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APEC Low Carbon Model Town (LCMT) Project Phase 7: Feasibility Study for Krasnoyarsk City

APEC Energy Working Group

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Scope of the study

The focus of this Feasibility Study is the whole city of Krasnoyarsk. Krasnoyarsk City was selected by APEC for the seventh phase of the LCMT project because it is a cold district. The district heat supplying system covers most of the city and it operates for 233 days per year. The primary objective of this Feasibility Study is to provide government officials and stakeholders in Krasnoyarsk city with valuable advice on how to design, develop and implement a low carbon development plan with measurable results and repeatable outcomes.

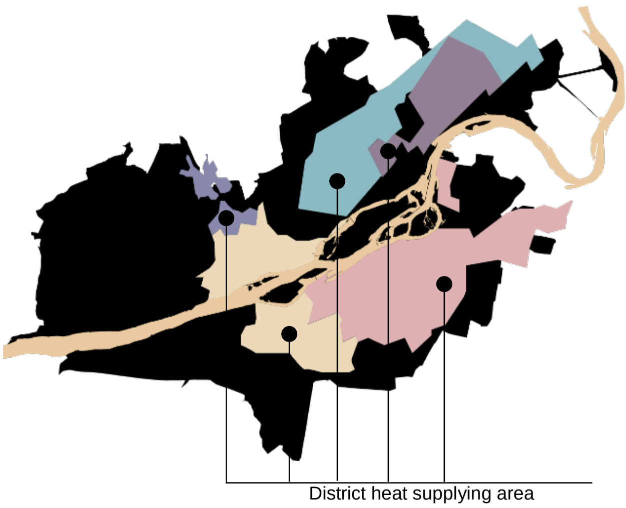
This Feasibility Study will be performed based on the following three principles.

1) Development of low carbon visions for Krasnoyarsk.
2) Package type approach to low carbon town development by integrating optimal combinations of low carbon measures.
3) Establishment of an action plan for low carbonization.

Key Infrastructure

Life in the city of Krasnoyarsk is supported by the following main infrastructure elements due to geographical features. Krasnoyarsk city has a heat supply system built from geographical features which are cold district.

Fig 1 District heat supply area map



Heat and electricity are supplied by large-scale CHP facilities and small-scale boiler houses. Therefore, CHP and Boiler Houses are infrastructures that are key to low carbonization.

But, the actual consumption amount is about 70% of the supply capacity from the current heat source supply system in operation, and the heat source loss is about 30%. In addition, lignite is used as the main fuel for the heat source, which is a major cause of carbon emissions.

High－level vision and carbon emission targets

Krasnoyarsk city has developed continuously as the central city of the Siberian Federal District. Within the Federal District, cities are continuously expanding and the population is continuously increasing. Therefore Krasnoyarsk City encounters many threats to its economic growth. LCMT concepts as an implementing methodology can lead Krasnoyarsk city to achieve a high-level vision.

Improve Efficiency;

Policy development with high standards of energy saving for all buildings.

Promotion CHP to refrain from using coal (Lignite) and policy to abolish Boiler Houses.

Improve QOL;

Policy development for promoting public transportation.

Promotion of comfortable indoor and outdoor environment.

Carbon emission reduction targets for Krasnoyarsk will be defined using Main Target and Sub Target indicators to encourage planned CO2 reduction and to appeal to stakeholders. Main Target of CO2 emission from building should consist of targets for new construction and for renovation of existing building. The “management” of CO2 reduction targets is essential to ensure that the mid and long term targets can be achieved through continuous efforts. The concept of Low Carbon Town Indicator (LCT-I) 1st edition by APEC EWG is suitable for the “assessment and maintenance” of the CO2 reduction targets, and therefore it will be applied in this Phase 7 study to establish Sub Targets taking into consideration the development progress of LCT-I.

Fig 2 LCT-I Assessment areas

	Tier 1	Tier 2	The chapter of report
Directly Related	Demand	1. Town Structure	Chapter 4
		2. Buildings	Chapter 5
		3. Transportation	Chapter 6
	Supply	4. Area Energy System	Chapter 10
		5. Untapped Energy	Chapter 8
		6. Renewable Energy	Chapter 9
		7. Multi-Energy System	Chapter 7
	Demand & Supply	8. Energy Management System	Chapter 10
Indirectly Related	Environment & Resources	9. Greenery	Chapter 11
		10. Water Management	Chapter 12
		11. Waste Management	Chapter 16
		12. Pollution	Chapter 13
	Governance	13. Policy Framework	Chapter 14
		14. Education & Management	Chapter 15

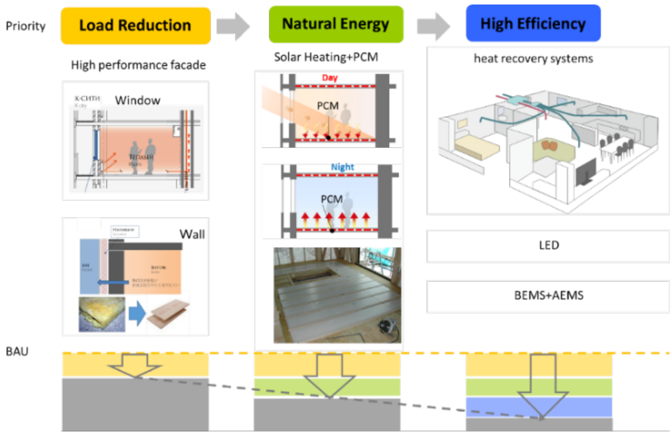
Detail of carbon emission targets

Summarize the Buildings, Transportation and Multi-energy system categories which greatly contribute to low carbonization.

1. Buildings

Comprehensive energy conservation strategies should consider the low carbon technologies both on the demand side and the supply side, including strategies for load reduction, natural energy utilization and high efficiency equipment introduction. Their priorities are suggested in Fig 3.

Fig 3 Priority for Low Carbon Strategy



The first step of energy conservation is load reduction. Especially in severe cold climates, heating energy consumption is responsible for almost half of building energy consumption. This can be controlled by a high performance building envelope, including thermal insulation, sunlight reflection, shading and façade engineering.

The second step of natural energy utilization with passive design. Natural energy utilization with passive design refers to building design that can effectively utilize natural energy, like natural ventilation and daylight, cutting the energy consumption for air-conditioning and lighting. The last step for energy conservation is the introduction of facilities with high efficiency, like LED lights and Heat recovery ventilation.

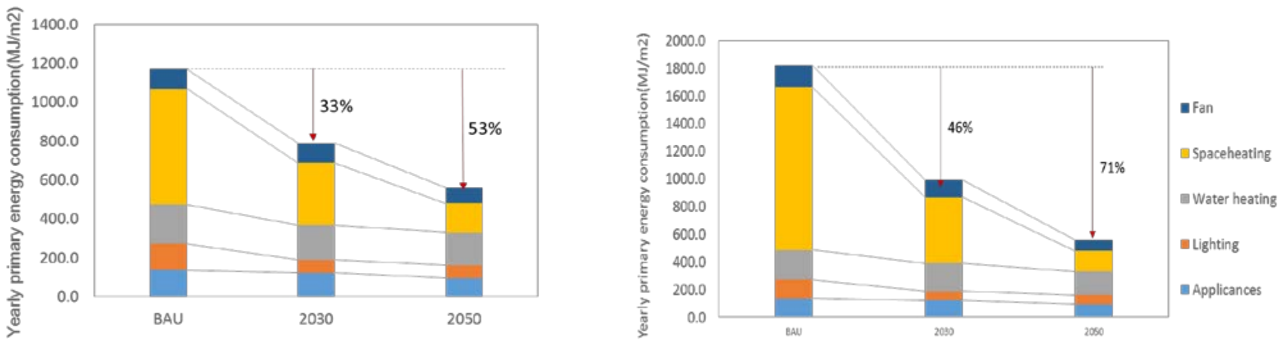
Energy simulation (by software Energyplus) is adopted to analyze the effect of low-carbon strategies. The process is outlined below:

- Setting the simulation model
  For both residential and non-residential buildings, a building with the “standard level” of construction is select as case study. The energy conservation effect of the proposed technologies for mid-term and long-term is sited in the scenario analysis.
- Existing building energy consumption (BAU) and its break down for different types of buildings. Energy plus is used for modeling and simulating the existing energy consumption of different buildings types. Further, the simulation result can also suggest the characteristics of energy consumption breakdown of different types of building.

- Effect of Low-Carbon Strategies
  Different low-carbon strategies, including high performance façade, high efficiency equipment and natural energy utilization are adopted in the simulation to show their energy conservation potential.

In the simulation, we conducted both existing and new construction buildings, while residential and non-residential use are also taken into consideration. The results of the calculation for the new building and the existing building are as follow.

Fig 4 Simulation result of New construction buildings (Left) and Existing buildings (Right)



In the case of existing buildings, it is expected that reduction effect is expected very high by only improving heat insulation performance, and the reduction effect is bigger than that of new building. Because of the low thermal performance of the building envelope, the energy used for heating of existing residential buildings are much higher than that in new constructions.

- The energy conservation technologies that proposed for new construction residential buildings can realize 33% yearly primary energy conservation reduction in the year 2030 and 53% in the year 2050.
- The simulation result suggests that compared with BAU, the existing residential buildings can realize 46% and 71%primary energy reduction in the year 2030 and 2050.

2. Transportation

Krasnoyarsk city was formed around the Yenisei River that crossed the center. And there are only three roads connecting the north-south urban areas bisected by the river. There are arterial roads mainly in the zones Tsentralniy and Zheleznodorozhny (the north side of the river).

Highways are located on the northern side of the Tsentralniy and Zheleznodorozhny zones, and there are main streets of citywide importance and of regulated traffic (red line in the figure) leading to the peripheral zone and outer districts.

Zone Oktyabrskiy (northwest of the river) has no organized major road network connecting other zones. In the zone south of the river (Leninskiy and Kirovskiy, Sverdlovskiy), most roads run east-west.

Fig 5 Geographic of Krasnoyarsk and Zoning

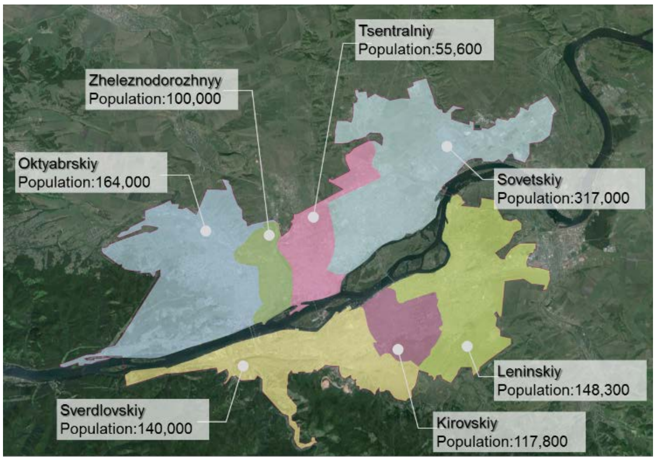
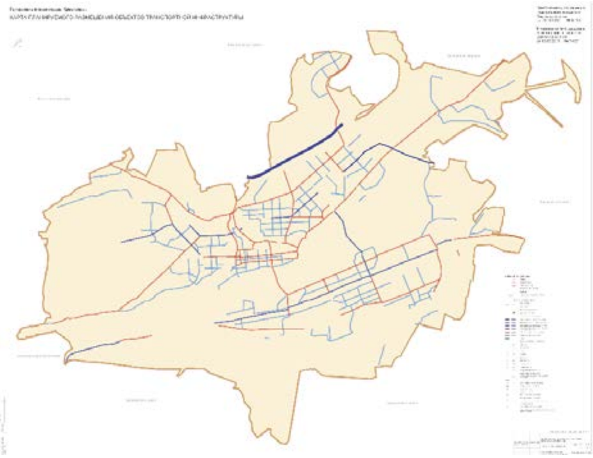


Fig 6 Present road map



Public transportation in Krasnoyarsk city is bus, trolleybus, Tram. The number of private cars is increasing year by year.

Based on the current situation analysis of the target area and the issues and characteristics of the district, consider the traffic plan with the target model of Zheleznodorozhny, Tsentralniy. Optimizing various movement modes lead to a public transportation system harmonized with automobile traffic.

In order to solve the increasing number of private-use vehicles and the parking problems accompanying, presenting the relevant policies for the development and operation, centering on serious parking problems in CBD area.

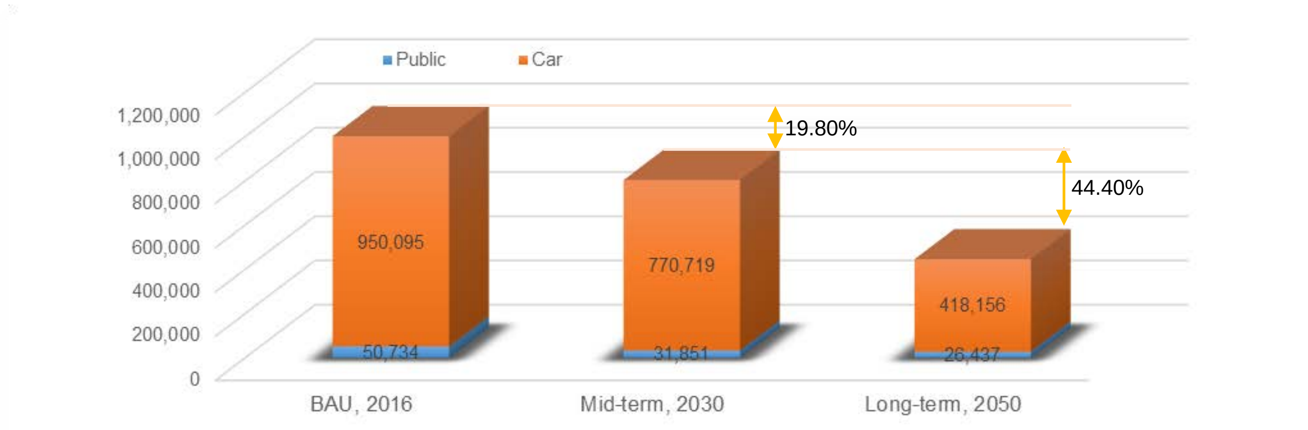
Traffic planning policy:

Construction of a transportation system harmonizing public transportation and automobile traffic by optimizing various movement modes

- Policy 1: Restructuring and strengthening the public transportation network
- Policy 2: Street parking control to reduce traffic load in the district
- Policy 3: Traffic optimization management
- Policy 4: Formation of traffic nodes
- Policy 5: Reducing CO_2 emissions through hard and soft measures

By promoting these three policies, we believe that by reducing car use and promoting public transportation, it is possible to achieve about 20% CO2 reduction in the medium term and about 45% in the long term.

Fig 7 Mid-term and long-term perspective of CO_2 emission



3. Multi – Energy System

The power generation in the Krasnoyarsk city comes from CHP Plant # 1, CHP Plant #2, and CHP Plant # 3. The electricity goes to the federal wholesale market of energy and power. The total electricity consumption of the city in 2016 is 6.78 billion kWh. (Excluding JSC "RUSAL Krasnoyarsk", which is aluminum smelter industry).

Krasnoyarsk has a humid subarctic continental climate with severe winters, no dry season, warm summers and strong seasonality. Over the course of a year, the temperature typically varies from -26°C to 25°C and is rarely below -35°C or above 29°C. According to the historical weather data of Krasnoyarsk city, the number of annual heating degree days (HDD) is 233 and the heating load of whole city is roughly 4567.5 Gcal/h. Most heating energy is supplied by the district heating system.

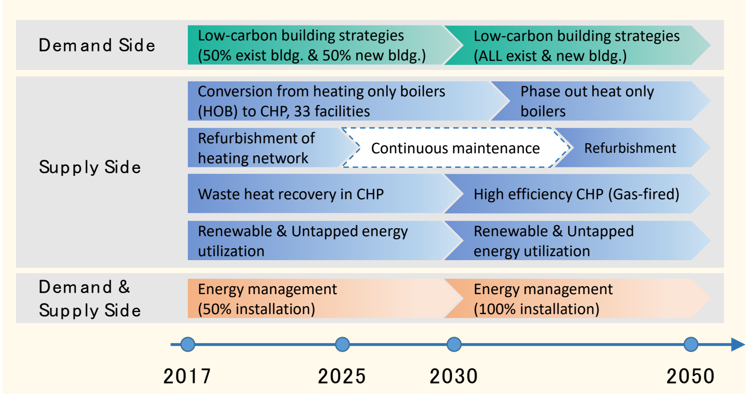
Lignite (brown coal), which is considered the lowest rank of coal due to its relatively low heat content, however, is used as the main heating fuel for heating. Meanwhile, most of the district heating system which has been constructed a long time ago, now is becoming aged and inefficient.

In the district heating segment, heat loss due to ageing transmission networks has to be taken into consideration. Strategy includes reducing heat loss in the supply chain by modernizing the transmission network. And in the future, it is advised to shut down those inefficient, small-scale boiler houses and gradually switch the heat supply to that of high-efficiency CHP plants, while promoting waste heat recovery in CHP plants and improving energy efficiency.

Since the city's main energy source is brown coal (lignite), the lower degree of coalification is a brownish black and lackluster low grade coal between peat and bituminous coal. The chemical reaction is strong, susceptible to weathering in the air, not easy to store or transport and a serious pollutant of the air when burnt. Therefore, this study also proposes a development route to replacing lignite with clean natural gas in the future (2050).

Figure 8. shows a low-carbon development roadmap for the energy sector. The sustainable energy roadmap for Krasnoyarsk city aims to develop and communicate low-carbon energy strategies that empower the whole city to reduce consumption of, and dependence on, fossil fuel such as brown coal.

Fig 8 Low-carbon development roadmap of energy sector



In 2016, about 5.8 million tons of brown coal in total was consumed in Krasnoyarsk city for power generation and district heating as well as hot water supply, making it a huge contributor to total greenhouse gas emissions and a major source of air pollution. If we focus on the breakdown of total brown coal consumption shown in Figure 9, district heating (including hot water supply) by CHP plants and heat only boiler houses make up a significant share (63%) of the total consumption, the remaining 37% of brown coal is consumed for power generation by CHP plants.

Fig 9 Breakdown of brown coal (lignite) consumption, 2016

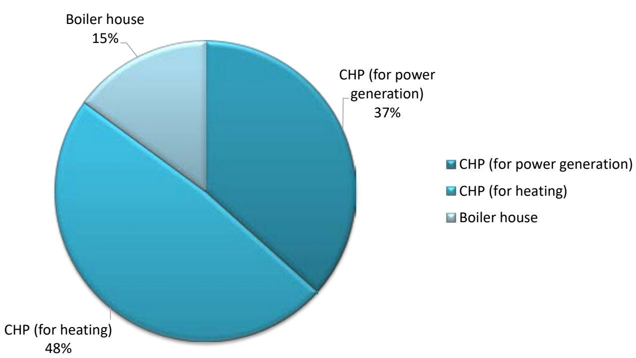
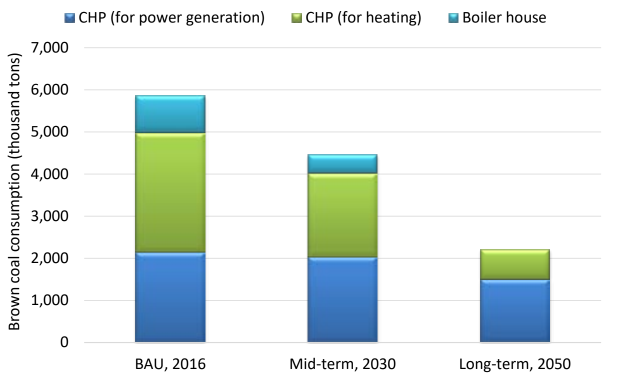


Fig 10 Long-term perspective of brown coal (lignite) consumption, 2050



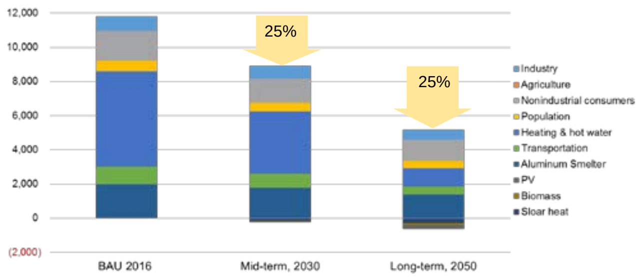
In figure10, a long-term perspective of brown coal consumption is provided while consumption in 2016 is set as BAU (Business as Usual). In mid-term target at 2030, it is expected that the consumers of inefficient heat only boiler houses will partially switch to the high efficiency heat supply provided by the Krasnoyarsk CHP plants, which have tall chimneys (providing for effective fume gas dispersion) as well as modern gas cleaning equipment.

In total, within the Krasnoyarsk heat supply scheme project lasting until 2030s, the switching of consumers from 26 boiler houses is expected. In the long-term target at 2050, all heat only boiler houses will be shut down and switch to heat supplied by CHP plants and renewable energy such as solar heat and biomass.

Low carbon development scenario

The following shows calculation results of the CO2 emissions reduction as well as mid-term and long-term perspective from building and energy supply sector in Krasnoyarsk city. CO2 emissions from buildings under BAU (2016) is roughly 12 million t-CO2/year. Figure 17.2.1 shows mid and long-term perspective of CO2 emission.

Fig 11 Mid-term and long-term perspective of CO_2 emission



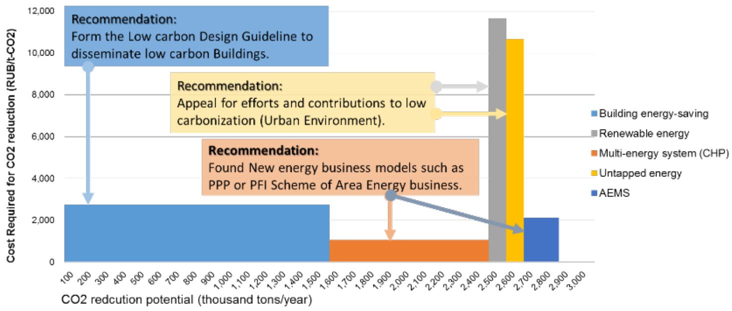
Compared to the BAU scenario of 2016, mid-term target of CO2 emission is expected to be reduced by more than 25% in which heating & hot water sector contributes the most due to applications of key energy-saving strategies proposed in this feasibility study. In 2050, besides existing technologies employed in each sector, technological innovation is also prospected and the long-term target of CO2 emission reduction is expected to reduce more than 62%.

Examination of cost performance

By 2030, Krasnoyarsk city could potentially cut over 2.8 million tons of CO2 emission if low-carbon strategies proposed in above chapters are implemented by phases. Specifically, energy-saving solutions in building sector can reduce most of CO2 emission and followed by low-carbon measures in multi-energy systems (CHP plants) sector.

Renewable energy and untapped energy are considered effect in promoting sustainable development, however, the contribution in reducing CO2 emission amount is still considered quite limited due to the small scale of applications by 2030.

Fig 12 Cost of CO2 emission reduction per ton and reduction potential in each sector (by 2030)



In the annual costs, the initial cost for building energy saving and multi-energy system as well as AEMS is relatively low compared with that of renewable energy and untapped energy systems, which is mainly because that renewable energy such as photovoltaic and biomass systems are still more expensive than fossil-based ones, meanwhile, the service life of renewable and untapped energy system is shorter in compare with other low-carbon measures in building and multi-energy sector. However, those problems could be solved in the long-term perspective as the initial cost becomes cheaper and much more energy efficient.

1 INTRODUCTION

1. INTRODUCTION

1.1. Low Carbon Model Town (LCMT) Project

In 2010, the Asia-Pacific Economic Cooperation (APEC) Forum initiated the Low Carbon Model Town (LCMT) Project with the goal of integrating low carbon measures (LCMs) and best practices in city planning across the APEC region.

The Krasnoyarsk city study is the seventh phase of the APEC LCMT Feasibility Studies. The previous six APEC phases included.

- Phase 1 (2011): Yujiapu Central Business District, Tianjin, China
  A new district where the central business district was being planned;
- Phase 2 (2012): Koh Samui in Surat Thani Province, Thailand
  A previous developed resort island;
- Phase 3 (2013): Da Nang City, Viet Nam
  A brownfield redevelopment in an existing urban district;
- Phase 4 (2014): San Borja, Lima, Peru
  An existing residential area;
- Phase 5 (2015): Bitung, North Sulawesi, Indonesia
- Special Economic Zone;
- Phase 6 (2016): Mandaue City, Cebu Province, The Philippines
  Central Business district, Light Industrial, Residential-Commercial;

Each phase of the LCMT Project incorporates the following elements: a low carbon town concept and vision for low carbon development, a Feasibility Study of LCMs to support the vision, a preliminary policy review of related initiatives, and a LCM GHG reduction analysis and cost estimate.

1.2. Feasibility Study Scope

The focus of this Feasibility Study is the whole city of Krasnoyarsk. Krasnoyarsk City was selected by APEC for the seventh phase of the LCMT project because it is a cold district. The district heat supplying system covers most of the city and it operates for 233 days per year.

The primary objective of this Feasibility Study is to provide government officials and stakeholders in Krasnoyarsk city with valuable advice on how to design, develop and implement a low carbon development plan with measurable results and repeatable outcomes.

This Feasibility Study will be performed based on the following three principles and 8-step work outline.

1) Development of low carbon visions for Krasnoyarsk.
2) Package type approach to low carbon town development by integrating optimal combinations of low carbon measures.
3) Establishment of an action plan for low carbonization.

1) Development of Low-Carbon visions for Krasnoyarsk
This study will be performed using a comprehensive and integrated approach that includes vision planning, goal development and low carbon realization strategies. In particular, the low carbon visions for Krasnoyarsk city will be developed based on the local social, natural and economic and severe climate circumstances. The Low-carbon vision will be made with local partners (Moscow branch of Nomura Research Institute, Monolit Holdings and Siberian Federal University) and relationship in Krasnoyarsk Government.

2) Package type approach to Low-Carbon Town (LCT) development by integrating an optimal combination of Low-Carbon measures.
In the formation of a city, geographical, climatic, historical, cultural factors and economic disparity are inextricably intertwined. Therefore, in the realization of a Low-carbon Town, it is essential that the local natural and social characteristics be taken into consideration when various low carbon technologies are introduced.

In this feasibility study, we plan to formulate Low-Carbon methodologies for Krasnoyarsk not only from the standpoint of technology (public transportation system, district heating system, renewable and untapped energy systems, sewerage and drainage) typically appropriate for new construction, but also from the standpoint of sustainable management (organizing body, Low-

Carbon activities that involve all community members regardless of social class).
The overall study will adopt a package type approach (including cost-effectiveness evaluation) to Low-Carbon Town development. Throughout the study process, supply side and demand side issues (as well as expectations of Krasnoyarsk) have been taken into account. For each sector of concern, we will make recommendations of Low-Carbon measures that are most appropriate and feasible for Krasnoyarsk and its community. The balance between demand side and supply side of energy will be the deciding factor in selecting the Low-Carbon measures.

3) Establishment of an action plan for Low-Carbonization
One of the long-term purposes of this study is to provide a reference case for LCMT development. Aside from providing publicity opportunities for the area, the realization of Krasnoyarsk as a Low-Carbon Model Town will not only contribute greatly to the economic and social development of Krasnoyarsk and of Russia, but also make considerable impact on the cold region and all APEC economies.

It is essential to establish an action plan for the development of Krasnoyarsk as a Low-Carbon town. In addition, resident participation and partnerships between public and private sectors will be essential towards a sustainable Low-Carbon Town (LCT) development. The operating and management structure as well as the operation procedure will therefore be included in this study.

Based on the above three principles, this feasibility study is proposed to be conducted following the steps as outlined below.

STEP-1
Conduct Background research

STEP-2
Develop a high-level Low Carbon Vision and Scenario

STEP-3
Define the CO2 emission baseline in Business as Usual (BAU) scenario

STEP-4
Define the CO2 reduction and environmental targets of the Low Carbon Town

STEP-5
Prepare a Low Carbon Guideline for categories of Low Carbon Town design challenges

STEP-6
Select CO2 reduction measures in each design category by existing community

STEP-7
Analyze CO2 reductions and costs for the selected design measures

STEP-8
Study implementing methodologies and action plans of proposed CO2 reduction measures including potential implementers and funding sources

2 KRASNOYARSK CITY CHARACTERISTICS AND CONDITIONS

2. KRANOYARSK City Characteristics and Conditions

This Chapter provides background on the local (Krasnoyarsk City) and regional (Krasnoyarsk Territory or Siberian Federal District of Russia) geography, climate and population and economic structures. It also outlines energy production and consumption information. The purpose is to provide context to readers so that may better understand the rationale for LCM recommendations made in this Feasibility Study.

2.1. Geography and Climate Conditions

1) Geography

Krasnoyarsk city is the largest industrial and cultural center of Eastern Siberia, and capital of Krasnoyarsk territory, the second largest region in Russia by area. The calculated flying distance from Krasnoyarsk to Moscow is to 3,352km.

Krasnoyarsk city is situated in the center of Russia at the confluence of the small river Kacha and mighty Yenisei. The town was founded in 1628 by Cossacks under troop leader Andrey Dubenskiy's command and was originally named "Krasniy Yar"

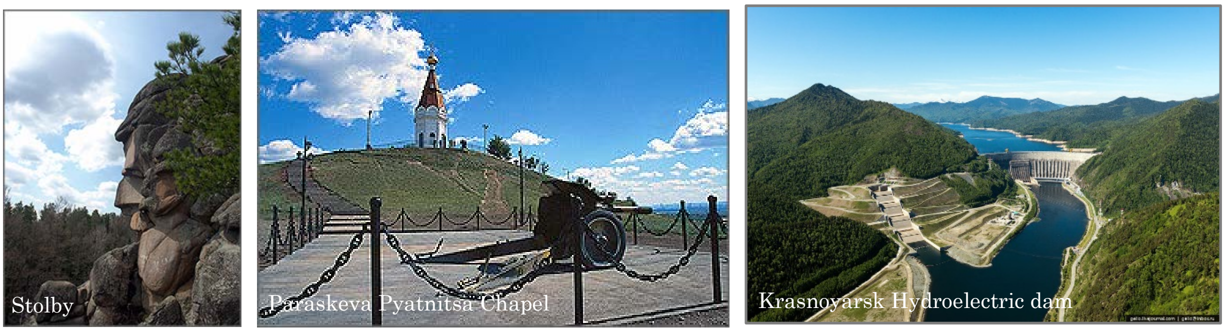
The Yenisei River flows from west to east through the city. Due to the Krasnoyarsk hydroelectric dam 32 kilometers upstream, the Yenisei never freezes in winter and never exceeds +14℃ in summer through the city. Near the city center, its elevation is 136 meters above sea level.

Fig 2.1.1 Map of Krasnoyarsk, River Kacha and Yenisei

Map: NIKKEN SEKKEI Research Institute, Photo: mapion, Sayan Ring

The city is distinguished by its unique landscape, mountain views, majestic Siberian forest and well-known Stolby Nature Reserve. This work of nature is a series of exotic rocky eminences situated in the taiga on the spurs of the Eastern Sayan Mountains. The territory of the reserve totals 47,000 hectares.

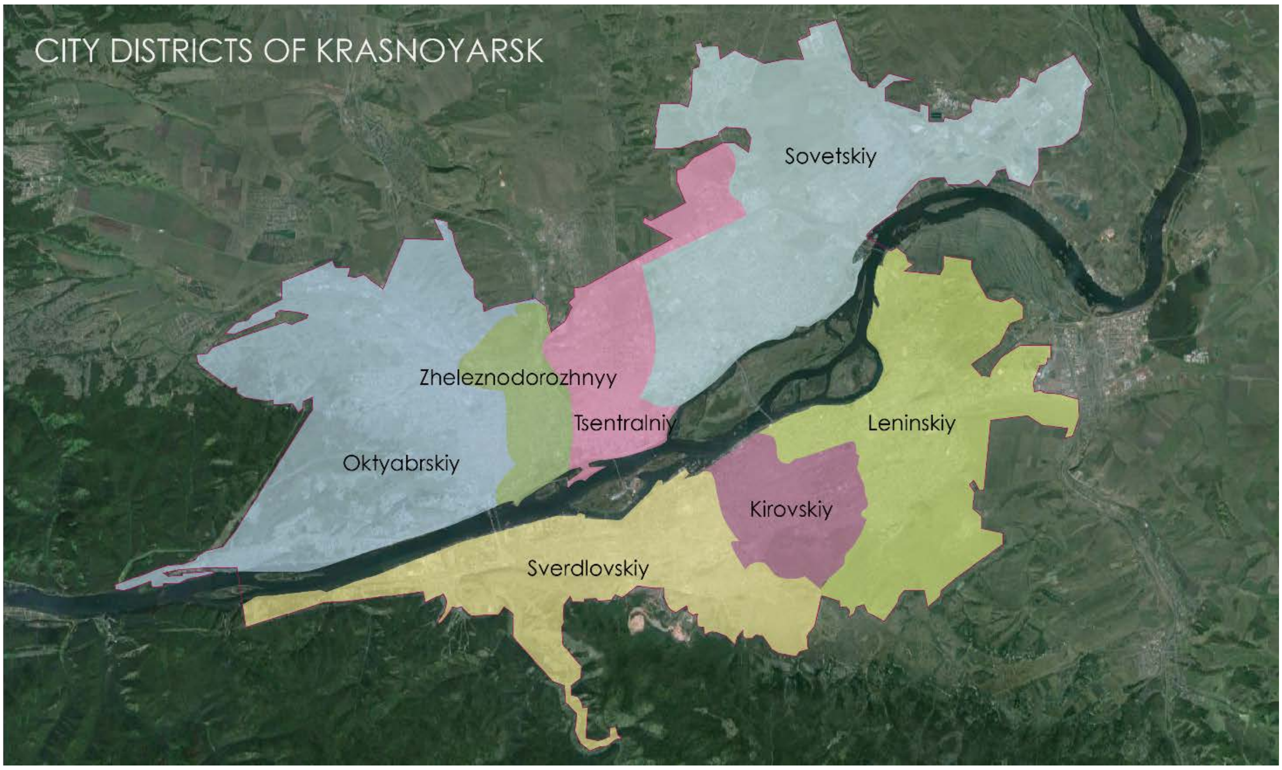
Fig 2.1.2 Krasnoyarsk Picture



Source: Krasnoyarsk city administration, snow-virus.ru

The total area of the city, including suburbs and the river, is 348 square kilometers with a population of 1,083,900 as of the 2017 Census.
The city is divided into 7 administrative districts; Zheleznodorozhnyy, Kirovskiy, Leninskiy, Oktyabrskiy, Sverdlovskiy, Sovetskiy and Tsentralnyy.

Fig 2.1.3 City Districts.



Source: NIKKEN SEKKEI Research Institute

2) Climate

Krasnoyarsk experiences a continental climate (Koppen climate classification Dfb) with long and very cold winters and short but warm summers. The annual minimum temperature is minus 26℃ and the highest average maximum temperature is minus 17℃. The summer temperature ranges are from 12℃ to 25℃.

Fig 2.1.4 Average Temperature

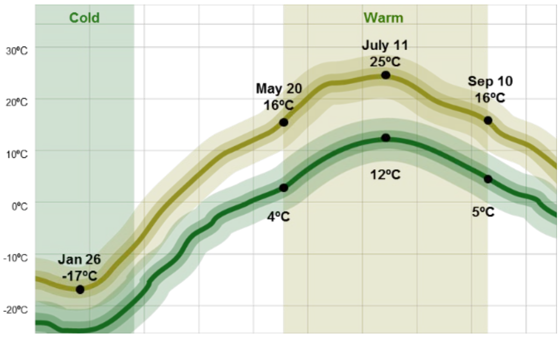
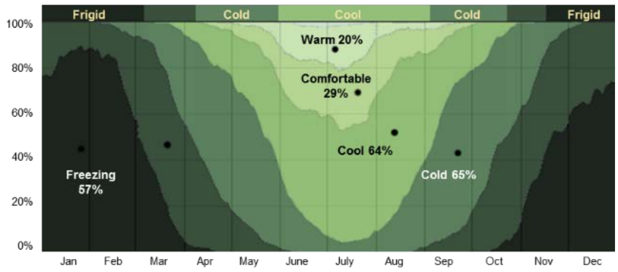


Fig 2.1.5 Annual Temperature



Source: Siberian Federal University

Most days between March and April, and in October have freezing temperatures; May and September have mostly cold days. Between Jun and August, 60% of the days have cool temperatures and the weather is warm or comfortable for the other days.

2.2. Community Demographics

1) Population

The population of Krasnoyarsk city has been continuously increasing, and it is estimated to exceed 1.1 million in 2018.

Table 2.2.1 Population Growth (Included forecast)

	2014 year	2015 year	2016 year	2017 year	2018 year (forecast)	2019 year (forecast)
population	1 044 907	1 060 543	1 075 382	1,083,900	1 105 666	1 120 724

Source: Data from 01.01.2017 (according to Krasnoyarskstat (Department of the Federal State Statistics Service for the Krasnoyarsk Region, the Republic of Khakassia and the Republic of Tuva) preliminary information

2) Gender and Age distribution

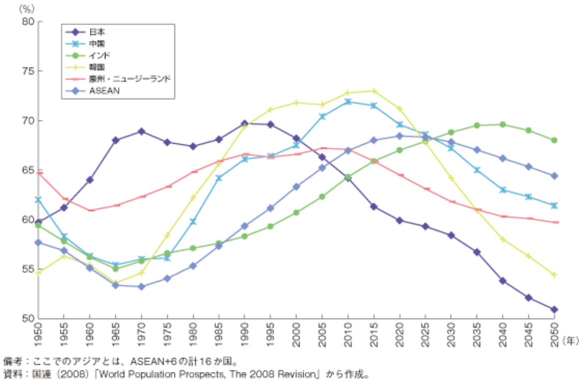
The female population is larger than the male population in Krasnoyarsk, which is 483,549 male and 583,385 female. In addition, the productive population ratio (15 to 64 years old) exceeds 70%, which is higher than surrounding Asian countries. Whereas, people over 65 years old accounted for over 11 percent.

Table 2.2.2 Age distribution

Age group	Number of people	Sub Total
0 to 4 years old	73041	
5 to 9 years old	54810	
10 to 14 years old	45276	173,127
15 to 19 years old	52010	
20 to 24 years old	88627	
25 to 29 years old	117494	
30 to 34 years old	109845	
35 to 39 years old	87629	
40 to 44 years old	73445	
45 to 49 years old	60759	
50 to 54 years old	64810	
55 to 59 years old	63495	
60 to 64 years old	55183	773,297
65 to 69 years old	44371	
70 to 74 years old	21223	
75 to 79 years old	31613	
80 to 84 years old	13126	
85 to 89 years old	7641	
90 to 94 years old	2196	
95 to 99 years old	281	
100 years old and more	59	120,510
TOTAL	1,066,934	1,066,934

Source: Krasnoyarsk city administration (data from 01.01.2016)

Fig 2.2.1 Changes in Proportion Age Population Ratio in Asian Countries



Source: Ministry of Economy, Trade and Industry, Japan

3) Income distribution

Russia's Annual Household Income per Capita reached 5,500.87 USD in Dec 2016. On the other hand, the average annual income is 8,700 USD among workers in middle and large companies in Krasnoyarsk city in 2016, higher than the average income in Russia. It is the mining and finance industry that raises the average income.

Table 2.2.3 Average annual accrued wages

Organizations scale	Period	Average Annual accrued wages, USD (RUB)	Comments
Large and medium-sized	January-December, 2016	8,699.88 (501,200.4)	In comparison with the same period of 2015 they increased by 4.8% in nominal terms, while in real terms decreased by 0.7%.
Small	January-December, 2016	4,423.82 (254,856.0)	

Source: Krasnoyarsk city administration, A Euromoney Institutional investor company (Russia Household income per capita)

Table 2.2.4 Average monthly accrued wages in large and medium sized organizations in 2016

Sphere of employment	Average monthly accrued wages, rubles
Agriculture, hunting and forestry	30,897.0
Extraction of minerals	126,374.5
Processing industries	38,824.7
Production and distribution of electricity, gas and water	49,115.7
Construction	35,391.0
Wholesale and retail trade; repair of motor vehicles, motorcycles, household products and personal items	33,775.7
Transport and communications	46,467.9
Financial activity	62,349.6
Public administration and military defense; compulsory social security	53,638.2
Education	29,847.5
Health care and social services	30,798.4

Source: Krasnoyarsk city administration

4) Vehicle ownership

The number of car ownership in Krasnoyarsk city is 291 vehicles (per 1000 people, 2016), against 245 vehicles in Russia (per 1000 people, 2011). Also, looking at forecasts of the growth rate of automobile sales figures, although it increased by 3.5 percent from 2000 to 2016, the rate is forecast to decline by 1.5 percent from 2016 to 2021. The rate has grown 1.5% from 2000 to 2016 in Russia, while it was predicted to grow by 4.3% from 2016 to 2021. Therefore, this trend seems to be similar in Krasnoyarsk city as well.

Table 2.2.5 Vehicle ownership

Types of vehicles	Number of registered vehicles
Cars	316812
Trucks	40540
Buses	5344
Motorcycles	3542
Total	**366238**

Source: Krasnoyarsk city administration (Data from 31.12.2016)

Table 2.2.6 Change in vehicle sales volume in major countries / regions

	Automobile sales volume (thousand cars) (Occupancy ratio in world sales volume)			growth rate	
	2000 year	2016 year	2021 year (Prediction)	2000 year → 2016 year	2016 year → 2021 year (Prediction)
China	2,089 (3.9%)	27,939 (29.7%)	29631 (29.2%)	17.6%	1.2%
Indonesia	842 (1.6%)	3,706 (3.9%)	5,177 (5.1%)	9.7%	6.9%
ASEAN(5 major economies)	1,019 (1.9%)	3,039 (3.2%)	3,863 (3.8%)	7.1%	4.9%
Brasil	1,489 (2.8%)	2,050 (2.2%)	2,328 (2.3%)	2.0%	2.6%
Russia	1.241 (2.3%)	1,564 (1.7%)	1,926 (1.9%)	1.5%	4.3%
USA, EU, Japan	39,398 (72.9%)	41,795 (44.4%)	42,894 (42.3%)	0.4%	0.5%
World	54,032	94,207	101,428	3.5%	1.5%

Source: MIZUHO Research & Analysis/12, MIZUHO Financial Group

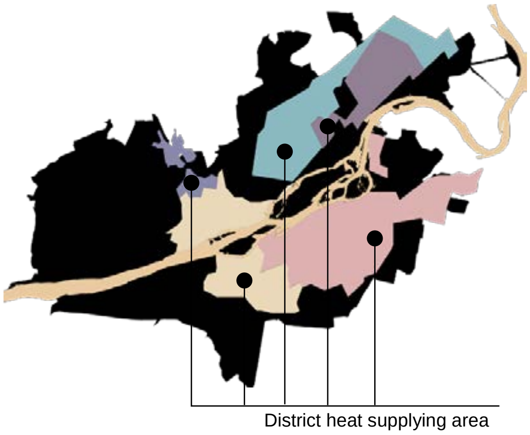
2.3. Infrastructure

Life in the city of Krasnoyarsk is supported by the following main infrastructure elements due to geographical features.

1) District heat supply system

Krasnoyarsk city has a heat supply system built from geographical features which are cold district. Heat and electricity are supplied by large-scale CHP facilities and small-scale boiler houses. And 233 days throughout the year are set as the heating period.

Fig 2.3.1 District heat supply area map



Source: NIKKEN SEKKEI Research Institute.

Fig 2.3.2 Boiler House(Top) and CHP facility(Bottom)

Photo: NIKKEN SEKKEI Research Institute.

But, the actual consumption amount is about 70% of the supply capacity from the current heat source supply system in operation, and the heat source loss is about 30%.
In addition, lignite is used as the main fuel for the heat source, which is a major cause of carbon emissions.

2) Hydroelectric power plant

Krasnoyarsk has the tenth largest hydropower plant in the world. The Krasnoyarsk Hydroelectric power plant is a 124meter high and 1,065meter length concrete gravity dam located on the Yenisei River about 30kilometers upstream from Krasnoyarsk in Divnogorsk, Russia. It was constructed from 1956 to 1972 and supplies 6,000MW of power, mostly used to supply the KrAZ (Krasnoyarsk Aluminievyy Zavod (Krasnoyarsk Aluminum Plant)). Both power and aluminum plants are controlled by the RUSAL company (RUSAL is the world's second largest aluminum company by primary production output (as of 2016)).

Fig 2.3.3 Krasnoyarsk Hydroelectric power plant

Photo: NIKKEN SEKKEI Research Institute.

It is contributing to carbon reduction by covering the electric power used in the aluminum plant with hydroelectric power plant.

But, the Krasnoyarsk hydroelectric power plant significantly influences the local climate; normally the river would freeze over in the bitterly-cold Siberian winter, but because the hydroelectric power plant releases unfrozen water year-round, the river never freezes in the 200kilometers to 300kilometers stretch of river immediately downstream of the dam. In winter, the frigid air interacts with the warm river water to produce fog, which shrouds Krasnoyarsk and other downstream areas.

3 LOW CARBON CONCEPT FOR KRASNOYARSK CITY

3. Low Carbon Concept for KRASNOYARSK City

3.1. Energy and Low Carbon policy in Russia

1) Trends in energy policy in Russia

Russia is the world's largest producer of crude oil (including lease condensate) and the second-largest producer of dry natural gas. Russia also produces significant amounts of coal. Russia's economy is highly dependent on its hydrocarbons, and oil and natural gas revenues account for more than 40% of federal budget revenues.

Russia is a major producer and exporter of oil and natural gas. Russia's economic growth is driven by energy exports, given its high oil and natural gas production. Oil and natural gas revenues accounted for 43% of Russia's federal budget revenues in 2015 according to EIA.

In response to the Russia government’s actions and policies toward Ukraine, in 2014 the United States imposed a series of progressively tighter sanctions on Russia. Among other measures, the sanctions limited Russian firms' access to U.S. capital markets, specifically targeting four Russian energy companies: Novatek, Rosneft, Gazprom Neft, and Transneft. Additionally, sanctions prohibited the export to Russia of goods, services, or technology in support of deep water, Arctic offshore, or shale projects. The European Union also imposed sanctions, although they differ in some respects.

In recent years, the Russian government has offered special tax rates or tax holidays to encourage investment in difficult-to-develop resources, such as Arctic offshore and low-permeability reservoirs, including shale reservoirs. Attracted by the tax incentives and the potentially vast resources, many international companies entered into partnerships with Russian firms to explore Arctic and shale resources. ExxonMobil, Eni, Statoil, and China National Petroleum Company (CNPC) all partnered with Rosneft in 2012 and 2013 to explore Arctic fields. Despite sanctions announced in March 2014, Total agreed in May to explore shale resources in partnership with Lukoil.

However, Total halted its involvement in September 2014, as additional sanctions were announced later in the year. ExxonMobil, Shell, BP, and Statoil also signed agreements with Russian companies to explore shale resources. Virtually all involvement in Artic offshore and shale projects by Western companies has ceased following the sanctions.

Arctic offshore and shale resources are unlikely to be developed without the help of Western oil companies. However, these sanctions will have little effect on Russian production in the short term as these resources were not expected to begin producing for 5 to 10 years at the earliest. The immediate effect of these sanctions has been to halt the large-scale investments that Western firms had planned to make in these resources.

At the same time as the United States and the European Union were applying sanctions, oil prices fell by more than half, from an average Brent crude oil price of $109/barrel in the first half of 2014 to just $52/b in 2015 and to $40/b in the first half of 2016. Both the sanctions and the fall in oil prices have put pressure on the Russian economy in general and have made it more difficult for Russian energy firms to finance new projects, especially higher-cost projects such as deep water, Arctic offshore, and shale projects.

With lower oil prices, Russian state revenues from oil and gas activities have declined dramatically, and the state's budget deficit has grown. In response, the Russian government has implemented or proposed various measures to increase revenues. The Russian government has changed the minerals extraction tax and export taxes on hydrocarbons several times over the last couple of years. The most recent changes and proposals for upcoming changes all tend to raise the taxes paid by oil and gas companies.

In addition to taxes, the Russian government also collects dividends from oil and gas companies in which the state is a shareholder. In April 2016, the Russian government directed state-controlled companies to pay out a minimum of 50% of 2015 net income as dividends, nearly double the dividends companies would normally pay. Oil companies have objected to both the tax and dividend increases, arguing they divert money from capital investment programs. Based on similar arguments, Rosneft negotiated a lower dividend payout.

In January 2015, the Russian government announced its intention to sell some of its shares in several Russian companies, including Bashneft and Rosneft. Bashneft was one of Russia's 10 largest oil producers. In October, the federal government sold its 50.08% controlling stake in Bashneft to Rosneft for $5.3 billion. The Russian government currently owns 69.5% of Russia's largest oil producer, Rosneft. It intends to sell up to 19.5% of the company, retaining a controlling interest.

2) Federal government energy policy and future plans

Energy policy is defined by Ministry of Energy of the Russian Federation at Federal Level and implemented by the local administrations in the regions.
Currently three key documents exist in Russia for energy Policy:

1. Energy Strategy 2020 (ES-2020)
2. Energy Strategy 2030 (ES-2030)
3. Energy Strategy 2025 (ES-2035)

In the years 2002 and 2003 Russia kept recovering from the crisis of 1990-s in nearly all the areas of its existence. On 28 August 2003, the first Energy Strategy of Russia, for the period until 2020 was approved by the Ministry of Energy of the Russian Federation.

The goal of the Energy Strategy 2020 (hereinafter ES-2020) was the most effective use of natural resources and potential of the energy sector for the purposes of sustainable economic growth, improvement of quality of life, and promotion of Russia's global interests.

Another target of ES-2020 is to define ways to achieve a brand new state of energy complex, and growth of competition capacity of its products and services on a global market. On 13 November 2009, the second Energy Strategy was approved, ES-2030, which merely kept the old vision: the goal was to maximize utilization and increase of effectiveness of energy complex in order to sustain economic growth, improve the quality of life and strengthen Russia's global position. ES-2030 also shaped new priorities of development of the energy industry framing a transition of the Russian economy toward innovational development – the vision that was introduced as part of a Concept of a Long-Term Socio-Economic Development of Russia until 2020 approved a year before ES-2030 was approved.

The Concept in turn determined the strategic goal of Russia as "formation of qualitatively brand new Russian Federation that complies with a profile of a world leader in the twenty first century" (Government of Russian Federation, 2008). The need for innovations together with its growing ambitions was determined by many factors: comparative strengthening of socioeconomic quality of Russian economy, world financial crisis, growing ambivalence towards Russia on the global political arena, exploration of Arctic, reformation of armed forces.

Change of accents in the vision on the role of energy industry in Russia from ES-2020 to ES-2030 was in many ways an expected transition for the once to be one of the greatest powers of the world that fell into a destructive revolutionary reorganization.

Energy strategy 2035

Russian energy Strategy 2035 says that starting from 2020 Russia will be implementing "new generation energy based on the new technology, highly efficient usage of traditional resources as well as new type of hydrocarbon and other sources of energy".

Favorable scenario includes:

- Increase of share of Atomic power from 17% to 21%
- Arctic shelf development to be implemented
- Renewable energy power generation is to be launched in rural areas

Issues, Challenges and expectations:

Current situation in the strategy is described as "complicated", due to the Russian energy industry not being in a good shape at the moment:

- Current mineral reserves are almost exhausted
- Infrastructure is old and worn-out
- Technology import dependency on developed countries is high while own technology development level is late
- Sanctions have negative influence on project finance

In the near future the Russian energy market niche will be narrowed because the majority of countries intend to develop "non-carbon fuels including non-traditional fuels". The future of Russian exports to Europe is limited by demand, while not enough infrastructure is available for exports to Asia. Development of export infrastructure to Asia requires a lot of investment.

Primary energy consumption in 2015~2035 is forecast to grow 17% in case of favorable scenario, and demand for power generation is expected to grow by 36% in this case. Transportation sector may increase usage of motor oil by more than 20%. Primary energy consumption is also set to grow by 17% in the utility and transportation sectors and by 12% in the production sector. Urals price is forecast to be at the level of $80 per barrel by 2020 and to reach the $95~100 level by 2035. This is attributed to the more optimistic scenario for world oil prices only.

Energy and Ecology Issue.

By 2035 Russia plans to implement structural transformation of the energy sector. One of the expected results is to reduce pollution levels from 2014~2020 period by 25% and by 50% within the 2014~2035 period.

Current environmental measures confirm that greenhouse gas emission levels decreased to 71% of the 1990 level. However, by 2035 emission levels should not exist 75% of 1990 level.
One of the measures to reduce negative impacts on the environment is specified as "clarity and availability of ecological information" and includes increase of collaboration with ecological organizations and movements.

Nuclear Power

Russia plans to maintain leadership in the Nuclear power sector due to its export potential and share of Nuclear power within its energy mix. By 2035 the share of Nuclear Power in its Power Generation mix is to increase from 17 to 19~21%, while installed capacity of NPPs is expected to grow by 1.4~1.7 times. Up to two power generation units are expected to be installed per year while all Soviet era installed plant is expected to be decommissioned.
In order to implement these ambitious plans, Russia plans to reduce NPP construction cost and establish technology based on fast nuclear reactors with closed cycles.

Renewable energy.

The document stipulates that many Russian technologies in the sector of renewable energy are outraged. Main problem is low economic competitiveness. For this reason isolated and rural energy areas are named as the potential niches for the wind energy power generation. Another alternative is the reserve supply of the energy.
2 main purposes of the Wind Energy are described:

- Installation of the new generation capacity is economically feasible
- Local unit production (including local and adopted foreign technologies)

Renewable energy is said to be supported by development of infrastructure and attracting investment into the sector.

Arctic

Large-scaled Arctic development made the list of strategic initiatives.
Northern territories of the Arctic shelf will substitute traditional deposits.
Development of the project in such extreme climate conditions will require special upstream and midstream technology and infrastructure.

Advanced trends

Russian Energy Strategy 2035 confirms that energy efficiency and development of renewable energy are the primary goals of developed countries.
Thus the EU energy strategy targets increasing the share of renewable energy by at least 27% compared to 1990. At the same time greenhouse pollution is to be reduced by 40% and energy efficiency is to be improved by 30%.

In Germany, renewables are to reach 60% of total energy consumption by 2050 and share of renewables in power generation is to reach 80%.
In China, the share of renewables in power generation is set to reach 20% by 2030, and the target for USA is 20% by 2020.

Improvement of energy efficiency and strengthening of ecological regulations will support the development of advanced technologies in the energy consumption segment including smart houses, and new types of fuel.

Russia has nothing to win from the mentioned forecasts, as increases in sales of EVs up to 80% of the total world sales in passenger and LCVs segments will reduce world oil demand by 25% while at the same time the installed plant for power generation will only increase by 8%. For Russia, two scenarios for the world energy sectors are considered: Evolutional and Breakthrough.

In case of the Breakthrough scenario, Russia will have to install and develop new technologies, such as renewable, hydrogen energy, storage and smart grid.

3) Energy saving policy situation in Private sector (including households, Social sphere)

Energy saving in Russia is regulated by the Federal law N 261-FZ "On Energy Efficiency" adopted on the 23rd of November, 2009. This law substituted one adopted in 1996 ("On energy saving").

Some measures required by the new law in the field of energy saving and energy efficiency had already been incorporated in the earlier legislation. The Following measures of state regulation were implemented by the old federal law (1996) and were among those maintained in the 2009 law: energy inspection of enterprises including obligatory inspection, and state control of compliance with the energy efficiency legislation requirements.

In some cases previous legal norms were adjusted to the present legislation and became more specific and got more importance. Thus the old law's requirements for avowal or obligatory certification of energy consumption products were converted in the new law into a requirement for some products to have information regarding their energy efficiency class included in technical documentation and labelling (article 10). Article 17 introduced an 'Energy Passport' based on energy inspection results as a legal term together with the rules on collecting and analysis of 'Energy Passport data'. Article 18 set the requirements for the self-regulated organizations in the field of energy inspection.

Some general articles of the 1996 law have been converted into specific requirements to provide energy efficiency for different types of buildings (article 11), energy saving in apartment buildings and suburban communities (article 12). Energy service contracts were also introduced by a new law in 2009 (article 19).

Features of the new law and especially the legal introduction of an energy service contract gave a real start to the whole energy efficiency sector whereas the previous law was sadly only a false start. Law enforcement practice in the field of energy efficiency is still developing, but the way it will go can be predicted now. Analysis of the 2009 law's structure shows its similarity to those in the EHS (environment, health, safety) field. It is especially similar to environmental legislation. Even the terminology looks identical: environmental efficiency / energy efficiency; environmental passport / energy passport, and more Academic articles on energy efficiency law are written by established specialists in environmental law.

So, if the energy efficiency law goes the same way the environmental law went we can expect similar results. Then energy efficiency would be just another useless burden for enterprises and an additional opportunity for the corruption officials. Law enforcement practice also may follow that of environmental law. Activity in the field of energy efficiency may repeat the fate of

environmental protection activity which is now suffering from a formal but false approach.
The Implementation of energy efficiency law, instead of being a real and useful activity will impose additional burdens on enterprises in the forms of:

- More Documentation;
- Inspections by state authorities;
- Litigation inviting fines.

These types of activities are much easier for the state to formalize than to stimulate a real increase in energy efficiency which indeed mostly depends on the management's political will.
Now in the EHS field of law we see the same trends have already started. There is a burden of Documentation developing which is obligatory for enterprises. Systematic inspections are obligatory for state officials and inspection inevitably leads to fines. If an official did not impose a fine he would face the prosecutor's suspicion that he has been bribed. This is of course the complete opposite to real corruption fighting.

Real energy efficiency could be reached better by civil means. The Smart owner or manager is interested without outside stimulus to use less expensive energy and save money. He or she does not need any additional administrative control. So far administrative control measures incorporated in the energy efficiency law look more or less like formalities with fines. It is essential to work with the legislators to exclude or at least minimize the formal part of energy efficiency law.

The law targets to establish a legal framework to promote energy efficiency in Russia as at that time it was claimed to be one of top priority factors of Russian economy modernization. Within the framework of the ES 2020, energy saving was to contribute the following:

Table 3.1.1 Outline of Russian energy strategy

Delivery period	2010 - 2015	2016 -2020
Targets	Decreasing the intensity of the economy by 7.4% by 2015	Decreasing the intensity of the economy by 13.5% by 2020
	Reducing primary fuel consumption by 85 Mtoe	Reducing primary fuel consumption by 170-180 Mtoe
	Increasing the share of electricity produced from renewable sources to 4.5% of total electricity production	
Federal budget	RUB 35 billion (USD 525 million)	RUB 35 billion (USD 525 million)
Regional budget	RUB 208 billion (USD 3.1 billion)	RUB 417 billion (USD 6.3 billion)
Private funding	RUB 3 310 billion (USD 50 billion)	RUB 5 527 billion (USD 83 billion)

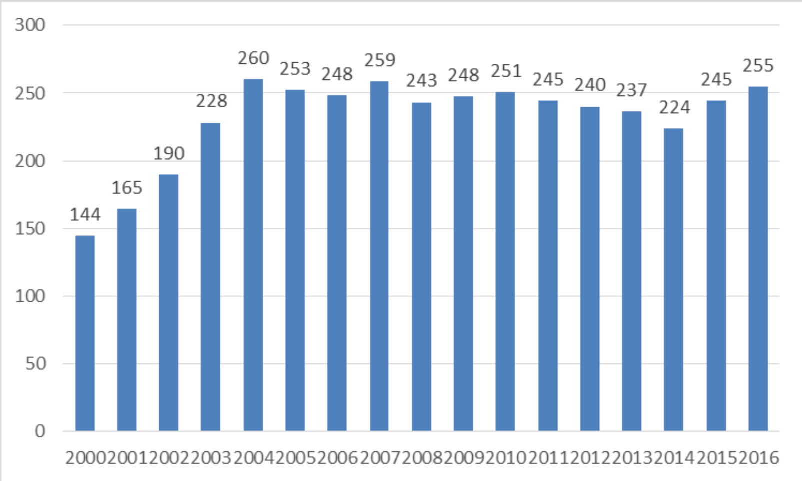
Source: Energy Strategy published by Ministry of Energy

The way the law enforcement practice in the energy efficiency will go - administrative or civil - depends largely on the efficiency of businesses.

4) Natural gas and crude oil exports and internal consumption

Russian crude oil exports remained at the 255 million ton level in 2016 according to the statistics of the central bank of Russia. However nominal contribution to the budget decreased after Urals oil price declined.

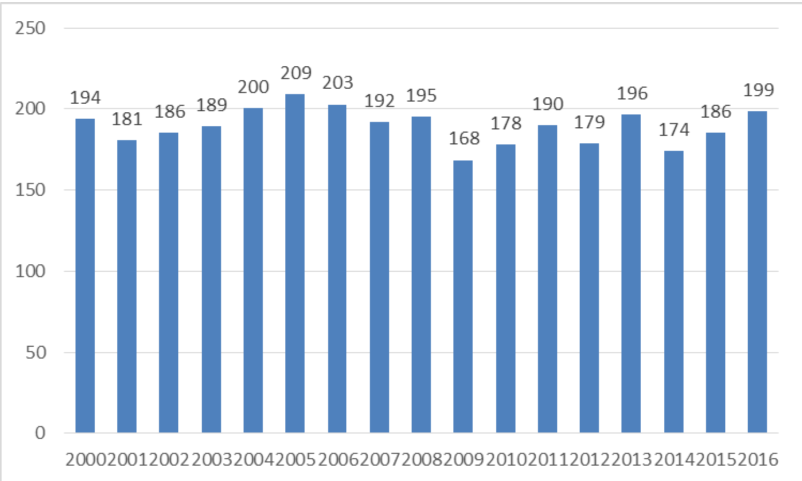
Fig 3.1.1 Russia Rude Oil Exports (2000 – 2016) (MM t)



Source: Energy Strategy published by Ministry of Energy

As for natural gas exports, it remains at 199 B cbm, around the same level as in 2013.
The natural gas industry is practically monopolized by Gazprom, however its solid position may be shaken in the near future. Some of the main reasons are the practical failure of LNG projects, the unclear situation with large-scale investment in the pipeline to China and shale gas development issues.

Fig 3.1.2 Russia Rude Oil Exports (2000 – 2016) (MM t)



Source: Energy Strategy published by Ministry of Energy

5) Situation regarding energy losses in Russia and future plans

Average losses in electric networks in Russia nun at about 12-14% compared with 4-9% in Europe, and substantial reduction in grid losses cannot be achieved using current equipment and control mechanisms. New equipment, control principles and better topological layout will therefore have to be deployed to drive increases in grid efficiency.

Russia is using district heating for industrial and residential applications. The district heating network is the largest in the world, serving 92% of the urban areas and 20% of the rural areas. This suggests that most residential buildings do not have a natural gas grid connection.

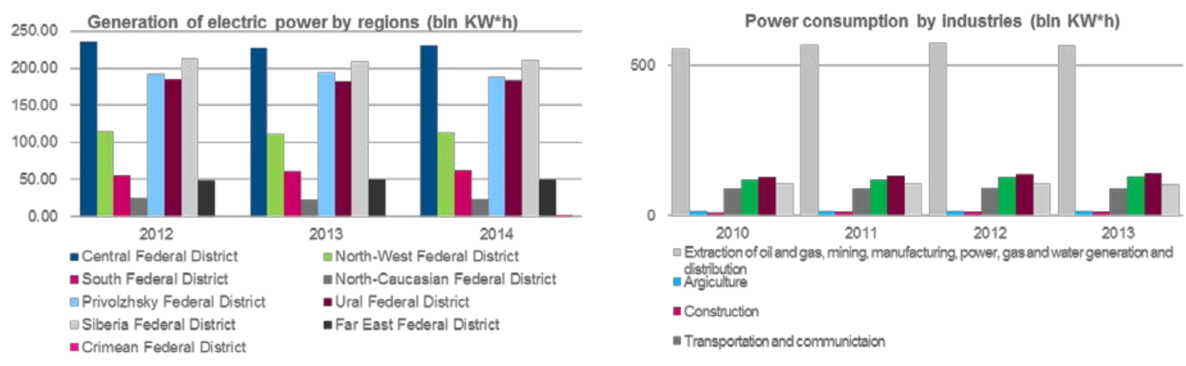
Low efficiency coal- and gas fired units are used and transmission losses are estimated at 20-25% as compared to 5-10% for Western countries.

6) CHP in Russia

Russia assume that main opportunity for the Distributed Generation and thermal solutions will come from CHP technology, i.e. generation, co-generation with advanced natural gas based technologies. One of the reasons is that natural gas generated power generation has more flexibility for upgrading solutions.

Demand for Distributed Generation comes from the regions with high levels of energy consumption as well as the oil & gas and metals and mining sectors.

Fig 3.1.3 Russia Generation market: Power consumption by regions of Russia and by sector



Source: Federal Statistics Service

Once availability of the natural gas in the region is confirmed CHP application can be estimated. About 50% of distributed generation capacity is based on diesel generators facilities. Gas turbine generator facilities account for 20.4% of total DG capacity, while gas engine type generator facilities and steam turbines have the same share of total DG capacity at about 14.5%.

The main obstacle for CHP development is the principle difference of legal regulation of the electric power market and the heating supply market. Electric power market is based on market instruments, while heating supply is fully controlled by government industry.

Table 3.1.2 Distributed Generation in Russia by type of technology

Type of power generation facility	Capacity (GW)	Share in total DG (%)	Potential for development	
Diesel	9	48.4	×	Limited due to fuel quality problem in applicable regions
Gas engine	2.7	14.5	○	High initial cost, however need for natural gas
Gas turbine	3.8	20.4	●	CHP modernization, however need for natural gas
Steam turbine	2.7	14.5	○	Limited application
Mini HPP	0.32	1.7	×	High ecological risk
Geo TPP	0.09	0.5	×	High cost
Wind PP	0.01	0.1	×	Unclear application, ecological risk
Total in Russia	18,6	100		

● High; ○ Medium; × Low

Source: Infoline, NRI estimation

7) Low Carbon policy (Federal Government plans)

Low carbon policy has high level support in Russia with president Putin's statement made in October 2016, stating that Russia plans to provide for rapid and economically efficient reduction of GHG emissions on the basis of the Paris Agreement.

Current legal basics of climate policy in Russia include:

- Governmental plan on ratification of the Paris Agreement
- GHG emission reduction indices for the various sectors of the economy
- Reporting of the indirect emissions draft methodology development
- Accounting of sinks draft methodology
- Introduction of the financial auditing standard 3410

Application form for registration of polluting installation, including GHG reporting Issues that require further clarification with Russian Government for foreign companies involved in the environmental projects:

- The decision on ratification of the Paris Agreement by Russian Federation has been delayed for an uncertain period, raising concerns over the terms of participation in global climate commitments and incentives.

- Current plans of the Russian Government do not envisage the creation of an adequate low-carbon “tool-kit”, mechanisms and tools instrumental for climate-responsible companies in Russia to perform efficiently in the field of low-carbon competition.
- Under these circumstances, the competitiveness of enterprises working in Russia has deteriorated, and they are further exposed to the threats and risks of external carbon regulation, pressure and potential border adjustment measures, not to mention down-stream loss of economic benefits derived from mitigation activities.

Key issues to monitor the development of the governmental steps are:

- Development of Presidential decree on emissions by 2030
- Low carbon strategy development 2050
- Preparation of GHG Federal regulation by June 2018

Main authorities involved in the process are: Ministry of Economic Development, Ministry of Energy and Ministry of Ecology. In general Ministry of Economic Development supports the idea of the process, while Ministry of Energy is criticizing it for the idea of creation of a no-carbon pilot zone in East Siberia. Ministry of Energy says that all additional payments, including carbon tax, can have negative impact on the competitiveness of the coal sector of the economy. As an alternative the ministry is trying to promote development of coal based chemical production in the region.

Some large corporations also oppose coal tax. SUEK and Russian Steel are just some of them. These companies also have lobby in the government represented by the ministry of Industry and trade. The Russian government currently employs a multi-level decision-making process.
The Prime Minister receives reports from the First Deputy Prime Minister; there are also Deputy Prime Ministers that may have both direct and indirect reporting to the First Deputy Prime Minister or Prime minister accordingly.

At the same time, Ministry of Natural Resources suggests to move step by step in the Implementation of low carbon regulations and privileges. One of the options is to introduce carbon intensity indexes to the list of best technologies. This will help many companies to reduce ecological tariffs.

The primary issue for the Russian government is to select a carbon regulations model with a smaller impact on business.

3.2. Low Carbon Concept for Krasnoyarsk City

1) Krasnoyarsk City Low Carbon Development Concept

Krasnoyarsk city has a population of 1 million, which has grown as a representative industrial city in the Siberian Federal District. It is a mining city mainly based on light industry and lignite, heavily oriented around the aluminum industry. It is a city that has grown through light industry and mining, but is surrounded by vast forests around the city center.

In addition, it has Russia's 1st and 2nd largest hydroelectric power plants, and most of the electricity used by the aluminum smelting factory is covered by these hydro power generation.

The city is geographically located in a cold district and 2/3 of its annual heating is supplied by CHP. Due to the aging of CHP facilities (including boiler houses) and aging of heat conduit facilities, and the use of brown coal as the main fuel, the current efficiency of power generation and efficiency of heat supply are bad.

Taking into consideration the above geographical features, industrial structure and infrastructure facilities, and the following concept is proposed for the promotion of low carbonization.

Russia's leading low-carbon model town Krasnoyarsk

~ Sustainable development of cold and industrial cities and compatibility of low carbon ~

2) High－Level Vision

Krasnoyarsk city has developed continuously as the central city of the Siberian Federal District. Within the Federal District, cities are continuously expanding and the population is continuously increasing. Therefore Krasnoyarsk City encounters many threats to its economic growth. LCMT concepts as an implementing methodology can lead Krasnoyarsk city to achieve a high-level vision.

LCMT FS in Krasnoyarsk city would be expected to take the initiative to demonstrate a prototype consistent with a growing industrial city within a cold district and low carbon development.

- Improve Efficiency;

  Policy development with high standards of energy saving for all buildings.

  Promotion CHP to refrain from using coal (Lignite) and policy to abolish Boiler Houses.

