

IMPROVING MECHANISMS FOR ATTRACTING INVESTMENT IN RENEWABLE ENERGY PROJECTS AT INDUSTRIAL ENTERPRISES

Makhmudov Mukhtorjon Abdumalik ugli

Lecturer

University of Business and Science

Annotatsiya

Maqolada sanoat korxonalarida o'z ehtiyoji uchun barpo etiladigan qayta tiklanuvchi energiya loyihalariga investitsiyalarni jalb etish mexanizmlari o'rganildi. Muallif investitsion qarorlarning risk va daromad nazariyasi, kapital qiymati va xavfni kamaytirish konsepsiyalarini umumlashtirib, korporativ elektr energiyasi xarid shartnomalari, ortiqcha energiyani tarmoqqa sotish, yashil kreditlar, yashil obligatsiyalar, energiya servis shartnomalari va xalqaro moliya institutlari ishtirokidagi aralash moliyalashtirishni yagona tizim sifatida talqin etdi. Energiyaning keltirilgan qiymati formulasi asosida kapitalning o'rtacha tortilgan qiymati 4 foizdan 20 foizgacha oshganda quyosh elektr stansiyasining keltirilgan qiymati 2,7 barobar ortishi aniqlandi. Natijalar kapital qiymatini pasaytiruvchi institutsional choralar loyihalar samaradorligini belgilovchi asosiy omil ekanini ko'rsatdi. O'zbekistonda sanoat korxonalari uchun yaratilgan moliyaviy va huquqiy vositalar tizimlashtirildi. Konseptual model ishlab chiqildi va investitsiyalarni jalb etishga oid takliflar asoslandi. Tadqiqot natijalaridan sanoat korxonalari, tijorat banklari va davlat organlari qayta tiklanuvchi energiya loyihalarini moliyalashtirish shartlarini belgilashda foydalanishi mumkin.

Kalit so'zlar: qayta tiklanuvchi energiya, sanoat korxonalari, investitsiyalar, kapital qiymati, energiyaning keltirilgan qiymati, yashil moliya, korporativ PPA, xavfni kamaytirish.

Аннотация

В статье исследованы механизмы привлечения инвестиций в проекты возобновляемой энергетики, создаваемые промышленными предприятиями для собственных нужд. Автор обобщил теорию соотношения риска и доходности инвестиционных решений, концепции стоимости капитала и снижения рисков и интерпретировал корпоративные договоры купли-продажи электроэнергии, продажу излишков в сеть, зеленые кредиты, зеленые облигации, энергосервисные контракты и смешанное финансирование с участием международных финансовых институтов как единую систему. На основе формулы приведенной стоимости электроэнергии установлено, что при росте средневзвешенной стоимости капитала с 4 до 20 процентов приведенная стоимость электроэнергии солнечной станции возрастает в 2,7 раза. Результаты показали, что институциональные меры, снижающие стоимость капитала, выступают ключевым фактором эффективности проектов. Систематизированы финансовые и правовые инструменты, созданные в Узбекистане для промышленных предприятий. Разработана концептуальная модель и обоснованы предложения по привлечению инвестиций. Результаты исследования могут быть использованы промышленными предприятиями, коммерческими банками и

государственными органами при определении условий финансирования проектов возобновляемой энергетики.

Ключевые слова: возобновляемая энергетика, промышленные предприятия, инвестиции, стоимость капитала, приведенная стоимость электроэнергии, зеленое финансирование, корпоративный РРА, снижение рисков.

Abstract

The article examined mechanisms for attracting investment in on-site renewable energy projects of industrial enterprises. The author synthesised risk-return theory and the concepts of the cost of capital and de-risking, and interpreted corporate power purchase agreements, the sale of surplus electricity to the grid, green loans, green bonds, energy performance contracts and blended finance involving development finance institutions as a single system. Using the levelised cost of electricity formula, the author found that an increase in the weighted average cost of capital from 4 to 20 percent raised the levelised cost of solar electricity 2.7 times. The results showed that institutional measures lowering the cost of capital were the decisive factor of project efficiency. The financial and legal instruments created in Uzbekistan for industrial enterprises were systematised. A conceptual model was developed and proposals for attracting investment were substantiated. The results can be used by industrial enterprises, commercial banks and public authorities in setting the terms of financing for renewable energy projects.

Keywords: renewable energy, industrial enterprises, investment, cost of capital, levelised cost of electricity, green finance, corporate PPA, de-risking.

