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Renewable energy in Russia: markets, development and technology transfer

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Abstract

Five potential markets in Russia offer commercial opportunities for renewable energy that are nearly cost-competitive with conventional forms of energy—grid-connected electricity from wind power, electricity for villages and small settlements from hybrid wind-diesel and biomass, district heating for buildings from biomass, hot water for buildings from solar thermal, and electricity and heat from geothermal. Over the last several decades the Soviet Union conducted research and development on several forms of renewable energy. Technological infrastructure, scientific and technical knowledge, engineering and technical skills, and factories and equipment are all well developed assets. But the translation of these assets into commercial renewable energy technologies and markets is a problem because associated market-oriented skills and institutions are still lacking. Many barriers also exist, including lack of information and demonstration experience, lack of long-term commercial financing, a perceived climate of high investment risk, technology acceptance, some direct and indirect energy price subsidies (most energy prices have risen to "market" levels), utility monopolies and the absence of operational regulatory frameworks for independent power producers, and historical enterprise specialization. Market intermediation is very important for renewable-energy investments and technology transfer, providing the knowledge, information, skills, services, financing, and analysis that is necessary to overcome barriers. Joint ventures with foreign multinational corporations represent another important means for overcoming barriers, one that takes advantage of Russian technological capabilities. Four case studies illustrate the most prominent examples of renewable energy technology transfer with Russia, Ukraine, and the Baltic States during the period 1992–1996. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Since the breakup of the Soviet Union in 1991, Russia's economy has undergone enormous changes, while at the same time many mentalities, institutional structures, and physical infrastructure are changing much more slowly. Enormous geographical potential for renewable energy, advanced scientific and technological capabilities, readily available materials, industrial capacity idled by severe economic downturns, decentralization of economic decision-making, and political desires for greater regional autonomy, would all suggest favorable prospects for renewable energy technology diffusion and international technology transfer. Russia is the third-greatest source of carbon-dioxide emissions worldwide, behind the U.S. and China, and Russia's international commitments to reduce greenhouse-gas emissions should also support renewable energy. Yet the legacy of the Soviet planned economic system and current economic transitions pose grave problems for innovation, commercialization, and diffusion.

This paper reviews the prospects and problems of renewable energy technology diffusion and international technology transfer in Russia. It begins by describing potential commercial or nearly commercial markets and technical-economic opportunities for renewable energy in Russia. It then discusses historic and recent efforts at domestic renewable energy technology development and manufacturing, the problems that Russian enterprises face in commercializing renewable energy technologies, and the barriers to renewable energy diffusion and international technology transfer. Finally, the paper stresses the importance of both market intermediation (such as developing a practical regulatory basis for independent power producers) and joint ventures as ways to overcome these barriers and facilitate diffusion and technology transfer.

In addition, four case studies are presented following the body of the paper (in Appendix A): (1) a joint venture to manufacture wind turbines in Ukraine; (2) Swedish government assistance to convert heating boilers to biomass in the Baltic States and Northwest Russia; (3) a joint venture to produce photovoltaics in Russia; and (4) U.S. government assistance for wind-diesel hybrid systems in Russia. These case studies illustrate the most prominent examples of renewable energy technology transfer with Russia and other formerly Soviet countries during the period 1992 to 1996. The case studies and much of the supporting evidence for this paper are taken from Martinot [1].

2. Markets, geography, and technical-economic opportunities

Available data and experience suggest five potential markets offering commercial opportunities for renewable energy that are nearly cost-competitive with conventional forms of energy. A comprehensive analysis of markets and technical-economic opportunities is hindered by lack of data and project experience [2]. Further, estimates of renewable energy resources are sketchy and incomplete because central economic planners in the Soviet era did not consider renewable energy as a priority, and the funds necessary for thorough resource measurements and analyses were never allocated. Nevertheless, a reasonable view of the opportunities can be developed. These five markets are described below, along with an evaluation of favorable regions for each market based upon geographic resources, infrastructure, and population.

2.1. Electricity for electric power grids from wind power

Grid-connected wind farms can be competitive with conventional electricity generation. In 1995, industrial electricity prices in Russia ranged from an equivalent of less than US 1 cent/kWh in Irkutsk to US 16 cents/kWh in Kamchatka, with prices in the central European part of Russia more typically US 4–6 cents/kWh [3]. Typical wind power production costs range from US 6–10 cents/kWh in the West, with newer wind turbine technology reducing these costs to the neighborhood of US 4–5 cents/kWh [4]. If Russian or Ukrainian manufactured wind turbines are used, the lower costs of these turbines in comparison with Western models can make electricity production costs even more competitive, although their performance and reliability is less certain (see Windenergo case study). Potential investors in grid-connected wind systems are regional electric power utilities, the national electric power utility RAO 'EES Rossii', municipal electric distribution utilities, or private power developers.

There are large regions of Russia and Ukraine with annual average wind speed greater than 5–7 m/s at or near ground level, although available wind-speed data often do not give the measurement height, limiting the usefulness of such data [5–7]. These areas include: the far-northern and far-eastern coastal areas of the Arctic and Pacific oceans; the areas adjacent to the Caspian, Azov, and Black Seas; and some high plains and mountain regions (see Fig. 1). Many of these regions have extremely low population densities and are not near electric power networks, so wind power would take the form of decentralized off-grid systems. Perhaps surprisingly, most of Siberia is not very windy on an annual average basis, and can be considered a poor wind resource. The department of renewable energy of the Russian national electric utility (RAO 'EES Rossii') has identified seventeen specific regions (out of 89 total) in Russia where it believes grid-connected wind power development is particularly viable: Murmansk, Arkhangelsk, Karelia, Leningrad, Kaliningrad, Astrakhan, Volgograd, Krasnodar, Stavropol, Kalmykia, Dagestan, Komi, Magadan, Maritime, Kamchatka, Sakhalin, and Khabarovsk [8]. More precise wind-speed data exist for a few wind farm sites under active development. For example, wind speeds measured at a site in Kalmykia near Elista showed annual average wind speeds of 7.6 m/s at a 38-m height. Another site in Karelia showed annual average wind speeds of 8 m/s at a 10-m height.

From an integrated geographical perspective, particularly favorable regions for grid-connected wind farms are Rostov, Stavropol, Krasnodar, Volgograd, Kalmykia, Kaliningrad, Leningrad, Maritime, Khabarovsk, and Sakhalin. The North Caucasus regions in particular (Rostov, Stavropol, Krasnodar, Kalmykia) provide a congruence of favorable conditions for wind farms, including good wind

