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RECONSTRUCTING DOMESTIC ENERGY AVAILABILITY IN AGRARIAN SOCIETIES: A CASE STUDY FROM THE IER VALLEY, 1900

Vlad RADA[1], Mihai-Ionuț DANCIU[1], Adina HORABLAGA[1]

*[1] **University of Life Sciences "King Michael I" from Timisoara***
Corresponding author: vlad.rada98@gmail.com

Abstract. *This paper examines the relationship between agricultural production and energy availability in Bihor County around 1900, employing a quantitative approach to estimate the theoretical energy yield per capita. Using historical data on land distribution, crop structure, and average yields, and converting agricultural outputs into kilowatt-hours (kWh) based on standard calorific values, we calculated that each inhabitant would have had access to approximately 2764 kWh of energy annually. The analysis shows that while this figure may appear substantial, it must be contextualized: much of the agricultural production was destined for animal feed, seeds, or was lost to spoilage, meaning that the net dietary energy available to humans was considerably lower. Compared to modern figures, the disparity is stark. Contemporary Bihor produces significantly more agricultural energy per capita, reflecting advances in agricultural practices, mechanization, and rural economic restructuring. Furthermore, when compared to modern overall energy consumption patterns, even the total agricultural energy available in 1900 remains negligible: current household electricity consumption alone exceeds 2000–2500 kWh per capita annually in Romania, while total energy use reaches 23,000–24,000 kWh. In the United States, annual energy consumption per capita is nearly 90,000 kWh. This investigation highlights the extreme efficiency and constraints of pre-industrial agrarian societies. It underscores how limited energy availability shaped daily life, economic activity, and survival strategies, in stark contrast to the vast energy surpluses that characterize post-industrial societies. By quantitatively reconstructing historical energy access, the paper provides a framework to better understand the transformative impact of increased energy availability on societal structures, economic complexity, and human expectations. The study demonstrates that energy abundance was not merely a technological achievement but a fundamental driver of historical change.*

Keywords*: domestic energy consumption, rural households, agrarian societies*

INTRODUCTION

As the issue of the energy crisis increasingly dominates the European public agenda, contemporary tools for monitoring and controlling energy consumption provide ever more precise data on the energy required to maintain standard household operations. These measurements highlight the energy abundance that today's post-industrial societies enjoy—an abundance unparalleled in human history (Calder, 2021). However, until relatively recently, most people lived in agrarian societies, where the amount of energy they could access was directly tied to agricultural productivity (Mazoyer & Roudart, 2006).

Despite the essential nature of this topic, few studies have explored the historical availability of energy at the household level in agrarian contexts. Understanding how much energy was available to past communities offers valuable insights into historical living conditions and helps contextualize contemporary energy consumption patterns. Gaining a historical view of energy dynamics is crucial to better understanding present realities and future challenges.

This article aims to contribute to this field by estimating the annual amount of active energy available to a typical rural household in the Ier Valley region around the year 1900, based solely on agricultural yields. By translating historical data into kilowatt-hours (kWh), the study offers a quantifiable framework for comparing the energy landscape of the past with that of modern domestic energy use.

MATERIAL AND METHODS

The Ier Valley is a microregion—in the sense defined by Hettne and Söderbaum (Hettne & Fredrik, 2002)—located in northern Bihor County, modern-day Romania. This geographical unit is perceived as coherent based on historical, linguistic, cultural, economic, and topographic continuities. Within the Natura 2000 network, it is marked as part of the broader Ier Plain, corresponding to the upper course of the Ier River across southern Satu Mare County and northern Bihor County (European Environment Agency). In the absence of a generally accepted convention, we adopt here the name "Ier Valley" for the area designated by the Natura 2000 program, given the consistent identity of the region and the tendency among local populations to refer to it under this common name.

To establish a representative case study, we selected a model household corresponding to the typical rural family unit of the Ier Valley around the year 1900. This selection was grounded primarily in the relevant scientific and professional literature, particularly works focused on agrarian structures and demographic dynamics in the region during that period (Mazoyer & Roudart, 2006) (Ștefănescu, 1989) (Prodan, 1990). Historical statistical records, including the Hungarian Crown censuses (A Magyar Kir. Központi Statisztikai Hivatal, 1924) served to supplement these references with quantitative validation.

Equally important in shaping the final selection were field observations and historical cartographic materials. These were not only used to corroborate the textual and statistical findings but also provided essential visual and spatial evidence for identifying patterns of land use, settlement morphology, and building distribution. Extracts from historical maps and photographs collected during fieldwork are employed in this study to illustrate and contextualise the selected household model. By integrating literary, statistical, visual, and spatial sources, the study constructs a representative case that is both historically consistent and geographically specific.

