Abstract
In human history forests always satisfied different needs of people like: food, energy, medicine plants, wood materials, fodder. From 20th century wood energy gradually was substituted by fossil fuel. But wood still remained irreplaceable resource for construction, furniture, paper industry. At the same time many new wood products have been developed from wood and agriculture residues, so called engineered wood, like: plywood, chipboards, fiberboards, MDF, etc. Bio-economy today uses biomass for manufacturing bio-based chemicals, plastics, pharmaceutical products as well as, residues for generating bio-energy. Nowadays, when the fossil fuel age declines due to its exhaustible character biomass regains a new importance. Biomass currently is the dominating renewable energy source for multiple use. Gradual substitution of fossil fuel by renewable energies instigates rapid growth of all renewable energy carriers like wind, solar, hydro, geo-thermal and bio-energy. It is the best strategy against climate change too.

Key words: forest, residue, waste, wood, bio-fuel, bio-refinery, chip

Introduction
Climate change is considered the most significant challenge of the world today. One of the means for mitigation of climate change consequences can be replacement of fossil fuels by renewable sources of energy and improvement of energy efficiency [1]. Until the end of the 20th century wood was considered as major energy source in the world, but then it was substituted by mineral oil and coal as having more energy potential and wood was mainly used in paper and furniture production, though in most developing countries of Africa and Asia it remains as major energy even today. In last decades wood energy came back in the focus of society and policy-makers as a renewable energy source to tackle issues of secure energy supply and climate change. In particular the European Union and its member states set policy target for renewable energy to increase on 20% by 2020 [2].

Among renewable sources of energy biomass play a major role in satisfying energy needs of the world. Biomass for energy originates from variety of sources classified into forestry, agriculture and waste streams. Some of the potential sources include: forests, wood biomass and residues, crops for bio-fuel, energy grass, short rotation forests and municipal solid waste. In 2012 the major part of bio-mass energy came from forests, almost 49 EJ out of total supply of 56.2 EJ. The World Bio-energy Association (WBA) estimates that by 2035 about 5% of the agricultural area can be used for growing dedicated energy crops for bio-fuels and solid bio-mass for energy [3].

By the conservative estimate potential of bio-mass from forestry, agriculture and waste sectors will total 150 EJ in the next 20 years. Approximately 43% from agriculture (residues, by-products and energy crops), 52% from forests (wood fuel, forest residues and by-products of forest industry) and 5% from waste streams [4]. The substitution of fossil fuels by renewable once in future will require substantial growth of all renewable energy carriers like solar, wind, hydro, geothermal and bio-energy.

Forestry residues are divided in primary and secondary residues. Primary residues include residues accruing from cultivation, harvesting and logging activities, from trees within and outside of forests. The latter includes landscape management (including urban green spaces). Secondary residues accrue in the wood processing industry, such as sawdust, woodchips, black liquor. These by-products of the processing industry are already utilized in a variety spheres as fiberboards and panels [5-7].

Wood for energy comprises different categories such as: wood fuel, charcoal, woodchips, pellets, bark, saw-dust, recycled wood, black liquor and other residues of forest harvest and wood industry. Some of these materials go directly from the forests to the energy consumers like firewood, tops, branches and small size wood. Other wood goes firstly to the industry (stem wood to saw mills, to the pulp industry) and residues in form of chips, saw dust, bark etc., that go to the energy sector. It must be underlined that in countries without bio-energy policy, a big share of these by-products is not used but dumped in landfills and rotten.

Results and analysis
2.1 Residues of forest loggings and industrial processing
Any kind of wood that is not considered for further use is residue or wood waste. Usually there are two types of residues: logging residues and industrial waste. Logging residues include: crowns, branches, damaged logs left in forest, cutting residues, stumps, stem off-cuts, trimmings. Industrial waste include log transportation residues that may be logs left or rejected at loading stations. Primary processing waste include: sawdust, trimmings, defective parts caused by wood processing, bark, core, slabs, and veneer waste. Secondary processing waste are: sawdust, shavings, mold wood, old construction roofs and stakes and so on [8-9].

The main sources of wood residues and waste are: forest biomass (generated mainly from commercial timber, log processing, cones, leaves, needles, branches, stumps and so on); residual by-products of wood processing (lumber, logs, firewood, veneer damaged cuttings, shavings, fencing materials: posts, poles, rails, bark, sawdust, chips, shavings) and urban wood waste (residues from urban management activities, lawn maintenance, municipal waste that include: everyday household and business garbage, buildings construction and demolition waste) (table 2.1.1)[10-11].

