# Energy Evolution of India's Agrarian Economy

Vaibhav Chowdhary[1] and Vikash Ranjan[2]

*Journal of Resources, Energy, and Development* **21** (1&2): 31–40



## Abstract

India is an agrarian economy with about 116 million farm holdings having an average size of 1.4 ha, accounting for about 17-18% of GDP and employing about 40% of the country's workforce. The energy demand in agriculture sector shall increase to 70 million tonnes of oil equivalent (Mtoe) in 2047 from 33 Mtoe in 2022@CAGR of 3.01%, primarily having demand in tractors and pumps. There could be some penetration of e-tractors starting from 2027, which will continue to grow and reach 12% of total tractors by 2047 in the agriculture sector. The share of electricity consumption in agriculture sector will decrease from 15% to 12% by 2047 due to increase of shares of solar-based pumping.

The future of India's agricultural growth will depend on two types of crops — 1) energy crops and 2) food crops. The sector needs to be self-sustainable with respect to energy use. National Biofuel Policy was enacted in 2018 to promote the production and consumption of biofuels. PM KUSUM programme by MNRE aims to add solar capacity of 30.8 GW till 2026.

Agriculture accounts for 5% of overall energy demand and about 85% of India's water demand. Water use efficiency on farms in India is among the lowest in the world. India needs a clear policy direction to switch from flood irrigation practices to targeted irrigation techniques. Market plays a significant role in the growth of Indian agriculture sector. By aligning market forces with sustainable practices, the agriculture sector is likely to achieve energy independence much faster. Low Carbon Farming (LCF) has the potential to provide multiple benefits to the farm sector. There is a rising need to have a single commission onagriculture demand management that could ensure sustainable and low carbon growth of the sector.

**Keywords**: Energy demand, Electricity consumption, Self-sustainable, Agriculture growth, Low carbon growth

[1] Prof. of Practice, IIT Kanpur, Director, Ashoka Centre for a People-centric Energy Transition (ACPET)
[2] CEO, Pledge4Earth, Collaborator, ACPET

## Key Trends and Projections

India is an agrarian economy with about 116 million farm holdings having an average size of 1.4 ha, accounting for about 17–18% of GDP and employing about 40% of the country's workforce (FAO, 2002; IFAD, n.d.). The cultivated area is about 141 million ha and has remained constant for the past 30 years although the cropping intensity has increased from 118–135% during this period (FAO, 2002).

Compared to other demand sectors, agriculture's contribution to GDP and to employment generation is decreasing. The sector is growing at 3.5% against a targeted growth of 4% with heavy dependence on traditional agro methods as a result the energy demand increased only marginally (IBEF, n.d.).

For higher productivity and profitability, the transition to modern Ag techniques is essential. Such modern technologies require energy at all stages, such as for "direct use" in farm machinery, water management, irrigation, cultivation and harvesting. And, for "indirect use" in the form of mineral fertilizers and chemical pesticides, insecticides, and herbicides, etc. This chapter focus only on the "Direct use" of energy in agriculture sector. The "indirect usages" will be captured in other sections like industry demand, etc.

Electricity is a critical source of energy for the agriculture sector in India constituting 16% of the overall electricity demand. Mostly used for irrigation, powering pumps, lighting, and running agro-processing units, etc. Fossil fuels, especially diesel and petrol, constitutes around 8% of overall fossil fuel demand. It is widely used in areas like powering tractors, transport, and agro-processing. However, the rising costs of fossil fuels, along with its environmental impact, have raised questions around its sustainability in the long run.

