

Material Flows of the Refinery and Petrochemical Sector in Russia and Difficulties Related to the Application of NEAT

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1. Special features of the oil and petrochemical industries in Russia important for non-energy use

Russia is one of the greatest world energy producers and consumers and hence a bigger emitter of green house gas (GHG) emissions. More than 90% of Russia's GHG is to a greater extent energy related. Russia plays a significant role in the world production of natural gas and oil, and exports of natural gas, oil and petroleum products is a major source of revenues of the national economy.

Energy intensity of Russian economy was 2-3 times greater than that in the USA or Western Europe by the beginning of the 1990s (RF Ministry of Fuel and Energy, 1998). During the last decade energy intensity of GDP raised up by more than 30%.

For these reasons energy and fuels are the prioritized purposes of production of oil and natural gas in Russia. For non-energy purposes were used:

- ✓ only 2.7% (1078.6PJ) from the total production of primary energy in 1996, excluding losses;
- ✓ 4.3% from the total consumption of primary energy resources, in particular:
 - From oil including LPG – 2.6%;
 - From natural gas – 3.5%;
 - From coal -- 0.4%.

To understand adequately the non-energy use in Russia a technological chain in petrochemical production should be considered starting from the stabilization process of crude products (NG and oil) as a first stage.

Greater part of oil and natural gas fields are situated in the remote parts of the country far from the regions where greater energy consumers are. So only some preliminary treatment (stabilization, stripping, etc.) takes place close to fields. Largest refineries and petrochemical facilities are places close to consumers. Among other important features needed to better understanding of non-energy use of petrochemical products it should be mentioned that as a result of the general economic crisis in Russia in the last decade there were no investments in replacement of outdated technologies. The use of these technologies determines an outdated product structure.

In contrast to the situation in European petrochemical industry NG and oil (input measured in energy units) play comparable roles in chemical production and at some stages of technological chain products derived from them come through the same processes like steam cracking, etc.

To understand better a scale of the non-energy use in Russia and, in particular, for petrochemical industry compared to the total energy production and consumption an information from the IEA statistics was taken (Table 1). Numbers on consumption by chemical industry from this source were compared with industrial statistics and corrected, and data for several more products were added from it.

Some discrepancy between two sources was observed (marked with *) which should be studied later.

Table 1. Final non-energy consumption in Russia, 1996, in 1000 t

Item	Total non-energy consumption	Chemical Industry *	Other sectors
HARDCOAL	767		767
BROWN	165		165
PEAT	53		53
OVENCOKE	629		629
BKB	2		2
CRUDEOIL	1112		1112
NGL			
Total Pet. Products	12992	5153	7839
REFINGAS	42	42	
*ETHANE	417	417	
*LPG	1055	1055	
MOTORGAS	62	62	
JETKERO	8	8	
OTHKERO	10	10	
GASDIES	9	9	
RESFUEL	25	25	
*NAPHTHA	3525	3525	
WHITESP	217		217
LUBRIC	2312		2312
*BITUMEN	4522		4522
PARWAX	160		160
*PETCOKE	628		628
Other Petrol. Prod.			
COKEOVGS			
BLFURGS			
NATGAS (PJ)	690101	690101	
TOTAL			

2. Flow material and processes diagram

A detailed analysis of technologies and material and product structure made it possible to develop a flow material and processes diagram (Fig. 1). The diagram covers all the stages of oil and natural gas treatment for chemical purposes and shows output used for fuel production that is marked with a different coloring at the diagram. Quite all the chemical products which play more or less significant role are shown at the diagram starting from the unstable crude oil and natural gas, basic chemicals, then intermediates and finalizing with most important polymers such as polyethylene, polypropylene, etc.

The processes showed at the diagram include: Stabilization → Fractionation (Refining) → Steam Cracking → Dehydrogenization → Polymerization.

The diagram looks enough complicated because at some stages of technological chain products derived from natural gas and oil come through different processes and at other stages -- through the same processes like steam cracking, etc.

Among the significant products and processes used which are typical only for Russia it should be mentioned:

- WCLH – a wide cut fraction of light hydrocarbons. It is derived at many plants from natural gas, associated oil gas, stabilized oil, refineries refluxes, and includes: methane (less than 0.1%), ethane (1.1-2.4%), propane (25-39%), butane (25-40%), isobutane (13.5-16.3%), pentane (4.9-8.5%), isopentane (6.6-7.5%), hexane (0.8-10%). So the content of WCLH from particular plants varies greatly that could influence a share of the WCLH used as a fuel and determine a content of the output from steam cracking process. It makes an accounting of carbon stored in the products more complicated and less accurate.
- GFU is a gas fractionating process used to divide WCLH and to get a wide range of products which are used then as inputs for steam cracking and dehydrogenation (see the diagram).
- Amounts of the products used as inputs and derived from the processes give more or less full product balance needed for NEAT model.

3. Some problems related to the application of the NEAT model to the Russian petrochemical sector

Some other problems related to the application of the NEAT model to the Russian petrochemical industry were studied.