INTRODUCTION

Economic theory treats investment in renewable energy as a decision taken under a specific combination of high initial capital expenditure, low operating costs and long payback periods, which makes the outcome highly sensitive to the perceived risk of future cash flows. R. Wüstenhagen and E. Menichetti conceptualised renewable energy investment as a strategic choice shaped by the interaction of energy policy, the risk-return profile of individual projects and the behavioural characteristics of investors, and argued that policy influences capital allocation primarily through the way it alters perceived risk rather than through expected returns alone [16]. For an industrial enterprise the same logic applies at the level of the firm: a rooftop or ground-mounted solar plant that supplies a production site is an investment in a long-lived asset whose value depends on the stability of electricity prices, the rules governing grid connection and the terms on which external finance can be obtained.

The second theoretical foundation concerns the structure of project costs. Unlike thermal generation, where fuel purchases dominate lifetime expenses, wind and solar installations concentrate almost all costs at the moment of construction. The price of capital therefore becomes the principal determinant of the cost of the electricity they produce. T. Schmidt showed that in developing countries the financing costs of low-carbon projects are considerably higher than in industrialised economies because investors add premiums for policy, currency and counterparty risks, and he proposed

de-risking instruments as the policy response that reduces these premiums and brings the cost of capital closer to that of mature markets [12]. The concept of de-risking thus links macroeconomic and institutional conditions with the micro-level profitability of an individual installation and explains why identical technology may be highly profitable in one country and marginal in another.

The third foundation is institutional and relates to the nature of the financier. M. Mazzucato and G. Semieniuk demonstrated that different types of investors, including utilities, corporations, commercial banks and state investment banks, differ in their appetite for risk and in the technologies they finance, and that public financial institutions tend to take on the riskier segments that private capital later enters [10]. Applied to industrial enterprises, this finding suggests that the mobilisation of investment depends on a sequence of actors: development finance institutions and state programmes establish the first bankable transactions, commercial banks replicate them through credit lines, and enterprises themselves then invest from their own funds once the risk profile becomes familiar. The mechanism of attracting investment is therefore a layered system of contracts, financial instruments and regulatory guarantees rather than a single incentive.

The aim of the article is to substantiate the theoretical and practical foundations for improving the mechanisms that attract investment in on-site renewable energy projects of industrial enterprises, with reference to the experience of the Republic of Uzbekistan. The following tasks were set: to systematise the concepts of risk-return, the cost of capital and de-risking in relation to industrial self-generation; to characterise contractual and financial instruments such as corporate power purchase agreements, net metering, green loans, green bonds and energy performance contracts; to assess the sensitivity of the levelised cost of solar electricity to the cost of capital under national conditions; and to develop a conceptual model of an investment attraction mechanism for industrial renewable energy.

LITERATURE REVIEW

The empirical literature on policy effectiveness provides the basis for selecting instruments. F. Polzin, F. Egli, B. Steffen and T. Schmidt systematically reviewed studies of how public policies mobilise private finance for renewable energy from the perspective of investors and concluded that instruments are effective when they reduce risks that investors cannot manage themselves, above all revenue risk and regulatory uncertainty, while long-term stability of the rules is valued as highly as the size of the incentive [11]. For industrial self-generation, revenue risk takes the form of uncertainty about the value of electricity that the enterprise does not consume on site. Guaranteed purchase of surplus output at a predetermined tariff and the legal possibility of selling electricity directly to other consumers therefore correspond precisely to the category of instruments that the review identified as the most effective in mobilising private capital.

The dynamics of financing conditions reveal why the cost of capital deserves separate attention. F. Egli, B. Steffen and T. Schmidt analysed financing conditions for solar and wind projects over nearly two decades and showed that the decline in the cost

of capital, driven by growing investor experience and lower general interest rates, made a substantial contribution to the fall in the levelised cost of renewable electricity alongside technological progress [3]. The finding implies that learning takes place not only in manufacturing but also in finance: as banks accumulate experience with a technology, they reduce risk premiums, lengthen loan tenors and accept higher debt shares. For countries at an early stage of industrial renewable deployment, the acceleration of this financial learning through demonstration projects and standardised contracts can lower costs as effectively as further declines in equipment prices.

Contractual models determine who bears the investment and who captures the savings. E. Vine surveyed the energy service company industry across a large number of countries and described energy performance contracting, under which a specialised company finances and implements an energy project and is repaid from the verified savings, as a model that overcomes the lack of capital and technical expertise at the client enterprise [15]. Corporate power purchase agreements follow a similar logic: a developer builds and operates the installation, while the industrial consumer commits to purchasing its output at an agreed price over a long period, which converts an uncertain future expense into a predictable contract. Both models are especially relevant for enterprises whose core business is manufacturing and which prefer to allocate capital to production assets rather than to energy infrastructure.