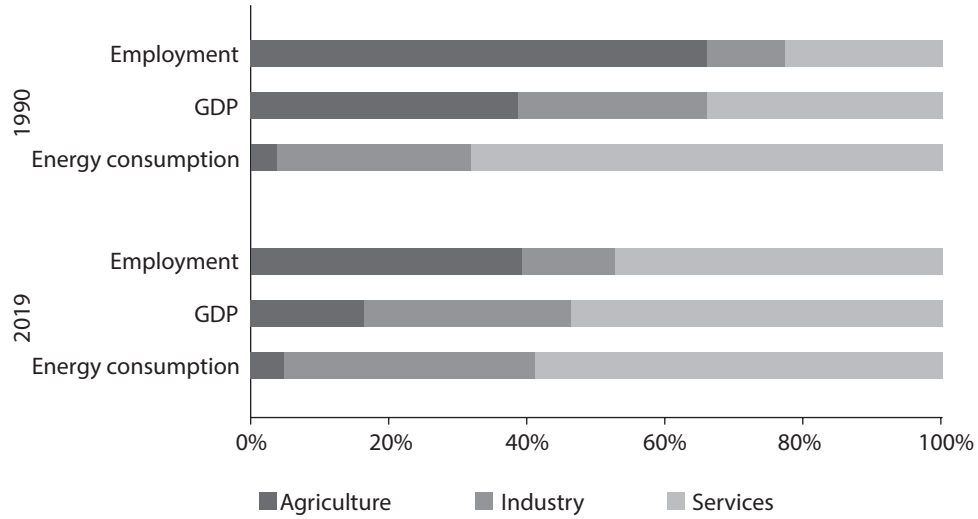


**Figure 1** GDP, employment and energy consumption 1990 vs 2019

**Table 1:** The future energy demand for agriculture sector

| Item | Energy Demand | 2020 | 2022 | 2027 | 2030 | 2032 | 2037 | 2042 | 2047 |
|---|---|---|---|---|---|---|---|---|---|
| Diesel Demand for Ag (Mtoe) | Tractors | 8.1 | 8.9 | 11.2 | 12.8 | 14.0 | 17.5 | 16.7 | 15.8 |
| | Pumping | 7.15 | 7.35 | 7.82 | 8.08 | 8.24 | 8.56 | 8.75 | 8.75 |
| Electricity Demand for Ag (Mtoe) | EV Tractors & Pumping | 15.75 | 16.77 | 19.61 | 21.56 | 22.95 | 26.89 | 31.50 | 36.92 |
| Renewable electricity penetration in Ag | Pumping | 0.13 | 0.40 | 1.21 | 1.82 | 2.29 | 3.70 | 5.53 | 7.88 |

(Source: NITI Aayog IESS Version 3.0)

The energy demand in the agriculture sector[3] shall increase to 70 Mtoe in 2047 from 33 Mtoe in 2022@CAGR of 3.01%, primarily having demand in tractors and pumps due to increase in the number of diesel tractors from 70,00,000 to 1,65,00,000 by 2047 and pumps from 3,13,00,000 to 5,70,00,000 by 2047. There could be some penetration of electric tractors starting from 2027, which will continue to grow and reach 12% of total tractors by 2047 in the sector.

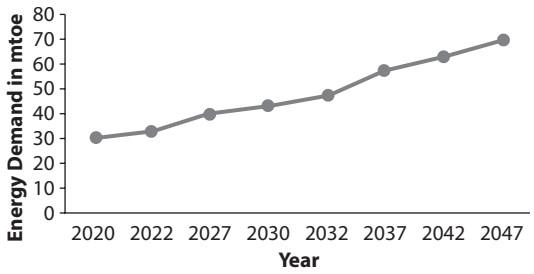


**Figure 2** Energy demand from pumps and tractors in agriculture sector

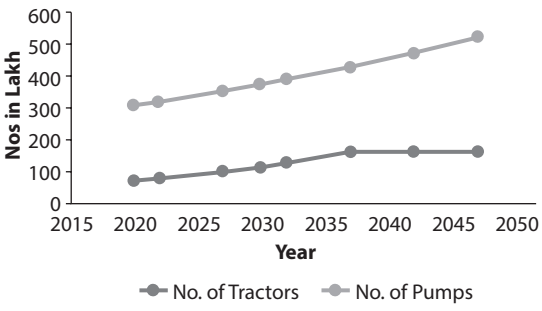


**Figure 3** Number of tractors and pumps in agriculture sector
(Source: NITI Aayog IESS Version 3.0)

Similarly, the share of electricity consumption[4] in Agriculture sector will decrease from 15% to 12% by 2047 due to increase in the share of solar-based pumping.

