# 14
# The Third Technological Paradigm: Electricity, Chemical Industry and Heavy Engineering

**Leonid E. Grinin**

*HSE University, Moscow; Institute of Oriental Studies, Russian Academy of Sciences*

**Abstract**

*The third technological paradigm was associated with the third Kondratieff wave which dated back to the 1890s – the late 1940s. It is known as the period of electricity, chemical industry and heavy engineering because these directions formed its basis. But, of course, many other technologies were also developing at that time, including those that later provided the basis of the fourth technological paradigm (automobile manufacturing, oil production and others). By the time the third paradigm formed, many of its basic technologies and structures had already taken shape; in particular, the chemical industry, heavy engineering and electric power generation were growing, telegraph and telephone started to connect territories, and even tramway appeared. But a number of technologies developed during the third paradigm. The spread of electric and internal combustion engines led to the appearance of machines capable of operating autonomously, which fundamentally changed the organization of production in particular functioning of factories and plants, transportation and daily life. Since the beginning of the 20th century, but especially since the 1920s, due to the appearance of diesel engines the machines began to perform the main operations in agriculture.*

***Keywords:*** *the third technological paradigm, the third Kondratieff wave, electricity, chemical industry, heavy engineering, electric power generation, internal combustion engine, automobile manufacturing, lamp electronics, oil production.*

The third technological paradigm was associated with the third Kondratieff wave or the long economic cycle. This wave dates back to the 1890s – the late

*Kondratieff Waves: Processes, Cycles, Triggers, and Technological Paradigms 2022 197–203 DOI: 10.30884/978-5-7057-6191-3_15*

1940s. The third paradigm is known as the period of 'electricity, chemical industry and heavy engineering', because these directions formed its basis. But, of course, many other technologies were also developing at that time, including those that later provided the basis of the fourth technological paradigm (automobile manufacturing, lamp electronics, oil production and refining, aircraft manufacturing and others). By the time the third paradigm formed, many of its basic technologies and structures had already taken shape; in particular, the chemical industry, heavy engineering and electric power generation were growing, telegraph and telephone started to connect territories, and even tramway appeared. But a number of technologies developed during the third paradigm.

## The Need for Socio-Political Changes

The transition to a new paradigm required certain modernization and significant changes in the social order, state administration, *etc.* But in general these changes were less significant than those during the transition from the first to the second paradigm. Nevertheless, in the 1860s – the 1880s major transformations occurred in a number of countries that became technologically advanced during the third paradigm (first of all in Germany and the United States). Germany unified the fragmented German states, abolished a number of obsolete provisions, adopted a new civil code and the fundamentals of labor and social legislation that became a model for other countries. There were rapid technological and industrial advances. In the United States, as a result of the Civil War and Reconstruction there was abolished slavery and the Southern States were reformed. At the same time there was an active settlement of the West. The U.S. became the leader in the rate of invention and innovation.

Great changes also took place in other countries, for example in Austria, which became Austria-Hungary, in Italy, which for the first time was able to create a unified state of Italians, in France, where after the Franco-German war a republic was finally established, in Russia, where serfdom was abolished and major reforms began, in Japan, which followed the path of modernization. In Great Britain, the labor movement was developing, and parliamentary reforms continued. Significant changes began to take place in government and in the functioning of the state machine, the European countries and the United States moved to a stage of mature state, in which the features of the social state became quite noticeable (see Grinin 2012, 2020a, 2020b).

Due to rapid expansion of railway and telegraph networks, as well as the spread of telephone communication, the world became, for the first time, truly connected. This led to profound changes in many countries and the World-System as a whole which from that time were affected by industrialization and a new culture. In particular, the export of capital began to grow rapidly, especially in the form of direct investment in industry, transportation and other sectors. This gave a powerful impetus to the rise of industry in the colonies and semi-colonies (see Grinin and Korotayev 2015). Capital exports in various

forms steadily increased and became the most important engine of world development, and in the periphery countries as well. Already on the threshold of the third paradigm, during the period from the 1880s to the 1890s Great Britain, France and Germany doubled their foreign investments. During the economic cycle of 1882–1893 the foreign investments almost equaled the investments for the entire previous history of these countries (see Mendelson 1959: 305; Rippy 1959).

> This continuous and increasing emigration of capital from the countries with the old capitalist culture presented a factor of utmost importance in the matter of distribution of the capitalist economy throughout the world. It was just due to the flow to emerging economies that capital conquers one country after another in our days: emigrating capital remains a capital and brings everywhere the new economic mode (Tugan-Baranovsky 2008 [1913]: 273).

This process, already evident in the late 19th and early 20th century, intensified even more in the first half of the 20th century. For example, before the Second World War the volume of European, American, and Japanese investments in South-East Asia amounted to no less than 3.2 billion dollars (Vassiliev 1977: 175; Hall 1955; 1958: 521; Amsden 2004: 108).