Capital market instruments complement bank lending for larger enterprises. C. Flammer found that the issuance of corporate green bonds is followed by a positive stock market response, by improvements in the environmental performance of issuers and by an increase in ownership by long-term and green investors, which indicates that green bonds serve as a credible signal of commitment [5]. The work of the International Renewable Energy Agency documents the other side of the equation: the global weighted average total installed cost of utility-scale solar photovoltaic plants fell from 5,283 US dollars per kilowatt in 2010 to 691 US dollars per kilowatt in 2024, and the levelised cost of electricity fell from 0.417 to 0.043 US dollars per kilowatt-hour [7]. With equipment costs at such levels, financing terms rather than technology prices have become the main variable that distinguishes profitable from unprofitable projects, yet the literature rarely quantifies this effect for industrial self-generation in emerging economies, and the article is intended to fill this gap.

METHODOLOGY

The methodological basis of the article is a systems approach in which an industrial enterprise is considered as an investor whose decision to build an on-site renewable installation depends on the cost of electricity purchased from the grid, the cost of the electricity produced by the installation and the terms of external finance. Methods of theoretical generalisation, comparative analysis of normative documents, financial modelling and conceptual modelling were applied. The information base comprises the renewable capacity statistics of the International Renewable Energy Agency [8], its cost benchmarks and methodological parameters [9], the legislation of the Republic of Uzbekistan published in the national legislative database, official data of the Central Bank on the policy rate [1] and exchange rates [2], and information on

projects of international financial institutions. The central analytical tool is the levelised cost of electricity (LCOE), calculated per kilowatt of installed capacity:

$$LCOE = \frac{I \cdot CRF + OM}{E} \quad (1)$$

where LCOE is the levelised cost of electricity, US dollars per kilowatt-hour; I is the total installed cost per kilowatt; CRF is the capital recovery factor; OM is the annual operation and maintenance cost per kilowatt; E is the annual electricity output per kilowatt, kilowatt-hours. The numerator represents the annual cost of owning and operating one kilowatt of capacity, and the denominator its annual output, so that the ratio shows the minimum price at which the electricity must be valued for the investment to be recovered. The capital recovery factor converts the initial investment into an equal annual payment over the economic life of the asset:

$$CRF = \frac{r \cdot (1+r)^n}{(1+r)^n - 1} \quad (2)$$

where r is the weighted average cost of capital (WACC) of the project; n is the economic life of the installation, years. Formula (2) captures the channel through which financing conditions affect the cost of electricity: the higher the rate r , the larger the annual payment required to recover each dollar of investment. The calculation used the global benchmark total installed cost of 691 US dollars per kilowatt and the capacity factor of 17 percent for 2024 [7], an economic life of 25 years and operation and maintenance costs of 11 US dollars per kilowatt per year adopted by IRENA for non-OECD countries [9]. The conservative annual output of 1,489 kilowatt-hours per kilowatt was derived from this capacity factor. The resulting cost was compared with the value of electricity for an industrial consumer, and the net present value per kilowatt was calculated as the discounted difference between avoided purchases and operating costs, reduced by the investment.

ANALYSIS AND RESULTS

The national context for industrial renewable investment is defined by strategic targets that are among the most ambitious in the region. The Strategy “Uzbekistan - 2030” sets the goal of increasing renewable energy capacity to 25 thousand megawatts and its share in total consumption to 40 percent, together with a twofold increase in the energy efficiency of economic sectors [19]. The earlier programme of green economy reforms envisages raising renewable generating capacity to 15 gigawatts, its share in electricity production to more than 30 percent, and energy efficiency in industry by at least 20 percent by 2030 [20]. The legal basis for industrial self-generation is the Law on the Use of Renewable Energy Sources, which grants producers the right to conclude contracts with consumers for the sale of surplus energy and establishes tax, customs and other preferences in the sector [17]. The dynamics of installed capacity that resulted from these reforms are presented in Table 1.

