Emerging Strategies for the Sustainable Development of Solar Energy Sector in Turkey: A SWOT Analysis

Ceyda Aksoy Tırmıkçı (caksoy@sakarya.edu.tr)
Sakarya University: Sakarya Universitesi https://orcid.org/0000-0003-0354-4022

Research Article

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Abstract

This paper performs a strengths, weaknesses, opportunities and threats (SWOT) analysis to present some recommendations for future renewable energy roadmap of Turkey with respect to legal and regulatory framework, science and technology capacities, markets and industries. The following queries are addressed to identify internal and external parameters: the contribution of latest legal regulations to the installed solar capacity, the most excessive burdens for solar PV system developers, the current situation in PV research, the level of coordination between PV-dedicated institutions, the level of coordination between PV-dedicated institutions and industry, the science and technology capacity for manufacturing related issues, the response of locals regarding solar energy systems, the main pillars of the national energy strategy. In conclusion, possible strategies are recommended to maintain the strengths, improve the weaknesses, seize the opportunities and overcome the threats for the sustainable development of the solar energy sector in Turkey.

Introduction

In the last decade, the world has experienced increasing challenges of climate change by global warming which has reached to an alarming level between 0.8 and 1.2 degrees Celsius (Intergovernmental Panel on Climate Change Summary for policymakers 2018). Recent climate change researches demonstrate that it is unavoidable to experience dangerous degradation levels, unless the warming is limited below 2 degrees Celsius above pre-industrial levels with serious global decarbonisation actions (Khan et al.2021, Paris Agreement 2015, Yin et al. 2020)

The climate combat is essentially an energy transition combat given historic records of emissions from energy sectors, more than 30 Gt CO_{2eq} (Dmitrii, B et al. 2021, Hanna, B et al. 2020, International Energy Agency CO2 emissions 2019). In this context, sustainable energy transition around the world, especially in emerging economies, must be one of the main pillars of policy makers to achieve the climate targets.

Turkey is an emerging economy with a growing population recorded 83.6 million in 2020. Access to reliable and affordable energy is prioritised within the country's sustainable development plan and energy strategy (Tırmıkçı et al 2020). However, the reports indicate that the country is heavily dependent on fossil fuel imports to meet the growing energy demand with the consistently growing population and economy. In 2019, fossil fuels drove the country's economy with 190 ktoe of imports (IEA Countries: Turkey 2020). Although the policy momentum in renewable energy market has boosted the installed capacity of domestic, sustainable energy resources, energy framework of the country still needs serious reforms to achieve sustainable development goals.

The main objectives of this paper is determine key factors essential for Turkey's present solar energy situation with respect to legal and regulatory framework, science and technology capacities, markets and industries. In this context, a SWOT analysis is conducted by examining national strategic plans and energy reports, legislations and regulations in the field, sector reports and academic journals. In

conclusion, 11 recommendations are provided to contribute the sustainable energy transition progress in Turkey.

Materials And Methods

SWOT analysis is a significant and effective technique used to make decisions for a complex strategic situation by evaluating its strengths (S), weaknesses (W), opportunities (O) and threats (T) (Dyson 2004, Elavarasan et al. 2020, Fertel et al. 2013, Kamran et al. 2020). Strengths and weaknesses are internal factors that can be controlled and changed. However, opportunities and threats are external factors that must be managed to take advantage and protect.

In this paper, a SWOT analysis is conducted to evaluate the solar energy situation in Turkey within the country's sustainable development plan by answering the following questions through national strategic plans and energy reports, legislations and regulations in the field, sector reports and academic journals.

- What is the contribution of latest legal regulations to the installed solar capacity?
- What are the most excessive burdens for solar PV system developers?
- What is the current situation in PV research?
- What is the level of coordination between PV-dedicated institutions?
- What is the level of coordination between PV-dedicated institutions and industry?
- What is the science and technology capacity for manufacturing related issues?
- What is the response of locals regarding solar energy systems?
- What are the main pillars of the national energy strategy?

