Energy Use in Agriculture:

Potential for Solar Irrigation & Reduction of Agricultural Emissions in India

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Introduction

- Agriculture requires energy inputs at all stages of agricultural production:
  - Direct use of energy (farm machinery, irrigation, cultivation and other crop operations).
  - Indirect or embedded energy consumption in the form of fertilizers and chemical pesticides, land transport, trade, financial services etc.

- Increase in mechanization of agriculture and increased use of fertilizers and pesticides
  - Imperative to assess inter-linkages between energy use and changes in consumption of inputs especially for an agrarian economy

- Increasing focus on green growth and sustainability of energy transitions
  - Emphasis on substitution of conventional sources to renewable sources of energy (primarily solar energy) in the agricultural sector

Energy Use in Agriculture – Key Indicators

Country	Per capita energy consumption in 2019 (in MWh/ person)	Per capita emissions from agriculture (in ktCO2/ person)	Consumption of fuel in agricultural sector per '000 hectare of cultivated area (in TJ/'000 ha)	Share of sectoral emissions by total annual emissions within country in 2017 (in percent)		
				Agriculture and related land use	Industrial processes and product use	Energy
India	7	0.05	4	0.2	0.5	68
China	27	0.03	8	0.01	10	73
US	80	5	3	1.5	3	78
UK	32	0.62	5	0.5	4	77

Source: Our World in Data, FAOSTAT (2020)

Research Objective & Methodology

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1. Estimation of direct and indirect energy consumption for the agricultural sector as well as for different crops
2. Estimation of direct and indirect emissions from the agricultural sector
3. Evaluation of potential for reduction in agricultural emissions

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Methodology:

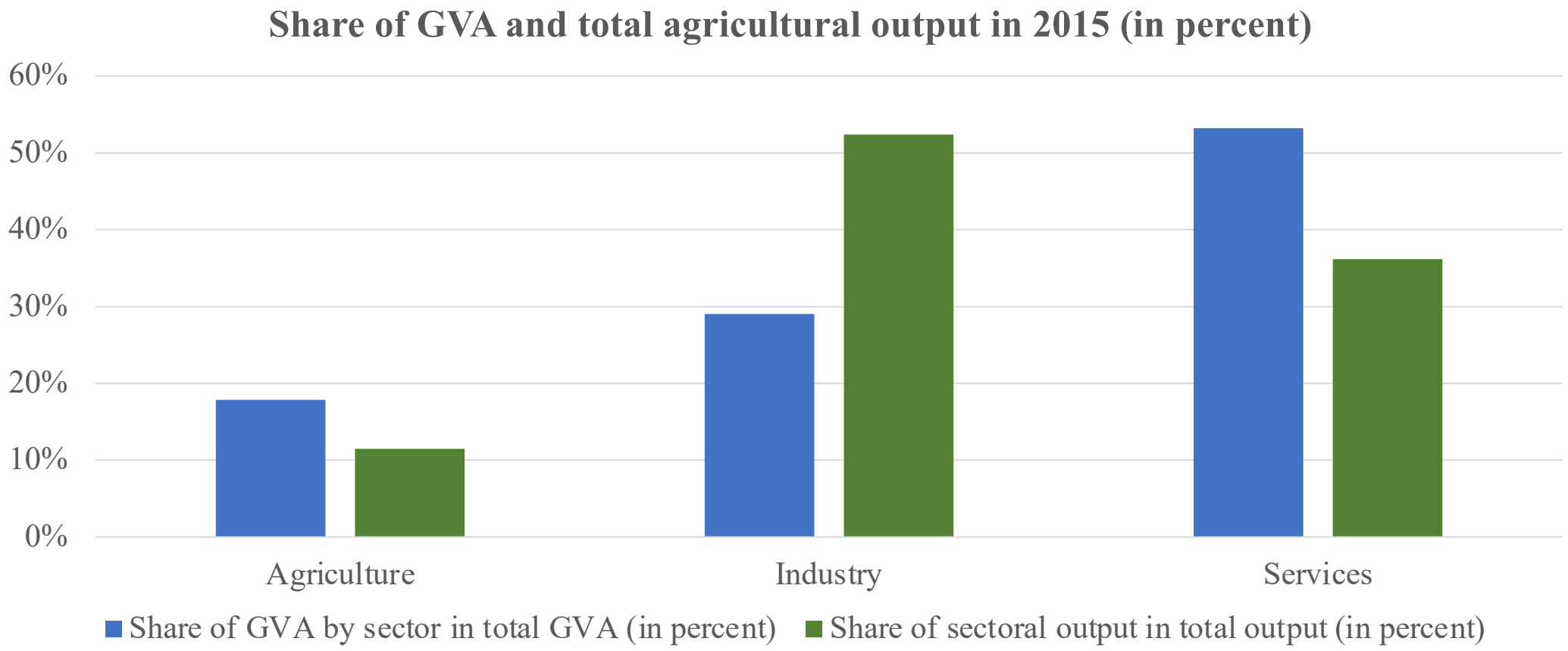
Using the Input-Output table (2015) to assess changes in the relationship between crops, their inputs and direct and indirect energy in each input

