

# Potential of reducing energy demand for lighting in Lithuania

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## KEYWORDS

Lighting installations, energy conservation potential, electricity tariffs, residential, industrial and street lighting, efficient lighting

## ABSTRACT

This paper describes the potential of reducing energy demand for lightning in Lithuania using experience of a group of researches from Kaunas University of Technology, Lithuanian Energy Institute and Danish Technological Institute.

Lithuania has been in transition to a free market economy since the first days of regained Independence in 1990, economy has undergone essential changes in all its sectors, including energy. This paper provides an overview of Energy Saving Policy, key findings from industry and residential sectors, conclusions and recommendations of substantial electricity savings for the country.

An analysis of illumination efficiency installed lamps in Lithuania shows, that an average light efficiency of the lamps installed is 37.2 lm/W - less than average of world.

The main ways for improvement of illumination efficiency are the replacement of incandescent lamps by compact fluorescent lamps (CLF) in residential and industrial lighting, replacement of high-pressure mercury lamps by high-pressure sodium lamps in street lighting installations. The advantage of replacement of incandescent lamps by CLF in residential lighting is examined in detail and the program for this replacement is prepared. The replacement of 3 mln. psc of lamps in residential lighting enables to get 432 GWh electric energy economy, which results in

reduction of environment pollution: SO<sub>2</sub> - 432 tons and NO<sub>2</sub> - 272 tons per year.

The high-pressure mercury lamps replacement by high-pressure sodium lamps in street lighting installation is also effective. Feasibility studies are finished for Kaunas (one of the largest city of Lithuania) and Utena.

## INTRODUCTION

During the last twelve years Lithuania's economy has undergone essential changes. In 1990, after restoration of Independence, Lithuania (area - 65300 km<sup>2</sup>, population - 3.7 million) inherited a developed electricity sector, which was not originally designed for needs of Lithuania, but for the demands of the entire region - Lithuania, Latvia, Belarus and Kaliningrad (Russia).

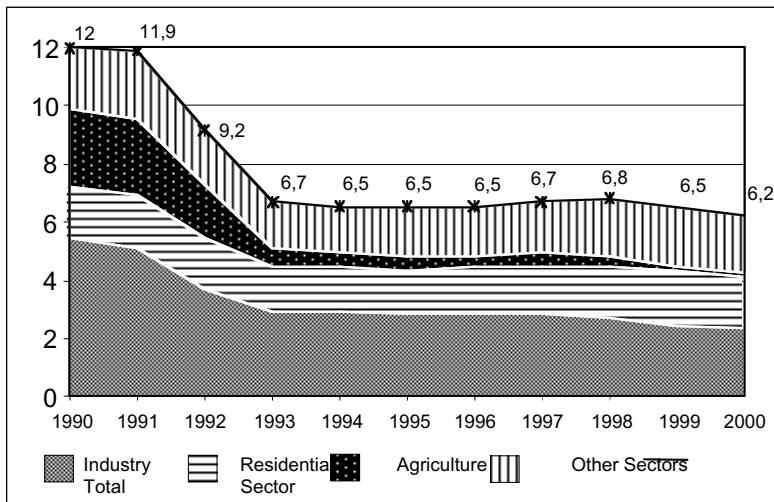
Total installed capacity of all power plants in the country at the beginning of 2000 was 6.54 GW. Maximum load of the Lithuanian electricity system in 1999 was 1.92 GW. [1]

Total final energy consumption in Lithuania decreased from 12 TWh in 1990 to 6.2 TWh in 2000 (recession of production due to lost market). The main consumers are industry (37%), residential sector (28.5%). Fig. 1.

The largest electricity consumers in industry are oil refining company "Mazeikiu nafta" and chemical industry. During 2000 electricity consumption for household purposes increased by 8.2%.

Since 1990 the scope of agricultural production is decreasing thus causing a constant electricity consumption decrease in agricultural sector. During 2000 the share of agriculture was 3.0% of total consumption.

Fig. 1 Final Electricity Consumption, TWh



The group other sectors includes companies, budget organizations, electrified means of transportation, etc. This group during 2000 consumed 31% of total consumption.