Results And Discussions

Table 1
SWOT Analysis of solar energy in Turkey

Strengths		Weaknesses	
P&M	-Law No.5343 (YEKK) -Law No.6094 -Law No.5627 (EVK) -Law No. 6446 (EPK) -The Electricity Market License Regulation (EPLY) -The Unlicensed Electricity Production Regulation (LEUY) -The Renewable Energy Resources Area (YEKA) -The Regulation on Domestic Manufacturing of the Parts Used in the Facilities Producing Electricity from RES	P&M	-Sectoral subsidies -Lack of incentives for global silicon-wafer manufacturers -Barriers in permitting procedures -Barriers related to grid connection -PV panel production standards
S&T	-Research Laboratories -Local solar panel manufacturers	S&T	-Very limited silicon wafer industry -Limited research and manufacturing capabilities
M&I	-6,667.4 MW installed solar PV capacity with 7,518 power plants	M&I	-Lack of public awareness -Lack of cooperation between industry and research laboratories
Opportunities		Threats	
P&M	-Growing interest in unlicensed generation	P&M	- The ambition of solar PV targets -National strategy to boost the domestic oil and gas production
S&T	-Solar water heating capacity	S&T	-The strength of foreign solar PV markets
M&I	-Attempts to export local solar panels to Europe and Middle East	M&I	- Competition from fast growing global market

3.1. Strengths and Weaknesses

3.1.1. Policies and measures

In terms of solar energy potential, Turkey is advantageous compared to most countries due to its favourable geographical location. Table 2 indicates monthly mean daily global solar radiation and sunshine duration of the country (National Renewable Energy Action Plan 2014).

Table 2
Monthly mean daily global solar radiation and sunshine duration of Turkey

Months	Global solar radiation [kWh/m^2-day]	Sunshine duration [h/day]
January	1.669	3.322
February	2.181	3.965
March	3.117	5.322
April	4.074	6.566
May	4.963	8.806
June	5.625	10.833
July	5.657	11.774
August	5.280	11.433
September	4.109	9.333
October	2.900	6.903
November	2.027	5.233
December	1.512	3.322

In parallel with the legal regulations regarding electricity generation from solar energy, the total installed solar energy capacity of Turkey reached to 6361 MW by the end of September 2020. the Law No. 5346 on the Utilization of Renewable Energy Resources for the Purpose of Electricity Generation (YEKK), the Law No. 6094 amending the Law No. 5346, the Electricity Market Law No. 6446 (EPK) and the Energy Efficiency Law No. 5627 (EVK) within The Electricity Market License Regulation (EPLY), the Unlicensed Electricity Production Regulation (LEÜY), the Regulation on Domestic Manufacturing of the Parts Used in the Facilities Producing Electricity from RES and the Renewable Energy Resources Area (YEKA) Regulation are the regulations which provide the greatest incentives to the market. By the Law No. 6446 (EPK), the installed capacity of unlicensed solar power plants increased to 6,102.3 MW which is 6.5% of total installed power capacity. The interest in licensed solar energy investments also increased due to the Law No.5346and the Law No.6094 and the total installed power reached a total of 258.9 MW with 25 new plants by the end of September 2020. Besides, the tenders within the scope of YEKA, made significant contributions to renewable energy generation with high domestic production content ratios. The Karapınar YEKA tender which is allocated in Konya-Karapınar for an installed capacity of 1000 MW has an obligation of 60% domestic content ratio. Therefore, a factory with a photovoltaic module production

capacity of at least 500 megawatts per year was established to fulfil the obligation (Attachment to the President's Decision 2019, Energy Efficiency Law No. 5627 2007, The Regulation Regarding Unlicensed Power Generation in relation to the Electricity Market 2011, The Regulation on Renewable Energy Resource Areas 2016, YEKA GES-3 2020). However, an obligation demand of a higher domestic content ratio within YEKA tenders was announced by local PV module manufacturers to contribute the development of local PV industry. The manufacturers also demanded incentives for global manufacturers producing PV panel raw materials to establish production facilities in Turkey and sectoral subsidies such as regulations related to customs taxation in raw material purchases and regulations related to VAT in sales in order to be able to compete with imported manufacturers (Market Research for PV Panel Production in Turkey 2020).

Permitting procedures are excessive burdens in Turkish solar energy market slowing down the development of PV systems, especially the ones with small capacity. Bureaucratic delays and insufficient preparation of authorities are the main obstacles which PV system investor faces to carry the process forward. Besides, long grid connection procedures also cause lead times due to the complexity of bureaucratic procedures with too many authorities.

3.1.2. Science and technology

The universities and laboratories which are involved in solar energy research in Turkey are listed in Table 3 (TUBA Solar Technologies Report 2018). These PV-dedicated units are vital for the country to accelerate the increase the PV share in electricity generation. However, the units are too fragmented and neglect cooperation.

