Modeling Russia for Climate Change Issues[1]

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1. INTRODUCTION

Russia is an important player in international efforts to prevent climate change. Over the last 15 years its share of global CO2 emissions has declined from 11% in 1990 to about 6.4% in 2003[2]. Despite this sharp decline in GHG emissions, Russia is still one of the world's largest emitters of greenhouse gases, ranking third just behind the United States and China and slightly ahead of Japan and India. Russia holds about 1/3-1/2 of the world's natural gas reserves, has abundant coal (about 20% of the world reserves) and large crude oil (10%) resources. Thus, Russian climate policy, combined with its energy and export-import policies, will significantly influence Russia's long-term carbon emissions levels.

The future of carbon emissions is uncertain. Nobody can tell exactly how long the existing driving forces of carbon emissions will determine these dynamics and when new factors will take over. Given the complex and dynamic interactions with regard to energy use and GHG emissions, the most relevant framework for such projection is the general equilibrium analysis.

In this paper we present the results of a study on the evolution of CO2 emissions by the Russian Federation over the time span 2008-2020. The projections are based on the dynamic CGE model RusMod.

2. MODEL SPECIFICATION

RusMod-2008 is a dynamic multi-sector general equilibrium model for the Russian Federation. It models the Russian economy from 2008 to 2020 and generates projections for the emissions of green house gases in the same period that are linked to the consumption of energy.

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[2] Calculation based on EIA data (http://www.eia.doe.gov/environment.html) and the Third Russian National communication to UNFCCC (http://www.eia.doe.gov/environment.html).

The model is constructed on several building blocks. In the CGE framework, behavioural assumptions are made for every agent in the model, that are fundamental to the outcomes since they will determine how the respective agents are dependent on the decisions of others, or on their results. These assumptions are exposed below, where particular attention is paid to the assumptions made for the different branches of activity in the economy and their production structure, since these are of considerable importance when deriving GHG emissions based on their activity. For the other agents in the model, the comments will be less in-depth; more detailed information can be found in the Technical Report.

The public and private enterprises that are active in Russia's economy are classified in 20 branches of activity (see Table 1). Each branch of activity produces one or several types of goods and services. In total, there are 20 types of commodities, which follow the disaggregation presented in Table 2. Five of the commodities presented in Table 2 represent energy inputs: Electricity, crude oil, refined petroleum and other fuels, natural gas and coal.

Table 1: Branches of activity in RusMod

1	Electricity
2	Crude oil
3	Refined petroleum and other fuels
4	Natural gas
5	Coal
6	Ferrous metallurgy
7	Nonferrous metallurgy
8	Chemical and petrochemical industry
9	Machinery
10	Lumber, pulp and paper industry
11	Construction materials
12	Light industry
13	Food processing industry
14	Other industries
15	Construction
16	Agriculture and forestry
17	Transport and communication
18	Trade, brokerage and catering
19	Housing, R&D and other services
20	Government and financial services

RusMod can be used for detailed impact and scenario analysis at the sectoral level, as well as for forecasting at the sectoral level. It helps its users understand the total macro and sectoral effects of policy decisions. It has the inter-industry detail from input-output, supply and use tables. It allows for behavioural responses to housing and consumer prices, wages, and production costs as in computable general equilibrium models. The model is dynamic, generating forecasts and simulations on an annual basis, and accounting for behavioural responses to wage, price, and other economic factors.

Table 2: Disaggregation of commodities

1	Electricity
2	Crude oil
3	Refined petroleum and other fuels
4	Natural gas
5	Coal
6	Ferrous metals
7	Nonferrous metals
8	Chemical and petrochemical products
9	Machinery and Equipment
10	Lumber, pulp and paper products
11	Construction materials
12	Light products
13	Food and beverages
14	Other industries
15	Construction services
16	Agricultural products and forestry
17	Transport and communication services
18	Trade, brokerage and catering
19	Housing, R&D and other services
20	Government and financial services

Given the importance of the productive sectors in the GHG emissions, we'll focus below on the technical description of the production structure in the model. Details for the household and the government behaviour, as well as the specification of the trade and capital flows are provided in the technical document of the model.

2.1 Firms

The CGE model does not take into account the behaviour of individual firms, but of groups of similar ones aggregated into branches. The model distinguishes 20 perfectly competitive branches of activity (summarized in Table 1).

When developing models in a CGE framework, it is typical to assume that producers operate on perfectly competitive markets and maximize profits (or, equivalently, minimize costs for each level of output) to determine optimal levels of inputs and output. For example, for the firms operating internationally, the world market dictates the output price to a large extent, and hence for an optimal outcome they have to produce as efficiently as possible. Some other firms are constrained in the costs level by domestic competitors. Thus, the optimizing producers minimize their production costs at every output level, given their production technology. Furthermore, production prices equal average and marginal costs, a condition that implies profit maximization for a constant returns to scale technology.

When determining the optimal combination of inputs in order to reach a certain output level, the firms are characterized by their production structure that describes the relation between inputs into the production process and the output resulting from that. For a quantitative analysis of these decisions, assumptions need to be made by the modeller on the functional form and structure of the production functions that the firms face. In RusMod, two types of production function are combined in a nested structure. On the one hand, a Leontief function defines fixed proportions of inputs that are required to yield a certain output. On the other hand, the Constant Elasticities of Substitution (CES) production function facilitates more flexibility, to the extent that it allows for substitution possibilities between inputs that are described by substitution elasticities. By combining the two functions in a structure consisting of multiple stages, the necessity to include certain (categories of) inputs and the flexibility to combine or replace others can both be sensibly represented in a nesting structure reflecting these characteristics. Besides, the importance of particular inputs in the production process of certain sectors can be incorporated by adapting the nesting scheme per sector.

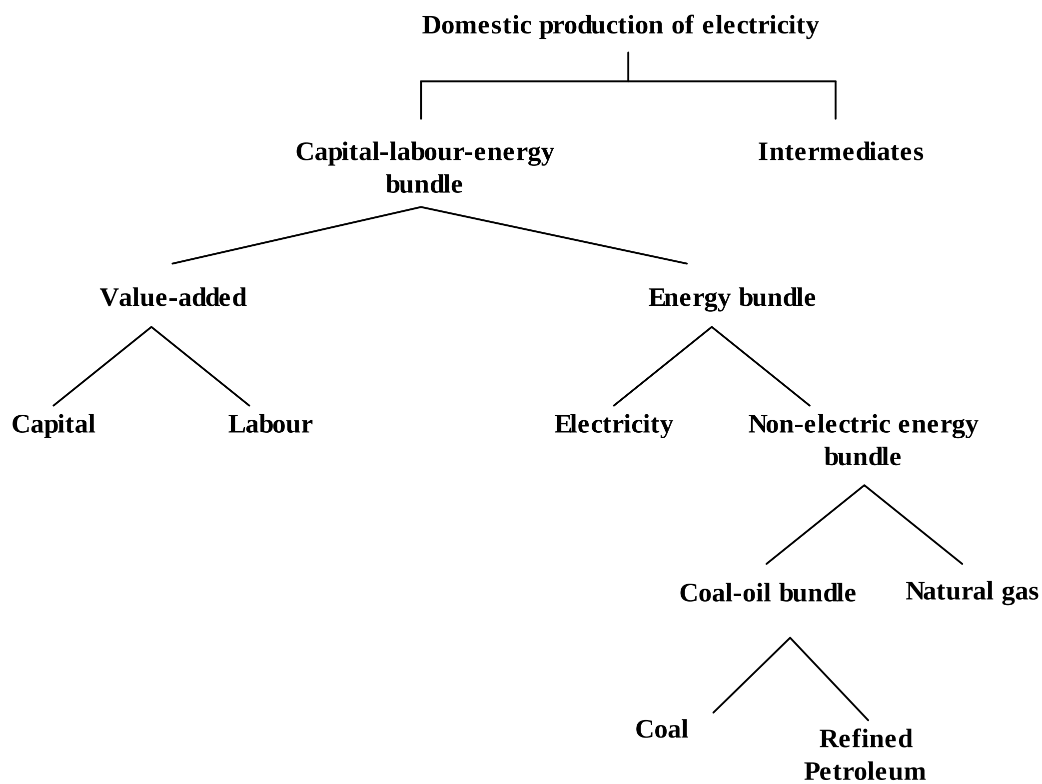

Figure1: The nested Leontief and CES production technology for the domestic production of electricity

For the electricity, gas and steam sector the producers are assumed to choose in the first stage between intermediate inputs and a capital-labour-energy bundle according to a Leontief production function. In the second stage, the optimal mix between value-added and energy is defined by a CES function. In the third stage, value added is given by a CES function of capital and labour while the energy bundle by a CES function of electricity and a non-electric energy bundle. In the fourth stage, the optimal mix between natural gas and the coal-oil bundle is given by another optimization process, where substitution possibilities between natural gas and the coal-oil bundle are represented by another CES function. Finally, in the fifth stage the optimal allocation of the coal-oil bundle between different energy inputs is provided by another CES function (see Figure 1). Firms' costs related to corporate income tax and social security contributions are also taken into account in the optimization process.

The domestic production by branch *sel* (XD_{sel}) is defined by a Leontief function with fixed proportions $aKLE_{sel}$ defining the required input of the capital-labour-energy bundle (KLE_{sel}) and, similarly, fixed technical coefficients $io_{c,sel}$ defining the required inputs of total intermediate inputs (IO_{sel}). Then, assuming an optimal allocation of inputs, the demand equations for the capital-labour-energy bundle and the intermediate inputs read:

$$KLE_{sel} = aKLE_{sel} \cdot XD_{sel} \tag{1}$$

and

$$IO_{sel} = \sum_{c} io_{c,sel} \cdot XD_{sel} \; . \tag{2}$$

Thus, domestic production valued at basic prices net of net taxes, $\left[PD_{sel} \cdot (1 - tp_{sel})\right]$, is given by the sum of the capital-labour-energy bundle (KLE_{sel}) for branch *sel* valued at basic prices $(PKLE_{sel})$ and intermediate commodities used by sector *sel* valued at the market price of the commodities (P_c), including the trade and transport margins $(\sum_{ctm} tcictm_{ctm,c} \cdot P_{ctm})$ and taxes (tic_c) on intermediate consumption:

$$PD_{sel} \cdot XD_{sel} \cdot (1 - tp_{sel}) \; = \; \sum_{nen} \{ io_{nen,sel} \cdot XD_{sel} \cdot [\, P_{nen} + \sum_{ctm} tcictm_{ctm,nen} \cdot P_{ctm} \,] \cdot (1 + tic_{nen}) \} \\ + PKLE_{sel} \cdot KLE_{sel} \tag{3}$$

The trade and transport margins are valued at the price (P_{ctm}) of the corresponding service (wholesale and retail trade services or transport services), while $tcictm_{ctm,c}$ represents the trade and transport services *ctm* per unit of intermediate consumption of commodity *c*.

The capital-labour-energy bundle is a CES aggregation of value added (KL_{sel}) and energy $(ENER_{sel})$:

$$KLE_{sel} = aKLEN_{sel} \cdot (\gamma KL_{sel} \cdot KL_{sel}^{-\rho KLEN_{sel}} + \gamma ENER_{sel} \cdot ENER_{sel}^{-\rho KLEN_{sel}})^{-1/\rho KLEN_{sel}} \tag{4}$$

The corresponding cost function is the sum of the costs related to each input, valued at their respective price indices:

$$Cost_{sel}(KL_{sel}, ENER_{sel}) = PKL_{sel} \cdot KL_{sel} + PENER_{sel} \cdot ENER_{sel}\ . \tag{5}$$

Minimization of this function subject to (4) yields the demand equations for value added and energy bundle:

$$KL_{sel} = KLE_{sel} \cdot (PKLE_{sel} / PKL_{sel})^{\sigma KLEN_{sel}} \cdot \gamma KL_{sel}^{\sigma KLEN_{sel}} \cdot aKLEN_{sel}^{(\sigma KLEN_{sel} - 1)} \tag{6}$$

$$ENER_{sel} = KLE_{sel} \cdot (PKLE_{sel} / PENER_{sel})^{\sigma KLEN_{sel}} \cdot \gamma ENER_{sel}^{\sigma KLEN_{sel}} \cdot aKLEN_{sel}^{(\sigma KLEN_{sel} - 1)} \tag{7}$$

and the associated zero profit condition:

$$PKLE_{sel} \cdot KLE_{sel} = PENER_{sel} \cdot ENER_{sel} + PKL_{sel} \cdot KL_{sel} \tag{8}$$

where $PENER_{sel}$ gives the price index corresponding to the energy bundle and PKL_{sel} stands for the price index corresponding to value added. The elasticity of substitution between value added and energy bundle is given by $\sigma KLEN_{sel}$, where $\sigma KLEN_{sel} = 1/(1 + \rho KLEN_{sel})$, and γKL_{sel} and $\gamma ENER_{sel}$ represent the distribution parameters corresponding to value added and energy bundle, respectively.