Table 1
Renewable energy capacity of Uzbekistan, 2019-2025, MW¹

Year	Total renewable capacity	Hydropower	Solar, wind and other	Share of non-hydro sources, %	Progress to the 2030 target, %
2019	1,912	1,908	4	0.2	7.6
2020	2,025	2,021	4	0.2	8.1
2021	2,056	2,052	4	0.2	8.2
2022	2,429	2,225	204	8.4	9.7
2023	3,250	2,382	868	26.7	13.0
2024	6,079	2,391	3,688	60.7	24.3
2025	10,027	2,441	7,586	75.7	40.1

Table 1 shows that between 2021 and 2025 total renewable capacity increased almost fivefold, from 2,056 to 10,027 megawatts, and that the entire increase was driven by solar, wind and other non-hydro sources, whose capacity rose from 4 to 7,586 megawatts. In 2025 these sources accounted for 75.7 percent of renewable capacity, and progress towards the target of 25 thousand megawatts reached 40.1 percent five years before the target date. The structure of growth indicates that the country has already passed the stage of first projects and entered the stage of scaling, at which financial learning of the type described by F. Egli and co-authors reduces risk premiums for subsequent investors [3]. For industrial enterprises this creates favourable preconditions: equipment suppliers, installers and banks with experience of solar projects are now present in the domestic market, and the transaction costs of an individual on-site project are correspondingly lower.

Industrial self-generation received targeted institutional support. Presidential Resolution PQ-57 provided for the commissioning in 2023 of renewable sources with a total capacity of 4,300 megawatts, including 550 megawatts of small photovoltaic plants built by entrepreneurs and 1,200 megawatts of solar panels on social facilities, buildings of business entities and households, and envisaged installing solar panels and small plants at the premises of 11 thousand entrepreneurs [21]. The same resolution exempted persons operating installations of up to 100 kilowatts from property tax, land tax and profit tax on electricity sold to the grid for three years, extended to ten years when a storage system of at least 25 percent of panel capacity is installed, and allowed electricity from renewable sources to be sold to other consumers at mutually agreed prices under direct, including long-term, contracts [21]. The latter provision creates the legal form of a corporate power purchase agreement, while Decree PF-220 guarantees the purchase of surplus output from installations of up to 1 megawatt built for own needs at 80 percent of the Group II tariff for at least ten years [18].

These instruments determine the value of electricity against which the cost of an on-site installation should be compared. For Group I consumers, which include large industrial enterprises, the standard tariff amounts to 1,100 soums per kilowatt-hour,

¹ Source: IRENA [8]; non-hydro capacity, shares and progress to the target of 25,000 MW set by the Strategy "Uzbekistan - 2030" [19] calculated by the author.

and from September 2026 a reducing coefficient of 1.5 applies in semi-peak daytime periods, so that the daytime price is about 733 soums per kilowatt-hour [13]. The new structure reflects the growing contribution of solar and wind stations to daytime supply and rewards consumers who shift loads to daylight hours. At the official exchange rate of 11,821.18 soums per US dollar on 30 September 2026 [2], the standard tariff corresponds to 9.31 US cents and the daytime tariff to 6.20 US cents per kilowatt-hour. The levelised cost of solar electricity calculated with formulas (1) and (2) for different values of the cost of capital is presented in Table 2.

Table 2

Sensitivity of the levelised cost of on-site solar electricity to the cost of capital¹

WACC, %	CRF	LCOE at 1,489 kWh/kW, US cents/kWh	LCOE at 2,700 kWh/kW, US cents/kWh	Capital share of LCOE, %	NPV per kW at 9.31 cents, USD
4	0.0640	3.71	2.05	80.1	1,302
8	0.0937	5.09	2.80	85.5	671
12	0.1275	6.65	3.67	88.9	310
14	0.1455	7.49	4.13	90.1	186
16	0.1640	8.35	4.60	91.2	87
20	0.2021	10.12	5.58	92.7	-60

The results in Table 2 confirm that the cost of capital is the dominant variable in the economics of industrial solar generation. When the WACC increases from 4 to 20 percent, the levelised cost at the conservative output level rises from 3.71 to 10.12 US cents per kilowatt-hour, that is 2.7 times, although the equipment and its output remain unchanged. The share of capital costs in the levelised cost grows from 80.1 to 92.7 percent, which means that each percentage point of the interest rate weighs more heavily than any plausible change in operating costs. The higher output column is based on the Nur Navoi plant, whose 100 megawatts are expected to produce 270 gigawatt-hours per year [6], or about 2,700 kilowatt-hours per kilowatt, and shows that the solar resource of the country substantially widens the margin of profitability. At the conservative output level the net present value per kilowatt remains positive up to a WACC of about 18 percent, and the project internal rate of return reaches about 18 percent, with a simple payback of about 5.4 years.