- Improve QOL;

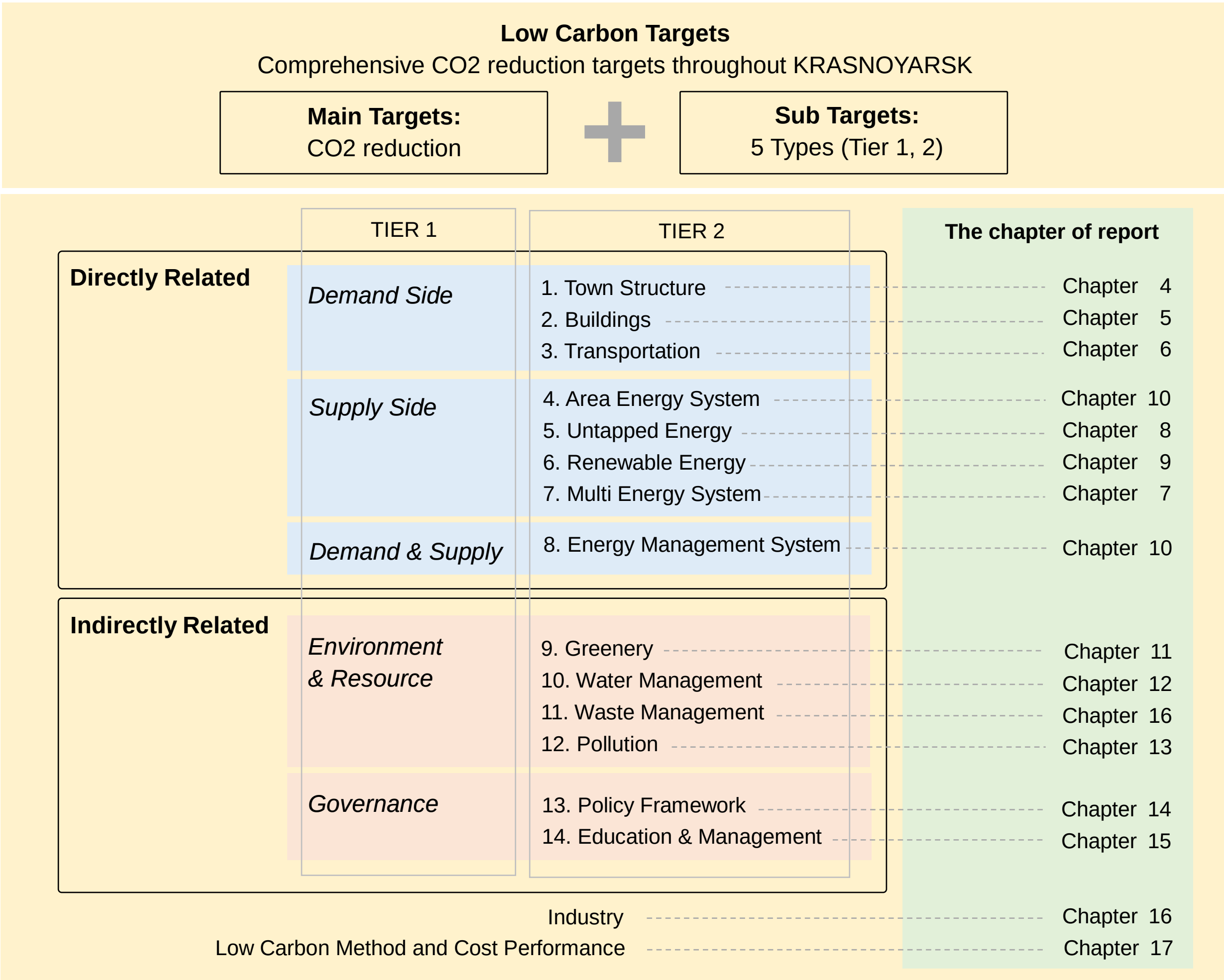
  Policy development for promoting public transportation.

  Promotion of comfortable indoor and outdoor environment.

3.3. Carbon Emission Reduction Targets

Carbon emission reduction targets for Krasnoyarsk will be defined using Main Target and Sub Target indicators to encourage planned CO2 reduction and to appeal to stakeholders. Main Target of CO2 emission from building should consist of targets for new construction and for renovation of existing building. The “management” of CO2 reduction targets is essential to ensure that the mid and long term targets can be achieved through continuous efforts. To “manage” the overall CO2 reduction targets, it is necessary to evaluate the impact of individual low carbon measures. The concept of Low Carbon Town Indicator (LCT-I) 1st edition by APEC EWG is suitable for the “assessment and maintenance” of the CO2 reduction targets, and therefore it will be applied in this Phase 7 study to establish Sub Targets taking into consideration the development progress of LCT-I.

Fig 3.3.1 Low Carbon Targets for Krasnoyarsk



Source: APEC Low-Carbon Town Indicator System Guideline, First Edition, November 2016, APEC Energy Working Group.

The economy of Krasnoyarsk city is that of an industrial city that has grown based on light industry such as aluminum. From the characteristic of an industrial city, we have added the "industry" field and make proposals to reduce carbon emissions.

4 TOWN STRUCTURE

4. Town Structure

4.1. Status and plan of town structure

1) City Structure

The characteristic feature of the urban structure is that it is severed by the Yenisei River, due to the river passing through from west to east. Moreover, balanced urban development is hampered by the inefficiency of transportation infrastructure connecting south and north areas, and the centralization of city area and administrative organization (Karla Marksa street, Lenina street) on the northern part.

Density of land use is another issue, with medium low-rise buildings of 10-stories or less distributed across the whole area. In the central part of the city, there are many 5-storey or lower buildings.

Therefore, balanced development between north and south sides of the city, as well as extension and connectivity to the outside are significant issues.

Fig 4.1.1 Geographic of Krasnoyarsk

Source: NIKKEN SEKKEI Research Institute

These challenges result in increased financial burdens on government administrations associated with infrastructure development from increases in energy consumption across the whole city, due to increased car ownership and underutilized land caused by inefficient development of the public transportation network.

Fig 4.1.2 Building in the city

Source: RussiaTrek.org

4.2. Low Carbon Strategy Urban Structure

Toward a Compact city

In this proposal, positioning the central urban area and the major traffic node points as a base (aggregation base) promoting accumulation of urban functions and organically linking the consolidation base and other areas with a public transport network, thereby achieving sustainable development, is the primary objective. This can be achieved through the following.

1) Induction of public facilities, service facilities and residential functions to consolidated bases

Striving to shift to an intensive urban structure according to characteristics such as main roads in the city, maintenance situation of public transportation, accumulation situation of city functions

Access to aggregated sites from other areas within the urban area will be secured as much as possible by linking the aggregation bases to each other via public transportation; by rail or high service level bus network. Depending on the accumulation of urban functions, it may be desirable to utilize community buses and improve road networks.

Regarding consolidated bases, urban areas should be improved and attempts made to accumulate various functions such as residential exchanges. Restrain urbanization in other areas and induce low density so that the living environment in urban areas in the suburbs that are hollowing will not deteriorate.

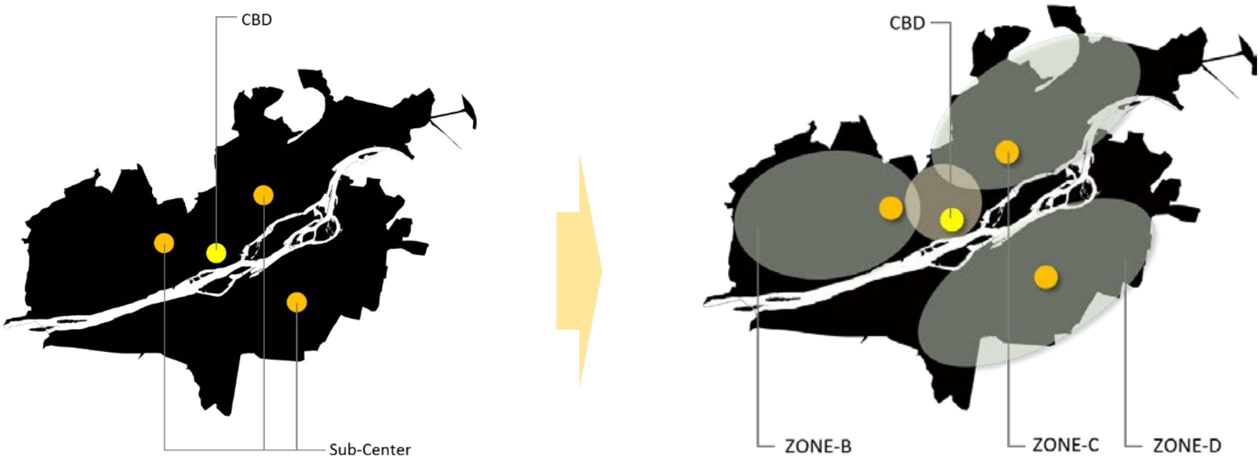
Reduce carbon dioxide emissions and energy consumption to realize city activities that reduce environmental impact.

This kind of urban image contributes to the improved efficiency of socio-economic activities in urban areas and the reduction of environmental burdens, and citizens should tackle realization.

Krasnoyarsk city plans an area to be a Sub-Center besides the current Central Business District (Karla Marksa street, Lenina Street) area in the future land use plan, and plans Sub-Center as an aggregation base to guide the location of public facilities and service facilities. In addition, by characterizing the surrounding area including the consolidated base, we are trying to develop equally balanced development and growth throughout the city.

By coordinating public transport networks such as buses and trams that organically connect these aggregation sites, this plan aims to provide smooth circulation within the city.

Fig 4.1.3 Conversion image to intensive urban structure



Source: NIKKEN SEKKEI Research Institute

2) Leveling of energy demand by efficiency of land use

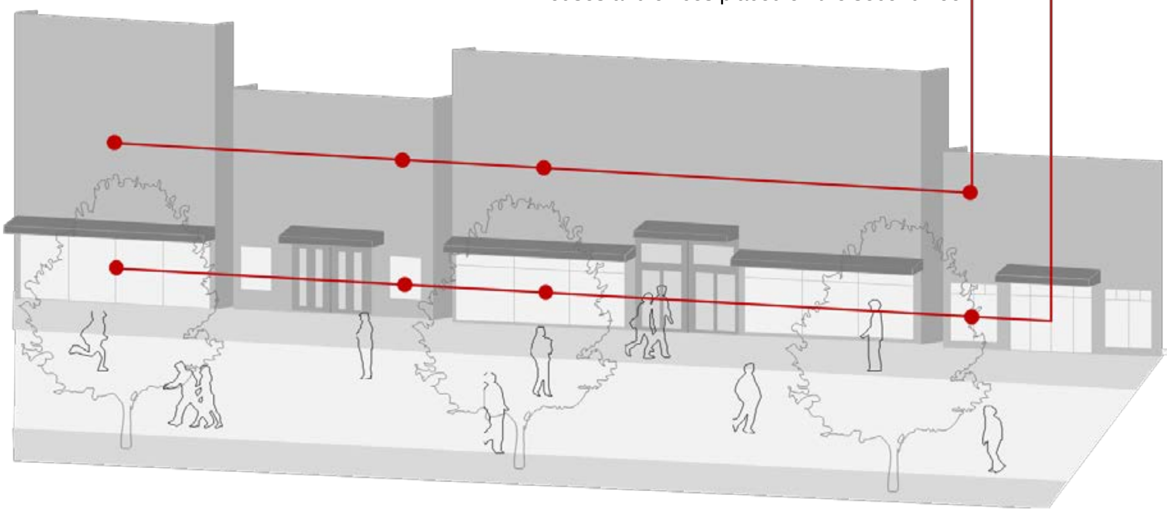
The energy usage pattern varies greatly depending on the use of the building, and the usage peak greatly differs greatly between residential and commercial, where the residential system energy demand peaks at nighttime while the business system energy demand peaks during the daytime.
In districts where complex utilization of land use (mixed use), it is important to take advantage of the difference in usage peak, to level out energy use, promoting a common energy system, leading to low carbonization.

By combining different functions such as office, commerce, and housing together through rebuilding and new construction centering on the main roads of the CBD and in Sub-Centers, it is possible to achieve energy efficiency as well as job proximity, This also leads to reduction in the use of private cars.

Also, by placing commercial facilities within low-rise areas, safe and lively streets are formed due to the creation of vibrant activity and the light from commercial facilities at nighttime.

Since Krasnoyarsk city is a townscape with many middle- and low-density buildings, this approach retains existing townscapes while guiding the complexity of functions and contributing to the formation of a vibrant city.

Fig 4.1.4 Composite use image



Source: NIKKEN SEKKEI Research Institute

3) Promotion of the use of public transport

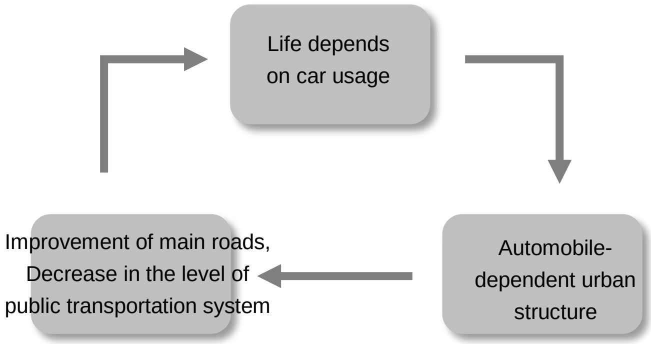
It is necessary to enrich the public transportation system according to the characteristics of the city, securing space for public transportation and securing its service level.

It is also desirable to improve the convenience intermodal connections and to achieve barrier-free traffic nodes such as at railway stations. This will help to secure smooth and comfortable mobility as much as possible without relying on automobiles reducing congestion within the cities and securing viable means of transport for the elderly.

The city of Krasnoyarsk is predicted to increase personal incomes with sustained population growth and economic growth, and progression towards motorization is expected to proceed. Arterial road development is increasing in response to increased vehicular usage of general roads, and the city is transforming into an automobile-dependent urban structure.

For this reason, the city is trying to improve the traffic demand (private car) by taking hard measures (traffic network expansion) and soft countermeasures (policies) such as expansion and improvement of the existing public transportation network, improvement of convenience, vehicle regulation to the central urban area Occurrence raises the need for further improvement of highway. It is important to prevent the occurrence of "motorization spiral" that improves convenience by road improvement enhances car dependency.

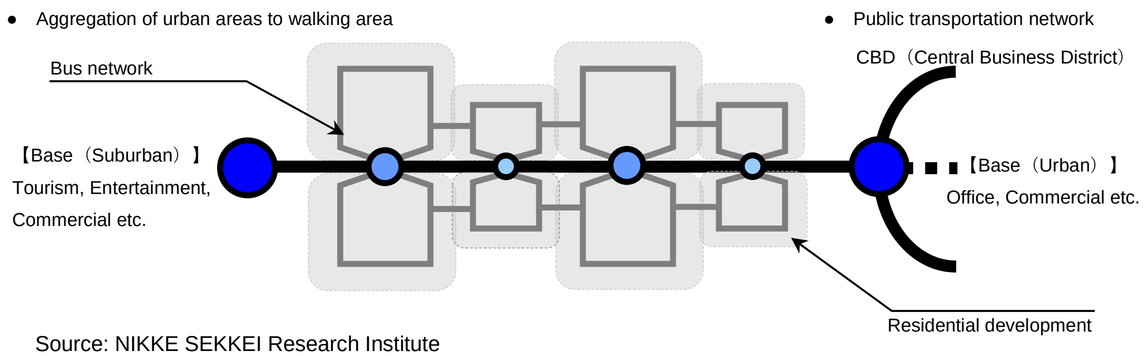
Fig 4.1.5 Image of motorization spiral



We will aim to optimize urban transport by improving the minimum necessary road infrastructure and by transforming to urban structure to emphasize the balance between public transport and automobile traffic.

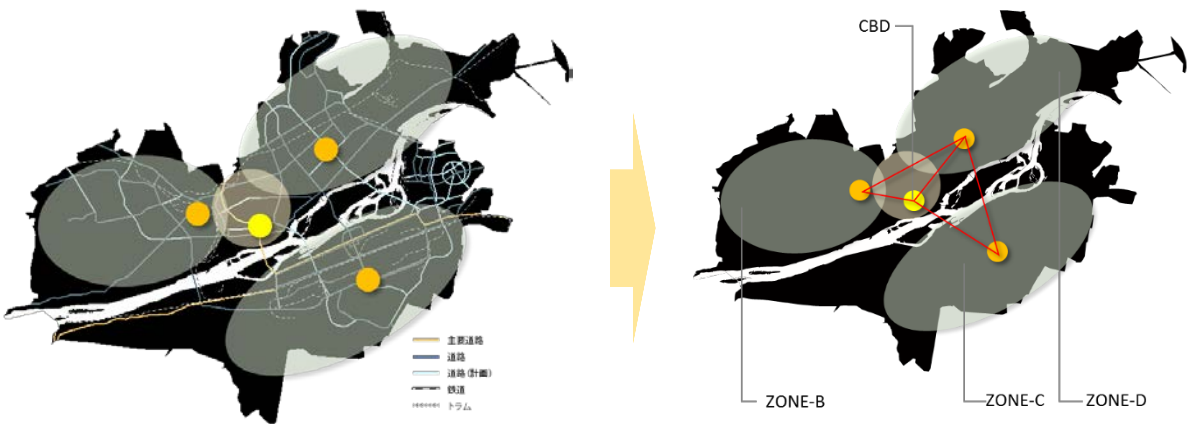
In order to optimize urban traffic, improving urban transportation such as adding bus lines, introducing BRT, extending LRT according to infrastructure development, and urban development with appropriate control of street parking are needed.

Fig 4.1.6 Urban structure image to promote the use of public transport



Source: NIKKE SEKKEI Research Institute

Fig 4.1.7 Image of public transportation network connecting bases



Source: NIKKEN SEKKEI Research Institute

5 BUILDINGS

5. Buildings

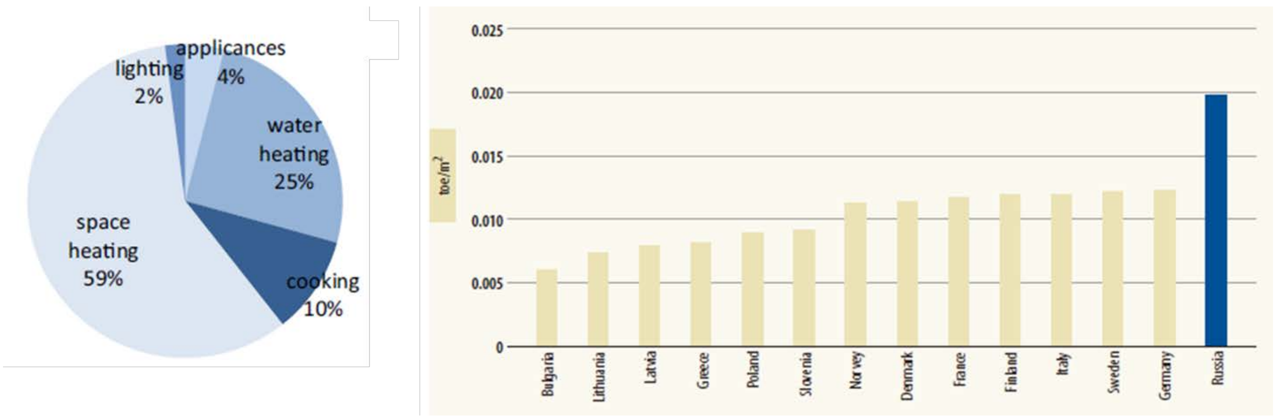
5.1. The present situation of building energy consumption in Russia

1) Building energy consumption and efficiency

The awareness of increased urban population, new building construction together with the environmental impact such as energy shortage, climate effects, and increasing greenhouse gas (GHG) emissions, have increased the concern on the trends of energy consumption. Within the context of energy conservation, building energy conservation has become the focal point, as buildings are responsible for around 40% of total energy consumption and GHG emissions.

Due to the long cold season and inefficient heating equipment, the energy consumption for heating represents the most important component for building energy consumption in Russia. With low energy efficiency, especially because more than half of the building stock was built at least 25 years ago, even though it shares a similar climate, geographical size the energy intensity of residential energy consumption and heating to Canada, Russia uses almost twice the amount of energy. Compared with other countries, Russia has the highest energy consumption intensity for heating (Fig 5.1.1).

Fig 5.1.1 Energy consumption breakdown for residential buildings and Energy Intensities of Residential Heating

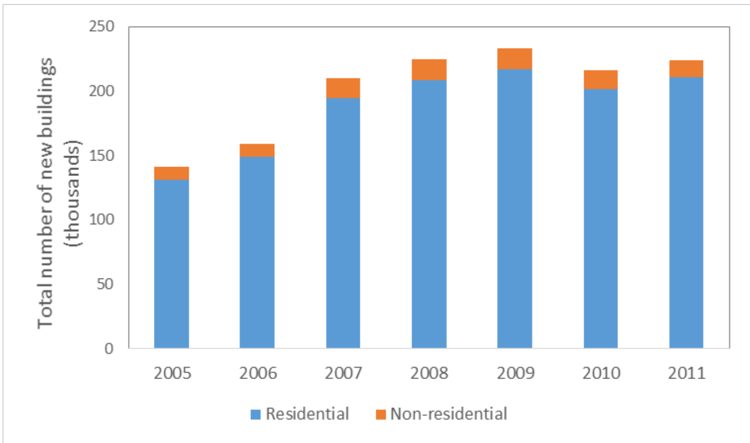


Source: Energy Efficiency in Russia, World Bank and ICF

2) Building construction trends and energy consumption

With a slightly increasing population, the construction sectors, especially residential buildings is expected to grow, which may translate to an increase in infrastructure development and higher demand for residential properties. Fig 5.1.2 suggests that residential buildings make up most of the new construction from 2005.

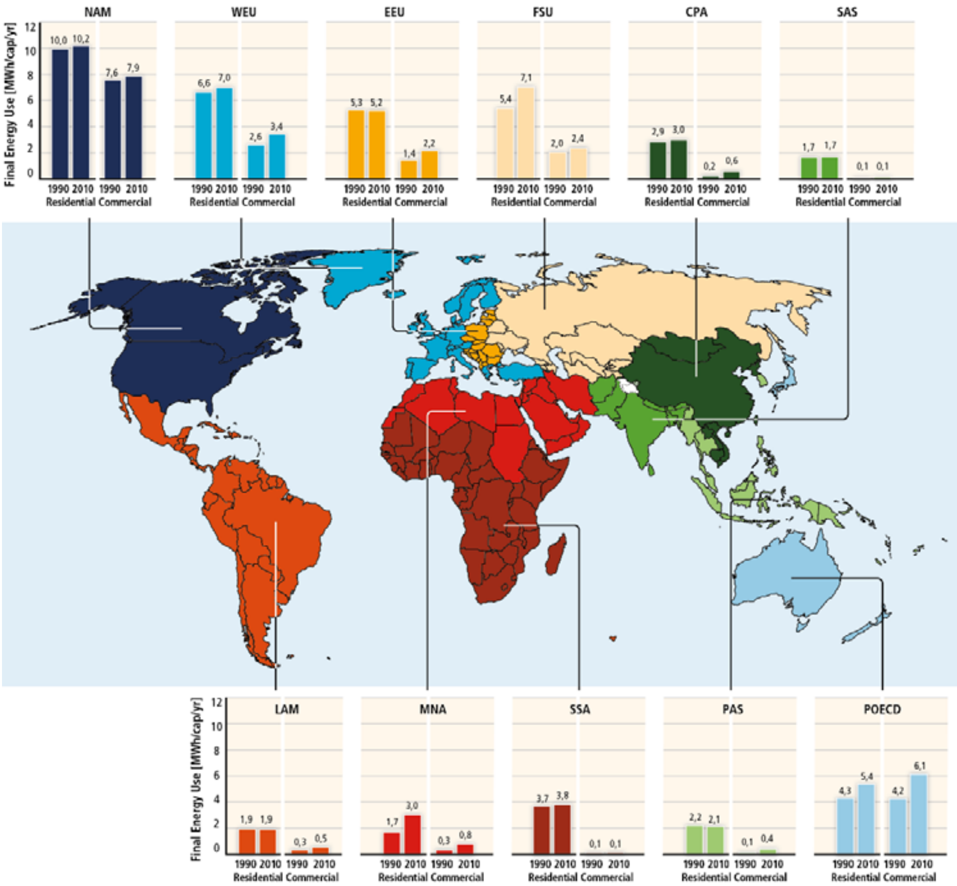
Fig 5.1.2 New Construction in Russia



Source: Analysis of the Russian Market for Building Energy Efficiency

Fig 5.1.3 suggests per capital final energy use of Russia continuously grew between 1990 and 2010, especially for residential buildings. Compared with other European countries in similar climates, the rate of increase is faster.

Fig 5.1.3 Annual per capita final energy use of residential and commercial buildings for eleven regions



Source: IPCC, 2014

Within the context of Russia's building energy consumption analyzed above, the appropriate approaches to energy saving in the building sector of Krasnoyarsk Krai should conceptually be the following:

1) The low carbon roadmap for the building sector should consider both new construction and existing buildings built before 2003, as a large proportion of buildings were built before that time. Thus the low carbon building scenarios should be divided into two: new high-performance buildings and retrofit actions to existing buildings.
2) As heating is responsible for more than half of the building energy, energy conservation strategies to reduce heating load and efforts to make no-cooling systems are the most important.
3) Further, residential buildings should be the primary focus, as they represent the highest potential within the construction market.

5.2. Building energy codes around the world

Integrating energy efficiency into building codes is recognized as a cost effective way to reduce building energy consumption both in residential and commercial buildings. Different countries independently design and implement energy conservation polices through building energy regulation according to their particular national characteristics, especially climate. This section lays out and compares the building codes of different countries such as the United Kingdom, United States, China, Japan, Germany and Korea with a view to suggest the effect and technical requirements for Krasnoyarsk Krai (Russia)

5.2.1. Energy code development and challenges in Russia

The national building code, "Thermal Performance of Buildings" was developed in 2003 as a mandatory code for both residential and commercial buildings. The code and related regulations were designed for the design and operation of buildings, aiming for 40 percent energy conservation for heating, which requires an increase of 2.5 to 3 times in thermal performance in new and renovated buildings in Russia.

Further, the "Energy Efficiency Class of Multifamily Building" for existing residential buildings and "Green Standards (2010)" have been approved as voluntary labels for commercial buildings.

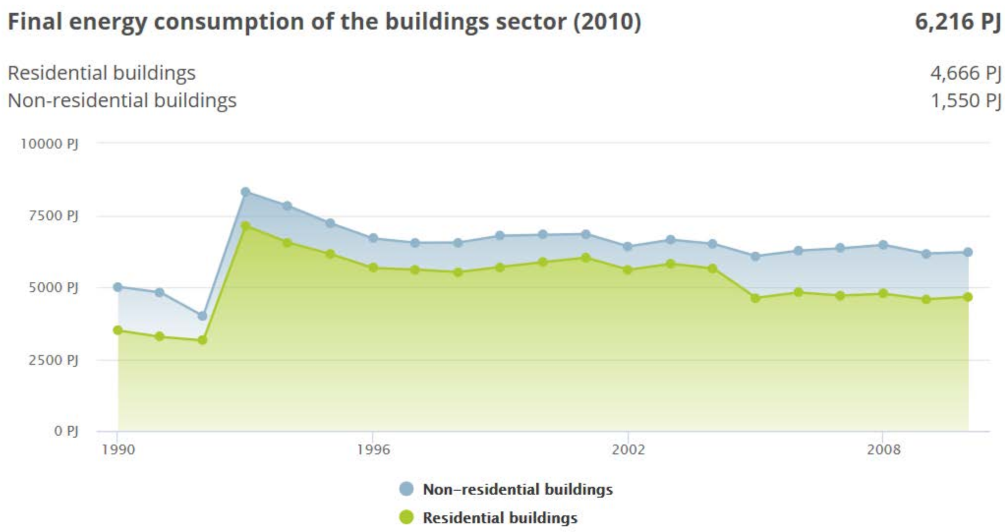
Principles as key for the creation of energy-efficient buildings:

- Selection of a geometric form for the building that reduces heat losses,
- Reduction of demand for energy by increasing thermal-performance level, including reduction of air permeability,
- Provision of required air exchange with the help of organized air intake,
- Meeting remaining needs for energy in the most effective manner.

Source: Increasing Thermal Performance and Energy Efficiency of Buildings in Russia: Problems and Solutions

As a result, in Russia's building sector, a fundamental transformation has taken place, including materials, energy efficiency and building design methods. It was suggested that the energy code in Russia will result in expected energy savings. Fig 5.2.1 suggests that energy consumption in the building sector has been slightly decreasing since 2003.

Fig 5.2.1 Final energy consumption of the buildings sector

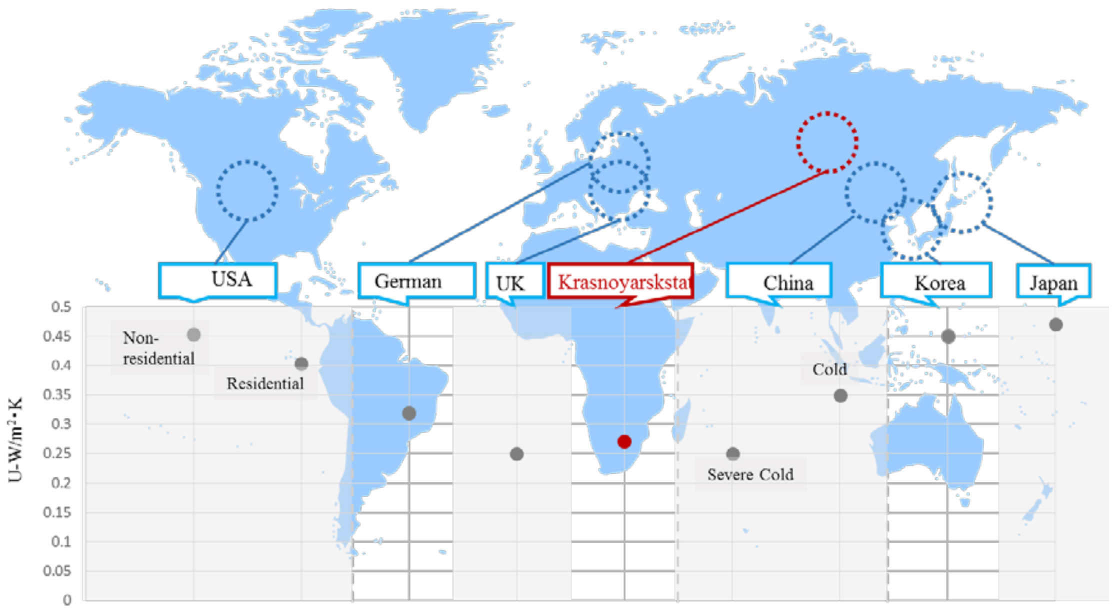


Source: http://www.iea.org/beep/russia/

5.2.2. Comparison of building energy code with other countries

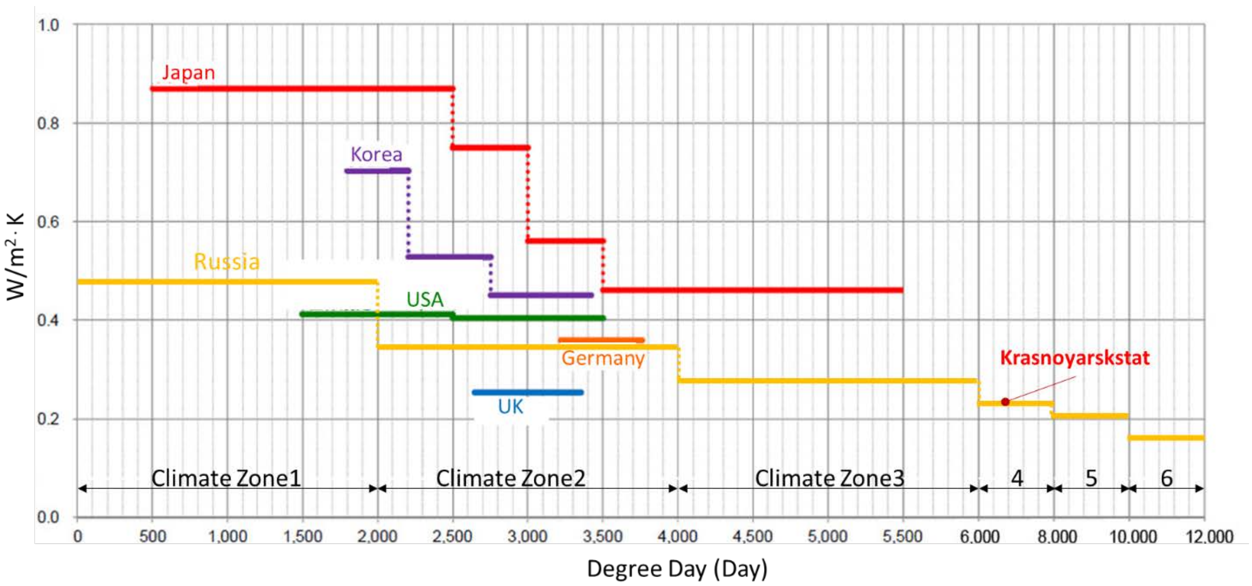
Thermal resistance of the building envelope is the key factor for building energy conservation. A comparison of thermal resistance of building envelope between different countries suggests that Russia has a high-level standard building envelop, including wall and window (Fig 5.2.2~ Fig 5.2.4).

Fig 5.2.2 Comparison of thermal resistance of wall



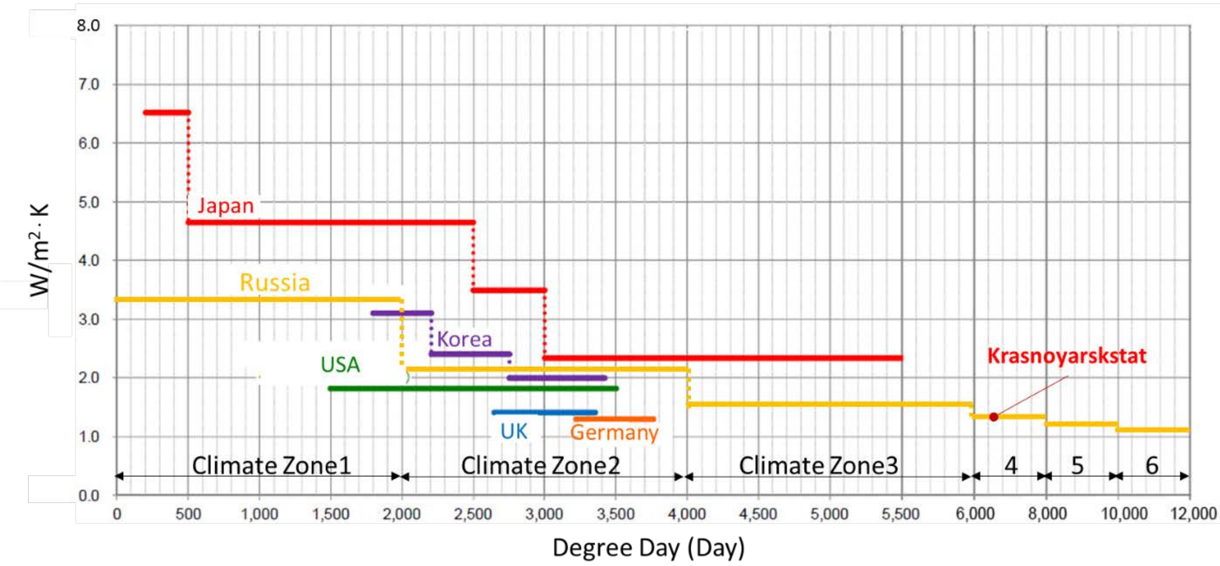
Source: NIKKEN SEKKEI Research Institute

Fig 5.2.3 Comparison of thermal resistance of wall with degree day



Data source: http://www.iea.org/beep/russia/ and NRI public management review, Jan, 2015

Fig 5.2.4 Comparison of thermal resistance of window with degree day



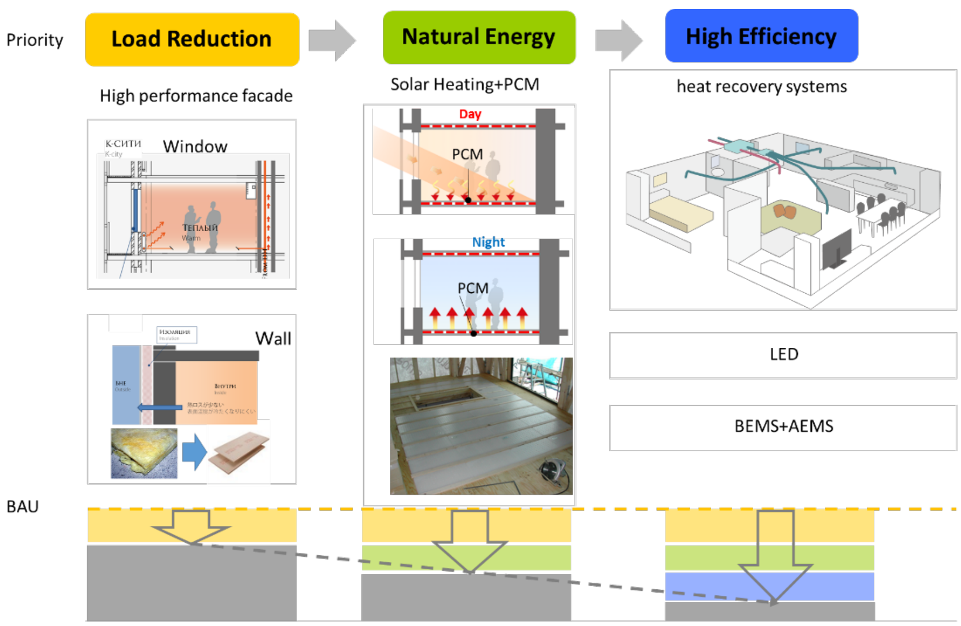
Data source: http://www.iea.org/beep/russia/ and NRI public management review, Jan, 2015

5.3. Energy-Conservation Measures

5.3.1. Priority for low-carbon building strategy

Comprehensive energy conservation strategies should consider the low carbon technologies both on the demand side and the supply side, including strategies for load reduction, natural energy utilization and high efficiency equipment introduction. Their priorities are suggested in Fig 5.3.1.

Fig 5.3.1 Priority for Low-Carbon Strategy



Source: NIKKEN SEKKEI Research Institute

5.3.2. Low carbon technologies for cold climate

1) Load reduction by high performance building envelope

The first step of energy conservation is load reduction. Especially in severe cold climates, heating energy consumption is responsible for almost half of building energy consumption. This can be controlled by a high performance building envelope, including thermal insulation, sunlight reflection, shading and façade engineering.

■ Building thermal insulation

Thermal insulation is the basic and most important factor for building energy saving in cold areas. Usually, the energy performance of the building is determined by the thickness of insulation material and sometimes both internal and external insulation is necessary.

■ Sunlight reflection and shading

With highly insulated building façades, buildings in cold areas face the problem of overheating during the summer time. The following should be considered during sunlight planning:

- Cutting the thermal load by sunlight shading
- Cutting the lighting energy consumption by utilization of indirect daylight

Nakashibetsu Junior High School is an example of the use of high performance external insulation and daylight control in a cold climate (Source: Hokkaido Nikken Sekkei)

Fig 5.3.2 Nakashibetsu Junior High School

Source: Hokkaido NIKKEN

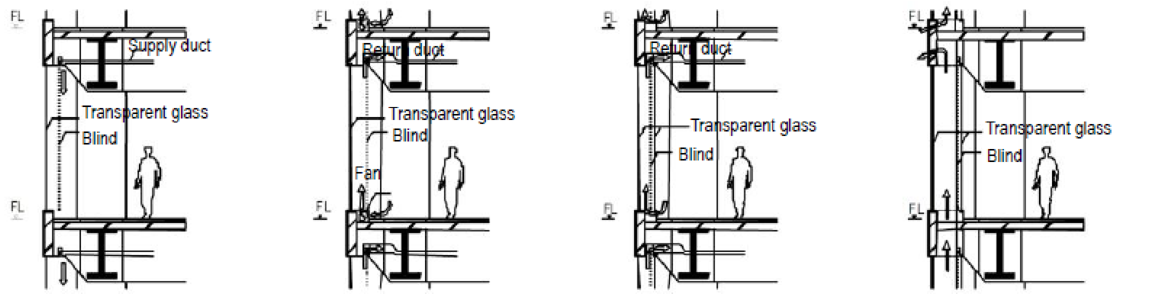
■ High performance fenestration surface

In addition to thermal load reduction, high performance fenestration surfaces such as duplex glazing and air flow windows are recommend for avoiding cold drafts and enhancing indoor environmental performance (thermal load reduction and Dew condensation prevention).

- Air flow windows

  Air flow windows improve the thermal environment nearby the windows. They create a kind of vertical airflow layer inside the double-layered glass equipped with a built-in blind to avoid heat transfer with high efficiency between the inside and outside of buildings

Fig 5.3.3 Examples of Air flow windows



The load around the window is handled by the air conditioner. In winter, some devices such as a panel heater is required because cold draft is generated.

By creating an air curtain barrier between the glass and the blind by a fan, the thermal load generated around the window is collected in order to cut in-room load.

The thermal load around the window is contained inside the Air Flow, and then collected by the air taken from the slits of sashes in the room in order to cut in-room load.

In summer, open air is taken in from the slits on the outer wall to naturally ventilate thermal load accumulated inside the double skin. In winter, open air is shielded off to collect heat.

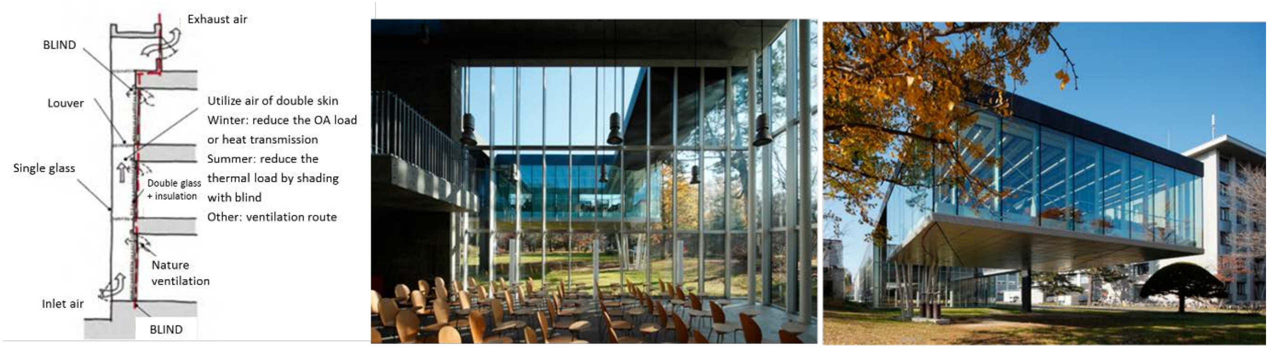
Fig 5.3.4 Hokuyo Odori Center

Source: Hokkaido NIKKEN

- Double-skins

  Double-skin façade is a fenestration system consisting of two panes of glass with an intermediate cavity. Ventilation in the cavity can be natural or mechanical. Usually, the ventilation in the cavity is used for heat extracting during the cooling season with the solar shading system fixed in the cavity to avoid direct daylight. Even if the cooling load is low in a severe cold climate area, it is still essential for making an air-conditioning system without cooling. The urban design studio of Hokkaido University's architecture school is an example of a cold climate double-skin façade (Fig 5.3.5).

Fig 5.3.5 Hokkaido University architecture School urban design studio



Source: Hokkaido NIKKEN

2) Natural energy utilization with passive design

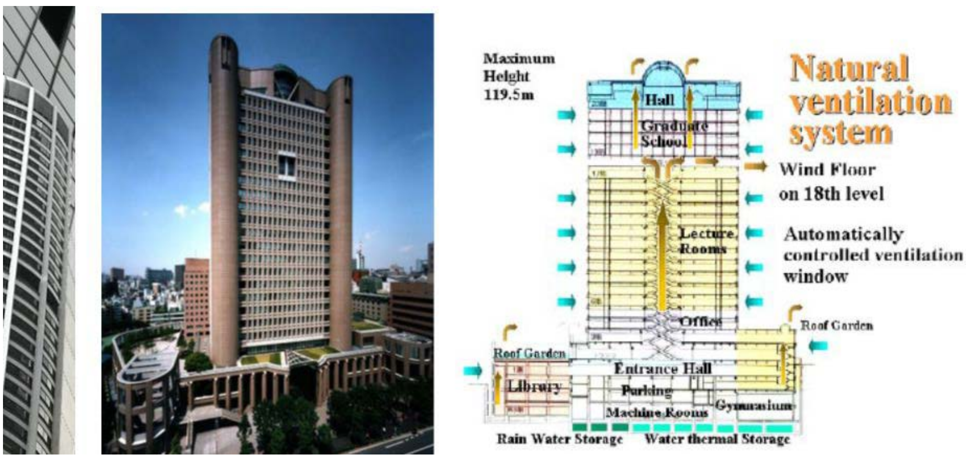
Natural energy utilization with passive design refers to building design that can effectively utilize natural energy, like natural ventilation and daylight, cutting the energy consumption for air-conditioning and lighting.

- Natural ventilation

  Intermediate-season air-conditioning energy can be reduced by natural ventilation, making use of the reginal climate features, temperature difference between inside and outside, and height difference between intake and exhaust windows. Natural ventilation cooling can contribute to realizing a building without a cooling system in severe cold climate.

  Usually, there are two kinds of building design that can utilize natural ventilation, one is by void in the building. Natural ventilation can be employed by void in the building even during calm conditions or using staircases. Meiji University Liberty Tower is an example of using natural ventilation with both void and staircase (Fig 5.3.6).

Fig 5.3.6 Meiji University Liberty Tower



Source: http://slideplayer.com/slide/4531252/

- Daylight Utilization

  Systematically incorporating natural light by utilizing the position, shape and sectional configuration of windows such as top lights, can reduce lighting energy. Nakashibetsu Junior High School is an example of introducing natural lighting by top light in an indoor communal space and classroom.

Fig 5.3.7 Nakashibetsu Junior High School


Source: Hokkaido NIKKEN

3) Facilities with High efficiency

The last step for energy conservation is the introduction of facilities with high efficiency.

- LED

  LED lamps consume only 1/3 ~ 1/9 primary energy compared to fluorescent and incandescent lamps, while providing an almost equal brightness of illumination.

  Advantages of LED lamps:

  - Environment friendly (absence of mercury and other harmful substances);
  - Longer service life (30-100 thousand hours);
  - Safety (low voltage and low heating - above 60 degrees Celsius);
  - LED lamps with motion sensor in supporting facilities allows to reduce the electricity cost up to 50%

- Heat recovery ventilation

  Ventilation is important for indoor air quality, affecting health and the indoor environment. However, in severe cold climate areas, ventilation intakes the cold outdoor air and represents a large part of the heating energy consumption. Heat recovery ventilation is an energy recovery system between the inbound and outbound air flow. It takes the heat from warm air and gives it to the cold air, which is expected to save heating energy even with the requisite ventilation.

5.4. Potential for low carbon building technologies

Energy simulation (by software Energyplus) is adopted to analyze the effect of low-carbon strategies. The process is outlined below:

- Setting the simulation model
  For both residential and non-residential buildings, a building with the "standard level" of construction is select as case study. The energy conservation effect of the proposed technologies for mid-term and long-term is sited in the scenario analysis.

- Existing building energy consumption (BAU) and its break down for different types of buildings
  Energy plus is used for modeling and simulating the existing energy consumption of different buildings types. Further, the simulation result can also suggest the characteristics of energy consumption breakdown of different types of building.

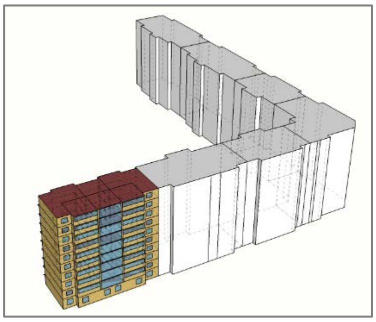
- Effect of Low-Carbon Strategies
  Different low-carbon strategies, including high performance façade, high efficiency equipment and natural energy utilization are adopted in the simulation to show their energy conservation potential.

5.4.1. Scenario analysis for residential buildings

- Basic Settings:
  Software: Energyplus8.7
  Weather information: Energyplus weather data in Moscow

- General information for simulation mode
  A series of ten-floor apartment buildings with residential on the first floor is adopted for the case study. General information is shown in table5.4.1.

Table 5.4.1 General information of simulation model

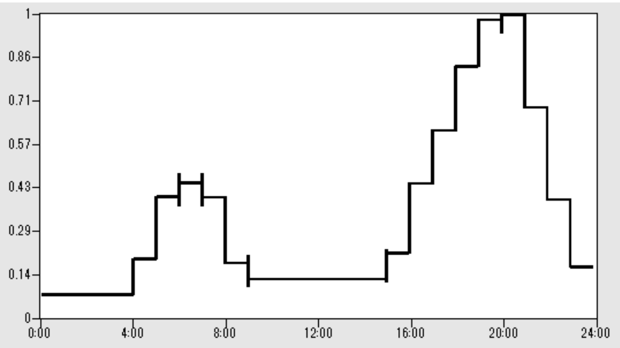
General formation	Model
Building area: 3740m^2 Number of floors: 10F Building use : 1F office, 2~9F Apartment Floor Height: 1F 3.3m, 2~9F 2.8m	

- Schedule

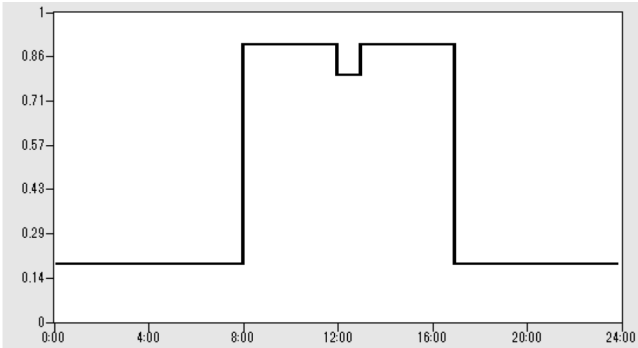
Lighting schedule, activity of people and equipment schedule is set as Table 5.4.2.

Table 5.4.2 General information of simulation model

Lighting

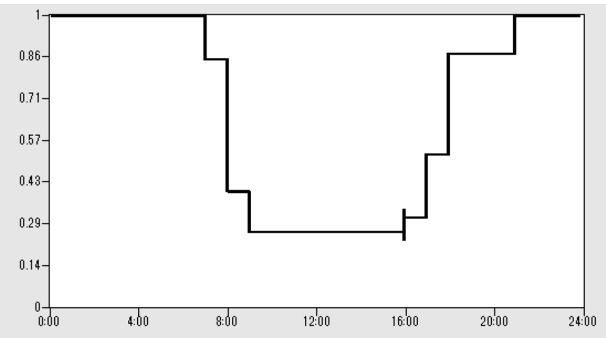


Apartment

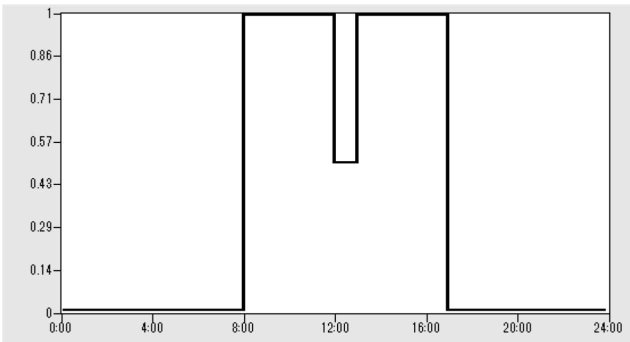


Office

People

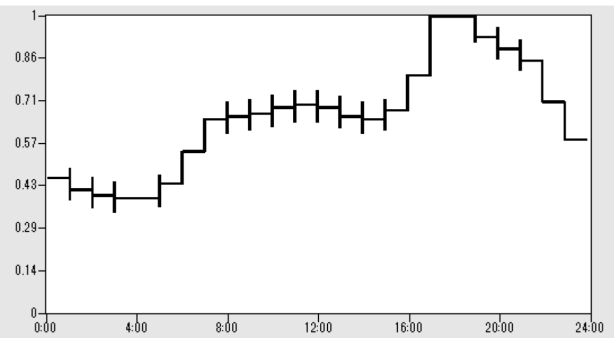


Apartment

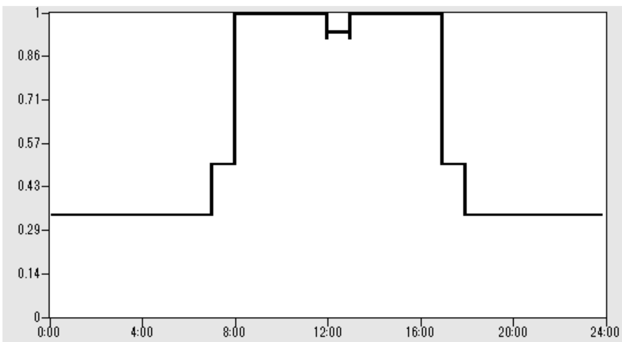


Office

Equipment



Apartment



Office

- Setting for air-conditioning
  Energy consumption intensity of people, lighting, equipment, indoor temperature and outdoor air system are set as per Table 5.4.3.

Table 5.4.3 Setting for air-conditioning system

Building use	Heating	People	Lighting	Equipment	Outdoor Air
	Temperature ℃	people/m^2	W/m^2	W/m^2	Air changes/h (or m^3/s・person)
Office	20	0.02	11.9	9.3	0.5 Air changes/h
Apartment	20	0.03	4.1	3.8	0.01 m^3/s・person
Corridor	―	0	7.1	-	-

1) Energy conservation scenario for new construction

New Construction refers to buildings constructed after the year 2003. Therefore, according to the Building Energy Efficiency Policies in Russia, the buildings should have a high performance envelope. In order to realize further energy conservation, the following technologies are suggested for mid-term and long-term benefits:

For midterm (2030):
- Improve the efficiency of hot water heaters
- Improve the efficiency of appliances with higher efficiency
- LED lighting
- Heat recovery

For long-term (2050):
- Advanced hot water heaters
- Advanced appliances
- Advanced building envelopes
- High air tightness

- Case setting
  Mid-term and long-term energy conservation technologies are proposed for thermal performance of the building envelope, efficiency of the facility and infiltration with targets as set in Table 5.4.4.

Table 5.4.4 Case Setting for new construction residential buildings

		BAU	2030	2050
Thermal Performance of Buildings*1(m2.K/W)	Door	0.7	0.7	1.0
	Roof	5.5	5.5	6.7
	floor	6.2	6.2	6.7
	Walls	4.2	4.2	6.7
	window	0.7	0.7	1.0
General efficiency of space heating*2		0.6	0.6	0.8
Efficiency of hot water		0.8	0.9	1.0
Infiltration(1/h)		0.38	0.38	0.2
Improved efficiency of appliance		−	10%	30%
LED		−	○	○
Heat recovery		−	○	○

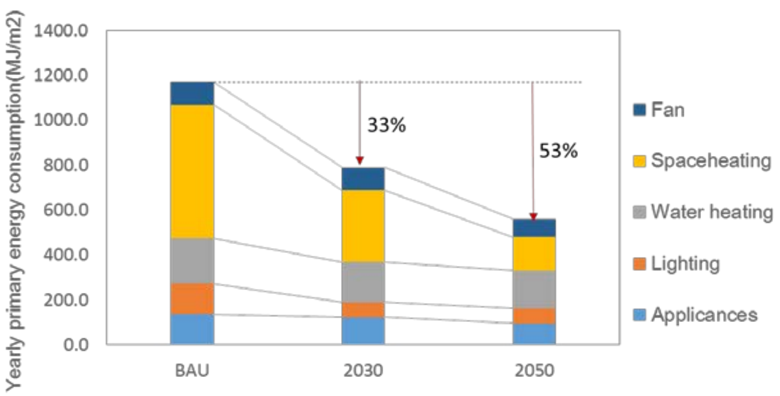
＊1 Thermal performance of building in BAU case is set according to the following information http://www.iea.org/beep/russia/codes/thermal-performance-of-buildings-2003.html
Thermal performance of building in 2030 and 2050 is set according to the following research: An energy analysis of a multifunctional facade system for energy efficient retrofitting of residential buildings in cold climates of Finland and Russia, Sustainable Cities and Society 15 (2015) 75–85
＊2 The primary energy consumption of space heating includes heat loss during the heat supply

- Result and analysis

As can be seen in the results displayed in Fig 5.4.1, heating energy makes up around half of the energy used in residential buildings, following by energy consumption for water heating. With the introduction of LED lighting and higher efficiency appliances, the energy consumptions for lighting and appliances decrease. Energy used for space heating is reduced by introducing heat recovery ventilation.

The energy conservation technologies proposed for new construction residential buildings can realize 33% annual primary energy conservation reduction in the year 2030 and 53% in the year 2050.

Fig 5.4.1 Energy conservation effect for new construction (residential buildings)



Source: NIKKEN SEKKEI Research Institute

2) Energy conservation scenario for existing building

The existing buildings refer to buildings built before 2003. Compared with new constructions, the building envelope has relatively low efficiency. The following scenarios are suggested for energy renovation for existing buildings.

For midterm (2030):

- Improve the efficiency of hot water heater
- Windows with higher air tightness
- Improve the efficiency of appliances with higher efficiency
- LED lighting
- Heat recovery

For long-term (2050):

- Reconstruction

- Case settings

According to the energy conservation technologies proposed for existing residential buildings, thermal performance of the building envelope, efficiency and infiltration are set as Table 5.4.5.

Table 5.4.5 Case Setting for existing residential buildings

		BAU	2030	2050
Thermal Performance of Buildings*(m2.K/W)	Door	0.3	0.3	1.0
	Roof	0.9	0.9	6.7
	floor	0.9	0.9	6.7
	Walls	0.9	0.9	6.7
	window	0.3	0.7	1.0
General efficiency of space heating		0.6	0.6	0.8
Efficiency of hot water		0.8	0.9	1.0
Infiltration(1/h)		0.50	0.38	0.2
Improved efficiency of appliances		–	10%	30%
LED		–	○	○
Heat recovery		–	○	○

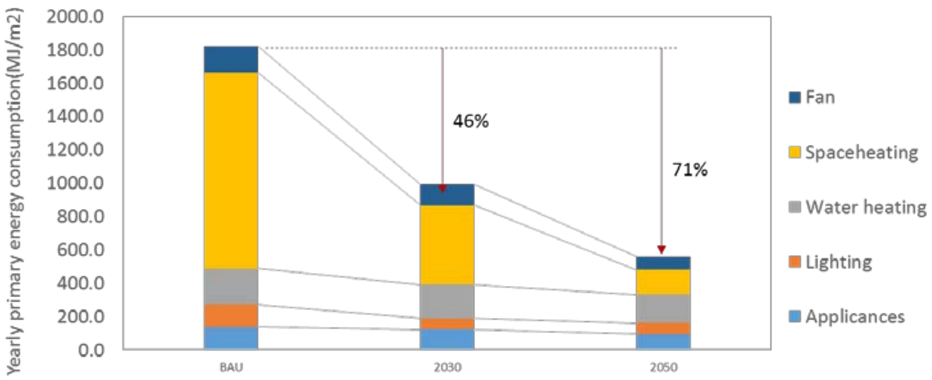
＊1 Thermal performance of building in BAU case is set according to following research: An energetic analysis of a multifunctional facade system for energy efficient retrofitting of residential buildings in cold climates of Finland and Russia, Sustainable Cities and Society 15 (2015) 75–85
The "current status" is adopted as BAU of existing building

- Result

  Because of the low thermal performance of the building envelope, the energy used for heating of existing residential buildings is much higher than that in new constructions. It can be reduced with the improvement of building envelope and introduction of heat recovery ventilation. For the year 2050, it is assumed that all the existing residential buildings built before the energy code are reconstructed with the same features as new residential buildings at that time.

  The simulation result (Fig 5.4.2) suggests that compared with BAU, the existing residential buildings can realize 46% and 71% primary energy reduction in the year 2030 and 2050.

Fig 5.4.2 Energy conservation effect for existing buildings (residential buildings)

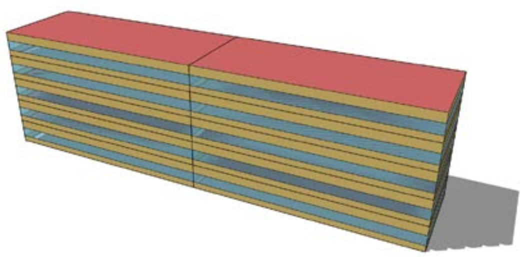


Source: NIKKEN SEKKEI Research Institute

5.4.2. Energy saving methods for non-residential buildings

A 5-floor existing office building is sited in the case study, the general information of which is as shown below.

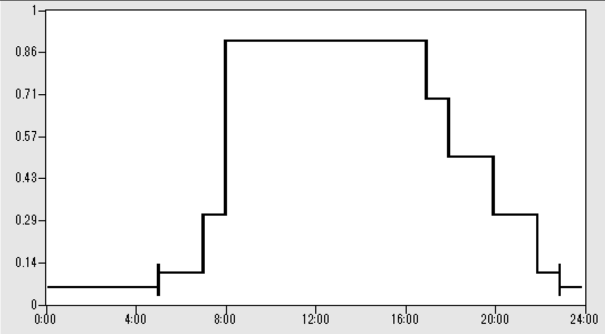
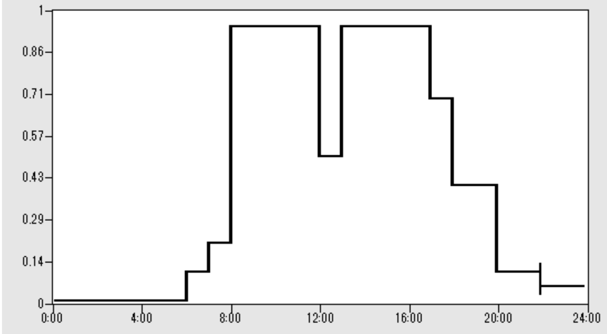
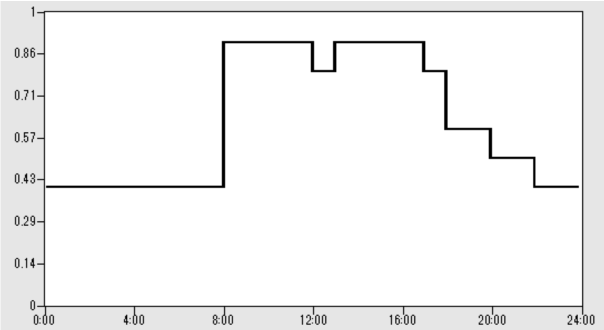
Table 5.4.6 General information of simulation model (existing office building)

General formation	Model
Building area: 3700m² Number of floors: 5F Floor Height: 1F~5F 3.3m Window to wall ratio: 40%	

- Schedule

  The schedules of lighting, activity of people and equipment are set as per Table 5.4.7.

Table 5.4.7 Schedule setting for office building

Lighting	People
	
Equipment	
	

- Setting for air-conditioning

  Energy consumption intensity of people, lighting, equipment, indoor temperature and outdoor air system are setting as per Table 5.4.8.

Table 5.4.8 air-conditioning related setting

Building use	Heating	People	Lighting	Equipment※	Outdoor Air
	Temperature	people/m^2	W/m^2	W/m^2	Air changes/h (or m^3/s・person)
Office	20	0.02	10.76	10.76	1.65 Air changes/h
Corridor	—	—	4.84	-	-

- Energy conservation scenario for existing office building

  Existing Office Buildings refer to office buildings built before 2003. Compared with new constructions, the building envelope has relatively low efficiency. The following scenarios are suggested for energy renovation for existing office buildings.

For midterm (2030):

- Improve the efficiency of hot water heater
- Windows with higher air tightness
- Improve the efficiency of appliances with higher efficiency
- LED
- Heat recovery

For long-term (2050):

- Reconstruction

- Case settings

According to the energy conservation technologies proposed for existing office buildings, thermal performance of the building envelope, efficiency and infiltration are set as Table 5.4.9.

Table 5.4.9 Case Setting for existing residential buildings

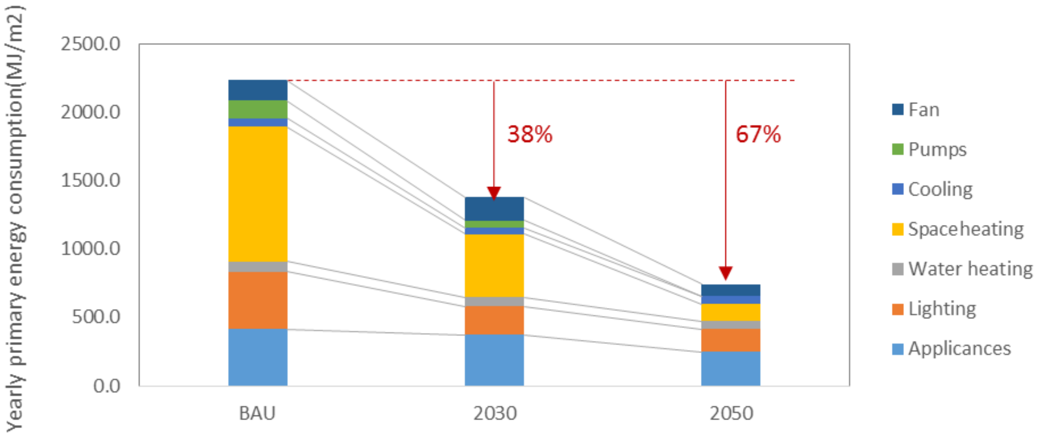
		BAU	2030	2050
Thermal Performance of Buildings*1(m2.K/W)	Door	0.3	0.3	1.0
	Roof	0.9	0.9	6.7
	floor	0.9	0.9	6.7
	Walls	0.9	0.9	6.7
	window	0.3	0.7	1.0
General efficiency of space heating		0.6	0.6	0.8
Efficiency of hot water		0.8	0.9	1.0
Infiltration(1/h)		0.50	0.38	0.4
Improved efficiency of appliances		−	10%	30%
LED		−	○(*2)	○(*3)
Hear recovery		−	○	○

＊1 Thermal performance of building in BAU case is set according to following research: An energetic analysis of a multifunctional facade system for energy efficient retrofitting of residential buildings in cold climates of Finland and Russia, Sustainable Cities and Society 15 (2015) 75–85
The "current status" is adopted as BAU of existing building
＊2 Energy consumption of LED in 2030 is set as half of BAU
＊3 Higher efficiency LED in 2050 is presumed to have 40% of the Energy consumption of BAU

- Result

  Compared with residential buildings, office buildings have a higher ratio of lighting and appliance energy usage but lower ratio of water heating. Our modelling indicates the energy conservation effect for existing office buildings under this scenario, could be a reduction in primary energy consumption by 38% in the year 2030 and 67% in the year 2050.

Fig 5.4.3 Energy conservation effect for existing buildings (office)

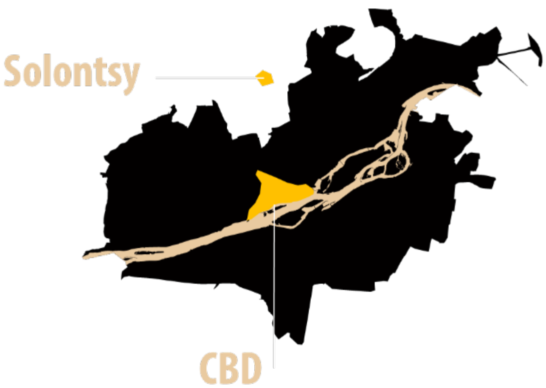


Source: NIKKEN SEKKEI Research Institute

5.5. Case study

Two communities are adopted in the case studies to suggest the effect of low carbon building strategies at the urban scale. One is a commercial business district in the urban center and the other is the solontsy residential area, a suburban area. CBD has a large amount of existing buildings, thus it represents low carbon building technologies for brownfield development (redevelopment of an existing city), while solontsy represents greenfield development

Fig 5.5.1 Site of case study



Source: NIKKEN SEKKEI Research Institute

5.5.1. Case study for existing building area--CBD

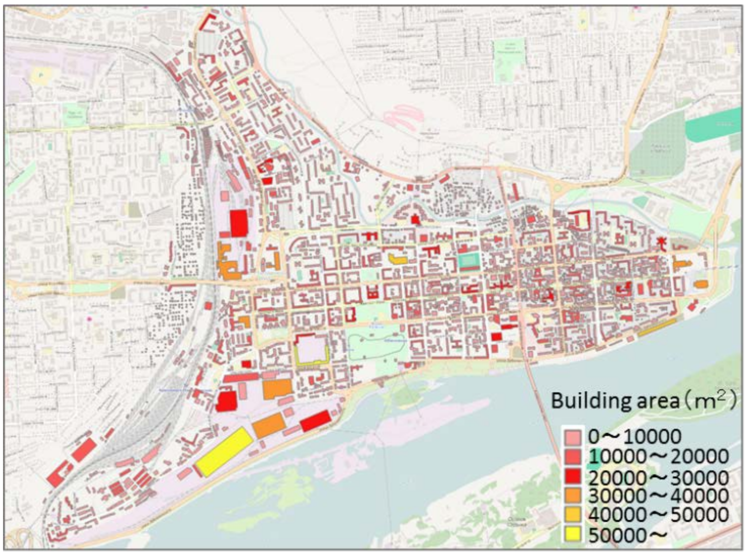
1) General information of the district

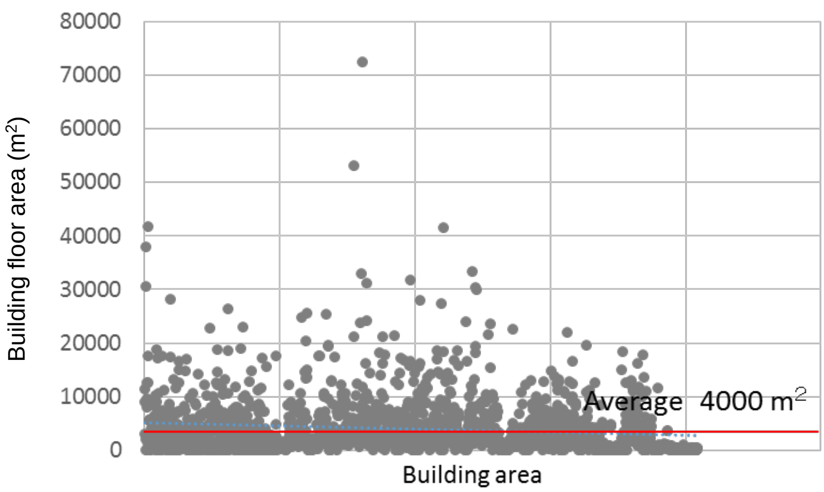
The commercial business district is located in the center of the city. Most of the buildings in this area were built before the year 2003, when the energy code was introduced. Building area of the district and residential to non-residential ratio are assumed as below:

- Building area and floor area

  Building area is calculated according to the open street map and the number of floors of the buildings are assumed according to the open street view in google earth. The total building floor area (Building floor area= Building area x No. floors) is 8,118,230m² and average is 4000m² per building (Fig 5.5.2).

Fig 5.5.2 Building floor area





- Residential to non-residential ratio
  Fig 5.5.3, the new construction in Russia suggests that the ratio of non-residential building floor area has been around 30% since the year 2005. Thus, it is assumed that in this district the ratio of non-residential building, which refers to the office building in this survey is 30%. In other words, it is assumed 2,311,574m² is office building and 5,806,656 m² is residential building.

