PEAT AND THE DUTCH GOLDEN AGE

THE HISTORICAL MEANING OF ENERGY-ATTAINABILITY *

J. W. DE ZEEUW

1. INTRODUCTION

The amazing prosperity of the small 'Republiek der Zeven Provinciën' and its exceptional position among the European powers during most of the seventeenth century has fascinated generations of historians. In spite of the abundance of research they have accomplished on the subject, resulting in a huge amount of valuable knowledge and understanding, this historical phenomenon cannot be considered fully explained. Recent publications added new insight on the topic and disclosed original views about the economic and social development.[1] The more comes in the open about the thriving Dutch Golden Age society, the more intriguing the question becomes, how so small a population (a million and a half at the vertex of its power) could manage to play leading parts on almost every scene of human activities. Looking around in the recent world, one easily discovers that even very few men are able to do big jobs making use of additional energy, i.e. replacing and amplifying their individual limited powers by means of other sources of energy. This study intends to investigate whether the seventeenth century Dutch had similar opportunities at their disposal, from which their contemporaries had to abstain. An analysis of energy consumption in the Republic reveals a so far overlooked foundation for its economic and cultural wealth.

To the extent that attention has been given to energy as a factor in the history of the Republic this had been concentrated almost exclusively on the national symbol, the windmill. It is undeniable that the Dutch played a pioneering part in the application of wind energy to industrial purposes. For some time they undoubtedly had a lead in this respect over other countries.[2] Their windy climate and flat, mostly treeless landscape were advantageous in this regard. Still, these favourable conditions can only provide a partial explanation of the extraordinary prosperity of their society in the seventeenth century. This is evident in the first place from the limited number of industrial windmills in existence in the Republic. (The basis for this assumption will be discussed below in section 8).

* The author is most grateful to Prof. dr. A. M. van der Woude for his keen interest and valuable suggestions and for teaching a land- and watermanagement specialist the basics of the historian's idiom. He feels equally indebted to Prof. dr. J. de Vries who suggested substantial improvements of the English presentation.

As a matter of fact the peak of windmill application did even not occur in the seventeenth century but, rather, in the second half of the nineteenth. Then some 9,000 windmills operated for industrial and land drainage purposes.[3] Also only then had technical improvements been achieved that permitted them to attain their biggest energy producing capacity.[4] Another fact to keep in mind is that Holland was not the only region of Europe with favourable conditions for the exploitation of windmills. By 1900 a total of 30,000 windmills were at work around the Northsea. Together they represented a constant effect of 100 megawatts, an average of 3.33 KW per mill.[5] Clearly, any examination of the energy supply situation of the Republic should be placed in a broader framework than that of wind energy alone.

2. Energy, needs and sources

By systematizing the different sorts of energy man needs, we can clarify the nature of the problem at hand. No society can do without the following:

1. *maintenance energy*,
in general solar energy accumulated through photosynthesis in vegetable and animal products. This is needed for food, clothing and shelter;

2. *heating energy*,
normally also solar energy, but especially in the form of fire-wood for domestic uses and for the heating of materials in manufacturing operations;

3. a. *stationary motion energy*,
in which originally solar energy also played the leading part in the form of human and animal muscular strength. These were complemented in a rather early stage in many societies by waterpower and windpower, which also derive their energy from the sun.

3. b. *mobile motion energy*,
for carrying or dragging loads, for plowing etc. Here again human and animal power played the major role. In land transport this was until recently the only possibility. In water transport, on the other hand, friction-resistance is sufficiently small that the wind can nearly always move floating loads. Skippers therefore enjoyed significant advantages over wagoners. A quantitative approximation of this advantage will be calculated below (section 7).

This short survey of energy provision shows that, in principle, a society depends on the productivity of the soil on which it lives for the acquisition of energy and, thus, for the attainment of a given level of economic and social development. A *limit* is imposed on its economic possibilities, determined by the number of productive hectares of its territory, by the productivity and fertility of these hectares and by the simple fact that a hectare destinated to the production of food, is not available to yield fire-wood or fodder for draughthorses. The different sorts of energy are mutually exclusive!

During the sixteenth century the countries of Southern and Western Europe hit this development limit as a consequence of continuing deforestation. Particularly in the large centres, wood for burning and construction material became progressively more expensive as a consequence of the ever increasing distances over which it had to be conveyed. Deforestation proceeded not only to satisfy wood demands, but also to augment supplies of maintenance energy through the clearing of woodland in favour of agriculture. Around 1640 the Dutch stock of harvestable wood lots had been reduced practically to zero. Before that time already, rising prices of heating energy caused by growing transport cost created problems in the densely populated parts of Europe.

3. Peat

Yet a chance of escape from these problems seemed to be near at hand. Millions of hectares of peat exist north of the Alps.[6] This enormous amount of potential fuel has however remained virtually untouched in the course of time. At best some of it was dug here and there for local use. Only since the end of the nineteenth century has its exploitation intensified with the introduction of mechanical peat digging for the sake of local industry or for firing electrical power plants. Transport of the thus obtained energy by way of the power grid is cheaper than moving a vast mass of turf[7] by road. Only one exception exists to this general picture. In the Netherlands nearly all usable peat has vanished. In remaining Dutch peat areas, the peat is either mixed with too much clay or too salty, so that its combustion would yield too much ash. Only the Netherlands, of all European countries, came to supplement its soil-dependent energy resources with the large-scale exploitation of its peat stock. In this way it succeeded in breaking through the development limit. The vital question which ultimately has to be answered is, thus, why where the Dutch able to make use of their peat, while the rest of Europe had to abstain from it?

The determining factor was not the peat quality. Growing conditions of peat had been virtually the same everywhere, so that all the peat had comparable properties. The only exceptions were those few places where rivers could deposit their clay in the peats, like in the above mentioned areas in the Netherlands where the peat still exists. The only real difference is, that peat deposits do not all lay on the same elevation with respect to sea level. The Dutch had the good fortune to find their peat very near to, partly even just below the overall water table. This fortunate situation was caused by the rising of the sea level during the holocene.

In this country the digging of navigable canals in the peat areas and, more important, the linkage of these canals to the already existing, extensive network of natural waterways was easily done. Since these natural waterways gave access to all important cities, the turf could be directly transported by ship from the peatery to the consumer.

The history of the Pee1[8], the only Dutch peat area located at a significant elevation (30 m above sea level, 15 m above the near-by flowing river Maas) is instructive in this connection. Its history runs parallel to those of foreign peats. In 1573 an attempt to link 's-Hertogenbosch with the Peel by making the river Aa navigable failed. The city remained dependent on turf from Holland. A description from 1670 shows that local people dug peat on the fringes of the Peel, not only for their own use but also to cart it for sale to near-by villages. Eindhoven also made energetic efforts for a great many years to achieve a water connection with the Peel. In 1816 the cloth-manufacturers of that city complained about the expensiveness of Peel turf, which had to be brought in by road (distance only 25 km!). Other fuels, they stated, were even more expensive. Large-scale peat digging begun in the Peel only after 1853 in which year it was connected by a canal to the Zuid-Willemsvaart, a through-traffic waterway, finished in 1826 and passing by the Peel at a distance of less than 15 km.[9] Finally in 1880, when the Peel was completely opened up by digging canals through the area itself, were the conditions created which other Dutch peat regions had enjoyed for centuries. Since, peat digging on a fairly large scale continued in the Peel till 1942.