Value-added is a CES aggregation of capital (KSK_{sel}) and labour, expressed in number of employees (LSK_{sel}):

$$KL_{sel} = aF_{sel} \cdot (\gamma FK_{sel} \cdot KSK_{sel}^{-\rho F_{sel}} + \gamma FL_{sel} \cdot LSK_{sel}^{-\rho F_{sel}})^{-1/\rho F_{sel}} \tag{9}$$

Minimizing the costs function:

$$\begin{aligned} Cost_{sel}(KSK_{sel}, LSK_{sel}) = {} & [PK_{sel} \cdot (1 + tk_{sel}) + d_{sel} \cdot PI_{sel}] \cdot KSK_{sel} + \\ & [PL \cdot (1 + premLSK_{sel}) \cdot (1 + tl_{sel})] \cdot LSK_{sel} \end{aligned} \tag{10}$$

subject to (9) yields the demand equations for capital and labour:

$$KSK_{sel} = KL_{sel} \cdot \{PKL_{sel} / [PK_{sel} \cdot (1 + tk_{sel}) + d_{sel} \cdot PI_{sel}]\}^{\sigma F_{sel}} \cdot \gamma FK_{sel}^{\sigma F_{sel}} \cdot aF_{sel}^{(\sigma F_{sel} - 1)} \tag{11}$$

$$LSK_{sel} = KL_{sel} \cdot \{PKL_{sel} / [PL \cdot (1 + premLSK_{sel}) \cdot (1 + tl_{sel})]\}^{\sigma F_{sel}} \cdot \gamma FL_{sel}^{\sigma F_{sel}} \cdot aF_{sel}^{(\sigma F_{sel} - 1)} \tag{12}$$

and the associated zero profit condition:

$$\begin{aligned} PKL_{sel} \cdot KL_{sel} = {} & [PK_{sel} \cdot (1 + tk_{sel}) + d_{sel} \cdot PI_{sel}] \cdot KSK_{sel} + PL \cdot (1 + premLSK_{sel}) \cdot \\ & [1 + tl_{sel}] \cdot LSK_{sel} \end{aligned} \tag{13}$$

where PL is the average wage in the domestic employment and $premLSK_{sel}$ is the wage differential of branch *sel* with respect to the average wage PL, tl_{sel} is the social security contributions rate for industry *sel* , PK_{sel} is the return to capital in branch *sel,* tk_{sel} is the capital income tax rate for branch *sel*, and d_{sel} is the depreciation rate in industry *sel*. The depreciation related to the private and public capital stock is valued at the price index corresponding to investments by branch of activity *sel* (PI_{sel}). The elasticity of substitution between capital and labour is given by σF_{sel}, where $\sigma F_{sel} = 1/(1 + \rho F_{sel})$, and γFK_{sel} and γFL_{sel} represent the distribution parameters corresponding to capital and labour.

At the third nest, the energy bundle is given by another CES function of electricity $(ENINP_{enel,sel})$ and a non-electric energy bundle $(ENERNE_{sel})$

$$ENER_{sel} = aENER_{sel} \cdot (\gamma ENEREL_{enel,sel} \cdot ENINP_{enel,sel}^{-\rho ENER_{sel}} + \gamma ENERNE_{sel} \cdot ENERNE_{sel}^{-\rho ENER_{sel}})^{-1/\rho ENER_{sel}} \tag{14}$$

Minimizing the costs function:

$$Cost_{sel}(ENINP_{enel,sel}, ENERNE_{sel}) = \sum_{enel} \{[P_{enel} + \sum_{ctm} tcictm_{ctm,enel} \cdot P_{ctm}] \cdot (1+tic_{enel}) \cdot ENINP_{enel,sel}\} + PENERNE_{sel} \cdot ENERNE_{sel} \tag{15}$$

subject to (14) yields the demand equations for electricity and the non-electric energy bundle:

$$ENINP_{enel,sel} = ENER_{sel} \cdot \{PENER_{sel} / \{[P_{enel} + \sum_{ctm} tcictm_{ctm,enel} \cdot P_{ctm}] \cdot (1+tic_{enel})\}\}^{\sigma ENER_{sel}} \cdot \gamma ENEREL_{enel,sel}^{\sigma ENER_{sel}} \cdot aENER_{sel}^{(\sigma ENER_{sel}-1)} \tag{16}$$

$$ENERNE_{sel} = ENER_{sel} \cdot (PENER_{sel} / PENERNE_{sel})^{\sigma ENER_{sel}} \cdot \gamma ENERNE_{sel}^{\sigma ENER_{sel}} \cdot aENER_{sel}^{(\sigma ENER_{sel}-1)} \tag{17}$$

and the associated zero profit condition:

$$PENER_{sel} \cdot ENER_{sel} = \sum_{enel} \{[P_{enel} + \sum_{ctm} tcictm_{ctm,enel} \cdot P_{ctm}] \cdot (1+tic_{enel}) \cdot ENINP_{enel,sel}\} + PENERNE_{sel} \cdot ENERNE_{sel} \tag{18}$$

where $PENERNE_{sel}$ gives the price index corresponding to the non-electric energy bundle. The elasticity of substitution between electricity and the non-electric energy bundle is given by $\sigma ENER_{sel}$, where $\sigma ENER_{sel} = 1/(1+\rho ENER_{sel})$, and $\gamma ENEREL_{enel,sel}$ and $\gamma ENERNE_{sel}$ represent the distribution parameters corresponding to electricity and the non-electric energy bundle, respectively.

As already explained, at the forth nest the producers choose between the optimal consumption of natural gas $(ENINP_{ng,sel})$ and a coal-oil bundle $(ENERCO_{sel})$ according to another CES function:

$$ENERNE_{sel} = aENERCO_{sel} \cdot (\gamma ENINPG_{ng,sel} \cdot ENINP_{ng,sel}^{-\rho ENERCO_{sel}} + \gamma ENERCO_{sel} \cdot ENERCO_{sel}^{-\rho ENERCO_{sel}})^{-1/\rho ENERCO_{sel}} \tag{19}$$

Minimizing the costs function:

$$Cost_{sel}(ENINP_{ng,sel}, ENERCO_{sel}) = \sum_{ng} \{[P_{ng} + \sum_{ctm} tcictm_{ctm,ng} \cdot P_{ctm}] \cdot (1+tic_{ng}) \cdot ENINP_{ng,sel}\} + PENERCO_{sel} \cdot ENERCO_{sel} \tag{20}$$

subject to (19) yields the demand equations for natural gas and the coal-oil bundle:

$$ENINP_{ng,sel} = ENERNE_{sel} \cdot \{PENERNE_{sel} / \{[P_{ng} + \sum_{ctm} tcictm_{ctm,ng} \cdot P_{ctm}] \cdot (1+tic_{ng})\}\}^{\sigma ENERCO_{sel}} \cdot \gamma ENINPG_{ng,sel}^{\sigma ENERCO_{sel}} \cdot aENERCO_{sel}^{(\sigma ENERCO_{sel}-1)} \tag{21}$$

$$ENERCO_{sel} = ENERNE_{sel} \cdot (PENERNE_{sel} \; / \; PENERCO_{sel})^{\sigma ENERCO_{sel}} \cdot \gamma ENERCO_{sel}^{\sigma ENERCO_{sel}} \cdot aENERCO_{sel}^{(\sigma ENERCO_{sel} - 1)} \tag{22}$$

and the associated zero profit condition:

$$PENERNE_{sel} \cdot ENERNE_{sel} = \sum_{ng} \{ [P_{ng} + \sum_{ctm} tcictm_{ctm,ng} \cdot P_{ctm}] \cdot (1 + tic_{ng}) \cdot ENINP_{ng,sel} \} + PENERCO_{sel} \cdot ENERCO_{sel} \tag{23}$$

where $PENERCO_{sel}$ provides the price index corresponding to the coal-oil bundle, $\sigma ENERCO_{sel}$ is the elasticity of substitution between natural gas and the coal-oil bundle, with $\sigma ENERCO_{sel} = 1/(1+ \rho ENERCO_{sel})$. $\gamma ENINPG_{ng,sel}$ and $\gamma ENERCO_{sel}$ represent the distribution parameters corresponding to natural gas and the coal-oil bundle, respectively.

At the fifth nest, the coal-oil bundle is given by another CES function of different energy inputs $(ENINP_{enco,sel})$:

$$ENERCO_{sel} = aENINP_{sel} \cdot (\sum_{enco} \gamma ENINP_{enco,sel} \cdot ENINP_{enco,sel}^{-\rho ENINP_{sel}})^{-1/\rho ENINP_{sel}} \tag{24}$$

Minimizing the costs function:

$$Cost_{sel} (ENINP_{enco,sel}) = \sum_{enco} \{ [P_{enco} + \sum_{ctm} tcictm_{ctm,enco} \cdot P_{ctm}] \cdot (1 + tic_{enco}) \cdot ENINP_{enco,sel} \} \tag{25}$$

subject to (24) yields the demand equations for mining and quarrying of energy producing materials, products of coke and refined petroleum products:

$$ENINP_{enco,sel} = ENERCO_{sel} \cdot \{ PENERCO_{sel} / \{ [P_{enco} + \sum_{ctm} tcictm_{ctm,enco} \cdot P_{ctm}] \cdot (1 + tic_{enco}) \} \}^{\sigma ENINP_{sel}} \cdot \gamma ENINP_{enco,sel}^{\sigma ENINP_{sel}} \cdot aENINP_{sel}^{(\sigma ENINP_{sel} - 1)} \tag{26}$$

and the associated zero profit condition:

$$PENERCO_{sel} \cdot ENERCO_{sel} = \sum_{enco} \{ [P_{enco} + \sum_{ctm} tcictm_{ctm,enco} \cdot P_{ctm}] \cdot (1 + tic_{enco}) \cdot ENINP_{enco,sel} \} \tag{27}$$

where $\sigma ENINP_{sel}$ is the elasticity of substitution between mining and quarrying of energy producing materials, products of coke and refined petroleum products, with $\sigma ENINP_{sel} = 1/(1+ \rho ENINP_{sel})$. Following the same notational rules, $\gamma ENINP_{enco,sel}$ represents the distribution parameters corresponding to mining and quarrying of energy producing materials, products of coke and refined petroleum products, respectively.

The nested production structure of all other branches of activity is similar to the one for electricity, gas and steam sector, except for the primary energy sectors, whose particular structure will be discussed in detail below. For the other sectors, the only difference with the sel sector stands at the fourth nest where the non-electric energy bundle is not split into a Coal-Oil composite on the one hand and other energy inputs on the other, but rather defined by a CES function of all non-electric energy products: mining and quarrying of energy producing materials, products of coke, refined petroleum products and natural gas (see Figure 2). The demand equations for these energy inputs are discussed below, whereas all other demand and zero-profit equation are identical to the one described above. The particular structure that is assumed for the electricity, gas and steam sector reflects the relative importance that Coal and Oil play in the production of this sector.

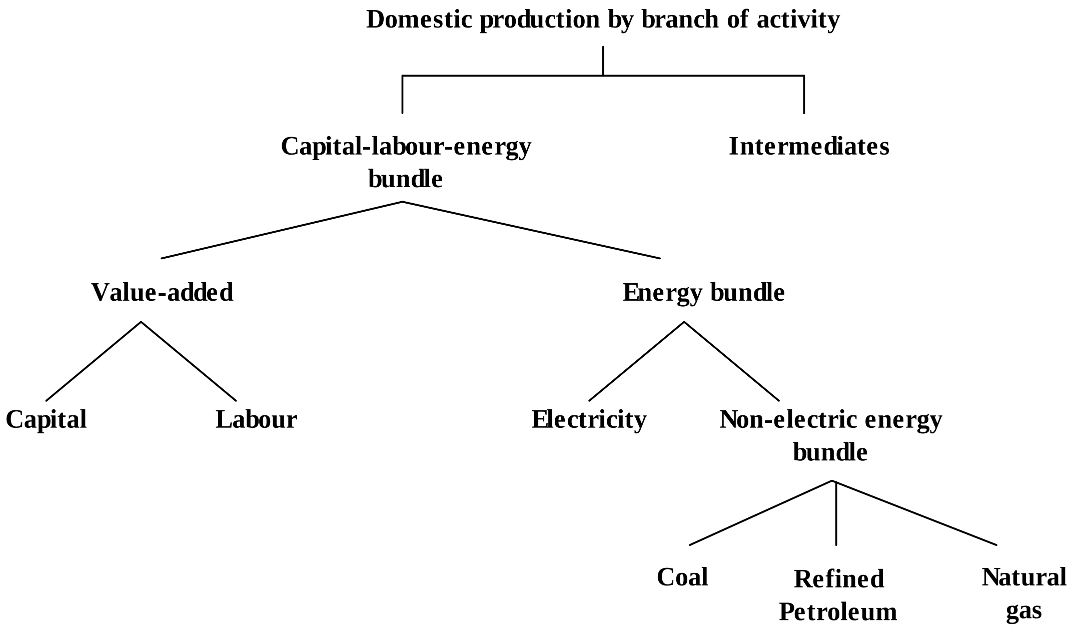

Figure 2. The nested Leontief and CES production technology for the domestic production of all branches of activity except the electricity sector and primary energy sectors.