The socio-economic profile of the selected household reflects the composition of a typical peasant family at the time, generally consisting of about five members, often spanning two or three generations (Mazoyer & Roudart, 2006) (Prodan, 1990). After the 1848 agrarian reform and the abolition of serfdom in Transylvania, including in Bihor County, former serfs became small landholders, though their plots were often marginal and insufficient for a secure livelihood. Most fertile land remained concentrated in the hands of large estates, particularly those of ecclesiastical institutions like the Roman Catholic Diocese and the Chapter of Oradea. The reform did not redistribute reserve lands or forests, maintaining the peasants' dependence on large landowners for essential resources such as firewood and pastures. Thus, by the end of the 19th century, the rural population of Bihor was composed mainly of smallholder peasants with limited economic autonomy (Ștefănescu, 1989). Their economic activities centred on mixed farming, combining crop cultivation with animal husbandry.

In spatial terms, the traditional household typology in the Ier Valley around 1900 was characterised by a clear functional zoning and coherent integration of residential and agricultural spaces. The typical rural homestead consisted of a courtyard (used for circulation and work), a vegetable garden (locally referred to as the teleac), and agricultural fields located behind it. The courtyard accommodated the dwelling house—usually a single-storey structure with a simple floor plan, accessed via a wooden porch located on one or more sides of the building—and a range of auxiliary constructions including a barn (animal shelter), hayloft, pantry, well, and

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occasionally spaces dedicated to crafts or tool storage. (Hagiu, Gheorghiu, Drimbău, Drimbău, & Grupul Rural al OAR, 2018)

The barn, hayloft, and storage annexes were commonly built together, separate from the main house, using a wooden frame filled with kiln-fired bricks, topped with a wooden roof structure covered in tiles or straw. The house itself typically comprised two or three rooms, with the porch acting as a transitional space between the courtyard and the interior. Construction techniques included stone foundations, wooden structural frames, and clay-insulated attics. Floors were often made of either earth or painted oak or hornbeam planks. Windows featured single or later double glazing, with double-sash openings becoming common. The orientation of the house within the parcel was consistent: usually set around 60 cm from one of the lateral boundaries and 1–2 metres from the street, with some exceptions placed directly on the roadside. Outbuildings were typically aligned along the plot in continuation of the house or separated by a narrow gap, with the summer kitchen and oven often situated between the house and the barn. (Hagiu, Gheorghiu, Drimbău, Drimbău, & Grupul Rural al OAR, 2018)

Historical maps of the Ier Valley villages reveal the striking regularity in the repetition of this household layout, with similar arrangements reproduced parcel after parcel across the rural settlements of the region. This spatial pattern underscores the strong material dependency and the structurally deterministic link between resource availability and local construction practices.

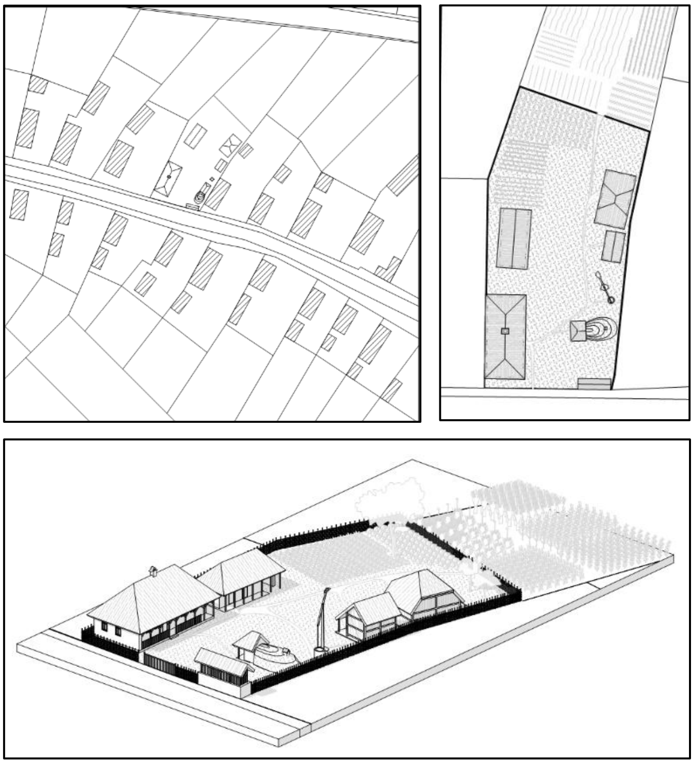

Figure 1: left: The highly uniformity of the historic fabric in the rural Ier Valley (plan); right: The typical Ier Valley household layout in 1900 (plan); Down: The typical Ier Valley household layout 1900 (axonometry) (Rada, Danciu, & Bădescu, 2023)

