Institutional constraints on knowledge management:

Energy efficiency and mobility in Hungary 1968-1989

Mária Hidvégi

The wide-ranging and profound impact of energy supply on innovation and long-term economic growth has recently been brought into the theoretical framework of energy development blocks.[1] It makes more clear why energy transitions offer a chance for peripheral economies to catch up.[2] However, these transitions make gaps in the resource and knowledge base particularly obvious. My project aims to contribute to the clarification of the interrelations of energy transition and structural economic change in (semi-)peripheral economies, more precisely how knowledge management in national energy policies influence their innovative capacity.

The current energy transition requires an efficient national knowledge management to meet the challenges of the energy trilemma[3] according to specific local resource endowments. The knowledge and capital -intensity of investments into energy supply and transport infrastructure narrow the number of choices for future developments. Increasing the efficiency of knowledge management considering energy supply is therefore seminal to help structural economic change.

Hungary being a country lacking natural resources, energy security was a main objective in its economic policy from the interwar era, considerable knowledge was produced in national energy management, also related to the development of the transport infrastructure.[4] The Diesel rail car and the mini car programs highlight however, an interrelated set of problems due to a lack of harmonizing goals of national energy supply and the development of the transport infrastructure, ultimately diminishing growth potential in crucial sectors and lowering the efficiency of energy rationalization.[5] In this short case study, I will take the example of the Diesel programme in socialist Hungary to investigate the influence of energy management on the innovative capacity and competitiveness of the main producer.

My previous research into the strategies of the two leading companies of the Hungarian electro-technical industry, Tungsram and Ganz & Co. and the Diesel rail car development in Hungary till 1949 as a starting point[6] With professor Nikolaus Wolf we investigated political and economic constraints of electrification in Central Eastern Europe 1919 – 1939 and re-assessed its achievement. The interwar era will be shortly considered as a point of reference for assessing the energy policy of Socialist Hungary. The analysis of the Socialist time period is based on primary sources about economic policy decision making and about engine development by Ganz & Co.

From 1959, after its merger with the machine building factory of the Hungarian State Railways, Ganz & Co. was called Ganz-Mávag. In 1946, Ganz & Co. was among the first five companies to be taken over into national management in order to meet the reparation duties of Hungary – as it was officially states. Practically, Ganz & Co. was nationalized a few months or years earlier than the rest of Hungarian industry. Though the planned economy strictly limited the room of manoeuvre of the directors there

[1] Enflo et al. 2008; Kander et al. 2013
[2] Perez 1988, 92-94
[3] World Energy Council 2015
[4] Haidegger 1938; Verebély 1935
[5] Hegedűs 2000
[6] Hidvégi 2014; Hidvégi 2016

was some scope for operational decision making. In 1968 a so-called new economic mechanism was introduced in order to reduce inefficiencies of the planned economy and enhance competitiveness by enlarging the scope of managerial freedom. Instead of one and five year plans, the party and the government wished to direct nationalized companies and the socialist industry more by prices. Profit, not fulfilling the plans was to decide on the success of the organisations. Though this new economic order could not change the path of development without a systemic political change the investigations into the constraints on economic development had left their mark on economic policy making.

The paper is divided in the following sections. First, I briefly outline the achievements and constraints of national energy management in post-WWII Hungary. Second, Diesel rail cars as a … Third, main turning points Fourth, problems Fifth, conclusions

Energy policy in post-1945 Hungary: Achievements and constraints

After the dissolution of the Austro-Hungarian Monarchy Hungary became a small open economy. Beyond the loss of the direct connection to Austria, nearly 2/3 of the territory of the Hungarian Kingdom was lost, 60 % of the population and a large part of the energy resources with it. Access to the hard coal deposits of the Monarchy was lost. The forests and streams in the Carpathians, the largest part of water power resources of Hungary and all known oil and gas fields remained outside the new borders. The urge to revise the territorial decisions made the government join forces with Nazi Germany. Hungary lost the WWII the consequences of which were equally devastating both in economic and human terms. More than 40 % of national capital was devastated during the war. Above a million people of a population of just over 9 million died. Hyperinflation, the heavy burden of reparation deliveries and hindrances in international trade relented the process of capital accumulation in the country that had not received substantial financial help for recovery. Despite hopes for a political status more or less as Finland enjoyed, in a few years Hungary was integrated into the Soviet block. This asymmetric hegemonic position has had a profound impact on her energy policy ever since.

