CHEMICAL ENGINEERING TRANSACTIONS
VOL. 70, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Timothy G. Walmsley, Petar S. Varbanov, Rongxin Su, Jiří J. Klemeš

ISBN 978-88-95608-67-9; **ISSN** 2283-9216
DOI: 10.3303/CET1870167

Assessment of Alternative and Local Energy Resources Potential of the Tomsk Region

Alexandr V. Dmitriev*, Ekaterina A. Kupressova, Sergey V. Romanenko

INO Tomsk Centre for Resource Saving and Energy Efficiency, Belinskogo Street, 51, Tomsk, Russian Federation, 634034
dmitriev777@mail.ru

There is a significant number of decentralized energy sources in the energy system of the Tomsk region (Russia). Heat supply sources are represented by boiler houses on solid (coal, wood, chips) and liquid fuel (oil). Besides technical factors, such as high percentage of wear of equipment used for power supply, low efficiency of energy production, loss of heat energy in transfer, there are important economic problem in the decentralized energy producing in the Tomsk region.
High cost of fuel transportation to remote settlements determines high tariffs for heat and electricity supply, which makes it necessary to provide subsidies for the population. A decision system has been developed to switch decentralized heat sources with low energy consumption to local and renewable fuels in the region. The scheme takes into account the practical use of long-term studies of local and renewable energy sources potential in the Tomsk region. Results of the work of scientists and the Administration of the Tomsk Region are presented in Geo-information system (2018). Pollutants emission into atmosphere (including greenhouse gas) are one of important indicators for energy and decision-making policy (Klemeš et al., 2017a). In this way, key objects for modernization and key types of fuel for new / modernized decentralized heat supply sources of low power are determined.

1. Introduction

Tomsk Region is a constituent entity of Russian Federation, part of the Siberian Federal District, occupying 314,400 km^2 (1.8 % of the Russian Federation territory). The size from North to South is about 600 km, from West to East - 780 km. The population of Tomsk Region as of 1 January 2017, is 1,078,891 people (0.7 % of the population of Russian Federation). Urban population accounts for 72.3 %. Tomsk Region consists of 4 urban districts (Tomsk, Strezhevoy, Kedrovy and closed administrative-territorial formation Seversk), 16 municipal entities (districts) including 3 urban and 115 rural settlements, 578 villages (City Population, 2017).
Tomsk Region almost entirely lies within the taiga zone. It has moderately continental cyclic climate with large diurnal and annual temperature ranges and a long winter season.
Mean annual temperature is +1.75 °C, the average temperature in July is +19.4 °C, the average temperature in January is – 19 - 21 °C. The frost-free season lasts 100 - 105 d. Mean annual precipitation is 435 mm. Forests cover 60 % of the territory of Tomsk Region.
Commercial forests occupy most of the forested area of the region. Valuable softwood species such as Siberian pine (Pinus sibirica), Scots pine (Pinus sylvestris), spruce, fir, and larch account for a half of the commercial forest stand.
Tomsk Region is rich in mineral deposits and raw materials. About half of the oil and gas reserves are proven. Tomsk Region has the second largest peat reserves in Russia. Potential hydrocarbons in place are 5.47 10^9 t and peat 28.7 10^9 t (Tomsk Region Administration, 2018).
Tomsk Region has a significant number of settlements with the decentralized electricity supply and heat supply zones from non-cogeneration sources (heat plant and power plant). Decentralized electricity supply to remote settlements, located mostly in the northeast of the Tomsk region, is carried out by 25 diesel power plants (DPP). DPP provide electricity to consumers from 32 settlements with a population of several dozen to several thousand inhabitants in 7 districts of the region.

Please cite this article as: Dmitriev A.V., Kupressova E.A., Romanenko S.V., 2018, Assessment of alternative and local energy resources potential of the tomsk region , Chemical Engineering Transactions, 70, 997-1002 DOI:10.3303/CET1870167

Heat supply is provided by more than 470 heat plants using solid and liquid fuel, and also natural gas with an annual output of 3.84 TWh, which is more than 30 % of the total heat production by all heat sources of the Tomsk region. This volume is sufficient to provide electricity and heat supply in different seasons, including during periods of peak loads. This volume is sufficient to provide electricity and heat supply in different seasons, including periods of peak loads.

