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New technology adoption for Russian energy generation: What does it cost? A case study for Moscow ☆

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HIGHLIGHTS

- Power generation cost is modelled for a Russian region under two gas price scenarios.
- Conventional, new and renewable technologies are compared based on levelised cost.
- Regional energy system is shown to be crucially dependent on natural gas prices.
- We conclude that new gas-fired technology adoption is feasible and cost-competitive.
- Biomass demonstrates cost competitiveness, whereas solar appears infeasible.

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ABSTRACT

Russia is frequently referred to as a country with substantial energy efficiency and renewable energy potential. In 2000–2008 energy-gross domestic product (GDP) ratios were improved by 35%, however, the contribution of technological progress accounts for only 1% of the energy-GDP ratio reduction. At the same time, although new policy mechanisms to stimulate renewable energy development have been recently introduced, renewable technology deployment has not yet taken off. Economic theory suggests that there is no better incentive for industry development than cost signals. This paper adapts the levelised cost of energy methodology to examine the cost structures associated with electricity generation by conventional and new technology types for a Russian region (Moscow). The model, run for two fuel price scenarios, allowed us to conclude that the regional energy supply system is heavily dependent on the natural gas price and that the diversification provided by technology development will be beneficial for the energy security of the region. We conclude that new and renewable technologies become cost-effective for electricity generation as domestic natural gas prices reach parity with export prices. However, strong political and financial support is needed to boost technological development and renewables application in Russia.

1. Introduction

Russia is a country with substantial energy efficiency (EE) potential, estimated as 45% of primary energy use, as well as carbon emissions reduction potential, estimated as 793 million tons of CO_2 or approximately 2.9% of global energy-related CO_2 emissions [1]. Although Russia has shown an improvement in decreasing energy intensity over the last decade – energy-GDP ratios were improved by 35% between 2000 and 2008 [2,3], this was mainly due to structural changes in the economy and growth in the service sectors rather than industry. The contribution of technological progress is estimated to account for only 1% of the energy-GDP ratio improvement in Russia [4]. The current value of energy-GDP ratio is still 2.5–3 times higher than in developed countries [2,3,5,6].

Electricity generation in Russia is mostly provided by thermal (including cogeneration) plants which account for 69% of electricity. Large hydroelectric plants contribute approximately 21% of total electricity generated and nuclear plants provide up to 10% of power [7]. However, the existing share of renewable energy source (RES) electricity generation in Russia (excluding large hydroelectric plants) is estimated at between 0.1% [8] and 0.5%

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Nomenclature

CO_2	carbon dioxide
Aux_j	auxilary energy use
B	equity beta
$Capex(t)_j$	capital costs
CF_j	capacity factor
$CM(t)_j$	technology depletion costs
D/V	debt capital share
E/V	equity capital share
$FC(t)_j$	fuel price
$FOM(t)_j$	fixed operating and maintenance costs
$FOM(t)_j$	fixed operating and maintenance costs
$Fuel(t)_j$	fuel cost
HR_j	heat rate
$I(t)_C$	growth parameters separately for cost flow
$I(t)_R$	growth parameters separately for revenue flow
$LCOE_j$	levelised cost of power generation
m^3	square meter
R_c	country risk
R_d	cost of debt
R_e	cost of equity
R_f	risk free rate of return
R_m	market rate of return
$size_j$	plant size (installed capacity)
$SO(t)_j$	sent out power
$SOR(t)_j$	revenue flow from energy production
T	tax rate
$TOC(t)_j$	total operating costs
VOC_j	variable operating and maintenance costs per MW
$VOM(t)_j$	variable operating and maintenance costs
$WACC$	weighted average cost of capital
$WACC_{Post\text{-}TaxNominal}$	post tax nominal WACC
$WACC_{Post\text{-}TaxReal}$	post tax real WACC
N	operating lifetime
R	revenue flow
T	time period

Subscripts

C	cost flow
J	technology type

Abbreviations

CAPM	Capital Asset Pricing Model
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CF	capacity factor
CPI	consumer price index
EE	energy efficiency
FOM	fixed O&M costs
FSSS	Federal State Statistics Service
GDP	gross domestic product
GJ	gigajoule
GRES	condenser type electricity thermal power station (from Russian: «ГРЭС»)
IEA	International Energy Association
kW	Kilowatt
LCOE	levelised cost of energy generation
MW	Megawatt
MW h	megawatt-hour
O&M	operating and maintenance
OECD	Organisation for Economic Co-operation and Development
OGK	power generating company on the wholesale energy market (from Russian: «ОГК»)
pa	per annum
PCC	pulverized coal combustion
PV	photovoltaic
RES	renewable energy source
RUR	Russian roubles
SC	supercritical
USC	ultra supercritical
USD	US dollars
VOM	variable O&M costs

[9]. However, RES resources in Russia are large and diverse, with a recognized volume of approximately 30% of Russia's primary energy supply [9,10].

Understanding the identified EE potential, improvement in EE was made a national goal initially targeting a 40% reduction in energy intensity by 2020 [2,3] and later reduced to 13% [11]. Improvement in energy generating technology and adoption of RES technology were identified as the key to achieve the goal. Current regulation sets national targets in RES development as shares: for 2015 – 2.5%; and for 2020 – 4.5%, excluding large hydroelectricity producers [12].

Future economic development of the country is reliant on the realisation of the EE potential that the national economy is "pregnant with" [4–6]. A boost of RES deployment in the country is crucial [9,13]. The conundrum for industry and policy makers is how to stimulate technological development and RES deployment in the Russian energy sector [5,6].

In addressing this problem, this paper relies on economic theory suggesting that an effective incentive for industry development is a reduction in costs. We apply a cost of energy modelling tool – levelised cost of energy generation (LCOE) which allows a comparison of new energy generating technology cost with conventional electricity generation. This paper therefore addresses issues of technology deployment feasibility for Russia to determine the cost competitiveness of new and renewable electricity generation. Specifically, the Moscow case study provides an insight into electricity generation costs for region specific economic and industrial conditions.

Moscow, the most populated region in Russia, with a large metropolitan area and substantial energy consumption is the case study. It accounts for 0.015% of land area and 8.3% of the population of Russia [14]. Moscow Region energy consumption accounts for 11.7% of Russian total energy consumption [15,16]. As compared to power generation in Russia, on average 97% of electricity in the Moscow and Moscow Region is supplied by thermal power stations of different types [15,16]. Moscow as a case study is particularly interesting as it raises issues about the energy supply system which could be encountered by megacities in other countries.

However, the issues raised in this paper go beyond the Russian regional and national level. This paper presents a step forward in the analysis of electricity generation options for countries and locations where feasibility of renewable generation is yet to be realised. Furthermore, we provide an analysis of technological development and RES deployment for countries whose cost of capital is high, a situation applicable to the many former Soviet Union countries.

This study demonstrates the application of a reliable and robust methodology to uniquely constructed datasets for the Russian energy system. It results in cost estimates, technology ranking and screening curves which form a basis for international