## The Basic Technological Changes

During this period, there were used not only machines powered by coal but also thanks to the invention of the internal combustion engine oil-fueled (fuel oil, gasoline, kerosene) automobiles and agricultural machines. Electric engines began to be widely used in industry. The spread of electric and internal combustion engines led to the appearance of machines capable of operating autonomously, which fundamentally changed the functioning of factories and plants, transportation and daily life.[1]

During this period electric engines were actively replacing steam engines and, consequently, machines operating on a common steam plant. As a result, electricity production became one of the fastest-growing branches of industry. Electricity eventually transformed everything, from manufacturing to everyday life. For example, electric power generation quadrupled in 12 years (from 1888 to 1900) (Mendelson 1959, vol. 2: 410). During this period in the U.S. manufacturing industry two-thirds of the increase in engines came from electric engines (*Idem* 1959, vol. 3: 32; about technological development at that period see Grinin and Grinin 2015).[2]

[1] In addition to illumination, electrical appliances were already common in the 1920s (especially in the U.S.) in the form of electric heaters, refrigerators, washing machines, *etc.*

[2] The development of electrical engineering in the late 19th and early 20th centuries was often referred to the second industrial revolution by the contemporaries and scholars of subsequent generations due to powerful changes associated with it. However, sometimes the second industrial

## The Changes in Other Spheres

During the period of the third technological paradigm which took half a century (the 1890s – the 1940s), enormous changes took place in other spheres as well. Let us try to summarize them.

First, there were radical changes in agriculture. Although the first machines had been used in agriculture since the late 18th century, it was still largely a manual-labor industry, and machines, if they existed, were mostly horse-drawn, and only in some cases steam-powered. At the end of the 19th century the number of horse-drawn and steam-powered agricultural machines was impressive, for example, in France there were almost 700 thousand, and in the USA the cost of used agricultural machines was almost half a billion dollars which was a very large sum for that time (Shirokov 1981: 24–25). Nevertheless, the mechanization of agriculture was delayed. Since the beginning of the 20th century, but especially since the 1920s, due to the appearance of diesel engines the machines began to perform the main operations in agriculture. This meant a complete victory of the Industrial production principle as mechanization covered the sphere of agriculture (the pre-industrial sector by its origin), which was rapidly becoming mechanized. Already in the last decades of the 19th century, the tractor (the caterpillar tractor was improved in the early 20th century, and about 1910, the light petrol tractor appeared), the combine harvester (the horse-drawn tractor which was sporadically used since the 1880s),[3] were introduced. In the 1920s and 1930s hundreds of thousands of tractors and combines were used in agriculture, which led to the most powerful migration of farmers to cities, the rise of industry in all industrial countries and correspondingly to the dramatic increase of urbanization, as well as the increase in productivity and general culture of the rural population.

## The Development of the Chemical Industry

The chemical industry also had a very significant impact on the development of agriculture due to rapid development of the mineral fertilizer industry which resulted in dramatic increase in yields and the solution of the soil depletion problem. The chemical industry also supplied pesticides to control weeds and pests. New ways of producing nitric and sulfuric acid appeared, and electrochemical technology developed, in particular, there was introduced the electrochemical way for the production of chlorine and caustic soda (using mercury cathode), as well as aluminum by electrolysis.

One should also mention the revolution in the production of synthetic paints. In particular, there was established the industrial production of blue

---

revolution is referred to an earlier period (from 1860 – the 1870s), associated with the powerful development of machine manufacturing, including the earlier stages of electric machine engineering, steelmaking, *etc.*

[3] In the manufacture of tractors Henry Ford's company is particularly worth noting.

paint (indigo), previously obtained from a plant with the same name that had been cultivated in India and other tropical countries. In the period from 1900 to 1913, indigo production in Germany increased from 1873 to 37,350 tons (Schukhardin *et al.* 1982). Germany became the leading country in the production of paints (and in the development of the chemical industry as a whole). Thus, exports from Germany of aniline and other organic dyes between 1880 and 1913 increased from 2,140 to 64,288 tons, alizarin and alizarin dyes – from 5,888 to 11,040 tons. Indigo exports in 1913 increased from 1,873 to 33,353 tons compared with 1900 (Shukhardin *et al.* 1982). The chemical industry began to play an important role in the production of medicines. It also made enormous changes in warfare (explosives, poisonous gases, *etc.*). In the 1930s and 1940s there appeared the first artificial materials, such as rubber and artificial fabrics, as well as plastics.

## The Changes in Military Technologies

Gasoline and diesel engines also fundamentally changed warfare. Since the 1920s military theorists began to predict that the future war would be a 'war of engines'. And so it happened, on the battlefields and in the air many tens of thousands of war machines (tanks, self-propelled vehicles, planes) encountered. All this, unfortunately, was used to exterminate the armies and populations of the fighting nations of the world.

As a result of the development of heavy engineering, labour productivity increased enormously due to its mechanization. In particular, mining, which until the 1870s had been the most backward branch of industry in the number of machines and mechanisms used, became one of the most advanced branches of the machine industry at the beginning of the 20$^{th}$ century (Shukhardin 1961: 140).