Sparse natural resources made energy security a main objective in Hungarian economic policy from the interwar era. Security meant an autarchic energy supply as long as possible both for strategic reasons and for reducing the passivity of the trade balance. Considerable knowledge was produced in national energy management, also related to the development of the transport infrastructure.[7] Experts agreed on the necessity of creating a national electric power grid as a key to improve the efficiency of using basic energy carriers. The power grid was to be based on a few large power centers fueled by the low quality coal remained within the new borders with additional seasonal supply by small water power centers. The single largest water power resource of the country, the Danube could not be tapped on adequately due to political tensions among Hungary and Czechoslovakia. Capital scarcity hindered the creation of a national power grid. All major towns had however, enjoyed at least public lighting as the first benefit of electricity. The government co-financed investigations of the oil and gas deposits of the country. Financial support was given to the development of furnaces using low quality coal, coal hydrogenation and the development of Diesel rail cars by Ganz & Co., all in order to economize on the consumption of imported black coal.

The main achievement of the planned economy, which was gradually implemented until 1949, was the creation of a national electric power grid. Basically it meant connecting villages in rural Hungary to the power supply system, eliminating the smallest, inefficient power stations and building the missing part

[7] Haidegger 1938; Verebély 1935

of the transmission network. Thereby the foundation for a higher efficiency in energy production and consumption was laid and unified, affordable prices became a reality. Another achievement was securing energy supply almost completely from domestic sources until the revolution in 1956.

Ratio of net import in energy supply

Energy carriers	1938	1949	1955	1960	
Primary	5,1	2,2	3,9	19,1	
Of which oil	3,4	-0,3	0,7	10,9	
Secondary	5,4	6,8	7,9	4,5*	
Total	10,5	9,0	11,8	23,6	

*1961 import constituted 5,9% of total electricity consumption Kerényi A. Ödön, A villamosenergia csere nemzetközi alakulása Európában (1961. I. 1. állapot), OMFB 1962. Május. MNL_ XIX-A-I6-j OT Ajtai Miklós 22. doboz

Source: Orosz, László, A hazai energiatermelés és –felhasználás struktúrája. *Statisztikai Szemle 40* (1961) 12, p. 1210

The achievement was paired by serious constraints on the improvement of the efficiency of the production, transmission and consumption of energy mainly due to capital scarcity for example neglecting the replacement of 50-60 years old furnaces. The picture is even far less bright if we consider the reasons for this situation, the price of it and the speed of the shift towards more efficient energy carriers.

Energy security was indeed the main concern of energy policy in post-war Hungary as well. First, energy resources were extracted at a high speed to restart production and to meet the reparation duties. Both the share of energy-intensive products in the expected deliveries and the fines for not meeting deadlines for delivery were very high. In 1956-1957 1,27 % of the national growing demand from domestic supply originated in coal deposit was extracted compared to the speed of yearly extraction in Austria 0,29 % and the Federal Republic of Germany 0,18 or Czechoslovakia 0,38 and Poland 0,10.[8]

Second, Soviet-Hungarian "joint ventures" such as the former Hungarian-American Oil Company constituted another, very important channel of direct resource extraction.[9]

Third, Hungary simply needed to use her domestic energy resources however expensive their production in international comparison was and however clear the strategic loss was as in absence of trade agreements Hungary could not import energy or earn the necessary hard currency to pay for it. Steam traction had constituted such a necessity. The production capacities of Ganz & Co., a pioneer of Diesel technology for the motorisation of the railways, were mainly used for the reparation deliveries and for export. The capital intensity of the electrification of the railways delayed such investments till the 1960s. As long as the demand of the railways and the electricity generation in the thermal power stations required it, the extraction of coal could not be stopped. This necessity appeared after the oil shocks again particularly clear when highly inefficient and expensive domestic coal was still a better option than not being able to pay hard currency, that is US-dollar, for coal or oil.