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Figure 3: Historical mapping reveals the striking uniformity of the rural fabric generated by the repetition of the typical Ier Valley household (extracts from The Third Josephinian Land Survey (1869-1887) (Arcanum Adatbázis Kft; Bundesamt für Eich - und Vermessungswesen, 1869-1887)

Figure 2: from left to right: Typical 1900 Ier Valley house and the granary seen from the street; the stable; the thatched cellar; the workshop; the hayloft (Institutul Național al Patrimoniului; Colecția de Etnografie Galoșpetreu 2025)

To convert the theoretical agricultural production available per inhabitant in Bihor around 1900 into kilowatt-hours (kWh), a multi-step methodological approach was employed. First, average historical yields per hectare were applied to the estimated surface area cultivated per capita. Then, the crop-specific quantities were multiplied by standard calorific values (expressed in kWh/kg) as documented in energy conversion literature (Food and Agriculture Organization (FAO), 2001). This process allowed for the estimation of the total annual energy potentially available to each individual in the form of agricultural output. The following paragraphs present a more detailed overview of the methodological steps undertaken to obtain the results discussed later in the article.

The estimation of agricultural products theoretically available to each inhabitant of Bihor County around 1900 was based primarily on data extracted from the Magyar Statisztikai Közlemények. According to these sources, the total population of Bihor County in 1900 was

577,312 inhabitants, while the total cultivated surface amounted to 670,035 cadastral *jugăre* (1 jugăr = 0.57 hectare). Of this, approximately 85% was worked by smallholders owning less than 100 *jugăre* each, corresponding to about 569,530 *jugăre*.

An average family cultivated approximately 3 to 6 hectares of arable land (A Magyar Kir. Központi Statisztikai Hivatal, 1924) (Mazoyer & Roudart, 2006), complemented by small plots for gardens and fodder production. Primary crops included maize, wheat, rye, and barley, alongside vegetable cultivation for domestic consumption.

Large estates, although owning about 17% of the agricultural land, represented less than 0.22% of the population, a proportion that justified their exclusion from the per capita calculations. The distribution of cultivated crops was also documented, with winter wheat accounting for 43% of the cultivated area, maize for 20%, oats for 11%, spring wheat for 8%, rye for 7%, and smaller percentages for barley, potatoes, forage beet, lucerne, clover, and millet.

The original unit of measurement (*jugăr*) was converted into hectares using the standard factor of 1 *jugăr* = 0.57 hectare to align with yield data expressed in kilograms per hectare. Yields for major crops were largely based on historical averages provided by the same statistical sources; for instance, winter wheat was recorded at 1238 kg per hectare.

Based on this information, the average theoretical annual agricultural output per inhabitant was calculated. Thus, a typical inhabitant would have had access annually to approximately 299 kg of winter wheat, 49 kg of spring wheat, 35 kg of rye, 28 kg of winter barley, 5 kg of spring barley, 58 kg of oats, 169 kg of maize, 56 kg of potatoes, 112 kg of forage beet, 135 kg of lucerne, and 39 kg of clover, as documented in historical agricultural records.

The annual agricultural output, serving both subsistence and modest market exchange, defined the household's available energy resources. However, these quantities remained closely dependent on climatic conditions, seasonal variability, and socio-political constraints such as taxation, tenancy obligations, and common rights restrictions.

Following Calder's approach, which transforms all types of available resources into a standardized energy unit, we determined the amount of energy a household had access to within a defined annual timeframe. The available resources were expressed uniformly in kilowatt-hours (kWh), enabling direct comparison across different historical and technological contexts.

RESULTS AND DISCUSSIONS

The theoretical calculation of agricultural production available per inhabitant in Bihor around 1900, when converted into kilowatt-hours (kWh), yields highly instructive insights. By applying average historical yields per hectare to the surface distribution per capita, and using standard calorific values for each crop type, the annual energy available to each inhabitant was estimated.

The total energy derived from crops per person amounted to approximately 2764 kWh per year. This figure was obtained by multiplying the per capita crop yields (in kilograms) by their respective calorific values (expressed in kWh/kg) (Food and Agriculture Organization (FAO), 2001) and summing across all crops. For instance, winter wheat provided roughly 299 kg per person, with an energetic value of about 3.7 kWh per kilogram, while maize provided 169 kg per person at approximately 3.7 kWh per kilogram. Other crops such as oats, rye, barley, potatoes, forage beet, lucerne, and clover added smaller but significant contributions to the overall energy budget.

While this result may initially appear substantial, it must be nuanced by considering the broader context. Firstly, not all agricultural production was destined for direct human consumption. A considerable share was allocated to animal feed, seed for the next planting cycle, or lost to spoilage and inefficiencies. Additionally, processing losses and caloric assimilation inefficiencies mean that the net energy available for human metabolic use would have been significantly lower. Furthermore, traditional food processing methods often resulted in additional losses of caloric content, reducing the effective dietary energy intake from the raw agricultural products.