Table 3
Solar energy research institutions in Turkey

Institution		Topics
Middle East Technical University, Solar Energy Research and Development Centre (GUNAM)		Crystal silicon, Heterojunction crystal silicon, CdTe thin film, CIGS thin film, Amorphous thin film, DSSC, Perovskite, OPV, CPV, CSP-STE
Ege University, Graduate Faculty of Solar Energy		OPV, lamination, system installation
Muğla Sıtkı Kocaman University, Clean Energy Resources Research and Development Centre		BIPV, solar car
Niğde Ömer Halis Demir University, Nanotechnology Application and Research Center		Heterojunction crystal silicon, Graphene, CZTS thin film, CIGS thin film, Perovskite, Tandem
Istanbul Technical University, Energy Institute		OPV
TÜBİTAK	Material Institute	OPV, Heterojunction crystal silicon
	Energy Institute	Inverter technology, li-ion battery
	National Metrology Institute	PV performance test
Anadolu University, Nanoboyut Research Centre		GaAs based multi-junction solar cell
Gazi University, Photonics Application and Research Center		DSSC, TiO_2 films, Tandem, QWSC
Yaşar University, Department of Energy Systems Engineering		BIPV

Table 4 presents 16 of 22 local PV panel manufacturers filling out the questionnaires provided by Stantec Turkey. 37.5% of the local PV panel manufacturing companies engages in production of solar modules. However, 13% of the companies operate in Engineering, Procurement and Construction (EPC) as well. 19% of the manufacturers are also Independent Power Producers (IPPs). The remaining 31% perform actively in all fields. Table 5 presents the distribution of PV panel and cell production capacities by companies in Table 4 (Market Research for PV Panel Production in Turkey 2020).

Table 4
16 of local PV panel manufacturers in Turkey

Company trade names	Abbreviated company trade names	Year of establishment	Location	Partnership Structure
Alfa Solar Enerji İnşaat Sanayi ve Tic. A.Ş.	Alfa Solar	2013	Kırıkkale	100% Turkish
Ankara Solar Enerji İnşaat A.Ş.	Ankara Solar	2013	Ankara	100% Turkish
CW Enerji Mühendislik Ticaret ve Sanayi A.Ş.	CW Enerji	2016	Antalya	100% Turkish
Elin Elektrik İnşaat Müşavirlik Proje Taahhüt Ticaret ve Sanayi A.Ş.	Elin Enerji	2017	Ankara	100% Turkish
Gazioğlu Solar Enerji Sanayi ve Ticaret A.Ş.	Gazioğlu Solar	2012	Tekirdağ	100% Turkish
GEST Enerji Sanayi ve Ticaret A.Ş.	Gest Enerji	2012	Hatay	100% Turkish
GTC Güneş Sanayi ve Ticaret A.Ş.	GTC	2013	Adıyaman	100% Turkish
2H Enerji ve Yatırım A.Ş.	2H Enerji	2018	Konya	100% Turkish
HT SOLAR Enerji A.Ş.	HT Solar	2016	İstanbul	100% Chinese
Mirsolar Enerji Sanayi ve Ticaret A.Ş.	Mirsolar	2017	Sakarya	100% Turkish
Ödül Enerji Taahhüt İnşaat Sanayi Ticaret A.Ş.	Ödül Enerji	2013	Kayseri	100% Turkish
Parla Solar Hücre ve Panel Üretim A.Ş.	Parla Solar	2015	Denizli	100% Turkish
Seha Mühendislik Müşavirlik Ticaret ve Makina Sanayi A.Ş.	Seha Solar	2016	Ankara	100% Turkish
Schmid-Pekintaş Güneş Enerji Sistemleri Sanayi ve Ticaret A.Ş.	Schmid-Pekintaş	2013	Düzce	Turkish and German
Smart Güneş Enerjisi Teknolojileri ArGE Üretim Sanayi ve Ticaret A.Ş.	Smart Solar	2017	Kocaeli	100% Turkish
Solarturk Enerji Sanayi Ticaret A.Ş.	Solarturk	2011	Gaziantep	100% Turkish

Table 5
The distribution of PV panel and cell production capacities by manufacturers presented in Table 4

Company	PV panel production capacity (MW/year)	PV cell production capacity (MW/year)
Alfa Solar	300	-
Ankara Solar	200	-
CW Enerji	1000	-
Elin Enerji	450	-
Gazioğlu Solar	140	-
Gest Enerji	150	-
GTC	135	100
2H Enerji	250	-
HT Solar	800	400
Mirsolar	200	-
Ödül Enerji	235	-
Parla Solar	150	130
Seha Solar	100	-
Schmid-Pekintaş	250	-
Smart Solar	1000	-
Solar Turk	250	-