Table 1: Existing municipal sources of energy in Tomsk Region

Districts	Power supply by DPP		Heat supply	
	Number of settlements	The total power of sources, MWh	Number of settlements	The total power of sources, MWh
Aleksandovskiy district	3	1.5898	5	71.57
Asinovskiy district	1	0.18	14	101.5
Bakcharskiy district	-	-	11	29.66
Chainskiy district	-	-	20	38.66
Kargasokskiy district	9	4.928	16	54.45
Kedrovyy city	-	-	3	29.9
Kolpashevskiy district	4	1.144	11	96.32
Kozhevnikovskiy district	-	-	23	38.57
Krivosheinskiy district	-	-	13	23.95
Molchanovskiy district	1	0.476	9	24.06
Parabelskiy district	1	2.230	9	24.98
Pervomayskiy district	-	-	17	29.41
Shegarskiy district	-	-	14	51.68
Strezhevoy city	-	-	1	352.39
Teguldetskiy district	-	-	6	16.01
Tomskiy district	-	-	47	233.6
Verkhneketskiy district	6	5.144	9	37.94
Zyryanskiy district	-	-	16	32.46

Despite the solid reserves of oil and gas, the prospects for using renewable energy sources in the Tomsk Region are determined by a number of objective factors:

- Technical factors: a high percentage of wear of equipment used for power supply, low efficiency of energy production, loss of heat energy in transfer;
- Economic factors: high tariffs for electric and heat energy in individual settlements due to their remote location. The main share of tariffs in these settlements is due to the high cost of fuel transportation. Currently, tariffs for electricity reach 70 RUB/kWh. For the population the fixed cost of electric energy is established: for the period 01.01.2018 - 30.06.2018 it is equal to 3.25 RUB, for the period 01.07.2018 - 31.12.2018 - 3.36 RUB (Map of tariffs for population, 2018). The difference in payments to resource-supporting organizations compensated from the regional budget. Currently, the amount of compensation for the costs of organizing electricity from diesel power plants is more than 250,000 RUB/y, and compensation for the cost of organizing heat supply by use oil – more than 100,000 RUB/y (Tomsk, 2018a).
- Environmental factors: significant emissions of pollutants into the atmosphere during the combustion of hydrocarbon fuels.

2. Investigation of the potential of local, including renewable, energy resources of Tomsk Region

The potential of local, including renewable, energy resources have been investigated for more than 15 y. The research on the potential of renewable energy sources has been conducted on wind energy; hydropower resources; solar energy; geothermal energy; logging waste and waste from timber processing.

Between years 2013-2015 research into the use of renewable and local energy sources was performed by the Tomsk Centre of Resource Saving and Energy Efficiency – the Regional Centre of Competence in Resource Saving and Energy Efficiency in conjunction with the Tomsk scientific, educational and expert organizations:

- Research on the potential for using biomass (waste from breweries (bard), sewage treatment plants (silt), poultry farms, livestock complexes, agricultural enterprises, etc.) in conjunction with the Institute for Monitoring of Climate and Ecological Systems of the SB RAS - Report on the conduct of research work (Tomsk, 2013);

- Research of the potential for peat use as an energy resource in the Tomsk region (field research and laboratory tests were conducted at nine fields). A feasibility study for the implementation of the project using the peat from the Temnoye field was developed together with the Siberian Research Institute of Agriculture and Peat, a branch of the Siberian Federal Scientific Centre of Agro-Bio Technologies of the Russian Academy of Sciences (Tomsk ,2014a);
- Research of the prospect of using geothermal waters of the Tomsk region, including work with stock materials and full-scale examination of some wells (Tomsk, 2014b).

3. Practical use of the investigation of the potential of local, including renewable, energy resources of Tomsk Region

The purpose of those research projects was to justify management decisions about priority technologies and types of fuel that should be taken as a basis for making technological decisions on modernisation or new construction of heat plants and DPP in the Tomsk region, which has to be subsequently included in the strategic development programs of the region (Figure 1).

