CHAPTER 2

Government and Growth in Imperial Russia, 1870–1886

THE DEVELOPMENT OF ELECTRIFICATION exemplifies the transfer and diffusion of a new technology into Russian society and the growing technological gap between Russia and the West. Electric lighting, power, and traction advanced greatly, but their geographic diffusion and intensity of application trailed the West's. In this chapter I explore five key factors that shaped prerevolutionary electrification: the restrictive institutional environment imposed by the tsarist government, the strong military role, the weak commercial reception of native invention, the development of the electrical engineering community, and significant foreign financial and technical involvement.

The administrative and legal environment of tsarist electrification helps explain why the Russian economy proved less supportive of electrotechnology than did Western European and American economies. Electrification suffered, as did most economic activities in Russia, from the government's restrictive procedures. The Russian army and navy were significant exceptions to this government indifference, and thus they played the major role in the initial establishment of electrotechnology. The general failure of inventors in Russia illuminates the weak social and institutional support for technological innovation, innovation supplied later by foreign firms. In both military and civilian spheres, electrical engineering societies tied Russian electrotechnology together. Never passive, electrical engineers gradually became involved in the politics of electrification. Their full involvement, however, came about only when World War I radically changed the political and economic environment.

The Role of Government

GOVERNMENTS SHAPE THE DEVELOPMENT, diffusion, and evolution of new technologies by, among other factors, their approach to risk, access to funding, decision making, and markets.[1] Budget priorities, tax structures, regulation, political favoritism, national security, and other goals of elites in power can aid, deliberately or otherwise, certain technologies while hindering others.

In circumstances of "business as usual," a new technology evolves within an established framework of precedent, regulation, and authority. The government neither gives the new technology special benefits nor penalizes it. Sometimes a government actively promotes one technology at the expense of other options for military, economic, political, and social goals. Such a state technology is supported directly and publicly as the government identifies itself with that technology. Similarly, supporters of that technology try to place themselves under government aegis. These technologies tend to be capital-intensive, regional in scope, and monopolistic, and they generally strengthen the central powers of the state. Although there is no intrinsic reason why state technologies must be capital-intensive high technologies (e.g., nuclear reactors instead of solar water heaters), the demands for large amounts of technical and economic resources, coupled with the centralizing tendencies of both the state and that technological approach, provide an alluring combination. The railroad and the space program are two examples. Railroads were revolutionary forces of modernization that helped solidify the nation-state as a political and economic entity. Governments promoted railroads to develop national markets, steel and manufacturing industries, and financial institutions while strengthening their military power.[2] Governments supported and guided domestic and international space programs, like railroads, for reasons of national security, political prestige, and economic and technological development.[3]

[1] Nathan Rosenberg and L. E. Birdzell, *How the West Grew Rich: The Economic Transformation of the Industrial World* (New York: Basic Books, 1986), 24–32; Thomas C. Cochran, *Frontiers of Change: Early Industrialization in America* (New York: Oxford University Press, 1981), 39, 121.

[2] Alfred D. Chandler, Jr., *The Visible Hand* (Cambridge: Harvard University Press, 1977), 79–187; Dennis E. Showalter, *Railroads and Rifles: Soldiers, Technology and the Unification of Germany* (Hamden, Conn.: Archon, 1976); Eugen Weber, *Frenchmen into Peasants* (Stanford: Stanford University Press, 1976), 205–6.

[3] John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Chicago: University of Chicago Press, 1970); Bruce Mazlish, ed., *The Railroad and the Space Program: An Exploration in Historical Analogy* (Cambridge: MIT Press, 1964); Walter

In developing a state technology, a government seeks to strengthen its economy while simultaneously increasing its domestic and international political standing.[4] In an economist's ideal market, governments distort the natural development of a new technology by promoting one technology over others. In reality, state actions are part of the normal development of a technology. As technology is identified with progress, economic growth, and military superiority, governments link themselves with it.

State technologies are marriages of convenience in which the promoters of a technology join with the government to pursue common interests, albeit for different reasons, in an evolving political process.[5] The promoters may seek tactical and strategic alliances with sections of the government on common ideological ground (such as national security or support for small farmers).[6] A financial speculator or steel manufacturer may see the railroad as a source of profits, a state official may see a strategic path of communications, and a local official may see the regional benefits of integration into a larger market. Michel Callon's "actor network" of heterogeneous associations captures the political linkages necessary to combine different institutions into supporting a common path of technological advance.[7]

The formation of an alliance is not without its risks: the state may push the technology in ways other than its initial supporters intended (e.g., different priorities for railroad construction, manned over unmanned space flight); the failure of its preferred technology and the neglect of other lines of development may harm the state (e.g., supporting light over heavy water nuclear reactors). An unintended consequence of a close political alliance is the potential loss of support if the faction or government loses power.[8]

A. McDougall, . . . *the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books 1985).

[4] The local equivalent is a "keeping up with the Joneses" boosterism; see Letty Anderson, "Fire and Disease: The Development of Water Supply Systems in New England, 1870–1900," in Joel A. Tarr and Gabriel Dupuy, eds., *Technology and the Rise of the Networked City in Europe and America* (Philadelphia: Temple University Press, 1988), 149–50.

[5] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge: Harvard University Press, 1987), 103–44.

[6] Roy Talbert, *FDR's Utopia: Arthur Morgan of the TVA* (Jackson: University of Mississippi Press, 1987).

[7] Michel Callon, "Society in the Making: The Study of Technology as a Tool for Sociological Analysis," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch, eds., *The Social Construction of Technological Systems* (Cambridge: MIT Press, 1987), 92–93.

[8] E. g., the identification of the B-1 as a partisan bomber; see Nick Katz, *Wild Blue Yonder: Money, Politics and the B-1 Bomber* (Princeton: Princeton University Press, 1988).

Old state technologies do not die, but neither do they necessarily fade away. A variety of paths exist: government–industry ties may loosen as interests and priorities change; technologies may become less economically reliant on government support; new technologies may replace the old; or the environment may change so drastically that both the government and the technology lose favor. In the late nineteenth and early twentieth centuries, no self-respecting government could afford not to harness the new industrial technologies to advance its economic and political modernization. The tsarist approach, however, created an environment that hindered industrialization.

To understand the evolution of Russian electric utilities, one must first understand the tsarist state, which feared any activity that threatened its primacy.[9] In comparison with its European counterparts, the Russian government exercised a greater control of the economy by its activities as an authorizer, regulator, producer, and consumer, although it never completely subordinated the economy.[10] Because of their role in the urban infrastructure, utilities operated under more government strictures than did the manufacturing industries. State authority for economic activity diffused into an administrative pluralism[11] in which large bureaucracies battled as they followed uncoordinated and even contradictory policies.[12] Because special interdepartmental committees (which, according to William Fuller, "as any bureaucrat knew could delay the resolution of a conflict for decades"[13]) often failed to coordinate ministerial policies, unified government action proved difficult, if not impossible. To the cost of the economy, the tsarist government did not lend itself to quick decisions.[14]

The main protagonists were the Ministry of Finance, the Ministry of Trade and Industry (MTP, Ministerstvo Torgorlvi i Promyshlennosti, a department of the Ministry of Finance until 1905), and the Ministry

[9] Tim McDaniel, *Autocracy, Capitalism, and Revolution in Russia* (Berkeley: University of California Press, 1988), 23.

[10] Peter W. Gatrell, *The Tsarist Economy, 1850–1917* (New York: St. Martin's Press, 1986), 232; Teodor Shanin, *Russia as a Developing Country. The Roots of Otherness: Russia's Turn of Century*, vol. 1 (London: Macmillan, 1985), 126–30.

[11] Theodore H. Von Laue, *Sergei Witte and the Industrialization of Russia*, 2d ed. (Philadelphia: Lippincott, 1971), 75.

[12] McDaniel, *Autocracy, Capitalism, and Revolution*, 28; Hans Rogger, *Russia in the Age of Modernization and Revolution, 1881–1917* (London: Longman, 1983), 39–47.

[13] William C. Fuller, Jr., *Civil-Military Conflict in Imperial Russia, 1881–1914* (Princeton: Princeton University Press, 1985), 255.

[14] M. C. Kaser, "Russian Entrepreneurship," in *Cambridge Economic History of Europe*, ed. M. M. Postan and H. J. Habakkak (Cambridge: Cambridge University Press, 1978), vol. 7, pt. 2: 416–93.

of Internal Affairs (MVD, Ministerstvo Vnutrikh Del). The Ministry of Finance, especially in the 1890s under Sergei Witte, and the MTP strove to create an institutional infrastructure and political climate conducive to industrial development. The MVD, in addition to overseeing local governments, had the responsibilities of approving the establishment of new industries and developing technical regulations.[15] Industrialization involved other ministries to a lesser extent.[16]

Insofar as the tsarist government supported a technology for industrialization, the railroad was that state technology.[17] Railroads consumed the lion's share of the billions of rubles invested in industrialization.[18] The government constructed, nationalized, and guided the amalgamation of railroads to serve military needs, stimulate the metallurgical and fuel industries, facilitate grain exports to earn hard currency, and create a nationwide transportation system.[19] According to Witte's trickle-down theory, development of this heavy industry would stimulate the development of the more consumer-oriented light industry.

Electrification did not receive the attention given to railroads because it did not appear economically important. Instead, utilities, like other industries, suffered from state overregulation and involvement in almost every area of operations. Utilities dealt with the central government primarily through its local branches. The administrative and financial controls of central ministries over municipal governments essentially constituted a parallel government, which often hurt municipal efforts to improve local conditions and kept local governments politically weak.[20] City *dumas* (legislative councils), elected by only a few, proved quite cautious about approving ventures that required

[15] Von Laue, *Sergei Witte,* 72–75, 92–99; Rogger, *Russia in the Age of Modernization,* 102–5.

[16] E. g., a 1904 attempt to establish a law for hydrostations included petitions to the ministries of finance, internal affairs, justice, communications, state domains, and agriculture: "Deiatelnost Obshchestva," *Zapiski Imperatorskogo russkogo tekhnicheskogo obshchestva* (*ZIRTO*), 1904, no. 2: 50.

[17] Roger Portal, "The Industrialization of Russia," in *Cambridge Economic History of Europe,* vol. 7, pt. 1: 814; Shanin, *Russia as a Developing Country,* 128.

[18] Approximately a quarter in 1896–1900 and nearly half in 1900–13; see Gatrell, *Tsarist Economy,* 151–52, 192–94, and J. N. Westwood, *A History of Russian Railways* (London: George Allen and Unwin, 1964), 140.

[19] D. N. Collins, "The Franco-Russian Alliance and Russian Railways, 1891–1914," *Historical Journal* 15, no. 4 (1973): 777–88; Clive Trebilcock, *The Industrialization of the Continental Powers* (London: Longman, 1981), 235–36; Von Laue, *Sergei Witte,* 76, 262–67.