Fourth, the energy demand of the economy rose due to a structural change of industrial production towards heavy and military industry. If we take into account that in less than ten years the ratio of heavy and military industry had grown considerably the fact of meeting demand mostly of domestic

[8] Orosz 1961, 1206-1207

[9] Borhi 2005

supply will appear as the achievement as it was. For example, in the mid-1950s, bauxite extraction and aluminium production used over 10 % of yearly consumption of electric energy Hungary was expected to develop and keep running on a high scale to supply the COMECON-partners. Though the first two constraints did not play a role from the middle of 1950s, the latter two remained constant. (Figures for changes in industrial structure and improving energy intensity of GDP).

The revolution in 1956 was then closely linked to a breakdown of the national energy supply. Hungary received emergency help in form of electricity. Comecon-partners were however far less ready to guarantee long-term, large-scale orders for less energy-intensive products that would have helped the country slowly redirect its industrial structure according to its natural resource endowments.[10]

The price for domestic supply under such circumstances was not only paid in a high speed of resource extraction and neglected investments into the upkeep of the production capacity of mines and oil fields. At least as important was the considerable delay in the shift towards more efficient energy carriers as shown in the figures of the proportions of basic energy carriers in Hungary's energy supply.

Proportions of the production of basic energy carriers according to their fuel value

Energy carriers	1938	1949	1955	1960
Coal	86,9	79,5	77,1	83,4
Oil	0,9	8,6	16,2	11,6
Gas	0,1	3,9	3,1	1,9
Wood	12,1	7,9	3,3	2,9
Lignite	0,0	0,1	0,3	0,1
Water	0,0	0,0	0,0	0,1
total	100,0	100,0	100,0	100,0

Source: Orosz, László, A hazai energiatermelés és –felhasználás struktúrája. *Statisztikai Szemle* 40 (1961) 12, p. 1205

Proportions of consumption of basic energy carriers according to their fuel value

Energy carriers	1938	1949	1955	1960
Coal	82,4	77,9	75,7	73,8
Oil	4,3	8,8	17,1	20,1
Gas	0,1	3,8	3,0	2,9
Wood	13,2	9,4	3,9	3,0
Lignite	0,0	0,1	0,3	0,1
Water	0,0	0,0	0,0	0,1
total	100,0	100,0	100,0	100,0

Source: Orosz, László, A hazai energiatermelés és –felhasználás struktúrája. *Statisztikai Szemle* 40 (1961) 12, p. 1207

The shift towards oil and gas, nuclear and renewable energies was relented by the high number of employees in mining (danger of unemployment), the costs of R+D for turning thermal energy production and more efficient (HÖKI) which reduced resources to be invested in R + D into other energy carriers. Though negotiations in preparation of the 1968 economic reform make it clear that one priority was the adjustment of industrial production to the resource endowment of the country and turning export into the "First World" more profitable. Electro-technical and mechanical machinery, among them vehicles, telecommunication and vacuum technical products were considered as product

[10] Javaslatok távlati energiapolitikájára, a KGST szerepére. SZIGORÚAN TITKOS! Javaslatok a KGST legközelebbi VIII. varsói ülésszakának előkészítésére. 1957 januar masodik fel´ere összehivando. Budapest, 1956. december 21 MNL XIX-A-16-i. 1. doboz. Géppel írt eredeti tisztázat

groups in this line. How did knowledge management in energy policy restrained the realisation of such hopes?

Shortcomings of knowledge management in energy policy

National energy management was a complex field of knowledge composed of technological, juridical, administrative, economic and environmental issues. The management of this field of knowledge therefore required careful consideration of interrelations among various sectors. The main centres of production had been

party and government authorities such as the National Planning Office, the (National Technical Development Committee, Országos Műszaki Fejlesztési Bizottság OMFB) and an office of the Ministry for Industry translating literature,

specialized research institutes such as the Electrical Energy Research Institute (VEIKI),

the Institute of Economics and the Institute of World Economics of the National Academy of Science[11],

the Hungarian Electrical Trust (Magyar Villamos Művek Tröszt) (Central Organisation of the Hungarian Power Centres)

and the Statistical Office.

Responsibilities among these groups were not clearly defined and communication processes not routinized.

