Policy Review for APEC Low-Carbon Model Town Phase 7 Krasnoyarsk City Russia

Final Report

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ABBREVIATIONS AND ACRONYMS

Acronyms

3R	Reduce, Reuse, Recycle
AAGR	Annual Average Growth Rate
AEMS	Area Energy Monitoring System
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
BAU	Business-as-Usual
BEMS	Building Energy Management Systems
CBD	Central Business District
CHP	Combined heat and power
DH	District heating
EE	Energy efficiency
EWG	Energy Working Group
FISU	International University Sports Federation
FS	Feasibility Study
Gcal	Gigacalorie
GHG	Greenhouse gas
GLONASS	Global Navigation Satellite System
h	Hour
HDD	Heating Degree Days
ICT	Information Communications Technology
ITS	intelligent transport system
JSC	Joint Stock Company
KrAZ	Krasnoyarsk Aluminium Smelter
kWh	Kilo Watt Hour
LCMT	Low-Carbon Model Town
LCT	Low-Carbon Town
LCT-I	Low Carbon Town Indicator
LED	Light-emitting diode
LEED	Leadership in Energy and Environmental Design
LLC	Limited Liability Company
LNG	Liquefied natural gas
MC	Management Company
METI	Ministry of Economy, Trade and Industry of Japan
MSW	Municipal Solid Waste
MW	Mega Watt
N-S	Nikken Sekkei
NGO	Non-governmental organisation
PhD	Doctor of Philosophy
PR	Public Relations
PV	Photovoltaic
QoL	Quality of Life
SUEK	Siberian Coal Energy Company
t	ton
US	United States
USD	United States Dollar

PREFACE

The APEC Low-Carbon Model Town (LCMT) project has been implemented as a response to the APEC Energy Ministers' directive. At the 9th APEC Energy Ministers Meeting held in Fukui, Japan in June 2010, the Energy Ministers discussed the low carbon paths in the context of energy security through cooperative solutions for energy-sustainable APEC region that would support the economic growth and development of member economies. To manage the growing energy consumption and the associated greenhouse gas emissions (GHG) in urban areas in the APEC region, the Energy Ministers recognised that low carbon technologies should be introduced in city planning to promote energy efficiency, as well as to reduce fossil energy use. Along this line, the Energy Ministers agreed to launch an 'APEC Low-Carbon Model Town Project (LMCT)' to demonstrate best practices and successful models in the implementation of advanced low-carbon technologies. The project is one of the priority initiatives under the APEC energy cooperation framework.

The key objectives of LCMT are:

(1) To develop the 'Concept of the Low-Carbon Town', which will serve as a guidebook on the principles and implementation of low-carbon urban design;

(2) To assist in the implementation of the concepts in selected Low-Carbon Model Towns by providing feasibility studies and policy reviews of these urban development projects; and,

(3) To share the best practices and real-world experiences on low-carbon urban design with planners and policymakers throughout the APEC region.

Based on the concepts of LCMT, a Feasibility Study is carried out by an urban planning consultant as a form of assistance extended to chosen urban areas. Likewise, a Policy Review is undertaken (as presented in this report) to review existing and planned policies and regulations in relation to the development of low-carbon town.

APEC has already conducted seven LCMT projects, which started in 2011. The Phase 1 project was held in Tianjin, China for Central Business District; the Phase 2 project in Samui Island, Thailand for Island Resort Area; the Phase 3 project in Da Nang, Viet Nam for Redeveloping Mixed-Use Urban District; the Phase 4 project in San Borja, Peru for Residential Area; the Phase 5 in Bitung, Indonesia for Industrial Area; the Phase 6 in Mandaue City, the Philippines for Cooperation with Neighbouring Areas. For Phase 7 in Krasnoyarsk City, the focus is Inland Region with High Demand for Heating and Cooling.

This report presents the findings of Policy Review for Krasnoyarsk City, Russia.

The reviewed economy and the Review Team share the accountability for the Policy Review. A team of six experts conducted the Policy Review in Krasnoyarsk City (see Appendix A). During the visit to Krasnoyarsk City from 5 to 7 December 2017, the Review Team held comprehensive discussions with representatives and experts from the Krasnoyarsk City Administration, Siberian Federal University, Ministry of Ecology and Rational Natural Resource Management of Krasnoyarsk Territory and some companies (see Appendix B).

The Review Team wishes to thank all the presenters and participants who spent time with the Review Team for discussions. We express our special thanks to the Krasnoyarsk City Administration and the Ministry of Energy of the Russian Federation for organising the LCMT Policy Review event.

EXECUTIVE SUMMARY

Krasnoyarsk is a million-strong city and the largest industrial and cultural centre of Eastern Siberia, 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 aluminium industry. It is a city that has grown through light industry and mining, but is surrounded by vast forests around the city centre. Due to the aging of CHP facilities (including boiler houses) and aging of heat conduit facilities, and the use of brown coal (lignite) as the main fuel, the current efficiency of power generation and efficiency of heat supply remains low.

The feasibility study conducted recognised that these low carbon-related projects could realise a significant reduction in GHG emission in the City once fully implemented. From this, Krasnoyarsk City could develop its low carbon targets while improving the Quality of Life of its residents through addressing high heating demand.

Krasnoyarsk is the subject of the APEC Policy Review (Peer Review) led by the Asia Pacific Energy Research Centre (APERC) to assist the City develop its plans on low carbon development and become a model town for others in the APEC region. It is expected to take the initiative to demonstrate a prototype consistent with a growing industrial city within a cold district and low carbon development. Part I of this report contains background information on Krasnoyarsk City and provides the context to the Part II, which is produced by the Review Team. The findings and 67 recommendations for implementation in this policy review are grouped by topic: legal and institutional frameworks, sustainable urban planning, low carbon buildings, area energy management systems, energy efficiency, renewable energy and untapped energy planning, transport, environmental planning and others. It should be noted that implementing these recommendations should take into account quantifiable issues (costs and timing), and less tangible considerations (leadership and stakeholder interest and support), as follows:

- Is the action cost effective? (e.g. a simple analysis of the unit cost of carbon emission mitigation).
- Is the action visible and engaging? (e.g. to what extent will the action educate residents and visitors about the importance of sustainability?).
- Does the action generate political and community support? (e.g. does strong leadership exist to promote the action?)
- Will community, businesses and other stakeholders engage to promote these changes?

An 'integrated framework' explains the rationale for the prioritisation. Leadership and community support along with an integrated framework could help Krasnoyarsk City to become a leading and model Low-Carbon Town (LCT). Recommendations set forth under immediate action are the highest priority considering that they are both cost effective and likely to solicit strong and greater community support. The public can embrace the low carbon path from the beginning and reap the benefits to having sustainable economic growth and better quality of life in the future.

The Review Team's recommendations are graded according to priority for implementation, which is intended to provide the policymakers a base to determine the timeframe for each recommendation contained in this report:

★★★	Recommendation for <u>immediate</u> action
★★	Recommendation for action in the <u>next 2-3 years</u>
★	Recommendation for action in the <u>longer term</u>

RECOMMENDATIONS

TOWN STRUCTURE

Recommendations for immediate action ★★★

Rec. 1: Introduce a network between multi-core strategic development zones.

Rec. 2: Improve liveability and walkability around the hubs.

Recommendations for action in the next 2-3 years ★★

Rec. 3: Allow mixed land use.

Rec. 4: Stimulate densification.

Recommendations for action in the longer term ★

Rec. 5: Introduce IT system to enable the data-driven management.

BUILDINGS

Recommendations for immediate action ★★★

Rec. 6: Improve energy efficiency by retrofitting insulation of existing buildings.

Rec. 7: Work closely with federal/regional agencies to develop a mechanism to enhance compliance with building energy efficiency codes.

Rec. 8: Promote efficient water heaters and appliances (e.g. LEDs) through government regulations and energy labelling programs.

Recommendations for action in the next 2-3 years ★★

Rec. 9: Build capacity for city officials, builders, and assessors for monitoring compliance with energy efficiency code for new buildings.

Rec. 10: Promote technologies and management systems for reuse of hot water and heat recovery in ventilation.

Rec. 11: Install and reform the metering system for heating of existing buildings to change people's behaviour.

Recommendations for action in the longer term ★

Rec. 12: Consider the entire life process in terms of energy consumption and carbon emissions for urban planning and building construction.

Rec. 13: Initiate government programmes for collaboration with NGOs and universities to educate the public of approaches to save energy.

TRANSPORTATION

Recommendations for immediate action ★★★

Rec. 14: Increase the effectiveness of existing road infrastructure.

Rec. 15: Restructure and strengthen the public transport network.

Recommendations for action in the next 2-3 years ★★

Rec. 16: Control the use of motor vehicles.

Recommendations for action in the longer term ★

Rec. 17: Reduce vehicle emissions.

Rec. 18: Coordinate with urban planning for mixed use of land to reduce transport demand.

Rec. 19: Conduct analysis for selection and implementation of transport solutions.

Rec. 20: Educate drivers (on vehicle maintenance, loading, etc.) and provide driver behavioural change (awareness campaign) program.

AREA ENERGY SYSTEMS & MULTI-ENERGY SYSTEMS

Recommendations for immediate action ★★★

Rec. 21: Adopt the recommendations in the Feasibility Study report.

Rec. 22: 'Close the loop': divert district heating hot water from being dumped into the Yenisei River to recirculating through DH system (or using heat recovery to preheat incoming river water).

Rec. 23: Implement research project to improve understanding of energy (electricity and heat) use and efficiency for each activity and level of energy services (comfort, light, food preservation, entertainment, cooking etc.) provided, especially in non-industrial businesses and residential sector.

Recommendations for action in the next 2-3 years ★★

Rec. 24: Optimise end-use efficiency of district heating and minimise distribution losses; trial targeted energy efficiency upgrades to allow closure of an old boiler house.

Rec. 25: Develop strategy to ensure that all investments in end-use equipment, district energy systems and selection of energy sources are compatible with a long-term zero emission future.

Rec. 26: Conduct detailed feasibility study for district heating options: high efficiency, flexible CHP able to use waste heat and multiple fuels/heat sources, e.g. gas-from-coal, biogas, natural gas, hydrogen, petroleum, renewable liquid fuels; electric heat pumps using heat from river water, industrial sources.

Recommendations for action in the longer term ★

Rec. 27: Introduce metering and unit pricing of heat/energy from district heating system for new buildings and, over time, existing buildings. Initial focus on business and industrial buildings. Develop alternatives to pricing to influence household behaviour, e.g. incentives, education.

Rec. 28: Investigate implications of changing climate and higher efficiency buildings for future role and technologies of district heating and, potentially, cooling system: more variable loads, need for summer cooling.

Rec. 29: Trial micrografts in selected areas, e.g. fringe of grid, old infrastructure and integrate with Area Energy and Service Management System.

UNTAPPED ENERGY

Recommendations for immediate action ★★★

Rec. 30: Promote the use of waste heat in the industries.

Rec. 31: Provide subsidies from the government.

RENEWABLE ENERGY

Recommendations for immediate action ★★★

Rec. 32: Set the target to increase the use of renewable energy.

Recommendations for action in the next 2-3 years ★★

Rec. 33: Support renewable energy data collection.

Rec. 34: Consider policy measures to provide incentives.

Rec. 35: Prepare support scheme for the renewable energy businesses.

Recommendations for action in the longer term ★

Rec. 36: Adopt the feed-in tariff

BUILDING AND AREA ENERGY MANAGEMENT

Recommendations for immediate action ★★★

Rec. 37: Adopt recommendations in the feasibility study report.

Rec. 38: Establish capabilities in government, academia and businesses to track and model the evolution of energy (and service) management technologies, services, business models, market designs and system management strategies, as well as their potential impacts on existing energy infrastructure and institutions, and societal costs and benefits of change.

Rec. 39: Learn from experience: identify and evaluate existing projects, trials, lessons from other places (avoid their mistakes!).

Recommendations for action in the next 2-3 years ★★

Rec. 40: Build supply chains and expertise in delivery of diversified energy solutions, including 'behind the meter' technologies, services and business models.

Rec. 41: Develop financial models so that interventions in energy consumer markets to drive low carbon solutions through pricing, incentives and other initiatives can be justified – also see Area Energy recommendations.

Rec. 42: Build capacity in government, academia and business to develop techniques and business models to motivate 'behind the meter' adoption of low carbon energy solutions within a context of provision of broader services valued by households and businesses.

Rec. 43: Trial smart micro-grids in suitable areas, integrated with trials of combinations of different energy pricing, education, incentives and other mechanisms to drive transition.

Rec. 44: Prevent incumbents from using market power or political influence to block innovation: delay will increase costs and difficulty of change management.

GREENERY

Recommendations for immediate action★ ★★

Rec. 45: Stimulate the private sector with incentive program.

Rec. 46: Promote planting and permeable paving.

Recommendations for action in the next 2-3 years ★★

Rec. 47: Introduce Green belt to secure compactness of the city.

Rec. 48: Open and share the greening progress with the citizens.

Recommendations for action in the longer term ★

Rec. 49: Involve neighbours in the maintenance of greenery.

WATER AND WASTE MANAGEMENT

Recommendations for immediate action ★★★

Rec. 50: Implement the water resource management system, establish the total water use control and water efficiency control.

Rec. 51: Promote wastewater reuse and recycling.

Recommendations for action in the next 2-3 years ★★

Rec. 52: Publicize water conservation policies and stimulate people by water pricing policy to change their traditional water use habit.

Recommendations for action in the longer term ★

Rec. 53: Promote the construction of 'Sponge City' of Krasnoyarsk.

Rec. 54: Improve water resource use assessment system, and introduce water footprint assessment.

POLLUTION

Recommendations for immediate action ★★★

Rec. 55: Develop the circular economy, realize the transformation from terminal management to source and process control.

Rec. 56: Improve the recycling and utilisation system of waste resources.

Rec. 57: Reform the energy structure and use clean energy.

Recommendations for action in the next 2-3 years ★★

Rec. 58: Deepen the market mechanism in the treatment of pollution end and establish the system of 'who improves the environment and who charges'.

Rec. 59: Establish environmental pollution control system.

Recommendations for action in the longer term ★

Rec. 60: Give full play to the positive role of various groups in environmental pollution control.

Rec. 61: Set up a pilot for carbon emission trading, give full play to the market mechanism in the decisive role of greenhouse gas emissions allocation.

POLICY FRAMEWORK

Recommendations for immediate action ★★★

Rec. 62: Coordinate closely with relevant divisions within the Krasnoyarsk City.

Recommendations for action in the next 2-3 years ★★

Rec. 63: Secure budget for the LCT development.

Recommendations for action in the longer term ★

Rec. 64: Transfer the regulatory authority on buildings and other urban developments from the federal government to Krasnoyarsk regional and city administrations.

EDUCATION AND MANAGEMENT

Recommendations for immediate action ★★★

Rec. 65: Enhance environmental education activities in compulsory education to build a common sense.

Recommendations for action in the next 2-3 years ★★

Rec. 66: Work together with residents through micro district management companies and support their activities by award system, etc.

Recommendations for action in the longer term ★

Rec. 67: Call on the citizens to design a logo/characters with low-carbon image for Krasnoyarsk City.

PART I: BACKGROUND INFORMATION

The City Government of Krasnoyarsk and the results of the Feasibility Study (NIKKEN SEKKEI Research Institute, 2018) contributed to the background information contained in this report. This information provides some context to the Policy Review Team's recommendations.

1. OVERVIEW OF KRASNOYARSK CITY

1.1 BRIEF HISTORY

In 1628, a platoon of Cossacks, sent to explore and protect the frontiers of the Russian empire, picked this location due to fertile lands, Taiga with plenty of wildfowl and fur animals, convenient location from geographical and military considerations. The city was founded by the troop leader Andrey Dubenskiy on 19 August 1628, when the construction of the burg near Krasny Yar was completed. Meaning "red shore", this is what gave the City its name. The settlement became a township in 1690, when Siberia was associated to Russia.

In XVIII century the Moscow Tract established trading routes from Central Russia to Russia's Far East. The city appeared to be on a crossroad of important sea and land routes. In 1822, Krasnoyarsk became the centre of Yenisei Province. A pivotal point was when the Great Siberian railway connected the city to Central Russia in 1895. This turned Krasnoyarsk into the largest transport hub of Siberia. In XIX century, Decembrists, rebels participated in the Decembrist revolt on 26 December in Saint Petersburg, were exiled to Krasnoyarsk. This was followed by establishment of educational and cultural facilities, local newspaper, and eventually made the City the cultural capital of Siberia.

First electricity was supplied in March 1912. The utilisation of hydropower resources of Angara and Yenisei rivers laid the foundation of accelerated industrial development. Ferrous and non-ferrous metallurgy, pulp and paper, medical and chemical industries quickly followed. Demand for skilled labour and technological development helped establish Krasnoyarsk as a large centre of academic science, higher and college education. Since 2012, this is the most eastern Russian city with the population of over one million, i.e. million-strong city.

1.2 GEOGRAPHY

Krasnoyarsk city is the largest industrial and cultural centre of Eastern Siberia, and capital of Krasnoyarsk territory, the second largest region in Russia by area. The direct distance from Krasnoyarsk to Moscow is 3 350 km.

Krasnoyarsk city is situated in the centre of Russia at the confluence of the small river Kacha and mighty river Yenisei. The Yenisei River flows from west to east through the city. Due to the low level of water intakes of Krasnoyarsk hydropower plant 32 km upstream, the Yenisei never freezes in winter and never exceeds +14°C in summer through the city. The elevation of the downtown area is 136 m above sea level.

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 East-Sayan Mountains. The territory of the reserve totals 47 000 hectares. The total area of the city, including suburbs and the river, is 348 km^2. It is divided into 7 administrative districts: Zheleznodorozhnyy, Kirovskiy, Leninskiy, Oktyabrskiy, Sverdlovskiy, Sovetskiy and Tsentralnyy.

1.3 CLIMATE

Krasnoyarsk experiences a moderate continental climate (Koppen climate classification Dfb) with long and cold winters with little snowfall and short, but warm summers. The annual minimum temperature is -26°C and the highest average maximum temperature is 17°C. The summer temperature ranges are from +12°C to +25°C. Record low temperature (-52.8°C) was recorded in 1931, and record high (+36.4°C) in 2002.