Building material types were analyzed in Germany to estimate the amount and quality of wood contained in the housing stock. The majority of wood was found in residential buildings as part of roof structures, walls and ceilings. The research made in Bavaria showed that 45% of the recovered wood from deconstruction can potentially be used as raw material for particle or fiberboard production. Much work remains in terms of efficient deconstruction of buildings to extract wood and other salvageable materials in good condition. Great amount of natural resources, energy and labor are embodied in building materials that often send to landfills after demolishing buildings [12].

**Table 2.1.1 Forest residues from different sources**

| Source | Kind of residues |
|--------|-----------------|
| From loggings | Branches, needles, leaves, stumps, low quality and rotten wood, sawdust, chop offs |
| From sawing | Bark, sawdust, cracked wood, trimmings, dust, shavings |
| From plywood production | Bark, core, sawdust, chop offs, powder dust |
| From production of different kind of boards | Bark, trimmings of boards, sawdust, powder dust |

Source: Zoya Tariq.2013. Utilization of Waste Wood. University of Arid Agriculture, Rawalpindi, Pakistan. 10pp. [11]

### 2.2. Residues for industry and agriculture

The spheres of using forest residues and other wood waste are: pulp and paper industry, different kind of boards, chemist industry, fodder for cattle and domestic animals, fuel for energy production, etc (table 2.2.1).

Expansion of pulp and paper industry from the end of the 20th century put great pressure on the traditional sources of the best coniferous wood species for pulpwood in many parts of the world. Result of this pressure was rapid expending use of wood residues in pulp production. It is considered that half of the fiber necessary for paper production is coming from wood and the other half from sawdust, straw, and even hemp. Coniferous species like spruce and fir-tree of course are the best source for paper production as the cellulose fibers in pulp of these species are longer and as a result the paper is becoming harder. Today, among the sources of paper production are used the residues of deciduous species like, poplars, elm-trees, etc. Besides, due to increasing demand on office paper and modern processing technologies, practically all species of trees are used for paper production in forestless areas such as: bamboo, flax, sugar-cane, etc.

**Table 2.2.1 Spheres of using forest residues**

| Types of residues | Pulp and paper industry | Boards | Chemical industry | Food | Fuel | Others |
|-------------------|-------------------------|--------|------------------|------|------|--------|
| 1. Chop residues, among them: |
| Slabs, lathes | + | + | + | - | + | + |
| Cracked wood of sawing and lathes | + | + | + | + | + | + |
| 2. Soft residues, among them: |
| Sawdust | - | + | + | - | + | + |
| Shavings | + | + | + | - | + | + |
| Tree dust | - | + | - | - | + | - |
| Wood bark | - | + | + | + | + | + |

Source: Zhuravliova L.N., Deviatlovskaya A. N. 2007. The main directions of using forest residues. Lesosibirsk branch of Siberian State Technical University. Lesosibirsk, R.F. 7pp. [13]

In hydrolytic production the main source is sawdust (about 38-41%). For example, from 1 ton of birch tree sawdust, after chemical processing we can get 185 liters of ethyl alcohol, 44kg of fodder albumen yeast, 5-6 kg. Furfural. 70 kg. Liquid carbonic acid, and other valuable products. In pyrolysis process from one cubic meter of birch-tree residues we can get 100 kg. Charcoal, 20 liter acetic acid, 5-6 liter wood-spirit and 10-15 kg. Pitch for making turpentine spirit, colophony rosin, etc. One of the most valuable products of wood-chemical production is charcoal which is widely used in different branches of economy [13].

Exhaustion of wood production base in most countries of the world increased demand on residues for pulp and paper industry. For example in Finland more than 85% of forest residues are used in pulp and paper industry [14-15]. Due to limited forest resources Norway use their forest residues in pulp and paper and boards making industries by ratio of 50/50. Increased demand on forest residues enlarged foreign trade of these resources among countries. Some countries are selling or buying residues and some of them are occupied with both businesses [16-18].
Another important option for wood waste is feedstock for so-called engineered wood that is the material derived from smaller pieces of wood that are bonded with different glues, resins and other chemicals to make wood-like product. Engineered wood include chipboards, particleboards, laminated timber, medium-density fiber (MDF), etc. By the way, MDF is denser than plywood and can be used as building material like plywood and particleboard. Major uses of particleboard are furniture, core stock, floor underlayement, wall paneling, interior applications, etc.