Even though PV panel production and PV cell production in Turkey is promising, domestic production capacity of PV panels and PV cells is not sufficient to achieve the sustainable development goal of 10 GW in 2023 (The Eleventh Development Plan (2019-2023)). The primary demand of local manufacturers from policy makers is to prioritise incentives for R&D studies and technological studies related to basic raw material production in renewable energy market policy. The first studies in the field of semiconductor Turkey started in 1983 with the establishment of YITAL Research Centre. IC design, mask production, wafer processing, wafer probing, packaging, circuit test and aging processes are all implemented in YITAL. The semiconductor manufacturing institutions which operate currently are given in Table 6 (Electronic Industry Study Report 2018).

Table 6
The semiconductor manufacturing institutions in Turkey

Institution	Technology
YITAL Research Centre	250 nm CMOS
YITAL Research Centre/ASELSAN	130 nm CMOS/SiGe
YITAL Inc./ASELSAN	90-65 nm CMOS
ODTU-MEMS/ASELSAN	MEMS
AB Mikro Nano/ASELSAN	GaN
ODTU KANAL, ASELSAN	GaAs, HgCdTe
ODTU KANAL, CUNAM, ASELSAN	InGaAs
Ermaksan	Fibre Laser

In the very competitive semiconductor market, incentives by governments are vital for sustainable and developing production in the field. The continuity of incentives in Turkey is vital to provide mass production and meet the local demand in the market, since the production capacities are too small to compete with the foreign markets. The primary demands of the local sector are land supply, tax exemption, discounts on electricity use, discounts on water use, support for employment costs, flexible working law, patents, intellectual property rights, investment support and subsidies (Electronic Industry Study Report 2018).

3.1.3. Market and industry

Turkey reached to 7,219.7 MW installed solar capacity with 7,922 power plants, 7.35% of total installed power capacity. The share of installed solar capacity is 6,572.3 MW by unlicensed plants and 647.4 Mw by licensed plants (TEIAS Installed Capacity Report, June 2021). Within the scope of the Law No. 6446 (EPK), the installed capacity of unlicensed plants was increased to 1 MW which led to a growing interest in unlicensed generation applications in the market. However, the rapid increase in unlicensed generation is not sufficient to meet the 10 GW installed solar capacity objective of the country within 2019-2023 Strategic Plan (The Eleventh Development Plan (2019-2023)).

Mid and long term sustainable development targets of many countries are mostly established presupposing that the local accepts the massive changes in producing and using energy. Several studies from the literature support that solar energy has the highest level of acceptance among the other renewable energy sources (Cranmer et al. 2020, Sütterlin et al. 2017). However, energy-related infrastructure implementations often receive local resistance for several reasons like the size of the plant, the visual and scenic factors, noise annoyance, emotional reactions and safety concerns (Batel et al. 2015, Cousse 2021, Devine-Wright 2019, Huijts et al. 2012). Local acceptance is vital in succeeding sustainable energy development plans, since the opposition from local communities causes delays and

raises public concerns. Therefore, policy actors must examine public responses before planning process for sustainability of sustainable energy technologies in the long term. Local prejudice against renewable energy projects is one of the important reasons why Turkey could not experience a higher expansion of renewables given its enormous resource deployment (Kul et al. 2020, Ozgül et al. 2020) .

The Industrial and Technology Strategy established by the Ministry of Industry and Technology announced that one of the primary short-term goals was to support strategic investments in high-tech priority sectors with an end to end mechanism. It is expected to experience a rapid increase in the number of innovative start-ups producing qualified technology integrated with global markets. However, lack of cooperation between industry and research laboratories slow down the process to increase the number and effectiveness of industrial and technology zones. (The Eleventh Development Plan (2019-2023)).

3.2. Opportunities and Threats

3.2.1. Policies and measures

In Turkey, real or legal persons are able to install renewable energy systems up to 5 MW without a license according to the updates introduced with the new Regulation on Unlicensed Electricity Production in Electricity Market (Electricity Market Unlicensed Generation List 2021). There is a growing demand from investors to install unlicensed solar PV energy generation. In 2018, the increase in installed renewable energy generation capacity was recorded 67.35% with 94,47% of solar PV capacity. The target for installed solar capacity by 2023 is reported 10 GW. It However, the ambitious of sustainable development targets of the country in terms of solar PV generation expansion is weak given its geographical favour.