4. Processed volume of peat

At one time there must have existed some 175,000 ha of high peat[10] in the Netherlands, of which at present only some 5,000 ha may be left in a more or less undisturbed state. Confining the calculations to the main bodies of peat (see fig. 1), it can be stated that in Southern Groningen and Eastern Drente ca 100,000 ha has disappeared and in Western Drente, Friesland and Overijssel ca 70,000 ha. The other important deposit of high peat, the Peel, measures only 6,000 ha. Since it was mainly exploited during the last century, it can stay out of consideration. The peat of South-Eastern Drente has received a thorough study of its natural conditions. Its original thickness was on average 4.5 m.[11] This, however, is not the thickness one can use to reckon the total volume of usable peat. Before being cut the peat was partially dehydrated by digging 1.5 m deep drainage trenches in its surface. In the course of some years this caused a shrinkage to ⅔ of ¾ of its original thickness.[12] To avoid overestimation, a reduction factor of ⅔ will be applied. Thus, the peat actually cut, had an average thickness of some 3 m. Regulations often obliged peat cutters to leave the upper-most half meter of peat to

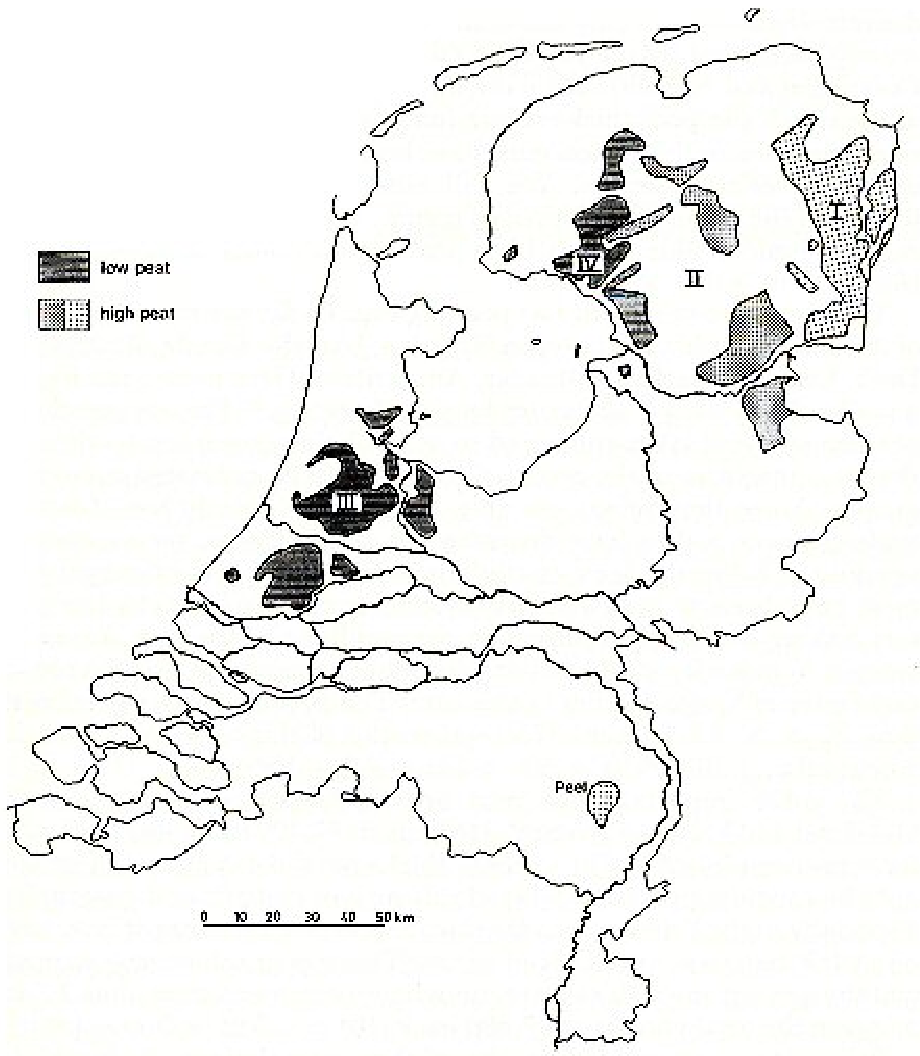

FIG. 1. Schematic outline of the main peat deposits with a sufficiently low ash content in the Netherlands that have been nearly completely removed. Roman figures refer to table I.

facilitate the later reclamation of the denuded underlaying sand. Although they did not always do this, in fact, this half meter will also be subtracted from the average thickness. The usable peat corresponds, therefore, to an average thickness of over 2.5 m, so that this peat region must have yielded at least 100,000 ha × 10^4 × 2.5 m = 2.5 × 10^9 m^3. This will be called the rated volume, because peat cutters worked on piece rates according to it.

The other high peat region covered 70,000 ha, but it consisted of discrete deposits of varying size scattered over a wide territory (approximately staked out by the towns of Zwolle, Steenwijk, Drachten, Assen, Coevorden and Almelo). Since the numerous deposits each had borders along which the peat thickness gradually reduced to zero, the average rated thickness in this region must have been less than in the precedingly discussed coherent region. We will estimate the thickness at 1.5 m instead of the 2.5 m of the previous region. Using this estimate, the total rated volume of this second high peat region comes to 70,000 ha $\times 10^4 \times 1.5$ m = 1.0×10^9m^3.

There are also two main low peat regions. By far the more important of the two lies within the polygon Naarden, Utrecht, Gouda, Rotterdam, Delft, Leiden, Haarlem, Alkmaar, Amsterdam. Here more than 61,000 ha of land was turned into water by peat dredging.[13] The average depth of these artificial lakes amounted to 4.3 m below mean sea level[14], but the total thickness of the removed peat should be estimated somewhat greater. Since the region was able to drain sufficiently well (natural drainage over rather long distances) to support a rather prosporous agriculture before dredging started, the surface level of the dredged peat must have been at least a few decimeters above sea level. In low peat turf making, the dredged substance was puddled and trodden in wooden troughs to make it cuttable. It can therefore be assumed that the reduction factor of ⅔ also applies in this case. The average rated thickness is, thus, $⅔ \times > 4.3 = 3$ m. The total output of this region can then be estimated at > 61,000ha $\times 10^4 \times$ 3m = 2.0×10^9m^3.

The other important low peat area is located in North-Western Overijssel and Eastern Friesland. Here about 47,500 ha of peat land must have been exploited.[15] The average thickness of the removed layer can only be roughly guessed because of this regions complicated geography. Especially in the Friesian area farmsteads and other patches of land were often left between the dredged areas. The topographic map suggests that the average rated thickness cannot have been much more than l.5 m, bringing the total volume to 47,500 ha $\times 10^4 \times 1.5$ m = 0.7×10^9 m^3. Before summarizing the results of these calculations, it should be stated that several less important peat regions have been left out of consideration. It is known that in other parts of Friesland and North-Holland, as well as near Veenendaal in Utrecht, near Roosendaal in North-Brabant, in Zeeland, and elsewhere peat extraction took place, mostly for local and regional use. This is another reason to regard the total peat extraction estimate of table I as conservative. The roman figures in table I indicate the peat regions as they are identified on the map of figure 1.

TABLE I. Summary of total estimated rated[1] volumes of peat extracted in the Netherlands.

I	High peat region of Groningen and Eastern Drente	$2.5 \times 10^9 m^3$
II	High peat region ofWestern-Drente, Friesland and Overijssel	$1.0 \times 10^9 m^3$
III	Low peat region of Holland and Utrecht	$2.0 \times 10^9 m^3$
IV	Low peat region of Friesland and Overijssel	$0.7 \times 10^9 m^3$
	The Netherlands	$6.2 \times 10^9 m^3$

[1] to approximate the volume of the geological formation removed, the figures have to be multiplied by 3/2.

5. CHRONOLOGY OF PEAT EXPLOITATION

Determining the rate of peat consumption in different periods is a difficult task. A description of the used method to approximate the timing of peat extraction will be given first as a general introduction to the subject. The starting years of canal digging in different areas were plotted on a map (scale, 1 : 200,000). With an eye on the type of landscape indicated on the map, lines were drawn around areas of which the marked year dates fall within the same period of 50 years. The outlined areas were then measured by counting square centimeters on a sheet of transparant millimeter paper covering the map. This worked out rather well for the regions I, II and IV (see table I), expecially because in all these cases clear-cut periods of increased activities could be distinguished. Region III required another approach, which will be discussed later.

The story of the exploitation of the Groningen-Drente peat region (region I) can be summarized as follows.[16] It started in the North where monks dug peat from the fifteenth century and before, on a relatively small scale. In 1600 companies of businessmen, most of them from Holland, began to dig canals which opened up the main body of the peat deposit. When this activity finished abruptly in 1649, some 30,000 ha of peat, including strips along natural streams could be reached for shipping the turf. Between 1770 and 1820 the canal system was extended, opening up another 10,000 ha. Finally, between 1850 and 1950 some 45,000 ha were made accessible. The rest, 15,000 ha, can be considered as the sum of what was cut before 1600 plus what was used in the course of the ages by local people living on the fringe of the peat plus what is still remaining today. To estimate the progress of peat consumption it has been assumed that additional canals were only dug when the exhaustion of earlier opened up areas created the need therefore. As far as the first mentioned 30,000 ha is concerned, we can be quite certain that this assumption is valid. It is a known fact that the peat in this first part of the region was completely exhausted before 1800.