[20] Robert W. Thurston, *Liberal City, Conservative State: Moscow and Russia's Urban Crisis, 1906–1914* (New York: Oxford University Press, 1987), 40.

new technologies or debt, partly because of tight state control of finances and discouragement of local initiative[21] but also because of reluctance to act without expressed authorization from the tsarist government.[22] Resolution of local questions often entailed extensive consultations and negotiations at the state level. For example, deciding which part of the government should pay for replacing kerosene with electric lighting in a St. Petersburg police building took six years and the attention of the state senate.[23] This central dominance of local affairs, coupled with interministerial disputes, hindered the development of the local political initiative essential to introduce and implement new technologies.

To operate, a utility needed several ministerial approvals. The Ministry of Finance had to approve the statutes and capital for every new company. The MVD controlled the regulations governing the construction and operation of electric stations. In 1885, its post and telegraph administration published temporary safety rules for electrical installations and cable networks.[24] In 1890–91, the MVD technical construction committee assumed the responsibility for technical reviews and physical inspections of projects.[25] The MVD did not deal directly with the utility but rather with the *gubernator*, the tsarist-appointed administrator of a city or region.[26] A city government submitted a proposal to the gubernator's committee on rural and urban affairs (Gubernskoe prisutstvie po zemskim i gorodskim delam), which then submitted its recommendation to the gubernator. If he approved, the proposal went to the MVD Main Administration for Municipal Affairs (Glavnoe upravlenie po delam mestnogo khoziaistva) in St. Petersburg. After the Main Administration gave a preliminary approval, the technical construction committee and post and telegraph administration reviewed the project. Requests to seek foreign loans followed the same path but also needed the approval of the Ministry of Finance.[27]

[21] H. Lerche, "State Credit for Town and County Councils," *Russian Review* 1 (1912): 46–48; Thurston, *Liberal City*, 47–49, 54–56, 183.

[22] Of the 140 replies to 700 questionnaires in a 1908 survey, three refused to answer without the permission of their gubernator, a timidity "characteristic of our self-government"; O. G. Flekkel, "VI Vserossiiskii elektrotekhnicheskii sezd," *Gorodskoe delo*, 1911, no. 5: 455.

[23] "Doklad gorodskoi upravy," *Izvestiia S. Peterburgskoi gorodskoi dumy*, 1908, no. 24: 2242–43; 1914, no. 11: 2865–66.

[24] "O vremennykh pravilakh kanalizatsii elektricheskogo toka bolshoi sily i ustroistva provodov i prochikh prisposoblenii dlia elektricheskogo osveshchesniia," *Sbornik rasporiazhenii po glavnomu upravleniiu pochty i telegrafov*, 1886, vol. 1, pt. I: 41–44.

[25] TsGIAL f. 90, op. 1, ed. kh. 466, 6–9.

[26] TsGIAL f. 23, op. 27, ed. kh. 841, 110–12.

[27] Thurston, *Liberal City*, 47.

Reviews were not necessarily rubber stamps. For example, the technical construction committee delayed the construction of the Nizhni-Novgorod municipal station until it made changes, including a stronger foundation in case future demand necessitated turbogenerators instead of vertical engines, a very reasonable demand.[28]

In 1904, a MVD reorganization reduced the authority of the post and telegraph administration to preventing interference with telegraph and telephone lines and increased the purview of the Main Administration for Municipal Affairs. This revision also increased the maximum voltage the gubernator could provisionally approve from the 200 volts set in 1901 to 250 volts.[29] These low voltages meant that nearly every project had to receive MVD approval. In parts, the 1904 rules reprinted verbatim the proposals submitted by the 1st All-Russian Electrotechnical Congress in 1901.[30] Although this can be viewed as an example of the close cooperation between the MVD and the electrical engineering community, it may be more accurate to interpret it as a slow bureaucratic process that demanded three years to produce conservative, technologically outdated regulations. Although it participated in rule making, the electrical engineering community considered the process unwieldy, overly conservative, and a hindrance to the commercial development of new technologies.[31] Efforts to change this process of approval and oversight constantly bogged down over interdepartmental disputes about jurisdiction and policy.

Despite its formidable powers, the state could not simply dictate economic policy but had to negotiate with local governments and industry, as the failure to tax electric energy demonstrates. To pay for the Russo-Japanese war, an interdepartmental commission proposed in 1906, among other measures, a tax on electric energy. Noting that the government taxed kerosene, electricity's main competitor, at approximately 4 kopecks per kilogram, the commission suggested an equivalent tax of 4 kopecks per kilowatt-hour (kWh). Widespread opposition quickly developed from utilities, city dumas, and industrial users, who feared that the tax would cripple the utility industry. The main electrical engineering society, the VI Section of the Imperial Russian Technical Society, simultaneously negotiated details of the tax

[28] "Iz gazet," *Elektrotekhnicheskoe delo*, 1914, no. 5: 21.
[29] TsGIAL f. 23, op. 27, ed. kh. 841, 6–17, 110.
[30] TsGIAL f. 90, op. 1. ed. kh. 471, 7–8.
[31] *Trudy Sedmogo Vserossiiskogo elektrotekhnicheskogo sezda, 1912–1913 gg. v g. Moskve* (St. Petersburg: Postoiannyi Komitet Vserossiiskogo elektrotekhnicheskogo sezda, 1913), 34.

with the Ministry of Finance and filed petitions against it.[32] In 1908, the Ministry of Finance dropped the proposal. War also brought the next proposed tax on electricity, in 1916, but the February revolution intervened before its introduction.[33]

The extensive, albeit distant, state involvement and concomitant slow diffusion of new technologies in Russia were the norm, not the exception: in most areas of public service, the time between proposal in the city duma and final approval was fifteen to twenty years.[34] Compared with other network technologies, electric utilities had an outstanding record of accomplishment: in 1910, 115 cities had utilities but only 40 had sewage systems.[35] Electric utilities spread faster because of the greater availability of foreign technology and financing, a larger customer base, lower construction costs, and the smaller area of coverage needed for profitable service.

The legal framework for electrification was similar to those for other industries in Russia but more restrictive than those in other countries.[36] In Canada and the United States, regulation usually followed rather than preceded new technologies. Although electrification in Europe proceeded under a more regulated regime than in North America, development was also more rapid than in Russia, as the next chapter shows.[37]

The tsarist government retarded the growth of electrification, not by intention but by benign neglect. The state's role was more one of conservative and reluctant authorizer than of entrepreneurial activist. The state neither favored nor disfavored electric utilities; they were

[32] P. P. Dmitrenko, "Ob aktsiz na elektricheskuiu energiiu," *ZIRTO Prilozhenie*, 1908, nos. 9–10: 51–52; "Deiatelnost obshchestva," *ZIRTO*, 1907, no. 11: 459–60; 1908, no. 2: 100–101.

[33] "Khronika," *Elektrichestvo*, 1916, no. 11: 204–5; "Khronika," *Elektrotekhnicheskoe delo*, 1917, no. 5: 14; Alexander M. Michelson et al., *Russian Public Financing during the War* (New Haven: Yale University Press, 1928), 161–65.

[34] Alfred J. Rieber, *Merchants and Entrepreneurs in Imperial Russia* (Chapel Hill: University of North Carolina Press, 1982), 102.

[35] *The Russian Almanac* 1919 (London: Eyre and Spottiswoode, 1919), 157.

[36] Rieber, *Merchants and Entrepreneurs*, 97–102, 283.

[37] Christopher Armstrong and H. V. Nelles, *Monopoly's Moment: The Organization and Regulation of Canadian Utilities, 1830–1930* (Philadelphia: Temple University Press, 1986), 130; Thomas P. Hughes, *Networks of Power* (Baltimore: Johns Hopkins University Press, 1983), 58–61, 71–72; Leslie Hannah, *Electricity before Nationalization* (Baltimore: Johns Hopkins University Press, 1979), 5–8; Brian Bowers, *A History of Electric Light and Power* (London: Peter Peregrinus, 1982), 152–61; John McKay, "Comparative Perspectives on Transit in Europe and the United States, 1850–1914," in Tarr and Dupuy, eds., *Rise of the Networked City*, 5–20.

simply one of many regulated activities. The major exception to the state lack of interest in electrotechnology came from the military.

The Role of the Military

In the 1870s in Russia, the electric light left the laboratory and ventured into the public domain. A distinguishing feature of this transition was the leading role of the army and navy. The military was similarly involved elsewhere, but only in Russia was it so important.[38] Over a decade before the first utilities came into being, the military provided the initial base and market for electrification, and it retained this leading position through the 1890s.

Unlike the civilian ministries, the military actively nurtured electrotechnology in a protective, fertile environment until the new technology could survive in the harsher civilian sphere. Compared with Europe, the Russian civilian economy was weakly developed and less industrialized. The army and navy commanded the resources to finance and develop new technologies, they had specific needs, and economic feasibility was subordinated to national security. And the consequences of failure were not as severe for military entrepreneurs. In such circumstances, the military's large role is understandable.

The military has been influential in the development of science, technology, and industry worldwide. Its most vital activities have been educating and hiring technical personnel, serving as an initial customer, and promoting domestic and international technology transfer. Other important ways of promoting new technologies include funding and conducting research and development, fostering domestic industry, and creating standards. In Russia, the army and navy engaged in all these activities, serving as a Gerschenkronian state substitute for the industrial development lacking in the backward civilian economy.[39]

The Russian military found many uses for electrotechnology. Electricity could detonate torpedoes and explosive mines, turn night into day outside fortresses, safely illuminate factories, transmit informa-

[38] Jonathan Coopersmith, "Electrification and the Military, 1870–1900," paper presented to the British Society for the History of Science Conference on Society and War, London, 1989.

[39] Alexander Gerschenkron, *Economic Backwardness in Historical Perspective* (Cambridge: Harvard University Press, 1966), 123–24; Trebilcock, *Industrialization of the Continental Powers*, 222.

tion, run clocks, and provide power. Although the army and navy conducted separate research and testing programs and deployed different equipment, they cooperated formally and informally via the exchange of information and personnel. Officers worked on the advisory committees of their brother service and assisted in testing, installation, and education.[40] These cross-service links helped spread electrotechnology within the military.

Army interest in electricity began in the late 1860s. The Main Artillery Administration (GAU, Glavnoe artilleriiskoe upravlenie) dominated army electrical engineering through the 1880s. The GAU was much more than simply the artillery arm of the army. Its troops, trained in GAU schools and academies, staffed fortresses equipped with weapons built and tested by its workshops, factories, and arsenals. GAU factories introduced new ideas and technologies, like the Harpers Ferry and Springfield armories did in the United States.[41] For example, Col. Vasilii F. Petrushevskii established an instruments section at the St. Petersburg cartridge factory that standardized mechanics' instruments and training in the mid-1870s.[42] Petrushevskii's activities typify the standardized testing and hierarchical control that characterize military technology.[43] Besides formal research and testing, unofficial research occurred at GAU installations at the discretion of the commander, but its very informality precludes an accurate assessment of its pervasiveness and importance.[44] Certainly such research supports the concept of Russian industrial fiefdoms in which the director had a great deal of leeway in managing his operations. Such activities indicate supportive environments for scientists and engineers.