In order to join the EU, the state energy sector must be reorganized in the manner that would create conditions and a possibility to manage it on economic principles. Electricity generation, transmission and distribution for competition activities must be unbundled, legal and technical conditions for competition – created. In 1995 approved the Energy law of the Republic of Lithuania provides for free connection of new independent electricity producers to the national electricity grid together with the establishment of open electricity market.

Restructuring and privatization of energy sector is continuing.

#### ENERGY SAVING POLICY

Lithuania inherited high-energy intensity, i.e. energy consumption per unit of GDP, due to prior low incentives for energy saving, because energy was cheap.

The national Energy Efficiency Programme (NEEP) was approved by the Government in 1992 and (revised) in 1996 and 2001. The total increase in energy efficiency is measured by the reduction in energy intensity.

In NEEP'96 electricity saving measures were analyzed for every sector of the national economy: industry, residential sector, trade and service sector, transport, agriculture [2]:

- new electric motors
- variable speed drives
- **efficient indoor lighting**
- new refrigerators
- **efficient outdoor lighting**
- organizational measures

Organizational measures included also low investment technical measures.

It was expected that in 2003 when both units at the Ignalina NPP are still in operation energy savings will be 580 GWh/year or 6.7% from the total consumption. With the closure of the first unit at the Ignalina NPP energy savings will increase and in 2005 will reach 920 GWh or 10.3% of the total final energy consumption. After closure of the second unit at Ignalina energy saving measures become even more attractive and by 2015 will exceed 2.1 TWh or more than 20% of the total final electric power demand.

Till year 2005 the main energy savings will be achieved in industry and service sectors. Later significant development could happen in the residential sector where energy efficient bulbs are implemented. Electric power savings in industry will reach 10.2% in 2005 and 19.3% in 2015.

The main energy savings are due to implementation of the organizational measures. Till year 2000 it takes about 60-65% of the total electric energy savings. Next are variable speed drives and light bulbs. Role of these lamps will be increasing in energy saving. About one fourth of electric energy saved during 2003-2015 will be due to implementation of the efficient bulbs. Share of organizational measures will go down but still make up more than 50% of total. Potential savings of electric energy in different sectors of the national economy are given in Table 1 and Table 2.

In 1995 established State Commission on Energy Pricing and Control of Energy Activities (today National Control Commission for Prices and Energy) sets up principles of energy pricing, prepares for the Governmental approval electricity, heat and gas tariffs (Table 3).

Table 1. Electric energy savings in various sectors of the national economy, GWh

Sectors of economy	YEAR			
	2000	2005	2010	2015
Industry and construction	157.8	344.2	552.9	785.3
Transport	6.2	14.3	24.8	35.9
Trade and service sector	82.4	202.1	354.4	530.1
Agriculture	23.2	53.8	79.3	105.5
Residential sector	66.9	304.3	484.0	713.9
TOTAL	336.5	918.7	1495.4	2170.7

**Table 2. Electric energy savings by various measures, GWh**

Measure	YEAR			
	2000	2005	2010	2015
Variable speed drives	40.6	127.3	201.9	282.6
Motors	15.0	47.7	74.7	107.9
<b>Lamps for indoor lighting</b>	<b>37.4</b>	<b>241.7</b>	<b>364.9</b>	<b>531.8</b>
Refrigerators	33.8	71.6	118.7	170.9
<b>Outdoor lighting</b>	<b>3.7</b>	<b>7.3</b>	<b>12.5</b>	<b>18.4</b>
Other organizational measures	206.1	423.1	722.7	1059.1