December, January and February are the coldest months of a year with average temperatures below -15°C. March and November are similar with average temperature of about -5°C. In April and October have freezing temperatures, but the average is slightly above 0°C. From May to September the average temperature exceeds +10°C, with June-August being the warmest period. Annual sediments are about 500 mm, with only quarter being snow.

1.4 DEMOGRAPHY

The population of Krasnoyarsk city has been increasing, see Table.1.

Table 1: Krasnoyarsk City Population, historical data for 2014-2017, and forecast for 2018 and 2019

Year	2014	2015	2016	2017	2018	2019f
Population	1 035 500	1 052 200	1 066 900	1 082 900	1 090 800	1 094 000

Source: Krasstat, retrieved on 30.05.2018 and APERC calculations

The female population is larger than the male population in Krasnoyarsk, accounting for 55% share. 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%.

Russia's annual household income reached 5 500 USD per capita in 2016. In Krasnoyarsk average annual income is 8 700 USD among employees of middle and large businesses in 2016, higher than the average income in Russia. It is the mining and finance industry that raises the average income.

Car ownership in Krasnoyarsk city was 291 vehicles per 1 000 people, against 245 vehicles in Russia in 2016. Although historically vehicle ownership grew at 3.5% annual average growth rate (AAGR) in 2000 - 16, the rate is forecasted to drop to 1.5% AAGR in 2017 - 21. Russia’s average ownership rate grew at 1.5% AAGR in 2000 - 16.

1.5 LAND USE

Since 2007, regional and City administrations have been merging and consolidating Krasnoyarsk with its satellite cities (Divnogorsk, Sosnovoborsk and Beryozovka) and a nearby settlement (Yemelyanovo) into a large metropolitan area "Greater Krasnoyarsk". Other settlements are expected to follow. When completed the population of "Big Krasnoyarsk" is expected to reach 1.5 million people by 2020. The Ministry of Regional Development and the Ministry of Economic Development included "Greater Krasnoyarsk" in a jointly developed programme of supporting Russian million-strong cities. The new formation will be included in the program for the development of Eastern Siberia.

Krasnoyarsk City ranked 12th most comfortable city in Russia. According to Forbes magazine, the City entered the top twenty most promising cities in Russia as a city "convenient for life and doing business". In 2012, the City ranked 9th in the urban environment quality rating[1].

Currently, Moscow's Giprodor and the St. Petersburg Urban Institute have developed a new master plan for the city and its transport system.

[1] The rating was compiled by the Ministry of Regional Development of the Russian Federation; the Russian Union of Engineers; the Federal Agency for Construction, Housing and Utilities; The Federal Service for Supervision of Consumer Rights Protection and Human Well-Being, and Lomonosov Moscow State University.

1.6 REGIONAL ECONOMY

Krasnoyarsk City is a developed industrial centre of Russia. On the territory of Krasnoyarsk there are over 17 000 enterprises, organizations and institutions. Leading industries are space industry, non-ferrous metallurgy, machine building, woodworking, transport, chemical, food, services, retail and wholesale trade.

In 1939, a resolution to construction a refinery in Krasnoyarsk was adopted. In 1942, the first local steam locomotive was produced. In 1943, platinum and palladium were affixed at the Krasnoyarsk non-ferrous metals plant from Norilsk slimes. In 1945, large-scale production of precious metals began at the plant. In 1954, the Krasnoyarsk TV manufacturing plant was established. In 1959, Krasnoyarsk pharmaceuticals plant started operation. However, as a result of the de-industrialization following the dissolution of the Soviet Union multiple factories have been closed.

The volume of the shipped goods is structured as follows metallurgical products (48%), manufacture of machinery, equipment and vehicles (20%) and production of food and beverages (11%).

LLC MC "Housing systems of Krasnoyarsk" is the largest housing management and communal services and also the founder of the Siberian Generating Company.

1.7 TRANSPORT

Krasnoyarsk is a major transit hub of Eastern Siberia, located at the intersection of the Trans-Siberian Railway and historically established trade routes along the Yenisei River.

Within the city there are six transport bridges across the Yenisei River, some are combined road and rail, some are purely for Trans-Siberian railway. One pedestrian cable-supported bridge leads to Tatyshev island. Thirty-one bridge, both automobile and pedestrian, are across the Kacha River within the City.

The Trans-Siberian Railway passes through the city, the key directions are Abakan-Taishet, Achinsk-Abakan, Krasnoyarsk-Boguchany, Achinsk-Lesosibirsk. It carries 3.2 million passengers in regional (long-distance) and 13.3 million in suburban traffic.

Highway "Siberia" P255 (M53) Novosibirsk - Krasnoyarsk – Irkutsk passes through Krasnoyarsk, and it is a part of the Moscow – Vladivostok route. Other key tracts include: ‘Yenisei’ M54 leading to Mongolia and ‘Yenisei Trakt’ P409 to the city of Yeniseisk.

In 2005, Yenisei River Shipping Company carried 3.3 million tons of cargo and about 140 thousand to Igarka, Dudinka, Divnogorsk. The Krasnoyarsk river station, built in 1948-52, is one of the most beautiful in Russia.

There are two airports in Krasnoyarsk: the largest airport in Eastern Siberia, ‘Emelyanovo’, providing freight and passenger services for domestic and international flights, and local airport ‘Cheremshanka’. The latter also serves as an airbase for state-owned planes. It is expected that the freight infrastructure of ‘Emelyanovo’ and ‘Sheremetyevo’ airports will be managed by ‘Interport’ company. In the future, it is possible to build a railway from Bugach station to the airport to organize easy passenger access.

Urban passenger transport modes includes bus, tram and trolleybus. The main type of public transport is a bus: on inventory there are nearly 1 200 buses on 76 bus routes, both municipal and commercial carriers. Municipal transport share is 30%. There are six trolleybus and four tramway routes. Tram ways are only located on the right-bank of the city, and the trolley lines are on the left-bank. Traffic is monitored by the GLONASS satellite system. On average business day one million passengers in transported. Development of high-speed tram and subway was initiated at some point. Currently, the city electric train carries passengers on a limited route.

There is a systematic renovation of municipal and commercial rolling stock of urban transport (trolley buses and large-capacity buses mainly imported), while small capacity buses are gradually being taken out of service. In the coming years, it is planned to increase the municipal rolling stock with emphasis on electric transport. Some buses are equipped with free internet service.

The payment for travel in public transport (bus, trolley and tram) could be made using an electronic card. Annually, over 10 million passengers pay by electronic card. Preferential categories of passengers have a so-called 'social' electronic card, which could be used in commercial transport.

The necessity of the metro in the dynamically developing Krasnoyarsk was realized back in the 60s of the XX century. In the city's general plan, the metro lines for the future were introduced already in the early 70's. In 1983, one of two exceptional decisions was made on the construction of a subway in the city of Krasnoyarsk, which had not yet become a million-strong city (another such exceptional case was Riga, the capital of Latvia).

The first line design included five stations with the average distance between the stations of 1.85 km, and a total length of 8.5 km. With the planned capacity of 55 million passengers per year, or 169 thousand passengers per day. The construction began in 1995, and was stopped in 2010 before completing the project. In 2017, regional authorities stated that completion of Krasnoyarsk subway remains a priority and is included in the master plan.

1.8 HEAT AND POWER SUPPLY

Krasnoyarsk city has a heat supply system to heat the houses and buildings in winter and provide hot water service. Heat and electricity are generated by large-scale CHP facilities and small-scale boiler houses. The heating period lasts for 233 days in a year. At that period the utilisation rate is around 70% of installed capacity. System's losses reach up to 30%. In addition, lignite is the main fuel for heating, and a major cause of carbon emissions.

Krasnoyarsk has the tenth largest hydropower plant in the world. The Krasnoyarsk Hydroelectric power plant is a 124 meter high and 1,065meter long, including concrete gravity dam, located in Divnogorsk, which is 30 km upstream on the Yenisei River from Krasnoyarsk. It was constructed 1956-1972 and supplies 6,000 MW of power, mostly used to supply Krasnoyarsk Aluminium Smelter (KrAZ). Some of produced aluminium is traded as carbon-free good, due to electricity being generated by renewable source.

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 200 km to 300 km 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.

1.9 WATER MANAGEMENT

The main sources of water supply are surface and underflow sources. The water quality of the central water supply system has improved according to the sanitary-chemical indicators of safety. Nearly 147 million m^3 of water was supplied in 2014. The quality of tap water in Krasnoyarsk is controlled by the Center of Monitoring Water Quality, accredited by the State Standard Department of Russia. 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 1 209 km. 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. Tap water is controlled by a number of indicators: colour, turbidity, content of salts and chemical elements and the presence of bacteria. Once a month each water intake is tested for the presence of sulphite-reducing clostridia spores in drinking water.

There are two self-contained sewage systems with 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 million m^3. The determined capacity of the treatment facilities is 700 thousand m^3 per day, or 255 million m^3 per year.

The quality of wastewater is determined in accordance with the standards of permissible concentrations in the river Yenisei from Krasnoyarsk hydroelectric complex, as well as a resolution for the discharge of substances into water bodies. There is also regulation on the temperature of reservoir water in comparison with natural water. Treated wastewater is discharged from the facilities into the Shumkovskaya channel. Currently, the provision of the city with rainwater drainage is about 20% of the regulatory requirements.

The length of the city rainwater sewerage network is 184 km, including 123 km on the Left Bank and 61 km on the Right Bank. The structure of the city rainwater drainage includes 3 132 manholes, intended for servicing and 3 441 rain surface inlets. In addition, the city has 800 linear meters of drainage pipes, 5 000 m of outdoor stalls, drainage systems, as well as 4 water overflow nodes located on the right bank of the city.

There are also 52 septic tanks with the total volume of 6 176 m^3 in 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.

1.10 WASTE MANAGEMENT

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 LLC "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 JSC "Avtospetsbaza".

2. LOW-CARBON POLICIES AND FRAMEWORK

FEDERAL GOVERNMENT LEVEL

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, and
    - 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, and
- 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.

KRASNOYARSK CITY

Krasnoyarsk is a million-strong city, which has grown as a representative industrial city in the Siberian Federal District. It has grown through light industry and lignite mining, heavily oriented towards the aluminium industry. It has Russia's 1st and 2nd largest hydroelectric power plants nearby, and most of the electricity used by the aluminium smelting factory is covered by these hydro power generation.

The city is geographically located in a cold climate zone and 2/3 of its annual heating is supplied by CHP plants. Due to the aging CHP (including boiler houses) and 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 low.

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

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. Russia's leading low-carbon model town Krasnoyarsk ~ Sustainable development of cold and industrial cities and compatibility of low carbon ~

- 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 Quality of Life (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 CO_2 reduction and to appeal to stakeholders. Main Target of CO_2 emission from building should consist of targets for new construction and for renovation of existing building. The “management” of CO_2 reduction targets is essential to ensure that the mid and long term targets can be achieved through continuous efforts. To “manage” the overall CO_2 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 CO_2 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.

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

3. KRASNOYARSK CITY FEASIBILITY STUDY

Scope of the study

The focus of the Feasibility Study is the whole city of Krasnoyarsk, as the concept of LCMT study for Krasnoyarsk City is "**Inland region with high demand for heating and cooling**" due to cold climate. The district heating system covers most of the city and operates for 233 days per year. The primary objective of the Feasibility Study was 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. It was performed following the three key objectives:

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.

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.

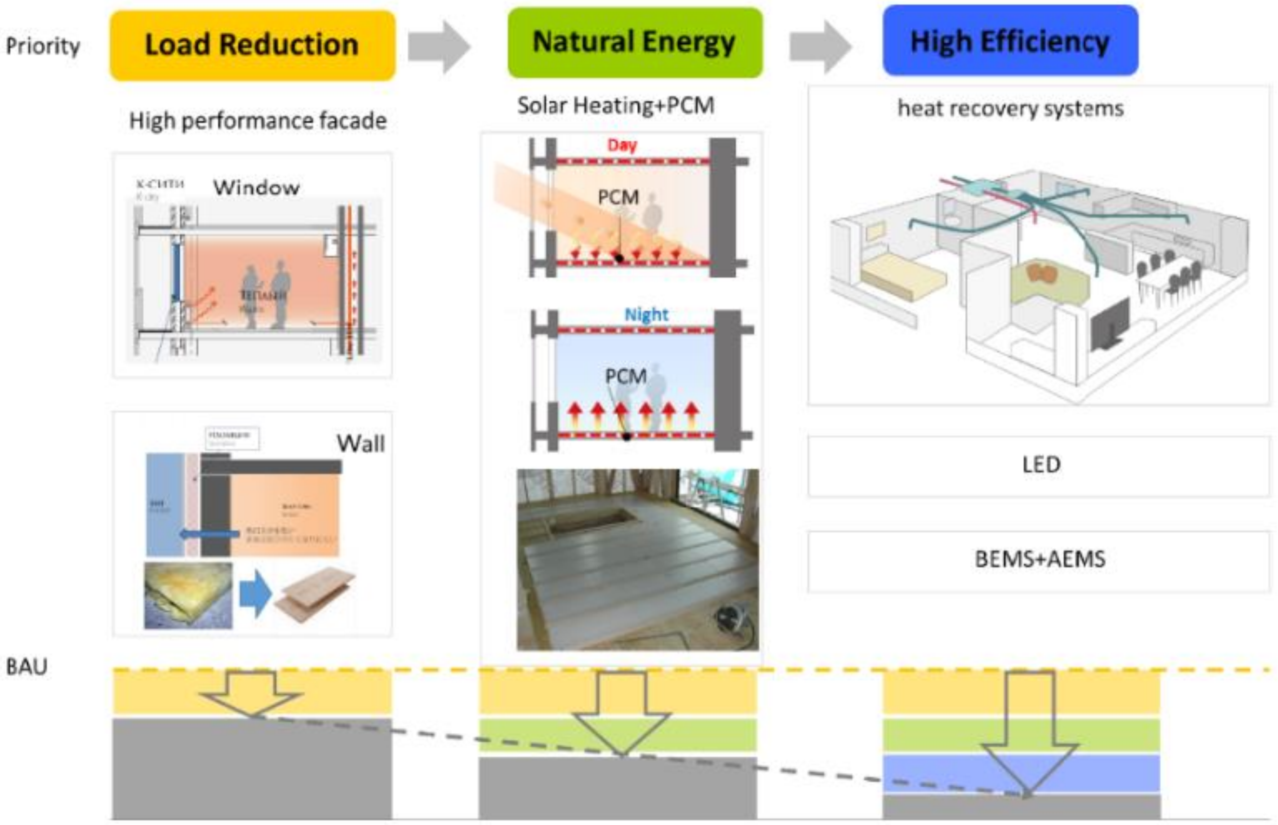
Carbon emission reduction targets for Krasnoyarsk will be defined using Main Target and Sub Target indicators to encourage planned CO_2 reduction and to appeal to stakeholders. Main Target of CO_2 emission from building should consist of targets for new construction and for renovation of existing building. The "management" of CO_2 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 CO_2 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.

Detail of carbon emission targets

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 1.

Figure 1: Priority for Low Carbon Strategy



Source: NIKKEN SEKKEI Research Institute

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 analyse the effect of low-carbon strategies.

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.

Transport

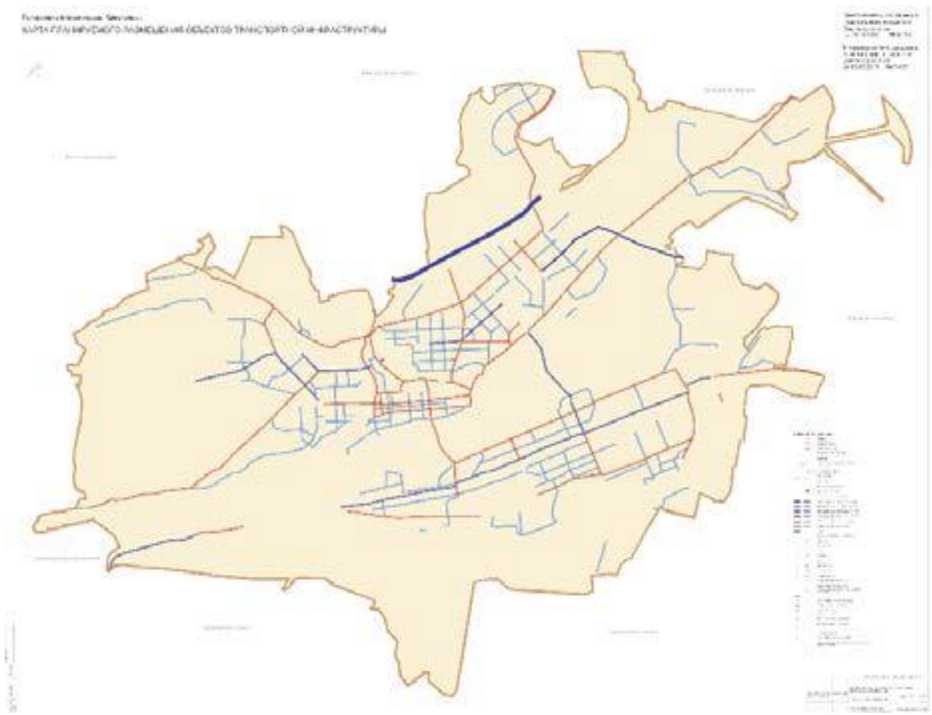
Krasnoyarsk city was formed around the Yenisei River that crossed the centre. And there are only three roads connecting the north-south urban areas bisected by the river. There are arterial roads mainly in the zones Tsentralniy and Zheleznodorozhny (the north side of the river).

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. 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.

Figure 2: Krasnoyarsk City scheme



Source: NIKKEN SEKKEI Research Institute

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, focusing 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% CO_2 reduction in the medium term and about 45% in the long term.

Multi – Energy System

The power generation in the Krasnoyarsk city comes from three CHP plants. 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 aluminium 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.