One achievement of the planned economy was to centralize applied research in form of specified research institutes such as the Electrical Energy Research Institute. In the early years, however such institutes typically suffered from the heavy toll of the WWII on qualified people and from the coercion applied by the authorities. The centralized research institute of the telecommunication industry constitutes a prime example for it. Tungsram the producer of light bulbs and radio valves had to send many of the engineers to the newly founded central organisation putting the fulfilment of its own production plans into danger which in turn could be used against the company's management and as an "explanation" for nationalising the company. Naturally, it took time until such institutes produced tangible results. However impressive the list of the cases solved by the Electrical Research Institute are the difficulties resulting from the scope of the field to cover (from optimising the production, transmission and use of both thermal energy and electrical power) and the material constraints (such as the number of computers) are far too obvious. Restraining public financial support in the 1950s or making such institutes yield a financial profit as part of the new economic reform constituted major changes for the organisation of research such institutes had to adjust.[12]

Though the system of planning and forecasting energy demand developed[13], the national plans regularly took the costs of energy supply account far too moderately. In consequence, the costs of replacement and development had been underestimated and many investments were not finished.[14]

[11] MTA KTI 1981
[12] MNL OMFBElnöki iratok such as 46 – 47 d, 193_d, 214 d all from 1966-1969
[13] Kovács 1973; Papp and Réczey 1958; Teőke Géza 1969
[14] Erdősi Pál 1980

One basic problem that became seminal from the late 1960s was not taking into account how much dollar had to be earned in export to buy one unit of energy.

An alimentation of Hungary by cheap oil and gas only became a reality after the completion of the COMECON transmission cables and oil and gas pipelines from the late 1960s onwards. The Soviet Union wished to profit from the price development and preferred convertible export resp. expected the Socialist countries to pay in dollar. The energy intensity of industrial production in Hungary grew to the forced restructuring of industrial production directly after WWII and it was perpetuated by the short but formative period of cheap oil and gas. Industry and households alike were not aware of the real costs of energy supply, subsidized prices did not force the realization of the necessity of structural change. Energy experts presented concepts of enhancing energy efficiency already in the early 1950s. Energy policy did not make considerable use of such plans for nearly two decades and once it did, within a short time the whole system of supporting energy efficient technologies had been changed.

Despite many years' struggling Hungary could not achieve COMECON cooperation in generating water power on the Danube. The only alternative for coal was nuclear power. Though a first small nuclear power station was built in the early 1950s for research and educational purpose, the nuclear power station large enough to finally supply 40 % of the country's demand on electric energy started production in 1982.

Vehicle industry

As the Diesel rail car development in interwar Hungary exemplifies, vehicle production may contribute to answering the challenge of energy transitions. The influence of the energy supply is directly felt in this branch.[15] Transport is a major factor in direct energy consumption the costs of which re-appear in the production costs of all sectors and in the costs and quality of living. The development of the transport infrastructure in harmony with the energy resource endowment of a country and strategic plans about national energy supply provides therefore an opportunity for economic growth in various channels. Most directly, such a coordination among the fields of energy policy and transport infrastructure development may provide a home market furthering the growth of a vehicle industry.

In Hungary, the interwar era was characterized by a search for the most efficient use of low-quality coal in national energy supply and the replacement of wood and high-quality coal, the country mostly lost due to the territorial changes, by other, more efficient energy carriers as far as possible. Large-scale electrification and motorization were the key factors in this shift towards a transition from coal to oil and electricity. With Nikolaus Wolf we prepared a paper about the main characteristic of electrification, the achievements and shortcomings of this process, therefore I won't go into details here.