The carbon emissions will start decreasing from 2037 onwards due to high penetration of solar pumping and low carbon farming besides other sustainability activities. However, the energy produced from agricultural crop has not been reflected in the scenario, perhaps achieve net zero if properly planned.

## Agriculture — a Prosumer

India's agricultural growth must be farmer centric, driven by technology, equity, affordability, economics, and sustainability. The future of India's agricultural growth will depend on two types of crops 1) Energy crops and 2) Food crops. The sector needs to be self-sustainable w.r.t. energy use. Which is possible when energy and food crops share equal share in cultivation.

### Crop residue generation and potential

The current availability of biomass in India is estimated at about 750 million metric tonnes per year (MNRE). The study indicated estimated

[3] Niti Ayog, IESS
[44] Niti Ayog, IESS

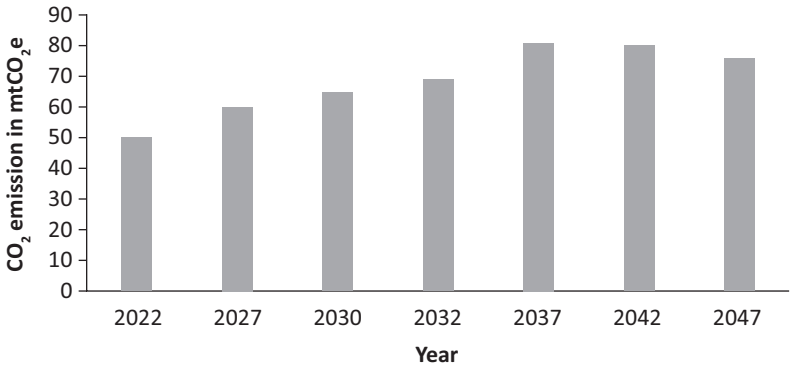


**Figure 4** Carbon emissions in agriculture sector (tractor and pumping energy consumption)
(Source: NITI Aayog IESS Version 3.0)

surplus biomass availability at about 230 million metric tonnes per annum covering agricultural residues corresponding to a potential of about 28 GW. This apart, about 14 GW additional power could be generated through bagasse-based cogeneration in the country's 550 sugar mills, if these sugar mills were to adopt technically and economically optimal levels of cogeneration for extracting power from the bagasse produced by them. As on October 31, 2022, a total capacity of 10.20 GW has been installed in biomass power and cogeneration sector.

### Biofuel potential

National Biofuel Policy was enacted in 2018 to promote the production and consumption of biofuels (PIB, 2022). Ethanol-blending percentage in petrol rose sharply from 0.67% in 2013 to 10% in May, 2022. The policy has translated into a reduction of 2.7 million tonnes of $CO_2$ emissions. India's ethanol demand is poised to grow to 10.16 billion litres (5.67 Mtoe) by 2025. India is set to launch a Global Alliance on Biofuels, along with USA and Brazil.

Global biofuel consumption can increase in a sustainable way from 55 Mtoe today to 750 Mtoe in 2050 (IEA, 2011). This would mean that the global share of biofuel in total transport fuel would grow from 2% today to 27% in 2050.As per new National Biofuel Policy, India is poised to increase ethanol-blending percentage in petrol by 20% by 2025-26.

### Solar power potential

PM KUSUM programme by MNRE aims to add solar capacity of 30.8 GW till 2026 (MNRE). It includes:

Component A: 10 GW of solar capacity through installation of small solar power plants of individual plants of capacity upto 2 MW

Component B: Installation of 20 lakh standalone solar powered agriculture pumps

Component C: Solarization of 15 lakh grid-connected agriculture pumps

## Water Energy Nexus

Agriculture accounts for 5% of overall energy demand and about 85% of India's water demand (Statista, 2023). Both water and energy intensive crops like rice, sugar, maize and cotton are most prevalent, and their export means that India is effectively the world's biggest water exporter. Water use efficiency on farms in India is among the lowest in the world: three to five times more water is used on Indian farms than on farms in China or the United States to produce the same