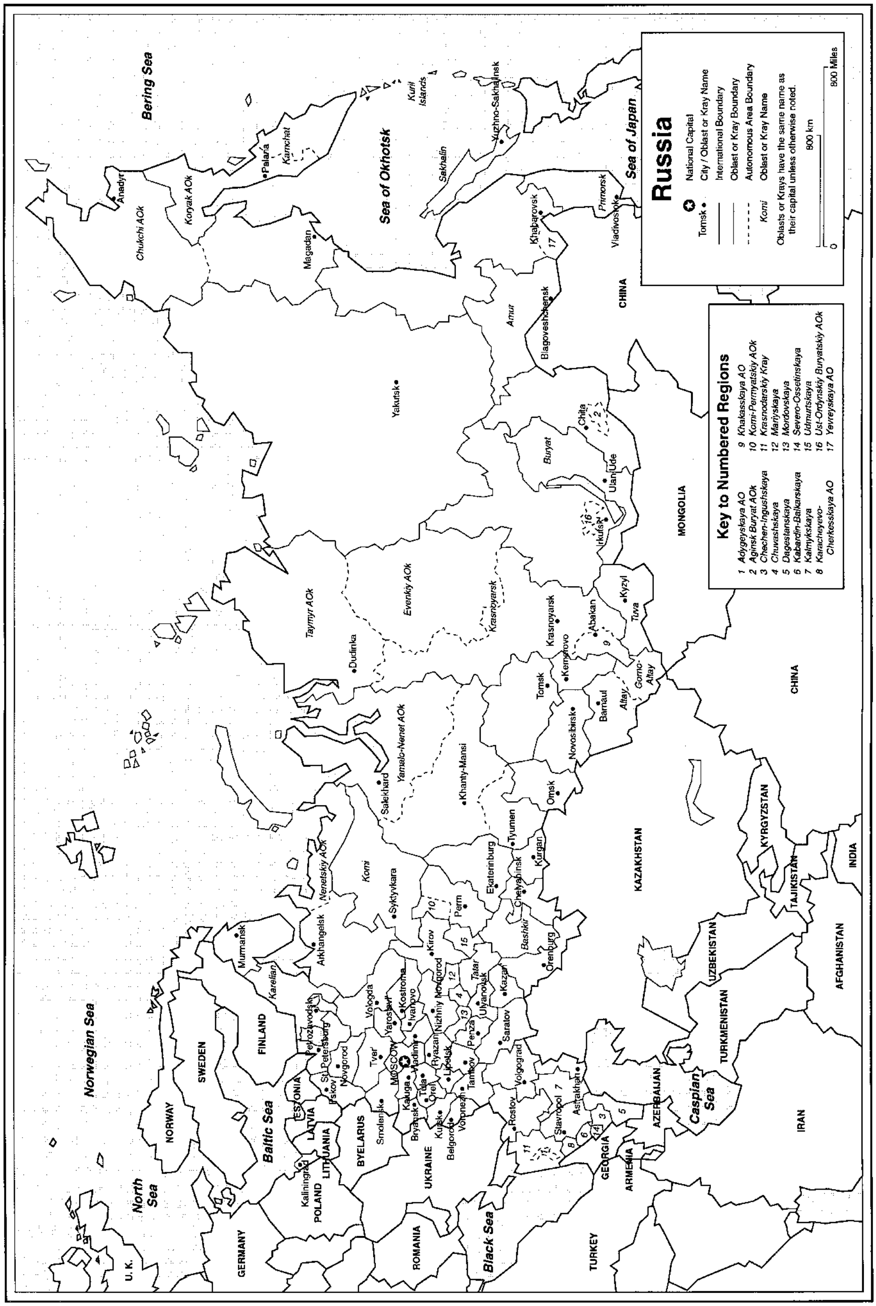

Fig. 1. Regions of Russia.

resources, flat terrain dominated by agricultural uses, high population densities, and severe electric power deficits in the regional electric grid (and thus the urgent need for new capacity). In most of these regions the fuel share for conventional electricity generation includes a large fraction of either oil-fired or gas-fired generation.

2.2. Electricity for villages and small settlements from hybrid wind-diesel and biomass

According to some estimates, approximately 20 million people in Russia live in regions where Russia's 'unified' electric power grid does not penetrate [9,10]. Most of these people are connected into smaller, autonomous power grids, but approximately 8 million of them are served by stand-alone generation systems using either diesel fuel or gasoline. A small fraction (estimated at 10%) of these 8 million people live in small single-family farms, while the majority live in larger collective farms, villages, or small settlements. These stand-alone systems are found primarily in the far northern regions of European Russia and in the Far East. Typically, diesel-generator systems of capacity up to 1000 kW serve a collective farm or a settlement (there are an estimated 10,000 such systems), or smaller gasoline generator systems of capacity in the range 500 W to 5 kW serve smaller farms or installations (there are an estimated 60,000 such systems). Close to half of these diesel and gasoline systems are reported to be no longer operating because of fuel delivery problems and/or high fuel costs. Historically, state farming collectives received electric power connections to grids free of charge. Now newly privatized farms (estimated at 250,000) must pay for grid connections themselves, and the costs are prohibitive.

Hybrid wind-diesel systems and biomass-fired steam boilers with turbine-generators can replace or supplement these existing diesel and gasoline generators cost-effectively. In 1995, diesel fuel prices for delivered fuel in the far northern regions of European Russia appeared to range from an equivalent of U.S. 30–60 cents/l. A wide variation exists because diesel fuel transport costs to remoter regions can almost double diesel fuel prices, and because of variations in generation efficiency and operating costs. It appears that electricity costs from these systems are U.S. 15–30 cents/kWh, common figures for diesel electricity production in other countries. Costs of wind-diesel hybrid and biomass systems can be very competitive with these costs [11]. Favorable regions for this market are Karelia, Murmansk, Vologda, Arkhangelsk, Komi, Maritime and Khabarovsk [12]. A fledgling commercial market for small wind turbines for remote applications has emerged in Khabarovsk and the Far East, where up to 60 small (10-kW or less) turbines, a mixture of Dutch and American, have been purchased in recent years. Potential investors in wind-diesel systems could be local industrial enterprises, third-party energy enterprises, settlement or village administrations, the regional administration, or the regional electric utility.

In a preliminary analysis of a 10-kW hybrid wind-diesel system for one specific site in the Murmansk region done by the National Renewable Energy Laboratory

(NREL), the existing 16-kW diesel generator was found to be oversized for the site load, severely reducing the efficiency of the existing system [13]. The estimated electricity production cost from the existing diesel system was an equivalent of US$ 0.30–0.75/kWh, while levelized electricity costs for the wind-diesel hybrid were US$ 0.23–0.27. The wide variations in estimates are partly due to lack of good data about loads and diesel fuel costs. Another analysis using data from five actual sites in Northern Russia showed wind-diesel hybrid systems displacing 50–85% of diesel fuel consumption at simple payback periods of less than five years [10].

Another preliminary analysis showed that electricity from biomass wastes can be significantly cheaper than diesel-fueled generation in remoter forest regions. A waste-biomass-fueled electricity generating plant was proposed to displace generation from three existing 315-kW diesel generators in a small logging settlement in the Archangelsk region of Russia [14]. Existing diesel fuel costs were approximately US 15–20 cents/kWh, while the cost of biomass fuel was estimated to be only US 0.3 cents/kWh. A pre-feasibility study suggested that a 470-kW biomass-waste plant could displace 87% of the diesel-fuel consumption with a financial rate of return of over 17%. In addition, waste steam from this plant would be fed into the existing district-heating system, reducing biomass consumption by 50% in the district-heating boiler in wintertime and eliminating the need for the district-heating boiler altogether in summertime.

