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Update Georgia's Climate Technology Needs Assessment through Development of a technology road maps for prioritized technologies

Technology Needs Assessment Report

Deliverable under Activity 2.1.4.: TNA Report (both mitigation and adaptation)

Version 1.1.

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Summary of the Results

The project "Updating of Georgia's technology needs assessment (TNA) through development of technology road maps for prioritized technologies" is aimed at supporting Georgian government in the assessment of the needs of innovative climate technologies and the development of a plan for the introduction of priority technologies. As a result of the project, the most critical sectors of the economy should respond to the challenges related to climate change.

Four priority sectors for the sustainable development of the country's economy were selected at the first stage of project implementation, which contribute significantly to the reduction of risks caused by climate change and greenhouse gases affecting the climate change.

In order to select the sectors, a detailed assessment of their priorities, barriers and needs was carried out, and the results served as a basis of the multi-criteria analysis method applied for the selection of the four priority sectors. Firstly were defined the criteria to be evaluated, then the experts' working group assigned weights to these criteria, and finally, the sectors were evaluated based on the criteria in order to conduct a multi-criteria analysis. From the 10 considered following sectors - energy, agriculture, transport, buildings, forests, natural disasters/infrastructure, industry, Black Sea coastline, waste and tourism (as an important direction for the country), the following 4 sectors were selected based on the total results of the multi-criteria analysis:

- Energy generation and supply
- Transport
- Buildings
- Agriculture

A detailed description of the selection process of the sectors is given in the corresponding chapter of the given document - "Prioritization of sectors".

The second stage of the project implementation involved the identification of promising technologies in the selected 4 sectors and the selection of priority technologies. The selection process was carried out similarly to the previous stage, based on a multi-criteria assessment carried by a working group of experts. 3 groups of criteria were used in the method, among which 14 criteria are distributed:

Table 1. Criteria used to evaluate technologies

Group of Criteria	Criteria
Group 1: Reasonability in terms of climate change	Emission reduction potential
	Additional accompanying emissions
	Adaptation potential to climate change
	climate change risk
	Vulnerability
Group 2: Technical feasability	Limitation of the area of application
	Functional efficiency
	Barriers to technical installation
	Operating barriers
	Economic lifetime

Group 3: Environmental and social feasability	Impact on the environment
	Impact on health care
	Impact on socio-economic development
	Impact on gender

It should be noted that the selected criteria did not include criteria related to finance, knowledge and awareness, and institutional and legislative barriers as such barriers can be eliminated, and a detailed discussion of these barriers and planning of their elimination means will be acomplished in the technology action plan and financial strategy. At the initial stage, It was necessary to determine the criteria for the groups and the weights/score for the criteria. Project experts, members of the coordination group and experts invited to the workshops participated in this process. As a result of the survey, the following weights were selected:

- With a score of **0.40**, **the first group of criteria** was found to be relatively important, examining the extent to which the technology has the potential to reduce and/or adapt to greenhouse gas emissions, the extent to which the introduction or consumption of the technology leads to additional emissions and climate change risks, or the extent to which it is vulnerable to climate change. Within the group itself, the highest weight/score was assigned to the criterion "emissions reduction potential".
- **The second group of criteria** was evaluated with **0.35** points, which evaluates various technical characteristics of technologies, which may represent an insurmountable barrier during the introduction or operation of this technology in Georgia. This group also takes into account the country's geographical features and other limiting barriers to the scope of application of technology. Within the group itself, the highest weight was assigned to the criterion "emissions reduction potential".
- Also **0.25** points were received by **the third group of criteria**, which considers the additional impact on the environment and social and economic development, accompanying the technology and not related to the emissions of greenhouse gases. Within the group itself, the highest weight was assigned to the criterion "emissions reduction potential".

The detailed definitions of criteria and weights assigned by experts are given in the Table 3 of the annex.

The majority of promising technologies from the 4 priority sectors were gathered at 4 working workshops, where members of the coordination group, experts, representatives of the priority sectors, representatives of the government, banking and commercial sectors were presented. The full list of technologies represents 48 technologies:

- energy generation and supply - 16 technologies;
- agriculture - 10 technologies;
- transport - 9;
- buildings - 13

which include mitigation, adaptation and combined technologies. The complete list is given in Table 4 of the annex.