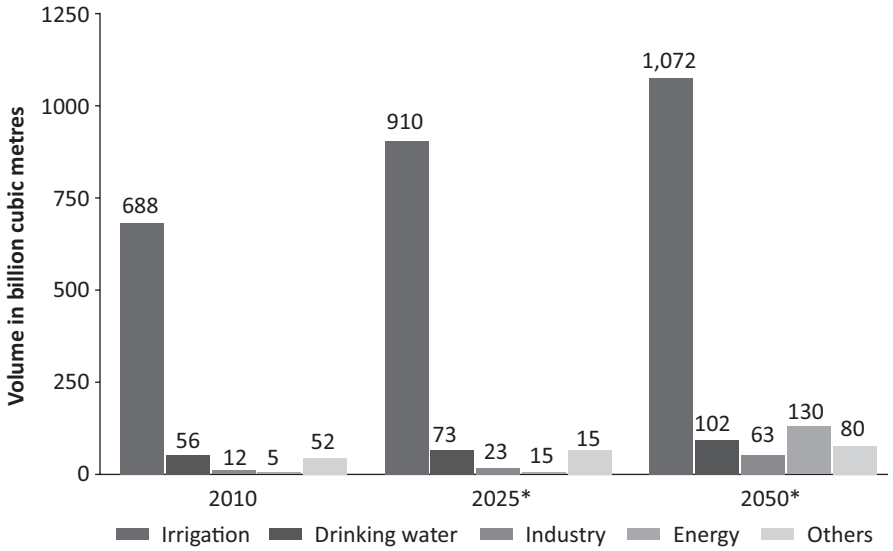


**Figure 5** Volume (in billion cubic metres) of water consumed in various agricultural activities

amount of crops, having a direct bearing on energy (NITI Aayog, 2018). Free (or low cost) electricity and poor governance contributed to the rapid decline of India's groundwater resources.

## Recommendations

1. Schemes like "Direct Benefit Transfer of Electricity (DBTE)" for agricultural consumers shall be scaled up with the objective of saving both the groundwater and electricity together.
2. Thegovernment shall also review the aggressive agricultural pump rollout schemes like PM KUSUM from water saving perspective.
3. Stategovernments to promote innovative cooperative mechanism like community owned and managed irrigation pumps with low upfront cost consisting of 5–10 low-income farmers as piloted by Professional Assistance for Development Action (PRADAN) in the Bastar district of Chhattisgarh. Such approaches can also leverage existing networks of self-help groups (SHGs) created under the National Rural Livelihood Mission.
4. India needs a clear policy direction to switch from flood irrigation practices to targeted irrigation techniques (micro irrigation), together with water management practices such as water harvesting, storage, and recycling. These efforts could save up to 47% of irrigation water and savings of 250 TWh electricity by 2030 on cumulative basis.
5. State nodal agencies (SNAs) need to work with financial institutions to try innovative models such as the farmer-developer special-purpose vehicle (SPV) piloted in Karnataka to overcome financing challenges with farmer-owned power plants. RESCOs can be a big support in this mode. Awareness on RESCO and ESCO projects needs to be disseminated by these SNAs.
6. Innovative cooperative mechanism for implementation of PM KUSUM can be thought of through successful models like - Surya Raitha Scheme –Karnataka through creation of farmer's cooperatives, channel

subsidies, soft-loans to the farmers. Power purchase agreements (PPAs) for a span of 25 years and ensure proper power supply to the pump sets.

## Promoting Low-Carbon Agro Products

Market plays a significant role in the growth of Indian agriculture sector. By aligning market forces with sustainable practices, the agriculture sector is likely to achieve energy independence much faster.

### Recommendations

1. Promote low carbon products market through certification, proper branding, together with behavioural nudging campaigns. Higher demand for low-carbon organic and sustainably produced food can incentivize farmers to adopt practices that reduce emissions and local pollution.
2. Certification schemes can enable farmers to access premium market rates for their products and gain a competitive advantage, which can encourage the adoption of sustainable practices. Awareness to the consumer and its health benefits are the key factors to promote carbon free or low carbon product.