As explained, at the fourth nest, the non-electric energy bundle $(ENERNE_{nsel})$ in branch *nsel* is given by another CES function of various non-electric energy inputs $(ENINP_{ennel,nsel})$:

$$ENERNE_{nsel} = aENINP_{nsel} \cdot \Big(\sum_{ennel} \gamma ENINP_{ennel,nsel} \cdot ENINP_{ennel,nsel}^{-\rho ENINP_{nsel}} \Big)^{-1/\rho ENINP_{nsel}} \qquad (28)$$

Minimizing the costs function:

$$Cost_{nsel}(ENINP_{ennel,nsel}) = \sum_{ennel} \{ [P_{ennel} + \sum_{ctm} tcictm_{ctm,ennel} \cdot P_{ctm}] \cdot (1 + tic_{ennel}) \cdot ENINP_{ennel,nsel} \} \qquad (29)$$

subject to (28) yields the demand equations for mining and quarrying of energy producing materials, products of coke, refined petroleum products and natural gas:

$$ENINP_{ennel,nsel} = ENERNE_{nsel} \cdot \{ PENERNE_{nsel} / \{ [P_{ennel} + \sum_{ctm} tcictm_{ctm,ennel} \cdot P_{ctm}] \cdot (1 + tic_{ennel}) \} \}^{\sigma ENINP_{nsel}} \cdot$$
$$\gamma ENINP_{ennel,nsel}^{\sigma ENINP_{nsel}} \cdot aENINP_{nsel}^{(\sigma ENINP_{nsel} - 1)} \qquad (30)$$

and the associated zero profit condition:

$$PENERNE_{nsel} \cdot ENERNE_{nsel} = \sum_{ennel} \{ [P_{ennel} + \sum_{ctm} tcictm_{ctm,ennel} \cdot P_{ctm}] \cdot (1 + tic_{ennel}) \cdot ENINP_{ennel,nsel} \} \qquad (31)$$

where $\sigma ENINP_{nsel}$ represent the elasticities of substitution between mining and quarrying of energy producing materials, products of coke, refined petroleum products and natural gas in branch *nsel*, with $\sigma ENINP_{nsel} = 1/(1 + \rho ENINP_{nsel})$. Besides, $\gamma ENINP_{ennel,nsel}$ represent the distribution parameters corresponding to these non-electric energy products.

Capital is industry specific, introducing rigidities in the capital market. The inter-sectoral wage differential is a parameter derived as the ratio between the wage by branch and the average wage in the domestic employment (Dervis, De Melo and Robinson, 1982). By holding the inter-sectoral wage differentials constant in counterfactual policy simulations, rigidities in the labour market can be introduced.

Each branch of activity in RusMod produces several types of goods and services. The optimal allocation of domestic production per sector over the different types of commodities is given by a Leontief function:

$$XDDE_c = \sum_s ioC_{s,c} \cdot XD_s \qquad (32)$$

where $XDDE_c$ represents the domestic production of commodity *c* by different branches, supplied on the home and foreign markets, XD_s is the domestic production of branch *s*, and $ioC_{s,c}$ is a fixed coefficient expressing the share of production of commodity *c* by the industry *s* per unit of production of industry *s*.

The corresponding zero profit condition is given by:

$$PD_s = \sum_c ioC_{s,c} \cdot PDDE_c \qquad (33)$$

where $PDDE_c$ is the domestic price of commodity *c* supplied on the home and foreign markets and PD_s is the price index corresponding to domestic production by branch *s*.

For the primary energy sectors (producing oil and natural gas), a specific production structure is assumed, that emphasizes the dependency of both sectors on the availability of the particular natural resources that represent the lion's share of their production. The prominence of these resources is reflected by their inclusion in the first nest, defining how a fixed factor (the natural resource) and a non-resource bundle (NRES) including all other commodities and production factors are combined in a CES function to reach total production:

$$XD_{oils} = aFRES_{oils} \cdot [\gamma FRES_{oils} \cdot FF_{oils}^{-\rho FRES_{oils}} + \gamma FNRES_{oils} \cdot NRES_{oils}^{-\rho FRES_{oils}}]^{-1/\rho FRES_{oils}}$$

Minimization of the associated cost function:

$$Cost_{oils}(FF_{oils}, NRES_{oils}) = PFF_{oils} \cdot FF_{oils} + PNRES_{oils} \cdot NRES_{oils} ,$$

subject to (34) yields the familiar factor demand equations:

$$FF_{oils} = XD_{oils} \cdot (PD_{oils} / PFF_{oils})^{\sigma FRES_{oils}} \cdot \gamma FRES_{oils}^{\sigma FRES_{oils}} \cdot aFRES_{oils}^{(\sigma FRES_{oils} - 1)} \qquad (34)$$

$$NRES_{oils} = XD_{oils} \cdot (PD_{oils} / PNRES_{oils})^{\sigma FRES_{oils}} \cdot \gamma FNRES_{oils}^{\sigma FRES_{oils}} \cdot aFRES_{oils}^{(\sigma FRES_{oils} - 1)} \quad (35)$$

and the associated zero profit condition:

$$PD_{oils} \cdot (1 - tp_{oils}) \cdot XD_{oils} = PFF_{oils} \cdot FF_{oils} + PNRES_{oils} \cdot NRES_{oils} \quad (36)$$

where PD_{oils} is the price index of domestic production of crude oil and natural gas, PFF_{oils} gives the return to natural resources and $PNRES_{oils}$ provides the price index corresponding to the non-resource input bundle. The tax rate on production of crude oil and natural gas is given by tp_{oils}. The elasticity of substitution between natural resources and the non-resource input bundle is provided by $\sigma FRES_{oils}$, where $\sigma FRES_{oils} = 1/(1 + \rho FRES_{oils})$, and $\gamma FRES_{oils}$ and $\gamma FNRES_{oils}$ represent the distribution parameters corresponding to natural resources and non-resource input bundle, respectively.

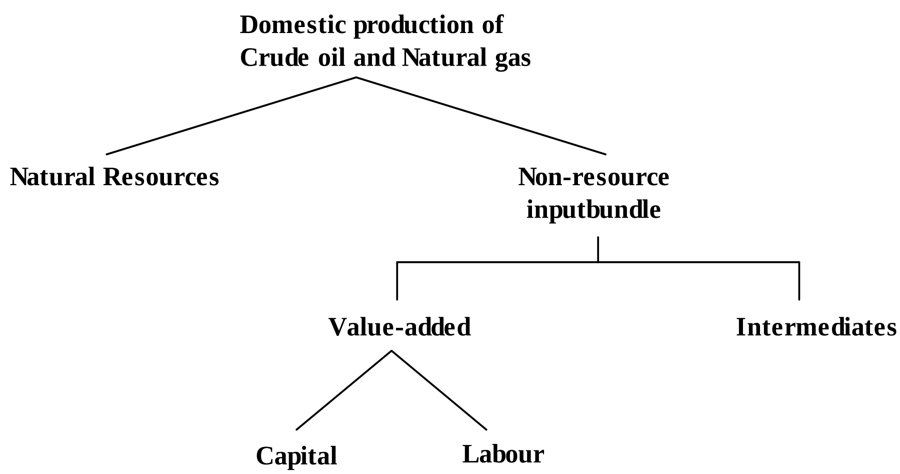

Figure 3: Production structure in the oil and natural gas sectors

At the second nest, the non-resource bundle is defined by a Leontief function of Value-added and all intermediates. As a consequence, minimization of the cost function subject to this Leontief function yields an optimal allocation of inputs that is a fixed fraction of the total non-resource bundle:

$$KL_{oils} = aKL_{oils} \cdot NRES_{oils} .$$

where aKL_{oils} is the fixed coefficient relating value-added to the non-resource input bundle. Similarly, total intermediate inputs used by industry *oils* (IO_{oils}) are derived as:

$$IO_{oils} = \sum_{c} io_{c,oils} \cdot NRES_{oils}$$

where $io_{c,oils}$ are the technical coefficients. Thus, the non-resource input bundle at basic prices is given by the sum of value added (KL_{oils}) for branch *oils* valued at basic prices

(PKL_{oils}) and intermediate commodities used by sector *oils* valued at the price of the commodity c (P_c).

$$PNRES_{oils} \cdot NRES_{oils} = PKL_{oils} \cdot KL_{oils} + \sum_c (io_{c,oils} \cdot NRES_{oils} \cdot P_c) \qquad (37)$$

Similar to the structure assumed in all other sectors, value-added in the crude oil and natural gas sectors is given at the third nest as a CES aggregation of capital (KSK_{oils}) and labour (LSK_{oils}):

$$KL_{oils} = aF_{oils} \cdot [\gamma FK_{oils} \cdot KSK_{oils}^{-\rho F_{oils}} + \gamma FL_{oils} \cdot LSK_{oils}^{-\rho F_{oils}}]^{-1/\rho F_{oils}} \qquad (38)$$

Minimizing the associated cost function:

$$Cost_{sel}(KSK_{sel}, LSK_{sel}) = [PK_{sel} \cdot (1+tk_{sel}) + d_{sel} \cdot PI_{sel}] \cdot KSK_{sel} + [PL \cdot (1+premLSK_{sel}) \cdot (1+tl_{sel})] \cdot LSK_{sel} \qquad (39)$$

subject to (9) yields the factor demand equations for capital and labour:

$$KSK_{sel} = KL_{sel} \cdot \{PKL_{sel}/[PK_{sel} \cdot (1+tk_{sel}) + d_{sel} \cdot PI_{sel}]\}^{\sigma F_{sel}} \cdot \gamma FK_{sel}^{\sigma F_{sel}} \cdot aF_{sel}^{(\sigma F_{sel}-1)} \qquad (40)$$

$$LSK_{sel} = KL_{sel} \cdot \{PKL_{sel}/[PL \cdot (1+premLSK_{sel}) \cdot (1+tl_{sel})]\}^{\sigma F_{sel}} \cdot \gamma FL_{sel}^{\sigma F_{sel}} \cdot aF_{sel}^{(\sigma F_{sel}-1)} \qquad (41)$$

and the corresponding zero profit condition:

$$PKL_{sel} \cdot KL_{sel} = [PK_{sel} \cdot (1+tk_{sel}) + d_{sel} \cdot PI_{sel}] \cdot KSK_{sel} + PL \cdot (1+premLSK_{sel}) \cdot [1+tl_{sel}] \cdot LSK_{sel}, \qquad (42)$$

where the symbols used are identical to the equations (10) – (13).

2.2 Households, Government, and the Rest of the World

In addition to the firms, two other institutional units are distinguished in the model: households and the government. Russia's trade and capital flows with the Rest of the World (ROW) are modelled as well.

The households provide production factors that are used by the firms in their production process. They are nearly completely responsible for the labour supply (the remainder being provided by ROW) and besides provide a share of capital. In turn for this, the households receive factor incomes, that are supplemented by unemployment benefits and net government transfers to yield total income. The absolute and relative sizes of the different components of total household's income can be derived from the SAM that was used as basis for the CGE model.

The households' expenditures can be categorized into three categories: taxes, savings and private consumption. Although the initial choices made can be easily found in the SAM, in order to run simulations or produce projections, behavioral assumptions need to be made describing the choices that the households face and make. In order to do this, it is assumed that there is only one representative household in the economy, that receives all income going to the households, and whose expenditures amount the aggregation of expenditures by individual households in the economy. This household is assumed to face an income tax rate, that determines the share of its total income that it will have at its disposal. Of this disposable income, it saves a proportion according to its propensity to save. The remainder, its consumption budget, is spent on the 20 commodities in the economy. When allocating the consumption budget to each of the commodities, the household is assumed to maximize a Stone-Geary (Linear Expenditure System) utility function. In this function, the household has subsistence levels that determine the minimum quantity of each commodity that it should consume. Any budget that is left after purchasing these quantities will be spent according marginal budget shares.

