

# Inter-Sector Inter-Region Analysis: Estimating Consequences of Realization of Large Investment Projects in Energy Sector of Russian Economy

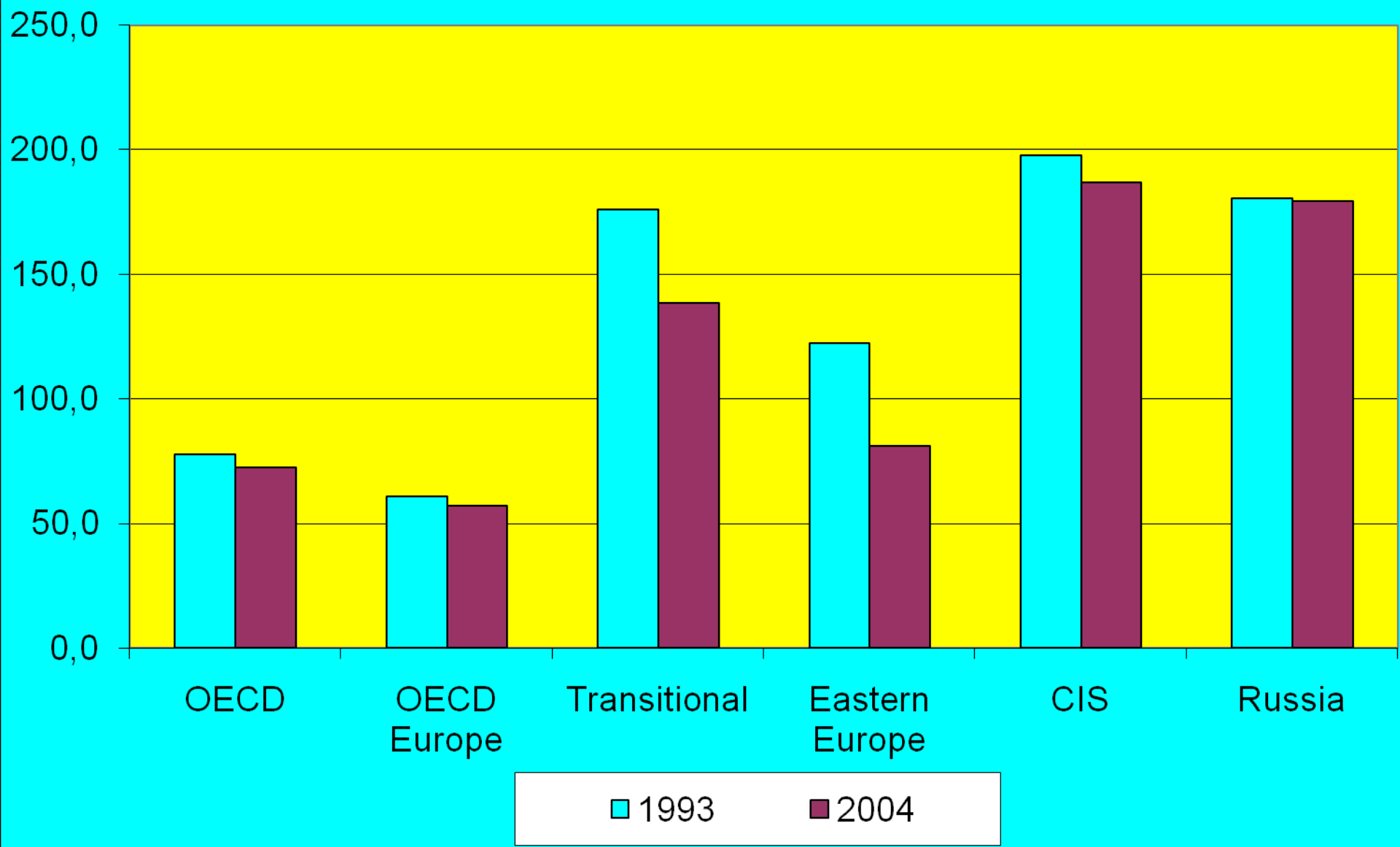
Nikita Suslov, IEIE SB RAS & NSU,  
Novosibirsk, Russia

