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Outcome Evaluation of Climate-Smart Research on Solar-Powered Irrigation in India

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IN PARTNERSHIP WITH:

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ACRONYMS

A4NH – CGIAR Research Program on Agriculture for Nutrition and Health
CBO – Community-based organization
CCAFS – CGIAR Research Program on Climate Change, Agriculture and Food Security
CRP – CGIAR Research Program
DISCOMs – Electricity distribution companies
DSC – Development Support Center
DSUUSM – Dhundi Saur Urja Utpadak Sahakari Mandali
EQ – Evaluation question
GERMI – Gujarat Energy Research and Management Institute
GESI – Gender equality and social inclusion
GHG – Greenhouse gases
GIZ –Deutsche Gesellschaft für Internationale Zusammenarbeit
GUVNL – Gujarat Urja Vikas Nigam Limited
GW – Gigawatts
hp – Horsepower
ITP – IWMI-Tata Water Policy Research Program
IWMI – International Water Management Institute
KUSUM – Kisan Urja Shakti evam Utthan Mahabhiyan
kV - Kilovolt
kW – Kilowatt
MGVCL – Madhya Gujarat Vij Company Limited
MNRE – Ministry of New and Renewable Energy
MW – Megawatts
NDDB – National Dairy Development Board
NGO – Not-for-profit organization
NPV – Net present value
PMKSY – Pradhan Mantri Krishi Sinchai Yojana
PV – Photovoltaic
REIL – Rajasthan Electronics and Instruments Limited
RTB – CGIAR Research Program on Roots, Tubers and Bananas
SDC – Swiss Agency for Development and Cooperation
SIPs – Solar irrigation pumps
SKY – Suryashakti Kisan Yojana
SoLAR-SA – Solar Irrigation for Agricultural Resilience in South Asia
SPaRC – Solar power as a remunerative crop
SPICE – Solar Pump Irrigators' Cooperative Enterprise
ToR – Terms of reference
WLE – CGIAR Research Program on Water, Land and Ecosystems

GLOSSARY OF TERMS

Champion – Someone who sees value in an outcome trajectory and engages with decision makers to strengthen it.

Energy-water-agriculture nexus – The long-running difficulty in finding financially and economically viable and politically acceptable solutions to the problems of providing highly subsidized electricity for pumping and avoiding overextraction of groundwater while allowing farmers' incomes to increase.
Feeder – The line from a step-down transformer (400 kV) out to farms.
Initiative – Coherent sets of activities such as breeding, dissemination, policy engagement and technical support that may or may not be project-related.
Outcome – A change in behavior (practices, relationships) or policies (that influence behavior) of individuals, groups, organizations or institutions.
Outcome-evidencing approach: An adaptation of outcome harvesting in which a case is built and challenged as to whether a program has contributed to one or more outcome trajectories.
Outcome trajectory **–** The pattern of interactions and causal links between actors, technologies and institutions that maintain and scale a coherent set of outcomes over time, e.g., the inclusion by the Government of India of SPaRC in the USD 50 billion KUSUM scheme.
Solar power as a remunerative crop (SPaRC) – Approaches by which farmers are able to sell solar power back to the grid and earn by doing so.
Social norms – Collective representations of acceptable group conduct as well as individual perceptions of particular group conduct. They can be viewed as cultural products (including values, customs and traditions) that represent individuals' basic knowledge of what others do and think that they should do.
WLE/CCAFS outcome – An outcome to which WLE/CCAFS have contributed.

EXECUTIVE SUMMARY

This summary extracts the conclusions and recommendations from an evaluation of the outcomes from the work of the CGIAR Research Programs (CRP) on Water, Land and Ecosystems (WLE) and Climate Change, Agriculture and Food Security (CCAFS). It is intended to serve as a stand-alone summary, as well as to direct readers to a more detailed description of the methodology, evidence and findings in the main report.

Introduction

WLE and CCAFS are global research-for-development programs supported by CGIAR, a global research partnership for a food-secure future.

In seeking to learn, improve and be more accountable, WLE has carried out three outcome evaluations in recent years, of which this is the third. The first two were on resource recovery and reuse in Ghana and Sri Lanka, and on WLE's water and soil outcomes in Ethiopia.

This evaluation concerns a significant policy outcome, specifically the CRP contribution to the incorporation of an approach to solar irrigation – solar power as a remumerative crop (SPaRC) – in two government programs: the Indian government's USD 50 billion Kisan Urja Shakti evam Utthan Mahabhiyan (KUSUM) initiative and the Gujarat State government's Suryashakti Kisan Yojana (SKY) scheme. The intention of KUSUM, the bigger of the two programs, is to help 2 million farmers adopt SPaRC by 2022 in expectation of much wider adoption thereafter.

The IWMI-Tata Water Policy Research Program (ITP) has worked on SPaRC since 2012 with support from WLE and CCAFS, among others. WLE and CCAFS decided to jointly commission this evaluation to better document and understand their respective contributions to the outcome, as well as to gain a sense of the likely impact of SPaRC under different adoption and usage scenarios.

The primary intended users of the evaluation are decision makers in WLE and CCAFS who are interested in better understanding how CGIAR research and other forms of intervention contribute to policy outcomes. Intended users also include staff from donor organizations; staff from other CRPs; and national partners and stakeholders working to scale up beneficial technologies and institutions. More generally, the report's findings and conclusions will be relevant to anyone who wants to better understand mechanisms by which research can contribute to developmental impact.

Methodology

This evaluation uses a version of outcome harvesting called outcome evidencing (Paz-Ybarnegaray and Douthwaite 2017), which was successfully used for an evaluation of WLE outcomes in Ethiopia (Douthwaite and Getnet 2019). Outcome evidencing is a theory-driven approach that is based on the presumption that outcomes result from evolving patterns of interactions between people, technologies and institutions. These patterns are called 'outcome trajectories.' Programs contribute to catalyzing, stabilizing and amplifying these patterns. Outcome evidencing is about describing and validating outcome trajectories and a program's contribution to them. This evaluation is of WLE's and CCAFS' contribution to the outcome trajectory that has led to SPaRC being adopted by the KUSUM and SKY programs. An existing theory of how policy change occurs – policy window theory – was used to help identify and understand underlying causal mechanisms.

The evaluation addressed five questions:

1. How can the policy window theory be made more specific to the SPaRC outcome trajectory so as to help answer subsequent evaluation questions 2, 3 and 4?
2. What were WLE and CCAFS solar irrigation outcomes in India and how did WLE and CCAFS contribute to them?
3. Did WLE and CCAFS help influence/contribute to the design and promotion of research that integrates/considers gender or the needs of marginalized groups within its partner centers?
4. Are WLE and CCAFS outcomes likely to be sustainable over the long term?
5. Looking forward to 2022 and 2030, what are the projected benefits for people and the environment?

Conclusions

Conclusion 1: Since 2012, CGIAR has catalyzed and played a key role in an outcome trajectory by which the idea of SPaRC gained recognition, became seen as workable, and has been adopted as one of the three components of the USD 50 billion Government of India KUSUM scheme.

Conclusion 2: The policy window theory helped understand how CGIAR contributed to the trajectory by:

- Framing SPaRC as a potential solution to at least five politically important issues;
- Maintaining and exercising the capacity to present, demonstrate and write about SPaRC in ways that together proved extremely effective at influencing government policy;
- Forming partnerships and a coalition to help create a more enabling environment for SPaRC;
- Identifying and answering research questions, the timely answer of which is needed to help SPaRC compete against other ways of solarizing mechanical irrigation that are less beneficial to farmers and the environment, but easier to implement.

Conclusion 3: WLE, CCAFS, Tata Trusts, the Swiss Agency for Development and Cooperation (SDC) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) together made a strong contribution to the SPaRC outcome trajectory:

- WLE funded International Water Management Institute (IWMI) senior scientist time to engage in SPaRC work, in particular to write the articles and papers and attend the key events that helped SPaRC gain recognition among policy makers;
- CCAFS funded and made possible the Dhundi pilot initiative that proved catalytic in moving the perception of SPaRC from a good idea in theory to an approach that worked on the ground, deserving inclusion in KUSUM;
- Tata Trusts funded other costs associated with attending key events; bonuses to SPaRC pilot farmers; and ITP interns who did the field work and data collection;
- SDC provided significant additional funding support, including funding the four-country IWMI-led Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) project from 2019;
- GIZ funded the Solar Irrigation Expansion in India Partnership to develop tools and case studies for solar irrigation promotion at scale, in particular for SPaRC.

Conclusion 4: By far the largest project supporting the SPaRC outcome trajectory – SoLAR-SA – has brought a strong emphasis on gender equality and social inclusion (GESI). This is manifest in addressing two policy-relevant questions in particular:

- How have current solar irrigation policies and programs impacted on farmers' livelihoods and gender equity?
- Which financial model generates maximum willingness among small-scale and marginal farmers to adopt solar irrigation?

The project has influenced the design of other solar irrigation projects that have also adopted a strong GESI focus.

Conclusion 5: The SPaRC outcome trajectory clearly shows that influencing policy is a route to scale, which is important for CGIAR. ITP has been very effective in influencing solar irrigation policy. Despite this, ITP is unique in CGIAR in the following ways:

- Its equal partnership between a CGIAR Center (IWMI) and a foundation concerned with development (Tata Trusts);
- Its objective to help policy makers at all levels address their water challenges by translating research findings into practical policy recommendations – this is not a research objective but rather one that speaks to bridging research and development;
- Its employment of people with a management rather than a research background; this aligns well with ITP's mandate for 'problem-solving' research with a strong bias toward field action;
- Its practice of giving more credit for policy-relevant publications than academic ones;
- Its level of comfort with policy engagement.

ITP is a bridging organization (Davila et al. 2006),[1] a type of organization that is identified in the literature as important for research impact (Ekboir 2009). There is much for CGIAR to learn from ITP's experience should it wish to see a greater return on its research investment through influencing policy.

Conclusion 6: It is useful to think of KUSUM, and the political imperative to tackle the energy-water-agriculture nexus (see Finding 12), as creating an ecosystem in which various versions of KUSUM's three options, as well as others, will compete in an evolving, complex and inherently uncertain process. Which versions find niches, where and whether they help India tackle the nexus, will depend on the timing and quality of decision making. The evaluation team has developed a simulation model to help, in a small way, decision makers to gain a better sense of likely outcomes for states, starting with Gujarat, adopting KUSUM-C and/or KUSUM-A.

Conclusion 7: The simulation model shows that under expected conditions, KUSUM-C gives better outcomes for farmers, electricity distribution companies (DISCOMs), groundwater extraction and reduction in greenhouse gas (GHG) emissions than KUSUM-A. KUSUM-C is likely to face the strongest competition from KUSUM-A if:

- Subsidies are decreased or removed;
- Loans are decreased;
- Tariff prices are reduced;
- Demand and price are high for buying water (e.g., cash crops);
- Non-payment by DISCOMs becomes prevalent;
- Groundwater is not limiting;
- Local institutions are weak;
- Land for solar banks is available;
- Daytime power is made available.

Conclusion 8: By far the greatest benefit derived from both KUSUM-A and -C is the reduction of GHG emissions by replacing fossil fuel use with solar power generation, when a notional price is paid for reducing CO_2 emissions. GHG emission reductions are large in both KUSUM-A and -C. KUSUM-C's unique attraction is that it can deliver other benefits, including increased farmer income, reduction in farm power subsidies and incentives for farmers to become energy and water efficient.

[1] Helps find useful information, mediates between researchers and other actors in the outcome trajectory and identify internal and external barriers to innovation

Recommendations

Recommendation 1: For ITP to continue to play a central role in the SPaRC outcome trajectory.
Given the potential impact of SPaRC, and the huge return on research investment that this would bring, WLE, IWMI, CCAFS and Tata Trusts should continue to support ITP in playing a central role in the SPaRC outcome trajectory. The policy window theory and progress to date suggest the following strategies are likely to be beneficial:

- Maintaining the reputation of ITP so it is invited to present to high-level decision makers;
- Maintaining the ability to take advantage of policy windows;
- Forming partnerships to build capacity to establish solar cooperatives at scale;
- Carrying out research to support the adaptation and evolution of SPaRC to maximize its benefits, in particular to marginalized groups;
- Strengthening a coalition of actors who believe in SPaRC as a way to tackle the energy-water-agriculture nexus.

Recommendation 2: For WLE and CCAFS to propose a synthesis across recent outcome evaluations as to how programmatic research has achieved impact at scale, to inform the move to One CGIAR.
Several CRPs have invested in outcome evaluations since 2019, including WLE, CCAFS, RTB (CGIAR Research Program on Roots, Tubers and Bananas) and A4NH (CGIAR Research Program on Agriculture for Nutrition and Health). At the same time, CGIAR is going through a reorganization to become One CGIAR such that scientific innovations are deployed faster, at a larger scale and at a reduced cost, having a greater impact where they are needed the most. [2] It would therefore be timely to carry out a synthesis across the evaluations to appreciate and learn lessons from what has worked. For example, this and the RTB/A4NH evaluation show that influencing policy is clearly important for achieving impact at scale, and advocacy is important for achieving policy change. CGIAR is generally uncomfortable with explicitly engaging in advocacy. Learning from how CRPs have successfully supported advocacy efforts, regardless of whether the term was used, would likely yield worthwhile lessons for One CGIAR.

Recommendation 3: For WLE and CCAFS to support the handing over of the simulation model to ITP
The simulation model is easily accessible as a native Microsoft Excel spreadsheet with a linked input data sheet and includes a dashboard with the graphical display of results and a facility to easily simulate various policy scenarios. The model input datasheet can be readily edited to apply the model to different states in India. As better data become available, especially for sensitive variables, such as adoption rates, the uncertainties in projected benefits will be reduced. Hence the model can be used as a learning tool and the projection of benefits updated regularly over time. The use of SIPmath tools for Excel makes it relatively easy for a graduate-level analyst to build new assumptions into the model. With further effort, additional solar models could also be added. ITP has had exposure to the model and has the technical knowledge to parameterize the input distributions. We recommend that WLE and CCAFS support the handing over of the simulation model to ITP and consider further training and technical support to help develop ITP's capacity in its use.

Recommendation 4: For the CGIAR System Organization to consider whether the simulation modeling approach used in this evaluation has broader applicability
Additional data or information from applied research have no value unless they improve decision making – for example, decisions on what interventions should be promoted to provide the most favorable livelihood and environmental outcomes at least cost and risk. It is impossible to know what research will produce value without first quantifying the current state of uncertainty and then seeing

[2] https://www.cgiar.org/food-security-impact/one-cgiar/

which uncertainties are critical for outcomes. There is also strong demand from donors and other stakeholders for CGIAR to project and monitor benefits.

In this evaluation, the simulation modeling approach required researchers to quantify their assumptions and uncertainty in adoption, costs, benefits and risks associated with alternative solar irrigation models. We think this process of quantifying the theory of change led to deeper thought and analysis on causal factors affecting adoption and impact of solar irrigation alternatives than would otherwise have been the case. The modeling identified several priority areas for research and monitoring, based on where uncertainty reduction would most affect projected outcomes.

The SIPmath™ open-standard approach used in this study could provide the foundation for an enterprise-wide platform for representing uncertainty and including uncertainty and risk in cost-benefit analysis. SIPmath™ is readily accessible to everyone in Excel but is also applicable across platforms (e.g., R, Python). We therefore recommend this approach for consideration as a CGIAR-wide complement in ex-ante and ex-post impact evaluations, and for use in research project screening at various stage gates based on projected benefits.

INTRODUCTION

This evaluation is one of a series of learning-focused outcome evaluations being undertaken by the CGIAR Research Program (CRP) on Water, Land and Ecosystems (WLE) to better understand how its research-for-development approach has worked, for whom and to what extent. Two evaluations have so far been completed: one on resource recovery and reuse in Ghana and Sri Lanka, and another on WLE's water and soil outcomes in Ethiopia.

This evaluation was commissioned through an open, competitive call for proposals which was won by Selkie Consulting Ltd to use the same theory-driven outcome-harvesting approach used for the WLE outcome evaluation in Ethiopia (Douthwaite and Getnet, 2019). The main modification is the addition of an ex-ante modeling component that will make projections about future impact.

Purpose and Objectives

The purpose of the evaluation, as given by the evaluation Terms of Reference (ToR), is to facilitate learning among intended users on:

1. How WLE/CRP on Climate Change, Agriculture and Food Security (CCAFS) work on solar-powered irrigation is catalyzing change;
2. The likely impact under different adoption and usage scenarios.

The objectives of the evaluation are to:

1. Determine and document how evidence from WLE/CCAFS research and engagement activities contributed to the achievement of intended and unintended outcomes, in particular, the incorporation of the solar power as a remunerative crop (SPaRC) model in the Government of India's large Kisan Urja Shakti evam Utthan Mahabhiyan (KUSUM) program;
2. Establish, based on findings of the evaluation, what has changed at the farmer level as a result of implementing the SPaRC model, for whom and why, including any measurable short-term benefits;
3. Calculate, using ex-ante simulation/modeling, the projected benefits at various time intervals (e.g., 2022 and 2030), and create a set of alternative scenarios;
4. Serve as a participatory learning experience for WLE and CCAFS and their partners.

Intended users

The primary intended users of the evaluation are decision makers in WLE and CCAFS who are interested in better understanding how CGIAR research and other forms of intervention contribute to policy outcomes. Intended users also include staff from donor organizations; staff from other CRPs; and national partners and stakeholders working to scale-up beneficial technologies and institutions. More generally, the report's findings and conclusions will be relevant to anyone who wants to better understand mechanisms by which research can contribute to developmental impact.

METHODOLOGY

This evaluation uses a version of outcome harvesting called outcome evidencing (Paz-Ybarnegaray and Douthwaite 2017) which was successfully used for an evaluation of WLE outcomes in Ethiopia (Douthwaite and Getnet 2020). Outcome evidencing is a theory-driven approach that is based on the presumption that outcomes result from evolving patterns of interactions between people, technologies and institutions. These patterns are called 'outcome trajectories.' Programs contribute to catalyzing, stabilizing and amplifying these patterns. Outcome evidencing is about describing and validating outcome trajectories and a program's contribution to them. This evaluation is of the outcome trajectory that has led to SPaRC being adopted by government-backed initiatives to solarize irrigation pumping in India.

The SPaRC outcome trajectory is the changing pattern of interactions between people, institutions and technology that has led to the inclusion of SPaRC into Gujarat's Suryashakti Kisan Yojna (SKY) program and the Government of India's USD 50 billion PM-KUSUM (Pradhan Mantri KUSUM) program.

The evaluation is formative and developmental in nature, in response to the purpose of the evaluation to facilitate learning among intended users. In the literature, developmental evaluations are positioned as an internal team function integrated into the process of gathering and interpreting data, framing issues and testing model developments.[3] Two IWMI-Tata Water Policy Research Program (ITP) staff members, Shilp Verma and Gyan Rai, provided extensive input into the evaluation, including identifying and explaining various aspects of the outcome trajectory; helping to identify and secure interviews with key stakeholders; helping to convene two stakeholder workshops; helping to identify key ITP publications; and as co-developers of the simulation model developed by the evaluation. The external evaluators – the two authors of this report – brought an external perspective manifest in seeking to double-check what they were being told through interviews and document review, in particular of online publications found though Googling the events and concepts described as important in interviews.

The evaluation is theory-driven in that the evaluation team assumes that the outcomes achieved by the work on SPaRC can be explained by existing theory. The assumed theory is the policy window theory described by Stachowiak (2013), originating from the field of political science (Kingdon and Stano 1984). The theory was chosen because the main SPaRC outcomes relate to policy, and the theory has been found to usefully apply in evaluations of other CGIAR contributions to policy processes (Douthwaite, in preparation). Policy window theory is what the Realists call middle-range theory, positioned between universal social laws and more location- and context-specific program theory/theory of change (Pawson 2013).