When in the 1930s the Hungarian State Railways extended their diesel railcar services they provided a solution to the problems arising from Hungary's new borders such as transport loops within the urban network and a shortage of high quality coal. The dire state of public finances strictly limited the extent and pace of investment into the modernization of the railways. However, orders on different types of cars induced product development and the diesel rail car service of the Hungarian State Railways provided both valuable experience for product and service development and reputation for the Ganz-Jendrassik railcars. The new diesel railcar technology exemplified the room for manoeuvre that even

[15] Power to the people

small and poor countries possessed for boosting innovation and sustaining national champions in times of protectionist policies and obstacles to capital import, too.[16]

In Socialist Hungary hopes had been high to capitalise on the reputation on the Ganz-Jendrassik Diesel rail cars and of the company, Ganz & Co., as a pioneer of Diesel technology for rail transport. Hungary was basically left untouched by the feverish development of the vehicle industry induced by the WWII in the Allied countries. Despite that, a highly ambitious project was outlined in late 1946 – early 1947. 4 new engine groups were to be developed – all at once.[17] The Diesel engines were to be used in rail and road transport and in shipping as well. Ganz & Co. was to play the central role in development. A range of authorities such as the National Planning Office, the coordinative office of the nationalised companies of heavy industry (NIK), the Ministry for Trade, and the Hungarian State Railways participated at the preparation of the plans. A couple of companies with more or less experience in vehicle production were chosen for production and occasionally for cooperation in development (Vagon factory Györ (MVG), Ikarus, Hofherr-Schrantz-Clayton-Schuttlework, Láng Machine building factory, Autóbuszüzem).[18] In spite of highest political support and high financial commitment, the project failed. As you may guess, the project failed. The main reason was certainly the far too ambitious goal compared to the R + D capacity of the Ganz engineers.[19] Many other factors played an important part as well that deserve our attention in order to recognise systemic problems of knowledge management.

The first problem was a lack of coordination between strategic goals of energy management, industrial development and the development of the transport infrastructure. Engine development for Diesel rail traction and diesel rail car development did constitute a line of development with the chance for 1) reducing the dependence on the import of high quality coal, 2) developing a product group that capitalised on home-grown industrial experience and international reputation and 3) contributing to answer existing demands towards the ailing transport system. Diesel rail engines and cars had a chance to become competitive on emerging markets at least as large deliveries to Argentina, Egypt etc. demonstrated. In my opinion, the minicar program constituted a similarly well-tailored idea. Minicars with hybrid, electrical and internal combustion engines were to answer the growing demand for individual mobility in the squeeze of shortage of fuel; they may have found their consumers well beyond the borders, too.[20] Instead of focusing rigorously on these two lines, Diesel engines were to be constructed for road transport and shipping as well, support to development such as the goals in both lines were far from constant. In eager expectation of success, the central foreign trade organisation sold many engines before the prototype was built, or simply resources were not allocated to finish innovation processes.

The second problem was a lack of strategic planning in the midst of too much planning. In the immediate post-war years, the production capacities of Ganz & Co. were mostly occupied by the reparation deliveries. This proportion, however, naturally declined during the following years leaving room for the Diesel engine development and the production of Diesel engines and diesel rail cars for export. Very soon, a problem identified at the eve of the WWII, re-appeared and was all prevailing as late as in the late 1960s. Ganz & Co. did not produce spare parts to the engines and rail cars parallel to their first production. In 1939, the technical manager of Ganz & Co. proposed to introduce a system of

[16] Hidvégi 2016 see the list of secondary literature there

[17] More about the Diesel engines to be developed for road transport: Germuska and Honvári 2014; engine development in Ganz & Co. and Ganz-MAVAG Tárnoki József; Ganz rail cars Szécsey 2006

[18] Ganz Holding Zrt. Company Archives Engine development department Dossier 19.8 Gombás Tibor okl. Gepeszmernök, Ganz Vagon- es Gepgyar jegyzete a Dieselmotorgyartas körülmenyeiröl 1955. 10.8.

[19] Somogyi 2010

[20] Négyesi 2012

production and delivery of spare parts using General Motors and other large vehicle producers' example. The introduction of the planned economy constituted a tabula rasa in this respect as if the memory of the company had been completely wiped out. Spare parts did not constitute part of the yearly production plans dictated by the National Planning Office. What was not included into the yearly plans could only be produced from material and by people the company had to apply for separately in every single case and the applications were allowed or were turned down.[21] Though the delivery of spare parts was a lucrative business for Ganz the management did not get room to develop it.

