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HOW TO GROW THE WORLD LEADER IN PHOTOVOLTAIC (THE CASE OF YINGLI SOLAR)

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КАК ВЫРАСТИТЬ КОМПАНИЮ – МИРОВОГО ЛИДЕРА ФОТОВОЛЬТАИКИ (НА ПРИМЕРЕ YINGLI SOLAR)

This paper researches qualitative regularities of company development in the fast-growing sector of power engineering for solar energy. This subject is topical due to the strategic plans of developing renewable energy sources in Russia up until the year 2020 and the related prospects of establishing domestic manufacturing in the respective sectors of energy machine building with a primarily domestic market orientation. The chosen research method is a retrospective case-study of the development dynamics of the worldwide leader in photovoltaic element, unit and system manufacturing on the basis of polycrystalline silicon: the Chinese company Yingli Solar. The analytic materials of the European Photovoltaic Industry Association for 2009–2013, as well as the annual reports of the company for the period of 2006–2014, have served as the information base for the research. The article gives an efficiency rating to the corporate structure of the company, studies the market strategy and the innovative activity model of the company, and determines the primary factors of growth and competitiveness. Using the learning curve methodology we obtain quantitative ratings of learning rates in production and research activity of the company. We identify possible reasons for relatively low learning rates in production that the company has demonstrated during the researched period. The determined qualitative regularities of development of high-tech companies in new sectors of power engineering, as well as obtained quantitative ratings of learning in production and R&D, can be used for improving and correcting the strategic plans of renewable energy in Russia or for practical construction of high-tech business in the area of photovoltaics.
SOLAR ENERGY; PHOTOVOLTAICS; POWER ENGINEERING; LEARNING CURVE; CASE-STUDY.

Исследуются качественные закономерности развития компаний в быстрорастущем секторе энергетического машиностроения для солнечной энергетики. Актуальность выбранного исследования определяется стратегическими планами развития возобновляемой энергетики в России до 2020 года и сопряженными с ними перспективами создания отечественных производств в соответствующих секторах энергетического машиностроения с ориентацией, в основном, на потребности внутреннего рынка. В качестве метода исследования выбран ретроспективный кейс-стади динамики развития мирового лидера по производству фотоэлектрических элементов, модулей и систем на основе поликристаллического кремния китайской компании Yingli Solar. Информационной базой исследования послужили ежегодные отчеты компании за период 2006–2014 гг., а также аналитические материалы Европейской ассоциации индустрии фотовольтаики (European photovoltaic industry association, EPIA) за 2009–2013 гг. В статье дана оценка эффективности корпоративной структуры компании, изучены стратегия завоевания доли рынка и модель инновационной деятельности компании, выделены основные факторы роста и конкурентоспособности. Согласно методологии кривых обучения получены количественные оценки темпов обучения в производстве и научно-исследовательской деятельности компании. Идентифицированы возможные причины сравнительно низких темпов обучения в производстве, продемонстрированных компанией на протяжении исследуемого периода. Выявленные качественные закономерности развития высокотехнологичных компаний в новых секторах энергетического машиностроения, а также полученные количественные оценки темпов обучения в производстве и НИОКР могут быть использованы как в процессе доработки и коррекции стратегических планов развития возобновляемой энергетики в России, так и в практике построения высокотехнологичного бизнеса в сфере фотовольтаики.
СОЛНЕЧНАЯ ЭНЕРГЕТИКА; ФОТОВОЛЬТАИКА; ЭНЕРГЕТИЧЕСКОЕ МАШИНОСТРОЕНИЕ; КРИВАЯ ОБУЧЕНИЯ; КЕЙС-СТАДИ.