The policy window theory proposes that policy changes during windows of opportunity help advocates successfully connect two or more components of the policy process. The components are:

- The way a problem is defined;
- The policy solution to the problem;
- The politics surrounding the issue (Stachowiak 2013; Sabatier and Weible 2007).

Windows of opportunity are moments when progress can be made. They can be created by natural events such as pandemics, droughts or earthquakes; for example, an earthquake is an opportunity to change building regulations. They can be anthropogenic events like spikes in air pollution that lead to changes in clean air regulations. They can also be changes in government or budget cycles, or landmark meetings and summits held as part of ongoing national, regional or global processes. Individuals can create policy windows by, for example, organizing a side event at a global meeting. Policy windows are often short in duration and may be predictable or unpredictable.

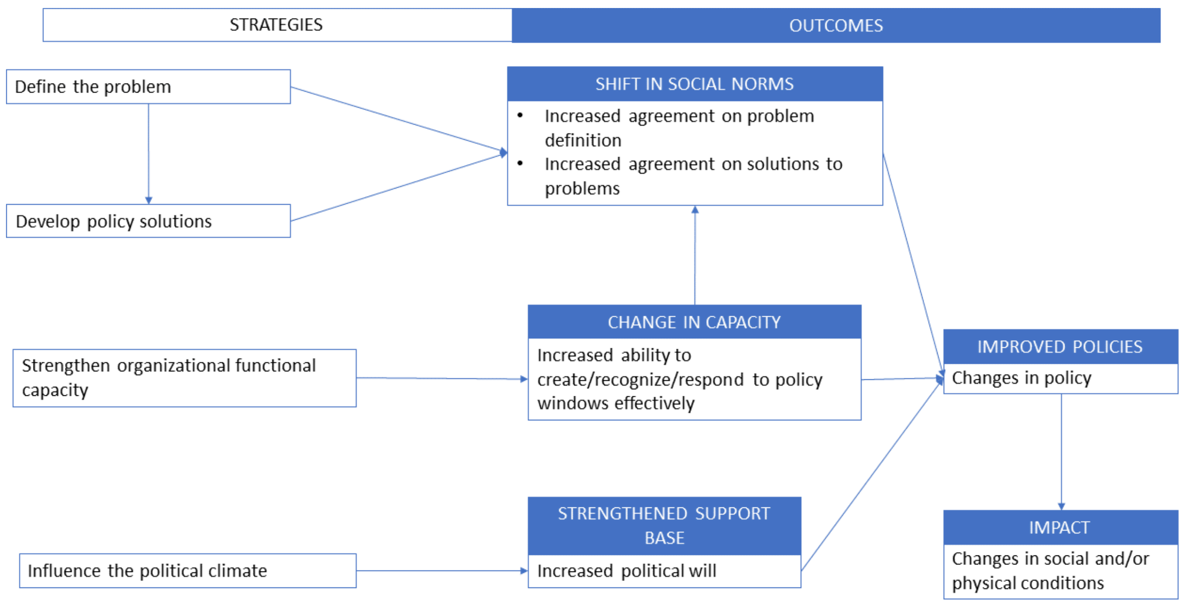
Policy window theory has been criticized for overly focusing on problem identification at the start of the policy cycle and ignoring the complex steps that follow involving stakeholders that hold confounding positions (Jann and Wegrich 2007). Our view is that this criticism does not apply to our evaluation approach because we work with the premise that policy change happens as a result of an outcome trajectory, that is, through the actions and interactions of stakeholders together with institutions and technology. Also, we use Stachowiak's (2013) depiction of the theory, which includes effort to develop policy solutions, strengthen organizational functional capacity and influence political will.

[3] https://www.betterevaluation.org/en/plan/approach/developmental_evaluation

Stachowiak (2013: 7) made a number of qualifying statements with respect to the theory of change:

- Often there are many competing ideas on how to address problems. To receive serious consideration, policy solutions need to be seen by policy makers as technically feasible and consistent with public values;
- The way a problem is defined makes a difference to whether and where the problem is placed on the agenda. Problem definition also has a value or emotional component; values and beliefs guide decisions about which conditions are perceived as problems;
- Advocates can attach their solution to an existing problem that has gained prominence on the agenda, even if that prominence is independent of their efforts;
- To effectively recognize and take advantage of open policy windows, advocates must possess knowledge, time, relationships and good reputations;
- Policy is translated into action plans that are implemented.

Figure 1. Policy window theory as to how policy changes, chosen as the best fit to describe how biofortification is being mainstreamed in the African Union (AU) (redrawn from Stachowiak 2013).



The evaluation is driven by the following set of questions. Questions 2 to 5 were provided in the ToR for the evaluation and represent what the main intended users want to learn from the evaluation. Question 1 relates to the choice of the policy window theory made after the evaluation began. The evaluation questions (EQs) are as follows:

1. How can the policy window theory (see Figure 1) be made more specific to the SPaRC outcome trajectory so as to help answer EQs 2, 3 and 4?
2. What were WLE and CCAFS solar irrigation outcomes in India and how did WLE and CCAFS contribute to them?
3. Did WLE and CCAFS help influence/contribute to the design and promotion of research that integrates/considers gender or the needs of marginalized groups within its partner centers?
4. Are WLE and CCAFS outcomes likely to be sustainable over the long term?
5. Looking forward to 2022 and 2030, what are the projected benefits for people and the environment?

EQs 2, 3 and 4 were addressed through the following steps.

1. The evaluation team carried out in-depth interviews with 19 key actors listed in Appendix 3 and a thorough document review to cross-check the information provided in the interviews.

2. The interviews and document review were used to develop both a timeline of the outcome trajectory and a narrative history, including rich, thick descriptions of important suspected causal aspects.
3. The timeline and history were used to develop the SPaRC outcome trajectory theory of change, based on policy window theory.
4. At the same time, policy window theory was used to focus the timeline and history. It did this by focusing inquiry as to how ‘shifts in social norms,’ ‘increased capacity,’ and ‘strengthened support base’ manifest themselves in the outcome trajectory.
5. The majority of the interviewees attended a workshop in which they validated and added to the timeline. They also commented on the validity of findings generated while answering EQ 1.
6. The timeline, history and specified theory of change were finalized after the workshop, after which all three were used to answer EQs 2, 3 and 4.

The insight developed in the process just described was used to inform the design of the simulation model used to answer EQ 5.

EQ 5 required the evaluation team to make projections about what impact the SPaRC model could have by 2022 and 2030 with respect to five indicators:

1. Number of people using clean energy in irrigation;
2. Number of people deriving additional income from surplus solar power sales;
3. Number of hectares irrigated with systems that use clean energy sources;
4. Change in greenhouse gas (GHG) emissions as a result of the implementation of the SPaRC model;
5. Net present value, return on investment and risk metrics through a risk-return analysis.

The evaluation team used the understanding of the SPaRC outcome trajectory generated in answering EQ 1 to develop a scenario-building model of the main factors influencing adoption, major costs, benefits and risks. This model was used as part of a probabilistic risk-return approach (Luedeling and Shepherd 2016) that quantifies the current state of uncertainty, including the costs, benefits and risks associated with a proposed intervention (Fenton and Neil 2018). This decision analysis approach is designed to provide insights even in data-limited environments by taking a causal approach, representing uncertainty and incorporating expert knowledge (Fenton and Neil 2018). Sensitivity analysis is used to help identify what further research or actions could help to enhance adoption and outcomes, and what variables should be closely monitored. In this case, the model was built in Microsoft Excel using freely available tools. To improve communication of the results to researchers and stakeholders, a simulation dashboard was provided that allows interactive simulation of the influence of key policy parameters on outcomes.

Key steps in the simulation modeling approach and modeling results are reported in a separate report, *Outcome Evaluation of Climate-Smart Research on Solar-Powered Irrigation in India: Simulation modeling*

Limitations

The main limitation relates to fieldwork, which was planned for late March and early April 2020, but was not possible because of the global response to the Covid-19 pandemic resulting in a lockdown in India, social distancing and the virtual cessation of international flights. By August it became clear that travel would not return to normal in 2020, so the decision was made to hold virtual stakeholder validation workshops of the outcome trajectory history, specified theory of change and results from the scenario-building model. The evaluators took extra care to guard against bias through validating a timeline of key events and inferences with the majority of people interviewed before and during the main validation workshop. Sources of information are indicated in the report so as to establish an audit trail for the findings generated.

FINDINGS

The findings come from answering the EQs described in the Methodology section.

EQ 1: How can the policy window theory be made more specific to the SPaRC outcome trajectory so as to help answer EQs 2, 3 and 4??

The SPaRC outcome trajectory theory of change is developed by identifying how the three immediate outcomes in the policy window theory are manifest in the SPaRC outcome trajectory described in Appendix 1, and what strategies the trajectory actors used to achieve them. The three immediate outcomes are: shifts in social norms; change in capacity; and strengthened support base. As in the policy window theory, the three immediate outcomes are together assumed to lead to improved policies, understood to be the inclusion of SPaRC in government initiatives to solarize irrigation in India.

EQ 1.1 How does the 'shift in social norms' outcome manifest itself in the outcome trajectory and what strategies did trajectory actors use?

Finding 1: The history of the SPaRC outcome trajectory (Appendix 1) shows that it was born out of the broader solar irrigation policy trajectory that in turn was born out of the longer-established groundwater irrigation trajectory (see Figure 2). In this initial trajectory, the social norm became that farmers in the drier parts of India have a right to free or very cheap electricity for pumping water for irrigation. Groundwater irrigation became seen as the backbone of the Green Revolution in northwest India, but also became a major problem. The solar irrigation trajectory began partly in response to groundwater irrigation contributing significantly to India's GHG emissions, as well as to ease the subsidy burden of providing very cheap electricity on electricity distribution companies (DISCOMs) and the Indian government. In turn, the SPaRC trajectory arose in response to the concern that widespread adoption of solar irrigation would exacerbate groundwater depletion.

The SPaRC timeline (Appendix 1) shows the outcome trajectory beginning in the 1950s and 1960s with a steady increase in mechanized pumping. In 1969, the Government of India established the Rural Electrification Corporation, which contributed to a rapid increase in the number of wells and pumps as the backbone of the Green Revolution in western India.[4] In the 1970s, politicians began to woo farmers with the promise of free electricity, with Tamil Nadu being the first state to provide it in the 1980s. This was in part to respond to the problem that farmers reliant on groundwater for irrigating their crops had to pay much more for water than their counterparts who could benefit from government-subsidized surface irrigation. Provision of very cheap electricity led to a rapid increase in the number of privately-purchased mechanized pumps from 5,000 in 1951 to 19 million at the turn of the millennium and between 22 and 25 million in 2018. Pumps were credited with "normalizing the vast difference in access to irrigation between canal commands and dryland areas, between uplands and valleys, between large and small farmers, between areas underlain by alluvial and hard-rock aquifers" (Shah 2009).

However, the success of groundwater pumping, and with it the rapid increase in grid-connected pumps, led to a growing awareness of two problems: impoverishment of DISCOMs supplying the very cheap electricity and the over-extraction of groundwater.

[4] Respondent 13

In 2000, Narendra Modi, the current Indian Prime Minister who was then Chief Minister of Gujarat, tried to tackle both problems by metering all pumps and charging for water consumed. The assumption was that farmers would pump less if they had to pay more for the water they consumed. However, the policy proved difficult to implement due to farmer protests. The norm that farmers had a right to very cheap electricity had become too well established.[5]

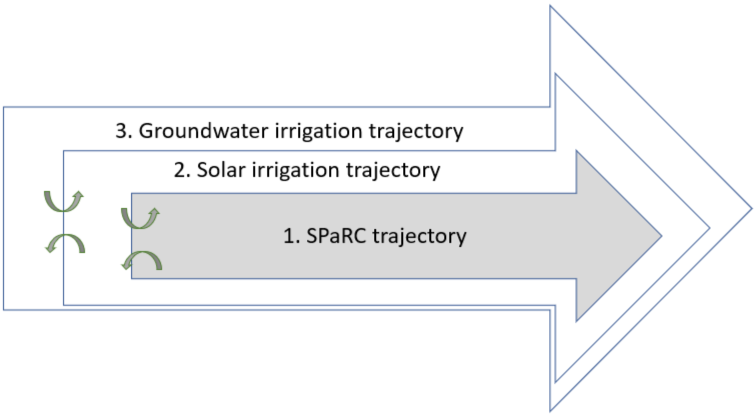
In 2001, ITP, which was also formed in 2000, wrote a paper (Shah et al. 2003) pointing out the strength of the norm, specifically that every Chief Minister that had tried to increase the cost of rural power had encountered serious electoral setbacks. The lead author, Tushaar Shah, suggested rationing rural electricity as an admittedly second-best solution to metering, an idea that the World Bank had supported for Andhra Pradesh in 1997, but which had not been implemented. The proposal was that rural power would be rationed to a few hours a day by supplying it through separate feeders, so as to not affect domestic electricity supply. To offset expected farmer complaints, the intent was to increase the reliability of power supplied. Realizing the power of the agrarian vote, Narendra Modi dropped the metering idea and instead used irrigation as a political strategy, which included doing what ITP had suggested, as well as providing 500,000 new rural connections and supporting community efforts to recharge groundwater. He took personal credit for the 9% annual growth in agriculture in Gujarat in the 2000s and was subsequently re-elected three times.

The third problem of mechanized pumps is their contribution to GHG emissions through their use of electricity from largely coal-fired power stations, or diesel. According to Dhillon et al. (2018), 6% of India's total GHG emissions come from groundwater pumping. The attraction of solar irrigation for policy makers is that the power it uses is renewable, thus showing progress towards meeting state and national commitments to reduce GHG emissions. It also is electricity that does not need to be supplied by DISCOMs at a loss. In 2008, Gujarat Urja Vikas Nigam Limited (GUVNL), the electrical services umbrella company operating in Gujarat, started working on solar pumping.[6]

Any solution can bring its own problems. In 2009, Gujarat launched its Solar Power Policy as the first comprehensive solar policy in India, offering incentives to investors over a 25-year period. The following year, the Government of Rajasthan started subsidizing 87% of the cost of solar pumps. By 2012, ITP had become concerned that the high capital subsidies offered by central and state governments would lead to rapid expansion of solar pump adoption. The rapidly falling cost of photovoltaics (PVs) also meant that it was only a matter of time before farmers would be able to afford solar pumps off-the-shelf, even without substantial government support. While this was desirable from the energy viewpoint and good for the parts of the country with a surplus of water, such a scenario could be potentially disastrous for water-deficient western and southern India where solar pumping could exacerbate groundwater depletion unless incentives were provided to prevent it. This led to the ITP team coming up with the idea of allowing farmers to sell the excess power they generated back to the grid, in a similar way as private companies were starting to do under the Gandhinagar PV Rooftop Program or the megawatt (MW)-scale solar power plants, both part of Gujarat's Solar Power Policy.[7] ITP's hypothesis was that if the feed-in tariff offered to farmers was high enough, farmers would economize on water use so as to have excess power to sell. In 2012, Tushaar Shah and Avinash Kishore wrote an ITP Water Policy Research Highlight in which they proposed the idea (Shah and Kishore 2012). The idea of Solar Power as a Remunerative Crop (SPaRC) was born.

[5] Respondent 11
[6] Respondent 17
[7] Respondent 6 and Pathak and Muller 2016

Figure 2. The concept of nested outcome trajectories that influence each other.



Finding 2: From its birth in 2012, SPaRC trajectory actors have been very successful in embedding the concept of SPaRC in two government programs: as the basis for Gujarat's SKY scheme and then as one of three components in the national PM-KUSUM initiative, which has a budget of USD 50 billion. SPaRC's policy successes are in part due to framing the model as being able to deliver on five politically important issues. ITP had particular success with the message that SPaRC offers a triple win for farmers, the state and water resources. The framings clearly resonated with policy makers.

The history of the SPaRC outcome trajectory shows that conceptually the idea proved compelling to fellow researchers and politicians in particular because it offered to solve the following problems (listed in order of political importance):

- Low and uncertain farm income by allowing farmers to effectively grow another, profitable crop and build climate resilience;
- The liability of DISCOMs to supply very cheap electricity by allowing farmers to produce their own;
- The unreliability of the power supplied through tubewell feeders, and providing it always during daylight hours;
- Groundwater depletion by assuming that farmers would choose to pump less so as to earn more by selling power back to the grid;
- GHG emissions by replacing fossil fuels with renewable energy.

ITP found particular resonance with the message that solar crops offer a triple win for farmers, the state and precious water reserves. As one respondent said, capturing a sentiment of most of those interviewed, "SPaRC is a brilliant idea."[8]

In June 2018, the Government of Gujarat launched the SKY scheme. Under the scheme, 80 out of Gujarat's 7,000 agricultural feeders are to be solarized, covering an expected 12,400 farms in 33 districts.[9] The SKY scheme was based on SPaRC's signature idea of connecting farmers to the grid and incentivizing them to pump less groundwater by paying them for excess power generated.[10] Panels are connected to the grid in a similar way to Gujarat's pre-existing Gandhinagar PV Rooftop Program. Given the timing and nature of the SKY scheme, it is highly likely that ITP contributed to the formulation of SKY.

SPaRC also became one of three components of KUSUM (i.e., KUSUM-C; see EQ 2.1 for description of other KUSUM components) with a total intended budget of USD 50 billion. KUSUM-C has a target of

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[8] Respondent 15
[9] https://www.gprd.in/sky.php
[10] Confirmed by respondent 3

installing 1 million grid-connected solar pumps able to sell back to the grid. KUSUM guidelines were published in July 2019.

Two potential benefits of SPaRC were highlighted in a World Bank publication on the Rajasthan water-food-energy nexus published in January 2020 (World Bank 2020). They are:

- Allowing marginal farmers to survive droughts without depending on handouts;
- Improving feeder governance.

Two ITP staff contributed to the report.

The drought argument is that income from selling power back to the grid would allow farmers to irrigate enough land to feed their livestock, thus allowing them to survive droughts without the indignity of seeking government handouts. Farmers could be offered a higher feed-in tariff during droughts to compensate for a fall in the production of hydropower.[11] The improved governance expectation is that farmers will become more proactive in ensuring better governance of their feeders once they start selling power back to the grid.

Finding 3: ITP has been successful in building support for SPaRC by:

- **Presenting the model to key decision makers in a number of very high-level meetings;**
- **Setting up successful pilots showing SPaRC could work in practice;**
- **Publishing articles in the *Economic and Policy Weekly* and national newspapers, including the *Hindu*, the *Times of India* and the *Business Post*.**

Support was built before results from the SPaRC pilots had been fully analyzed.

As the timeline shows, ITP began successfully advocating for SPaRC in 2012. ITP staff, in particular Tushaar Shah, had very good links and relationships with key decision makers, based on more than 10 years of providing useful policy advice, not least to separate rural feeders and ration rural power to 8 hours a day.

In 2013, Tushaar Shah met with the Principal Secretary of the Gujarat Energy Department who asked if ITP could implement SPaRC on the ground. At about the same time, CCAFS proposed a pilot project to do the same. ITP agreed to act on both opportunities,[12] beginning with a proof-of-concept trial working with one banana farmer in Thamna village in 2014. ITP paid the farmer for the power he fed back into the grid because, at this point, DISCOMs still needed to be convinced of the technical feasibility of the SPaRC model, including concerns over grid safety.[13] In 2016, a larger proof-of-concept trial began in Dhundi, involving six farmers who had previously used diesel engines to power their pumps. The aim of this trial was to validate the prediction that SPaRC would result in farmers increasing their income while pumping less water. The expectation that farmers would be prepared to give up their right to cheap electricity from the grid was validated in a third trial led by the National Dairy Development Board (NDDB) that began in 2018.