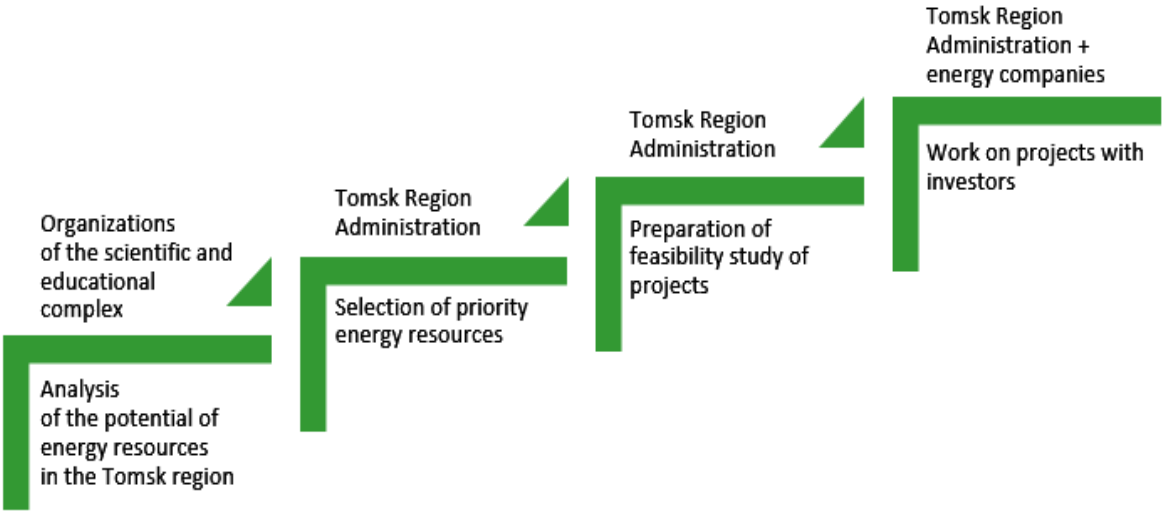

Figure 1: Scheme of interaction in the preparation of projects for the modernization of energy sources

The main technologies for the modernisation of the DPP have been selected as follows:

- Synthesis gas production from wood chips for the production of electric power (gas-generating sets);
- Generation of electric power by means of reciprocating gas generators;
- Cogeneration based on high-tech thermal mini power plants (mini-TPP) using wood chips as fuel;
- Generation of electric power by means of a hybrid diesel-solar power plants.

The main types of fuel proposed for the modernization or for new construction of boiler plants have been:

- Wood chips;
- Wood pellets;
- Natural gas.

Also, for the stand-alone facilities in the area of centralised heat supply, the use of low-potential ground heat through heat pumps has been selected.

To provide access to information on the potential of local energy resources and potential investment projects developed on the basis of these studies, the geo-information system Renewable Energy Sources in Tomsk Region (2018) was created and is publicly available (Figure 2).