# What I'm going to do now?

To present:

1. The Problem: Energy Intensity Puzzle
2. The model
3. Examples of Model Applications

# Energy Intensity of GDP in World Economies and Groups of Economies, USA in 1993=100%



# Specification:

$$\ln(e) = \beta_0 + \beta_1 \cdot DISTE + \beta_2 \cdot INST \cdot \ln(P/P_E) + \beta_3 \cdot \ln(P/P_E) + \varepsilon$$

$e$  is energy intensity of GDP,

$DISTE$  – climate variable,

$INST$  – institutional strength variable,

$P$  – average price,

$P_E$  - energy price.

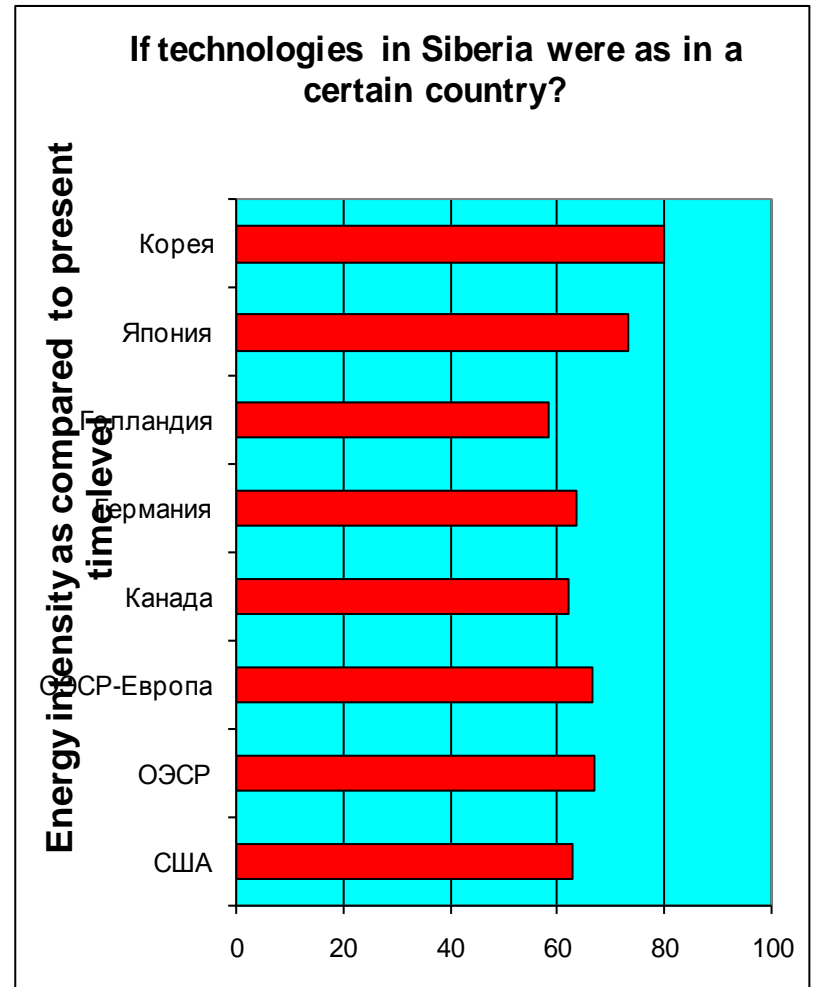
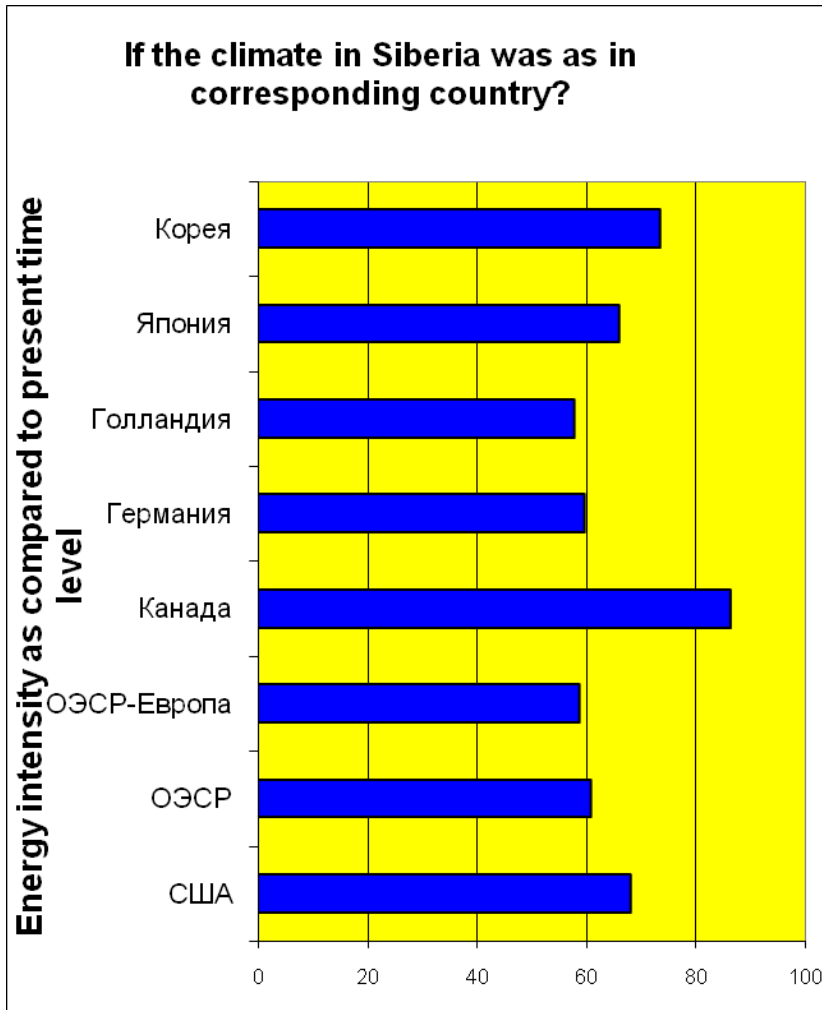
$(\beta_2 \cdot INST + \beta_3)$  – price elasticity of energy intensity  
(energy conditional demand price elasticity)

