ABSTRACT
The main aim of the paper was to investigate the use of renewable energy sources (RES) in Latvia, for which — as well as for other European states — this is the issue of high importance.

The renewable energy resources: wind, sun, hydro, biomass, biogas, etc., are additional sources of energy - the energy that could be produced independently of the import. Increasing demand for energy, limited reserves of fossil fuel, as well as environmental pollution and global climate changes observed in the world in the last years have given rise to an intense interest in renewable energy resources. Support to the use of RES has become a significant part of the European Union’s policy. In the paper only those renewable energy resources have been investigated from which a real contribution to the energy balance under Latvian conditions could be expected – i.e. biomass, hydro-energy, biogas, wind and solar energy.

It is established that the renewable energy resources give the greatest yield in combined schemes in which fossil fuels are also involved. Such combinations allow for considerable decrease in emissions into the atmosphere; these are more environment-friendly, which means a higher environment protection level.

KEY WORDS
Renewable energy sources, environment, pollution reduction.

1. Introduction
In the last ten years a 10% increase in the energy consumption in Latvia has been observed; this means increasing import of electricity and energy resources, since the volumes of electricity produced in Latvia are insufficient for covering the energy demand. This demand, being ever increasing, along with the limited fossil fuel reserves as well as environmental pollution and global climate changes, has aroused an active interest in renewable energy resources. In the EU, support for the RES use has become an integral part of its policy. For Latvia (as for other European countries) this issue is especially topical. In the world, a tendency is developing fast — that of the necessity to replace, step-by-step, the traditionally used energy carriers by those of higher quality, with inclusion of renewable energy resources - biomass, solar and wind energy. This would undeniably lead to the cost reduction for the RES use technologies, which, in turn, would mean their increased competitiveness and wider utilization [3].

The significant role of renewable energy resources in the Latvian energy policy, which is connected with positive impact of their utilization that could be expected in various aspects, e.g.:
- possibility to save fossil energy resources,
- reduction in GHG emissions into the atmosphere,
- possibility to vary the types and sources of energy production, to use the domestic resources, thus raising the energy supply security and reducing the dependence on energy import,
- the RES use makes it possible to reduce the risk that is characteristic of the fossil fuel based energy supply systems,
- since RES are mostly domestic resources, the regional development is promoted – new work places are created and farming, forestry, industry, and the RES technology related research work developed,
- RES will be one of the main means for fulfillment of the Geneva Convention “The Cooperative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe” as well as the UNO General Convention on limitation of global climate changes and the corresponding requirements of the Kioto protocol [3].

The investigation carried out is connected to the forecasting of RES use in compliance with economic changes in the country, and includes the analysis of the energy balance and the evaluation of the RES potential, with due consideration of the world’s innovative technologies.

Application of mathematical models to the choice of optimal usage scheme described in the work concerns the combination of fossil fuel with solar energy, the
passive use of the latter, as well as financial aspects, climatic and geographic factors, and so on. Investigation of the rational use of biofuel has been made taking into consideration the extraction, transportation, consumption, energy generating plants, standards, etc. The role of biofuel in the energy industry and transport is also analyzed. The work devoted to the use of solar energy – in particular, to the solar collectors and solar batteries (PV), and to possibilities of their different combinations, e.g. that of their integration into the traditional schemes of energy use. The work also contains results concerning the use of wind energy – the wind potential in Latvia has been estimated; the wind energy calculations have been performed for land and sea shelf. Based on the mathematical models volumes of RES use has been optimized. The fuel – energy balance is optimized taking into account the potential of the renewable energy resources and the prospects of their use in the country.

2. Analysis of renewable energy resources use in Latvia

The utilization of RES (biomass, biogas, the solar and geothermal energy, the wind energy, hydro energy) was studied taking into consideration not only innovative technologies, state economy development tendencies and structural changes, legislation and governmental policy aspects but also the fulfillment of the EU requirements concerning the environment protection and employment, the wind energy and that energy produced from waste is also utilized. The RES share in the consumption of primary resources increased from 27.3% in 2008 up to 30.9% in 2010 (see Figure) [4]. This happened owing to the wide utilization of wood resources. The production of electricity from RES in 2010 was 58.5% of the total its production.

The utilization of wood (the most widely used energy resource) is especially expressed in the heat production. The second in significance is hydro-energy resources. The contribution of wind, biogas and peat plants is 0.5% of the total energy produced from RES.