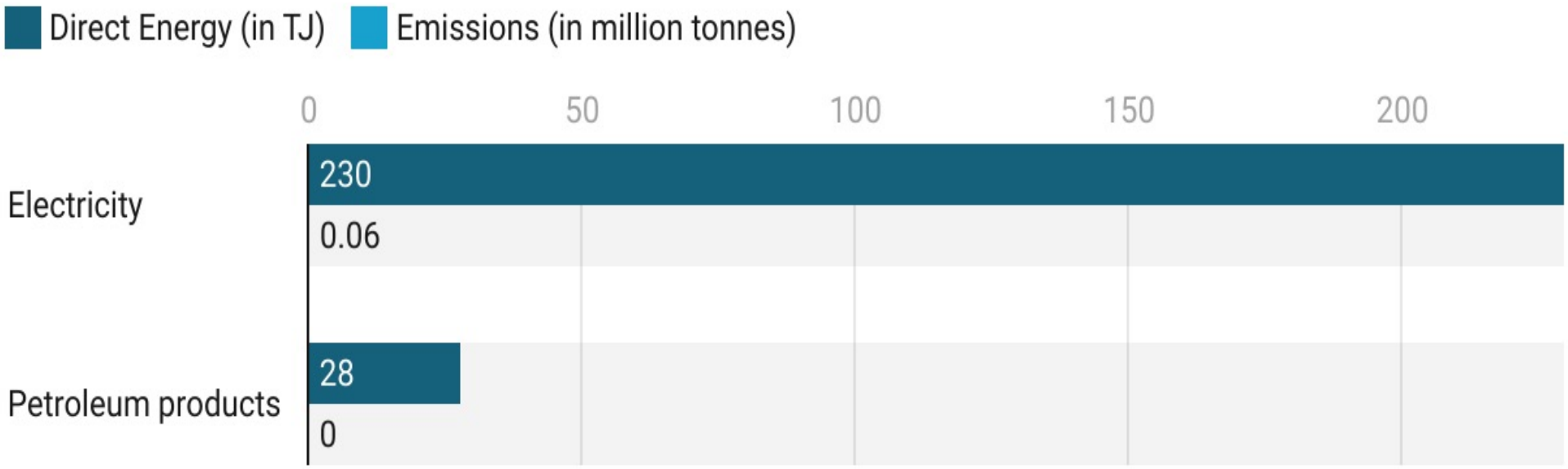
- From the total value of inputs to agriculture, percentage contribution of each input was calculated.
- Direct energy use was assessed by estimating primary and secondary energy sources going into agriculture directly as inputs. Conversion factors were used to convert value of input (in Rs.) to energy terms
- Indirect Energy Use: Coefficients were calculated for share of energy used by indirect inputs into agriculture. e.g. Share of fertilizer used per unit of agricultural output was multiplied with the energy used per unit of fertilizer output produced to estimate indirect energy

Energy Use & Emissions in Indian Agriculture

1. Estimation of Direct & indirect energy use and resulting emissions
2. Comparison of energy use and emissions for different crops