When compared to contemporary figures, the historical agricultural energy per capita seems modest. In modern-day Bihor County, with a population of approximately 540,000 and an annual maize production of about 350,000 tons, the energy per capita derived from maize alone exceeds 640 kg per year, translating into approximately 2,368 kWh from maize alone, assuming similar caloric values. Including other crops, the current energy availability easily surpasses 4000–5000 kWh per capita from agricultural production. This impressive growth reflects not only the improvement in agricultural practices, such as mechanization, fertilization, and crop breeding, but also a fundamental shift in the organization of rural economies and land use patterns.

Further, when compared to modern overall energy consumption patterns, the gap becomes even more evident. The average annual per capita energy consumption in Romania today is around 2000–2500 kWh for household electricity alone, while total energy consumption per capita (including transport, heating, and industry) reaches approximately 23000–24000 kWh. In the United States, the figures are even more striking, with an average annual per capita energy consumption of around 80000 kWh (Ritchie, Rosado, & Roser, 2025). These values highlight the staggering disparity between pre-industrial and post-industrial societies in terms of energy usage, standard of living, and economic complexity.

The contrast is further sharpened when considering that in 1900, the energy extracted from agriculture was practically the sole form of primary energy available to the rural population, supplemented only minimally by traditional biomass (firewood) and manual or animal labor. Modern energy systems, by contrast, rely heavily on fossil fuels, electricity, and advanced technologies, multiplying the available energy per capita by factors of ten or even a hundred.

Thus, the 2764 kWh/year theoretically available to a Bihor inhabitant circa 1900 would have covered basic metabolic needs and minimal household operations (such as food preparation, heating through firewood, and basic manual tasks) but would have been utterly insufficient for any of the energy-intensive activities characterizing modern life, such as industrial production, automotive transport, telecommunications, or climate control.

The analysis highlights both the extreme energy efficiency and the physical limitations of pre-industrial agrarian societies. Every calorie produced was precious, and survival depended on the careful management of agricultural outputs, the tight integration of human and animal labor, and the seasonal rhythms of food production and consumption. In contrast, modern societies benefit from vast energy surpluses that allow for complex economic, social, and technological systems, but also bring challenges related to sustainability, resource depletion, and environmental degradation.

Looking ahead, one compelling direction for further research involves assessing the energy requirements associated with the construction activities and material inputs necessary to establish and maintain the household typology described earlier in this study. Estimating the embodied energy in building materials such as stone, wood, and brick, as well as the human and animal labor involved in construction, would offer a valuable complement to the analysis of agricultural energy availability. Moreover, relating these construction energy costs to the typical domestic energy consumption of such households—expressed in standard categories like heating, lighting, and cooking—could reveal important insights about energy allocation and efficiency. Previous studies applying the national framework for building performance evaluation (the official methodology for calculating the energy performance of buildings, formulated within the Romanian Law 372/2005 (Ministerul Transporturilor, 2025) and Ministerial Order No. 157 of February 1st, 2007 (Ministerul Transporturilor, Construcțiilor și Turismului;, 2025)) have already classified vernacular Romanian dwellings within the F category, reflecting their low energy performance by contemporary standards (Hagiu, Gheorghiu, Drimbău, Drimbău, & Grupul Rural al OAR, 2018). Integrating such metrics into the broader energetic profile of historical households could significantly enhance our understanding of sustainability in traditional rural architecture.

CONCLUSIONS

This study has demonstrated that the energy available to a typical rural household in the Ier Valley around the year 1900 was deeply constrained by the limits of agrarian productivity. By converting historical crop yields into kilowatt-hours, it was estimated that an average inhabitant had theoretical access to approximately 2764 kWh per year—an amount barely sufficient for meeting basic metabolic and domestic needs. This figure, when contrasted with contemporary energy consumption patterns, underscores the radical transformation of rural life under the influence of industrialisation, technological development, and fossil energy.

The findings highlight the close relationship between agricultural structure, demographic composition, and energy access, offering a measurable lens through which to evaluate the energetic logic of traditional societies. Moreover, the analysis sheds light on the resilience, but also the fragility, of self-sufficient rural economies where energy was produced locally and circulated through tightly regulated social and ecological rhythms.

Beyond quantitative assessment, this study points to the broader potential of interdisciplinary research at the intersection of energy history and vernacular architecture. By integrating energy metrics into historical and spatial analyses, scholars can better understand how material culture and landscape were shaped not only by aesthetic or functional criteria, but by the hard limits of energy availability.

Future research will aim to complement this initial reconstruction by evaluating the energy invested in constructing the very household typology discussed here, as well as its operational energy needs. Such inquiries promise to deepen our understanding of pre-industrial energy systems and their relevance to today's sustainability discourse.

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