2.3. District heating for buildings from biomass

In smaller cities and towns where coal or fuel oil (mazut) fired district-heating boilers are small (less than 10 MW), these boilers can be converted to burn biomass fuels (especially wood wastes). Actual examples of these types of conversions can be seen in Estonia, Latvia, Lithuania, and Russia by the Swedish government, and as part of the World Bank's Estonia District Heating Rehabilitation project (see Swedish Government Biomass case study) [15,16]. The experience from Estonia and other Baltic countries is relevant to Russia because the boilers used in the Baltics are Soviet models that are also found in Russia, although Russian district heating systems in urban areas tend to use larger capacity boilers. Simple payback times for these conversions have been demonstrated at around 3–5 years, and positive financial returns have also been demonstrated. Russia now faces Western-market-level mazut prices, and thus wood wastes could replace mazut for heat production in a cost-effective manner. The greatest uncertainty in the profitability of these boiler conversions lies in future market prices for waste wood products and harvested wood chips. Favorable regions for this market are Leningrad, Karelia, Vologda, Novgorod, Maritime and Khabarovsk. Potential investors in district heating boiler conversions are either municipal or privatized district heating companies, or the responsible local or regional administrations.

Potential biomass resources from forest harvesting are plentiful in much of the Taiga and Mixed Forest vegetation zones of Russia. Nilsson et al. [17] conducted an extensive survey of the forest resources of the former Soviet Union. The 'forest fund' of the former Soviet Union (primarily Russia, the Baltic countries, and Belarus) includes 1.2 billion hectares (about half the total area of the former Soviet Union), with 810 million hectares classified as forested land with a total standing volume of 86 billion m^3. Of the remaining 440 million hectares of non-forested land, 30% is considered suitable for afforestation. The actual forest harvest in 1990 was 300 million m^3 for the entire Soviet Union, and 175 million m^3 for the European part only. The annual growth increment is estimated as 1.5 billion m^3/year, and the exploitable increment in the European part is estimated at 360 million m^3/year. Regions where forest and biomass potential corresponds with denser population centers include Leningrad, Karelia, Murmansk, Vologda, Archangelsk, Komi, Perm, Yekaterinburg, much of the northern portion of European Russia, Khabarovsk, and Amur. Forest harvesting for biomass fuel wasn't significant in the Soviet era because of the emphasis by central planners on fossil fuels, and the fact that Soviet forest industries faced institutional and economic difficulties in harvesting enough timber simply to meet demand for wood and paper.

Biomass wastes from agriculture, industry, and other sources in Russia are estimated at more than 300 million tons per year [6]. The availability of wood waste for heat production in the northern forest regions—St Petersburg, Karelia, Murmansk, Vologda, Arkhangelsk, Komi—appears promising. Unpublished figures provided by the Leningrad Oblast Forest Committee indicate that the total annual production of wood waste in Leningrad Oblast is about 250,000 m^3 (12% of annual wood processing), of which perhaps one-third to one-half goes completely unused. The Committee estimates that for the rest of the North-West economic region (which includes Karelia, Vologda, Komi, and Arkhangelsk), annual production of wood waste is about 2.5 million m^3 to 7.5 million m^3, depending upon how much of existing production capacity is actually being utilized in these regions. Taking an estimate of 5 million m^3/year, and assuming that half of these wastes are available for heat production, total annual heat production could be on the order of 7 million MWh, demonstrating the potential for total biomass-fueled boiler capacity of 1000–2000 MW in this region.

2.4. Hot water for buildings from solar thermal

Even though most of Russia is located north of 40° latitude, there is still a large potential for utilizing solar energy for both electricity generation and thermal heating [18,19]. Practical regions for solar generated electricity in Russia include those below or near 50° latitude, including Stavropol, Rostov, Krasnodar, Volgograd, Amur, Astrakhan, Kalmykia, Dagestan, Altay, and Maritime. Incoming solar energy in these regions varies from 1000 to 2500 kWh/m^2 per year, based upon a useful operation of 2000–3000 h/year [6]. Examples of solar insolation in more northern cities are 1340 kWh/m^2 for Irkutsk (52° latitude), 1290 kWh/m^2 for Yakutia-Sakha (62° latitude), and 850 kWh/m^2 for St Petersburg (60° latitude) [20]. One estimate for the former Soviet Union stated that 60 million people lived in regions where solar energy is feasible for water heating, although most of this population would have been counted in the regions of Central Asia, the Transcaucasus region and Ukraine [21]. Potential investors in solar collectors on apartment buildings are households and homeowner associations, as well as other entities that may still be responsible for operating and maintaining these buildings, such as city administrations or industrial enterprises. Municipal district heating companies would need to be involved in these investments as well.

One potentially promising market is solar hot-water heating in the summer months for apartment buildings and single-family houses which are connected to heat-only boilers in district-heating systems. In most of these district-heating systems, centralized boiler plants must operate in the summer months merely to produce hot water for residents. During the summer, the energy consumption to produce this hot water is especially inefficient; boilers are operated at low loads and distribution-system losses are substantial whether hot water is demanded or not. In these applications, rooftop solar hot water collectors could replace the existing source of hot water during the summer and allow the district-heating boilers to be shut down. This market has potential throughout much of Russia during four to five summer months of each year. The cost-effectiveness of the application depends upon an autonomous district heating system with individual boilers fired by oil, gas, or coal without cogeneration (cogenerated district-heat makes a positive valuation of the saved hot water problematic). Further study of costs and applications is needed.

2.5. *Electricity and heat from geothermal*

Geothermal resources have been identified in Stavropol, Krasnodar, Sakhalin and Kamchatka, and generation costs can be competitive with current electricity prices, especially in Sakhalin and Kamchatka in the Far East [6,22,23]. One estimate puts the geothermal potential of Kamchatka alone at 2000 MW in generation capacity. High industrial electricity rates in Kamchatka (equivalent to about US 16 cents/kWh in 1996) make geothermal electricity generation economically very attractive. An initial 12-MW geothermal plant under development in Kamchatka estimated an electricity production cost of only US 2 cents/kWh. In the Stavropol and Krasnodar regions in the North Caucasus, there exist deep geothermal zones that could be exploited by fluid circulation systems. The potential for geothermal energy as a form of heat supply also appears promising, and there is a demonstration of this application through a Global Environment Facility project in Lithuania [24].

3. Domestic technology development and manufacturing

Russia has technological capabilities that parallel most developed countries. Technological infrastructure, scientific and technical knowledge, engineering and technical skills, factories and equipment are all well developed. Substantial evidence indicates that Russian capabilities to develop and produce most renewable energy technologies are excellent. Capabilities to install, operate, and maintain these technologies are also highly developed. Nevertheless, there are two persistent technological shortfalls: (a) production technology lags behind Western levels, especially in the degree of automation and quality assurance; (b) there is evidence to suggest that specific components and materials needed for renewable energy technologies may need to be imported (e.g., electronics, fiberglass, epoxy resins, and other composite materials) because development of these materials in the Soviet economic system lagged behind the West. In particular, the lag in computers, electronics, and modern materials has been well documented [25].

Over the last several decades the Soviet Union conducted research and development on several forms of renewable energy, including solar thermal, solar photovoltaic, wind, geothermal, biomass, and tidal power [21,26]. These efforts resulted in a few test installations and some fairly well-developed science and technologies, especially in solar photovoltaic cells for Russia's space program. But practically no commercial use of renewable energy has occurred to date, with the exception of a few small geothermal installations. Of course, wood is burned for heating and cooking, but this consumption is less than 1% of the total primary energy input for Russia.