In June 2014 and January 2015, ITP, represented by Tushaar Shah, presented the idea of SPaRC to the Finance Minister of the Government of India as part of a consultation process to develop the annual budget.[14] In promoting SPaRC, ITP used the strategy of inviting people to visit the trials, including receptive politicians and the media, writing articles (see Table 1) and promoting the novelty of the work. For example, the *Business Standard* published an article on July 13, 2015, after ITP paid the banana farmer in Thamna village for the electricity he supplied back to the grid. The article allowed ITP to put across its message, quoting Tushaar Shah as saying:

[11] Respondent 13
[12] Respondent 6
[13] Respondent 6
[14] Respondent 5

> "Solar irrigation pumps provide farmers water to irrigate their fields and also gives them an incentive to sell their remaining power to the grid. Solar power can be a steady source of income for farmers. This will also address the issue of groundwater depletion. The buyback scheme could also protect farm incomes in the event of crop failure. And, if adopted widely, this could help ease pressure on the state's overburdened electricity board. Solar crops are a very exciting example of a 'triple' win — for farmers, the state, and the precious water reserves, all benefit from a single intervention" (Cherian 2015).

On May 9, 2016, the Chief Minister of Gujarat recognized the Dhundi pilot project [15] as an innovative initiative for providing climate-smart benefits to its members and the following day the farmers involved were commissioned as the world's first Solar Pump Irrigators' Cooperative Enterprise (SPICE). About 500 visitors came to the site over the next six months, and within a year, an online article appeared on *IndiaSpend* (Patel 2017) about Dhundi being the first solar irrigation cooperative, and having a solution to India's groundwater crisis. This was picked up by the *Economic Times of India*[16] and *Bloomberg India*.[17] The original article included a 14-minute video on Dhundi.

NDDB also publicized the success of the Mujkuva village cooperative in Gujarat which it helped set up with 11 farmers who agreed to relinquish their right to cheap electricity from the grid. Their cooperative was inaugurated by the Indian Prime Minster Narendra Modi in September 2018.[18] The inauguration was covered in articles in the *Hindu Business Line*[19] and the *Times of India*[20] among other online publishers. The *Times of India*'s headline was "Anklav farmers forgo subsidized electricity, operation for solar power." According to one respondent, the initial conceptualization of the cooperative went through many design iterations so as to best accommodate the needs and requirements of farmers and the DISCOMs.[21]

A main part of ITP's policy-influencing strategy was to publish (see Table 1). The strategy was to prioritize publications read by the decision makers ITP was trying to influence, over and above academic high-impact journals that they did not read. ITP learned that the journal *Economic and Political Weekly* had the greatest reach and the editor would publish articles quickly if he thought the paper was interesting.[22] ITP published four articles in this journal between 2014 and 2019, as well as two in the *Financial Express* and one in the peer-reviewed journal *Environmental Research Letters*.[23] Other publications included a chapter making the case for SPaRC in a book targeting the new government in Delhi in 2014, with a Foreword written by Ratan N. Tata, Chairman of Tata Trusts. ITP adopted the International Water Management Institute's (IWMI's) strategy of writing relatively short

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[15] http://www.iwmi.cgiar.org/iwmi-tata/PDFs/dhundi_solar_energy_producers_cooperative_society-tri-annual_report-2015-18.pdf

[16] https://economictimes.indiatimes.com/news/politics-and-nation/gujarats-solar-irrigation-cooperative-has-a-solution-for-groundwater-crisis/articleshow/58998274.cms

[17] https://www.bloombergquint.com/business/gujarats-solar-irrigation-cooperative-has-a-solution-for-indias-groundwater-crisis

[18] https://www.thehindubusinessline.com/economy/agri-business/nddb-to-promote-use-of-solar-irrigation-pumps-among-farmers/article25949946.ece

[19] https://www.thehindubusinessline.com/economy/agri-business/nddb-to-promote-use-of-solar-irrigation-pumps-among-farmers/article25949946.ece

[20] https://timesofindia.indiatimes.com/city/vadodara/anklav-farmers-forgo-subsidized-electricity-opt-for-solar-power/articleshow/66011203.cms

[21] Respondent 8

[22] Respondent 6

[23] With an impact factor of 6.1 compared to 4.2 for Agricultural Systems

research highlights explaining policy implications, backed up by a longer research report. ITP published two highlights on SPaRC.

ITP also produced a professionally made video in January 2016 called "SPaRC'ing a Revolution,"[24] which one respondent said was useful because it could be shown to ministers and other high-level decision makers as visual evidence of farmers benefiting from SPaRC.

The decisions to include SPaRC in SKY and KUSUM-C were made and acted upon before the proof-of-concept trials had been completed and their results fully socialized and debated. This is in accordance with the policy window theory that says policy change can happen even if the policy solution is not fully formed or tested, if the problem has broad support and the politics around the issue carry weight. ITP released promising figures that were published by the *Times of India* on the basis of projected results from the pilots, e.g., that through SPaRC a farmer could earn USD 870 in a year, more than half the average annual farm income of just USD 1,440. ITP also said that 10 million solar farmers could adopt SPaRC and 'grow' 130 billion units of solar power, earning up to INR 65,000 crore (USD 8.7 billion) per year net of input costs.[25]

[24] https://www.youtube.com/watch?v=LOnhwuOnWLg

[25] https://timesofindia.indiatimes.com/city/ahmedabad/solar-harvests-changing-lives/articleshow/66900778.cms

Table 1. ITP authored publications in support of SPaRC in India.

Year	Authors	Title	Type of publication
2012	Shah, Kishore	Solar-powered pump irrigation and India's groundwater economy: a preliminary discussion of opportunities and threats	IWMI-Tata Water Research Highlight
2014	Shah, Verma	Addressing water management	Chapter in the book *Getting India back on track*
2014	Shah, Durga	Karnataka's smart, new solar pump policy for irrigation	Article – *Economic and Political Weekly*
2015	Shah, Durga, Verma	Harvesting solar riches	Article – *Financial Express*
2016	Shah, Durga, Jani, Magal	A new Anand cooperative model – this time, in solar farming.	Article – *Financial Express*
2016	Shah, Durga, Verma, Rathod	Solar power as remunerative crop	IWMI-Tata Water Research Highlight
2016	Durga, Rathod	Paving the way for an orange revolution in India	Article – *Energy Next*
2017	Shah, Durga, Rai, Verma, Rathod	Promoting solar power as a remunerative crop	Article – *Economic and Political Weekly*
2018	Shah	Kick-starting the Kisan Urja Suraksha evam Utthaan Mahabhiyan	Article – *Economic and Political Weekly*
2018	Shah, Rajan, Rai, Verma, Durga	Solar pumps and South Asia's energy-groundwater nexus: exploring implications and reimagining its future	Article – *Environmental Research Letters* journal
2018	Shah	Kick starting KUSUM (Kisan Urja Suraksha evam Utthaan Mahaabhiyam)	IWMI-Tata Water Research Highlight
2018	Shah, Durga, Verma, Rai, Rathod	The promise of Dhundi solar pump irrigators' cooperative	IWMI-Tata Water Policy Research Brochure
2019	Verma, Durga, Shah	Solar irrigation pumps and India's energy–irrigation nexus	Article – *Economic and Political Weekly*

Finding 4: A number of questions relating to the supposed benefits of SPaRC require further research, such as under what conditions will farmers willingly agree to give up their grid connections; whether DISCOMs will cooperate in establishing what will effectively be a competing distributed power generation network; and whether farmers do pump less groundwater overall if they can sell power back to the grid.

The fact that these questions still need to be answered might suggest that SPaRC is not yet ready to go to scale. One respondent[26] said he thought there were so many moving parts that it was impossible to know how KUSUM will play out, so the only option would be to start and then adapt quickly to how farmers, DISCOMs and other key stakeholders responded. A hope is that simulation modeling being carried out as part of this evaluation can help manage some of the uncertainty. Answers to the Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) project's key research questions will also be important.

[26] Respondent 13

As well as advocating for SPaRC, SPaRC trajectory actors have been active in answering some key research questions implied by the claims made about the benefits of SPaRC. In 2019, the Swiss Agency for Development and Cooperation (SDC) began funding the SoLAR-SA project,[27] which seeks to answer two key questions:

1. To what extent do farmers pump less water if they can sell power back to the grid?
2. How much water does one unit of electrical power pump for different depths of the water table and different hydroecologies?

The answers will help solar irrigation programs understand how best to incentivize farmers to pump less water.[28] Other research questions include:

- To what extent does the establishment of cooperatives help or hinder farmers in succeeding with SPaRC?
- If farmers start selling surplus power to the grid will they stop supplying marginalized neighbors with water?
- Will DISCOMs cooperate in what will effectively be the setting up of a competing supplier of electricity?
- What is the relationship between the feed-in rate paid and whether farmers choose to sell power back to the grid?

Also, in August 2019, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), IWMI and CCAFS began the first phase of an ongoing partnership to understand the success factors and barriers to large-scale adoption of solar irrigation pumps (SIPs). A key output will be a compendium of case studies of different technical, financial and institutional models of SIP promotion.

EQ 1.2 How does the 'change in capacity' outcome manifest itself in the outcome trajectory and what strategies did trajectory actors use?

Finding 5: A number of different types of capacity were needed for SPaRC trajectory actors to contribute to SPaRC becoming the basis of SKY and a core part of KUSUM. The capacities required were:

- **A well-framed and compelling solution to a number of priority issues;**
- **A sufficiently strong track record and reputation to be invited to present to government and state secretaries and ministers and other high-level decision makers;**
- **The ability to take advantage of these policy windows by making well-framed and persuasive presentations;**
- **The foresight and flexibility to establish successful pilots that convinced key decision makers that SPaRC was practical, as well as conceptually promising;**
- **The capacity to respond to much greater than expected media interest in the pilots;**
- **The ability to write, and the contacts to have published, articles in national newspapers that helped pique and direct the interest of the broader print and TV media.**

The capacities match well with the policy window theory. Improvements in capacity were generally self-taught rather than produced through formal training. The one capacity that the theory does not foreshadow strongly is the capacity to be flexible and adapt to opportunities other than policy windows. In this sense, ITP was fortunate in its membership of CCAFS, which provided the funding for the Dhundi pilot. A well-recognized strength of CCAFS, WLE and CRPs in general is their quick and straightforward provision of relatively small grants for innovative yet sometimes risky ideas.

As described in Figure 3, the story of how ITP and other key trajectory actors were able to change thinking and opinion to help bring about the inclusion of SPaRC in KUSUM is also a story of the

[27] SoLAR SA-Proposal-Document_2019.pdf
[28] Respondent 15

deployment of substantial capacity by these actors. ITP likely first influenced policy thinking at a ministerial level when Tushaar Shah made a presentation in January 2013 to the Minister of Finance, Palaniappan Chidambaram. Tushaar Shah knew how to prepare for such an opportunity, having been invited to present at similar annual budget consultations in the past. He knew to present a fundable proposal in less than 5 minutes. The proposal was for a fund to promote solar pumping, which enabled ITP to put forward the idea that solar pumping could address several priority policy issues at the same time. While the proposal was not funded in 2013, the claim is that the presentation resonated with the minister and helped embed the idea that the Government of India should support solar pumping.[29]

The following year, Tushaar Shah was invited to present SPaRC to the new Minister of Finance, Arun Jaitley and the Minister of Commerce, Nirmala Sitharaman at the finance minister's office in New Delhi. Both ministers talked to Shah after the meeting and said they would put money into the Union Budget. The budget, when it came out a few weeks later, included an allocation of USD 67 million for solar pump promotion. Although no specific mention of SPaRC was made, prior intent makes it plausible that the ITP presentation was influential.

It is also plausible that ITP ideas influenced the Surya Raitha solar irrigation policy, launched a few months later by the Government of Karnataka. The policy adopted the SPaRC signature idea of paying farmers a high feed-in tariff as an incentive to pump less groundwater, although SPaRC was not mentioned.

ITP continued to be invited to make high-level presentations. In 2015, Tushaar Shah presented to the:

- Minister of Finance as part of the consultation process for developing the annual budget;
- World Bank in New Delhi;
- Development Support Center (DSC) public lecture in Ahmedabad;
- World Energy Council, New Delhi;
- Innovative Thought Forum, New Delhi;
- Power Secretary, Government of Gujarat;
- Power Secretary, Government of Maharashtra.

According to one respondent, a game-changer was the setting up of the three pilots showing that farmers could successfully sell power back to the grid (see Finding 3). The demonstrations appear to have reassured observers that the promise of SPaRC could be realized in practice. The demonstrations generated an unexpectedly large amount of interest, with visits from the press, television, hundreds of farmers from Gujarat and other states, and politicians, including a visit from Gujarat's energy minister in May 2018.

The capacity employed by the SPaRC trajectory actors, in particular ITP, was multifaceted. As the trajectory timeline shows, ITP did not set out in 2012 with a clear plan as to how to persuade the governments of Gujarat and India to fund large programs based on SPaRC. ITP did not develop an advocacy strategy. Indeed, ITP and other trajectory actors see themselves as suggesting policy hypotheses to decision makers rather than advocating – a term associated in India with campaigning organizations.

The capacity that ITP had was largely inherent and functional: inherent in the sense that it had been built up in the 12 years prior to 2012; and functional in the sense that that ITP had the capacity to respond to policy windows and opportunities to communicate as they emerged.

ITP's inherent capacity stemmed in part from having developed a reputation for generating useful and innovative ideas. For example, in the early 2000s, Tushaar Shah and colleagues argued in an IWMI

[29] Respondent 5

Research Report for a compromise option to solve the problem of the overuse of near-free electricity by farmers to pump water (Shah et al. 2003). They proposed that, rather than charge metered tariffs, as commonly suggested at the time, feeders supplying power to tubewells should be separated from other rural feeders and intelligent rationing should be employed for tubewells. During 2001-02, this proposal was presented in several workshops and conferences in Gujarat and other states. In Gujarat, the proposal was shared with the state Minister of Power, the Gujarat Electricity Regulatory Authority and the chairman of the Gujarat Electricity Board. In September 2003, the Government of Gujarat launched the Jyotirgram Yojana scheme to install separate feeders to 90% of Gujarat's 18,000 villages.[30] Most of the work was carried out in 1,000 days between 2006 and 2008. Other states followed suit.

ITP's reputation for generating useful and innovative ideas contributed to Tushaar Shah becoming one of 20 or so agricultural experts invited to present on a regular basis to the Minister of Finance's annual consultation on the Union Budget. This provided the opportunity for ITP to first present SPaRC at ministerial level. Other invitees included the Director of the Indian Council of Agricultural Research.

ITP backed up its ideas and 'policy hypotheses' with approachable, well-written policy briefs in addition to newspaper articles. ITP's objective is to help policy makers at the central, state and local levels address their water challenges by translating research findings into practical policy recommendations. One of the contributions of the Tata Trusts in the equal partnership with IWMI is to bring a very practical and use-oriented perspective. ITP has published more than 13 publications that explain and make the case for SPaRC (see Table 1).

ITP's ability to take advantage of policy windows and opportunities to communicate about SPaRC has also been important. As the trajectory history shows, ITP was able to secure a series of invitations for what turned out to be highly influential presentations to ministers and secretaries of power, energy, finance and commerce at state and national levels, as well as to other prominent organizations such as the World Bank. The key ability was to be able to present SPaRC as a solution to a number of priority concerns of the audience, in ways that were compelling within the time available. It appears this was a self-taught skill rather than one in which presenters had been trained.

A raft of opportunities to communicate about SPaRC largely flowed from ITP's decision to set up demonstrations of SPaRC working in practice. ITP, through its partnership with CCAFS, was able to secure USD 200,000 in May 2015 for the "promotion of climate-smart agriculture through solar pump irrigation cooperative in Gujarat." ITP originally expected to find farmers who would give up their right to a grid connection in return for becoming part of a cooperative and receiving a subsidy for the capital cost of the equipment from the Madhya Gujarat Vij Company Limited (MGVCL) under the Government of Gujarat's solar pump scheme. In practice, ITP found that farmers were unwilling to give up their connections; instead, it switched to working with farmers in Dhundi village who had no right to a grid connection and were using expensive-to-run diesel-powered pumps. CCAFS was flexible enough to allow this change. Without this capacity to be flexible and run a convincing pilot, the Dhundi cooperative would not have been established, and the communication opportunities that followed (as already described) would not have arisen. Initial interest from print and TV journalists generated output that stimulated further interest. ITP was able to influence the stories that came out by authoring its own newspaper articles on SPaRC, e.g., "Harvesting solar riches" in the *Financial Express* on April 1, 2015[31] and "A new Anand cooperative model – this time, in solar farming" in the *Indian*

[30] Respondent 3 confirms the importance of ITP's earlier contribution to the idea of separating feeders
[31] https://www.financialexpress.com/opinion/harvesting-solar-riches/59262/

Express on May 19, 2016.[32] ITP also released a Water Policy Research Highlight on SPaRC in 2016 to provide more detailed background information (Shah et al. 2016).

Finding 6: Supporting farmers to form solar cooperatives is thought to be an important part of the SPaRC model, for which capacity will not fully exist once KUSUM-C begins full-scale implementation. NDDB plans to support solar cooperative formation among its members, but this by itself will not be sufficient. The preference that farmers form solar cooperatives could be written into KUSUM-C guidelines so as to exert additional leverage for support to cooperative formation.

An important part of making the SPaRC model work is that farmers form solar cooperatives with a single connection to the feeder to reduce the number of meter readings and payments made by the DISCOM to manageable levels. Another advantage of cooperative membership is shared responsibility and collective action to maintain the microgrid that connects individual farmers to the feeder as well as to provide additional leverage when requesting the DISCOM to maintain and fix the feeder itself. Farmers require time and support to set up and successfully run cooperatives. Several respondents voiced concern that this capacity will be lacking once states start installing 1 million grid-connected pumps for 1 million farmers. NDDB has indicated its intention to support the establishment of solar cooperatives among its members but this will not be sufficient. Also, respondents point out that the preference to provide grid-connected pumps to cooperatives is not yet made explicit in the KUSUM-C guidance material and should be.

Finding 7: Early indications are that among farmers who have adopted SPaRC, those who understand how it works pump less water and export more power to the grid. Supporting farmers to form solar cooperatives at feeder level helps build this understanding. There is a view that politicians need to be more forceful in putting across the message to farmers that unless efforts are made to save groundwater now there will be severe shortages in the future.

Research carried out by the Gujarat Energy Research and Management Institute (GERMI) is showing that while some of the solarized farmers in the SKY scheme are reducing the amount of water they are pumping, many are not.[33] For these farmers, it is proving more attractive to irrigate more or sell more water to neighbors than sell power back to the grid. This is in part because they do not necessarily trust that they will be paid by the DISCOM for their evacuated power, nor do they know how much they could be earning. Some are also not clear that they first need to pay off the loan they received towards the cost of the solarized system before they earn any money themselves, and if they do not pay back the loan in full, they will need to make up the shortfall in cash. This understanding is better in the 10 feeders on which ITP and GERMI worked as part of the SDC SPICE project, and as a result, more farmers in these feeders are pumping less water and earning more from the sale of exported power.

One respondent[34] expressed the view that politicians should be more strongly promoting the message that farmers need to save groundwater now or there will severe shortages in the future. He said that the Ministry of New and Renewable Energy (MNRE) should be communicating this, but MNRE did not have the resources to do so by itself.

[32] https://indianexpress.com/article/india/india-news-india/sustainable-agriculture-a-new-anand-cooperative-model-this-time-in-solar-farming-2807828/
[33] Respondent 16
[34] Respondent 11

EQ 1.3: How does the 'strengthened support base' outcome manifest itself in the SPaRC outcome trajectory and what strategies did trajectory actors use?