1000

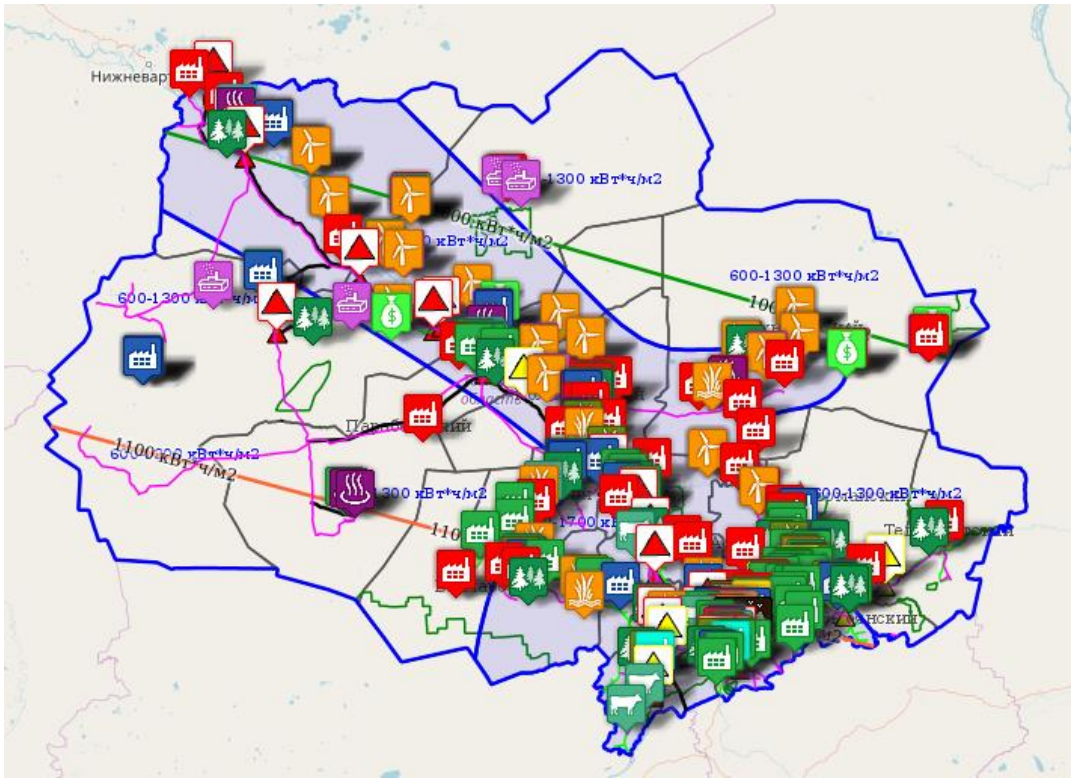

Figure 2: Geo-information system Renewable Energy Sources in Tomsk Region (2018)

Geo-information system is an interactive tool for working with potential investors and other interested parties.

4. Results and discussion

Systematic work has been carried out to implement these suggestions in practice. The state lead program "Improving Energy Efficiency in Tomsk Region" was developed and implemented. The program started the implementation of key projects for the modernisation of heat and power supply sources. Tomsk Centre for Resource Saving and Energy Efficiency was created within the framework of this program. The Centre participates in the preparation of projects for transferring energy sources to more effective.

There are pilot projects to convert boiler houses to wood chips and pellets have been implemented with the support of Tomsk Centre for Resource Saving and Energy Efficiency in Tomsk Region. For logging and timber processing areas, where the distance of delivery of fuel to the object is not more than 100 km, the priority fuel is wood chips. An example is the district centre of Verkhneketskiy district - Belyi Yar village. Currently, two out of six boiler houses (a total capacity of 3.5 MW) are transferred to wood chips. Project with the modernisation of the remaining four and construction of one new boiler house has been developed and its realization is planned in the near future, the approximate term – year 2020. This project will allow reducing SO_2 emissions by 1.5 times, ash and soot emissions – by 1.5 times, CO_2 emissions – by 2 times.

Table 2: Indicators of the project for the transfer of municipal boiler houses to wood chips

Settlements	Used fuel	SO_2 emissions, t/y	Ash and soot emissions t/y	CO_2 emissions, t/y	Planned fuel	SO_2 emissions, t/y	Ash and soot emissions, t/y	CO_2 emissions, t/y
Belyi Yar village	coal+ woods+ wood chips	49.04	232.90	11,313	wood chips	32.02	152.13	5,196

For objects that are located at a significant distance from logging and timber processing sites, wood pellets are the priority fuel for modernization. A plan for the transfer of more than 150 decentralized low-capacity boiler houses (0.3 MW) to wood pellets was developed. At present, these boiler houses are working on coal and oil. Transferring them to local fuel will allow not only to use logging waste and waste from timber processing and

reduce emissions of pollutants from fuel combustion but also to reduce the cost of fuel delivery, reduce the cost of the budget for compensation for the cost of organizing heat supply by use oil. The approximate term of the project – year 2022. Currently, more than 10 boiler houses on wood pellets function on the territory of the region. A state lead program "Improving Energy Efficiency in Tomsk Region" include gasification program in Tomsk region. This program provides for the transfer of more than 50 heat plants in district centres of Tomsk Region from liquid and solid fuels to gas (Tomsk, 2018b). There are the objects included in the gasification plan in Table 3.

