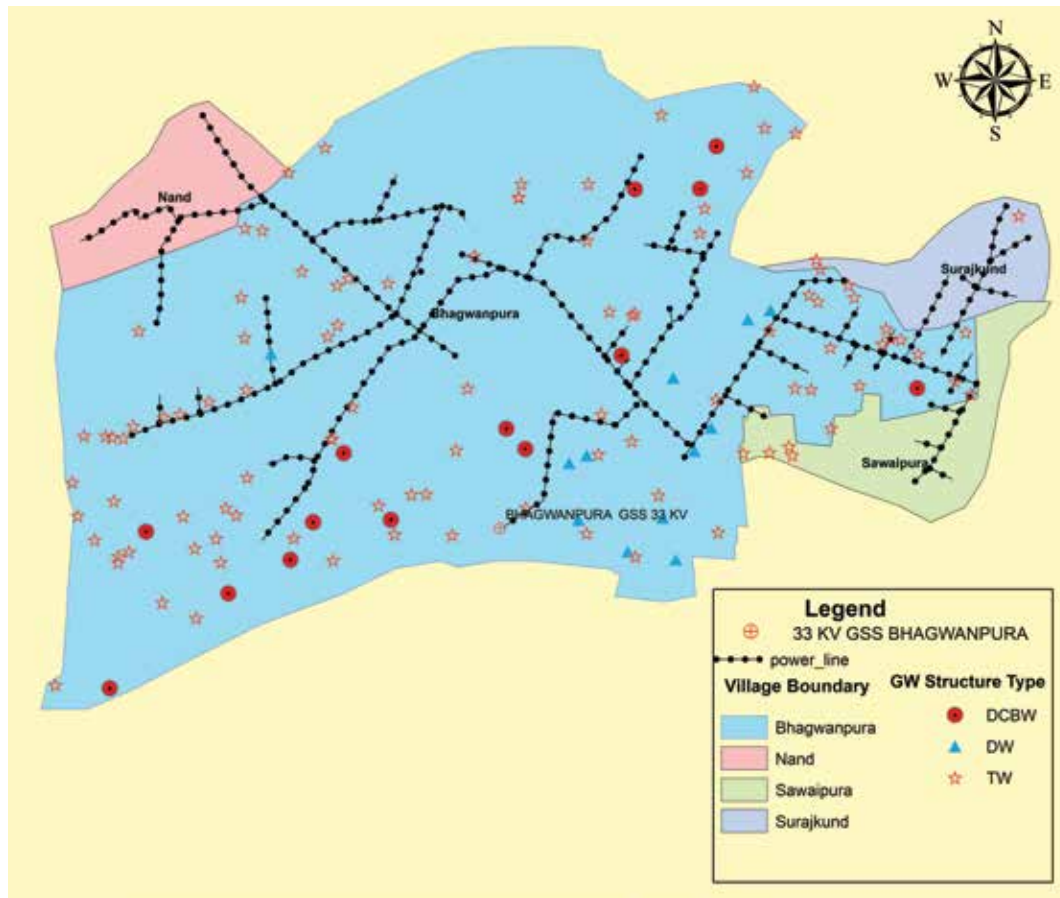
Overview and Baseline

17. Nand Sawaipura is the second feeder in Pisangan which was selected for simulation to analyse the

TABLE - D.8: PARAMETERS FOR NANDSAWAI PURA FEEDER

| Parameter | Value | Parameter | Value |
|--|-----------|--|-------|
| Total No. of Connections | 237 | T & D loss | 22% |
| Total Connected Load (kW) | 1184.7 | Average Cost of Supply (₹/kWh) | 6.97 |
| Total Consumption(kWh) | 1,261,343 | Electricity Tariff for Agriculture (metered) (₹/kWh) | 0.9 |
| No. of Agriculture Connections (metered) | 128 | Average DisCom Tariff (₹/kWh) | 6.86 |
| Agriculture Load (metered) (HP) | 1208.4 | Subsidy per unit of agriculture supply (₹/kWh) | 6.07 |
| Average Pump Size (HP) | 5 | Annual Power Purchase Cost (₹/kWh) | 3.69 |

FIGURE D.12: LOCATION OF NANDSAWAI PURA FEEDER



expected results of different business models. The feeder supplies electricity to Bhagwanpura region in Pushkar block of Ajmer district. Table D.8 summarizes the characteristics of the feeder. Fig D.12 indicates the feeder and locations of groundwater structures in the command area of the feeder.