**Table 3. Summary of Electricity Tariffs as from 22.12.1999 (VAT included, 1 EURO = 100 ct)**

Specified tariffs	Units	Primary voltage		
		Low voltage 0.4 kV	Medium voltage 6 kV<110 kV	High voltage 110 kV
<b>1. One Part Tariffs:</b>				
1.1 Residential, without stationary electric stoves	ct/kWh	7.94	5.16	
1.2 Residential, with stationary electric stoves	ct/kWh	6.38		
1.3 Other				4.20
<b>2. Two Part Tariffs:</b>				
2.1 Residential Day Tariff (from 7 a.m. to 11 p.m.) without stationary electric stoves	ct/kWh	9.28	6.81	
2.2 Residential Day Tariff with stationary electric stoves	ct/kWh	7.54		
2.3 Residential Night and Weekend Tariff without stationary electric stoves	ct/kWh	4.35	3.25	
2.4 Residential Night and Weekend Tariff with stationary electric stoves	ct/kWh	3.48		
<b>Different Tariffs:</b>				
- off-peak (from 11 p.m. to 7 a.m.)	ct/kWh	4.96	3.57	3.25
- mid-peak	ct/kWh	6.32	4.55	3.86
- on-peak	ct/kWh	10.17	7.33	5.57
- during weekends and national holidays (from 7 a.m. to 11 p.m.)	ct/kWh	4.96	3.57	3.25

## LIGHTING IN INDUSTRY

### In general

Good lighting is lighting that will do its job, that will be economical to install and use, and which will be durable and safe. The light should be sufficient in quantity, reasonably evenly distributed over the lighted area without excessively dark or light patches, and should have an acceptable color appearance as well as a color rendering that will be sufficient for its purposes.

These objectives cannot be achieved by improvisation, nor if the appropriate types of lamps and luminaries (lighting fittings) are not employed. Durability and electrical safety cannot be achieved if the equipment is not correctly

installed. It is important to follow standards and recommendations on electrical services and lighting.

Choosing the best lamp for the job is an important factor in achieving these objectives. Ordinary Tungsten filament (GLS) lamps are poor producers of light compared with fluorescent tubes and high intensity discharge (HID) lamps - which produce some four to six times as much light for the same energy consumed compared with GLS lamps. Under typical conditions, if a lamp is used for an average of ten hours or more per week, it will be more economical to use a fluorescent tube or HID lamp, rather than a GLS filament lamp.

Choosing the best luminaries is another important cost factor. Often, the fixture, which is slightly more costly to

buy, is the most cost effective. For example, a high proportion of the light from a bare fluorescent tube is emitted without obstruction, but only about half of this will reach useful places; the rest will be absorbed by the ceiling and walls instead of being directed towards the task or movement area. But if a fixture with a suitable reflector or enclosure is used, a higher proportion of the light will become useful-without any extra use of energy. Up till 25% more light will be available. Thus, with suitable fixtures it is possible to get good lighting with lower overall cost and with less electricity consumed - as well as lighting, which produces less glare.

The choice of fixture also affects safety. A hot bare lamp could be a danger where flammable dusts abound; a fragile fixture could cause fire or electric shock if damaged; one not designed to withstand damp and corrosion could give rise to danger in a damp or corrosive area, as well as having only a short life span. Danger can arise from the effect of excessive glare from unshielded lamps, or from dense shadows which may hide a potential hazard. Good lighting design, with careful selection of equipment, will reduce these risks.

Human efficiency is greatly affected by the quantity and quality of light available for vision. Work in a factory or at the bench in the workshop, will be done more efficiently and more safely if there is plenty of light and reasonable freedom from glare in and around all the buildings. The job will better, or faster, and always more safely, if the lighting is of correct design and well maintained.

#### Key findings from energy audits in industry

The project "Recommendations for improving energy efficiency in Lithuanian industry" was carried out by the Danish Technological Institute, Lithuanian Energy Institute, Danish Energi Analysis A/S, Energy Efficiency Centre, Vilnius in 2000 [3]. The recommendations are based on experience from the 20 audits carried out in 6 industrial sectors: textiles and clothing, wood, food, chemicals and pharmaceuticals, electronics and instruments, construction materials. The general finding are:

- The fixtures are generally produced without a shield or reflector. The tubes are marked 40 or 80W. To this power consumption should be added to the ballast.
- Many tubes are "burnt out" (the light is very weak) and dirty. The lighting level is generally very bad. On many production machines/operator places the local lighting has a separate switch off device. Due to cleaning - 20-40% of electricity could be saved.