3.1. NEU statistics in the energy balance of Russia

There are different approaches to accounting energy and non-energy use of feedstocks for petrochemical processes in national statistics of the countries. An analysis of the instructions for filling-in a line in the energy balance of Russia and discussion of this problem with the experts from the Statistical Committee and from the industry leads us to conclusion the formula used in Russia is as follows:

$$Q_{NEU, NL, i} = Q_{TF, i} - Q_{F, i} - Q_{E, int, i}$$

It means that energy and fuels produced by the process as by-products and used for internal combustion needs at the plant or sold as fuels for combustion outside basic chemical production should be subtracted from the amount of feedstock for the process.

3.2. Conversion factors of energy statistics into mass flows

Conversion factors (low heat value) to transform data on mass flows through petrochemical industry to energy units used in NEAT model for Germany were compared with their values used in Russian manuals. Some differences were observed (see Table 2) where products with different LHV are marked with * and LHV used in Russia are in brackets. The reason for the differences could result from the different standards for fuels and products (humidity, percentage of particular substances, etc.) used in the countries. LHV for some more products were added to the list (marked with +).

Conversion of energy statistics into mass flows	
Product	LHV [PJ/Mt]
Natural gas	50,00
Methane	47,50
*Ethane	46,30(47,52)
*Propane	45,60(46,40)
*Butane	45,30(45,68)
*Pentane	40,60(45,41)
Benzene	40,90
Toluene	41,20
Ethylene	47,20
Propylene	45,80
Butadiene	45,50
Methanol	21,10
Naphtha	44,00
Gas oil	42,70
LPG	46,00
Aromatics	41,00
Other light oils	44,00
Petroleum	43,00
*Gas-, diesel-, fuel oil	43,00(41,36-42,62)
*Heavy fuel oils(mazut)	42,00(39,78-41,32)
Other oil products	43,00
Bitumen	42,00
Coal oils and tars	43,00
Lubricants	44,00
+Butylene	45,35
+Acetylene	47,77
+Kerosene	42,96
+Gasoline	43,75

3.3. Long life versus short life products division

An important role in accounting a carbon stored in products plays a separation of short living products from long living ones. As a result of discussion of the problem a corrected list of long and short life products for Russia was developed (see Table 3).

		Long life [%]	Short life [%]
		Should be split	
ISIC rev.2	PRODUCT	Cons/exp	
	BASIC CHEMICALS		
	351105 Acetylene	Total 50	50
	351158 Ammonia	Non relevant	
	351107 Benzene	Other 50	50
353034A	Bitumen	Total 100	0
	351109 Butadiene	Other 100	0
	Butene	Other 100	0
	352901 Carbon black	Total 100	0
	351110 Ethylene	Other 50	50
	353025 Lubricants	Total 0	100
	351121 Methanol	Other 50	50
	353031 Petroleum coke	Total 0	100
	Pitch	Total 100	0
	351113 **Propylene	Other 20	80
	351114 Toluene	Total 0	100
	Waxes, paraffins	Total 0	100
	351115 Xylenes (o-,m-,p-,mixed xylene)	Other 0	100
	INTERMEDIATES		
	**Acetic acid	Total 0	100
	**Acetone	Total 0	100
	Acrylic acid	Other 100	0
	Acrylonitrile	Other 100	0
	Aniline	Total 80	20
	Bisphenol A	Total 100	0
	**Cumene	Other 0	100
	Cyclohexane	Other 0	100
	Cyclohexanone	Other 0	100
	Dimethylterephthalate	Other 100	0
	Ethanol	Total 0	100
	Ethylbenzene	Not relevant ?	
	Ethylene glycol	Other 0	100
	Ethylene oxide	Other 0	100
	Formaldehyde	Other 0	100
	I-Propanol	Other 0	100
	MTBE	Not relevant	
	Phenol	Other 0	100
	Phthalic anhydride PSA	Total 0	100
	Propylene oxide	Other 0	100
	Styrene	Other 100	0
	Terephthalic acid TPA	Other 100	0
	Vinylchloride monomer VCM	Other 100	0
	PRODUCTS		
	**ABS	Not used	100 0
	Epoxy resin	Total 100	0
	Melamineformaldehyde resin	Total 100	0
	Other plastics	Total 100	0
	Phenolic resin	Total 100	0
	Polyacrylates	Total 100	0
	Polyacrylonitrile	Total 100	0
	Polyamide 6,66	Total 100	0

Polycarbonate	Total	100	0
Polyethylene PE	Total	100	0
Polyethyleneterephthalate PET	Total	100	0
Polypropylene PP	Total	100	0
Polystyrene PS	Total	100	0
Polyurethane PUR	Total	100	0
Polyvinylacetate	Total	100	0
Polyvinylchloride PVC	Total	100	0
**SAN	Not used	100	0
Saturated polyester	Total	100	0
SBR	Total	100	0
**Unsaturated polyester/alkyd resin	Not used	100	0
**Urea formaldehyde resin UF	Not used	100	0
Solvents	Total	0	100

4. Conclusion

Substantial advance was gained in understanding of the non-energy use and applicability of NEAT model to petrochemical industry in Russia. Flow material and processes diagram was developed which could be used for construction and adjusting the NEAT model. Other factors and formulas were studied and corrected. All this opens an opportunity for testing the NEAT model as an instrument to analyze non-energy use in Russia at the next stage of the project.