FINANCIAL ANALYSIS

18. The three business scenarios mentioned in Table D.9 were simulated for Nandsawai Pura feeder to analyze the financial impact of different capital structures. It is assumed that kWp:HP will be

TABLE - D.9: PERFORMANCE METRICS FOR NANDSAWAI PURA FEEDER ACROSS THREE SCENARIOS

| | Scenario Base case | Scenario 1 | Scenario 2 |
|--|--------------------|------------|------------|
| DESI (₹/kWh) | - | 1.82 | 2.72 |
| Farmer's Annual Income (₹) during loan repayment | 17,311 | 18,298 | 18,791 |
| Farmer's Annual Income (₹) after loan repayment | 52,556 | 52,556 | 52,556 |
| Debt Service Coverage Ratio | 1.40 | 1.25 | 1.22 |
| IRR (%) | 21.05% | 18.92% | 18.20% |
| RoE (%) | 25 | 26 | 27 |

1.5 (1.5 kWp for a HP will be deployed). Table D.9 summarizes the results of three scenarios and Fig D.13, D.14 and D.15 show the change in performance matrices across initial 10 years for scenario base case, 1 and 2 respectively.

SCENARIO BASE CASE

19. All the performance metrics look attractive for different stakeholders i.e. farmer being able to generate an IRR of 21% and state government being able to generate a return on capital subsidy at 27.6%. The income of farmer during the debt repayment period (initial 7 years) is ₹ 17,311 which shoots up to ₹ 52,556 post debt service. Hence, the proposition looks attractive for both farmer and the government. The debt service coverage ratio is more than 1.4 making it attractive for lender to extend loan to the farmer under the assumed scenario. Even though, all the performance metrics look acceptable in the scenario, the initial commitment and outlay required by the state government is substantially high, which may lead to slow speed of implementation or unspecified delays.

SCENARIO 1 (PARTIALLY DEFERRED SUBSIDY)

20. In this scenario, the subsidy by center remains the same (30% upfront capital subsidy) but the state subsidy is split into 10% upfront and 20% staggered form i.e. additional tariff to repay the debt taken by the farmer to finance gap in subsidy. To align the interests of both the farmer and the government, an evacuation-based incentive (DESI) of ₹ 1.82/kWh is paid to the farmer. Farmers debt increases to 50% as the state upfront subsidy reduces but the equity contribution by farmer remains at 10%. The debt service coverage ratio remains close to 1.25 making it acceptable for the lender. The average cash flow for the farmer during the debt repayment period increases to ₹ 18,298 making the proposition more attractive for farmers because of significant income addition. The income post debt service remains the same as in Scenario 1 i.e. ₹ 52,556. The conversion of a part of state upfront subsidy to a staggered form will reduce the upfront commitment by the state government, therefore improving the scalability of the model.