On the whole, the national renewable energy policy is oriented on promotion of RES use, with due regard for environment protection and CO$_2$ emission reduction. The main objectives of the new RES-related energy policy are to be as follows:

- electricity production from RES – 49.3% of the total electricity produced in 2010;
- the RES share – at least 40% for 2020 in the total energy mix;
- the share of biofuels in the total market volume of transport fuel used should be 5.75% in 2012 [3].

3. Biomass

One of the ways to reduce the GHG emissions is to use biomass as a renewable energy resource in order to applying the imitation and optimization models. The most widely used RES in Latvia are wood and hydro. Besides, replace the most widely employed fossil fuels – coal and oil products. When burnt, biomass emits carbon dioxide.
gases in a volume that is neutral for the environment; this means that the amount of harmful emissions and therefore negative impact on the environment followed by its degradation is considerably reduced. Utilization of biomass in a heat production process is not only an environment-friendly but also economically-efficient solution.

The biomass used in Latvia could be classified in three groups: wood, wood waste and wood products; straw; and by-products (BP) of farming. The wood for heat production in Latvia is used in the form of: firewood, wood BP, and wood from energy wood plantations. The wood granules and briquettes (a highly valuable fuel) as well as firewood are mainly utilized for individual heating by households. For district heating there are used: firewood, wood processing remainders and sawdust; the utilization of granules is also under use now. Taking into account the yearly volumes of Latvian forestry products and well-developed their processing system, the level of wood biomass utilization for heat production is insufficient.

Analysis of the Latvian electricity and heat energy balance which was made, shows that co-production of electricity and heat in one process (i.e. cogeneration) is to be developed both from the viewpoint of energy supply security in the state and from that of non-utilized heat load potential in DHSSs. The necessity is shown to develop biomass cogeneration in residential places where natural gas is not available but, at the same time, the heat load potential is rather high.

Latvia has signed the UN General Convention “On climate changes” and the Kioto protocol; this means that our state takes on obligations to promote implementation of the mentioned measures at the national and the international level, which would allow for reduction in the total emissions.

One of the ways to reduce the concentration of greenhouse effect gases is to use biomass as a renewable energy resource in order to replace the most widely employed fossil fuels – coal and oil products. When burnt, biomass emits carbon dioxide gases in a volume that is neutral for the environment; this means that the amount of harmful emissions and therefore negative impact on the environment followed by its degradation is considerably reduced. Utilization of biomass in a heat production process is not only an environment-friendly but also economically-efficient solution.

Analyzing the possibilities of biofuels use in Latvia it could be concluded that:

- in energy balance consumption of fuelwood increased by 20% in last years, for heat production some renewable are used in Latvia - wood, wood products, straw, biowastes, etc. The analysis of fuelwood consumption dynamic for heat energy shows increasing use of wood. Exploring the potential for use of fuel wood, it was found that the greatest potential is for wood by-products (forest exploitation residues - 12-18 PJ, wood waste - 14-37 PJ) [2].

Different ways of energy production from biomass and those economic criteria were investigated:
- low energy density of biomass, the high transportation costs determine a necessity to convert the biomass for energy production in the most efficient form. It prescribes not only heat but also other forms of energy demand and energy sources use comfort - ergonomics, heat generation or other energy-use automation options, etc.;
- calculation of biomass transportation costs shows that the transportation costs are increasing with distance. The largest share of transportation cost is fuel cost. This means that with the rapidly rising fuel prices, the fuel wood is mainly used for local utilization, and only after special processing, it is used in the wider region;
- calculations showed that the biomass can be competitive with other energy resources and their use for domestic consumption cheaper than buying increasingly expensive natural gas. In addition, when biomass is used in cogeneration plants for electricity and heat production, it becomes more valuable;
- the amount of the heat energy produced in cogeneration cycles in Latvia in 2010 was ~50% of the DHS-produced. Evaluates the fuels and applied technologies used in cogeneration, and indicates and substantiates the solutions that are the most suitable for the Latvian conditions. The most recommended fuels for cogeneration cycle are natural gas and biomass.

4. Wind energy

Use of wind energy makes possible significant reduction of environmental pollution. Since the early nineties the use of wind energy expanded, taking over the world's advanced technologies and achievements in this field. Studies on the utilization of wind energy showed that the best conditions for wind turbine installation are along the Baltic Sea coast from Ventspils to Liepaja and around Ainazi.

