

**Definition:**

$$\frac{\textit{Embodied Energy}}{\textit{Area of land}}$$

**Description**

**Benefit:** Energy content can be used for an integrated evaluation of crops. Generally, the type of energy should be specified to distinguish between use as fuel or use as food and feed. For use as animal feed, further definitions are required to determine if lignocellulosic crops qualify. Crops with high per hectare yield will show high efficiencies in this impact area.

**Resource:** Agricultural land is always a limited resource. The type of land can be specified to distinguish between different land qualities. Distinctions are often made, for example, between cropland and pasture, high nature value (HNV) farmland and other farmland, or based on soil fertility and yield potential. For this indicator, the temporal reference must always be specified. However, in case of the standard period of one year, this information is sometimes omitted in scientific publications.

**Correlation with soil management**

[58] Systems based on sugarcane, sweet sorghum and oil palm performed best when comparing net energy per area of land.

[182] Improving the conditions of mineral nutrition by introducing balanced doses of fertilizers for all elements contributed to a sufficiently high yield.

[214] In Brazil, biodiesel addition into diesel is mandatory and soybean oil is its main source. Energy balance showed linearity with yield, whereas for EROI, the increases in input and yield were not affected.

[248] Small rice-producing farms ranging from 0.61 to 1.0 ha yielded higher energy ratios (4.14) than larger ones

[270] Energy consumption from irrigation process is converted to electricity, thus the corresponding GHG emission caused by irrigation is included into that of electricity

**Strength & weaknesses pertaining to measurement of this impact area**

**Embodied Energy:** Indicators for embodied energy are generally easy to measure and allow integration of or comparison between benefits from very different crops. However, their information value for questions of nutrition is limited because the provision of amino-acids and vitamins is not considered.

**Area of land:** While area of land is a standard measure that is used as reference in most statistics and inventories, a weakness of this indicator is that other relevant information like soil type, soil fertility or management history is often not provided.



In short, one hectare of dry, sandy cropland soil is very different from one hectare of pasture on drained peat soils.

## Sample Indicators










<b>Indicator values from</b>		Survey	
Experiment or direct measurement		Statistical- or census data	
Expert assessment		Literature values	
Model		Maps or GIS	
Stakeholder participation		Not provided	

Table 1: Region Scale










<b>Indicator</b>	<b>Unit</b>	<b>Indicator values from</b>
[182] Aggregate energy output+ increment of energy (grain tillage crop rotation+ grain grass tillage rotation)/Area of land	GJ * ha <sup>-1</sup>	
[214] Output energy flow (potential oil in the grains)/Area of land	MJ * ha <sup>-1</sup>	 , 
[248] Land use efficiency (Output energy/Area of land)	MJ * ha <sup>-1</sup>	 , 
[248] Net energy gain/Area of land	MJ * ha <sup>-1</sup>	 , 
[270] Net energy gain/Area of land	GJ * ha <sup>-1</sup>	 , 



Table 2: Global Scale




Indicator	Unit	Indicator values from
[58] Net energy (Net energy yield (Energy content of biofuel and its coproducts – energy used for production, transportation and conversion)/Area of land)	GJ * ha <sup>-1</sup>	

Table 3: National Scale

Indicator	Unit	Indicator values from
[270] Net energy gain [GJ]/Area of land [ha]	GJ * ha <sup>-1</sup>	 , 



## References

ID	Citation	<sup>1</sup> Soil type/ texture
58	de Vries, S. C., et al. (2010). "Resource use efficiency and environmental performance of nine major biofuel crops, processed by first-generation conversion techniques." <u>Biomass and Bioenergy</u> <b>34</b> (5): 588-601.	n/a
182	Neshchadim, N. N., et al. (2018). "Bioenergetic assessment and economic efficiency of predecessors and fertilizer systems in the cultivation of winter wheat." <u>International Journal of Engineering and Technology(UAE)</u> <b>7</b> (4.38 Special Issue 38): 685-689.	Ordinary chernozem with low content of humus (4.5-5.5%)
214	Romanelli, T. L., et al. (2012). "Material embodiment and energy flows as efficiency indicators of soybean (Glycine max) production in Brazil." <u>Engenharia Agricola</u> <b>32</b> (2): 261-270.	n/a
248	Talukder, B., et al. (2019). "Energy efficiency of agricultural systems in the southwest coastal zone of Bangladesh." <u>Ecological Indicators</u> <b>98</b> : 641-648.	n/a
270	Wu, H., et al. (2017). "Temporal trends and spatial patterns of energy use efficiency and greenhouse gas emissions in crop production of Anhui Province, China." <u>Energy</u> <b>133</b> : 955-968.	n/a

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<sup>1</sup>Soil type/ texture: If provided, what are type and texture of the soils studied in the paper?