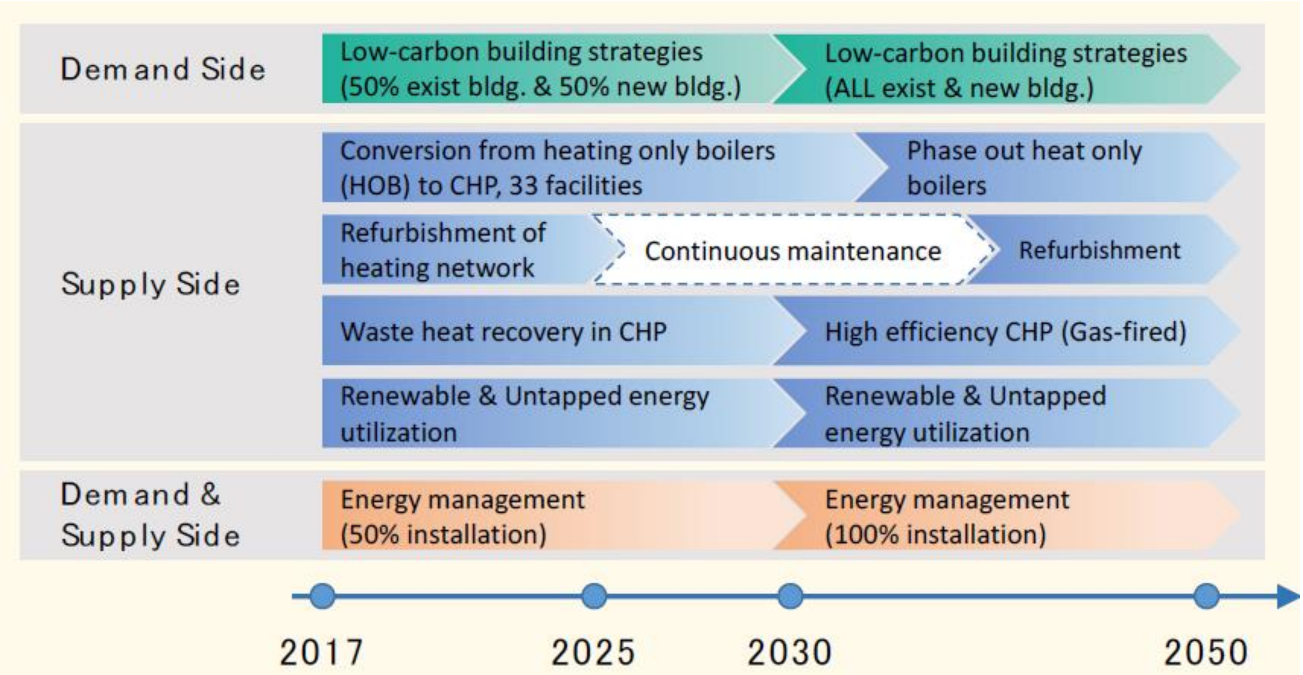
Lignite (brown coal), which is considered the lowest rank of coal due to its relatively low heat content, however, is used as the main heating fuel for heating. Meanwhile, most of the district heating system which has been constructed a long time ago, now is becoming aged and inefficient.

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 lacklustre 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).

Fig. 3 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.

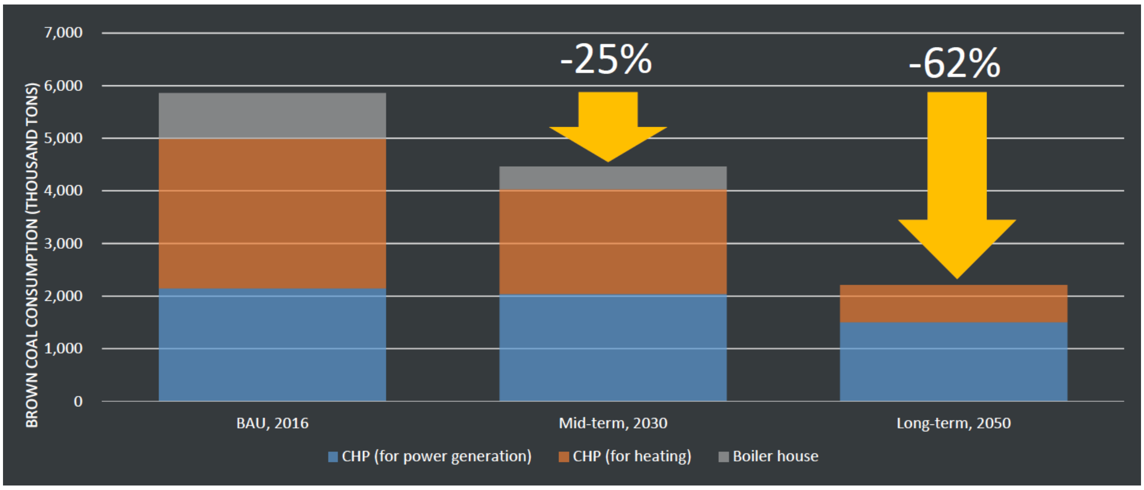
Figure 3: Low-carbon development roadmap of energy sector



Source: NIKKEN SEKKEI Research Institute

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 Fig. 3, 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.

Figure 4: Krasnoyarsk City brown coal consumption , 2016-2050 (thousand tons)



Source: NIKKEN SEKKEI RESEARCH INSTITUTE

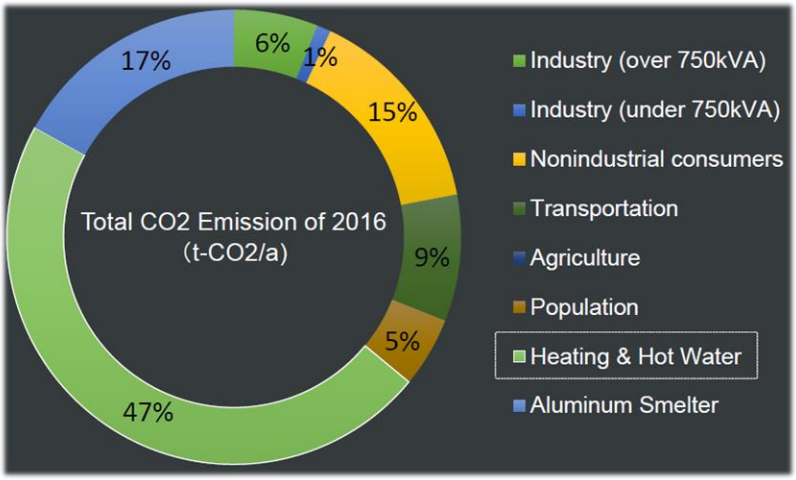
In Fig. 4, a long-term perspective of brown coal consumption is provided while consumption in 2016 is set as BAU (Business as Usual). In mid-term target at 2030, it is expected that the consumers of inefficient heat only boiler houses will partially switch to the high efficiency heat supply provided 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 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.

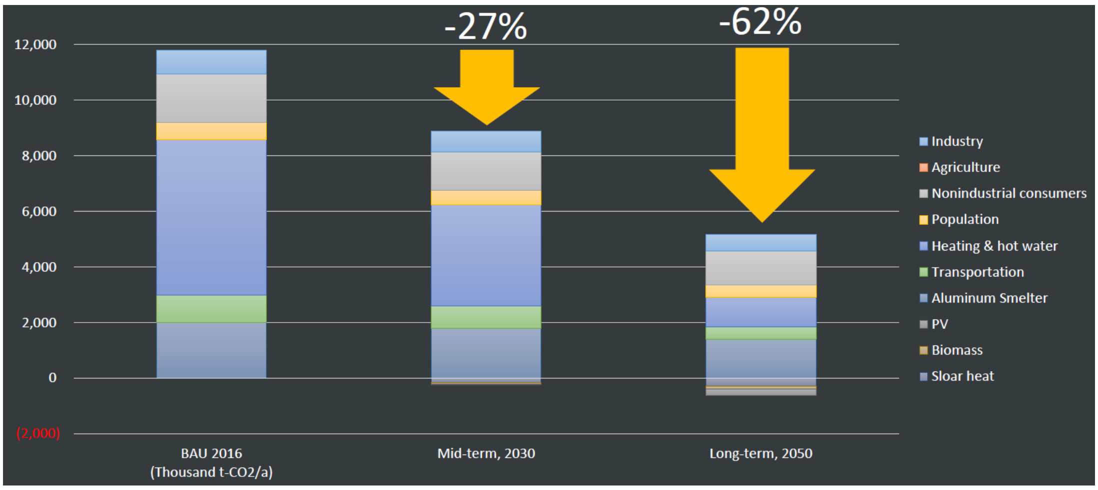
Figure 5: Energy related GHG Emission of Krasnoyarsk City in 2016



Source: NIKKEN SEKKEI RESEARCH INSTITUTE

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%.

Figure 6: Krasnoyarsk City GHG Emssion Projections and Targets (thousand tons CO_2)



Source: NIKKEN SEKKEI RESEARCH INSTITUTE

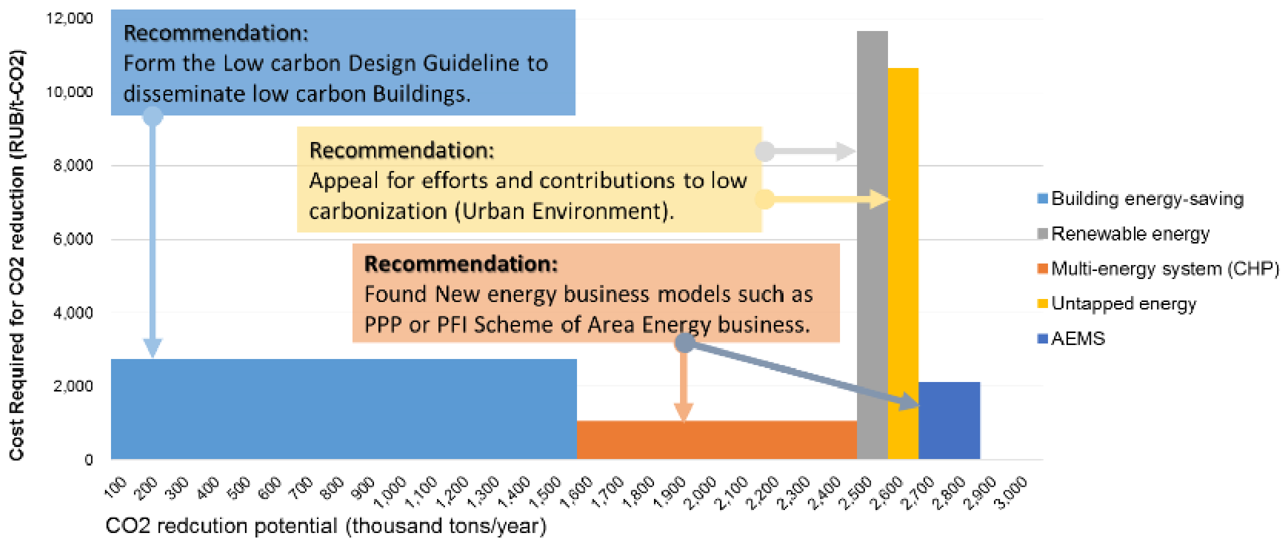
Examination of cost performance

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.

Figure 7: Cost of CO_2 emission reduction per ton and reduction potential in each sector (by 2030)



Source: NIKKEN SEKKEI RESEARCH INSTITUTE

PART II: POLICY REVIEW TEAM REPORT

This part of the report presents the Policy Review Team's conclusions and recommendations for low-carbon town development in Krasnoyarsk City, Russia.

The Policy Review Team evaluated the recommendations using an assessment framework of the APEC Low-Carbon Town Indicator (LCT-I) System.

1. TOWN STRUCTURE

FINDINGS

- Low-dense land use in the central areas

  Central area of the city is mostly covered with medium to low-rise buildings of 10-stories or less.

- Separated location of residential and business districts

  Residential areas and office areas are separated in the city, which consequently generates congestion in the commuting time.

- Private vehicle oriented land use (parking spaces)

  As the citizens are highly dependent on their private cars, the city needs to provide sufficient parking spaces in the central commercial and business areas. This leads to the situation that prevents the city to achieve efficient high dense land use in the central area.

- Disconnection between private vehicle and public transport hubs

  Existing public transport stations are not conveniently adjacent to the parking lot for people to feel easy to transit when they think necessary.

- Absence of sustainability assessment/evaluation system

  The sustainability assessment system such as LEED from the US that motivate industries to build low carbon urban structure has not been introduced in the city.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 1. Introduce a network between multi-core strategic development zones. ★★★
Define intensive development zones in the proximity of transport hubs and connect them by public transport to motivate people to use public transport more frequently.

Rec. 2. Improve liveability and walkability around the hubs. ★★★
Locate public facilities and life-convenience facilities around public transport hubs and introduce park-and-ride in the periphery area of the CBD to control private vehicle entry to the central area.

Rec. 3. Allow mixed land use. ★★
Introduce diverse or mixed land use within the central districts to level energy usage. This also minimize unnecessary travel distance by private vehicles for the city to be more low-carbon.

Rec. 4. Stimulate densification. ★★
Allow higher floor area ratio on condition of introducing public amenities on the ground level (open spaces, parks, public amenities, air space rights, etc.), providing sufficient amount of pleasant amenity spaces on the ground level and simultaneously achieving efficient high dense land use in the central area.

Rec. 5. Introduce IT system to enable the data-driven management. ★
Introduce a 'cockpit' or 'dashboard' that provides cross-sectional monitoring, audits, and directs the overall progress of low carbon development. This function would be taken by setting a new department right underneath the city mayor in order to oversee and mitigate relevant departments in the city government. Introducing IT operation system that utilizes various city data also help the city to reduce the cost of human labour to manage the low carbonization process.

2. BUILDINGS

FINDINGS

- Building sector is most important in terms of energy consumption and carbon emissions, while heating represents the most important component (59%).

- Two-thirds of each year require heating and most heating energy is provided by low-efficient brown coal-fired CHP (nearly 65%), inefficient boiler houses, and very inefficient household coal stoves (16,000 units).

- Russia has the highest energy consumption intensity for heating, compared to other economies.

- New buildings have much better energy efficiency than existing buildings.

- Almost 40% of the heat dissipates with ventilation and huge amounts of hot water are dumped and wasted.

- The heating bill for most existing residential buildings and households is calculated based on the area of a building or a household, but not the amount of energy consumed.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 6. Improve energy efficiency by retrofitting insulation of existing buildings. ★★★

Rec. 7. Work closely with federal/regional agencies to develop a mechanism to enhance compliance with building energy efficiency codes. ★★★

Rec. 8. Promote efficient water heaters and appliances (e.g. LEDs) through government regulations and energy labelling programs. ★★★

Rec. 9. Build capacity for city officials, builders, and assessors for monitoring compliance with energy efficiency code for new buildings. ★★

Rec. 10. Promote technologies and management systems for reuse of hot water and heat recovery in ventilation. ★★

Rec. 11. Install and reform the metering system for heating of existing buildings to change people's behavior. ★★

Rec. 12. Consider the entire life process in terms of energy consumption and carbon emissions for urban planning and building construction. ★

The life process includes the production of the building materials, construction and utilisation of buildings.

Rec. 13. Initiate government programs for collaboration with NGOs and universities to educate the public of approaches to save energy. ★

3. TRANSPORTATION

FINDINGS

- Private vehicle and public transport are major transport modes.

- Private vehicle ownership rate in Krasnoyarsk city was 291 vehicle per 1,000 people in 2016, higher than Russia's and world averages.

- Road traffic congestion is a problem during morning (7:00 to 9:00) and evening (18:00 to 19:00) rush hour, in particular in CBD area.

- Street parking affects traffic flow for both private cars and public transport.

- Even though the car ownership is high, 40% of the public are willing to shift to public transport.

- Lack of transportation infrastructure and the connection between private and public transport, e.g. connecting south and north areas of the River Yenisei.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 14. Increase the effectiveness of existing road infrastructure. ★★★

The city should coordinate working hours with major companies and government agencies to reduce traffic jams. Establishing the intelligent transport system (ITS) and smart transport (smart corridor, Wi-Fi devices for traffic information, traffic control centre) will help effectively use roads and reduce traffic congestion. Introduction of traffic lanes for ridesharing during peak traffic periods is also necessary.

Rec. 15. Restructure and strengthen the public transport network. ★★★

Extension of bus lines along the river Yenisei and construction of trams between north-south areas is an option. In the long-run, BRT may provide a good alternative public transit mode in high density areas due to its high capacity and reliability, and relatively lower cost compared to subways. It is recommended to develop more transport nodes (a network of underground pedestrian passages, bus terminal, subway stations) to encourage the use of public transit and non-motorized modes (e.g. bicycles).

Rec. 16. Control the use of motor vehicles. ★★

The City could start from imposing a ban on the use of private vehicles in historical areas, control the street parking by introducing varying parking fees dependant on the land use (e.g. higher in business district), and charge for the congestion on certain roads or parts of roads with heavy traffic.

Rec. 17. Reduce vehicle emissions. ★

It is important to introduce fuel efficiency standards for vehicles at the economy/regional level and increase the quality of gasoline and diesel to meet Euro emission standards. It is also effective to impose a ban for non-environmentally friendly vehicles (e.g., vehicles not meeting Euro IV emission standards) in the city centre. Continuous efforts to promote electrified urban transport, such as electric bus, tram, and trolleybus are expected.

Rec. 18. Coordinate with urban planning for mixed use of land to reduce transport demand. ★

Rec. 19. Conduct analysis for selection and implementation of transport solutions. ★

Rec. 20. Educate drivers (on vehicle maintenance, loading, etc.) and provide driver behavioural change (awareness campaign) program. ★

4. AREA ENERGY SYSTEMS & MULTI-ENERGY SYSTEMS

FINDINGS

- Present Krasnoyarsk District heating has high losses, old and inefficient equipment.

- Revolution in demand-side, distributed and smart energy and efficiency technologies is improving performance and reducing costs. This is challenging past links between energy use, economic output and quality of life.

- Microgrids (for both electricity and thermal energy) are emerging: they offer resilience, flexibility, and suit distributed energy, 'smart' solutions and diverse management models.

- Using a range of alternative energy sources and technologies, it may be possible to develop a district heating and cooling system suitable for future climate and buildings. This may be complemented or even partially replaced by greater use of distributed energy options.

- Energy prices are low – likely due to subsidies. This means consumers have little incentive to improve efficiency or to invest in emerging energy technologies. For example, Russian households seem to pay about a fifth as much for electricity as do Australians. However, there is a strong incentive for government action, as the cost of subsidies seems very high, so reducing them should be a significant financial benefit to government.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 21. Adopt recommendations in the Feasibility Study report. ★★★

The recommendations on the Feasibility Study report are summarised in the table below.