### Table 2.2.2. Chemical composition in trees of different species (%)

| Category          | Volatile Substances | Ashes | Lignin | Cellulose | Hemicellulose |
|-------------------|---------------------|-------|--------|-----------|---------------|
| Soft wood species | 0-5                 | 0.5   | 25-35  | 40-45     | 25-28         |
| Pine              | 0.7                 | 0.5   | 34.5   | 40.4      | 24.9          |
| Hard wood species | 0-5                 | 1     | 15-25  | 40-50     | 25-40         |
| Poplar            | 1                   | 2.1   | 25.6   | 41.3      | 32.9          |

Source: McKendry P. 2002. Production from biomass (part 1): Overview of Biomass. Bio-resource Technology 83, pp. 37-46. [19].

Today one of the major fields of using wood energy is pellet production from wood residues [20]. Beside wood residues for source of pellet production are used peat, bark, sawdust, chips and other residues and waste of loggings and agriculture, like maize straw, straw, waste of cereals, husks of sunflower, etc. Pellets are ecologically clean fuel with ash content of 3% and lesser. Pellets differ from wood by high dryness (moisture of pellets-8-12%, moisture of damp wood is 30-50% [13]. It guarantees their higher warming capacity comparing ordinary firewood of hard wood species. Hardwood tree species tend to contain more hemicelluloses and less lignin than soft-woods. Ratio of cellulose and lignin is the main factor that determines the priority use of wood species for energetic purposes (table 2.1.3). In different countries pellets are of different size and quality. Production of pellets are growing every year in many countries of the world. Beside wood residues in pellet production are used small diameter trees getting from young forests thining operation, biomass utilization of forest stand shrubs and low-value trees.

The simplest and cheapest use of forest residues is their use as fodder additives and fertilizers. Sawdust without any further processing can be used as fodder additives for cattle up to 25 % of total fodder composition. Bark contains more mineral substances (3-5.5 % of total volume) than sawdust useful for agricultural plants. Besides, bark has ability to infiltrate and adsorption of detrimental compounds for plants coming down with water. Using bark and sawdust as fertilizers is better after composting. Composting process increase composition in fertilizer that increase soil structure and fertility. Fodder composts are the natural, organic fertilizers as bark contains much lignin and has big humus potential [13].

### 2.3 Some adverse effects of excessive extraction of residues

Forests provide a number of environmental services from which the major are: soil and water protection, carbon sequestration, biodiversity, which must be maintained during and after harvesting. Removal of residues after harvesting can increase the risk of detrimental effects on these services. Therefore, there is conflict between increased extraction of forest residues on one side and ecosystem services with long-term site sustainability from the other [21-22]. Removal of forest residues after harvesting might increase risk of detrimental effects on the environment services provided by forests such as: soil and water protection, carbon sequestration and biodiversity. In order to minimize the adverse effects following the forest residue extraction new research and guidelines are needed to be developed [23].

The existing practice of developed countries show that forest residue extraction is more suitable for clear-felling method, than for selecting loggings due to the fact that space for moving around in letters is limited. Some other impediments can be: long distance, steep terrain, small felling site size and ecological restrictions. In most cases it is recommended that about 25% of logging residues must be left on site. The most important elements for tree growth are ammonium, potassium, calcium, magnesium, nitrate, sulfate and phosphorus. From extracted forest residues branches, twigs, leaves and needles have the largest part of nutrients within the tree. Hardwood species usually have higher nutrient concentrations than coniferous. Leaves as a rule have the highest mineral content from all tree parts. Therefore, decay of leaves is a very important process by which minerals are returned to soil [24].

Excessive extraction of forest residues can reduce soil organic matter (SOM), destabilize carbon-nitrogen balance, Increase erosion risks and reduce nutrient availability through removal of branches and tops. Therefore establishing sustainable guidelines for acceptable extraction rates is critically needed. The further uncertainties concerning achievable extraction rates for forest residues are created by uncertain future climate impacts like extreme weather and storm events affecting forest stands [25].