Sanctions and restrictions imposed by Western countries against the most export-oriented and competitive sectors of the Russian economy, as well as the prolonged worldwide decrease in oil prices, have actualized the problem of searching for the most effective and safest ways of Russia's participation in the global production chains. The issue of import substitution in the last year has taken a central place in scientific research and business forums of various levels. Most studies focus upon justifying the possibilities of production development in various branches of the economy that have either received certain temporary market advantages (decrease in competition, increase in consumer demand, reduction of market entry barriers) [1] or those that have a strong technological potential that has been accumulated during the Soviet era and still has not been fully realized [2–3]. Factually, these are either low-tech industries (agriculture, processing) or high-tech aerospace industry, defense industry and mechanical engineering traditional for our country. However, the issue of achieving the technological leadership (or, at least the level of technological development, which is enough to ensure economic security in a new situation [4]) in fast-growing industries such as solar and wind energy and, directly associated with them, power engineering, is not well-covered by the modern economic literature.

Energy industry and power engineering at the present stage of development of the national economic system have high market potential, including export, and play a backbone role in the Russian economy. However, due to the unavoidable (in the long term) change of the techno-economic paradigm in the power industry, the economic and political position of Russia in the world will greatly depend on how successfully new branches of the economy will develop, since they represent the «core» of the new technological paradigm, and it will declare whether the country will be able to hold leading positions on new energy markets or become a dependent importer [5].

This study focuses solely on investigating patterns in the development of high-tech companies in the new fast-growing industry of power engineering for solar energy. The main tasks are to determine the primary growth drivers and factors for the sustainable development of companies during the periods of stagnation or recession in the industry. The choice of the industry for research is explained by the following factors:

a) photovoltaics is a fast growing market: the Compound Annual Growth Rate (CAGR) of PV installations was more than 30 % between 2000 to 2014, despite some underproduction and overproduction crisis during this period [6];

b) worldwide prices for photovoltaic products have decreased during the researched period more than 5.5 times, which indicates the presence of strong learning and scale effects in the industry [7];

c) the Russian manufacturers (LLC «Hevel», OJSC «Rostovteploelectroproyekt», RAS JIHT, CJSC «Noviy solnechniy potok», OJSC «Quant» and others) possess the necessary production technologies for photovoltaic modules and systems as well as access to the developments of domestic scientific schools that allows increasing the performance of generating equipment several times in comparison to the best foreign alternatives [8–9].

In order to develop a possible vision of patterns for the stable growth on developing markets, information will be drawn primarily by the case-study method. The successful case of establishment and development on the global photovoltaic market is the Chinese solar panel manufacture Yingli Solar. According to [10], «a case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident». It allows gaining some qualitative and quantitative information and learning lessons, which help in the theory development. What is of interest is the particular conditions that led to use the acquired experience in another location. Therefore, the aim of case studies under analytical generalization is to answer the following questions:

– What factors determine sustainability of the company over a long period, including the phases of growth and decline in the industry?

– What kind of strategy can be considered optimal for a company: export orientation or emphasis on the development of the internal market?

– Would a vertically integrated or a networked form of the production chain be better, and under which conditions?

– Would performing R&D, commercializing results or working with licensed technologies be preferable during early stages of the company development, and would that change overtime?

The annual reports of the company for the period of 2006–2014, found on the official company website (http://www.yinglisolar.com/en/), as well as the analytic materials of the European Photovoltaic Industry Association (EPIA) for 2009, 2011, 2012 and 2013 have served as our information base.