The third problem was an ambiguous attitude towards buying and selling licences. In the case of the first party officials feared of dependency, an outflow of hard currency, cheating, and a low return on investment. In case of selling licences they feared of selling unique knowledge. The persecution of the general manager of Ganz & Co., György (Georg) Jendrassik for selling the license on Diesel rail cars to Sentinel, a British machine building company in the hope of a quick return to the world market while the reparation deliveries consumed all the remaining production capacities of his company is a telling example. In the mid-1960s, Hungary invested a much lower share of her yearly R + D budget on buying licences than the industrialized small countries of Western Europe, complained the Ministry for Metallurgical Industry and Mechanical Engineering.[22] Knowing of the COCOM-lists and political restraints East-West co-operation such a finding should not have appeared as a unique problem of the country. Nevertheless, the officials put their finger on a major point. The Hungarian industry simply produced such a large range of products and most of them using local technology that no specialisation was possible. COMECON-co-operation in research, specialization of production and as a consequence, intra-industry trade, remained far below expectations, too. For example in 1964 only 2,7 % of the production of the Hungarian machine building industry represented products allocated to Hungary according to such co-operations.[23] Export of Diesel rail cars towards the industrialized countries suffered from the low quality of various components and the lack of spare parts. The oil shocks at latest made the requirements for energy efficiency or reduced weight a priority the Hungarian products could not compete with. Subsidized prices of energy and a sheer lack of information about the real costs of specific components developing engineers found themselves in a bad position to construct products they could sell on export markets from the onset.

The fourth problem was the early, forces orientation of the Diesel rail production according to the needs of the Soviet market. Though during the 1960s this orientation constituted a security, negative consequences of the asymmetric relation presented themselves strongly already in the 1970s such as locking in a path of energy-intensive development.[24]

Conclusions

This short case study highlighted a few factors I plan to investigate in my research project about the institutional constraints on business innovation. I aim to contribute to ongoing investigations on the various ways how energy supply has influenced economic growth[2526] and how especially the planned economy played its part in it.[27] This short study presented a few characteristics of the institutional

[21] Interview with engineer István Horányi, former employee of Ganz & Co. in the 1960s and 1970s, production director of many socialist companies afterwards. Budapest June 2017
[22] KGM Műszaki Tudományos Tájékoztató Intézet 1967 (?)
[23] Honvári 2005
[24] Várnai 1982
[25] Stern and Enflo 2013
[26] Stern and Kander 2012
[27] Compare: Nielsen 2017;

framework that influenced the development of the energy supply infrastructure of Hungary and using existing knowledge about national energy policy in a way furthering economic growth.

The Diesel program exemplified first how energy management not consistent with the resource endowment of the country relented business innovation reducing the opportunity for growth within the energy development block based on oil. Second, it made the consequences of a strategic plan, or rather its consequent and co-ordinated application apparent which restrained the already restricted room of manoeuvre of the country significantly. It highlighted the shortcomings of a national innovation system in furthering innovation and growth suiting the resource endowments of the country.[28] As a consequence failed investments amassed, R + D investments could not reach significant results[29], knowledge was not applied and developed to prepare the vehicle industry for fundamental changes after 1989.

The presentation will include charts with the most important data about the development of energy supply and transport, energy intensity of production, the development of prices on different export markets.

Works Cited

Borhi, L. 2005. *Magyarország a hidegháborúban. A Szovjetunió és az Egyesült Államok között, 1945-1956.* Budapest: Corvina.

Enflo, K., A. Kander, and L. Schön. 2008. "Identifying development blocks - a new methodology. Implemented on Swedish industry." *Journal of Evolutionary Economics* 18(1):57–76.

Erdősi Pál. 1980. *Az energiaigényesség népgazdasági szerepe, az éves folyó ráfordításokban, a külkereskedelmi mérlegben, a népgazdasági beruházásokban.* Budapest.

Freeman, C. 1988. "Technology gaps, international trade and the problems of smaller and less-developed economies." In *Small Countries Facing the Technological Revolution*, edited by C. Freeman, and B.-Å. Lundvall, 67–84. London, New York. Pinter Publishers.

Germuska, P., and J. Honvári. 2014. "The History of Public Vehicle Production in Győr from 1945 until 1990." In *Industrial Districts and Cities in Central Europe.*, edited by E. Somlyódyné Pfeil, 130–57. Győr. Universitas-Győr Nonprofit Kft.