Table 2: Krasnoyarsk City Feasibility Study recommendations summary

	2017 - 2030	2030 - 2050
Demand side	• Low-carbon buildings (50% exist. & 50% new)	• Low-carbon buildings (100% exist. & new)
Supply side	• Conversion of 33 heat only to CHP facilities • Refurbishment of heat distribution network • Waste heat recovery in CHP • Renewable and untapped energy utilisation	• Phasing out heat only facilities • Continuous maintenance and refurbishment • High efficiency gas-fired CHP • Same as for 2017-2050
Demand & supply side	• Energy management (50% installation)	• Energy management (100% installation)

Source: NIKKEN SEKKEI RESEARCH INSTITUTE

Rec. 22. 'Close the loop': divert district heating hot water from being dumped into the Yenisei River to recirculating through DH system (or using heat recovery to preheat incoming river water). ★★★

Energy losses from dumping of large quantities of hot water from the district heating system into the river are substantial, and should be eliminated.

Rec. 23. Implement research project to improve understanding of energy (electricity and heat) use and efficiency for each activity and level of energy services (comfort, light, food preservation, entertainment, cooking etc.) provided, especially in non-industrial businesses and residential sector. ★★★

More emphasis on analysis of energy use by activity, and by non-industrial (commercial/services) energy consumers and related scope for emission reduction would be useful. End-use services and the technologies to provide them are the fundamental drivers of energy requirements. This recommendation is also relevant to the Buildings area.

Greater emphasis on options to cut energy losses associated with air leakage and ventilation from buildings would be useful, as this seems to be a very large contributor to energy requirements. This comment is also relevant to the Buildings area.

Rec. 24. Optimise end-use efficiency of district heating and minimise distribution losses; trial targeted energy efficiency upgrades to allow closure of an old boiler house. ★★

According to the Ministry of Energy, replacement of old boiler houses with combined heat and power, and district heating distribution losses reduction could save a large proportion of fuel input. It is important to introduce heat metering for existing and new buildings to ensure that customers' bills reflect the actual heat energy demand.

Rec. 25. Develop strategy to ensure that all investments in end-use equipment, district energy systems and selection of energy sources are compatible with a long-term zero emission future. ★★

Rec. 26. Conduct detailed feasibility study for district heating options: high efficiency, flexible CHP able to use waste heat and multiple fuels/heat sources, e.g. gas-from-coal, biogas, natural gas, hydrogen, petroleum, renewable liquid fuels; electric heat pumps using heat from river water, industrial sources. ★★

The feasibility study report rates solar energy as a relatively low potential option. The use of vertical or near-vertical Building Integrated PV or larger-scale PV may offer useful winter output, with daylight reflected by winter snow adding to output, while problems of snow build-up can be avoided.

Energy from the Yenisei River could potentially be a very large source of heat for heat pumps. However, the feasibility study report does not state what the winter temperature of the river is, other than that it is above freezing point and below 14°C. Cascaded or multi-stage heat pumps are likely to be required if high efficiency is to be achieved for the relatively large temperature differential.

Rec. 27. Introduce metering and unit pricing of heat/energy from district heating system for new buildings and, over time, existing buildings. Initial focus on business and industrial buildings. Develop alternatives to pricing to influence household behaviour, e.g. incentives, education. ★

Energy pricing provides a signal to business for investment in higher efficiency solutions. In extreme climates, high energy prices for households can create inequity and fuel poverty.

Rec. 28. Investigate implications of changing climate and higher efficiency buildings for future role and technologies of district heating and, potentially, cooling system: more variable loads, need for summer cooling. ★

The global warming trend is now well established, with both extreme hot and extreme cold periods being warmer. This will undermine the viability of traditional District Heating systems. Demand will fall, especially in increasingly long periods of moderate weather, and when cooling is required. As demand falls, fixed energy losses and non-energy operating costs become a larger proportion of total District Heating costs.

Rec. 29. Trial microgrids in selected areas, e.g. fringe of grid, old infrastructure and integrate with Area Energy and Service Management System. ★

An evaluation is needed of impact of major building upgrades on heating and cooling energy requirements, as part of a broader system analysis. Funding of trials could be justified by estimation of reductions in government subsidies for energy and energy infrastructure, as well as consumer savings, reduced costs of carbon emissions and air pollution, and improved quality and reliability of services.

Further findings and recommendations are provided in Appendix C.

5. UNTAPPED ENERGY

FINDINGS

- Waste heat recovery from the process in CHP can increase the efficiency of the boiler and contribute to the energy saving of the factories. .

- Waste heat recovery in waste incineration plants and industries has a potential to increase the energy efficiency for burning the waste in the factories.

- Reuse hot water in the hospitals and hotels in order to rewarm the water. The picture below left shows the waste water from the hot shower being collected to warm the cold water. In-house heat recovery of domestic waste water can also increase the energy efficiency of the buildings.

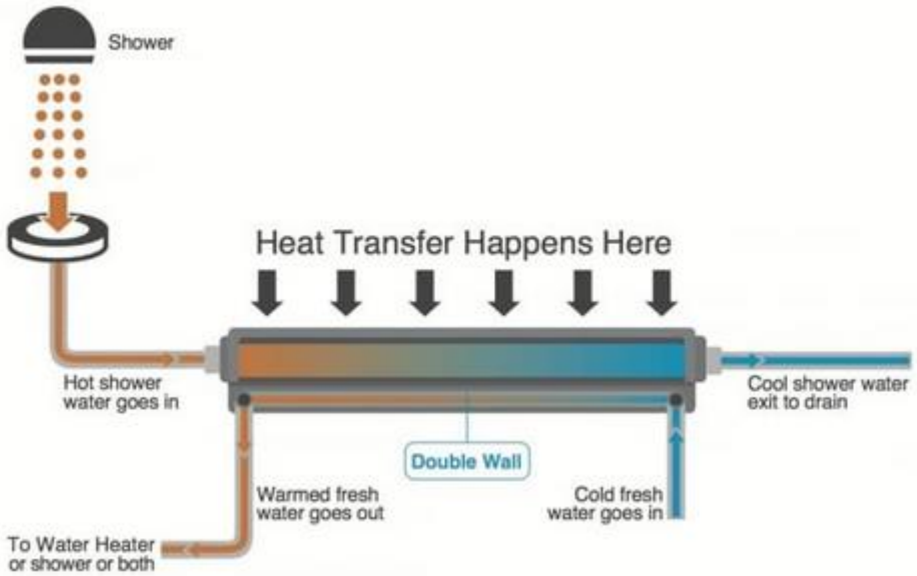
RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 30. Promote the use of waste heat in the industries. ★★★

The city can disseminate the energy saving method, such as waste heat recovery system, and this is an important message from the authorities to let the customers know how much money is lost. Provide technical support (information, knowledge and experts) to ease the shift towards waste heat recovery systems.

Figure 8: An example of shower water heat exchange system



Source: (Angieslist, 2017)

Rec. 31. Provide subsidies from the government. ★★★

Energy saving from waste heat utilisation would lower the fuel cost and thus operating expenses. For instance, to quantify this effect large consumers could reports the energy demand reduction to the government. Government could also partially subsidise the initial capital costs of heat/cooling recovery systems. This would support the adoption of such systems at early stages.

6. RENEWABLE ENERGY

FINDINGS

- The Russian government announced a new plan called 'Russian Energy Strategy 2035'. It includes the development of renewable energy.

- Biomass can be introduced in CHP to generate electricity and heating. Biomass can replace the use of the coal through the co-firing technology.

- The use of biogas in waste incineration plant is possible. Waste water and sewage can also be a source of biogas.

- MSW (municipal solid waste) energy requires waste separation and waste recycling guideline.

- Based on existing data, the potential of solar and wind power is low. It is better to reconsider their installation when new technology and data are available in the future.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 32. Set the target to increase the use of renewable energy. ★★★

The city should set the target to inform the private sector and power plants to inform the promotion of renewable energy based on the Russian Energy Strategy 2035. It is better to identify such targets specifically, i.e. by fuel, technology, sector etc. This will serve as a good sign for renewable energy investors.

Rec. 33. Support renewable energy data collection. ★★

Data collection is essential as it will form a basis for energy projections and policy efficiency analysis. This should be the first step in the process. In order to collect necessary data, one stop service centre can be established to monitor the progress of data collection in renewable energy development and prepare energy resource maps such as for biomass.

Rec. 34. Consider policy measures to provide incentives. ★★

A number of incentive schemes that encourage investments should be considered: exemption of import duties on equipment and machinery, and exemption of income-corporate taxes for the profit from selling renewable energy, energy savings and conservation.

Rec. 35. Prepare support scheme for the renewable energy businesses. ★★

The government can provide a support scheme to lower the risk of the renewable energy businesses such as equity investment, equipment leasing and credit guarantee facility.

Rec. 36. Adopt the feed-in tariff. ★

Premium could be paid for power or heat generated from renewable sources.

7. BUILDING AND AREA ENERGY MANAGEMENT

FINDINGS

- Improving and cheaper communications, monitoring, data analysis techniques (e.g. 'machine learning' and data analytics) are supporting smart management, system optimisation, distributed energy solutions.

- It is increasingly important to manage peak electricity and heat demand, cope with more diverse and distributed energy sources, manage storage and variable demand, and improve system reliability

- There is an increasing potential to manage a range of highly valued non-energy services for optimal city management through energy management systems, such as personal security, traffic management, infrastructure management, reducing risk of infrastructure failure, etc.

- Increasing diversity of smart management solutions and service providers means 'top-down' management and centralised control of energy systems may not work in future.

- Changes in 'behind the meter' technologies (energy efficiency, demand management, energy storage and on-site energy production) in residential, commercial and industry sectors that deliver services better have disruptive impacts on the energy system by reducing demand, changing demand profiles and encouraging the development of new business and service delivery models.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 37. Adopt recommendations in the feasibility study report. ★★★

The feasibility study outlines three key pillars:

i. establish community-based area energy management system (AEMS), these would be first adopted in demonstration areas, where energy consumption is higher or is a priority within the low carbon development master plan,

ii. further develop community-based AEMS into bi-directional smart grid with demand-supply management; connected to building energy management systems (BEMS) these would be used to collect and gather building energy consumption data, study the energy conservation strategies introduced in the buildings and estimate their effect, and analyse and gather information from the supply side and realize an optimal status in the city level, and

iii. comprehensive town management system will ensure that local people, including residents, business operators, and landowners (land ownership holders) of an area take initiatives to improve their regional environment and community values.

Rec. 38. Establish capabilities in government, academia and businesses to track and model the evolution of energy (and service) management technologies, services, business models, market designs and system management strategies, as well as their potential impacts on existing energy infrastructure and institutions, and societal costs and benefits of change. ★★★

The culture and institutional capacity necessary to drive strong action on energy efficiency, demand management, energy storage, renewable energy and smart energy systems on the consumer side of the meter are very different from traditional 'top down' energy (and most other areas such as urban planning) policy and strategy. Yet success and increased supply chain capability here are essential if the benefits of AEMS are to be captured.

An essential first stage is to establish a project team that can research options for practical application of BEMS and AEMS in Krasnoyarsk.

Rec. 39. Learn from experience: identify and evaluate existing projects, trials, lessons from other places (avoid their mistakes!). ★★★

The following are some potential examples. Growing numbers of air conditioners could shift the balance towards higher summer usage, and especially higher summer peaks: planning should aim to avoid problems due to such a shift. High heating electricity use, despite the availability of district heating may increase electricity demand, although advanced heat pumps utilising waste heat or river water may play key roles in progress towards a zero carbon economy. Improved on-site energy efficiency, connection to district energy systems or other strategies may have a large impact on their energy use.

Climate change and the policies needed to respond to it will also drive accelerating change. As the multiple impacts of climate change become more visible to the community, pressures for change will increase. Jobs in some areas like coal mining will be lost, but they will be replaced by jobs in mining for materials needed for zero carbon solutions and new businesses that will create many more jobs with a much broader range of skill requirements and locations, and which have much reduced impacts on worker and community health.

Rec. 40. Build supply chains and expertise in delivery of diversified energy solutions, including 'behind the meter' technologies, services and business models. ★★

The development of skilled, trusted supply chains and knowledge among energy users is important to underpin transition. This requires substantial resources, including educational and training programs, and is likely to involve a broader range of businesses than those traditionally involved in energy. Further discussion of how these sectors and related policy agencies and business associations could be engaged should be encouraged.

Rec. 41. Develop financial models so that interventions in energy consumer markets to drive low carbon solutions through pricing, incentives and other initiatives can be justified – also see Area Energy recommendations. ★★

Energy Management Systems help to optimise energy systems but, where energy pricing does not reflect real time supply costs and energy prices are subsidised, their capacity to attract consumer interest may be limited unless other non-energy benefits such as health and productivity improvement are recognised and valued. Russian energy prices typically do not seem to reflect costs, and pricing structures may not support actions that reduce the need for investment in energy supply infrastructure. So there may be a need for development and application of methodologies that identify the savings for governments through reductions in subsidies and provide price signals, incentives or policies to support emerging energy solutions. There may also be a case for redesign of business and industrial energy pricing to better reflect real costs and provide positive incentives for change: energy pricing and policy changes for businesses do not have to consider equity, health and other issues that could impact on some vulnerable households if changes were made to pricing of household energy.

Rec. 42. Build capacity in government, academia and business to develop techniques and business models to motivate 'behind the meter' adoption of low carbon energy solutions within a context of provision of broader services valued by households and businesses. ★★

The new model (see Fig. D.1) will require coordination, high quality information and new options for financing. It will be driven by many players, each responding to their own agendas, pursuing opportunities and seeking benefits. Emphasis will shift from large scale supply of energy, although that will still be important, to much greater focus on delivery of 'useful services' to household, business and industrial consumers through more complex supply chains more like the present appliance industry and service businesses than traditional energy utilities.

Rec. 43. Trial smart micro-grids in suitable areas, integrated with trials of combinations of different energy pricing, education, incentives and other mechanisms to drive transition. ★★

Adoption of Energy Management Systems may be faster if they are packaged with other useful services such as personal security, traffic management, etc. Practical trials and demonstrations support 'learning by doing' and provide visible examples to build support for change.

Rec. 44. Prevent incumbents from using market power or political influence to block innovation: delay will increase costs and difficulty of change management. ★★

Energy policy analysts who fail to look beyond the energy supply aspects of service provision will continue to be surprised by dramatic changes in energy use, changes in consumer expectations, and emerging businesses that disrupt the energy industry. Krasnoyarsk policy makers, academics and businesses need to understand the changes, develop response strategies, and show leadership. This will not be easy. Many just want things to 'stay the same': but trying to maintain business as usual is now the more risky path, even though disruptive change is also risky. Many large energy utilities and fossil fuel businesses in Europe, America and the Asia-Pacific have discovered that failure to move with the tide of change might lead to loss of asset value, declining profits and management changes.

The disruptive changes in energy will involve major cultural and institutional changes, as transition drives a shift from centralised, 'top-down' control driven by a small number of large and powerful organisations with access to capital and political influence.

Further findings and recommendations are provided in Appendix D.

8. GREENERY

FINDINGS

- Insufficient greening in the central district (19% coverage)

  Although the city has approximately 19% of green coverage as a whole, which is relatively high compared to other large cities that has about a million population in the world, the central area doesn't still have sufficient amount of trees.

- The city is promoting a planting program to be greener

  The city promotes 'one million trees in one million cities' project (20,000 trees/year)

- The city is mostly covered by impermeable concrete surfaces

  Concrete pavement is widely applied in the Krasnoyarsk city which is not pedestrian friendly in terms of falling accidents due to slippery ground condition. Impermeable surface also increases the load to drainage channels to treat the surface rainwater.

- Air pollution caused by car exhausts

  As most citizens are dependent on their private vehicles for their daily trips, air quality of the city does not sustain comfort or a healthy level.

- Low level of environmental awareness

  Citizens are not highly conscious of the city's environmental conditions nor motivated to take low carbon actions due to the lack of alternative lifestyle options that are more convenient or comfortable than present situation.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 45. Stimulate the private sector with incentive program. ★★★
Introduce award giving program with economic benefit to stimulate the private sector driven greening projects and integrate greening with deregulation programs (e.g. extra floor area).

Rec. 46. Promote planting and permeable paving. ★★★
Improve hydraulic quality of streets and ease the drainage load to the infrastructure by testing the freeze suppression pavement technology.

Rec. 47. Introduce Green belt to secure compactness of the city. ★★
Prevent unnecessary urban sprawl that make the city inefficient. Green belt can be utilised as the distance between the citizens' amenity and agricultural field will be shortened so that it can minimise the food mileage.

Rec. 48. Open and share the greening progress with the citizens. ★★
Collect real-time monitoring data of low-carbonisation progress and open/share it with the citizens to make them aware the changes and motivate them to take continuous actions.

Rec. 49. Involve neighbours in the maintenance of greenery. ★
The maintenance activities of the greenery would be better if neighbouring citizens are involved as it helps them grow their civic pride of their home town and simultaneously lower the maintenance cost.

9. WATER AND WASTE MANAGEMENT

FINDINGS

The quality of tap water in Krasnoyarsk is controlled by Centre of monitoring water quality. The water quality of the central water supply systems has improved according to the sanitary-chemical indicators of safety for the last three years in Krasnoyarsk. 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. Volume of supplied water for 2014 is 146,621.4 thousand m3. 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.

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. 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.

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. Volume of wastewater for 2014 is only 121,488.2 thousand m^3 (333 thousand m^3/day). The determined capacity of the treatment facilities is 700 thousand m^3/day. According to the city's forecast, sewage will also increase as population increases.

In addition, the city has 800 linear meters of drainage pipes, 5,000 meters of outdoor stalls, drainage systems, as well as 4 water overflow nodes located on the right bank of the city. The length of the city rainwater sewerage network is 184.37 km.

Also there are 52 septic tanks with the total volume of 6,175.6 m^3 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. Drainage of rainwater is carried out through channels along the roads in the septic tanks and into the rivers. Water resources used in residential and office buildings are discharged as waste water without recycling. Therefore, it is necessary to develop policies such as the introduction of water-saving equipment and mandatory reuse of water for buildings.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 50. Implement the water resource management system, establish the total water use control and water efficiency control. ★★★

Respect the laws of nature and the law of economic and social development of Krasnoyarsk, and coordinate the relationship between water resources development and protection. Improve water resources management system and mechanism of Krasnoyarsk, improve management methods. Adjust measures to local conditions, implement classification guidance, and pay attention to the feasibility and effectiveness of the implementation of the system.