Gross Value Added by Agriculture





Direct Energy Use & Emissions in Agriculture

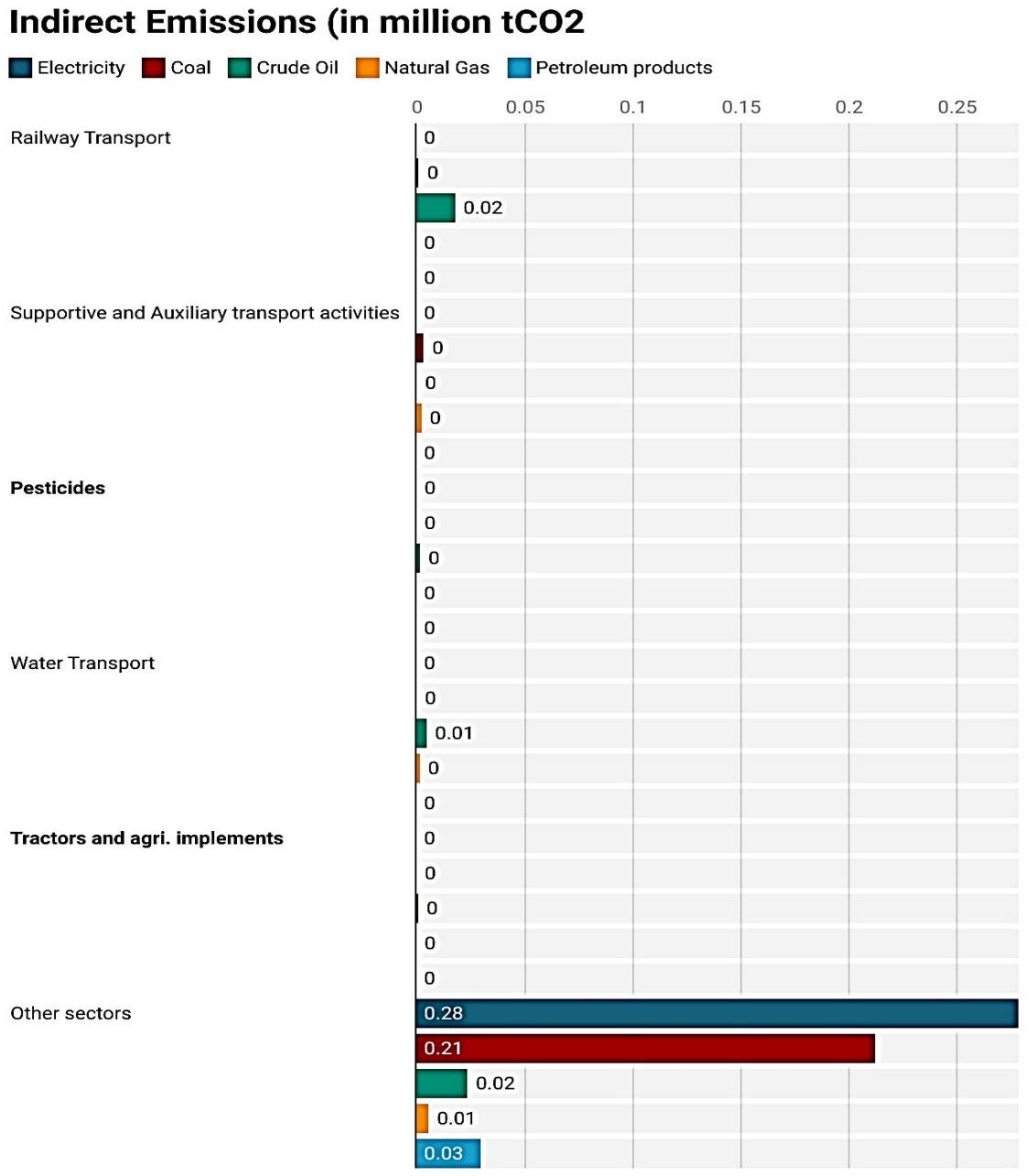
- Direct energy utilization in agriculture (2015) was 258 TJ which formed only 3% of the total energy (direct and indirect energy) used in the agricultural sector.