It is a fact that almost all natural gas demand of Turkey, 99%, is met by imports. The country priorities to boost domestic gas exploration and production within energy security strategies. It is announced that the recent Sakarya gas discovery in the Black Sea could promises to greatly diminish the country’s dependence on imported gas. The ambitious of the targets of natural gas security strategies is promising for Turkish economy. However, mid-term long-term clean energy transitions and emission reduction targets must be defined more clearly and ambitiously to achieve sustainable development target in terms of both environment and economy.

Turkey is one of the leading countries for solar water heater systems with a total installed capacity reached to 108,455 [MWth] in 2012 (Benli 2016). However, the great potential of the country can still meet the hot water needs of many more buildings. The key to maximise the potential is to provide government support policies or subsidies for solar water heating applications. Currently, manufacturers benefit from general industry support policies or special projects. On the other hand, there is no incentive for householders to purchase the systems.

PV module manufacturers in Turkey mostly focus on meeting the domestic market demands. Figure 1 shows the production capacity for domestic market and exports. The most important export markets of the companies are Middle East Market with 27.5%, Europe Market with 19.6% and North Africa Market

with 15.7% (Market Research for PV Panel Production in Turkey 2020). Nevertheless, the available exporting capacities of local manufacturers are still too small to compete with foreign industry, especially Asian industry.

3.3. Recommended strategies

Table 7
Strategies recommended by SWOT analysis presented in Table 1

	Strengths	Weaknesses
Opportunities	- Using the combination of subsidy mechanisms - Directing RE policies in accordance with the mechanism of National Appropriate Mitigation Actions (NAMAs) to benefit international funding	- Simplifying procedures for small-scale PV system projects - Improving communication between local governments, local universities, local manufacturers and other local shareholders - Providing training programs on solar PV for engineering, testing, financing and administration - Introducing support policies and subsidies for promoting the application of solar water heater systems in the buildings - Improving co-operation between research laboratories and industry
Threats	- Including PV panel and PV cell manufacturers in policy making process - Increasing the ambitious of solar targets to maximise the respected potential	- Setting up independent ministry offices to inform and support all shareholders about legal procedure, technical standards and grid connection rules - Organizing seminars, workshops or conferences cooperating with universities and local government to examine public responses towards solar energy applications

3.3.1. Strength and opportunity (SO) strategies

The SO1 strategy focuses on using the combination of subsidy mechanisms to drive more interest across the country with very abundant solar resources far surpassing many market leaders (Global Solar Atlas 2020).

The SO2 strategy focuses on directing RE policies in accordance with the mechanism of National Appropriate Mitigation Actions (NAMAs) to benefit international funding. Since solar energy transition actions promise significant greenhouse gas emission reduction, the government can benefit the instrument to strengthen the national response to climate change (Fridahl et al. 2017).

3.3.2. Weakness and opportunity (WO) strategies

The WO1 strategy focuses on simplifying procedures for small-scale PV system projects. Reducing the number of authorities involved in permitting procedures and defining reasonable deadlines for permitting procedure can remove administrative obstacles that PV system investors tackle.

The WO2 strategy focuses on improving communication between local governments, local universities, local manufacturers and other local shareholders to determine local solar energy transition policies more accurately. Resilient green cities with economies of scale and educated society have a key role to achieve sustainable development goals of governments.

The WO3 strategy focuses on providing training programs on solar PV for engineering, testing, financing and administration to sustain technical, institutional and political improvement on local and national level.

The WO4 strategy focuses on introducing support policies and subsidies for promoting the application of solar water heater systems to minimize the building based greenhouse gas emissions.

The WO5 strategy focuses on improving co-operation between research laboratories and industry to reach a critical mass for national solar energy infrastructure.

3.3.3. Strength and threat (ST) strategies

The ST1 strategy focuses on including PV panel and PV cell manufacturers in policy making process. The sector report indicates that the target of local PV manufacturers is to increase their share in the foreign market aggressively to compete the fast-developing foreign industry. However, additional tariff support, interest rate cut in investment incentives and simpler investment permit processes are requested to achieve the targeted growth in both local and foreign market.

The ST2 strategy focuses on increasing the ambitious of solar targets to maximize the respected potential in all sectors. A more ambitious growth in solar can help the country to achieve the sustainable development goals of domestic energy resource use and emission reduction in energy sector. However, national strategy to boost the domestic oil and gas production may interfere the environmental goals of energy sector.