The resulting private demand for commodities is only one of the demand categories over which total supply (consisting of domestic supply and imports) is divided. The other categories are: intermediate consumption, public demand, investment demand, change in inventories and exports. Public consumption is the consumption by the government, that divides it budget according to a Leontief function over the particular selection of commodities that it demands. Besides, the government saves a proportion of its revenues (or lends it, according to whether there is a budget surplus or deficit, respectively), that is constructed as the difference between total governmental revenues (i.e. net tax revenues, property income (including royalties on natural resources), operating surplus, received current transfers and social contributions) and total governmental expenditures, including social benefits, property income, other transfers paid and expenditures for public consumption.

The demand for investment goods is determined by an investment bank, that allocates total savings minus depreciation over the different commodities according to a Leontief function.

The incorporation of dynamics in the model is reached by creating a sequence of yearly temporal equilibria, that are linked to each other through the evolution of the capital stock in the economy, facing capital accumulation through investment and depreciation. Thus, this endogenous determination of investment behaviour is essential for the dynamic characteristics of the model. Investment and capital accumulation in year *t* depend on expected rates of return for year *t+1*, which are determined by actual returns on capital in year *t*.

Next to the investment stock, the availability of natural resources over time is modeled endogenously as well, by taking into account the crude oil and natural gas reserves and their depletion profile. Whereas the extraction of natural resources depletes the reserves, they are on the other hand supplemented by the discovery of new reserves. In the model, both the extraction rate, which is the speed at which the existing proven reserves are depleted, and the discovery rate, which is the rate at which new reserves are discovered (as a proportion of the total estimated availability of unproven natural resource reserves) are determined endogenously.

2.3 Green House Gas Emissions

RusMod models GHG emissions explicitly by linking them directly to the consumption of energy. By specifying the energy consumption by the different agents and branches of activity in the model in detail, this link provides an equally detailed insight in the contribution that each agent makes to total GHG emissions. Since the CGE model provides this detailed disaggregation into different agents and multiple sectors, and particularly takes into account how the various agents depend on each other, it facilitates a thorough study on the various contributors to GHG emissions. Especially when incorporating dynamics in the analysis and running models over time, this methodology provides a very useful set of tools to acquire insights in the evolution of GHG emissions in general, and more particularly into the relative share of the contribution that every type of energy, all branches of activity, or the households make to total emissions.

In the model, two types of emitters are distinguished. The biggest contributors to total emissions are the different branches of activity. Their emissions stem from the intermediate consumption of energy commodities as part of their production process, as was described in the section on the sectoral production structure. Besides, the residential sector contributes by consuming energy commodities, mainly for heating purposes.

In order to link the economic data on consumption and the more physically oriented data on emissions, the consumption of energy commodities needs to be expressed in units of energy, rather than in Rubles. In line with the data on energy consumption and green house gas emissions that served as the source for this study, in the model the energy consumption is expressed in kilo tones of oil equivalents. The ratio between energy consumption in Rubles and energy consumption in ktoe expresses the implicit price related to the energy vector. Subsequently, the ktoe-consumption of each type of energy commodity by each type of emitter is linked to actual GHG emissions through emission factors. These are typically expressed in kt or Mt per ktoe, depending on the type of GHG, and describe the amount of emissions of every type of GHG that is caused by combustion of each of the particular energy commodities. They typically vary over the sectors, due to differences in the amount of pollution caused by employment of dirty or cleaner technologies in different sectors.

When modeling the evolution of GHG emissions over time, there are various parameters to take into account. One of them is the amount of emissions associated with the combustion of a particular fuel in a particular sector, like described above. Another important factor is the energy intensity, that determines how much of every energy commodity is required for production by a particular branch of activity. This efficiency typically improves over time, which implies that the amount of energy required per unit of production decreases. As a result, the emissions per unit of production will decrease accordingly, provided that no changes occur to the emission factors.

3. ASSUMPTIONS

The full time period under consideration in RusMod, 2003-2020, needs to be split in two parts, according to the availability of actual historical data until 2007, and the necessity to include projections starting from 2008. For the first part of the sample, the model solves dynamically according to a path of variables like GDP growth, population growth and energy efficiency that are imposed to be reached exogenously based on observations of these variables since 2003, the base year of the study. Next, in the second part of the sample, projections are used, that allow for the formulation of various scenarios.

Tables 3 and 4 report the macroeconomic series that are underlying the forecasts that will be reported in the next section. In order to interpret these assumptions and results properly, it is important to elicit one methodological choice. As highlighted above, in the first period of the subsample, 2003-2007, the model is reproducing historical figures on GDP growth. As a consequence, factor productivity is left free and adapts according to the evolution of GDP. However, in the remainder of the sample, 2008-2020, it is labour productivity that will be assumed to be determined exogenously, and real GDP will adapt. This is particularly sensible in the light of the evolution of energy efficiency, which will play an important role in the empirical analyses that will follow; the impact of different efficiency scenarios on real GDP growth will be a major concern. In order to enable this variable to be endogenously determined and still be able to identify different scenarios of economic growth, labour productivity will capture the degree of acceleration starting from 2008. In line with official Long Run scenarios provided by the Russian government, table 3 reports three series, yielding 260, 240 and 200 percent improvements of labour productivity respectively, between 2006 and 2020. The first scenario of these three is the innovative scenario that is chosen as baseline by the European Commission in its long run projections for Russia.

Table 3: GDP deflator and labour productivity annual growth rates (in percent)

	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
GDP deflator	20.1	19.2	15.8	13.5	23.9	9.5	7.8	7.7	7.7
Labour Productivity									
• Innovative	-	-	6.00	5.59	7.92	6.83	7.07	6.95	6.46
• Energy and Raw Materials	-	-	6.00	5.12	7.26	6.26	6.49	6.37	5.93
• Inertial	-	-	6.00	4.03	5.71	4.93	5.10	5.01	4.66

Source: Commission Services

Table 3: GDP deflator and labour productivity annual growth rates (in percent)

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
GDP deflator	7.3	7.2	6.2	4.8	4.5	3.9	3.9	3.7
Labour Productivity								
• Innovative	6.76	7.06	7.66	7.98	7.72	7.06	6.93	6.53
• Energy and Raw Materials	6.20	6.48	7.03	7.32	7.08	6.48	6.35	5.99
• Inertial	4.88	5.09	5.53	5.76	5.57	5.10	5.00	4.71

Source: Commission Services

Table 3 reports the macro economic variables at the most aggregated level. The GDP deflator and the evolution of labour productivity under the first, innovative, scenario are obtained from a document called '*Long-run Macro Projections for Russia*', provided by the European Commission. The other two scenarios are based on the first one, but scaled down in order to be in line with the Russian governmental projections.

Table 4: Labour force assumptions

	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*
Active population (in millions)	72.7	73.1	73.1	73.2	74.9	74.8	74.6	74.2	73.7
Active population Growth rate	-	0.53	0.07	0.09	2.38	-0.15	-0.29	-0.58	-0.59
Unemployment rate	8.6	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2

Source: Commission Services

Table 4: Labour force assumptions

	2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Active population (in millions)	73.5	73.0	72.5	72.0	71.2	70.6	70.2	69.7	69.4
Active population Growth rate	-0.30	-0.74	-0.60	-0.75	-1.06	-0.92	-0.62	-0.62	-0.47
Unemployment rate	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2

Source: Commission Services

Table 5: Emission Factors

Emission factors (kt/ktoe)	*Refined petroleum and other fuels*	*Natural gas*	*Coal*
Electricity	3.00	2.34	4.27
Crude oil	3.50	2.34	
Refined petroleum and other fuels	7.17		4.01
Natural gas	6.12	2.34	
Coal	2.36		4.01
Ferrous metallurgy	2.69	2.34	7.31
Nonferrous metallurgy	2.84	2.34	4.06
Chemical and petrochemical industry	2.71	2.34	4.52
Machinery	2.42	2.34	4.29
Lumber, pulp and paper industry	2.57	2.33	4.55
Construction materials	2.53	2.32	4.07
Light industry	2.42	2.35	3.74
Food processing industry	2.60	2.34	3.97
Other industries	3.80	2.34	3.68
Construction	2.41	2.32	4.07
Agriculture and forestry	2.83	2.34	3.96
Transport and communication	2.36	2.34	
Trade, brokerage and catering	2.38	2.34	3.88
Housing, R&D and other services	2.90	2.33	3.91
Government and financial services	2.39	2.34	3.88

Source: Commission Services and own calculation

Next to the GDP growth, projections on the size of the active population and the level of unemployment are used, that were obtained from the same source provided by European Commission services and the IMF country report for Russia from 2005, respectively. The numbers in table 4 show that the active population is expected to have reached its peak in 2007. In the following years, it will start to decrease at a ratio that grows from 0.15 to over one percent in 2016. The unemployment rate is assumed to be constant over the period at its level in 2004 of 8.2 percent.

Table 6: Energy intensity assumptions (annual growth rates)

	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Energy intensity									
• Innovative scenario EC: 42%	-2.62	-4.98	-5.07	-5.68	-5.39	-4.42	-4.36	-3.96	-3.80
• Alternative 1: 30% improvement	-2.62	-4.98	-5.07	-5.68	-3.45	-2.83	-2.79	-2.54	-2.44
• Alternative 2: 60% improvement	-2.62	-4.98	-5.07	-5.68	-8.67	-7.12	-7.02	-6.38	-6.13

Source: Commission Services and own calculation

Table 6: Energy intensity assumptions (annual growth rates)

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Energy intensity								
• Innovative scenario EC: 42%	-3.75	-4.25	-4.62	-4.41	-4.35	-3.99	-3.92	-3.70
• Alternative 1: 30% improvement	-2.40	-2.72	-2.96	-2.82	-2.79	-2.56	-2.51	-2.37
• Alternative 2: 60% improvement	-6.04	-6.85	-7.43	-7.10	-7.00	-6.43	-6.31	-5.96

Source: Commission Services and own calculation

Table 5 reports the emission factors used in the current version of the model, for CO2 emissions by each of the three energy categories (refined oil, coal and natural gas) over the 20 sectors. In this table, no emission factor is assigned to branches of activity that do not consume a particular energy commodity in their production process, e.g. the coal sector does not consume refined petroleum and natural gas, and the transport sector does not consume coal.

Table 6 reports the assumptions that were made regarding energy intensity, on the aggregate level. Main source for these projections is the document '*Long-run Macro Projections for Russia*', provided by the European Commission. The first, innovative scenario is constructed by figures from this file. Under this scenario, overall energy intensity will improve by 43 percent, which is slightly more than a 40 percent improvement that was demanded by president Medvedev in a recent decree. The other two scenarios are obtained by scaling the annual growth rates of the innovative scenario down and up, respectively. For the disaggregation of the overall efficiency gains over the branches of activity, data on Romania were used, combined with a World Bank report on the efficiency growth potentials for Russia. Hence, the overall efficiency gains vary over the different scenarios, whereas the relative contribution of each of the twenty sectors in the model is fixed.

The specification of the model is based on the assumption of exogenously fixed world prices of commodities; both the prices of exports and imports remain constant over time for all goods except energy commodities. Projections on the yearly development of energy prices, as reported in table 7, are derived from a POLES report on post-Kyoto scenarios obtained from the EC. Finally, the exchange rate is set to grow at a rate equal to the growth rate of the GDP deflator.

Table 7: Development of World prices of energy commodities

	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Electricity	8.68	8.68	7.05	7.05	7.05	7.05	7.05	-1.99	-1.99
Crude oil	6.46	6.46	7.27	7.27	7.27	7.27	7.27	-1.03	-1.03
Refined petroleum and other fuels	9.79	9.79	11.02	11.02	11.02	11.02	11.02	-1.56	-1.56
Natural gas	10.01	10.01	8.13	8.13	8.13	8.13	8.13	-2.29	-2.29
Coal	13.73	13.73	2.13	2.13	2.13	2.13	2.13	2.30	2.30

Source: Commission Services and own calculation

Table 7: Development of World prices of energy commodities

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Electricity	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99
Crude oil	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03	-1.03
Refined petroleum and other fuels	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56
Natural gas	-2.29	-2.29	-2.29	-2.29	-2.29	-2.29	-2.29	-2.29
Coal	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30

Source: Commission Services and own calculation

4. PROJECTIONS

Based on the assumptions that were elicited in the previous section, projections are obtained for all endogenous variables in the model between 2008 and 2020. Various scenarios are analysed, regarding the evolution of energy intensity, economic growth and the application of a policy instrument: the introduction of a CO2-price. As a starting point, a baseline scenario will be defined and analysed that will act as reference for the other scenarios under consideration in this section. This baseline scenario can be seen as a formulation of the most likely path of evolution for the Russian economy, based primarily on sources provided by the European Commission and the Russian government.