Small (1–10-kW) water-pumping wind turbines were produced in the earlier decades of the Soviet Union through to 1990, with an estimated 10,000 installations in place by the 1950 s. Other technologies developed historically in the Soviet Union included wind turbines up to 100-kW for electricity generation (with a few test installations), residential solar hot-water heaters (with test installations in Ukraine, Kazakhstan, and Central Asia), passive solar heating of buildings, solar photovoltaic cells for use in satellites (and more recently development of amorphous silicon and gallium arsenide cells), geothermal power (one 11-MW plant was built), tidal power stations, and solar-thermal electric power (one 5-MW plant was built). A 1-MW grid-connected solar photovoltaic power plant in Stavropol was under development in the early 1990 s (using 50-kW of panels and 20× concentrators), but a lack of funding postponed this project. With the breakup of the Soviet Union, Russia inherited most of this renewable energy technology, although Ukraine also possesses significant technological expertise and some research installations for wind turbines and solar-thermal power. In the early 1990 s, government funding for renewable energy research declined and by 1995 most research on renewable energy continued only within the context of commercialization by private enterprises and research institutes, often working collaboratively.

There have been several domestic technology developments in large-scale wind turbines in the early 1990 s involving collaborations of research institutes, enterprises, design bureaus, and science-production associations [8,27].[1] The

[1] Because of the highly specialized and fragmented nature of industry and technology development in the Soviet period, such associations and collaborations are still often necessary.

national electric utility RAO 'EES Rossii' has been supporting many of these technology developments. For example, a commercial 1000-kW wind turbine has been developed by a prominent aerospace factory 'Radyga' located near Moscow in cooperation with the Tushinskiy production enterprise, and prototypes have been built. The first application of these 1000-kW turbines is a planned 22-MW wind farm in Kalmykia by the regional electric power utility, in which one 1000-kW turbine had been installed at the site near Elista by 1995. The science-production association Vetroen in Russia, a long-time wind turbine developer, and the Yuzhnoye factory in Ukraine also jointly developed a 250-kW turbine and installed several of them in the Crimea in 1994 with financing by the Ukrainian government. In 1993, Yuzhnoye claimed turbine costs of approximately US$ 400/kW [28]. By 1995, several small wind farms of sizes 2–5 MW were being planned in Russia, including one as a test station for turbines in arctic weather conditions, although financing was questionable for most projects. Production-cost estimates by these domestic manufacturers were in the range of US$ 800–1000/kW equivalent for initial production of 250- and 1000-kW turbines, with lower prices expected for mass serial production.

The Russian Scientific Committee for New and Renewable Energy Sources publishes a catalog of renewable energy equipment available from Russian enterprises [29,30]. This catalog lists five different product lines of solar PV modules, seven different product lines of solar collectors and water heaters, 18 models of wind turbines ranging in size from 50 watts to 1 megawatt, five small hydro products, a variety of end-use devices suited to renewable energy sources, and biogas digesters, all manufactured by a total of more than 20 different Russian enterprises. Although no sales data are available, the market size for these technologies still appears small. A few notable joint ventures have also appeared (see Sovlux and Windenergo case studies), and a few direct imports have taken place (for example, Germany funded ten 30-kW wind turbines to be imported and installed in Saratov [31]).

4. The problem of commercialization

Although Russian enterprises may be developing renewable energy technologies and have advanced scientific and technical capabilities and skilled workforces, the translation of these capabilities into commercial products is still a major problem. The associated market-oriented skills and institutions to take full advantage of these technological capabilities are still lacking. These market-related deficiencies are the persistent legacy of the former Soviet paradigm of central economic planning and development. Central planning avoided the need for many market-oriented skills and created a variety of disincentives and structural economic conditions that stifled innovation, creativity, efficiency, and quality [25,32–34].

Key underdeveloped capabilities are business management, finance, marketing, creative product development and innovation, quality assurance, economic analysis (like cost-benefit and lifecycle analysis), legal, contracting, and accounting skills. "No one knows how to write a Western-style business plan here", said one businessman in a 1994 interview, although many have also emphasized that Russians are learning fast. The main problem is a lack of commercial 'know-how'—the innovative, creative, and marketing-based ability to turn an idea or design into a reliable, quality commercial product or service. A common theme expressed in the author's interviews was that "great ideas and opportunities exist if only they can be evaluated and commercialized." Quality in particular is still a big stumbling block. Quality assurance, statistical quality control, management for quality, and other methods common in the West are uncommon in Russian industries not in the military sector because incentives in the Soviet economic system emphasized quantity over quality. The defense industry is a special case, because incentives in the Soviet era were much more oriented to production for quality. Yet examples of Western joint ventures and subsidiaries exist which show that Russian workers can easily produce to a Western quality standard given the proper training, motivation, and tools.

Other important aspects of commercialization are continuous product improvement and cost reduction. Product improvement was often intentionally avoided in the former Soviet economic system because enterprise incentives encouraged quantity over quality, and because design changes could mean changes in needed inputs that might not be available, which could jeopardize output targets. Further, cost reduction was unnecessary because profits were based on costs. Now, Russian managers must learn product improvement and cost reduction. In the West, extensive experience with operating and maintaining wind-turbines through commercial markets over the past 15 years has led to a refinement of designs and cost reductions. This experience has been critical to the current performance of modern wind turbines. Russia's wind turbine designs do not have the benefit yet of such experience. In discussing Russian production of wind turbines, the head of the renewable energy department of the national electric utility RAO 'EES Rossii' acknowledged that international experience with operating and maintaining turbines would be critical to the success of Russia's technology development efforts [1]. In fact, in the view of one Western European wind turbine manufacturer interviewed, the Russians seem poised to make some of the same mistakes that were made in the West over the past fifteen years.

5. Barriers to renewable energy diffusion and technology transfer

There are a wide array of barriers to renewable energy technology diffusion and technology transfer in Russia [1,35–37]. Many of these barriers are similar to those in other countries. For example, the lack of information about renewable energy costs, benefits, geographic resources and opportunities creates added risk and uncertainty for potential investors. As mentioned previously, renewable energy never received priority in the Soviet economic system, so good resource data are lacking. The lack of demonstration experience creates further uncertainties about the performance of technologies in Russian conditions;

technology acceptance of renewable energy technologies, a key barrier, is hindered by the lack of visible demonstrations and experience. Although most energy prices have risen to 'market' levels and now reflect true production costs (are no longer directly subsidized), electricity prices are based upon fuel and operating-and-maintenance costs, and still do not reflect adequately the capital replacement costs of the generation system. These indirect subsidies are a handicap for competing renewable energy generation. Direct price subsidies remain for residential heating and hot water (subsidies covered 60–80% of true costs in 1997), preventing the proper incentives for households to invest in solar hot water heating. Government subsidies also still remain for diesel-generated electricity in off-grid applications, also reducing incentives to replace these systems with renewable energy.

Utility electric-power monopolies and the absence of regulatory frameworks for independent power producers make third-party renewable energy development difficult or impossible. A 1996 Russian law *On Energy Efficiency* for the first time allowed independent power production in Russia, but implementation of this law in a practical manner is still problematic. Non-utility producers of electricity may sell electricity to regional utilities, and regional utilities must buy this power from the producer at a contracted price that is subject to approval by the regional energy commission. But regional energy commissions have yet to address how such agreements and contracts should be regulated, and no contractual models have been developed. Part of the problem is that these regional energy commissions still lack staff, budget, and the capabilities needed to regulate. The lack of viable regulatory frameworks for independent power producers is compounded by the lack of viable contract institutions, upon which a power-purchase agreement would be based, and without which third-party developers face enormous risks. Contract enforcement is problematic because a viable court system for resolving contract disputes does not yet exist. Other means have evolved, such as private third-party arbitration, and emphasis on personal trust and long-term business relationships.