Table 3: Plan for the transfer of municipal boiler houses to natural gas (Tomsk, 2017a; Tomsk, 2017b; Tomsk, 2018c; Tomsk, 2018d)

Settlements	Total power of existing sources, MWh	Used fuel, t			Current emissions, t		
		Oil	Coal	Wood	SO_2	Ash and soot	CO_2
Asino city	84.62	-	38,744	-	387	1,821	70,235
Podgornoe village	19.62	2,149	-		129	2,150	6,427
Teguldet village	9.06	63	3,114	934	150	211	6,866
Bakchar village	16.26	2,389	592	305	149	2,418	8,555
Pervomayskoe village	19.53	1,475	3,719	517	126	1,651	11,725
Zyryanskoe village	9.53	1,677	1,763	-	118	1,761	8,211
Total	158.62	7,753.42	9.188.97	1,755.25	1,059.76	10,011.32	112,019.76

Natural gas is used in those territories for which it is economically feasible to build gas pipelines or transport liquefied natural gas. Transfer of heat plants from liquid and solid fuels to gas allows reducing CO_2 emissions by almost 1.5 times: from 92,084 t/y to 64,648 t/y (except for Pervomayskoe village and Zyryanskoe village. Indicators of those planned sources should be calculated in the process of developing a heat supply scheme in years 2018 - 2019) and reduce close to zero SO_2, ash and soot emissions.
Heat pumps are installed in free-standing buildings (schools, kindergartens, shops, etc.) located in the places of accessible connection to electric power and lack of free capacities of the operating thermal generation in Tomsk and in the districts of Tomsk Region. Six objects in the social sphere, including kindergartens and schools (total capacity more than 600 kW) and more than eighteen objects in the consumption sphere (total capacity more than 1,150 kW) have been transferred use heat supply by heat pumps. Since the year 2014 in the Tomsk region produced heat pumps "ECO" developed by the company "ECOCLIMAT".

5. Conclusions

a) There is a decision-making system has been developed for the transfer of decentralized low-power heat supply sources to local and renewable fuels in the region.
b) The key types of fuel for new / modernized decentralized heat supply sources of low power are determined. The key objects for modernization have been identified.
c) Pilot projects have been implemented to transfer decentralized heat sources of low power to local and renewable fuels. The proposed project to convert boiler houses to wood chips and pellets allow to reduce SO_2 emissions by 1.5 times, ash and soot emissions – by 1.5 times, CO_2 emissions – by 2 times. The plan for the transfer of municipal boiler houses to natural gas allows to reduce CO_2 emissions by almost 1.5 times (from 92,084 t/y to 64,648 t/y) and reduce to zero SO_2, ash and soot emissions.
d) CO_2 emissions from the combustion of wood fuel (woods, wood chips, pellets) are included in the fast carbon cycle in contrast to CO_2 emissions from the combustion mineral fuels (oil, coal, gas) and do not affect the global carbon cycle. CO_2 emissions from the combustion of wood fuel should not be taken for the assessment of the impact of greenhouse gas emissions into the atmosphere.
e) Complex projects have been developed for the transfer of 150 decentralized heat sources of low power to local and renewable fuels. Projects for the modernization of DPP are being prepared.
f) There has been a need to further extend the research in energy saving and efficiency technologies exploiting the Process Integration (Klemeš et al., 2017), extended to Total Sites (Klemeš at al., 1997) and even Integrated Sustainable Regions (Perry at al., 2008). The future work has been directed to use the leading PI technologies in this direction.

Acknowledgements

The authors would like to express the gratitude for the funding from Tomsk Region Administration.

References

City Population, 2017, Tomsk Region, <https://www.citypopulation.de/php/russia-siberia-admin.php?adm1id=69>, accessed 21.01.2018.

Klemeš J., Dhole V.R., Raissi K., Perry S.J., Puigjaner L., 1997. Targeting and Design Methodology for Reduction of Fuel, Power and CO_2 on Total Sites. Applied Thermal Engineering, 17(8-10), 993 - 1003.