At the peak of the GAU's technological investment stood the artillery committee, or Artkom. Established in 1869, Artkom succeeded the technical committee in directing GAU's technical priorities, allocating resources, and appraising Russian and foreign research. In

[40] "Mikhail Matpevich Boreskov," *Elektrotekhnik*, 1897–98, no. 8: 495–96; P. Berkhman, *Sudovye miny: Rukovodstvo dlia slushatelei minnogo ofitserskogo klassa* (St. Petersburg, n.d.), 1; TsGVIA f. 506, op. 1, d. 409, 537, 547–48, 552.

[41] Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca: Cornell University Press, 1977).

[42] "General-Leitenant Petrushevskii (nekrolog)," *Russkii invalid*, 1 May 1891, 4; "Petrushevskii," *Entsiklopediia voennykh i morskikh nauk* (St. Petersburg, 1891), 5: 628; A. Ia. Averbukh, *Vasilii Formich Petrushevskii* (Moscow: Gosenergizdat, 1967), 14.

[43] "Introduction," in Merritt Roe Smith, ed., *Military Enterprise and Technological Change* (Cambridge: MIT Press, 1985), 17–21.

[44] "N. M. Alekseev," *Elektrichestvo*, 1903, no. 4: 48–49; A. A. Chekanov and B. N. Rzhonsnitskii, *Mikhail Andreevich Shatelen, 1866–1957* (Moscow: Nauka, 1972), 12.

an example of stimulation by knowledge about work elsewhere, the GAU technical committee in July 1868, sparked by a Prussian article about harbor lighting in the American civil war, asked Col. Petrushevskii to study searchlights for fortress defense.[45] Petrushevskii was the embodiment of the Russian scientist-soldier. Educated in the military schools where he later taught, he conducted research on electric mines and lighting and invented an artillery rangefinder. Petrushevskii was a consulting member of Artkom until 1881, when he was promoted to lieutenant-general and became a permanent member. He founded and headed its electrotechnical department in 1886 until his death in 1891.[46]

Petrushevskii tested Drummond lamps, magnesium lights, battery-powered lamps, and arc lights. With the exception of the last, these systems were mature technologies. Thomas Drummond, for example, invented his "limelight" in 1826. Petrushevskii's tests, completed in 1870 significantly over budget and schedule, demonstrated the "full advantage of electric light," but he continued to study recent European equipment.[47] The tests were a model of how to judge new technologies, with frequent trips abroad to inspect the latest developments and inspectors to assure that factories sent functional equipment. Petrushevskii's problem was when to halt testing and actually install a specific system, knowing that better systems would soon appear. In this case of the perennial conflict between developers and users, the decision came from his superiors, whose interest was not the most advanced technology but the best defense of their fortresses.[48]

GAU involvement with electricity created a career pattern for its technical officers similar to their modern counterparts, with management in the factory and office as important as command of troops. Less common, but not unusual, were assignments to other parts of the government to install electric lighting.[49] Many officers taught, lec-

[45] TsGVIA f. 506, op. 1, d. 409, 3–4.

[46] "General-Leitenant Petrushevskii," 3–4; Averbukh, *Petrushevskii.*

[47] TsGVIA f. 506, op. 1, d. 409, 395–96, 424.

[48] For more information, see Jonathan Coopersmith, "The Role of the Military in the Electrification of Russia, 1870–1890," in E. Mendelsohn, M. R. Smith, and P. Weingart, eds., *Science, Technology and the Military* (Dordrecht: Kluwer Academic Publishers, 1988), 12: 291–305.

[49] E. g., A. I. Smirnov spent two decades working for the Ministry of the Court; see Ia. I. Senchenko, "Vydaiushchiisia elektrotekhnik Aleksandr Ivanovich Smirnov," *Trudy Instituta po istorii estestvoznaniia i tekhniki*, 1962, no. 44: 171–78.

tured, or wrote manuals as part of their duties. Indeed, the GAU published some of the first Russian books on electrotechnology.[50]

Navy activity paralleled the army's. The navy began experimenting with French electric searchlights in 1869 in the Baltic Sea, and tests continued through 1873.[51] In 1874, the Russian navy was the world's first to switch from the Alliance generator to the new, more powerful Gramme generator, a sign of technical leadership and financial backing.[52] The navy established the Mine Officer Class in October 1874 at Kronstadt near St. Petersburg as its center for electrotechnical training, testing, and research.[53] The navy had a large investment in electrotechnology, including an explosives factory, manufacturing facilities, and repair shops—in effect, a self-contained industrial complex. The officers and men formed one of the few competent pools of electrical workers in Russia. Besides training, the Mine Officer Class tested equipment and electrified government buildings and events.[54] The 1881 coronation of Aleksandr III featured a massive display of searchlights and Edison incandescent lights in the Kremlin by the Mine Officer Class assisted by English engineers.[55]

The military provided opportunities for civilians, often on groundbreaking projects. The most prominent example of a civilian expert working for the military was Vladimir N. Chikolev. Officially a low-level GAU clerk, Chikolev proved as important as Petrushevskii in guiding the army's adoption of electricity. He was a dynamic entrepreneur in both military and civilian spheres, albeit more successful in the former because of the military's friendlier environment for elec-

[50] V. N. Chikolev, *Elektricheskoe osveshchenie v primenenii k zhizni i voennomu iskusstvu* (St. Petersburg: F. Pavlenkov, 1885), and *Lektsii po elektrotekhnike* (St. Petersburg: Artilleriiskii zhurnal, 1887).

[51] "Otchet predsedatelia uchenogo otdeleniia morskogo tekhnicheskogo komiteta i komiteta morskikh uchebnykh zavedenii za 1871," *Morskoi sbornik*, September 1872, no. 1: 9; "Otchet predsedatelia uchenogo otdeleniia morskogo tekhnicheskkogo komiteta i komiteta morskikh uchebnykh zavedenii za 1872," *Morskoi sbornik*, September 1874, no. 9: 11–12.

[52] Rondolphe van Wetter, *L'Eclairage électrique à la guerre* (Paris: G. Carre, 1889), 82; Em. Alglave and J. Boulard, *The Electric Light: Its History, Production and Applications* (New York: Appleton, 1884), 393.

[53] "Polozhenie o Minnom ofitserskom klasse i o minnoi shkole dlia nizhnikh chinov," *Morskoi sbornik*, March 1875, no. 3: 25.

[54] E. g., Edison, Swan, and Maxim incandescent lights in 1882–83; *Materialy k istorii Minnogo ofitserskogo klassa i shkoly* (St. Petersburg: Minnyi ofitserskii klass, 1899), 95.

[55] "Notes," *Telegraphic Journal and Electrical Review*, 24 February 1883, 334, and 30 June 1883, 538; V. Iu. Gorianov, "Ie. P. Tveritinov—osnovopolozhnik sudovoi elektrotekhniki v Rossii," *Elektrichestvo* 1960, no. 12: 78–81.

trification. A graduate of military schools and an external student at Moscow University, he worked in Moscow as a laboratory assistant and for Pavel N. Jablochkov's electric light company. After a bad investment depleted his resources, Chikolev moved to St. Petersburg in 1876. He served as the initial editor of *Elektrichestvo*, the first Russian electrotechnical journal. His company, Elektrotekhnik, attempted to light Nevskii Prospekt in St. Petersburg in 1880. Although this financial failure was bought out by Siemens and Halske, he did install some electric street lights in Moscow in 1883.[56] Chikolev also published a novel about electricity, in 1895.[57]

The GAU hired Chikolev as a clerk in 1877, beginning an association that lasted until his death in 1898. Working closely with Petrushevskii, Chikolev organized electric lighting systems for fortresses, reviewed research proposals, developed searchlights, tested new equipment, and traveled abroad for the GAU.[58] He nearly saw frontline duty with a mobile searchlight unit in the 1877–78 Russo-Turkish war, but typhus intervened.

Until the diffusion of utilities in the 1890s, the army and navy provided the major markets and support for electric lighting. The military strengthened the Russian scientific and technical infrastructure by supporting research, education, technical societies, foreign trips, and prize competitions. It also tested materials and equipment, which assisted the development of a domestic industry and aided standardization.[59] Possibly the most important contribution was thousands of engineers and technicians educated in military schools and academies, far more than in all civilian schools.[60] By creating this infrastructure and market in the 1870s and 1880s, the military provided the underpinnings of later civilian electrification. Thomas J. Misa's description of the development of the transistor in America applies equally well

[56] "V. N. Chikolev," *Elektrotekhnik*, 1897–98, no. 8: 497–502; "Vladimir Nikolaevich Chikolev," *Entsiklopedicheskii slovar* (St. Petersburg: Brogaus-Efron, 1903), vol. 76: 826–27; N. A. Shotsin, "Vladimir Nikolaevich Chikolev," *Elektrichestvo*, 1945, no. 8: 7–12; I. D. Artamonov, "V. N. Chikolev—voennyi elektrotekhnik," ibid., 13–16; V. V. Zapolskaia, "Iz vospominanii V. V. Zapolskoi o V. N. Chikoleve," *Elektrichestvo*, 1948, no. 6: 77–79.

[57] *Ne byl, no i ne vydumka—electricheskii razskaz* (St. Petersburg: Babkin, 1895), cited in Richard Stites, *Revolutionary Dreams: Utopian Vision and Experimental Life in the Russian Revolution* (New York: Oxford University Press, 1989), 30.

[58] E. g., TsGVIA f. 506, op. 1, d. 437, 42, 80, 88, 154, 191, 198, 247, 293.

[59] Voennoe Ministerstvo, *Vsepoddanneishii otchet Voennogo Ministerstva za 1881 god* (St. Petersburg: Gogenfelgen, 1883), 18–19; *Vsepoddanneishii otchet Voennogo Ministerstva za 1892 god* (St. Petersburg: Gogenfelgen, 1894), 34.

[60] *Materialy k istorii Minnogo ofitserskogo klassa*, 257–58.

to electric lighting in Russia a century earlier: "Military sponsorship helped shield the new technology from undue criticism and economic constraint and also provided the necessary potential to push it through the development stage to commercialization."[61] The introduction and promotion of electrotechnology saw the military sector paralleling Western activities and the civilian sector lagging, a frequent pattern in Russian history. Without the Russian military, electrotechnology would have developed even more slowly, more expensively, and with more foreign involvement than it did.