Finding 8: The SPaRC outcome trajectory would not have made the progress it has without support from:

- **WLE and Tata Trusts – for the proof-of-concept single-farmer SPaRC pilot in Thamna;**
- **CCAFS and Tata Trusts– providing timely and flexible funding to the Dhundi pilot;**
- **SDC – for providing additional support for solar cooperative formation as part of SKY and then SoLAR beyond India;**
- **GIZ – for tools and case studies for solar irrigation promotion at scale.**

Crucial to the success of the SPaRC policy outcome trajectory to date has been the resources available to the trajectory actors. As discussed under Finding 3, the pilots that showed farmers earning money from SPaRC by selling power back to the grid proved pivotal in winning over high-level champions of SPaRC. Champions included Sujit Gulati, Gujarat's Energy Secretary who visited Dhundi in 2018.

As the timeline shows, the first pilot began in 2015 with a single banana farmer in Thamna village in Gujarat, with funding from IWMI/WLE and Tata Trusts. Also in 2015, CCAFS provided a USD 200,000 grant for "promotion of climate-smart agriculture through solar pump irrigation cooperative in Gujarat" that allowed ITP to establish the Dhundi pilot the following year. In 2018, IWMI/WLE provided support to NDDB and Rajasthan Electronics and Instruments Limited (REIL) to establish a third pilot – the Majkuva Village Solar Cooperative.

Building on the success of the Dhundi pilot, SDC approved an ITP proposal for the "Solar Pump Irrigators' Cooperative Enterprise (SPICE) with Grid-Connected Farmers in Gujarat." The project supported the formation of about 10 solar cooperatives on SKY feeders. The project laid the foundation for the SoLAR partnership between SDC, ITP and GERMI.[35]

SDC supported the SoLAR-SA project, which began work in 2019 in Bangladesh, India, Nepal and Pakistan, with GERMI as a partner in India and a budget of USD 5.4 million. As discussed under Finding 4, the objective of SoLAR-SA is to answer research questions to help solar irrigation programs, such as SKY and KUSUM, understand how best to incentivize farmers to pump less water. All four countries included in the project are working on grid-connected solar pumps, i.e., on SPaRC. At the same time, GIZ funded the "Solar Irrigation Expansion in India Partnership" to develop tools and case studies for solar irrigation promotion at scale.

Finding 9: The SPaRC outcome trajectory has gained momentum by trajectory actors showing the model's relevance to four priority policy processes, in order of importance:

- **To provide farmers with a reliable electricity supply during the day, while at the same time reducing the burden to DISCOMs of providing heavily subsidized power, a policy pursued by the Ministry of Power and the MNRE;**
- **A commitment to double farmer income between 2016 and 2022 made by Prime Minister Narendra Modi;**
- **A plan by the Government of India to install 100 gigawatts (GW) of solar capacity by 2022 – a fivefold increase on its original target of 20 GW;**
- **The need to reduce groundwater depletion in the dry west and south of the country.**

The ability to harness a policy trajectory to other, bigger trajectories, is a key capacity flagged by the policy window theory. Reputation is also flagged and perhaps more than anything else, what

[35] SoLAR SA-Proposal-Document_2019.pdf

SPaRC has had in its favor is that ITP's leader – Tushaar Shah – was known for his policy advice by Narendra Modi while he was Chief Minister of Gujarat from 2001 to 2014. There is also some evidence of a coalition of trajectory actors in support of SPaRC, something that is identified in the literature as important in bringing about and implementing policy change. The coalition engages to some extent in 'impact tracking,' identified as a set of behaviors important to achieving impact in another evaluation of WLE outcomes.

Several policy processes have supported and are supporting the SPaRC policy outcome trajectory. The timeline shows that the first was the policy process pursued by the Ministry of Power and the MNRE to provide farmers with a reliable electricity supply during the day, while at the same time reducing the burden to DISCOMs of providing heavily subsidized power, and the resulting need for the government to regularly bail them out. An added attraction of this trajectory is that it gives a greater role to farmers and their organizations in the governance of rural feeders, with the promise of reducing losses.

The second trajectory has resulted from the call by Prime Minister Narendra Modi in 2016 to double farmer income by 2022.[36] This paved the way for a number of large government programs, in particular the launch of Pradhan Mantri Krishi Sinchai Yojana (PMKSY; Prime Ministers' Irrigation Development Program) with a commitment to invest USD 6.7 billion over 5 years in universalizing irrigation access, as well as SKY and KUSUM.

A third trajectory stems from India's global commitment to reduce its GHG emissions and the pressure the national government has been putting on state governments to increase the amount of electricity generated from renewable resources, notably wind and solar. The Government of India is currently upgrading its target from 20 GW to 100 GW of solar generating capacity by 2022.[37]

A fourth policy trajectory relates to the need to reduce groundwater depletion. To date, the push for solar irrigation has come largely from the energy and power sectors.[38] ITP sees itself as having an important role in continuing to flag the importance of finding solutions that solve the power supply problem without exacerbating groundwater depletion while doubling farmers' incomes – in other words to tackle the energy-water-agriculture nexus.[39] Nevertheless, the sense from participants in the validation workshop was that this trajectory, while becoming more important, is still not the main policy driver.

Some of the interviewees were clearly motivated by a common belief that SPaRC could finally tackle the energy-water-agriculture nexus. They also talked about others, including state secretaries (see Finding 8), sharing the vision and becoming champions of SPaRC. This may amount to a 'coalition,' something that is identified as important in policy change and defined as a network of stakeholders who coalesce around a broad, shared agenda, who also bring resources.[40] The SPaRC coalition also shares a view that widespread adoption of KUSUM-A will exacerbate the nexus.

Several respondents suggested that more than anything else, what the SPaRC coalition has in its favor is that the leader of ITP – Tushaar Shah – was known and respected by Narendra Modi while he was Chief Minister of Gujarat, before he became Prime Minister of India (see Finding 5).

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[36] https://economictimes.indiatimes.com/news/economy/agriculture/how-will-you-double-farmers-income-european-union-to-pm-modi/articleshow/69837021.cms?from=mdr
[37] https://sustainabledevelopment.un.org/partnership/?p=34566
[38] Respondent 13
[39] https://www.worldbank.org/en/news/feature/2020/06/05/unshackling-india-energy-water-agriculture-nexus
[40] See coalition theory in Stachowiak (2013)

The concept of a coalition in policy change theory is similar to 'impact tracking,' which was identified as a key ingredient of success in another outcome evaluation of WLE research (Douthwaite and Genet 2020). Impact tracking involves senior nationally based researchers using their professional networks to establish and move an outcome trajectory forward, using a set of behaviors akin to 'product championing,' including overcoming obstacles and taking advantage of policy windows. A common component in both is champions who have good access to policy makers.

Finding 10: In 2020, the World Bank and the Reserve Bank of India helped create an enabling environment for the adoption and scaling of SPaRC. In December 2020, the World Bank and MNRE were discussing potential support for the KUSUM scheme, including KUSUM-C. The Reserve Bank of India is revising priority sector lending guidelines to support environment-friendly lending policies and placing a stronger focus on group lending to farmer organizations.

In 2020, there have been a number of bank-led developments with the potential to support farmer adoption under KUSUM-C. In December, a respondent[41] reported that the World Bank was discussing the provision of a large loan to support KUSUM to be administered through MNRE. A World Bank publication on the energy-water-agriculture nexus in Rajasthan published in January 2020 came out strongly in favor of KUSUM-C (i.e., SPaRC) and against KUSUM-A in water-deficit states (World Bank 2020).

In September 2020, the Reserve Bank of India issued revised priority sector lending guidelines to encourage and support environment-friendly lending policies to help achieve the Sustainable Development Goals. Indications are that lending for solar water pumps would be included under the guidelines. There is also a stronger focus on group-based lending to farmers' cooperatives, farmers' producer companies and self-help groups and joint liability groups. This policy change may encourage organized groups to avail themselves of affordable finance for engaging in forms of collective production and use of energy, such as KUSUM-C.[42]

Finding 11: KUSUM-C faces some competition. A strong political push to solarize irrigation by the Government of India is, somewhat surprisingly, threatening the enabling environment for SPaRC described in Findings 9 and 10. In Gujarat, the state that has been the leading supporter of SPaRC, the state government has realized that SPaRC is a more complex intervention than KUSUM-A because it requires farmers to form solar cooperatives while KUSUM-A requires no farmer involvement at all. At the same time, MNRE and others are exploring off-grid installations in which farmers sell excess power for local uses other than pumping water, so as to sidestep possibly uncooperative DISCOMs.

Some participants in the validation workshop were of the opinion that improving farmers' electricity supply remains a main driver of the large push to solarize irrigation in India. This, they suggested, is evident in the October 2020 commitment by the Government of Gujarat to provide all tubewells with reliable, 100% daytime power within one year.[43] Other states, apparently, are considering similar announcements. Participants thought that this could not be achieved without rapid installation of additional solar generating capacity, and confirmed that KUSUM would be used to do so in Gujarat. If so, this will give a massive boost to KUSUM-A compared to KUSUM-C, because the former is much simpler and quicker to implement: KUSUM-A can be implemented without involving farmers or helping them form solar cooperatives through which to connect to the grid. The Government of

[41] Respondent 13
[42] Respondent 8
[43] Respondent 16

Gujarat had previously said that it would not consider KUSUM-A; however, a participant[44] said that the government was taking a much more circumspect attitude with KUSUM-C compared to SKY, because of the complexities it encountered in making SKY work properly (see Finding 14).

Respondents interviewed suggested that MNRE is also somewhat reticent towards KUSUM-C because of the costs it envisages to strengthen rural grids. MNRE has run a program since 2010[45] to install off-grid solar generating capacity in areas where grid power is either unavailable or unreliable. In such settings, MNRE encourages connecting together a number of farmers to create a microgrid to supply power for other purposes, such as refrigeration or drinking water purification. MNRE is considering providing a universal controller to allow farmers to use the power they generate for local purposes other than pumping water.

Finding 12: There is some degree of optimism that community-based organizations (CBOs) and not-for-profit organizations (NGOs) can help facilitate the formation of the approximately 20,000 farmer organizations needed to connect the 1 million farmers targeted by KUSUM-C. This would be made easier by the existence of a quasi-governmental organization providing a framework into which CBOs and NGOs could contribute. Winning the support of DISCOMs may also be possible given the considerable political backing for power sector reform and that the idea of the energy-water-agriculture nexus has gained traction.

One respondent likened SPaRC to Participatory Irrigation Management.[46] Both require forming farmer organizations through committed and competent facilitating agencies – NGOs and CBOs – that are sometimes difficult to find. Secondly, both are dependent on the service provider – DISCOMs and water resources departments, respectively – that often perceive a threat to their existence and become a bottleneck to scaling up.

Assuming 50 farmers per cooperative, it would require 20,000 cooperatives to connect the 1 million farmers targeted by KUSUM-C. Participants gave some grounds for optimism for mobilizing NGOs and CBOs to become effective facilitation agencies at a large enough scale. The facilitation role is well within the remit of many NGOs and CBOs, which have become more used to meeting with each other as a result of Covid lockdowns and the need for remote working. Nevertheless, the approach suggested by one respondent would be for a quasi-government body to provide the framework to which NGOs and CBOs could contribute.[47]

One respondent was hopeful that winning the support of DISCOMs may be possible given the considerable political backing for power sector reform and that the idea of the energy-water-agriculture nexus has gained traction.

EQ 1.4: Based on the answers above, what is the SPaRC outcome trajectory theory of change?

Finding 13: Like the policy window theory, the SPaRC outcome trajectory theory of change is based on strategies that contribute to three immediate outcomes:

- **A shift in social norms manifest as increased shared agreement that widespread adoption of SPaRC will contribute to several priority issues;**
- **A change in capacity manifest as the continued capacity of trajectory actors to: 1) embed SPaRC in existing policy processes; and 2) support the establishment of solar cooperatives needed for SPaRC to work well;**

[44] Respondent 16
[45] https://mnre.gov.in/solar/solar-offgrid
[46] Respondent 8
[47] Respondent 8

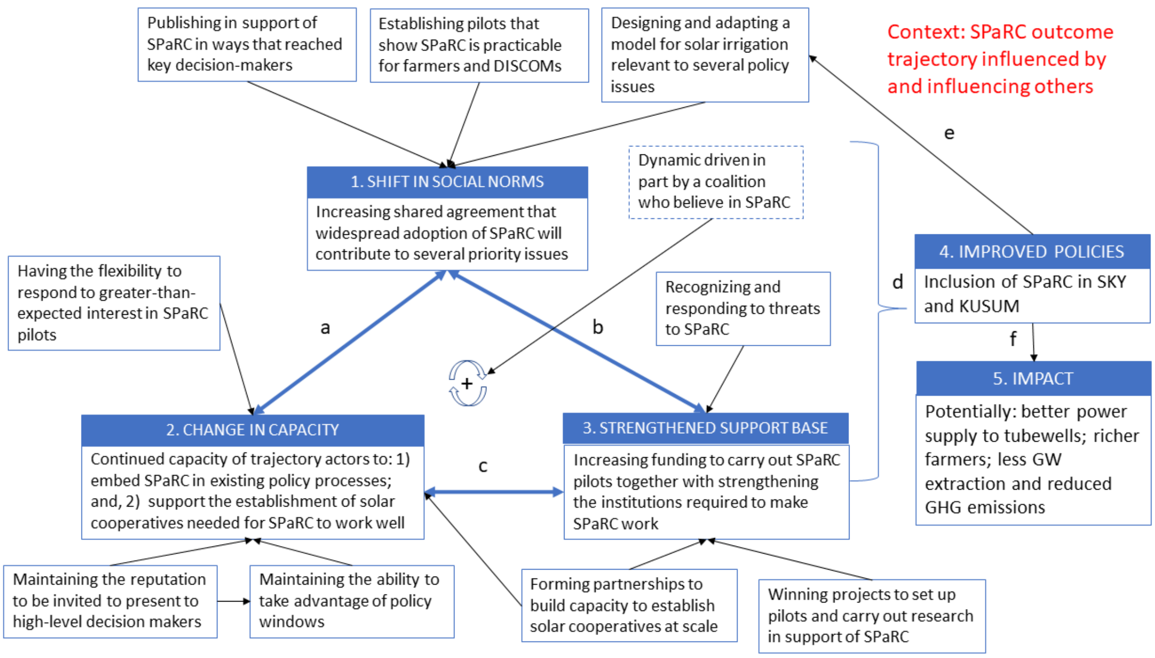
- **A strengthened support base manifest as increased funding to carry out SPaRC pilots together with strengthening the institutions required for SPaRC to work well.**

The main mechanistic difference in the theory of change compared to the more generic policy window theory is to recognize that the three immediate outcomes are linked to each other in a self-reinforcing loop that drives the outcome trajectory. The specific strategies used to achieve the immediate outcomes are shown in theory of change diagram (Figure 3) and further detailed in Table 2.

The evaluation team presented the findings from EQ 1.1 to 1.3 in a validation workshop to key individuals involved in or very knowledgeable of the outcome trajectory.[48] The team used the findings, and the feedback on them, to identify and describe the strategies used by SPaRC trajectory actors to contribute to the three immediate outcomes – 'shift in social norms,' 'change in capacity' and 'strengthened support base.'

The main adaptation to the policy window theory is to show the three immediate outcomes in a self-reinforcing feedback loop, linked to each other as described in a list of causal assumptions (Figure 3).

Figure 3. SPaRC outcome trajectory theory of change, based on policy window theory.



The causal assumptions underpinning the theory of change are indicated by letters in Figure 3 and are as follows:

a) The capacity and reputation of SPaRC champions invited to make presentations to high-level decision makers, their ability to take advantage of these policy windows, and the setting up of pilots, help convince said decision makers that SPaRC is an attractive and viable solution to one or more of the policy issues they face.
b) The positive view of SPaRC adopted by high-level decision makers helps SPaRC trajectory actors find funding support for pilots and research in support of SPaRC. The realization among decision makers that SPaRC requires farmers to form cooperatives or similar to work effectively calibrates their support to rapid scaling of SPaRC.

[48] See Appendix 2 – 13 participants attended, not including the evaluation team

c) The ability to take advantage of policy windows and being able to harness SPaRC to broader policy processes contributes to strengthened institutional support for SPaRC as a model that should be implemented. Increasing funding supports capacity development, including maintaining capacity.
d) SPaRC has been included in SKY and KUSUM, but so far, its implementation on the ground has been restricted to pilots. Adoption of SPaRC by the target 1 million farmers depends on how SPaRC fairs in competition with KUSUM-A and -B (off-grid solar).
e) Trajectory actors are involved in learning from SKY and adapting the SPaRC model accordingly.
f) The impact of SPaRC on groundwater extraction and farmers' income will depend upon a number of factors, including the subsidies, loans and feed-in tariffs offered to prospective adopters.

The specific strategies used to achieve the immediate outcomes are shown in the theory of change diagram (Figure 3) and further detailed in Table 2.

Table 2. Strategies used to contribute to the three immediate outcomes driving the SPaRC outcome trajectory.

Strategy	Specifics from the timeline
1. SHIFTING SOCIAL NORMS	
Designing a model for solar irrigation – SPaRC – that is relevant to several policy issues	The idea of solar power as a remunerative crop (SPaRC) emerged within ITP in 2012 and 2013. The term SPaRC was coined in a chapter for a book written to influence the then-new government (Shah and Verma 2014)
Establishing pilots that show SPaRC is practicable for farmers and DISCOMs	First pilot with a single banana farmer in 2015, followed by Dhundi cooperative in 2016 and Majkuva cooperative in 2018. ITP and SDC support solarization of 10 feeders under SKY starting in 2017
Publishing in support of SPaRC in ways that reached key decision makers	ITP targets the publication *Economic and Political Weekly* as having the highest readership among key decision makers and publishes four articles on SPaRC between 2014 and 2019
2. CHANGE IN CAPACITY	
Maintaining the reputation needed to be invited to present to high-level decision makers	Tushaar Shah and ITP included SPaRC in invited presentations to national and state ministers and secretaries six times from 2013 to 2016. Presentations also made to World Bank, Food and Agriculture Organization of the United Nations and World Energy Forum
Maintaining the ability to take advantage of policy windows	The main policy windows were the opportunities to present at high-level meetings. The presentations made were apparently well judged
Having the flexibility to respond to much greater than expected media interest in SPaRC pilots	In 2018, the Energy Secretary of Gujrat visited the Dhundi pilot followed by 500 visitors over the following six months
3. STRENGTHENED SUPPORT BASE	
Forming partnerships and building capacity to establish solar cooperatives at scale	ITP support to NDDB and REIL set up the Majkuva Village Solar Cooperative in 2018, followed by NDDB announcing an intent to use its experience setting up dairy cooperatives to help its members set up SPaRC ones in 2019
Winning projects to set up pilots and carry out research in support of SPaRC	ITP, together with partners, won four projects supported by three donors from 2015 to 2019, with a combined budget of more than USD 6 million
Recognizing and responding to threats to SPaRC within KUSUM	Recognition that the necessity of organizing farmers into groups for SPaRC to work well will be a disincentive to the fast and widespread implementation of KUSUM-C. The response is for ITP to start raising the issue among trajectory partners

EQ 2: What were WLE and CCAFS solar irrigation outcomes in India and how did WLE and CCAFS contribute to them?

This overall evaluation question is tackled by answering the following sub-questions, agreed in the evaluation inception report.

EQ 2.1: What are the main solar irrigation outcomes to which WLE and CCAFS have contributed?

Finding 14: The main outcome to which WLE and CCAFS have contributed has been the inclusion of SPaRC in two government programs: as one of three components in the USD 50 billion KUSUM initiative and at the center of Gujarat's SKY scheme (see Finding 2). The SKY scheme has reached 3,400 farmers through 80 feeders solarized by 21 companies. SKY has had implementation issues that have led to some scaling back from the original targets, not least in explaining SPaRC to farmers and gaining the consent of at least 70% in pilot feeders. The SDC-funded and IWMI-led SoLAR-SA project is working with GERMI in India to learn lessons to guide the implementation of KUSUM-C. The field research planned as part of this project is delayed because Covid-19 has prevented any fieldwork.