On the basis of this assumption, the following figures are generated as average extraction estimates:

30,000/170	= 175 ha/year for 1600-1770
10,000/ 80	= 125 ha/year for 1770-1850
45,000/100	= 450 ha/year for 1850-1950

Considering the fierce canal digging activity between 1600 and 1650 and the dropping of the number of ha/year in the eighteenth century, it seems reasonable to assume that during the seventeenth century an average of 200 ha/year of peat was cut to be exported from this region.

In region II local peat cutting is known to have started in some places around 1300.[17] On a commercial scale the first efforts were made in 1551. Before 1600 a total of about 14,000 ha might have been cut or made accessible. Between 1600 and 1670 canals were dug to reach some 30,000 ha; between 1750 and 1800 an additional 14,000 ha were made accessible, while another 12,000 ha became accessible only after 1860. Because of the earlier mentioned dispersion of peat areas within this region, the historical picture is less clear. But here, as in region I enhanced activities can be noted in the first half of the seventeenth century and in the second half of the eighteenth. The chronological distribution of peat extraction might have proceeded as follows:

7,000/250	= 30 ha/year for 1300-1550
7,000/ 50	= 140 ha/year for 1550-1600
30,000/150	= 200 ha/year for 1600-1750
14,000/110	= 125 ha/year for 1750-1860
12,000/ 90	= 135 ha/year for 1860-1950

For the same reasons as in region I - i.e. the intense canal-digging activity of the second half of the sixteenth and the first half of the seventeenth century, and the reduction of extraction after 1750 - it does not seem an exageration to accept an average extraction of 200 ha/year also from this region for the period 1600-1700.

Since low peat areas can be reached by shipping without the execution of expensive, and for the contemporary observer impressive, undertakings like digging canal systems, its history drew less attention. As a result, the datings of starting activities in low peat areas can hardly be reconstructed. For region IV (the Friesland-Overijssel low peat region) the following indications could be found.[18] Small-scale peat winning was practiced since the Middle Ages, expicially in its Overijssel part. There a canal was constructed across the peat region to the port of Zwartsluis in the sixteenth century. During the next century some small natural waterways were widened. From the Friesian side of the border it is mentioned that in the second half of the seventeenth century some low peateries existed. In 1751 dredgers from Overijssel, notably from Giethoorn, came to Friesland to introduce their special way of dredging. Thereafter, low peat exploitation in Friesland became more important. It is hard to establish the chronological distribution of the exploitation of the 47,000 ha[15] of dredged peat on the basis of so little information. The year 1751 seems to be a crucial point. The migration of the Giethoorners indicates that the Overijssel area was nearly exhausted by then.[19] Assuming that before 1550 peat was dug for local use only, the following quess may not be unreasonable for Overijssel:

2,500/250 = 10 ha/year for 1300-1550
12,000/200 = 60 ha/year for 1550-1750
2,000/200 = 10 ha/year for 1750-1950

In Friesland 31,000 ha must be distributed[15], apparently between about 1600 and 1950. The description of the dredging methods employed[2O] indicates that there must have been a marked difference between the yields before and after 1751. A fair guess about the Frisian low peat area might be:

6,000/150 = 40 ha/year for 1600-1750
25,000/200 = 125 ha/year for 1750-1950

The seventeenth century output of region IV could then reasonably be set at 60 + 40 = 100 ha/year.

The reclamation for agricultural use of a great part of the dredged-out area in this region IV did not occur until after 1890, when drainage and polder construction was an unemployment relief measure.[21] In these rather scarcely populated parts, reclaiming of the sandy bottoms of the lakes was not economically attractive. In the other low peat region (region III) however, circumstances were completely different. There, in the most densely populated western part of the country, the artificial lakes posed a threat at the same time as they held a promise. As their waves ate away the soft peaty lake-shores, the lakes tended to widen themselves, often interrupting roads and undermining dwellings. Whole villages were swallowed and cities endangered by the 'waterwolf'. On the other hand the lake bottoms in these parts consisted chiefly of good clay soils, the reclamation of which could give valuable support to the food-supply. Even the general amenity of living-space exerted some attraction already in the seventeenth century. These were the main reasons for people to be eager to pump dry these lakes soon after peat dredging was finished. The technical means were available at an early date. As a matter of fact the first lakes had already been pumped dry in the second half of the sixteenth century.

An exact picture of the progress of peat exploitation in region III is hard to come by. Even if one should be able to study maps of different dates, these maps would not show water-depths, i.e. they would not indicate how far dredging had proceeded. The only set of data known with a great measure of certainty is formed by the years of reclamation of pumped dry polders.[13] The fat line in figure 2 represents the cumulation of the areas of reclaimed artificial lakes (natural lakes having been left out) of successive 50-year periods, thus indicating the latest years in which peat dredging could have been finished in a given number of hectares. Because of the threat and the promise just mentioned, it seems reasonable to suppose that few lakes created by peat digging would long have remained undrained. Consequently, the real dates of exhaustion of the peateries must not have preceded the reclamation dates by much. Other data related to turf winning in this region as a whole, are only available in a descriptive form. It started in the Middle Ages with digging, which removed the upper layers above the natural water table. During the fourteenth, fifteenth and sixteenth centuries dredging of peat was practiced, which created lakes of ever increasing size; around 1600 they occupied most of the area between the rivers Oude Rijn, Gouwe and Hollandse IJssel and threatend the villages of Nieuwerkerk, Zevenhuizen, Moerkapelle and Waddinxveen.[22] In 1630 the church of Jacobswoude, north of the Oude Rijn, was pulled down because by then the rest of the village had been swallowed by the waves of encircling man-made lakes. Around 1550, when pumping mills came into full operation, peat winning operations could be intensified through deeper dredging[23] after lowering the water table in the peatery by pumping it down. In the course of the seventeenth century apparently only a few new peateries were started in this region, still fewer in the eighteenth and nearly none in the nineteenth century.

Quantification of this description will be performed with the aid of a calculation model, the input of which will be the 61,000 ha of peat-land brought into peateries in the course of time.[13] Two sets of assumptions are made for the situation in l600: a lower estimate of 25,000 ha incorporated in peateries by that year (about the area as measured from the map around and between the afore mentioned villages, including Jacobswoude) and an upper estimate of 55,000 ha of peateries in 1600. The lower estimate is indicated in figure 2 with white dots, the upper estimate with black. It is further assumed that before 1600 the area of peateries grew linearly (dotted lines) since 1300, around which year peat dredging seems to have started. But, before ca 1550 deep dredging could not be practiced. We have assumed, therefore that the peateries only produced one half of their peat content before they could be pumped down. The solid lines before 1600 reflect this adjustment; their sharp upward bend after 1550 indicates the intensification of peat winning after that date. The difference between the ultimate 61,000 ha and the figures assumed for 1600 are divided in such a way that the extension of peateries in the seventeenth century is three times as big as that in the eighteenth century. By 1800 all peateries in this region are assumed to have been started.

The horizontal distances in figure 2 between the input lines and the fat curve showing the progress of the drainage of artificial lakes, correspond to about 300 years for the higher and to about 200 years for the lower assumed input. The calculation models for both situations are based on this observation. They are shown schematically at the bottom of figure 2. It is assumed that during the average duration of life of peateries their yield fell off linearly.