Technical Societies

Scientific and technical societies have played major roles in the creation, diffusion, and application of knowledge.[62] They have played a no less important role in the development, professionalization, and political activities of the knowledge holders themselves. As technical knowledge became more important for the industrializing economy, so did the technical societies.[63]

Russian engineers founded their first technical society, the Imperial Russian Technical Society (IRTO, Imperialskoe Russkoe Tekhnicheskoe Obshchestvo), in 1866. Aided by government funding, the IRTO was oriented toward industry and the military, with sections for chemical production and metallurgy, mechanics and machine construction, construction and mining, and naval and military technology.[64] An umbrella organization, the IRTO expanded to fifteen sections and forty local branches by World War I. Engineers founded more than forty-five other technical societies.[65] Increasingly located outside St. Petersburg after 1905, these societies reflected the geo-

[61] Thomas J. Misa, "Military Needs, Commercial Realities, and the Development of the Transistor, 1948–1958," in Smith, ed., *Military Enterprise*, 255.

[62] "Scientific Institutions," in *Dictionary of the History of Science* (Princeton: Princeton University Press, 1984), 377–78.

[63] Edwin T. Layton, Jr., *The Revolt of the Engineers* (Baltimore: Johns Hopkins University Press, 1986).

[64] James H. Swanson, "The Bolshevization of Scientific Societies in the Soviet Union" (Ph.D. diss., Indiana University, 1968), 21.

[65] N. G. Filippov, *Nauchno-tekhnicheskie obshchestva Rossii (1866–1917)* (Moscow: Moskovskii gosudarstvennyi istoriko-arkhivnyi institut, 1975), 32–33, 35. At least forty-five: Filippov omits the Russian Electrical Society, founded in 1900 at the St. Petersburg Electrotechnical Institute; see M. A. Shatelen, "Russkoe elektricheskoe obshchestvo," *Elektrichestvo*, 1900, nos. 22–24: 351–52.

graphic spread of industry and the growing professionalization of the engineering community.[66]

The first electrotechnical organization grew from the IRTO and scientific societies in St. Petersburg and Moscow.[67] Late in 1879, a group of engineers petitioned the IRTO to form a new section. On 30 January 1880, fifty-six people attended the first meeting of the new VI (electrotechnical) Section in St. Petersburg.[68] Like other sections, the VI Section consulted on projects, developed official standards, petitioned and worked with the government, collected information, advanced its members' prestige, and popularized electrification.

Continuing the IRTO orientation, a military presence dominated the early years of the VI Section: Gen. F. K. Velichko was president, candidate-president Pavel N. Jablochkov's firm dealt mainly with the navy, and the military employed at least three of the nine permanent members. This military involvement remained strong through the 1880s. Of the eighty-two active members in 1885, half worked in or for the military.[69] A sample of twenty-five active members in 1889 found eleven military employees, a slight drop by percentage.[70]

Military support did not benefit only the VI Section. The Electrotechnical Society, established in 1892, initially met in the St. Petersburg Naval Museum and received other navy support.[71] Electrical exhibits benefited from War Ministry awards and exhibits.[72]

In 1880, the VI Section published the first IRTO section journal, *Elektrichestvo* (Electricity). Despite financial and editorial struggles, *Elektrichestvo* continued to publish until 1918.[73] Other journals appearing in the 1890s focused on more practical applications—*Elektrotekhnicheskii vestnik* (Electrotechnical Herald) and *Elektrotekhnik* (Electrotechnician)—or were directed to technicians rather than engineers—

[66] After 1905, sixteen of twenty-nine new societies formed outside the capital, compared with six of eighteen in the four decades before 1905; see Filippov, *Nauchno-tekhnicheskie obshchestva*, 206–13.

[67] Lev D. Belkind, *Pavel Nikolaevich Jablochkov* (Moscow: Izdatelstvo Akademii SSSR, 1962), 57–67.

[68] "Kratkii obzor deiatelnosti," *Elektrichestvo*, 1880, no. 1: 2.

[69] Forty-two members in military or military-related occupations, twenty-three nongovernment, ten in civil government, six academic, and one unknown; see "Sostav IRTO," *ZIRTO*, 1885, no. 2: 8–33.

[70] "Lichnyi sostav IRTO," *ZIRTO*, 1890, no. 7: 1–55.

[71] "Elektrotekhnicheskoe obshchestvo," *Elektrotekhnicheskii vestnik*, 1894, no. 1: 5.

[72] E. g., "Raznye izvestiia," *Elektrichestvo*, 1888, no. 15: 142; "Uspeki v elektrotekhnike,' *Elektrichestvo*, 1893, no. 1: 2.

[73] M. A. Shatelen, "'Elektrichestvo' (1880–1930)," *Elektrichestvo*, 1930 Jubilee Issue, 3–4; A. V. Netushil and Ia. A. Sheibert, "Osnovanie zhurnala 'Elektrichestvo' i pervykh dvadtsat let ego deiatelnosti," *Elektrichestvo*, 1979, no. 7: 1–11.

Elektricheskoe delo (Electrical Affairs)—but *Elektrichestvo* remained the preeminent Russian electrical journal.

The VI Section provided invaluable technical and economic expertise to city administrations. Its commissions studied a city's technical demands, judged proposals, calculated operating costs, and worked out consumption, system efficiency, and the best equipment.[74] The numerous requests for assistance and guidance literally buried the section as utilities spread after 1900.[75] From 1899 to 1914, the section handled more than fifty requests from cities and towns; that is, it assisted one-third of all electrified cities.[76]

Like electrotechnical societies elsewhere, the VI Section worked with state ministries on issues ranging from standards to siting.[77] Members served on government panels, formed committees to handle government requests, and published standards in *Elektrichestvo*. The VI Section and, after 1900, the Permanent Committee of the All-Russian Electrotechnical Congresses routinely petitioned the MVD for changes in laws and regulations. The section usually worked with the MVD and Ministry of Trade and Industry, but it also dealt with other ministries on specific issues, such as the Ministry of Finance's proposed tax on electric energy.[78] Although it worked well with the MVD and MTP, the VI Section's influence was fairly weak, for it had no active constituency inside the government until World War I.

Membership was small for Russia's leading electrotechnical society. The section contained approximately 140 members in 1891 (90 percent in St. Petersburg), 156 active members in 1906, 196 active members in 1908, and 243 active members in 1910.[79] The latter was only one-third the average attendance at the All-Russian Electrotechnical Congress

[74] "Zakluchenie Komissii po rassmotreniiu tekhnicheskikh zadanii na ustroistvo elektricheskogo osveshcheniia v g. Nizhnem-Novgorode i po rassmotreniiu predstavlennykh proektov," *ZIRTO*, 1907, no. 6: 329.

[75] Filippov, *Nauchno-tekhnicheskie obshchestva*, 132.

[76] See TsGIAL f. 90, op. 1, ed. kh. 480–82, and the regular "Deistviia Obshchestva zhurnala zavedenii VI-ogo otdela" section in *ZIRTO*. See also, Filippov, *Nauchno-tekhnicheskie obshchestva*, 132.

[77] E. g., the German Verband Deutscher Elektrotechniker; see "The German Electrotechnical Societies," *Electrical World*, 2 February 1911, 290.

[78] The archival records of the VI Section are rich with these communications (e. g., TsGIAL f. 90, op. 1, ed. kh. 456–58, 466, 471, 480–82). See also, "Sobraniia chlenov VI otdela IRTO," *Elektrichestvo*, 1901, nos. 11–12: 176, and "Otchet o deiatelnosti VI otdela," *Elektrichestvo*, 1906, nos. 11–12: 160.

[79] For 1891, see TsGIAL f. 90, op. 1, ed. kh. 458, 68–69; for 1906 and 1908, see "Deiatelnost obshchestv," *ZIRTO*, 1908, nos. 6–7: 280–83; for 1910, see "Otchet o deiatelnosti IRTO v 1910 godu," *ZIRTO*, 1911, nos. 6–7: 247. Categories also existed for honorary and inactive members.

or one-half the membership of the Moscow-based Society of Electrotechnicians that year.[80] By comparison, the British Institution of Electrical Engineers had 4,010 members in 1901, the German Verband Deutscher Elektrotechniker had 4,653 members in 1910, and the American Institute of Electrical Engineers had 7,100 members in 1910.[81]

The VI Section and *Elektrichestvo* remained unique until the creation of new electrical journals in the 1890s to serve the growing number of electrical engineers. The economic boom after the 1905–6 revolution further expanded the number and size of professional societies. The spread and geographic concentration of these societies reflects the slow diffusion of electrification. Of the seven prewar electrotechnical societies, only two existed before 1900 and three began in 1909. St. Petersburg housed four societies; Moscow, Kharkov, and Kiev each contained one.[82]

Electrotechnical societies cooperated more than they competed; multiple membership was not uncommon. They jointly sponsored the biannual All-Russian Electrotechnical Congress, a united, albeit weak, voice of the electrical engineering community. Between 1899 and 1913, congresses met seven times in St. Petersburg, Moscow, and Kiev and drew an average of 600 people.[83] The war caused the cancellation of the eighth meeting, planned for Kharkov in 1915. The congresses promoted professionalism, passed resolutions, and served as clearinghouses for the latest technical information.[84]

The Electrical Engineers

THE VI SECTION and other societies played a vital role in the creation and diffusion of electrification, especially in promoting and providing technical knowledge and skills. Societies, however, ultimately de-

[80] "Deiatelnost Obshchestva elektrotekhnikov v Moskve," *Elektrichestvo*, 1914, no. 9: 291.

[81] British data produced by Geoffrey Tweedale for W. J. Reader's *A History of the Institution of Electrical Engineers* (London: IEE, 1987); "The German Electrotechnical Societies," *Electrical World*, 2 February 1911, 287; *AIEE Yearbook* (New York: AIEE, 1914), 19.

[82] Filippov, *Nauchno-tekhnicheskie obshchestva*, 206–13; M. A. Shatelen, "Russkoe elektricheskoe obshchestvo," *Elektrichestvo*, 1900, nos. 22–24: 351–52.

[83] B. S. Sotin and L. G. Davydova, "Russkie elektrotekhnicheskie sezdy," *Trudy Instituta istorii estestvoznaniia i tekhniki* 26 (1959): 6–41.

[84] E. g., the original draft of the contract between the 1886 Company and the Bogorod local government stated that MVD rules would guide the placement of transmission lines, but that information from the fourth and fifth congresses would guide operations; TsGIAMO f. 722, op. 1, ed. kh. 876, 2.

pended on their individual members, the electrical engineers. Engineers provided both the skilled personnel to construct, operate, and expand Russian utilities and a firm link with the international electrotechnical community. These men—and very few women[85]—formed the technical societies, educated and trained their successors, advised cities and, with less success, the national government, and proposed plans for the social and industrial transformation of Russia.