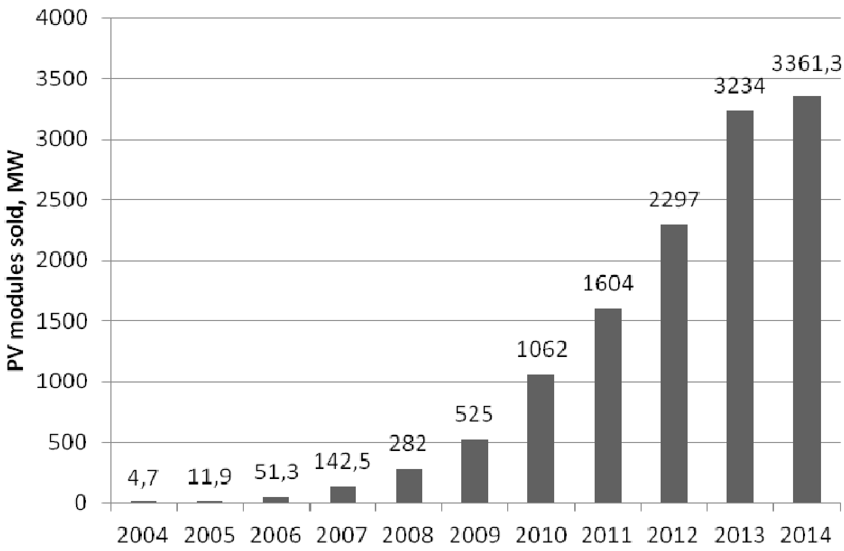

Fig. 1 Yingli Solar's shipment growth in 2004-2014.
Source: own analysis based on company's annual reports

The company started its operation in 2002 as a private entity named Chengdu Yingli, controlled by the Yingli Group financial group, involved in the development of the industrial park in Baoding. Chengdu Yingli began producing PV modules with an initial annual production capacity of three megawatts and significantly expanded production capacities of our PV products in the next five years. A high demand for the company products from foreign customers initiated the search for possibilities of quick expansion of production capacities and bringing in investors. The main source of financing during the initial period of the rapid production capacity growth (2004—2006) was the Chinese Tianwei Yingli company, a participant of the Yingli Group. In 2006 with the participation of Tianwei Yingli the company was incorporated in the Cayman Islands with the name Yingli Green Energy as part of a restructuring of equity interests in order to facilitate investments by foreign financial investors in Tianwei Yingli. In 2007 the company initiated IPO and hereby attracted a significant amount of private investment. By the end of 2014, the market capitalization of the company had been almost 500 million dollars. The Yingli Solar name became a recognisable brand and the production volume reached a record of 3361.3 MW/year (Fig. 1), which allowed the company to take up an 8.2 % share of the worldwide photovoltaic market.

Along with the growth of financial possibilities in 2005—2009, a vertically integrated structure was actively formed, later manufacturing capacity covered the photovoltaic value chain from ingot casting and wafering through solar cell production and solar panel assembly. In 2004—2005, Tianwei Yingli acquired a 50 % equity interest in Tibetan Yingli, the company that sells and installs PV systems. In July 2007, the company acquired a 30 % equity interest in Dongfa Tianying, which manufactures and sells tempered glass and accessories. The same year, an international branch of the company known as Yingli Green Energy Holding (International)[1] was founded [1], with marketing and logistics departments in Europe and production and research subsidiaries in China. The purposes of this branch were to export and promote products on international markets. Thus, the basis of the corporate structure of the company was fully formed (Fig. 2) and later underwent only minor changes.

In 2009, in order to decrease production costs and market risks associated with the increase in world prices for polysilicon, the Chinese Cyber Power and Fine Silicon companies were acquired, which used to be producers of solar-grade polycrystalline silicon. It was planned to substantially increase their production capacities. However, the overproduction crisis of polycrystalline silicon in 2011—2012 (which decreased its price from $200 to $14 per kg [11—12]) made the manufacture of polysilicon unprofitable and the company made a decision to close the Fine Silicon manufacturing capacity.

[1] Shown in the figure as no. 2.