Haidegger, E. 1938. *A magyar energiagazdálkodás racionalizálása.* Budapest.

Hegedűs, M. 2000. *Az energiaszektor és a versenyképesség összefüggései*.

Hidvégi, M. 2014. "A Ganz–Jendrassik dízel motorkocsik Argentínában." *AETAS*(4):45–64.

———. 2016. *Anschluss an den Weltmarkt. Ungarns elektrotechnische Leitunternehmen 1867–1949.* Göttingen: Vandenhoeck & Ruprecht.

Honvári, J. 2005. *Magyarország gazdaságtörténete Trianontól a rendszerváltásig.* Budapest: Aula Kiadó.

Kander, A., P. Malanima, and P. Warde. 2013. *Power to the people. Energy in Europe over the last five centuries.* Princeton, NJ: Princeton Univ. Press.

KGM Műszaki Tudományos Tájékoztató Intézet. 1967 (?). *A gépipari ágazat fejlődése és helyzete 1938-1966. 2. sz. Melléklet. Tanulmány. A KGST-országok és a magyar gépipar fejlédésének és helyzetének összehasonlítása az 1950-1966 évek közötti időszakban.* Budapest.

Kovács, T. 1973. "Az energiagazdálkodás elemzése az energiamérlegek segítségével." *Statisztikai Szemle* 51(3):3 219-236.

[28] Freeman 1988; Mokyr 2016

[29] Compare: MOL XIX-A-I6-j. 21. doboz. Thész János: A kutatómunka és a tudomány irányítás tökéletesítése, 1966. szeptember 20., cited by Honvári 2005

Mokyr, J. 2016. *The Culture of Growth. The Origins of the Modern Economy.* Princeton, NJ: Princeton University Press.
MTA KTI. 1981. *Természeti erőforrásaink szerepe a gazdasági struktúra hosszú távú alakításában.* Budapest.
Négyesi, P. 2012. *Cars made in Hungary.* Torino: Il Cammello.
Nielsen, H. 2017. *Coal, commerce and communism. Empirical studies on energy history in the Czech Republic.* Lund Studies in Economic History. Lund: Lund University.
Orosz, L. 1961. "A hazai energiatermelés és –felhasználás struktúrája." *Statisztikai Szemle* 40(12).
Papp, I., and G. Réczey. 1958. "Az energiagazdálkodás elemzése az ágazati kapcsolatok mérlege alapján." *Statisztikai Szemle* 36(12):1133–44.
Perez, C. 1988. "New technologies and development." In *Small Countries Facing the Technological Revolution*, edited by C. Freeman, and B.-Å. Lundvall, 85–97. London, New York. Pinter Publishers.
Somogyi, F. 2010. "Ganz dízelmotor fejlesztések Jendrassiktól napjainkig." http://somogyisomi.uw.hu/ganz_motorfejlesztesek/ganz_motorfejlesztesek.html.
Stern, D.I., and K. Enflo. 2013. "Causality between energy and output in the long-run." *Energy Economics* 39:135–46.
Stern, D.I., and A. Kander. 2012. "The Role of Energy in Industrial Revolution and Modern Economic Growth." *The Energy Journal* 33(3):125–52.
Szécsey, I. 2006. *Az Árpádtól a Hargitáig. A Ganz gyorssínautóbusz, motorkocsi és motorvonat gyártásának aranykora (1934-1959).* Budapest: MÁV Zrt.
Tárnoki József. "Motorgyártás a Ganz és a MÁVAG gyárban 1889 és 1986 között."
Teőke Géza (szerk.). 1969. *Az energiatervezés időszerű kérdései.* Budapest.
Várnai, I. 1982. *A kitermelő, illetve energetikai egyedi nagyberuházások főbb termékei világpiaci áralakulásának elemzése az előrejelzés megalapozásához. Kandidátusi értekezés.* Budapest.
Verebély, L. 1935. *Tanulmány Csonkamagyarország villamosításának tervszerű fejlesztésére.* Budapest: [Élet Ny.].
World Energy Council. 2015. *The energy policy trilemma. Priority actions on climate change and how to balance the trilemma.* London.