Fig 5.5.3 New Construction in Russia (2005-2011)

Source: Analysis of the Russian Market for Building Energy Efficiency

2) Low carbon effect of retrofit actions on existing buildings

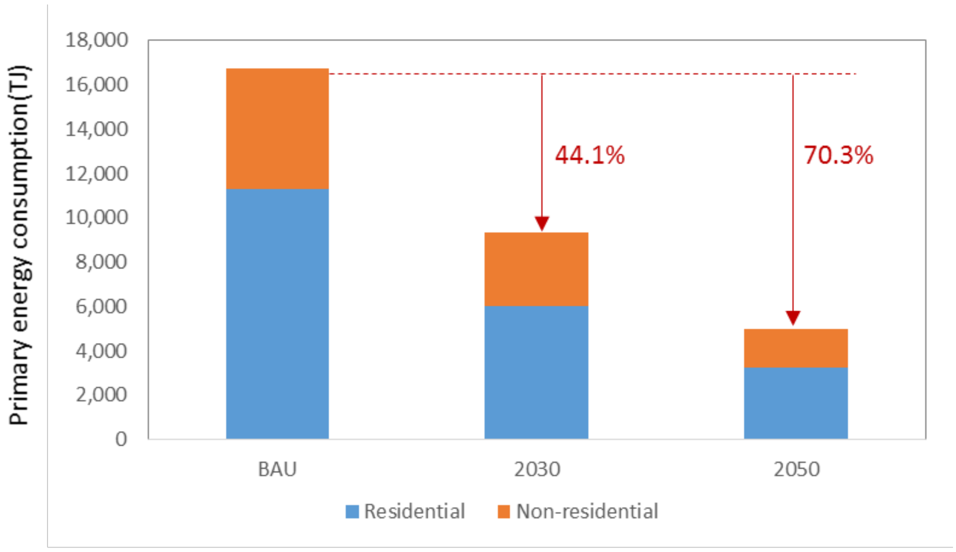
As a result, the whole district can cut around 44% primary energy consumption in the year 2030 and around 70% in the year 2050. This translates to a reduction of around 49% CO_2 emission in the year 2030 and around 76% in the year 2050.

Table 5.5.1 Primary energy and CO_2 emission reduction

	Building area (m²)	Primary energy consumption (TJ)			CO2 emission※ (TCO_2)		
		BAU	2030	2050	BAU	2030	2050
Residential	5,806,656	11,286	6,041	3,257	1,611,887	808,171	397,248
Non-residential	2,311,574	5,451	3,314	1,712	614,135	328,640	131,613
Total	8,118,230	16,737	9,355	4,970	2,226,022	1,136,811	528,861

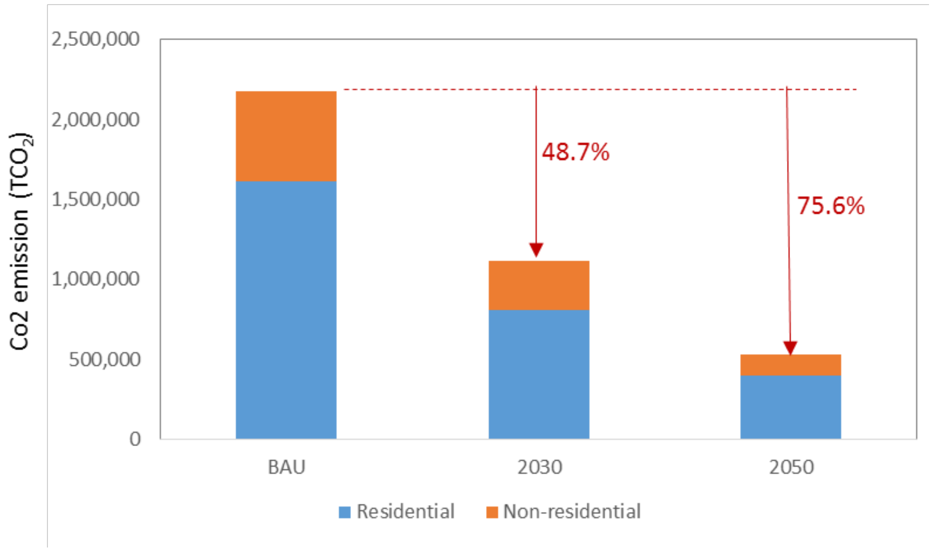
※The CO2 emission intensity for electricity is set as 0.4755 kg・CO_2/kWh and heat supply is 0.183 kg・CO_2/MJ.

Fig 5.5.4 Primary energy conservation effect



Source: NIKKEN SEKKEI Research Institute

Fig 5.5.5 CO2 emission reduction effect



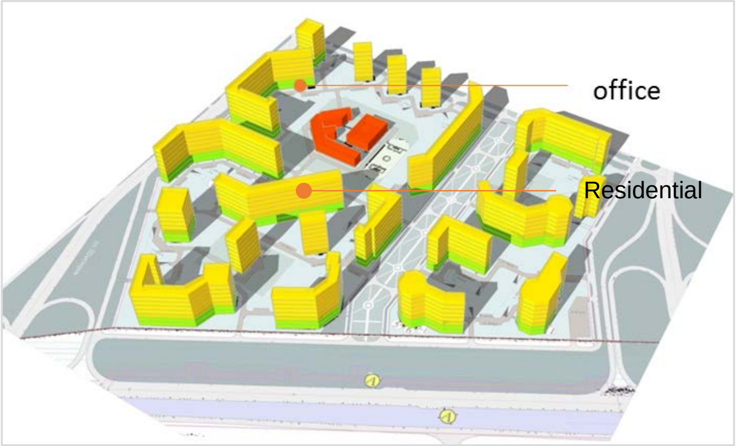
Source: NIKKEN SEKKEI Research Institute

5.5.2. Case study for new high-performance buildings – Solontsy

Solontsy is a new planned residential area with 2,034,000 m^2 complex apartments. The masterplan and community plan is displayed in Fig 5.5.6.

Fig 5.5.6 Community plan of solontsy

Source: Monolit Holding's



Source: NIKKEN SEKKEI Research Institute

1) Low carbon effect

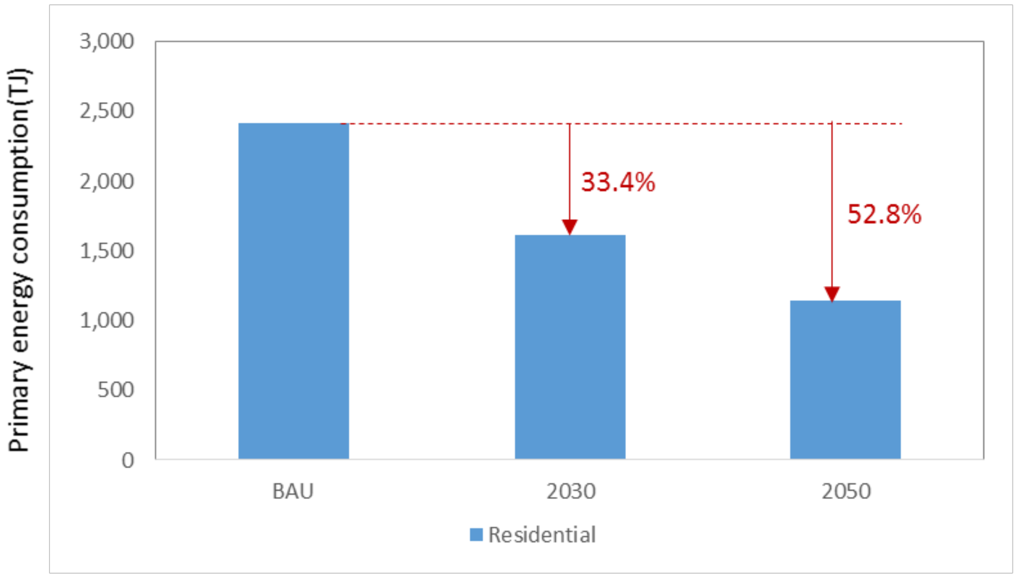
The community can cut around 33% primary energy consumption in the year 2030 and around 52 % in the year 2050. This translates to reducing CO_2 emissions by around 36% in the year 2030 and by around 57% in the year 2050.

Table 5.5.2 Primary energy and CO_2 emission reduction

	Building area(m2)	Primary energy consumption(TJ)			CO2 emission (TCO2)※		
		BAU	2030	2050	BAU	2030	2050
Residential	2,034,000	2,417	1,610	1,141	329,942	210,582	139,151

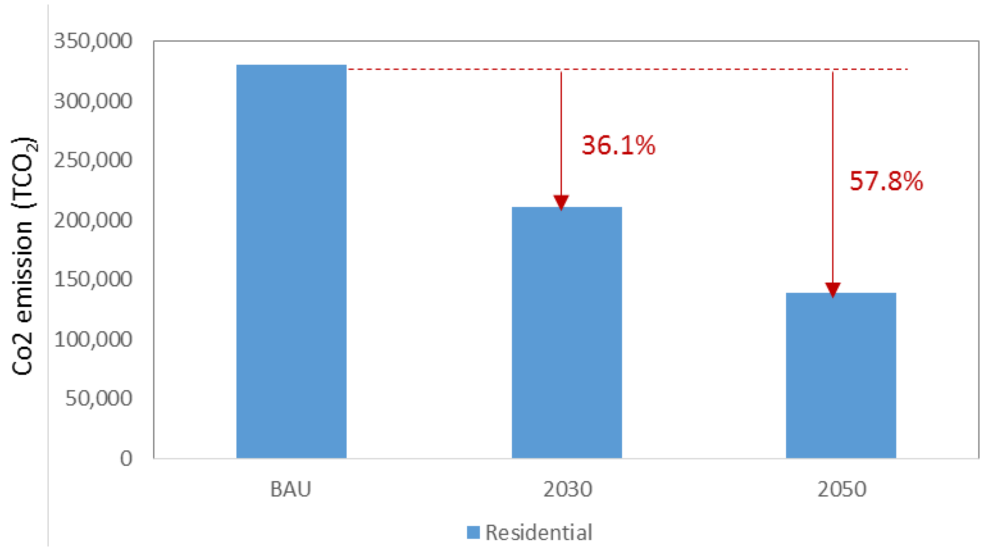
※The CO2 emission intensity for electricity is set as 0.4755 kg・CO_2/kWh and heat supply is 0.183 kg・CO_2/MJ.

Fig 5.5.7 Primary energy conservation effect



Source: NIKKEN SEKKEI Research Institute

Fig 5.5.8 CO2 emission reduction effect



Source: NIKKEN SEKKEI Research Institute

5.6. Best practice of Low Carbon technologies and building

5.6.1. Taisei Sapporo Building, Japan

- Basic information

  Location: Sapporo, Hokkaido, Japan

  Building type: office, retail, parking

  Site area: 863 m2

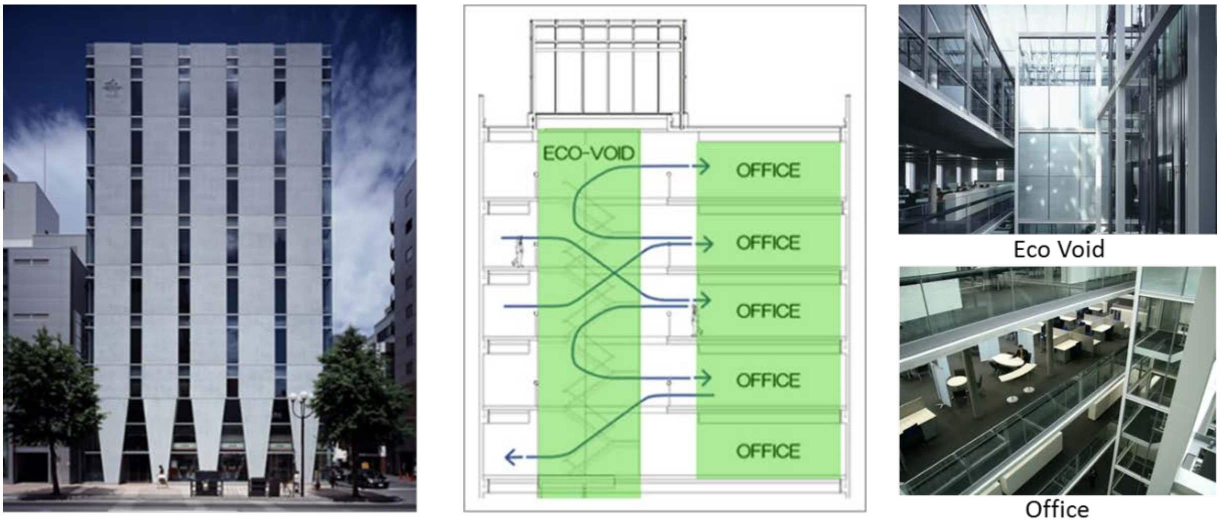
  Building area: 770 m2

  Floor area: 6970 m2

  Building height: 8 floors above ground, 1 floor below ground

  Structure: Reinforced concrete construction, steel frame construction

Fig 5.6.1 Taisei Sapporo Building



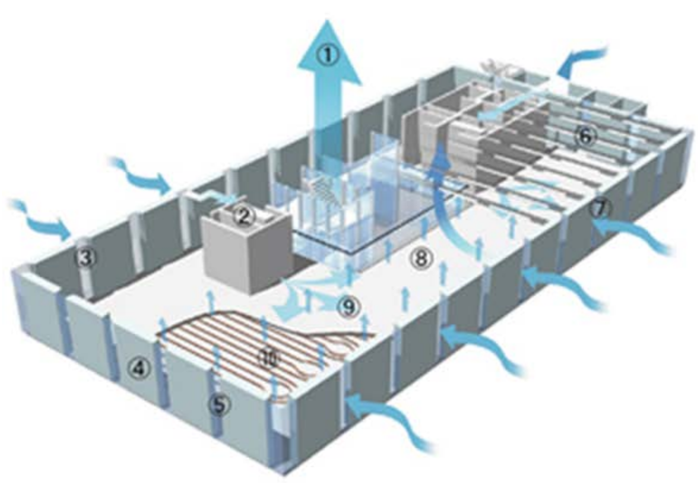
Source: http://www.taisei-design.jp/de/feature/eco_arch/sapporo/index.html

- Air-conditioning system

  The Air Conditioning system introduced in the building is a system that balances ideal air conditioning, energy saving and comfort in a cold climate.

  The air conditioning system includes underfloor air distribution, out air economizer, radiant heating and cooling, all integrated with the architectural and structural design, making use of the cool weather.

Fig 5.6.2 Air-conditioning system



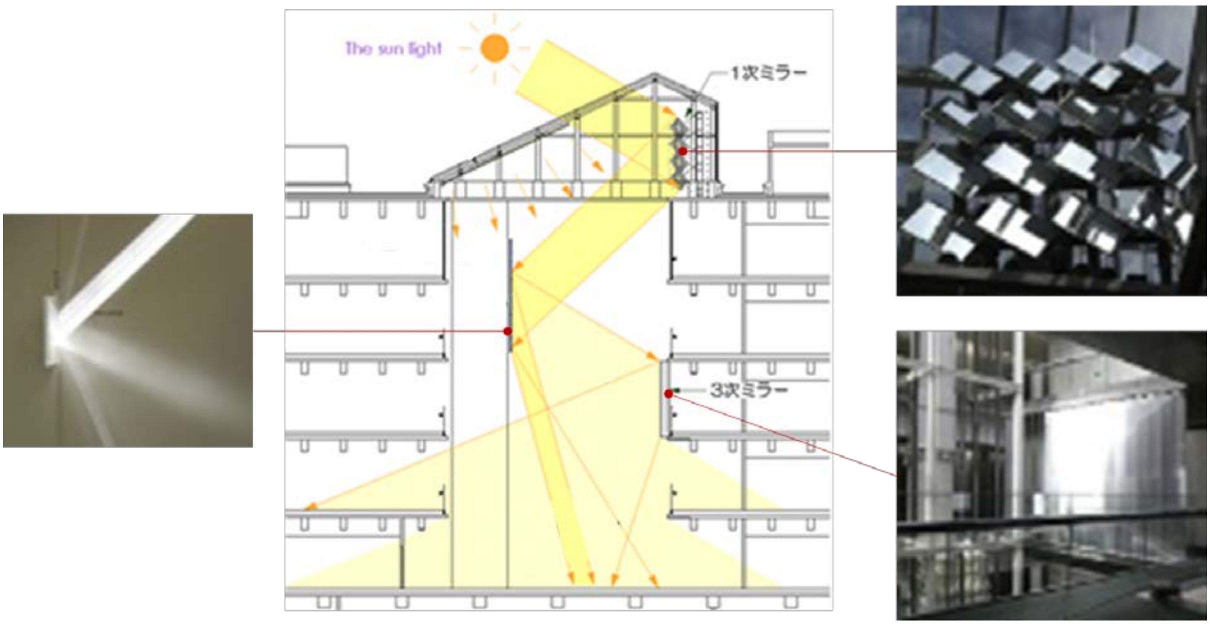
1. Draft effect of Eco-void
2. Underfloor air distribution system
3. Fresh air intake for air-side economizer
4. External insulation
5. High-heat shielding glass
6. Radiant heating&cooling
7. Fresh air intake for ventilation
8. OA floor (chambers)
9. T-Breeze Floor System
10. Radiant heating&cooling

Source: http://www.taisei-design.jp/de/feature/eco_arch/sapporo/index.html

- Eco void

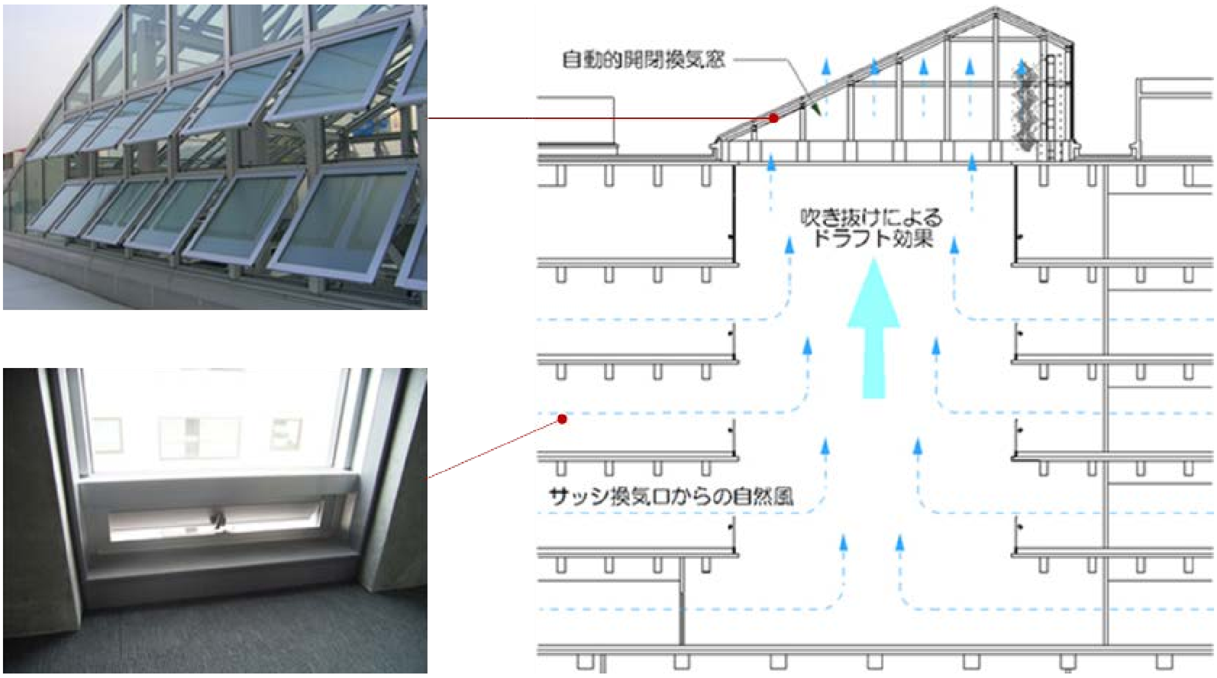
  The Eco void can introduce the daylight to cut the lighting energy. Further, it facilitates natural ventilation which contributes to reducing cooling loads.

Fig 5.6.3 Daylight utilization with eco void



Source: http://www.taisei-design.jp/de/feature/eco_arch/sapporo/index.html

Fig 5.6.4 Natural ventilation with eco void



Source: http://www.taisei-design.jp/de/feature/eco_arch/sapporo/index.html

5.6.2. Preobrazhenskiy, Russia

A residential project developed in Preobrazhenskiy, the largest district in Krasnoyarsk. It is recognized as a pioneering example of Smart City implementation in Russia. In addition to the comprehensive area management system (which will be introduced in chapter10), it is also an example for advanced energy conservation and low carbon residential building design.

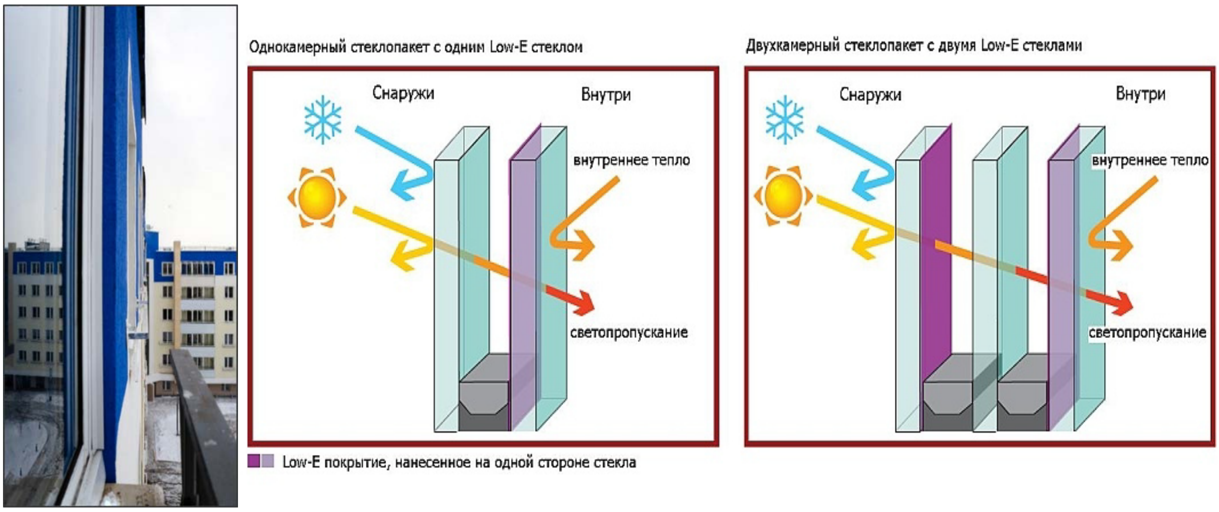
Fig 5.6.5 Image of Preobrazhenskiy

Source: NIKKEN SEKKEI Research Institute

- Load reduction energy saving windows-- Energy saving double-glazed windows

  Energy saving double-glazed windows incorporate special glass with reflective layers. This differentiates them from usual windows. The layers comprised of various metals effectively reflect thermal energy. The glass unit prevents heat from leaving the room, reflecting it inside. In summer energy saving double-glazed windows effectively keep the interior atmosphere cool and blocking the heat inside the room.

Fig 5.6.6 Double-glazed windows



Source: NIKKEN SEKKEI Research Institute

- Wall insulation

  The insulation of the envelope is vitally important for energy conservation in Siberia. Usually, buildings and apartments require special thermal insulation systems, since more than 40% of building heat radiates through the walls.

Fig 5.6.7 Wall insulation

- LED Lighting

  LED lighting is used in corridors and other public spaces. It can save lighting energy consumption, especially when used in conjunction with motion sensors.

Fig 5.6.8 LED Lightening

Photo: NIKKEN SEKKEI Research Institute

- Heat recovery system

  In this area, almost 40% of the heat dissipates with ventilation. The heat recovery system can realize energy conservation by heating the cold air before it enters into a room.

Fig 5.6.9 Heat recovery system

Source: NIKKEN SEKKEI Research Institute

6 TRANSPORTATION

6. Transportation

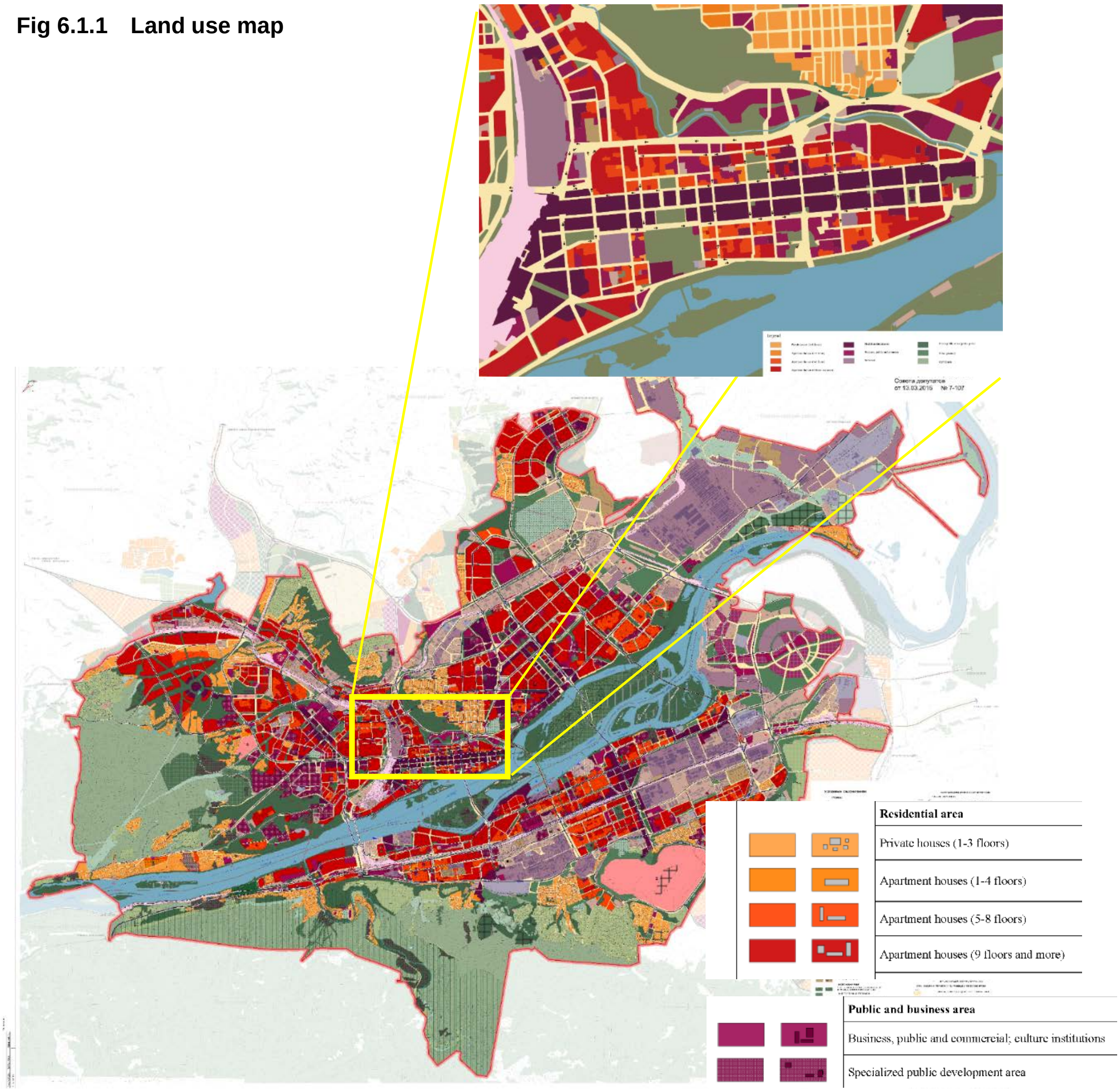
6.1. Current status analysis of target area

1) Land Use

Within the city, Zheleznodorozhnyy zone, Tsentralniy zone, and Kirovskiy zone businesses, public institutions and commercial functions are gathered, and residential functions are located around these.

Even in the center of the city, between Karla Marxa street and Renina street is a public institution and business zone, and residential areas are located in the immediate vicinity, so there are features of mixed land use.

Fig 6.1.1 Land use map



Source: Krasnoyarsk city administration

2) Population

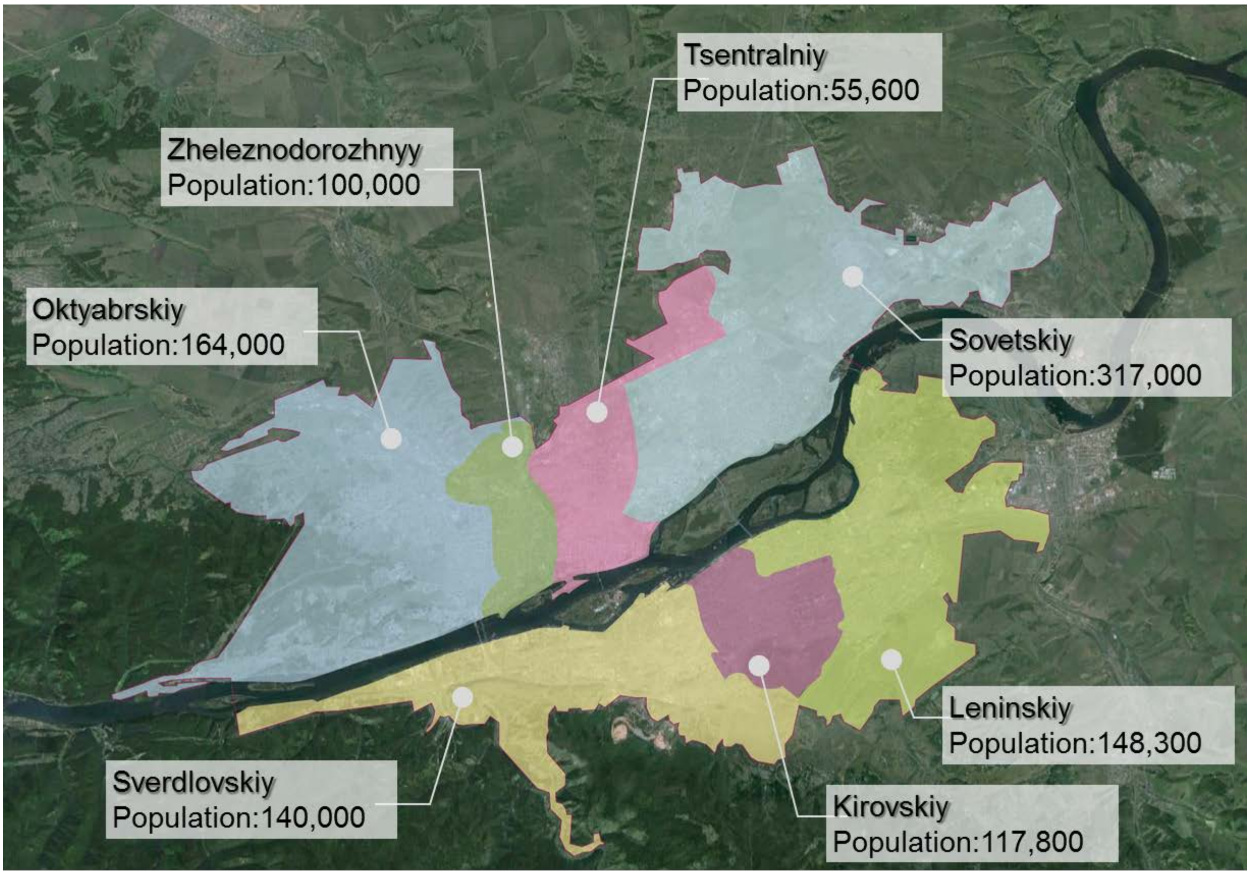
As of 2017, the population of Krasnoyarsk city is approximately 1,083,900. Forecasts estimate the population will rise to about 1,120,724 people by 2019, and issues such as increased traffic congestion and an increase in environmental burden are likely to occur.

	2014 year	2015 year	2016 year	2017 year	2018 year (forecast)	2019 year (forecast)
Permanent population, average figure for the period	1 044 907	1 060 543	1 075 382	1,083,900	1 105 666	1 120 724

Table 6.1.1 Current population and future prospects

Source: Krasnoyarsk city administration

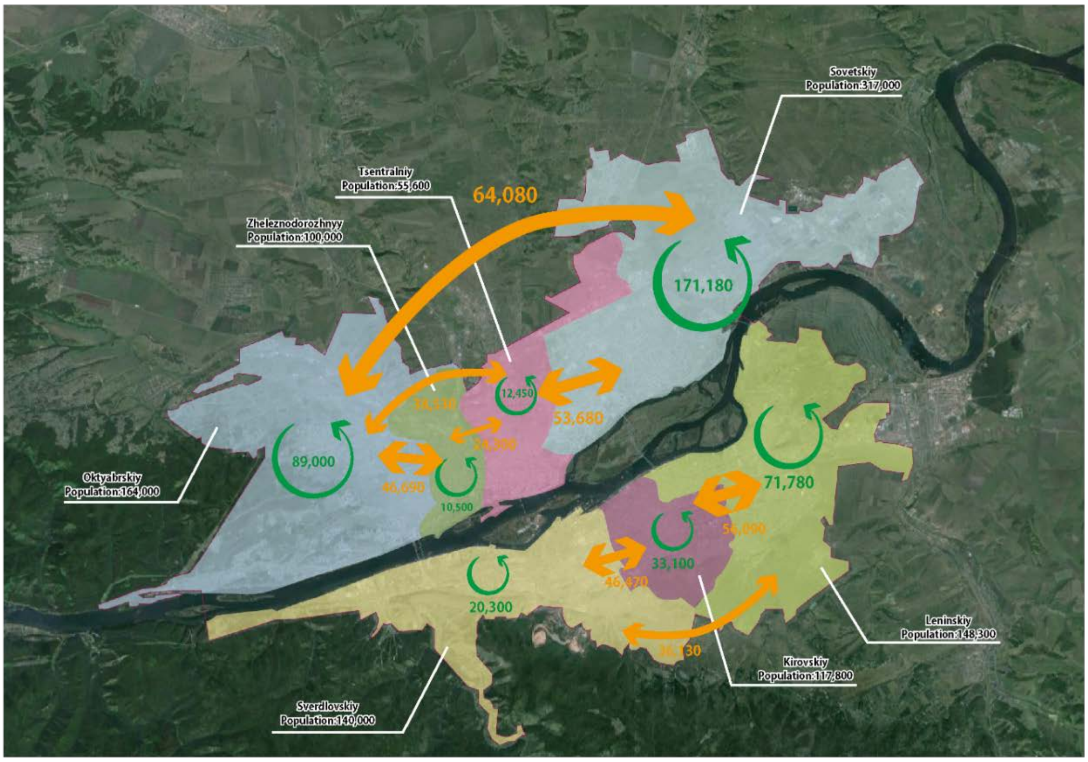
Fig 6.1.2 Population of each zone

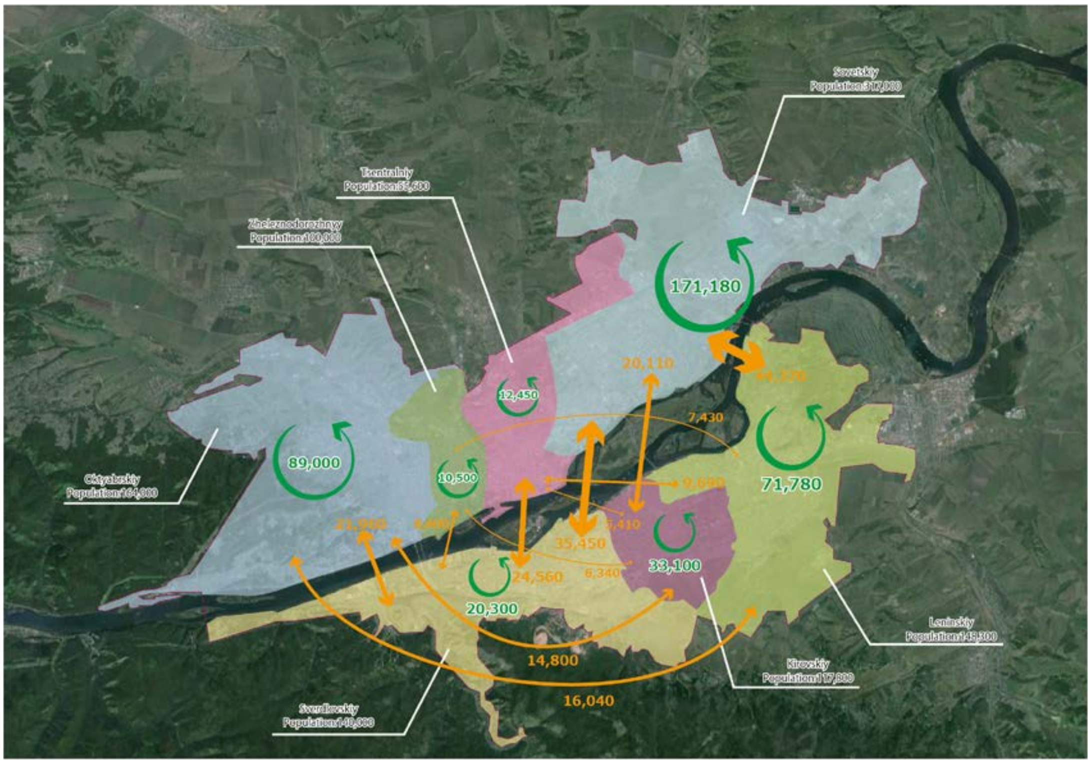


Source: NIKKEN SEKKEI Research Institute

The population of each zone in Krasnoyarsk city and the movement of people between zones are as follows. There is no big difference between movement within each zone and movement between zones, and people move evenly across the city. It is necessary to control the traffic load and environmental load caused by such movement.

Fig 6.1.3 People's movement between zones





Source: NIKKEN SEKKEI Research Institute

3) Road Infrastructure

The following is a major road map of the present situation and a future plan for Krasnoyarsk city.

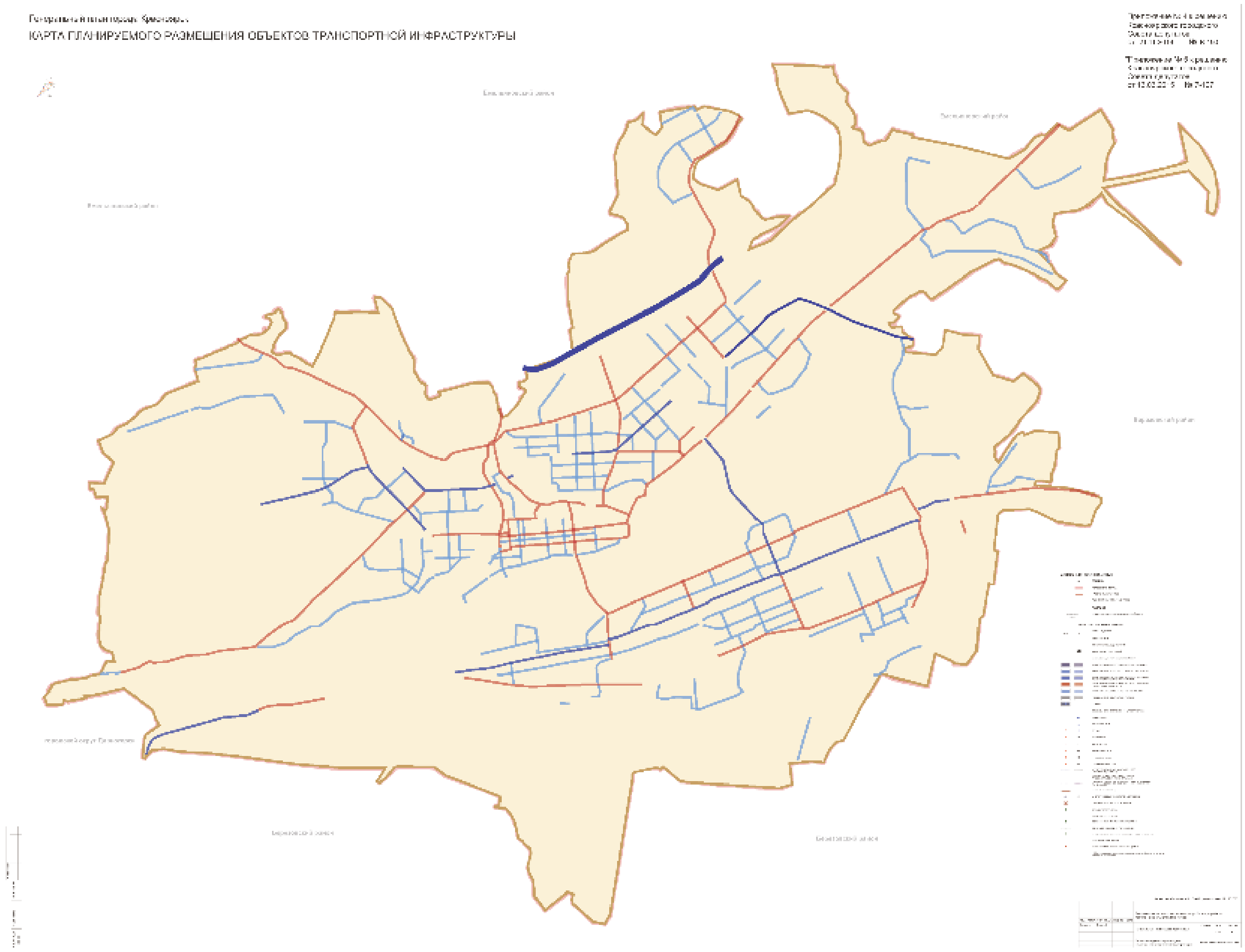
Present Situation

The river crosses the center of the Area, and there are only three roads connecting the north-south urban areas bisected by the river. There are arterial roads mainly in the zones Tsentralniy and Zheleznodorozhny (the north side of the river).

Highways are located on the northern side of the Tsentralniy and Zheleznodorozhny zones, and there are main streets of citywide importance and of regulated traffic (red line in the figure) leading to the peripheral zone and outer districts.

Zone Oktyabrskiy (northwest of the river) has no organized major road network connecting other zones. In the zone south of the river (Leninskiy and Kirovskiy, Sverdlovskiy), most roads run east-west.

Fig 6.1.4 Road map (present)



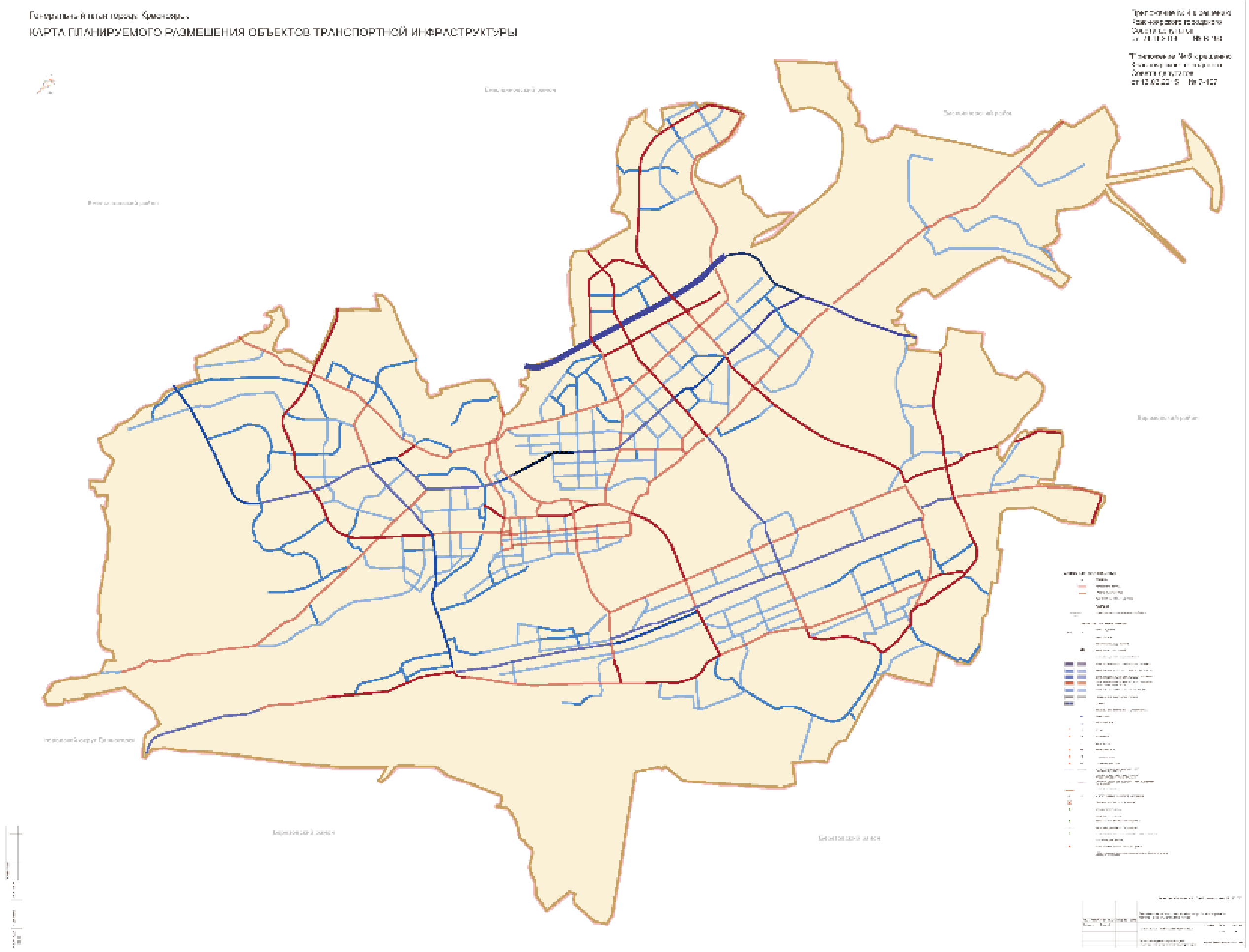
Source: Krasnoyarsk city administration

Plan

A new road connecting the north and south sides of the river has been proposed, in an effort to expand north - south road network crossing the river. The Oktyabrskiy zone (northwest of the river) is planned to form the main road network connecting the zones.

While the road network connecting the north and south sides of the river has been improved, a new road has also been planned to connect the south zones (Leninskiy and Kirovskiy, Sverdlovskiy) of the river.

Fig 6.1.5 Road map (plan)



Source: Krasnoyarsk city administration

4) Traffic

The number of registered vehicles in Krasnoyarsk city, broken down by type, is as shown below. The number of private cars is 316,812.

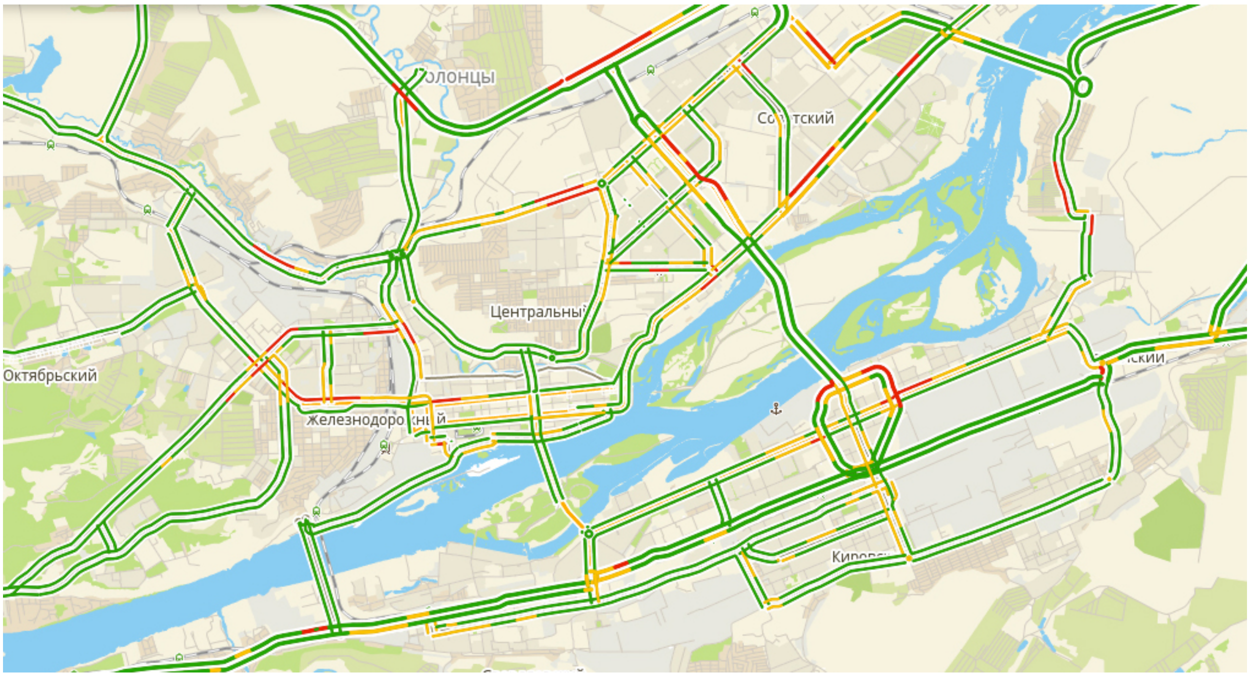
Table 6.1.2 Vehicle registration number

Types of Vehicles	Number of registered vehicles
Cars	316,812
Trucks	40,540
Buses	5,344
Motorcycles	3,542
Total	366,238

Source: Krasnoyarsk city administration

The situation of traffic congestion on the roads during the evening rush hour is as shown below. Congestion is occurring in front of a bridge crossing Yenisei river and on the periphery of the CBD.

Fig 6.1.6 Status of congestion on road



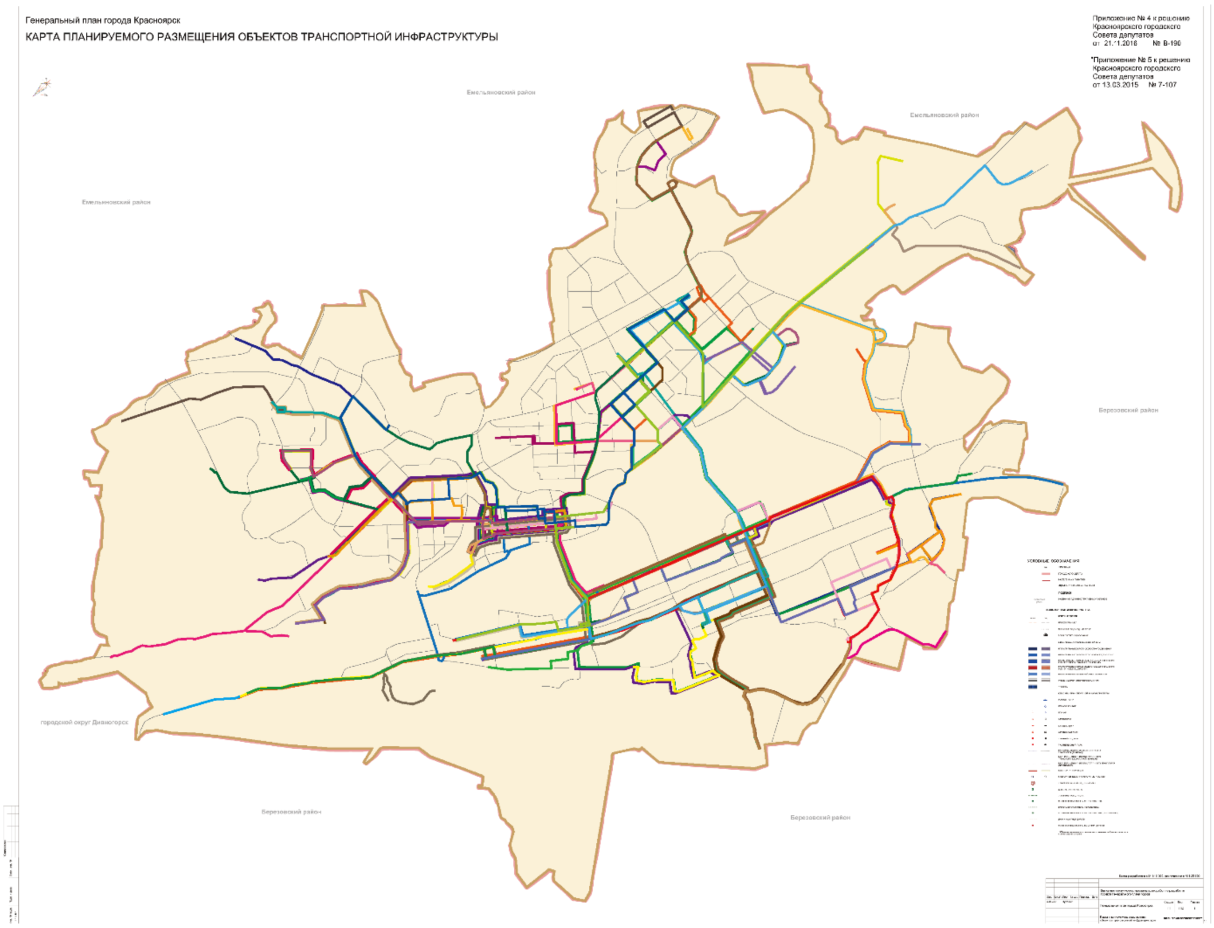
Source: Krasnoyarsk city administration

5) Public Transformation

Bus

The following is the bus route map for Krasnoyarsk city. On the north side of the river, the route passes mainly through the center of the Zheleznodorozhny and Tsentralniy zones. On the south side of the river, bus routes are set along the main north-south roads. There are a number of bus routes crossing the river, and this public transport serves to connect the north and south sides of the river.

Fig 6.1.7 Bus route map



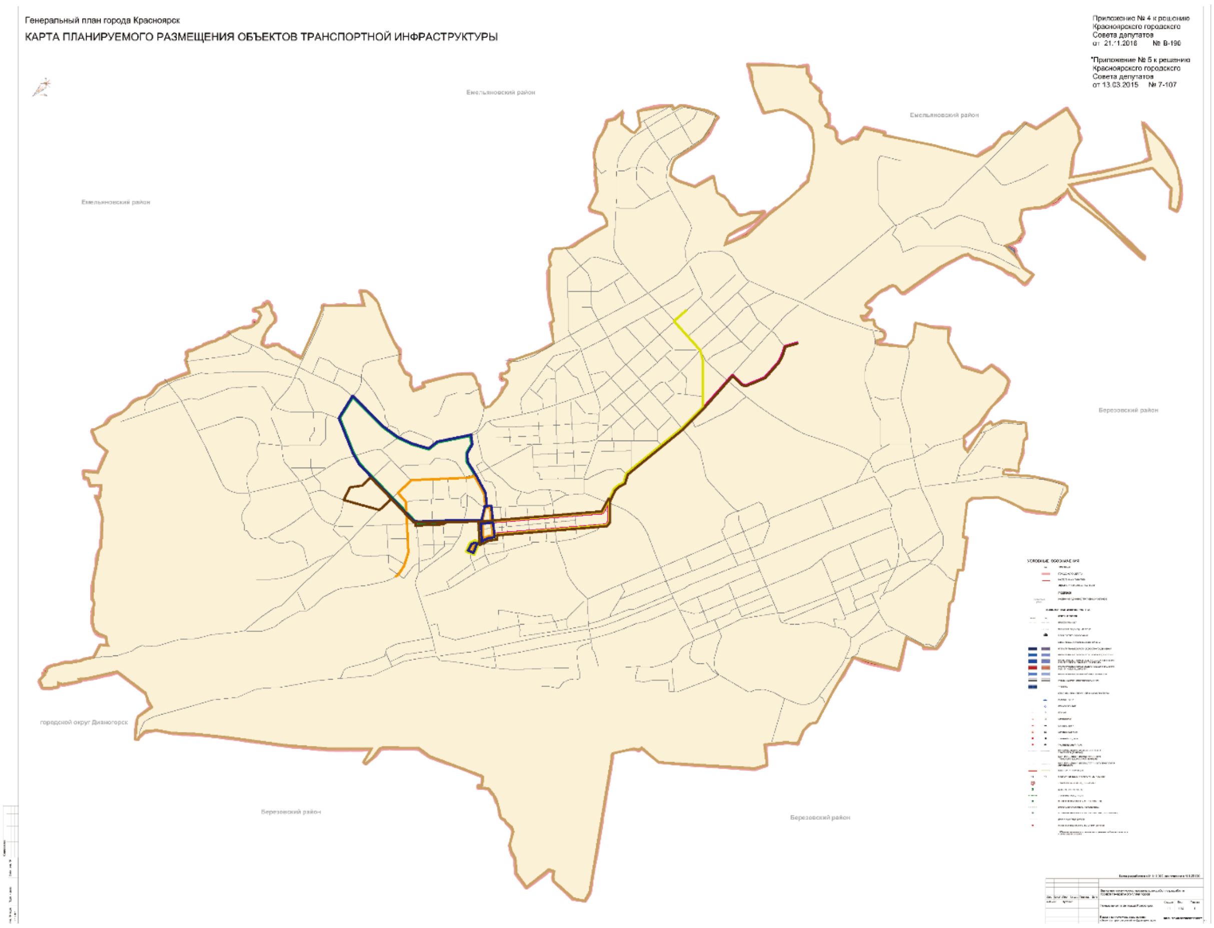
Source: Krasnoyarsk city administration

Trolley Bus

The following is trolley bus route map for Krasnoyarsk city.

The trolley bus routes are set only on the north side of the river. The route passing through the center of Zheleznodorozhnyy and Tsentralniy zones (north side of the river) has been set.

Fig 6.1.8 Trolley bus route map

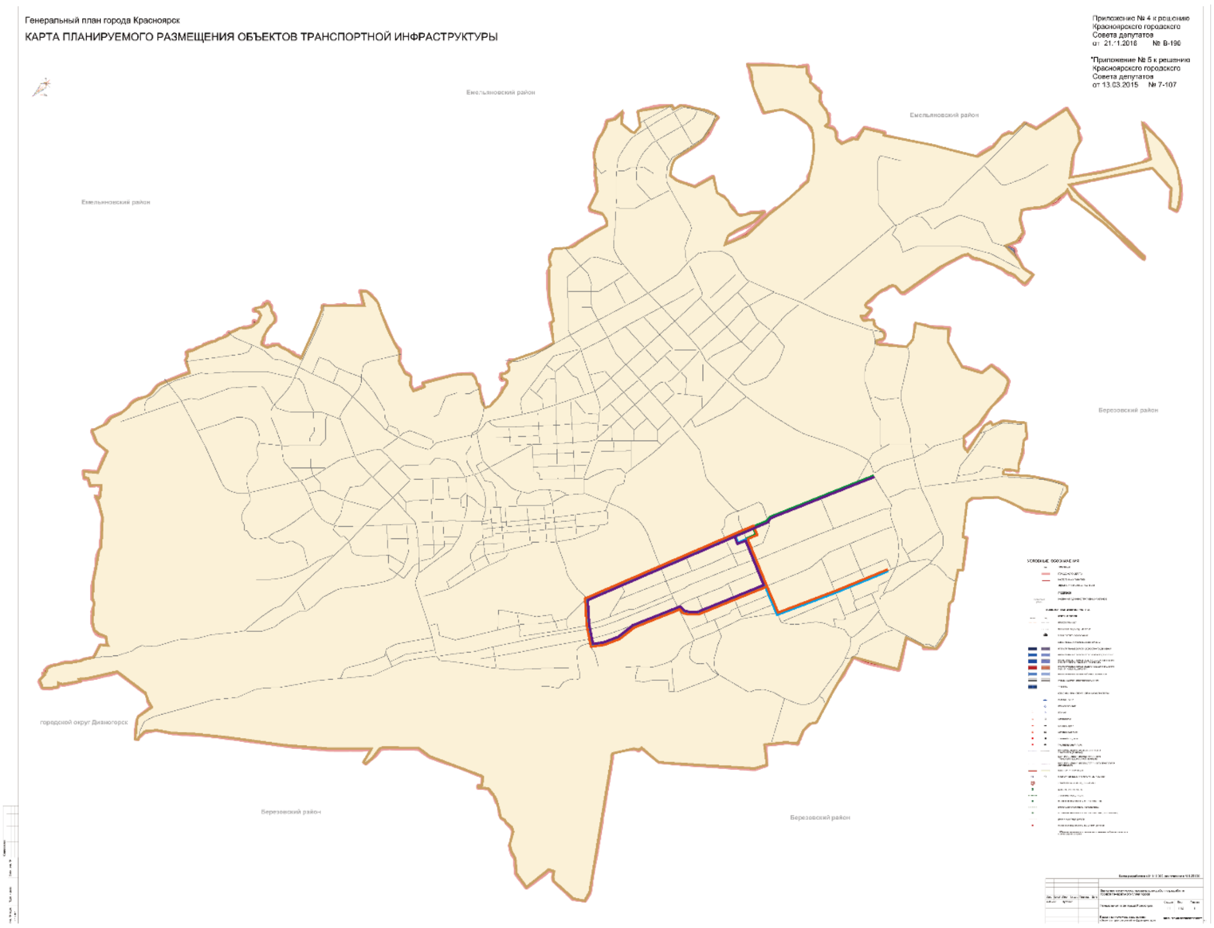


Source: Krasnoyarsk city administration

Tram

The following is the tram map for Krasnoyarsk city. Tram routes only run on the south side of the river.

Fig 6.1.9 Tram route map



Source: Krasnoyarsk city administration

Railroad Station

The locations of rail, subway and tram stations in the transportation plan are as follows. (*Including planned railway stations)

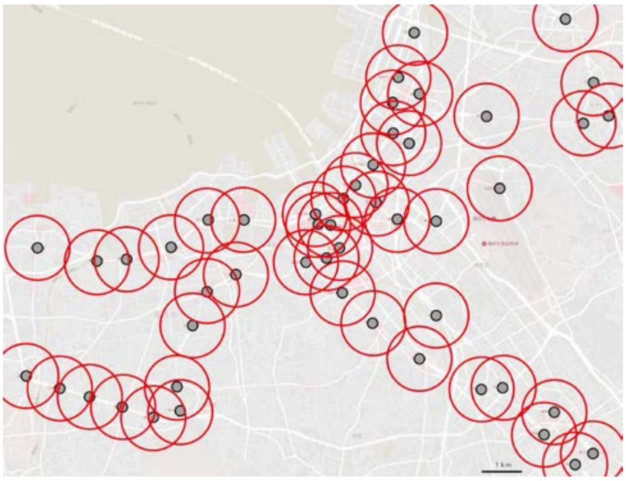
The walking area coverage rate considering the walking area (800 m) of the station is as follows.

The following are the location of the railway station and the 800m walking distance in Fukuoka city (population of 1.5 million people) in Japan. The density of the railway station is roughly comparable to the coverage rate of the walking distance.

Improvements to the subway line are planned, with extension planned to go through the CBD's Karla Marxa street. Since Karla Marxa street is a major flow of bus transportation, it is considered that there is potential to become a public transportation node.

Fig 6.1.10 Railroad Station Range Spot Chart

Fig 6.1.11 Location map of railroad station in Fukuoka (Same scale)



Source: NIKKEN SEKKEI Research Institute

6.2. District characteristics / tasks

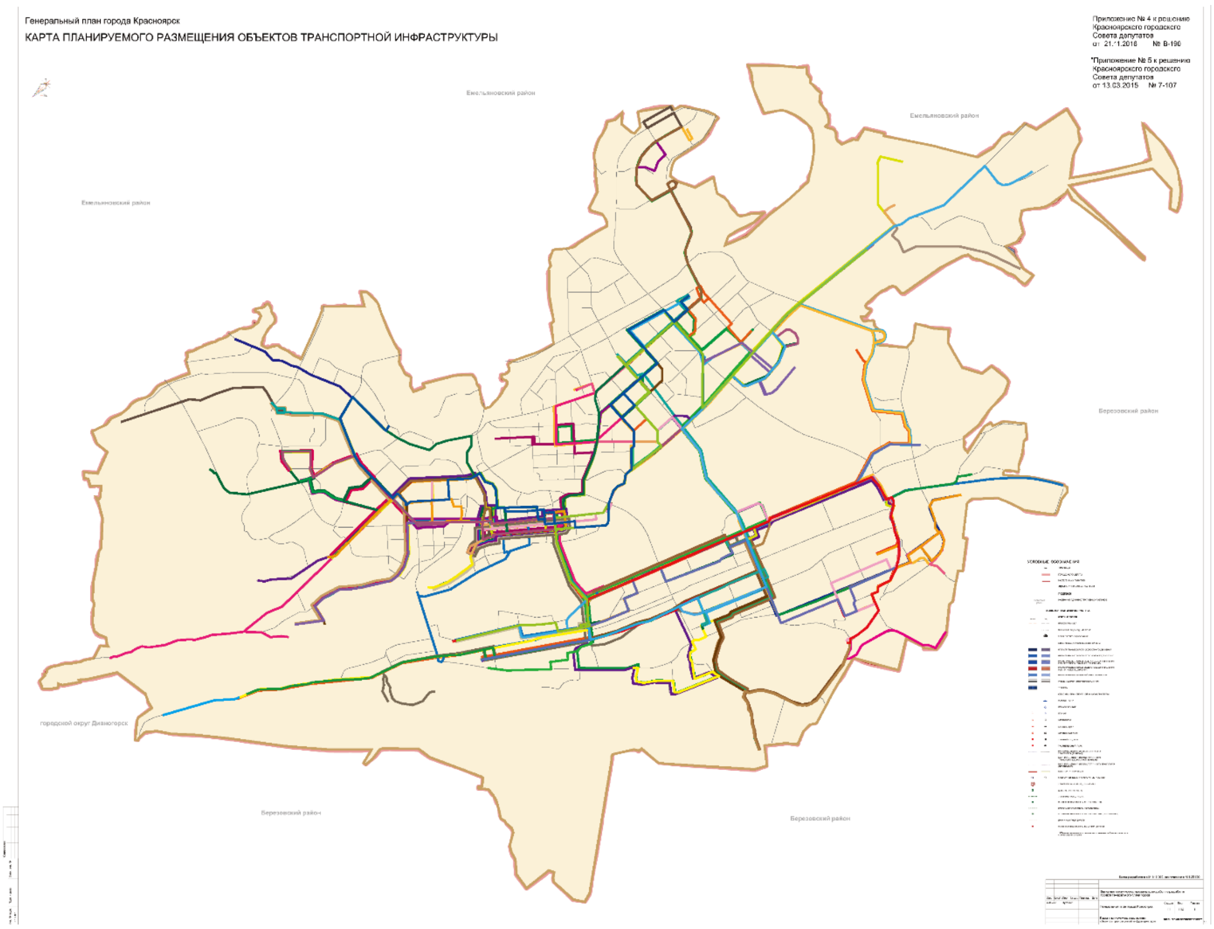
1) Characteristics: High potential area where public transportation is concentrated

Buses as the primary means of public transportation have routes to travel through each area via the CBD's Karla Marxa Street and Renina Street. Improvements to the subway line is also planned, and there is potential to become a significant intermodal node point.

This area is a mixed area of business, public, commercial, and residential functions, and many employees and visitors come in and out of the peripheral zone, which is a cause of traffic congestion.

Therefore, it is important to take measures to realize smooth movement of both public transportation and car traffic for CBD area.

Fig 6.1.12 Public transport route map



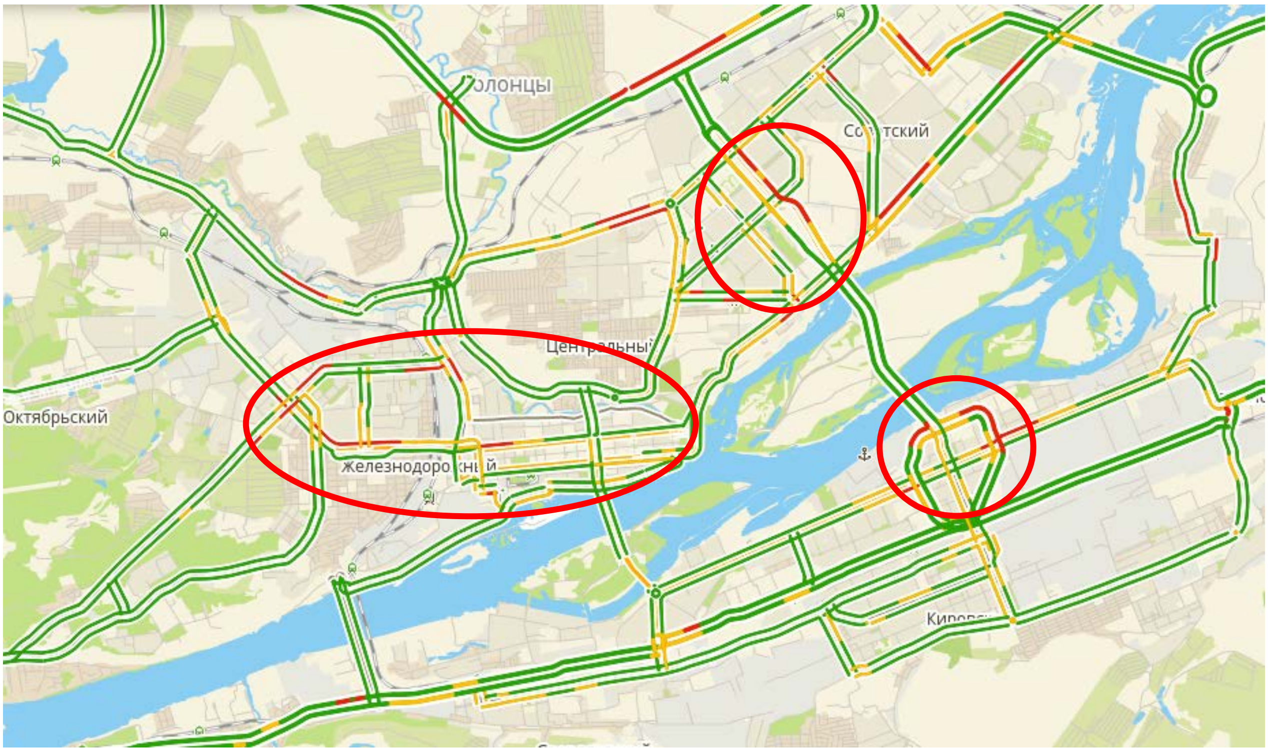
Source: Krasnoyarsk city administration

2) Task 1: Road traffic congestion in the pedestrian center area

In the center of Zheleznodorozhny and Tsentralniy, there is a concentration of traffic leading to congestion during morning and evening peaks.

Many pedestrians pass through the center of the city and cars and pedestrians are competing for the same space, so a safe and comfortable pedestrian space is not formed.