4.1 The baseline scenario

Most of the assumptions underlying the baseline scenario have been exposed in the previous section. However, two of them require particular attention, since they will define the differences between the several scenarios under consideration in the following sections. Labour productivity is used as driver of economic growth, and is assumed to grow by 260% between 2006 and 2020. This is in line with an evolution marked as innovative scenario by the European Commission, and besides corresponds to an official scenario with the same name provided by the Russian government. Energy efficiency, defined as the total consumption of energy resources in physical terms per unit of GDP, is assumed to grow according to the same innovative scenario by 42.95% between 2007 and 2020. This is in line with a recent decree by president Medvedev in which he calls for an improvement in energy intensity of 40% in the same period.

Tables 8a and 8b present in detail the evolution of the GDP and its various components under the baseline scenario. Whereas table 8a provides this evolution in levels, table 8b presents annual growth rates. The results exhibit an overall GDP growth in the time period 2007-2020 by a factor 2.33, with annual growth rates starting at 7.8% in 2008 and fluctuating between 6 and 7% over the rest of the sample. The share of private consumption in GDP grows over the sample period, from 50.7% in 2003 to 54.4% in 2020. While the role of governmental consumptive spending in the domestic product declines slightly, the increase in private consumption and particularly gross fixed investment comes at the expense of the foreign balance, showing only a minor increase in real terms over the entire time span, driven by growth rates of imports that are consistently higher than export growth.

In table 11, the projected CO2 emission are reported, split up in a contribution made by the production sectors in the economy (including the local and federal governments) and a share of the residential households. The latter diminished over the years, from a share of more than 9% in 2008 to just 7.4% in 2020. Tables 14 and 15 in the appendix provide a further disaggregation into the twenty branches of activity of the CO2 emissions.

Table 8a: Macroeconomic projections (bln roubles)

	2003	*Share in GDP (%)*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
GDP	13,201.1	100.0	17,481.4	18,857.9	20,146.5	21,512.0	22,992.5	24,478.3
Private consumption	6,694.5	50.7	9,392.6	10,030.2	10,678.0	11,375.1	12,152.6	12,949.1
Government consumption	2,332.3	17.7	2,910.9	3,155.6	3,370.8	3,595.7	3,831.8	4,068.1
Gross fixed investment	2,669.9	20.2	3,279.2	3,648.7	3,962.3	4,299.9	4,660.7	5,033.1
Foreign balance	1,504.3	11.4	1,898.6	2,023.3	2,135.4	2,241.4	2,347.4	2,427.9
Exports	4,560.6	34.5	5,932.6	6,326.9	6,708.0	7,107.0	7,539.3	7,965.2
Imports	3,056.3	-23.2	4,034.0	4,303.5	4,572.6	4,865.6	5,191.9	5,537.2

Table 8a: Macroeconomic projections (bln roubles)

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
GDP	26,031.2	27,736.1	29,645.5	31,676.1	33,831.6	36,044.6	38,356.8	40,718.1
Private consumption	13,805.3	14,736.2	15,761.6	16,869.1	18,071.0	19,352.2	20,720.7	22,156.6
Government consumption	4,309.3	4,582.5	4,892.1	5,215.6	5,550.3	5,880.8	6,218.8	6,555.7
Gross fixed investment	5,417.1	5,893.3	6,464.4	7,090.4	7,761.0	8,439.2	9,143.1	9,855.9
Foreign balance	2,499.5	2,524.0	2,527.4	2,500.9	2,449.2	2,372.3	2,274.3	2,150.0
Exports	8,402.4	8,832.5	9,293.8	9,769.1	10,263.3	10,765.9	11,286.4	11,814.2
Imports	5,902.9	6,308.5	6,766.3	7,268.2	7,814.0	8,393.6	9,012.2	9,664.3

Table 8b: Macroeconomic projections: growth rates

	2003 values (bln. Ruble)	*Share in GDP (%)*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
GDP	13,201.1	100.0	7.87	6.83	6.78	6.88	6.46	6.34
Private consumption	6,694.5	50.7	6.79	6.46	6.53	6.84	6.55	6.61
Government consumption	2,332.3	17.7	8.41	6.82	6.67	6.57	6.17	5.93
Gross fixed investment	2,669.9	20.2	11.27	8.59	8.52	8.39	7.99	7.63
Foreign balance	1,504.3	11.4	6.57	5.54	4.96	4.73	3.43	2.95
Exports	4,560.6	34.5	6.65	6.02	5.95	6.08	5.65	5.49
Imports	3,056.3	-23.2	6.68	6.25	6.41	6.71	6.65	6.60

Table 8b: Macroeconomic projections: growth rates

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
GDP	6.55	6.88	6.85	6.80	6.54	6.41	6.16
Private consumption	6.74	6.96	7.03	7.12	7.09	7.07	6.93
Government consumption	6.34	6.75	6.61	6.42	5.95	5.75	5.42
Gross fixed investment	8.79	9.69	9.68	9.46	8.74	8.34	7.80
Foreign balance	0.98	0.13	-1.05	-2.07	-3.14	-4.13	-5.47
Exports	5.12	5.22	5.11	5.06	4.90	4.84	4.68
Imports	6.87	7.26	7.42	7.51	7.42	7.37	7.24

Table 9: CO2 emissions under the baseline scenario

	1990	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Total CO2 emissions (Mt)	2,138.7	1,644.2	1,680.3	1,718.2	1,765.5	1,812.2	1,857.7
Total CO2 emissions (annual growth rate - %)		1.95	2.19	2.26	2.76	2.64	2.51
CO2 emissions from the residential sector (Mt)	182.1	148.8	149.8	150.9	153.6	155.3	156.9
CO2 emissions from the residential sector (annual growth rate - %)		0.26	0.68	0.70	1.82	1.08	1.02
CO2 emissions by branches of activity (Mt)	1,956.6	1,495.3	1,530.4	1,567.3	1,611.9	1,656.9	1,700.8
CO2 emissions by branches of activity (annual growth rate - %)		2.12	2.35	2.41	2.85	2.79	2.65

Table 9: CO2 emissions under the baseline scenario

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Total CO2 emissions (Mt)	1,895.7	1,932.9	1,974.9	2,017.7	2,063.8	2,109.0	2,154.5
Total CO2 emissions (annual growth rate - %)	2.05	1.96	2.17	2.17	2.28	2.19	2.15
CO2 emissions from the residential sector (Mt)	157.7	158.0	158.6	159.1	159.7	160.1	160.1
CO2 emissions from the residential sector (annual growth rate - %)	0.49	0.22	0.35	0.32	0.41	0.22	0.03
CO2 emissions by branches of activity (Mt)	1,738.1	1,774.9	1,816.3	1,858.7	1,904.1	1,949.0	1,994.4
CO2 emissions by branches of activity (annual growth rate - %)	2.19	2.12	2.34	2.33	2.44	2.36	2.33

4.2 Three scenarios on energy efficiency and two policy scenarios

Table 1 reports the evolution of real GDP under three different scenarios of energy efficiency growth, and two policy simulations. Whereas labour productivity is assumed to grow according to the ‘*innovative*’ projections under all four scenarios, reaching 260 percent growth between 2006 and 2020, the first three rows of table 1 report results on GDP growth for different assumptions regarding energy efficiency, as reported in section 3. The first scenario is once again the baseline scenario as shown in tables 8a and 8b, reported to facilitate a smooth comparison; the second scenario assumes a stronger improvement in energy intensity, of 60% over the period 2007-2020; and the third scenario assumes an improvement of just 30% over the same period.

The fourth and fifth row provide projections on policy simulations, assuming the introduction of a CO2 price of 22 EUR/tCO2, starting in 2015, which is in line with the PRIMES database. In order to simulate the adaptation that would in reality take place, when the introduction of CO2 pricing would be announced, the CO2 price is included gradually in the model, starting in 2012 and increasing linearly until the price of 22 EUR is reached in 2015. The fourth row applies this CO2 price to the initial baseline scenario with 43% energy efficiency gains, whereas the fifth row takes as basis the pessimistic scenario with just 30% of efficiency improvement. In the model, the revenues from pricing the CO2 emissions are recycled into firms’ savings, simulating the current Emission Trading Scheme.

Table 1 shows the impact of energy efficiency as a driver of economic growth; whereas in the baseline, the average annual growth rate is 6.6%, stronger gains in energy efficiency alone, up to 60%, will stimulate economic growth by an additional 0.4 percentage point per year. On the other hand, when in the more pessimistic scenario the efficiency stays behind compared to the goals president Medvedev formulated, this will have a negative impact on economic growth of more than 0.3 percentage point per year on average. The gradual introduction of a CO2 price will decrease economic growth by slightly less than a percent for the first years, between 2012 and 2015, one year, but growth rates are projected to catch up quickly afterwards in both the scenarios to which it applies. The neutral scenario of 43% efficiency gains and a CO2 price leads a GDP level in 2020 that is very close to the more pessimistic scenario without intervention.

Having evaluated the economic impact of different paths of efficiency evolution, table 11 reports the projected evolution of CO2 emissions under all five scenarios. A comparison of the first three cases yields quite intuitive results. Under the baseline scenario, emissions grow by approximately 2.1% per year on average, whereas under the pessimistic scenario, emissions grow by 53% between 2007 and 2020, which comes down to an annual growth rate of 3.3% on average. On the other hand, if Russia can realise a 60% improvement in efficiency in this period, this will lead to a slight decrease of emissions. Hence, the strong efficiency gain enables Russia to increase its GDP by a factor of 2.5 between 2007 and 2020, while emissions will not increase.

Figure 4: GDP evolution under 3 energy efficiency scenarios with 2 policy simulations

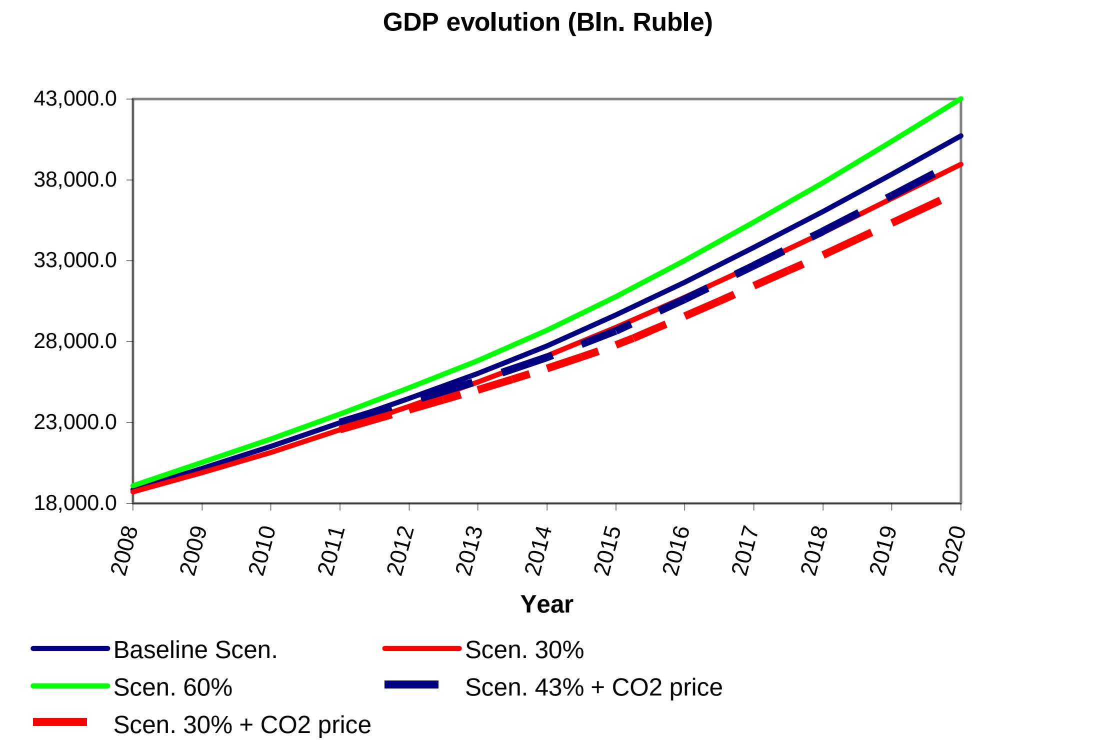

Figure 5: Evolution of total CO2 emissions under 3 energy efficiency scenarios with 2 policy simulations