Even given information, proper price signals, and a conducive regulatory and contractual framework, one of the most serious barriers is the lack of long-term commercial financing and a perceived climate of high investment risk. Lack of financing is a particular problem for renewable energy technologies compared to conventional generation because renewable energy technologies have higher front-end capital costs for equivalent capacity. Most financing is still very short term. "The maximum time horizon for [domestic] bank loans is two years now," an economist with a leading Russian bank said (*Moscow Tribune*, 27/7/94), "no one will touch real investment while there's so much uncertainty." Uncertainty partly results from macroeconomic instabilities in inflation, currency rates, and changing and conflicting tax laws. At a microeconomic level, banks are unwilling to lend because information about the financial condition and solvency of a particular enterprise is difficult to obtain or determine—there are no established financial disclosure rules, norms, or laws. Compounding this problem is a cultural legacy of deceit from the Soviet era, when enterprise managers routinely misreported economic information and performance, a practice considered necessary for normal enterprise operation [38]. Loan risks are also increased because large interenterprise debt makes the financial conditions of borrowers indeterminate and contingent upon the likelihood of debt repayment along chains of debtors. Availability of collateral for loans is hindered because the land itself under privatized enterprises and buildings is still state-owned and thus not available for collateral purposes. Finally, enterprise managers and government officials are unused to thinking about the costs of capital in investment decisions because in the Soviet economic system capital was essentially a free good allocated on the basis of politics and economic planning.

Other barriers are illustrated in the Windenergo case study—historical enterprise specialization, macroeconomic conditions, need for government approvals, technical design translation and transfer of tacit knowledge, and poor quality of components produced for export. Barriers related to utility acceptance of renewable energy technologies are similar to those in other countries—high front-end capital costs, analytical conservatism, technology acceptance, and integration of intermittent sources into dispatch regimes [38]. Nevertheless, utilities in Kalmykia and Crimea have forged ahead with grid-connected wind farms, as discussed in Section 3 and in the Windenergo case study.

6. The importance of market intermediation

One implication of the barriers described above is that market intermediation is very important for renewable-energy investments and technology transfer. Market intermediation provides the knowledge, information, skills, services, financing, and analysis that is necessary to overcome barriers, but that either or both parties to a potential transaction may be unwilling or unable to provide. The character of these intermediaries is not strictly economic, but may involve substantial political, bureaucratic, and legal functions. Table 1 lists important market intermediation functions in Russia. Few of these functions existed in the Soviet planned economy because they were simply not needed.

Independent power producers represent one specific form of market intermediary that has been successful in the U.S. and Europe, one which is also important for Russia. Grubb [39] says that probably the most important market obstacle to renewable energy lies in the need for market intermediation. He sees utility regulation fostering independent power producers as critical, since utilities, industries, or fuel consumers by themselves may not be able to understand in sufficient detail the local conditions, resources, and opportunities associated with renewable development, which all vary greatly on a case-by-case basis. This understanding requires a third party who can evaluate opportunities, secure financing, exploit the opportunities, and sell power to a utility or fuel to a consumer. Thus Grubb notes that another key reason why wind-power development in California proceeded so quickly in the 1980 s was the quick adoption and implementation of PURPA in California, a regulatory framework which provided a clear and practical stimulus for independent power production.

Table 1
Important market intermediation functions in Russia

Securing the support of government officials
Finding and matching potential investment and joint venture partners
Arranging sources of finance and engineering financing schemes
Evaluating and verifying information about partners and projects
Obtaining information about technologies and understanding markets
Identifying potential investment projects
Estimating the costs, benefits, and risks of investment projects
Packaging projects for public or private investors
Securing and structuring credit guarantees and guarantees of project performance
Developing licensing arrangements
Negotiating and writing contracts
Engendering trust among project participants
Obtaining necessary licenses and government approvals
Preparing technical specifications and bidding documents
Bidding and selecting bids for equipment and installation services
Managing, supervising, monitoring, and evaluating projects

As noted above, better regulatory frameworks are needed to support independent power producers in Russia.

In general, the need for market intermediation to overcome barriers is often discussed in the context of international technology development, and these perspectives apply equally well to Russia. For example, Heaton et al. [40] have proposed sector-specific market intermediation as an important policy goal for greater international technology transfer, development and cooperation: "In intermediation, third parties create linkages, transmit knowledge, and expedite other transactions for the principals. The greater the barriers that separate parties who could create relationships of mutual benefit, the greater the need for intermediation. In technology development, the value of intermediation is well-recognized" (p. 20).

In describing the government interventions necessary for developing renewable energy production and marketing systems in developing countries for mature energy technologies, Hurst [41] makes the case for governments to play an intermediary role, and this analysis applies equally well to Russia. Interventions include provision of information to consumers and manufacturers, taxes and subsidies, credit services, direct support of the distribution system, and direct participation in equipment manufacture. These interventions are linked to the key factors he attributes to market building and technology transfer and dissemination: (1) demand must exist, with clear financial incentives and understanding of the costs and benefits; (2) credit must be available; (3) reliability must not be a question; (4) local manufacturers must be reasonably certain of the market and the opportunities for profit; (5) manufacturers must have access to technology, either through licensing agreements or other more passive forms like trade journals, trade fairs, and trips abroad; and (6) some type of marketing and distribution system must exist.

7. The importance of joint ventures

Joint ventures with foreign multinational corporations represent another important means for overcoming barriers, one that takes advantage of Russian technological capabilities. In fact, 'indigenous absorptive capacity' is seen by many authors as an important and necessary condition for technology transfer with developing countries. Rosenberg [42] argues that "the most distinctive factor determining the success of technology transfer is the early emergence of an indigenous technological capacity" (p. 271). The president of a US elevator company, in speaking of its joint venture in Russia to manufacture, install, and maintain elevators, said that "although our new Russian employees may lack expertise in sales, marketing, and accounting, their engineering skills are terrific....The transfer of Western technology into the ventures is going relatively smoothly for that reason" (*Harvard Business Review*, May–June 1994, p. 37).

Joint ventures with the Soviet Union, allowed for the first time in 1987, were seen by the Soviets as an active technology transfer mode that provided access to needed technological innovation and commercial know-how while making use of existing Soviet technological capabilities [43]. Further, the continuing gap in mutual understanding across the old East-West border means that the close working relationships and long-term commitment that a joint venture brings are important, as opposed to more arms-length technology transfers that have traditionally worked between developed countries.

Research on joint ventures suggests that they work best when both sides have similar technological capabilities, can share complementary skills and resources, and where relations with host-country governments and institutions are difficult for foreign partners alone [44,45]. These conditions are all present in the Russian context. In a Russian joint venture, foreign partners can supply capital and the business, financial, marketing, and commercial know-how that Russians lack (especially commercialization of already-developed but unmarketed Russian technologies). Russian partners can help to overcome many serious obstacles that foreign businesses face operating in Russia: obtaining information through highly personalized contact networks, negotiating the maze of conflicting laws and regulations, getting government approvals, dealing with corruption, finding domestic suppliers and partners, obtaining licenses, contracting, and understanding markets [1].