Fig 6.1.13 Traffic congestion situation



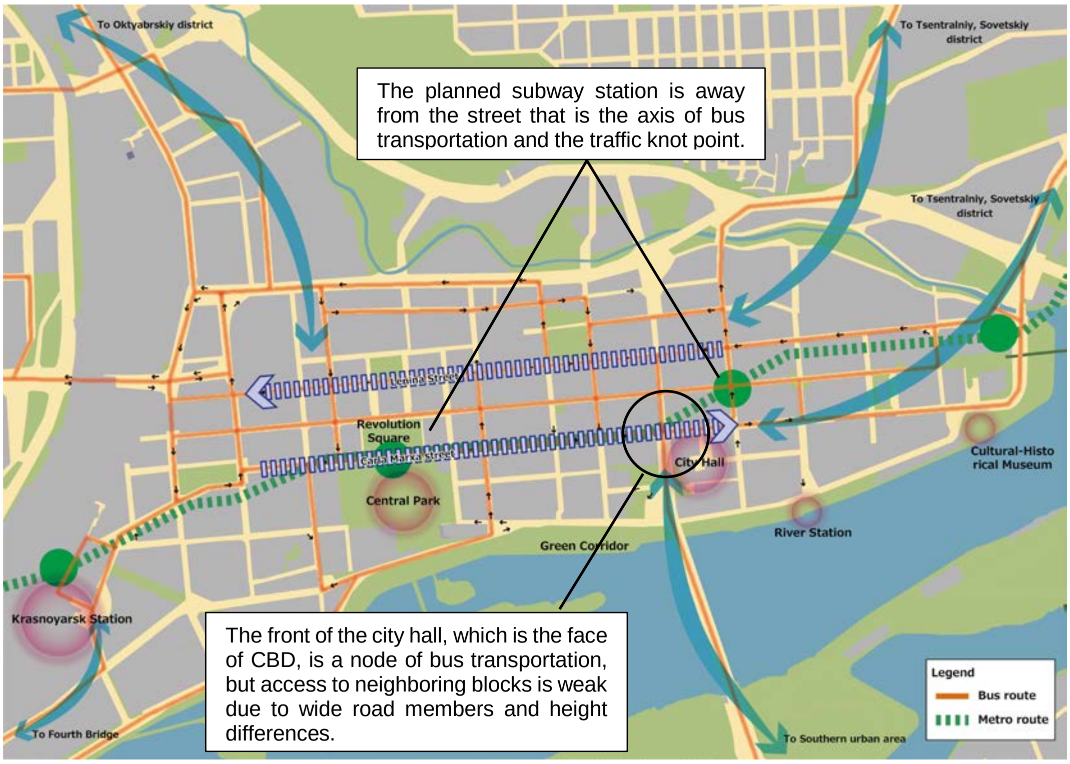
Source: NIKKEN SEKKEI Research Institute

3) Task 2: Nodule function of public transport

The bus transportation network is formed with Karla Marxa street and Renina street as a circulation line. However, access from the bus stop in the vicinity of the city hall, which is a major transportation node, to the surrounding blocks is divided by broad main roads and elevation differences.

Furthermore, the planned new subway station is far from the node and is considered to not sufficiently integrate with the existing public transportation network.

Fig 6.1.14 Network diagram of public transportation (current situation and current plan)



The bus stop and the surrounding blocks are connected by a deck, but there is a difference in height.

Source: NIKKEN SEKKEI Research Institute

4) Task 3: Traffic load on road by street parking

Residents of the district typically park on the street outside their house, so one street lane is used as a parking zone.
Even on major roads with heavy traffic, parking zones are installed on the street. As a result, entry and exit of parked vehicles affects both traffic and public transportation.
Paid street parking spaces are set up in the center, but due to the free parking located in the surrounding areas, proper use has not been achieved.

Since the City center comprises a mixture of business, commercial and residential facilities, and various parking lots are used, it is necessary to set detailed rules for using parking lots according to land use in each block.

Fig 6.1.15 Status of the parking lot on the road in the center

Street parking in a residential area

Impact on traffic due to street parking on the main street

Source: NIKKEN SEKKEI Research Institute

Fig 6.1.16 Position of street parking lots

Source: Krasnoyarsk city administration

6.3. Traffic planning policy

Based on the current situation analysis of the target area and the issues and characteristics of the district, consider the traffic plan with the target model of Zheleznodorozhny, Tsentralniy. Optimizing various movement modes lead to a public transportation system harmonized with automobile traffic.

Traffic planning policy : Construction of a transportation system harmonizing public transportation and automobile traffic by optimizing various movement modes

Traffic strategy

			Specific measures in the short-term, medium- and long-term in the model area
Optimization of automobile / public transport	Rebuilding and strengthening the public transportation network	◆Formation of transportation network where pedestrians, public transportation, automobiles coexist ・Organize the public transportation line that comprehensively passes through the district and the flow lines of pedestrians and cars and propose a way of a transportation network to aim for ◆Formation of a new public traffic flow line for facilitation of movement within the district ・Propose new public transportation necessary for the district while looking forward to the Universiade	◆Public transportation network ・Formation of a network for pedestrian, public transportation and automobile transportation within the district ・Formation of service flow line connecting major facilities in the district (proposal of bus route along river) ・Public transportation compatible with the Universiade and proposals for public transport becoming legacy (BRT maintenance) ・Proposal of new public transport connecting the north-south urban area combined with the 4th bridge development (tram extension)
	Parking control for reducing traffic load in the district	◆Reduction of traffic load by control of street parking ・Construct parking permission program in area unit according to land use and user attributes, control street parking in the district ・Build a cost burden scheme for street parking and promote necessary public facilities development ◆Parking management ・Creating a more accessible parking environment by sending accurate information to users ・Management of dispatch of parking space availability information	◆Parking plans ・Comprehensive parking regulation and relaxation according to the land use of the district（Area Parking Permit Program） ・Proposal on the mechanism of public toll collection for street parking ・Information on parking lot usage within the district
	Traffic optimization management	◆Smooth operation management of public transportation ・By facilitating the operation of public transport by operation management utilizing IT technology, creation of use environment excellent in punctuality and expressability	◆Traffic optimization management ・Proposal of optimization system for bus transportation utilizing IT technology ・Introduction of public vehicle priority system (PTPS)
Enhancement of traffic knot function	Formation of transport nodule base	◆Formation of transportation nodule base with superior convenience for transfer ・We plan to improve the convenience of bus transportation already developed by establishing a bus terminal in the district and building a pedestrian network connecting to neighboring block areas ・In terminal maintenance, we form a transportation base that will be the face of the district with excellent convenience and visibility	◆Formation of traffic node ・Formation of the transportation nodule base of the city hall (bus terminal maintenance), improvement of convenience for transfer ・Formation of pedestrian network traversing arterial road
Reduction of environmental burden	Efforts to reduce CO2	◆CO2 reduction ・Reducing CO2 by replacing general transportation and public transport vehicles with environmentally-friendly vehicles	◆Reduction of environmental burden ・Reducing CO2 emissions by replacing vehicles and changing public transit

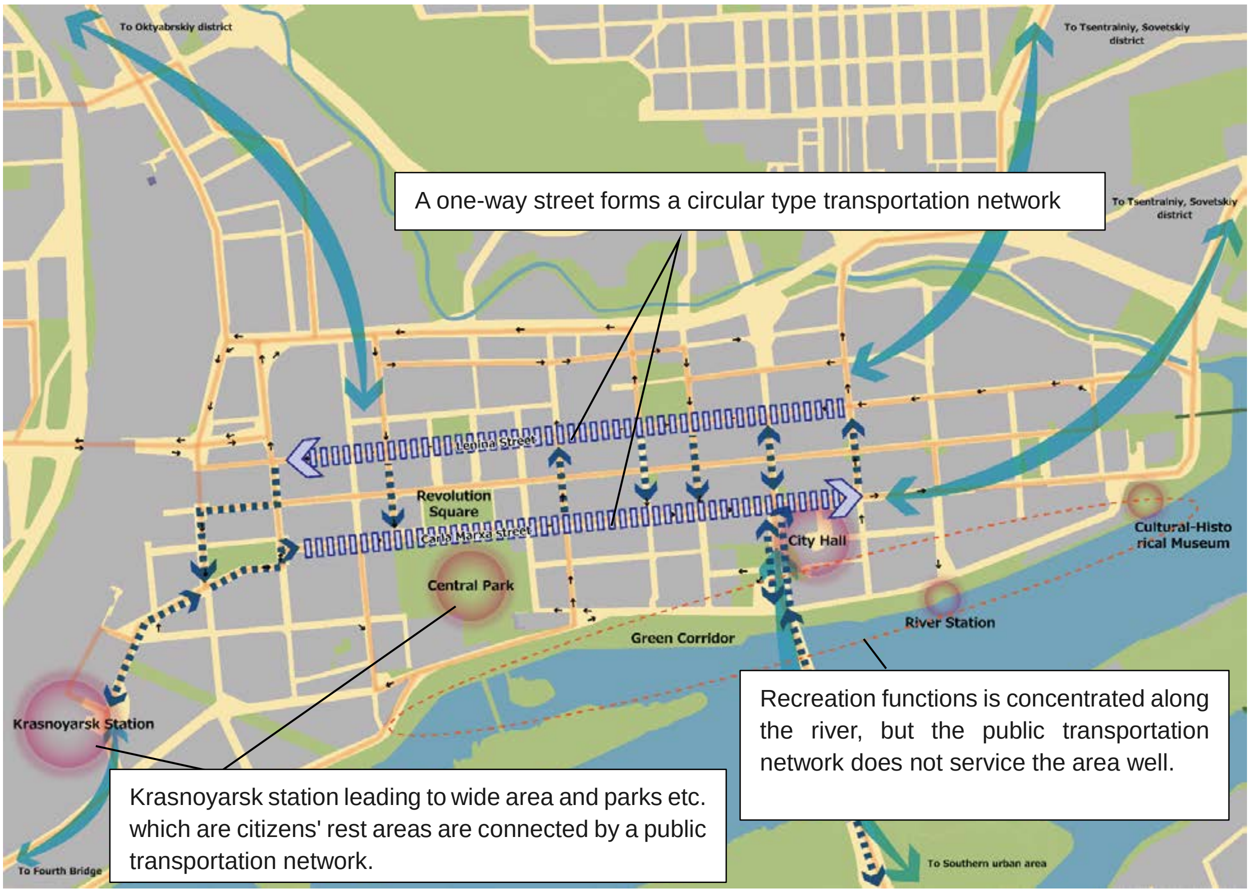
1) Optimization of automobile / public transport

Policy 1: Restructuring and strengthening the public transportation network

Formation of a transportation network where pedestrians, public transportation, automobiles coexist.

In the central area, bus traffic circulates through Karla Marxa Street, Renina Street and Krasnoyarsk station, which are predominantly one way, and connections from peripheral areas are structured to feed into this circular route. In addition, one lane of Carla Marxa Street and Lenina Street is designated as a bus lane. Traffic networks that see pedestrians and cars sharing the same space are formed around the main streets of such public transportation.

Fig 6.3.1 Public transport network diagram



Source: NIKKEN SEKKEI Research Institute

Formation of a new public traffic flow line for facilitation of movement within the district

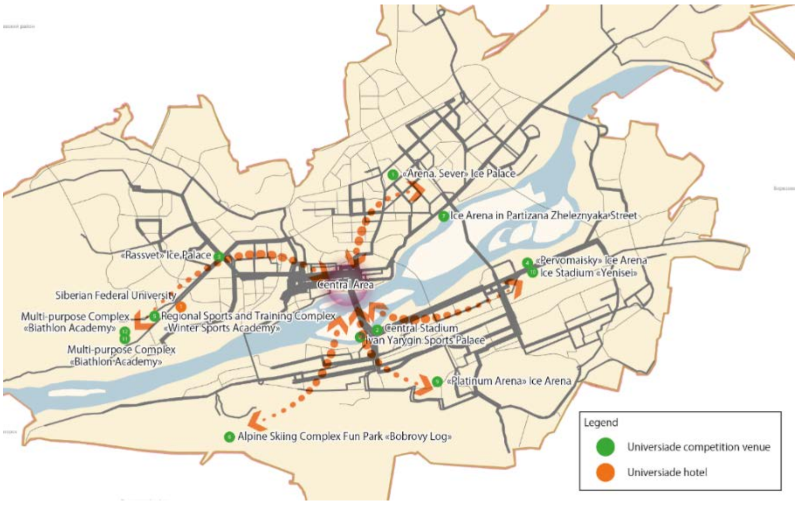
Along the river Yenisei on the north side of the city, green roads, cafes, docking spaces, museums and cinemas are located, and events are held in the plaza, making it a popular space for citizens to stop by and rest. On the other hand, there are few bus lines accessing this area along the River Yenisei, making it inconvenience to access by public transportation. We propose a new bus route as a service flow line in the area connecting resources in the area.

At the Universiade in 2019, 3,000 competitors, 25,000 visitors and 5,000 volunteers are expected to participate. During the period the event is being held (9 days), temporary priority transportation bus routes connecting the city's sports facilities and accommodation facilities will be provided. At that time, utilizing the bus lanes of Carla Marxa Street and Lenina Street as dedicated bus only lanes, improved express service is proposed. Depending on the results of this operation, it is intended that the bus exclusive lanes will become permanent as a legacy of the Universiade.

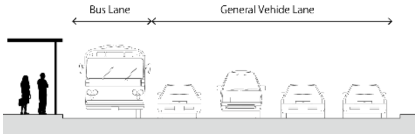
There are three flow lines connecting the north and south urban areas of the Yenisei river, and provision of a fourth bridge is scheduled near Krasnoyarsk station. Although it is planned to respond to the movement demand in the Sverdlovskiy district and Oktyabrskiy district, it is necessary to respond to the demand for movement from the south side city area to the Sovetskiy district & Tsentralniy district. (*Movement in southern urban area → Oktyabrskiy district · Zheleznodorozhnyy district to 9%, migration in southern urban area → Sovetskiy district · Tsentralniy district by 25.4%)

As a long-term effort, the tram line will be extended in the southern urban area in line with the development of the bridge connecting the Kirovskiy district to the Tsentralniy district (as described in the transportation plan) in response to the movement demand from the southern urban area to the Sovetskiy district & Tsentralniy district. By introducing a tram extending to the transit node in front of the city hall, (described later), a highly convenient transfer environment to the bus network is formed. This will encourage ridership of public transportation between north and south urban areas, and will help to alleviate congestion in the bottleneck area near the crossing bridge.

Fig 6.3.2 Bus network connecting Universiade facilities

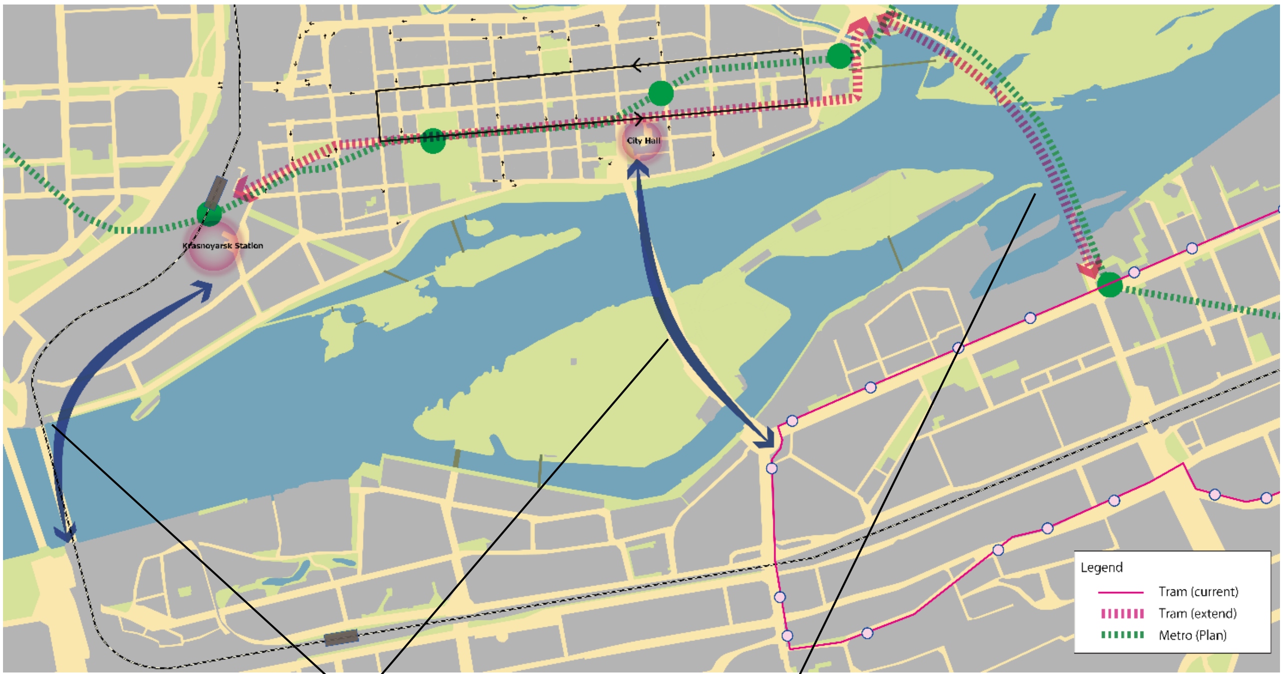


As a strengthened transportation in the Universiade, a one-lane dedicated bus lane is to be operated, and BRT developed within the district as a legacy



Source: NIKKEN SEKKEI Research Institute

Fig 6.3.3 Improvement of the city's north-south public transportation network by extending the tram in the future



A network of bus transportation utilizing bridges connecting the north-south city areas.

Extend the Tram in the southern urban area in conjunction with a new connecting bridge to strengthen connection with the CBD on the north.

Source: Krasnoyarsk city administration

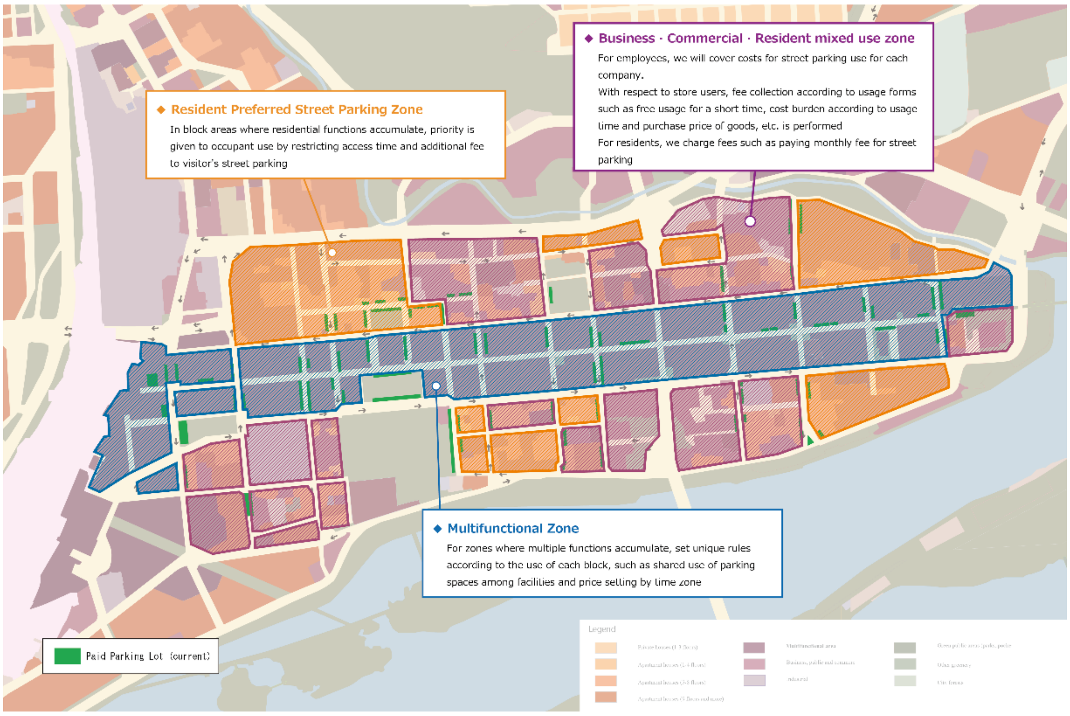
Policy 2：Street parking control to reduce traffic load in the district

Reduction of traffic load by control of street parking

The central area has an accumulation of business, commercial, residential, public, culture, green space functions, etc., and there is a variety of mixed land uses. Accordingly there are many types of users with varying demands for on-street parking space. Instead of uniformly regulating on-street parking within the central area, it is proposed to implement a parking permission program in units of streets according to the land use of each block, to control street parking in the central area. (※ See the case of San Francisco, and Portland)

A pilot project for paid parking in the center of Krasnoyarsk has been in effect since April 2015, but because there is free parking in the nearby vicinity, it is difficult to effectively utilize. In Korea, a resident preferred street parking system was established and a private parking area was set up on "back roads" (alleys with a road width of less than 12-m, which is closely related to residential units), and then a resident preferred parking system. We propose a legal framework that can be introduced. Although it has been free until now, the establishment of the system, is expected to gain citizen understanding by providing a discounted rate relative to private parking lots. By introducing such a mechanism in the area, it is possible to construct a mechanism of paying a fee for using the public space and to promote the improvement of public facilities utilizing the revenues arising from these resources.

Fig 6.3.4　Zoning to control street parking



Source: NIKKEN SEKKEI Research Institute

Parking management

Creating an efficient and easy-to-use parking environment by accurately transmitting information on parking usage within the district to users.

Example of improving convenience for parking lots –Marunouchi park-in service-17 locations covering the Marunouchi and Yurakucho areas from Otemachi and approximately 3,500 parking lot operators will work together to receive the same service at any parking lot. By installing signs of the same design at the entrance of the parking lot, we provide easy-to-understand guidance to users.

Fig 6.3.5 Marunouchi park-in service

Marunouchi Park In Overall view

Source: Marunouchi Park in

Common parking lot entrance sign

Example of a parking lot search system -Times parking search system-Search parking position on the map. We can check the latest full empty vehicle information in real time. Route search from your current location to Times parking lot is also possible.

Fig 6.3.6 Times parking Information

Parking lot operated

Source: Times24 Co., Ltd.

Parking lot search by smartphone

CASE (resident preferred type): San Francisco

SFMTA uses a combination of parking meter, residential parking permission (RPP), time limit, color restraint regulation to manage on-street parking.
SFMTA considers factors of "land use" and "peak stay" when determining the optimum parking management for each block of the whole city.

Fig 6.3.7 San Francisco Residential Parking Permit Areas

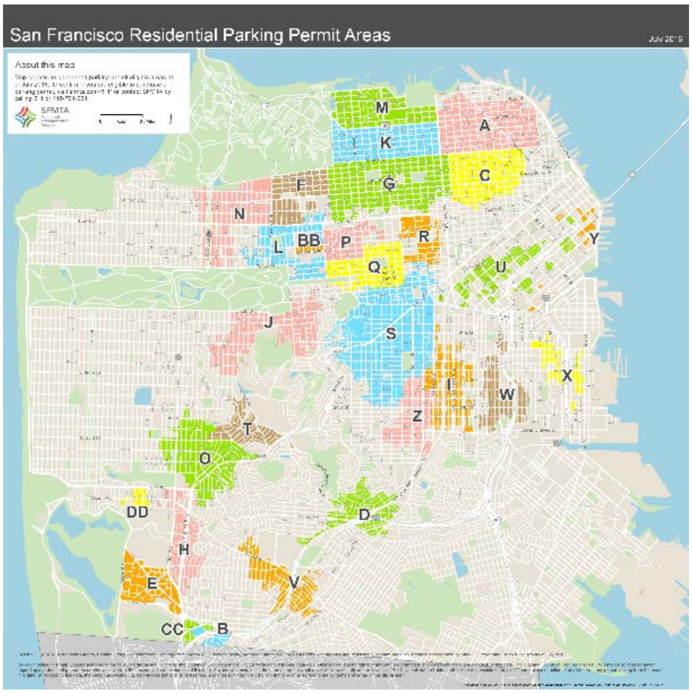


Table 6.3.1 Parking management decision chart

Parking Management Decision Chart

Parking Zone	Peak Occupancy > 80%	60%–80%	< 60%
Residential – Low Density	RPP[1]	Unregulated	Unregulated
Residential – Med. Density	Furthenalysis[2]	Further analysis[2]	Unregulated
Residential – High Density	Meter	Further analysis[3]	Unregulated
Mixed Use	Meter	Further analysis[3]	Unregulated or time limit
Industrial/PDR	Meter	Further analysis[3]	Unregulated or time limit
Neighborhood Commercial	Meter	Meter or time limit	Unregulated or time limit
Public	Meter	Meter or time limit	Unregulated or time limit

[1] For a block/area to qualify for RPP more than 50 percent of parked cars must be attributable to commuters. This is measured by a license plate survey from a sample of vehicles. This analysis is part of the routine review of RPP applications.

[2] The built environment within these zoning categories varies significantly in density and context. As a result, further SFMTA analysis as outlined in this document will help determine the correct tool for these blocks. For example, there are some blocks with many single family homes in these categories, which may be best managed using the RPP program, but there are also multi-level apartment buildings adjacent to commercial corridors which may be best managed by parking meters.

[3] These cases may require additional SFMTA analysis.

Fig 6.3.8 Sticker showing parking zone

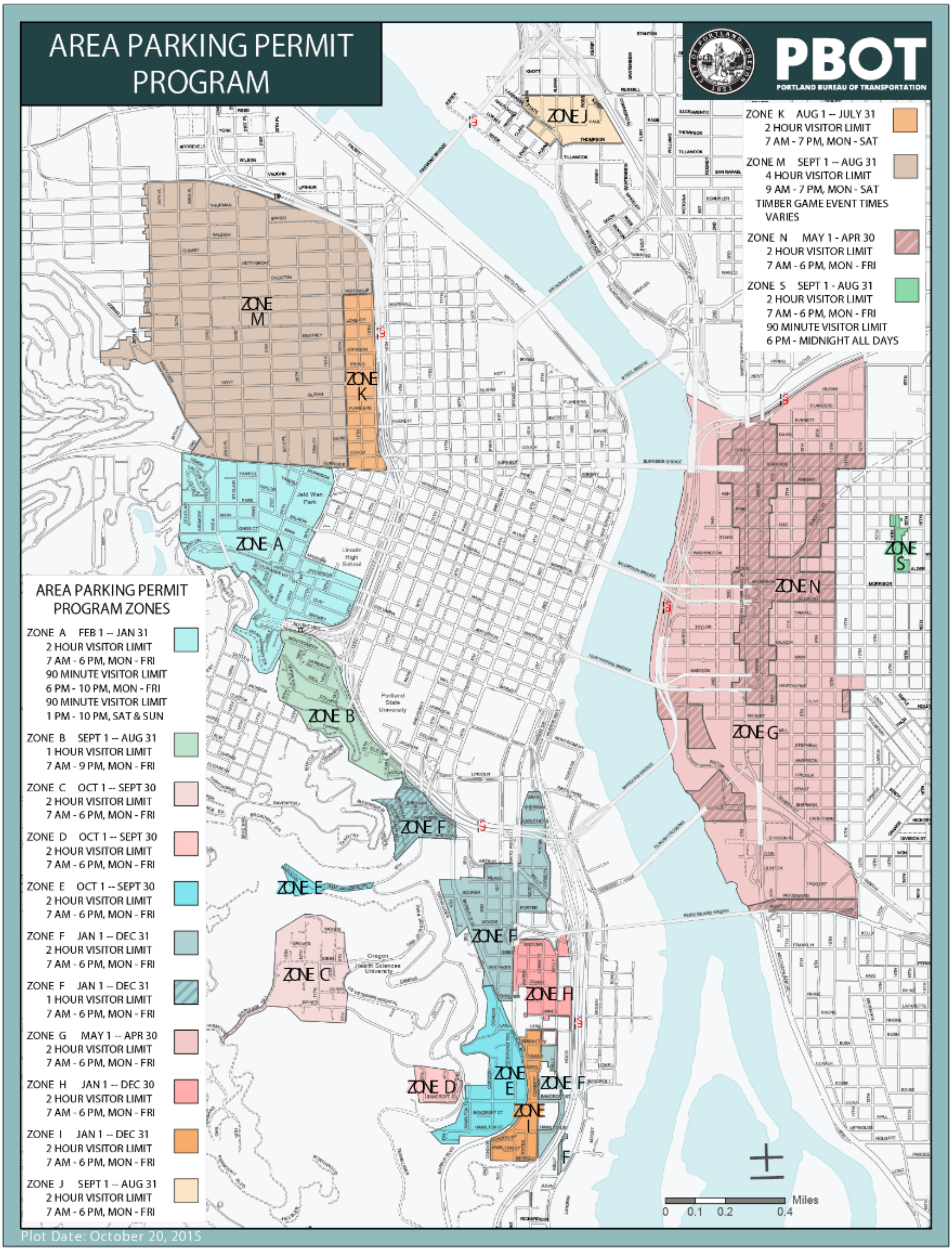
Fig 6.3.9 A system that indicates the availability of parking lots on the road

Source: San Francisco Municipal Transportation Agency

CASE (Restricted visitor): Portland

This program is designed to help people living or working in areas with commuting parking problems by creating time limits for visitors. People who are doing business or living in that area can purchase permission so that they can park beyond visitor restrictions.

Fig 6.3.10 Area parking permit program



Source: Portland bureau of transportation

CASE: Resident preferred parking system / Seoul, South Korea

System Overview:

This system was designed to encourage a pleasant traffic environment by eliminating parking difficulties and traffic congestion. Residents are assigned a paid parking space in their neighborhood. Parking spaces are secured for residents by preventing outsiders from parking their cars in the neighborhood. Exceptions are emergency aid vehicles, which may access the area at all times and do not require an assigned parking spot. Parking orders are secured to eliminate conflicts among neighbors.

Background and detailed rules:

The parking law was amended on 29 December 1995; after establishing a private parking area on "back roads", nearby resident domicile with less than 12m width, to secure parking space, legal framework was established to introduce preferential parking systems for residents. On 11 March 1996, in accordance with this, the resident priority parking system detailed enforcement standard was established in Seoul. Since 1 July 1996, boroughs have been encouraged to revise and tailor their ordinances. Although there are some differences between boroughs, parking is charged, and costs 30,000 won during the daytime per month, 20,000 won during the evening, and 40,000 won for all day for a month. Although there was opposition from citizens to charging fee for previously free parking space, to date it seems that it is by no means a big burden. The accepted average price of a private parking space in Seoul is 140,000 won a month. It can be said that this policy has been effective in raising citizen awareness that "parking costs money".

Each borough, when allocating a parking space to residents, sets the priority as follows.

First: For families with disabilities, homes for the elderly, people with serious illness, etc., a parking space closest to place of residence is preferentially allocated.

Second: One parking space is allocated per household who have lived in the area for three months or more

Third: The remaining parking spaces are allocated by lottery

In fact, management including distribution is carried out by each borough, and special cases might be set up by resident committee when necessary.

Fig 6.3.11 Status of the parkable area on the street

Fig 6.3.12 Crackdown on parking violators

Source: Seocho city, South Korea

Policy 3: Traffic Optimization Management

Smooth operation management of public transport

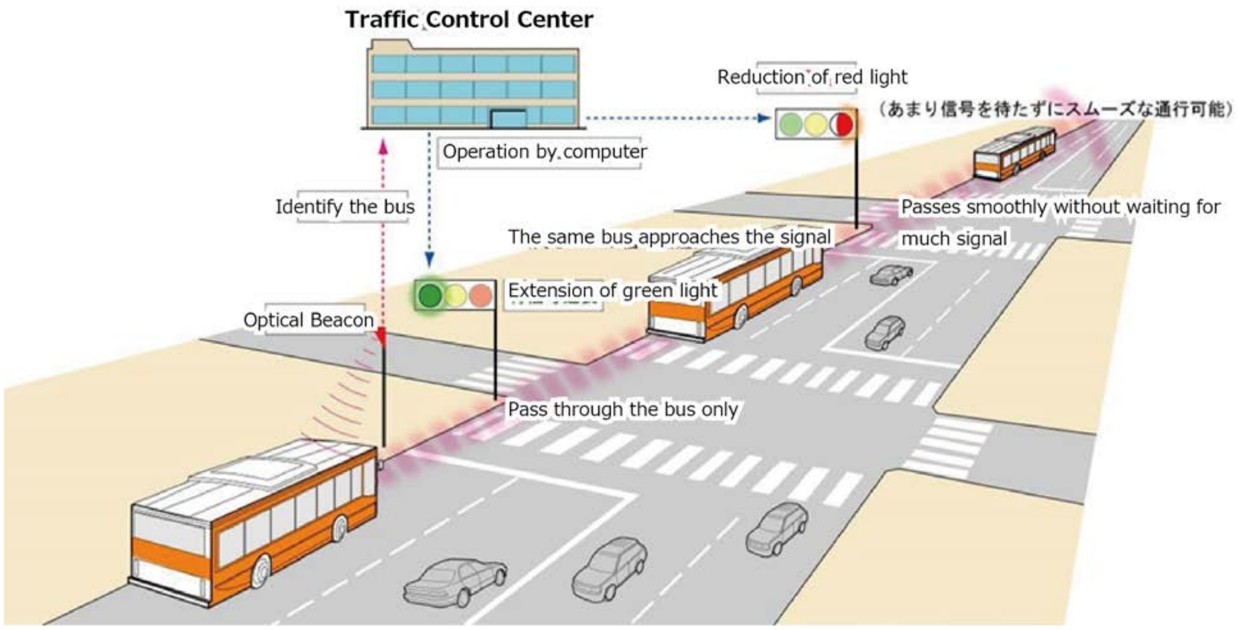
By facilitating the operation of public transportation through operation management utilizing IT technology, an excellent punctual service can be provided with potential for provision of express service.

Case study on punctuality and express service operation of public transportation

Public Transportation Priority System（PTPS）

The Public Transportation Priority System (PTPS) is a traffic system that conducts priority signal control for buses. The proximity of the bus is sensed by the communication system through optical beacons installed at the intersections and devices mounted on the buses, controlling traffic such as buses in cooperation with traffic lights. This system increases the scheduling of bus operations and improves user convenience.

Fig 6.3.13　Public Transportation Priority System



CASE：Bus route of Sagamihara city, Kanagawa prefecture, Japan

【Section】

・Lobby City intersection – Sagamihara Park entrance intersection Distance: Approximately 3.5 km

・Kamimizo Station intersection – Takada Bridge intersection Distance: Approximately 3.9 km

【Effect】

・Reduced average travel time during weekday peak hours（16%～17%）

Case of demonstration experiment on safety operation of transportation

SAFETY MAP is a service that displays on a map frequent sudden breaking points collected from Telematics car navigation systems and traffic accident information from police. Local residents are also able to participate in this map creation, and they are able to write information such as "poor visibility", or "there are many speeding cars", etc.

※Telematics

A coined word combining “telecommunications” (communication) and “informatics” (information science). It refers to an information service provided in real time to vehicles.

Fig 6.3.14 System of safety map

Source: Honda

Fig 6.3.15 Image of safety map screen display

Source: Honda Motor Co., Ltd.

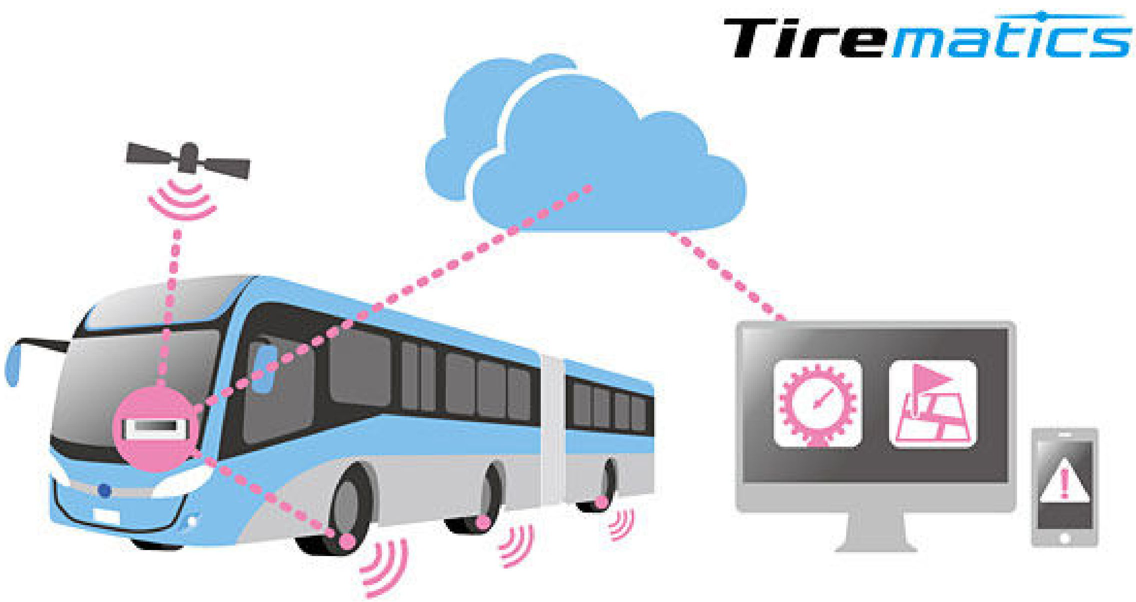
Demonstration experiment on efficiency of maintenance:

BRT transportation demonstration experiment utilizing tire sensors in Rio de Janeiro, Brazil.

Outline of experiment

The demonstration set out to test a new transport solution utilizing the IT system, "Tirematics" with BRT transportation companies, the major means of public transportation in Rio de Janeiro. (Implementing company:
Bridgestone Inc., Bridgestone do Brasil Industria e Comercio Ltda (BSBR)). Tirematics is an IT system that measures air pressure and temperature of truck/bus tires using sensors and monitors remotely in real time through a network, together with vehicle position information.

Fig 6.3.16 Image of Tirematics



Source: Bridgestone

Possibility of additional value

1. Contribution to safety and scheduled operation
   The system enables tire information to be quickly understood during operation with a high level of precision in real time. When abnormal air pressure/temperature is detected, vehicle managers and drivers are notified by an alert. This makes it possible to prevent unexpected operation troubles due to tire failure and contributes to safe transportation and scheduled operation.

2. Contribution to improving the economic efficiency
   Monitoring the tire information remotely makes it unnecessary to check the internal pressure manually, enabling significantly more efficient and effective tire maintenance.

2) Enhanced traffic integration functionality

Policy 3: Formation of traffic nodes

Formation of multimodal transportation hubs for superior transfer convenience

Establish bus terminals in the district together with integrated pedestrian networks connecting to surrounding block areas to improve the convenience of the existing bus transportation system.

Specifically, develop a bus terminal within the city hall premises located at the intersection of Carla Marxa Street and Communal Bridge, on the main arterial bus route, to form a transfer zone for buses from the central city to various areas. By utilizing the difference in level between Carla Marxa Street and Communal Bridge, a bus terminal can be developed in the basement of the city hall and connected to the surrounding blocks across the main road with a network of underground pedestrian passages, providing easy access, convenience and visibility. It will also form a transit hub area to comfortably spend a few moments during the cold season, and a present a fresh face of the public transit system.

The bus terminal will provide information functions such as sending operation information of each bus route and city event information, a guide center, a lounge in which to take a break, etc., to form a highly convenient traffic terminal.

A concentration of commercial facilities around the bus terminal will form a bustling space integrated with commercial buildings, movie theaters, etc. in the surrounding blocks.

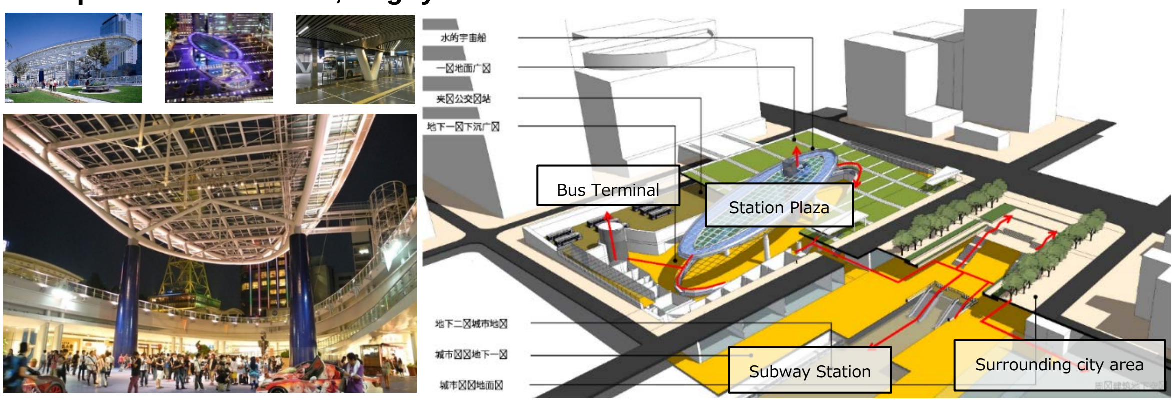
In addition, by arranging accommodating a variety of mobility modes, such as setting a rental cycle facility in the transportation node, a true transportation hub catering to the various needs of users is formed.

The tram extension is proposed in the medium to long term plan and the subway plan is a component of the traffic plan. By planning the tram line and the subway station together with the bus terminal and preparing it as a multimodal node for smooth and comfortable interchange, it is possible to further improve access convenience in the city's public transportation system.

Fig 6.3.17 Image of enhanced traffic integration functionality

Source: NIKKEN SEKKEI Research Institute

Example of Bus Terminal, Nagoya Oasis 21



Example of Bus Terminal, Shinjuku, Tokyo

Source: Oasis21, Busta Shinjuku, Japanvisitor.com

3) Reduction of environmental burden

Policy 1: Reducing CO2 emissions through hard and soft measures

CO2 reduction through hard efforts

CO2 in the traffic field is mainly emitted by private automobiles. One reason for this is because, as compared with public transportation such as railways and buses, automobiles emit a large amount of CO2 per person. In order to reduce CO2, it is effective to control the traffic volume of automobiles, use forms of public transportation with less CO2 emissions, reduce travel distance and reduce the amount of CO2 emitted by each car. In addition, it is effective to change bus transportation, which is the main form of public transportation, to vehicles with low CO2 emissions, and to reduce the amount of CO2 emitted by each bus.

Based on the above, measures to reduce CO2 emissions in the transport sector are as follows.

CO2 emission ＝ Traffic (Traffic volume) × Travel distance (Distance traveled) ×Emission factor (Emission intensity)

(A) Case where no measure is taken (Business As Usual)

A. Public Transportation

CO2 emissions for each form of public transport are as shown in the table below.

[Calculation expression]

Calculate the total daily travel distance of each public transport and the product of CO2 emission indicator per fuel.

※ CO2 emission indicator uses the average value from the Ministry of Land, Infrastructure and Transport's automobile fuel consumption list (route bus). This numerical value is the numerical value of the vehicle currently being produced, taking into consideration that the current running vehicle is an old vehicle, the correction value based on the transition of the fuel regulation value is reflected.

Public Transportation	Fuel	Daily km	CO2 emission indicator ※ (g-CO2/km)	Correction value	CO2 emission (g-CO2)	CO2 emission (t-CO2)
Buses	Diesel	197,022	556	1.2	131,453,078	131.45
	Gas	8,683	456	1.2	4,750,504	4.75
Trolley buses	Electricity	6,317	145	1.2	1,095,823	1.10
Trams	Electricity	9,795	145	1.2	1,699,158	1.70
TOTAL					138,998,563.30	139.00

B. Car Transportation

CO2 emissions for car transport are as shown in the table below.

[Calculation expression]

To calculate the mileage per day for the whole city, multiply the population of the city by the average daily trip number per capita and the average mileage per trip. To that value, CO2 emission indicator is integrated to calculate the CO2 emissions of the car. For the average mileage per trip, the numerical value of an equivalent-scale population city in Russian Federation urban traffic characteristics survey result shall apply mutatis mutandis.

※ CO2 emission indicator uses the average value from the Ministry of Land, Infrastructure and Transport's automobile fuel consumption list.

Population (2016)	Number of trips by car per person (per day)	Trips by car per day	1 trip km	Total km per day	CO2 emission (g-CO2/km)※	CO2 emission (g-CO2)	CO2 emission (t-CO2)
1,075,382	1.4	1,505,534.8	13.3	20,023,613	130	2,603,069,669	2,603.0697

(B) Case of 2030

As for CO 2 reduction in 2030, we propose to switch to bus transportation and general automobiles to environmentally friendly vehicles. For environmentally-friendly vehicles, the efficiency of EV vehicles in cold areas is low, so we assume the introduction of gasoline and electric hybrid vehicles.

Public Transportation	Fuel	Daily km	CO2 emission indicator ※ (g-CO2/km)	Correction value	CO2 emission (g-CO2)	CO2 emission (t-CO2)
Buses	Diesel	197,022	411	1	80,976,042	80.98
	Gas	8,683	456	1	3,958,753	3.96
Trolley buses	Electricity	6,317	145	1	913,186	0.91
Trams	Electricity	9,795	145	1	1,415,965	1.42
TOTAL					87,263,946	87.26

For conversion of general vehicles to environmentally conscious vehicles, we have assumed a level of 50% in 2030 and 100% in 2050.

The population of 2030 refers to the World Population Forecast of the United Nations, and the population estimation ratio of Russia as a whole applies mutatis mutandis.

Population (2016)	Population (2019)	Population (2030)	Population (2050)
1,075,382	1,120,724	1,127,170.802	1,124,080.729

Population (2030)	Number of trips by car per person (per day)	Trips by car per day	1 trip km	Total km per day	CO2 emission (g-CO2/km)※	CO2 emission (g-CO2)	CO2 emission (t-CO2)
1,127,171	1.4	1,578,039	13.3	20,987,920	71	747,343,790	747
					130	1,364,214,822	1,364
TOTAL							2,112

(C) Case of 2050

As for CO2 reduction in 2050, CO2 can be reduced by switching from general automobiles to environmentally-friendly vehicles and switching to public transportation across the north-south urban areas by extension of LRT.

A. Car Transportation

Population (2030)	Number of trips by car per person (per day)	Trips by car per day	1 trip km	Total km per day	CO2 emission (g-CO2/km)※	CO2 emission (g-CO2)	CO2 emission (t-CO2)
1,124,081	1.4	1,573,713	13.3	20,930,383	71	1,490,589,982	1,491

B. Modal Shift from automobile traffic between north-south urban areas to public transport

Traffic volume	Transition (50%)	1 trip km	Total km per hour	Total km per day	CO2 emission indicator (g-CO2/km, Reduction amount)	CO2 emission (g-CO2, Reduction amount)	CO2 emission (t-CO2, Reduction amount)
16,626	8,313	13.3	110,563	2,653,510	130	344,956,248	345

C. Changes in CO2 emissions in 2030 and 2050 due to these efforts are as follows.

	BAU 2016 (t-CO2/a)	Mid-term (2030)	Long-term (2050)
Public transportation	50,734	31,851	26,437
Car transportation	950,095	770,719	418,156
TOTAL	1,000,829	802,570	444,593

D. Cost validation

The costs necessary for implementing the above CO2 reduction menu are as follows.

For public transportation, the cost was calculated by replacing the currently registered bus with an environmentally-friendly bus.

For stretching of the tram, the stretching distance was multiplied by maintenance cost per km. The maintenance cost was set based on Japanese LRT maintenance case.

E. Public transportation

Number of registered bus	Bus cost per unit	Total Cost (Thousand Ruble, 1YEN = 0.52Ruble)
5,344	31,400,000	167,801,600

F. Transition to public transportation between north-south urban areas

Tram extension distance (km)	Cost per km	Total Cost (Thousand Ruble, 1YEN = 0.52Ruble)
7.5	1,094,200,000	8,206,500

7 MULTI-ENERGY SYSTEM

7. Multi Energy System

7.1. Background of the energy supply in Russia and Krasnoyarsk city

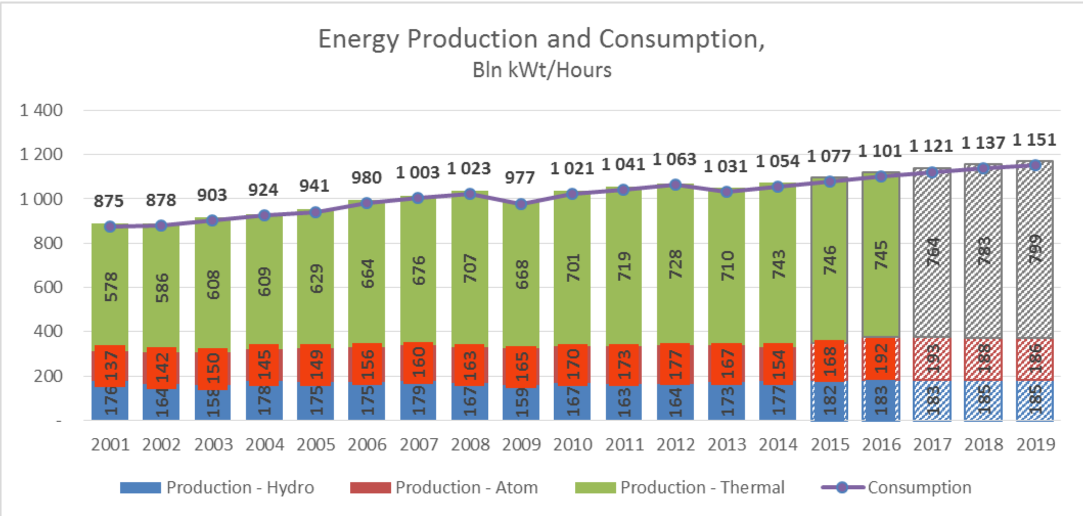
7.1.1. Background of the energy supply in Russia

1) Electricity

The Russian energy system consists of 69 regional energy systems that are brought together into seven interconnected power systems (IPS): Northwest, Centre, Middle Volga, Urals, South, Siberia, and East. Six out of seven systems are run in synchronous mode at a frequency of 50 hertz, while the East IPS forms a separate synchronous zone that is connected to the Siberia zone via a back to back reversible station (200 MW) which is now in test operation. (Source: Russia 2014, IEA)

As shown in Figure7.1.1, Total electricity generation in Russia in 2016 was 1,119 terawatt hours (TWh) and the total electricity consumption was 1,101 TWh. Electricity production has been increasing since the late 1990s, with a slight decline during the economic recession in 2009. Total electricity output increased by 20.2% from 2002 to 2012, notwithstanding a moderate increase of 3.8% in total generation capacity according to the IEA report.

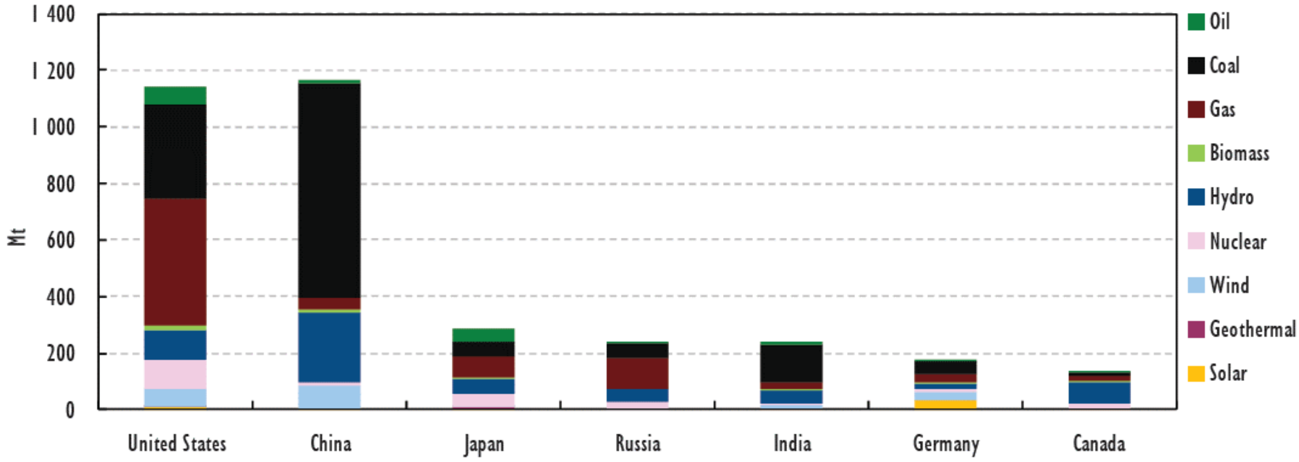
Figure.7.1.1 Power production and consumption of Russia, 2001-2019



Source: Nomura Research Institute, Russia Branch

In 2012, as shown in figure 7.1.2, Russia's installed capacity is the fourth-large in the world, after the United States, China and Japan. As a main fuel source for electricity generation, natural gas usage has grown in the past decades and has reached 109GW of the total 223 GW of installed capacity in 2012.

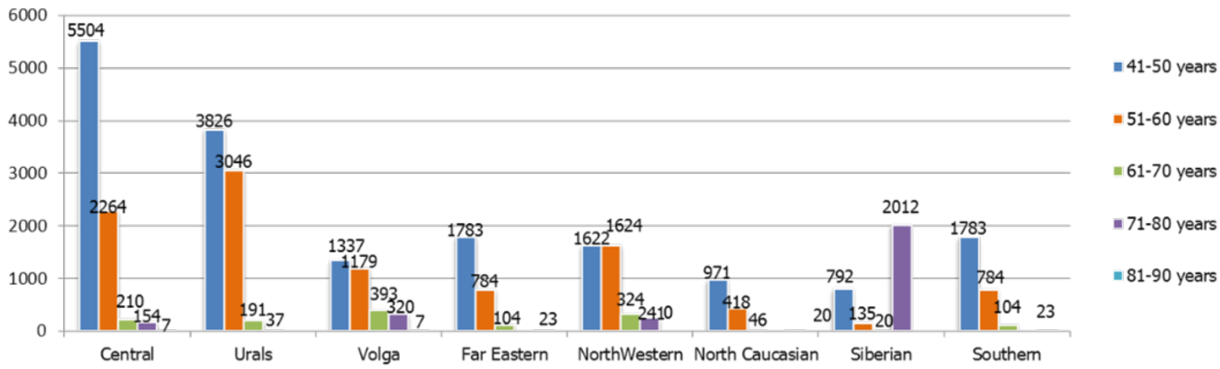
Figure.7.1.2 Installed electricity generation in key global economies by fuel, 2012



Source: Russia 2014, IEA

As shown in figure 7.1.3, majority of Russian CHP plants are more than 40 years old and average between 50 years old and 60 years old. The potential to reduce losses in generation, transmission and distribution as well as end use is particularly large.

Figure.7.1.3 Russia CHP Plants: Years in operation, MWt (all fuels)



Source: Nomura Research Institute, Russia Branch

Meanwhile, Capacity Utilization Factor (CUF) in Russia has been declining. If we compare electricity consumption data in 2012 with 1990, installed capacity in 2012 is 32.7 GWt higher. Main reasons for the CUF declining include:

(1) Increase of the requested reserved capacities,

(2) Worsening of technical conditions.

2) District heating

Russia has the largest district heating system in the world. Heat supply facilities in the city supply heating energy for two-thirds of the year, due to its severe cold climate. Currently, heat supply facilities are extremely inefficient due to aging of facilities and the use of lignite.

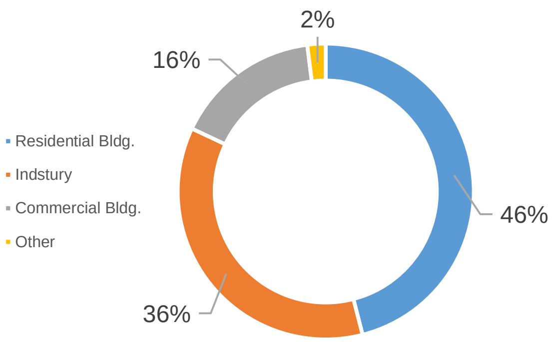
According to reports from IEA, total heat production from centralized district heating systems in Russia was about 1.6 billion gigacalories (Gcal) in 2012, marking an increase of more than 10% since 2000. Heat production from non-centralized systems was estimated at about 45 million Gcal in 2012. Meanwhile, over 30% of heat or 484 million Gcal was produced by around 651 CHP plants, and 56% was produced by roughly 73,600 heat-only boiler houses. Co-generation from industrial plants represented about 8% of centralized heat production.

Fuel consumption for district heating systems is larger than for power generation and represents around one-third of total primary energy consumption. The fuel mix of the district heating systems primarily consists of natural gas, coal and oil products. Renewable energy accounts for about 4% of total heat supply but is only rarely used for district heating.

About 70% of the population, or about 100 million people, are connected to district heating systems, and on average, a Russian household consumes from 15 to 18 Gcal/yr of heat. In addition, about 12.5 million houses are heated by burning wood, peat or coal.

The heating season for centralized district heating systems starts at different times and has varying lengths across Russia, depending on geography and local climate conditions, which has an impact on production and loss levels.

Figure.7.1.4 Heat load proportion by end-user in Russia



Source: METI, 2016

Figure.7.1.5 Centralized heating system (heat-only boiler house in Krasnoyarsk city)

Source: NIKKEN SEKKEI Research Institute

7.1.2. Background of the area energy supply in Krasnoyarsk city

1) Electricity

As shown in figure 7.1.6, power generation in the city comes from CHP Plant # 1, CHP Plant #2, and CHP Plant # 3. The electricity goes to the federal wholesale market of energy and power.

The total electricity consumption of the city in 2016 is 6.78 billion kWh. (Excluding JSC "RUSAL Krasnoyarsk", which is aluminum smelter industry).

Table.7.1.1, Power consumption by sector in 2016 (excluding Krasnoyarsk Aluminum Smelter)

Groups of consumers (excl. "RUSAL Krasnoyarsk")	Consumption for 2016 (MWh)	Consumption for Jan. 2016 (MWh)	Consumption for June. 2016 (MWh)
Industrial consumers over 750 kVA	1,388,681	151,267	84,720
Industrial consumers below 750 kVA	375,134	37,240	22,397
Electric public transport	19,172	1,876	1,087
Nonindustrial consumers	3,665,074	516,026	162,425
Agricultural production consumers	5,581	609	314
Population	1,329,192	128,383	95,603
TOTAL	**6,782,834**	**835,401**	**366,546**

Source: Krasnoyarsk city administration

2) District heating (DH)

Since Krasnoyarsk city is an extremely cold district, the district heat supplying system covers most of the city, and roughly 8 months is set as the heating period throughout the year from NSRI's research. Therefore, district heat supplying system is an important infrastructure as a lifeline for Krasnoyarsk citizens.

Krasnoyarsk has a humid subarctic continental climate with severe winters, no dry season, warm summers and strong seasonality. Over the course of a year, the temperature typically varies from -26°C to 25°C and is rarely below -35°C or above 29°C. According to the historical weather data of Krasnoyarsk city, the number of annual heating degree days (HDD) is 233 and the heating load of whole city is roughly 4567.5 Gcal/h. Most heating energy is supplied by the district heating system.

Lignite (brown coal), which is considered the lowest rank of coal due to its relatively low heat content, however, is used as the main heating fuel for heating. Meanwhile, most of the district heating system which has been constructed a long time ago, now is becoming aged and inefficient.

Table.7.1.2 Heating energy supplied in 2016

Company	Thousands of Gcal per year	Thousands of Gcal per month	Thousands of Gcal per day
Siberian Generating Company	9252,6	1156,6	38,5
"KrasTEK"(Krasnoyarsk heat and energy company)	404,8	50,6	1,6
"KrasKom"(Krasnoyarsk Housing and Communal Complex)	52,9	6,6	0,2

Source: Krasnoyarsk city administration

Table.7.1.3 Fuel consumption of CHP plants in 2014

Facility	Installed Capacity (MWt)	Working Capacity (MWt)	Fuel Consumption	
			Coal (toe)	Heavy Oil (toe)
CHP-1	481	270.6	986,680	-
CHP-2	465	332.4	1,099,424	776
CHP-3	208	164.6	589,336	1,337

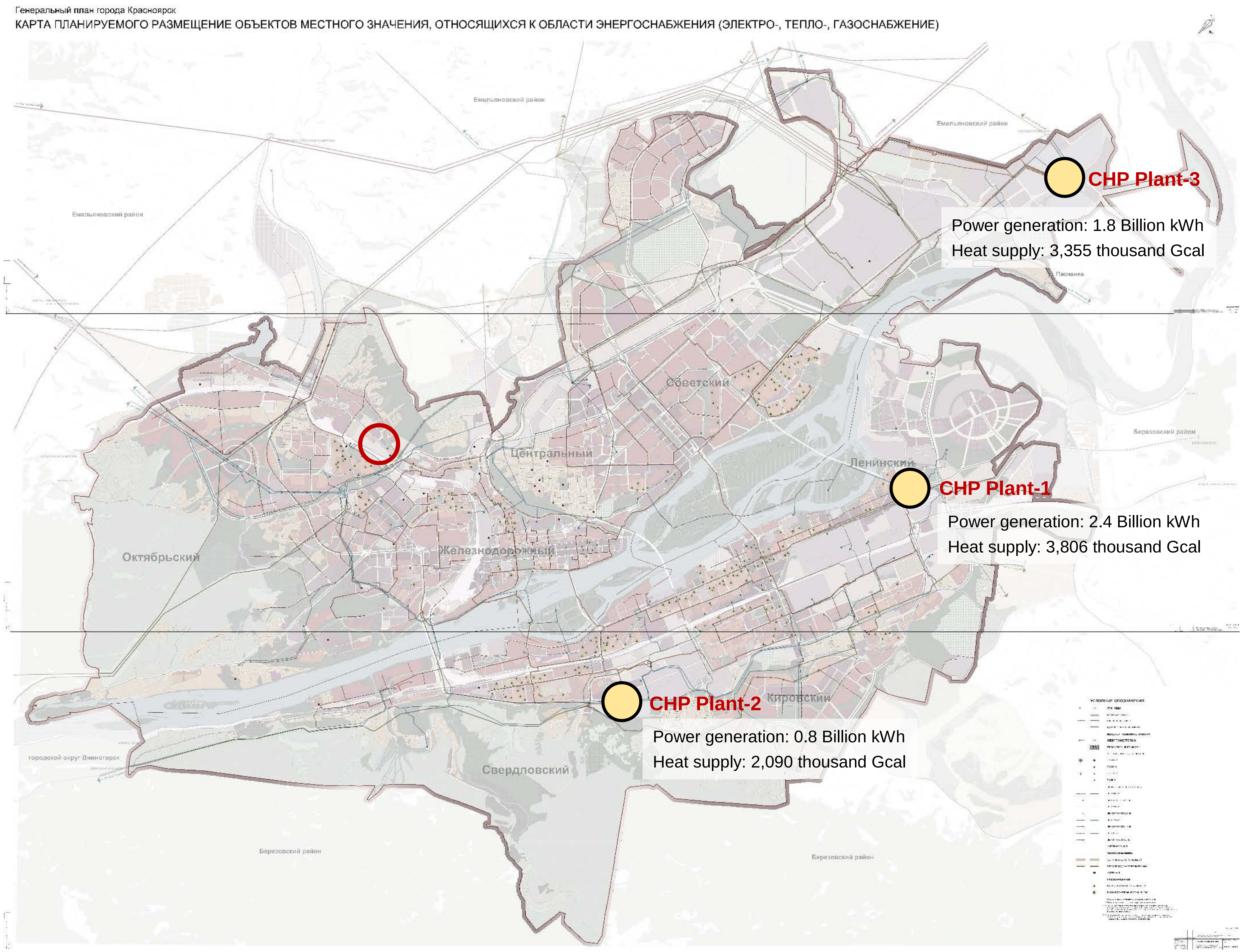
Source: Nomura Research Institute, Moscow branch

Table.7.1.4 Energy consumption by fuel type of energy organizations (2014)

Organization	Type	Fuel Type	2014 consumption (thousand toe)
CHP 1~3	Combined Heating and Power Plant	Coal	2,675.4
		Heavy Oil	2.1
Kraskom	Boiler house	Coal	39.6
Krastek	Boiler house	Coal	135.2
Regional Thermal Company	Boiler House	Coal	70.3
Kramzenergo	Boiler House	Coal	130.4
Other	Boiler House	Coal	94.2

Source: Nomura Research Institute, Moscow branch

Figure.7.1.6 Electricity and district heating energy supply map (2016)



Source: Krasnoyarsk city administration

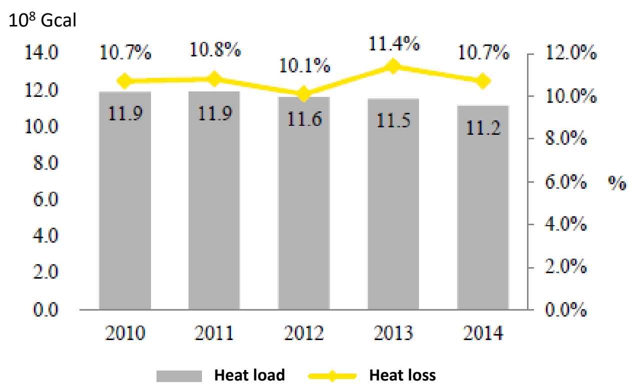
7.2. Low-carbon development strategy of multi energy system

7.2.1. Reduce heat loss in the existing heating pipe network

In the district heating segment, heat loss due to ageing transmission networks has to be taken into consideration. Strategy includes reducing heat loss in the supply chain by modernizing the transmission network.

There are in particular massive energy losses in distribution, especially between substations and radiators, due to lack of insulation and leakages. According to Rosstat (Russian Federal State Statistics Service), more than 10% of heat loss occurs during the heating distribution process, compared with 5% to 10% for the OECD average. Yet in some regions and municipalities, heat network transmission losses can be over 40%.

Figure.7.2.1 Heat load and heat loss ratio in Russia



Source: Rosstat

Figure 7.2.2 Thermal Insulation of High-temperature Heating Pipe Network

Source: Regulation and planning of district heating in Denmark, 2015, Danish Energy Agency.

Good insulation not only prevents personal injuries and damage caused by fire, it also substantially contributes to the prevention of heat loss.

Fortunately, insulation material used for heat transfer pipes is continually improving, allowing heat to be distributed over long distances with relatively lower losses. This will facilitate using surplus heat from power plants. Further improvements in the performance of district-heating systems could develop low-temperature systems with reduced losses and more efficient operating conditions for CHP plants.

As a strategy for low-carbon heating supply, modernizing heating networks would reduce heat losses to only 4%~5% through good pipe insulation & reduced leakage.

7.2.2. Reducing inefficient boiler houses

In the future, it is advised to shut down those inefficient, small-scale boiler houses and gradually switch the heat supply to that of high-efficiency CHP plants, while promoting waste heat recovery in CHP plants and improving energy efficiency.

7.2.3. Promote waste heat recovery in CHP plants and improved energy efficiency

All steam turbines can be classified into two categories; extraction-condensing steam turbines and back pressure steam turbines.

1) Back pressure turbines

The back pressure turbine uses high-pressure steam for the rotation of blades. This steam then leaves the turbine at atmospheric pressure or lower pressure. The pressure of outlet steam depends on in the load. This low-pressure steam is used for processing and no steam is used for condensation. The schematic diagram of the back pressure steam turbine with cogeneration system is shown in figure 7.2.3. There are numerous benefits of this steam turbine but at the same time there are also some disadvantages which are listed below.

Advantages:

-The configuration of this steam turbine is very simple

-They are relatively inexpensive compared to extraction steam turbines

-They require very little or no cooling water

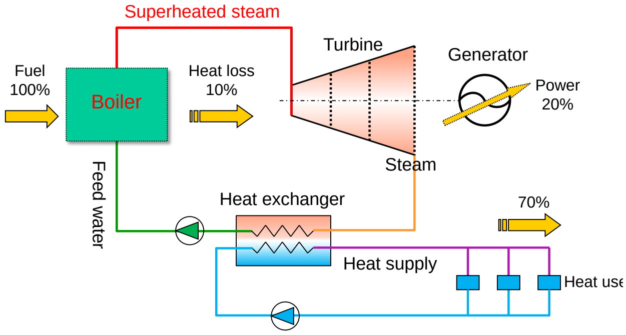
-Their efficiency is higher as they do not reject heat in the condensation process

Disadvantages:

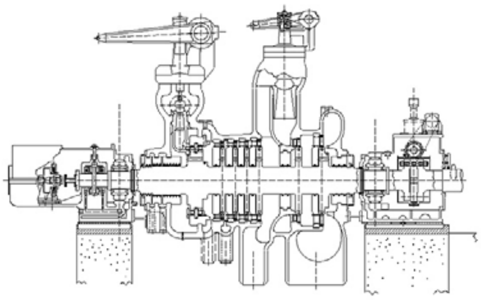
-The biggest disadvantage of this type of steam turbine is that it is highly inflexible. The output of this turbine can't be regulated as it does not allow changing the pressure and temperature of steam in the turbine, therefore, it works best under constant load.

-The thermal load of this turbine defines the flow of steam mass which makes it difficult to change the output value. Other methods to regulate output reduce the efficiency of the overall system.

Figure.7.2.3 Back pressure steam turbine



Source: NIKKEN SEKKEI Research Institute



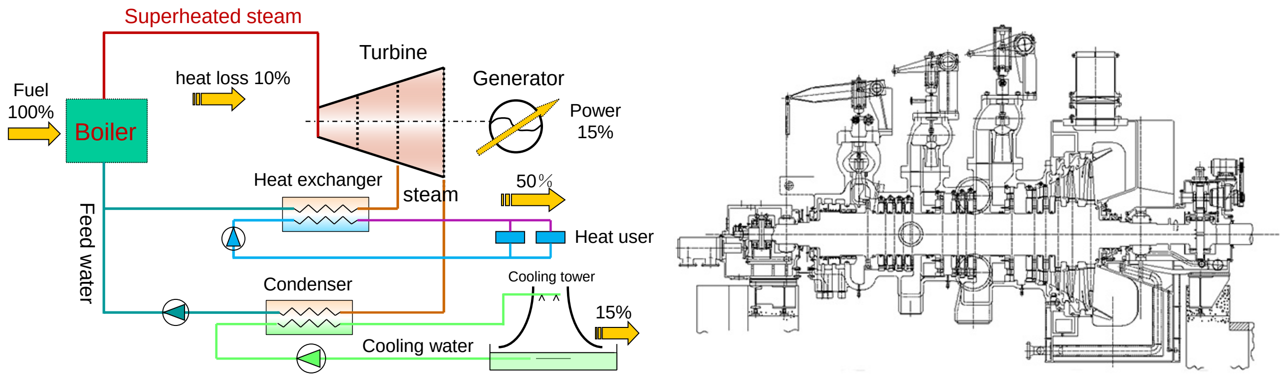
Source: Mitsubishi Hitachi Power Systems, Ltd.

2) Extraction – condensing turbine

Extraction type turbines are common in all applications. In some applications, when required, steam can be extracted from the turbine before steam flows through the last stage, thus why it is named “extraction turbine”.

These turbines are typically used for co-generation where the turbine meets both the power and steam demand of the process plant. In these type of turbines the power generated can be maintained more or less at a steady level despite variation in process steam demands. In some cases it may be necessary to have both bleed and controlled extraction steams from the condensing turbine. The schematic diagram of the Extraction –condensing turbine with cogeneration system is shown in figure 7.2.4.

Figure.7.2.4 Extraction - condensing turbine



Source: NIKKEN SEKKEI Research Institute

Source: Mitsubishi Hitachi Power Systems, Ltd.

From the above introduction, it can be seen that there is a large number of condenser exhaust heat in thermal power plant, which is directly discharged into the atmosphere through the cooling tower. If the waste heat energy could be recovered and utilized for space heating, this will undoubtedly improve the total efficiency of thermal power plant, and can reduce the evaporation of cooling water, as well as saving water resources, and reduce emissions of heat and moisture to environment.

Meanwhile, with the development of economy and the city population will continue to increase, according to the Krasnoyarskstat preliminary information, it is expected that by 2019, the population of Krasnoyarsk city will increase from the current 1.07 million to 1.2 million. Population growth and the expansion of city scale will lead to growth in the district heating load. Thus the capacity of heating also needs to increase to meet the heating needs of new construction.

Moreover, in addition to the three large-scale thermal power plants (CHP1~3), there are also many small and medium-sized coal-fired boiler houses scattered throughout the city, to provide winter heating and hot water for the city. Because of the lower efficiency and high pollution intensity of these small boiler houses, the crucial challenge for the future is how to replace these scattered coal-fired boiler houses and achieve lower emissions.

Therefore, the full recovery of waste heat from the combined heat and power (CHP) steam and supplying it to the city, to make up for the lack of heat sources, and replacement of the seriously polluting coal-fired boiler houses, will have great energy-saving effect as well as emission reduction significance.