Klemeš J.J., Liu X., Varbanov P.S., 2017a, Virtual greenhouse gas and water footprints reduction: emissions, effluents and water flows embodied in international trade, Chemical Engineering Transactions, 56, 55-60 doi:10.3303/CET1756010.

Klemeš J.J., Varbanov P.S., Fan Y. V., Lam H.L., 2017b, Twenty Years of PRES: Past, Present and Future – Process Integration towards Sustainability, Chemical Engineering Transactions 61, 1 - 24, doi: 10.3303/CET1761001.

Liu X., Klemeš J.J., Čuček L., Varbanov P.S., Yang S.Y., Qian Y., 2015, Export-Import of Virtual Carbon Emissions and Water Flows Embodied in International Trade, Chemical Engineering Transactions, 45, 571-576.

Official Website of Tariff Regulation Department of Tomsk Region Administration, 2018, Map of tariffs for population, <rec.tomsk.gov.ru/map.html>, accessed 20.01.2018.

Official Website of Tomsk Region Administration, 2018, Overview, <https://en.tomsk.gov.ru/overview>, accessed 15.02.2018.

Perry S., Klemeš J., Bulatov I., 2008. Integrating Waste and Renewable Energy to reduce the Carbon Footprint of Locally Integrated Energy Sectors. Energy, 33(10), 1489-1497, DOI: 10.1016/j.energy.2008.03.008.

Renewable Energy Sources in Tomsk Region, 2018, Geo-information system, Renewable Energy Sources in Tomsk Region", <green.tsu.ru/tomres/>, accessed 20.01.2018.

Tomsk, 2013. Research on the potential for using biomass, 2013, Report on the conduct of research work Tomsk Centre of Resource Saving and Energy Efficiency, Institute for Monitoring of Climate and Ecological Systems of the SB Russian Academy of Sciences, Tomsk, Russian Federation.

Tomsk, 2014a. Research of the potential for peat use as an energy resource in the Tomsk region, 2014, Report on the conduct of research work, Tomsk Centre of Resource Saving and Energy Efficiency, Siberian Research Institute of Agriculture and Peat, Tomsk, Russian Federation.

Tomsk, 2014b. Report on the conduct of research work “Research of the prospect of using geothermal waters of the Tomsk region”, 2014, Report on the conduct of research work, Tomsk Centre of Resource Saving and Energy Efficiency, Tomsk, Russian Federation.

Tomsk, 2017a. Heat supply scheme of the Asinovskiy urban settlement of Asinovskiy district of Tomsk region for the period from 2013 to 2031. Update for 2017. <www.gorodasino.ru/files/normdoc_2017/shema_teplosnab_ 2017-1.rar>, accessed 20.01.2018.

Tomsk, 2017b. Heat supply scheme of the Podgornoe rural settlement of the Chainskiy district of the Tomsk region for the period from 2015 to 2031. Update for 2017. <www.podgorn.tomsk.ru/upload/files/norm_doc/2017/post/post_25.doc>, accessed 20.01.2018.

Tomsk, 2018a. Departmental target program of Tomsk Region "Providing assistance to individual municipal entities of the Tomsk region to ensure compliance with the balance of economic interests of consumers and suppliers of fuel and energy resources" <dgz.tomsk.gov.ru/file/download?id=819>, accessed 20.01.2018.

Tomsk, 2018b. State lead program of Tomsk Region "Improving Energy Efficiency in Tomsk Region" <tomsk.gov.ru/documents/front/view/id/16407>, accessed 20.01.2018.

Tomsk, 2018c. Heat supply scheme of Bakchar village of Bakcharskiy district of Tomsk region for the period up to 2032. Update for 2018. <www.spbakchar.tomsk.ru/files/2017/proj/proj.doc>, accessed 20.01.2018.

Tomsk, 2018d. Heat supply scheme of Teguldetskoe village of Teguldetskiy district of Tomsk region for the period up to 2032. Update for 2018. <tegsp.tomsk.ru/files/GKX/pril%202.pdf>, accessed 20.01.2018.