FIGURE D.13: PERFORMANCE METRICS FOR SCENARIO BASE CASE FOR NANDSAWAI PURA FEEDER

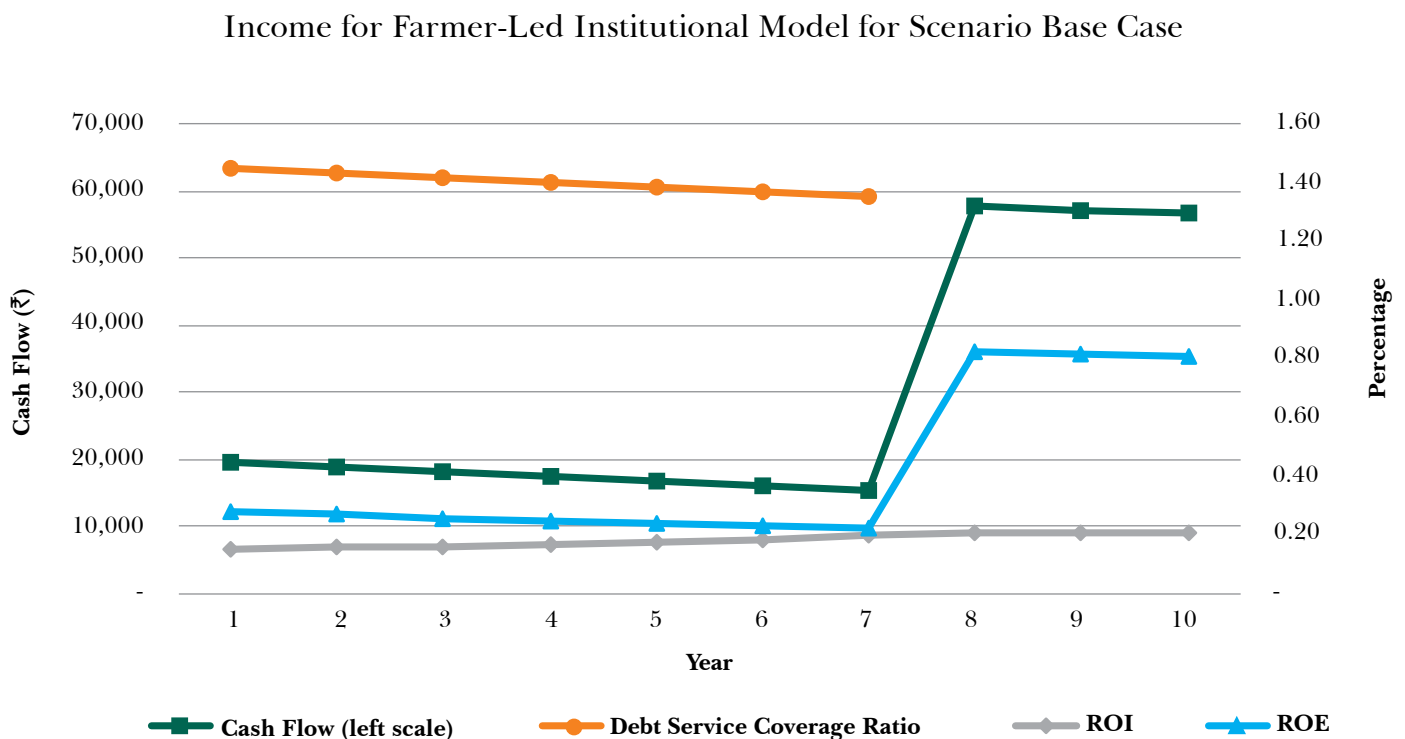
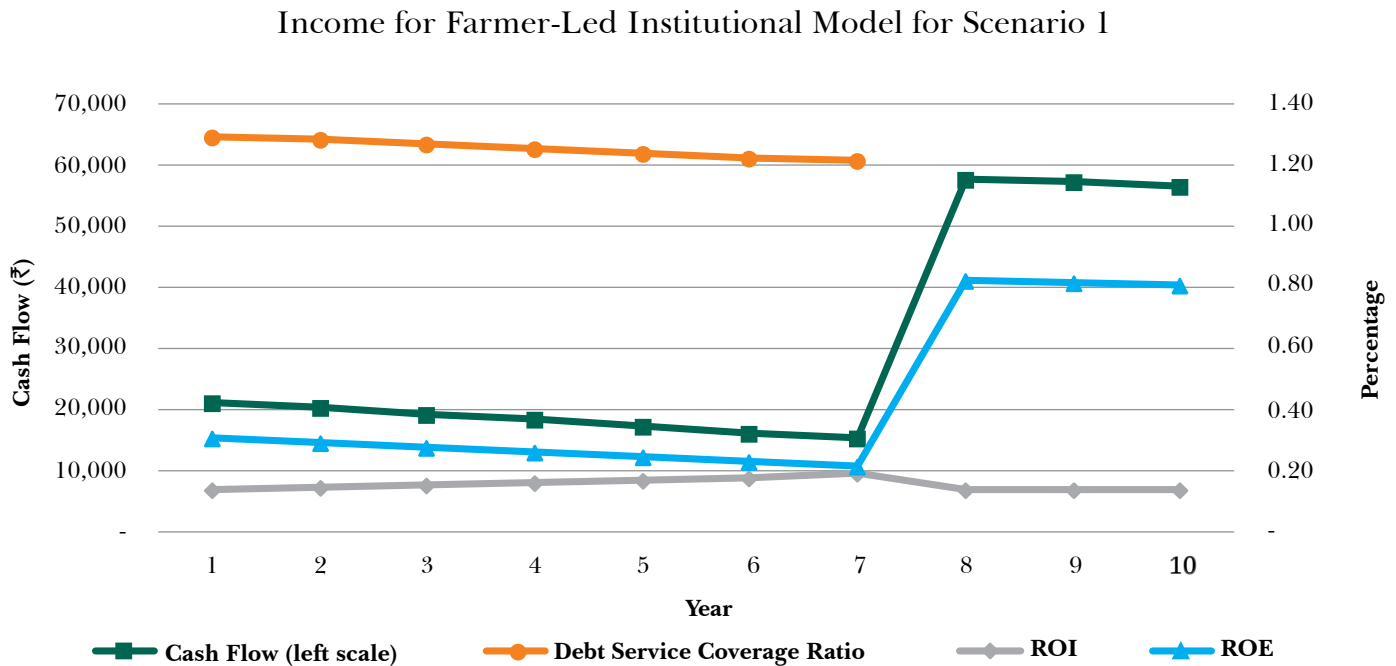