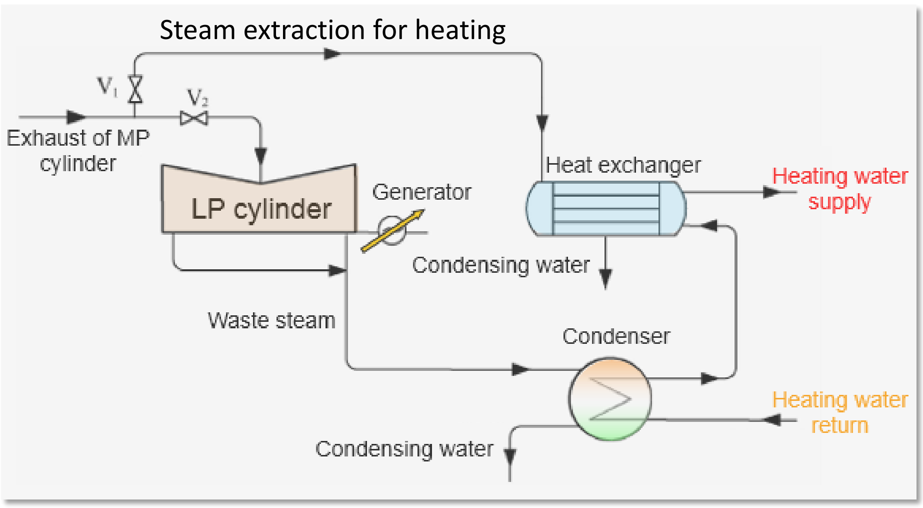
At present, waste heat recovery technology is divided into three types; high back pressure and low vacuum heating technology, absorption heat pump technology and compression heat pump technology.

Heat recovery technology-1: High Back Pressure Heating Supply with Exhaust Steam Heat Recovery

High back pressure heating supply technology could potentially recover the exhaust heat from condenser (usually exhausted to air or river as waste heat), although the amount of power generation decreases compared to a pure condensing power plant due to the high back pressure, and the internal efficiency of the turbine also declines, however, as heat loss has been reduced in the thermodynamic cycle, the total heat efficiency of the device will still be significantly improved. Figure.7.2.5 demonstrates the diagram of high back pressure heating supply operation.

The circulating water is heated to 50~60 °C in the condenser. The exhaust steam pressure of the turbine is increased from 0.04 bar (t_s=29 °C) ~ 0.06bar (t_s=36 °C) to about 0.3bar (t_s=70 °C) For successful operation, this technology is generally used in small and medium-sized units up to 50MW.

Figure.7.2.5 High Back Pressure Heating Supply of turbine



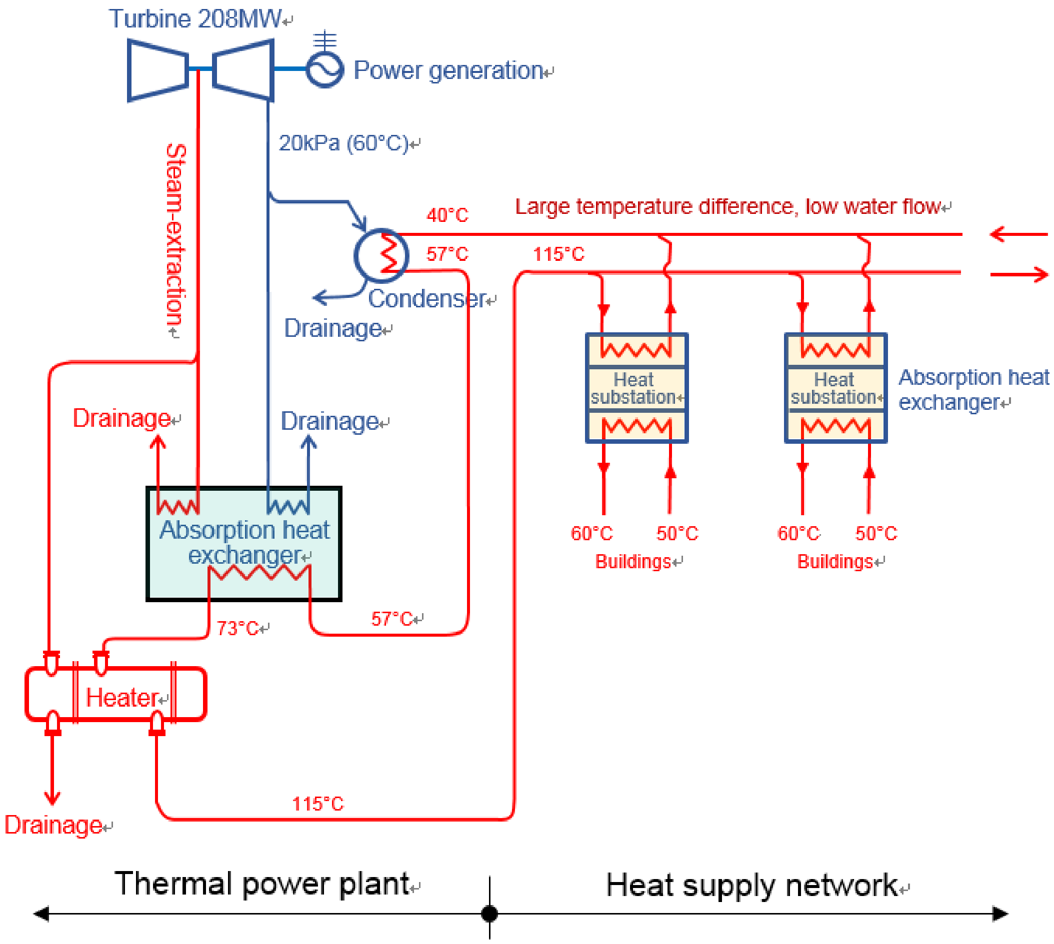
Source: NIKKEN SEKKEI Research Institute

Heat recovery technology-2: Absorption heat pump technology

Absorption heat pump is a kind of device that uses high grade heat energy (overheated steam or high temp water) to drive heat from a low temperature heat source to a medium temperature heat source. Figure7.2.6 demonstrates a renovation solution for CHP-3 in Krasnoyarsk using absorption heat pump technology that could recover waste heat from the condenser of the CHP.

Meanwhile, the heat substation could also adopt absorption heat exchangers so that lower water return temperature could be achieved which means large temperature difference and low water flow in heat supply network.

Figure.7.2.6 New heat recovery system using absorption heat pump technology in CHP-3



7.2.4. Real-time energy monitoring system and energy management

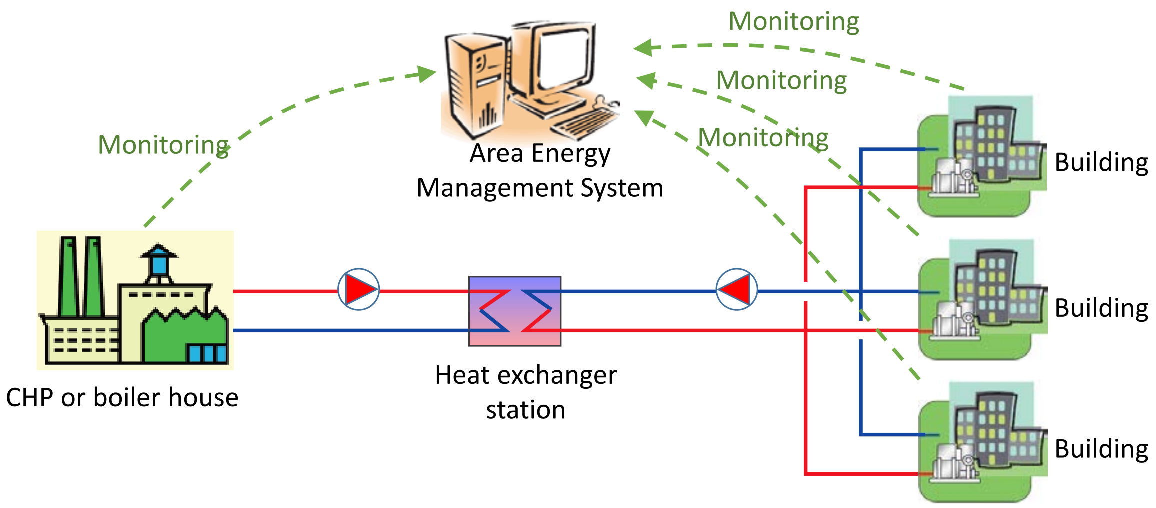
Possible solutions include introducing a real-time energy monitoring system and performing energy management from both the energy supply side and demand side (heat users).

(1) Monitor heat utilization status of demand side.

(2) Create optimal heat supply plan (Supply=demand).

(3) Implementation of optimum operation.

Figure.7.2.7 Real-time energy monitoring and management system



Source: NIKKEN SEKKEI Research Institute

7.2.5. Renewable & Untapped energy utilization

Detailed solutions will be introduced in Chapter 8 and 9.

7.3. Analysis of the CO2 emission reduction potential

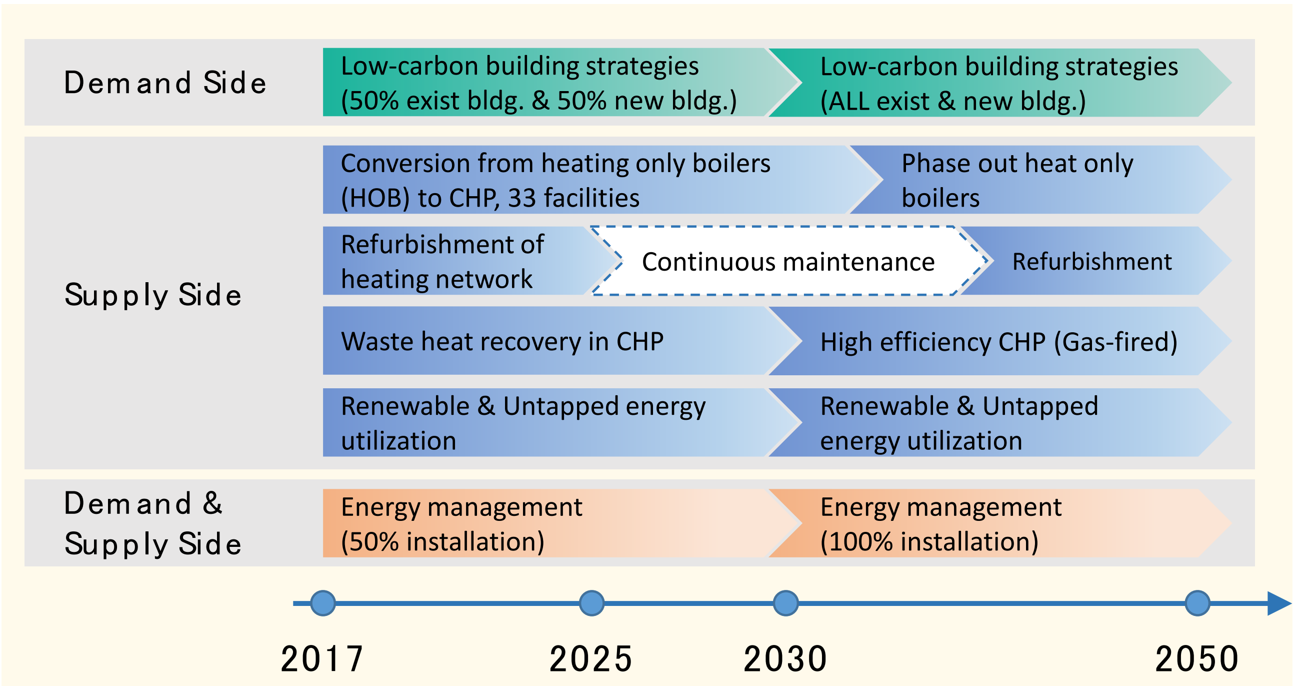
7.3.1. Low-carbon development roadmap of energy sector

Since the city's main energy source is brown coal (lignite), the lower degree of coalification is a brownish black and lackluster low grade coal between peat and bituminous coal. The chemical reaction is strong, susceptible to weathering in the air, not easy to store or transport and a serious pollutant of the air when burnt. Therefore, this study also proposes a development route to replacing lignite with clean natural gas in the future (2050).

Figure 7.3.1 shows a low-carbon development roadmap for the energy sector. The sustainable energy roadmap for Krasnoyarsk city aims to develop and communicate low-carbon energy strategies that empower the whole city to reduce consumption of, and dependence on, fossil fuel such as brown coal. Meanwhile, it also helps find effective ways for policy makers to increase energy security; reduce energy costs, local pollution, and greenhouse gas emissions; and create new business opportunities as well as promoting new energy innovations.

In the sustainable energy roadmap, mid-term and long-term targets are devised, respectively. The targets are ambitious, but also realistic and practicable.

Figure.7.3.1 Low-carbon development roadmap of energy sector



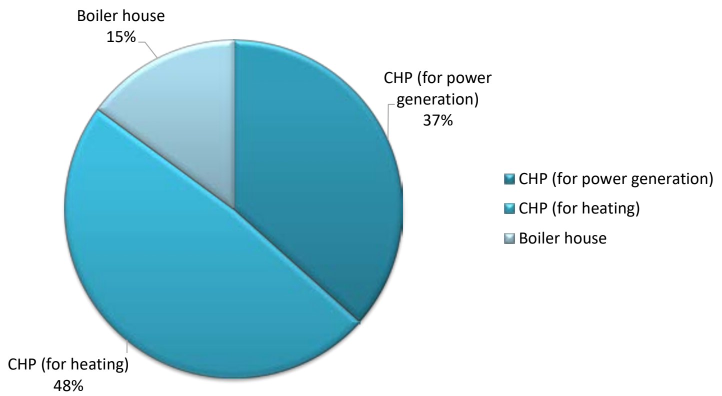
Source: NIKKEN SEKKEI Research Institute

7.3.2. CO2 emission reduction potential of energy sector

In 2016, about 5.8 million tons of brown coal in total was consumed in Krasnoyarsk city for power generation and district heating as well as hot water supply, making it a huge contributor to total greenhouse gas emissions and a major source of air pollution. As known, brown coal creates more pollution than other fuels such as anthracitic coal or natural gas and much more than clean renewable energy, thus ways to reduce brown coal consumption are the biggest opportunities for low-carbonization development for Krasnoyarsk city.

If we focus on the breakdown of total brown coal consumption shown in Figure 7.3.2, district heating (including hot water supply) by CHP plants and heat only boiler houses make up a significant share (63%) of the total consumption, the remaining 37% of brown coal is consumed for power generation by CHP plants. The proportion of heating is relatively high compared with other cities in Russia and even higher than the average proportion of Russia. This is because the electricity consumed by the Aluminum Smelter, the main industry in Krasnoyarsk city, is excluded. The industrial processes of the Aluminum Smelter consume huge quantities of electrical energy which is generated by hydropower station rather than CHP plants.

Figure.7.3.2 Breakdown of brown coal (lignite) consumption, 2016



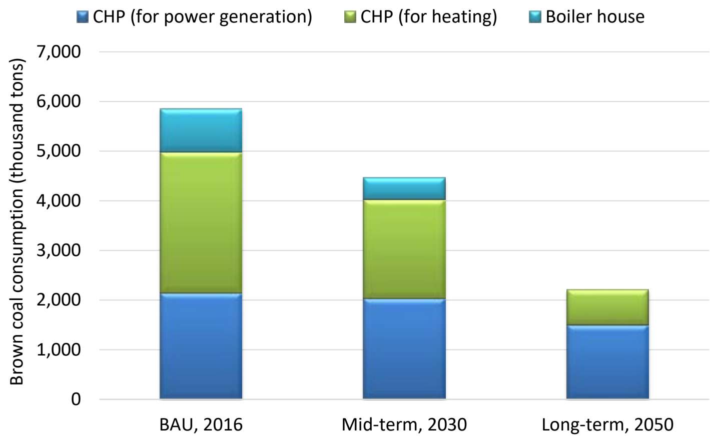
Source: Krasnoyarsk city administration

In figure7.3.3, a long-term perspective of brown coal consumption is provided while consumption in 2016 is set as BAU (Business as Usual). In mid-term target at 2030, it is expected that the consumers of inefficient heat only boiler houses will partially switch to the high efficiency heat supply provided by the Krasnoyarsk CHP plants, which have tall chimneys (providing for effective fume gas dispersion) as well as modern gas cleaning equipment.

In total, within the Krasnoyarsk heat supply scheme project lasting until 2030s, the switching of consumers from 26 boiler houses is expected. In the long-term target at 2050, all heat only boiler houses will be shut down and switch to heat supplied by CHP plants and renewable energy such as solar heat and biomass.

Moreover, a number of measures will be planned at the Krasnoyarsk CHP plants, aimed at improving environmental performance, in particular the installation of electrostatic precipitators and the reconstruction of battery cyclone collectors.

Figure.7.3.3 Long-term perspective of brown coal (lignite) consumption, 2050

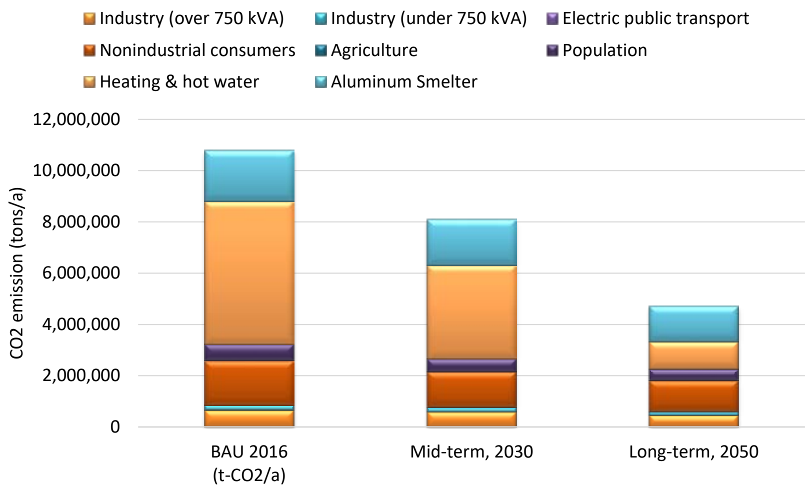


Source: NIKKEN SEKKEI Research Institute

Figure 7.3.4 shows mid and long-term perspective of CO_2 emission (not including CO_2 emissions associated with fossil fuels in the transportation sector, see Transportation Chapter). Compared to the BAU scenario of 2016, the mid-term target for CO_2 emissions is expected to be reduced by 25% in which the heating & hot water sector contributes the most due to applications of key energy-saving strategies proposed in this feasibility study.

In 2050, in addition to existing technologies employed in each sector, technological innovation is also anticipated and the long-term target of CO_2 emission reduction is expected to reduce by more than 56%.

Figure.7.3.4 Long term perspective of CO_2 emissions (Low-carbon development scenario)



Source: NIKKEN SEKKEI Research Institute

7.4. Best practice of area energy supply system

7.4.1. Denmark

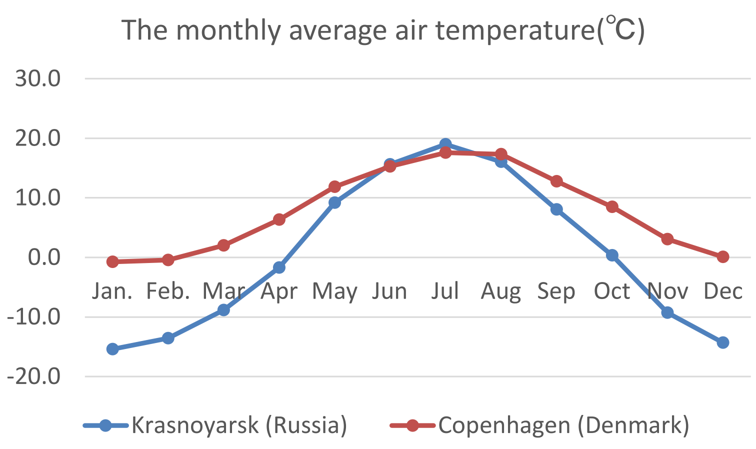
Denmark is one of the most energy efficient countries in the world. According to the Danish Energy Agency, 63 % of all private Danish houses are connected to district heating - not only for space heating, but also for domestic hot water. The first CHP plant in Denmark was built more than 100 years ago in 1903 to supply electricity and heating for a hospital. After the oil crisis of the 1970s, Denmark developed district heating schemes which heat homes more cheaply and efficiently.

Renewable energy for heating supply became a priority in the 1990s when targets were set for the increased use of biomass at both centralized and small-scale plants. The use of biomass was supported by policy and by financial subsidies from government. In particular, the use of biomass in centralized plants was facilitated by the Biomass Agreement on 14 June 1993.

This agreement required power plants to use 1.2 million tons of straw and 0.2 million tons of wood chips annually by the end of 2000. Later, the agreement was altered to allow a more flexible choice of biomass. In 1987, a biogas action plan was set up with the purpose of creating competitive biogas plants. In 2013, roughly half of heating was supplied by renewable energy such as biomass, municipal waste plants as well as solar energy.

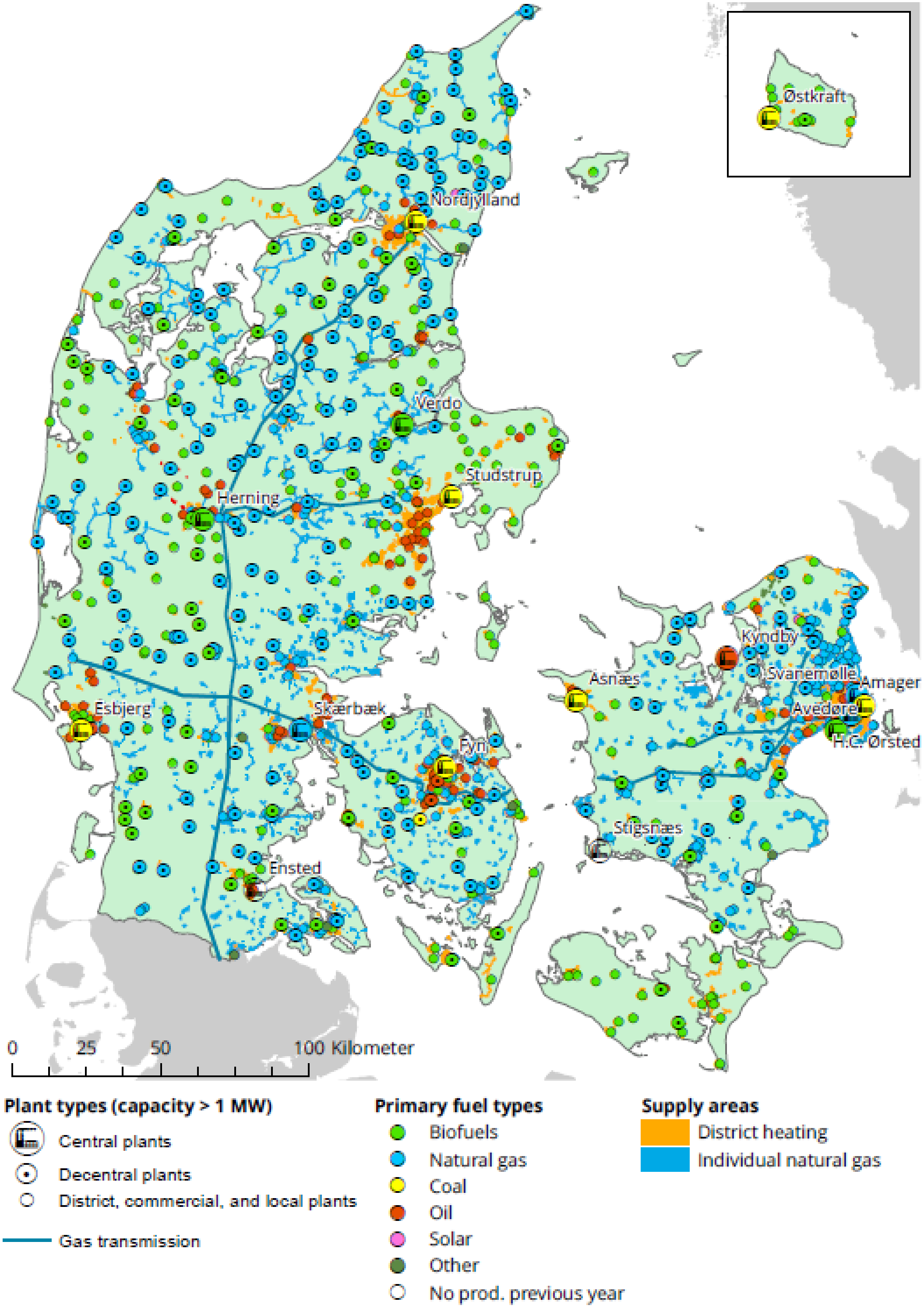
Figure 7.4.1 shows comparison of monthly average air temperature of Krasnoyarsk and Copenhagen, despite the fact that Krasnoyarsk has a more severe cold climate and longer heating season, undeniably, the successful experience of highly efficient and clean heating supply in Denmark will provide reference for Krasnoyarsk city to achieve a sustainable future.

Figure 7.4.1 Comparison of monthly average air temperature



Source: NASA Langley Research Center Atmospheric Science Data Center, Edited by NIKKEN SEKKEI Research Institute

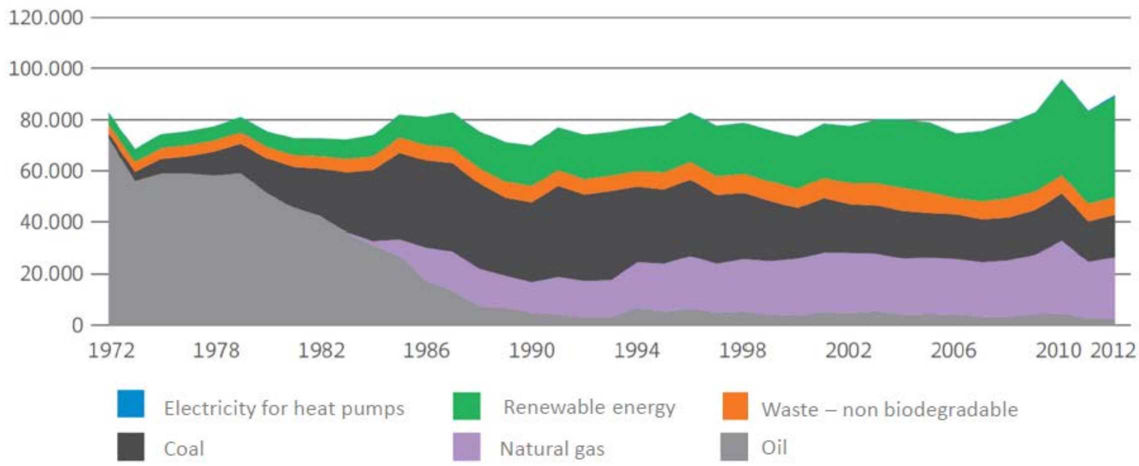
Figure.7.4.2 Map of Denmark's heating supply



Source: Regulation and planning of district heating in Denmark, 2015, Danish Energy Agency.

In Denmark, it is common that the heating supply is controlled by the heating demand of consumers. Consumer metering measures the actual heating demand, which means that consumers have an incentive to save heat. Payment for heating is most often divided into a fixed part (per installation and/or capacity) and a variable part (per gigajoule of consumption).

Figure.7.4.3 Change in fuel used for district heating generation 1972-2012 in Denmark (PJ)



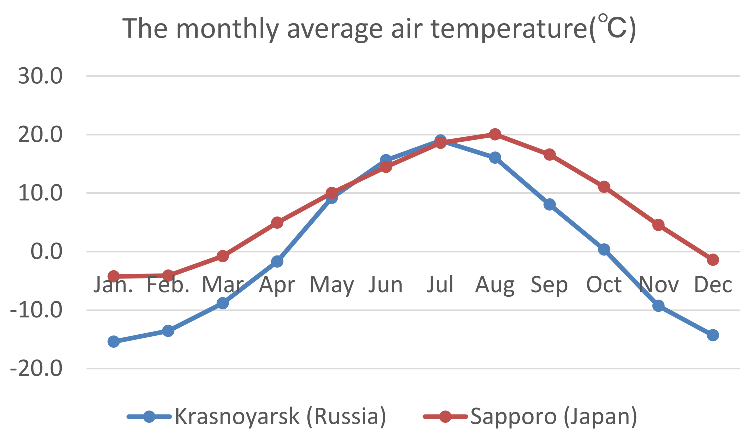
Source: Regulation and planning of district heating in Denmark, 2015, Danish Energy Agency.

7.4.2. Hokkaido Pref, Japan

This section introduces a high efficiency district heating system in Hokkaido, Japan, in which natural gas is used as the main energy source for district heating and, waste heat from incineration plant is effectively utilized in this system.

Figure7.4.4 shows similar climate data of Sapporo city and Krasnoyarsk city.

Figure 7.4.4 Comparison of monthly average air temperature

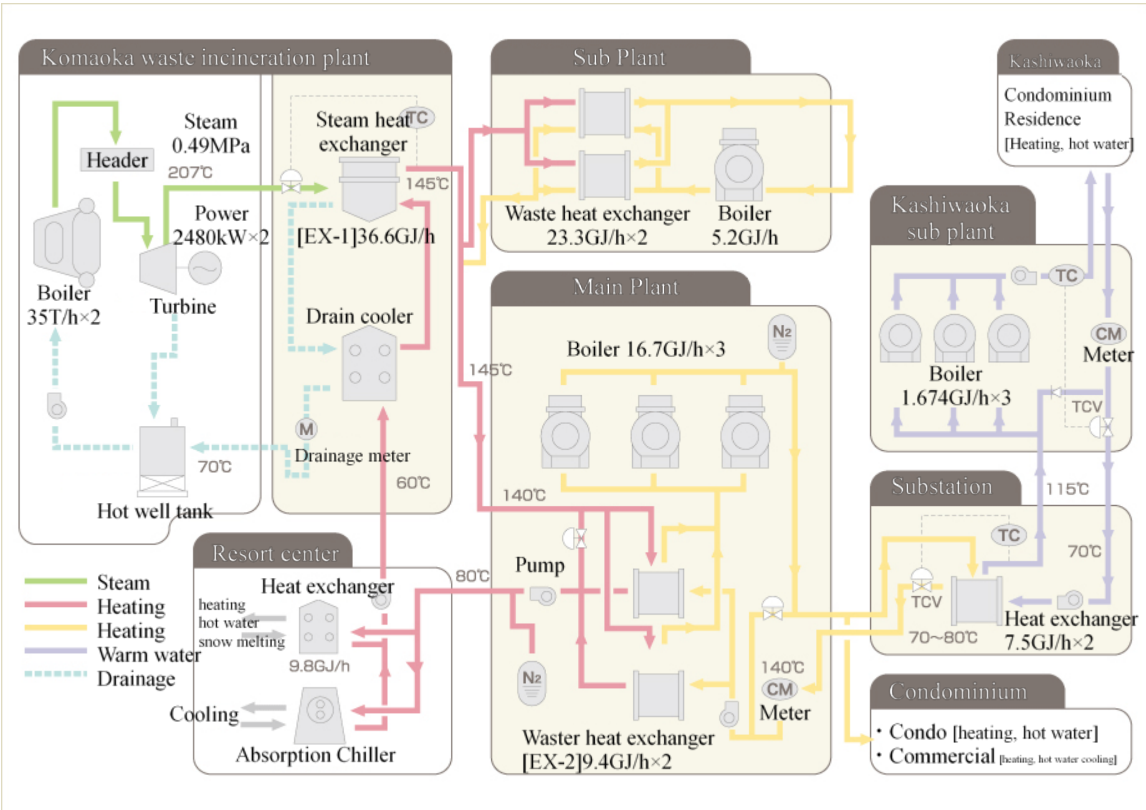


Source: NASA Langley Research Center Atmospheric Science Data Center, Edited by NIKKEN SEKKEI Research Institute

Figure 7.4.5 District heating supply map of Makomanai area in Sapporo city

Source: Hokkaido District Heating Co.Ltd.

Figure 7.4.6 Diagram of Makomanai area in Sapporo city



Source: Hokkaido District Heating Co.Ltd.

Table 7.4.1 Configuration of DHC plant

Equipment	Specification		Amount
Heat exchanger for high pressure steam	Type	Shell and tube	1
	Heating surface area	317m²	
	Capacity	55.3GJ/h(13.2Gcal/h)	
Heat exchanger for low pressure steam	Type	Shell and tube	1
	Heating surface area	475m²	
	Capacity	36.8GJ/h(8.8Gcal/h)	
Boiler	Type	Flue and smoke tube boiler	1 1
	Heating surface area	99m²	
	Capacity	16.7GJ/h(4.0Gcal/h)	
	Heating surface area	160m²	
	Capacity	26.8GJ/h(6.4Gcal/h)	
	Type	Flow-through boiler	1 1
	Heating surface area	507m²	
	Capacity	83.7GJ/h(20.0Gcal/h)	
	Heating surface area	507m²	
	Capacity	67.0GJ/h(16.0Gcal/h)	
Boiler	Type	Steam	3 (Sub-plant)
	Heating surface area	9.9m²	
	Capacity	3.4GJ/h(0.81Gcal/h)	
High temperature water pump	$600m^3/h \times 45m \times 110kw$ $400m^3/h \times 45m \times 75kw$ $300m^3/h \times 45m \times 55kw$ $180m^3/h \times 20m \times 15kw$		1 1 1 1
Pipe	Double tube steel（350A～25A） Copper pipe（190φ～30φ）		14,242m×2 1,157m×1 6,238m×2

7.4.3. China

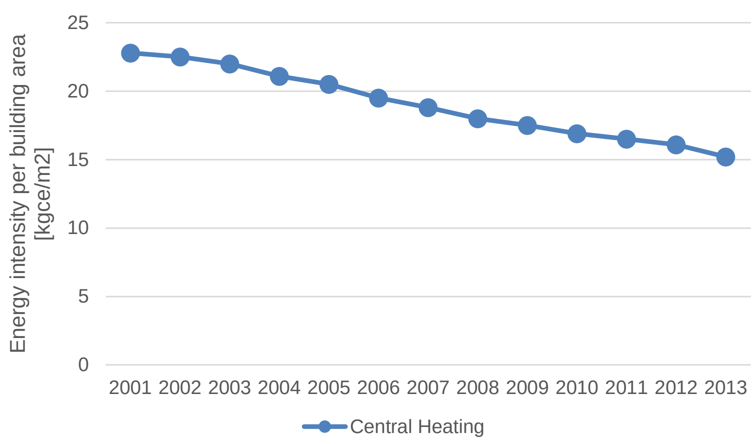
In 2013, Chinese north town of heating energy consumption was 181 million TCE, accounting for 24% of the building energy consumption in total. From 2001 to 2013, the northern town of building heating area increased from 5 billion m^2 to 12 billion m^2, an increase of 150%, while the total energy consumption increased by 100%.

The total energy consumption growth was significantly lower than growth in construction in the area, showing the effectiveness of energy saving work. The average heating energy consumption per unit area decreased steadily, from 22.8 kgce/m^2a in 2001 to 15.1 kgce/m^2a in 2013, a drop of 34%. The main reasons include the following points:

1) Significant improvement of building insulation level and airtightness.
2) The proportion of efficient heat sources increased rapidly
3) Heating efficiency improved

Successful experience from the central heating in China could provide reference to Krasnoyarsk city for energy saving.

Figure 7.4.6 Energy usage intensity trend between 2001 and 2013

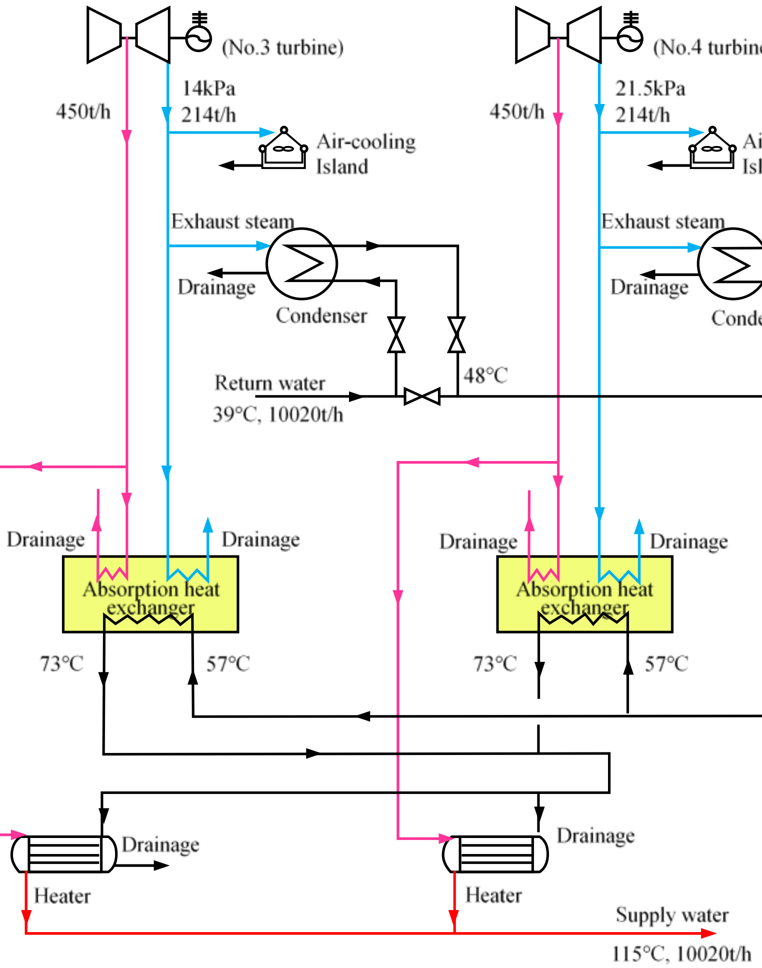


Source: 2015 Annual Report on China Building Energy Efficiency, THUBERC.

CASE: Yungang thermal power plant renovation project

Datang Yungang power station is a four-unit coal-fired power plant with a total capacity of 1,040 MW in Shanxi Province, China. The first two units, totaling 440 MW, were completed in 2003. Units 3 & 4, totaling 600 MW, were completed in 2009. In recent years, with the increasing demand of district heating due to the construction rush, the thermal power plants were renovated to recover condenser waste heat as well as to raise heat supplying capacity of the plant in winter. Figure 7.4.7 shows the diagram of heat supply renovation.

Figure 7.4.7 Diagram of heat supply renovation in Yungang thermal power plant, Datong city, China



Source: 2015 Annual Report on China Building Energy Efficiency, THUBERC.

Table 7.4.2 Heat-supply parameters after renovation

Contents	Working condition (Heat load 100%)	Working condition (Heat load 80%)	Working condition (Heat load 60%)
Total heat output (MW)	885.7	708.5	529.4
Outdoor temp (°C)	-17	-10	-3
Water supply temp (°C)	115	97.1	78.9
Water return temp (°C)	39	36.3	33.5
Extracted steam (t/h)	450/450	196/450	80/259
Exhaust steam (t/h)	214/214	430/214	529/381
Steam recovery ratio (%)	100%/100%	49.4%/100%	40.2%/69.7%
Back pressure (kPa)	14.0/21.5	11.7/18.3	10.0/18.9
Power generation (kWh)	430,275	469,920	515,933

Source: 2015 Annual Report on China Building Energy Efficiency, THUBERC.

Table 7.4.3 Performance after renovation, 2013~2014.

Contents	Extreme cold season	Cold season
Total heat output (MW)	564.6	332.1
Water supply temp (°C)	100	70
Water return temp (°C)	49	40
Power generation (kWh)	478,557	532,271
Overall heat efficiency (t/h)	77.6%	64.3%

Source: 2015 Annual Report on China Building Energy Efficiency, THUBERC.

In this thermal power plant renovation, absorption heat pumps were introduced to recover heat energy from exhaust steam and, at the same time, to heat the return water from 57 to 73 °C. Meanwhile, heating stations of heat-supply network also partially adopted absorption heat pumps and thus return water temperature can be reduced under 40 °C (39°C at design condition), consequently, large temperature difference of heating water was achieved which significantly reduced energy consumption in transmission. Moreover, low return water temperature can possibly recover waste heat from condenser. In extreme cold season, the overall heat efficiency can reach as high as 78% as shown in table 7.4.3. Because of the waste heat recovery application, steam extraction for heating was successfully reduced so power generation increased by 7% after the renovation.

8 UNTAPPED ENERGY

8. Untapped Energy

8.1. Outline of untapped energy (New energy)

1) Definition

Untapped energy is, despite the possibility of effective use such as waste heat from factories, exhaust heat from subway or underground shopping centers, potential heat energy from rivers, sewage, snow, etc., which have large temperature difference between outside temperature, however, have not been effectively utilized yet. As untapped energy is often characterized as being widely distributed and there are many cases where the energy supply source is far from the energy demand site, an efficient utilization strategy is required. Specifically, heat pump systems, snow and ice utilization technology, off-line heat supply (conveyance) technology and sea water/lake water temperature difference utilization technology can be considered.

Generally, untapped energy utilization technology can be combined with various other environmental and energy technologies to help create a low carbon society.

Table 8.1.1 demonstrates several typical examples of Utilization forms of untapped energy and usages.

Table 8.1.1 Utilization form of untapped energy and usage (typical example)

Energy source	Form	Usage
Seawater	Water	Heat pump, heat sink, cooling water, etc.
River water	Water	Heat pump, heat sink, cooling water, etc.
groundwater	Water	Heat pump, heat sink, cooling water, etc.
Sewage	Raw sewage	Heat pump, heat sink, etc.
	Treated sewage	Heat pump, heat sink, etc.
Incineration waste heat	Hot water (Condenser for power generation)	Heat pump, etc.
Subway or underground shopping center	Air	Heat pump, etc.
Electric power substation	Cooling water	Heat pump, etc.
Factory	High-temperature gas	Heat recovery from steam, power generation, heating, etc.
	Hot water	Heat pump, etc.
	LNG waste heat	Power generation, air liquefaction, etc.
Power plant (condenser)	Hot water	Heat pump, etc.

Source: NIKKEN SEKKEI Research Institute

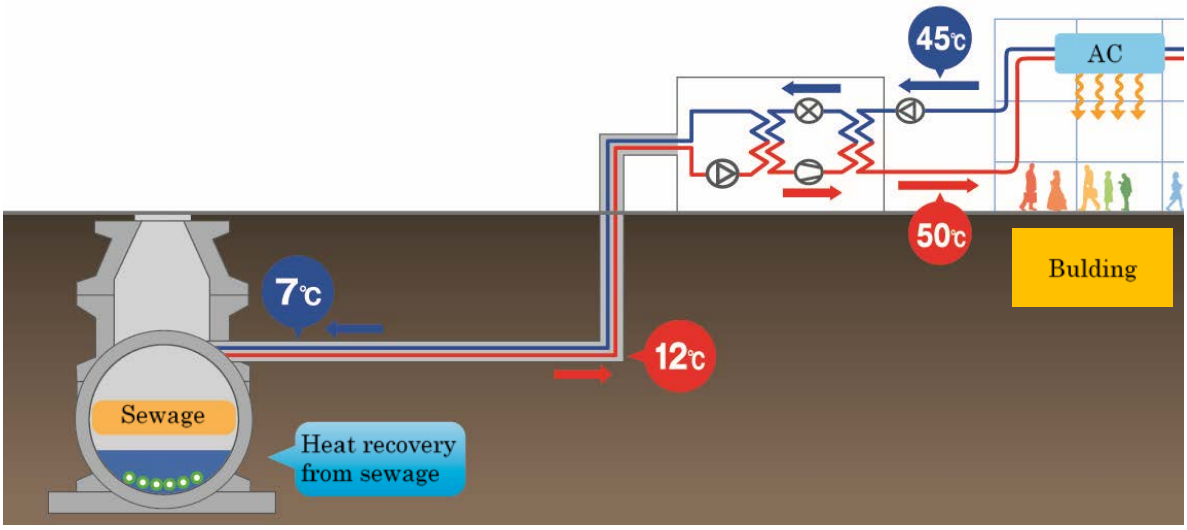
8.2. Technology review of untapped energy in Krasnoyarsk

1) Sewage heat use

Since the sewage temperature is lower in summer and higher in winter than the air temperature as described for river water, it is used for the heat source water when systems such as heat pumps are used. It also contributes to the restraint of heat islands.

Water temperature of sewage is stable throughout the year compared to the atmosphere, warm in winter, cold in summer and abundant in the city. By utilizing the temperature difference energy between this sewage water temperature and the atmospheric temperature for air conditioning, hot water supply, etc., it is possible to achieve energy saving and CO_2 reduction.

Figure 8.2.1 Utilization of sewage heat use



Source: Ministry of Land, Infrastructure and Transport, Japan, edited by NIKKEN SEKKEI Research Institute.

There are two self-contained sewage systems with their treatment facilities in Krasnoyarsk on the left and on the right bank of the Yenisei River. The volume of wastewater for 2014 was only 121,488 thousand m^3. The determined capacity of the treatment facilities is 700 thousand m^3 per day.

The quality of wastewater is determined in accordance with the standards of permissible concentrations in the river Yenisei from Krasnoyarsk hydroelectric complex to the confluence of Angara river without Kan river, as well as a resolution for the discharge of substances (with the exception of radioactive substances and microorganisms) into water bodies.

The temperature of the reservoir water should not rise in comparison with natural water body temperature more than to 5°C (up to 20°C - in summer and to 5°C - winter); summer water temperature due to discharge should not rise by more than 3°C in comparison to the average water temperature in the hottest month of the year for the last 10 years. Right Bank treatment facilities of drainage system of Krasnoyarsk has a design capacity of 360 thousand m^3/day.

They work on the scheme of full biological wastewater treatment. Mechanical cleaning is carried out on the grids, sand traps and primary sedimentation tanks. Biological treatment is carried out at the aeration tanks and secondary sedimentation tanks. Treated wastewater is discharged from the facilities into the Shumkovskaya channel by three collectors (reinforced 1700 × 1800mm concrete channel and two 1500mm diameter pipes).

Table 8.2.1 Information on the actual and expected flow of sewage into the centralized water disposal system (TOTAL)

Current period, 2015-2016					
№	Type of sewage	Q, m^3/year	Q, m^3/month	Q, average, m^3/day	Q, max., m^3/day
1	Residential sewage	86,529,764	7210,814	237,068	272,628
2	Industrial sewage	28,067,136	2,338,928	768,96	88,431
Total (accounted sewage)		**114,596,900**	**9,549,742**	**313,964**	**361,059**
3	Unaccounted sewage of local industry	21,275,525	391,098,690	83,113	95,581
Total		**135,872,425**	**400,648,432**	**397,078**	**456,640**

Source: Krasnoyarsk Municipal Government

8.3. Low-carbon development strategy of untapped energy

1) Feasibility analysis of potential untapped energy

Feasibility analysis of untapped energy has been conducted and the potential of each energy source is shown in table 8.3.1.

Table 8.3.1 Feasibility analysis of potential untapped energy

Content	Potential of Usage	Background of introducing the measure
Waste heat from waste incinerator plant	★★★	The efficiency is affected by the location of the electric power plant and the waste incinerator plant.
Waste heat from factory	★★½	The potential density of waste heat from factory depends on the industrial process, such as aluminum smelter, oil refining, or steel manufacturing could be major sources of waste heat.
Waste heat from Sewage treatment facilities	★★	Using heat pumps could effectively utilize the heat energy from sewage water from treatment facilities.
River water	★	The city is divided into be two parts by the Yenisei river, because of the hydro power plant, the Yenisei never freezes in winter and never exceeds +14°C in summer. A high efficiency heat pump system (especially cooling system) using the river water energy as pre-heating of district heating system could reduce energy consumption.

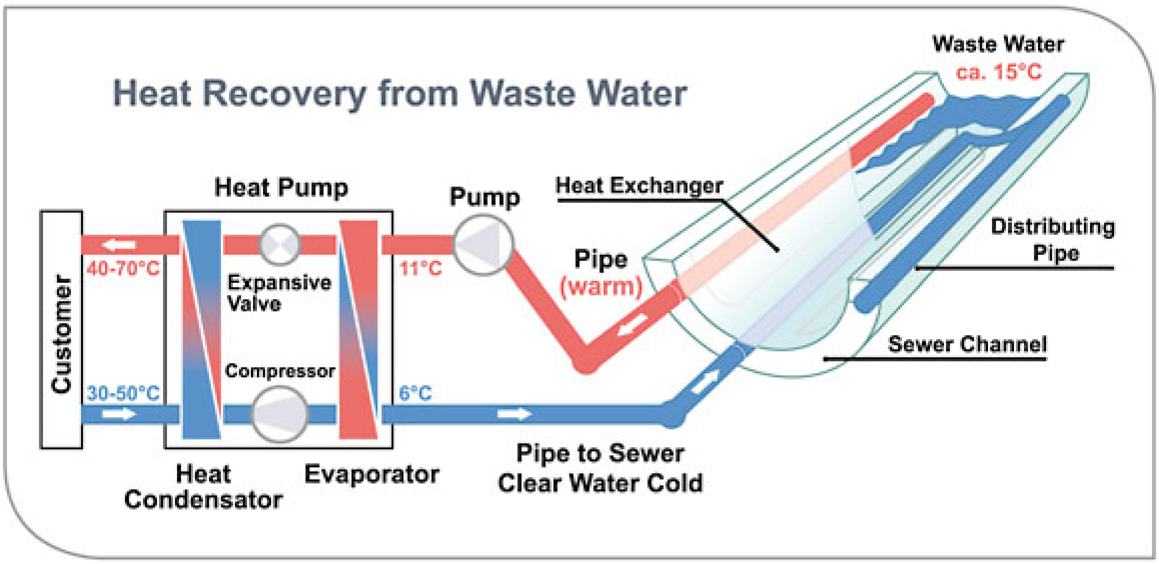
8.4. Best practice examples of untapped energy

1) Sewage heat use

Sewage is a source of energy which can be used for heating and cooling buildings with heat pumps. The temperature of sewage is relatively high, as values under 10°C are rare and the temperature can climb to over 20°C, especially in summer. Hence, heat pumps in sewage networks are a satisfactory heating source for premises (such as swimming pools, hospitals, hotels, etc.) requiring a temperature between 5°C and 65°C.

In Berlin (Germany), an IKEA furniture store (43,000 m^2) is supplied with heating and cooling from sewage water by Berliner Wasserbetriebe. Thanks to an installation consisting of a bypass from the sewage network, heat exchanger and heating pump, heat is recovered from wastewater delivering 70% of the energy needed for heating the premises and 100% of the energy needed for cooling. As a result, greenhouse gas emissions have decreased by 770 tons of carbon equivalent per year. Heat recovery amounts to 1,100 kW and cooling recovery amounts to 1,700 kW.

Figure 8.4.1 Best practice of heat pumps in sewage network, Berlin, Germany



Source: VEOLIA.COM

2) River source heat pump

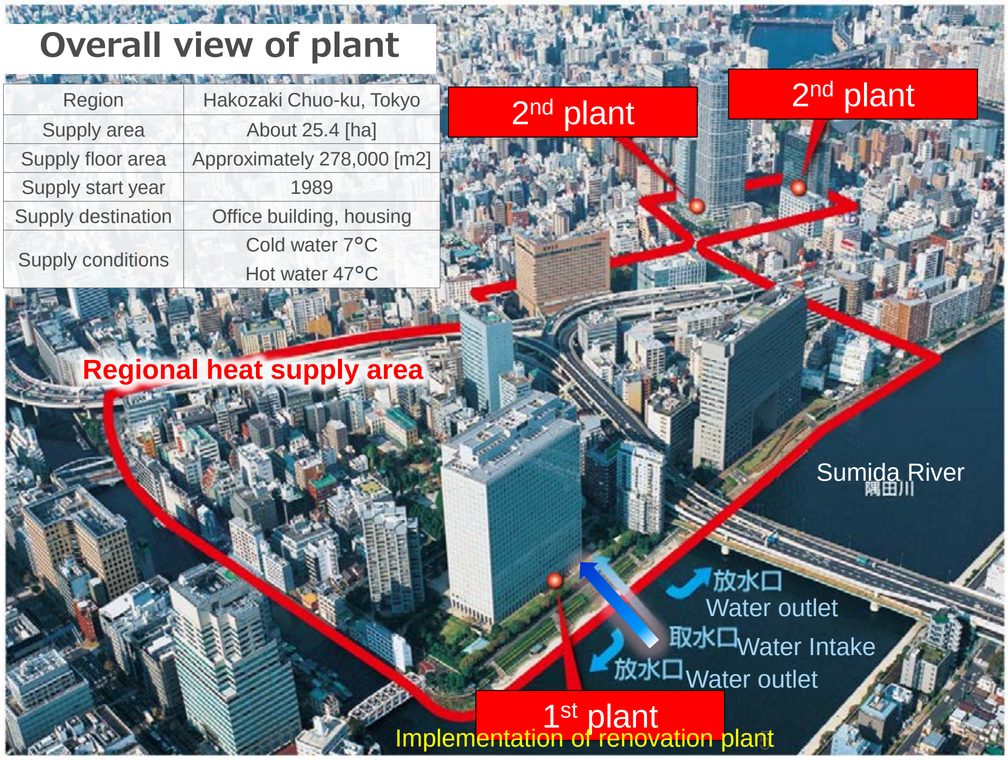
Hakozaki DHC plant retrofit project is well known for its significant improvement of primary energy performance in Japan, in which river source heat pumps are employed in this plant. The following section explains the details of the energy system (Figure 8.4.2) and major solutions proposed in the energy system retrofit.

Major improvement measures practiced and verified at this facility are:

1. Combining "capacity optimization" and "high efficiency" of heat supply equipment to be a renovation model for DHC plants.
2. "Optimization of utilization of renewable energy" by optimizing river water flow control.
3. Optimizing the transportation system of the thermal storage system and further improving control "further expansion of load leveling effect"

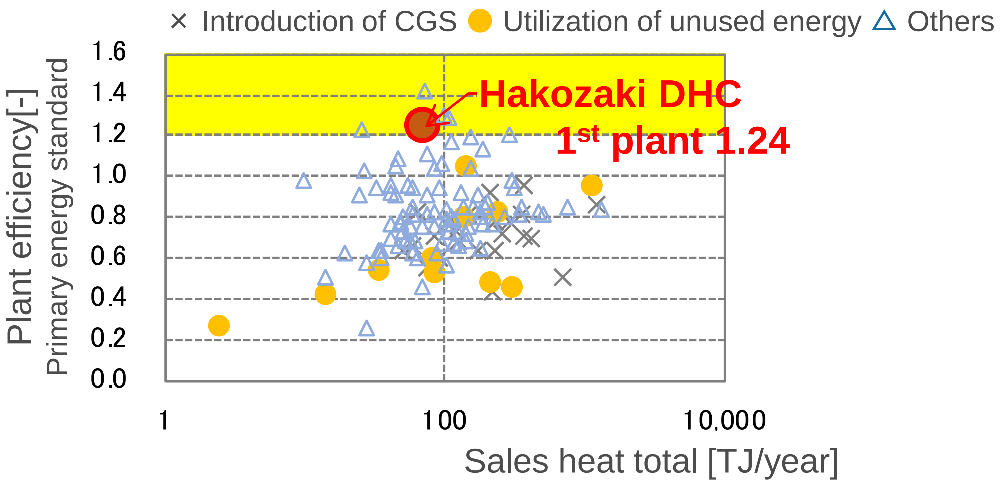
As a result of retrofitting the DHC plant, primary energy efficiency has been significantly improved from 0.96 to 1.24, roughly 30% more efficient than before, which makes the plant archive the highest performance of any facility in Japan today. (Figure 8.4.3)

Figure 8.4.2 High Efficient DHC system Using Thermal Energy of River Water in Hakozaki, Tokyo, Japan



Source: NIKKEN SEKKEI Research Institute

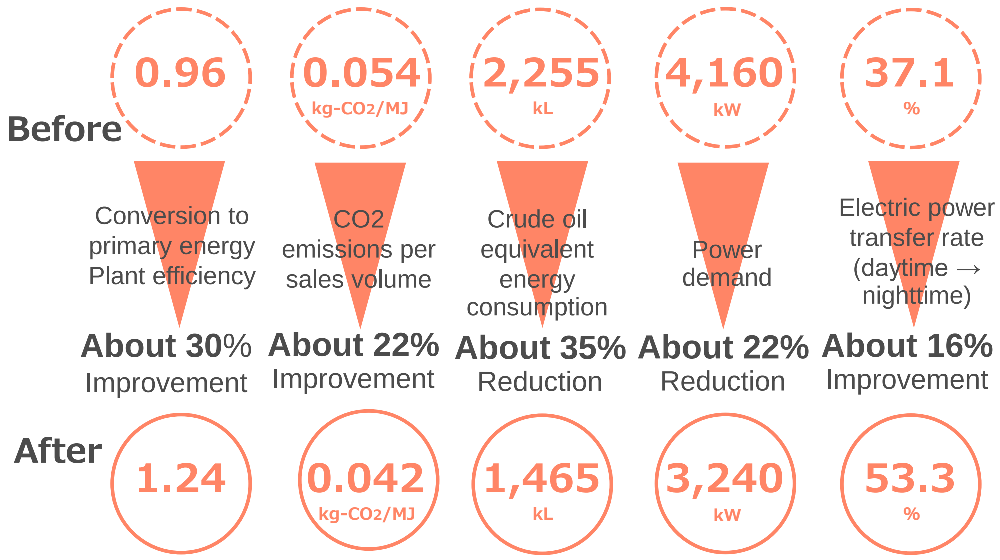
Figure 8.4.3 Plant efficiency of Hakozaki DHC, actual performance data.



Source: NIKKEN SEKKEI Research Institute

The energy retrofit of the Hakozaki DHC plant not only significantly improved the energy performance and reduced annual CO_2 emissions, as shown in Figure 8.4.4, it also reduced by 22% the electrical power demand, which led to great money saving due to the lower basic electrical charge of whole plant. The positive economic effect achieved in this project enabled the retrofit investment to be recovered within a short period of time.

Figure 8.4.4 Main achievement of energy-saving and electric power load leveling.



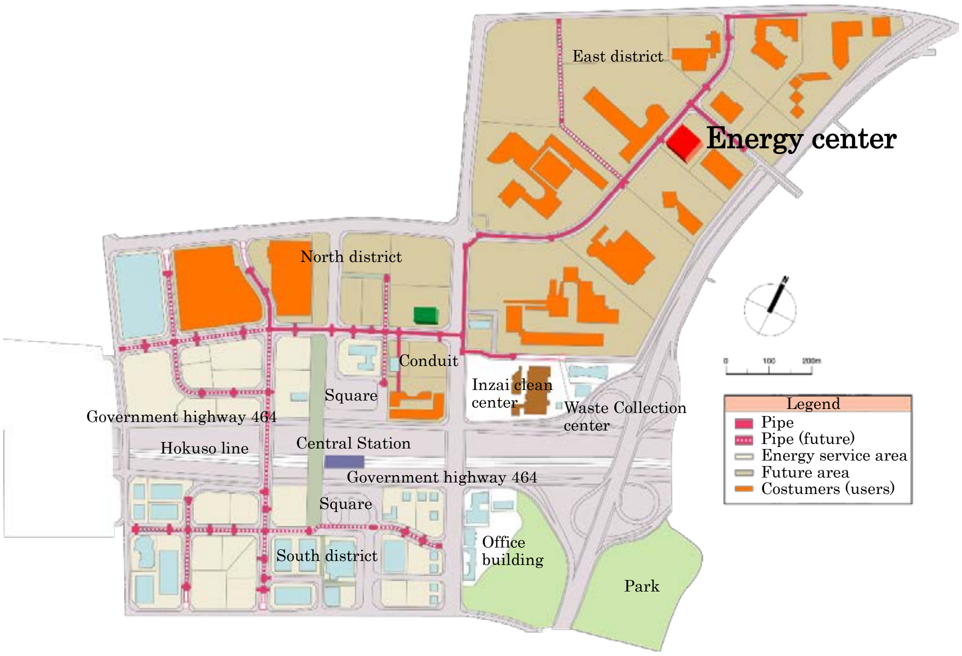
Source: NIKKEN SEKKEI Research Institute

3) Waste heat utilization from Waste incinerator plant

Chiba Newtown Center (District heating and cooling plant) concentrates and unifies the heat sources for heating and cooling required for public buildings located in the central area of Chiba New Town and, at the same time, it effectively utilizes the waste heat of the neighboring Inzai Clean Center (garbage incineration facility). Meanwhile, by implementing a safe and secure regional energy supply, it also aims to promote energy conservation and urban disaster resiliency, as well as improving urban landscape.

Specifically, burnable garbage generated in residential, business and commercial facilities in this area will be collectively burned and incinerated at the Inzai Clean Center. By incorporating the waste heat generated by incineration into the heat supply plant and effectively utilizing it as a heat source for heating and cooling, it contributes to the prevention of air pollution, conservation of the global environment and promotion of energy conservation. Figure 8.4.5 shows the energy supply map of whole district.

Figure 8.4.5 Energy supply map of Chiba Newtown Center, Chiba prefecture, Japan.



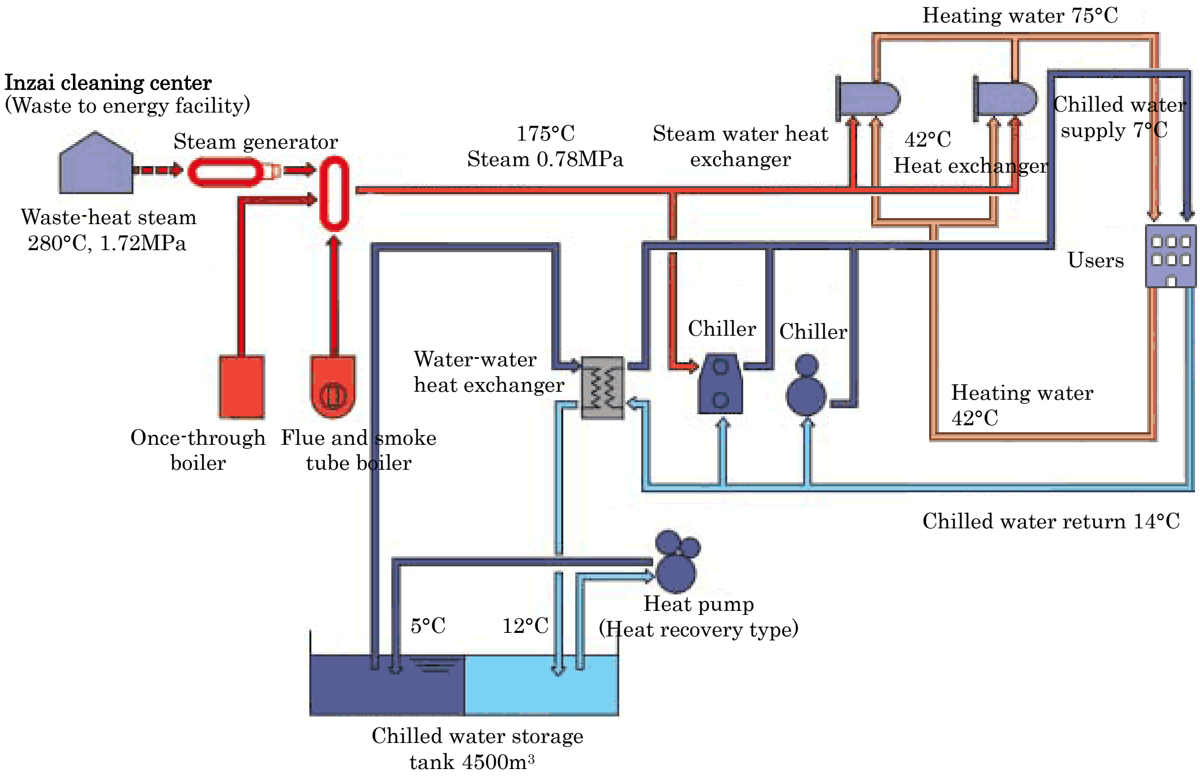
Garbage incineration facility

District heating and cooling plant

Utility tunnel

Source: Chiba Newtown Center, Japan (http://www.nt-cnc.co.jp/)

Figure 8.4.6 Schematic diagram of Chiba Newtown Center energy plant.



Source: Chiba Newtown Center, Japan (http://www.nt-cnc.co.jp/)

9 RENEWABLE ENERGY

9. Renewable Energy

9.1. Renewable energy policy of Russia

1) Renewable energy policy of Russia

Russia has considerable potential for the development of large amounts of diverse renewable energy sources (RES) across the whole territory. The potential is particularly large for wind, biomass, hydro, geothermal and solar, depending on the region.

This potential and its economic and social benefits have been progressively acknowledged at the federal and regional levels. Since 2007, Russia has developed a comprehensive political and regulatory framework for renewables in the wholesale and retail markets. The fine - tuning of the framework and actual deployment have been very slow due to the large availability and share of fossil fuels used for heat and power generation, the concern about avoiding higher end - user electricity prices, and challenges of how to integrate renewables into the electricity system.

After an initial focus on a premium support scheme, Russia has introduced a capacity-based support scheme for the wholesale market. Key regulatory changes and improvements were adopted in 2012 and 2013 and there are continued legislative adjustments. Yet the 2009 target to achieve a 4.5% of electricity generation from RES (excluding hydro over 25 megawatts [MW]) by 2020 is highly unlikely to be achieved. However, Russia stands a good chance of achieving this target by 2030 if remaining regulatory uncertainties are addressed and obstacles are lifted. Regions also need to develop the necessary capabilities and leverage to foster the deployment of RES, especially in the retail market. (Source: Russia 2014, IEA)

Table 9.1.1 Key data of renewable energy in Russian Federation.

Key Data in Russia (2012)

- **Target: 4.5% (2.5%)** of electricity production from RES (excluding hydropower stations with a capacity larger than 25 MW) by 2020
- **Share of renewable energy:** 3% of TPES and 15.8% of electricity generation
- **Hydro:** 1.9% of TPES and 15.5% of electricity generation
- **Biofuels and waste:** 1% of TPES and 0.3% of electricity generation
- **Other renewable energy:** 0.1% of TPES
- **Installed capacity:** 2,300 MW including large hydro.

Source: Russia 2014, IEA. Edited by NIKKEN SEKKEI Research Institute

Russian energy Strategy 2035(ES-2035) mentioned that starting from 2020 Russia will be implementing “new generation energy based on the new technology, highly efficient usage of traditional resources as well as new types of hydrocarbon and other sources of energy”. In which, a favorable scenario includes:

-Increased share of Atomic power from 17% to 21%.

-Arctic shelf development to be implemented.

-Renewable energy power generation is to be launched in the rural areas.

Russian Energy Strategy 2035 also confirms that energy efficiency and development of renewable energy are as main goals of the developed countries.

9.2. Technology review of renewable energy in Krasnoyarsk city

1) Photovoltaics (PV)

A Outline of PV

Photovoltaic (PV) devices generate electricity directly from sunlight via an electronic process that occurs naturally in semiconducting materials. Electrons in these materials are freed by solar energy and can be induced to travel through an electrical circuit, powering electrical devices or sending electricity to the grid. (Source: SEIA)

B Types of solar cells

Solar power generation technology is roughly divided into silicon type, compound type, III - V type and organic type, and solar cells listed in Table 9.2.1 are mainly developed.

Table 9.2.1 Types and characteristics of solar cells.

Type		Specification	Efficiency	Practical use
Silicon	monocrystal	Expensive since it uses high purity silicon but it has high conversion efficiency & reliability	～20%	Practical
	polycrystal	Since polycrystalline silicon in which small crystals are gathered is used, the cost is lower than monocrystal, most widespread currently	～15%	Practical
	amorphous	Since silicon is not crystallized, it is lower in cost than polycrystalline silicon, but its conversion efficiency is also low.	～9%	Practical
	Multi-junction	Amorphous silicon and thin-film polycrystalline silicon, etc. Tandem structure made by superimposing different solar cells	～18%	Practical
Compound semiconductor	CIS	Copper, indium and selenium are used as raw materials, and the conversion efficiency is relatively low at low cost	～12%	Practical
	CIGS	Gallium is added to three elements of CIS solar cell and made into four elements	～13%	Practical
	CdTe	Cadmium and tellurium are used as raw materials, spreading mainly in Europe and US	～11%	Practical
	GaAs	Gallium and arsenic are used as raw materials. Efficient but expensive, mainly for applications such as artificial satellites.	25%	Practical
Organic	organic thin film	An organic semiconductor is used as a material. The manufacturing cost is low, and research is actively being conducted now	～8%	R & D phase
	Dye-sensitized	It can be manufactured with very low cost materials except electrodes of platinum.	～11%	R & D phase
Quantum dot		Third generation solar cells with a potential theoretical efficiency of 75%. Issues such as scaling up to size with utility	～19%	R & D phase

Source: http://www.solartech.jp/cell_type/, Edited by NIKKEN SEKKEI Research Institute

C Technical potential of PV systems

Every hour, the sun radiates more energy onto the earth than the entire human population uses in one whole year and, there is no shortage of solar energy. How to utilize abundant solar energy is one of the important issues for solving the world energy problem.

In addition, solar energy is the most abundant resource on the planet with low localized ubiquity. If it is a place where solar radiation can be obtained, a certain amount of power generation can be obtained by installing a solar cell module. Compared to solar thermal power generation and wind power generation where the magnitude of the viability greatly affects the amount of power generation and business profitability, the introduction barrier is considered to be relatively small for PV systems. In the future, the prices of PV panels will obviously continue to decline, which makes this technology much more profitable and competitive.

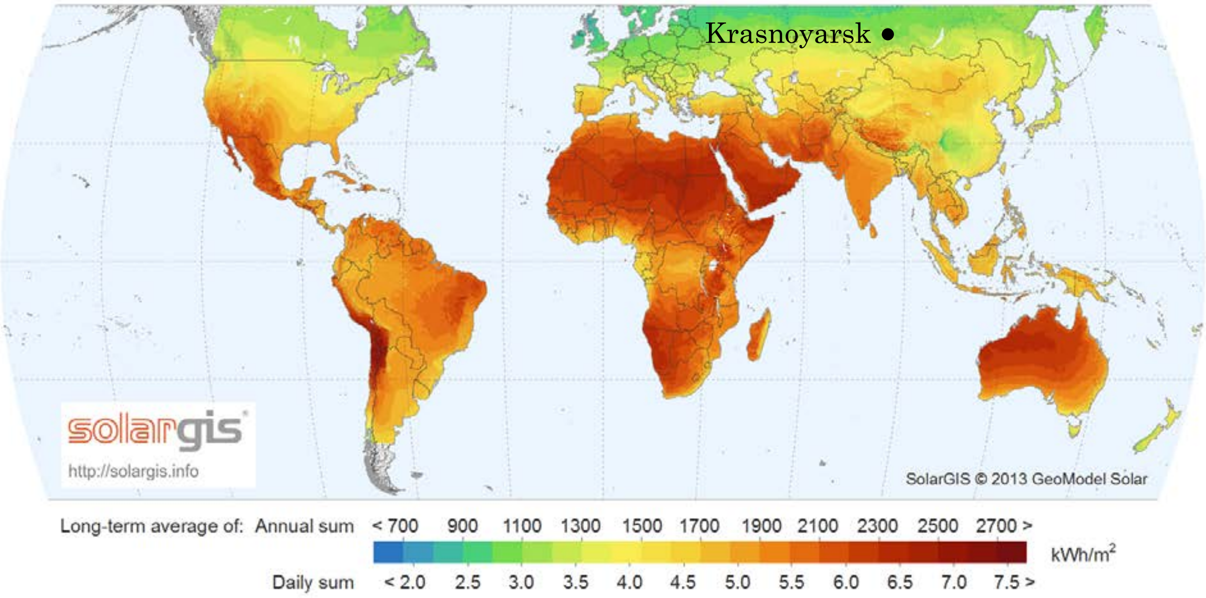
Figure 9.2.1 shows the average insolation at horizontal surface. Large amounts of reserves are available in the southwestern part of the United States, the Middle East, Africa, Australia, Southern Europe, India, Mexico, South America, etc., and solar radiation of approximately 2,000 to 2,500 kWh/m^2 per year can be obtained. These areas are called sunbelts. In the Sunbelt, solar radiation is extremely abundant, and it is hoped that it will be able to generate more electricity than other areas, so there is great expectation.