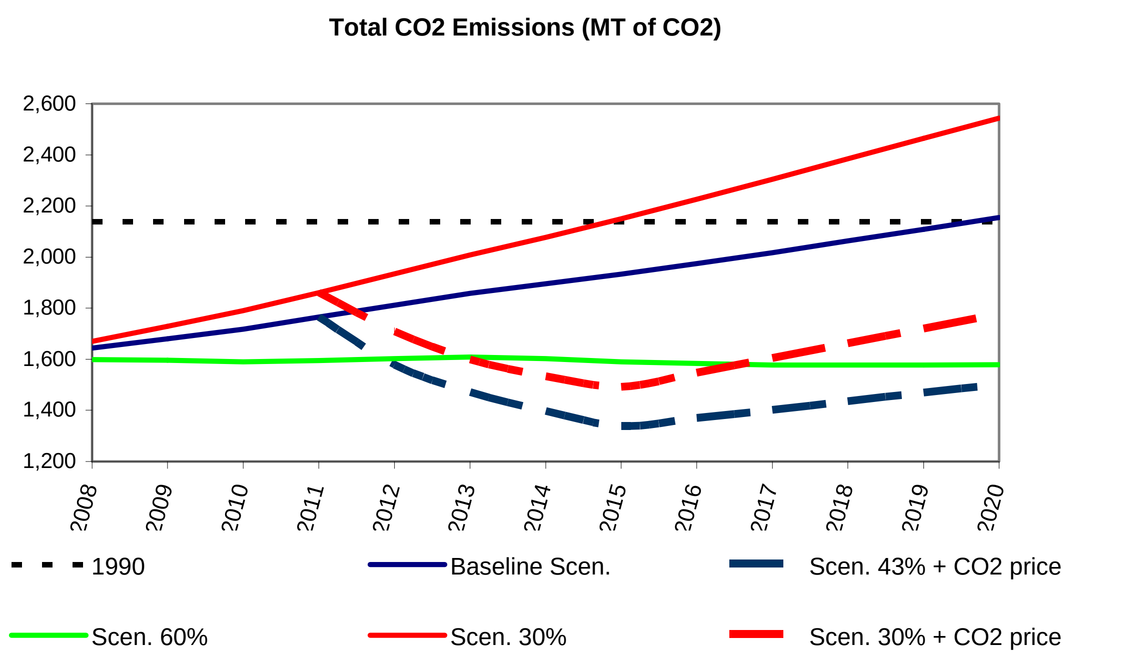

Table 10: 3 scenarios on energy efficiency and 2 policy simulations: GDP (in Bln.Rubles)

	2003	2007	2008	2009	2010	2011	2012	2013
• Baseline Scenario	13,201.1	17,481.4	18,857.9	20,146.5	21,512.0	22,992.5	24,478.3	26,031.2
• Scenario: 60%	13,201.1	17,481.4	19,090.0	20,535.7	21,985.0	23,526.0	25,141.9	26,827.3
• Scenario: 30%	13,201.1	17,481.4	18,714.2	19,895.1	21,153.9	22,545.6	23,995.1	25,500.9
• Scenario: 43% + CO2 price	13,201.1	17,481.4	18,857.9	20,146.5	21,512.0	22,992.5	24,266.8	25,562.2
• Scenario: 30% + CO2 price	13,201.1	17,481.4	18,714.2	19,895.1	21,153.9	22,545.6	23,775.2	25,001.8

Table 10: 3 scenarios on energy efficiency and 2 policy simulations: GDP (in Bln.Rubles)

	2014	2015	2016	2017	2018	2019	2020
• Baseline Scenario	27,736.1	29,645.5	31,676.1	33,831.6	36,044.6	38,356.8	40,718.1
• Scenario: 60%	28,692.0	30,785.7	33,014.6	35,385.8	37,827.0	40,385.8	43,011.0
• Scenario: 30%	27,108.4	28,870.4	30,741.2	32,718.9	34,740.9	36,839.6	38,967.1
• Scenario: 43% + CO2 price	27,017.4	28,653.7	30,612.7	32,688.0	34,807.3	37,010.6	39,239.3
• Scenario: 30% + CO2 price	26,332.5	27,784.3	29,566.3	31,445.1	33,353.7	35,322.0	37,295.0

Table 11: 3 scenarios on energy efficiency and 2 policy simulations: CO2 emissions (MT)

	1990	2007	2008	2009	2010	2011	2012	2013
CO2 emissions (MT)								
• Baseline Scenario	2,138.7	1,612.8	1,644.2	1,680.3	1,718.2	1,765.5	1,812.2	1,857.7
• Scenario: 60%	2,138.7	1,612.8	1,598.7	1,596.0	1,590.3	1,595.4	1,602.9	1,608.7
• Scenario: 30%	2,138.7	1,612.8	1,670.3	1,728.8	1,790.1	1,860.8	1,934.4	2,008.2
• Scenario: 43% + CO2 price	2,138.7	1,612.8	1,644.2	1,680.3	1,718.2	1,765.5	1,578.7	1,470.7
• Scenario: 30% + CO2 price	2,138.7	1,612.8	1,670.3	1,728.8	1,790.1	1,860.8	1,708.4	1,599.1

Table 11: 3 scenarios on energy efficiency and 2 policy simulations: CO2 emissions (MT)

	2014	2015	2016	2017	2018	2019	2020	2020 (%1990)
CO2 emissions (MT)								
• Baseline Scenario	1,895.7	1,932.9	1,974.9	2,017.7	2,063.8	2,109.0	2,154.5	100.7%
• Scenario: 60%	1,602.2	1,590.1	1,583.6	1,577.8	1,577.7	1,577.0	1,577.9	73.8%
• Scenario: 30%	2,077.9	2,149.6	2,226.0	2,304.2	2,384.1	2,464.0	2,543.6	118.9%
• Scenario: 43% + CO2 price	1,396.8	1,339.5	1,370.1	1,401.9	1,436.2	1,469.1	1,500.2	70.1%
• Scenario: 30% + CO2 price	1,533.5	1,491.9	1,547.2	1,604.3	1,662.9	1,720.8	1,776.4	83.1%

The last column of table 11 expresses the projected emissions in 2020 as a percentage of emissions in 1990, which is the reference year under the Kyoto protocol. Under the baseline scenario, emissions will be slightly larger than in 1990; if energy efficiency gains stay behind, the 1990 level will be exceeded by close to 19%. However, in the fourth and fifth rows of the table, the strong effect of the introduction of a CO2 price becomes clear: whereas until 2012, the emissions grow at the same pace as under the initial 43% and 30% scenarios, in the last nine years a significant gain can be made, that is gradually reached between 2012 and 2015, when the emission price is fully applied and equal to its assumed value of 22 euros per KT of CO2. Thanks to this improvement, overall emissions are projected to reach a level that is close to 30% smaller than the level in 1990 when efficiency grows by 43%, and 16% smaller when it grows by 30%, whereas in both cases emissions are 30% smaller than under the same scenario without the introduction of a CO2 price. Figures 4 and 5 present these projections graphically, and together show the existing trade-off between persistent economic over the entire sample and a significant reduction of CO2 emissions by introduction of a CO2 price.

4.3 Three scenarios of economic growth and energy efficiency

The results that were presented in the previous section were all obtained under the assumption that labour productivity, as driver of economic growth, followed a fixed path, increasing by a factor 2.6 over the period 2006-2020. In this section, this assumption will be loosened, and the impact of lower growth rates will be analysed. In the three official long run scenarios for Russia that were developed by its government, the scenario that is identified as baseline in this study, in line with the projections made by the European Commission, is in fact the most optimistic scenario. Therefore, in this section this optimistic scenario will be compared to a neutral and pessimistic scenario, with growth factors of 2.4 and 2.0, respectively.

The positive impact of energy efficiency gains on economic growth was exhibited in the previous section. In figure 4, the size of this effect is gently visible. In the reverse direction, a similar effect exists, where one can interpret economic growth as a stimulus for energy efficiency investments and resulting gains. While various argumentations can be brought up to explain this effect, that is commonly observed in many developing economies or countries in transition (e.g. cost advantages as a result of a decrease in energy consumption, attempts to fight externalities from energy consumption, increasing economic and political independence, etc.), in this study it is particularly relevant to evaluate its consequences; if economic growth stays behind, energy efficiency gains might respond accordingly. Particularly since labour productivity is used as driver of economic development, the linkages between economic growth and efficiency gains are strong; both depend heavily on technological improvements. For this reason, in this section the two evolutions are coupled and together evaluated in three scenarios:

- Optimistic scenario:
    - Labour productivity: + 260% between 2006-2020
    - Energy efficiency: + 60% between 2007-2020.
- Neutral scenario:
    - Labour productivity: + 240% between 2006-2020
    - Energy efficiency: + 43% between 2007-2020.
- Pessimistic scenario:
    - Labour productivity: + 200% between 2006-2020
    - Energy efficiency: + 30% between 2007-2020.

Tables 12 and 13 provide the results for the three scenarios, comparing them based on GDP growth and CO2 emissions. In these tables, the effect of a coupled evolution of productivity and efficiency is clearly illustrated. Tables 16-19 in the appendix provide sector-specific projections on the evolution of emissions over time and an insight in the contribution of the industries as a whole and the residential sector. On the aggregate level, under the optimistic scenario, GDP is multiplied by a factor 2.5 between 2007-2020, whereas the pessimistic scenario yields an increase of just 85%. On an annual basis, GDP growth rates fluctuate around 7% in the main part of the sample in the optimistic case, while in the pessimistic scenario, they start at 6% and decline to 4.3%. On top of that, emissions are significantly lower under the optimistic scenario, despite the considerably larger growth rate, and evolve to a level well below the 1990 level. On the other hand, under the pessimistic scenario they come closest to the level in 1990, even when economic growth is low, due to a lack of efficiency gains.

Table 12: Three scenarios of economic growth and energy efficiency: GDP

	2003	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
• Optimistic scenario								
GDP (Bln. Rubles)	13,201.1	17,481.4	19,090.0	20,535.7	21,985.0	23,526.0	25,141.9	26,827.3
GDP growth (%)		8.10	9.20	7.57	7.06	7.01	6.87	6.70
• Neutral scenario								
GDP (Bln. Rubles)	13,201.1	17,481.4	18,800.3	20,019.7	21,296.2	22,663.7	24,027.3	25,444.7
GDP growth (%)		8.10	7.54	6.49	6.38	6.42	6.02	5.90
• Pessimistic scenario								
GDP (Bln. Rubles)	13,201.1	17,481.4	18,523.9	19,479.3	20,449.1	21,485.9	22,533.1	23,576.4
GDP growth (%)		8.10	5.96	5.16	4.98	5.07	4.87	4.63

Table 12: Three scenarios of economic growth and energy efficiency: GDP

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
• Optimistic scenario							
GDP (Bln. Rubles)	28,692.0	30,785.7	33,014.6	35,385.8	37,827.0	40,385.8	43,011.0
GDP growth (%)	6.95	7.30	7.24	7.18	6.90	6.76	6.50
• Neutral scenario							
GDP (Bln. Rubles)	27,000.0	28,713.2	30,517.6	32,422.5	34,372.4	36,405.2	38,486.7
GDP growth (%)	6.11	6.35	6.28	6.24	6.01	5.91	5.72
• Pessimistic scenario							
GDP (Bln. Rubles)	24,715.8	25,934.5	27,170.7	28,429.7	29,698.5	30,999.7	32,320.5
GDP growth (%)	4.83	4.93	4.77	4.63	4.46	4.38	4.26

Table 13: Three scenarios of economic growth and energy efficiency: CO2 emissions

	1990	*2003*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
• Optimistic scenario	2,138.7	1,484.0	1,612.8	1,598.7	1,596.0	1,590.3	1,595.4	1,602.9
• Neutral scenario	2,138.7	1,484.0	1,612.8	1,638.1	1,667.8	1,698.2	1,737.0	1,774.8
• Pessimistic scenario	2,138.7	1,484.0	1,612.8	1,649.3	1,685.7	1,720.9	1,762.0	1,803.6

Table 13: Three scenarios of economic growth and energy efficiency: CO2 emissions

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
• Optimistic scenario	1,608.7	1,602.2	1,590.1	1,583.6	1,577.8	1,577.7	1,577.0	1,577.9
• Neutral scenario	1,811.5	1,841.2	1,867.7	1,898.2	1,929.3	1,964.0	1,998.1	2,033.2
• Pessimistic scenario	1,842.6	1,879.9	1,915.7	1,952.5	1,987.5	2,024.6	2,061.4	2,099.3

Nevertheless, it is remarkable that under all three scenarios, the total CO2 emissions in 2020 are lower than they were in 1990. When comparing these results to the three energy efficiency scenarios presented in the previous subsection, it is indicative that only when labour productivity grows strongly and energy efficiency stays behind, CO2 emissions clearly exceed their levels in 1990. The baseline scenario leads emissions to hit this level by 2020, and under all other scenarios – i.e. when energy efficiency gains are stronger or economic growth smaller – they will be considerably smaller than in 1990.