FIGURE D.14: PERFORMANCE METRICS FOR NANDSAWAI PURA FEEDER FOR SCENARIO 1

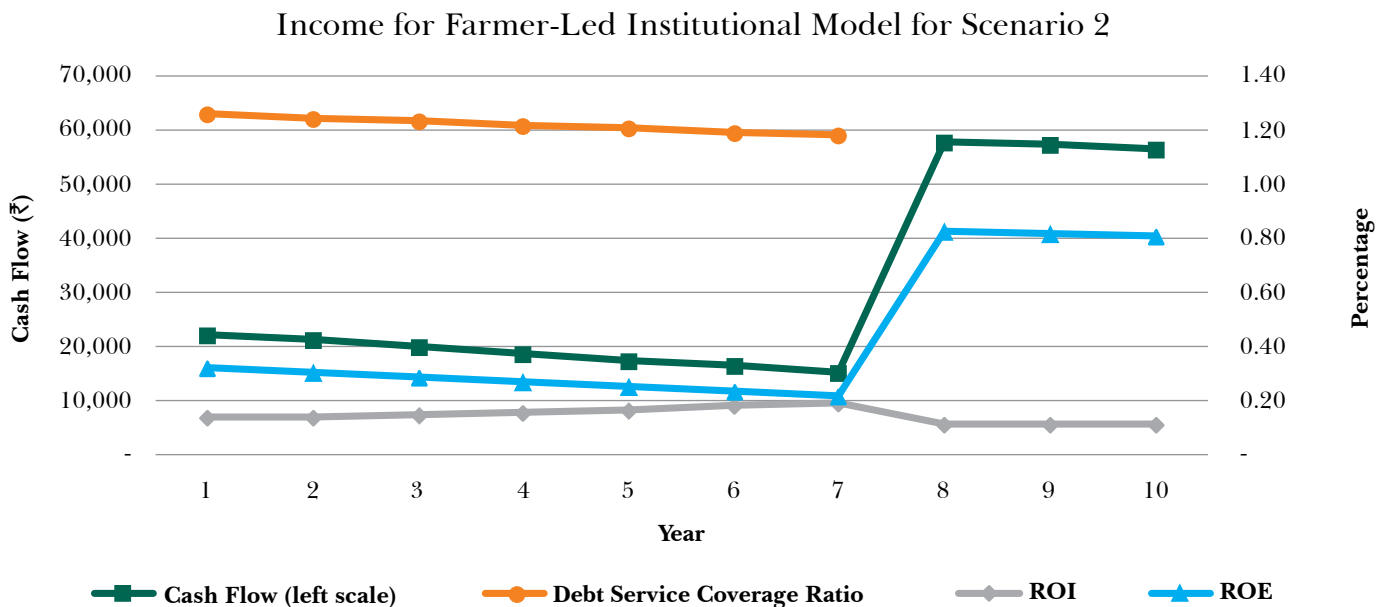


SCENARIO 2 (FULLY DEFERRED SUBSIDY)

21. In this scenario, the 30% state subsidy is fully staggered through DESI of ₹ 2.72/kWh and farmers takes 60% debt apart from contributing 10% equity. The DESI enables the farmer to pay the loan and

also augment his cash income. The cash flow further increases to ₹ 18,791 in the debt repayment period making it attractive for farmers from one point. But because they will be required to take a higher debt compared to scenario base case and 1, there may be skepticism among farmer community about this proposition. All other performance metrics remain attractive as in other cases.

FIGURE D.15: PERFORMANCE METRICS FOR NANDSAWAI PURA FEEDER FOR SCENARIO 2



ANNEX E

FARMER PRODUCER COMPANIES AND AGGREGATION OF SOLAR ENERGY

PREAMBLE

1. A Producer Organization (PO) is a legal entity formed by primary producers, viz. farmers, milk producers, fishermen, weavers, rural artisans, craftsmen. A PO can be a producer company, a cooperative society or any other legal form which provides for sharing of profits/benefits among the members. In some forms like producer companies, institutions of primary producers can also become members of a PO.
2. As formal, voluntary membership-based, higher-tier collective organizations working for the economic benefit of their producer-members, POs perform a wide range of roles and functions to serve their members: policy advocacy as enabling agencies; input aggregation and collective marketing services as delivery agencies; and facilitating member access to external resources and benefits as user agencies.
3. Some salient benefits of organizing farmers into collectives include: reduction in cost of production; aggregation of produce reduces marketing cost and enhances net income of the producer; access to finance and credit without collaterals helps bring-in economies of scale at farm gate; access to technologies, capacity building, extension and training as well as traceability of the produce; value addition and value chain development; assured return such as contract farming; Improved awareness by information, education and communication campaign; improved access to govt funded program and schemes; and improved bargaining power and social capital.
4. An FPO can be registered under any of the following provisions of different laws:
 - a. Cooperative Societies Act/ Autonomous or Mutually Aided Cooperative Societies Act of the respective State
 - b. Multi-State Cooperative Society Act, 2002
 - c. Producer Company under Section 581(C) of Indian Companies Act, 1956, as amended in 2013
 - d. Section 25 Company of Indian Companies Act, 1956, as amended as Section 8 in 2013
 - e. Societies registered under Society Registration Act, 1860
 - f. Public Trusts registered under Indian Trusts Act, 1882
5. Institutions registered as cooperative societies and producer companies have legal provisions for sharing of profit earned by the FPO by way of dividend. Other legal forms do not explicitly provide for profit sharing. A Solar FPO would be only an aggregator and a cost center for the purpose of maintenance of feeder and other operating costs. It would not earn any profit nor would it borrow since solar systems would be owned and installed by the farmers.