Russia is located between 41 and 82 degrees north latitude, and solar radiation levels on its territory vary considerably. According to estimates, the average solar radiation in the remote northern regions is 810 kWh/m^2 per year whereas in the southern areas it is more than 1400 kWh/m^2 per year.

Solar energy potential is greatest in the south-west (North Caucasus, the Black and Caspian Sea regions) and in Southern Siberia and the Far East. Regions with significant solar resources include: Kalmykia, Stavropol, Rostov, Krasnodar, Volgograd, Astrakhan, and other regions in the south-west, as well as Altay, Maritime, Chita, Buryatia and other regions in the south-east. In some parts of Western and Eastern Siberia and in the Far East, the annual solar radiation is 1300 kWh/m^2 exceeding levels in the southern regions of Russia.

For instance, in Irkutsk (52° north latitude) incoming solar energy reaches 1340 kWh/m^2, and in the Republic of Yakutia-Sakha (62° north latitude) the figure is 1290 kWh/m^2.

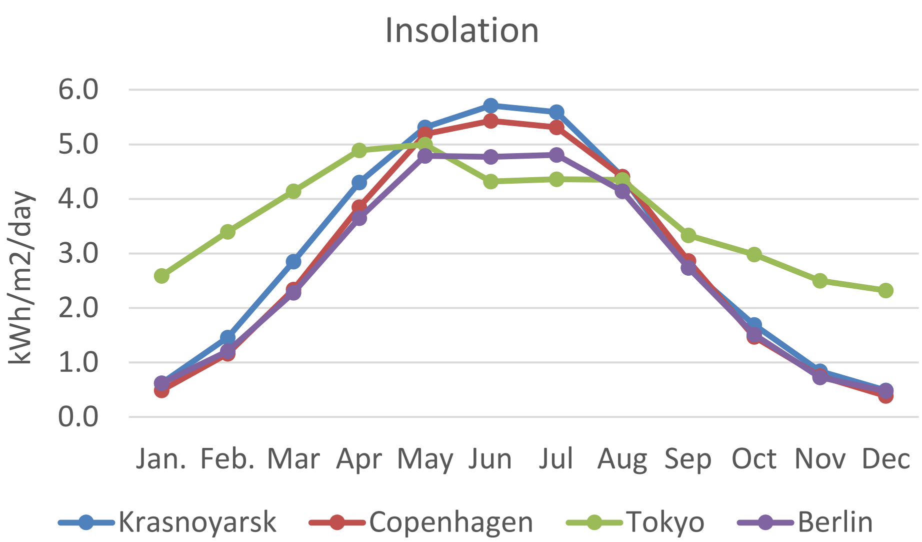
Figure 9.2.1 Average insolation at horizontal surface.



Source: Solar GIS, http://solargis.info

Generally in Krasnoyarsk, solar radiation of approximately 1,000 to 1,200 kWh/m² per year can be obtained. The situation of Krasnoyarsk is quite similar to Berlin in Germany and Copenhagen in Denmark, which are considered to be the most leading countries in the world in promoting PV power generation as well as renewable energy. Figure 9.2.2 shows the comparison of average insolation of different cities

Figure 9.2.2 Comparison of average insolation of different cities.

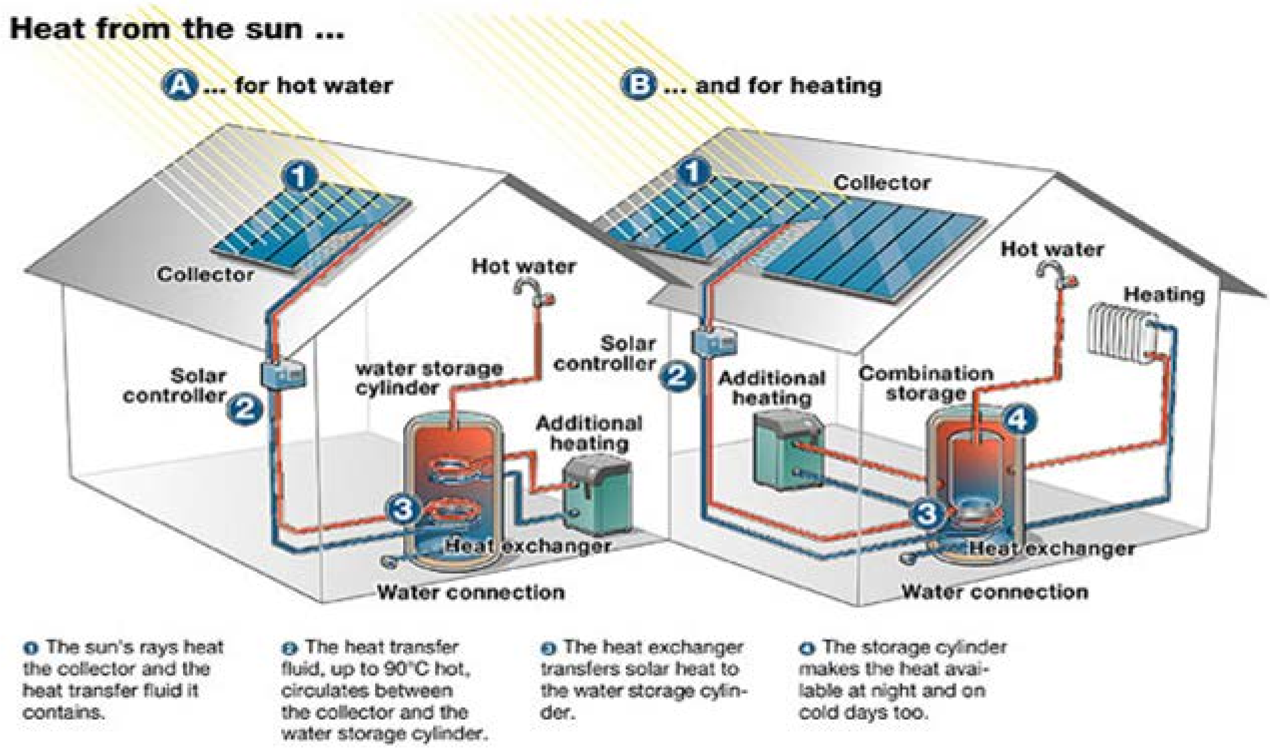


Source: NIKKEN SEKKEI Research Institute

2) Solar thermal energy

In addition to the solar power generation, there is solar thermal power generation as a method of generating electricity using solar energy. Both of them use the energy of the sun, however while solar cells use electric waves of sunlight to obtain power, solar thermal power generation generates steam by using the heat of sunlight. As with most methods of power generation, power is obtained by rotating a turbine. The main point of using solar energy as heat is for solar power generation. This solar thermal power generation is expected to grow in the future, and it is also an active investment field.

Figure 9.2.3 Solar thermal energy utilization and Solar thermal energy work image



Source: AP Photo/SkyFuel, Jack Dempsey

Source: The European Energy Centre

A. Basic technology

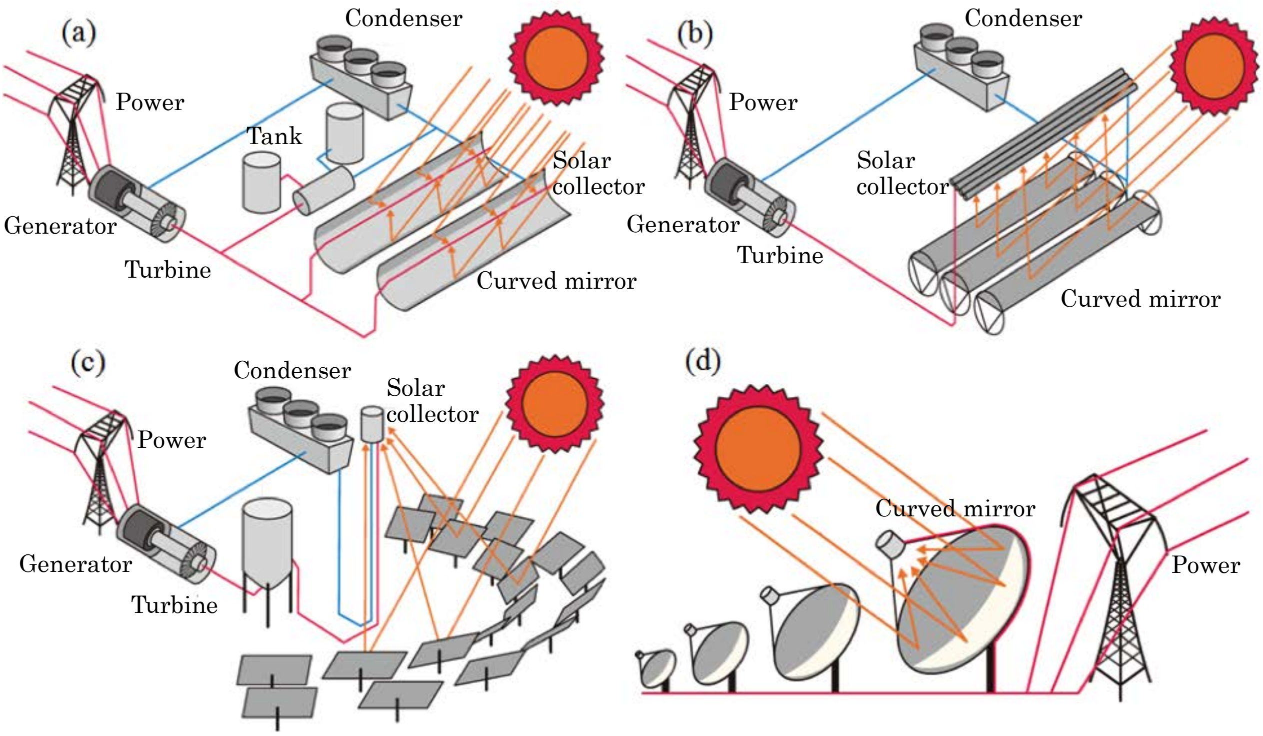
The basic structure of solar thermal power generation is roughly divided into an aggregate part that collects sunlight, a power generation part that rotates a turbine to obtain power, and a heat storage part that stores heat.

B. Type of focusing technique

In order to efficiently collect sunlight, it is necessary to optimize the structure used for convergence and its substances. Because both sunlight and radio waves have wave properties that travel in straight lines, structures that collect solar heat are similar in shape to antennae that collect radio waves. Highly reflective mirrors can be used to concentrate light waves. Concentrating structures can be divided into several types. Figure 9.2.4 shows a schematic diagram.

a) Trough / parabolic type
b) Linear · Fresnel type
c) Tower type · Beam down type
d) Dish type

Figure 9.2.4 Comparison of average insolation of different cities.



Source: New Energy and industrial technology Development Organization, Japan

3) Wind power

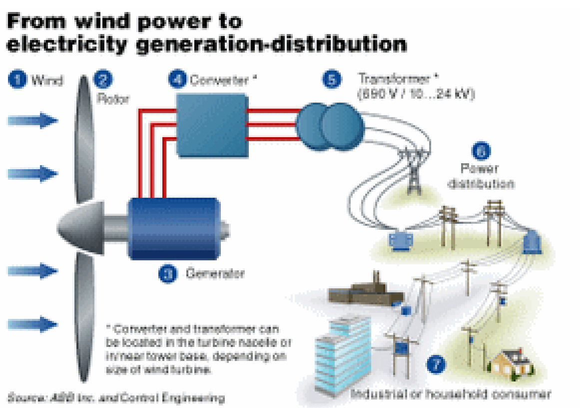
A Outline of wind power

Humans have harnessed wind power for thousands of years, using sails to propel ships and windmills to pump water. It has, however, only been in the past 40 years that wind has been viewed as a viable way to generate electricity on a grand scale.

Wind power generation is a power generation system that converts the kinetic energy of wind into rotational energy by a wind turbine that transmits the rotation to a generator directly or after passing through a speed increasing gear, and converts it into electric energy. Since wind energy increases in proportion to the third power of wind speed, selection of a place with good wind conditions is essential for improving economy, and it is estimated that the optimal annual average wind speed is 7 m/s or more.

Figure 9.2.5 Wind power generation

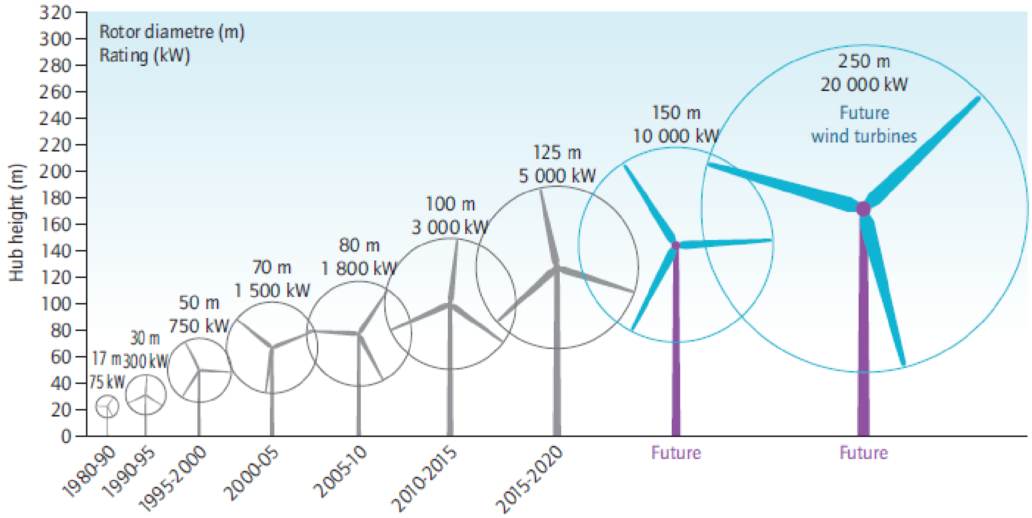
Source: Hokkaido Otonrui Wind Farm, Hokkaido, Japan



Source: Control Engineering Europe

Even without the support of massive subsidies, wind energy is becoming cheaper than coal. This is a major development and today most of the countries that have historically relied the most on coal for their electricity are the ones now investing most heavily in wind (China, USA, Germany, and India). China has reached the upper limit of the amount of coal it can produce without rapidly exhausting its supplies. It is no coincidence that they are now the world's biggest producers of wind power.

Figure 9.2.6 Growth in size of Wind turbines since 1980 and prospects.



Source: Technology Roadmap, Wind energy, 2013 edition, IEA

B Types of wind power

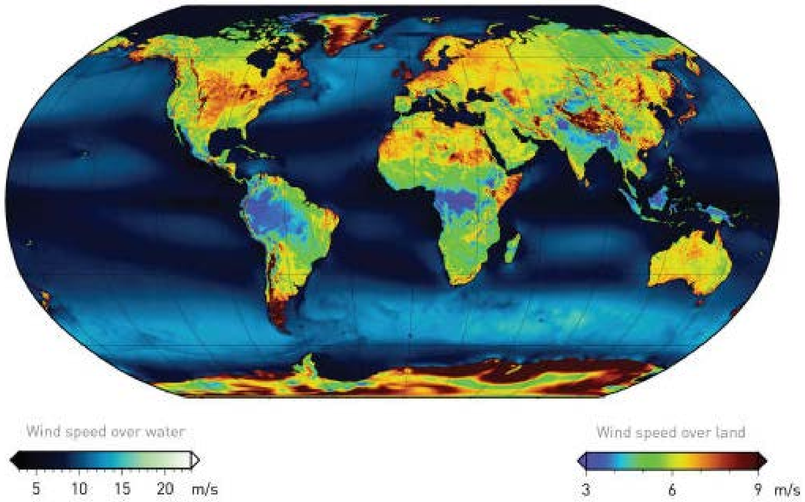
Types of wind power generator can be roughly divided into "horizontal axis" and "vertical axis" depending on the direction of the rotation axis. Furthermore, according to the working principle, they can be divided into "lift type" which obtains high speed rotation by utilizing the lift of a wing and "drag type" which rotates at lower speed by the pushing force of the wind. For medium- and large-sized wind turbines, the three-blade propeller type horizontal axis windmill shown in Figure 3-4 is the mainstream.

C Technical potential of wind power

To acquire as much wind power energy as possible, it is important to install the windmill at a location where wind suitable for wind power generation can be obtained. Since the power generation output per windmill increases relative to size and the output from the entire wind farm increases by installation of multiple windmills (i.e., power generation cost can be reduced), the wind farm has become large in recent years. Figure 9.2.7 is a global wind atlas map showing which areas in the world have the most wind. In the map we can see that wind conditions are especially plentiful in the central part of the United States, the western part of Britain and the southern part of Argentina.

Meanwhile, better wind conditions can be obtained near the ocean than inland. As shown in the wind map, the wind conditions such as the eastern coast of the United States, the North Sea off the UK and Norway, coastal areas of Japan etc. are excellent especially in the winter. Also, the coast of Australia, South Africa, southern Argentina, etc. are blessed with wind throughout the year.

Figure 9.2.7 Comparison of average insolation of different regions.

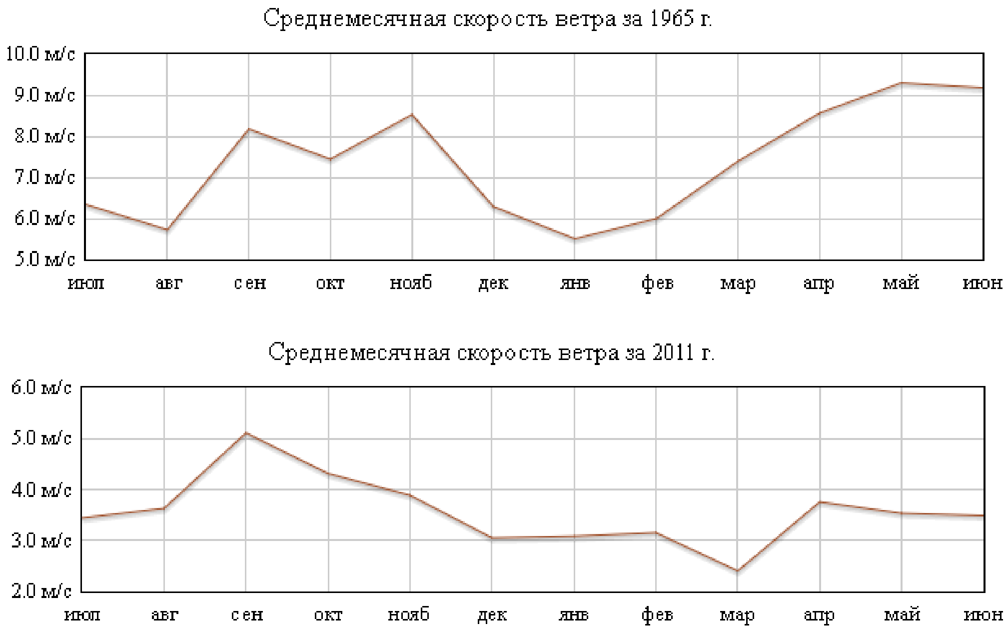


Source: EnergyBC, http://www.energybc.ca/wind.html

In Krasnoyarsk, the average annual wind speed has significantly decreased and the number of windless days has increased over the past decades.

The rapid increase in the density of urban development has influenced the deterioration of the environmental situation over recent years. This has led to frequent windless days. However, there is a more global trend. The total amount of windless days in the region in winter is related to the increasing influence of the Siberian anticyclone, which strongly reduces the potential of self-cleaning capacity of the atmosphere in the city, resulting in emissions of pollutants accumulating in the air.

Figure 9.2.8 Comparison of historic wind speed from 1965 to 2011.



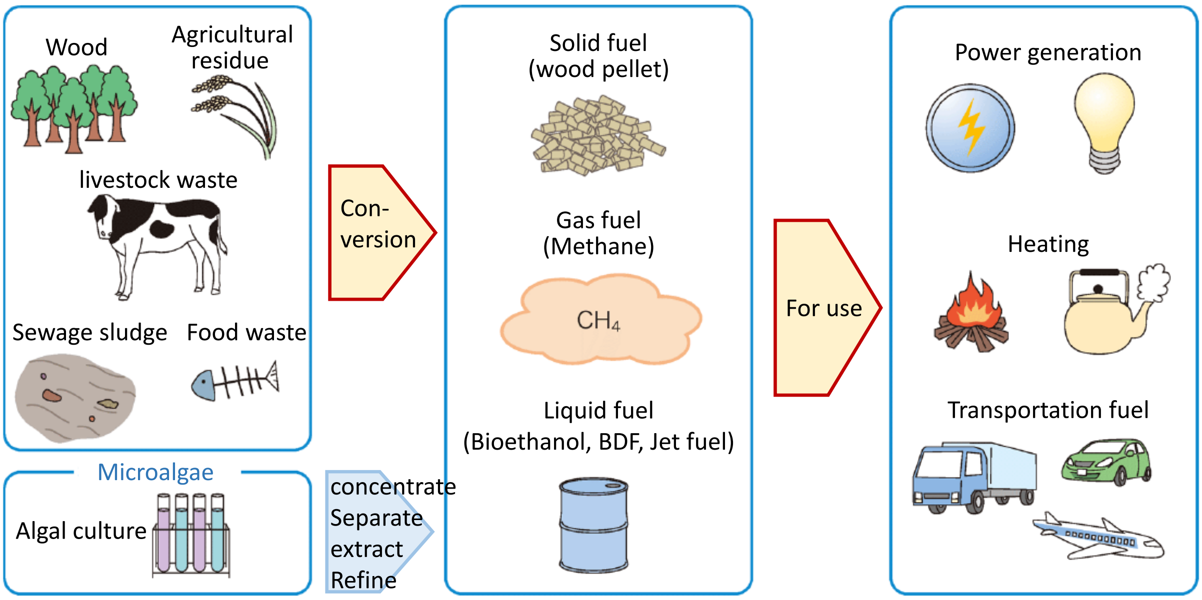
Source: Siberia Federal University, Russia

4) Biomass

A Outline of biomass

Biomass is fuel that is developed from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power.

Figure 9.2.9 Flow of energy use of biomass resources.



Source: New Energy and industrial technology Development Organization, Japan.

Biomass power is carbon neutral electricity generated from renewable organic waste that would otherwise be dumped in landfills, openly burned, or left as fodder for forest fires. Some examples of materials that make up biomass fuels are: scrap lumber; forest debris; certain crops; manure; and some types of waste residues.

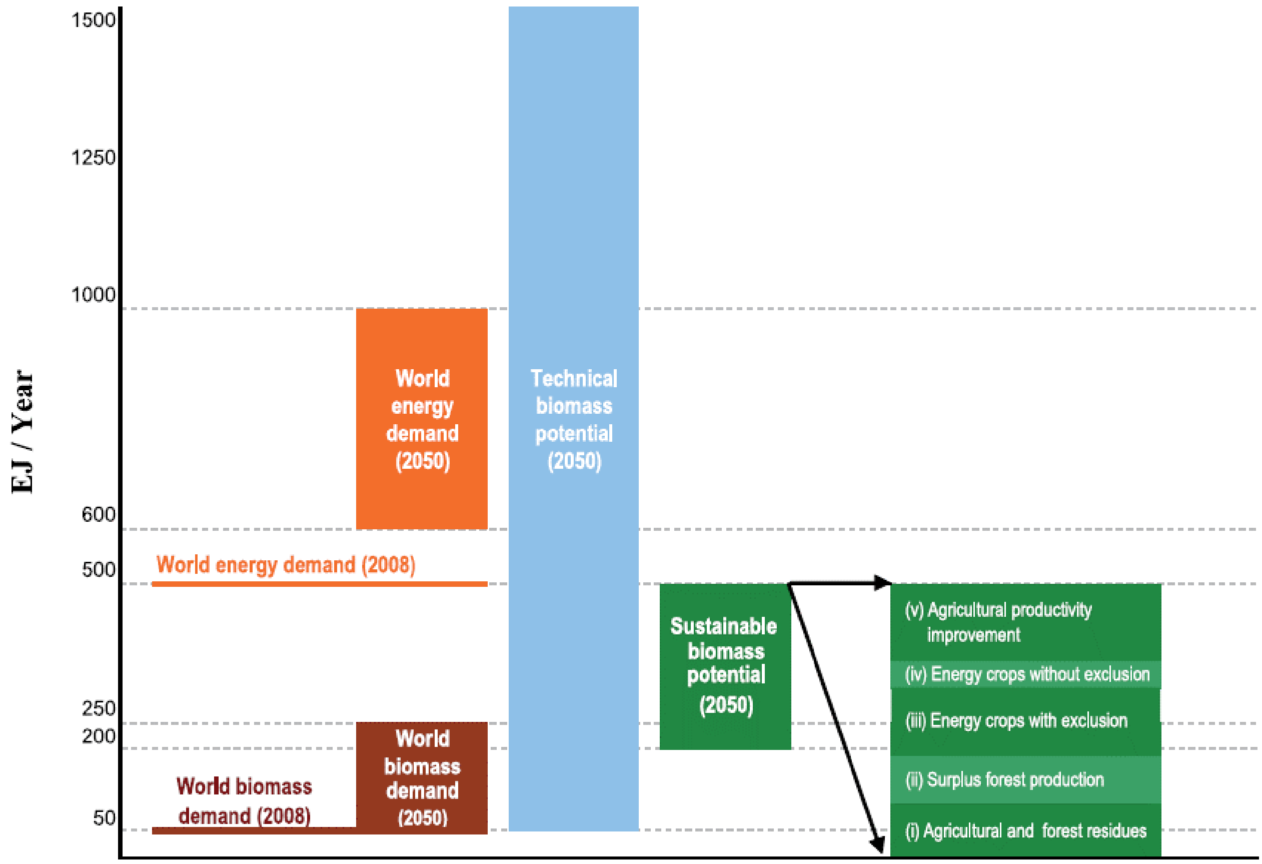
In biomass power plants, wood waste or other waste is burned to produce steam that runs a turbine to make electricity, or that provides heat to industries and homes. Fortunately, new technologies including pollution controls and combustion engineering have advanced to the point that any emissions from burning biomass in industrial facilities are generally less than emissions produced when using fossil fuels (coal, natural gas, oil).

B Potential of biomass

There is a large potential to develop the use of biomass and agricultural, municipal and industrial wastes to produce energy for power generation and district heating systems.

Based on this diverse range of feedstock, the technical potential for biomass is estimated in literature to be possibly as high as 1500 EJ/yr by 2050, although most biomass supply scenarios that take into account sustainability constraints, indicate an annual potential of between 200 and 500 EJ/yr, which is shown in figure 9.2.10.

Figure 9.2.10 Technical and sustainable biomass supply potentials and expected demand for biomass (primary energy) based on global energy models and expected total world primary energy demand in 2050.



Source: Bioenergy – a Sustainable and Reliable Energy Source MAIN REPORT. IEA Bioenergy, 2009.6

9.3. Low-carbon development strategy of renewable energy in Krasnoyarsk city

1) Feasibility analysis of potential renewable energy

Feasibility analysis of renewable energy has been conducted and the potential of each energy source is shown in table 9.3.1.

Table 9.3.1 Feasibility analysis of potential renewable energy.

Content	Potential of Usage	Background of introducing the measure
Photovoltaic power (PV)	★★½	PV is considered to be a highly efficient renewable energy with significant innovation. Large-scale PV panels could be installed around the greenbelt along the river.
Solar thermal energy	★★	Effective for saving on heating energy and hot water in residential areas, successfully used in Nordic countries which have similar solar insolation.
Wind power	★	Wind conditions are not optimal in Krasnoyarsk, the average annual wind speed in the city has significantly decreased due to the deterioration of environmental situation.
Biomass	★★★	There will be enormous kitchen wastes from commercial, hotel, and residences for use as waste resources for biomass plants. Sludge from sewage treatment facilities can also be used for biomass.
Geothermal power	½	Some geothermal energy is used in local areas. For example, RusHydro has existing geothermal plants in Kamchatka.

A Low-carbon strategy to promote PV power generation in Krasnoyarsk city.

Figure 9.3.1 summarized the roadmap of promoting PV power generation in Krasnoyarsk city at different time and scale.

Step-1. Short-term development target: rooftop PV panel installation (Model project)

As a short-term model project, the installation of PV panels on the roof of houses and the canopies in parking lots and gas stations is proposed at small scale.

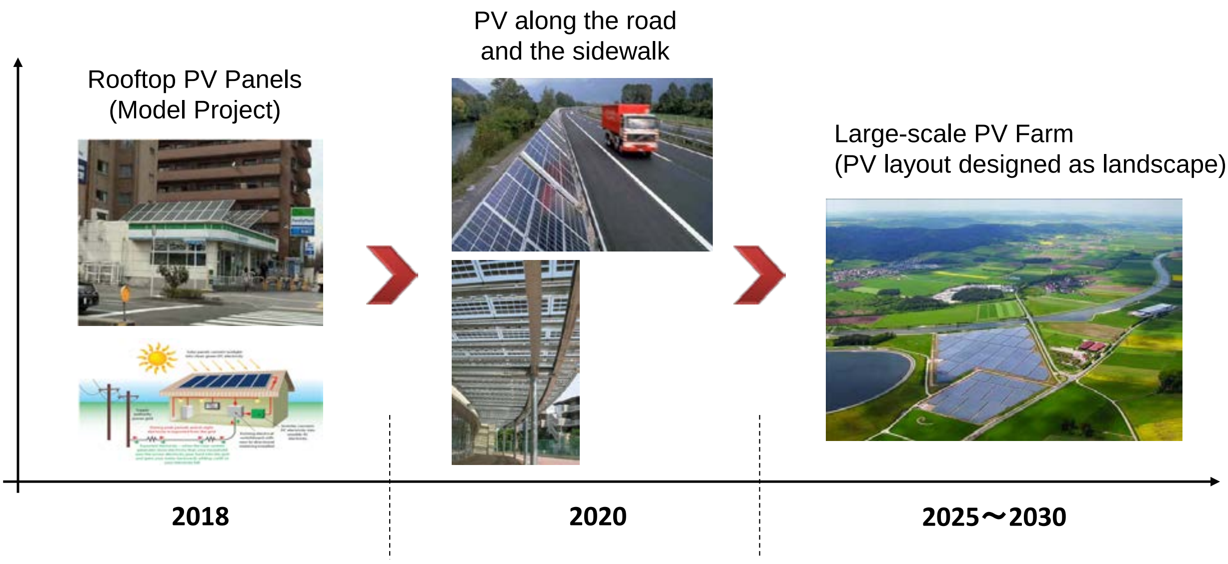
Step-2. Mid-term development target: PV panel installation

In 2020s, following continuous price reduction of PV modules and development of PV technology, PV power generation is expect to be widely adopted in Krasnoyarsk city. In addition to building roofs, PV panels can be placed along the road and the sidewalk.

Step-3. Long-term development target: large-scale PV farm construction

Large-scale PV Farm, PV layout can be designed as landscape.

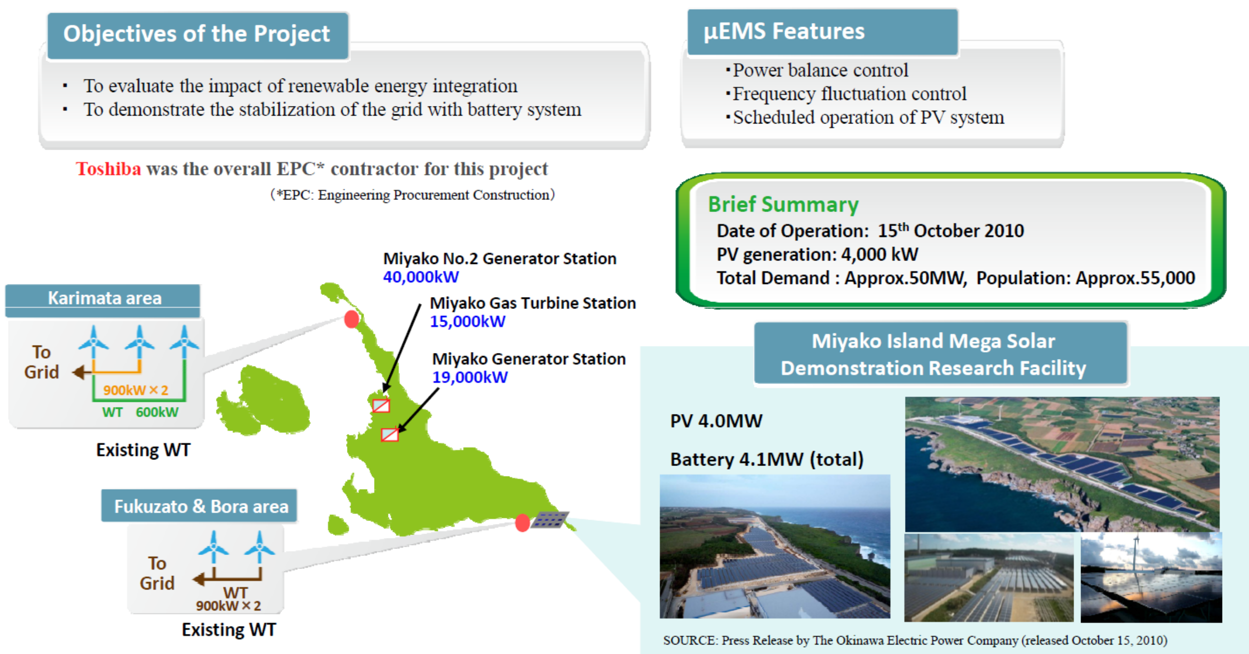
Figure 9.3.1 Roadmap of solar energy application.



Source: NIKKEN SEKKEI Research Institute

Technology improvements and economies of scale have been driving sharp cost reductions, in particular for PV. Solar PV can be cost-competitive with fossil fuel generation without specific financial support in the near future. Figure9.3.2 shows the best practice of a Mega Solar Plant with Storage Batteries on Miyako Island, Japan.

Figure 9.3.2 Example of Mega Solar Plant with Storage Batteries- Case study of Miyako Island.



Source: US-Japan Renewable Energy Policy Business Roundtable, Session3, 3 December 2012, Toshiba Corporation

B Low-carbon strategy to promote biomass energy in Krasnoyarsk city

Biomass energy has been attracting increasing attention around the world as well as in Russia in recent years and gradually more and more companies are tapping into the biomass energy market, which has stimulated the development of the biomass industry at the same time.

In order to promote biomass energy in Krasnoyarsk city, waste separation will be encouraged and waste recycling guidelines need to be established in the short term. Then, an incineration plant (also known as a waste-to-energy plant) will be constructed in a suburban area, which uses trash as fuel for generating power and heat. The burning fuel heats water into steam that drives a turbine to create electricity. The process can reduce landfill volume by up to 90 percent, and prevent one ton of CO_2 release for every ton of waste burned.

Meanwhile, used oil from household and commercial kitchens (recycled restaurant grease) will be collected and delivered to a BDF (biodiesel fuel) plant. Finally, BDF fuel produced from the waste oil will be used as an alternative liquid fuel replacing fuels containing triglycerides as a main raw material (both light oil and heavy oil) for operating diesel engines. The BDF is carbon neutral, that is, even if CO_2 is generated when BDF is burnt, it does not increase the total amount of CO_2 in the atmosphere.

Figure 9.3.3 describes the conceptual diagram of energy utilization from waste in Krasnoyarsk city.

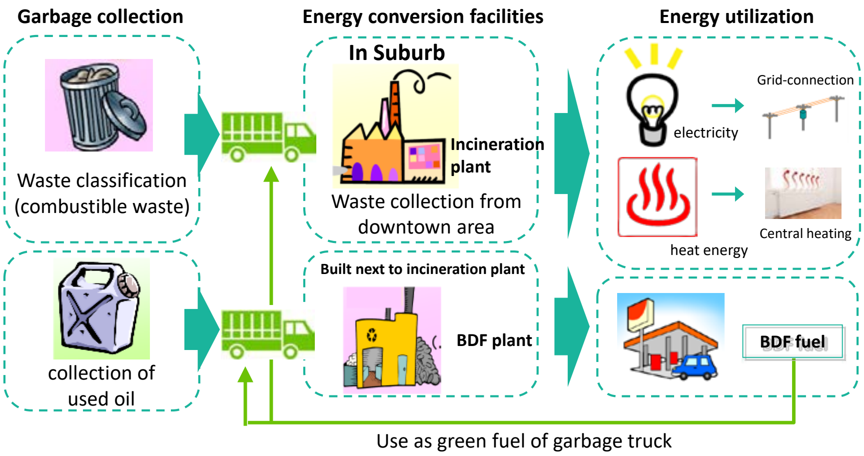
Burnable waste: To be burned in an incineration plant.

Electricity: To be sold into the power companies grid.

Heat energy: To be supplied to the surrounding districts.

BDF fuel: To be used as fuel for waste collection vehicles.

Figure 9.3.3. Conceptual Diagram of Energy Utilization from waste



Source: NIKKEN SEKKEI Research Institute.

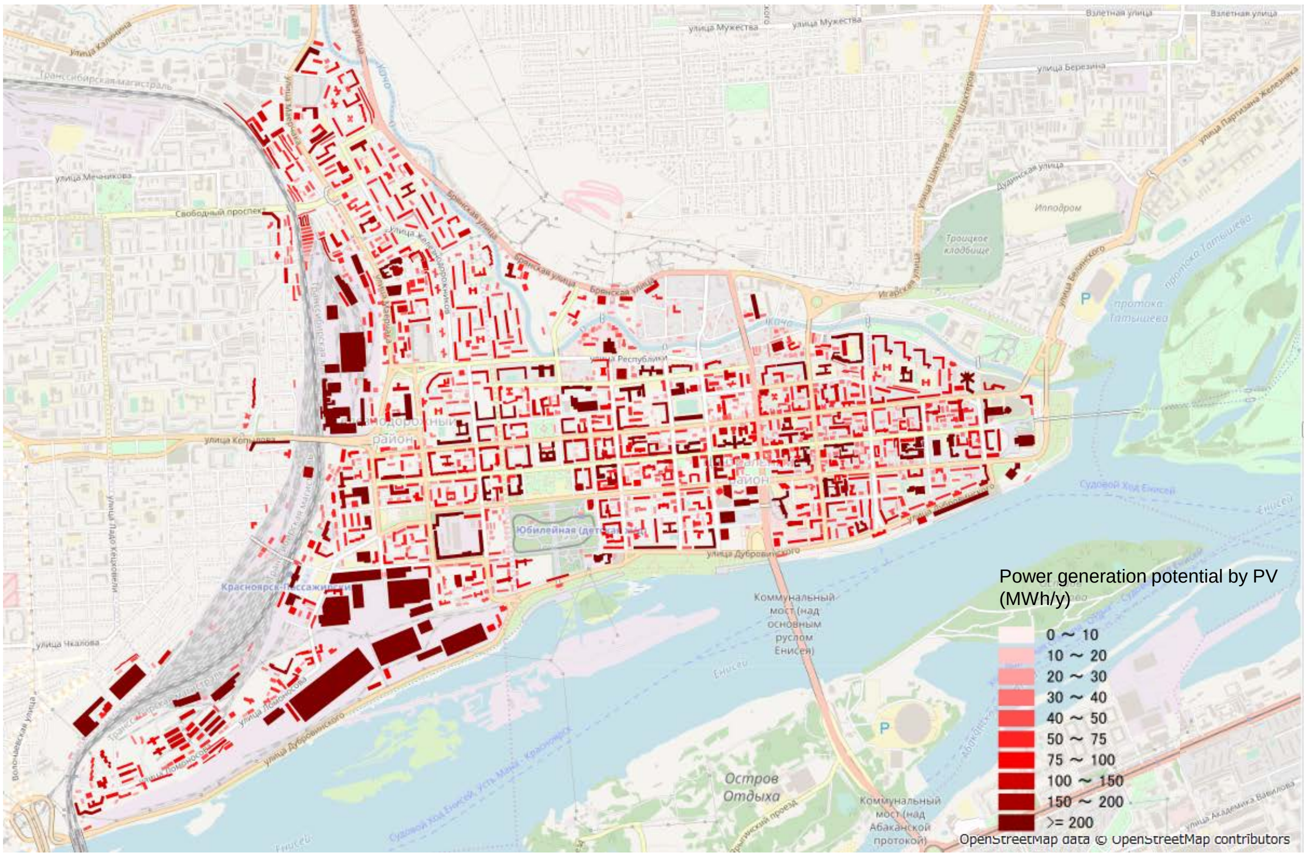
9.4. Analysis of the CO2 emission reduction potential

According to the feasibility analysis of renewable energy utilization potential in section 9.3, further study of CO_2 emission reduction effect has been conducted quantitatively for “photovoltaic power generation” and “biomass power generation”, whose low-carbon effects seem to be relatively high in Krasnoyarsk city.

1) Photovoltaic power generation

In this study, application of photovoltaic power generation in an existing CBD (Central Business District) area is analyzed quantitatively to demonstrate its effectiveness. As a result, roughly 114 GWh power can be potentially generated annually if half of the building roofs in the CBD area have PV panels installed , which is equivalent to 1.7% of total power consumption of Krasnoyarsk city excluding KrAS (Aluminum Smelter), figure 9.4.1 and 9.4.2 show distribution of PV power generation potential. It is clear that large-scale buildings located on the west of the CBD area have greater potential for power generation due to their lager roof area.

Figure 9.4.1. Distribution of PV power generation potential in CBD area.



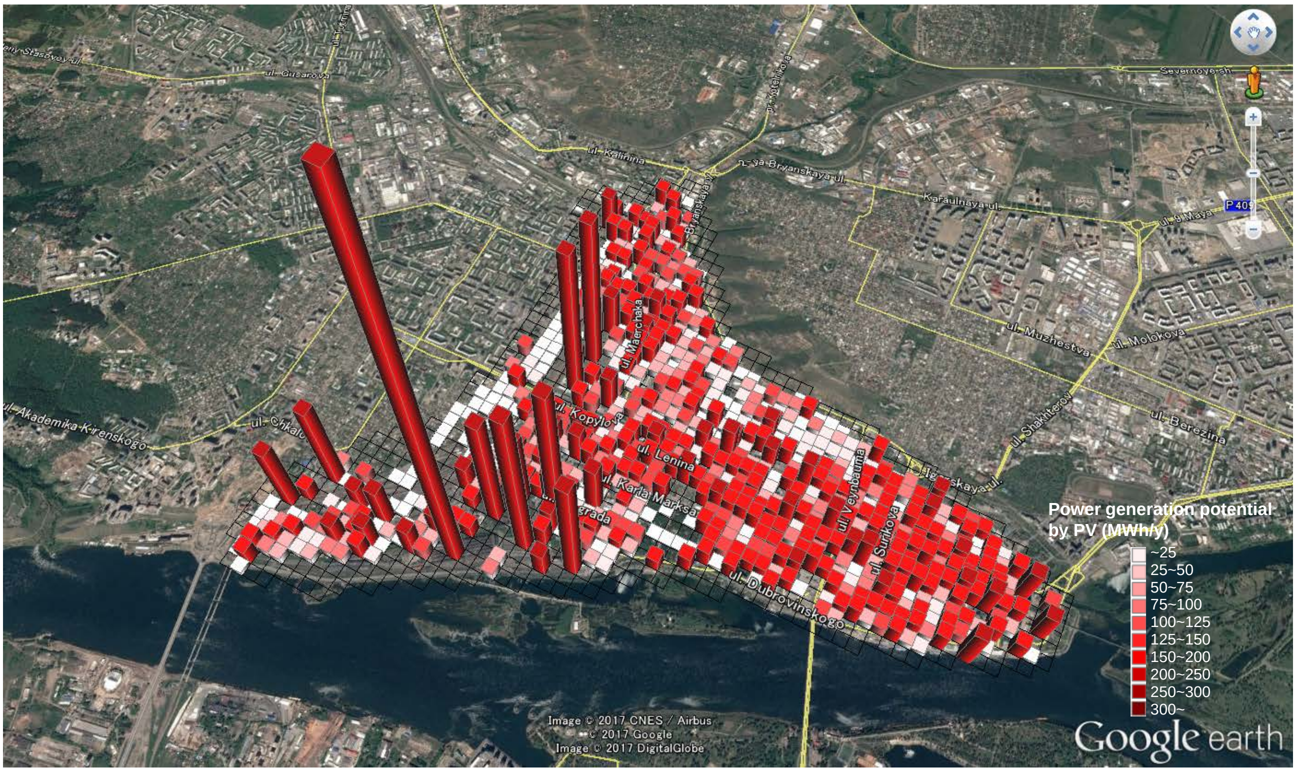
Source: NIKKEN SEKKEI Research Institute.

Table 9.4.1. Estimate of PV power generation potential in the existing CBD area

District	Roof area (million m^2)	PV installation area (million m^2)	Possible PV capacity (MW)	Power generation (MWh/y)	CO_2 reduction effect (t/year)	Equivalent number of trees
CBD	1.9	0.95	126	113,914	54,166	1,354,150

Source: NIKKEN SEKKEI Research Institute.

Figure 9.4.2. Distribution of PV power generation potential in CBD area.



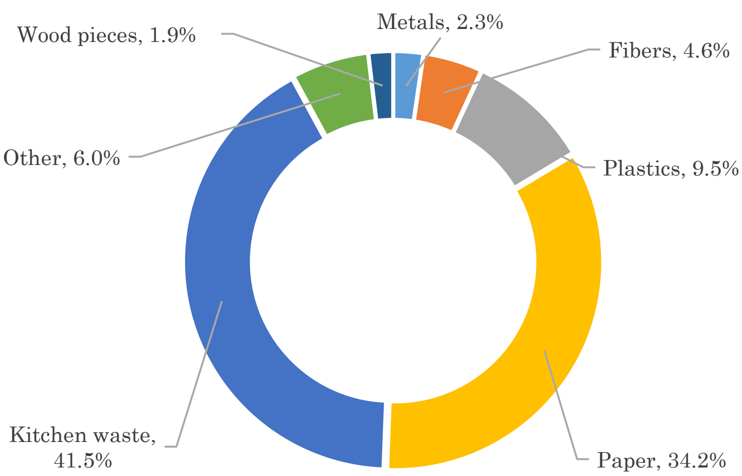
Source: NIKKEN SEKKEI Research Institute.

2) Biomass

A Estimate of waste amount

This section estimates the quantities of general waste that would be generated by household and business sectors in Krasnoyarsk city. Since the real data of waste amount is not available, estimates of waste amounts are based on the real data of Kyoto city, Japan, which has similar population scale to Krasnoyarsk city. The population of Krasnoyarsk city is 1.07 million while Kyoto city is 1.4 million. Figure 9.4.3 shows the breakdown of different trash in Kyoto city, kitchen waste takes majority in garbage and followed by paper, plastic and others. Table 9.4.2 demonstrates the resultant estimation of waste amount.

Figure 9.4.3. Ratio of different trash types, Kyoto city, Japan



Source: http://sukkiri-kyoto.com/data/gomidata#gomidata2. Edited by NIKKEN SEKKEI Research Institute

Table 9.4.2. Estimate of waste amount, Krasnoyarsk city

Year	2014	2015	2016	2017	2018	2019
Permanent population (p)	1,044,907	1,060,543	1,075,382	1,083,900	1,105,666	1,120,724
household garbage (ton)	236,112	239,645	242,998	244,923	249,841	253,244
Commercial garbage (ton)	116,294	118,034	119,685	120,634	123,056	124,732
TOTAL (ton)	352,405	357,679	362,683	365,556	372,897	377,975

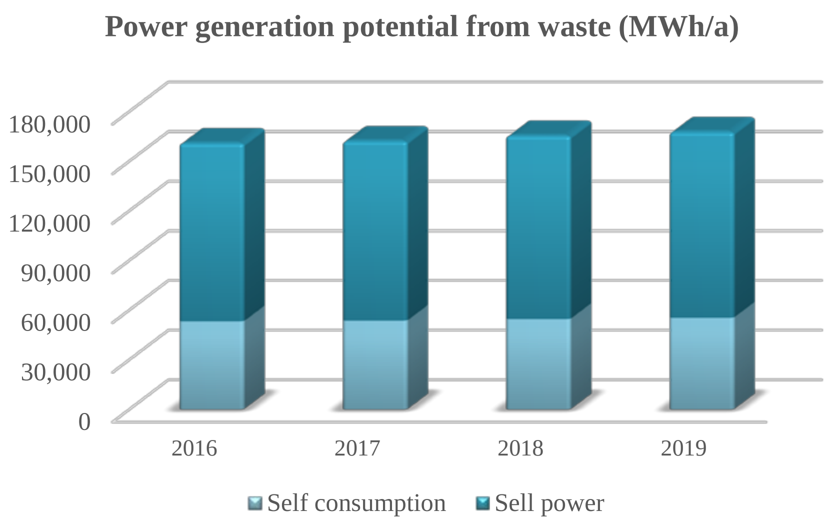
Source: NIKKEN SEKKEI Research Institute.

B Estimate of CO_2 emission effect

In general, 90% of municipal solid waste could be burned in the waste-to-energy plants to generate power and heat energy after removing the recyclable items. As shown in figure 9.4.4, approximately 167,000 MWh electricity could be potentially generated by waste-to-energy plants in 2019, in which 25% of power generated will be consumed inside the plant while the rest will be supplied into power grid.

According to the analysis, power sold from the waste-to-energy plants can roughly provide 1.6% of total power consumption of Krasnoyarsk city. It can also reduce CO_2 emission of 53,000 tons annually, noting that the calorific value of waste is set as 10MJ/kg.

Figure 9.4.4. Potential of power generation from municipal waste



Source: NIKKEN SEKKEI Research Institute.

(A) Waste cooking oil

The usable quantity of waste cooking oil is calculated using the basic unit below:
Waste cooking oil from kitchen: 1.5 kg/ person/ year
In 2016, the potential collective amount of used cooking oil was assumed to be 968 ton (approximately 1,075 kL).

10 AREA ENERGY MANAGEMENT SYSTEM

10. Area Energy Management System

10.1. Overview of area energy management

The energy conservation methods in each building or technical innovation in supply side are not sufficient to achieve optimal low carbon development in the city level. It is necessary to make effort to gather information and comprehensively design and operate the method that introduced in individual buildings, not only during design but also during construction and operation phases.

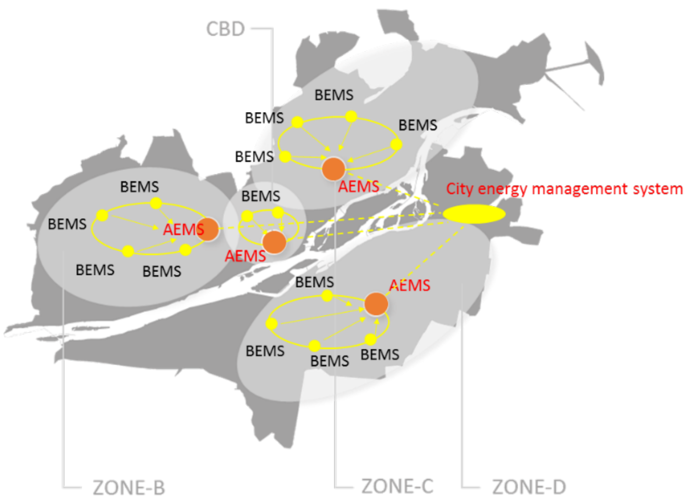
Area energy management system (AEMS) is an information based management system that can collect information of both demand side and supply side, analyze and manage this information to realize optimal operation. It is an approach to environment and energy (low-carbon) as well as a support system for implementing, maintaining and improving the environment through cooperation between buildings. AEMS can efficiently operate, monitor, and control energy across the entire region.

The basic concept of AEMS for Krasnoyarsk city are

1) Community-based AEMS

From the viewpoint of feasibility, AEMS for the whole city is difficult to develop in one step. The aim of community based AEMS is to develop the AEMS system in a demonstration area first, where energy consumption is higher or is a priority within the low carbon development master plan. In this survey, the central business district of the city center and Solontsy are recommended as demonstration areas of the community based AEMS.

Fig 10.1.1 Concept of community based AEMS



Source: NIKKEN SEKKEI Research Institute

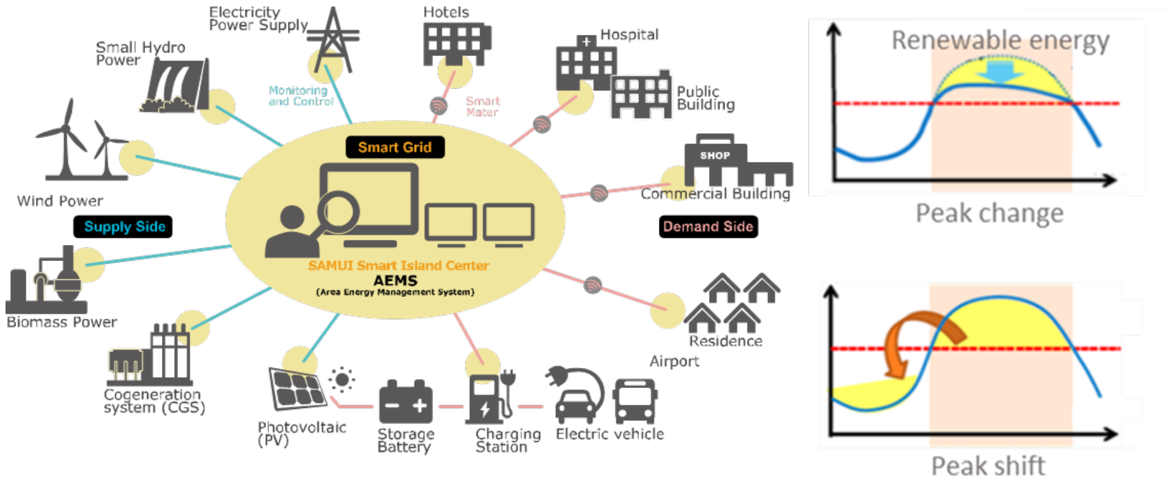
2) A bi-directional smart grid with demand-supply management

Community based AEMS system is an intermediate scale within a hierarchical system, a bi-directional smart grid with demand-supply management. It is connected to the BEMS in buildings and functions to 1) collect and gather building energy consumption data; 2) study the energy conservation strategies introduced in the buildings and estimate their effect; 3) analyze and gather information from the supply side and realize an optimal status in the city level.

In addition to the data connection on the demand side, AEMS connects to the energy supply side, gathering data on renewable energy generation and comprehensively manages the generation, storage, and multi-energy distribution system.

Further, with optimized control by AEMS system, the city energy system can realize peak cut and peak shift by utilizing renewable energy within the existing infrastructure.

Fig 10.1.2 AEMS with conscious of Demand-supply side



Source: NIKKEN SEKKEI Research Institute

3) Comprehensive town management system

In addition to energy management, AEMS is also a comprehensive concept derived from the idea of area management where local people, including residents, business operators, and landowners (land ownership holders) of an area take initiatives to improve their regional environment and community values. Therefore, besides energy management, it can also offer a comprehensive platform and community service.

Fig 10.1.3 Comprehensive AEMS with city information

Source: NIKKEN SEKKEI Research Institute

10.2. Conceptual design for AEMS

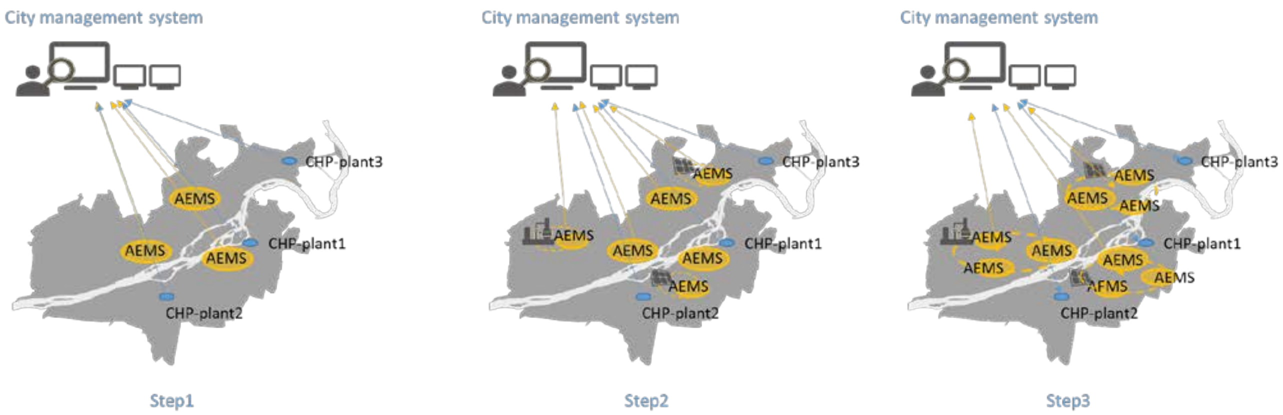
10.2.1. Roadmap for community-based AEMS

A community is generally considered to be a certain area in which people live together with a sense of being a cluster, or a group of such people. A city is formed of a number of such communities, in other words, communities are a core factor in the formation of a city.

With the same concept, the area energy management system is also developed as community base. There are different kinds of communities in the city, such as communities with historic buildings, commercial business districts (CBD) and communities with primarily residential buildings. Different communities have their own energy consumption features and renewable energy utilization potential.

However, their basic configuration and diagram are similar. All these AEMS for various communities, when connected form the city management system.

Fig 10.2.1 Roadmap for city management system



Source: NIKKEN SEKKEI Research Institute

It is constructed in the following steps:

- **Step1:**

(1) Select the demonstration area

The AEMS system is difficult to implement city-wide within a short timeframe. Therefore, as a first step in the short term, a number of communities are selected as demonstration areas for constructing micro-grid and AEMS. Communities with different features are recommend, such as the example below:

- CBD consisting of diverse building types, with high building density, high population density and energy consumption;
- Community with historic buildings, including residential and retail
- Community with new construction residential buildings

(2) Construction of micro-grid and AEMS in demonstration communities

The micro gird for each community consists of two types of infrastructure, the power grid and information network. Major public buildings, commercial buildings and residential buildings are connected to the power grid. The power grid also connects distributed resources, including the on-site renewable and untapped power resources. Information network is responsible for collecting data from both demand side and supply side.

AEMS are introduced in every community. They collect the data from EMS in both demand side and supply side trough the information network. Based on the analysis of this data, optimized system patterns with different architecture, construction, and management methods are suggested for different types of communities.

(3) Set up city energy management system for general control and data monitoring;

Initially, when the AEMS is not widely spread, a city energy management system with data monitoring of both energy supply side and demand side is recommended. It can be set up within the city government.

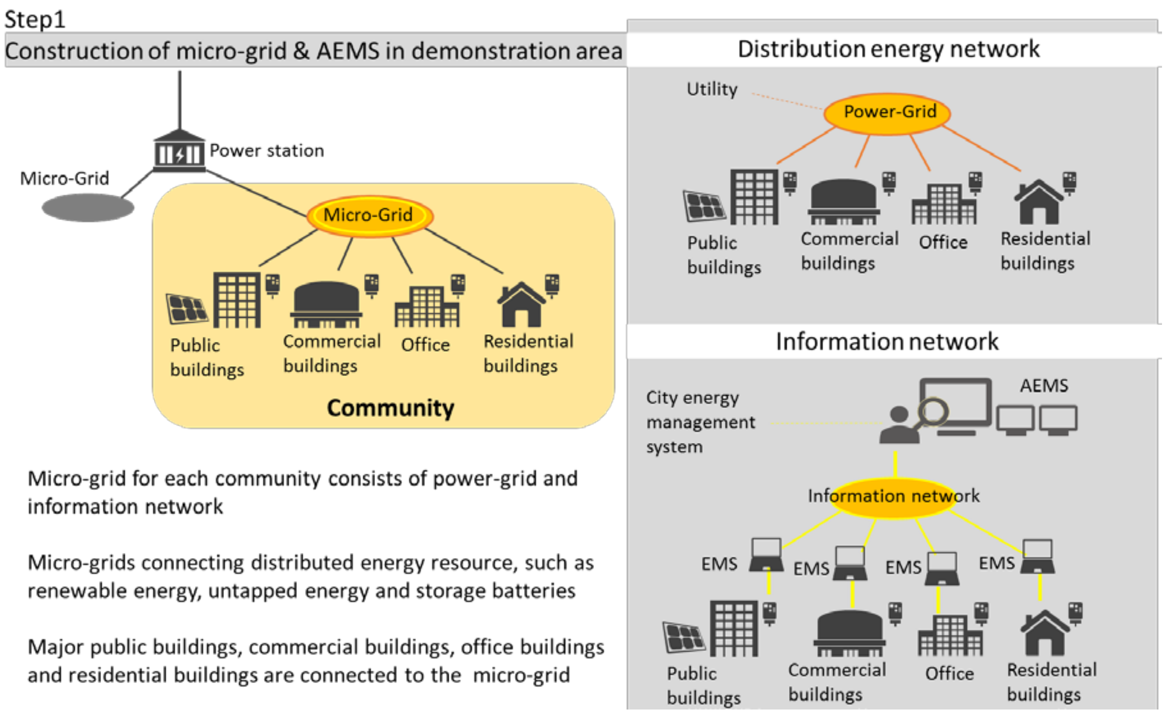
- **Step2:**

(1) Development of micro-grid and AEMS in other areas

The different patterns of AEMS from step1 are developed and utilized in other communities in the city.

(2) Utilization of on-site distributed energy resources through micro-grid.

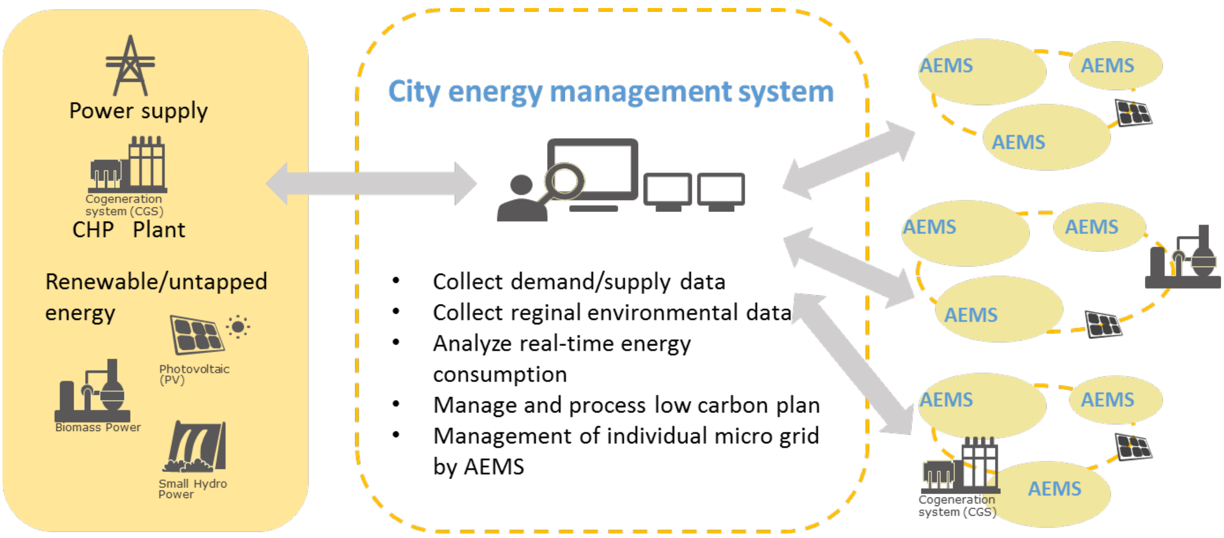
Fig 10.2.2 Concept for Step1—Step2



Source: NIKKEN SEKKEI Research Institute

- **Step3:** Construction of smart grid and energy management system throughout the entire city The individual AEMS for different communities are connected and controlled to form an energy management system for the entire city. This step, with the smart grid for the entire city, represents the final step in implementing the city energy management system with demand and supply management.

Fig 10.2.3 Concept for Step3



Source: NIKKEN SEKKEI Research Institute

10.2.2. Diagram for community-based AEMS

For the concepts proposed for community based AEMS, two types of infrastructures are needed for every micro-grid in the community; the power-grid and the information network.

1) Diagram for distributed power grid

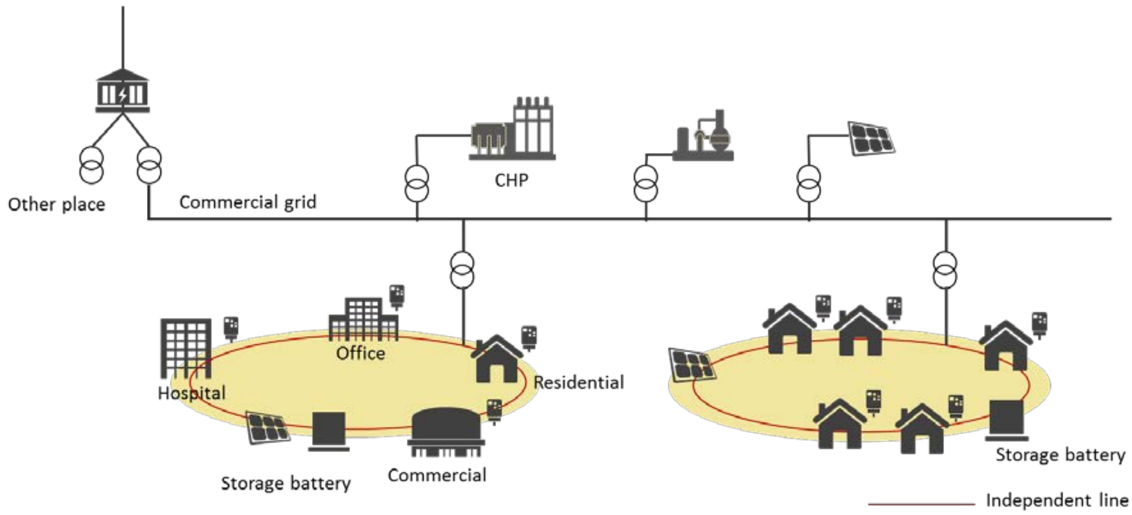
Distributed power grid integrates the buildings (demand side) and all the distributed power sources including onsite renewable energy, untapped energy and storage batteries. There are two main options for constructing the power grid:

A Micro-grid with independent power grid

This method connects the buildings and distributed energy sources with an independent power grid, which is developed for that community only. The independent power grid is connected to the existing commercial power grid at one interconnection.

This type of micro-grid has only one interconnection point, therefore it is easier to achieve. It has less effect on the commercial grid and has better energy security. However, the disadvantage of this type is that it requires an extremely high initial investment cost.

Fig 10.2.4 micro-grid with independent line

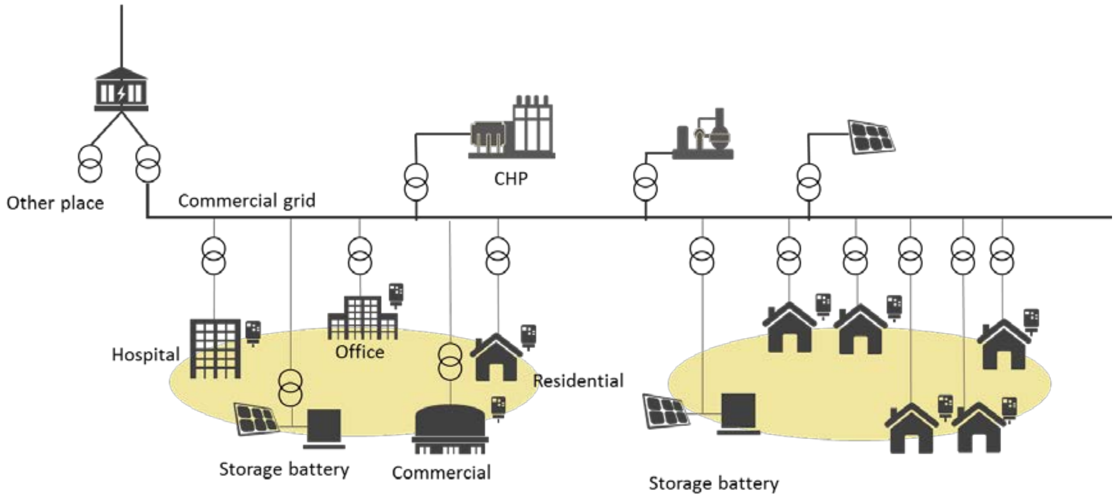


Source: NIKKEN SEKKEI Research Institute

B Micro-grid by existing commercial grid

This method makes use of the existing commercial power grid by connecting individual distributed power sources to nearby power grid lines.

Fig 10.2.5 micro-grid with commercial line



Source: NIKKEN SEKKEI Research Institute

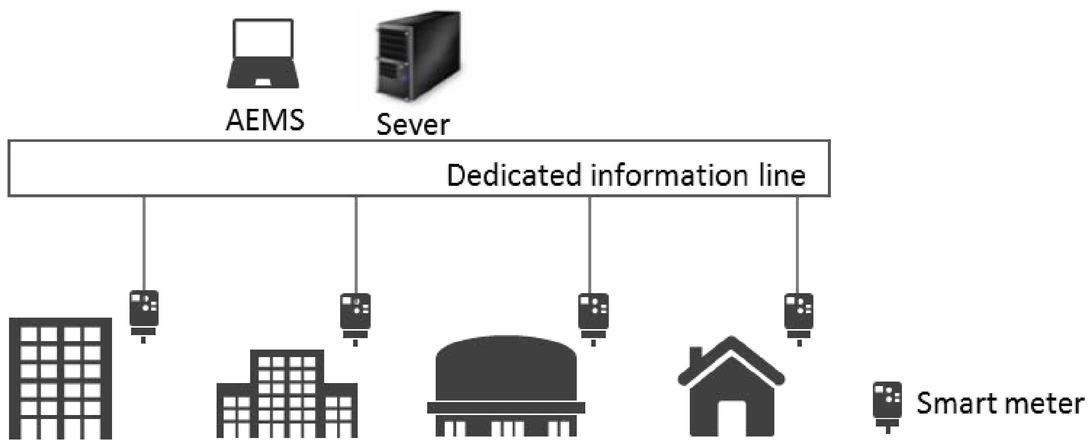
The main advantage of this option is its low cost to develop the power system by cutting down the installation costs for power transmission lines.

Its disadvantage would be that the output powers of distributed sources fluctuate greatly, which impact the power quality (voltage and frequency deviations, etc.) of the existing power grid. Mitigation measures must be put in place to ensure the power quality of the entire grid.