Based on the multi-criteria analysis, the top scoring 16 technologies were selected and analysed separately. , from which 11 technologies were finally selected by the TNA coordination group based on the following considerations:

- "Pasture Rehabilitation" and "Wind Strip Cultivation/Rehabilitation" are considered as very important and priority technologies, although it was decided to discard them from the final list, because both technologies already have significant research and large-scale projects in the progress phase, the implementation of which will most likely change the current picture/need.
- "Water-storage hydroelectric power plants" is also considered as priority and important technology, however, since the knowledge/many years of experience of this technology exists in the country and the barriers are mainly of a political nature, it will not be discussed in details in this document.
- Another high-scoring technology that is also not discussed further is “highway waterproofing emulsions”. Despite the fact that modern emulsions are relatively effective for the waterproofing coating used in Georgia, this technology is more or less implemented in the country and the quality of the used emulsions mainly depends on the tender terms.
- Taking into account the opinions of experts, "Urban technology of creating a network of pedestrian and bicycle traffic" was replaced by "Technology of improving public road transport". The main argument was the difficult geographical landscape of Tbilisi, which creates a serious barrier to the mentioned technology.

According to the opinion of experts and the coordination group, among the adopted 11 priority technologies , The "Technology for increasing biodiesel production" was also included, being the important direction for the country as it has export potential and in order to fulfill the obligation to increase the share of renewable energies taken by the country by 2030, in the case of diesel-powered transport, it practically has no alternative.

The list of 12 selected technologies is given below 3 of them are adaptation technologies (where 2 of them also have mitigation potential), and 9 are mitigation technologies (where 2 of them also have adaptation potential). The important factors that influenced their selection are discussed below.

Energy Generation and Supply

1. **A combination of wind power plants and hydro-accumulating hydropower plants.** Wind stations in Georgia have high potential, however, due to variable generation levels (higher generation at night and lower generation during the day) and off schedule peak consumption, there is a need to store excess energy and provide inertion. In order to solve this problem, the most appropriate technology for Georgia is hydro storage stations. Their construction will increase the system's sustainability, flexibility and enable the integration of additional capacities generated by wind. It is also worth noting that, unlike reservoir-based hydropower plants, small reservoirs are sufficient for hydroaccumulating technology, and their arrangement/construction is also possible on existing reservoirs

(Sioni, Zhinvali, etc.), which is why this technology is characterized by a relatively weak climatic risk.

2. **A combination of run-of river hydropower plants and green hydrogen.** The maximum generation of flowing HPPs coincides with the minimum consumption of the system - in spring-summer, therefore, it is necessary to "accumulate" excess energy for a long period. For this purpose, "green hydrogen" technology is used worldwide- when energy is converted and stored into hydrogen during the peak generation period, and then electricity generation is carried out with this resource to meet the maximum consumption of the system (in winter). Depending on the capacity of green hydrogen batteries, if necessary, it is possible to store both domestically generated and imported energy (at low prices), which will significantly reduce fuel imports.
3. **A combination of photovoltaic power plants and batteries.** Among the technologies selected from the energy sector, photovoltaic power plants and a combination of batteries are characterized by the shortest generation-storage cycle. In the case of equipping photovoltaic (PV) power plants with energy storage batteries, the uneven output of solar plants is smoothed out, which occurs only during the day and is also strongly dependent on the weather (especially cloudiness). Therefore, such combined technology is friendly to network operators and requires minimal intervention on their part. Based on the world practice, the introduction of this technology in Georgia has a high potential, it is not characterized by vulnerability and does not cause climate changes. It is important to involve the state for ensuring the collection/utilization process of end-of-life batteries.

Transport

The transport sector is the most important sector - in 2017, the highest share of the country's emissions fall on the transport sector (23%). At the same time, a significant increase in emissions from the transport sector by 2030 is expected in case of not taking appropriate measures, and on the contrary, in case of taking measures, the transport sector has the highest potential for reducing greenhouse gases. According to the mitigation scenarios considered in the Climate Strategy and Action Plan and National Energy and Climate Plan, this sector is expected to achieve 41% of the overall emission reduction by 2030.

The transport sector includes road, rail, inland navigation and aviation transport, however, road transport accounts for the largest share. All three selected technologies belong to road transport:

1. **Strengthening of electric road transport and infrastructure.** This technology is quite relevant as electric vehicles consume on average 70% less energy to drive 1 km than their corresponding fossil fuel technologies. Interest in this technology is high both from the government, banking and commercial sectors and the population. A significant reduction in travel and service costs is the very factor that will allow the project implementers to attract a large part of the funding from the population as well and, accordingly, increase the scale of the project. Of course, the technology involves the active engagement of the banking sector in terms of creating banking products tailored to this project, both for the retail market (for purchasing an electric car) and for importing companies (for ordering from electric car manufacturers). An important part of the project is the development of the country's infrastructure (charging stations, battery service and delivery/utilization

centers, etc.) and public transport, the gradual replacement of which requires the active participation of state structures.