# Coefficients of Price Elasticity of Production Energy Intensity by the Economies and the Groups Economies of the World.

	2002	2003	2004	2005	2006	In average
World in Average, 118 economies	-0,546	-0,519	-0,506	-0,278	-0,317	-0,433
OECD, 26 economies*	-0,889	-0,838	-0,910	-0,596	-0,666	-0,780
Former Socialist, 27 economies	-0,451	-0,436	-0,406	-0,212	-0,243	-0,349
EEE and Baltic, 14 economies	-0,559	-0,540	-0,551	-0,322	-0,362	-0,467
CIS, 11 economies	-0,318	-0,308	-0,234	-0,082	-0,102	-0,209
Russian Federation	-0,374	-0,374	-0,320	-0,124	-0,128	-0,264

\* Without new members

# Results of analysis of energy demand model



# Inter-Region Input-Output (IRIO)

Models with intraregional IO Tables and interregional transport blocks (Granberg A. G., 1973, “Optimizatsija territorialnykh proporsij narodnogo hozjajstva”. Moskva: «Ekonomika», 1973. – 248 c. ) –

OMMM (OIIM)

## *A brief story*

1. 1967 - first experimental forecast calculations for the period 1966-1975 for the Soviet Union, involving 16 economic sectors and 11 regions,
2. 1978 - experimental forecast calculations for the period 1975-1990 for the Soviet Union, involving 16 economic sectors and 11 regions,
3. 1978-1982 Modeling world economy using “Siberian” models and database of “Future of World Economy” Project as a suggestion of UN AG Secretariat
4. 1980-1995: Two systems of Models: SYRENA & SONAR
5. Up to the present time forecasting Russian Economy by regions and economic sectors