FARMER PRODUCER COMPANY:

6. Producer organizations registered under Section 581(C) of Indian Companies Act, 1956, as amended in 2013 are termed as Farmer Producer Company. Principally the structure, concept and philosophy of Co-operative Societies formed under the Co-operative Societies Act, 1961 has been kept intact as a basic framework and then the same has been improvised. Provisions relating to conversion of the existing Co-operative Societies registered under various other statutes have been also incorporated that gave an opportunity to the cooperative sector to corporatize itself.
7. Over the period, Producer Company has gained popularity due to: a) Co-operatives have largely been state promoted, with a focus on welfare

rather than to do business on commercial lines and more State government intervention in the management of Co-operatives; b) Whereas Companies Act is central legislation comparatively more liberal and minimal government control in the management of the Company; c) A Producer Company is hybrid of Company and Co-operative Society; and d) It combines the goodness of a co-operative enterprise and vibrancy and efficiency of a company and accommodates the unique elements of cooperative business with a regulatory framework similar to that of a company.

FPC FORMATION AND MANAGEMENT

8. The formation and regulation of Producer Company is governed under the provisions of Sections 581A to 581ZL of Companies Act, 1956, read with Companies Act, 2013, and the rules made thereunder. As per section clause (1) of section 581C of the Companies Act, 1956, any one of the following combinations can form a Producer Company:

- Any ten or more individuals each of them being a producer
- Or any two or more Producer Institutions
- Or Combination of 10 or more individuals and Producer Institutions

COMPLIANCE REQUIREMENTS:

9. There are number of compliances that have been defined for effective and transparent management of FPOs. Generally, the area of coverage of a Farmer Producer Company is ideally in a radius of 15 to 20 km. Each FPC can have 10 to 15 first promoters out of whom, five are registered as the first directors of the FPC and the FPC can pass any decision with 3/5th majority. Generally, each promoter is responsible for around 100 members or 5-6 farmer groups or 2-3 villages. Each village is also represented by a village leader who acts as a link between the promoters, and the member farmers. This structure helps both backward and forward integration of all communication related to information dissemination, input demand

collection and crop aggregation. An equity contribution of ₹ 1000 per subscriber and up to ₹ 10,000 for first promoter makes each member act responsibly towards the FPC.

10. The fiduciary management of a FPC include preparation of several activities every year which include: filing of balance sheet; general body meeting; filing of Accounts; filing of income tax return with department, filing of Know Your Customer with to the directors, returns with FSSAI and periodic filing of as decided by FPC executives. In addition, quarterly board meeting is convened, and first general body meeting is conducted within 90 days of incorporation; proper maintenance of KYC and registration of members; and several statutory registers covering the details of equity of each member, share certificate distribution register, bonus and transfer equity etc.

FPC BENEFITS

11. An awareness campaign and capacity building of farmers and position holders in FPCs should be done on regular interval to help them understand the real benefit of institution. For example FPC offers: a) a separate legal entity offering limited liability and perpetuity; b) the Producer companies offer greater creditability than that provided by unregistered producer's organization; c) changes in the Board of management of a producer company can easily and swiftly be made just through filing some simple forms with designated authorities; d) a registered Producer company entitled to own, sell, enjoy, or alienate a property in its own name; e) a producer company can accept deposit in the form of recurring deposit/fixed deposit, and give maturity as well as distribute loans to its farmer/agriculturist members, and charge reasonable interest from them.; f) producer company can take benefits of SFAC (Small Farmers' Agri-Business Consortium, Govt. of India) schemes like equity grant, credit guarantee and venture capital fund for organization and business support; and g) FPC can help in substantially increase income of member farmers through collectivization of agri-input purchase and sell after value addition of agri-produce.

POTENTIAL FOR FARMER PRODUCER COMPANY AND AGGREGATION OF SOLAR ENERGY

12. Around 80% of fresh water in India is being used for irrigation. Out of this, around 60% is met through ground water. Use of ground water requires energy and farmers are always in stress to use proper type of energy for their irrigation requirements. While use of conventional diesel pumps is highly cost intensive, availability of electricity at the time of watering requirement is also a challenge. Though all villages in India are now electrified, maintaining supplies through grid to all farm fields is highly challenging for the DisComs. At the same time, the solar irrigation system of many farmers lies idle for most of the time after fulfilling the irrigation requirement of the farm. Village level aggregation of solar energy can offer a potential solution to the energy crisis in rural India. Farmers can be promoted to install solar systems along with solar pumps and those could be connected to a local grid managed by a local Resource Institution which would redistribute the power to other needy farmers in the area. This would thus act as an income generating proposition for the farmers who install such system and a reliable source of electricity for other farmers in the area. This will also ensure perineal income for the farmers and thus may be a vehicle to achieve the doubling farmer's income target of the Central Government.