3.3.4. Weakness and threat (WT) strategies

The WT1 strategy focuses on setting up independent ministry offices to inform and support all shareholders about legal procedure, technical standards and grid connection rules. Clear and consistent guidance in administrative procedures can help to increase the number of solar PV systems accessing to the grid in the short-term.

The WT2 strategy focuses on organizing seminars, workshops or conferences cooperating with universities and local government to examine public responses towards solar energy applications. Addressing all types of responses to solar energy development on policy making can help to achieve the sustainability of solar technologies with a good public acceptance in the long-term.

Conclusion

This paper investigates the current situation and progress of solar energy in Turkey. For this purpose, a SWOT analysis is carried out to evaluate the internal and external environment for solar technology area in the country with respect to legal and regulatory framework, science and technology capacities, markets and industries. According to the SWOT analysis presented in Table 1, possible strategies are recommended to boost the deployment of solar energy applications by seizing the opportunities and overcoming the threats:

- Using the combination of subsidy mechanisms
- Directing RE policies in accordance with the mechanism of National Appropriate Mitigation Actions (NAMAs) to benefit international funding
- Including PV panel and PV cell manufacturers in policy making process
- Increasing the ambitious of solar targets to maximise the respected potential
- Simplifying procedures for small-scale PV system projects
- Improving communication between local governments, local universities, local manufacturers and other local shareholders
- Providing training programs on solar PV for engineering, testing, financing and administration
- Introducing support policies and subsidies for promoting the application of solar water heater systems in the buildings
- Improving co-operation between research laboratories and industry
- Setting up independent ministry offices to inform and support all shareholders about legal procedure, technical standards and grid connection rules
- Organizing seminars, workshops or conferences cooperating with universities and local government to examine public responses towards solar energy applications

The results of the paper indicate that Turkey can experience an impressive growth in installed solar energy capacity by developing its approach on the renewable energy policy regime with more ambitious targets, more cooperation with shareholders in the sector and local government.

Declarations

Ethical Approval

Not Applicable

Consent to participate

Not Applicable

Consent to Publish

Not Applicable

Authors Contributions

Concept-CAT, Data Collection-CAT, Literature Research-CAT, Writing-CAT

Funding

Not Applicable

Competing Interests

The author declare that she has no competing interests

Availability of data and materials

All data generated or analysed during this study are included in this published article

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Figures

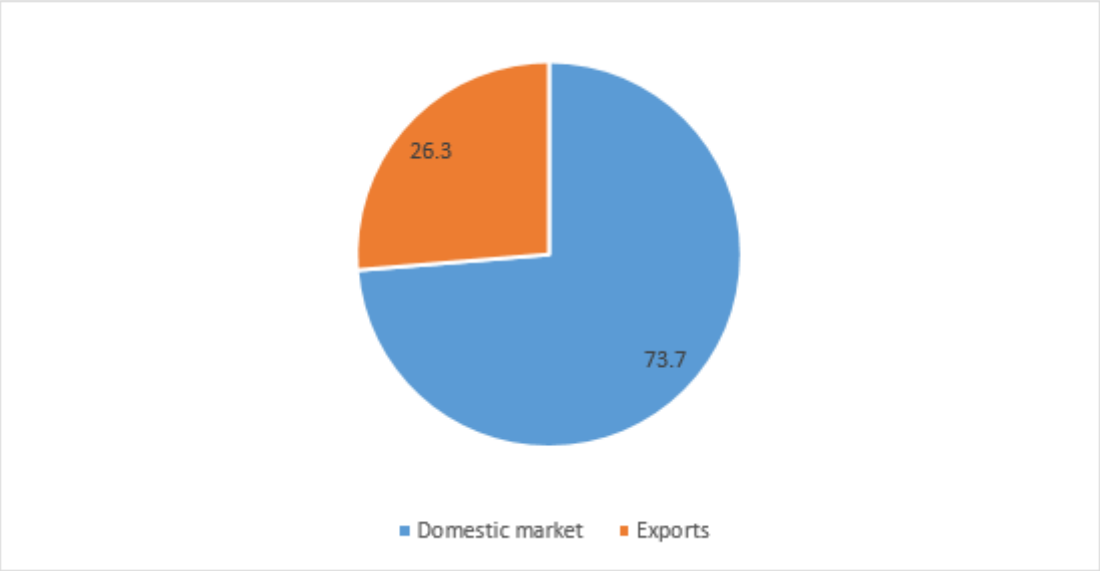

Figure 1

The production capacity for domestic market and exports

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