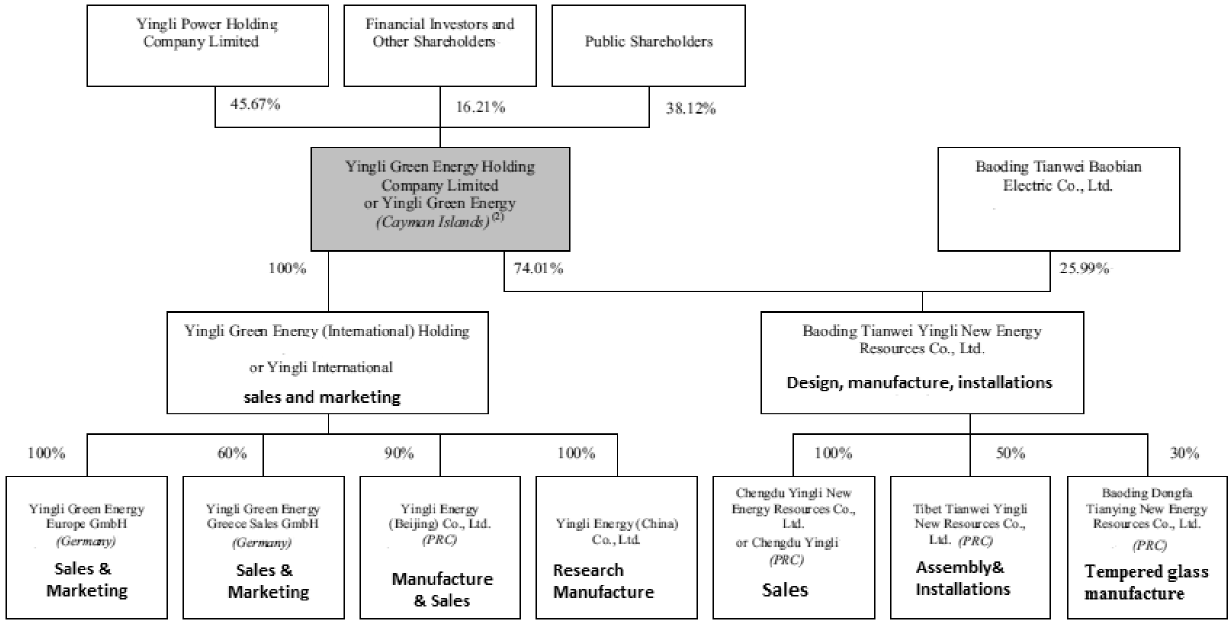

Fig. 2. The structure of Yingli Solar at the end of 2007
Source: own analysis based on company's annual reports

Another reason for building a vertically integrated structure is the company's commitment to quality control of production in all parts of the production chain. A rapid growth in demand for photovoltaic cells stimulated the development of a large number of related industries, not all of which are technologically and organizationally able to ensure the quality of their products. During the formation and rapid increase of production capacities in 2004, the company obtained an international certificate of compliance with the ISO 9001:200 standard for its quality management system, and kept the certificate up-to-date. From 2004 to 2007, the company repeatedly conducted tests of its products (inverters, modules and various models of photovoltaic systems) for compliance with IEC 61215 and obtained safety certificates of UL (USA) and TÜV (Germany). In 2011 the IEC 61215 compliance certificate was confirmed in the United Kingdom, Japan and Korea. Since the production of polycrystalline silicon ingots is associated with forming large amounts of wastewater and presents a potential risk for employee health, the company certified the relevant production divisions with the BS OHSAS 18001:2007 standard. The company also obtained the ISO 14001:2004 certificate in 2007 for the environmental management systems of all production divisions. The received certificates have been updated multiple times later.

The company's certification activity has achieved the expected results. Consumer confidence in the Yingli Solar brand has enabled the company to conquer new markets (Fig. 3).

In 2005, the lion's share of the company's products was exported to Germany (65.5 % of total revenues in 2005), but by 2014, the dependence on this major customer declined to 5.2 %, partly due to the emergence of regular customers in Japan (19.3 % of revenues in 2014), the UK (7.7 % of revenues in 2014), the Netherlands, the Czech Republic, Greece and South Korea. Diversification of sales markets allowed the company to maintain its leading positions during the sharp decline in demand for photovoltaic cells and modules due to scaling down state programs of solar energy support in several European countries and the US in recent years, as well as anti-dumping measures undertaken by the EU and the US against the cheap Chinese production in 2010—2013 [13—14].

An important factor in the company's success in this difficult period was also the rapid development of solar energy in China, which thanks to government incentive programs caused the rapid growth of demand for the company's products in the country (Fig. 4).