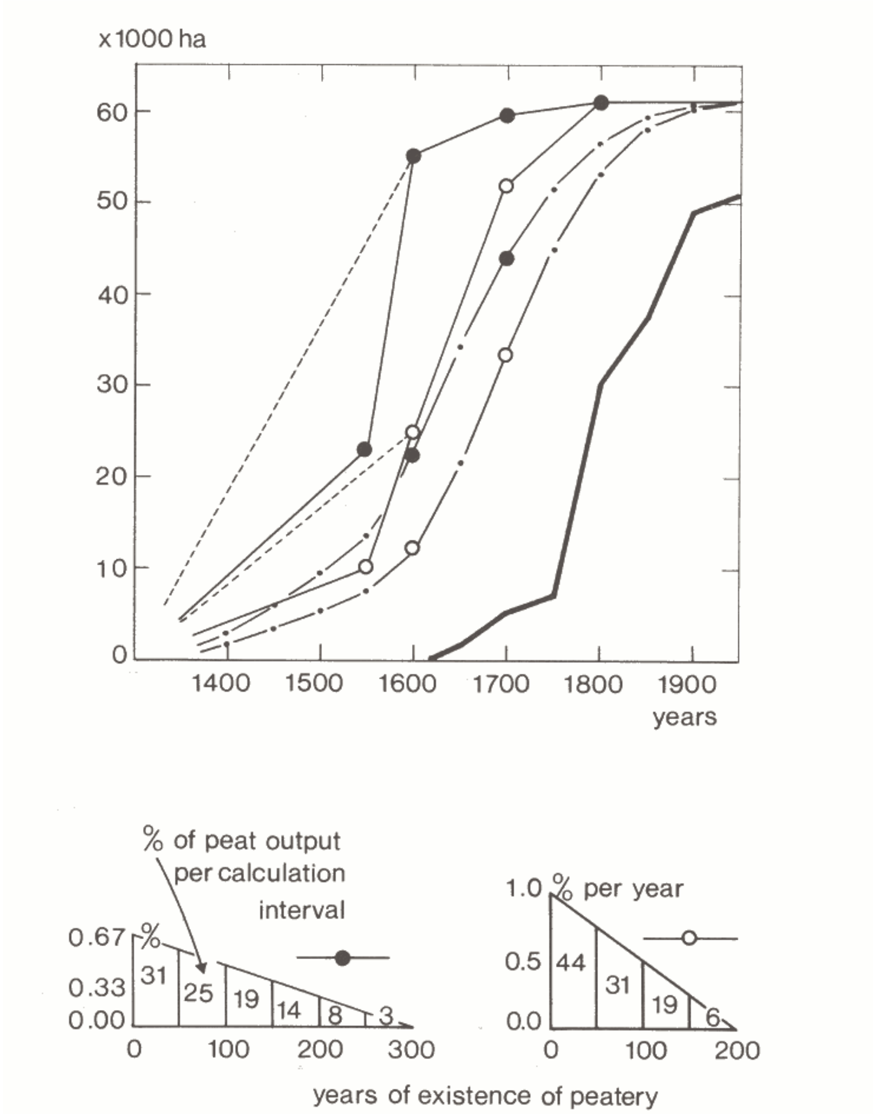

FIG. 2. Computation of the progress of peat exploitation in the Holland-Utrecht low peat region.

The right-hand fat line indicates the known cumulation of pumped dry artificial lake areas. The left hand straights represent two different assumptions for the cumulation of areas incorporated in peateries. The central, s-shaped curves are computed cumulations of full-depth hectares of dredged peat. Models for gradual average exhaustion of started peateries, used in the computations, are shown at the bottom. Fuller explanation in text.

The hypotenuses of the triangles indicate this falling off. Calculations were performed in 50-year intervals. The figures within the triangles enumerate the percentages of total yield of peateries for subsequent intervals. These percentages were applied as multiplicants for constant mean input quantities, obtained for subsequent intervals by quantitative transformation of the sloping input lines into histograms. The results of these calculations are shown in the two S-shaped curves. The parts of the curves between the dots hold the answer to the question how great peat extraction was in this region in the seventeenth century. The calculation for the lower assumption resulted in 21,280 ha for the whole century, that for the higher assumption gave 21,540 ha. The truth may be supposed to lie in between, so that an average peat extraction of 200 ha/year seems a modest figure for region III in the seventeenth century.[23]

Table II summarizes the results which have been described in this section. Reference is made to table I for explanations.

TABLE II. Summary of estimated rated volumes of peat extracted in the Netherlands in an average year between 1600 and 1700.

Region	ha/year	mean depth[1] m	m^3/year
I	200	2.5	5×10^6
II	200	1.5	3×10^6
high peat total	400		8×10^6
III	200	3.0	6×10^6
IV	100	1.5	1.5×10^6
low peat total	300		7.5×10^6
grand total	700		15.5×10^6

[1] see section 4.

6. Fossil energy in the golden age

Besides turf, some coal, mainly imported from England and Scotland, was used in the Netherlands during the seventeenth century. Quantities are unknown, but coal consumption could not have been very important. Blacksmiths used coal and sometimes some brewers, notably those working in crowded cities, where room was lacking to store large volumes of turf (1 m3 of coal provides six times as much heat as 1 m^3 of piled up turf).[24] The brewers, however, restricted their coal use to the winter months. They generally preferred turf because it apparently was far cheaper. Comparative prices are not available. Another indication that coal consumption in the seventeenth century must have been rather unimportant, can be derived indirectly from the first complete statistics about fuel consumption in the Netherlands.[25] From a total consumption of $6{,}084 \times 10^9$ kcal around 1840 only two fifths was supplied by coal. This means that there was still a great dependence on turf even at that time, despite the fact that coal had become much cheaper than it could have been two centuries before while turf, on the contrary, is known to have become more expensive especially during the second half of the eighteenth century.[26,27] From these considerations it seems clear that between 1600 and 1700 the contribution of coal must have been negligeable except perhaps for some special situations like in the years 1621 and 1622, when turf supplies were abnormally small after some extremely wet summers.[28]

The stream of imported coal - however small or big it might have been - was opposed by a stream of exported turf, whose quantity is, likewise, unknown.[29] Turf skippers, mainly from Groningen and Friesland went as far as Antwerpen and other Flemish cities to sell their cargo. After 1648 they served in the same way the markets of Emden, Bremen and Hamburg, whose forests had been destroyed during the Thirty-years war. Though considerable deposits of peat existed in the hinterlands of these cities they could not be exploited because these deposits were in the same position as the Peel, described in section 3. In relation to the overall picture of Dutch peat consumption the quantitative aspect of this turf export is not essential. However big it might have been during certain periods, it did contribute to the national income of the country, the more so, since the whole turf trade was apparently in Dutch hands. Besides there was this mutual compensation of turf exports and coal imports. Therefore both will be neglected in further considerations.

The next step is to translate the rated volumes of peat, summarized in table II, into labour requirements, transport requirements and heat contents. In high peat digging a 'day-work', performed by 6 to 7 men, generally contained 110 rated m^3 of peat.[30] The average annual peat production of 8 million m^3 from table II, was equal to about 72,500 'day-works', which required about 7 times as many, i.e. 500,000, man-days or when 300 working days are reckoned in one year, about 1,600 man-years. (Actually four times as many workers were required for peat digging, since this activity could only be practised during a period of about three months in spring and early summer. However, as seasonal workers did do other jobs during the rest of the year, throughout this study all labour requirements are expressed in man-years for the sake of simplicity and for mutual comparison).

No figures could be uncovered describing productivity in low peat winnings. However, we know that the cutting of the peat could only start after it had been dredged (requiring one man), puddled and trodden (requiring another man). High peat, on the other hand, could be cut directly in its natural position. It can be accepted, therefore, that labour requirements in low peateries were about three times as high as in high peateries. This is confirmed by turf prices.[31] Consequently the labour requirement for the processing of 7,5 million m^3 of low peat could have required $(3 \times 7.5 \times 1{,}600)/8 = 4{,}500$ man-years, making the grand total for both types of peat $1{,}600 + 4{,}500 = 6{,}100$ man-years. To complete the picture of labour needs in turf production it should be remembered that the peat had to be dried. Turning and piling up of turfs on the drying field was mainly done by women. As a guess 900 man-years per year could be attributed to these and other supplemental activities, bringing the total labour requirement of turf winning in the seventeenth century to about 7,000 man-years per year. Conversion figures to weights and heat equivalents for rated volumes of peat can be reckoned as follows: 110 m^3 of peat (1 day-work) give as an average ca 42 m^3 of piled up turf (or 65 m^3 of dumped turf) weighing 11,000 kg or 11 tons, while 1 kg of high peat turf has a heating value of about 3,700 kcal, this being 4,000 kcal for low peat turf (both medium quality) .[32] (The other mentioned figures are good approximations for turf of both origins). Volumes of stored turf are mentioned here only for the sake of completeness; the weights are more to the point for the calculation of comparative transport needs. So table III only contains the weights and heat-equivalents for the turf yields in the different regions (see again table I for fuller explanations). It is striking that the last figure of table III coincides with the earlier mentioned total fuel consumption around 1840, when population was one and a half times that of the seventeenth century but economic activities were at a low level.