2) Diagram for information network

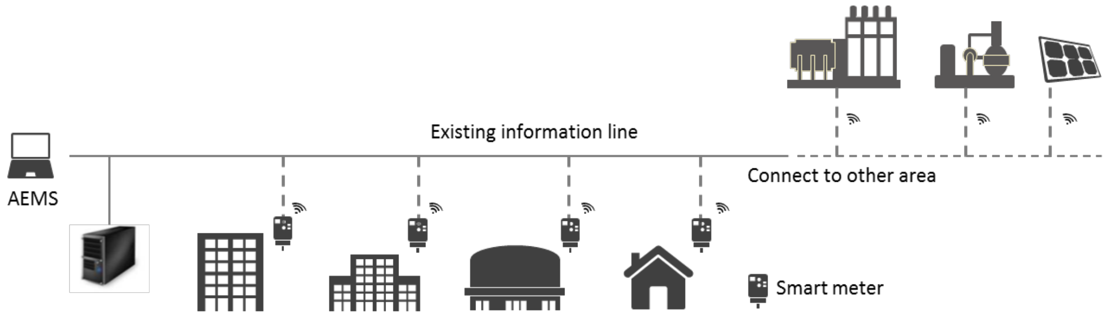
Along with the power grid, there are also two types of method for information network construction; constructing a dedicated information network and use of existing infrastructure.

Fig 10.2.6 Information network with dedicated information line



Source: NIKKEN SEKKEI Research Institute

Fig 10.2.7 Information network with existing information line



Source: NIKKEN SEKKEI Research Institute

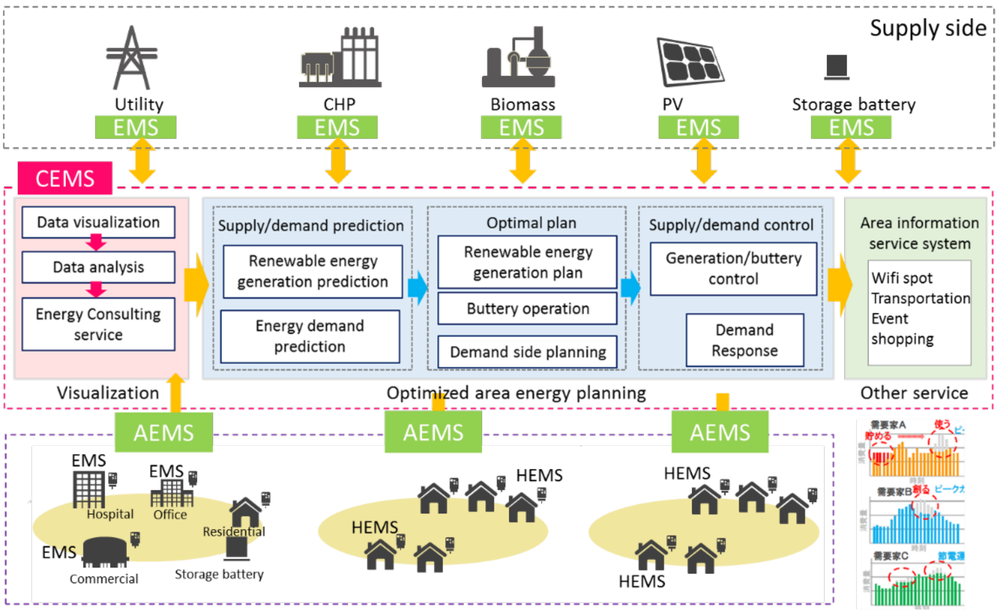
Information networks utilizing existing information lines are a low-cost method, however they have a higher security risk.

Therefore, for large-scale communities, especially communities with more existing buildings, the micro-grid utilizing existing information network and commercial grid are recommended. For middle or small-scale communities, especially communities needing a high level of security, such as hospital or university communities, an independent power line and dedicated information is recommended.

10.2.3. Components and functions of AEMS

AEMS responsible for energy management of the community, has the capability to monitor, control, and optimize the operation of EMS.

Fig 10.2.8 Example of AEMS system



Source: NIKKEN SEKKEI Research Institute

■ Demand forecast

- Gather energy consumption data from EMS
- Energy demand forecast based on collected data

■ Supply forecast

- Gather energy supply data
- Forecast generation of renewable energy and other kinds of generation.

■ Demand-supply plan

- Optimization plan for storage batteries and distributed generation
- Optimal control based on the demand-supply forecast (distributed power resource, demand response)
- Optimal energy supply during disaster occurrence
- Visualization of regional energy
- Energy-saving diagnosis and management

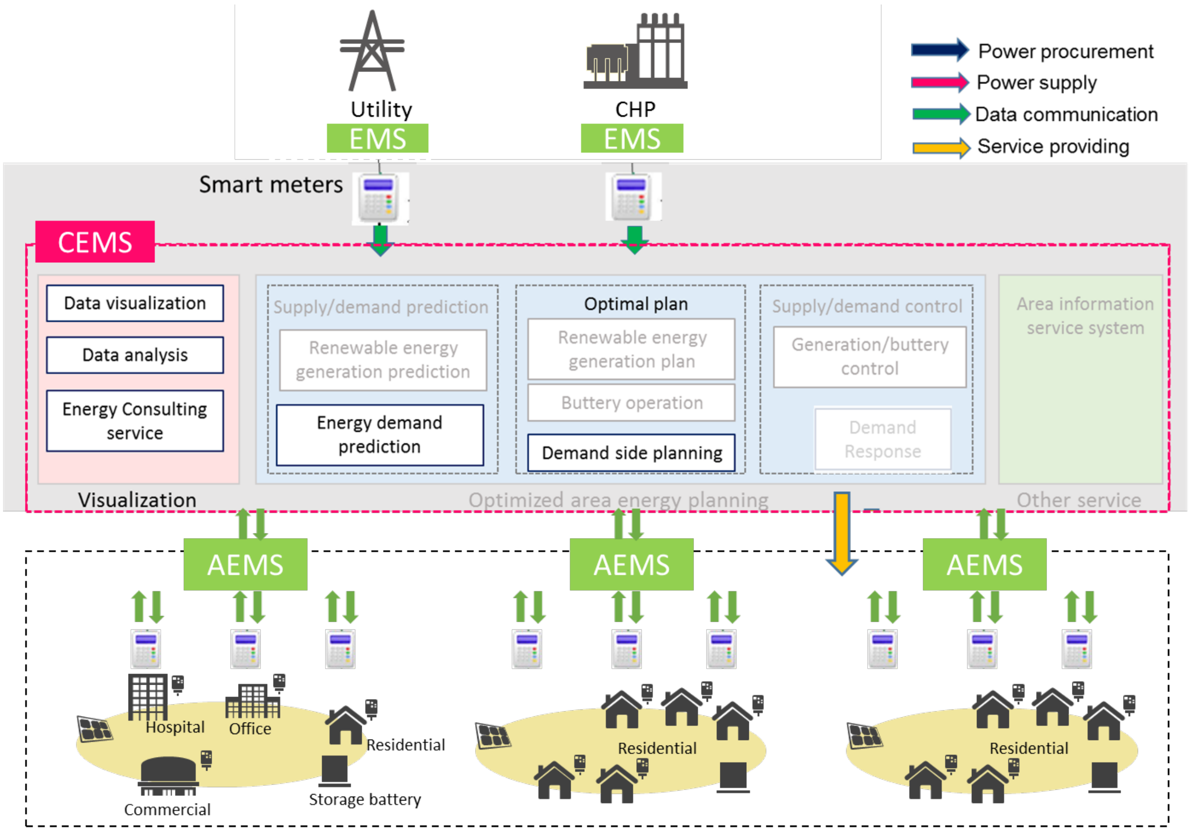
10.2.4. Functions for Step1~Step3

For phased development concept of AEMS, the functions for each phase can be described as below:

Step1: Short-term (AEMS in demonstration area)

- Set up EMS in target buildings, as public buildings, commercial buildings with higher energy consumption.
- Set up AEMS for those demonstration area, control and manage through the EMS
- Set up the city energy management system for monitoring the data from supply and demand side

Fig 10.2.9 Functions of AEMS in short-term

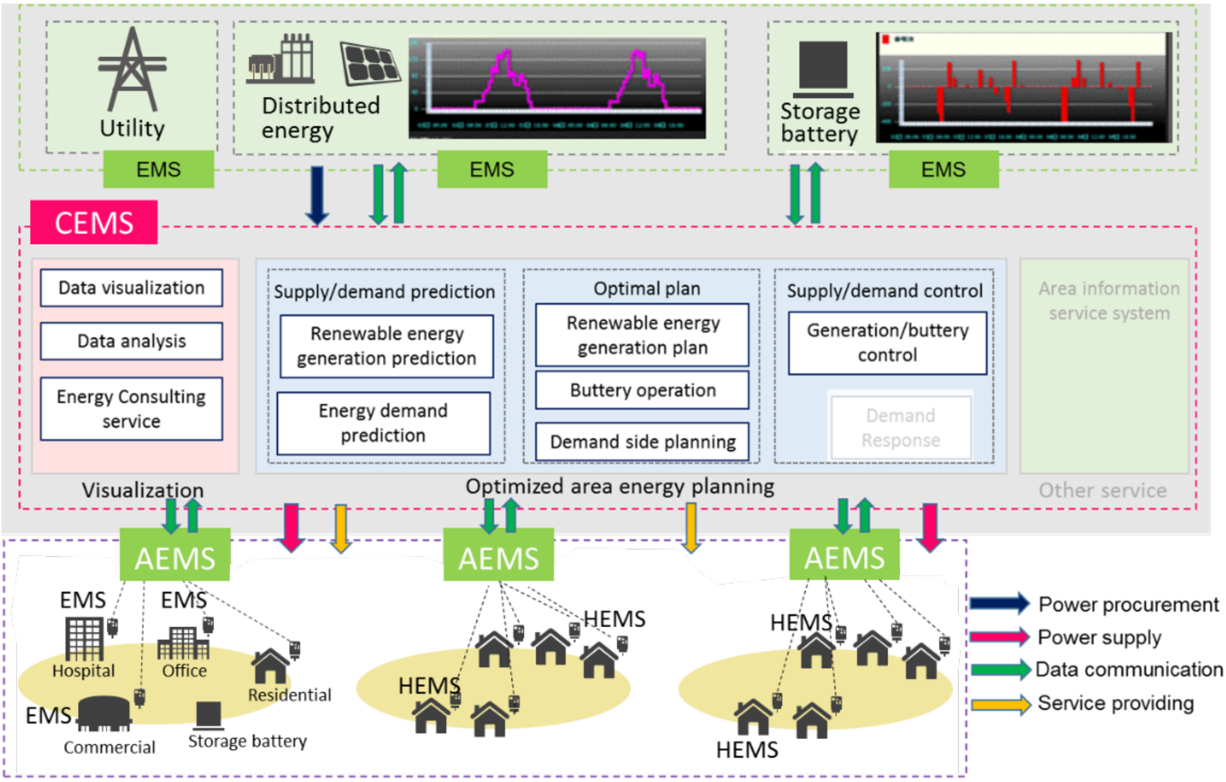


Source: NIKKEN SEKKEI Research Institute

Step2: Mid-term

- Introduce storage batteries, onsite renewable energy during renovation of existing buildings.
- Cooperative control of AEMS and local storage batteries to realize optimal operation

Fig 10.2.10 Mid-term Functions of AEMS

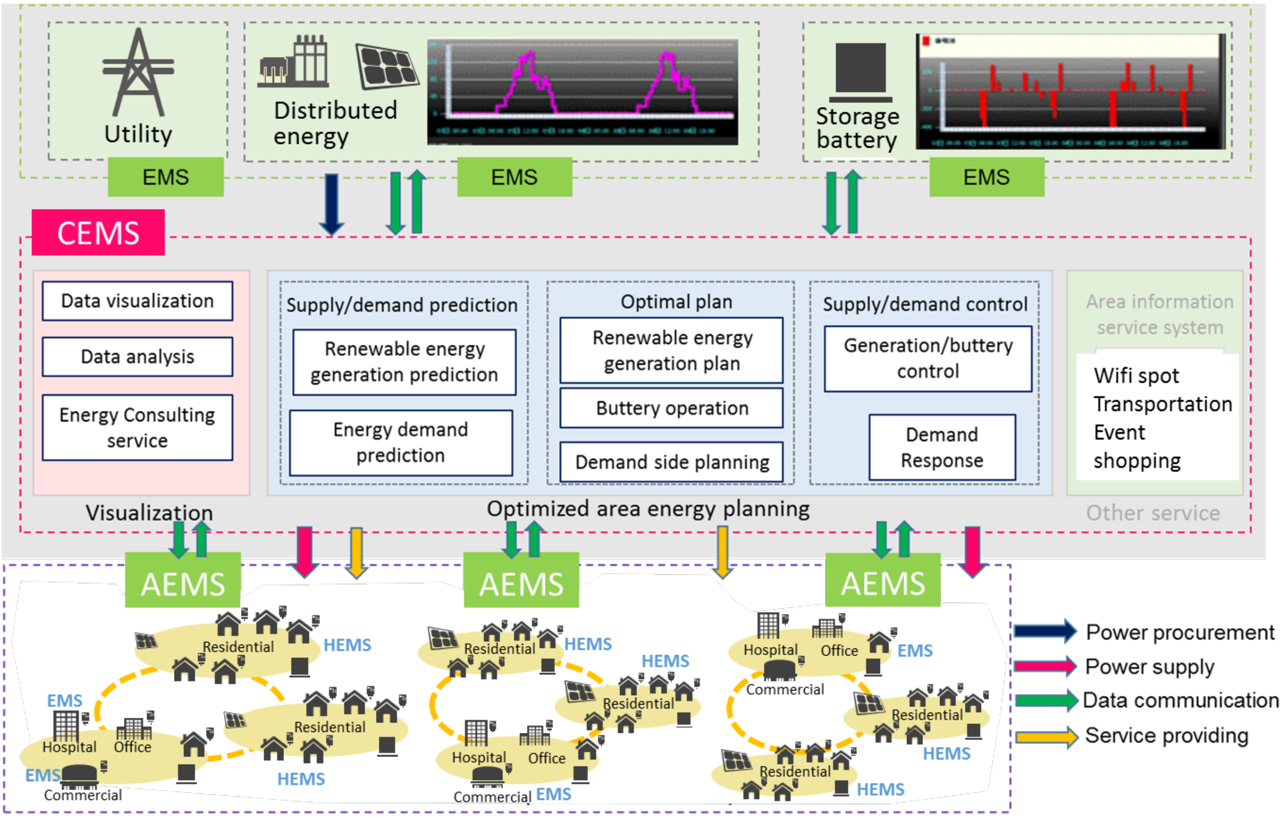


Source: NIKKEN SEKKEI Research Institute

Step3: Long-term

- As the micro-grid develops across the whole city, the bi-directional smart grid with demand-supply management should be implemented.

Fig 10.2.11 Functions of AEMS in long-term



Source: NIKKEN SEKKEI Research Institute

10.3. Comprehensive service with Area-management system

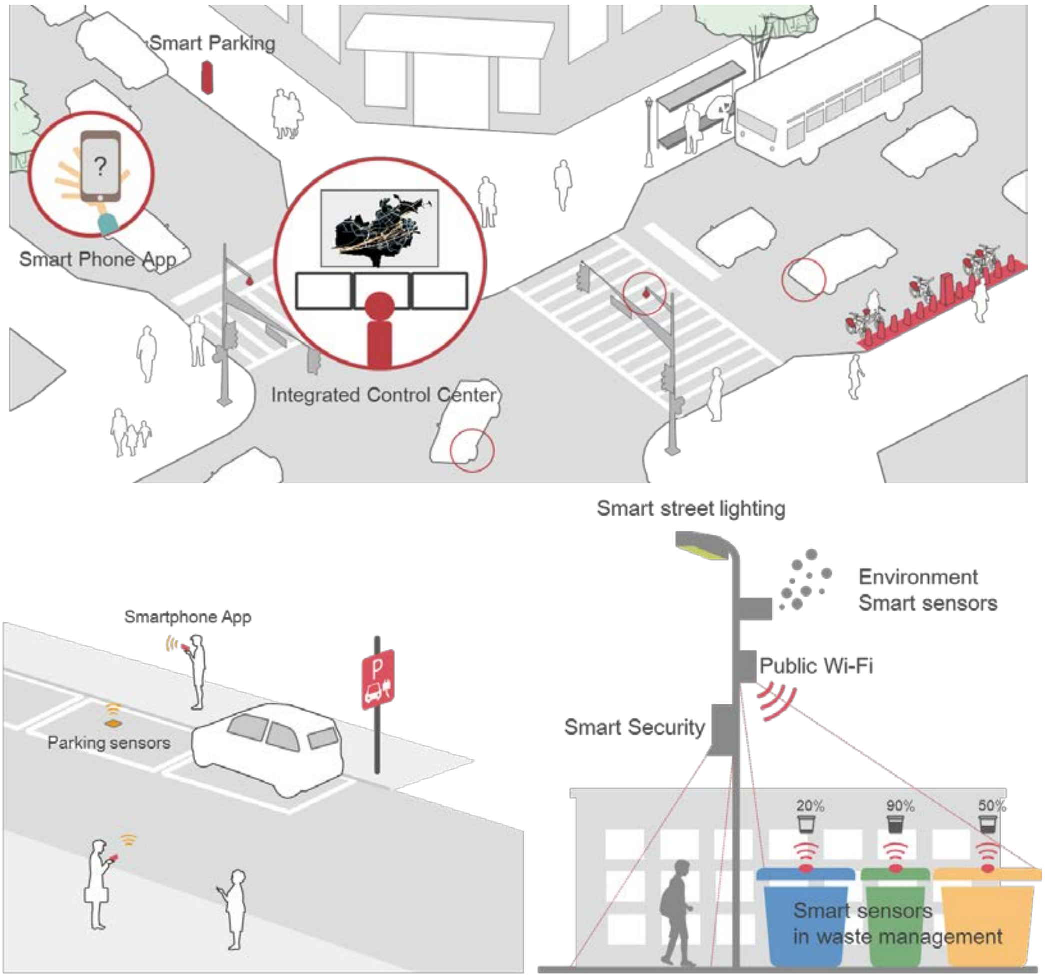
In addition to the energy management system, the platform set up by AEMS can also be used for various community services, such as a security system, car parking system and health care system.

1) AEMS with integrated control in the city

With the development of sensors in various fields, city big data can be collected and visualized in the city smart center. This data is analyzed and an optimal suggestion is fed back to users through their devices. For example, integrated control of traffic lights, public transportation and parking system can collect traffic information derived from sensors, analyze it and give feedback suggestions to user's devices.

In this way, the operation of the traffic lights can be optimized according to the on-time traffic volume. Further, users can visualize the on-time traffic information or chose public transportation according to parking information and real-time traffic conditions.

Fig 10.3.1 AEMS with integrated Control



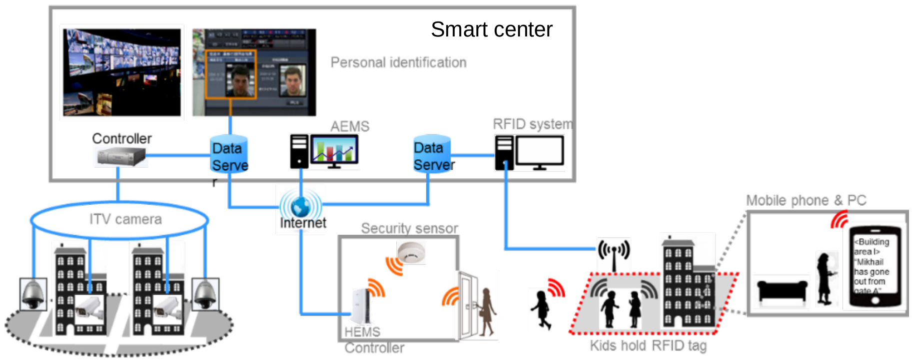
Smart Parking(Image) Integrated Lighting System (Image)

Source: NIKKEN SEKKEI Research Institute

2) Advanced Security System

Security, especially the security system for children is essential for improving the quality of life. Security sensors such as ITV cameras and children carrying individual RFIDs is responsible for collecting security data. All this data is sent back to the data sever in city center to provide security care across the whole city.

Fig 10.3.2 AEMS with advanced Security System



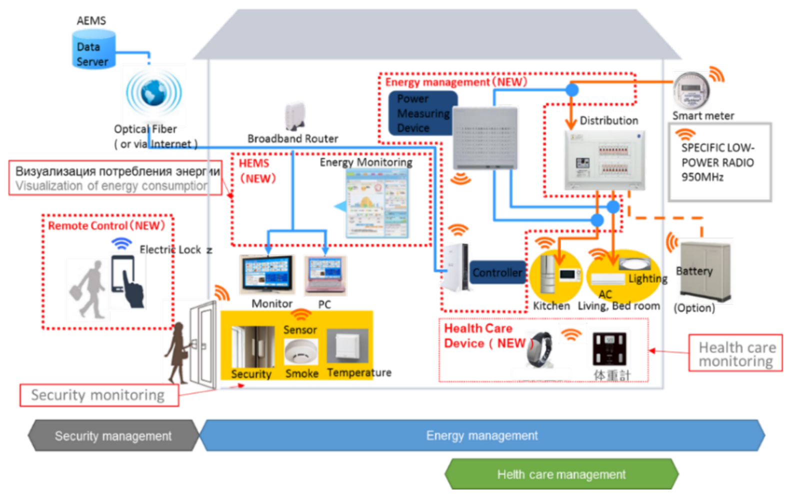
Source: NIKKEN SEKKEI Research Institute

3) Comprehensive home energy management system (HEMS)

Home energy management system (HEMS) is the energy management system for residences. For energy conservation, it monitors the indoor environment and energy consumption with sensors to optimally balance between indoor environment and energy conservation.

The system automatically controls the air-condition system and other electronic facilities according to the indoor environment. In addition to the energy aspect, it is also connected to security sensors and the RFID tags carried by children, collecting information and feeding it back to the smart center for security control. Furthermore, data from health care devices is send to the health care center. It analyses the data and provides advice for residents.

Fig 10.3.3 Comprehensive HEMS



Source: NIKKEN SEKKEI Research Institute

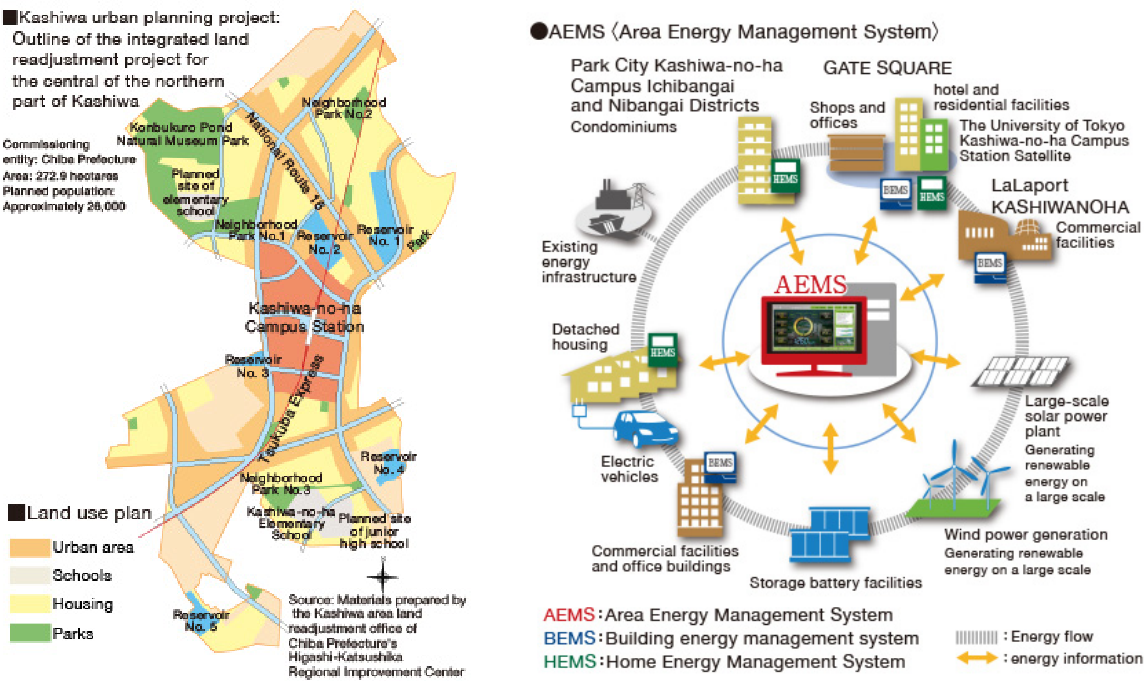
10.4. Base practice of community-based area energy management system

10.4.1. Kashiwa-no-ha Smart City

Kashiwa-no-ha Smart City, is the latest smart city model in Japan. With an area of 273 ha covered by the integrated land readjustment project, it optimizes energy usage from the point of view of the entire community.

Fig 10.3.4 displays the image of AEMS-based smart grid in Kashiwa-no-ha. It is a comprehensive bi-directional system with the technologies both on the demand side and supply side. The distributed energy resources such as solar power, storage batteries and gas cogeneration are controlled by AEMS for optimal energy supply according to the on-time demand side (hotel & residential buildings, commercial buildings, offices…) energy consumption information provided by EMS.

Fig 10.3.4 AEMS system in Kashiwa-no-ha



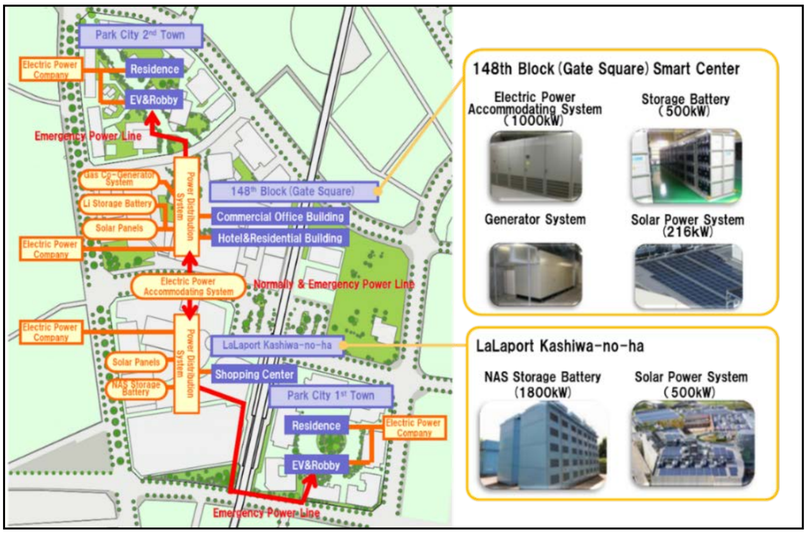
Source: http://www.kashiwanoha-smartcity.com/en/concept/makekashiwa.html

1) Smart grid with independent power grid

Kashiwanoha smart city has Japan's first smart grid with independent power grid, which connects the distributed power resources to share the electricity among the entire community. The distributed power resources, including solar storage cells can cut the peak electricity consumption by sharing the electricity between the buildings.

For example, during week days, office buildings have a higher energy consumption so they get electricity from commercial buildings. During the weekend, the office buildings have low energy consumption so that they can offer the electricity to commercial buildings which have higher electricity consumption.

Fig 10.3.5 Power Supply



Source: NIKKEN SEKKEI Research Institute

2) Area-Wide energy management with ICT control

The energy management system network consists of AEMS and BEMS (including smart meters and BAS). Energy supply and demand information for every building is collected by BEMS. This information is sent to AEMS, which analyzes and conducts optimal control between supply and demand sides.

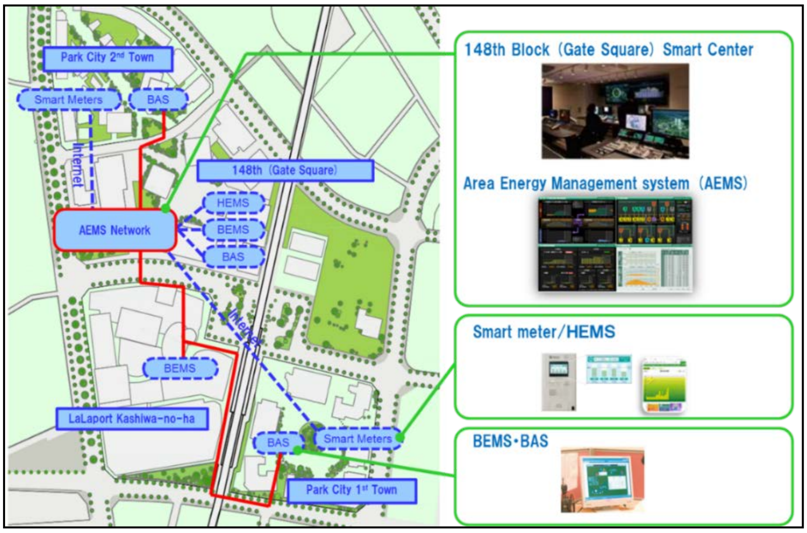


Fig 10.3.6 ICT Network

Source: NIKKEN SEKKEI Research Institute

3) Disaster resistance

During a disaster, distributed energy resources, mainly referring to renewable energy and storage batteries, can offer electricity to the community through the independent grid. It is suggested that during a utility breakdown, Kashiwanoha's Gate Square can supply 60% of normal power requirements and maintain this for three days. The system offers elevators, lighting in the common spaces of the residential buildings while water resources can be supplied by groundwater pumps.

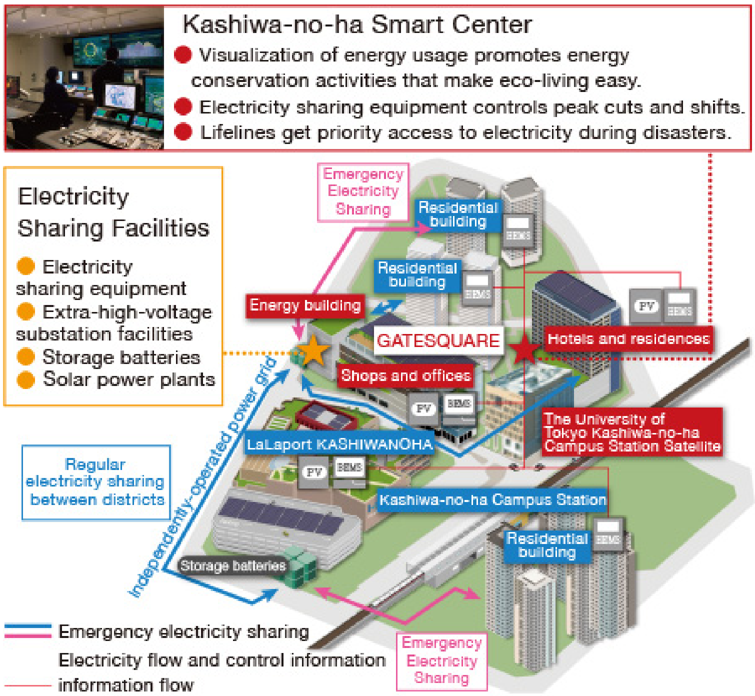


Fig 10.3.7 Smart energy during the disasters

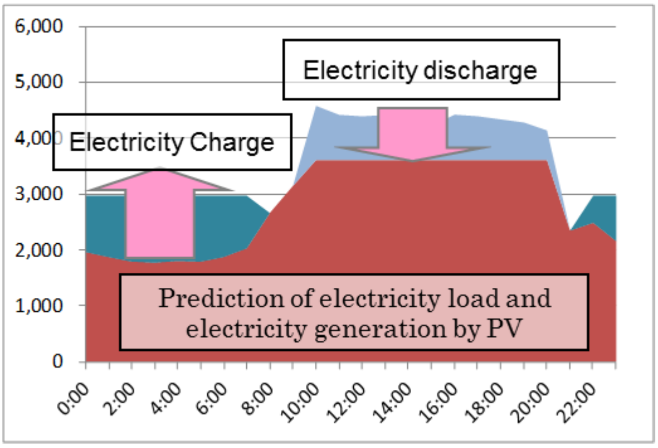
Source: NIKKEN SEKKEI Research Institute

4) Effect with AEMS-based smart grid

- **Smooth out the electricity load at building level :**

  At building level, optimal operation of renewable energy and storage batteries cut the electricity peak and minimize the electricity capacity. For example, for office and commercial buildings, energy consumption peak comes during the daytime when batteries discharge their stored electricity. During the night, the off-peak time for office and commercial buildings, the batteries are charged with electricity. Fig 10.3.8 shows the effect of peak cut and peak shift through electricity sharing.

Fig 10.3.8 Peak shift with management of storage battery

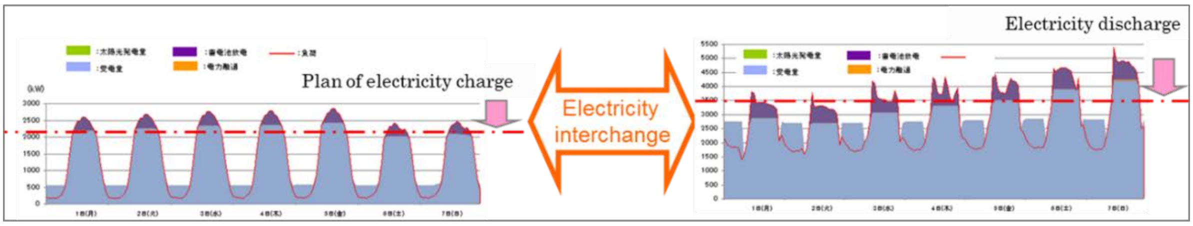


Source: NIKKEN SEKKEI Research Institute

- **Leveling the electricity load at district level**

  Electricity sharing between buildings in the community can minimize the electricity capacity at district level. Fig 10.3.9 shows the electricity sharing between buildings in the gate square.

Fig 10.3.9 Power interchange plan between buildings



Source: NIKKEN SEKKEI Research Institute

10.4.2. Preobrazhensky, Russia

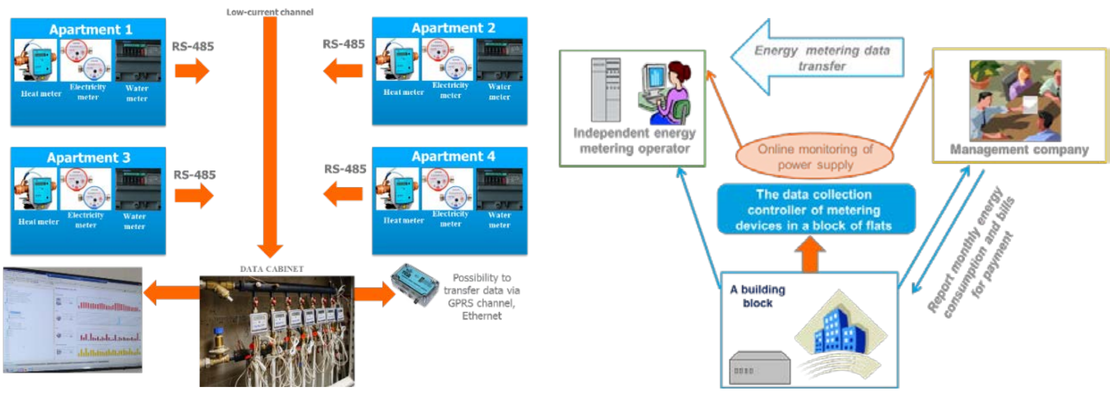
The advanced residential area Preobrazhensky that was mentioned in chapter 5 is also a best practice case with AEMS, and is located within Krasnoyarsk city. The AEMS system includes an automatic energy metering system, video intercoms and access control and video surveillance as well as fire and security alarm systems.

1) Automatic energy metering system

Fig 10.4.1 shows the metering scheme and information scheme in PREOBRAZHENSKY. Every apartment is implemented with an energy meter, which collects the real-time energy consumption and sends data back to the data cabinet. The energy data from the cabinet is analyzed by an independent energy metering operator or Management Company.

The result, including monthly energy report and bills is fed back to the apartment. It is assumed that the visualization of energy consumption for residents can help to realize energy conservation. As Fig 10.4.1 suggests, the quality monitoring reduced electricity consumption and tariff by more than 5%.

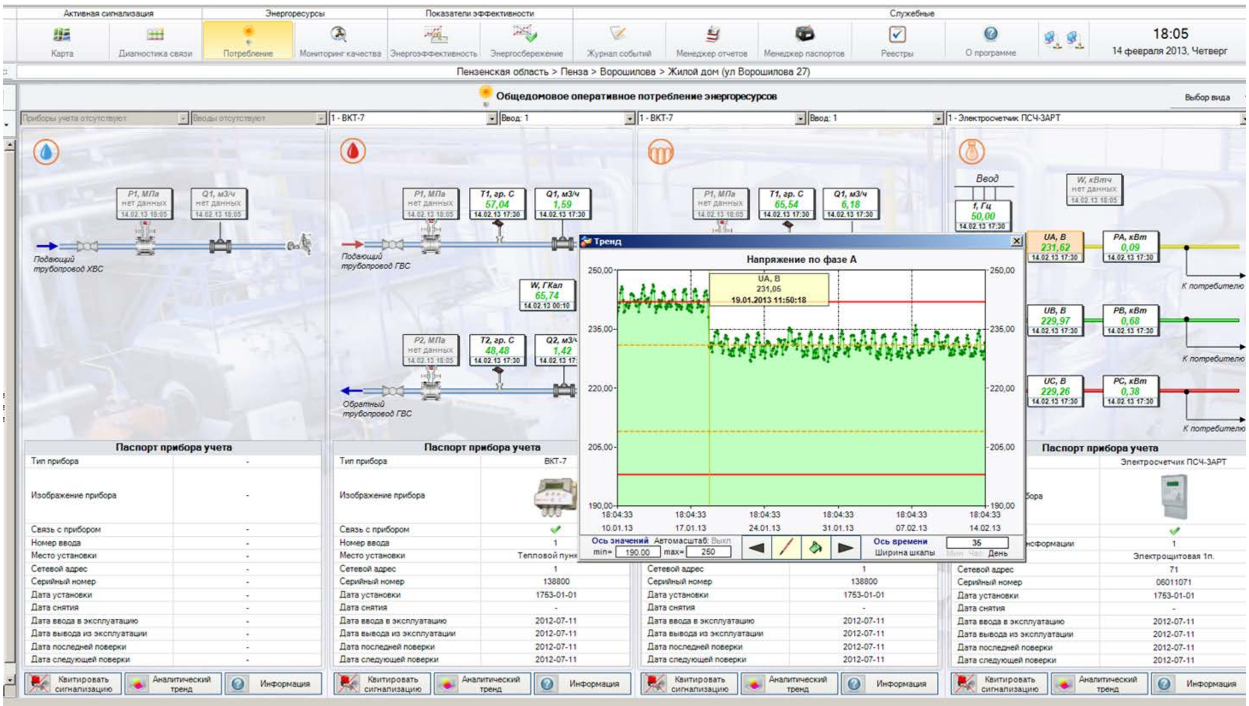
Fig 10.4.1 Apartment metering scheme and information scheme



Metering scheme

Source: Monolit Holdings

Fig 10.4.2 Quality monitoring



Source: Monolit Holdings

2) Video intercoms and access control

District Intercoms are connected with call units implemented in every unit. Every call unit is equipped with IP cameras, a dial pad and a magnetic key reader.

The video from the interphone cameras is transferred in the general monitoring network, and is available even without the internet. The equipment has a web interface and is available from any mobile device. In addition, the video intercom is a means of communication with the management company.

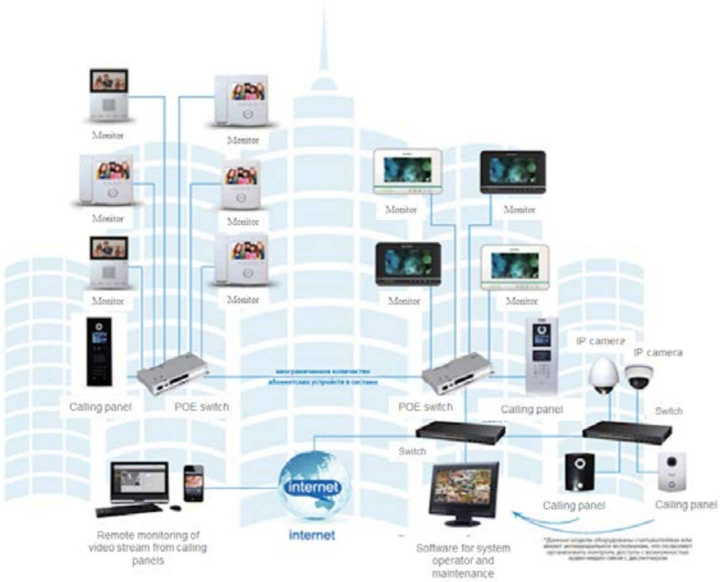


Fig 10.4.3 Video intercoms and access control

Source: Monolit Holdings

In addition to access control, the intercom monitor also functions as a water leakage sensor, climate control, news reminder and fire alarm detector. Furthermore, it can also act as a communication tool with neighborhoods and the management company.

11 GREENERY

11. Greenery

11.1. Current Status

The total area of public green space within the city boundaries is 6,418 hectares. The total area of city, including suburbs and the river is 348 square kilometers. The greening rate of Krasnoyarsk city is therefore about 18.44%, which is higher than many other large cities.

Source of Green space area: Krasnoyarsk city administration

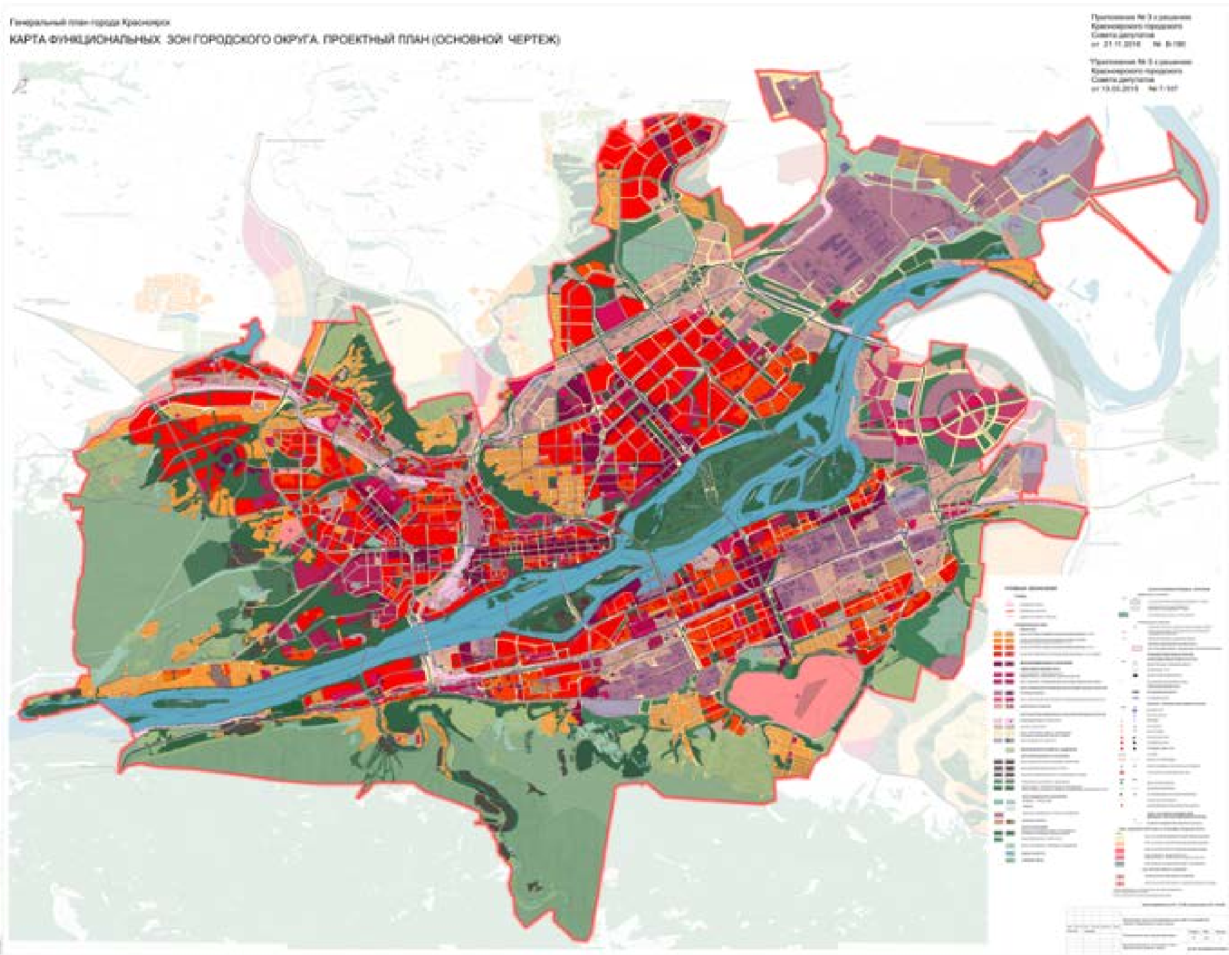
Table 11.1.1 % of public green space (parks and gardens)

City	Figure	Date	Source
Amsterdam	13.00%	2015	Statistics Netherlands/TNO
Austin	15.00%	2015	City of Austin
Berlin	14.40%	2011	Berlin.de
Bogotá	4.40%	2013	Alcaldía Mayor de Bogotá, Departamento Administrativo del Espacio Público
Brussels	18.80%	2015	IBGE
Buenos Aires	8.90%	2013	CABA
Dubai	2.00%	2015	Dubai Culture and Arts Authority
Edinburgh	16.00%	2009	Edinburgh City Council
Istanbul	2.20%	2015	Istanbul Metropolitan Municipality
Johannesburg	24.00%	2002	State of the Environment Report, City of Johannesburg 2009
London	33.00%	2013	Greenspace Information for Greater London CIC
Los Angeles	6.70%	2012	Greater Los Angeles County Open Space for Habitat and Recreation Plan
Madrid	35.00%	2014	Archivo del de Gobierno de Las Artes, Deportes y Turismo. Ayuntamiento de Madrid
Melbourne	9.00%	2015	Metropolitan Planning Authority
Montréal	14.80%	2013	Ville de Montreal, Direction des grands parcs et du verdissement
Mumbai	2.50%	2011	Tata Institute of Social Sciences
New York	27.00%	2010	New York City Department of City Planning Land Use
Paris	9.50%	2013	IAU
Rio de Janeiro	29.00%	2013	SIG Florestas do RIO
Rome	34.80%	2014	Roma Capitale
San Francisco	13.70%	2012	San Francisco Recreation and Parks Department Community Report / US Census Bureau
Seoul	26.60%	2015	Seoul Metropolitan Government
Shanghai	2.80%	2014	Shanghai Theatre Academy
Shenzhen	45.00%	2013	Shenzhen Statistical Yearbook 2014
Singapore	47.00%	2011	National Parks Board
Taipei	3.60%	2014	Parks and Street Lights Office, Taipei City
Tokyo	7.50%	2015	Bureau of Urban Development - Tokyo Metropolitan Government - "Survey of City Planning Park and Green Space in Tokyo 2015"
Toronto	12.70%	2012	Toronto Parks, Forestry and Recreation Park Plan 2012-2017
Warsaw	17.00%	2015	Head Office of Geodesy and Cartography

Source: World Cities Culture Forum 2017

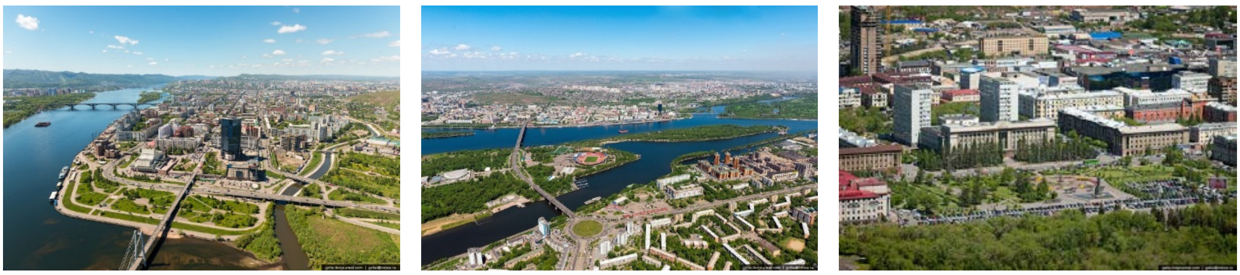
In addition, courtyard houses are popular, and there is also a lot of greenery within blocks. Furthermore, the city is currently promoting greening by planting about 20,000 trees each year as a catchphrase “One million trees in One million cities”.

Fig 11.1.1 Land use map



Source: Krasnoyarsk Administration

Fig 11.1.2 Bird's eye view of the city



Source: RussiaTrek.org

Fig 11.1.3 Street view of the city

Source: NIKKSEN SEKKEI Research Institute

11.2. Symbiosis with nature

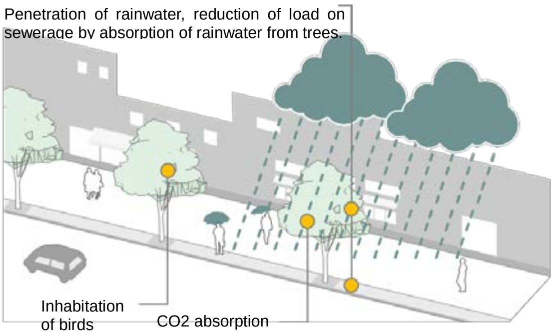
Green in the city contributes to reducing greenhouse gas emissions. There are many roles that green plays such as functioning as urban landscape and healing to people.

1) Conservation and Creation of green

From the viewpoint of reducing greenhouse gas emissions, green conservation and promotion of urban greenery are important for promoting the creation of low-carbon type cities. The Greenery ratio of Krasnoyarsk city is about 25% (Including public green space and Urban green space), which is higher than many other large cities, but further efforts need to be made to secure more green space.

In particular, systematically planting street trees along the roadside, will contribute to the formation of rich street spaces contributing to greenery and to biodiversity and CO2 reduction. Moreover, by improving the road trees, and increasing the penetration area of rainwater, it also leads to water resource recycling and load reduction on sewerage by absorbing rainwater from street trees. These effects can be expected further when done in conjunction with the campaign of 1 million trees in one million cities that the city is strategically promoting.

Fig 11.1.4 Image of the effect of green



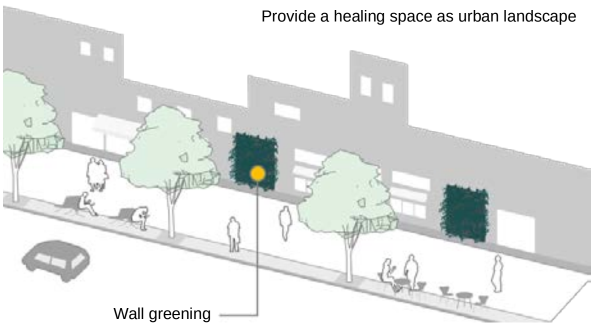
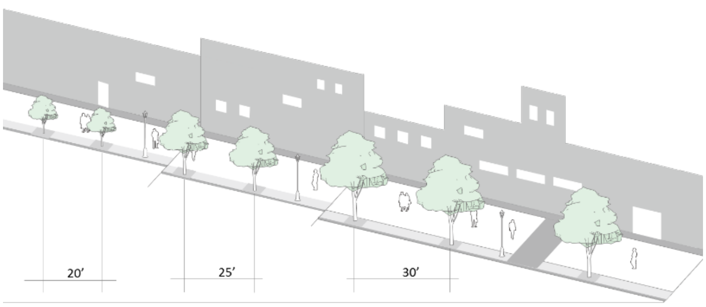


Fig 11.1.5 Image of placement interval by trees size



Source: NIKKSEN SEKKEI Research Institute

2) Creating a green network

Preserving nature and re-connecting divided natural environments secures movement paths for wildlife and restores various functions of nature. Quality urban environment can be realized through reproducing the rich nature of the city. When planning parks and street trees in cooperation with 1) above, plan to be constructed as a network in the future.

In urban development (mainly residential) in Krasnoyarsk city, many development blocks take the form of a quadrilateral, perimeter blocks, and it is common that a green (garden) is built in the central courtyard. As a result, the organic link to surrounding green (network) is weak

When renovating existing buildings or in new developments, it is desirable to arrange the buildings and planting arrangement so that the block and the block are organically connected.

Fig 11.1.6 Image of build a green network

Source: NIKKSEN SEKKEI Research Institute

12 WATER MANAGEMENT

12. Water Management

12.1. Current Status

1) Water

The main sources of water supply are surface (water intake "Gremyachyi Log") and underflow sources (water intakes of Otdykha Island, Nizhniy Atamanovski Island, Kazachi, Island Posadnyi Island, Tatyshev Island, and Verkhne-Atamanovski) Island. The water quality of the central water supply system has improved according to the sanitary-chemical indicators of safety for the last three years in Krasnoyarsk and over that period improved conditions of microbiological indicators have been maintained (for 2014 the proportion of water samples of water sources not meeting hygienic standards was 0).

The volume of supplied water for 2014 was 146,621.4 thousand m3. The quality of tap water in Krasnoyarsk is controlled by the Center of Monitoring Water Quality. The Center is accredited by the State Standard Department of Russia, than confirms technical competence and a high level of professionalism. Water samples for analysis are taken every day in different parts of the city: at the pumping stations, stand-pipes and water taps. Analysis of the content of residual chlorine in the water is conducted on intakes every two hours.

The length of the water supply network providing the central water supply in Krasnoyarsk city is 1208.86 kilometers. From 1913 until 1928 water supply was an integral part of the hydroelectric power station and for those fifteen years the network increased from 12 km to 30km.

The water supply underwent rapid construction in 1936. The ceramic sewer pipes started to be installed in the main streets of the city.

In 2014 the water in the distribution network of central water supply of the city of Krasnoyarsk did not meet the sanitary-chemical and microbiological parameters of the health standards.

The quality of underground water allows it to be ducted to the city without purification, after disinfection with chlorine or sodium hypochlorite. River water is ducted to the city after purification and disinfection at the water treatment facility "Gremyachiy Log". The dose of chlorine is calculated according to the degree of water pollution. The dose of chlorine added to the water is kept to a minimum, so that at the distribution network, residual chlorine is not registered. The chemical composition of natural Yenisei water has an ideal composition for human consumption, it is very soft.

The indicator for the overall hardness of tap water is strictly regulated and must not exceed 7 ° dH (° F). Krasnoyarsk city's drinking water ranges from 1.1 to 1,8 ° F. The content of iron in the maximum allowable concentration (MAC) of 0.3 mg / dm² for most intakes is less than 0.025 mg / dm², but usually it is less than 0.01 mg / dm². Tap water is controlled by a number of indicators: color, turbidity, content of salts and chemical elements and the presence of bacteria. Once a month each water intake is tested for the presence of sulfite-reducing clostridia spores in drinking water.

Table 12.1.1 Information on the actual and expected consumption of hot, drinking technical water (annual, average daily, maximum daily), TOTAL

№	Population (thousands of people)	Thousands of m3/year	Thousands of m3/month	m3/day	m3/day (maximum)
1	Stage 1 -2015-2016, current				
	1049.18	155591	12788	385426	462299
2	Stage 2 – 2017-2019, short-term				
	1113.20	228409	18773	556672	653358
3	Stage 3 – 2020-2023, mid-term				
	1171.32	228650	18793	556065	652582
4	Stage 4 – 2024-2028, mid-term				
	1279.00	239588	19692	582178	683160
5	Stage 5 – 2029-2033, long-term				
	1300.10	236479	19436	576306	676192

Source: Krasnoyarsk city administration

Table 12.1.2 The values of design capacity of water intake facilities and estimated water consumption (left bank)

№	Productivity of water intake facilities on the left bank, m3/day	Short-term water consumption, 2017-2019, Q, max. m3/day	Mid-term water consumption, 2020-2023, Q, max. m3/day	Mid-term water consumption, 2024-2028, Q, max. m3/day	Long-term water consumption, 2029-2033, Q, max. m3/day
1	506400	390672	396014	416062	418810

Source: Krasnoyarsk city administration

Table 12.1.3 The values of design capacity of water intake facilities and estimated water consumption (Right bank)

№п/п	Productivity of water intake facilities on the left bank, m3/day	Short-term water consumption, 2017-2019, Q, max. m3/day	Mid-term water consumption, 2020-2023, Q, max. m3/day	Mid-term water consumption, 2024-2028, Q, max. m3/day	Long-term water consumption, 2029-2033, Q, max. m3/day
1	385200	262686	256568	267098	257382

Source: Krasnoyarsk city administration

2) Sewage

There are two self-contained sewage systems with their treatment facilities in Krasnoyarsk, one on the Left Bank and one on the Right Bank of the Yenisei river. The volume of wastewater processed in 2014 was only 121,488.2 thousand m3. The determined capacity of the treatment facilities is 700.0 thousand m3 per day.

The quality of wastewater is determined in accordance with the standards of permissible concentrations in the river Yenisei from Krasnoyarsk hydroelectric complex to the confluence of Angara river without Kan river, as well as a resolution for the discharge of substances (with the exception of radioactive substances and microorganisms) into water bodies.

The temperature of the reservoir water should not rise in comparison with natural water body temperature more than by 5C (up to 20C in summer and to 5C in winter); summer water temperature due to discharge should not rise by more than 3C in comparison to the average water temperature in the hottest month of the year for the last 10 years. The Right Bank drainage system treatment facilities for Krasnoyarsk have a design capacity of 360 thousand m3/day. They work on the scheme of full biological wastewater treatment. Mechanical cleaning is carried out on the grids, sand traps and primary sedimentation tanks. Biological treatment occurs in aeration tanks and secondary sedimentation tanks. Treated wastewater is discharged from the facilities into the Shumkovskaya channel through three collectors (reinforced concrete channels 1700 × 1800 and two pipes with a diameter of 1500 mm).

The actual volume of mixture of wet sediment and excess activated sludge produced during wastewater treatment of facilities sewage is 30 tons per day for a dry matter basis; humidity of mix - 97.5%.

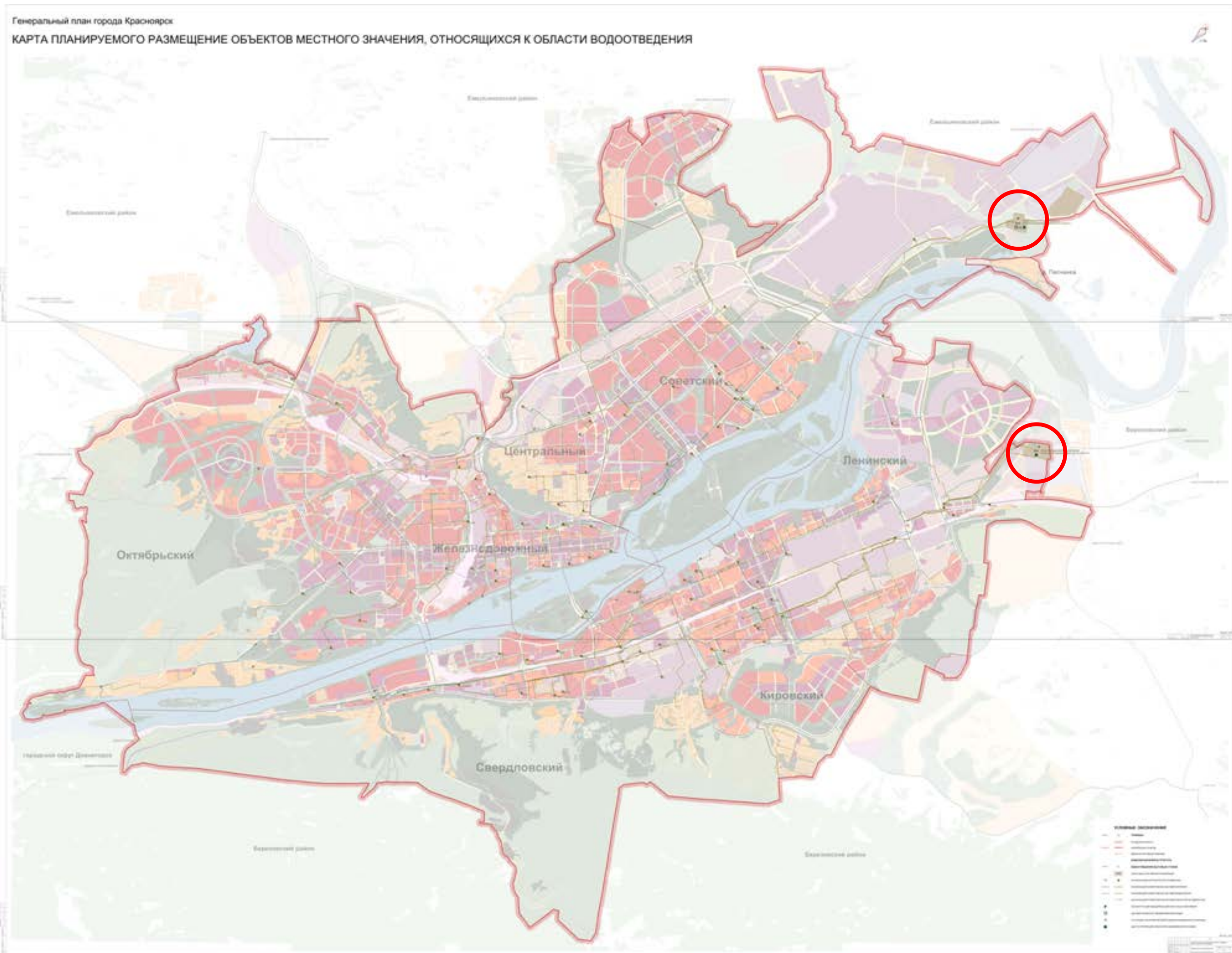
Sludge treatment is carried out as follows: 100% of excess sludge is fed into preparatory, then into primary radial sedimentation tanks, where the mixture of sludge and raw sediment is pumped into tanks with a working capacity of 300m3. From there, the mixture is transferred by pumps, installed in the main sludge pumping station №1, through two 250mm diameter pipelines to the existing sludge ponds located in the area of the "Chuvolaki" tract. Because of the large length of sludge cables (16km) there is an additional pumping station, sludge pumping station №2. The existing sludge beds are made on a natural basis, without drainage.

Currently, the provision of the city with rainwater drainage is about 20% of the regulatory requirements.

Fig 12.1.1 Sewage treatment facility in Krasnoyarsk (Bacterial treatment facility)

Source: NIKKEN SEKKEI Research Institute

Fig 12.1.1 Map of Krasnoyarsk city sewage infrastructure



Source: Krasnoyarsk City administration

Table 12.1.4 Information on the actual and expected flow of sewage into the centralized water disposal system

Current period, 2015-2016

№	Type of sewage	Q, m3/year	Q, m3/month	Q, average, m3/day	Q, max m3/day
1	Residential sewage	86529764	7210814	237068	272628
2	Industrial sewage	28067136	2338928	76896	88431
Total (accounted sewage)		114596900	9549742	313964	361059
3	Unaccounted sewage for the needs of local industry	21275525	391098690	83113	95581
Total		135872425	400648432	397078	456640

Short-term period, 2017-2019

№	Type of sewage	Q, m3/year	Q, m3/month	Q, average, m3/day	Q, max., m3/day
1	Residential sewage	100766864	8397237	276073	317485
2	Industrial sewage	29136347	2428029	79826	91800
Total (accounted sewage)		129903211	10825266	355900	409284
3	Unaccounted sewage for the needs of local industry	20153373	1679447	55215	63497
Total		150056584	12504713	422128	472781

Mid-term period, 2020-2023

№	Type of sewage	Q, m3/year	Q, m3/month	Q, average, m3/day	Q, max., m3/day
1	Residential sewage	106027886	8835655	290487	334061
2	Industrial sewage	29719074	2476589	81422	93635
Total (accounted sewage)		135746960	11312245	371909	427696
3	Unaccounted sewage for the needs of local industry	21205578	1767131	58098	66812
Total		156952538	12414205	408138	494508

Mid-term period, 2024-2028

№	Type of sewage	Q, m3/year	Q, m3/month	Q, average, m3/day	Q, max., m3/day
1	Residential sewage	111538744	9294894	305585	351424
2	Industrial sewage	30313456	2526121	83051	95508
Total (accounted sewage)		141852200	11821015	388636	446932
3	Unaccounted sewage for the needs of local industry	22307749	1858979	61117	70285
Total		164159948	13679993	449754	517216

Long-term period, 2029-2033

№	Type of sewage	Q, m3/year	Q, m3/month	Q, average, m3/day	Q, max., m3/day
1	Residential sewage	117685052	9807086	322425	370788
2	Industrial sewage	31222860	2601905	85542	98373
Total (accounted sewage)		148907912	12408991	407967	469162
3	Unaccounted sewage for the needs of local industry	23537011	1961417	64485	74158
Total		172444921	14370408	472452	543320

Source: Krasnoyarsk City administration

3) Rain water

The first networks of rainwater drainage in Krasnoyarsk were built in 1952. The length of the city rainwater sewerage network is 184.37 kilometers, including 122.8 kilometers on the Left Bank and 61.5 km on the Right Bank. The structure of the city rainwater drainage includes 3132 manholes, intended for servicing and 3441 rain surface inlets. In addition, the city has 800 linear meters of drainage pipes, 5000 meters of outdoor stalls, drainage systems, as well as 4 water overflow nodes located on the right bank of the city.

Also there are 52 septic tanks with the total volume of 6175.6 m3 within the territory of Krasnoyarsk. Drainage of rainwater is carried out through channels along the roads into the septic tanks and discharging into the rivers. Special equipment pumps water from septic tanks after filling and also discharge it into the rivers.

12.2. Low-Carbon Strategy

The city is expected to continuously increase in population. It is expected that consumption of water will continue to increase if no measures are introduced. An increase in the amount of water used places further burden on water and sewage infrastructure and contributes to exhaustion of resources and energy consumption required for water treatment.

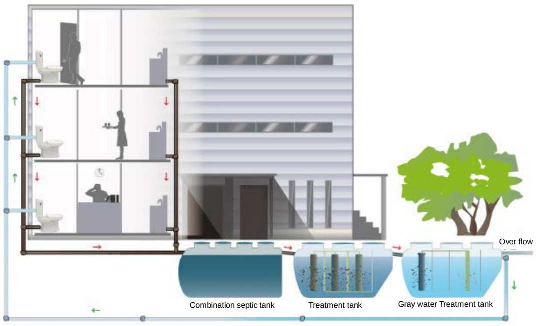
Therefore, it is necessary to develop policies such as the introduction of water-saving equipment and mandatory reuse of water for buildings. Especially in Krasnoyarsk city where there are many large-scale residential facilities, it can be expected that taking such measures will be effective.

1) Water Management

Water resources used in residential and office buildings are discharged as wastewater. To reuse wastewater, a large amount of energy is required. Wastewater that cannot be treated flows directly to the river, which causes water pollution.

Therefore, it is important to develop water supply and sewage infrastructure that can handle appropriate water treatment. In addition, it is also important to reduce the amount of water used in all building types; residential and office buildings. In facilities of a certain size, trials can be made of gray water treatment systems and the introduction of water-saving equipment, thereby achieving reduced energy consumption and water conservation through savings on water usage and reprocessing.

Fig 12.2.1 Grey water treatment facility system



Source: DaiwaKasei

- Wastewater reuse (Grey water)
  The wastewater reuse means to use water of low water quality compared with water supply (clean water), such as regenerated water, sewage and rain water for applications such as toilet flushing water, landscaping irrigation, car washing, air conditioning etc.
- Effect of re-utilization of water
  ・Decrease in water usage
  ・Relaxation of the supply-demand gap in the water supply and demand tightening region
  ・Improve consciousness of water conservation, form a society resilient to drought
  ・Improvement of aquatic environment through reduction of sewage

To protect important water resources, facilities can incorporate a variety of equipment designed to conserve water, including water-saving hygienic equipment, and automatic combined tap water faucets in restroom facilities. Wastewater can be used in ponds, basins, and other scenic water landscaping. Water recycling systems can be designed to preserve water resources.

Fig 12.2.2 Water Conservation Equipment

Fig 12.2.3 Water Recycling for Landscape Water

Source: On the Green, Tokyo Midtown

Krasnoyarsk city has a policy to develop water fountains throughout the city. Therefore, a lot of water is consumed. Reuse of wastewater from the surrounding buildings and rainwater can be trialed to circulate water resources. By using ICT technology and sensor technology to adjust the water quality of the fountain, the running time of the fountain could adjusted to take into account the outside temperature. This will help to demonstrate appropriate use of water while maintaining clean water used in the fountain.

Fig 12.2.4 Krasnoyarsk, city fountains

Source: Krasnoyarsk Fair

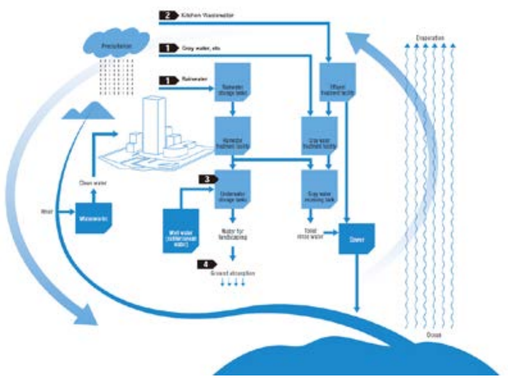
2) Sewage

Details are described in Chapter 8

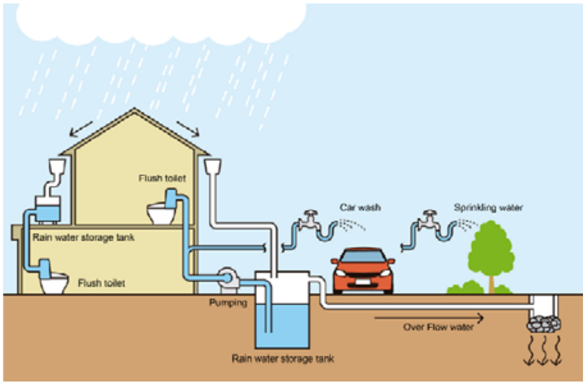
3) Rainwater

In terms of securing and effectively utilizing water resources, there is a viewpoint to use rainwater in addition to the reuse of wastewater. Depending on the scale of the building, it may be most efficient to use a combination of grey water and rainwater. In detached houses and small-scale buildings, rainwater reuse is the only measure to contribute to securing water resources.

Fig 12.2.5 Image of rain water (including Gray water) reuse.



Source: On the Green, Tokyo Midtown



Source: mizkan

There are many convenient and useful aspects to using rainwater, as well as contributing to address social environmental problems, when seen in from a broad perspective.

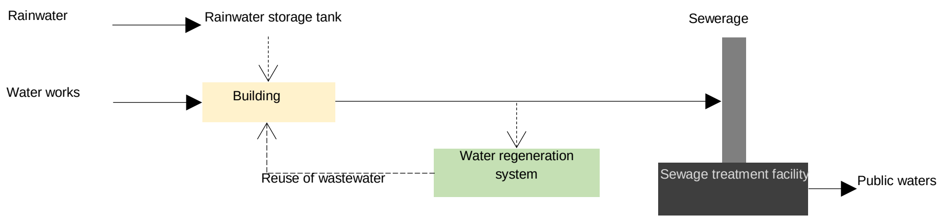
- Increased awareness of water conservation
  When using rainwater, there is a realization that water is a valuable resource. It becomes easy to see the overuse of water in small places. However small, the effect is great when piled up little by little.
- Energy Conservation
  It is possible to reduce the energy required to produce purified water. Energy is necessary to make water drinkable and to send water to each household. Through considering what kind of tap water is needed, it may well be that rainwater is often enough.
- Responding to natural disasters
  Water fit for drinking, during times of disasters, may run out early, but water suitable to use for other miscellaneous uses will not run out. Much more water is used for toilet water and washing water, than drinking water, so having reused water protects drinking water.
- Suppression of rainwater outflow
  Urban floods are a big problem. By storing and permeating rainwater, temporarily storing it can suppress outflow of rainwater.