# Approach to Modeling National Economy

- Inter-sector interactions: Leontief Input-Output framework;
- inter-region interactions: each region of a large country is described by its own input-output (intra-regional) block; inter-region transportations of sector products are modeled using transport modeling techniques incorporating transport technologies;
- the model includes both a scope of input-output tables and transport blocks, thus optimization is feasible;
- all the endogenous variables are defined for the last year of a long period considered; at the same time investments (gross fixed capital formation) for this year are non-linear functions of investments in initial (base) year of the period;
- the total volume of investment for all the years of the period considered is also an endogenous variable;



$X^{10}$	$X^{11}$	$U^1$	$X^{20}$	$X^{21}$	$U^2$	$X^{12}$	$X^{21}$	Z
Region 1						-1	+1	CONSUMPTION
$I-A^0$	$I-A^1$					Transport cost		
Transport								
Investment								IMPLICATION
Labor								
Region 2						+1	-1	IMPLICATION
$I-A^0$	$I-A^1$					Transport cost		
Transport								
Investment								IMPLICATION
Labor								

Inter-region transport

IV

$b_1$

$-L_1$

$b_2$

$-L_2$

A principle structure of OMMM for 2 regions: Intra-regional IO matrixes for all identified regions are a basis

# The Model

Product balances:

$$x_i^{r0} + x_i^{r1} - \sum_{j=1}^n a_j^{r0} \cdot x_j^{r0} - \sum_{j=1}^n a_j^{r1} \cdot x_j^{r1} - u_i^r - \alpha_i^r \cdot z - \\ - \sum_{\tau=1}^T \sum_{s \neq r} x_i^{rs} + \sum_{\tau=1}^T \sum_{s \neq r} x_i^{sr} - NEX_i^r \geq b_i^r, \quad i = 1, \dots, n$$

Balances of transport services:

$$x_\tau^{r0} + x_\tau^{r1} - \sum_{j=1}^n a_{\tau j}^{r0} \cdot x_j^{r0} - \sum_{j=1}^n a_{\tau j}^{r1} \cdot x_j^{r1} - \\ - \sum_{k, s \neq r} \sum_{j=1}^n a_{\tau r j}^{ks} \cdot x_j^{ks} \geq b_\tau^r, \quad \tau = 1, \dots, T$$

# The Model

Balances of labor:

$$\sum_{j=1}^n l_j^{r0} \cdot x_j^{r0} + \sum_{j=1}^n l_j^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^T l_{\tau}^{r0} \cdot x_{\tau}^{r0} + \sum_{\tau=1}^T l_{\tau}^{r1} \cdot x_{\tau}^{r1} \leq L^r,$$

$$\tau = 1, \dots, T$$

Balances of investment:

$$\sum_{j=1}^n k_j^{r0} \cdot x_j^{r0} + \sum_{j=1}^n k_j^{r1} \cdot x_j^{r1} + \sum_{\tau=1}^T k_{\tau}^{r0} \cdot x_{\tau}^{r0} + \sum_{\tau=1}^T k_{\tau}^{r1} \cdot x_{\tau}^{r1} - f^1(u_g^{r0}, u_g^{r1}) \leq 0, g \in G$$

Goal function:  $Z \longrightarrow \max$

# Statistical Sources

- Input-Output Table for Russian national economy 1995 including 100 sector products,
- Aggregate Input-Output Tables for Russian national economy for further years up to 2004 including 20 sector products,
- Tables of use of goods and services in Russia in consumer prices,
- *Storing regional differences in input coefficients since the end of 1980ths,*
- Other statistics from Russian Statistical Council (ROSSTAT)