TABLE III. Summary of estimated weight and heat-equivalent of turf consumption in the Netherlands in an average year- between 1600 and 1700

Region	peat m3/year	turf tons/year[a]	heat equivalent kcal[b]
I	5×10^6	0.50×10^6	$1,850 \times 10^9$
II	3×10^6	0.30×10^6	$1,110 \times 10^9$
high peat turf		0.80×10^6	$2,960 \times 10^9$
III	6×10^6	0.60×10^6	$2,400 \times 10^9$
IV	1.5×10^6	0.15×10^6	600×10^9
low peat turf		0.75×10^6	$3,000 \times 10^9$
grand total		1.55×10^6	$6,000 \times 10^9$

[a] 1 ton = 1,000 kg
[b] 3,700 kcal/kg for high peat turf and 4,000 kcal/kg for low peat turf

7. The importance of turf shipping

To appreciate the significance of turf in the seventeenth century world and of its easy transportability by water, two assumptions will be made in succession. The first one is that the Netherlands could *not* have used *any turf* in the seventeenth century, but would have had to produce an equal amount of energy mainly with fire-wood like other countries. In that case the Dutch would have had to practise forestry to satisfy their for that time enormous energy consumption. As the heatcontents of wood and turf are nearly equal, they would have had to produce 1.55

million tons of wood every year. The annual growth of forests in those days will have amounted to ca 2 ton per ha.[33] The Netherlands would, therefore, have needed a permanent forest reserve of 800,000 ha, which means that a quarter of the present area of the country would have had to have been covered completely with producing forest, in which every cut-down area would have had to have been replanted immediately. The labour requirements for such activities can only be guessed. In modern forest management one man per 75 ha is a normal standard. In those days, without mechanised tools and means of transport a standard of one man per 25 ha seems appropriate. This would bring the total labour requirement for fire-wood supply from organised forestry to 30,000 man-years per year. It is assumed that the transport and distribution of fire-wood require efforts equal to those computed for turf in the next paragraph.

The second assumption is that in the Netherlands *no coherent system of waterways* had existed. Then the turf transport would have had to have taken place by road, as in other countries. The calculations presented in table IV are intended to provide an impression of the magnitude of this transport problem.

The calculation combines the turf *production* estimates of table III and a rough allocation of turf *consumption*. The allocation is based on the fact that half of the seventeenth century population lived in Holland, where most of the economic activity occurred as well. The calculation in table IV also assumes that the influence of minor volumes destinated to cities in the northeast of the country is compensated by that of, equally small quantities going to Zeeland and other regions in the south. The calculated transport capacity of 240 × 10^6 tonkm per year can also be expressed as 800,000 tonkm per day over 300 working days.

Figures related to road transport possibilities under seventeenth century circumstances can be derived from the agricultural tradition of a hundred years ago. Then, to move a loaded wagon of 1 ton over unmetalled roads with a mean velocity of 4 km per hour, 2 horses were needed. Since a horse could work 6 hours a day, 2 teams were required

TABLE IV. Scheme of efforts to be made for turf transport in the Netherlands in an average year of the seventeenth century

From region	to	average distance (km)	weight of turf (tons)	transport capacity (tonkm)
I	cities of Holland and Utrecht	250	0.50×10^6	125×10^6
II + IV		200	0.45×10^6	90×10^6
III		40	0.60×10^6	24×10^6
			Total	240×10^6

to perform 50 tonkm in a l2-hours working-day. Providing the full 800,000 tonkm per day would therefore have required 4 × 800,000/50 = 64,000 horses. The empty wagons and the horses had to return, of course. We can assume that turf transport would have been part of a more general transport system. If we suppose that half of the wagons would have managed to find suiting return-freight and, further, that the extra loading and unloading times required for that would have been compensated by a somewhat greater velocity of the empty returning wagons, then 1.5 × 64,000 = 100,000 horses should be layed directly to the charge of turf transport. A daily working, medium sized horse needs 8 kg of hay, 4 kg of oats and some straw, in total ca 5,000 kg per year including 3,000 kg of hay and 1,500 kg of oats. Both of these latter quantities represented under seventeenth century conditions the yield of at least 1 ha. A modest estimate of the land needed to maintain a working horse is therefore 2 ha, which implies a total of 200,000 ha for the total required number of horses. This should be supplemented by 10 or 20% for breeding and nursing of young animals (a horse works from its third to its tenth year), which brings us to 230,000 ha. Since in those days even on the best soils only 40% of the cultivated area of a farm could be destinated to the growing of market-crops[34], a total cultivated area of 2.5 × 230,000 = 600,000 ha would have been involved.

This cultivated area in its turn would have been part of a region in which also dwelling centres, roads etc. occurred and especially waste lands. Even by the end of the eighteenth century one third of the country's total land area of about 3 million ha laid waste because it could not be reclaimed as long as modern chemical and technical means were lacking. For this reason the 600,000 ha of cultivated area would have represented at least 900,000 ha of geographical area, from which the forage produced in it, would have to be transported, again with horses, to the relaystations along the turfroutes. For 100,000 turfhorses at 50,000 kg each this means another 500,000 tons. If this supply would be moved over an average of 25 km (taking into account that the wagons had to return empty) it would ask for a transport capacity of another 25 × 10^6 tonkm per year, equal to 10% of the turf transport capacity itself. Ultimately, then the turf transport by road would have occupied 110,000 horses and, for their maintenance, the complete yield of market crops of 1.1 × 900,000 = 1 million ha or one third of the countries total area.

How many people would have been involved in these imaginary transport activities? True enough, on the long stretches not every turf wagon would have needed a driver, but on the other hand one should not forget stablemen at the relay-stations, people attending young horses, keeping up roads etc. When as an average 1.5 men are reckoned per 2 teams of working horses, this would result in a labour requirement of 1.5 × 110,000/4 = 40,000 man-year for the assumed turf transport by road. From these figures it is clear why other countries, depending on road transport, could not draw on their peat deposits in the seventeenth century. The enormous transport problem involved could only be tackled with the use of ships, as the following estimation shows. Round 1848 turf skippers from Hoogeveen and Meppel made as an average a good twenty trips per year each to Holland.[35] By reckoning the distance per trip at 200 km the yearly distance covered per skipper comes to 4,000 km, and the average daily performance over 300 working days amounts to 13 or 14 km. For their colleagues of two centuries before with their smaller ships, 12 km per day does not seem unreasonable. Since in those days the average size of ships in inland navigation was about 25 tons, the daily transport capacity of a turf vessel can be set at 300 tonkm. Using assumptions that conform to the calculations of horse numbers made above (introducing a factor 1.5 in connection with available return freight), 1.5 × 800,000/300 = 4,000 ships would have been needed for turf transport. Most of the skippers had their wife as only crew-member. Only on some of the bigger ships were two men involved. Keeping in mind that in the course of time people had to be employed in digging and keeping up canals and improving other water-ways, the total manpower involved in turf transport by water still would not have exceeded 1.5 × 4,000 = 6,000 man-years per year. Just as cartwrights etc. were overlooked in the calculations on road transport, the workers on shipyards are forgotten in this case.

8. The importance of wind-power

With regard to wind-power, the quantity of energy it produced is less interesting in the framework of this study than the degree to which it was able to replace manpower and energy yielding hectares. Wind-energy originates from two sources: stationery motion energy from windmills and mobile motion energy from sailing ships. For neither category could statistics relating to the whole country be found in literature relating to the seventeenth century. From personal communications[36] I have gained the impression that 3,000 to 4,000 wind-mills were operating in the Netherlands of the seventeenth century. From this total the few hundred polderdrainage windmills must be subtracted. However important they were to the Dutch economy by raising the quality of low lying land to a standard comparable with that of land found naturally in higher lying regions, they could not make any net contribution to the national energy supply. Subtracting these polder-mills from the total, about 3,000 are left consisting of flour- and oil-mills of local and regional service together with real industry-mills of many different types, working for the national and world markets. These 3,000 mills can be reckoned to have contributed to the national energy supply.

In section 1 it was mentioned that around 1900 a windmill had a capacity of 3.3 kW. Seventeenth century windmills will have been less effective. Let them be put at 2.5 kW as an average. This means an energy yield per working day of 2.5 × 24 = 60 kWh, or per year converted to kcal 300 × 60 × 859 kcal/kWh = 15 million kcal per mill. For 3,000 mills it amounts to a total of 45 milliard kcal, which indeed sinks into insignificance besides the 6,000 milliard kcal found for turf in table III. As a matter of fact the figure of 45 milliard looks even more unimportant in international comparison. Windmills (and watermills of course) also existed in other countries, although it can be taken for granted that their number per capita was nowhere as high as in the Republic. The favorable characteristics of its climate and landscape, the extensive transport facilities by water, which often allowed ships to reach the door of the mill itself, and the thriving industrial climate evoked by turf (see also section 9) all contributed to a comparatively high concentration of industrial windmills in the Republic. For the study of energy relations within this country it is interesting to investigate what the Dutch milling business meant as a substitute for human or animal labour.