Give full play to the basic guiding role and rigid restraint of the planning, and coordinate the usage of water in producing, living and zoology, taking the measures to ensure the water using in the area where the ecological environment is frail. Handle correctly social benefit, ecological benefit and economic benefit relationship, to ensure the safety of living water use, the production water use, and the ecological water use.

Optimize and adjust the industrial layout, strictly control the development of high-water consumption industries, and improve the reuse rate of industrial water use. Strengthen the supervision and management of water consumption and water balance test in high-water enterprises.

Water footprint assessment is a useful tool to quantify and locate water footprints, to evaluate whether footprints are sustainable and to identify options to reduce water footprints where necessary.

Rec. 51. Promote wastewater reuse and recycling. ★★★

To protect important water resources, a variety of equipment designed to conserve water should be used, 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.

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 trialled to circulate water resources. By using ICT (Information Communications Technology) 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.

Rec. 52. Publicize water conservation policies and stimulate people by water pricing policy to change their traditional water use habit. ★★

Promote water-saving social construction. Strengthen propaganda of water resources management policies and regulations, improve the social public water saving consciousness, let the general public to participate in together to cherish every drop of water, and form a good social atmosphere of water conservation. Jointly protect and cherish the water resources!

Rec. 53. Promote the construction of "Sponge City" of Krasnoyarsk. ★

The "Sponge city" is the city that can be like a sponge. It can absorb, store and purify water, when it rains, and "release" and use it, when needed. Sponge city construction, plan as a whole play a natural ecological function and function of human intervention, which repair urban water ecosystem, water conservation, promote the harmonious development of human and nature.

Using the sponge city rainwater collection system, rainwater can be stored and biological purified, then it can be used for a large amount of green irrigation, flushing and washing cars.

The construction of sponge city of Krasnoyarsk mainly has the following aspects, one is the protection of the original ecosystem of the city. To protect water ecological sensitive area, such as the river, lake, wetland, pits, and ditch to the maximum extent. And to maintain natural hydrological characteristics of urban development before, this is the basic requirement of the sponge city construction; second, the ecological restoration. Under the traditional extensive urban construction mode, restore the water and other natural environments that have been damaged by ecological means, and maintain a certain proportion of ecological space. Third, low impact development. According to the development and construction concept which has the lowest impact on the urban ecological environment, the development intensity should be controlled rationally, and enough ecological land should be reserved in the city, so as to control the proportion of urban impervious area. To minimize the damage to the original water ecological environment of Krasnoyarsk, and to excavate the river and lake channels and increase the area of the water according to the demand, so as to promote the accumulation, infiltration and purification of rainwater.

Rec. 54. Improve the water use assessment system, and introduce water footprint assessment. ★

The water footprint is an indicator of freshwater use that considers consumptive water use and water pollution. The water footprint of a product is an empirical indicator of how much water is consumed and polluted, when and where, measured over the whole supply chain of the product. The water footprint is a multidimensional indicator, showing volumes but also making explicit the type of water use (consumptive use of rainwater, surface water or groundwater, or pollution of water) and the location and timing of water use. The water footprint of an individual, community or business, is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

Water footprint of the whole city of Krasnoyarsk consumption is the total amount of fresh water that is used to produce the goods and services consumed by the inhabitants of the city. The water footprint of Krasnoyarsk consumption can be assessed in two ways. The bottom-up approach is to consider the sum of all products consumed multiplied with their respective product water footprint. In the top-down approach, the water footprint of Krasnoyarsk consumption is calculated as the total use of domestic water resources plus the gross virtual water import minus the gross virtual-water export.

The water footprint thus offers a better and wider perspective on how a city relates to the use of freshwater systems. It is a volumetric measure of water consumption and pollution. It is not a measure of the severity of the local environmental impact of water consumption and pollution. The local environmental impact of a certain amount of water consumption and pollution depends on the vulnerability of the local water system and the number of water consumers and polluters that make use of the same system.

10. POLLUTION

FINDINGS

Currently, the environmental condition in Krasnoyarsk is complicated. Various factors such as factories, automobiles, heating fuels, etc. involve complicated environmental pollution. These are unavoidable circumstances for running urban life and economy, and it is also true that accompanying enormous cost to reduce environmental pollutants.

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 291 vehicles per 1000 people in 2016); The key sources of atmosphere pollution are thermal power plants, metallurgy and motor transport.

In practice the contribution of private sources of stove heating are not appropriately taken into account in the atmosphere pollution. 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.

Most of water pollution such as domestic wastewater and industrial wastewater discharged by economic activities etc. is caused by "drainage". Especially, domestic wastewater (toilet, shower, etc.) shows 60 to 70% of water pollution, the wastewater of the kitchen is the dirtiest among them. For that reason, it is necessary to update and expand the factory and domestic wastewater treatment infrastructure.

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. Some paper, plastic, bottle, etc., are separated and remaining garbage goes to landfill.

Due to economic development, industrialization and increasing population, problems related to the expanded consumption and depletion of resources, and the increased output of wide-ranging types of waste are becoming more serious than ever. It is important for environmental pollution to perform appropriate treatment before becoming polluted, and it will take a lot of time, a large amount of energy and enormous cost to cope after pollution without proper measures.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 55. Develop the circular economy, realize the transformation from terminal management to source and process control. ★★★

Krasnoyarsk should step up government efforts to promote the development of a circular and a low-carbon economy. This could be achieved by improving the utilization of resources, reducing pollution and reducing and neutralising the waste at its source and production process. Then environmental governance should be applied from end to source and process control.

Krasnoyarsk should encourage the community and the public to take an active part in the reduction of the source， and continuously promote cleaner production. Limit excessive packaging of products, encourage packaging recycling, develop green packaging, and strengthen producer responsibility. Promote decorated newly-built houses, promote suitable decoration, and reduce the amount of house decoration waste. Actively guide green consumption, moderate consumption; and continue to promote clean vegetables on sale and reduce kitchen waste.

Rec. 56. Improve the recycling and utilization system of waste resources. ★★★

Encourage the community to participate in the recycling of waste materials, improve the recycling and utilization system of community waste, and further improve the network of recycling and utilization of waste materials. Krasnoyarsk should increase policy guidance and support to promote the large-scale and standardized development of recycling enterprises. Establish and improve the electronic waste recycling system, encourage qualified enterprises to participate in the recycling channels construction.

Expand the construction decoration waste utilization way. Establish and improve the centralized collection, standardized transportation and fixed point disposal mechanism for building decoration garbage.

Promote the utilization of kitchen waste resources. Guide social forces to actively explore new technologies and new ways of kitchen waste processing, kitchen waste recycling use product development, promote kitchen garbage source dehydration technology.

Increase the use of leaves and dead branches recycling, encourage qualified suburban areas to accept the pre-treatment of greening garbage. Realize the comprehensive utilization of greening garbage by means of crushing fermentation and decomposing compost.

Support the construction of landfill biogas utilization; deepen relevant policies to support the utilization level of power generation of bio-gas and incineration.

Accelerate the construction of facilities and improve the capacity of harmless disposal of garbage.

Rec. 57. Reform the energy structure and use clean energy. ★★★

Use more pollution-free energy, such as solar energy, wind energy, hydroelectric power, and low pollution energy, such as natural gas. Pre-process the fuel (e.g., the desulfurization processing of coal), and improve combustion technology, thus reducing pollution emissions. In addition, before the pollutants into the atmosphere, use dust smoke abatement technology, condensing technology, liquid absorption technology, recycling technology to eliminate some pollutants in the exhaust, and it can reduce the amount of pollutants into the atmosphere. Local government should promote industry to actively seek clean fuel and green production mode, promoting the development of technology to reduce costs, to achieve economic benefit and environmental protection and development. Natural gas is encouraged to replace lignite as fuel, and the government should enact a ban on the coal stoves used for detached houses.

Rec. 58. Deepen the market mechanism in the treatment of pollution end and establish the system of "who improves the environment and who charges". ★★

The polluter pays is an important base condition to deepen the market mechanism in the end of pollution. Krasnoyarsk should reasonably determine the standard of charges for pollution control, and gradually achieve a level of profit beyond the reasonable cost of compensation, in order to realize transformation from " Who pollutes the environment who improves the environment" system to " who improves the environment, who charge" system, and actively guide social capital into the field of pollution control and ecological construction through the preferential policies of tax, finance and other aspects .

Rec. 59. Establish environmental pollution control system. ★★

Elements need to be configured in accordance with the principles of effectiveness, fairness, efficiency and flexibility, including improved legal structures, advanced technical means, competitive markets and efficient government. establish effective institutional arrangements between the government, the media, the enterprise and the social public , including cooperation mechanism, the participation mechanism, the rewards and punishment mechanism, supervision mechanism, realize reasonable configuration and operation of elements between different governance, and to achieve the result of environmental pollution control though the combined action of two kinds of governance model: the market adjustment and government supervision.

Form a governance mechanism that is guided by the government, dominated by the market and Shared by the whole society though technology, law, economy and other measures.

In addition, the government of Krasnoyarsk should build environmental protection information platform to establish receiving and transmission, distribution channels of effective public information, widely accepted good advice from all sectors of society, accept supervision from the people and enterprises.

Rec. 60. Give full play to the positive role of various groups in environmental pollution control. ★

Each group is a powerhouse in environmental pollution treatment, such as NGOs, they can accomplish the information dissemination and resource mobilization activities which cannot be realized by the unified management of the government to some extent. The sustained attention to certain specific environmental pollution problems and governance policies enables them to integrate considerable manpower and material resources for voluntary monitoring, research and joint governance actions. Krasnoyarsk should encourage the participation of NGOs through institutional innovation, including the improvement of the registration management system for non-governmental organizations and the active guidance and support in policies, funds and information.

Rec. 61. Set up a pilot for carbon emission trading, give full play to the market mechanism in the decisive role of greenhouse gas emissions allocation. ★

In order to control greenhouse gas emissions of Krasnoyarsk, achieve low carbon development target, local government and enterprise should promote the construction of the carbon emissions trading market together.

Carbon emissions trading system sets carbon emissions targets for key units to encourage enterprises to strengthen the management of carbon emissions, and promote the adjustment and upgrade of industrial structure, to carry out the carbon intensity drop goal, advance the total amount control and quota management system of greenhouse gas emission. Carbon emission trading can give full play to the role of the market in the allocation of resources, enhance the participation initiative of enterprises, and reduce the cost of reducing emissions in the whole society. In addition, the implementation of carbon emission trading can also promote the development of emerging services, drive energy conservation, low-carbon and recycling industry investment, and make positive contributions to accelerating the implementation of innovation-driven development strategy.

11. POLICY FRAMEWORK

FINDINGS

- The Krasnoyarsk City Administration takes a divisional management approach and the mayor coordinates all divisions. Relevant divisions to lead Low-Carbon Town (LCT) development are already identified. However, within the coming few months, a change to 'phrasal' management based upon each phase of a citizen's life cycle is planned.

- Budget of the City Administration is limited of course depending upon city tax revenues.

- Buildings and urban development regulations are administered and enforced by the Russian Federal Government and its agencies. Regional and Municipal (City) Administrations coordinate between project owners and the main regulator, and cooperation among all levels of governments is going well.

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 62. Coordinate closely with relevant divisions within the Krasnoyarsk City. ★★★

Administration will be required for LCT development. It might be necessary to set up a special coordinating mechanism headed by a senior official (e.g. First Vice-Mayor) under the guidance of the Mayor. This necessity will be even greater after the change of the management method. Senior leadership is important so that other divisions do not 'delegate' responsibility for LCT action to an under-resourced team instead of taking responsibility for relevant action themselves.

Rec. 63. Secure budget for the LCT development. ★★

LCT development often requires considerable amount of initial investment. Special budget for LCT development is hoped to be earmarked, or at least LCT development should be prioritized in the city budget planning. Appropriate design of measures can generate revenue, reduce costs, recover costs over time or enhance value of outcomes.

Rec. 64. Transfer the regulatory authority on buildings and other urban developments from the federal government to Krasnoyarsk regional and city administrations. ★

The Russian Federal Government is expected to yield its regulatory authority on buildings and other urban developments in order to promote Krasnoyarsk's LCT development, continuing good cooperation with the Krasnoyarsk Regional and City Administrations.

12. EDUCATION AND MANAGEMENT

FINDINGS

In order to develop LCT successfully and efficiently, education for residents, development of skills and involvement of various stakeholders including companies, schools, households is very important. It is necessary to increase citizens' awareness through low-carbon development, thus the key is how to connect their daily life with energy-savings and environmental conservation activities.

In Russia, the work in the field of environmental studies has become intensive since approximately 1990s (Sitnikova, 2017). According to the representatives of Krasnoyarsk City, there are all levels of environmental education available from the primary level to higher and professional level now in Krasnoyarsk. The municipal budget has been provided for inviting 800 children to eco camps in national parks during the summer vacation since 15 years ago. Some primary schools have eco events such as eco poster competition, paper collection for recycling, etc. In Siberian Federal University, there are PhD programs related to LCT development such as Urban Design and Planning, Environmental and Resource Economics, etc. In addition, a lot of low-carbonization related educational activities are conducted on informal basis for nurturing citizens' environmentally friendly way of living. The new educational standard of Russia considers ecological, financial and cultural understanding as three main pillars. For the low-carbon development of the Krasnoyarsk City, necessary contents under the compulsory education is expected to be examined in the local context.

On the other hand, during the interview, the review team heard that the citizens are not energy conscious as they feel energy cost is not expensive. It is difficult to encourage behavioural changes unless they face problems in daily life. Community/Residents' associations are not common in Krasnoyarsk City, but micro district management companies or mothers' groups could take a leadership in grass-root level activities. Schools play an important role in influencing change.

Krasnoyarsk City will host the 29th Winter Universiade, an international multi-sport event, organized for university athletes by the International University Sports Federation (FISU), in 2-12 March 2019. The official mascot is Siberian husky named U-Laika. It is a great chance to advertise Krasnoyarsk City as LCT to the international audience, especially the younger generation.

Figure 9: U-Laika: image and 29th Winter Universiad mascot

U-Laika

Source: International University Sports Federation

RECOMMENDATIONS

★★★ Recommendation for immediate action
★★ Recommendation for action in the next 2-3 years
★ Recommendation for action in the longer term

Rec. 65. Enhance environmental education activities in compulsory education to build a common sense. ★★★

In order to improve energy literacy and environmental consciousness of citizens, it is encouraged to develop the environmental program/textbooks in local context of Krasnoyarsk City. In successful schools, environmental education is conducted on daily basis together with special events like school festivals, camps, etc. For example, 3R (Reduce, Reuse, Recycle) activities are typical everyday activities in Japanese elementary schools.

Rec. 66. Work together with residents through micro district management companies and support their activities by award system, etc. ★★

For the sustainability of the activities, involvement of local stakeholder is essential. In the case of Krasnoyarsk City district Management Company could be the key player in developing the sustainable activities for low-carbon town development.

Rec. 67. Call on the citizens to design a logo/characters with low-carbon image for Krasnoyarsk City. ★

Krasnoyarsk City can advertise its efforts in low-carbon town development by creating a logo or a character incorporating motifs that represent local culture, history or products, etc. The city can utilise events like Universiade and other international/domestic events as chances to advertise its image as a low-carbon town in the future. Use of the logo should be driven by funding, and by linking rights to display it to shops and buildings achieving specified outcomes.

Further findings and recommendations are provided in Appendix E.

APPENDIX A: MEMBERS OF THE LCMT POLICY REVIEW TEAM

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APPENDIX B: ORGANISATIONS AND OFFICIALS CONSULTED

Krasnoyarsk City Administration

Mr. Vladislav Loginov, First Vice Mayor

Mr. Vadim Falaleev, Head of International Affairs Division and Deputy Head of Mayor's Department

Mr. Yuriy Shestopalov, Acting Vice-Mayor and Acting Head of Department of Municipal Services

Mr. Oleg Zhivotov, Vice-Mayor and Head of Department of Urban Development

Ms. Olga Sosnova, Acting Head of Department of Architecture

Mr. Anatoly Zuev, Deputy Head of Department of Transportation

Mr. Maksim Baturov, Deputy Head of Department of Social and Economic Development

Mr. Sergey Demchenko, Head of Energy Supply Division, Department of Municipal Services

Ms. Nataliya Orlova, Head of Environment Protection Division, Department of Municipal Services

Ms. Yuliya Goryacheva, Deputy Head of International Affairs Division

Mr. Roman Teleshun, Chief Specialist of International Affairs Division

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Ms. Irina Shulikova, Head of Environment Protection Division

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Mr. Rashit Nazirov, Counsellor for Vice-Chancellor

Mr. Vasiliy Panteleev, Director of Polytechnic Institute

Mr. Vadim Servatinskiy, Head of Department of Roads and Urban Buildings, Civil Engineering Institue

Ms. Irina Endzhievskaya, "Construction materials" programme curator, Civil Engineering Institue

Ms. Olga Dubrovskaya, Deputy Director for Studies of Civil Engineering Institute

Ms. Evegeniya Buharova, Director of Economic, Management and Natural Resource Management Institute; "Krasnoyarsk Smart City" concept developer

Monolit Holding LLC

Ms. Adelina Abasova, Chief Commercial Office, FSK Monolitinvest LLC

Mr. Aramais Papikyan, President, Krasnoyarsk-City LLC

Mr. Ivan Voroshilov, Specialist

Ms. Mariya Pavlenko, PR-manager

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Mr. Alexander Krys, International Projects Administrator – CIS Region, Global Marketing Center, NIKKEN SEKKEI LTD

APPENDIX C: COMMENTS ON FEASIBILITY STUDY RELEVANT TO AREA ENERGY SYSTEMS & MULTI-ENERGY SYSTEMS

Area and multi-fuel energy systems and options have been described in detail in the feasibility study report, as noted above. The report's recommendations are generally supported, however, some comments may influence response to their recommendations, or underpin additional recommendations.