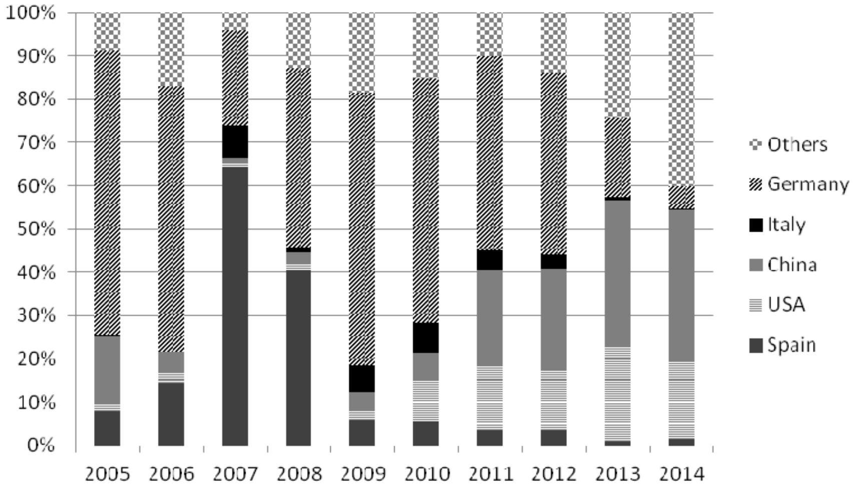

Fig. 3. Main markets of Yingli Solar in 2005—2014
Source: own analysis based on company's annual reports

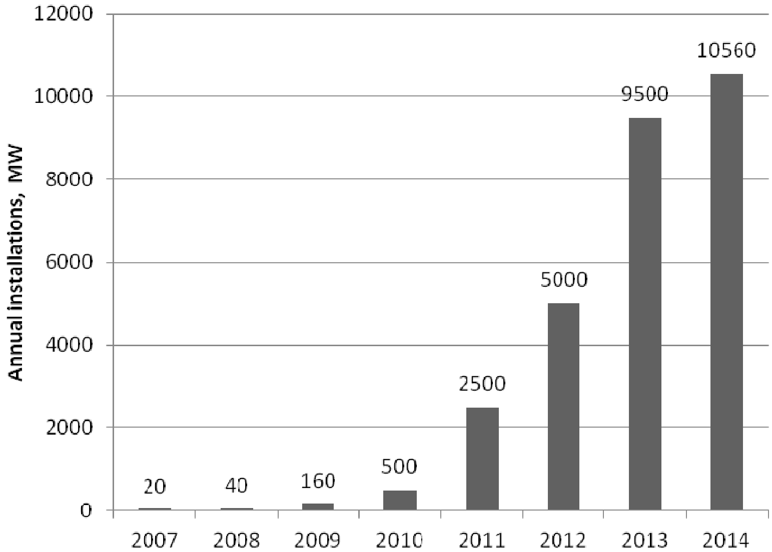

Fig. 4. Annual PV Installations in China in 2007—2014
Source: Technology Roadmap: Solar Photovoltaic Energy — 2014 edition. IEA, 2015.

The reorientation on the domestic market that took place in 2011—2012, allowed Yingli Solar not only to avoid reducing production, but even to gradually increase it (Fig. 1) Given the fact that the country currently ranks second in the cumulative installed capacity (after Germany), and by 2017 the Chinese government plans to increase the cumulative capacity to 70 GW [15], the company is currently primarily oriented to the domestic market, with gradual access to emerging markets in other world regions, such as Latin America, Middle East and Africa.

The well-known factors of cost cutting are usually economies of scale through large-volume manufacturing, learning-by-doing and improving in technical efficiency, which refers to Research & Development and is sometimes called «learning-by-doing in R&D». The learning curves can be built on statistical data about the Yingli Solar annual performance, collected from financial reports and presented in Table.