A well fed man can, without hurting his health, give at best a continuous daily performance of not more than 0.6 kWh. Since the comparable figure for the stationary motion energy production of an average windmill was 60 kWh, its replacement with men would have required a gang of over 60/0.6 = 100 men. This means that other things remaining equal but without mills at least 3000 × 100 = 300,000 extra labouring people would have had to have been employed for the maintenance of an equal industrial production. If animal power (e.g. horse-mills) had been used instead of human power in the preceding exercise, the following calculations could be made. One farm horse of three years and older can perform 0.6 kW as a constant average. In a six-hour working day this gives 3.5 kWh. The performance of a wind-mill would answer to that of 60/3.5 = 17 horses; the replacement of all mills would have required 3,000 × 17 = 50,000 horses. The land required for the maintenance of these horses calculated in the same manner as for the fictitious turf transport by road (where 100,000 directly involved horses were found to ultimately require a geographical area of 1 million ha) amounts to 0.5 million ha, or another sixth of the total land area of the Netherlands. It is interesting to note how small a yield of stationary motion energy (only 45 milliard kcal per year) suffices to create such enormous savings in human and animal labour.

To appreciate the energetic importance of inland navigation an impression of its total volume is needed in the first place. In this case nothing more can be expected than a rough guess. Besides turf a great diversity of goods found its way by water. All together, they most likely represented many more tons in weight than the turf. On the other hand their average transported distances would have been shorter. One could perhaps double the 4,000 turf-ships computed above as an approximation of the total fleet of inland sailing vessels.[37] If, following our earlier calculations, these 8,000 ships are again assigned a productivity of 300 tonkm per day over 300 working days, they would have had a collective transport capacity of 720 × 106 tonkm per year. A global standard for energy need of a modern inland ship is 50 kcal per tonkm. Though it is not quite correct to apply this figure on the far smaller ships of those days, its use once again permits us to observe that the 36 milliard kcal needed for the 720×10^6 tonkm, is dwarfed by the turf figure. But is not the attraction of navigation as a substitute for road transport precisely its small energy requirement? Once again, the land and labour saving character of inland shipping should be stressed. The estimated size of the inland shipping fleet, double the number of turf ships, can be assumed to replace double the amounts of hectares and manpower computed for the imaginary turf transport by road. So, as 8,000 inland ships seems to be a modest estimate, total inland navigation can be reckoned to have saved at least a geographical area of 2 million hectares and 80,000 male workers.

9. The golden age born of turf

The seventeenth century Republic produced a, for that time, tremendously wide variety of goods and services, partly for inland consumption, partly to obtain on the world market those commodities which the country could not itself produce in sufficient abundance. This production was accomplished by the exertion of its inhabitants, by the application of additional energy in processing raw materials and by the manipulation of expedients resulting from these activities. However, in consequence of the exceptional geophysical construction of their territory, the Dutch were able to save human and animal energy to a degree unprecedented in those days.

The importance of their applying additional energy can best be appreciated by comparison with contemporary conditions elsewhere and with the present day conditions. To start with the latter, the yearly total of inanimate energy consumed in the seventeenth century Republic was computed at 6,000 (turf) + 45 (mills) + 36 (inland navigation) = over 6,000 milliard kcal for a population of a good 1.5 millions. This amounts to an annual consumption of 4 million kcal per capita. The comparable figure for the Netherlands in 1973 was 50 million kcal and for India 2 million kcal per capita. For the comparison with seventeenth century circumstances outside the Republic, tables V, VI and VII can be of use. It goes without saying that the presented figures must not be regarded as exact in view of the assumptions and estimations upon which they are based. They can however be looked upon as mutually comparable to a sufficient degree.

TABLE V. Approximating survey of labour and hectares the Netherlands spent on the acquisition of additional energy in the Golden Age.

For:	man-years per year	geographical area ha ×10^6
A. heating energy from turf	7,000[a]	none
B. mobile motion energy from inland navigation	12,000[b]	none
C. stationary motion navigation From windmills	3,000[c]	none

TABLE VI. Approximating survey of the sacrifices the Netherlands would have had to make in order to acquire equal energetic possibilities, without having the disposal of their special resources.

For:	man-years Per year	geographical area ha ×10^6
K. *heating energy* from firewood	30,000[d]	0.8[d]
L. *mobile motion energy* From horses (and wagons)	2,000[e] + p.m.[f]	2.0[e]
stationary motion navigation		
M. from human labour	300,000[e]	none
N. from horse-mills	p.m.[f]	0.5[e]

Explanation to tables V and VI:

[a] see section 6

[b] see section7: 6,000 for 4,000 ships means 12,000 for 8,000 ships (section 8); horse towed vessels are considered to be left out of the number of 8,000

[c] see section 8: 3,000 mills with one man per mill to keep it going day and night; other workers in mils were not occupied with winning of energy but only with applying it in the industrial production process.

[d] see section 7

[e] see section 8

[f] 'p.m.' stands for a great many people, in fact for the complete active rural population of the area mentioned in the right hand column. That area would not have been able to contribute to the national economy any other market crop but horse fodder. Therefore all its labour force has to be attributed to this economy.

TABLE VII. Summary of computed efforts needed to get the disposal of equivalent quantities of energy under different circumstances.

For:	man-years per year	geographical area ha ×10^6
X = C + K + L	113,000 + p.m.	2.8
Y = K + L + (M + N)/2	260,000 + p.m.	3.05
Z = A + B + C	22,000	none
(X + Y)/2 – Z	165,000 + p.m.	2.93

Confidence may also be given to their order of magnitude. The first two of the tables speak for themselves with the aid of the explanation presented in notes a-f. Table VII summarizes the results of all foregoing considerations and calculations. Situation X refers to an imaginary country (size, population and energy consumption equal to those of the Republic) *with* windmills but *without* navigable inland waterways and *without* access to turf. In situation Y conditions are the same as in X with the exception that all mills are missing as well. It is assumed that in this latter case half of the mills would be replaced by human, the other half by animal labour. Situation Z represents the actual situation in the seventeenth century Republic. As mills were used in all surrounding countries, though less frequently than in the Republic, intermediate circumstances (between X and Y) seem to offer the best base of comparison. This suggestion is presented in the term (X + Y) /2 in the bottom line of table VII. Subtracting situation Z yields the differences which show the savings in labour and in hectares the Republic was able to enjoy. It should be emphasized that the figure in the last column represents the Netherlands complete land area of ca 3 million hectares. This means that 'p.m.' in this bottom line (see note for explanation) stands for at least the whole active rural population of the Republic, while the other 165,000 can easily represent its active urban population.

In regard to heating energy the Dutch lived a style - measured to contemporary foreign criteria - as if they used the greater part of their territory for nothing else but energy production and distribution. They were apparently able to command energy sources that replaced 0.8 million ha of permanent forest and 1.0 million ha of area that should have produced fodder for turf horses. Under these conditions they could easily run industries based on *thermal* processes. Breweries, brick-, roof- and paving-tile, pipe-, stoneware- and faience-factories, salt refineries, madder- and chicory-works, bleachers, dyers and printers of textiles are all mentioned as being big turf consumers.[38] Other users of turf were furnaces, kilns, cookeries, bakeries, distilleries, drying-houses and roasters and smelters processing a great variety of materials and products, even charcoal burners applying turf to heat their wood-stocks.[39]

Thanks to the cheap fuel all these activities were able to produce goods that could easily compete on the international market. Add to this the cheap transport facilities by water, from which these products in their turn benefitted, and one has to expect a very profitable commercial climate along with the favourable industrial one, each pushing the other up. Under these circumstances one must also expect a relatively high price of labour, which stimulated, in turn, capital intensive investment. In this context and helped by the geophysical climate, the Dutch were able to make a special succes of designing and building dozens of types of industrial mills to run, for the first time in history, a large-scale industrial sector based on *dynamic* processes without human or animal force as the motor. It should be kept in mind that the building of a mill, and particularly a specialized industrial mill, must have been very expensive. As was stated before, such a development based on so high an energy consumption would have lead to impossible consequences without inland navigation and turf. According to the bottom line of table VII it would have absorbed the productive capacity of the whole territory of the country. In reality the Dutch could realize all this and at the same time keep all their fertile hectares for a normal, all-round agriculture. Indeed, they could even devote a portion of their land to the production of important raw materials for processing in their mills (e.g. colza).

