NATIONAL POLICY INTERFACE OF SDGS AND SUSTAINABLE AGRICULTURE

Goal 7. Ensure access to affordable, reliable, sustainable, and modern energy for all

Agriculture is a significant consumer of energy, with modern farming practices relying heavily on fossil fuels and chemical inputs. This leads to greenhouse gas emissions and environmental damage. Around 30% of the world's energy is consumed by agri-food systems (IRENA and FAO, 2021). From 2000 to 2018, global energy consumption in agri-food systems rose by over 20%, driven mainly by mechanization in Asia, such as irrigation pumps, farm machinery, processing equipment, and fertilizers. The production and distribution of food, along with post-harvest stages, contribute to this energy usage and emissions profile (FAO, 2011). Food systems and energy systems are interlinked and measures related to clean energy can reduce its environmental impact, while also improving efficiency and productivity (IRENA and FAO, 2021). There are also opportunities for clean energy in agricultural processes, such as decentralized energy applications (for example, in cold storage), solar-powered irrigation systems, energy-efficient agriculture implements, and the generation of bioenergy from agri-food residues.

National Policy and Stakeholder Mapping

Policies/Schemes	Stakeholders	Pre-production	Production	Post-production
The National Smart Grid Mission (NSGM)	• Ministry of Power • Central Electricity Regulatory Commission • Central Electricity Authority • Power Finance Corporation • Energy Efficiency Services Limited (EESL)	X	X	X
Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Waste	• Ministry of New and Renewable Energy	X		
GOBARdhan Scheme	• Ministry of Jal Shakti			X
Standards and Labelling	• Ministry of Power • Bureau of Energy Efficiency	X		
Perform, Achieve and Trade (PAT)	• Ministry of Power • Bureau of Energy Efficiency	X		

Sahaj Bijli Har Ghar Yojana (Urban) - Saubhagya (SBHGY)	• Ministry of Power • Rural Electrification Corporation Limited	X	X	X
Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)	• Ministry of Power • Rural Electrification Corporation Limited	X	X	X
Manufacturing of Pellets and Briquettes and Promotion of Biomass Cogeneration in Industries	• Ministry of New and Renewable Energy			X
Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM)	• Ministry of New and Renewable Energy • Solar Energy Corpo -ration of India Ltd (SECI)		X	
The Grid-Connected Solar Rooftop Programme	• Ministry of New and Renewable Energy • Solar Energy Corpo -ration of India Ltd (SECI)	X	X	X
National Wind-Solar Hybrid Policy	• Ministry of New and Renewable Energy	X	X	X
Development of Solar Parks and Ultra-mega Solar Power Projects	• Ministry of New and Renewable Energy • Solar Energy Corpo ration of India Ltd (SECI)	X	X	X
Small Hydropower	• Ministry of New and Renewable Energy	X	X	X
Programme on Energy from Urban, Industrial, Agricultural Wastes/Residues and Municipal Solid Waste	• Ministry of New and Renewable Energy			X
Biogas Power Generation (off-grid) and Thermal Energy Application Programme	• Ministry of New and Renewable Energy			X

Pradhanmantri Krishi Sinchayee Yojana (PMKSY)	• Ministry of Agriculture and Farmer's Welfare		X	
Demand Side Management (DSM) Scheme	• Ministry of Power • Bureau of Energy Efficiency • Indian Council on Agricultural Research (ICAR) • Energy Efficiency Services Limited (EESL)	X	X	X
Integrated Power Development Scheme (IPDS)	• Ministry of Power • Rural Electrification Corporation Limited • Power Finance Corporation	X	X	X
Sub-mission on Agricultural Mechanization (under National Mission on Agricultural Extension and Technology)	• Ministry of Agriculture and Farmer's Welfare			X

Synergies and Trade-offs

The energy and environmental aspects of the agriculture value chain have been extensively studied. Wu, et al. (2021) advocated using bioenergy over solar power to enhance food and energy self-sufficiency along with life cycle considerations. Addressing the heavy reliance on fossil fuels in the agricultural food supply chain (AFSC) is the key to climate mitigation (Gorjian, et al., 2022). Electricity feeds irrigation, mechanization, and storage in agriculture and is pivotal in boosting agricultural productivity, income, and food security (World Bank, 2008). Other applications of clean energy include cost-effective options such as solar dryers (Kawuma, 2022) and off-grid solar refrigeration (Kumari, 2022) to aid post-production activities. Organic farming has been highlighted for its energy savings, CO_2 reduction potential, and other benefits (Smith, Williams, and Pearce, 2015). Energy efficiency improvements are also linked to input use (Swanton, et al., 1996). Inputs in agriculture, such as pesticides and fertilizers, have a highly energy-intensive production process (Khan, Ali, and Ashfaq, 2018).