### 2.4 Present level of using forest residues in Georgia

In early centuries Georgia’s territory was covered with thick forests, but due to historical reasons in early and middle centuries (constant foreign invasions), as well as extensive overexploitation in the 20th century, resulted in deforestation and forest degradation of major part of forests. This detrimental process continued intensively after breakup of the Soviet Union until 2010 [26, 27]. According to informal information about 5-6 million cubic meter of valuable forests (mostly beech) was annually logged illegally and taken abroad for very cheap price. Currently the situation improved a little but still stay at high level, taking into account the present condition of forests.

### Table 2.4.1 Total volume of logging by regions (cubic meter)

| Region          | 2000  | 2005  | 2010  | 2015  | 2016  | 2017  | 2018  |
|-----------------|-------|-------|-------|-------|-------|-------|-------|
| Georgia, total  | 442,140 | 810,615 | 876,749 | 712,336 | 628,035 | 630,462 | 578,031 |
| Adjara AR       | 44,648 | 73,007 | 77,868 | 75,510 | 65,422 | 69,034 | 58,631 |
| Guria           | 24,463 | 56,384 | 16,193 | 12,269 | 8,526  | 13,185 | 9,268  |
| Imereti         | 45,270 | 103,718 | 97,440 | 80,775 | 57,443 | 53,277 | 45,483 |
| Kakheti         | 61,893 | 119,479 | 181,706 | 140,086 | 121,773 | 132,067 | 97,051 |
The major part of rural population in Georgia use firewood for warming and cooking meal. In the Soviet Period the greater part of firewood was imported from Russia, but presently this source is closed due to the political and economic reasons [27]. In last decades annually was logging about 700,000 cubic meter of wood by principle loggings (table 2.2.1). Average illegal loggings in the same period was about 45,000 cubic meter (table 2.2.2) [28]. So, altogether annually was logging about 745,000 cubic meter. In our forest practice logging residues never been estimated and used. They have always been neglected, left in forests and rotten. Only the residues of forest processing were used in the Soviet period. In 1980s about 40,000 cubic meter of chip-boards have been made that were used in doing school and office furniture [28]. Today, if we take only 30% of residues and it is about 260,400 cubic meter and leave 20%–about 112,000 cubic meter in forests, we can use 260,400 cubic meter for board, paper and fuel production.

Practice of other countries show that the ratio of commercial wood taken from forest and the amount of residues left in forests not vary much and depends considerably on local conditions and species. Ratio of 50/50 is most often found in literature. E.G. for every cubic meter of log removed from the forest a cubic meter of waste remains in the forest. Other sources give a ratio of 60/40 e.g. 6 cubic meters of logs versus 4 cubic meters of waste remained in forest. The 40% consists of stem wood (above first branches), branch wood, natural defects, stem wood below first branches, felling damage, stump wood and other losses including sawdust, chop offs etc.[13] After sawing and further wood processing another 25-35% of residues are left that consist: sawdust, trimmings, powder dust, shavings, chop offs etc.

### Table 2.4.2 Illegal logging by regions (cubic meter)

| Region                          | 2005   | 2010   | 2013   | 2014  | 2015  | 2016  | 2017  | 2018  |
|---------------------------------|--------|--------|--------|-------|-------|-------|-------|-------|
| Georgia, total                  | 61,042 | 32,802 | 6,039  | 45,915| 44,612| 28,586| 35,022| 32494 |
| Adjara AR                       | 2,676  | 2,040  | 1,671  | 1,895 | 1,880 | 1,044 | 1,514 | 1,250 |
| Guria                           | 1,436  | 333    | 225    | 474   | 729   | 647   | 331   | 194   |
| Imereti                         | 8,673  | 1,717  | 1,182  | 9,105 | 3,087 | 3,958 | 4,539 | 6,947 |
| Kakheti                         | 13,299 | 3,757  | 432    | 565   | 18,868| 9,568 | 9,685 | 5,769 |
| Mtskheta-Mtianeti               | 8,480  | 4,698  | 102    | 20,498| 1,576 | 993   | 447   | 362   |
| Racha-Lechkhumi and Kvemo Svaneti| 1,672  | 613    | 268    | 802   | 1,993 | 320   | 2,032 | 1,717 |
| Samegrelo-Zemo svaneti          | 3,052  | 916    | 236    | 2,291 | 1,766 | 2,119 | 3,928 | 1,562 |
| Samtskhe-Javakheti             | 16,342 | 15,977 | 752    | 1,583 | 10,648| 7,170 | 9,022 | 6,253 |
| Kvemo Kartli                   | 1,747  | 1,934  | 229    | 6,636 | 1,783 | 1,738 | 1,227 | 6,015 |
| Shida Kartli                   | 3,665  | 817    | 188    | 1,596 | 1,581 | 845   | 2,975 | 1,632 |
| Protected areas                 | -      | -      | 756    | 472   | 883   | 185   | 324   | 793   |