The KUSUM-C target is to support 1 million farmers to adopt SPaRC. As of October 2020, two states other than Gujarat have pilot schemes – Andhra Pradesh and Karnataka – to reach a combined total of little more than 500 farmers. All three pilots are designed differently, suggesting experimentation is happening to identify what works best, under what conditions.

The impact of SPaRC on the ground is so far limited in relation to the 1 million farmers that KUSUM-C intends to help adopt SPaRC. There are about 20 farmers involved in the pilots being run by ITP and NDDB. The great majority of farmers currently engaging in SPaRC are enrolled in Gujarat's SKY program that began in June 2018, as described in **Error! Reference source not found.**. As of March 2020, 80 o ut of Gujarat's 7,000 agricultural feeders had been solarized, involving 3,400 farmers.[49]

Box 1: Gujarat's SKY scheme

SKY was a pilot scheme, first announced in 2017 and launched in 2018. Under the scheme, 80 out of Gujarat's 7,000 agricultural feeders were to be solarized, covering an expected 12,400 farms in 33 districts.[50] SKY continues to be implemented in 2020. Farmers are provided with solar panels set at 1.5 times the power rating of their grid-connected electric pumps, so, for example, a 7.5 hp pump would receive 9.5 kW of panels.

The panels are connected to the grid in a similar way to the Gandhinager PV Rooftop Program. Farmers are paid on the basis of the power generated by their panels minus the power their pump consumes. If they are net consumers, they are charged for the difference. Most farmers are net suppliers because they generally grow two crops a year, not three, meaning that there are more than 100 days a year when they are not irrigating and so only supplying power to the grid.

According to figures provided by GUVNL, 9.5 kW of panels costs INR 470,000. Of this amount, the farmer is expected to pay 5%. Loans are made available for 35% of the price, to be paid back over 7 years at an interest rate of 4.5–6% during which time the farmer receives INR 7/net unit supplied to the grid. After 7 years, the net feed-in rate drops to INR 3.5/unit. In exchange for being part of SKY, famers agree to relinquish their 'right' to receive very cheap power from the grid and therefore the large subsidy that this requires the respective utility companies to make.

[49] Respondent 17

[50] https://www.gprd.in/sky.php

As of March 2000, 80 feeders had been solarized involving 3,400 farms.[51] This represents a generating capacity of 80 MW. The work to connect the farms has been carried out by 21 contracted solar agencies on 5-year contracts.

In March 2019, the *Times of India* reported that the Government of Gujarat had decided to scale SKY back because of implementation problems, including that farmers were finding it difficult to make money and were proving unwilling to give up the right to receive highly subsidized power from the grid. In December 2019, a *Hindu BusinessLine* article reported on two farmers with relatively large installations who were finding SPaRC profitable. One knowledgeable respondent confirmed that, while initially reluctant, farmers were now wanting to enroll in SKY.[52] Another explained that some of the difficulty related to the variable frequency of power supplied to the feeders by the main grid, which was causing farmers' systems to burn out, leaving them unable to earn income until their system was fixed.[53]

The SKY scheme was designed by GUVNL and implemented through DISCOMs. Under the scheme, private sector companies were invited to tender to solarize feeders: in total 21 companies won contracts. According to one respondent, companies were ill equipped to convince at least 70% of the farmers to agree to solarize their feeder. The respondent felt that it would be better if a third-party organization sought farmers' approval and carried out any social organization required, before companies tendered for the work.

The recent SDC-funded SoLAR-SA project has been supporting farmers in 10 feeders to set up a cooperative. According to a respondent in the validation workshop, farmers have had more success in these 10 feeders because they have better understood how the system works; for example, how payments are calculated and made.[54] Under the project, IWMI and GERMI are collaborating to better understand the costs and benefits of SKY, what is working well and what needs improving, so as to help inform implementation of KUSUM-C. This field research has been delayed as Covid-19 has prevented fieldwork since April 2020.

In March 2019, the KUSUM scheme was given administrative approval with a budget of USD 50 billion over 5 years. The scheme has three components (KUSAM-A, KUSAM-B and KUSAM-C) for the installation of:

A. 10,000 MW of decentralized ground-mounted, grid-connected power plants;
B. 1.75 million stand-alone solar pumps 7.5 hp;
C. 1 million grid-connected solar pumps 7.5 hp able to sell back to the grid;

In addition to Gujarat's SKY scheme, Andhra Pradesh and Karnataka have launched KUSUM-C pilots.[55] In Andhra Pradesh, the Andhra Pradesh Eastern Power Distribution Company Limited (APEPDCL) is implementing a pilot project that is replacing inefficient AC pump sets with more efficient DC ones connected to solar panels. Farmers can sell excess power back to the feeder but can only use power

[51] Respondent 17
[52] Respondent 16
[53] Respondent 9
[54] Respondent 16
[55] https://mnre.gov.in/img/documents/uploads/c01a8c19c786436ab33ed3e1136b935c.pdf

generated by their own solar panels. As of July 2019, 216 solar pumps were installed on one feeder. Farmers receive INR 1.50/kWh feed-in tariff.[56]

The Government of Karnataka launched the Sury Raitha Scheme in January 2020 to replace 310 inefficient pumps. Under this scheme, grid-connected farmers can sell back a maximum of one-third of the power they generate per year, at the much higher feed-in tariff of INR 7.5/kWh. Farmers will first need to pay off the loans they received to purchase the equipment. A document describing the scheme estimated the payback period as 12 to 14 years.[57]

EQ 2.2: Have there been any unexpected or negative outcomes?

Finding 15: There are two potentially negative outcomes that derive from SPaRC being included in large government programs before pilots could be completed and lessons learned. Under SKY, the companies that have been subcontracted to solarize feeders are worried that they have been tied into overly rigid 7-year maintenance contracts when there is much to learn and improve to make SPaRC work. More generally, there is a risk that SPaRC will become seen as too complex to be scaled quickly because of the need to work with farmers and that this will leave the door open for KUSUM-A, which does not require farmer involvement.

A negative outcome for at least some of the companies that won tenders under SKY to solarize the feeders is that they have lost money, or expect to do so.[58] SKY is designed such that the winning companies enter into a 7-year maintenance contract. It is only at the end of this contract that they will know if they have made a profit. Experience to date suggests some will not, because maintenance costs are much higher than expected, due in part to poor-quality power from the grid causing damage to components. The other unexpected cost has been the time and effort required to persuade 70% of the farmers in their respective feeders to agree to feeder solarization (Finding 14). The sense is that the contracts companies have entered into are too rigid for a pilot where there is much to learn and improve.

Another potential negative outcome is that premature inclusion of SPaRC at the center of a large government program, before pilots have been completed and learning harvested from them, will lead to SPaRC becoming seen as too complex to be implemented quickly and at scale (see Finding 4). There is some evidence of this happening: it was reported in the validation workshop that Gujarat is more reticent about SPaRC in KUSUM-C than it was with SKY. The sense in the validation workshop was that a recent political commitment made by the Government of Gujarat to provide all farmers with daytime power within a year will likely favor KUSUM-A, which does not require farmers to be involved.

EQ 2.3: How did WLE and CCAFS contribute to SPaRC outcomes?

Finding 16: WLE and CCAFS are two of a number of trajectory actors that contributed to SPaRC outcomes, as described by the SPaRC theory of change shown in Figure 3 and Finding 13. WLE contributed through ITP, which is mapped onto WLE. Three of the four projects that have supported work on SPaRC were mapped onto WLE. The fourth was mapped onto CCAFS. ITP's contribution has been central: ITP has led or co-led on all nine of the strategies found to be driving the theory of change. CCAFS' contribution was catalytic in providing flexible funding that made the Dhundi pilot possible. ITP and SPaRC have influenced WLE's work in Africa.

[56] P 12 of http://www.greenbusinesscentre.com/energyawards/enepresent19/General_104_APEDCL_0.pdf
[57] https://sarkariyojana.com/surya-raitha-scheme/
[58] Respondent 9

It is credible to claim that without ITP/WLE and CCAFS, SKY and KUSUM-C would not have happened, or would have been very different with less emphasis on reducing groundwater depletion.

The way that SPaRC trajectory actors contributed to these policy outcomes is described in the theory of change shown in Figure 3 and Finding 13. Trajectory actors are shown in Table 3. WLE's contribution is that of ITP, as ITP is mapped onto WLE. The contribution of the funding support organizations is as follows: [59]

- WLE funded ITP senior scientist time to engage in all SPaRC work, in particular to write the articles and papers and attend the key events that helped SPaRC gain recognition among policy makers as discussed under Finding 3 and Finding 5;
- CCAFS funded and made possible the Dhundi pilot that proved catalytic in moving the perception of SPaRC from a good idea in theory to an approach that worked on the ground, deserving inclusion in KUSUM;
- Tata Trusts funded other costs associated with attending key events; bonuses to SPaRC pilot farmers; and ITP interns who did the field work and data collection;
- SDC provided significant additional funding support, including funding the four-country IWMI-led SoLAR-SA project from 2019;
- GIZ funded the Solar Irrigation Expansion in India Partnership to develop tools and case studies for solar irrigation promotion at scale, in particular for SPaRC.

Table 3. SPaRC trajectory actors.

Funding support	CCAFS, GIZ, SDC, Tata Trusts and WLE
Implementing actors:	GERMI, GUVNL, ITP, MGVCL, NDDB and REIL
Boundary partners:	Aga Khan Rural Support Program India, DSC, MNRE, Shashvat Cleantech and World Bank

ITP's contribution to the SPaRC outcome trajectory has been pivotal. It was agreed by the participants in the validation workshop that if ITP had not run the pilots, then "SPaRC would have remained a theory," and that the trajectory "came together because of ITP."[60] This is consistent with Table 2 which shows that ITP was the lead actor in all of the strategies identified in the timeline shown in Appendix 1, except in the establishment of the Majkuva Village Solar Cooperative which was led by NDDB, supported by ITP.

CCAFS played a vital role in providing the funding for the Dhundi pilot, which has been the most influential of the three pilots, two led by ITP and the one led by NDDB.

SPaRC has influenced WLE's work in Africa.[61] While grid-connected solar pumps are not appropriate for much of Africa, what is relevant is the ITP/WLE approach to supplying solar irrigation through developing business models and other ways of organizing farmers so they can sustainably and inclusively benefit from solar pumping. Also, ITP's SPaRC analysis has highlighted the role that subsidies and policy can play in adoption and farmers' behavior, both positively and negatively, with respect to such issues as groundwater overextraction. WLE has provided ITP staff with a platform to share their experience with Mercy Corps and the USAID-funded Innovation Lab for Small-Scale Irrigation,[62] both of which work in Africa. To facilitate such sharing, WLE has organized its work on solar irrigation into one project, entitled "On and off-grid solar in Africa and Asia."

[59] Respondents 19 and 6
[60] Respondent 13 made these comments in response to a direct question as to ITP's role in the trajectory during the validation workshop.
[61] Respondent 19
[62] https://cgspace.cgiar.org/handle/10568/35730

EQ 3: Did WLE and CCAFS consider gender or the needs of marginalized groups in their work to achieve outcomes?

Finding 17: The ongoing IWMI-led SoLAR-SA project has a strong focus on gender equality and social inclusion (GESI). Largely through carrying out policy-relevant research with key national actors, the project hopes to increase the proportion of women owning SIPs from 5% to 10% and the proportion of small and marginal farmers owning SIPs from 10% to 30% in four years, in Bangladesh, India, Nepal and Pakistan. The way the SoLAR-SA project is tackling GESI has influenced recent WLE project development in Africa.

By far the largest research investment to support the SPaRC outcome trajectory is the USD 5.4 million being provided by SDC to the IWMI-led project SoLAR-SA. The four-year project, which began in 2019, works in four countries – Bangladesh, India, Nepal and Pakistan. According to one respondent, "SPaRC literally sparked the idea of the project,"[63] which is partnering with relevant government organizations to pilot grid-connected solar pumps and the institutional arrangements needed to ensure they deliver the benefits expected.

A main focus of the project is on GESI. The project aims to "influence SIP policies to enhance the outreach of SIPs to vulnerable groups." The project document notes that "currently, only 10% of SIPs are owned by small and marginal farmers and less than 5% are owned by women farmers."[64] By influencing SIP policies, the project hopes that, by 2024, 30% of SIPs will be owned by small and marginal farmers and 10% will be owned by women farmers in each of the countries. Broad GESI-sensitive policy questions that the project aims to answer include:

- How have current SIP policies and programs fared in terms of their impacts on farmers' livelihoods and gender equity?
- Which financial model generates maximum willingness among small-scale and marginal farmers to adopt SIPs?
- What kinds of technical and institutional modalities work best for grid connection of SIPs and how can these modalities be optimized for better groundwater governance in the long term?

More specific questions include:

- Will farmers who own SIPs in India continue selling water to their more marginal neighbors who do not?
- What is the impact of solar pumps on irrigation accessibility for small and marginalized farmers in Bangladesh?
- What incentives can increase the women's ownership of SIPs in Nepal?

Other GESI-aware project activities include training both male and female pump technicians.

The way the SoLAR-SA project is tackling GESI has influenced recent WLE project development in Africa, in particular how to deal with gender gap and creditworthiness issues in the development of solar irrigation business models.[65]

EQ 4: Are WLE and CCAFS outcomes likely to be sustainable over the long term?

[63] Respondent 15
[64] SoLAR-SA-Proposal-Document_2019.pdf
[65] Respondent 19

Finding 18: The sustainability and impact of KUSUM-C will depend in part on whether the target of 1 million farmers adopting SPaRC is met and how SPaRC is made to work. Whether KUSUM-C is fully implemented will depend to a large extent on how different actors make sense of KUSUM-C pilots with respect to two questions: whether the time, cost and difficulty of involving and organizing farmers to make SPaRC work in practice are worth the benefit; and whether adopting farmers can convincingly increase their income while at the same time pumping less groundwater. The answers to both questions remain uncertain.

The different actors that will individually and collectively decide the impact and sustainability of SPaRC include state governments, certain ministries, in particular MNRE, DISCOMs and their umbrella organizations, CBOs and NGOs and farmers. With regard to whether forming solar cooperatives or similar is worth the cost and difficulty, Finding 12 concludes that there are some grounds for optimism that NGOs and CBOs can facilitate the formation of solar cooperatives or similar. On the other hand, as discussed under Finding 15, recent political commitments to provide all farmers with daytime solar power within a year may favor KUSUM-A, which can be scaled up faster than KUSUM-C.

The question as to whether adopting farmers can convincingly increase their income while pumping less water is being addressed by the project SoLAR-SA, as discussed under Finding 4. The project is also carrying out research on the formation of farmer solar cooperatives. If farmers start to actively lobby to adopt SPaRC, because they believe it can benefit them, then this would work in favor of KUSUM-C.

Finding 19: The future sustainability and impact of SPaRC also depends on how KUSUM-C competes against KUSUM-A and -B. It is useful to think of KUSUM, and the political imperative to tackle the energy-water-agriculture nexus (see Finding 12), as creating an ecosystem in which various versions of KUSUM's three options will adapt and find their niches in an evolving, complex and uncertain process. All three models have advantages and disadvantages:

- **KUSUM-A – can be rapidly scaled but currently includes no incentive to pump less groundwater;**
- **KUSUM-B – solar pumps do not require the complication of a grid connection, no need to organize farmers but equally no incentives have been included to pump less groundwater;**
- **KUSUM-C – provides farmers with an alternative source of income and an incentive to pump less groundwater but scaling will likely be slow due to the need for farmers to organize.**

KUSUM-A and -C are initially being implemented in pilot mode to install 1,000 MW capacity and 100,000 grid-connected pumps, respectively[66] while KUSUM-B is in full implementation.
Under KUSUM-A, typically a private sector company signs a contract with a utility company to provide power to an agricultural feeder at a rate fixed for 25 years. The utility provides the land to set up the solar power plants. As far as farmers are concerned, the difference they see is that power is provided during daylight hours, which should be more reliable than the power previously supplied from the national grid. The attraction of KUSUM-A is that it requires very little public sector funding and can be rolled out quickly as a way to increase the proportion of renewable power used in agriculture. The disadvantage of KUSUM-A is that it provides no incentive for farmers to pump less groundwater, and indeed is likely to lead to further overextraction if the electricity supply to farmers improves as expected. However, an incentive scheme could be retrofitted to KUSUM-A along the lines of the "save water, earn money" scheme that the World Bank is piloting in Punjab. Under this scheme, farmers are

[66] https://energy.economictimes.indiatimes.com/news/renewable/kusum-scheme-for-solar-uptake-by-farmers-a-fineprint/68514675

given a free power allocation per cropping season and are paid for power they do not use at a rate of INR 4/unit. The pilot has shown water savings of 30%.[67]

KUSUM-B aims to support the installation of 1.75 million off-grid solar pumps to replace diesel pumps. It is also an option where strengthening and extending rural feeders to allow for grid-connected solar pumps is seen as prohibitively expensive. Two respondents favored establishing microgrids[68] that would connect a number of KUSUM-B farmers together to collectively generate and supply power at a local level. MNRE is considering providing farmers with a universal controller to allow them to use surplus power for such activities as powering stationary farm machinery, water purification and cold storage with batteries, as well as for domestic use. The hope is that the value of power from these microgrids could be high enough to provide farmers with an incentive to reduce solar power used for pumping water. This could be considered a SPaRC/KUSUM-B hybrid.

Under KUSUM-C, farmers acquire solar panels matched to their pump (typically, 1.5 times the pump power rating, i.e., a 1 kW pump would qualify for solar panels that can generate a peak of 1.5 kW) and the equipment to meter and connect them to grid. They pay for the panels through a portion they pay themselves, plus a loan and a subsidy. They are also given a guaranteed feed-in tariff for a number of years.

The farmer contribution, the loan percentage and its terms, the subsidy, the feed-in tariff and the length of the price guarantee can all vary, making SPaRC more or less attractive to farmers and state politicians, and more or less likely to provide an incentive to reduce groundwater extraction. For example, under the SKY pilot, farmers pay 5% of the cost, the Government of India provides a grant of 30% and the loan is 65% to be repaid over 7 years at an interest rate of about 5%. Farmers receive a relatively high feed-in tariff of INR 7 per net unit supplied to the grid to help repay the loan. The tariff drops to INR 3.5/unit after 7 years and is guaranteed for a further 18 years. If, as expected, the cost of solar generation continues to fall – one estimate is it will fall to INR 1.9/unit by 2030[69] – pressure will come to reduce feed-in tariffs or reimpose subsidies. If this happens, the subsidy will be on power sold back to the grid only, not on all electrical power supplied for pumping, as is currently the case. In addition, the capital cost of SPaRC will also likely fall, meaning that new adopters will be prepared to accept a lower feed-in tariff while still viewing SPaRC as profitable.

Finding 20: In evolving processes, the quality and timing of decision making about what variants to select is critical to achieving beneficial outcomes (Alexrod and Cohen 2000). The evaluation team developed a simulation model to help with decision making and so help the evolving process achieve beneficial outcomes. The model finds that, in Gujarat, KUSUM-C is more beneficial than KUSUM-A, if it can be made to work. It also identifies the conditions under which KUSUM-C faces the strongest competition from KUSUM-A. The model identifies policy implications, which are written up in the companion simulation modeling report.