Targets	Synergy	Trade-off
Target 7.1: By 2030, ensure universal access to affordable, reliable, and modern energy services		
Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix		
Target 7.3: By 2030, double the global rate of improvement in energy efficiency		

Target 7.a: By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology		
Target 7.b: By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing states, and landlocked developing countries, in accordance with their respective programmes of support		

Literature has also examined trade-offs between hunger alleviation and energy production, particularly in biofuel-reliant countries (Mainali, et al., 2018). While small renewable energy plants have a minimal environmental impact, their limited energy generation and potential farmland diversion pose challenges (Choobchian, et al., 2018). The volatility of global energy prices influences land use for the choice of food crops (Steinbuks and Hertel, 2013). The issue of solar panel waste generation may also pose a challenge in the future (Wu, et al., 2021).

The profitability of photovoltaic systems is influenced by geographical factors and local considerations (Sacchelli, et al., 2016). Water-stressed regions adopting alternative resources like wastewater treatment and desalination experience increased energy demands, impacting water efficiency and emissions in agriculture (Rodríguez-Díaz, 2012). The distance in agriculture value chains influences the energy footprint in food distribution systems (Halberg, et al., 2005). The indiscriminate use of agriculture pumps can exacerbate groundwater depletion, especially in water-stressed regions. While solar pumps enable farmers to access groundwater for irrigation, their unchecked use can lead to over-extraction of water resources. This can result in declining water tables, reduced aquifer recharge, and, ultimately, the depletion of vital groundwater reserves (Garg, et al., 2017; Kumar, et al., 2007). The adoption of energy-efficient and renewable energy technologies, especially for smallholder farmers with limited resources, raises questions about the affordability and accessibility of these technologies.

Gaps and Barriers

Several obstacles hinder the adoption of renewable energy technologies in agriculture. One major obstacle is the lack of knowledge and awareness about these technologies, particularly among those who own agricultural lands (Kumar and Majid, 2020). People are hesitant to give up their cultivated lands for renewable power plants due to a lack of understanding about these technologies. Additionally, the dependence of renewable energy on varying climate conditions contributes to lower popularity among the general public (Kumar and Majid, 2020). To enhance renewable energy capacity in agriculture, it is crucial to address several key factors, such as increasing awareness, bolstering the capacity of financial institutions, providing supplier support, promoting gender equality, and offering training. Moreover, factors such as cost, social acceptance, policy support, and local conditions must be considered (Gorjian, et al., 2022). Another challenge is the inadequate baseline data on energy efficiency in agriculture. Addressing this lack of data is essential for driving investments in renewable energy systems, enabling better technological design and cost-benefit analysis, and creating awareness of the benefits, including increased incomes, job creation, productivity, food and energy security, and emission reductions (Garg, et al., 2017). Policy evaluation is vital, especially for emerging renewable energy technologies. Governments play a critical role in reducing investment risks

and facilitating progress through well-crafted policies in the financial sector (Gorjian, et al., 2022).

Furthermore, the low energy efficiency of agricultural pump sets in India, partly due to electricity subsidies provided to farmers, highlights the need for technical enhancements, cost reductions, and government incentives to implement sustainable renewable solutions in agriculture and food production (Bhattacharya and Cropper, 2003). It is crucial to manage residues for renewable energy generation, compost preparation, and livestock feed. Collaborative efforts among ICAR institutes and organizations, such as the National Institute of Bio-Energy (NIBE), are needed to formulate policy guidelines for proper management (Gorjian, et al., 2022).