## Low-Carbon Farming

India has signed a sustainable agriculture action agenda at COP26 summit. The aim is to make farming sustainable and environment friendly. Low-carbon farming (LCF) has the potential to provide multiple benefits to the farm sector like improved soil health and fertility, increased water retention, enhanced biodiversity, increase in jobs, and sustainable agricultural production, etc.

### Recommendations

1. For the overall framework of carbon farming to be successful, it would have to include sound policies, public-private partnerships, accurate quantification methodologies and supportive financing to efficiently implement the idea. It requires to be done at a scale where measurable carbon capture can be achieved along with maintaining healthy soils that absorb and store carbon.
2. Recently announced market mechanisms such as "green credits" can create financial incentives for farmers to adopt climate-friendly practices, such as agroforestry, crop rotation, organic farming, which can sequester carbon from the atmosphere and promote energy efficient farming machineries to reduce GHG emissions.

## Support to R&D and Agritech

Energy efficient technologies in agriculture tend to require substantial upfront investments to support the transformational changes necessary to heighten farmers' productivity and their capacity to adapt to climate change while reducing the emission intensity of what they produce.

### Recommendations

1. The budgetary support to R&D and agritech sector needs to be continued and should be increased in the later years as this will not only help in optimizing agri resources but also provide required boost to the climate change issue.
2. The subsidy needs to be implemented in such a way that it covers upfront investment for longer period with more flexible conditions (repayment schedules adjusted to cash flows) so that farmers can make the necessary investments to maintain or increase current yields, produce more food on less land, and adopt climate smart practices and technologies to increase their resilience while also reducing emissions.

## Role of Regulators

There have been multiple regulators influencing the growth of agriculture sector, having different backgrounds, skills and expertise. Ministry of Agriculture and Farmers' Welfare promotes the increase of Ag productivity, MNRE regulates the renewable penetration into agriculture; BEE pushes for energy efficiency by setting standards and ratings; MOEFCC/PCB regulates the environmental impact from agricultural practices, etc.

### Recommendations

1. There is a rising need to have a single commission on agriculture demand management that could ensure sustainable and low carbon growth of the sector. This authority shall develop -
    a. Conducive low carbon growth strategy for agri sector suiting farmers need.
    b. Initiate a redressal mechanism to address complaints, concerns, and feedback from stakeholders regarding the implementation of the policy.
    c. Robust monitoring and evaluation mechanisms to assess the progress and impact of policies in the agriculture sector like – PM KUSUM, Pradhan Mantri Krishi Sinchai Yojana (PMKSY), etc. This includes regular data collection, analysis, and reporting on key performance indicators (KPIs) and outcomes related to climate change mitigation, adaptation, and sustainable agricultural practices.
    d. Co-design new interventions for agri sector reform and co-ordinate with other energy and environment departments and ministries. E.g. – carbon market for agriculture could be initiated by this regulator.
    e. Conduct pilot on smart farming techniques, using IoT based devices for smarter demand/load management, for better managing time-of-day issues, and thereby encouraging farmers to use grid electricity only during non-peak hours.

## Role of Financing

Majority of Indian farmers are poor, own less than 1 hectare of land, and are vulnerable to climate change. It re-emphasizes the need for climate-resilient agricultural practices, risk management strategies, access to credit and insurance, market diversification, and supportive policies to mitigate the financial impacts on such marginalized communities.

So far, the climate bonds announced by the government have looked at mitigation solutions mostly in the urban setting, transport and built environment. More innovative financing options like green bond, blended financing, risk guarantee and weather insurance products will enhance the resilience of the agriculture sector.

### Recommendations

1. Clean agriculture finance - mainly from national, bilateral, and multilateral sources, and DFIs - shall be catalysed, for which an enabling environment must be created. "Dedicated line of credit for clean agriculture" shall be introduced to promote workable solutions.
2. Innovative ESCO models and/or Farmers-Private Partnership (FPP) models shall be developed for large scale procurement and implementation of energy efficient farming technologies, as was achieved under UJALA LED program. EESL's capacity shall be enhanced for developing and piloting such business models. Awareness on RESCO and ESCO projects needs to be disseminated by state nodal agencies (SNAs).