- At visits to several enterprises the ceiling light was not on. Only the special local lighting at the production machines/operator places, which were in use, was switched on.
- A higher lighting level is needed in many enterprises. This can be obtained by cleaning the armatures and tubes and change the used tubes. Furthermore, all windows should be cleaned in order to utilize the daylight.
- It should be considered whether the 80 W tubes can be replaced by the 58 W and possibly be equipped with reflectors, which directs the light towards the working place. Also, it should be examined if the increased lighting with reflectors can be utilized to reduce the number of fixtures, or the number of tubes per armature.
- The light intensity should be 200 lx in walks and 500 lx at machines.
- It should be noted that in Denmark it is required, due to the danger of fire, that fixtures in rooms with wood dust must be closed. This is obviously not the case in Lithuania.

*Case study. Energy audit in pharmaceutical enterprise.*

*Energy saving proposal: changing old lighting bulbs into high frequency fluorescent lights (old 100 W lighting bulbs into high frequency fluorescent lights 18 or 15 W).*

*The enterprise produces various kinds of liquid herb medicines. Electricity consumption is ~ 54000 kWh/year. Electricity users are: pumps - 64% of power consumption, vents & blowers - 3%, light - 31%, other - 2%. The light equipment consists of glow lamp 100 W. The number of lamps in the workshops is 40.*

*The calculations of the savings are made for 10.000 working hours equal to 5 working years at enterprise. The working life of high frequency fluorescent lights is 10000 hours and 1000 hours for lighting bulbs.*

**Money saved:**  $220.00 - 87.60 = 132.40$  Lt per lamp  
40 lamps x 132.40 Lt per lamp = 5.300 Lt (= 1.060 Lt/year).

**Pay back period:** Approximate 1.5 years.

*The high frequency fluorescent lights will reduce the electricity consumption for lighting 82%. The result is a 25% reduction of the total electricity consumption.*

The results of audits are summarized and presented in Tables 5 and 6.

Light consumption variations covers interval from 3.5% (in manufacturing of non-metallic mineral products) to 20.9% (manufacturing of textiles). Light savings are de-

**Table 4. Calculation of proposal expenses. (rate 1 EURO = 3.45 Lt or 345 ct)**

Expenses	100 W lighting bulb	18 W fluorescent lights mech.	15 W fluorescent lights electron.
Price of lamp [Lt]	$1.00 \times 10 = 10.00$	48.00	69.00
Electricity [Lt] (10000 hours)	$1000 \times 0.22 = 220.00$	$180 \times 0.22 = 39.60$	$150 \times 0.22 = 33.00$
Total [Lt]	230.00	87.60	102.00

**Table 5. Electricity consumption in manufacturing**

	Electrical consumption per technology (% of total consumption)								
	Compressed air	Cooling	Ventilation	Pumps	Process blowers	Process heating	Light	Machinery	Misc.
All manufacturing	6.5	16.9	6.5	6.2	11.9	13.7	<b>7.4</b>	28.1	2.8

**Table 6. Electricity savings in manufacturing**

	Electricity savings per technology (estimated %)								
	Compressed air	Cooling	Ventilation	Pumps	Process blowers	Process heating	Light	Machinery	Total
All manufacturing	0.9	2.1	1.2	0.9	2.2	2.8	<b>1.8</b>	1.6	13.5

fined from 0.3% (manufacturing of wood products except furniture) to 12.5% (manufacturing chemical and chemical products).

#### RESIDENTIAL LIGHTING

All lamps on the Lithuanian market are imported. The majority of residential lighting is provided by incandescent lamps with market size from 5 to 13 million lamps annually. [4] Russian-made incandescent lamps, because of their low price (1.0-1.2 Lt), and also produced in Poland and Hungary dominates in the market. In terms of lamp wattage, 60 and 100 W incandescent lamps are most popular.

Lighting contributes from 20% to 30% or even 40% of total residential electricity consumption.

Electricity conservation potential of CFL's in Lithuanian residential sector was calculated, using the electricity tariff 0.22 Lt/kWh, and the price of, incandescent lamps – 1.0 Lt. It was found, that if 1.3 million of Lithuanian households could replace at least two of the most heavily used 60 W incandescent lamps operating 4h a day by 15 W CFL's, the annual savings in end-use electricity would equal 170 GWh, worth almost 40 million Lt for consumers at the current tariff structure. Over the 10,000 h lifetime, CFL's would save around 1.2 TWh of electricity [4].