Cost reductions in sensors, control units, and photovoltaic (PV) modules are essential for adopting solar-powered robots and tractors in farming. These machines can significantly contribute to the renewable energy transition in agriculture (Kumari, 2022). Lastly, transitioning to renewables in agriculture requires a restructuring of mechanization processes to replace fossil fuel-based vehicles with electric ones. There are opportunities to set up decentralized cold storage facilities in rural areas powered by solar PV or other forms of decentralized renewable energy. This can reduce operating costs compared to using fossil energy sources (Gorjian, et al., 2022).

Emerging Policy Solutions

***Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM-KUSUM) can be strengthened by incorporating the RESCO (Renewable Energy Service Company) model in all its components:**

- **Social factors in agriculture technology adoption:** Addressing land sharing and diversion issues is crucial. Building trust with small farmers, identifying local champions, and involving decentralized organizations such as SELCO can facilitate community involvement and adoption of innovative agro-technologies.
- **Challenges of agro-voltaic systems:** Small farmers face challenges with agro-voltaic systems due to land pressure and crop diversification issues. Trade-offs between renewable energy and agriculture also need to be considered.
- **Innovative approaches to machinery:** Innovative methods such as installing solar PV plants on canals and utilizing floatovoltaics can save the land and enhance income. Selling surplus water from solar pumps to maintain solar panels can provide additional revenue sources. Additionally, solar pumps can also be equipped with variable speed control mechanisms, allowing farmers to adjust the pump's output to match the actual water requirements of their crops.
- **Challenges in implementing government schemes:** Schemes such as PM-KUSUM hold promise, but face issues related to trust, long-term contracts, capital constraints, and procedural hurdles. Ensuring accessibility through vernacular information, training, and awareness campaigns is essential.
- **The whole value chain approach:** Currently, PM-KUSUM is skewed towards the production stage; there is immense potential to include a pre-production focus by including industries powered by renewables and a post-production focus by including solar dryers and food processing systems.

Agriculture demand-side management (AgDSM) needs to go beyond solar pumps and offer integrated energy solutions across agricultural implements through ESCO models:

- The integration of energy-efficient solutions across agriculture implements such as tractors and harvesters through the ESCO model can promote energy efficiency.

National Smart Grid Mission's Integration with RESCO Model

- **National Smart Grid Mission (NSGM):** NSGM presents both challenges and opportunities in addressing grid failures and grid management. Behavioural economics, AI, and machine learning can improve data collection through a user-friendly interface and analysis. Integrating NSGM with the RESCO model can improve technology utilization. Persistent grid failures and issues such as grid choking require effective solutions, including grid management through systems like SCADA.
- **Maintenance with subscription models:** Implementing subscription models for maintenance can help ensure the longevity and sustainability of mechanized systems. In addition, solar-powered cooling systems can leverage post-production activities and other valuable techniques such as solar-powered devices emitting ultrasonic or sonic vibrations to repel pests from agricultural fields and further reduce the reliance on pesticide industries at the production stage.

Cross-Cutting

- **Tailored technology for small farmers:** Small farmers require technology suited to their scale, as larger landowners often have access to advanced machinery. Overcoming barriers like land diversity and geography is crucial for successful adoption.
- **Support and continuous handholding:** Providing ongoing support and continuous guidance throughout the adoption process is essential to help small farmers make the most of agricultural technology.
- **Engaging civil society and grassroots organizations:** Involving civil society and grassroots organizations is vital to bridging the community engagement gap and gaining a deep understanding of local dynamics. These intermediaries can connect with farmers on the ground and facilitate technology adoption.
- **Local champions for innovation:** Identifying and empowering local champions can accelerate the adoption of innovative solutions among farmers. These champions can provide continuous demonstrations and share success stories, shedding light on the current realities and power dynamics within their respective areas.

Strengthen Reporting on Metrics for Policy Design and Implementation

Some proposed metrics that could be monitored include:

- Frequency and duration of electricity outages in rural agricultural areas
- Performance indicators of PM-KUSUM for all three components
- Percentage of renewable energy use in agriculture (off-grid and on-grid)
- Percentage of renewable energy in cold storage
- Energy productivity in agriculture
- Energy efficiency policies extending to agriculture implements such as tractors and harvesters