Two groups dominated the electrotechnical community through the early years of Soviet power. St. Petersburg housed one group in educational institutes and firms. The Moscow section of the 1886 Company, the country's largest utility, and Elektroperedacha, Russia's first regional station, housed the second group. A third group of Moscow academics in the heat committee contributed greatly to electrification planning after 1914 but never assumed leadership. These groups controlled the VI Section and other professional activities. During the tsarist era, these engineers were academics or high-level managers for German utilities. Wartime participation in state, city, and Central War Industries Committee activities introduced electrical engineers into the country's leadership circles. After the February revolution, these engineers built a base in the government. After the October revolution, they took charge of developing and implementing state electrification plans.

The VI Section served as an institutional focus for St. Petersburg electrical engineers, who worked for a range of employers. Academia contributed the most prominent engineers, followed by manufacturers, utilities, and, before 1895, the military. Among the academics were professors Mikhail A. Shatelen, who tried to professionalize electrical education and the VI Section; P. D. Voinarovskii, the director of the Electrotechnical Institute after 1906; Aleksandr V. Vulf, a railroad electrification advocate; and Piotr S. Osadchii, who led electrical engineers into close cooperation with the provisional government in 1917. Leonid B. Krasin was the most notable electrical engineer in industrial management. The military figures included Gen. F. K. Velichko, the first president of the VI Section, the inventor Jablochkov, and Chikolev, electrotechnology's Renaissance man.

The utility-based Moscow group stood out as a proving ground for

[85] The St. Petersburg Women's Technical Institute, established in 1906, had graduated only fifty female engineers by 1916; see Richard Stites, *The Women's Liberation Movement in Russia: Feminism, Nihilism, and Bolshevism, 1860–1930* (Princeton: Princeton University Press, 1978), 176. See also V. M. Buzinova-Dybovskaia, "Pervye zhenskie politechnicheskie kursy," *Elektrichestvo*, 1970, no. 7: 91–92.

Russian manager-engineers and for its Bolshevik electrical engineers, one of the few such prerevolutionary clusters. The 1886 Company's Moscow section consciously switched from German to Russian managers, engineers, and technicians after 1900. Its summer program for students attracted young men from all the country's technical institutes and allowed the 1886 Company to select and groom promising future engineers.[86] The Moscow section of the 1886 Company and Elektroperedacha became a haven for Bolsheviks, who held major positions of responsibility before 1917, including Gleb M. Krzhizhanovskii, Robert E. Klasson, Aleksandr V. Vinter, Ivan I. Radchenko, Piotr G. Smidovich, and V. Z. Esin.[87]

The professional and political links among the Bolshevik engineers began in their student days at the St. Petersburg Technological Institute, where in 1890 Klasson founded the first study group to introduce successfully Marxism to workers. The original group included Nadezhda Krupskaia, Lenin's future wife, and Stephan I. Radchenko, "perhaps the first truly professional *apparatchik*." An excellent example of an "old-boy network," the graduates of the St. Petersburg Technological Institute, the center of Russian electrotechnical education, formed a "kind of electrician's mafia" which "enjoyed a certain immunity from prosecution because of the desperate need in a rapidly industrializing economy for native technology."[88]

After working in Germany with Mikhail O. Dolivo-Dobrovolsky on long-distance transmission and studying Marxism, Klasson directed Russia's first 3-phase AC project in 1895 at the GAU Okhtensk gunpowder factory; this was the last major example of military leadership in electrotechnology.[89] Two decades later, Klasson, Vinter, and Ivan I. Radchenko, brother of Stephan, led the prerevolutionary and Soviet efforts to utilize peat and brown coal. Krzhizhanovskii, future head of GOELRO and Gosplan, directed the 1886 Company cable network in

[86] TsGANKh f. 9508, op. 1, ed. kh. 14, 4. TsGIAMO f. 722, op. 1, d. 602 contains scores of summer job applications.

[87] Mark O. Kamenetskii, *Robert Eduardovich Klasson* (Moscow: Gosenergoizdat, 1963), 78–79; Gleb V. Lipenskii, *Moskovskaia energeticheskaia* (Moscow: Moskovskii rabochii, 1976), 19–23, 27; Vladimir Kartsev, *Krzhizhanovskii* (Moscow: Molodaia gvardiia, 1980), 226–27; Alek G. Cummins, "The Road to NEP, the State Commission for the Electrification of Russia (GOELRO): A Study in Technology, Mobilization and Economic Planning" (Ph.D. diss., University of Maryland, 1988), 23.

[88] According to James H. Billington, *Fire in the Minds of Men: Origins of the Revolutionary Faith* (New York: Basic Books, 1980), 448, 453–55.

[89] R. E. Klasson, "Elektricheskaia peredacha sily trekhfaznymi tokami na Okhtinskikh porokhovykh zavodakh bliz Peterburga," *Elektrichestvo*, 1897, no. 19: 257–67; Kamenetskii, *Klasson*, 13–15; Billington, *Fire in the Minds*, 448.

Moscow. At a lower level of the company worked Smidovich, who had been expelled from Moscow University in 1895 for political agitation and completed his education in electrical engineering in Paris.[90]

Another member of Klasson's study group was Krasin, who served as a director of Siemens and Halske, the main electrotechnical manufacturer in Russia and a major supplier for the 1886 Company. While constructing and operating the electric utility in Baku in 1900–4, Krasin used his position to hire and protect other Bolsheviks. Klasson, himself in internal exile for his political activities, had given Krasin the Baku position, which Krasin used to construct and operate an illegal printing plant. At one point, Krasin purchased printing equipment from a 2,000 ruble city loan intended for utility expenses. During the war, Krasin worked for the Central War Industries Committee to organize trading resources, a task he continued under Soviet rule.[91]

The evolution of the electrical engineering community reflected the development of electrotechnology in Russia. St. Petersburg, with its preponderance of educational, military, and industrial facilities, housed the leadership of the electrical engineering community, though Moscow increasingly took the technological and political lead after 1910.

Inventions

One glaring exception to the accomplishments of the Russian electrical engineering community was invention—only the first step in the larger process of translating an idea into a commercial success. A good idea is not enough; its creator must endow it with the social and economic characteristics it needs for survival.[92] The paucity of commercially successful inventors is a striking aspect of Russian electrification and indicative of the societal and economic weaknesses that hindered its development.

Russian engineers and scientists were not passive recipients of for-

[90] Vasilii Iu. Steklov, *Lenin i elektrifikatsiia*, 3d ed. (Moscow: Nauka, 1975), 169.

[91] *Who Was Who in the Soviet Union* (Metuchen: Scarecrow Press, 1972), 311; Michael Glenny, "Leonid Krasin, the Years before 1917: An Outline," *Soviet Studies* 22 (1970), 194–95; Billington, *Fire in the Minds*, 461; Robert W. Tolf, *The Russian Rockefellers: The Saga of the Nobel Family and the Russian Oil Industry* (Stanford: Hoover Institution Press, 1976), 154; Lubova Krassin, *Leonid Krassin, His Life and Work* (London: Skeffington and Son, 1929), 41.

[92] See, e. g., Thomas P. Hughes, "The Evolution of Large Technological Systems," in Bijker, Hughes, Pinch, eds., *Social Construction of Technological Systems*, 63.

eign technologies; they invented and developed their own equipment too. A glance through the pages of *Elektrichestvo* quickly dispels any notion of a lack of creativity. Many ideas brought to fruition in the West, such as incandescent lighting, had Russian counterparts in conception and experimentation although not in transfer and production. Yet only three Russian inventors received national and international recognition in the late nineteenth century: Aleksandr N. Lodygin, Jablochkov, and Dolivo-Dobrovolsky.[93] Why did invention not translate into success in innovation and application? Responsibility falls on two intertwined causes: a systemic failure of the Russian economic and social environment to support and foster domestic inventions, and technological prematurity, the development of an idea before its supporting materials and components attain technological and economic feasibility.

Invention does not occur in a vacuum. The frequency of simultaneous discovery and invention illustrates the extent to which separate inventors share a common world of interests, materials, equipment, financing, and ideas.[94] Thomas Edison has been widely recognized and promoted as the inventor of the incandescent light,[95] but many others invested time and money in the quest for a commercially viable incandescent light.[96] A few professional inventors, such as Elmer Sperry, successfully combined good ideas, financial backing, and customer support;[97] most, however, failed. Failure is a normal outcome in technological development; success, the exception. Perhaps Russia was unexceptional and Europe the aberration. But what made Russia so unexceptional?

The inventor did not find Russia hospitable. Although research facilities existed in military and civilian educational institutes, financial

[93] A close contender is Achilles de Khotinsky, a former naval officer who participated in the early searchlight experiments and manufactured light bulbs in Russia and the West in the 1880s; see "Achilles de Khotinsky," *National Cyclopaedia of American Biography* (New York: J. T. White, 1936), 25, 63–64; A. Heerding, *The History of N. V. Philips' Gloeilampenfabrieken: The Origin of the Dutch Incandescent Lamp Industry*, vol. 1 (Cambridge: Cambridge University Press, 1986), 139–40, 148.

[94] Robert K. Merton, "Singletons and Multiples in Science," in Norman W. Storer, ed., *The Sociology of Science* (Chicago: University of Chicago Press, 1973), 343–82.

[95] Wyn Wachhorst, *Thomas Alva Edison: An American Myth* (Cambridge: MIT Press, 1981).

[96] E. g., Moses G. Farmer, Hiram S. Maxim, St. George Lane-Fox, and Joseph W. Swan; see Arthur A. Bright, Jr., *The Electric Lamp Industry: Technological Change and Economic Development from 1800 to 1947* (New York: Macmillan, 1949), 42–55.

[97] Thomas P. Hughes, *Elmer Sperry: Inventor and Engineer* (Baltimore: Johns Hopkins University Press, 1971).

support proved hard to obtain, manufacturing was difficult, and weak sales diminished profits. Furthermore, the quality, robustness, and suitability of the marketed products played a critical role. Technological prematurity, facing weaknesses in materials, equipment, components, and theoretical approaches, can keep a good idea from fruition.[98] Whereas Lodygin's incandescent lamp failed technically and commercially in Russia in the early 1870s, Jablochkov's arc lamp succeeded in Europe in the mid-1870s partly because he took advantage of advances in supporting components in the intervening three years. The two lamps offer a study in contrasts.