- More emphasis on analysis of energy use by activity, and by non-industrial (commercial/services) energy consumers and related scope for emission reduction would be useful. End-use services and the technologies to provide them are the fundamental drivers of energy requirements. This comment is also relevant to the Buildings area.
- Greater emphasis on options to cut energy losses associated with air leakage and ventilation from buildings would be useful, as this seems to be a very large contributor to energy requirements. This comment is also relevant to the Buildings area.
- Energy losses from dumping of large quantities of hot water from the District Heating system into the river are substantial, and should be eliminated.
- It may be necessary to cut carbon emissions from energy use faster, and to lower levels than proposed in the feasibility study report, to respond to the increasingly urgent need to limit climate change. Zero emission energy scenarios and strategies should be developed.
- CO_2 emissions from the aluminium smelter are estimated at 17% of total emissions. However, this seems to be based on its use of zero emission hydro-electricity for its core process, so emissions are related to anode production and use, and possibly PFC emissions. The smelter operators, on their website, have indicated that they may shift to inert anodes in future. This could eliminate emissions from anode production and use, while increasing electricity use per tonne by around 20%. In the long term, additional hydro development or redirection of some hydro-electricity from smelting to higher added value, less energy intensive activities may deliver net economic and employment benefits for the region.
- 'Behind the meter' energy options, ranging from energy efficiency, demand response, energy storage (thermal and electricity), smart management and on-site renewable energy deserve more attention. This includes estimation of the fundamental energy requirements to provide energy services, as this is the fundamental driver of demand for energy. These issues are also relevant to the buildings, renewable and untapped energy and area energy management sections. The drivers of 'behind the meter' energy solutions, as well as the technologies, can be very different from those driving district or regional energy solutions. They include higher energy prices, price stability, empowerment, status/image, etc.
- The feasibility study report rates solar energy as a relatively low potential option. The use of vertical or near-vertical Building Integrated PV or larger-scale PV seems to offer useful winter output, with daylight reflected by winter snow adding to output, while problems of snow build-up can be avoided.
- Energy from the river could potentially be a very large source of heat that could be upgraded by heat pumps. However, the feasibility study report does not state what the winter temperature of the river is.
- More data on employment by sector/industry and their contributions to the regional economy would be useful. This would provide a basis for long-term low carbon economic and energy planning, as some sectors are more employment intensive and much less energy intensive than others.
- The graph of primary energy (slide 107 of the N-S PowerPoint presentation) may provide a distorted perspective on the relative significance of nuclear and renewable electricity sources. The International

Energy Agency methodology for energy accounting adjusts the primary energy allocated to uranium upwards based on the efficiency of thermal power stations, because it is generally seen as a coal or gas replacement option. In contrast, each unit of non-thermal renewable electricity (wind, solar, hydro) is treated as only one unit of primary energy. This means each unit of nuclear electricity is effectively adjusted to be 2.4 to 3 units more primary energy than the same amount of electricity in data tables and graphs, So primary energy data that uses this approach gives the impression that renewable electricity is a significantly smaller proportion of primary energy than it would if it was adjusted in the same way as nuclear energy.

Introduction

To progress towards a low carbon future for area heating and multi-energy systems, Krasnoyarsk faces several opportunities and challenges. First, there is substantial scope to improve the performance of the existing systems through incremental actions that can be integrated with ongoing maintenance and upgrades. Second, by looking to the longer-term context, it must create a model for a low carbon, economically viable means of delivering comfort (in summer, winter and variable weather conditions), hot water, electricity for appliances and lighting, and healthy living and working environments for residents and workers, within a changing context. Energy-efficient buildings and changing climate are already driving changes in heating and cooling requirements.

The city's district energy system has traditionally been viewed as a way of providing space heating and hot water for the community in a climate dominated by very cold weather. However, increasing rates of installation of air conditioners reflect both changing climate and design of buildings that work well in winter but not in warm conditions.

Short Term ISSUES AND OPPORTUNITIES AND Present circumstances

The following analysis and discussion underpins some additional recommendations.

Most of the heat for the District Heating System is provided by large lignite-fired Combined Heat and Power (CHP) units that provide both heat for the District Heating system and electricity for the community. Several smaller, old boiler houses provide some of the heat: these are being phased out over time. The District Heating system operates for around 235 days of the year. It is not clear from the N-S report how or if the DH system and its CHP units operate outside that period.

If the CHP units are needed for electricity supply in warmer months, a substantial amount of potentially useful waste heat could be produced for up to 130 days of the year. Consumers who use the DH system for hot water supply would need to switch to an alternative energy source if the DH system is not operating, possibly resistive electric heating in the storage tank used with the DH system. [CONFIRM] It is not known how consumers maintain comfort if there are cold periods outside the operating season of the District Heating system. If they use resistive electric heating, this is inefficient, and potentially costly [INFORMATION ON ELECTRICITY PRICES AND USAGE OVER THIS PERIOD?]. It may also contribute peak loads to the electricity system that may require intermittent or sustained use of CHP at relatively low efficiency, as the heat output may not be used [OR IS HYDRO USED FOR PEAKS?].

Approximately 16,000 households use their own coal-fired heating units. These are inefficient and polluting, and the environmental authority is increasing pollution standards, so they must be replaced in the next few years. Research into options for replacement has begun. It is not clear how much these households pay for their coal, or how much they use. [DATA?] It is also not clear what heating options are used by the large number of households not served by district heating or coal: while detailed data are not available for this report, it seems likely that 50,000 or more households are not covered by either district heating or coal heating. Efficient, smart energy solutions for these homes could contribute to a low carbon future.

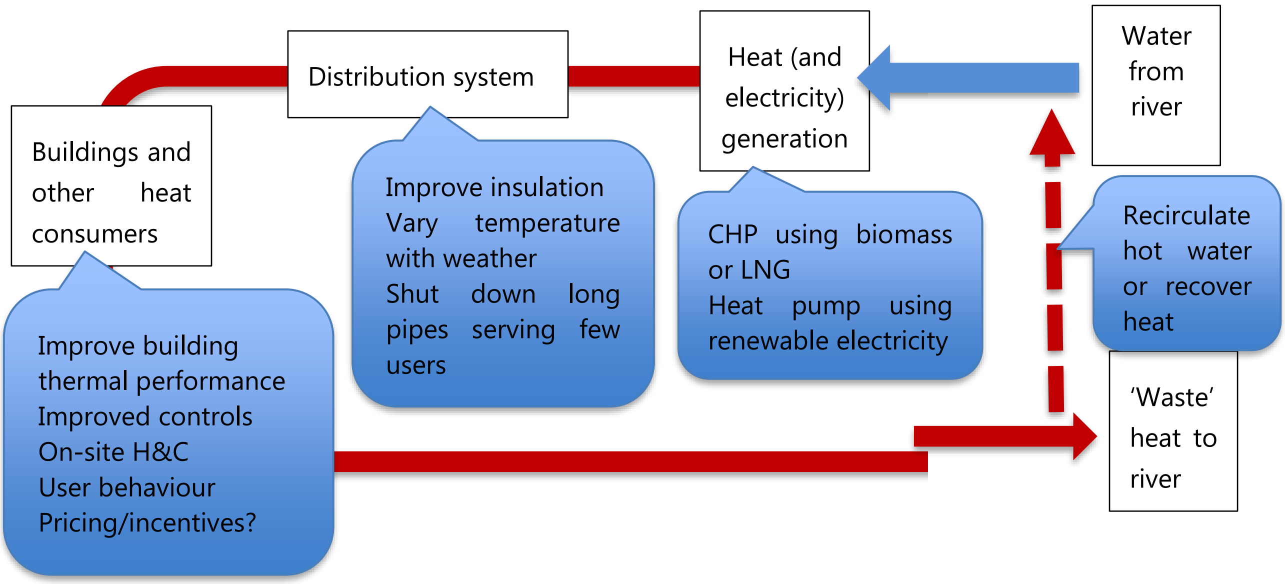
In recent years, increasing numbers of households and businesses have installed split system air conditioners. These operate independently of the District Heating system. It is not known what proportion of these air conditioners are capable of providing both heating and cooling [in Australia we call these 'reverse cycle air conditioners']. If they can heat and cool, and they are efficient models, they could provide a useful resource for future district heating and cooling solutions, as discussed below. [DATA?]. Encouraging installation of units that can heat and cool could contribute to a low carbon future.

A systems approach to area energy

The District Heating system exists to deliver comfort and hot water to the people and businesses of Krasnoyarsk.

Figure 1 shows the main elements of the system, and key options for reduction of carbon emissions. These options are described in more detail in following sections. The following sections of the Review discuss the main elements of this system, and opportunities to cut carbon emissions associated with them.

Figure C.1. Krasnoyarsk district heating system and potential carbon reduction measures



Heat management in buildings

Building thermal performance

Heat flows through the building envelope dominate heating and cooling requirements, although internal heat production (e.g. from cooking and lights) can reduce heating needs but increase discomfort and cooling needs in warmer weather.

Effective insulation and high performance windows (e.g. triple glazing with low emissivity coatings) are essential in an extreme climate like that of Krasnoyarsk. It is not known how widely these are installed. Thermally poor buildings should be upgraded or replaced.

A local expert commented that cold outdoor air entering buildings was a major contributor to heating energy requirements in winter. Analysis confirms this: the heat loss for 1 air change per hour of fresh air for a 100 square metre home is equivalent to the heat loss through more than 20 square metres of double-glazed window with no curtain, or 200 square meters of insulated wall. So ventilation (and air leakage) is likely to be the major source of heat loss from most buildings over much of the winter. This issue is addressed in the Buildings area, but some comments are made here.

Energy recovery ventilation, which can provide the necessary fresh air and is widely used in many cold countries, can reduce this energy problem by around 80%. Simple modular energy recovery units such as the Lunos (http://www.lunos.de/en/), are suitable for retrofit, and could be installed in new and existing homes. Larger systems are available for commercial buildings. Heat pumps can also efficiently extract energy (both sensible and latent heat) from exhaust air and use it to provide useful heat.

In many parts of the world, a ventilation rate of 0.5 air changes per hour is considered adequate. Local experts suggest 1 full air change per hour is necessary/regulated. Reduction of air leakage/ventilation to 0.5 would save large amounts of energy. However, local issues such as management of water vapour, provision for indoor smoking or other local factors may make this difficult to implement.

Thermal imaging cameras are now widely available, and can be used to identify heat leaks from buildings. Indeed, attachments that convert mobile phones into thermal imaging cameras are now available. Sealing air leaks as well as ensuring insulation is properly installed are both important.

Other sections of the Review discuss buildings in more detail.

Heating Equipment in Buildings

Management of heating within at least some buildings using the District Heating system may be crude and inefficient, as illustrated by the heating system in a hotel room – see Box. At a detail level, a range of measures could be applied, such as:

- crude heating controls could be replaced by thermostatic controls, timers and occupancy sensors;
- controls could be clearly labelled and people shown how to operate them;
- thermal weaknesses could be fixed, for example where pipes are inadequately insulated, or hot heating panels are next to windows or poorly insulated walls. Insulating panels can be placed between heating panels and windows or walls to reduce local heat loss. When a heating panel is near a double glazed window on a cold day, the heat loss through the window near the panel could be 200 watts per square metre, compared with 15 watts if it is located next to a highly insulated wall.

Figure C.2. Hotel radiator case study

CASE STUDY

In my hotel room, when I arrived, the temperature was almost 30C. The heater control was an unmarked lever that controlled the flow valve. When this was turned off, the room temperature never fell below 25C. This seemed to be partly due to the 5 metres of uninsulated pipe on the 'supply side' of the valve that continued to heat the room: this was providing around 500 watts of heating. Heat from overheated surrounding rooms probably also helped to maintain the temperature at a level 5C above my preferred temperature of 20C. In addition, when the curtains were closed, the heating panel and pipes were located between the curtain and the window/external wall. This raised the temperature next to the window and external wall, increasing heat loss.

The window was triple-glazed and the external wall seemed to be well-insulated. But smart controls and modification of the curtain offer energy savings and improved occupant comfort.

User Behaviour

If appropriate controls are installed, users can set room temperatures. Common international standards are 20-22C in living rooms and around 18C in bedrooms in winter. The reviewer noted that many of the rooms occupied or visited during our visit were noticeably hotter. If present indoor temperatures are 5C higher than necessary, turning the heat down would save 10% of the thermal energy delivered to the building at minus 30C ambient temperature or 20% at around zero degrees. It should be noted that, if there are large fixed energy losses from the distribution system (see later section), overall percentage energy savings would be lower.

It has not been determined how people manage provision of fresh air in most buildings. If they open windows or the building is poorly sealed, very large energy losses will occur in extreme weather, as discussed previously.

Water vapour from clothes drying, cooking and bathing can cause condensation, mould problems and damage to the building itself in cold climates. And evaporating water is an energy-intensive activity of itself. Recovery of the latent heat in water vapour is a potentially significant energy source. So education on managing water vapour is important. This issue has not been considered in this review.

Energy Pricing and Incentives

As noted earlier, Krasnoyarsk residents and businesses are believed to pay very low energy prices by global standards. However, it seems that this is seen as 'normal'. Enforced changes could cause negative reactions if people see themselves as 'victimised'. And in an extreme climate, provision of energy for at least basic services is definitely a social essential, and important in avoiding freezing and bursting of pipes and other physical impacts. Health impacts from lack of heating can be serious.

If Krasnoyarsk citizens are to contribute to a low carbon energy future, as well as reducing government operating costs to free up funds for other purposes, 'energy smart' behaviour will be important. Further, action at home can help them to accept other changes such as shifting to public transport. So options to encourage this behaviour, other than crude pricing, need to be developed and introduced. Pilot and trial projects can be important to refine approaches to work in local circumstances. Often a combination of approaches that work in parallel and/or evolve over time works best.

As discussed in the section on Area Energy Management, non-industrial (commercial/service) consumers seem to use a surprisingly large amount of electricity in winter, three times as much as they use in summer. It is likely (but requires confirmation through field research) that much of this extra consumption is for electric space heating. So there may be a case to combine an increase in non-industrial electricity prices with incentives for them to shift to district heating. Combining incentives with pricing is important, as many businesses lack access to suitable finance, skills to address energy issues and trusted supply chains for energy efficiency advice and equipment.

Some possibilities include:

- education activities for children at school, and 'energy' or 'climate action' clubs
- financial incentives and information to encourage people and businesses to buy energy-efficient appliances and equipment; bulk buying programs can provide efficient equipment at a lower installed price through economies of scale. Provision of low interest, long term finance so that costs can be repaid from savings and benefits of improved service
- media campaigns that alert the community to the local signs of climate change, the actions cities around the world are taking to cut emissions, positive stories about actions local people are taking, promote availability of efficient products, etc. are vital
- real time feedback on energy use and advanced analytics can advise people on energy waste, identify appliances and equipment that is faulty, etc. This is discussed in the Area Energy Management section.
- development and up-skilling of supply chains to provide energy efficiency services and products

- creative pricing models, such as low prices for 'basic' energy supply but higher prices for excessive use; incentives for those who cut energy usage at peak times; cost-reflective pricing for businesses, combined with access to finance, can be used, as they do not face the social and health issues households face.

Building Cooling

Many buildings in Krasnoyarsk now have air conditioners installed. This may reflect factors such as:

- many buildings are highly insulated with double or triple glazing. So small amounts of heat generated internally and/or sunshine entering the building through windows can raise internal temperatures significantly. The relatively low altitude of sun, even in summer, increases this 'solar oven' effect
- buildings do not have external shading, to block out summer sun: note that shading that blocks out summer sun but allows in winter sun is preferable
- climate change is increasing ambient temperatures and humidity, in both day and night. This means high mass buildings may warm up and remain uncomfortable overnight more often
- more people expect higher levels of comfort over time and ageing people are more vulnerable to health impacts if temperatures are too low or too high
- since people are used to focusing on cold weather, they may not realise that opening windows to ventilate buildings overnight can cool them down, so they remain comfortable during the day: education could encourage such behaviour. It may be necessary to install screens to block out insects when windows are open in warmer weather

At present it seems that cooling is treated as a voluntary 'luxury' choice, outside core service provision. At the new green housing development reviewers visited, the designers have incorporated discreet camouflaged spots where air conditioners can be located, but has not considered it necessary to provide cooling.

Commercial buildings, which have relatively higher internal heat production and high glazed areas (with higher solar gains) are more likely to need cooling.

It is clear that an increasing number of buildings are uncomfortable in sunny, warm (and even cool) weather. And temperatures will continue to rise. The periods when some buildings (or parts of buildings) need heating while others need cooling will extend as the proportion of the year when temperatures are mild and variable increases. At times, many buildings may require some heating then some cooling on the same day. The increasing need for cooling, and the increasing diversity of heating and cooling requirements, raise a number of challenges and opportunities for the District Energy System, which are discussed later.

Hot water provided by District Heating System

Water-efficient showerheads, taps and appliances can significantly reduce hot water consumption. Faulty pressure-temperature relief valves can also waste large amounts of hot water. Inadequate tank and pipe insulation can also waste heat, although if equipment is located in a room that requires heating, this may not matter – depending on how efficiently space heating is provided relative to water heating.

An important question not yet answered is how people who use the district heat for hot water gain access to hot water when the district system is not running. This may have both capital and running cost implications for households. If resistive electric heating is used, this may add to summer demand for electricity at times: this may become a bigger issue in the future if summer electricity demand increases, or there are shortages of hydro-electricity.

ENERGY DISTRIBUTION SYSTEM

According to both Nikken Sekkei and City staff, energy distribution system losses seem high relative to best practice. They are particularly high in some areas, reaching up to 40%. There is an ongoing maintenance and upgrading program, and N-S have recommended this be accelerated.

A potentially serious design flaw of the present energy distribution system, as described by a local expert, is that it does not recover the heat remaining in the water after it has circulated through the District Heating system. According to local experts, this hot water is released into the river. This is a major energy waste. One expert suggested that 4,000 tonnes per hour of hot water was being released into the river from the system. This is a very large amount of energy. If it is correct, it is the equivalent of wasting around 130 tonnes of coal per hour. If this energy was recovered it could heat 20,000 to 50,000 homes (depending on how energy-efficient they are) and increase the effective capacity of the existing CHP units to supply overall heat service demand.

District heating systems typically recirculate the hot water from the distribution system or, if water quality is poor, recover the heat via a heat exchanger.

In recently designed District Heating systems (and the internal system for the Monolith Holdings project) improved pipe insulation systems are used, as well as lower supply temperatures and variable pumping speeds when demand is low and/or temperatures are milder. See reports at https://www.euroheat.org/ and at the UNEP-sponsored site http://www.districtenergyinitiative.org/publications

A number of suggestions beyond the above upgrades are included below, and in the *Long Term* section of this report.