2. **Development of public road transport.** The technology serves to replace private cars with public transport, and foresees the increase of the level of comfort, speed, accessibility, reliability and safety of the public transport for the population**.** The technology includes such sub-technologies as introduction of multimodality, convenient information system for passengers, high frequency and speed of movement, comfort. Replacement of diesel-powered transport with electric transport is also an additional sub-technology. The development of public road transport is a priority direction in the cities of the world, because, in addition to the mitigation effect, it has the greatest impact on the environment, health care and socio-economic development of the country. The active participation of all involved parties (state/donors) is very important for the establishment of the technology, because due to its complexity, it requires qualified, coordinated and coherent management of the implementation process.
3. **Increasing biodiesel production.** This technology involves scaling up biodiesel production and consumption, and has both mitigation potential (biodiesel replaces fossil diesel) and positive health and environmental impact. The latter is conditioned by the fact that biodiesel will be produced from secondary (waste) edible oil, and therefore the use of secondary oil as feed in livestock and poultry farming or the cases of its getting into waste water will be reduced. Technology is important because biodiesel has no alternative in terms of replacing diesel fuel (which Georgia is committed to), and building such an enterprise in Georgia will allow the country to produce biodiesel both for the domestic market and for export. It is appropriate for the state to promote the consumption of biodiesel in the diesel-powered transport segment (eg, in the form of imposing a lower tax on biodiesel), and from the donors - financial support of the given process.

Buildings

Despite the relatively small share in the total emissions of the country - 13% as of 2017 (82% - residential and 18% - state/commercial buildings), the technologies of the construction sector are interesting as the most of them, in addition to reducing greenhouse gas emissions, also have an adaptation component – contributing to adaptation to temperature extremes caused by climate changes.

The two technologies that were selected (insulation of the thermal covering of buildings and electric water heat pumps) represent the technologies with the highest potential for reducing emissions in the building sector, and in the nearest future both of them will be regulated by the law on energy efficiency of buildings, which the state has been actively working on for several years (enactment of the most important regulations planned from summer 2023).

Due to the mountainous terrain and frequent hazardous geological processes (landslides), buildings and infrastructure in Georgia are quite vulnerable to climate change. Accordingly, along with the climate change mitigation technologies, the technology of adapting to the natural circumstances caused by the climate change has also been included in this sector.

1. **Insulation of the thermal envelope of buildings.** The greatest potential for reducing emissions from the building sector can be achived by the building's thermal envelope, as 50% or more of energy flow occurs through the thermal envelope. The new legislation,

which is planned to enter into force from the summer of 2023, will regulate the energy efficiency requirements on the thermal envelope of buildings in the case of new constructions and significant reconstruction of existing buildings**.** Due to the low level of awareness and high initial cost, this technology is currently only used in special cases in the country, for its introduction it is necessary to actively involve all interested segments (state, commercial, banking, consumer) in order to: take the right legislative and institutional measures, study the construction materials and technologies available on the international market, raising awareness in the commercial sector and facilitating imports, creating technology-friendly banking products and introducing them to the consumer market. Considering the fact that insulation of thermal envelope of the building will reduce heating and cooling costs up to 50%, the technology has the potential to attract investment from the consumer segment, which will facilitate the application of this technology to existing buildings. Given that the insulation of the building's thermal envelope contributes to the adaptation to climate change, as it reduces the negative effects (thermal discomfort) caused by extreme temperatures, the technology also has adaptation potential