Mobile wind speed measurement complex LOGGER-9200, which allows to determine wind speed and direction at different heights (0-10-100 m) with different measurement intervals, the complex can work in automatic mode have been installed. Complex connected to PC can modulate the obtained data at different spins. This equipment is used before wind turbine installation, for wind parameters determination and for calculation of potential energy production. Wind measurements are made across the territory of Latvia. Using the measurements wind map of Latvia has been developed. Research on wind energy use will be continued with the new equipment.

Analysing wind energy use it could be conclude:
- at the present time, in Latvia wind generators with the total capacity of 30 MW have been installed, yielding 1.2% of the total electricity consumption in the country. The regulations worked out by the Ministry of Economy envisage in the nearest years the wind energy volumes for guaranteed sales raising five times and the specific weight of the wind energy will reach almost 7% of the total energy consumption. This means that the installed power is to be approximately 150-160 MW.

- that the energy “hidden” in wind is (in the geometrical progression) dependent on its velocity: for example, doubling the wind velocity gives eight-fold increase in energy. From that the following conclusion can be drawn: first, at installation of a wind power plant (WPP) at a 50-65 m height the electricity generation potential increases by 30-35% (since the wind velocity increases in comparison with a 10 m height); second, the deciding factor is the right siting of a WPP. Here is the situation as everything should be estimated: the (non-) uniformity of landscape, the distance from water sources, the surrounding forests, orchards, buildings and other obstacles that could disturb the air flows. The most significant problem is that the wind energy resource distribution in Latvia is irregular.

- in the sea shelf zone of Latvia the wind energy potential is 2.2-2.5 times higher than on the shore. Wind speeds were practically tested using the mobile complex for wind parameters measuring at a height of 60 meters. Received results allow to compare the calculated relations of wind speed at a height of up to 100 meters, and the actual values that are in region. Calculated difference of wind speeds on 10 meters height is 25% and a height of 100 meters - 75%. Therefore the theoretically achievable potential of the Kurzeme coastal zone could be estimated as about 75 000 MW producing up to 200 TWh [1].

It is concluded that, if we want to obtain 30-40% of the state consumption, then, at its average value of 7.5 TWh is 2.6 TWh per year. For this energy amount it is necessary to install 175 turbines, and the corresponding farms would occupy 86 km² of the shelf area. The figures obtained could be considered as the available economic potential [2].

5. Solar collectors

Research work carried out in investigations on a new type of solar collector design with a high heat transfer. Experimental and industrial solar collectors for hot water production were developed. The combined system of solar collectors and solar batteries (PV) developed and tested. Combined systems for solar energy use in combination with conventional energy sources (gas, liquid fuels or electricity) were developed. The largest solar installation in the Baltic States in Aizkraukle town (155 m²) implemented in practice with cooperation with Danish experts. The “Solar energy research polygon” was installed on the roof of Institute of Physical Energetics, which Latvian Academy of Science recognized as the most important achievements in science in 2008.

Investigations of solar energy use in Latvia enable to summarize:

- As concerns solar energy it could be used for production of thermal energy (by solar collectors) and electric energy (by PV).

- As shown by experimental studies, the application of solar collectors in Latvia can give good results. Solar energy can be used for hot water production during summer, because the demand for hot water throughout the year can’t be satisfied by using only solar energy. It needs to be combined with traditional energy sources, which increases the capital and operating costs;

- Investigations on the possibilities of using combined solar heating systems have been carried out applying the PolySun model (sun+electricity, sun+gas, sun+biomass, and others), in which solar collectors are combined with other energy sources. Economic indices of a heat supply system with solar collectors have been calculated. Additional calculations made for a combined system with a gas-fuelled boiler and solar collectors showed that such a boiler taken as a secondary heating source is cheaper than an electrical boiler. However, since the prices on gas and electricity are instable and are rising fast every year and gas is imported energy resources, and, as was just mentioned, the price on natural gas is instable and every year rising; moreover, natural gas is not available in the entire Latvian territory, it would be more reliable to take a secondary boiler that operates on biomass;

- Under laboratory conditions experimental examination of this system was made; it was concluded that heating system with solar collectors and solar batteries can be used in non-electrified private houses (or when it is necessary to save electricity), with PV serving as the pump feeding source.

It is concluded that currently solar energy cannot compete with other energy resources because of its high cost; at the same time, the solar energy resources are sufficient in Latvia to be used in practice.