The comparison of these thresholds with the monetary environment clarifies the role of financing mechanisms. The Central Bank kept its policy rate at 14 percent per annum in September 2026 [1], and the cost of local-currency borrowing for an enterprise includes a margin above this rate. The break-even WACC at which the levelised cost equals the daytime tariff of 6.20 cents is about 10.9 percent at the conservative output level and about 22.5 percent at the higher output level, while against the standard tariff of 9.31 cents the corresponding thresholds are about 18.2 and 34.7 percent. For a large enterprise that consumes solar output mainly during the

¹ Source: calculated by the author using formulas (1) and (2) with cost parameters of IRENA [7], the output of the Nur Navoi plant [6] and the exchange rate of the Central Bank [2].

day, the conservative scenario therefore becomes attractive when the cost of capital falls below the policy rate, which is achievable through concessional credit lines, foreign-currency loans from development institutions and green bonds. The global range of WACC assumptions used by IRENA, from 3.8 percent in Europe to 12 percent in Africa [7], shows the scale of the gain that de-risking can deliver. The instruments available to industrial enterprises in Uzbekistan are summarised in Table 3.

Table 3

Instruments for attracting investment in industrial renewable energy in Uzbekistan¹

Instrument	Risk or barrier addressed	Parameters in Uzbekistan
Guaranteed purchase of surplus output	Revenue risk for electricity not used on site	Up to 1 MW, 80 percent of the Group II tariff, at least 10 years [18]
Direct contracts (corporate PPA)	Price risk for consumer and developer	Sale to other consumers at mutually agreed prices, including long-term contracts [21]
Tax exemptions	High initial cost	Property, land and profit tax exemptions for 3 years, 10 years with storage of at least 25 percent [21]
Green credit lines	Limited access to long-term credit	EBRD loan of up to USD 30 million to Hamkorbank under GEFF II for MSMEs and households [4]
Blended finance and guarantees	Country and counterparty risk	Nur Navoi 100 MW: IFC and ADB up to USD 60 million, World Bank payment guarantee of USD 5.1 million, tariff 2.679 US cents/kWh [6]
Green bonds	Scale and investor base	First green sovereign Eurobonds in the CIS, UZS 4.25 trillion, 2023 [14]

Table 3 demonstrates that the country has already formed instruments covering each of the principal risks identified in the literature. Guaranteed purchase of surplus output and direct contracts reduce revenue risk, which F. Polzin and co-authors identified as the most important barrier for private investors [11], and tax exemptions reduce the initial capital requirement. Green credit lines of the EBRD transfer the experience of international lenders to local banks, and the EBRD has invested more than 6.6 billion US dollars in Uzbekistan through 196 projects [4], which forms a substantial base of financial learning. The Nur Navoi project, financed with IFC, ADB and Canadian blended climate funds and supported by a World Bank guarantee, secured a tariff of 2.679 US cents per kilowatt-hour fixed for 25 years [6] and demonstrated how de-risking translates into a low cost of electricity. The placement of green sovereign Eurobonds in national currency opened the international capital market for green instruments denominated in soums [14], creating a benchmark for future corporate issues by large industrial companies.

¹ Source: compiled by the author on the basis of normative documents and data of the EBRD, IFC and UNDP.

The results of the analysis made it possible to combine the sources of capital, the de-risking layer, contractual models and the financial outcome into a conceptual model of the investment attraction mechanism for industrial renewable energy (Figure 1).