Indirect Energy Use across sectors

Sector	Source of energy	Indirect Energy (in TJ)
Trade	Electricity	290
	Coal	959
	Crude Oil	11
	Natural Gas	7
	Petroleum products	183
Agriculture	Electricity	109
	Coal	0
	Crude Oil	0
	Natural Gas	0
	Petroleum products	28
Land transport	Electricity	60
	Coal	0
	Crude Oil	0
	Natural Gas	0
	Petroleum products	472
Financial services	Electricity	268
	Coal	0
	Crude Oil	0
	Natural Gas	0
	Petroleum products	21
Fertilizers	Electricity	0
	Coal	11
	Crude Oil	7
	Natural Gas	6
	Petroleum products	1

Sector	Source of energy	Indirect Energy (in TJ)
Construction and construction services	Electricity	233
	Coal	14
	Crude Oil	0
	Natural Gas	0
	Petroleum products	62
Railway Transport	Electricity	49
	Coal	221
	Crude Oil	0
	Natural Gas	0
	Petroleum products	19
Pesticides	Electricity	2
	Coal	28
	Crude Oil	0
	Natural Gas	2
	Petroleum products	1
Tractors and agri. implements	Electricity	18
	Coal	18
	Crude Oil	0
	Natural Gas	0
	Petroleum products	2
Other sectors	Electricity	1012
	Coal	2226
	Crude Oil	332
	Natural Gas	161
	Petroleum products	415

Emissions due to Indirect consumption



Possible Reduction in Emissions

- Emissions can be reduced theoretically only in the following inputs to agriculture:
  - **Direct and indirect consumption of electricity in agriculture** (through deployment of solar pump-sets)
  - Indirect electricity consumption across other sectors (such as fertilizers, pesticides, land transport, trade, financial services etc.) is hard to abate

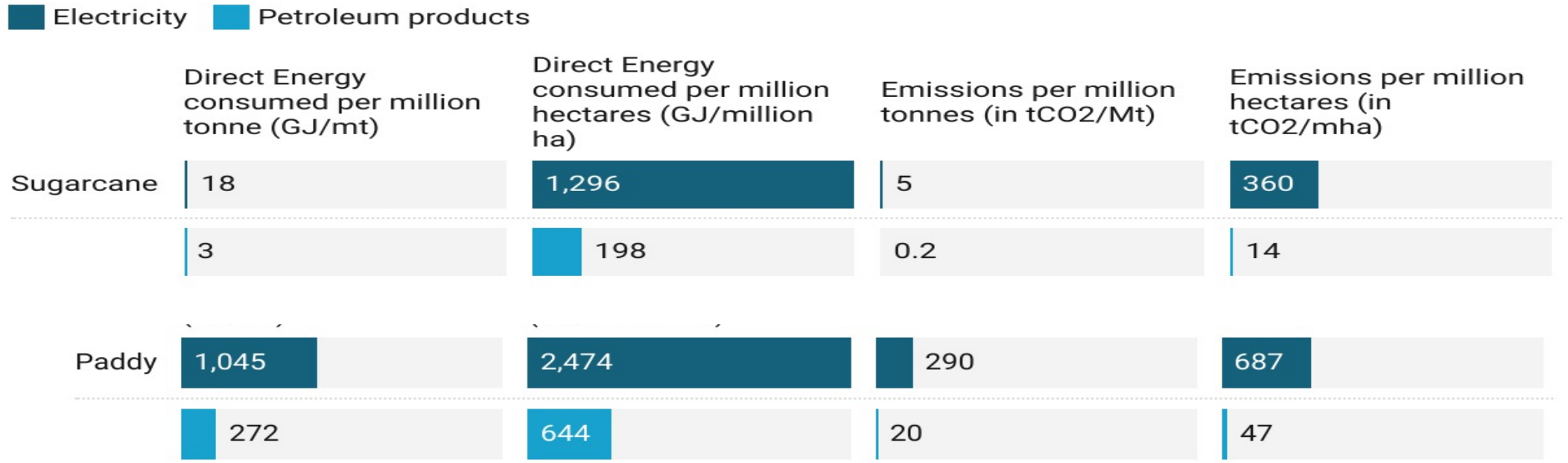
- Replacement or substitution of petroleum with electricity and biodiesel is currently not viable
  - Studies (such as TERI & Shell (2021) suggest a transition away from petroleum to biodiesel and electricity
  - Current scales of production and costs it is not feasible