CONCLUSIONS

This study has provided a set of results on CO2 emissions in Russia between 2007 and 2020, under various scenarios of economic development and several paths of improvements considering energy efficiency. An interpretation of these results can be used for drawing instructive conclusions on realistic paths of evolution of both economic growth and emissions, and on requirements and potentials for Russia in attempts to reduce or control emissions over the next decade.

First, the projections provide an indication for credible goals to be set in post-Kyoto negotiations; even when facing strong and persistent economic growth, emissions can be controlled to stay below their benchmark level. This is an encouraging message, when compared to the considerable challenges that exist at the global level to cut back emissions, using 1990 as a reference year. However, at the same time it raises the question whether 1990 is the proper benchmark to be applied, especially given the particular circumstances in Russia, where the economic downturn and turmoil in the 1990s led to a sharp reduction of CO2 emissions; in 2003, the base year of this study, emissions reached a level smaller than 70% of the amount in 1990.

Second, the results emphasise the importance of accomplishing strong energy efficiency gains, and their effect on the economy and on emissions of greenhouse gases. Efficiency improvements were identified as a strong driver of economic growth. Besides, they play a crucial role in reducing the effects of persistent GDP growth as it is foreseen in most projections on the Russian economy. For this goal, the targets as they were articulated by president Medvedev in a recent decree seem to be effective and capable to control emissions under the most optimistic growth scenario. However, results also show that emissions can be expected to grow at a much higher rate when the efficiency improvements are not realised or when they stay behind compared to the 40% goal as it was set by Russian the president. In other words, given the high expectations of economic growth for Russia over the next 14 years, a strong commitment is required to stimulate structural changes in the economy that will realise an efficiency gain of 40%.

Finally, next to the active stimulation of a strong reduction of energy intensity, the introduction of a CO2 price as a policy instrument can have a strong structural impact on the emissions, which comes at the expense of a decline in economic growth that is of a much more temporary nature. Although particular details of such a measure will be likely to influence the effect to a considerable extent, the reasonable choice in this study of a price that is in line with current standards proves to lead to very promising results, with emissions that are reduced by 30%. The set of results provided in this study can play a guiding role as well when considering alternative configurations for cap-and-trade instruments.

APPENDIX

Table 14: CO2 emissions under the baseline scenario by branch of activity (in kt)

	1990	***2003***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***
Electricity	1,158,030	865,650	954,082	977,492	1,001,941	1,027,432	1,052,755	1,077,458	1,100,134	1,123,267	1,150,655	1,179,573	1,211,798	1,245,180	1,281,104
Crude oil	10,762	16,019	18,346	19,406	20,449	21,669	22,472	22,934	22,133	21,118	19,840	18,319	16,576	14,667	12,620
Refined petroleum and other fuels	23,076	26,947	32,012	32,436	32,909	33,902	35,147	36,205	36,248	36,026	35,645	35,031	34,199	32,996	31,359
Natural gas	10,762	16,019	17,485	18,125	18,783	19,454	19,871	20,292	20,756	21,225	21,787	22,375	23,023	23,669	24,341
Coal	1,620	1,536	1,790	1,831	1,879	1,921	1,994	2,071	2,153	2,241	2,345	2,459	2,587	2,726	2,879
Ferrous metallurgy	137,980	90,860	96,354	98,925	101,781	105,193	109,208	113,249	117,329	121,579	126,294	131,201	136,377	141,570	146,801
Nonferrous metallurgy	14,340	32,040	32,203	32,633	33,122	33,933	34,739	35,549	36,237	36,875	37,614	38,370	39,202	40,004	40,792
Chemical and petrochemical industry	24,970	26,900	29,793	30,301	30,821	31,917	32,967	33,968	34,663	35,211	35,682	36,012	36,218	36,203	35,914
Machinery	11,020	6,070	6,556	6,746	6,938	7,184	7,382	7,563	7,746	7,934	8,137	8,325	8,497	8,637	8,748
Lumber, pulp and paper industry	5,310	2,100	2,337	2,360	2,387	2,462	2,536	2,608	2,656	2,694	2,730	2,757	2,777	2,781	2,767
Construction materials	12,655	1,395	1,472	1,496	1,524	1,570	1,621	1,670	1,717	1,767	1,822	1,876	1,928	1,973	2,008
Light industry	240	190	238	243	248	256	263	269	275	279	284	289	295	300	305
Food processing industry	15,190	5,190	5,680	5,721	5,768	5,893	6,027	6,164	6,257	6,325	6,402	6,477	6,564	6,641	6,707
Other industries	15,640	5,990	6,697	6,785	6,877	7,070	7,273	7,479	7,637	7,775	7,917	8,053	8,191	8,309	8,400
Construction	12,655	1,395	1,497	1,545	1,598	1,663	1,728	1,792	1,865	1,947	2,038	2,131	2,223	2,311	2,393
Agriculture and forestry	48,500	15,980	19,490	19,709	19,954	20,520	21,180	21,872	22,410	22,878	23,381	23,892	24,459	25,002	25,495
Transport and communication	272,970	193,460	225,660	230,198	234,995	243,408	252,153	260,878	267,922	274,601	281,341	287,804	294,057	299,560	303,938
Trade, brokerage and catering	49,675	5,040	5,662	5,745	5,837	5,978	6,104	6,234	6,341	6,433	6,546	6,667	6,810	6,952	7,097
Housing, R&D and other services	81,500	28,370	32,630	33,232	33,852	34,695	35,607	36,545	37,487	38,465	39,529	40,627	41,780	42,950	44,124
Government and financial services	49,675	5,040	5,362	5,484	5,606	5,770	5,901	6,020	6,122	6,219	6,321	6,412	6,495	6,559	6,605
Total (kt)	1,956,570	1,346,190	1,495,346	1,530,415	1,567,268	1,611,889	1,656,928	1,700,818	1,738,086	1,774,859	1,816,309	1,858,650	1,904,055	1,948,990	1,994,397

Table 15: CO2 emission growth rates under the baseline scenario per branch of activity (in %)

	Initial Values: 1990 (in kt)	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***	***2020***
Electricity	1,158,030	2.18	2.45	2.50	2.54	2.46	2.35	2.10	2.10	2.44	2.51	2.73	2.75	2.89
Crude oil	10,762	6.90	5.78	5.37	5.96	3.71	2.05	-3.49	-4.59	-6.05	-7.67	-9.51	-11.52	-13.96
Refined petroleum and other fuels	23,076	0.38	1.33	1.46	3.02	3.67	3.01	0.12	-0.61	-1.06	-1.72	-2.38	-3.52	-4.96
Natural gas	10,762	3.65	3.66	3.63	3.57	2.15	2.12	2.29	2.26	2.65	2.70	2.90	2.81	2.84
Coal	1,620	1.48	2.29	2.58	2.27	3.78	3.84	3.96	4.12	4.63	4.86	5.22	5.37	5.60
Ferrous metallurgy	137,980	2.25	2.67	2.89	3.35	3.82	3.70	3.60	3.62	3.88	3.89	3.94	3.81	3.69
Nonferrous metallurgy	14,340	0.68	1.33	1.50	2.45	2.38	2.33	1.93	1.76	2.00	2.01	2.17	2.05	1.97
Chemical and petrochemical industry	24,970	1.66	1.70	1.72	3.56	3.29	3.04	2.05	1.58	1.34	0.93	0.57	-0.04	-0.80
Machinery	11,020	3.45	2.89	2.85	3.54	2.76	2.45	2.41	2.43	2.55	2.31	2.06	1.66	1.28
Lumber, pulp and paper industry	5,310	0.67	1.00	1.13	3.13	3.02	2.82	1.86	1.44	1.32	0.99	0.73	0.16	-0.51
Construction materials	12,655	1.82	1.64	1.83	3.02	3.23	3.05	2.84	2.91	3.10	2.96	2.76	2.32	1.82
Light industry	240	1.43	2.11	2.17	3.22	2.56	2.47	1.94	1.62	1.84	1.79	1.95	1.76	1.63
Food processing industry	15,190	-0.04	0.73	0.81	2.17	2.28	2.28	1.50	1.09	1.22	1.16	1.34	1.17	1.00
Other industries	15,640	0.94	1.31	1.36	2.79	2.88	2.82	2.12	1.80	1.83	1.71	1.71	1.44	1.10
Construction	12,655	4.01	3.26	3.38	4.07	3.94	3.71	4.03	4.41	4.68	4.58	4.32	3.95	3.54
Agriculture and forestry	48,500	0.39	1.12	1.24	2.84	3.22	3.27	2.46	2.09	2.19	2.19	2.37	2.22	1.97
Transport and communication	272,970	2.06	2.01	2.08	3.58	3.59	3.46	2.70	2.49	2.45	2.30	2.17	1.87	1.46
Trade, brokerage and catering	49,675	0.52	1.47	1.60	2.42	2.10	2.14	1.72	1.45	1.76	1.84	2.14	2.08	2.09
Housing, R&D and other services	81,500	2.10	1.84	1.87	2.49	2.63	2.64	2.58	2.61	2.77	2.78	2.84	2.80	2.73
Government and financial services	49,675	2.54	2.28	2.21	2.93	2.27	2.02	1.70	1.58	1.65	1.44	1.29	0.98	0.69
Total (kt)	1,956,570	2.12	2.35	2.41	2.85	2.79	2.65	2.19	2.12	2.34	2.33	2.44	2.36	2.33

Table 16a: CO2 emissions under the optimistic scenario

	1990	*2003*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Total CO2 emissions (Mt)	2,138.7	1,484.0	1,598.7	1,596.0	1,590.3	1,595.4	1,602.9	1,608.7	1,602.2	1,590.1	1,583.6	1,577.8	1,577.7	1,577.0	1,577.9
Total CO2 emissions (annual growth rate - %)			1.57	1.81	1.82	2.28	2.17	2.07	1.64	1.44	1.63	1.64	1.80	1.74	1.76
CO2 emissions from the residential sector (Mt)	182.1	137.8	146.8	145.6	142.8	141.5	140.6	139.6	137.6	135.1	133.0	131.1	129.7	128.2	126.7
CO2 emissions from the residential sector (annual growth rate - %)			0.24	0.56	0.51	1.50	0.78	0.73	0.23	-0.10	0.03	0.02	0.18	0.09	0.05
CO2 emissions by branches of activity (Mt)	1,956.6	1,346.2	1,451.9	1,450.4	1,447.5	1,453.8	1,462.3	1,469.1	1,464.5	1,455.0	1,450.6	1,446.7	1,448.0	1,448.9	1,451.2
CO2 emissions by branches of activity (annual growth rate - %)			1.70	1.94	1.95	2.36	2.31	2.19	1.77	1.58	1.78	1.78	1.94	1.88	1.90

Table 16b: CO2 emissions under the neutral scenario

	1990	*2003*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Total CO2 emissions (Mt)	2,138.7	1,484.0	1,638.1	1,667.8	1,698.2	1,737.0	1,774.8	1,811.5	1,841.2	1,867.7	1,898.2	1,929.3	1,964.0	1,998.1	2,033.2
Total CO2 emissions (annual growth rate - %)			2.26	2.21	2.08	2.39	2.36	2.16	2.02	1.91	1.92	1.80	1.87	1.82	1.84
CO2 emissions from the residential sector (Mt)	182.1	137.8	148.8	149.7	150.4	152.7	153.9	155.0	155.3	155.2	155.2	155.3	155.5	155.7	155.8
CO2 emissions from the residential sector (annual growth rate - %)			0.91	0.98	0.78	1.71	1.47	1.24	0.90	0.50	0.36	0.23	0.28	0.22	0.23
CO2 emissions by branches of activity (Mt)	1,956.6	1,346.2	1,489.3	1,518.1	1,547.8	1,584.3	1,620.9	1,656.5	1,685.9	1,712.5	1,743.0	1,774.0	1,808.4	1,842.4	1,877.5
CO2 emissions by branches of activity (annual growth rate - %)			2.40	2.33	2.21	2.45	2.45	2.25	2.13	2.04	2.06	1.94	2.01	1.96	1.97