To help improve decision making as to whether to opt for KUSUM-A or -C and the terms to offer farmers adopting KUSUM-C, this evaluation developed a simulation model to explore the conditions that favor KUSUM-C versus KUSUM-A. The model is described in a companion report entitled *Outcome Evaluation of Climate-Smart Research on Solar-Powered Irrigation in India: Simulation Modeling*. That report helps answer EQ 5 as well as identifying policy implications for tackling the energy-water-agriculture nexus. In terms of the competition between KUSUM-A and -C, the model finds that KUSUM-C is likely to face the strongest competition from KUSUM-A when:

[67] Respondent 13
[68] Respondents 11 & 13
[69] https://energy.economictimes.indiatimes.com/news/renewable/solar-power-cost-will-fall-to-rs-1-9-per-unit-in-india-by-2030-teri-study/67972162

- Subsidies are decreased or removed;
- Loans are decreased;
- Tariff prices are reduced;
- Demand and price are high for buying water (e.g., cash crops);
- Non-payment by DISCOMs becomes prevalent;
- Groundwater is not limiting;
- Local institutions are weak;
- Land for solar banks is available;
- Daytime power is made available.

EQ 5: Looking forward to 2040, what are the projected benefits for people and the environment?

Finding 21: Running the simulation model developed to answer the evaluation question for KUSUM-A and -C yielded the following expected values, assuming KUSUM runs for 20 years in Gujarat with a target population of nearly 1 million farmers. Units of millions are denoted with 'm.'

Indicator	KUSUM-C	KUSUM-A
Number of people using clean energy in irrigation	**439,940**	**268,260**
Number of farmers deriving additional income from surplus solar power sales	**439,940**	**0**
Area irrigated using clean energy sources (ha)	**476,093**	**292,575**
Change in farm water use (m^3/yr)	**-14,272**	**40,039**
Net present value per farm (USD)	**13,332**	**1,137**
Aggregate net present value without taking GHG savings into account (USD)	**3,358 m**	**183 m**
Aggregate net present value taking GHG savings into account (USD)	**1,032,194 m**	**307,003 m**

The evaluation went beyond the original ToR to compare KUSUM-C with KUSUM-A, to run a number of scenarios of interest to stakeholders, and to identify policy implications and priorities for future research and monitoring. This analysis and its findings can be found in the companion report *Outcome Evaluation of Climate-Smart Research on Solar-Powered Irrigation in India: Simulation Modeling*.

The original intent was to answer the evaluation question (EQ 5) for the water-scarce and energy-rich states in India for which SPaRC can work. These states include Punjab, Haryana, Western Uttar Pradesh, Gujarat, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Telangana and Tamil Nadu.

After finding that different variations of SPaRC were being piloted in different states (see Finding 14) it became clear that data input would also vary from state to state. Hence, the evaluation team decided to address the evaluation question to Gujarat, which has the most developed SPaRC pilot and, therefore, the most solid set of input data. At the same time, the evaluation team developed the model in close collaboration with ITP such that ITP can take over the running of the model and carry out a similar analysis for other states once the versions of SPaRC that they intend to use become clearer.

The other change from the original plan was the inclusion of KUSUM-A in the model. This was at the request of ITP, which sees KUSUM-A as the main competition to KUSUM-C. KUSUM-A does not provide any opportunity for adopters to earn money from selling power, nor any incentive to pump less groundwater. It does not help address the energy-water-agriculture nexus. It was felt important to show the comparative performance of both parts of KUSUM to help states decide whether to opt for KUSUM-A, KUSUM-C or both.

Since limited adoption is projected to have occurred in the first few years, and general patterns carry through to 2040, we have omitted the presentation of projected benefits in 2022 and 2030 as originally envisaged in the ToR for the evaluation.

As Table 4 shows, expected values of farm-level net present value (NPV) are over 10 times greater for KUSUM-C than KUSUM-A. The high net income in KUSUM-C is driven by the sale of power back to the grid (about two-thirds of the income on average) and savings due to the adoption of solar (about one-third of the income on average). The higher aggregated NPV for KUSUM-C reflects the higher farm income and the higher adoption rate.

Table 4. Distribution of net present values (NPV) in USD in 2040 at different levels of aggregation. The expected value (EV) and the 10th and 90th percentile values are shown. Units of millions are denoted with 'm'. Greenhouse gas (GHG) benefits are included.

	Net present value (USD)		
Level	**NPV 10th percentile**	**NPV EV**	**NPV 90th percentile**
Farm KUSUM-C	1,720	13,332	28,938
Farm KUSUM-A	431	1,137	2,128
Aggregated KUSUM-C	-1 m	3,358 m	10,184 m
Aggregated KUSUM-A	1 m	183 m	463 m
Aggregated all	1 m	3,541 m	10,454 m
DISCOM KUSUM-C	-138 m	1,014 m	3,086 m
DISCOM KUSUM-A	-353 m	-65 m	146 m
DISCOM all	-263 m	949 m	3,047 m
Water KUSUM-C	0 m	92 m	248 m
Water KUSUM-A	-327 m	-125 m	0 m
GHG KUSUM-C	1,046 m	1,032,194 m	2,352,328 m
GHG KUSUM-A	549 m	307,003 m	806,512 m
Environ all	2,202 m	1,339,163 m	3,235,047 m
Project	2,318 m	1,343,654 m	3,251,793 m

The farm-level distribution of NPV is much wider in KUSUM-C than KUSUM-A and there is a 5% chance of making a loss in KUSUM-C due to combinations of lower income and higher discount rates in some trials. However, there is a large upside tail on KUSUM-C, with a 10% chance of obtaining over USD 30,000/ha discounted net benefit over 20 years. Further disaggregation of the downsides and upsides is warranted and would provide pointers to which policies may increase opportunities and reduce risks.

Results for additional indicators in 2040 are presented in Table . The wide (100-fold) range in the number of adopters reflects the wide range in the Bass model adoption parameters.[70] At the farm

[70] The Bass model has been widely used to model technology adoption in industry, including of PV systems. The model has two parameters: the 'p' parameter determines the initial rate of adoption by 'innovators' and

level, KUSUM-C incurs a small chance of loss, as previously described, whereas KUSUM-A has no chance of loss. Consequently, the number of farmers profiting is 97% of adopters on average. The wide range in the irrigated area reflects the wide range of adoption rates and its distribution between KUSUM-C and KUSUM-A.

There are opportunities for moderate water savings (water use of -14,300 $m^{3/}$yr on average) with KUSUM-C even at the 90th percentile, compared with increased water use in KUSUM-A (40,000 $m^{3/}$yr on average). The project-level return on investment is very large on average, even without considering GHG benefits, but is slightly negative at the 10th percentile. Including GHG benefits, the return on investment is extremely high at all levels of probability.

Table 5. Distribution of values of additional indicators in 2040. The expected value (EV) and the 10th and 90th percentile values are shown.

Indicator	10th percentile	EV	90th percentile
Target population (number of farmers)	804,469	997,505	1,193,770
Adopters KUSUM-C	7704	439,940	828,491
Adopters KUSUM-A	4861	268,260	567,569
Adopters total	13,594	708,201	1,139,426
Chance of farm-level loss KUSUM-C	-	5%	-
Chance of farm-level loss KUSUM-A	-	0%	-
Number of farmers profiting	-	687,963	-
Irrigated area KUSUM-C (ha)	7732	476,093	1,116,923
Irrigated area KUSUM-A (ha)	5100	292,575	705,821
Irrigated area total (ha)	13,671	768,668	1,737,344
Change in farm water use KUSUM-C (m^3/yr)	-35,087	-14,272	-1342
Change in farm water use KUSUM-A (m^3/yr)	9304	40,039	74,914
Return on investment without GHGs (%)	-29	349	882
Return on investment with GHGs (%)	4088	112,059	273,393

In addition to helping to answer EQ 4 and EQ 5 on sustainability and potential impact, respectively, the write-up of the model presents the simulation of several scenarios. The scenarios were identified by experts and through two stakeholder workshops as important for policy decision making and supporting research. The choice of scenarios was also informed by a sensitivity analysis. The scenarios involve the varying of the following parameters:

- Adoption;
- Subsidies and loans;
- Feed-in tariff prices;
- Degree of farmer organization into solar cooperatives, or similar;
- Risk of non-payment by DISCOMs;
- Availability of land for KUSUM-A;
- Low existing groundwater levels;
- Proposal to provide daytime power.

The report also identifies policy implications and priorities for future research and monitoring.

the 'q' parameter determines the subsequent adoption by 'imitators.' The Bass model determines the fraction of the target population that adopts each year.

CONCLUSIONS

Conclusion 1: Since 2012, CGIAR has catalyzed and played a key role in an outcome trajectory by which the idea of solar power as a remunerative crop (SPaRC) gained recognition, became seen as workable, and has been adopted as one of the three components of the USD 50 billion Government of India KUSUM scheme.

Conclusion 2: The policy window theory helped understand how CGIAR contributed to the trajectory by:

- Framing SPaRC as a potential solution to at least five politically important issues;
- Maintaining and exercising the capacity to present, demonstrate and write about SPaRC in ways that together proved extremely effective at influencing government policy;
- Forming partnerships and a coalition to help create a more enabling environment for SPaRC;
- Identifying and answering research questions, the timely answer of which is needed to help SPaRC compete against other ways of solarizing mechanical irrigation that are less beneficial to farmers and the environment, but easier to implement.

Conclusion 3: WLE, CCAFS, TATA Trusts, SDC and GIZ together made a strong contribution to the SPaRC outcome trajectory:

- WLE funded IWMI senior scientist time to engage in all SPaRC work, in particular to write the articles and papers and attend the key events that helped SPaRC gain recognition among policy makers;
- CCAFS funded and made possible the Dhundi pilot initiative that proved catalytic in moving the perception of SPaRC from a good idea in theory to an approach that worked on the ground, deserving inclusion in KUSUM;
- Tata Trusts funded other costs associated with attending key events; bonuses to SPaRC pilot farmers; and ITP interns who did the field work and data collection;
- SDC provided significant additional funding support, including funding the four-country IWMI-led SoLAR-SA project from 2019;
- GIZ funded the Solar Irrigation Expansion in India Partnership to develop tools and case studies for solar irrigation promotion at scale, in particular for SPaRC.

Conclusion 4: By far the largest project supporting the SPaRC outcome trajectory – SoLAR-SA – has brought a strong emphasis on GESI. This is manifest in addressing two policy-relevant questions in particular:

- How have current solar irrigation policies and programs impacted on farmers' livelihoods and gender equity?
- Which financial model generates maximum willingness among small-scale and marginal farmers to adopt solar irrigation?

The project has influenced the design of solar irrigation projects that have also adopted a strong GESI focus.

Conclusion 5: The SPaRC outcome trajectory clearly shows that influencing policy is a route to scale, which is important for CGIAR. ITP has been very effective in influencing solar irrigation policy. Despite this, ITP is unique in CGIAR in the following ways:

- Its equal partnership between a CGIAR Center (IWMI) and a foundation concerned with development (Tata Trusts);
- Its objective to help policy makers at all levels address their water challenges by translating research findings into practical policy recommendations – this is not a research objective but rather one that speaks to bridging research and development;

- Its employment of people with a management rather than a research background;[71] this aligns well with ITP's mandate for 'problem-solving' research with a strong bias toward field action;
- Its practice of giving more credit for policy-relevant publications than academic ones;
- Its level of comfort with policy engagement.

ITP is a bridging organization (Davila et al. 2006),[72] a type of organization that is identified in the literature as important for research impact (Ekboir 2009). There is much for CGIAR to learn from ITP's experience should it wish to see a greater return on its research investment through influencing policy.

Conclusion 6: It is useful to think of KUSUM, and the political imperative to tackle the energy-water-agriculture nexus (see Finding 12), as creating an ecosystem in which various versions of KUSUM's three options, and others, will compete in an evolving, complex and inherently uncertain process. Which versions find niches, where, and whether they help India tackle the nexus, will depend on the timing and quality of decision making. The evaluation team has developed a simulation model to help, in a small way, decision makers to gain a better sense of likely outcomes for states, starting with Gujarat, adopting KUSUM-C and/or KUSUM-A.

Conclusion 7: The simulation model shows that under expected conditions, KUSUM-C gives better outcomes for farmers, DISCOMs, groundwater extraction and reduction in GHG emissions than KUSUM-A. KUSUM-C is likely to face the strongest competition from KUSUM-A when:

- Subsidies are decreased or removed;
- Loans are decreased;
- Tariff prices are reduced;
- Demand and price are high for buying water (e.g., cash crops);
- Non-payment by DISCOMs becomes prevalent;
- Groundwater is not limiting;
- Local institutions are weak;
- Land for solar banks is available;
- Daytime power is made available.

Both KUSUM-A and -C are at risk from a falling market rate for solar-generated power in India.

Conclusion 8: By far the greatest benefit derived from both KUSUM-A and -C is the reduction of GHG emissions by replacing fossil fuel use with solar power generation, when a notional price is paid for reducing CO_2 emissions. GHG emission reductions are large in both KUSUM-A and -C. KUSUM-C's unique attraction is that it can potentially deliver other benefits, including increased farmer income, reduction in farm power subsidies and incentives for farmers to become energy and water efficient.

RECOMMENDATIONS

Recommendation 1: For ITP to continue to play a central role in the SPaRC outcome trajectory.
Given the potential impact of SPaRC, and the huge return on research investment that this would bring, WLE, IWMI, CCAFS and Tata Trusts should continue to support ITP in playing a central role in the SPaRC outcome trajectory. The policy window theory and progress to date suggest the following strategies are likely to be beneficial:

- Maintaining the reputation of ITP so it is invited to present to high-level decision makers;
- Maintaining the ability to take advantage of policy windows;
- Forming partnerships to build capacity to establish solar cooperatives at scale;

[71] Respondent 6

[72] Helps find useful information, mediates between researchers and other actors in the outcome trajectory and identify internal and external barriers to innovation

- Carrying out research to support the adaptation and evolution of SPaRC to maximize its benefits, in particular to marginalized groups;
- Strengthening a coalition of actors who believe in SPaRC as a way to tackle the energy-water-agriculture nexus.

Recommendation 2: For WLE and CCAFS to propose a synthesis across recent outcome evaluations as to how programmatic research has achieved impact at scale, to inform the move to One CGIAR. Several CRPs have invested in outcome evaluations since 2019, including WLE, CCAFS, RTB and A4NH. At the same time, CGIAR is going through a reorganization to become One CGIAR such that scientific innovations are deployed faster, at a larger scale and at a reduced cost, having a greater impact where they are needed the most. [73] It would therefore be timely to carry out a synthesis across the evaluations to appreciate and learn lessons from what has worked. For example, this and the RTB/A4NH evaluation, show that influencing policy is clearly important for achieving impact at scale, and advocacy is important for achieving policy change. CGIAR is generally uncomfortable with explicitly engaging in advocacy. Learning from how CRPs have successfully supported advocacy efforts, regardless of whether the term was used, would likely yield worthwhile lessons for One CGIAR.

Recommendation 3: For WLE and CCAFS to support the handing over of the simulation model to ITP
The simulation model is easily accessible as a native Microsoft Excel spreadsheet with a linked input datasheet and includes a dashboard with the graphical display of results and a facility to easily simulate various policy scenarios. The model input datasheet can be readily edited to apply the model to different states in India. As better data become available, especially for sensitive variables, such as adoption rates, the uncertainties in projected benefits will be reduced. Hence the model can be used as a learning tool and the projection of benefits updated regularly over time. The use of SIPmath™ tools for Excel makes it relatively easy for a graduate-level analyst to build new assumptions into the model. With further effort, additional solar models could also be added. ITP has had exposure to the model and has the technical knowledge to parameterize the input distributions. We recommend that WLE and CCAFS support the handing over of the simulation model to ITP and consider further training and technical support to help develop ITP's capacity in its use.

Recommendation 4: For the CGIAR System Organization to consider whether the simulation modeling approach used in this evaluation has broader applicability
Additional data or information from applied research have no value unless they improve decision making – for example, decisions on what interventions should be promoted to provide the most favorable livelihood and environmental outcomes at least cost and risk. It is impossible to know what research will produce value without first quantifying the current state of uncertainty and then seeing which uncertainties are critical for outcomes. There is also strong demand from donors and other stakeholders for CGIAR to project and monitor benefits.

In this evaluation, the simulation modeling approach required researchers to quantify their assumptions and uncertainty in adoption, costs, benefits and risks associated with alternative solar irrigation models. We think this process of quantifying the theory of change led to deeper thought and analysis on causal factors affecting adoption and impact of solar irrigation alternatives than would otherwise have been the case. The modeling identified several priority areas for research and monitoring, based on where uncertainty reduction would most affect projected outcomes.

The SIPmath™ open-standard approach used in this study could provide the foundation for an enterprise-wide platform for representing uncertainty and including uncertainty and risk in cost-benefit analysis. SIPmath™ is readily accessible to everyone in Excel but is also applicable across platforms (e.g., R, Python). We therefore recommend this approach for consideration as a CGIAR-wide

[73] https://www.cgiar.org/food-security-impact/one-cgiar/

complement in ex-ante and ex-post impact evaluations, and for use in research project screening at various stage gates based on projected benefits.