# OMMM-Energy: present version

- **OMMM-Energy** – Optimization Inter-sector Inter-region Model including energy with energy products in physical units. It captures both inter-sector and inter-region relations of national energy sector,
- **Presentation of economic dynamics**: it is a composition of two sub-models for time periods 2008-2020 and 2021-2030. The dynamics of investment are treated as non-linear functions being adapted with the help of linearization techniques;
- **Includes 45 products** and within them **8 energy products**:
  - ✓ rough oil
  - ✓ Gas
  - ✓ coal,
  - ✓ dark petroleum products
  - ✓ light petroleum products,
  - ✓ products of coal processing,
  - ✓ Electricity
  - ✓ heat

# OMMM-Energy: present version

• **Model also includes some non-energy** sectors which are **important** given energy sector analysis:

- ✓ drilling for oil and gas,
- ✓ pipelines (as a kind of transport),
- ✓ production of special equipment for energy production, transportation and consumption
- ✓ petroleum chemistry

• **Model captures some peculiarities** of energy production and consumption which detracts the model from canonical OMMM:

- ✓ Oil and gas reserves are monitored: annual output to volume of reserves ratio is fixed in the model; output growth is followed by investment into growth of reserves;
- ✓ Diminishing returns to scale in oil and gas extraction sector are captured,
- ✓ substitution between different kinds of energy is captured as well: 20 types of technologies to produce heat and electricity in each region are incorporated

# Model application: scenario approach

Model makes it feasible to evaluate complex consequences and efficiency of realization of policy measures in the sphere of energy production, processing and consumption.

Previously it was applied to treat the following problems:

□ evaluation of the economic consequence of concentration of energy-intensive production in the South Siberia areas,

□ evaluation of the economic consequence of gasification in the regions of the South Siberia,

□ evaluation of the economic consequence of reduction of energy intensity of production in national economy,

□ evaluation of the economic consequence of spreading of heat pumps technology in the different regions of national economy.

# Forecast Variants of Development of Russian Economy for the period 2011-2030

	Variants		
	Conservative	Innovative	Breaking
Change of:			
GDP	187	220	277
Employment	93	94	97
Fixed Capital	150	161	204
Saving rate in GDP	144	150	177
Total Factor Productivity	141	156	164
Share of:			
Saving rate in GDP	26,6	27,8	32,8
“New” Capital in Total Fixed Capital in 2030	86,1	89,2	97,4



# Report to State Council RF «About Raising energy efficiency in Russian Economy» of Center for Energy Efficiency, 2008

***Technical potential of energy saving*** – 45% (415-450 Mill. t coal equivalent)

***Economic potential of energy saving*** – 34% (310-340 Mln. t coal equivalent)

***Market potential of energy saving*** – 29% (270-295 Mln. t coal equivalent.)

Technical potential of heat saving = 120 Mln. t coal equivalent.

= more than 13% of total energy consumption in Russian economy

= more than 1/4 of total Technical potential of energy saving

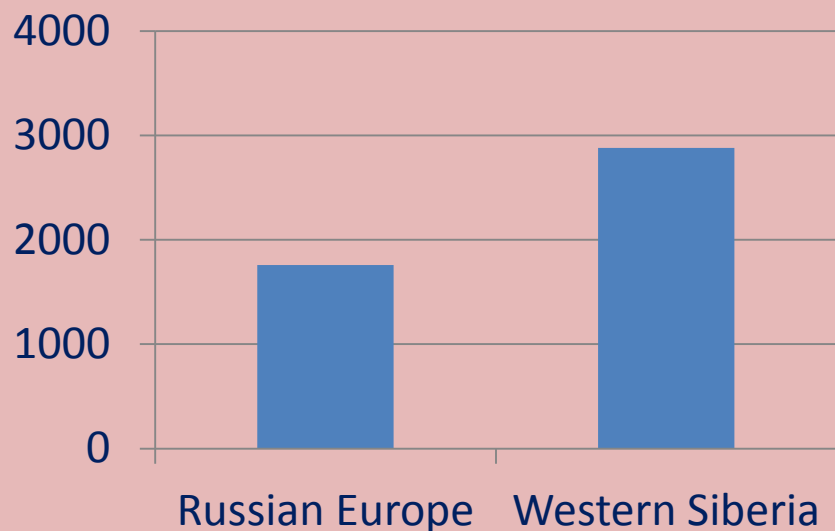
Annual market for compression heat pumps – 40-55 mill. of coal equivalent.