Lodygin's incandescent light bulb, developed in 1872, received the Lomonosov Prize from the Academy of Sciences in 1874 despite bad design, an inadequate vacuum, and poor filaments.[99] Lodygin's lamp underwent constant modification by the inventor and his senior mechanic, Vasilii F. Didrikhson. They tested different materials and designs to increase the duration of burning, the brightness of the light, and the strength of the vacuum.[100] Lodygin worked without benefit of the army's Volkovo field test facility, despite a request to use the installation.[101] Military interest in searchlights did not extend to an outsider working on a smaller light. Lodygin formed a company to manufacture and market an improved version, but a light "more appropriate for laboratory tests and lectures than continual lighting" ruined his first financial backer.[102] The major problem that plagued him, as many other unsuccessful inventors, was the disintegration of the carbon filament.[103] In 1875, Lodygin had to work at the St. Petersburg arsenal as a metalworker, despite the efforts of another investor, banker Stanislav V. Konn. Konn marketed an improved version under his name with a Gramme generator, but he died in late 1876.[104] Lodygin's company, unable to find further support, withered away.[105]

[98] E. g., the theory of forward-swept wings preceded the availability of the needed composite materials and computers by four decades; see Gadi Kaplan, "The X-29: Is It Coming or Going?" *Spectrum*, June 1985, 54–60.

[99] Liudmila N. Zhukova, *Lodygin* (Moscow: Molodaia gvardiia, 1983), 117–19, 137–45.

[100] E. O. Bukhgeim, "K istorii vozniknoveniia elektricheskogo osveshcheniia," *Pochtovo-telegraficheskii zhurnal*, 1900, no. 2: 158–63; Ia. I. Kovalskii, ed., *Ocherk rabot russkikh po elektrotekhnike s 1800 po 1900 god* (St. Petersburg; 1900), 35–41; "Vasilii Fedorovich Didrikhson," *Elektrichestvo*, 1930, no. 14: 615.

[101] TsGVIA f. 506, op. 1, ed. kh. 419, 770, and 774.

[102] Kovalskii, *Ocherk rabot russkikh*, 38.

[103] Alglave and Boulard, *Electric Light*, 119–21.

[104] Van Wetter, *L'Eclairage électrique*, 82.

[105] The company ceased paying its gold duty after 1876; TsGIAL f. 1287, op. 7, ed. kh. 2618, 3.

Financial speculation, a recurring problem of start-up firms, may have aided the firm's demise.[106]

From 1878 to 1884, Lodygin worked for Jablochkov's company. Beginning in 1881, Jablochkov's firm manufactured Lodygin's Russian lamp until it was overwhelmed by imported Edison incandescent lamps.[107] For the next two decades, Lodygin worked on electric lighting in France and the United States as a researcher, inventor, and manager before returning to Russia in 1906. Able to find employment only as manager of a St. Petersburg tram substation, he returned to the United States, where he died in 1923 while working for the Sperry Gyroscope Company.[108]

The lack of financial support directly caused its demise, but even with more funding Lodygin's lamp ultimately would have merely joined the ranks of unsuccessful lightbulbs. The lamp was commercially impractical. It had a short life of several hours (versus the thousand hours of the first Edison bulbs) and operated in small clusters that required their own generating station, a major investment. By contrast, the Edison lamp was the visible part of a complete system, designed from conception to be economically competitive and technically superior to gas lighting.[109] Whereas Lodygin developed a lamp, Edison developed an entire system that demanded minimal investment and attention from the consumer.

The Lodygin lamp would have failed in Russia or Europe. The Jablochkov arc lamp, by contrast, succeeded abroad but failed in Russia. The inventor initially worked in St. Petersburg, but in 1875 he went to Paris, either to flee his creditors or to seek financial support.[110] Certainly, Paris, the international center of electrical engineering in the 1870s, offered a stronger technical base than St. Petersburg.

In an arc light, an electric current passes between two carbon electrodes to generate a bright, intense arc of light. The electrodes must be constantly readjusted as they burn to provide even lighting. The "Jablochkoff candle" solved this problem with electrodes placed side

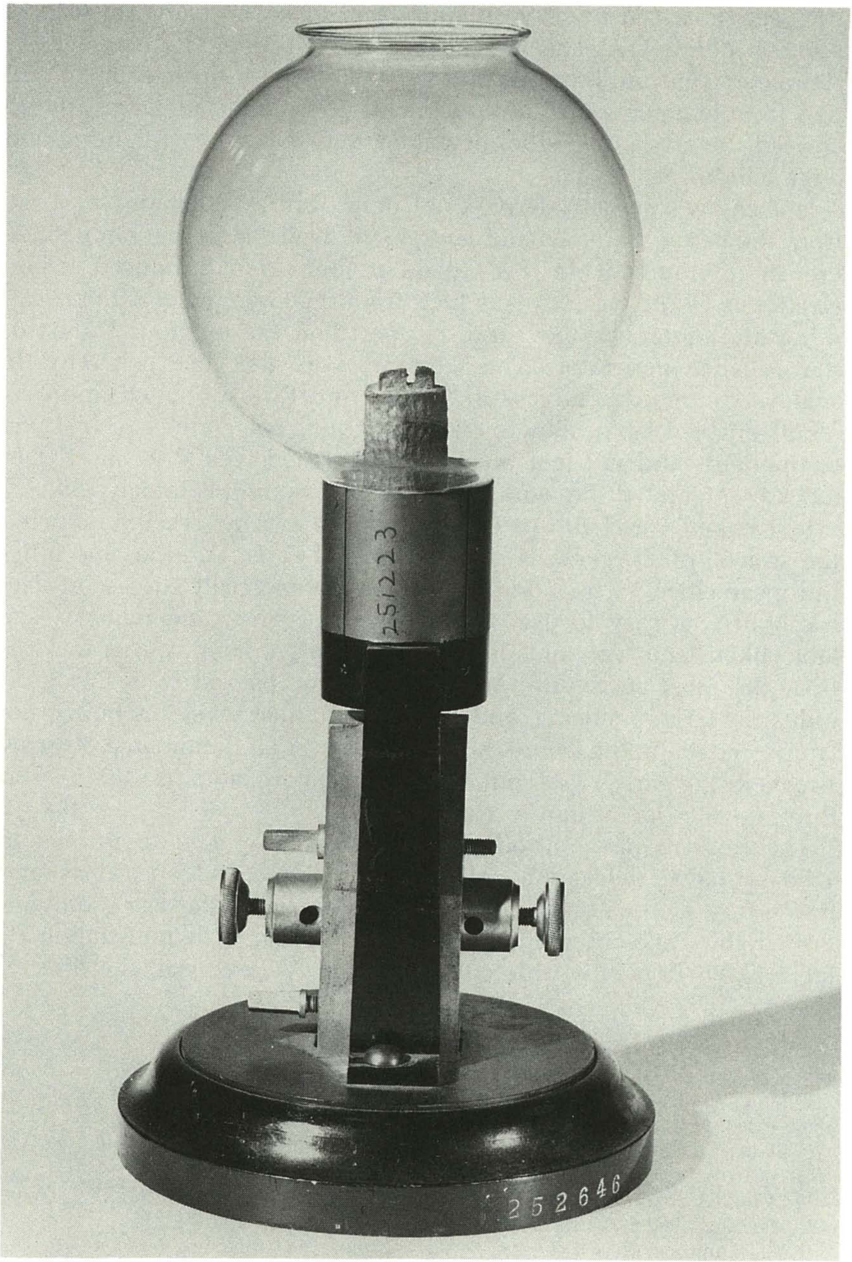
[106] V. L. Chikolev, "Istoriia elektricheskogo osveshcheniia," *Elektrichestvo*, 1880, no. 5: 73.

[107] S. A. Gusev, *Razvitie sovetskoi elektrotekhnicheskoi promyshlennosti* (Moscow: Energiia, 1964), 20.

[108] "Khronika," *Elektrichestvo*, 1923, no. 12: 644–46; M. A. Shatelen, "Lodygin, Jablochkov, Edison, 1847–1947," *Elektrichestvo*, 1947, no. 10: 68–74: "Obituary," *Journal of the AIEE*, May 1923, 553; Bright, *Electric Lamp Industry*, 120–21.

[109] Hughes, *Networks of Power*, 19–20.

[110] Belkind, *Jablochkov*, 84, and "P. N. Jablochkov: Nekrolog," *Elektrotekhnicheskii vestnik*, 1894, no. 4: 121–22.



Jablochkov arc light. Courtesy of the Smithsonian Institution.

by side, separated by an insulating layer of kaolin china, instead of point to point. The sixteen-candlepower lamp offered advantages of simplicity, constant burning, and the ability to run several sets of candles from one generator. Improvements and modifications greatly increased the arc lamp's efficiency and utility for outdoor lighting and large buildings.

Jablochkov's success derived not only from a better idea but also from the better materials and equipment available in the competitive French environment. In 1876–77 alone, four firms introduced carbon electrodes.[111] The Russian benefited from the Gramme generator, significantly lighter, smaller, and cheaper than the previous standard, the Alliance generator. The Gramme was the first generator to achieve commercial success in Europe and Russia.[112] Such improvements enabled Jablochkov to create a lighting system in which all the components and not just the lamp functioned well.[113] In short, Jablochkov integrated the work of others and thought commercially.

Jablochkov's arc light, patented in France in 1876, soon illuminated the streets, public gardens, and factories of Paris, London, and other European cities.[114] The world's first truly commercially successful electric light was easy to use, relatively inexpensive, and reliable. The Jablochkov lamp was not the only Russian arc lamp, but it was the first, the most successful, and the only one backed by a European industrial base, financing, and market.[115] Russian inventors built other lamps, including the Dobrokhotov arc lamps that illuminated Moscow streets in the early 1880s, but the most used arc lamp in Russia—and Europe—was Jablochkov's.[116]

The Russian navy introduced the Jablochkov light to Russia. In 1878, a naval delegation, including five electrical specialists and headed by Gen.-Adm. Konstantin N. Romanov, the tsar's brother, visited the Paris international exhibition. After a demonstration by Jablochkov, Romanov ordered Vladimir P. Verkhovskii, the director

[111] Hippolyte Fontaine, *Electric Lighting: A Practical Treatise* (London: E. & F. N. Spon, 1878), 38–50.

[112] James E. Brittain, "The International Diffusion of Electric Power Transmission, 1870–1920," *Journal of Economic History*, March 1974, 108.

[113] D. A. Lachinov, "Poslednye uspekhi v elektricheskom osveshchenii," *ZIRTO*, 1879, no. 2: 77–80.

[114] "The Jablochkoff System of Electric Illumination," *Engineering*, 26 July 1878, 63–65.

[115] Heerding, *Philips' Gloeilampenfabrieken*, 89.