SCOPE OF FPC FOR PROMOTING SOLAR ENERGY IN INDIA:

13. FPCs have a strong base and outreach in their coverage villages through a network of 10-15 promoters who have a direct outreach to 80-100 farm families. Each promoter has a coverage of 2-3 villages and each village is being represented by a village representative. Each village has 2-3 Farmer Groups and they elect the village representative among the Group leaders. All FPCs have some basic infrastructure i.e. an office or input shop or a warehouse or grain cleaning grading unit or a vegetable pack house. The FPCs also have a qualified CEO for professional management

and are mostly supported or hand held for a period of 2-3 years by a professional agency. The Board members and Lead farmers of the FPC along with the CEO are also being provided with regular training and capacity building by the promoting institutions. Rajasthan currently has 250 plus FPCs in the state i.e. the FPCs have a good outreach in most of the rural parts of the State. This makes FPCs one of the most equipped vehicles for facilitating outreach of solar energy in rural areas in Rajasthan.

FPC MANAGED GRID CONNECTED SOLAR PUMPS:

14. FPCs can be the implementer for the program, wherein it can act on behalf of the grid to act as a point of contact between the grid and its member farmers, seeing the limited outreach of the DisComs in the rural area. The FPC can earn a fair amount of commission for operation and maintenance of the system and can employ rural youth.

15. Roles and responsibility of FPC managed grid connected solar pumps can start by organizing village level meetings through the existing FPCs, their Village leaders, Group leaders and respective Board members to spread awareness of the scheme and educate farmers on the income potential of the farmers. Invite officials of the DisCom to train farmers on the modus operandi of the system i.e. how the farmers can install the systems, get logged in to the grid, share excess power to the grid. Identify villages where more than 70% farmers show interest to the scheme. Recommend list of such farmers who intend to incur 40% as promoter contribution (ex: 30% of which can be bank financed and rest 10% as promoters' equity) and villages to the DisCom or any nodal agency for initiating application from farmers. Facilitate application of farmers to the DisCom/ any designated agency for installation and grant of subsidy from Central/ State Government. Prepare loan documents for the farmers and facilitate approval 30% loan. Facilitate signing of contract between Farmer and DisCom. Facilitate distribution of the excess power to other farmers in the area. Facilitate smooth

invoicing and payments to ensure maintenance of the grid connected solar ecosystem. Facilitate exposure visits of village leaders/ lead farmers to FPOs already operating such business models.

BENEFIT TO FARMERS

16. The farmer producer companies and aggregation of solar energy will offer a stable source of income to landowners for at least 25 years. A minimum installation height will ensure that farming activities can take place along with solar plants in case of cultivable lands. The design of the solarization of irrigation is meant to generate surplus solar power that can not only fulfil the agriculture and other power requirements of the household but also to evacuate the same through the Solar FPCs to the grid to sell. Solar pumps can save a huge amount of cost that is spent on buying diesel. They provide a reliable source of irrigation to farmers and solar pumps can also help in curbing pollution that is caused by burning diesel.

CONCLUSION

17. The main functions of a Solar FPO would be to aggregate the surplus power produced by the farmers, keep energy accounting of members contribution, losses, and delivery to the off-taker at the net meter at substation, maintain the feeder, deliver the invoice for sale of power to the DisCom and to the commercial bank for distribution of sale proceeds received from the DisCom. The Solar FPO would be a cost center and not earn profits or distribute dividend. Given the role of Solar FPO being narrower than a normal FPO, it would be advisable to register it as an FPO instead of FPC, at least in the beginning since registration and operationalization of an FPO is quicker than an FPC. At a later stage the FPO can be converted into an FPC if its business expands or the members find an FPC would serve their interest better.

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