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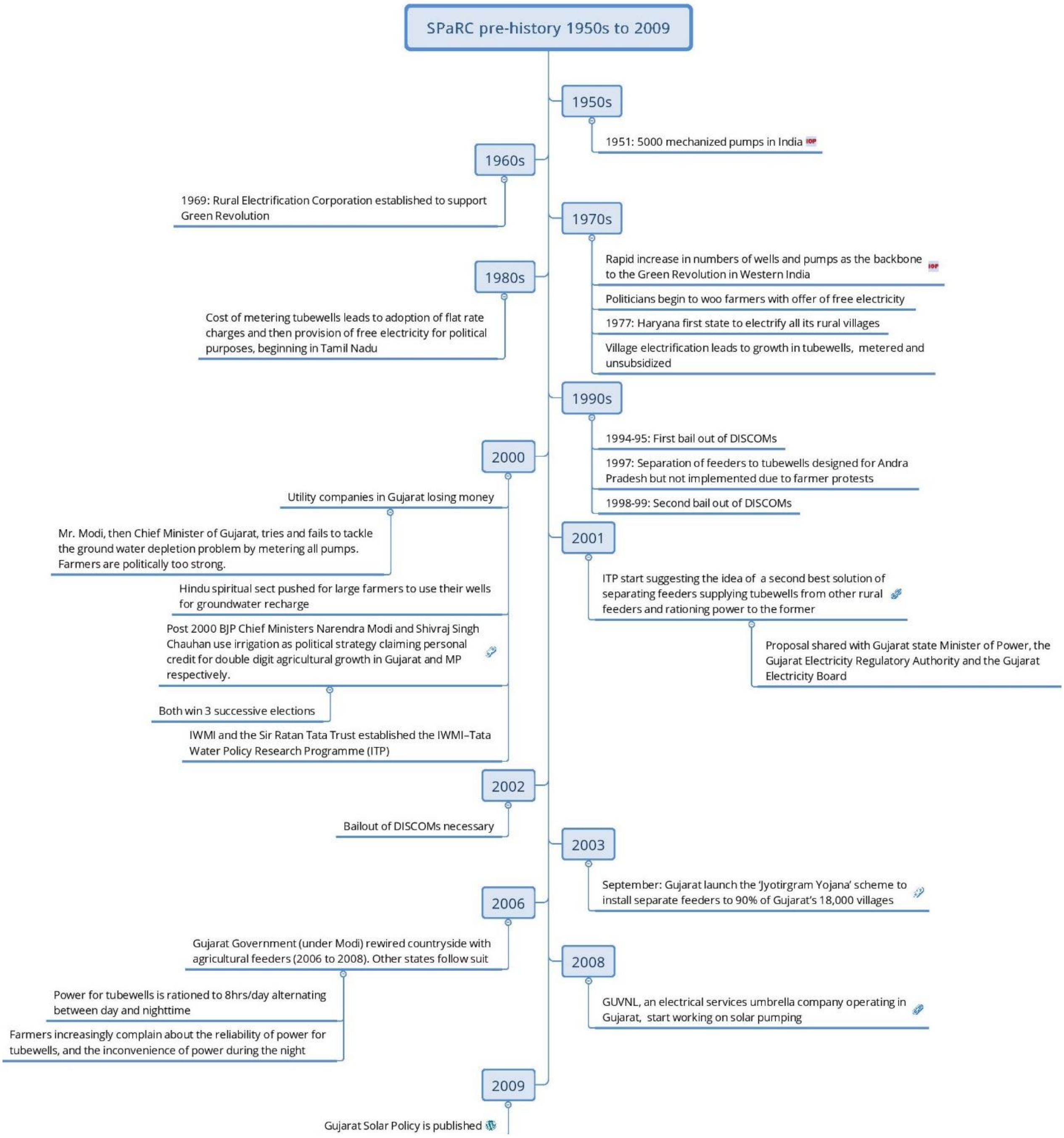
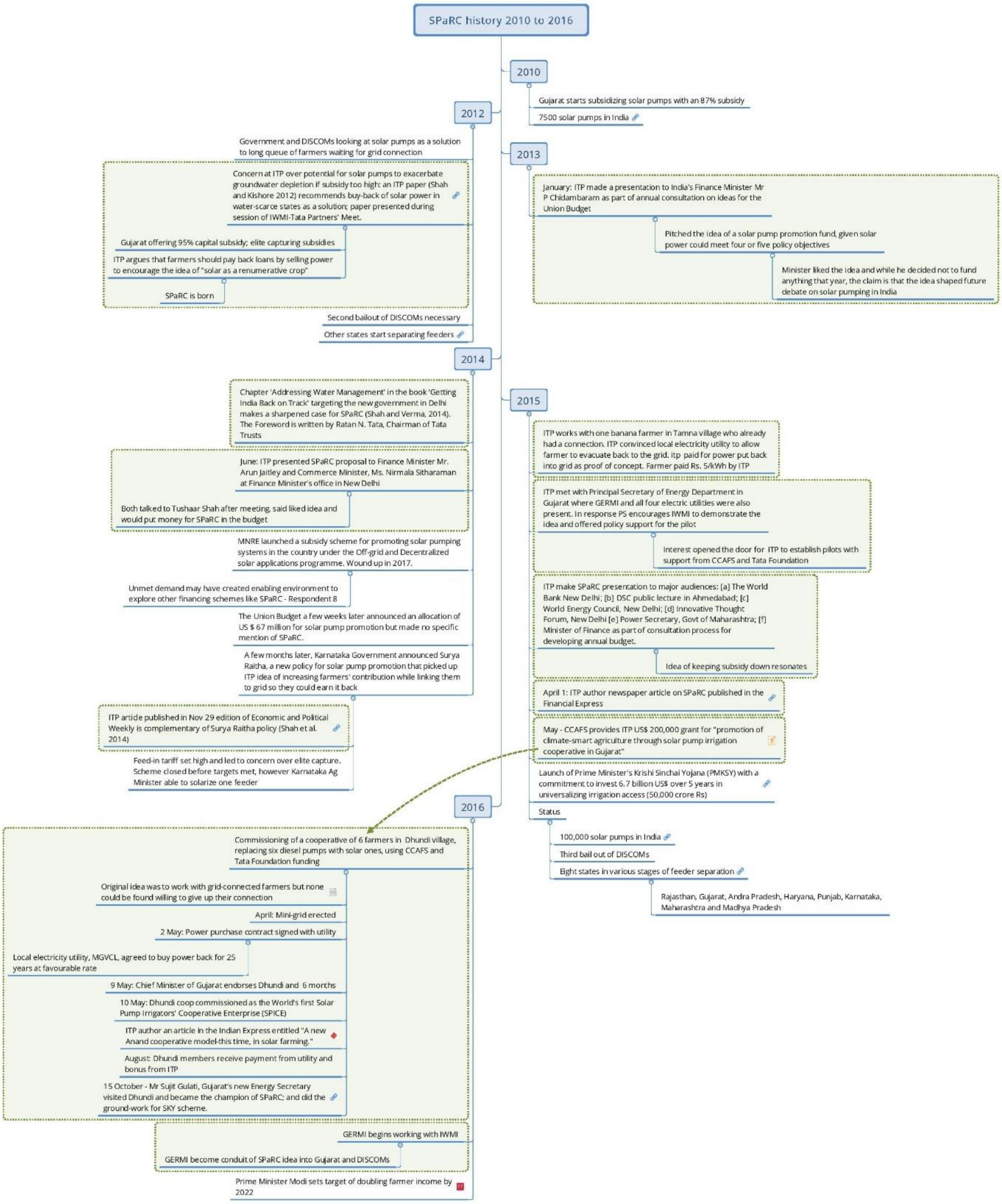
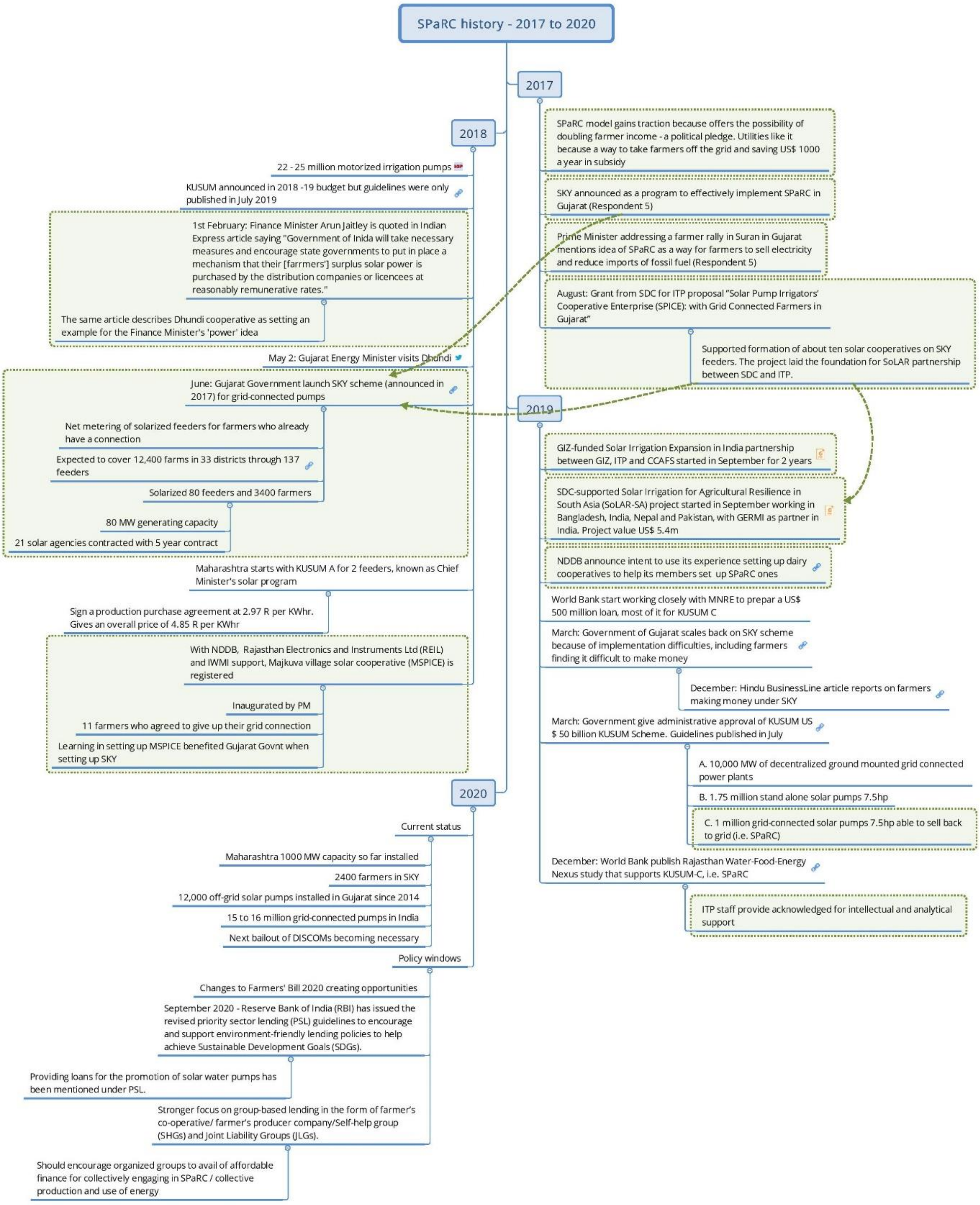
APPENDICES

Appendix 1: Timeline of the SPaRC outcome trajectory

The SPaRC outcome trajectory is the changing pattern of interactions between actors, institutions and technology that has led to the inclusion of SPaRC in the SKY and KUSUM schemes. To understand how ITP, WLE and CCAFS contributed, it is necessary to understand how the SPaRC trajectory was influenced by a broader solar irrigation trajectory and, in turn, how this broader trajectory was influenced by a groundwater irrigation trajectory (see Finding 1). The following timeline describes key events and processes in all three trajectories. It was constructed by the evaluator though interviews and document review and then validated by 13 out of 19 interviewees in a virtual workshop (see Appendix 3). A narrative that links elements of the timeline together is provided in Appendix 2.




SPaRC history 2010 to 2016
2010
Gujarat starts subsidizing solar pumps with an 87% subsidy
7500 solar pumps in India
2012
Government and DISCOMs looking at solar pumps as a solution to long queue of farmers waiting for grid connection
Concern at ITP over potential for solar pumps to exacerbate groundwater depletion if subsidy too high: an ITP paper (Shah and Kishore 2012) recommends buy-back of solar power in water-scarce states as a solution; paper presented during session of IWMI-Tata Partners' Meet.
Gujarat offering 95% capital subsidy; elite capturing subsidies
ITP argues that farmers should pay back loans by selling power to encourage the idea of "solar as a renumerative crop"
SPaRC is born
Second bailout of DISCOMs necessary
Other states start separating feeders
2013
January: ITP made a presentation to India's Finance Minister Mr P Chidambaram as part of annual consultation on ideas for the Union Budget
Pitched the idea of a solar pump promotion fund, given solar power could meet four or five policy objectives
Minister liked the idea and while he decided not to fund anything that year, the claim is that the idea shaped future debate on solar pumping in India
2014
Chapter 'Addressing Water Management' in the book 'Getting India Back on Track' targeting the new government in Delhi makes a sharpened case for SPaRC (Shah and Verma, 2014). The Foreword is written by Ratan N. Tata, Chairman of Tata Trusts
June: ITP presented SPaRC proposal to Finance Minister Mr. Arun Jaitley and Commerce Minister, Ms. Nirmala Sitharaman at Finance Minister's office in New Delhi
Both talked to Tushaar Shah after meeting, said liked idea and would put money for SPaRC in the budget
MNRE launched a subsidy scheme for promoting solar pumping systems in the country under the Off-grid and Decentralized solar applications programme. Wound up in 2017.
Unmet demand may have created enabling environment to explore other financing schemes like SPaRC - Respondent 8
The Union Budget a few weeks later announced an allocation of US $ 67 million for solar pump promotion but made no specific mention of SPaRC.
A few months later, Karnataka Government announced Surya Raitha, a new policy for solar pump promotion that picked up ITP idea of increasing farmers' contribution while linking them to grid so they could earn it back
ITP article published in Nov 29 edition of Economic and Political Weekly is complementary of Surya Raitha policy (Shah et al. 2014)
Feed-in tariff set high and led to concern over elite capture. Scheme closed before targets met, however Karnataka Ag Minister able to solarize one feeder
2015
ITP works with one banana farmer in Tamna village who already had a connection. ITP convinced local electricity utility to allow farmer to evacuate back to the grid. itp paid for power put back into grid as proof of concept. Farmer paid Rs. 5/kWh by ITP
ITP met with Principal Secretary of Energy Department in Gujarat where GERMI and all four electric utilities were also present. In response PS encourages IWMI to demonstrate the idea and offered policy support for the pilot
Interest opened the door for ITP to establish pilots with support from CCAFS and Tata Foundation
ITP make SPaRC presentation to major audiences: [a] The World Bank New Delhi; [b] DSC public lecture in Ahmedabad; [c] World Energy Council, New Delhi; [d] Innovative Thought Forum, New Delhi [e] Power Secretary, Govt of Maharashtra; [f] Minister of Finance as part of consultation process for developing annual budget.
Idea of keeping subsidy down resonates
April 1: ITP author newspaper article on SPaRC published in the Financial Express
May - CCAFS provides ITP US$ 200,000 grant for "promotion of climate-smart agriculture through solar pump irrigation cooperative in Gujarat"
Launch of Prime Minister's Krishi Sinchai Yojana (PMKSY) with a commitment to invest 6.7 billion US$ over 5 years in universalizing irrigation access (50,000 crore Rs)
Status
100,000 solar pumps in India
Third bail out of DISCOMs
Eight states in various stages of feeder separation
Rajasthan, Gujarat, Andra Pradesh, Haryana, Punjab, Karnataka, Maharashtra and Madhya Pradesh
2016
Commissioning of a cooperative of 6 farmers in Dhundi village, replacing six diesel pumps with solar ones, using CCAFS and Tata Foundation funding
Original idea was to work with grid-connected farmers but none could be found willing to give up their connection
April: Mini-grid erected
2 May: Power purchase contract signed with utility
Local electricity utility, MGVCL, agreed to buy power back for 25 years at favourable rate
9 May: Chief Minister of Gujarat endorses Dhundi and 6 months
10 May: Dhundi coop commissioned as the World's first Solar Pump Irrigators' Cooperative Enterprise (SPICE)
ITP author an article in the Indian Express entitled "A new Anand cooperative model-this time, in solar farming."
August: Dhundi members receive payment from utility and bonus from ITP
15 October - Mr Sujit Gulati, Gujarat's new Energy Secretary visited Dhundi and became the champion of SPaRC; and did the ground-work for SKY scheme.
GERMI begins working with IWMI
GERMI become conduit of SPaRC idea into Gujarat and DISCOMs
Prime Minister Modi sets target of doubling farmer income by 2022


SPaRC history - 2017 to 2020
2017
SPaRC model gains traction because offers the possibility of doubling farmer income - a political pledge. Utilities like it because a way to take farmers off the grid and saving US$ 1000 a year in subsidy
SKY announced as a program to effectively implement SPaRC in Gujarat (Respondent 5)
Prime Minister addressing a farmer rally in Suran in Gujarat mentions idea of SPaRC as a way for farmers to sell electricity and reduce imports of fossil fuel (Respondent 5)
August: Grant from SDC for ITP proposal "Solar Pump Irrigators' Cooperative Enterprise (SPICE): with Grid Connected Farmers in Gujarat"
Supported formation of about ten solar cooperatives on SKY feeders. The project laid the foundation for SoLAR partnership between SDC and ITP.
2018
22 - 25 million motorized irrigation pumps
KUSUM announced in 2018 -19 budget but guidelines were only published in July 2019
1st February: Finance Minister Arun Jaitley is quoted in Indian Express article saying "Government of Inida will take necessary measures and encourage state governments to put in place a mechanism that their [farrmers'] surplus solar power is purchased by the distribution companies or licencees at reasonably remunerative rates."
The same article describes Dhundi cooperative as setting an example for the Finance Minister's 'power' idea
May 2: Gujarat Energy Minister visits Dhundi
June: Gujarat Government launch SKY scheme (announced in 2017) for grid-connected pumps
Net metering of solarized feeders for farmers who already have a connection
Expected to cover 12,400 farms in 33 districts through 137 feeders
Solarized 80 feeders and 3400 farmers
80 MW generating capacity
21 solar agencies contracted with 5 year contract
Maharashtra starts with KUSUM A for 2 feeders, known as Chief Minister's solar program
Sign a production purchase agreement at 2.97 R per KWhr. Gives an overall price of 4.85 R per KWhr
With NDDB, Rajasthan Electronics and Instruments Ltd (REIL) and IWMI support, Majkuva village solar cooperative (MSPICE) is registered
Inaugurated by PM
11 farmers who agreed to give up their grid connection
Learning in setting up MSPICE benefited Gujarat Govnt when setting up SKY
2019
GIZ-funded Solar Irrigation Expansion in India partnership between GIZ, ITP and CCAFS started in September for 2 years
SDC-supported Solar Irrigation for Agricultural Resilience in South Asia (SoLAR-SA) project started in September working in Bangladesh, India, Nepal and Pakistan, with GERMI as partner in India. Project value US$ 5.4m
NDDB announce intent to use its experience setting up dairy cooperatives to help its members set up SPaRC ones
World Bank start working closely with MNRE to prepare a US$ 500 million loan, most of it for KUSUM C
March: Government of Gujarat scales back on SKY scheme because of implementation difficulties, including farmers finding it difficult to make money
December: Hindu BusinessLine article reports on farmers making money under SKY
March: Government give administrative approval of KUSUM US $ 50 billion KUSUM Scheme. Guidelines published in July
A. 10,000 MW of decentralized ground mounted grid connected power plants
B. 1.75 million stand alone solar pumps 7.5hp
C. 1 million grid-connected solar pumps 7.5hp able to sell back to grid (i.e. SPaRC)
December: World Bank publish Rajasthan Water-Food-Energy Nexus study that supports KUSUM-C, i.e. SPaRC
ITP staff provide acknowledged for intellectual and analytical support
2020
Current status
Maharashtra 1000 MW capacity so far installed
2400 farmers in SKY
12,000 off-grid solar pumps installed in Gujarat since 2014
15 to 16 million grid-connected pumps in India
Next bailout of DISCOMs becoming necessary
Policy windows
Changes to Farmers' Bill 2020 creating opportunities
September 2020 - Reserve Bank of India (RBI) has issued the revised priority sector lending (PSL) guidelines to encourage and support environment-friendly lending policies to help achieve Sustainable Development Goals (SDGs).
Providing loans for the promotion of solar water pumps has been mentioned under PSL.
Stronger focus on group-based lending in the form of farmer's co-operative/ farmer's producer company/Self-help group (SHGs) and Joint Liability Groups (JLGs).
Should encourage organized groups to avail of affordable finance for collectively engaging in SPaRC / collective production and use of energy

Appendix 2: History of the SPaRC outcome trajectory

The following is a written description that links together the events and processes shown on the timeline in Appendix 1, as a way of identifying causal links between them. It represents part of the analysis that went into identifying the findings in the main report, as well as helping the reader understand the SPaRC trajectory story.

1951

Groundwater irrigation – the pumping of water from wells – has always been used in India but at relatively low levels. In 1951 there were only 5,000 mechanized pumps in India but by 2000 this had increased to 19 million and stands at 22 to 25 million in 2018. [74]

1970s

The rapid increase in the numbers of wells and pumps began in the 1970s, with the onset of the Green Revolution, which has also been called the tubewell revolution (Repetto 1994). The ability for farmers to irrigate using groundwater helped address a large difference in access to irrigation between farmers within the command area of surface irrigation schemes and those in dryland areas, and between large and small farmers (Shah 2009). As of 2019, 60% of India's irrigated agriculture is via groundwater.[75]

1980s

In the 1980s, government policy was to continue to support the installation of tubewells as a way of reducing inequality between areas with canal-fed surface irrigation and those without. In Gujarat, and elsewhere, decentralized village-level groundwater markets became established in which farmers with pumps sold water to their neighbors, at a relatively high price compared to water available to farmers in areas with surface irrigation. The Chief Minister of Gujarat put pressure on the Gujarat Electricity Utility to reduce the cost of electricity for pumping. Research in Uttar Pradesh and Tamil Nadu found that tubewell owners charged less for water when they were charged for power according to the capacity of their pump rather than by metered power consumption. This was because reading the meters of thousands of pumps was expensive to the distribution companies and some corruption had built up around the use of meters. Tushaar Shah, who was then working for the Rural Management Institute in Anand, Gujarat, shared the research findings with the Chair of the Gujarat Electricity Utility and Gujarat stopped metering two months later, in 1989.[76] The price of water fell by 60%.[77]

1990s

In the 1990s, the overextraction of groundwater began emerging as a serious problem, caused by an increasing number of wells connected to cheap power. At the same time, the cheap electricity that was helping to keep politicians in power was putting a financial strain on the government and the DISCOMs.