Spreading compression heat pump :

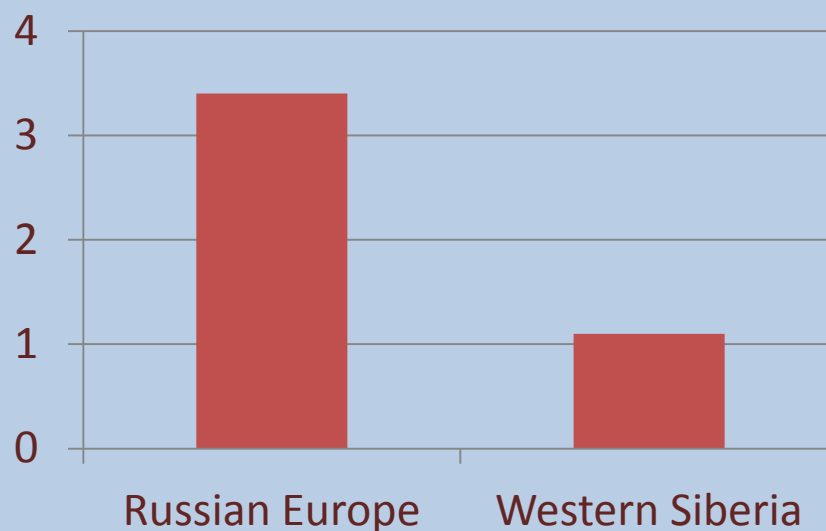
- reduction of fuel consumption in energy generation sphere and, so, energy intensity reduction.
- Increase of capital intensity because of:
  - 1) Heat pumps are more expensive,
  - 2) Additional electricity generation capacity is needed,
  - 3) Additional gas pipelines could be needed
- Heat pumps are efficient in Siberia under the transformation coefficient of 4
- Heat pumps are efficient in European Russia under the transformation coefficient of 5
- ***Volume of fuels saved per a unit of electricity consumption averages 270 gram of coal equivalent per a kWt-hour***

# Effects of Heat Saving

**GDP increment per 1 cilocalories of heat saved, in Roubles 2007**



**Energy saving per a unit of heat conserved, in units**



*Interregional integration project of SB RAS:*

**«UTILIZATION OF HEAT WASTE IN EASTERN REGIONS OF RUSSIA AS AN IMPORTANT FACTOR OF ENERGY CONSERVATION AND EFFICIENCY OF ECONOMY DEVELOPMENT»**

## Change of Macroeconomic Indices in 2030 as a Result of Gas-Coal Exports Reduction in 2010 \$mill.

	Scenario of gas exports reduction by 30 bill cubic m		Scenario of both gas and coal exports reduction by 20 mill t	
	Russia	Siberian Federal Okrug	Russia	Siberian Federal Okrug
<b>GDP/GRP</b>	<b>1090</b>	<b>890</b>	<b>1389</b>	<b>1465</b>
<b>Household consumption</b>	<b>-5041</b>	<b>-596</b>	<b>-5294</b>	<b>-625</b>
<b>Gross output</b>	<b>-247</b>	<b>1695</b>	<b>-763</b>	<b>2245</b>
<b>Total internal demand</b>	<b>-13525</b>	<b>488</b>	<b>-15849</b>	<b>391</b>
<b>Total material cost</b>	<b>-1377</b>	<b>815</b>	<b>-2131</b>	<b>789</b>
<b>Energy production, bill t of coal equivalent</b>	<b>-40,10</b>	<b>-1,50</b>	<b>-55,00</b>	<b>-5,70</b>
<b>Energy consumption, bill t of coal equivalent</b>	<b>-5,50</b>	<b>-1,40</b>	<b>-5,70</b>	<b>-1,50</b>

**Thank You!**