Lighting market transformation towards more efficient lighting could be reached under a strong market push from the manufacturer, or international organizations.

The price of CFL's are higher than of incandescent ones, so information campaigns, consumer education, rebates, subsidies lease programs, bulk purchases by homeowner's associations could help overcome first cost and insufficient awareness barriers, thus expanding market-driven penetration of CFL's. Energy efficiency standards for lighting, especially for new construction, would facilitate rapid dispersion of energy efficient lighting technologies.

#### TOTAL LIGHT ENERGY CONSERVATION POTENTIAL

A group of researches from Department of Electrical and Lighting engineering of Kaunas University of Technology carried out a study "Economic estimation of effective, energy saving lamps and working out the Programme of implementation" [5].

More than 500 lighting energy users had been investigated. It includes: 150 residents of the homes in blocs of flats, 51 – detached houses in towns and 216 – in the rural. 22 – higher and secondary schools has been investigated more detail [6]. The information were included from 11 – hospitals, 10 – industrial enterprises, 8 towns – street lighting services and others.

On the basis of calculations the structure of installed lamps was evaluated (Table 7). The main part of lamps is incandescent. More than 96 % of lamps in the residential and about 20 % in the industry and commercial sectors - incandescent. The 250 W mercury lamps were main for the street and outdoor lighting in industry. The high-pressure sodium lamps use was very short for the street and the outdoors lighting. Fig.2 presents the structure of installed lamps in percent. The use of compact fluorescent lamps in 1994 was negligible. The main lamps for the industry and commercial sector were tubular T12 and T8 fluorescent lamps with the conventional ballasts.

The detail investigation schools lighting installations [6] have had been carried out. We calculated the mean installed lamps power per m<sup>2</sup> equal to 23 W/m<sup>2</sup> and the mean desk illumination level 187 lx in the classrooms. The installed lamps power was more than 12 W/m<sup>2</sup> per 100 lx. This so big quantity can be explained by use in large scale of incandescent lamps and part of fluorescent lamps not replaced after out of operating. The lighting fittings bed conditions because they are on maintenance 20-30 years have had great influence too.

It was very large potential of saving energy for schools lighting if compare results given from California Energy

**Table 7. Number (million units) of lamps used (1994) in Lithuania**

User	Incandescent	Florescent	Mercury	Sodium	Other	Total
Industry	0.42	2.31	0.134	0	0.023	2.89
Commercial	0.94	3.03	0.038	0	0	4.00
Residential	18.30	0.57	0.023	0.002	0.06	19.00
Agricultural	0.54	0.41	0.05	0	0	1.00
Street lighting	0.005	0	0.114	0.012	0	0.13
Total	20.205	6.32	0.359	0.014	0.083	27.02

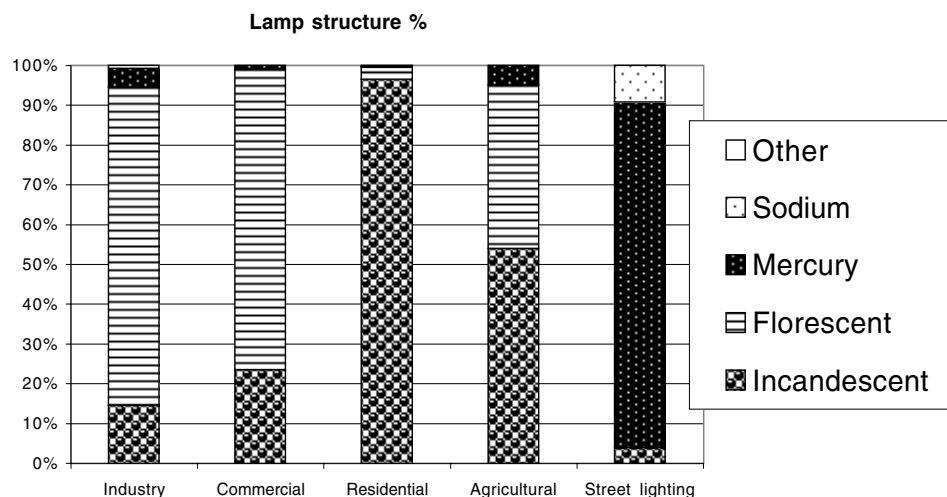
Commission [7]. There are installed lamps power in the schools 17.4 W/m<sup>2</sup>, mean lumens per m<sup>2</sup> - 1055 and mean lumen efficacy - 60.6 lm/W. In the Lithuanian schools installed lamps power was more than 30% large but the lighting was much worse. The same was in other lighting installations.