A slight increase in unit costs occurred in 2005—2006 due to a significant rise in prices for polysilicon, which is the most important raw material used in the PV-cells manufacturing process. Further cost reduction demonstrates effects of the economies of scales through large-volume manufacturing, and learning-by-doing.

Indicators of Yingli Solar's industrial activity

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PV modules sold, MW	11.9	51.3	142.5	282	525	1062	1604	2297	3234	3361.3
Net revenue, mill. RMB	362	1639	4059	7553	7255	12500	14668	11392	13418	12927
Cost of revenue, mill. RMB	254	1186	3102	5923	5540	8347	12228	11761	11959	10689
Unit expenses (per watt in RMB)	21.3	23.1	21.8	21.0	10.5	7.9	7.6	5.1	3.7	3.2
R & D expenses, mill. RMB	1.791	23.14	17.54	57.25	184.3	137.52	284.9	187.54	288.59	573.8
Average selling price of PV modules (per watt in USD)	3.49	3.82	3.87	3.88	2	1.75	1.43	0.77	0.55	0.52
Cell conversion efficiency (average), %	n/a	n/a	n/a	15.6	16.2	16.5	17.0	17.3	17.5	17.8
Cell conversion efficiency (PANDA pilot lines), %						18.5	19.0	19.4	19.8	20.2

Source: compiled by the author according to the annual reports of the company.

The learning rate, estimated according to the Boston Consulting Group methodology [16–17] is 6.2 %, which is quite low, comparing to average learning rates in photovoltaic, estimated in most souses as high as 20 % [18]. The most likely explanation of this fact is that the company had to undergo a crisis period with the collapse in polysilicon prices, when the production facilities of Yingli Solar were basically idle, and long-term contracts with suppliers of raw materials signed during the periods of the polycrystalline silicon price growth with the future transaction scheme became extremely unprofitable [14]. It should also be noted that the manufacturing cost also includes the warranty price, according to which within 10 years of operation the efficiency of photovoltaic modules cannot decrease by more than 10 %, and within 25 years – no more than 20 %. At the beginning of the production activity, the warranty hardly contributed to company's costs, however, later its share has increased. In 2012 the warranty costs amounted to 12.3 million yuans, in 2013 and 2014 that value has increased to 14.3 and 39.3 yuans respectively [19].

Another factor that affected the pace of training in the production is China's tightening the environmental legislation. For example, in 2014 the provincial government of Hainan suspended activities of three product lines divisions of Hainan Yingli because the company's environmental impact assessment system was considered inadequate for the new rules. However, Hainan Yingli managed to solve this problem in just three months and obtain permission to restart production as well as avoid a 0.28 million RMB fine [19].

It should be noted that the company started active research only in 2009, with the launch of the PANDA research project. During 2002–2008, Yingli Solar could be considered a low-tech company, since its R&D coefficient ranged between 0.41–0.75 % [20]. The share of R&D personnel did not exceed 5 % of the total number of employees. Yingli Solar had no international or Chinese patents, and its production technologies were protected merely by a trade secret.

The sharp increase in spending on R&D since 2009, as well as an increase in the research staff share up to 8 %, has led to a significant progress in the photovoltaic cell manufacturing technology. The average energy conversion coefficient increased from 15.6 in 2008 to 17.8 in 2014, and the experimental equipment manufactured as part of the PANDA research project reached the record of 20.2 %[2] [2]. Other indicators of the technological progress are the decrease in silicon wafer thickness (from 325 microns in 2003 to 130 in 2014) and increase in silicon ingots (240 kg in 2003, 800 kg in 2014). Since 2009, the R&D intensity coefficient of the company is 1.1–2.54 %, and in 2014, it reached 4.44 %, which allows attributing the company to the medium-tech sector. Along with the R&D development, the company started the patent activity: in 2009, Yingli Solar owned 34 Chinese patents, but the number increased to 1171 in 2014.