HEAT PRODUCTION

As noted earlier, there are plans to replace the existing inefficient coal boiler houses, and a study of options has just begun. The N-S study has also made recommendations to improve efficiency of existing CHP units and the distribution system, so that no additional heat production capacity is needed when the boiler houses are decommissioned. This Review has also proposed that improvements to building and end-use equipment performance could reduce the amount of heat required.

It is likely that pressure will increase during the lives of the replacement equipment to dramatically reduce carbon emissions, well beyond the level that can be achieved by best practice lignite-fired CHP units. Further, the economics of smaller, distributed energy solutions are improving relative to larger centralised equipment. These compete with the District system.

On this basis, the proposed study should consider:

- options that can operate on a range of fuels, such as biogas, biomass, urban waste or hydrogen, as well as lignite
- smaller, modular equipment that could be located around the District Heating system, serving 'micro-grids for heat' and large buildings, and could offer greater flexibility of operation.

Multi-fuel engines that can operate in CHP mode and are modular are emerging. One example that can run on an improved slurry of lignite and water is the Australian DICE engine (see http://www.dice-net.org/).

This project provides an opportunity to consider a range of innovative options as trials in limited areas for potential wider application if they are successful. This approach could potentially target an area where distribution losses were high and buildings were old and thermally poor. These could involve combinations of upgrading building and end-use equipment efficiencies (especially energy recovery ventilation), innovative distribution system design, and even alternative sources of energy provision, including provision of cooling, combining central and distributed heating and cooling solutions, or other options.

A first step would be to understand the energy flows within the local system, including losses from heat production, distribution, end-use equipment and buildings. Potential requirements for cooling into a future of climate changes should also be considered. This would support development of a computerised system model to explore the implications of options. A range of possibilities is listed in the following section of this review.

Heat pumps, both large and small, are improving in performance and declining in cost. In extreme climates, there are several ways of maximising efficiency of heat pumps:

- reduce temperature difference between condenser and evaporator through measures such as:
    - using warmer (or cooler for cooling) sources of energy such as:
        - the river (summer temperature 15C but winter temperature not known, other than 'it never freezes' – but heat removal from river water must be managed to avoid freezing of water in heat exchangers);
        - ground temperature or geothermal heat resources (the International Energy Agency has published a *Technology Roadmap Geothermal Energy and Power* in 2011 and articles such as http://www.thinkgeoenergy.com/russia-its-renewable-energy-drive-and-the-geothermal-opportunity/ seem to suggest that this region has potentially useful 'warm' geothermal resources for heat pumps or direct use for district heating
        - active pre-heating (or pre-cooling for cooling) of air or water before it reaches the evaporator, e.g. from a 'low temperature' district energy system, discussed below or, for cooling, evaporative pre-cooling using mist sprays or moist permeable pads
    - using cascaded or multi-stage heat pumps: effectively these put heat pumps in series, so each one works across a smaller temperature difference, using the previous heat pump's output temperature as its input temperature
    - optimising heat exchanger design, e.g. by increasing effective surface area of heat exchange
- optimisation of heat pump design elements such as compressors, selection of refrigerant, real time optimisation of refrigerant pressures, etc.

It is important to recognise that the amount of energy in air is relative to Absolute Zero (minus 273C) so even 'very cold' air still contains a lot of potentially useful energy. The laws of thermodynamics also show that changing the temperature difference across a heat pump by just one degree Celsius changes efficiency by between 1 and 3%, which is why reducing the temperature difference in ways listed above can deliver very large efficiency improvements.

Natural gas may also be an option for heating and cooking. While Krasnoyarsk is distant from gas pipelines, Liquefied Natural Gas (LNG) can be transported by water, rail or road from coastal terminals. It would still be much more expensive than present coal, but this may be offset by more flexible and efficient use, cheaper equipment, lower carbon emissions and lower air pollution.

OPTIONS FOR TRIALS

First, an evaluation is needed of impact of major building upgrades on heating and cooling energy requirements, as part of a broader system analysis, outlined earlier.

Funding of trials could be justified by estimation of reductions in government subsidies for energy and energy infrastructure, as well as consumer savings, reduced carbon emissions and air pollution, and improved quality and reliability of services.

This approach could lead to several system options, including:

- avoiding the need for additional District Heating capacity when old boiler houses are shut down through reduction of demand in buildings that keeps total demand within the limits of the remaining plant capacity
- development of a local system that could provide heat (and possibly cooling) using an alternative approach, such as:
    - a central heat pump that could provide both heating and cooling
    - a low temperature water loop that could be used by modular heat pump equipment at each building, or group of buildings, to provide both heat and cooling. This could allow on-site reverse cycle air conditioners (which can heat or cool) to use water at a temperature of around 15C for either cooling or heating – so a single district energy loop could support efficient heating and cooling at the same time, depending on what each dwelling or building needed – see discussion on climate change, below. It may also be possible to integrate such a system with domestic water supply if water treatment is adequate.

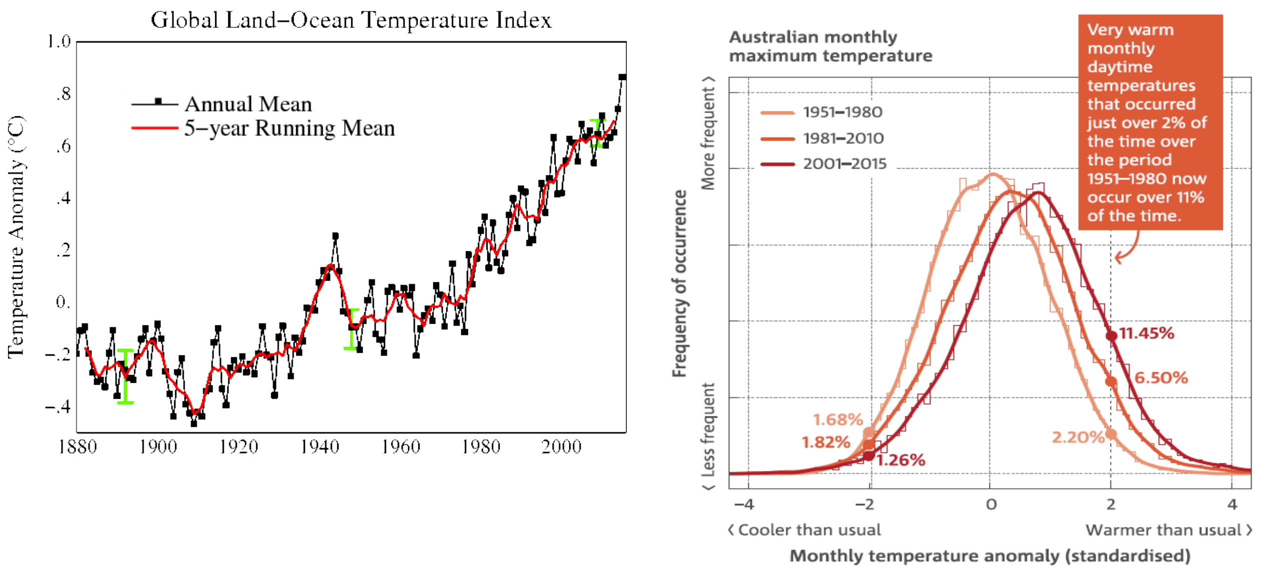
This could also provide an opportunity to trial unit pricing or incentives, smart metering and other emerging systems discussed earlier in this report.

LONGER TERM OPPORTUNITIES

The overall trends in demand for District energy systems are influenced by trends in building thermal performance, climate change, available technologies, costs (both capital and operating, as well as who pays and over what period) and consumer expectations.

As shown below, the global warming trend is now well established, with both extreme hot and extreme cold periods being warmer. Warming in regions further from the equator is likely to be greater. Indeed, the visits of APEC teams (in autumn of 2016 and winter of 2017) have coincided with temperatures significantly higher than historical data suggested.

Figure C.3. Temperature index and anomaly



Importantly, the frequency of extreme hot days is increasing disproportionately. Further, the amount of time when weather is 'moderate' and potentially variable is increasing. This increases the proportion of time when different buildings or parts of buildings will require either heating or cooling or neither, all at the same time. The individual requirement for space conditioning in this kind of weather will depend on orientation, thermal properties of the building envelope, solar gain and heat produced by internal activities.

This will undermine the viability of traditional District Heating systems. Demand will fall, especially in increasingly long periods of moderate weather, and when cooling is required. As demand falls, fixed energy losses and operating costs become a larger proportion of total costs. All things being equal, system losses will increase as a proportion of energy use, affecting profitability. Krasnoyarsk is already seeing this play out, as increasing numbers of buildings install air conditioning. At the same time, households and businesses will invest more in heating and cooling equipment: this money could potentially be better used if some of the options discussed earlier were pursued.

Improved building performance in extreme weather – both hot and cold, will help people to cope with changing climate, while reducing energy infrastructure and supply costs.

The N-S report has proposed a strategy for action to 2050. This is supported by the Review.

However, increasing pressures to cut global carbon emissions further and faster are emerging. And technologies are changing fast. In particular, modular, flexible energy solutions reduce risk at a time of uncertainty, have rapid learning curves, can capture economies of scale from mass production, and roll-out can be matched to requirements quickly. In contrast centralised systems take a long time to build, tie up capital for long periods, rely on ongoing revenue streams to repay investments, and may not be responsive to change driven by unexpected innovations or external pressures.

So it is important that investments in new infrastructure are compatible with, and even facilitate, a zero emission, or beyond zero emission energy system. Attention must be given to:

- end-use efficiency, scope to manage demand, energy storage (thermal as well as electrical) and smart management systems
- provision of energy services by a mix of point-of use, local and centralised systems that are flexible and adaptable
- zero or very low emission solutions, or solutions that can be easily adapted to meet this criterion.

Approaches outlined above in this section meet these criteria, and other sections of the Review report will also address them. Some approaches beyond those mentioned so far in this section include:

- Building-integrated Photovoltaic systems. While Krasnoyarsk's solar resource is not outstanding, vertical or near-vertical PV systems on building facades potentially deliver quite useful winter electricity output, amplified by reflection from snow. This approach avoids the problem of snow build-up and maximises winter output when the sun is very low in the sky (as long as overshadowing is minimised).
- High efficiency appliances and equipment, including induction cooktops, lightweight super-insulated ovens and insulated cookware, high efficiency refrigerators, TVs etc. While traditionally release of waste heat from these appliances (and lighting) has provided useful heat in winter, this is rapidly changing because:
  - Climate is changing, so summer heat is becoming more of a problem – when heat from equipment adds to discomfort and cooling requirements
  - Low carbon, high efficiency heating solutions are far more efficient ways of providing heat than waste heat from inefficient appliances
- A shift from heat and electricity generated from fossil fuels to renewable energy-sourced electricity for transport, as well as residential, business and industrial activity, is seen by many as an important means of shifting to a low or zero carbon economy. This also has implications for the feasibility of shifting to heat pumps for district energy, or alternatives to district energy systems. In addition to Building Integrated PV, other renewable electricity options could include:

- The nearby hydro-electricity plant provides large amounts of renewable electricity. However, climate change may reduce snow melt, which may reduce output and, at present, around 85% of its output is allocated to the nearby aluminium smelter. Over 70% of the region's electricity is used by the smelter. Further, if the smelter switches to inert anode technology, its electricity consumption per tonne of aluminium will increase by up to 20% as electricity replaces the fossil fuels used to produce carbon anodes. In coming years, it will be relevant to evaluate the highest value uses for the electricity from this plant. What activities will deliver the most jobs and the greatest economic output per kilowatt-hour of electricity from this system? The services sector can contribute 10 times as much to GDP per unit of energy consumed, and it is far more employment intensive than metal production. To what extent will use of its excess generating capacity (6,000 megawatts peak capacity, compared with around 2,200 MW average output) be important to maintain reliable services for the community and businesses at times of peak electricity demand? Aluminium smelting may not rate as high as other uses in the long term.

- Run of river energy production from river currents or small hydro-electric generation systems on the river. This option has not been investigated in this review, but an indicative calculation suggests that a run of river 12 metre diameter turbine similar to a wind generator but under water, in a 5 metre/second current, could generate around 0.5 Megawatts of electricity. Energy available from a small hydro unit would depend on the head (height between collection and release of water) and flow rate.

- Efficiency of existing hydro generation systems may be improved through redesign of inlets and outlets, and higher efficiency generators and turbines

There may be potential to produce more hydro-electricity within the region, depending on access to suitable resources

APPENDIX D: COMMENTS ON FEASIBILITY STUDY RELEVANT TO BUILDING AND AREA ENERGY MANAGEMENT SYSTEMS

Area Energy Management Systems and options have been described in detail by Nikken Sekkei (N-S) in their report. The report's recommendations are generally supported by the Review. However, some comments outlined below may influence response to their recommendations, or underpin additional recommendations.

- More emphasis on the potential roles of 'behind the meter' innovation and its implications for design and operation of future energy systems could build a stronger case for development of Area Energy Management Systems
- The development of skilled, trusted supply chains and knowledge among energy users is important to underpin transition. This requires substantial resources, and is likely to involve a broader range of businesses than those traditionally involved in energy. Further discussion of how these sectors and related policy agencies and business associations could be engaged would be useful
- Motivating consumers, existing energy businesses and utilities to change from a 'top-down' centralised culture to distributed, diversified models is a major challenge that must factor in local circumstances. This needs more discussion. Local processes are likely to be needed to develop suitable approaches within the local circumstances and conditions.

CONTEXT FOR DEVELOPMENT AND INTRODUCTION OF AREA ENERGY MANAGEMENT SYSTEMS

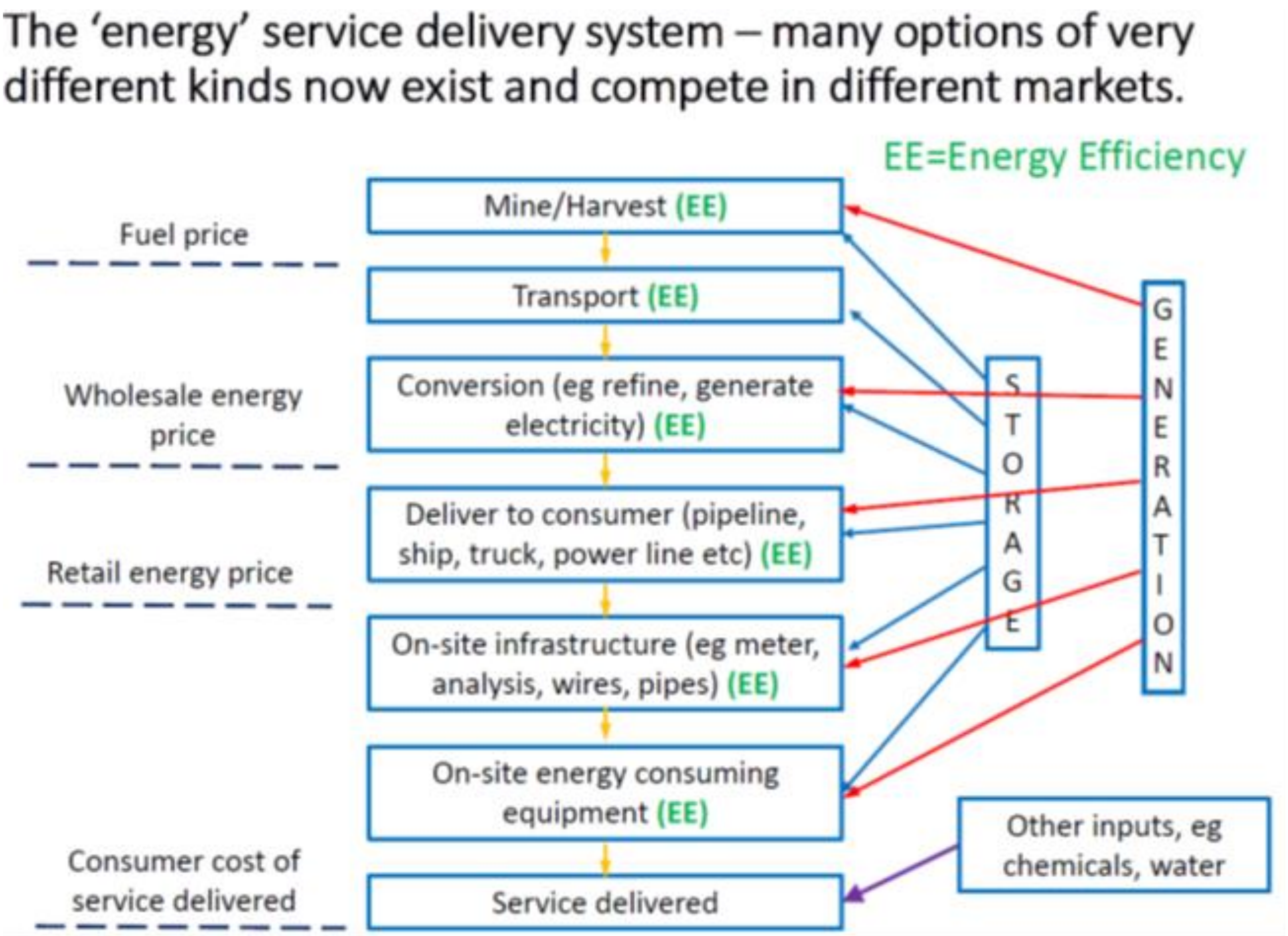
Rapid expansion of communications technologies and networks, with more flexible, modular technologies, are driving disruptive change across the global economy. This has major implications for energy (see Figure 1) as the energy system becomes much more diverse and decentralised. But the changes flow across all aspects of the economy and our lives. Indeed, energy management systems can be seen as a subset of broader systems that support improved solutions for access to services such as information, entertainment, health care, personal security, etc as well as optimisation of provision of services.

There is no doubt that 'smart' energy solutions will play an increasingly significant role in energy for all sectors of the economy. Failure to manage development and application of these solutions will potentially lead to confusion and financial waste as innovators move to capture market shares without appropriate standardisation or protection of consumer rights.

The disruptive changes in energy will involve major cultural and institutional changes, as transition drives a shift from centralised, 'top-down' control driven by a small number of large and powerful organisations with access to capital and political influence. The new model (see Figure 1) will require coordination, high quality information and new options for financing. It will be driven by many players, each responding to their own agendas, pursuing opportunities and seeking benefits. Emphasis will shift from large scale supply of energy, although that will still be important, to much greater focus on delivery of 'useful services' to household, business and industrial consumers through more complex supply chains more like the present appliance industry and service businesses than traditional energy utilities.