2. **Highly efficient heating-cooling systems (electric water heat pump).** Electric water heat pumps are often referred to as a renewable energy technology because it imports at least 2 times more energy from the atmosphere (COP >3.1). The technology is widely used in Europe and America, however, it is not popular in Georgia due to the high initial cost. The new regulations, which are prepared on the basis of the European directive, significantly tighten the energy efficiency requirements of the heating and cooling systems of the building, which will increase the demand for heat pumps. At the same time, it is important to increase awareness among the population and the construction sector and create incentive schemes and banking products for these segments. Similar to the thermal insulation, it has the potential to be adaptive as it reduces the negative effects of extreme temperatures in buildings.
3. **Soil nailing against landslides.** This technology can be quite effective in a country that is rich with difficult terrain and landslide-prone areas like Georgia. The technology is often used based on preliminary monitoring and study data of the hazardous area and requires individual design. This technology has already been used in several collapsed sections in Georgia, although with the active participation of foreign specialists. Despite the small scale of application due to the need for special equipment and technology experts, the contribution of the tecnology to the improvement of road infrastructure is quite high. It has no mitigation potential, however, it has a very high potential in terms of adaptation, as it reduces the risk of one of the most dangerous natural processes - landslides.

Agriculture

The agricultural sector, with a 21% share of energy and non-energy emissions of greenhouse gases in the country (according to 2017 data), occupies the second place and is just behind the transport sector. Despite high emissions from the sector, adaptive technologies prevail in agriculture in general. The 10 technologies reviewed also reflected this pattern,

although all 3 technologies that were selected have significant mitigation potential (along with adaptation), partially conditioning their high scores.

1. **Conservation methods of land cultivation.** Unlike other land amelioration/reclamation technologies, which have already been applied in the country at different scales, conservation tillage technology is not actually used in the country. This technology involves plowing arable seedbeds with special narrow-blade plowing equipment or implementing zero-tillage practice, which significantly reduces the degree of soil damage and consequently increases the carbon sequestration potential of soils. Depending on the degree and specificity of erosion, it is advisable to use this technology in combination with other soil reclamation technologies. The involvement of the state/donors/local and foreign field experts is necessary in order to increase the interest against this technology in the country, to make available special tillage equipment (which currently does not exist in the country) and to implement qualified management of the process, because it takes time to move to a new method of soil cultivation (improvement of the soil condition may take several years). The technology is characterized by the effect of both mitigation (at the expense of reducing the fuel currently used for plowing the land) and adaptation (reducing the erosion of arable lands). It should also be noted that under the proper conditions, the effect of adaptation is lifelong and is implemented witout the use of chemical means, which increases the environmental friendliness of the product.
2. **Breeding of highly productive cattle.** This technology allows for the reduction of enteric fermentation emissions from the agricultural sector, which accounts for a significant share of emissions from this sector. The technology does not reduce overall productivity, as introducing twice or more productive breeds and/or improving domestic breeds (in terms of productivity) allows reduction of livestock mortality, and corresponding emissions. In addition, the impact of a special nutritional diet, which is common, if the technology is effectively implemented, makes it possible to reduce emissions even more. The involvement of,the state/donors/ local and foreign field experts is necessary both in selecting/introducing the best varieties in terms of adaptation for different regions of the country, as well as in arranging food ration/diet and artificial insemination laboratories and centers.
3. **Use of agricultural waste as fertilizer.** This technology is aimed at improving the productivity of agricultural soil with natural fertilizer - compost or manure and the production of this fertilizer. The technology is characterized by both adaptation and mitigation potential, as it prevents/reduces soil erosion on the one hand, and on the other hand reduces methane produced by rotting agricultural waste and significantly increases the carbon capture effect of the soil through compost/manure/biochar enrichment. An additional positive impact of this technology is the cleaning of plots from residues and the means of growing organic products. The technology actually has no geographical area limitation and after raising the awareness in the target segments, its application can be quite easy due to the interest of the population and companies.

The 12 technologies considered in the TNA result in reduction of emissions from 7 different source categories and increase in removals in one source category. In total, emissions from these categories amount to 11,533.8 g CO2 EC, which makes 54.0% of the country's emissions in 2017, and absorption amount to 2,257.8 g CO2, which is 25.8% of the total absorption in the country in 2017, and in total they make up 73.2% of the country's net emissions.

Source categories and their emissions/removals according to the 2017 national inventory are shown in Table 2.

Table 2. Source-categories and their emissions/removals in 2017 considered for the impact assessment of the priority technologies reviewed in the TNA.