Considering the energy conversion factor of the photovoltaic cells as the primary indicator of

[2] Energy conversion efficiency of solar cells produced in the laboratory, reached in 2014 a record for this type of technology index of 21.5 %.

the technological progress, and applying well-known methods of evaluating learning rates in R&D with a simple logistic curve [21], we'll obtain the rate of learning in Yingli Solar R&D equal to 2.8 %. This means that with doubling the cumulative volume of investments in R&D, the efficiency of solar cells produced by the company increases by 2.8 %. Note, that this value is significantly higher, for example, than that of the American manufacturer of cadmium-tellurium based photovoltaic cells, First Solar [22].

Conclusions. After analyzing the activity of Yingli Solar, we can define the following most important drivers of the company growth:

1) Increasing production and capacity growth actively started at the same time as the period of growing the demand for the company's products, which was related to forming and developing solar energy as a full-fledged branch of the global economy with investment and market volumes comparable to those of other commercially mature high-tech industries, such as civil aircraft industry [3].

2) Creating a vertically-integrated structure at the stage of the intensive (and, quite often, chaotic) growth in the number of manufacturers of similar products allowed the company to reduce costs associated with the procurement of raw materials and to provide quality control on all parts of the production chain. This increased consumer confidence in the brand and helped to diversify the geography of sales.

3) During the crisis period in the photovoltaic sector, which was caused by the oversupply and a shrinking demand, leading to a drop in prices for solar cells and modules, the company was able to shift to the growing domestic market and even to increase production volumes. This allowed maintaining the conditions for the effects of scale and training in production, being the primary factors of competitiveness in high-tech business [3, 7, 18].

4) In the context of increasing competition in the photovoltaic cell/module production sector, the company opted for the innovative development and achieved a significant increase in functionality of its products through an increase in R&D intensity. The increase in the research activity has led to significant changes in the intellectual property protection policies of the company.

Despite the fact that unique historical conditions of Yingli Solar's development are unlikely to reoccur or be reproduced artificially, the analysis of company's experience and its comparison with the results of the research (e. g. [22]) allows identifying some qualitative patterns. In particular, it is notable that the feasibility of targeted domestic or foreign markets depends solely on the current situation in the relevant markets. A stable domestic market with transparent and clear strategic development goals can become a certain guarantee of viability, regardless of the situation on foreign markets and protectionist activity of other states. However, to achieve global competitiveness, the domestic market capacity needs to be large enough to provide conditions for the effects of scale and learning in production.

Considering the optimal corporate structure of companies in the renewable energy industry, it can be noted that in the period of production formation, establishment and improvement of the production process and increasing capacities, a vertically integrated structure allows reducing costs and ensuring quality control. However, once the branch (or a particular sector) achieves technological maturity and the price competition increases, a vertically integrated structure may become ineffective.

Innovation activation becomes necessary to maintain leading positions at a certain point of the branch development, which is determined by the technological maturity. However, up to that point, the strategy that is aimed at increasing production and conquering new markets by lowering prices and improving product quality remains viable.

Policy Implications. In the coming years, Russia plans to develop its own renewable energy production (e. g. [23-24]), oriented, primarily, to the domestic market. However, the pace of growth of domestic demands for energy products, currently stated in governmental documents (including the draft of the Russian energy strategy until 2035, which is currently at the expert approval stage), may be insufficient to ensure competitiveness of Russian manufacturers, primarily in the price performance. The identified qualitative patterns in the high-tech company development in new sectors of power engineering, as well as the quantitative assessment of the training pace in production and R&D can be used to revise and correct strategic plans for the development of renewable energy in Russia, as well as in practice, to create high-tech photovoltaic businesses.

Areas for further research. Given the fact that the development of solar energy and power engineering for solar energy occur rapidly, the obtained quantitative estimates of learning rates in R&D need to be reviewed and updated along with the publication of new statistics on the technological progress in the field of solar energy conversion. In addition, in order to improve reliability of the results, the identified qualitative patterns of Yingli Solar's development can be compared with the patterns of other leaders in the industry.

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