## Metallurgical Industry

Of course, machine engineering could not develop without changes in metallurgy. In particular, strong alloy steel appeared. In 1898 F. Taylor and M. White invented high-speed steel, which enormously increased the possibilities of machine engineering, and in 1913 Harry Brearley invented stainless steel. The invention of electric welding machine (1886) and thermite welding (1908) also played a huge role in machine engineering, eliminating the need to rivet or bolt. Oxygen cutting (oxy-acetylene torch and other similar methods) also came into use at the turn of the 19$^{th}$ and 20$^{th}$ centuries. Enormous changes also took place in nonferrous metallurgy. In addition to nonferrous metals of the past, such as copper (extremely necessary in electrical power engineering and electric machine industry), production of new metals such as aluminum, nickel, chromium, cobalt and others was actively developing.

The ‘storeys’ of the industrial economy which we have mentioned in the previous article, became much more powerful. In the advanced countries, the proportion of urban population was almost half of the total population, and by the end of the third paradigm, the urban population made up the majority. Thus, at that time industry, especially heavy engineering formed the basis of GDP. Heavy industry became much more complex, since machine engineering achieved a dominant position in the ‘storeys’. Electricity generation was also highly differentiated.

Thus, as a result of the third technological paradigm, there appeared a colossal ‘storey’ of heavy industry which eventually became the leading sector of the economy.

## References

**Amsden A. H. 2004.** *The Rise of ‘the Rest’. Challenges to the West from Late-industrializing Economies.* New York, NY: Oxford University Press.

**Grinin L. E. 2012.** *Macrohistory and Globalization*. Volgograd: Uchitel.

**Grinin L. E. 2020a.***The State and the Historical Process: Evolution of Statehood: From the Early State to the Mature State*. Moscow: URSS. *In Russian* (Гринин Л. Е. Государство и исторический процесс: Эволюция государственности: от раннего государства к зрелому. М.: URSS).

**Grinin L. E. 2020b.** *The Political Cross-Section of the Historical Process. State and Historical Process.* Vol. 3. URSS). *In Russian* (Гринин Л. Е. *Политический срез исторического процесса. Государство и исторический процесс.* Кн.3. URSS).

**Grinin L. E., and Grinin A. L. 2015.** *From the Biface to Nanorobots. The World is on the Way to the Epoch of Self-Regulating Systems (History of Technologies and Description of their Future).* Moscow: Moscow branch of ‘Uchitel’ Publishing House. *In Russian* (Гринин Л. Е., Гринин А. Л. *От рубил до нанороботов. Мир на пути к эпохе самоуправляемых систем (история технологий и описание их будущего).* М.: Московская редакция изд-ва «Учитель»).

**Grinin L. E., and Korotayev A. V. 2015.** *Great Divergence and Great Convergence: A Global Perspective.* Springer.

**Hall D. Y. 1955.** *A History of South-East Asia.* London: MacMillan.

**Hall D. J. E. 1958.** *History of Southeast Asia.* Moscow: Inostrannaya literatura. *In Russian* (Холл Д. Дж. Е. *История Юго-Восточной Азии.* М.: Изд-во ин. лит-ры).

**Mendelson L. A. 1959.** *Theory and History of Economic Crises and Cycles*. Vol. 2. Moscow: Izd-vo sotsialno-ekonomicheskoi literatury. *In Russian* (Мендельсон Л. А. *Теория и история экономических кризисов и циклов*. Т. 2. М.: Изд-во соц.-экон. лит-ры).

**Rippy F. F. 1959.** *British Investments in Latin America. 1822—1949.* Minneapolis: University of Minnesota Press.

**Shirokov G. K. 1981.** *The Industrial Revolution in the Countries of the East.* Moscow: Nauka. *In Russian* (Широков Г. К. *Промышленная революция в странах Востока.* М.: Наука).

**Shukhardin S. V. 1961.** *Fundamentals of the History of Engineering: Experience of Theoretical and Methodological Problems*. Moscow: Publishing House of the Academy of Sciences of the USSR. *In Russian* (Шухардин С. В. *Основы истории техники: Опыт разработки теоретических и методологических проблем.* М.: Изд-во АН СССР).

**Shukhardin S. V., Laman N. K., and Fedorov A. S. (Eds.) 1982.** Technique in Its Historical Development (1870 – the Beginning of the 20th Century). Moscow: Nauka. *In Russian* (Шухардин С. В., Ламан Н. К., Федоров А. С. (Ред.). *Техника в ее историческом развитии (1870 – начало XX в.).* М.: Наука).

**Tugan-Baranovsky M. I. 2008 [1913].** *Periodical Industrial Crises.* Moscow: Direktmedia Publishing. *In Russian* (Туган-Барановский М. И. *Периодические промышленные кризисы.* М.: Директмедиа Паблишинг).

**Vassiliev A. M. 1977.** *Difficult Pass.* Moscow: Nauka. *In Russian* (Васильев А. М. *Трудный перевал.* М.: Наука).