It would not be correct to summarize this analysis with the observation that the Dutch lived as if their country was twice its actual size. A larger territory would have meant longer transport distances, consequently higher costs and thereby smaller possibilities of development. One should put it like this: the Dutch lived (again, measured by the standard of countries without turf and inland navigation) as if their country had two floors, as if every hectare yielded a double crop: one of that which was actually grown (on the ground level) and the other a full harvest of fire-wood and horse fodder (on the imaginary first floor).

How about the people? In this respect a similar phenomenon occurred. It was noticed before that the 165,000 + p.m. of table VII represent something like the complete active population of the country. Without turf and inland navigation this would again create an impossible situation: all inhabitants would have had to have occupied themselves with the winning and transporting of energy sources; nobody would have been left to apply this energy in industrial processes or to perform other social activities. Again, it would be misleading to conclude that the Republic acted as if it had twice its actual number of inhabitants. More people would have meant that the possibilities for development would have been fewer, because the provision with their primary needs of a double population would have absorbed a far greater part of the general resources. The situation can best be understood if one imagines that the Dutch lived as if each one of them led a double existence. In the first place they carried on with undivided attention their own professions (on the ground level) ; in the mean time everyone's alter ego seemed to perform a full job in nursing, harvesting and transporting the crops of the imaginary first floor. Compared with other countries the Republic offered its inhabitants in this way *twice doubled* opportunities for development, based on both the double apparent yield of its hectares and the double apparent achievement of its active population. This can explain the explosion of creative power, referred to in the introduction. Among the computed 165,000 + p.m. people we recognize those who manned ships and explored the world, who pursued commerce and science, who printed books and maps, who made arms and clocks, who painted or served other Muses, who pumped dry polders and pursued all the other activities, most of these lucrative activities at that, which helped to push the spiral of prosperity vigorously upward. But at the base of all this the sailing inland skipper with his deck-load of turf was holding the helm.

10. Conclusions

This study was motivated by the historical problem of why around 1600 the Republic assumed the mantle of leadership on the path of mankind's economic and social development. The answer is: because it was able to extensively apply inland navigation and, by that, to fall back on its peat deposits when everywhere (also in the Netherlands itself) deforestation had progressed to such an extent, that wood had become an expensive fuel. Its exceptional position becomes even more evident, when it is considered that at the beginning of the Dutch explosion of prosperity each one of the cities in the ring Amsterdam, Utrecht, Gouda, Rotterdam, Delft, Leiden, Haarlem had an abundance of easily transportable (low peat) turf of excellent quality within a few kilometers of its gates. No wonder, that the centre of gravity of economic development became located in this part of the country.

To round off the argument, the further developments are recalled in a broad outline. Toward the end of the seventeenth century the Republic started to loose its dominant position. Some of the reasons are: turf became gradually more expensive because of increasing difficulties in supplying it to the main centres of consumption.[40] Also, the application of wind energy in transport became more and more expensive to the Dutch, as harbours and rivers became shallower by silting. Examples of this added expense are the ship's 'camel', needed to drag vessels across the sandbank of Pampus near Amsterdam; and the costly dredgings in several other waterways and harbours. To these internal causes of retardation must be added a growing foreign competition, notably from the side of Britain, whose development was based on an increasing use of pit-coal. In the field of navigation the Dutch position was worsened still more severely, as most other countries did not have troubles with the depth of their harbours. They could turn to better sailing, heavier-draught ships, which made mobile motion energy even cheaper to them. Just as it is unjustified to ascribe exceptional qualities to the Dutch at the origin of the Golden Age, so their slowly stepping back from the van of technological and social progress should not be blamed on their failing judgment or initiative. It was not the people who changed but the circumstances.

These observations concerning Dutch history can be generalized to the rest of the world. As was already stated, the British took over the torch when a more advanced technology made the winning, distribution and application of their coal gradually more easy. In addition they were able to improve their navigation. As an energy-bearer coal had advantages over turf; it is more compact and easier to handle, therefore asking less effort per kcal. What can be said for coal when compared to turf applies with equal strength to oil and natural gas, in comparising to coal. On oil and natural gas the succession of the United States to the leadership of economic development was in large part founded. Another important feature in this latter case was the cheap maintenance energy derived from the exploitation of vast and initially fertile prairie-lands. Finally, the flourishing of Western Europe and Japan after 1950 can be ascribed to the discovery of quantities of easily exploitable oil in the technologically undeveloped Middle-East. This oil-stream sought its way to places where sufficiently advanced knowledge was available to make it profitable.

These considerations lead to the following general rule:

In a given period the greatest prosperity (with opportunities for the advancement of technological and social attainments) arises in the area, where - depending on geophysical circumstances governing the winning and transport of energy – the acquisition and application effort (in the light of already available skill) per serviceable energy-unit is the smallest. The economic decline of an area is inevitable as soon as these circumstances become relatively less favourable in that area.

Abundant evidence to support the validity of this general rule can be traced in the history of mankind. If somewhere a less troublesome, therefore more profitable, possibility of energy-acquisition arises, that fits into the development-pattern already reached, then prosperity increases there. Here are a few examples: agriculture was invented on fertile, naturally well-drained, loess-soils with good water-holding capacity; the steam-engine was invented in a coal-mining area; tracts of fertile land, streams of irrigation water, deposits of fuel, natural harbours were discovered, often stumbled upon unexpectedly. They determined the attainability and profitability of maintenance-, heating- and motion energy and consequently the outline of the distribution of prosperity on the earth's surface. The reverse also occurred. Lands eroded, irrigated areas grew saline, harbours silted up, mines had to be deepened, all of which made energy application more difficult and less profitable.

Some final remarks are due in this context. Of course, the general rule presented here only gives the rough background of historical phenomena. In its application all kinds of details have to be filled in in accordance with specific political, religious and other interhuman influences. Geology, geography, topography, climatology, hydrology, however, are setting the stage and delimiting the boundaries of the possible. Perhaps the most important feature to be stressed is, that for understanding the pace of development it is *not the volume* of an energy-deposit which is of primary importance, but the smallness of the efforts for its exploitation and application. Remember the contrast- between the historical developments of Dutch and other European peats! Quantities of energy-bearers only come into the picture when the continuation of an already attained thriving situation is at issue. The smaller the volume of easily attainable energy, the sooner recourse has to be had to more costly ways of energy acquisition, with its apparently inevitable adverse consequences. Extrapolation of the general rule to the future raises the intriguing question of what path the future of mankind will take, given the increasing difficulties in the obtaining of energy, which have now, for the first time in history, arisen on a world wide scale.

February, 1976
Department of Land and Water Use
Agricultural University, Wageningen.