"Joint ventures offer a unique opportunity of combining the distinctive competencies and the complementary resources of participating firms," wrote Datta [44] (p. 86). Benefits from joint ventures can be informational, as in knowledge of local market-related information, but in fact, "the biggest set of benefits in a joint venture are often 'political' in nature" (p. 86) in terms of the local partner's relations with local government authorities and institutions. Where transactions costs are high for a foreign firm to operate alone, as is the case in Russia, joint ventures will be favored. However, there are also serious risks to joint ventures in Russia from the foreign partner's side, primary among them are the uncertain financial condition of Russian venture partners, the inability of

Russian partners to contribute required capital shares (see Sovlux case study), difficulties in obtaining needed inputs domestically, and the problems of repatriating royalties and profits.

8. Conclusions

Renewable energy is attractive in Russia because it can contribute to the conversion of military, idle or undercapacity factories to useful production of commercial technologies. Wind turbines, solar-thermal collectors, and solar photovoltaic cells are all materials-intensive technologies that require skilled labor and well-equipped production facilities. Because of the general decline in industrial production in Russia since 1990, especially the reduction of military production, many manufacturing facilities and their workers in Russia stood idle or partially idle by 1995. These enterprises were searching for opportunities to manufacture alternative products, and many saw renewable-energy technologies as attractive and promising. Other enterprises, already having developed many renewable energy technologies, are looking for joint-venture partners to help them commercialize these technologies.

Renewable energy is also attractive in Russia because it can contribute to greater autonomy on a regional level. As more and more regions of Russia see that they must become more independent of Moscow and be responsible for their own development, they are looking for political, economic, and technical solutions for greater autonomy. As an example, the strong support for wind energy by the Crimean electric utility, Crimenergo, and its willingness to purchase wind turbines from the American-Ukrainian joint venture Windenergo has been in part due to Crimean desires for more autonomy (see Windenergo case study).

In a 1994 interview, the president of the Kalmykia regional electric power utility, which was building a 22-MW wind farm using Russian designed and manufactured turbines, gave five main reasons why he had decided to pursue wind energy development in his region: (i) to increase regional independence; (ii) to mitigate against increasing gas and oil prices in the future; (iii) to reduce the influence and control of Gazprom over the economy and enterprises in the region; (iv) to put defense factories in many parts of Russia back in business; and (v) to showcase Russian technologies to demonstrate a certain national pride in technology, like the space program was three decades earlier. "We want this wind power plant to show the best that we can do in Russia—using our best aerospace technology," he said. When finished, this windfarm will be the largest in Russia and the leading edge of Russian wind-power development [1].

Commercial potential and cost-effective projects for renewable energy appear feasible in several regions of Russia with varied renewable energy technologies. The most promising of these from an investment standpoint appear to be grid-connected wind farms in the North Caucasus region (especially in light of a recent law allowing independent power producers) and settlement-scale hybrid wind-diesel and biomass power systems to replace existing diesel generators in the far north and eastern portions of Russia (Murmansk, Archangelsk, Karelia, Maritime, and Khabarovsk). Biomass-fueled district-heating boilers and solar hot water heating for apartment buildings also deserve further consideration.

Serious barriers prevent realization of these opportunities, but market intermediation, joint ventures, and practical implementation of regulations for independent power producers should go a long way towards overcoming these barriers. The policy challenge is thus to promote all three of these strategies, while additionally providing information and demonstration experience to overcome technology acceptance barriers, and strengthening those private-sector market-oriented capabilities that are essential to technology commercialization.

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Appendix A: Case Studies

A.1. Case study 1: Windenergo wind-turbine joint venture in Ukraine

In 1993, Kenetech Windpower of the United States, along with the international consulting firm Putnam, Hayes, and Bartlett and the Ukrainian government formed a Ukrainian joint venture to produce wind turbines in Ukrainian factories and sell them in Ukraine and abroad. This joint venture, called Windenergo, is one of the most significant examples of industrial conversion for renewable-energy technologies in the former Soviet Union. The joint venture was formed subsequent to a formal purchase agreement with the Crimean electric power utility, Crimenergo, which called for 500 MW of wind turbines to be produced by the joint venture, sold to Crimenergo, and installed in the Crimea by 1995. As the difficulties in establishing the joint venture and producing the turbines became clear, this purchase agreement was later amended to a more realistic figure of 50 MW by 1995, with options for further purchases.

Windenergo licensed Kenetech Windpower's 56–100 110-kW wind turbine technology, invested substantial effort in modifying the turbine design to accommodate Ukrainian/Soviet technical standards and materials, and contracted with a group of Ukrainian industrial enterprises to produce turbine components, assemble, and install the turbines. By 1994, Kenetech Windpower had invested over US$ 5 million in technology transfer, technical assistance, contracting, and operation costs of the joint venture. By 1996, production capacity had grown to about 5 to 7 wind turbines per month (6–8 MW/year), although Windenergo hoped to increase this capacity to 20 to 30 turbines per month by bringing in more production partners from Ukraine and Russia. By 1996, a total of about 10 MW of Ukrainian-produced 56–100 wind turbines was installed and operating in the Crimea. Windenergo claimed a selling price of US$ 50,000, less than half of the price for the equivalent wind turbine sold in the United States or Europe, with an associated electricity production cost of US 4 cents/kWh for the Crimea site evaluated [46,47]. When Kenetech Windpower filed for bankruptcy in 1996, Windenergo continued to operate and seek other partners and sources of finance and markets.

A.1.1. Motivations and choices

Motivations. Motivations by the Ukrainian government and the Crimean electric utility to undertake this project were both economic and political. While little measurement data was available on the wind power resource in the Crimea, indications were that wind resources were good in the Crimea and that wind power could be economic when compared with conventional electricity production costs in Ukraine. One early estimate showed comparable costs of electricity production from Ukrainian-produced turbines and average electricity production costs in Ukraine (both estimated at about US 3 cents/kWh in 1994). The Ukrainian government was quite supportive of wind power as a means to enable defense-industry conversion and retain industrial jobs, as evidenced by the approval of a 0.7% tax on electricity sales to help finance defense conversion, environmental projects, and wind power specifically. Motivations by Kenetech for the joint venture included gaining a foothold in the perceived promising market of the former Soviet Union, and lower production costs for wind turbine components which could be exported to Western Europe. Kenetech also employed a number of commercial and contractual mechanisms designed to reduce risk and exposure from the joint venture, increasing the viability of the joint venture from an investment standpoint.

In addition to economic benefits, the strong support for wind energy by the Crimean electric utility, Crimenergo, has been in part due to Crimean desires for more regional autonomy. Crimenergo receives a large share of its electric power from elsewhere in Ukraine, and is thus vulnerable to disruption of its supply for political reasons. Such concerns have a basis in reality; in 1994, Ukrainian officials partially cut electric power to the Crimea, citing unpaid energy debts as the reason, yet many regions of Ukraine also had huge energy debts to the government, and there was evidence that the electricity cut was part of the political battle between the Crimea and Ukraine over greater autonomy.

Technology choice. The 56–100 wind turbine was developed and produced by Kenetech Windpower (formerly US Windpower) in the U.S. during the 1980 s. The technology is rather simple, with few sophisticated electronics, a fixed rotation speed, and straightforward construction. The 56–100 was considered an older technology which had been superseded by more modern and efficient designs with variable-speed operation and more sophisticated electronics. Kenetech selected the 56–100 turbine for the joint venture for a number of reasons, not all of which are known. Simplicity of design and construction was one factor, given the uncertain capabilities of Ukrainian industrial enterprises to tool and produce them. Another was the desire for a high Ukrainian content with few imported components, in order to provide further economic benefits for Ukrainian industry. Kenetech was probably also concerned about protection of proprietary technology for more advanced models. The choice of technology proved correct with respect to a high domestic content for the produced turbines: initial turbines had 87% Ukrainian content and 13% US content based upon component costs. However, the 56–100 model was soon considered obsolete in U.S. and European markets, and thus the export potential for Windenergo has declined. The original purchase agreement with Crimenergo did specify the option to purchase a more advanced variable-speed wind turbine model, but production of this model in Ukraine appeared problematic, and the more advanced design would have required substantially greater imports of U.S.-made components, thus increasing its price.