IPCC Category code	IPCC Category	Totals (CO2eq)		
		Emissions	Removals	Net Emissions
1.A.1	Fuel combustion in energy industries	1,533.40	-	1,533.40
1.A.3	Fuel combustion in transport	4,144.59	-	4,144.59
1.A.4.a	Fuel combustion in commercial/institutional buildings	541.08	-	541.08
1.A.4.b	Fuel combustion in residenital buildings	1,895.00	-	1,895.00
1.A.4.c	Fuel combustion in agriculture	293.00	-	293.00
1.B.2	Fugitive Emissions from oil and natural Gas	1,416.86	-	1,416.86
3.A.1	Enteric Fermentation	1,829.52	-	1,829.52
3.B.2.	Cropland	-	2,257.80	(2,257.80)
Total		**11,653.45**	**2,257.80**	**9,395.65**

Two scenarios were elaborated to assess the impact that TNA technologies can have on Georgia's GHG emissions: the first scenario (without TNA technologies) describes the growth of Georgia's GHGs in accordance with the Energy and Climate Action Plan of Georgia, but without the 12 technologies selected in this TNA (i.e. all measures that include these technologies are removed), and the second scenario (with TNA technologies) determines the increase of greenhouse gases in accordance with the Energy and Climate Action Plan of Georgia, but with the inclusion of TNA technologies.

TIMES-Georgia model was used to estimate energy emissions scenarios, and calculations based on IPCC inventory methodology for non-energy sectors. The mentioned model and calculations are the same as those applied to prepare the Energy and Climate Action Plan of Georgia.

Figure 1 shows the total emission reductions by TNA technologies in 2030 and 2050 in the "with TNA technologies" scenario compared to the "without TNA technologies" scenario. As it can be seen, the greatest results are achieved in the household and transport sectors. Concurrent reductions in fugitive emissions resulting from reduced gas consumption in various sectors are also high.

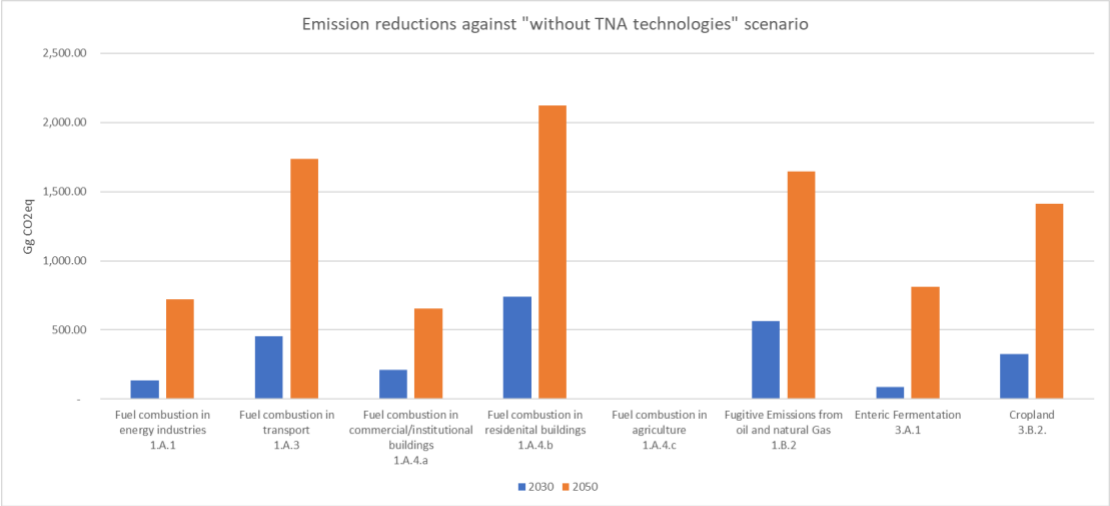

Figure 1. Emission reductions in the scenario "with TNA technologies" compared to the "without TNA technologies" scenario.