[116] V. Tikhmorov, "Elektricheskaia vystavka: Spiralnaia lampa dlia elektricheskogo osveshcheniia," *Elektrichestvo*, 1882, no. 6: 73–74; N. Sluginov, "Elektricheskaia vystavka: Elektricheskaia lampa A. V. Dobrokhotov-Maikova," *Elektrichestvo*, 1882, no. 7: 88–89; "Deiatelnost obshchestva," *ZIRTO*, 1910, no. 5: 69.

of the Mine Officer Class, to test the inventor's lamp in Russia. The navy convinced Jablochkov to return to Russia and open a factory.[117]

The practicalities of electric light deterred many. The obstacles were high. Owning an arc light required a substantial financial investment for the engine, generator, and other equipment, plus the skilled technical personnel to operate and maintain the equipment. A Jablochkov four-light system cost 1,750 rubles, an insurmountable obstacle for many in 1878.[118] The military had the skilled personnel and the funding, and military orders constituted over two-thirds of the company's initial business. Of the approximately 750 arc lights in Russia in 1881, one-third illuminated military installations and military-related factories and another third illuminated forty ships of the Baltic and Black sea fleets.[119]

Civilian users were either more technically advanced than most firms, such as the Poltava railroad workshop, or, like the Hermitage Gardens, used the lights as a novelty to attract customers. St. Petersburg, site of most of the advanced, Western-related industries, housed nearly 60 percent of the lamps.[120] The largest potential market, city governments, despite illuminating some bridges and squares electrically in St. Petersburg and Moscow, proved reluctant to replace the less costly kerosene and gas lamps for street lighting.[121]

Despite the military orders, Jablochkov's company never really succeeded in Russia. It finally succumbed in 1887 to an inadequate domestic market, manufacturing problems, and competition from foreign firms.[122] Jablochkov himself returned to Paris in 1880, where he continued his research, obtaining thirty-four French patents before he died in 1891.[123]

Jablochkov's major contributions to Russian electrical engineering were twofold. He introduced arc lighting to the country and, more

[117] Belkind, *Jablochkov*, 168–70, 176–77.

[118] *Tovarishchestvo dlia ekspluatatsii elektricheskogo osveshcheniia v Rossii* (St. Petersburg: A. E. Munster, 1878), 12–16; Chikolev, *Lektsii po elektrotekhnike*, 10.

[119] For the survey, "Raznye izvestiia," *Elektrichestvo*, 1882, no. 5: 69; for the fleets, Belkind, *Jablochkov*, 178, 180; Averbukh, *Petrushevskii*, 48.

[120] "Raznye izvestiia," *Elektrichestvo*, 1882, no. 5: 69.

[121] "Elektricheskoe osveshchenie Imperatora Aleksandra II, v S.-Peterburga," *Elektrichestvo*, 1880, no. 2: 24–27; N. I. Falkovskii, *Moskva v istorii tekhniki* (Moscow: *Moskovskii rabochii*, 1950), 437.

[122] Ie. P. Tveritinov, *Elektricheskoe osveshchenie: Kurs Minnogo ofitserskogo klassa* (St. Petersburg: Morskoe Ministerstvo, 1883), 334; Shatelen, "Lodygin, Jablochkov, Edison," 68–74; Gusev, *Razvitie sovetskoi elektrotekhnicheskoi promyshlennosti*, 11.

[123] M. A. Shatelen, "Pavel Nikolaevich Jablochkov," *Elektrichestvo*, 1926, no. 12: 496–98; "Lists des brevets français pris par P. Jablotchkoff," ibid., 518.

important, in the eyes of fellow entrepreneur Chikolev, "by his energy and labor he cleared the road for other inventors" and brought attention and capital to the Russian electrotechnical industry.[124] Not all this attention was favorable: Jablochkov at times received a curiously hostile reception from the Russian electrotechnical community, possibly because of his international renown.[125]

A third inventor, Dolivo-Dobrovolsky, also spent most of his career outside Russia. Initially, this was involuntary, stemming from his 1878 expulsion from the Riga Polytechnic Institute for political activities. He went to Darmstadt to complete his education and stayed after 1887 to work for the German electrotechnical firm AEG. In 1888, he began research on 3-phase AC transmission. In 1891, he demonstrated long-distance transmission of electricity over the 170 kilometers from Lauffen to Frankfurt, a major technological milestone. Dolivo-Dobrovolsky advanced electrical engineering in Russia from Germany by contributing papers to journals and to the first All-Russian Electrotechnical Congress, donating his library, and supplying equipment to the St. Petersburg Polytechnic Institute. His visits to Russia, however, were short, partly for reasons of health. He declined a position at St. Petersburg Polytechnic Institute to remain with AEG until just before his death in 1919.[126]

The careers of these inventors share several similarities. All spent much of their professional lives in the West, where they achieved greater success than in Russia. Only Lodygin did his major creative work in Russia, work that was ultimately unsuccessful. Mikhail Shatelen explains Lodygin's failure in terms of Russia's poorly developed social-economic base.[127] Shatelen is correct, but the reasons are deeper than he proposes. The West did have the technical base, the financial support, and the market that Russia lacked. But commercial success also demands the full development of all components of a system, including packaging for the consumer. As W. Bernard Carlson and A. J. Millard, biographers of Edison, noted, "success did not

[124] Cited in Lachinov, "Poslednye uspekhi v elektricheskom osveshchenii," 89.

[125] If *Elektrichestvo* articles are a guide, Jablochkov had strained relations with his peers. One article stands out. Written by "S. S.," "Novyi element gospodina Jablochkova" (*Elektrichestvo*, 1884, nos. 20–21: 163–64), in addition to the gratuitous title "Mr.," begins with a venomous satire on the inventor. The reader is told that the article is presented solely because of requests; only foreign information is used. Jablochkov's obituary in *Elektrichestvo* (1894, no. 7: 97–99) significantly lacks information about his activities after returning to Russia in 1878.

[126] Oleg N. Veselovskii, *Dolivo-Dobrovolsky, 1862–1919* (Moscow: Izdatelstvo Akademii nauk, 1963); "Nekrolog," *Elektrichestvo*, 1930, no. 5: 258–59.

[127] Shatelen, "Lodygin, Jablochkov, Edison," 68.

come necessarily to the fellow who invented something first. It came to the fellow who could make a new device simple and functional, who could figure out how to manufacture it cheaply and in quantity and then convince people to buy it."[128]

Jablochkov's success can be better understood with Hughes's concept of reverse salients—"obvious weak points, or weak components, in a technology which are in need of further developments."[129] In the West, Jablochkov found the auxiliary technologies and financial support he needed. Like Lodygin, Jablochkov invented a component, not a system. Unlike Lodygin, Jablochkov's French environment provided the other components needed to create a successful lighting system. Unlike Lodygin, Jablochkov utilized French financial and manufacturing support to transfer his laboratory prototypes into commercial products.

The unsuccessful efforts of another Russian, Fedor A. Pirotskii, illuminate the difficulties of the independent Russian inventor and the limits of military interest.[130] An artillery captain, Pirotskii promoted electric power transmission, electric railroads, and electric lighting. In 1874, he proposed a small hydrostation to power a state gunpowder factory. In 1880, the GAU finally offered grudging support of 300 rubles to demonstrate his system of electric transmission, a pittance compared with the tens of thousands of rubles Petrushevskii had spent in his lighting experiments a decade earlier. The project was moderately successful, but it suffered from insulation problems exacerbated by the cold, damp St. Petersburg climate and the erroneous but prevailing assumption that large quantities of electricity demanded a conductor with a large cross section.[131] Like Lodygin, Pirotskii was slightly ahead of the materials and ideas of his time and lacked resources and patrons. His biographer claims that Pirotskii built the world's first electric railroad for the 1880 St. Petersburg electrical exhibition. A Siemens representative reportedly talked to Pirotskii and asked for information about his work, which led to changes in the Siemens electric railroad, first displayed at the 1881 Berlin exposition.[132] In September 1880, Pirotskii did conduct a series of tests at the St. Petersburg horse tram park, which left observers

[128] W. Bernard Carlson and A. J. Millard, "Edison as a Manager of Innovation: Lessons for Today," *New Jersey Bell Journal*, winter 1985–86, 27.

[129] Hughes, *Networks of Power*, 22.

[130] For another failure, see N. Popov, "Pamiati A. I. Poleshko," *Elektrichestvo*, 1916, no. 9: 945–47.

[131] TsGIAL f. 506, op. 1, d. 411, 28, 145–50.

[132] B. N. Rzhonsnitskii, *Fedor Apollonovich Pirotskii* (Moscow: Gosenergoizdat, 1969), 45, 55–57.

less than impressed at his "toy."[133] The train suffered from slow speed and costly, unreliable batteries, the same problems that bedeviled engineers in the West. Although Pirotskii thought that he had built an electric railroad before Siemens, his Russian contemporaries ignored his work and credited Siemens for the first electric railroad, as did early Soviet writers.[134]

Pirotskii is interesting, not because he was a military inventor, but because he failed to win acceptance and support from his peers. Part of his failure is not surprising: the GAU served military needs, and Pirotskii's research was not directed to existing needs. Even if his electric railroad had proved practical, what would the GAU have done with it? Siemens, by contrast, was a manufacturing firm creating, shaping, and meeting the needs of customers in the military and civilian spheres. Pirotskii highlights another instance of a technology developed successfully outside and unsuccessfully inside Russia.[135] Russian governmental, financial, and industrial decision makers suffered from a "foreign is better" bias toward technology which handicapped native inventors and firms as Western criteria and activities took precedence over Russian equivalents.[136] In a society where German was the language of the businessman and French the language of the court, this foreign bias is not surprising. This preference for foreign technology and engineers strengthened contacts between Russia and Europe but weakened domestic industrial development.

The activities, ideas, and interests of Russian inventors in the early decades of the electrical industry paced their Western counterparts. In development, diffusion, and application, however, the advantages lay with the more hospitable economic and social environment of the West, with its larger, more advanced technical and financial base. This base, better able to sustain failure and support new ideas and systems, proved the key factor in the rapid Western expansion of electrical applications. The failure of Russian inventors indicates not personal inadequacies but more general societal handicaps.

[133] *Golos*, 17 September 1880, 3; *Russkii invalid*, 16 September 1880, 2.

[134] TsGIAL f. 506, op. 1, d. 411, 70; Iv. Sviatskii, *Istoriia elektrichestva* (St. Petersburg: P. P. Soikin, 1897), 120–21; V. P. Kashchinskii, "Znamenatelnye sobytiia v istorii razvitiia generirovaniia i kanalizatsii elektricheskoi energii za poslednie polveka," *Elektrichestvo*, 1930 Jubilee Issue, 88.

[135] Calling Pirotskii the inventor of the electric tram is misleading; he was one of several inventors around the world working on the same idea at the same time; see John P. McKay, *Tramways and Trolleys: The Rise of Urban Mass Transport in Europe* (Princeton: Princeton University Press, 1976), 35–40.

[136] Rieber, *Merchants and Entrepreneurs*, 102–3.