4) Method of using rainwater and wastewater

The following methods for using rainwater and regenerated water can be considered.

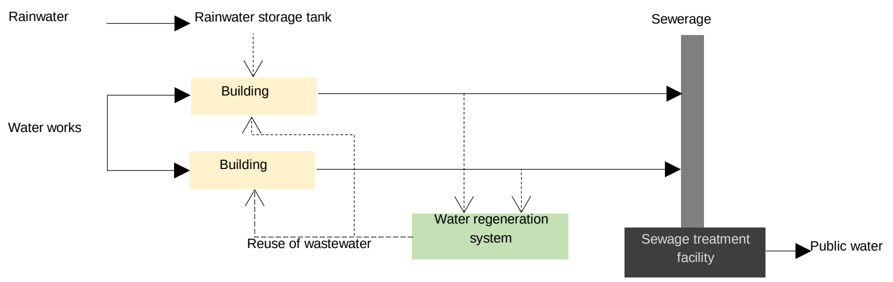
A. Individual circulation method to purify and reuse wastewater within office buildings and houses.

Fig 12.2.6 Image of Individual circulation method.



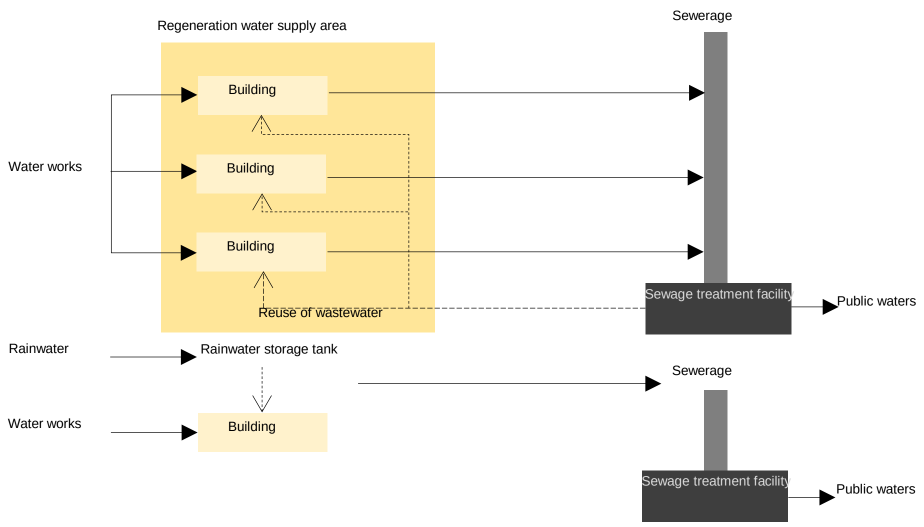
B. District circulation system where multiple buildings such as large-scale multi-family houses and urban redevelopment districts cooperatively manage miscellaneous water supply.

Fig 12.2.7 Image of District circulation method



C. In addition to the wide-area circulation system that supplies and uses wastewater widely at sewage treatment plants, there is also a non-circulation type system that mainly uses rainwater.

Fig 12.2.8 Image of Wide-area circulation method and use of rainwater



Source: NIKKEN SEKKEI Research Institute

13 POLLUTION

13. Pollution

13.1. Current Status

The materials present a brief summary of the current situation of environmental pollution, especially atmospheric air within the territory city of Krasnoyarsk. Adverse environmental conditions definitely impact negatively the health of the population. This is confirmed both by public services and independent experts. It severely affects emerging image of Krasnoyarsk as a regional center.

First of all, changes of macro-environment (macro-climatic) parameters and increased density of urban development have reduced the self-cleaning capacity of the atmosphere for the last 10 years. Thus, the environmental situation is getting worse despite decreased emissions to the atmosphere.

The main sources of air pollution are well known and can be easily identified. In order to reduce the level of air pollution, however, a positive effect cannot be achieved in one direction alone - work should be done on all fronts and by all sources, particularly with regards to illegal activity.

At present, the role of unaccounted sources of atmospheric pollution should be evaluated to the fullest extent. Small and medium boilers which are becoming more popular in small businesses. Private stove heating and illegal technological fuel-burning installations.

There is a high risk of underestimation of the role of motor transportation in emission of different compounds to the atmosphere in the city.

The new maximum permissible discharge (MPE) volumes being developed will not be representative without taking into account the actual amount of emissions coming from motor transport and individual sources of stove heating and these distributions in the surface layer of the atmosphere, especially in adverse weather conditions. It is unlikely to have any significant affect in improving the condition of the surface layer of the atmosphere within the city.
On the other hand, almost all enterprises in the city will have to reduce MPE, which will lead to quite certain financial and social risks.

1) Current position of the problem

Currently, the environmental condition in Krasnoyarsk is complicated. The most acute problem is the quality of the atmospheric air. This is attributed to: Large industrial factories in the city; use of brown coal as the main source of thermal and electrical energy; high level of motorization of the population (about 400 automobiles per 1000 people); and the complex combination of relief and atmosphere processes due to the presence of the ice-free the Yenisei river [1]. Combination of these factors make high risks for the health of Krasnoyarsk's citizens [2].

The key sources of atmosphere pollution are thermal power plants, metallurgy and motor transport. The amount of vehicles is steadily growing and its role in pollution of air is equal to the role of industrial factories [3,4].

In practice the contribution of private sources of stove heating are not appropriately taken into account in the pollution the atmosphere. Preliminary assessment indicates Krasnoyarsk has in the order of 16 thousand such point sources. The main fuels used in these are coal and wood. The burning regime in private houses is very different from industrial installations and cannot be considered optimal. Negative impact becomes more noticeable during the cold season.

The highest pollution indexes of atmospheric air are typical for winter time. This is associated with a high intensity of formation of elevated and surface radiation inversion of air temperature. Accumulated pollution of the atmosphere from individually minor sources of emissions (vehicles and stoves of private households) becomes extremely noticeable in such conditions [5]. Moreover, as mentioned earlier, the amount of emissions sharply increases in winter time due to the use private stove heating, boiler plants, and even motor transport (warming-up engines etc.).

The rapid increase in the density of urban development influences the deterioration of environmental conditions during the last years. It contributes to the increased frequency of windless days [6]. However, there is a more global trend – the total amount of windless days in the region in winter is related to increasing influence of the Siberian anticyclone. This strongly reduces the potential self-cleaning capacity of the atmosphere in the city.

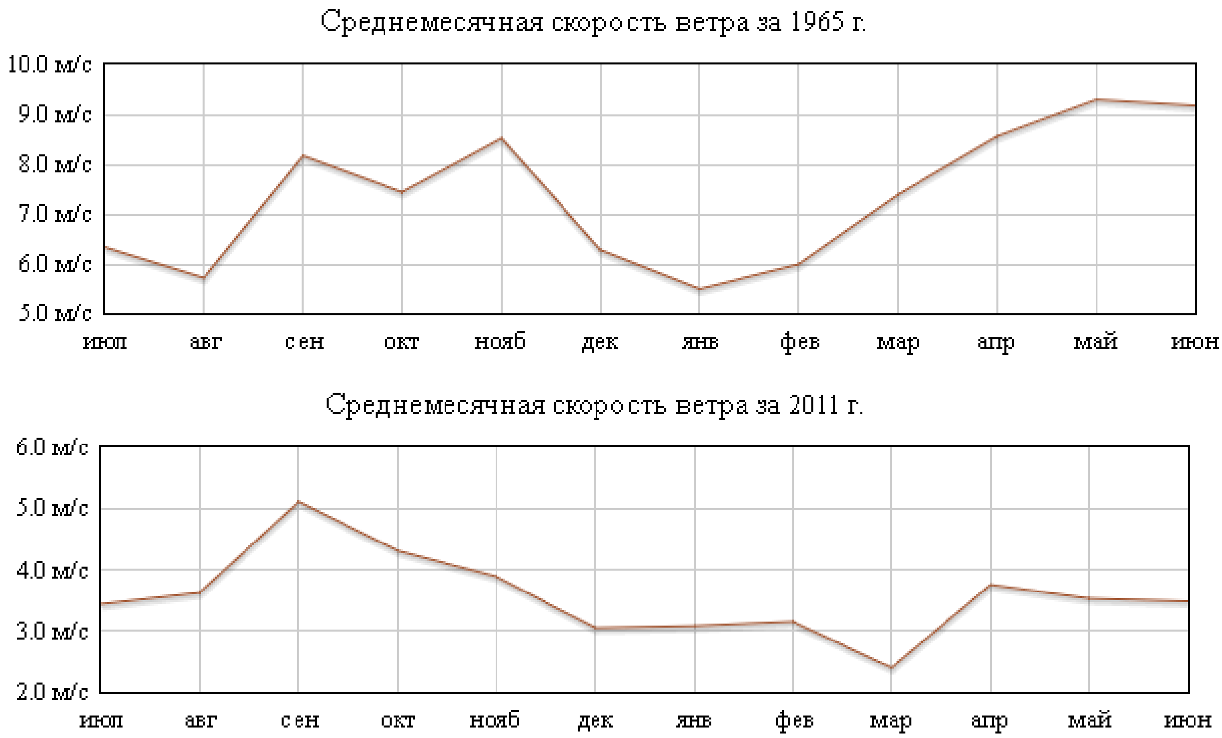
1. Hrebtov, M. HanjalićK. Numerical Studyof Winter Diurnal Convection Over the Cityof Krasnoyarsk: Effectsof Non-freezing River, Undulating Fog and Steam Devils Boundary-Layer Meteorology, Springer Nature, 2017 DOI:10.1007/s10546-016-0231-0
2. Красноярск. Экологические очерки: монография / Р.Г. Хлебопрос, О.В. Тасейко, Ю.Д. Иванова, С.В. Михайлюта. – Красноярск: Сибирский федеральный университет, 2012. – 130 с.
3. Лобанов А.И., Шефер В.В., Степень Р.А. Загрязнение атмосферного воздуха г. Красноярска выбросами автотранспорта: натуральные и стоимостные оценки // Эколого-экономические проблемы региональных товарных рынков. Красноярск: КГТЭИ, 2004. - С. 18-22.
4. Воздушная среда городов Красноярья: состояние, прогноз, управление: сборник материалов / М-во образования и науки Рос. Федерации, Сиб. федер. ун-т ; [науч. ред.: Р. Г. Хлебопрос, В. Г. Суховольский]. - Красноярск : СФУ, 2015. - 71 с.
5. Ахметшина, А. С. Assessment of thermal structure of boundary layer atmosphere of western Siberia / А. С. Ахметшина // BioClimLand (Biota, Climate, Landscapes). – 2013. – № 1. – С. 5–8.
6. Михайлюта С. В., Леженин А. А., Тасейко О. В., Битехтина М. А. Экологическая индустрия: ветровые потоки в городской застройке Красноярска // Инж. экология. 2012. № 3. С. 26-37.

2) Pollution of atmospheric air and the role of meteorological parameters

When it comes to pollution, the most important meteorological parameters are average wind speed and number of days without wind (light breeze or absent). These parameters affect quality of the atmosphere in the city. An equal successive combination of windy and windless days is much more favorable than long calm periods.

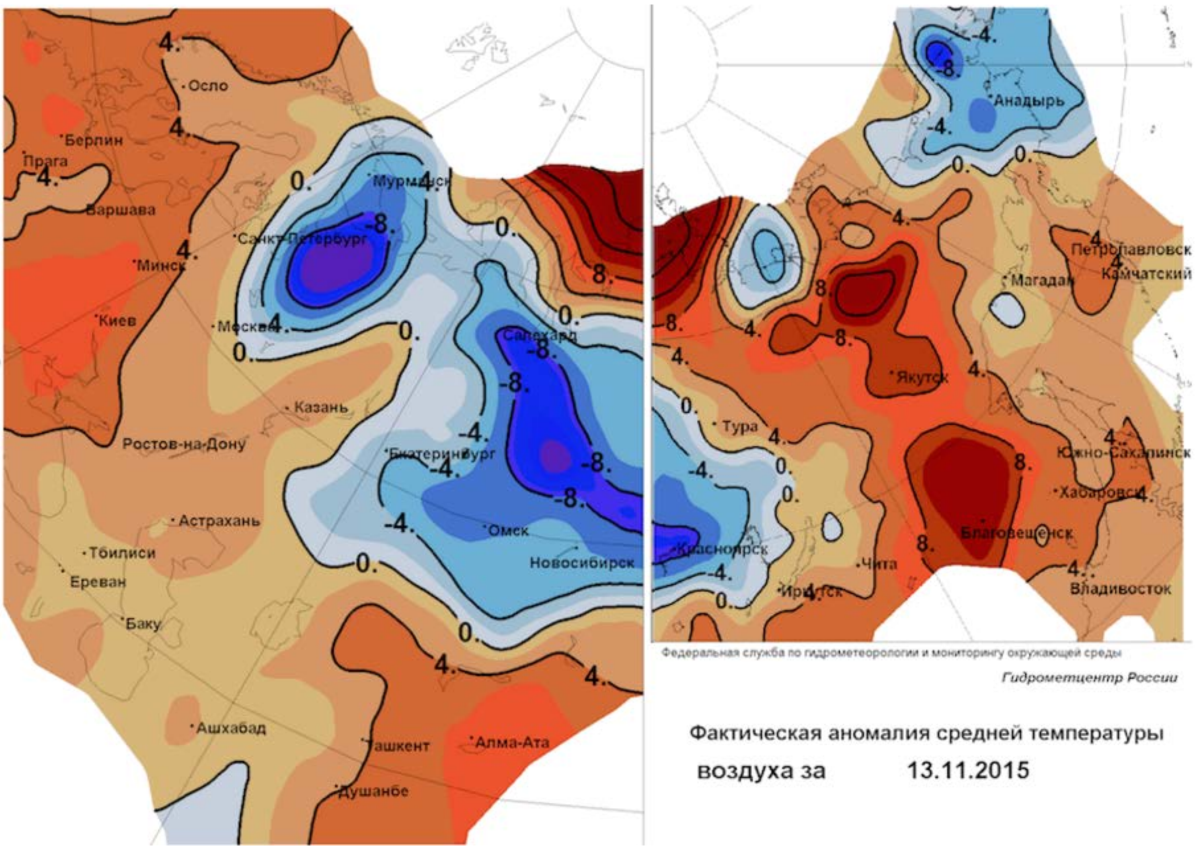
When there is an absence of strong wind for a long time, the potential self-cleaning capacity of the atmosphere is strongly reduced. Emissions of pollutants accumulate in the air, to concentrations much higher than are safe for the health of those living in the city. Citizens of Krasnoyarsk are faced with this problem. The average annual wind speed in the city has significantly decreased and the number of windless days has increased over the past decades (Fig 13.1.1).

Fig 13.1.1 Comparison of average daily wind speed for 1965 and 2011



Source: Siberian Federal University

The influence on the territory of the Siberian anticyclone has increased over the past decades. This is one of the most stable seasonal atmospheric formations on the planet. The Siberian anticyclone defines calm weather or a light variable wind in winter (when boiler plants are running at full capacity) and determines distribution of the temperature inversion (radiation inversions). The calculations (which may be not accurate) indicate that current conditions will remain the same for decades (Fig 13.1.2).



Source: Siberian Federal University

These conditions let us understand why, despite the bankruptcy and closure of many industrial companies in the city since the collapse of the USSR, Krasnoyarsk city do not record improvements in its environmental conditions. Even if the amount of emissions gradually reduce, the state of the atmosphere will only worsen.

One important additional factor should also be take into account - the development of surface and elevated atmospheric inversions in winter. This phenomenon causes the cooled layers of air to move down and accumulate under the warm air layers. This leads to a reduction of pollutant dispersion and an increase in their concentration in the surface layer of the atmosphere. That is, all emissions in the surface layer cannot rise up to be dispersed. As they are not able to overcome the inversion layer, they remain at the surface and accumulate for several days or even weeks.

"Second city surface" has a significant impact on the temperature field in Krasnoyarsk city, namely the average level of the roof surface in the city. This influence is manifested in often temperature inversions in the autumn within the range from 25 to 50 m. This level is a very important, on the territory of the city where majority of urban buildings almost the same height.

The environmental situation in the city is getting sharply worse because of the lack of wind (horizontal mixing of air masses). This is how NMU appears in the winter and off-season. The situation in Krasnoyarsk city is not a special case. Research of pollution in Russian cities and, in particular, Tatars tan showed that in 80% of cases recorded increased levels of pollution and there is a low-gradient baric field of high pressure in the presence of surface and elevated inversions. But Krasnoyarsk has one distinctive feature. There are dozens of peat-burning plants and industrial factories that use brown coal (for example, one of the world's largest aluminum plants with huge emissions of pollutants).

Extremely important to highlight in the above:

There are huge number of ground emissions sources in the city (vehicles and stoves of private households, illegal fuel-burning plants, etc.). These sources additionally and sharply worsen the environmental situation in conjunction with developed surface inversion. At this time, concentration of pollutants in the atmosphere of the city can increase by 20 times.

The chimneys of large plants in the city are located at a considerable height – 170m or more, and above the inversion layer. This probably can have a beneficial effect, because the inversion layer prevents transfer of emissions to the earth's surface. But such high chimneys are characteristic only of large companies.

However, when the elevated inversions dominate, the emissions of almost all sources to accumulate in the city. However, it is quite difficult to talk about the safe height of chimneys in different meteorological situations due to the lack of data.

Priority actions and constraints:

There is "fast" achievement of a positive effect in the condition of the atmosphere (2-5 years). Consider the partial or complete liquidation of the private households in the center of the city of Krasnoyarsk (first of all, Pokrovka, Mykolaivka). Significant part of the new territory would have to transfer to the making of parks and squares for forming stable corridors for "ventilation"

3) Transportation

Krasnoyarsk is the largest center of Eastern Siberia, where population increases annually. Population growth entails a need for people to move and a directly proportional rise in the amount of personal transport. Today, Krasnoyarsk ranks the second in terms of motorization in Russia. Public transport has become less and less popular and the volume of public transportation has fallen from 70.2 to 57.5 million passengers per year over the last three years.

People refuse to use public transport due to the quality of the provided services and the considerable availability of cars. Despite the objective reasons, the number of traffic jams increases every year. The emissions from industrial factories, an increase of the number of vehicles and a general decrease in the speed of its traffic affect the increase of air pollution in the city.

Understanding the reasons.
The first reason is the mistakes of past transport planning.
During the first years after the collapse of the USSR, accumulated problems were not resolved, but rather worsened considerably. The "sleeping" areas began to appear and expand. This led to major parts of the population having to commute from Vetluzhanka, Severny and others areas to work and back every morning and evening. The road network could not cope with such a traffic flow. The result of the situation is traffic jams, well known to the residents.

There are some examples of quite interesting decisions on how to solve these problems. In the urban district of Khulun-Buir (China), administrative buildings were taken out of the city for a large enough removal. As a result, key objects began to appear close to administrative buildings and sitting of majority workplaces has changed. The city began to grow in the direction where local government administration is located. Other parts of the city were freed. The administration will be relocated again as its necessary.

The appearance of subway in Krasnoyarsk would be a more ordinary and obvious option. The decision to build it was made back in 1983. If this plan was realized, the subway could link the main centers of residence (sleeping areas) and work places of population. The need for daily moving on traffic jams would be removed. How long could this project pay off? That is an incorrect question because subways of only two cities – Moscow and St. Petersburg – are economically profitable in Russia. However, transport and environmental problems could be definitely reduced.

City traffic jams is also a serious financial brake in the development of agglomeration. According to experts of the Moscow State Automobile and Road Technical University the economic losses from traffic jams in Moscow is about 38.5 billion rubles annually. Probably the economic losses from the unresolved transport problems of the city in the next decade will be equal or higher the cost of measures to aimed at solution.

Krasnoyarsk does not really need new sleeping areas and giant shopping centers. New layout plans with more developed infrastructure are necessary in order for people to move as little as possible from one point of the city to another.

4) Industrial factories

Large plants, such as the Krasnoyarsk Aluminum Smelter and other industrial factories, are reluctant to reduce their atmospheric emissions by 20-25%.

There is a hope that the new developed maximum permissible discharge volumes MPE will contain strict updated rules. If they are adopted taking into account emissions from the private sector and vehicles, this will radically change the working conditions of plants.

Fig 13.1.2 Krasnoyarsk Aluminum plant

Source: Siberian Times

5) Air

In 2015, the level of pollution in Krasnoyarsk was characterized as "high"[10]. API5 (air pollution index) was >7. The average annual concentrations of formaldehyde, benzapyrene, suspended solids, nitrogen dioxide and nitrogen oxide contributed to the assessment of air pollution in the city. During the year, in the atmosphere of the city, cases were recorded where single concentrations of suspended solids, carbon monoxide, nitrogen dioxide, nitric oxide, hydrochloride, formaldehyde, ethylbenzene, benzene and toluene all exceeded the corresponding hygienic standards; 2 cases of 10 times the average daily MPCs (maximum permitted concentration) of benzapyrene were recorded and 2 cases of 10 times the average daily MPCs of hydrochloride.

The highest values of SI (standard index) were recorded in January (SI - 15.6), February (SI - 8.0), November (SI - 18.5), December (SI - 13.3). This is due to high concentrations of benzapyrene in the cold season. In June, a high value of SI for hydrochloride was recorded - 13.3. The maximum exceeding recurrence over MPC (MER) was observed in April - 57,7% on suspended substances.

The greatest contribution to the air pollution of the city is made by the enterprises of metallurgy and power generation, as well as by motor transport. In 2015, 195 thousand tons of pollutants were emitted into the atmosphere of the city, including 128,7 thousand tons from enterprises and 66,3 thousand tons from vehicles.

6) Water

The basin of the Yenisei River

The main pollutants found in the Yenisei are the compounds of zinc, aluminum, manganese and iron, as well as oil products and organic elements characterized by COD (chemical oxygen demand).

According to the classification of water by the maximum exceeding recurrence over MPC (MER) of oil products in water bodies, the contamination of the Yenisei water for the stretch of river from Selevaniha village to the town of Igarka is defined as "distinctive" (exceeding of MPC was observed in 91.7-100% of samples). Pollution of the Yenisei with metals is non-homogeneous and is characterized as "stable" - "distinctive" for copper, manganese, aluminum ions (exceeding the MPC was observed in 30-91.7% of the analyzed samples) and as "unstable" - "occasional" for zinc, cadmium and total iron ions (less than 30% MPC exceeding) in most sections. In relation to biochemical consumption of oxygen, BOD5 (biological oxygen demand) and Synthetic surfactant, a "low" level of water pollution was observed (the partial estimate did not exceed 1.8).

For oil products, iron, zinc and manganese compounds, the level of pollution is different throughout the river and is defined as "low" - "medium" (the partial estimate is between 1.1 and 2.4). Phenols, copper and aluminum ions are characterized by an "average" level of pollution (the partial estimate for these ingredients is 2.0-2.3).

The SCWPI (specific combinatorial water pollution index) value of the water quality of the Yenisei in the river stretches: "0.5 km downstream from the town of Divnogorsk" and "35 km upstream from Krasnoyarsk" varied from the third class, category "a" ("polluted") to the third class, category "b" ("very polluted).

The Kacha River

The monitoring of water pollution in the river Kacha is done at three observation points of the SMS (state monitoring system): 1 km upstream from the Pamyati 13 bortsov village, 1 km upstream from Krasnoyarsk, and within Krasnoyarsk.

The most common pollutants are phenols, petroleum products, metal compounds: iron, aluminum, copper, manganese, zinc and organic substances (characterized by COD).According to the classification of water by the maximum exceeding recurrence over MPC (MER) of most pollutants in water bodies, the contamination of water in the Kacha is defined as "distinctive". Exceptions are aluminum ions, phenols and petroleum products in the river stretch "within Krasnoyarsk" (in 38.5% of analyzed samples); phenols and aluminum ions in the river stretch "1 km upstream from Krasnoyarsk" (30.8-38.5% of the excess), the pollution of the river water in these river stretches is defined as "stable", for the rest of the ingredients it is defined as "unstable" and "occasional". According to the classification of water by the maximum exceeding recurrence over MPC (MER), "low" level of water pollution was observed for bichromate oxidation, biochemical oxygen consumption and zinc ions, for the remaining pollutants the "average" level of water pollution was observed.

In 2015, by the value of the SCWPI (specific combinatorial water pollution index) the water quality of the Kacha belongs to the 4th class, category "a" (“dirty”). The average annual concentrations of nitrogen ammonium and nitrogen nitrate do not exceed or slightly exceed the MPC.

The content of organic substances in 2015 was: by COD 24.5-28.0 mg / dm3, by BOD5 2.08-2.24 mg / dm3. The content of oil products remained at the level of the previous year and amounted to 0.05-0.10 mg / dm3, phenols 0.001 mg / dm3.

The water in the river stretches "1 km upstream from Krasnoyarsk" - "within Krasnoyarsk" is characterized by a high content of manganese ions. The average annual concentrations were 0.059-0.082 mg / dm3. The maximum concentrations were 15.0 - 18.9 MPCs, respectively.

In 2015 there was an increase in average annual total iron concentrations from 0.225-0.395 mg / dm3 to 0.422-0.464 mg / dm3 over the entire length of the river. The maximum concentration was observed in the river stretch "within Krasnoyarsk" - 19.3 MPCs.

The largest pollutant of the river Kacha are aluminum ions, which makes them one of the critical indicators of the pollution of the river water. Three cases of "high pollution" with aluminum ions were recorded: 11.0 Fishing Purposes MPCs - "1 km upstream from the Pamyati 13 bortsov village", 13.4 Fishing Purposes MPCs - "1 km upstream from Krasnoyarsk" and 16.4 Fishing Purposes MPCs "within Krasnoyarsk".

The contamination of the river with other metals remained at the level of the previous year: copper ions 0.002 - 0.003 mg / dm3 (in 2014 0.001-0.002 mg / dm3), zinc 0.004-0.006 mg / dm3 (in 2014 0.009-0.011 mg / dm3). Toxic chemicals of the γ-HCH (hexachlorocyclohexane) group were found in the river water. The maximum concentration of γ-HCH was 0.001 μg / dm3 in the river stretch "1 km upstream from Krasnoyarsk".

7) Soil

In Krasnoyarsk, an improvement in the situation is observed, expressed in decreasing indicators of the share of non-standard sanitary samples of soil taken in the residential area in 2015, compared to 2014 (from 22.2% to 15.3%), and the share of soil samples in the residential area that do not meet hygienic requirements for microbiological indicators, in 2015, compared with 2014 (from 39.7% to 1.7%).

8) Solid Waste

At present, in Krasnoyarsk, the collection of municipal solid waste (MSW) in the multi-apartment housing stock is carried out by means of container equipment. In the private sector, the collection of MSW is carried out in a combined way: container and container less collection (trash bags).

The services for the collection and removal of MSW in the city are provided by about 10 private companies. No municipal enterprises are engaged in the collection, transportation, processing and disposal of MSW in Krasnoyarsk. Since 2011, the centralized sorting of MSW on the left bank of the city, has been carried out at the waste sorting complex of OOO "Chistyi Gorod" ("Clean City") (currently temporarily suspended).

In 2014 the right-bank waste sorting complex of LLC "Ecoresource" was put into operation. MSW is buried at the MSW landfill site that belongs to OAO "Avtospetsbaza".

Fig 13.1.1 Separation work at municipal waste disposal Facility（Paper, Pet, Plastic, Glass, etc.）

Source: NIKKEN SEKKEI Research Institute

14 POLICY FRAMEWORK

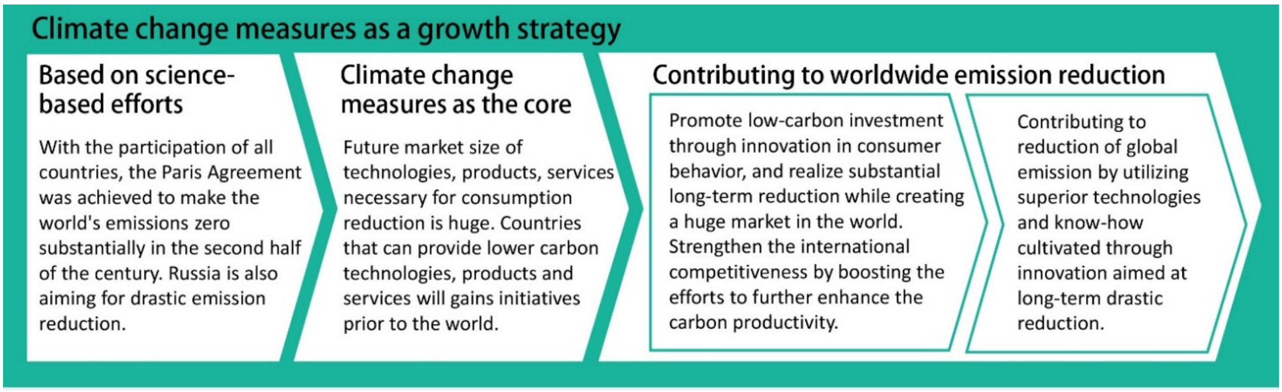
14. Policy Framework

14.1. Present policy concerning low carbon

Russia has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, the Kyoto Protocol in March 1999 and has established Russian law in October 2004. Regarding ratification of the Kyoto Protocol, Russia has put the initiative of the Protocol into force (February 2005) and gained a dominant position in the emissions trading market.

Government agencies responsible for environmental policy design, regulation, and compliance act at both federal and local government levels, and environmental policy implementation is increasingly decentralized. In Krasnoyarsk, innovative policy instruments have been adopted or further promoted, and traditional instruments have been under reform.

Figure.14.1.1 Climate change policy for green growth

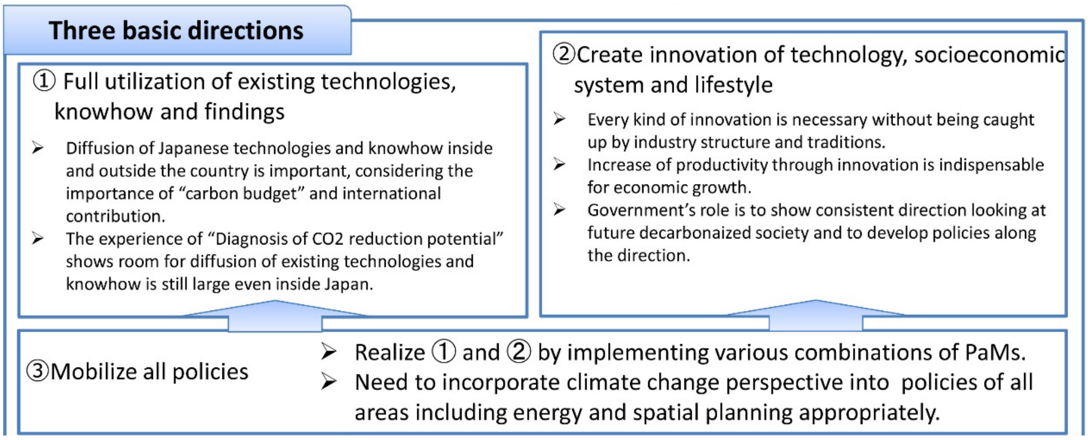


Source: Outline of Long-term Low-carbon Vision, Japanese Ministry of the Environment

While long-term goals lie ahead, the mid-term goals of 2030 are impending. Steady actions based on the current “Climate Action Plan” are the first step. Implementation of Policy and Measures (PaMs) is needed to accelerate reduction, promoting actions based on the “Climate Action Plan” in the following areas.

A. Utilize market dynamism through carbon pricing. Enhance market competitiveness of low-carbon technologies, products and services. Develop a market environment for innovation acceleration.
B. Other PaMs for significant Greenhouse Gas (GHG) reduction: Disclose environmental information, Regulation, Promote and diffuse innovative technology, land use, Contribute to global GHG reduction.

Figure.14.1.2 Policy direction towards long-term significant reduction



Source: Outline of Long-term Low-carbon Vision, Japanese Ministry of the Environment

14.2. Federal Government plans regarding CO2 reduction

Application form for registration of polluting installation, including GHG reporting Issues that require further clarification with Russian Government for foreign companies involved in the environmental projects:

- Decision on ratification of the Paris Agreement by Russian Federation has been delayed for an uncertain period raising concerns over the terms of participation in global climate commitments and incentives;
- Current plans of the Government of Russia do not envisage creation of an adequate low-carbon "tool-kit", mechanisms and tools instrumental for climate-responsible companies in Russia to perform efficiently in the field of low-carbon competition.
- Under the circumstances competitiveness of enterprises working in Russia has deteriorated; they are further exposed to the threats and risks of external carbon regulation, pressure and potential border adjustment measures, not to mention advance loss of economic benefits derived from mitigation activities.

Key issues to monitor the development of the governmental steps are:

- Development of Presidential decree on emission by 2030
- Low carbon strategy development 2050
- Preparation of GHG Federal regulation by June 2018

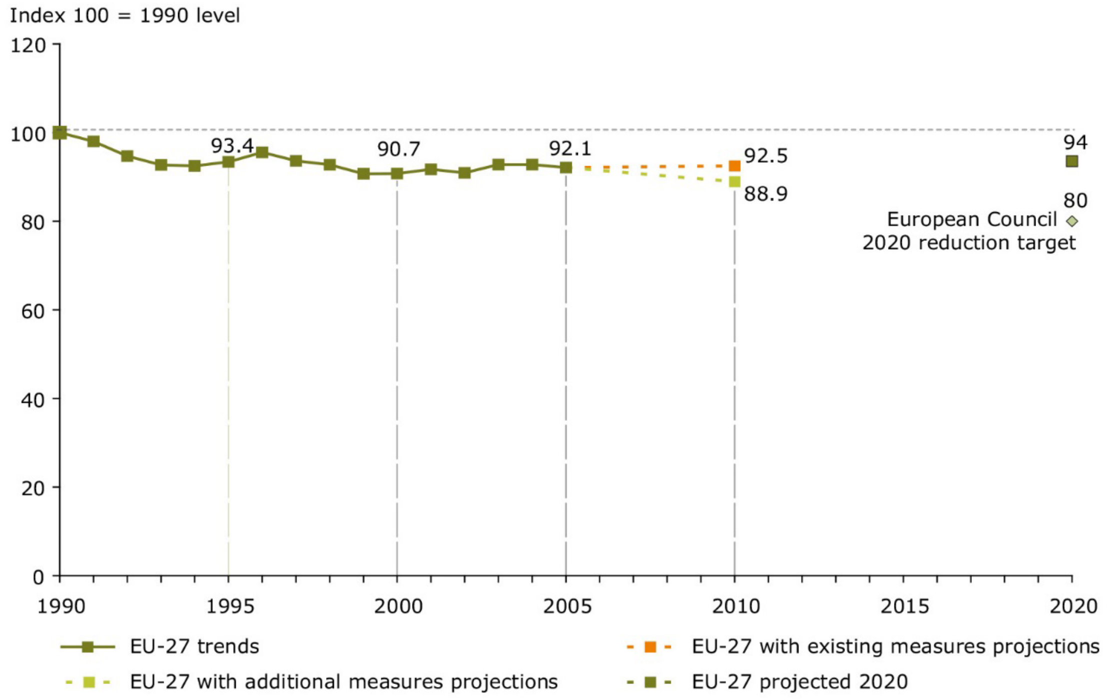
Main authorities involved in the process are: Ministry of Economic Development, Ministry of Energy and Ministry of Ecology. In general, the Ministry of Economic Development supports the idea of the process, while the Ministry of Energy is critical of the idea of the creation of a no-carbon pilot zone in East Siberia.

The Ministry of Energy says that all additional payments, including carbon taxes, can have negative impact on the competitiveness of the coal sector of the economy. As an alternative, the ministry is trying to promote development of coal based chemical production in the region.

Some large corporations also oppose coal tax. SUEK and Russian Steel are just some of them. These companies are also lobbying the government represented by the ministry of Industry and trade. Multi-level decision-making process is currently executed by the Russian government. Prime minister has reports from First Deputy Prime ministers; there are also Deputy Prime Ministers that may have both direct or dotted line report to the First Deputy Prime Minister or Prime minister accordingly.

At the same time, Ministry of Natural Resources suggests to move step-by-step in the implementation of low carbon regulations and privileges. One of the options is to introduce carbon intensity indexes to the list of best technologies. This will help many companies to reduce ecological tariffs. Main issue for Russian government is to select carbon regulations model with smaller impact on the business.

Figure.14.2 EU-27 greenhouse gas emission trends and projections to 2020



Source: Greenhouse gas emission trends and projections in Europe 2007

The report, 'Greenhouse gas emission trends and projections in Europe 2007', presents an evaluation of data between 1990 and 2010. More importantly, the report evaluates Member State projections of future greenhouse gas emissions and provides a good indication of progress towards Kyoto targets. The report is of particular relevance in the context of the rapidly approaching 'first commitment period' of the Kyoto Protocol which runs from 2008 to 2012.

15 EDUCATION & MANAGEMENT

15. Education & Management

15.1. Social education concerning low carbon

Strategic goals in federal government policy in this field are the development of cooperation between environmental education and society and reproduction of human resources in the energy sector. The efficient exchange between environmental education and society is the most important premise for the successful realization of strategic objectives and goals.

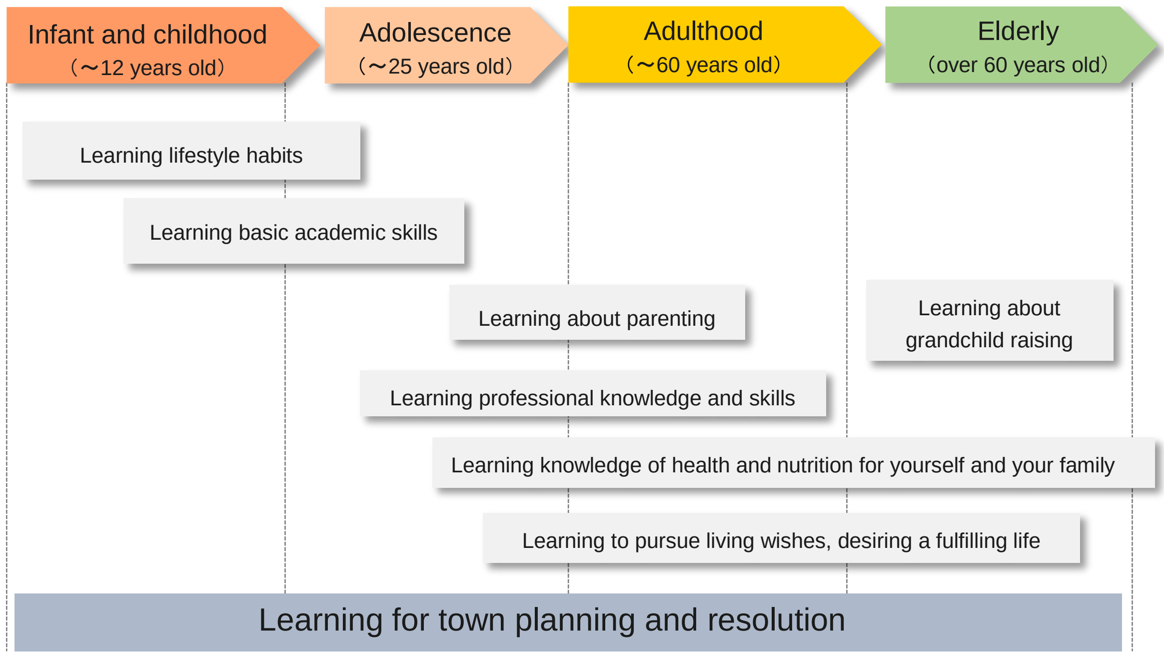
Recent trends in this field are the increase in consumption of energy products and services by citizens, and the role of human resources in the development of fuel and energy complexes increase. To enhance efficiency in environmental education, it is becoming increasingly important to educate citizens of all levels to help them meet modern demands.

1) Society to keep learning

There is no longer epoch that things pass through all their lives, and it is necessary to shift the fundamental recognition and education system. Therefore, people will pursue a purpose throughout their life, even after they get a job, any number of times.

Moreover, it is important to realize life cycles which people return the outcome to society and play an active role on the new stage. In order to transform into a society where education and labor, childbirth and child rearing can be balanced more smoothly, it is necessary to strengthen cooperation between educational administration and welfare administration, through seamless support that learned outcomes can be utilized in society.

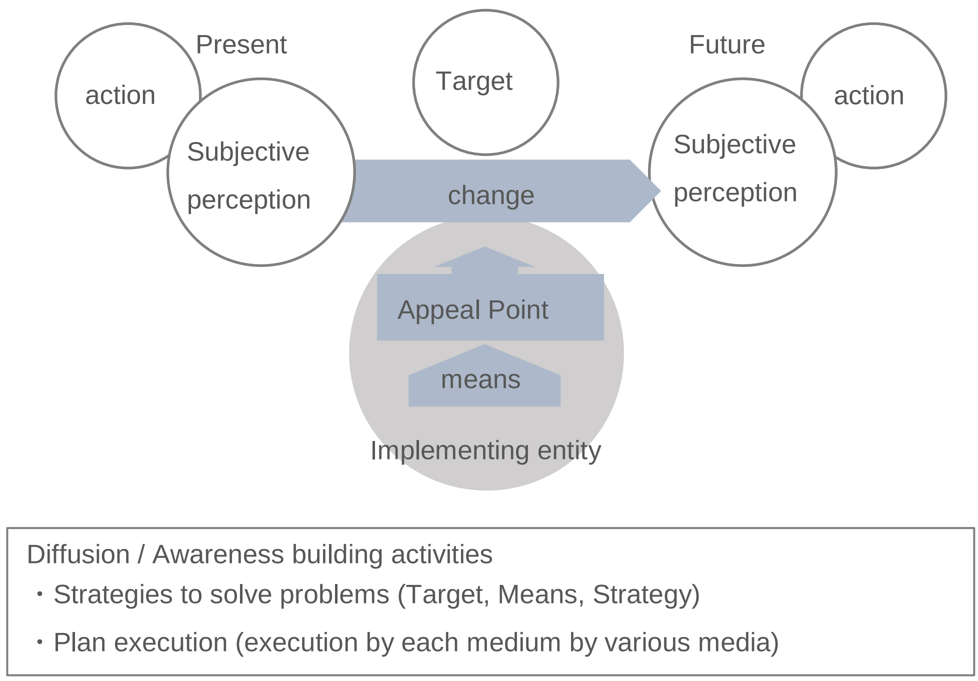
For this reason, it is necessary to construct an effective system that eliminates administrative vertical division. And also, as a result of changes in the industrial structure and the shift in corporate strategy, from the point of view, understanding and support of companies are indispensable in order to realize smooth talent movement.



2) Enlightenment

In order to make energy conservation sustainable, it is important to enlighten through education at schools and homes for people who are engaged in urban life, in addition to the role of governance. For example, by conducting high consciousness and voluntary efforts on eco-lifestyle, individual behavior in life leads to energy saving activities. This requires educational awareness and education through schools and families.

Figure.15.1 Process of diffusion



15.2. Opportunity in sustainable development

The Russian government is generally supporting the development of Smart Cities. Moscow, St. Petersburg and Kazan lead the process. Depending on the region, the value of smart city may be different, however.

In the case of Krasnoyarsk, smart city solutions should contribute to the ecological situation as the main priority. Finance is the core issue. In the case of Kazan, funds come from an Innovation budget. The model city is Techno Park Innopolice with some smart solutions required of the tenants. About 20 billion rubles has been provided from the federal budget, however the ROI is unclear. A landmark project for Moscow region is Skolkovo. Some of the smart grid solutions are applied. For example, Skolkovo Institute of Science and Technology has the agreement with ROSSETI (grid company) to use some of the equipment for the electricity supply in the nearby locations. At the same time, a 15 billion ruble investment was made. Centralization of the energy system is a key issue to the successful implementation of the smart city project.

Main restrictions on the sustainable development in Russia include:

1. Not prepared and approved technological solutions. The high cost of energy storage, the problem of Distributed Energy integration in the United Energy system of Russia.
2. Integration platform with unique smart devices is not approved at Federal Level
3. In general, Russia is technically behind developed countries and import opportunities are limited due to high cost and compatibility issues.
4. Entrepreneurship is not developed and this limits supply/demand opportunities for both equipment and solutions.

1) Hills Machi-Iku Project

The "Hills Machi-Iku Project" is an attempt for children in Tokyo, who will play important roles in the future to experience, and to think about what the next-generation city will be like, through an enjoyable learning environment. Since 2007, Mori Building has been developing with the themes of "safety" "environment" and "culture", implementing careful and thoughtful city planning as a “place to learn”. At Roppongi Hills and Ark Hills in Tokyo, over 6000 people have participated so far. It also contributes to providing learning opportunities for children in the local community, not only as a program of public offering but also as part of classes in conjunction with neighboring elementary schools.

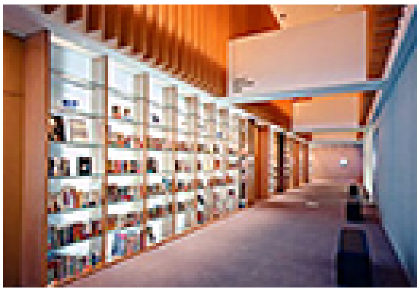
   

2) Roppongi Academy Hills

Roppongi Hills was born with the concept of "cultural city center", aiming at the "ultimate destination" where people will come from all over the world. It aspires to be a place where the best players gather and valuable exchange of the latest information occurs. Security and hospitality, stimulation and relaxation are consistent, and a rich space that can accept diverse lifestyles and work styles is supported.

Put into one place school, forum and library, providing a place for people to interact

"Roppongi Academy Hills" constantly provides a place enabling "creation", "exchange" and "outgoing" through gathering superior personnel, technology, funds and information from around the world. At the same time, they hold large-scale international symposiums and press conferences using advanced technologies and also have a membership library that provides rich spaces and services that support members' knowledge work. In addition, they are developing various schools for all urban dwellers, started with the professional school developed since 1987 targeting business people who are active on the front line.

16 INDUSTRY

16. Industry

16.1. Energy consumption of the industry sector

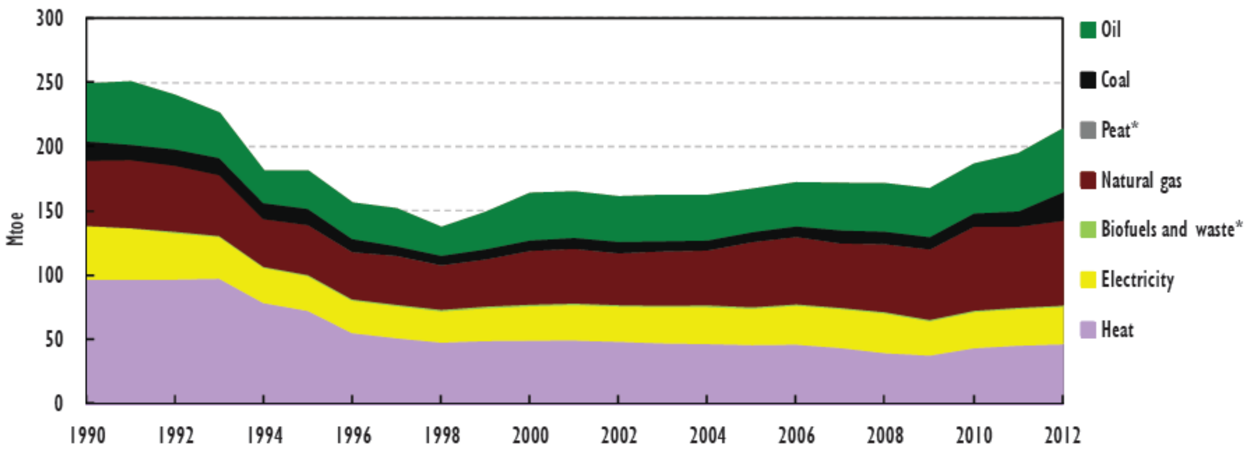
1) Energy consumption of the industry sector in Russia

Russia is the fourth-largest primary energy consumer after China, USA and India. Total final consumption (TFC) in Russia was 463.1 Mtoe in 2012, which is the highest level of energy consumption in Europe. Since the start of the 21st century, Russia's TFC has been increasing steadily each year, except in 2009 due to the global financial and economic crisis, and in 2012 had increased by 13.4% compared to 2002. Before 1999, the level of consumption was consistently falling, decreasing from a high of 625 Mtoe TFC in 1990.

In 2012, the industry sector accounted for 46.2% of TFC in Russia, followed by the residential sector (23.6%), transport sector (20.2%) and commercial public services sector (10.1%).

The industry sector consumes the largest share of final energy, amounting to 213.8 Mtoe in 2012, or 46.2% of TFC, which is shown in Figure 16.1.1. Consumption in this sector has increased at a faster rate compared with TFC, with its share up from 39.5% of TFC in 2002.

Figure 16.1.1 Total final consumption of the industry sector by source, 1990-2012



Source: Russia 2014, IEA

2) Energy consumption of the industry sector in Krasnoyarsk city

Historically, Krasnoyarsk's economy has a poly-economic structure with 12 major industries as shown in table 16.1.1, in which metallurgical production and production of finished metal products account for nearly 75% of total sales.

Table 16.1.1 major industries in Krasnoyarsk city

Branches of manufacturing industry	2016, million. rubles	Structure
1. metallurgical production and production of finished metal products	208,749.1	74.5%
2. production of machinery and equipment	16,849.6	8.9%
3. production of food products, including beverages	14,021.4	5.0%
4. chemical production	9,021.8	3.2%
5. production of electrical equipment, electronic and optical eqpt.	7,206.2	2.6%
6. production of vehicles and equipment	6,943.8	2.48%
7. production of other non-metallic mineral products	6,190.3	2.2%
8. wood processing and woodworking	791.6	0.28%
9. publishing and printing	641.7	0.2%
10. production of rubber and plastic products	555.9	0.2%
11. production of leather, leather goods and footwear	257.5	0.09%
12. textile and clothing production	133.5	0.05%
other	882.0	0.3%
Total:	**280,207**	**100%**

Source: Krasnoyarsk City administration

The total electricity consumption in Krasnoyarsk city is 6.7 billion kWh in 2016, and if the aluminum industry is added, the figure becomes 23.9 billion kWh. Table 16.1.2 shows a breakdown of power consumption in 2016. It is clear that the aluminum industry accounts for most of power consumption.

Table 16.1.2 Power consumption by consumers, 2016

Groups of consumers	Power consumption for 2016 (MWh)
KrAS / RUSAL (Aluminum Smelter)	17,134,777
Industrial consumers with an attached capacity of 750 kVA and above	1,388,681
Industrial consumers with an attached capacity less than 750 kVA	375,134
Electric public transport	19,172
Nonindustrial consumers	3,665,074
Agricultural production consumers	5,581
Population	1,329,192
TOTAL	**23,917,611**

Source: Krasnoyarsk municipal government

(1) Aluminum Industry

Krasnoyarsk aluminum smelter is one of the largest smelters in the world, accounting for around 29% of aluminum production in Russia and 2% of the global aluminum output. This facility is RUSAL's key site for testing and introducing new cutting-edge technologies. The plant is focused on high quality products with a 36% share of hi-tech products and alloys. It's the only smelter in Russia and CIS to produce high-purity aluminum.

As part of the overhaul of reduction cells, work to replace the "Old Soderberg" with environmentally friendly "Clean Soderberg" has been being carried out since 2015. The replacement of the cells is planned to be completed by the end of 2019.

Table 16.1.4 shows the annual production of primary aluminum by different technologies and actual CO_2 emission in 2016.

Figure 16.1.2 KrAS (Krasnoyarsk Aluminum Smelter) Factory

Source: RUSAL homepage. http://www.rusal.ru

Table 16.1.3 Information about KrAS

Item	Information
Geography	Krasnoyarsk, Russia
Products	Primary aluminum, alloys (slabs, billets, small ingots and T-bars), high-purity aluminum
Annual production capacity	1,013,000 tones
Capacities	25 pot rooms, 3 cast houses, anode production unit
Energy source	Krasnoyarsk HPP (Hydro Power Plant)
Smelting technology	Most of the smelter's cells use «dry» anode technology. Each 3rd Krasnoyarsk smelter's pot room has been converted to the "Clean" Soederberg technology
Development	As part of a large-scale modernization programme, carried out in 2004-2009, the smelter was converted to «dry» anode technology and equipped with dry gas scrubbing stations and automated alumina point feeders. The program led to a considerable cut in emissions: hydrogen fluoride was reduced by 1.5 times, tar substances by 2.7 times, and benzo (a) pyrene by 2.5 times.

	The plant is currently undertaking a second stage of modernization, which is scheduled to be completed by 2018. It includes converting the pot rooms to the environmentally friendly technology "Clean Soederberg" and improving the efficiency of the SEI calcining systems which are used in anode paste production. A complex environmental program in 2015 led to pollution reduction by 1.3%. The second phase of the modernization plan is expected to result in a 39% reduction of pollutant emissions. The major part of Krasnoyarsk smelter's output is wrought alloys. The construction of a new foundry complex to increase billets production from 203 to 457 mm is underway. Inert anode technology is being tested in one of the Krasnoyarsk smelter's sections
Certificates	ISO 14001:2004 (environmental management standard) ISO 9001 (quality management standard) ISO/TS 16949:2002 (quality management standard for automotive industry) OHSAS 18001 (health and safety management standard)
Headcount	4,300 people

Source: RUSAL homepage. http://www.rusal.ru

Table 16.1.4 Annual production of primary aluminum and CO_2 emission of KrAS in 2016

Smelter cell	daily production t/d	Year production t/yr	Emission intensity kg CO_2/t	Annual Emission t-CO_2/yr
Soderberg	2455.35	898,659	1930	1,734,412
prebaked	328.8	120,341	2090	251,513
Total	2784.15	1,019,000	-	1,985,925

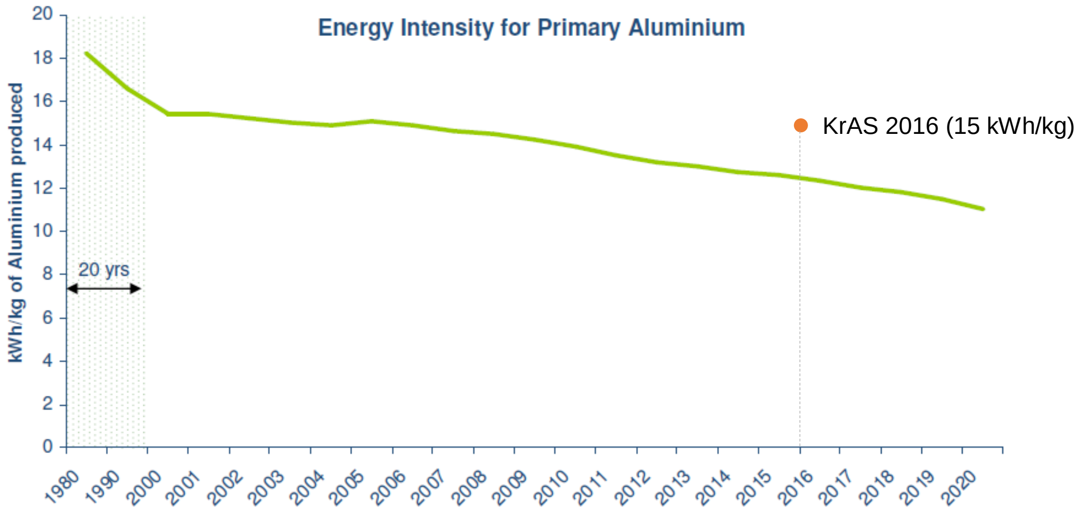
Source: Krasnoyarsk city administration

16.2. Low-carbon development strategy of the industry sector

1) Energy intensity for primary aluminum

Figure 16.2.1 shows the consistent improvement in the energy intensity for the production of Aluminum, and particularly with regards to the Hall-Heroult cell (Processes), has made significant impact as shown in the figure below. In the 1900s, one kilo of Aluminum processed required nearly 50kWh from start to finish (excl. transport). In 2020, it is forecasted that only 11kWh will be required. Moreover, the increased use of recycled aluminum (Secondary Aluminum) from around 500,000 tons in 1980 to 2.9 million tons in 2009, further reduces the overall energy intensity of the industry. Secondary Aluminum requires less than 20% of the energy of Primary Aluminum per unit weight.

Figure 16.2.1 Energy intensity for primary aluminum



Source: Frost & Sullivan 2010

In KrAS (Krasnoyarsk Aluminum Smelter), both “Soderberg” and “Prebaked anode” technologies are employed, while “Soderberg” is divided into 2 different processes called "Old Soderberg" and "Clean Soderberg" due to different environmental influence.

Since 2015, as part of the overhaul of reduction cells, the replacement of the "Old Soderberg" with the environmentally friendly "Clean Soderberg" has been carried out. The replacement of the cells is planned to be completed by the end of 2019 in KrAS.

In 2016, 15.3 kWh electricity was consumed during the production of 1kg primary aluminum, in which “Soderberg” technology consumed 15.5 kWh per kg aluminum and “prebaked anode” technology consumed 14.2 kWh/kg. Although great improvement of energy intensity has been achieved by KrAS in the primary aluminum process, further progress is still expected in comparison to other advanced aluminum smelter facilities.

The following process improvements in the existing technologies, including the minimization of anode effect, and implementation of new technologies can assist in achieving reduced process energy requirements by 16%, according to SUBODH DAS' report, 2012:

Process improvements for existing technologies:

(1) Replace rotary with fluid bed calcines,

(2) Reduce electricity needed for smelting,

(3) Lower anode effect,

(4) Decrease carbon anode consumption,

Development and adaption of new technologies:

(1) H-Center break prebake at 4.5 cm anode–cathode distance (ACD)

(2) Wetted drained cathode at 2 cm ACD

(3) Wetted cathode and inert anode at 2 cm ACD

(4) Carbothermic electric furnace

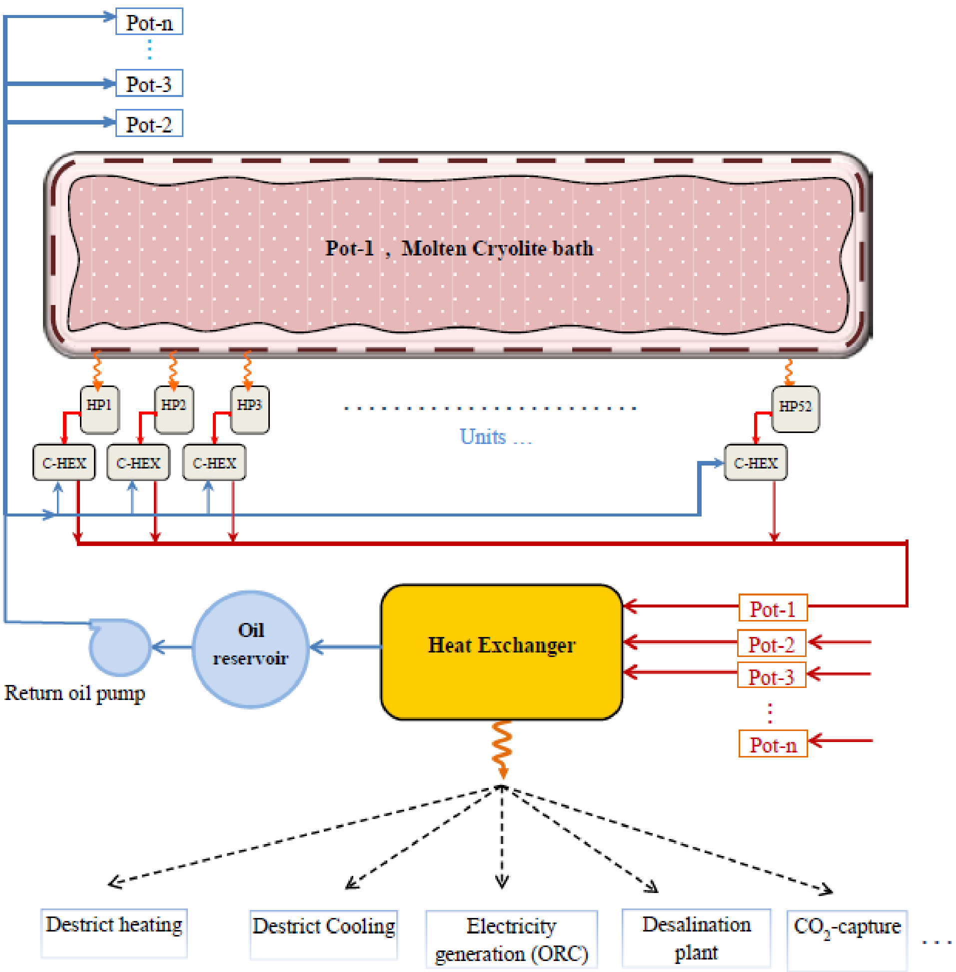
(5) Clay carbochlorination and chloride electrolysis

2) Waste heat recovery technology in aluminum smelter

Energy can be recovered from the waste heat developed in the electrolytic process used for making aluminum, thereby reducing the specific energy consumption per kilo of aluminum produced. The accumulated waste heat can be used to produce electricity or as process heat for processes with a high energy requirement.

The heat recovery technology is to place heat collection units at the outside of the pot shell. The collection units are based on the heat pipe (thermosiphon) principle and include the thermosiphon and the insulation layer attached behind it. They are connected in a parallel piping system and the heat is removed using thermal oil. The heat is collected by passing thermal oil through a condenser at the top of the thermosiphons to be used in an energy utilization system. The thermal oil used is Prather NF with an optimum temperature range of between 40 °C to 340 °C. The principals of the heat recovery system for an aluminum reduction cell are shown schematically in Fig.16.2.2.

Figure 16.2.2 Principals of the proposed heat recovery technology for an Aluminum reduction cell



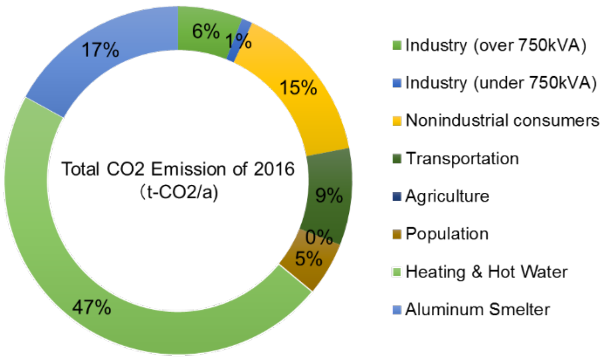
Source: Yasser Mollaei Barzi, A NOVEL HEAT RECOVERY TECHNOLOGY FROM AN ALUMINUM REDUCTION CELL SIDE WALLS: EXPERIMENTAL AND THEORETICAL INVESTIGATIONS. TMS, 2014

17 LOW-CARBON METHOD AND COST PERFORMANCE

17. Low carbon method and cost performance

17.1. CO2 emission related to energy consumed in 2016

Figure 17.1.1 shows the ratio of CO_2 emissions related to energy consumed in 2016 year. From the characteristics of cold districts, the Heating & Hot Water sector shows 50% of the total CO_2 emissions. This means that low carbon countermeasures in the CHP plants contribute to reduction in Krasnoyarsk city.



. **Fig 17.1.1 Total CO_2 emissions of 2016**

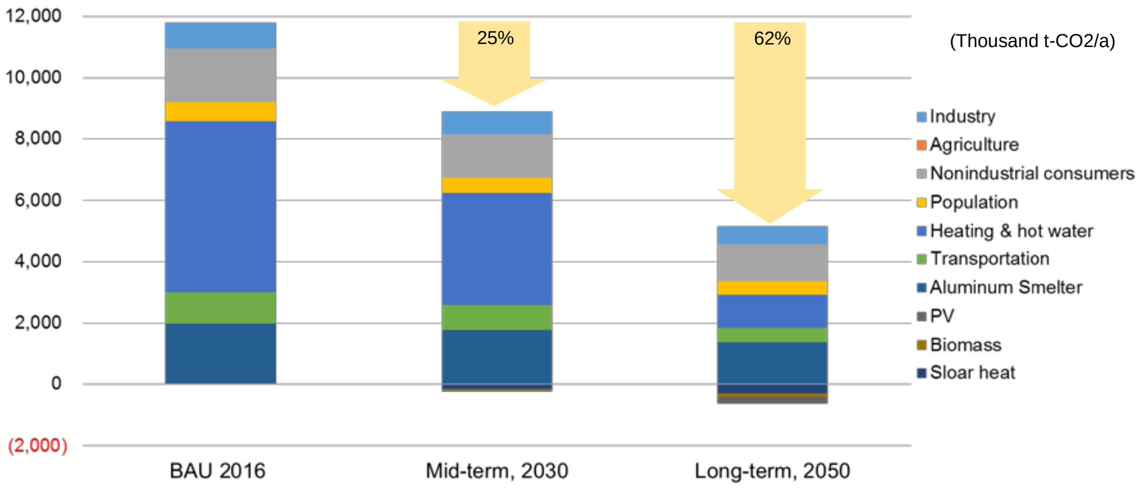
Source: NIKKEN SEKKEI Research Institute

17.2. Low Carbon development scenario

The following shows calculation results of the CO_2 emissions reduction as well as mid-term and long-term perspective from building and energy supply sector in Krasnoyarsk city. CO_2 emissions from buildings under BAU (2016) is roughly 12 million t-CO_2/year. Figure 17.2.1 shows mid and long-term perspective of CO_2 emission.

Compared to the BAU scenario of 2016, mid-term target of CO_2 emission is expected to be reduced by more than 25% in which heating & hot water sector contributes the most due to applications of key energy-saving strategies proposed in this feasibility study. In 2050, besides existing technologies employed in each sector, technological innovation is also prospected and the long-term target of CO_2 emission reduction is expected to reduce more than 62%.

Fig 17.2.1 Mid-term and long-term perspective of CO_2 emission (Low-carbon development scenario)



Groups	Power consumption for 2016 (thousand kWh)	BAU 2016 (t-CO2 / a)	Mid-Term 2030 (t-CO2 / a)	Long-Term 2050 (t-CO2 / a)
Industry (over 750kVA)	1,388,681	660,313	594,282	462,219
Industry (under 750kVA)	375,134	178,375	160,537	124,862
Transportation	19,172	1,009,945	810,775	450,974
Nonindustrial consumers	3,665,074	1,742,731	1,394,184	1,219,911
Agriculture	5,581	2,654	2,388	1,858
Population	1,329,192	632,026	505,621	442,418
Heating & Hot water	-	5,588,534	3,649,324	1,068,821
Aluminum Smelter	17,134,777	1,985,925	1,787,332	1,390,147
TOTAL	23,917,611	11,800,502	8,904,444	5,161,212

Source: NIKKEN SEKKEI Research Institute

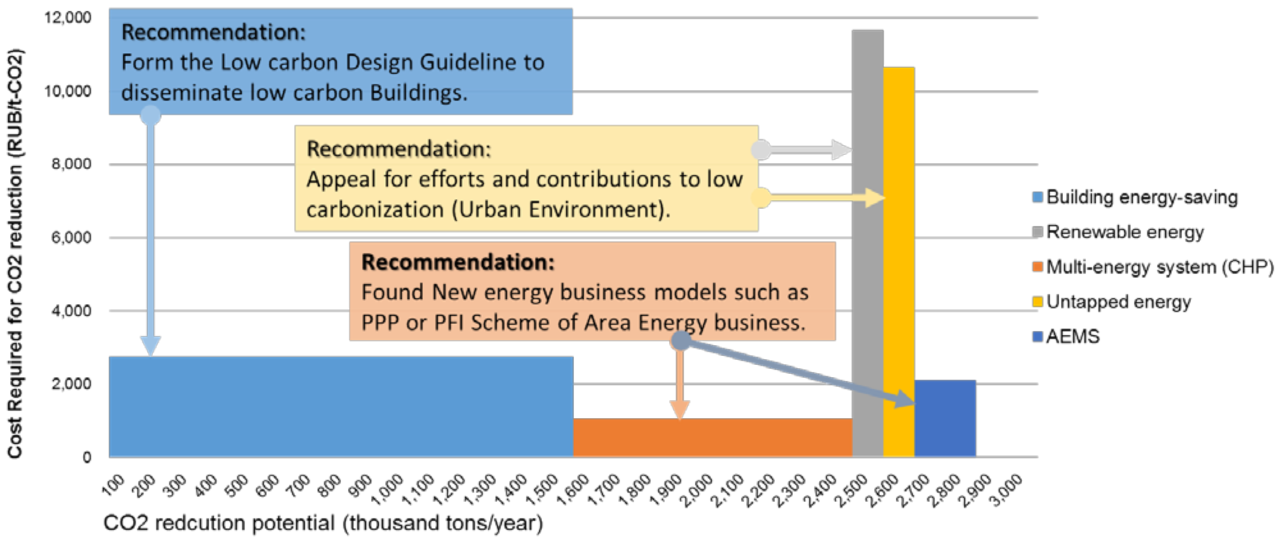
17.3. Examination of Cost Performance

In the building and multi-energy supply sector, the annual cost is obtained by dividing the increment of the initial costs for the building energy saving, waste heat recovery and other low-carbon technologies of the multi-energy systems (CHP plants), untapped energy, renewable energy as well as Area Energy Management System (AEMS) by the equipment's life-span (years).

Since the life of the building energy saving strategies, multi-energy system such as CHP plant, and AEMS is mainly based on the building materials, piping and general-purpose equipment, the life-span is assumed to be around 30 years. Meanwhile, since the life of the renewable energy and untapped energy is mainly based on such devices as the solar panel and biomass power generator, the life-span is assumed to be about 15 years.

In addition, the CO_2 reduction cost required to reduce 1 ton of CO_2 emission in a year is defined by dividing the annual cost by the reduced amount of CO_2 emissions (tons) for each sector calculated in above Section. Figure 17.2.1 demonstrates cost of CO_2 emission reduction per ton and total reduction potential in each sector.

Fig 17.3.1 Cost of CO_2 emission reduction per ton and reduction potential in each sector (by 2030)



Source: NIKKEN SEKKEI Research Institute

By 2030, Krasnoyarsk city could potentially cut over 2.8 million tons of CO_2 emission if low-carbon strategies proposed in above chapters are implemented by phases. Specifically, energy-saving solutions in building sector can reduce most of CO_2 emission and followed by low-carbon measures in multi-energy systems (CHP plants) sector.

Renewable energy and untapped energy are considered effect in promoting sustainable development, however, the contribution in reducing CO_2 emission amount is still considered quite limited due to the small scale of applications by 2030.

In the annual costs, the initial cost for building energy saving and multi-energy system as well as AEMS is relatively low compared with that of renewable energy and untapped energy systems, which is mainly because that renewable energy such as photovoltaic and biomass systems are still more expensive than fossil-based ones, meanwhile, the service life of renewable and untapped energy system is shorter in compare with other low-carbon measures in building and multi-energy sector. However, those problems could be solved in the long-term perspective as the initial cost becomes cheaper and much more energy efficient.