Table 16c: CO2 emissions under the pessimistic scenario

	1990	*2003*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Total CO2 emissions (Mt)	2,138.7	1,484.0	1,649.3	1,685.7	1,720.9	1,762.0	1,803.6	1,842.6	1,879.9	1,915.7	1,952.5	1,987.5	2,024.6	2,061.4	2,099.3
Total CO2 emissions (annual growth rate - %)			1.57	1.81	1.82	2.28	2.17	2.07	1.64	1.44	1.63	1.64	1.80	1.74	1.76
CO2 emissions from the residential sector (Mt)	182.1	137.8	149.8	151.3	152.5	155.1	157.3	159.3	160.7	161.5	162.1	162.5	162.9	163.3	163.7
CO2 emissions from the residential sector (annual growth rate - %)			0.24	0.56	0.51	1.50	0.78	0.73	0.23	-0.10	0.03	0.02	0.18	0.09	0.05
CO2 emissions by branches of activity (Mt)	1,956.6	1,346.2	1,499.5	1,534.5	1,568.4	1,606.9	1,646.3	1,683.3	1,719.1	1,754.2	1,790.4	1,825.0	1,861.7	1,898.1	1,935.6
CO2 emissions by branches of activity (annual growth rate - %)			1.70	1.94	1.95	2.36	2.31	2.19	1.77	1.58	1.78	1.78	1.94	1.88	1.90

Table 17: CO2 emissions under the optimistic scenario by branch of activity (in kt)

	1990	*2003*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Electricity	1,158,030	865,650	933,694	923,239	921,341	917,623	916,402	916,722	916,536	910,751	902,203	898,136	895,273	897,130	899,989	906,026
Crude oil	10,762	16,019	17,161	18,763	20,024	20,765	21,573	22,324	22,637	21,791	20,735	19,417	17,848	16,044	14,040	11,845
Refined petroleum and other fuels	23,076	26,947	31,891	31,233	31,120	31,295	32,040	32,820	33,347	32,912	32,180	31,302	30,203	28,919	27,277	25,187
Natural gas	10,762	16,019	16,870	17,102	17,324	17,172	17,014	16,895	16,798	16,664	16,471	16,387	16,334	16,389	16,461	16,600
Coal	1,620	1,536	1,764	1,700	1,678	1,690	1,706	1,728	1,752	1,772	1,791	1,821	1,857	1,905	1,960	2,024
Ferrous metallurgy	137,980	90,860	94,233	93,193	93,348	94,284	95,909	97,660	99,374	100,717	101,865	103,431	105,077	107,061	108,993	110,984
Nonferrous metallurgy	14,340	32,040	31,986	31,238	30,901	30,542	30,530	30,594	30,670	30,543	30,302	30,197	30,124	30,193	30,250	30,330
Chemical and petrochemical industry	24,970	26,900	29,306	29,301	29,332	29,292	29,786	30,292	30,718	30,787	30,664	30,512	30,260	29,974	29,516	28,843
Machinery	11,020	6,070	6,338	6,380	6,418	6,396	6,425	6,454	6,473	6,470	6,455	6,463	6,467	6,480	6,477	6,466
Lumber, pulp and paper industry	5,310	2,100	2,322	2,281	2,257	2,233	2,256	2,282	2,304	2,300	2,282	2,267	2,246	2,225	2,193	2,147
Construction materials	12,655	1,395	1,446	1,416	1,395	1,382	1,390	1,400	1,407	1,408	1,408	1,413	1,417	1,422	1,423	1,417
Light industry	240	190	235	232	233	231	231	232	233	233	231	230	230	231	232	233
Food processing industry	15,190	5,190	5,682	5,496	5,392	5,293	5,280	5,283	5,291	5,246	5,172	5,116	5,064	5,038	5,008	4,976
Other industries	15,640	5,990	6,635	6,512	6,444	6,385	6,428	6,484	6,536	6,529	6,492	6,468	6,441	6,431	6,407	6,365
Construction	12,655	1,395	1,439	1,449	1,455	1,465	1,488	1,511	1,531	1,552	1,576	1,606	1,637	1,667	1,693	1,715
Agriculture and forestry	48,500	15,980	19,414	18,939	18,719	18,586	18,781	19,030	19,286	19,354	19,324	19,343	19,375	19,483	19,567	19,611
Transport and communication	272,970	193,460	221,106	220,948	220,826	220,997	224,658	228,567	232,037	233,365	233,846	234,495	234,846	235,310	235,096	234,006
Trade, brokerage and catering	49,675	5,040	5,632	5,503	5,453	5,371	5,342	5,331	5,329	5,290	5,227	5,193	5,172	5,184	5,202	5,232
Housing, R&D and other services	81,500	28,370	31,960	31,721	31,486	31,319	31,414	31,546	31,671	31,695	31,667	31,728	31,803	31,957	32,114	32,288
Government and financial services	49,675	5,040	5,229	5,227	5,230	5,188	5,189	5,192	5,187	5,152	5,102	5,068	5,030	5,003	4,968	4,929
Total (kt)	1,956,570	1,346,190	1,464,342	1,451,875	1,450,374	1,447,510	1,453,843	1,462,348	1,469,118	1,464,530	1,454,992	1,450,592	1,446,702	1,448,047	1,448,866	1,451,226

Table 18: CO2 emissions under the neutral scenario by branch of activity (in kt)

	1990	2003	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity	1,158,030	865,650	933,694	949,684	968,750	988,232	1,008,272	1,028,038	1,046,800	1,063,048	1,078,849	1,098,029	1,118,298	1,141,567	1,165,356	1,190,874
Crude oil	10,762	16,019	17,161	18,333	19,348	20,325	21,441	22,173	22,855	22,644	21,881	20,897	19,710	18,335	16,819	15,184
Refined petroleum and other fuels	23,076	26,947	31,891	31,988	32,366	32,763	33,668	34,773	35,864	36,193	36,022	35,729	35,266	34,679	33,868	32,828
Natural gas	10,762	16,019	16,870	17,416	17,974	18,533	19,076	19,388	19,677	19,975	20,294	20,694	21,116	21,600	22,081	22,583
Coal	1,620	1,536	1,764	1,779	1,810	1,847	1,879	1,938	1,998	2,059	2,125	2,203	2,287	2,383	2,485	2,596
Ferrous metallurgy	137,980	90,860	94,233	95,872	97,969	100,276	103,099	106,445	109,729	112,966	116,312	120,036	123,920	128,079	132,263	136,526
Nonferrous metallurgy	14,340	32,040	31,986	32,123	32,473	32,872	33,574	34,269	34,962	35,531	36,035	36,633	37,256	37,975	38,688	39,424
Chemical and petrochemical industry	24,970	26,900	29,306	29,738	30,187	30,636	31,642	32,596	33,539	34,247	34,762	35,222	35,586	35,891	36,067	36,111
Machinery	11,020	6,070	6,338	6,506	6,647	6,788	6,975	7,122	7,249	7,376	7,510	7,658	7,798	7,932	8,046	8,142
Lumber, pulp and paper industry	5,310	2,100	2,322	2,331	2,348	2,368	2,434	2,498	2,562	2,608	2,641	2,671	2,697	2,720	2,734	2,740
Construction materials	12,655	1,395	1,446	1,460	1,472	1,486	1,517	1,552	1,585	1,617	1,649	1,686	1,722	1,758	1,790	1,818
Light industry	240	190	235	238	242	247	254	260	266	270	274	278	282	287	292	296
Food processing industry	15,190	5,190	5,682	5,675	5,712	5,752	5,868	5,990	6,117	6,202	6,258	6,322	6,385	6,465	6,541	6,620
Other industries	15,640	5,990	6,635	6,684	6,757	6,832	7,002	7,180	7,361	7,501	7,611	7,725	7,836	7,955	8,066	8,171
Construction	12,655	1,395	1,439	1,481	1,513	1,546	1,590	1,634	1,674	1,721	1,776	1,838	1,901	1,964	2,024	2,081
Agriculture and forestry	48,500	15,980	19,414	19,484	19,692	19,916	20,446	21,047	21,678	22,170	22,554	22,964	23,381	23,860	24,341	24,830
Transport and communication	272,970	193,460	221,106	224,994	228,787	232,668	239,952	247,448	255,071	261,387	266,808	272,262	277,536	282,862	287,849	292,459
Trade, brokerage and catering	49,675	5,040	5,632	5,657	5,731	5,810	5,931	6,035	6,141	6,220	6,283	6,365	6,453	6,565	6,678	6,799
Housing, R&D and other services	81,500	28,370	31,960	32,476	32,930	33,384	34,045	34,765	35,488	36,197	36,907	37,680	38,475	39,326	40,194	41,087
Government and financial services	49,675	5,040	5,229	5,334	5,430	5,523	5,655	5,757	5,849	5,925	5,995	6,070	6,138	6,206	6,262	6,309
Total (kt)	1,956,570	1,346,190	1,464,342	1,489,253	1,518,139	1,547,802	1,584,320	1,620,911	1,656,464	1,685,857	1,712,547	1,742,961	1,774,044	1,808,410	1,842,445	1,877,477

Table 19: CO2 emissions under the pessimistic scenario by branch of activity (in kt)

	1990	2003	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity	1,158,030	865,650	933,694	956,894	979,999	1,002,363	1,023,711	1,046,093	1,066,961	1,087,270	1,107,090	1,127,724	1,148,844	1,171,841	1,194,866	1,218,753
Crude oil	10,762	16,019	17,161	18,070	18,853	19,573	20,447	21,216	21,900	22,560	23,123	23,567	23,341	22,907	22,404	21,845
Refined petroleum and other fuels	23,076	26,947	31,891	32,391	32,992	33,533	34,484	35,417	36,291	37,026	37,704	38,404	38,590	38,648	38,632	38,566
Natural gas	10,762	16,019	16,870	17,463	18,033	18,585	19,119	19,651	20,147	20,635	21,059	21,455	21,918	22,439	22,960	23,502
Coal	1,620	1,536	1,764	1,805	1,852	1,901	1,939	1,985	2,030	2,076	2,129	2,191	2,259	2,334	2,411	2,491
Ferrous metallurgy	137,980	90,860	94,233	96,499	98,849	101,238	103,909	106,756	109,515	112,325	115,316	118,558	121,978	125,634	129,352	133,188
Nonferrous metallurgy	14,340	32,040	31,986	32,488	33,091	33,707	34,581	35,488	36,377	37,213	38,001	38,826	39,665	40,583	41,517	42,497
Chemical and petrochemical industry	24,970	26,900	29,306	29,864	30,414	30,945	32,028	33,084	34,093	35,052	35,953	36,842	37,589	38,302	38,970	39,615
Machinery	11,020	6,070	6,338	6,484	6,593	6,692	6,834	6,978	7,100	7,234	7,370	7,499	7,633	7,771	7,899	8,023
Lumber, pulp and paper industry	5,310	2,100	2,322	2,348	2,378	2,406	2,479	2,550	2,617	2,680	2,738	2,797	2,846	2,894	2,939	2,983
Construction materials	12,655	1,395	1,446	1,462	1,472	1,481	1,503	1,526	1,544	1,564	1,587	1,612	1,636	1,662	1,685	1,708
Light industry	240	190	235	240	246	252	260	268	276	283	289	294	300	305	311	316
Food processing industry	15,190	5,190	5,682	5,772	5,884	5,994	6,171	6,349	6,523	6,676	6,811	6,951	7,078	7,215	7,350	7,491
Other industries	15,640	5,990	6,635	6,758	6,890	7,015	7,226	7,434	7,631	7,811	7,978	8,148	8,301	8,457	8,610	8,765
Construction	12,655	1,395	1,439	1,469	1,486	1,499	1,519	1,539	1,553	1,572	1,597	1,623	1,653	1,683	1,712	1,738
Agriculture and forestry	48,500	15,980	19,414	19,787	20,233	20,666	21,363	22,051	22,722	23,312	23,846	24,398	24,886	25,389	25,888	26,401
Transport and communication	272,970	193,460	221,106	226,008	230,681	235,245	242,968	250,500	257,630	264,553	271,361	278,282	284,388	290,460	296,458	302,508
Trade, brokerage and catering	49,675	5,040	5,632	5,738	5,866	5,990	6,144	6,298	6,446	6,572	6,676	6,781	6,888	7,008	7,128	7,254
Housing, R&D and other services	81,500	28,370	31,960	32,624	33,219	33,802	34,553	35,309	36,008	36,711	37,429	38,175	38,926	39,714	40,508	41,323
Government and financial services	49,675	5,040	5,229	5,345	5,444	5,535	5,664	5,792	5,906	6,019	6,126	6,228	6,326	6,427	6,522	6,615
Total (kt)	1,956,570	1,346,190	1,464,342	1,499,509	1,534,475	1,568,423	1,606,905	1,646,284	1,683,271	1,719,143	1,754,183	1,790,356	1,825,047	1,861,673	1,898,121	1,935,583