2000s

In 2000, IWMI and the Sir Ratan Tata Trust – one of the oldest philanthropic institutions in India – established the IWMI–Tata Water Policy Research Program (ITP). ITP's objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Tushaar Shah was part of ITP from the outset.

[74] https://iopscience.iop.org/article/10.1088/1748-9326/aae53f/pdf
[75] https://www.thehindubusinessline.com/opinion/solar-irrigation-can-transform-rural-india/article28322085.ece#
[76] Respondent 5
[77] Respondent 5

In 2000, in an attempt to solve the twin problems of the overextraction of groundwater and overly cheap electricity, the then Chief Minister of Gujarat, Narendra Modi, tried to introduce metering of all pumps so that farmers would be charged on their water consumption. The attempt failed because farmer protests forced the government to make a U-turn. DISCOMs continued to lose money and the Government of India was forced to bail them out for the first time in 2002, in Gujarat, as well as in other water-scarce states dependent on tubewells.

During this time, Shah et al. (2003) wrote a paper that put forward a compromise solution in which farmers would be rationed to 8 hours a day of reliable power. This would involve creating separate feeders for agricultural power, independent of domestic supply.

Appreciating the power of the agrarian vote, from 2002, Narendra Modi in Gujarat and Shivraj Singh Chauhan in Madhya Pradesh, pursued agricultural growth through irrigation development as a political strategy, claiming personal credit for double-digit agricultural growth in their states.[78] They both went on to win three elections on this platform.

As part of agricultural development in Gujarat, separate agricultural feeders were established in 1,000 days from 2006. Other states have followed Gujarat's example.

In 2008, GUVNL, the electrical services umbrella company operating in Gujarat, started working on solar pumping.[79] Gujarat has 320 days of sunshine a year, which makes PVs an obvious choice as a green alternative to diesel and grid-connected power supply where power comes largely from coal- and nuclear-fired power stations. The cost of PVs was more than USD 5,000 per installed kW generating capacity in 2008, making solar pumping a very expensive option. However, over the next 5 years costs fell by 50%.[80]

2009

In 2009, Gujarat launched its Solar Power Policy, as the first comprehensive solar policy in India, offering incentives to investors over a 25-year period. The policy helped the state increase from 20 MW solar generation capacity in 2010 to 5,500 MW in 2016 (Pathak and Muller 2016). By 2013, Gujarat had over 50% of the share of solar power capacity in the country.

Gujarat's policy was in response to the National Solar Mission, also approved in 2009. The mission set a national target of 20,000 MW of grid-connected solar power by 2022 (which was increased to 100,000 MW by 2015). Importantly, the mission established Renewable Purchase Obligations (RPOs) that compel DISCOMs to purchase a given percentage of solar power. Gujarat adopted RPOs for its utility companies in the following year (Pathak and Muller 2016).

2010

In 2010, the Government of Gujarat started subsidizing 87% of the cost of solar pumps. At this point there were only 7,500 solar pumps in all of India.[81]

2012

As part of Gujarat's Solar Power Policy, the state launched the Gandhinager PV Rooftop Program, the first of its kind in India. In the program, private sector companies rent rooftops on public and private

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[78] http://www.iwmi.cgiar.org/iwmi-tata/PDFs/iwmi-tata_water_policy_research_highlight-issue_01_2016.pdf

[79] Respondent 17

[80] Estimates based on https://www.pv-tech.org/news/balance-of-system-costs-key-to-further-solar-system-cost-reductions-says-ir

[81] https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/CM_LII_45_111107_TushaarShah_etal.pdf

buildings to install PV panels. The companies, selected in a competitive bidding process, were paid INR 3/kWh supplied.

In the 10 years since ITP was established, its researchers had become increasingly concerned about the potential for solar pumps to exacerbate groundwater depletion in dry areas, because pump owners paid almost nothing for pumping more water than they needed. The ITP team hit upon the idea of allowing farmers to sell the excess power they generated back to the grid, in a similar way as private companies were starting to do under the Gandhinager PV Rooftop Program.[82] Their hypothesis was that if the feed-in tariff offered to farmers was high enough, farmers would economize on water use so as to have excess power to sell. In 2012, Tushaar Shah and Avinash Kishore wrote an ITP Water Policy Research Highlight in which they proposed the idea (Shah and Kishore 2012). Their argument was that the falling cost of PVs meant it was only a matter of time before the Indian government began aggressive promotion of solar pumps. This would be good for eastern India, which has surplus water, but potentially bad for western and southern India, where there is a water deficit and solar pumping could exacerbate groundwater depletion unless incentives were provided to prevent it. The idea of solar power as a remunerative crop (SPaRC) was born. Key to the idea was to incentivize farmers to sell power back to the grid by making a substantial part of the purchase price a loan to be paid back through offering high, but time-limited, feed-in tariffs.[83]

Also in 2012, the government bailed out the DISCOMs for a second time, reinforcing the need for DISCOMs to find a way out of having to provide rural power at prices well below cost. As part of a potential solution, other states followed Gujarat's example and started installing separate agricultural feeders.

2013
In 2013, ITP met with the Principal Secretary of the Gujarat Energy Department, who asked if ITP could implement SPaRC on the ground. At about the same time, the CCAFS proposed a pilot project to do the same. ITP agreed to act on both opportunities.[84]

2014
In June 2014, and again in January 2015, Tushaar Shah, on behalf of ITP, presented the idea of SPaRC to the Minister of Finance as part of a consultation process to develop the annual budget.[85] In 2014, the government first conceived the KUSUM program to support the use of solar power for tubewell irrigation: one of the three components was SPaRC. It is credible to assume that the inclusion of SPaRC in KUSUM was because of ITP's work.

2015
In 2015, the Government of India launched the Prime Minister's Krishi Sinchai Yojana (PMKSY) scheme with a commitment to invest USD 6.7 billion (INR 50,000 crore) over 5 years in universalizing irrigation access.[86] This provided an important impetus for irrigation development in India, including for expanded use of solar power through KUSUM.

[82] Respondent 6 and Pathak and Muller 2016
[83] Respondent 5
[84] Respondent 6
[85] Respondent 6
[86] https://pmksy.gov.in/

Also in 2015, the government was forced to bail out the DISCOMs for a third time,[87] adding further pressure to find a solution. Each farmer with a grid connection costs the DISCOMs USD 1,000/year,[88] which is paid for by charging other customers more (cross-subsidization) and from grants and bailouts from the government.

By 2015, the number of solar pumps in India had increased by more than 13-fold since 2010.[89] At the same time, a World Bank report found that eight states were in various stages of feeder separation as a way to ration farm power. The eight states were Rajasthan, Gujarat, Andra Pradesh, Haryana, Punjab, Karnataka, Maharashtra and Madhya Pradesh.[90]

As part of agreements made with the Government of Gujarat and CCAFS in 2013, ITP began working with a farmer, Raman Parmar, in Thamna village in Gujarat as a proof of concept. CCAFS funding was used to provide the farmer with solar panels that were connected both to his pump and the feeder, with the help of the utility company MGVCL. After using the pump for four months, IWMI paid the farmer INR 7,500 (USD 100) for the 1,500 kWh of energy generated by the panels when not pumping water. IWMI paid the farmer because, at this point, MGVCL had not yet agreed to buy back power.

The payment to the farmer generated state and national interest. An article in the *Business Standard* on June 13, 2015 quoted Tushaar Shah as saying:

> "Solar irrigation pumps provide farmers water to irrigate their fields and also gives them an incentive to sell their remaining power to the grid. Solar power can be a steady source of income for farmers. This will also address the issue of groundwater depletion. The buyback scheme could also protect farm incomes in the event of crop failure. And, if adopted widely, this could help ease pressure on the state's overburdened electricity board. Solar crops are a very exciting example of a 'triple' win — for farmers, the state, and the precious water reserves, all benefit from a single intervention."[91]

Raman Parmar was labeled as India's first solar power farmer by the *Times of India*.[92]

Inspired by Raman, ITP worked with six farmers from Dhundi village to form India's first solar irrigation cooperative – Dhundi Saur Urja Utpadak Sahakari Mandali (DSUUSM) – in December 2015. ITP, with funding from CCAFS, replaced their six diesel-powered pumps with solar ones.[93]

2016

ITP worked with DSUUSM to erect a minigrid connecting the six farmers to the grid. On May 2, 2016 DSUUSM signed a contract with the utility company MGVCL to purchase power from them at INR 4.63/kWh, which was seen as a favorable rate. ITP also paid them a bonus on top of the MGCVL payment. The six farmers paid 7% of the equipment cost.

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[87] Respondent 11
[88] Respondent 6
[89] https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/CM_LII_45_111107_TushaarShah_etal.pdf
[90] http://documents.worldbank.org/curated/en/220801468042879882/Lighting-rural-India-load-segregation-experience-in-selected-states
[91] https://www.business-standard.com/article/economy-policy/a-gujarat-farmer-who-supplies-power-to-grid-115061200812_1.html
[92] https://timesofindia.indiatimes.com/city/ahmedabad/solar-harvests-changing-lives/articleshowprint/66900778.cms
[93] https://timesofindia.indiatimes.com/city/ahmedabad/solar-harvests-changing-lives/articleshowprint/66900778.cms

On May 9, 2016, DSUUSM was endorsed by the Chief Minister of Gujrat and the following day it was commissioned as the world's first Solar Pump Irrigators' Cooperative Enterprise (SPICE). Over the following six months DSUUSM was seen by about 500 visitors.[94]

In 2018, a *Times of India* article quoted Pravin Parmer, secretary of DSUUSM, as saying:

> "Until three years ago we used diesel pumps to draw irrigation water. I had to shell out INR 1,000 per day to buy diesel. Apart from selling excess power we are in a position to sell surplus irrigation water to neighbouring farmers as well, at INR 250 per bigha per irrigation. Both of these were additional sources of income. Until date, DSUUSM has made INR 10 lakh (USD 13,300) by selling power and nearly INR 6 lakh (USD 8,000) by selling water."[95]

2017

The SPaRC model continued to generate interest in 2017 and the triple win argument made by Tuhaar Shah began to gain traction.[96] The idea of SPaRC was attractive to the government, which had promised to double farmers' income as part of the PMKSY (see above). ITP released figures showing that a single farmer could generate 13,000 units of power worth INR 65,000 (USD 870) in a year on just 1/25th of a hectare. To put this into context, the average income of an agricultural household in India is less than INR 108,000 (USD 1,440) per year, of which only about half is contributed by farm income (Nabard All India Financial Inclusion Survey 2017). ITP also said that 10 million solar farmers could 'grow' 130 billion units of solar power and earn up to INR 65,000 crore (USD 8.7 billion) per year net of input costs.[97]

The government was also interested in the purported environmental impacts of more 'green' power generation that would help it meet its international commitments and reduce groundwater depletion. The promise of more reliable power and the opportunity to sell power back to the grid was attractive to farmers. Utility companies were attracted by the opportunity to free themselves from the commitment to supply farmers with virtually free electricity, which was costing them USD 1,000/year for each farmer. In Gujarat, 30% of total power goes to agriculture[98] but accounts for just 3% of revenue. Farmers pay INR 0.6/unit. GUVNL wanted the price to be nearly six times this figure (INR 3.5/unit), but such an increase is not politically feasible.[99]

In short, SPaRC promised to tick a number of boxes for the main stakeholders involved, namely:

- The opportunity for farmers to double their farm income by selling power back to the grid;
- Reduction in groundwater depletion;
- Reduction in loss-making power DISCOMs have to supply to farmers;
- Reduction in power generated by burning fossil fuels.

The growing interest in SPaRC led to a visit to DSUUSM from the Gujarat Energy Minister. Two months later, in June 2017, Gujarat announced the Suryashakti Kisan Yojna scheme, popularly known as SKY as part of KUSUM, to contribute to "achieving Prime Minister Narendra Modi's dream to double the

[94] Respondent 18
[95] https://timesofindia.indiatimes.com/city/ahmedabad/solar-harvests-changing-lives/articleshowprint/66900778.cms
[96] https://www.planetcustodian.com/indias-new-climate-smart-cash-crop-triple-win-for-nation-and-its-farmers/3303/
[97] https://timesofindia.indiatimes.com/city/ahmedabad/solar-harvests-changing-lives/articleshow/66900778.cms
[98] Respondent 16
[99] Respondent 17

income of farmers by year-2022."[100]. Given the timing and nature of the SKY scheme, it is highly likely that ITP contributed to its formulation.

2018

In February 2018, the KUSUM scheme was announced, with a budget of USD 50 billion over 5 years. The scheme has three parts; namely, to install:

A. 10,000 MW of decentralized ground-mounted, grid-connected power plants;
B. 1.75 million stand-alone solar pumps 7.5 hp;
C. 1 million grid-connected solar pumps 7.5 hp, able to sell back to grid (i.e., SPaRC).

Also in 2018, Maharashtra started a pilot of KUSUM-A for two feeders, in a program that has been named the Chief Minister's Solar Program. Under KUSUM-A, typically a private sector company signs a contract with a utility company to provide power to an agricultural feeder at a rate fixed for 25 years. The utility provides the land to set up the solar power plants. As far as farmers are concerned, the difference they see is that power is provided during daylight hours, which should be more reliable than the power previously supplied from the national grid. The attraction of KUSUM-A is that it requires very little public sector funding and can be rolled out quickly as a way to increase the proportion of renewable power used in agriculture. As of 2020, 1,000 MW of generating capacity have been installed under KUSUM-A.[101] The State Government of Maharashtra has fixed the purchase price at INR 2.97/unit.

One of the question marks over the viability of SPaRC is whether farmers will be willing to give up their 'right' to a grid connection and with it their virtually free electricity for pumping water. The Dhundi farmers were willing adopters of SPaRC because they did not have a connection to the grid and had previously been using expensive diesel-powered pumps. Accordingly, ITP worked with the NDDB to set up a solar cooperative with farmers who agreed to give up their grid connection. NDDB's experience is described in Box 2

Box 2: The experience of NDDB in supporting a solar cooperative in Gujarat

NDDB worked with 11 farmers in Majkuva village in Gujarat who were prepared to give up their grid connections in exchange for the opportunity to earn income by selling surplus solar power to the grid. The farmers paid 15% of the cost of the project, NDDB paid 68% and the balance came from a private company, Rajasthan Electronics and Instruments. The project budget was INR 18 million (USD 240,000). Part of NDDB's contribution was to help the farmers form a cooperative. The project was inaugurated by the Prime Minister in 2018.

As of early 2020, the cooperative has earned INR 700,000 (USD 9,100). The feed-in tariff offered by the DISCOM was INR 3.47/kWh with ITP adding INR 2.50/kWh. According to one respondent, the total income would have been more if solar panels and poles had not been damaged. Other issues included:

- Reluctance from the DISCOM to disconnect farmers from the grid because it meant losing customers;
- Uncertainty over whether the DISCOM or the cooperative was responsible for the transformer linking the microgrid to the national grid;
- The need to generate reserves to cover disasters, and to hire a technical person to help with maintenance;
- Jealousy of, and possible sabotage by, neighbors.

[100] Quote from Gujarat Power Research and Development Cell, webpage https://www.gprd.in/sky.php
[101] Respondent 11

Despite some setbacks, NDDB remains convinced that solar cooperatives are essential to the success of KUSUM because they give farmers bargaining power in negotiations with DISCOMs on feed-in tariffs, regular payments and timely resolution of problems connecting to the grid.

2019

In 2019, the World Bank started working closely with MNRE to prepare a USD 500 million loan, most of it for KUSUM-C

On July 9, 2019, Mohinder Gulani, former Adviser on Energy for Europe and Central Asia Region and VS Sampath, former Chief Election Commissioner of India, wrote an article in the BusinessLine section of the *Hindu* newspaper entitled "Solar irrigation can transform rural India." The article projected the likely benefits for four feeders in Rajasthan from adopting KUSUM-C (i.e., SPaRC). Its authors found that:

"Farm income of a typical farmer would increase by about 30 per cent during the 7-year period of loan repayment and by more than 100 per cent thereafter. During drought and crop failure, farmer can reduce the scale of agriculture and earn more money from sale of power. Government subsidy is not an expenditure but a very profitable investment which would save the government a recurring subsidy of INR 56,000 per farmer – a return of about 30 per cent."[102]

In December 2019, the World Bank published the results of a large study on Rajasthan's water-food-energy nexus that examined different solar irrigation options for the state. The study came out firmly in support of KUSUM-C (i.e., SpaRC) over KUSUM-A, in large part because KUSUM-A provides no incentive for farmers to pump less water, no pathway for utility companies to free themselves from providing subsidized power indefinitely, and no way for farmers to earn money from 'growing' solar.[103] The report acknowledged the intellectual and analytical support provided by ITP staff.

2020

In 2020, the Covid-19 pandemic delayed the implementation of KUSUM. At the beginning of the year, there were an estimated 21 million pumps connected to the grid and 8.8 million diesel-powered pumps. The number of solar pumps had risen to 130,000, mostly added in the past 5 years.[104] In Gujarat, 12,000 off-grid solar pumps had been installed since 2014, and 2,400 farmers were enrolled in the SKY program. As already mentioned, Maharashtra had installed 1,000 MW of solar-generating capacity under KUSUM-A. Despite the start of KUSUM, the next bailout of DISCOMs was becoming necessary.

[102] https://www.thehindubusinessline.com/opinion/solar-irrigation-can-transform-rural-india/article28322085.ece#
[103] https://openknowledge.worldbank.org/handle/10986/33375
[104] https://energypost.eu/can-indias-30m-grid-diesel-irrigation-pumps-go-solar/

Appendix 3: List of interviewees

Name	Gender	Affiliation	Job title/role	Attended the validation workshop
Jeevan Kumar Jethani	M	Ministry of New and Renewable Energy (MNRE)	Director	No
Pramod Agarwal	M	CCAFS	Head of CCAFS in India	Yes
Mohinder Gulati	M	World Bank	Former Adviser on Energy, Europe and Central Asia Region	Yes
Alok Sikka	M	IWMI	IWMI India Representative	Yes
Aditi Mukherji	F	IWMI	Principal Researcher	No
Akhilesh Magal	M	Gujarat Energy Research and Management Institute (GERMI)	Head, Renewable Energy, Environment and Energy Efficiency (RE4)	Yes
R J Vala	M	GUVNL	Solar Division	No
Apoorva Oza	M	Aga Khan Rural Support Program India	Chief Executive, Aga Khan Rural Support Program India	Yes
Sachin Oza	M	Development Support Center (DSC)	Director	Yes
Ganesh Neelam	M	Tata Trusts	Executive Director – Collectives for Integrated Livelihood Initiatives	Yes
Niranjan Karade	M	National Dairy Development Board (NDDB)	Manager	Yes
Tushaar Shah	M	ITP/IWMI	Former IWMI Principal Scientist	Yes
Shilp Verma	M	ITP/IWMI	Researcher, Water-Energy-Food Policies	Yes
Gyan Rai	M	ITP/IWMI	Consultant	Yes
Divya Sharma	M	Swiss Agency for Development and Corporation (SDC)	Project Officer for SDC support to SPaRC	Yes
Nilanjan Ghose	M	GIZ	Project Leader, Promotion of Solar Water Pumps	Yes
Karan Dangayach	M	Shashvat Cleantech	Managing Director	No
Neha Durga	M	IWMI	Previously worked for ITP	No
Petra Schmitter	F	WLE/IWMI	Leader of WLE Flagship 2	No

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