Traditionally, energy demand has been viewed as 'an insatiable, ever-growing monster that must be satisfied'. But, with today's technologies, each decision about buying an appliance, constructing a building or establishing an industrial facility involves decisions that could reduce demand for energy, shift requirements to different energy sources, or include on-site or local energy production. It could also include capability to manage demand to match variable energy supply.

Figure D.1. The modern energy system



Source: from presentation "Our efficient, smart, flexible, distributed and diverse energy future" by Alan Pears to APEC Energy Ministers at October 2015 meeting in Cebu-Mactan, Philippines. http://www.environment.gov.au/submissions/nem-review/pears.pdf

So the future level of demand, and its nature, are uncertain. For example, in Australia's main energy market, demand has fallen by over 10% since 2010, after many decades of ongoing growth. This makes investments in large projects that take years to complete much more risky: by the time they are operating, they may not have customers. In turn, this means investors are increasingly reluctant to support large projects. In Australia, the focus of electricity supply has shifted from 'base load' to 'dispatchable' generation and demand management, so demand and supply can both be managed and matched. No new large power stations are planned. Energy planning is now focused on much more detailed data collection, modelling of demand trends, new business models that match demand and supply, and a diverse range of energy supply and energy storage projects.

Economies of scale now come from mass production of modular products, not ever-larger centralised plant. This approach means that rates of innovation are accelerating, because of 'learning by doing' and ongoing refinement of products. Risk is reduced because the rate of installation of new energy equipment can be varied to match changing circumstances.

At the same time, the supply chains, financing mechanisms, knowledge and skills to drive emerging energy solutions are in their early stages of development. So there is confusion and conflict, and mistakes are made – and lessons learned.

AREA ENERGY MANAGEMENT SYSTEMS ISSUES AND OPPORTUNITIES

As N-S state in their report:

"Area energy management system (AEMS) is such an information based management system that can collect information of both demand side and supply side, analyse and manage to realize an optimal operation."
The N-S report provides a detailed explanation and discussion of Area and Building Energy Management Systems, and proposes a phased approach to implementation. It also provides some useful case studies. It notes that a sophisticated AEMS has been incorporated into the new housing development by Monolith Holdings and their partners. This provides a valuable basis for 'learning by doing' in application of energy management systems.

An essential first stage is to establish a project team that can research options for practical application of BEMS and AEMS in Krasnoyarsk. A number of local factors must be addressed, and approaches used elsewhere will need to be adapted to take advantage of local opportunities and circumstances:

- Rapid change in technologies and efficiencies of appliances, equipment, buildings and industrial processes means that traditional energy modelling based on incremental change and 'top-down' modelling based on population trends and energy intensity of economic development are no longer adequate. 'Bottom-up' modelling based on trends in energy service requirements (e.g. comfort, cleaning, food preservation, etc.) is now essential if over-investment in energy supply infrastructure is to be avoided and opportunities from emerging energy solutions are to be captured. 'Bottom-up' modelling requires much more detailed data on end user behaviours, technologies and energy use.
- Energy Management Systems and related software and business models are evolving rapidly, so it is important to avoid proprietary software and hardware, and to develop suitable communication protocols. For example, in Australia, firms such as Greensync are developing platforms that can work with almost any consumer-based software and hardware, including demand management, energy storage and on-site renewable energy, and can aggregate consumer data to a level suitable for use by large energy utilities. Other companies are developing software that allows individual consumers to trade electricity with each other and manage their demand.
- Energy Management Systems help to optimise energy systems but, where energy pricing does not reflect real time supply costs and energy prices are subsidised, their capacity to attract consumer interest may be limited. Russian energy prices typically do not seem to reflect costs, and pricing structures may not support actions that reduce the need for investment in energy supply infrastructure. So there may be a need for development and application of methodologies that identify the savings for governments through reductions in subsidies and provide price signals, incentives or policies to support emerging energy solutions. There may also be a case for redesign of business and industrial energy pricing to better reflect real costs and provide incentives for change: energy pricing and policy changes for businesses do not have to consider equity, health and other issues that could impact on some vulnerable households if changes were made to pricing of household energy.
- Adoption of Energy Management Systems may be faster if they are packaged with other useful services such as personal security, traffic management, etc.

The Table below, from the N-S report, shows a number of issues relevant to energy management:

- Over half of annual electricity use is by non-industrial consumers, presumably the commercial/services sector. Winter electricity use (Jan) is over three times summer use (June). This is unusually high winter consumption for these types of businesses, potentially due to high heating electricity use, despite the availability of District Heating. Improved on-site energy efficiency, connection to district energy systems or other strategies may have a large impact on their energy use.
- Population electricity use, presumably household usage, is 1226 kilowatt-hours per person per year. While this is slightly lower than in many developed countries, most Krasnoyarsk households source most of their space and water heating from the district heating system. So appliance and lighting usage may be unnecessarily wasteful. Winter average household consumption is 34% higher than summer at

present, but this may blur a wide range of situations. Growing numbers of air conditioners could shift the balance towards higher summer usage, and especially higher summer peaks. Planning should aim to avoid problems due to such a shift.

Figure D.2: Electricity consumption in Krasnoyarsk, excluding aluminium smelter

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

Groups of consumers (without 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

Note: Aluminium smelter consumption is 17,134,777 MWh pa.

'BEHIND THE METER' ACTION AND SURPRISES

The culture and institutional capacity necessary to drive strong action on energy efficiency, demand management, energy storage, renewable energy and smart energy systems on the consumer side of the meter is very different from traditional 'top down' energy (and most other areas such as urban planning) policy and strategy. Yet success here is essential if the benefits of AEMS are to be captured.

At the same time, it is here that the scope for very large reductions in energy consumption over relatively short periods exists. Heat pumps for space and water heating can cut energy use by two-thirds or more relative to resistive electric equipment. The best new televisions use less than a quarter as much electricity as older (and smaller) flat screen TVs. Tablet and laptop computers use 90% less electricity than older desktop machines. LED lighting cuts fluorescent lamp energy use by more than half. High efficiency motors with variable speed drives running high efficiency pumps and fans using smart controls can cut electricity use by 70%. Process technologies like micro-filtration, heat pumps recovering and upgrading the temperature of 'waste' heat, and 3-D printing are transforming industrial energy use and business models.

On-site energy storage reduces vulnerability to energy supply system failures and increases flexibility of management. Advanced data analytics and machine learning (where intense data collection and advanced analysis identify emerging faults and optimise performance) improve product quality and avoid costly production shut-downs. These solutions are, in many cases, being adopted because they work better, or are cheaper. They deliver the services that households and businesses really want, with better outcomes, while using a lot less energy.

Climate change and the policies needed to respond to it will also drive accelerating change. As the multiple impacts of climate change become more visible to the community, pressures for change will increase. Jobs in some areas like mining will be lost, but they will be replaced by new businesses that will create many more jobs with a much broader range of skill requirements and locations, and which have much reduced impacts on worker and community health.

Energy policy analysts who fail to look beyond the energy aspects of service provision will continue to be surprised by dramatic changes in energy use, changes in consumer expectations, and emerging businesses that disrupt the energy industry. Krasnoyarsk policy makers, academics and businesses need to understand the changes, develop response strategies, and show leadership. This will not be easy. Many just want things to 'stay the same': but trying to maintain business as usual is now the more risky path, even though disruptive change is also risky. As many large energy utilities and fossil fuel businesses in Europe, America and Asia are now discovering, failure to move with the tide of change leads to loss of asset value, declining profits – and management changes.

APPENDIX E: COMMENTS ON EDUCATION AND MANAGEMENT

Relevant to recommendation 65.

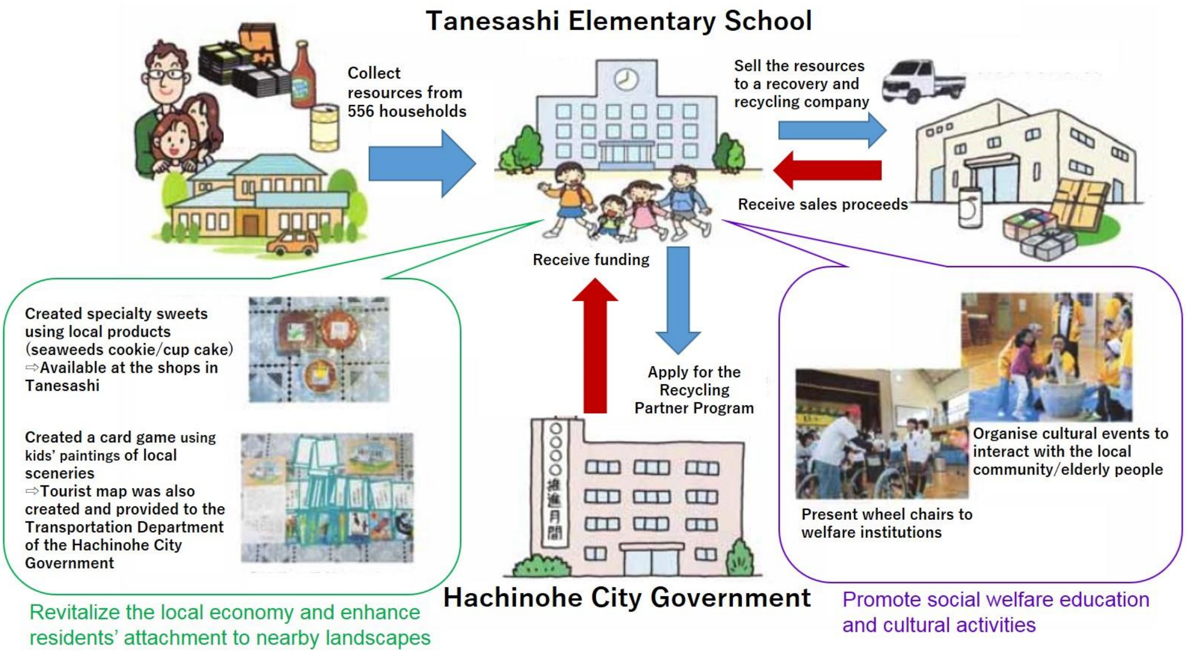
Tanesashi Elementary School in Hachinohe City, Aomori Prefecture, Japan won the Prime Minister's Prize of the 3Rs Promotion Merit Awards in FY2017 (Tanesashi Elementary School, 2017). The awards program has been held annually since 1992 to recognise individuals, groups, schools, enterprises, and other entities for their outstanding levels of unique, community-based, and pioneering contributions to promoting the 3Rs, thereby encouraging the development of further activities to this end. The program is hosted by the 3Rs Promotion Council and supported by seven related ministries, including Ministry of Economy, Trade and Industry (METI). Tanesashi elementary school has developed four main activities such as: cleaning the nearby coast; recycling resources collection from surrounding households; Zero day activity on 10th, 20th and 30th every month (cleaning on the way to school); and composting of sea urchin shells. They applied for Hachinohe City's Recycling Partner Program which provides subsidy for groups such as neighbourhood association, children's club, parent-teacher association (PTA), women associations, elderly groups, etc. The registered recycling partners collect resources from households in Hachinohe City based on five categories: paper (newspaper, cardboard and other paper materials), metal (steel can, aluminium can and other metallic materials); bottles; used clothes; and plastics. Tanesashi elementary school has only 20 kids and 19 PTA members, but collect resources from 556 households in four towns, then separate and sell them to a recovery and recycling company. The city's subsidies are paid twice a year depending on the volume of resources they collected (JPY 3 (RUB 1.5) per kg). As the school is facing the sea coast which produces sea urchin, the children learn how to make fertilizer from sea urchin shells and use it for growing vegetables in the school garden. Those activities are successful in connecting school, home and community. Involvement of parents is especially important to encourage behavioral change in daily life. Their 3R activities are exercised as a part of environmental education, but also contribute to vitalise the community and welfare education in super aging society in Japan.

Figure E.1: Educational activities: zero day activity and cleaning a coast

Sources: Tanesashi Elementary School

In Japan, METI started Energy Education Model School Program in FY2014 to promote energy education. It is intended to encourage children/students to learn energy through subjects (Science, Social Studies, Technical Course, Home Economics, Integrated Studies, etc.) in classroom and extra-curricular activities so that they will have knowledge to make appropriate decisions and take necessary actions for the energy issues in the future. Thirty schools including elementary schools, junior high schools and high schools are selected as the model school. The model schools will receive support fund which can be used for education activities such as honorarium and transportation fee for inviting experts as a lecturer, transportation fee to visit energy related facilities, expenses for making teaching materials and purchasing books, experimental equipment, etc. There're also opportunities to exchange experiences with other model schools (ANRE, 2018). On its website, textbooks, teaching materials, experiences of model schools, etc. are available. The below table shows the examples of the keywords covered in the subjects of elementary/junior high schools (Japanese compulsory education is nine years).

Figure E.2: Environmental educational at Tanesashi Elementary School



Sources: Tanesashi Elementary School

Table E.1: Environmental keywords in the subjects of elementary and junior high school programmes

Elementary School		
Subject	Grade and Unit	Keywords
Science	4th Grade: Functions of electricity	Renewable Energy (solar, wind, etc.)
	6th Grade: Mechanism of combustion Power generation and utilisation	Carbon dioxide, fossil fuels, global warming, electric energy, various power generation methods and advantages and disadvantages of each power generation method
Social Studies	4th Grade: Comfortable living	Journey of electricity and gas, economical use of resources, waste management
	6th Grade: Economical use of electricity	Power generation and storage (hand crank generator, capacitor, photocell), experiment of bicycle power generation
Home Economics	5th and 6th grades: Consumption habits and surrounding environment	Energy saving, 3R (Reduce, Reuse, Recycle), local production for local consumption, food mileage
Junior High School		
Subject	Grade and Unit	Keywords
Science	Physics and Chemistry: Current of electricity and its utilisation	Life and electric energy, energy conversion, power generation and power transmission
	Biology and Geology: Science technology and human being	Various power generation methods and their advantages and disadvantages, nuclear power generation and radiation
Social Studies	Geography: Resources, energy and industry	Fossil fuels, energy self-sufficiency rate, power generation methods in the world, shale revolution
	History: Industrial revolution and modernisation of Japan	Modern industry and energy (coal, iron ore), pollution problems
	Civics: Resources and energy issues	Japan and world energy situation, Paris agreement, liberalisation of electricity and gas
Technical Course/ Home Economics	Technical Course: Energy conversion and utilisation	Technologies of LED (light-emitting diode), motor, power generation, power transmission, etc., manufacturing, maintenance and check-up
	Home Economics: Our consumption habits and environment	Economical use of resources (5R (Reduce, Reuse, Recycle, Repair, Refuse), Eco cooking), merits of fossil fuels

Source: Energy Model school

Relevant to recommendation 66.

Funabashi Morino City, Chiba Prefecture in Japan, which is a project developed by Funabashi City, Nomura Real Estate Development Co., Ltd. and Mitsubishi Corporation, was awarded ÉcoQuartier (eco-district certification) from the French government (NOMURA REAL ESTATE DEVELOPMENT). Their participatory community-building approach together with its advanced environmental technologies and low-carbon infrastructure were highly acclaimed. In 2013, the project owners called residents and businesses in the community to establish Morino City Town Association as a platform to discuss the development of the community. Over 90% of the residents have joined the association. The main activities of the association reflect the priorities and needs of all the residents. Many programs have been implemented by the initiative of the members by forming bonds and work together for the improvement of the community such as neighbourhood beautification, disaster defence, summer festival, cultural activities, etc.

The Morino City Community Building Association was established to provide the residents and corporations a platform for discussing community development. The main activities of the Association are those that are essential to all residents, such as neighbourhood beautification and disaster defence. Over 90% of the residents have joined the Association. The Council has been operated independently by the members after receiving support from project owners for three years. In 2015, the third year of its establishment, the Council was registered as a residents' association of Funabashi City at the proposal of the residents. Many programs have been implemented at the initiative of the members.

Figure E.3: Funabashi Morino City case study

Note: emergency drill (top left), Greening and cleaning activities (top right), Summer festival (bottom left) and Forest City Big Band (bottom right).

Source: NOMURA REAL ESTATE DEVELOPMENT Co., Ltd.

<u>Relevant to recommendation 67.</u>

For example, Kitakyushu City, Fukuoka Prefecture, Japan designed a bear mascot named TEITAN. In Japanese, TEITANSO means low-carbon, TEITAN sounds like the abbreviation of low-carbonization. In 2011, Kitakyushu city government called on the citizens to design a mascot character of white bear (symbol of victims of global warming) for enhancing the environmental consciousness of the citizen. The selection committee chose six candidate characters designed by the citizens and they put voting box in department stores and government offices. There were 4,517 votes from the citizens in total (population in Kitakyushu City in 2011 is 974,287) and TEITAN was chosen by 37% of the voters. TEITAN was designed by a student of Nishinippon Institute of

Technology in Fukuoka Prefecture. The nose and mouth of TEITAN expressed with a combination of Japanese character 'エコ' which means 'eco' and it wears a scarf with the motif of sunflower which is the flower of Kitakyushu City on its neck. In 2014, a friend of TEITAN named Black TEITAN was also born. At first, Black TEITAN's nose and mouth were 'エゴ' which means 'ego (egoistic)' in Japanese, but in 2016, Black TEITAN passed the Kitakyushu City World Environmental Capital Examination, now its nose was changed to 'エコ (eco)'.

Figure E.4: Kitakyushu Ecolife case study

Note: characters TEITAN and Black TEITAN (top left), Environmental events held by Kitakyushu Ecolife Executive Committee (top right), Examination poster (bottom left) and Examination room (bottom right)

Sources: City of Kitakyushu

Kitakyushu City created the Kitakyushu City World Environmental Capital Examination in 2008 for the citizens to learn about the city and its environment in an enjoyable manner. Anyone can take the exam being held once a year with free of charge and textbook is also available (City of Kitakyushu, 2009). Kitakyushu City is one of the leading environmentally conscious city in Japan as it has experiences of serious pollution problems caused by industrial wastewater and air pollution in the 1960s. The city worked very hard together with the private sector and the citizens to improve pollution control measures, 3R activities and energy-efficiency technologies, etc. The city was selected as an Eco-Model City in 2008 and a Future City in 2011 (both are environmental city award programs by the Japanese government).

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