	Actual Emissions (using an EF of 1 tCO2/MWh)	Emissions (using an EF of 0.96 tCO2/MWh) for all inputs	Emissions (using an EF of 0.82 tCO2/MWh) for all inputs	Emissions (using an EF of 0.56 tCO2/MWh) for all inputs
Emissions due to direct consumption	0.07	0.06	0.05	0.04
Emissions due to indirect consumption	2.15	2.10	0.07	0.05
Total Emissions	2.21	2.16	0.12	0.08
Percentage change in total emissions (in %)		2	6	22

Note: Emissions factors have been taken from the following study Institute for Global Environmental Strategies (2021)

Direct Energy Use & Emissions – Paddy & Sugarcane

- Wide variation in direct energy use for paddy and sugarcane
- Sugarcane requires lesser energy input and is more energy efficient than paddy



Indirect Energy Use – Paddy & Sugarcane

Sector	Source of energy	Paddy - Indirect Energy used per million hectares (in GJ/mha)	Sugarcane - Indirect Energy used million hectares (in GJ/mha)
Trade	Electricity	6578	58895
	Coal	21734	194581
	Crude Oil	252	2254
	Natural Gas	151	1355
Land transport	Petroleum products	4155	37201
	Electricity	2474	1296
	Coal	0	0
	Crude Oil	0	0
	Natural Gas	0	0
	Petroleum products	644	198
Financial services	Electricity	1351	12098
	Coal	0	0
	Crude Oil	0	0
	Natural Gas	0	0
	Petroleum products	10693	95731
Fertilizers	Electricity	6065	54296
	Coal	0	0
	Crude Oil	0	0
	Natural Gas	0	0
	Petroleum products	484	4333

Sector	Source of energy	Paddy - Indirect Energy used per million tons of output (in GJ/mha)	Sugarcane - Indirect Energy used million tons of output (in GJ/mha)
Pesticides	Electricity	1103	140
	Coal	5010	634
	Crude Oil	0	0
	Natural Gas	0	0
	Petroleum products	431	55
Tractors and agri. implements	Electricity	34	4
	Coal	626	79
	Crude Oil	0	0
	Natural Gas	46	6
	Petroleum products	27	3
Other Inputs	Electricity	6934	878
	Coal	561	71
	Crude Oil	167	21
	Natural Gas	134	17
	Petroleum products	2700	342

Total Energy Use & Emissions – Paddy & Sugarcane

Crop	Total Energy use (in GJ/ha)	Total Energy use (in GJ/Mt)	Total Emissions (in MtCo2/ha)	Total Emissions (in MtCO2/Mt)
Paddy	75	28	10	4
Sugarcane	623	8	79	1

Conclusions

1. **Direct Energy use in agriculture is low**
    - Energy supply and consumption in agriculture is low and needs to be increased
    - Need for enhanced agricultural productivity through increased mechanization of irrigation and other crop operations
    - Adherence to SDG 2.2– Double agricultural productivity and incomes which necessitates need for enhanced utilization of inputs and investments

2. **Majority of total energy use is through indirect consumption which includes dependence on natural gas, crude oil and coal**
    - Studies such as TERI & Shell 2021 have suggested that agricultural sector is apt for energy transitions as energy use is entirely replaceable
    - Agricultural sector is hard to abate

Conclusions

3. **Variations in direct and indirect energy consumption across crops**
   - With changes in cropping patterns, increase in economic activity, energy use in agricultural sector will change
   - Need for estimation of energy use for individual crops and use the inter-linkages with agricultural inputs to inform policy-making

4. **Agricultural sector is a site for adaptation rather than climate mitigation**
   - Emissions from direct consumption of energy in agriculture are low
   - Shifts emphasis of energy transitions and climate mitigation on agricultural sector
   - Disregards emissions in energy and industry from the developed world and shifts mitigation burden onto developing nations