NOTES

1. A.M. van der Woude, *Het Noorderkwartier*, A.A.G. Bijdragen 16, 3 vols., 858 p., Wageningen 1972. J.A. Faber, *Drie eeuwen Friesland*, A.A.G. Bijdragen 17, 2 vols., 760 p., Wageningen 1972 (A broad recapitulation of these investigations in English: A.M. van der Woude, 'The A.A.G. Bijdragen and the study of Dutch rural history,' *Journal of European Economic History* 4 (1975) pp. 225 – 242. Jan de Vries, *The Dutch rural economy in the Golden Age 1500 – 1700*, 316 p., New Haven 1974.
2. Export prohibitions for mills and mill parts can be regarded as indirect proof.
3. H. Besselaar, *Molens van Nederland*, Amsterdam 1974, p. 22.
4. J.G. de Roever, *Jan Adriaenszoon Leeghwater*, Amsterdam 1944, p.51.
5. C. Daey-Ouwens in: *Energie*, Studium Generale kursus, voorjaar 1973, T.H. Eindhoven 1973, p. 76.
6. A. Hausding, *Handbuch der Torfgewinnung und Torfverwertung*, Berlin 1917, p. 15. The author mentions the following figures in millions of hectares: Northern Germany 2.4, Southern Germany 0.2, Austria 0.4, Sweden 5.0, Norway 1.0 to 1.5, Denmark 0.1, Finland 10.0 and Russia 17.0
7. Because peat business as meant in this study is an uniquely Dutch activity, it is difficult to describe it in English. For the sake of clarity, we make the following distinctions:
   peat – the geological formation,
   turf – material noun for the dried substance,
   a turf – a block of dried peat,
   low peat VS high peat – refer to its position in respect to the general water table of the area. This distinction does not coincide with bog peat and moor peat, as the latter distinction refers to the growing conditions (conf. eutrophic vs. oligotrophic),
   low peat turf – in general the same as dredged turf, though in low peat areas some of the peat was situated so high above water that it could be cut or dug. Most of this upper layer disappeared however before 1500,
   high peat turf – in general the same as cut or dug turf, though in high peat areas some of the peat stays under water. From the nineteenth century on these soaked layers might be dredged, but seventeenth century cutters left them in place.
8. P. van Schaik, 'De economische betekenis van de turfwinning in Nederland,' *Economisch-Historisch Jaarboek* 32 (1969) pp. 170 – 171.
9. R. Schuiling, *Nederland, Handboek der aardrijkskund*, 2 vols., Zwolle 1934, p. I 711 and I 723 for dating of canals.
10. *Het veen en zijn ontginning* (edited by the Nederlandsche Heidemaatschappij), Arnhem 1942, p. 56.
11. G.J.A. Mulder, *Handboek der geografie van Nederland*. 6 vols., Zwolle 1949 – 1959, p. V 194.
    A review is presented of the different layers of which the profile is composed. Aggregating the maxima and minima indicated for the layers, the height of the profile runs between 2.62 and 6.35 m, the average being 4.5 m.
12. See 11, p. V 244.
13. See 11, p. IV 304. A table is given of all lakes south of the IJ pumped dry between 1610 and 1941. Their total area amounts to 78,143 ha. Some of them are known to have been natural lakes (often evident from the names: 'meer' instead of 'plas'). Subtracting the total area of these natural lakes amounting to 27,230 ha, leaves 51,000 ha. The last figure is too small because many of the natural lakes are known to have been widened by peat dredging. Artificial lakes covering 8,500 ha continue to exist today. North of the IJ some 1,500 ha have been dredged out. Thus the total area for this part of the country comes to > 51,000 + 8,500 + 1,500 = > 61,00 ha.

14. P.R. Bos, *Schoolatlas der gehele aarde*, 35th ed., Groningen 1936. On its map 13 surface level marks are indicated for 21 spots in pumped dry artificial lakes. They average at 4.3 m below mean sea level.
15. See 11, pp. V 71 – 72. A quantitative enumeration of 'veenpolders' (peat polders) in Friesland is given. Total area 29,000 ha in the south-eastern part of the province. Some other partly dredged-out areas more to the north are only mentioned. They consist of real mixtures of land and water. A rough estimation based on the map indicates ca 2,000 ha of land-loss in these areas. The Overijssel low peat area forms a coherent rectangle of about 16,500 ha. Thus the total area of region IV adds up to 29,000 + ca 2,000 + ca 16,500 = 47,500 ha.
16. See 11, pp. V 141 – 155 for historical data; numbers of hectares cited were measured form the map.
17. See 11, pp. V 42 – 43 for data on Friesland; see 11, pp. V 240 – 242 for data on Drente; see 11, pp. IV 269 – 270 for data on Overijssel.
18. See 11, p. V 71 for data on Friesland; see 11, pp. VI 248, 249 and 300 for data on Overijssel.
    Also: *Beschijving van de Provincie Overijssel behorende bij de Waterstaatskaart*, Algemene Dienst van de Rijkswaterstaat, 's Gravenhage 1937, pp. 19 and 107.
19. F.J. DE BOER, *Skiednis fan de lege feanterij yn Opsterlân en Smellingerlân*, Ljouwert 1954, p. 19.
20. See 11, p. V 71; see 19, pp. 19 – 32 for a full description of different methods of low-peat winning.
21. See 19, p. 56
22. See 11, pp. IV 298 – 299.
23. See 8, p. 146. According to VAN SCHAIK peat dredging in the west of the country did not really start before 1530. He presumes that before that date peat only was dug. This would imply a tremendous expansion of dredging activity after 1530 since it is known that several villages were threatened by artificial lakes around 1600. It also would mean that the lower parts of the input lines of figure 2 would be far steeper and that consequently the peat consumption in the seventeenth century would have been considerably more than the 200 ha/year estimate according to the description in the text.
24. P. VAN SCHAIK, De economische betekenis van de turfwinning in Nederland, *Economisch-Historisch Jaarboek* 33 (1971) p. 227.
25. J. TEIJL, 'Brandstofaccijns en nijverheid in Nederland gedurende de periode 1834 – 1864,' in: *Lof der Historie; Opstellen over geschiedenis en maatschappij*, Rotterdam 1973, pp. 153 – 183. On p. 164 it is mentioned that the total of $6{,}084 \times 10^9$ kcal included 1,040 from low-peat turf, 2,561 from high peat turf and $2{,}483 \times 10^9$ kcal from coal.
26. See 24, p. 229
27. As a consequence of improvements in winning and transportation procedures coal must have become cheaper between the middle of the seventeenth and the middle of the nineteenth centuries. Moreover, since coal could be used to produce motion energy in the 19th century, it had become, trough its versatility, more profitable than peat. The $6{,}084 \times 10^9$ kcal did contain a portion of motion energy. The rise in turf prices after 1750, claimed to have been considerable, must be due to the near exhaustion of the most productive peat deposits. Concerning region III see figure 2, in which the output curves become more flat. The description of region 1 in section 5 demonstrates that the most easily accessible part of it was exhausted by then.
28. See 24, p. 228
29. See 8, pp. 198 – 199.
30. See 10, p. 44.
31. See 25, p. 169. Turf prices on the spot in the peatery are given for the middle of the nineteenth century: high peat turf 14 to 20 cents per turf-cask (200 liters), low peat 40 to 60 cents. Since labour costs are the chief determinants of spot prices,

these prices confirm a 1 to 3 labour ratio. The more expensive low peat turf had better burning qualities. It was used for domestic heating. High peat turf was nearly synonymous with industry turf. The difference is similar to the one between anthracite and bituminous coal.

32. See 10, p. 44 and see 25, p. 181.
33. Data on forest management are mainly based on personal communications from Ir. J.J. Westra of the Department of Forestry of the Agricultural University, Wageningen.
34. C. BAARS, *De geschiedenis van de landbouw in de Beijerlanden*, Wageningen 1973, p. 130.
35. See 8, p. 196.
36. Inquiries were made with the society 'De Hollandsche Molen' at Amsterdam. They gave as a maximum the figure of 3,000 or 4,000, stressing that there were rather few polder-mills in those days. Prof. A.M. van der Woude in a personal communication made some approximating extrapolations based on the few known figures. He agrees with the total of 3,000 to 4,000 and distinguishes ca 1,800 windmills of local and regional importance, ca 1,500 industrial mills and some 500 polder-mills. To stay on the safe side the total of mills contributing to the producing capacity (including local industries) was put at 3,000.
37. See 8, p. 197. VAN SCHAIK comes to the conclusion that a large, if not the largest part of inland navigation in those days on the Zuiderzee can be ascribed to turf shipping. The proportion of other cargo in the mutual traffic between the cities in the western part of the country and between these cities and their surroundings (food supplies, industrial goods) must have been greater than in the trans-Zuiderzee traffic.
38. See 24, pp. 202 – 210.
39. See 24, p. 226.
40. These difficulties not only increased when turf provision was shifted to peat deposits in distant parts of the country, but also from the necessities of deeper dredging, of extending approach canals to and within peat areas and of other circumstances raising labour requirements per energy-unit. In addition to the already mentioned considerable rise of turf prices in the second half of the eighteenth century there was a gradual rise from the sixteenth century on. Relative turf prices in the Republic were (see 24, p. 223): 1585 – 1589 = 100; 1600-1604 = 145; 1665 – 1669 = 284.

    This effect cannot be ascribed to rising wages. BAARS (see 34, pp. 193 – 194) showed that wages of agricultural labourers remained constant at least from the beginning of the seventeenth to the middle of the nineteenth century. Seasonal workers in the peateries and on the farm were largely the same people. So it is not likely that wages in the peateries showed substantial changes over time either, before 1850.

IPS Commission VIII reproduced this text from:

Afdeling Agrarische Geschiedenis, Landbouwhogeschool

A.A.G. BIJDRAGEN 21, pp. 3 – 31

WAGENINGEN 1978

IPS Commission VIII gratefully acknowledges the help from Annelies Veldman