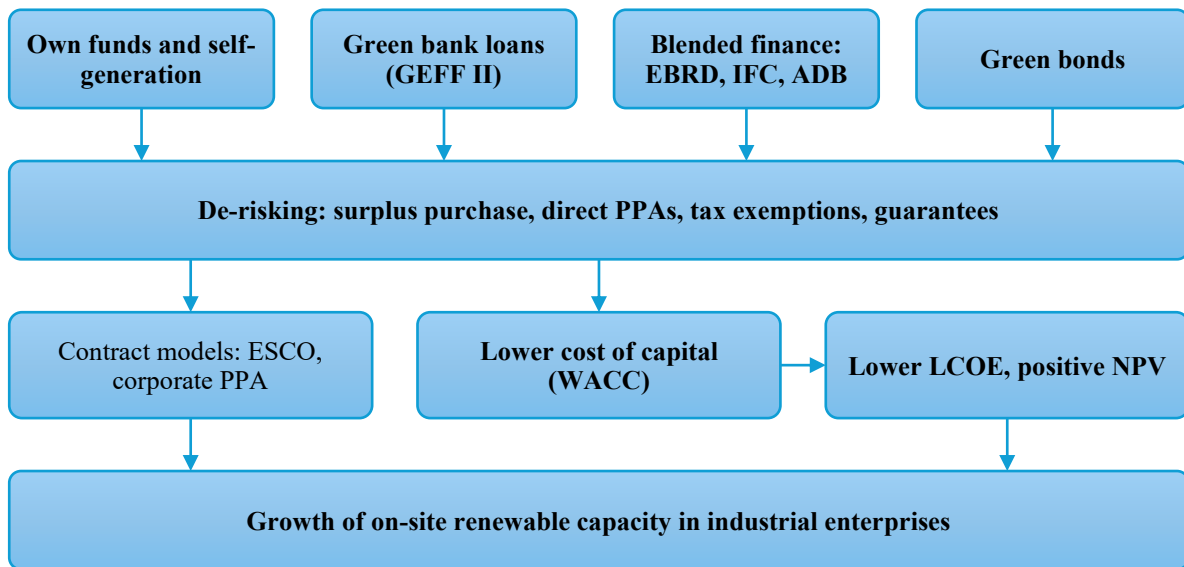


Figure 1. Model of the investment attraction mechanism for industrial renewable energy¹

Note: the arrows show the sequence through which sources of capital and de-risking instruments lower the cost of capital and make on-site renewable projects profitable; contract models allow enterprises to obtain renewable electricity without investing their own capital.

Figure 1 presents the mechanism as a three-level system. At the upper level, four sources of capital are available to an industrial enterprise: its own funds invested in self-generation, green loans of commercial banks, blended finance of development institutions and green bonds for large issuers. These flows pass through the de-risking layer formed by the guaranteed purchase of surplus output, direct contracts, tax exemptions and guarantees, which reduces the risk premiums embedded in the cost of capital. At the second level, the lower WACC translates into a lower levelised cost of electricity and a positive net present value according to formulas (1) and (2), while contract models based on energy service agreements and corporate power purchase agreements allow enterprises without spare capital to participate. The final level captures the growth of on-site renewable capacity in industry, which supports the achievement of the national targets and reduces the energy cost component of industrial output.

CONCLUSION AND SUGGESTIONS

The article substantiated that the attraction of investment in on-site renewable energy projects of industrial enterprises is governed primarily by the cost of capital. Since more than four fifths of the levelised cost of solar electricity consists of capital

¹ Source: developed by the author on the basis of R. Wüstenhagen and E. Menichetti [16], T. Schmidt [12] and the analysis of Tables 1-3.

costs, an increase in the WACC from 4 to 20 percent raises this cost 2.7 times, from 3.71 to 10.12 US cents per kilowatt-hour at a conservative output level, and the efficiency of a project is determined by the terms of finance as much as by the solar resource or equipment prices. Uzbekistan has created a comprehensive institutional base for industrial self-generation, including guaranteed purchase of surplus output, direct contracts, tax exemptions and green credit lines, and the fivefold growth of renewable capacity in 2021-2025 confirms the effectiveness of the reforms and the accumulation of market experience that lowers risk premiums.

On the basis of the results, the following proposals are put forward:

1. It is advisable to develop a standard long-term direct contract for the sale of renewable electricity to industrial consumers, with model clauses on price indexation, delivery volumes and dispute resolution, which would reduce transaction costs and make such contracts acceptable to banks as collateral;
2. Concessional credit lines for industrial self-generation could be linked to the daytime tariff structure by combining solar installations with storage and load shifting, which would allow enterprises to capture the extended tax exemptions and raise the value of each kilowatt-hour produced;
3. It is recommended to create a framework for energy performance contracting in industry, including measurement and verification rules, so that energy service companies can finance installations and be repaid from verified savings;
4. Large industrial companies may use the experience of the sovereign green bond issue to place corporate green bonds in national currency, with proceeds allocated to on-site renewable projects;
5. A register of industrial renewable projects recording capacity, output, financing terms and the cost of capital would provide banks with data for pricing risk and accelerate financial learning.

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Ingliz tili muharriri:
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Sahifalovchi va dizaynerlar:

Turobova Hulkar Rustamovna
Oripov Mahmud Ashurovich
Xidirova Gavxar Rustamovna
Qudratov Aziz Dehqonboyevich
Sadikov Shoxrux Shuxratovich
Abidjonov Nodirbek Odijon o'g'li

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