The problem to use lighting installations in full is big charges of electric energy bill. The lighting installations renovation was slow. Only new lighting installations are arranged according new lighting standards [8]. Fittings and lamps of new installations are not best quality because the investments are limited.

The programme of saving electric energy for lighting was carried out after lighting investigation in Lithuania. This included replacement of 2,7 million intensively used 100W incandescent lamps to 20 - 23W CFL. It enables save 36 MWh electric energy monthly. This programme was proposed for Lithuanian Government but was not realised. The Lithuania - Municipal Development Project [9] as part of The World Bank Group Projects in Eastern and Central Europe was more successful for Lithuanian towns street lighting. The feasibility studies of Kaunas and Utena street lighting projects [10,11] have been carried out. The installed capacity would be reduced twice after renovation due to replacement mercury fittings by sodium one. The Kaunas street lighting renovation project is in final stage now [9,10]. All renovations let improve mean lamps effi-

ciency from 37.2 lm/W up to 48 lm/W and save the peak electric energy.

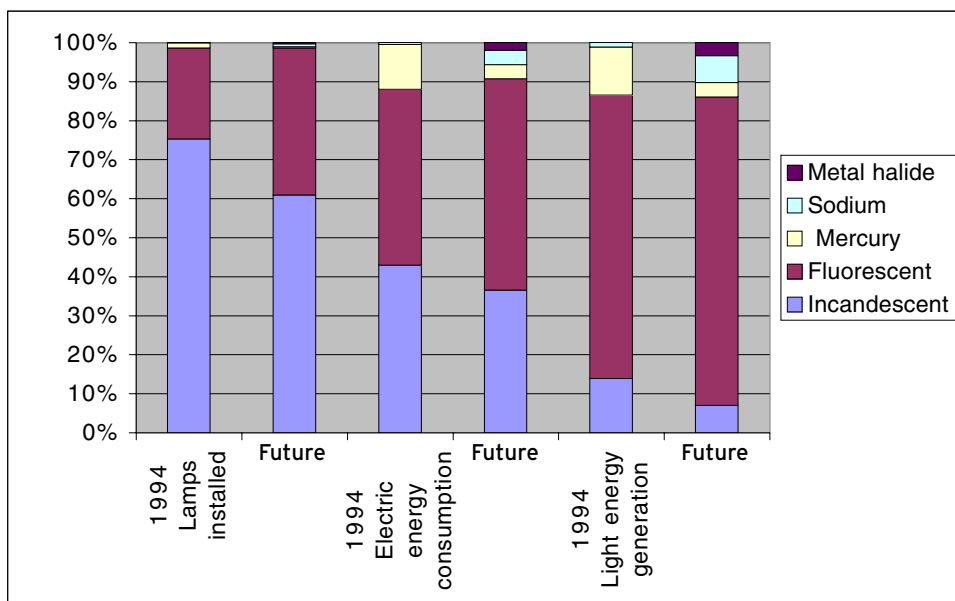
Our estimations show the total energy savings for lighting in future could not be large. They can be about 15% or less (Table 8) because lighting installations is not used in full range now and the amount of illumination is less than recommended standards [12]. The light generated by lamps is only 17 Mlmh per year per capita. It would increase to 20 Mlmh after renovation lighting installations.