Transfer mode. A joint venture was necessary because Kenetech needed strong Ukrainian partnership and government support in order to undertake the contracting it did with Ukrainian industrial enterprises and to secure a customer (Crimenergo) for the produced turbines. Licensing seemed logical from the Ukranian side to develop the Ukrainian wind industry and obtain financing and managerial expertise from a foreign firm. Although Ukraine had developed its own wind turbine designs, they had not been commericalized yet. Said the general director of Windenergo, "Now we are poor and have no money, so we have to produce a licensed machine—we just can't do it on our own with our technology anymore, like we could have 10 years ago."

Windfarm siting. The site chosen for the Crimea wind farm was on the shore of Lake Donuzlav. This site was considered very favorable for wind power, with good winds, flat unobstructed terrain, and no need to construct roads to or around the site. The climate is moderate, with rare snow and sleet. To demonstrate its turbines on Crimean soil, Kenetech Windpower provided and installed three US-built turbines on this site in 1993. A year later these turbines were still running and producing power, although performance data were not readily available. This site was also favorable because local skilled labor for turbine installation and maintenance was readily available, as many technically qualified people formerly with the navy or military lived in the region. Finally, the site was favorable because of the availability of an electric power substation for connecting the wind plant to the electric grid. The long lead times for building new substations in Ukraine necessitated using an existing substation.

A.1.2. Key technology transfer obstacles

Historical enterprise specialization. Industrial production in the Soviet era was characterized by highly segmented and monopoly production, in which an enterprise may have produced only one very specialized or narrow range of products. This specialization means that enterprises lack production flexibility. This problem became evident when Windenergo proved unable to select one lead enterprise which would be responsible for producing the entire turbine. As an alternative, Windenergo was forced to solicit bids on individual wind turbine components and had to subcontract with 22 separate component suppliers plus a final assembly subcontractor. For example, the towers are produced at a high-voltage tower plant, the generators are produced at a electric power machinery plant, and the reduction gears are produced at a machine building production association. This scheme required much more resources from Windenergo and Kenetech Windpower personnel to supervise and coordinate contracts and technology transfer among the many suppliers.

Ukrainian economic conditions. When the joint venture was being formed in 1992 and 1993, the Soviet Union had just recently disbanded and the severe and sustained economic declines and chaos that enveloped much of the region, and hit Ukraine particularly hard, were not anticipated. The Ukrainian economy became very unfavorable for foreign investment and many problems plagued businesses there, including high inflation, unconvertibility of currency, changing tax and banking laws and procedures, enterprise indebtedness and insolvency, non-payments of energy bills by consumers and enterprises, unavailability of commercial credit, and the rise of a barter-based economy. In this environment, the Crimean electric power utility had great difficulty in generating the cash necessary to purchase the turbines, and this lack of cash flow limited the ability of Windenergo and its suppliers to expand turbine production.

Need for government approvals. Many approvals were required at all stages of the project. In all, the project obtained more than 120 separate signatures of approval related to both production and siting of the wind turbines (examples include the Inter-Ministerial Commission on Allocation of Productive Forces in Ukraine, local farmers at a collective farm near the proposed windfarm site, and settlement councils near the proposed windfarm site).

Technical design translation and transfer of tacit knowledge. The Ukrainian version of the 56–100 required substantial effort to translate all the Kenetech Windpower design documents into a form understandable by subcontracting enterprises, to translate dimensions and sizes into the standard metric sizes and dimensions available in the former Soviet Union, and to identify and apply appropriate Soviet/

Ukrainian technical standards. Different tolerances, materials grades, hardness, and strength of Ukrainian inputs also required design changes. Other adaptations included different generator voltage and current levels and frequency. Shielded twisted-pair cables didn't exist in the former Soviet Union, and the wiring had to be redesigned to use available single-wire shielded cables. Thus the Ukrainian version of the turbine required substantial re-engineering and re-dimensioning. Transfer of tacit knowledge by Kenetech Windpower engineers further required substantial field visits to the subcontractors. In other words, despite the simplicity of the technology and design, and the impressive technical capability of Ukrainian enterprises and engineers, the technology was by no means transferred through a simple conveyance of drawings.

Poor Quality Components. Not all enterprises could meet the component quality requirements that Kenetech established, and this proved a persistent problem for Kenetech in exporting components to Western Europe. Further, disputes and incompatibility related to testing standards and procedures were difficult to resolve.

Lack of good wind resource data. Little high-quality wind resource data exists for Ukraine, and uncertain performance of the wind turbines has continued to cloud the Crimea installations. While a US windfarm developer would demand conclusive wind resource data before developing a site, Crimenergo appear satisfied with far less stringent requirements. Average wind speeds at Lake Danuslav site were originally reported to be up to 7 m/s year round, increasing to 10 m/s and higher in the winter. But low initial capacity factors, some under 10%, during the summer months for the first set of turbines installed, were not promising.

A.2. Case study 2: Swedish Government program for biomass boiler conversions in the Baltic States

In 1993, the Swedish government through the agency NUTEK (The Swedish National Board for Industrial and Technical Development) began a program to assist district-heat-supply companies in the Baltic States (Northwest Russia, Poland, Estonia, Latvia, and Lithuania) to convert coal-fired and oil-fired heating boilers to burn biomass fuels (wood chips and wood wastes). One goal of the program was environmental: to promote cost-effective projects which reduce CO_2, SO_2, and NO_x emissions on a sustainable basis. Another goal was to encourage partnerships between Swedish and Baltic commercial firms able to carry out such conversions on a commercial basis, and promote technology transfer of Swedish boiler conversion technology to these countries. These projects were considered highly viable from an economic and financial perspective; estimated conversion costs were about US$ 80–90/kW, and simple payback times of about 3–6 years were estimated, based upon wood-chip costs that were about half the cost of oil per unit of energy production. The first conversion, a 6 MW boiler in Estonia, was completed in 1993 (with a total time from conception to operation of less than six months). By 1997, about 30 boiler conversion projects had been completed. Almost 300 million SEK was spent on the program (this figure also includes about 25 energy efficiency projects), most of which was provided as loans rather than grants.

NUTEK's program was designed to overcome the key barriers to technology transfer: lack of financing, project performance risks, unavailability of the technology in the Baltics, lack of understanding by boiler owners of the technical feasibility and economic benefits of these boiler conversions, and lack of competitive-bidding procurement capabilities by boiler owners. NUTEK administered financing of the boiler conversion projects with 10-year loans at 7–8% interest and a 3 year initial grace period (terms are similar to World Bank loans). NUTEK reduced project performance risk associated with future biomass fuel prices by guaranteeing a 15% minimum fuel cost reduction no matter what happens to relative wood and oil prices (provided through reduced interest payments if necessary). NUTEK provided technical assistance, in the form of local consultants able to speak the language of the boiler owners, for understanding the technical feasibility and economic benefits of these boiler conversions. NUTEK staff also provided technical assistance to the heat-supply companies for issuing tenders, evaluating bids, selecting suppliers, negotiating biofuels supply contracts, and operating the converted boilers.