6. Solar batteries (PV)

Due to the requirements to reduce environmental pollution under the Kyoto Protocol, countries are required in the future to make the transition to renewable energy sources, including the generation of electricity using solar cells, which relies on photo-voltaics effects.
For Latvia, in the framework of EU directives 2001/77/EC a target programme was worked out, which indicates that by 2020 in the energy balance the electric energy production from renewable energy resources is to be raised up to 59.8% of the total electricity consumption [3].

Today's solar cells, which are mainly made of silicon-based, are too expensive to obtain electricity could replace other energy sources. Experts estimate the success of producing organic or hybrid solar cells in thin polymer films with a coefficient of efficiency of > 10%, the PV costs can be reduced more than 10 times compared to silicon solar cells. But now this coefficient of efficiency visible light spectrum in organic solar cells has not yet been reached.

Organic compounds photoconductivity and photovoltaics effects are studied intensively since 50th of the last century. In order to reduce the cost of new solar cells significantly, it would be necessary to build them in the incorporation of electron donor and acceptor molecules 100-200 nm in thin polymer films. As an alternative to using the vacuum evaporated electron donor and acceptor thin films.

Currently the best results are obtained with poly(3-hexylthiophene) (P3HT) and soluble fullerene derivative composites. But their main disadvantage is the narrow range of photosensitivity, adjacent to 650 nm. The investigations were extended to the highly photosensitising composite spectral range of the infrared part of the direction by using additional electron - donor molecules - GaOH phthalocyanine (GaOHPc). This organic matter is characterized by strong intermolecular charge transfer (CT) band infrared spectrum in the region of the 850 nm [5].

Managed to get a new composite material consisting of organic electron - electron donor and - acceptor molecules and the photosensitivity is practically constant in range from 400 to 900 nm.

7. Biofuel production

Taking into account the considerable rise of oil prices and increasing doubts as to stable, reliable and environment-friendly energy supply, the promotion of biofuel for transport is one of the priorities of European policy. Today biofuel is the only real possibility to reduce the transport dependence on the oil products. In the process of European energy policy realization the European Commission has made the decision to promote the biofuel production and utilization, and propose to take up the minimum obligations – by 2020 10% of transport fuel should be covered by biofuel [3].

The biofuel is fuel produced from organic substances. The development of this branch will give new working places, as farming industry will obtain a new market. Apart from that, promotion of biofuel use will allow such general problems to be solved as the diversification of energy sources and fulfilment of the Kyoto protocol obligations.

Taking into account the support for the producers involved in the biofuel production and utilization programme, the biofuel potential could be estimated as follows [2]:
- Biodiesel fuel (to be used in a pure form or in mixtures) 43 000 t = 1,72 PJ,
- Bioethanol (to be used as 5% ethanol additive) 32 000 t = 0,86 PJ.
It is estimated that the potential can rise if:
- the biofuel production for export has been organized (but this does not affect the Latvian domestic energy balance),
- the biofuel utilization in Latvia exceeds the level indicated by the EU.

From the economic profitability point of view the priority should be given to the rape-seed oil export as compared with the bio-diesel fuel export for the following reasons: first, investments in this case could be made step-by-step and thus would be paid back sooner, since in this case they would ensure the initial oil production phase (cycle) and then its realization; second, the rape-seed oil supplies would help to meet quality requirements. The financial resources accumulated, in the next stage would be investmented into the bio-diesel fuel production cycle, and, depending on its profitability, the bio-diesel fuel could be realized.

The bioethanol utilization potential has also been estimated. The advantages of this substance (which under our conditions could be produced from cereals, sugar-beet and other renewable products) are the following:
- utilization of surpluses of cereals, sugar-beet, potatoes (and, as a future alternative, lignocelluloses-containing biomass);
- its high potential as petrol additive; no need for special logistics;
- no need for new selling forms.

In turn, the disadvantages of bioethanol production are:
- rather poor comparative energy balance;
- the economic profitability could be justified only for production at major enterprises;
- the external economic protection is needed against the import of cheap bioethanol.

From the utilization point of view the issue is quite clear: rich technical experience has been accumulated in many world countries. The raw material base is wide: cereals, sugar-beet, potatoes, etc., with using technological fermentation and distillation. Besides, the by-products are realizable.