**Fig. 2. Lamp structure in per cents.**

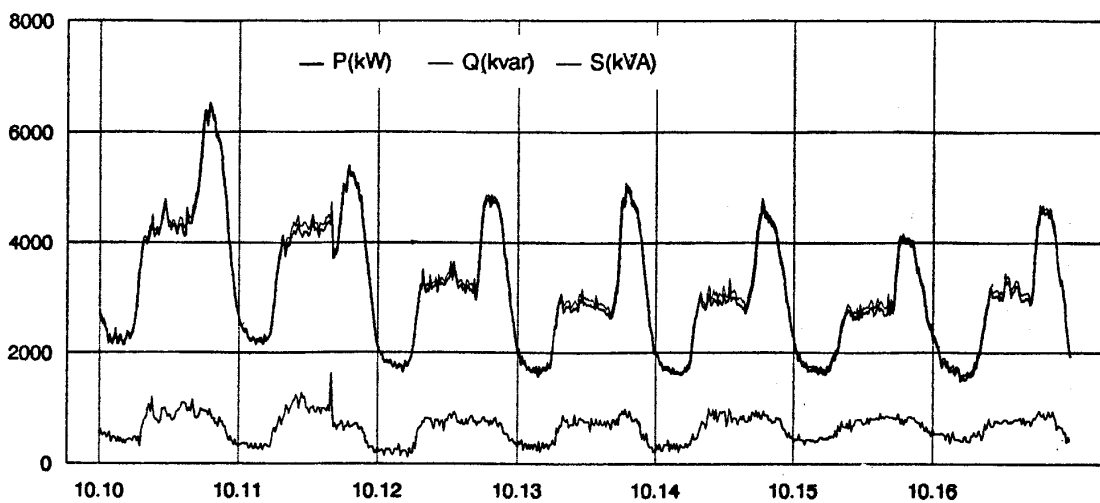
**Table 8. Number of installed lamps, electric energy consumption for lighting and light energy generation per year in Lithuania**

Lamps	Lamps installed, mln pcs		Electric energy consumption, TWh		Light energy generation, Tlmh	
	1994	Estimation	1994	Estimation	1994	Estimation
Incandescent	20.3	17.0	0.728	0.546	8.74	5.00
Fluorescent	6.3	10.5	0.765	0.811	45.90	56.77
High pressure mercury	0.36	0.10	0.195	0.054	7.80	2.70
High pressure sodium	0.014	0.2	0.008	0.055	0.71	4.95
Metal halide	0	0.1	0	0.03	0	2.4
Total	26.974	27.9	1.696	1.496	63.15	71.82

**Fig.3. Percentage lamp structure their energy consumption and light generation in 1994 and after realization of the Programme in all sectors of Lithuania.**



**Fig. 4. The weekly electric loading diagram in Kaunas (from 10th to 17th of October, 1994) [15].**



It is significant less than in Scandinavian countries. The Lithuanian roads are not lighted. The first steps only are made for architectural lighting in towns. It is necessary to enlarge the light generation in Lithuania without increase electrical energy demand.

The residential, street lighting and other lighting installations use peak energy. In the Lithuanian towns peak energy demand is significant. Fig.4 presents the weekly electric load diagram in Kaunas [13]. The peak energy saving is useful for electric energy supply system.

#### CONCLUSIONS

1. The reconstruction of Lithuanian energy sector to a free market conditions was followed by significant decrease of energy consumption, however the energy intensity, which shows the efficiency of consumption of energy sources, remains one of the highest in Europe.

2. Average light efficiency of lamps installed in Lithuania is 37.2 lm/W – less than average in the world.

3. On the basis of energy audits carried out by Danish-Lithuanian auditors the light energy conservation potential for the Lithuanian industry was estimated – from 0.3 up to 12.5% (dependently on kind of manufacture).

4. 1.2 TWh of electricity per 10000 h could be saved in residential sector with replacing in 1.3 million households of two 60 W incandescent lamps by the 15 W CFL's.

5. The renovation of street lighting in towns of Lithuania would reduce installed capacity twice. It lets improve lighting services and to reduce total electric energy demand about 15%.

6. The renovations of lighting installations in nearest future let's improve mean lamps efficiency up to 48 lm/W and to save peak electric energy.

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