The Role of Foreign Firms and Investment

FOREIGN INVOLVEMENT was crucial to the industrial development of Russia; envisaging Russia without the large migrations of monies, technologies, ideas, and people from West to East is inconceivable. Although the exact numbers remain a source of contention, foreign investment accounted for significant amounts of government and nongovernment capital formation.[137]

Financing is the underlying sine qua non of commercial technologies. The best equipment in the world is useless without the money to purchase and operate it. High technology did not come cheap, and the Russian financial infrastructure was woefully unsuited to provide the necessary capital.[138] One contributing factor was the tsarist restrictions on the Russian stock exchange, which, by hindering the efficient creation and transfer of capital, increased the country's dependence on foreign capital to finance capital-intensive industries—such as electrification.[139] In the West, financial markets evolved to meet the demand for electric light, power, and traction beginning in the 1880s. The early loans and exchanges of stocks between manufacturers and utilities evolved into banking syndicates, such as the Zurich-based Elektrobank, holding companies, and other mechanisms to transfer equipment to the utilities and profit to the providers.[140] The Russian electrotechnical market did not expand rapidly until the late 1890s and, by then, better-capitalized foreign firms had established Russian subsidiaries that often provided financial support with their technical offerings.

Foreign banks and companies financed the vast bulk of prewar Russian electrification, usually with a Russian bank, especially the Inter-

[137] Arcadius Kahan, "Capital Formation during the Period of Early Industrialization in Russia, 1890–1913," *Cambridge Economic History of Europe*, vol. 7, pt. 2: 273; P. V. Ol, *Foreign Capital in Russia*, trans. Geoffrey Jones and Grigori Gerenstain (New York: Garland Publishing, 1983), 9; Fred V. Cartensen, "Numbers and Reality: A Critique of Foreign Investment Estimates in Tsarist Russia," in Maurice Levy-Leboyer, ed., *La Position internationale de la France* (Paris: L'Ecole des Hautes Etudes en Sciences Sociales, 1977), 275–83.

[138] Trebilcock, *Industrialization of the Continental Powers*, 224–25.

[139] *Potrebitelskie elektricheskie stantsii* (Moscow, 1913), 3; Rieber, *Merchants and Entrepreneurs*, 105.

[140] M. Giterman, "Elektrichestvo i munitsipalitety," *Izvestiia Moskovskoi gorodskoi dumy*, 1914, no. 11: 64; Armstrong and Nelles, *Monopoly's Moment*, 116; Chandler, *Visible Hand*, 310, 426–33; Walther Kirchner, "Siemens and AEG and the Electrification of Russia, 1890–1914," *Jahrbucher für Geschichte Osteuropes* 30 (1982): 408; A. J. Millard, *A Technological Lag: Diffusion of Electrical Technology in England, 1879–1914* (New York: Garland Publishing, 1987), 155–56.

national and Private banks.[141] According to Valentin Diakin, of 139 million rubles invested in utilities by 1914, German monies accounted for nearly half, Belgium-channeled capital for a quarter, Russian funding for about 10 percent and other countries provided the rest.[142] In trams, Belgian firms held 73 percent, Germans 13 percent, and Russians 12 percent of the 94 million ruble investment. German and Belgian firms accounted for 90 percent of the 61 million rubles invested in manufacturing.

No less significant were the flows of foreign technology. Technology transfer took several forms during this half-century, including equipment, such as Parsons turbines, and manufacturing technology, such as factories to produce lightbulbs. Foreign financing and ownership often accompanied these visible forms of technology transfer. The German firm Siemens and Halske dominated Russian manufacturing, in competition with AEG, Brown-Boveri, Westinghouse, Metropolitan Vickers, and other foreign and Russian firms. The strength of German firms lay in their aggressive and thorough marketing. The German businessman in Russia knew Russian, carried brochures and catalogs in Russian, and could arrange long-term credit, a vital consideration.[143] A less visible but important form of technology transfer consisted of "stocks of knowledge," including people, information, and ideas.[144] Foreign companies sent engineers and managers to operate their Russian facilities, train Russians, and sell equipment. Tens of thousands of Russians traveled abroad for technical and scientific training.[145] Trips abroad enabled engineers to meet their Western counterparts and to see and work on the latest technologies.

Electrical engineers proved no exception. Of forty prominent prerevolutionary electrical engineers, two-thirds studied or worked abroad.[146] The tsarist police inadvertantly encouraged travel and emigration by restricting and punishing political activities, as in the cases of Dolivo-Dobrovolsy and Achilles de Khotinsky.[147] The Russian government, particularly the military, and technical societies also sent

[141] V. A. Diakin, *Germanskie kapitaly v Rossii* (Leningrad: Nauka, 1971), 41–44, 84–85.

[142] Ibid., 268–69. Diakin excluded an unknown number of municipal operations and domestic concessions, thereby somewhat understating the Russian contribution.

[143] Walther Kirchner, "Russian Tariffs and Foreign Enterprises before 1919: The German Entrepreneur's Perspective," *Journal of European History* 11 (1981): 361–80.

[144] Simon Kuznets, *Toward a Theory of Economic Growth* (New York: Norton, 1968), 62.

[145] Trebilcock, *Industrialization of the Continental Powers*, 268, 290.

[146] Data compiled from *Elektrichestvo* obituaries and *Great Soviet Encyclopedia* articles.

[147] Heerding, *Philips' Gloeilampenfabrieken*, 140, 148.

delegations to Europe for electrotechnical congresses, exhibitions, and factory tours.[148]

Although a major conduit of information about Western electrotechnology, engineers abroad were a small fraction of the Russian electrotechnical community. The majority received information mainly from foreign and Russian periodicals. Graduates of the St. Petersburg Polytechnic Institute in 1913 read thirteen electrical journals. Seven were German, three Russian, and three English or American. Half of these engineers read the German *Elektrotechnische Zeitschrift*; 70 percent read *Elektrichestvo*.[149] Russian electrotechnical periodicals contained numerous translated articles, Russian articles on Western developments, and sections devoted to foreign activities. *Elektrichestvo* began in 1880 with a table of contents in Russian and French. By the late 1880s and 1890s, French articles declined and articles of German and British origin increased. American articles did not reach significant numbers until the 1910s. These changes corresponded to the shift in the frontiers of electrical engineering from Paris to Berlin. A German transfer of knowledge reflected dominance of the Russian electrical market. Even the technical language was German.[150] Fifty-five percent of the St. Petersburg Polytechnic graduates in 1913 knew German; only 28 percent knew English.[151]

The migrations between Europe and Russia included organizational links and ideas. In some areas, Russia–Europe connections proved stronger than intra-Russian ties. A Russian association of utilities did not exist until 1917, but twenty Russian utilities belonged to the Vereinigung Deutscher Elektrizitatewerke, a German association of utilities, in 1914.[152] As the shortages in World War I proved, Russia strongly depended on German electrotechnology and finance. Even the first effort by the VI Section in 1908 to publish statistics on Russian utilities depended on German information.[153] This dependence developed voluntarily; Russian engineers, scientists, and managers

[148] TsGVIA f. 506, op. 1, d. 409, 46–47, 81–85.

[149] M. A. Shatelen, "Iz 'Ankety sredi inzhener-elektrikov' okonchivshikh STP Politekhnicheskii institut Imperatora Petra Velikogo," *Elektrichestvo*, 1914, no. 4: 130.

[150] E. g., Russians used the German *schwachstrom* (weak current) and *starkstrom* (strong current) to distinguish between telecommunications (telegraph and telephone) and the power industry.

[151] Shatelen, "Ankety," 136.

[152] "Khronika," *Elektrichestvo*, 1917, nos. 9–10: 145.

[153] "Statisticheskie svedeniia o tsentralnykh elektricheskikh stantsiiakh v Rossii," *Elektrichestvo*, 1910, no. 1: 1.

saw themselves as part of the larger international community and gravitated toward Germany. The most important foreign society for Russian electrical engineers was the German Verband Deutscher Elektrotechniker. In 1888, 319 of its 1,452 members were non-German.[154] Fifty-four members—17 percent of all foreign members, about half the active membership of the VI Section—were Russians. Non-German societies did not attract similar interest, further proof of the German domination.[155]

Foreign influence permeated every aspect of Russian electrotechnology. The larger European and American bases of production and consumption enabled Western development to create technical, educational, and financial infrastructures that provided commercial advantages abroad in such less developed areas as Russia. Foreign financing permitted Russian electrification to develop as quickly as it did, despite the inadequate Russian credit market. Superior foreign financing provided the means to acquire superior foreign electrotechnology, and Western institutions provided education to Russian engineers. Equally important, the West provided ideas, concepts, and legitimation for Russian electrification proposals that appeared after 1910.

The Russian economic, political, and governmental environment greatly shaped the evolution of technologies in Russia. Electrification was handicapped by a governmental morass that left basic questions unresolved, a time-consuming system for obtaining permission, and government regulations that consistently lagged behind technical developments. National regulations governed the extent and timing of municipal activities, company formation, and the construction and operation of utilities. The structure of rules and reviews slowed the diffusion of new technologies and the creation of utilities. The legal framework hindered the development of indigenous small companies. Larger, better-capitalized foreign firms could endure the time needed to obtain permission and funding more easily than smaller Russian firms. In everyday operations, the process of evaluating proposals for utilities operated sluggishly. For technologies that required new laws, such as hydropower and long-distance transmission, politi-

[154] "Raznye izvestiia," *Elektrichestvo*, 1888, nos. 17–18: 176. The destruction of association membership records in World War II makes full knowledge of Russian involvement impossible (VDE personal communication, 26 June 1982).

[155] E. g., Russian membership in the British Institution of Electrical Engineers varied from none to three from 1872 to 1915; data produced by Geoffrey Tweedale for Reader, *History of the Institution of Electrical Engineers*.

cal struggles among ministries slowed or prevented commercial implementation.

The major role played by European firms reflected both Russian weaknesses and foreign advantages in organization, financing, and technology. Capital-intensive electrotechnology fared poorly in risk-adverse, credit-poor, conservative Russia. Compared with the West, Russian electrification advanced quickly in the military sector but more slowly in the civilian sphere, as the poor commercial record of Russian inventions demonstrates. Was the military dominance in the early years of electrification an example of prescience or civilian weakness? Were the Russian army and navy ahead of their time or was the Russian civilian economy behind the times? Similar questions could—and should—be asked of previous and contemporary military research.[156]

The failure of Russian inventors in Russia and the success of some, such as Jablochkov, abroad demonstrates that the receptivity of the environment plays a major role in the invention, development, and diffusion of technologies. This is not a new conclusion, but it bears repeating. Similarly, the major role of the VI Section in the development and transfer of electrotechnology demonstrates the importance of key groups of technical experts. Although few in numbers, the members of the section played vital roles in Russian–Western and intra-Russian technology transfers. In the prewar period, the role of electrical engineers in tsarist policy making was limited to advising. As the importance of electrification increased in the war and postwar periods, so too did the importance of electrical engineers in setting and implementing state policy.

[156] Possibly the best nineteenth-century American example is the four decades of military investment before large-scale manufacturing of truly interchangeable rifles became feasible; see Smith, *Harpers Ferry*, and David A. Hounshell, *From the American System to Mass Production, 1800–1932* (Baltimore: Johns Hopkins University Press, 1984), 15–50.