The bioethanol application in farming is, however, problematic, since it could not be added to diesel fuel. But bioethanol 5% addition to moto transport petrol will bring great environmental benefits due to improvements in exhaust gas from transport. The opinion exists that the bioethanol factories based on the raw materials from
farming should be built as major centralized plants. At the existing filling stations additional sale places are not required.

8. Biogas production

Agricultural, industrial and municipal waste in Latvia may become a source of bioenergy, in which energy and environmental issues will combine into a single complex problem, which is ecology key role.

Total installed capacity of electricity production plants, that burn biogas, now is 10 MW.

It is possible to obtain approximately 290 mln.m³/year of biogas that is approximately 5 PJ. Evaluating the technical and organizational possibilities, the total annual biogas potential can be obtained as 121 mln. m³, from which can get about 2 PJ of energy [2].

Assessing the volumes of by-products obtained at processing the cattle-breeding, milk and meat products and, correspondingly, for the raw material potential of biogas production allow the following conclusions to be drawn:

- biogas is a significant resource for energy production near major farms; provided the environment protection problem has been solved, this also gives solution to the energy supply problem;
- the total raw material potential for biogas production is sufficiently high, whereas from the big farms the following quantities for the biogas-produced energy can be obtained: for cattle farms ~57 TJ, for pig farms ~33 TJ, and for poultry farms ~36 TJ, which is sufficient for covering the energy demand for a farm and its surroundings. Other anaerobic processing provided by-products (biogas from sewage sludge and landfill) are inspected [1];
- the potential of biogas production from sewage sludge were estimated (7 milliard.m³/year). At present, approximately 30% of sewage sludge are used in farming (the Riga's, Valmiera’s, Cesis’ Waste Water Treatment (WT)), while the rest is stored on temporary polygons. Every year the amount of stored sewage sludge increases by 10-15 tons of its dry residual. Therefore these must be utilized in the nearest bio-energy installation which will be built for treatment of farming waste;
- the biogas production potential of solid household waste deposited in dumps were estimated to be 23 milliard. m³/year. It would be best to collect biogas from dumps in order to reduce the emissions of GHG. Biogas from small dumps should be burnt or transformed into harmless chemical compounds, while the biogas from greater ones can be utilized for production of electricity and heat.

9. Efficient use of energy

Energy efficiency significantly reduces the environmental pollution that was created producing heat with fossil fuels. By studying the Latvian energy balance was found out that one of the greatest heat consumers in Latvia are housing and public sector. About 65% of the total annual heat consumption of residential buildings is used for heating [1]. This means that the technical condition of buildings and building envelope thermal resistance is directly dependent on how much is paid out for heat. As the first step is to require the building's internal heating system alignment and adjustment, which gives about 10% of thermal efficiency [1]. After that - building insulation, which gives a much higher thermal efficiency, but requires considerable financial resources. It is essential for tracking and ordering system implementation.

10. Conclusion

There is a numerous potential in Latvia for RES use development in terms of all factors: technical, social and the market. Biomass will remain the most important form of bio-energy in the Latvia in the future. However, some increasing contribution of bio-energy is closely related with objectives in Latvia to use it not directly as fuel for generation of electricity and heat but also for production of fuel for transport.

The fuel wood is a significant national resource, which can be utilized for energy production in order to increase the security and independence of energy supply; the energy projects consider its wide use as one of the co-burning products. However, the energy wood is mainly meant for local utilization.

Taking into account the whole spectrum of problems associated with the utilization of renewable energy resources – beginning with the fuel market realities and ending with the legislation and state policy aspects – the research into these problems is highly actual and important in Latvia, since there still exists urgent need to replace the outdated energy generating equipment and technologies with modern ones; it should also be realized that the necessity to promote the RES utilization is dictated by ever increasing prices of imported fuel.

To summarize:
1. Renewable energy resources can cover up to 40 % of the energy consumption balance.
2. It is worthwhile to maximally use renewable energy resources in combined schemes together with fossil fuels.
3. A growth in the use of renewable energy resources is expected from the application of innovative technologies.
4. Rising prices of fossil fuels will raise the specific weight of renewable energy resources in the fuel energy balance.
5. Utilization of renewable energy resources allows reducing the amount of emissions into the atmosphere; it is environment-friendly and environment-protective.

Acknowledgements

This work has been supported by State Research Program “LATENERGY” and ESF within the project “Support for the implementation of doctoral studies at Riga Technical University”.

References