## Transparency

India shall practice an open, transparent, evidence based and engaging policy making process for the agriculture sector. This will minimise the implementation challenges.

### Recommendations

1. **National data bank** on agriculture sector, wherein data on sustainable agriculture and climate change could be made available for R&D by the regulatory authority.
2. **Knowledge exchange platform (KEP)** could be established for transparent sharing of proven and established information to the farmers on this subject. Linked to mission LiFE for nudging farmers' behaviour towards sustainability.
3. **International Centre of Excellence (ICoE)** required for awareness, knowledge dissemination, training and capacity building of farmers in India through internationally acclaimed institutions.

## Role of Government

There exist pertinent programmes like National Mission for Sustainable Agriculture (NMSA), PM KUSUM; Pradhan Mantri Krishi Sinchai Yojana (PMKSY); agricultural mechanization programme, etc., that together with state policies supplement for energy use and its conservation.

### Recommendations

1. A mechanism should be designed to conduct third party impact evaluation of such critical missions and programmes to address the loose ends (if any), share learning and scale workable solutions. There is a huge demand from global south to learn from India.
2. As agriculture being a state subject, the state government is primarily responsible for the growth and development of the sector. The state shall therefore create an energy transition task force in the sector consisting of ministries, NGOs, technocrats, think tanks and private sector with a task of reducing emissions, and renewable energy sources such as solar, wind, and bioenergy can help in reducing the agriculture sector's reliance on fossil fuels, the job of the task force would be –
   - » Transition to electric power and robotics in agriculture involves internal combustion engine (ICE) driven vehicles to battery or solar energy driven farm vehicles.
   - » Energy smart agriculture (ESA), for reducing emissions includes crop-diversification, improving water productivity, and manure management.
   - » Digital agriculture technologies to be used to promote crop assessment, digitization of land records, spraying of insecticides, and nutrients.
   - » Development of bio-brick industry for manufacturing bio-bricks from agro waste or byproducts (straw bales, bamboo, bagasse residue, corn cobes waste, coir fiber, hempcrete) as an alternative and sustainable building material that acts as an alternative to stubble burning.
   - » Development of measurement tools for farming to achieve sustainability goals.
3. The Skill Development Department of each state shall empanel the training of trainers (ToTs) as *Kisan Mitra* to provide required capacity building and awareness to the local farmers.

## Role of Technologies in Agri Demand Management

1. In recent years, many Indian farmers have started to consult data about important agri variable factors like soil, crops, livestock, and weather. Yet, few of them have had access to advanced digital tools that would help

to turn these data into valuable, actionable insights. In less-developed regions, almost all farmwork is manual, involving little or no advanced connectivity or equipment.

2. With the advent of smart connectivity to the remotest places of the country, the advanced connectivity has the potential to radically transform the aspects of farming.

### Smart crop monitoring

Aimed at optimizing resource usage and crop growth through real time, precise location dependent adjustments.

### Drone farming

Drone surveillance and remote interventions based on image analysis and connected sensors. Kisan drones are being used for crop assessments, digitization of land records, and spraying of pesticides and nutrients. The Union Budget 2023 provides a boost to smart agriculture through Kisan drones, digital agriculture are all potential sustainable alternatives to traditional energy-intensive practices.

### Energy smart agriculture (ESA)

For reducing emissions include crop-diversification, improving water productivity, and manure management. ESA practices such as laser land levelling, zero tillage, direct-seeded rice, site-specific nutrient management, and precision irrigation management are reducing energy inputs in various farm operations.

### Digital agriculture technologies

Being used to promote crop assessment, digitization of land records, spraying of insecticides, and nutrients.

3. Development of measurement tools for farming to achieve sustainability goals.

4. Transition to electric power and robotics in agriculture involves ICE driven vehicles to battery or solar energy electric driven farm vehicles.

5. Agriculture robots for performing complex tasks, solar-powered or electric driven precision agriculture practices, mobile agricultural robot swarms (MARS), and solar or battery-powered weeding robots (SPWR).