Boiler owners were responsible for making decisions and applying to NUTEK for participation in the program, and selecting the supplier of their equipment. They are also responsible for ultimately repaying the loan to the Swedish government. Further, with wood-chip markets in their infancy in the Baltics, NUTEK stipulated that 70% of the wood fuel needed for the first 3 years be contractually guaranteed before project completion. Other NUTEK requirements concerned boiler size (3–10 MW), ability to physically accommodate a pre-oven modification, representativeness of a 'typical' application that could be replicated throughout the region, a nearby source of fuel, and availability of necessary supporting organizations.

The Swedish technology specified for these boiler conversions has been well-proven; it has been used at 4000 sites in Sweden over the past 25 years, and has also been used in former Czechoslovakia, New Zealand, and other countries. Boiler emissions conform to ordinary Swedish standards. This technology is compatible with many of the small boilers used in the Baltics, an important factor for the viability of the program. The boiler conversion technology was simple enough that NUTEK believed that eventually Baltic companies themselves could replicate it. Although Baltic companies could not themselves design a pre-oven because the design requires substantial design experience over time, these companies could buy a license to produce a pre-oven based upon existing Swedish designs. Since one of the goals of the program was to encourage joint ventures between Swedish and Baltic companies, the program encouraged Swedish firms to have a local Baltic partner when bidding on the projects, and including local suppliers and service firms whenever possible.

The program has been quite successful in promoted technology transfer, capacity building, and institutional development in the Baltics. The degree to which capacity has been built among local firms is perhaps unusual for a government assistance program, and can be credited to the program's emphasis on providing more than just financing and equipment. The program has played a large role in creating a self-sustaining biomass-equipment industry, biomass-fuel markets and supply infrastructure, and a positive public attitude toward biomass fuels. A commercial biomass-fuel market did not exist in these countries prior to the program, but the program has now provided a market for industrial wood wastes.[2] Two major joint ventures between Baltic and Swedish boiler manufacturers were established, and a third Baltic boiler manufacturer forged significant technology cooperation links with Swedish and Danish firms. Through the program, many Baltic firms have been coached in international competitive bidding procedures, economic and financial evaluation methods, and cost-minimizing decision-making.

A.3. Case study 3: Sovlux photovoltaic joint venture in Russia

In 1990, Energy Conversion Devices (ECD) of the United States and the Russian enterprise KVANT formed a Russian joint venture to produce solar photovoltaic (PV) cells and nickel metal hydride (NiMH) batteries. The joint venture, called Sovlux, represented the marriage of Russian industrial and scientific capabilities with U.S. advanced technologies and commercial expertise. Energy Conversion Devices, a company developing alternative energy technologies, wanted to expand its proprietary technologies into the Russian market. KVANT had specialized in power systems for the Russian space program and was interested in obtaining ECD's PV and battery technologies and applying its resources to these new technologies. KVANT provided capital, scientific expertise, facilities, and skilled personnel to the venture. A third partner subsequently entered the joint venture, the Russian Ministry of Atomic Energy, because of interest in converting several of its enterprises to civilian production through participation in the venture.

Approximately US$ 10 million was spent to develop a state-of-the-art PV module production line in Moscow with a 2-MW-per-year capacity. The plant was designed and built by Energy Conversion Devices and utilized their amorphous silicon-based PV technology, which was licensed to the joint venture. Because commercial markets for photovoltaics in Russia are still small, it was expected that initial production would be geared for export. In addition, Sovlux expects a growing export and Russian NiMH battery market, for example for electric vehicles. Sovlux plans to begin production of NiMH materials and components

[2] A market has also been created for additional forest harvesting, and the sustainability of such harvesting is uncertain, given the relatively undeveloped state of environmental regulation and management in these countries.

soon, to be followed later by full battery production, also using technology licensed from Energy Conversion Devices.

The joint venture has so far been unable to operate the PV production facility on a commercial basis because of a lack of financing. Commercial credit has been very difficult to obtain in Russia's difficult post-Soviet financial environment. A promised infusion of US$ 1.4 million in operating funds by the Ministry of Atomic Energy, in return for its equity interest in the venture, has been limited to a much smaller amount because of cash shortages in the ministry due to persistent non-payment problems in Russia's electricity sector. The plant began start-up operations and pre-commercial production in 1996, financed in part with grants provided by the US government, but was forced to reduce operations in 1997 until further financing could be obtained.

A.4. Case study 4: U.S. Government technology transfer of wind-diesel systems to Russia

As part of a memorandum of cooperation for technical and market assistance for energy efficiency and renewable energy that was signed between the US Department of Energy and the Russian Ministry of Fuel and Energy in 1993, the National Renewable Energy Laboratory (NREL) has provided technical assistance and wind-resource assessment for village-power opportunities for hybrid wind-diesel systems in remote regions of the Russian far north. In conjunction with these efforts, the US Agency for International Development awarded US$ 1.79 million in 1996 for small-scale (1–30 kW) hybrid windpower systems in the Russian far north to the Russian Ministry of Fuel and Energy, as part of USAID's Commodity Import Program. As required by USAID procurement rules, the systems were purchased from a US manufacturer under a competitive bid process using technical specifications developed cooperatively with the Russian Ministry of Fuel and Energy. Procurement and installation of 1.5- and 10-kW turbines was proceeding in 1997 at 21 sites under the direction of the Ministry of Fuel and Energy, primarily in the Murmansk and Arkhangelsk regions.

This US government focus on hybrid wind-diesel systems was prompted in part by the earlier efforts of a Russian-Dutch joint venture and a US wind turbine company to develop small wind-turbine applications in Eastern Russia and Siberia. From 1992 to 1994, over 40 installations were completed using Dutch and American equipment through the joint venture. During this period, and in dialogue with the joint venture, the Russian Ministry for Nationalities Affairs and Regional Policy initiated the *Northern Russia Rural Power Project*, which is a program to provide rural electrification to farmers, fishermen, small communities, and medical complexes in the Far North using small wind turbines and associated equipment. The program outlines development of 500 MW electric and 600 MW heat capacity in 31 regions involving 930 specific projects. Although ambitious, the program was receiving very little financing or attention. The U.S. government, under its technology cooperation agreement with the Russian government, viewed the program positively and saw its assistance as furthering the development of the program.

One question surrounding these governmental efforts is how to transfer the experience to be gained from systems provided by government grants into the development of a private, commercial market for such systems. The first barrier to commercial markets is that the primary customers for wind-diesel hybrid systems—settlements, border outposts, and fishing villages—receive diesel fuel subsidized by the regional administration. So fundamental economic incentives are lacking. (Regional administrations themselves might purchase and install these systems to reduce their subsidy burden, although consumers would still need reasonable incentives to properly operate and maintain the systems.) Secondly, private sources of credit are very difficult to obtain in urban areas, and even more so in these remote, rural areas. Finally, there is no maintenance and spare parts infrastructure in place, so that technical problems may mean significant down time while expertise or spare parts are sought from far away (this is a problem even for the systems provided under government grants; the economic incentive problem even calls into question the willingness of consumers to pay for maintenance and spare parts). Thus the only model for replication of the experience gained under these technology transfer activities appears to be further government grants.

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