Annex

Table 3. Description of criteria and their weights

Criterion	Description	Units/ Scale	Weight
Group 1: Reasonability in terms of climate change			**0.4**
Emission reduction potential	The criterion assesses the potential of this technology in terms of reducing emissions in Georgia by 2030.	Tons of CO2eq	0.23
Additional accompanying emissions	The criterion assesses the additional emissions of greenhouse gases accompanying the process of using the technology. "Additional emissions" mean more emissions than the most common alternative technology.	Interval [0,3] 0 - strong; 3 - does not have;	0.20
Adaptation potential to climate change	The criterion reflects the potential of this technology to reduce the negative effects of climate change in Georgia by 2030.	Interval [0,3] 0 - strong; 3 - does not have;	0.19
climate change risk	The criterion assesses the extent to which a technology causes climate risks (other than greenhouse gas emissions) that require adaptation.	Interval [0,3] 0 - strong; 3 - does not have;	0.20
Vulnerability	The criterion assesses how vulnerable the technology will be (relevant infrastructure, resources, etc.) to climate change.	Interval [0,3] 0 - strong; 3 - does not have;	0.18
Group 2: Technical feasability			**0.35**
Limitation of the area of application	The criterion evaluates geographical/zonal/functional limitations that characterize the technology.	Interval [1,3] 1 – very limited; 3 - unlimited;	0.19
Functional efficiency	The criterion evaluates how well the technology performs its function on 1 unit of activity both in mitigation and adaptation.	Ranking according efficiency parameter defined for each sector/technology	0.23
Barriers to technical installation	The technology is evaluated based on how technically difficult it is to install - installation process, possible barriers, technical / human resources and time required for installation.	Interval [0,3] 0 - difficult; 3 - simple;	0.21
Operating barriers	The technology is evaluated according to how difficult it is to operate - possible barriers, technical/human resources and the intensity of the intervention.	Interval [0,3] 0 - difficult; 3 - simple;	0.18
Economic lifetime	The criterion defines the period of time during which the technology is useful to the owner, that is, it generates more benefits than it costs to maintain and operate.	years	0.20
Group 3: Environmental and social feasability			**0.25**
Impact on the environment	The criterion evaluates what impact the technology will have on the environment (natural resources, biodiversity, local climate) in addition to the impact caused by the reduction of greenhouse gas emissions.	5 - strongly positive; 4 - weakly positive; 3 - neutral; 2 - weakly negative;	0.29

		1 - strongly negative impact;	
Impact on health care	The criterion assesses the impact the technology will have on health beyond the impact of reducing greenhouse gas emissions.	5 - strongly positive; 4 - weakly positive; 3 - neutral; 2 - weakly negative; 1 - strongly negative impact;	0.25
Impact on socio-economic development	The criterion assesses the impact the technology will have on socio-economic development (for example, on the labor market, new jobs, the country's external trade balance, etc.). In addition to the impact of reducing greenhouse gas emissions.	5 - strongly positive; 4 - weakly positive; 3 - neutral; 2 - weakly negative; 1 - strongly negative impact;	0.27
Impact on gender	The criterion assesses the impact the technology will have on gender.	5 - strongly positive; 4 - weakly positive; 3 - neutral; 2 - weakly negative; 1 - strongly negative impact;	0.19

Table 4. The long list of considered technologies

#	Technology
Energy Generation and Supply	
1	A combination of wind power plants and hydro-accumulating hydropower plants
2	A combination of run-of river hydropower plants and green hydrogen
3	A combination of photovoltaic solar power plants and batteries
4	Wind power plants
5	Photovoltaic solar power plants
6	Concentrating solar power plants
7	Run-of river hydropower plants
8	Regulating hydropower plants with dams
9	Li-thion batteries
10	Green Hydrogen
11	hydro-accumulating hydropower plants
12	Production of sustainable biomass
13	Electricity generation from biogas
14	Electricity generation from geothermal energy
15	Cooling system for Thermal power plants
16	Aluminum Conductor Composite Core
Transport	
17	Strengthening of electric road transport and infrastructure
18	Development of public road transport
19	Increasing biodiesel production
20	Extending Subway
21	Promotion of walking and cycling.
22	Highway waterproofing emulsions
23	Use of paraffin when laying asphalt
24	Cableways
25	Renovation of railway infrastructure
Buildings	
26	Insulation of the thermal envelope of buildings

27	Highly efficient heating-cooling systems (electric water heat pump)
28	Soil nailing against landslides
29	Ventilation heat/cold recuperator
30	Building management systems
31	Condensing natural gasboiler
32	Thermal envelope management technologies (shading, ventilated facade, brightness management, greening, etc.)
33	Solar wastr heating
34	Energy Efficient Stove using bio-waste
35	VRF Heat pump
36	District-wide utility service systems
37	Green roof
38	Flooding protechtion system Tigerdam
Agriculture	
39	Conservation methods of land cultivation
40	Breeding of highly productive cattle
41	Use of agricultural waste as fertilizer
42	Irrigation
43	Soil drainage
44	Biogas production from manure
45	Increasing energy efficiency and replacing fuel in agricultural equipment (water pumps), food processing lines, refrigerated containers, agricultural transport (tractors, combines), infrastructure
46	Application of "precision" agriculture technology to agricultural soils
47	Rehabilitation of pastures
48	Construction of windbreaks