### Autonomous farming machinery

6. Self operated machinery and robots able to perform targeted interventions based on sensor data, GPS data, imaginary analysis, aimed at optimizing resource usage, reducing labour requirement, and boosting yield through more precise and individualized attention.

### End-to-end platform for crop advisory

7. An end-to-end platform for crop-advisory is a platform that provides farmers with personalized crop advisory services using digital crop monitoring platforms. The platform is designed to provide farmers with site-specific crop advisory services that are tailored to their specific needs. *(The Indian government has proposed to create an AgriStack - a unified platform to provide end-to-end services across the agriculture food value chain to farmers. Microsoft has also signed an MoU with the Indian government to create a Unified Farmer Service Interface through its cloud computing services).*

In addition, there are several private companies that are building end-to-end platforms for farmers. For example, AgroStar is building the largest and most impactful agri-solutions platform to provide end-to-end solutions for Indian farmers. Similarly, Famrut is an innovative ecosystem that delivers future-ready farming solutions and connects farmers with all relevant stakeholders of the entire agricultural sector.

8. E-Tractors: Electric tractors are becoming increasingly popular in India due to their low operating costs and environmental benefits. There are several electric tractors available in India. *(For example, Sonalika has launched the first field-ready electric tractor in India called the Tiger Electric. The Tiger Electric has a 25.5 kW battery that can deliver a maximum power of 34 hp and a lifting capacity of 1,500 kg Another option is the HAV 45 S1 electric tractor which has a 44 hp engine and a 40 hp PTO power. the Autonxt X45H2 is another great option for an electric tractor in India. It has a 32 kW battery that can deliver a maximum power of 45 hp and a lifting capacity of 1800 kg)*

## References

Food and Agriculture Organization of the United Nations. (2002). *High-level conference on world food security: The challenges of globalization and climate change* [PDF]. Food and Agriculture Organization of the United Nations. https://coin.fao.org/coin-static/cms/media/9/13170962616430/2002_03_high.pdf

International Fund for Agricultural Development. (n.d.). *India*. International Fund for Agricultural Development. https://www.ifad.org/en/web/operations/w/country/india#:~:text=Agriculture%20employs%2042%20per%20cent,still%20live%20in%20rural%20areas

India Brand Equity Foundation. (n.d.). *Agriculture and food industry in India*. India Brand Equity Foundation. https://www.ibef.org/exports/agriculture-and-food-industry-india#:~:text=In%202022%2D23%2C%20India's%20agriculture,is%20expected%20to%20be%205.5%25

Food and Agriculture Organization of the United Nations. (n.d.). *Crops and cropping systems*. Food and Agriculture Organization of the United Nations. https://www.fao.org/4/a0257e/a0257e02.htm#:~:text=The%20net%20cultivated%20area%20has,is%20about%20190%20million%20ha

Ministry of New and Renewable Energy. (n.d.). *Home*. Ministry of New and Renewable Energy. https://mnre.gov.in/

NITI Aayog, IESS

Puri, H. S. (2022, October 19). *There is a need to massively upscale production of flex-fuel engine vehicles in country*. Ministry of Petroleum & Natural Gas, Government of India. Press Information Bureau. https://pib.gov.in/PressReleasePage.aspx?PRID=1869250

International Energy Agency. (2011, April 20). *Biofuels can provide up to 27% of world transportation fuel by 2050, IEA report says: IEA roadmap shows how biofuel production can be expanded in a sustainable way and identifies needed technologies and policy actions*. International Energy Agency. https://www.iea.org/news/biofuels-can-provide-up-to-27-of-world-transportation-fuel-by-2050-iea-report-says-iea-roadmap-shows-how-biofuel-production-can-be-expanded-in-a-sustainable-way-and-identifies-needed-technologies-and-policy-actions

Ministry of New and Renewable Energy. (n.d.). *PM-KUSUM*. Ministry of New and Renewable Energy. https://mnre.gov.in/pm-kusum

Statista. (2023, February 06). *India - Water demand by sector 2010-2050*. Statista. https://www.statista.com/statistics/1111839/india-water-demand-by-sector/