### Conclusions

Climate change threatens global development led by excessive use of fossil fuels. The rapid replacement of fossil fuels by renewable energies is the essential strategy against climate change. Currently biomass is the dominative source for multiple use in different branches of economy. The global consumption of wood is likely to increase in future due to population growth and increasing demand for biomass. Utilization of biomass of forest, agricultural and urban wood waste along with residues from urban management activities, lawn maintenance and municipal waste that include: everyday household and business garbage, buildings construction and demolition waste is getting economically more and more popular. At the same time decrease of world forest area, deforestation and forest degradation threaten with shortage of forest raw timber and residues and what is most important loss of world’s biodiversity and climate change. It is obvious that local governments are not able to control the constant acceleration of this process. So this process must be monitored by such non-governmental organization as UN, FAO and others. They must be given extra rights to control and if it’s necessary to impose sanctions on those countries which are noticed in unsustainable forest management, overexploitation and forest degradation.
References

1. IPCC Forth Assessment Report: Climate Change. 2007. www.ipcc.ch
2. McKendry P.(2002). Production from biomass (part 1): Overview of Biomass. Bio-resource Technology 83. pp. 37-46.
3. Global Biomass Potential towards , World Bio-energy Association (WBA). WBA fact sheet. www.worldbioenergy.org
4. WBA, Global Bio energy Statistics. Stockholm. (2015).
5. Ralph Sims. (2014). Bio-energy options for clearer environment: In developed and developing countries. www.e-sevier.com
6. Demianov V.V. (1963). Ways of utilization of wood resources. 79pp.
7. Parfionov V.I. (1993). Utilization of residues of wood sawing and processing. 59pp.
8. Bob Falk.(1997). Opportunities for the Wood waste Residues. Forest Products Journal, vol.47.N6, pp 17-22.
9. Chubinski G. S., Varankina G. S. (2015). Utilization of forest residues. 29pp.
10. FAO. (1990). Energy Conservation in the Mechanical Forest Industries. FAO Forestry Paper N93, FAO, Rome
11. Zoya Tariq. (2013). Utilization of Waste Wood. University of Arid Agriculture, Rawalpindi, Pakistan. 10pp.
12. Lynette Leighton (2014). Structural wood as secondary resources. Yale Environment Review. February. Environment.review.yele.edu
13. Zhuravliova L.N., Deviatlovskaya A.N. (2007) The main directions of using forest residues. Lesosibirski Branch of Siberian State Technical University. Lesosibirsk, R.F.pp.7.
14. Arke Koopmans and Yaap Koppejan. (1998). Agricultural and forest residues-Generation, Utilization and availability. Regional Wood Energy Development Programme in Asia. FAO, 23pp.
15. Adams M.(1995). Technical report: Forest products, Harvesting and Utilization Component. Paper presented to a Project Formulation Workshop on Management and Utilization of Tropical Rainforests in Asia.GCP/RAS/148/AUL, Bangkok, 6-8 February,
16. Bettina Kretschmer et.al. 2019. Recycling agricultural, forestry & food wastes and residues for sustainable bio-energy and biomaterials. 40pp.
17. Mark Vank and Marieke Theunissen.2007. The harvest of logging residues in the Dutch forests and landscapes. 29pp. Follow-up Study of BUS quick scan 24., The harvest of forest residues in Europe.
18. GOI.1990. Situation and outlook of the Forestry Sector in Indonesia. Ministry of Forestry, Government of Indonesia in cooperation with FAO, Rome.
19. McKendry P.2002. Production from biomass (part 1): Overview of Biomass. Bio-resource Technology 83. pp.37-46.
20. Wood residues availability and demands-Implications of renewable energy polices. 2007. UNECE/FAO Policy Forum on Impacts and opportunities of bio-energy polices on forest and other sectors.
21. De Jong,et.al. 2012. Consequences of an increased extraction of forest bio-fuel in Sweden. A Synthesis from the Bio-fuel Research Program 2007-2011. pp.38.
22. Bergstedt J. & Milberg P. 2001. The Impact of logging industry on field-layer vegetation in Swedish boreal forests. Forest Ecology and Management, vol.154, N3, pp105-115.