Biomass

An Online Continuing Education Course for Engineers

Course Number: R-4011

Credit: 4 Hours / 4 PDH / 4 CPD

Biomass

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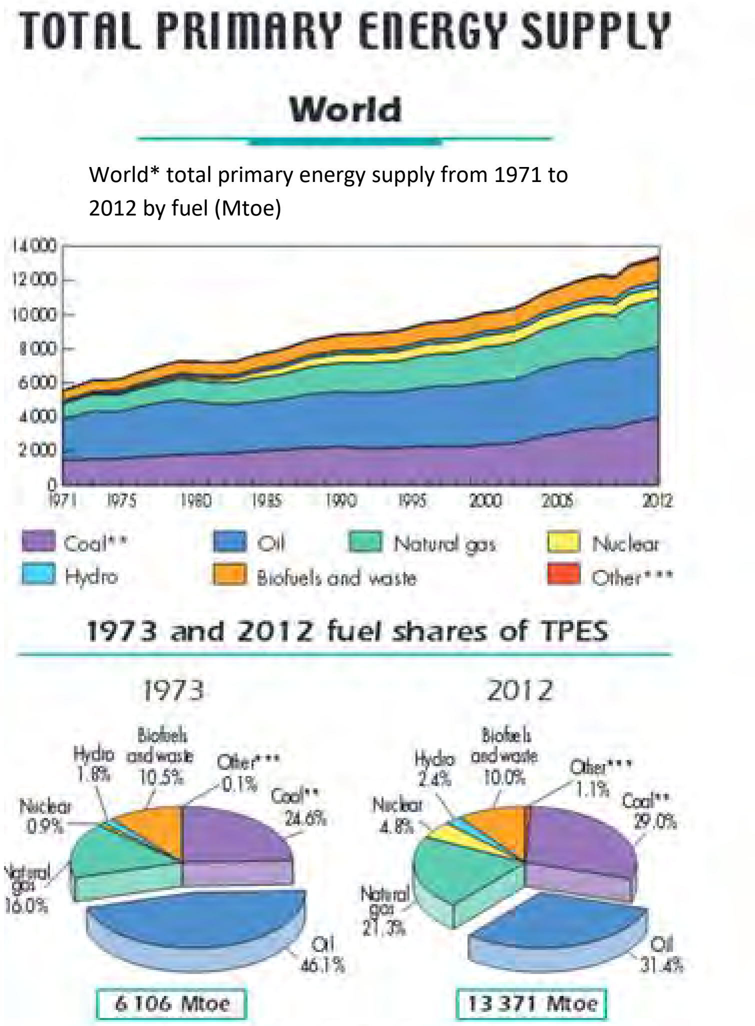
Course Learning Objectives:

a) Be able to identify the six types of commonly available biomass materials;
b) Understand the entire process of biomass utilization and at what point resources are available for collection;
c) Develop an awareness of how biomass resources are currently collected and utilized;
d) Understand the problems associated with biomass utilization; and
e) Be able to evaluate a potential biomass utilization project.

1) What is Biomass?

Biomass is a general term for a biologically-derived physical material. Wood, vegetative debris from growing crops, animal carcasses, animal waste, grain, and plant fiber can all be considered biomass. Biomass is all around us within the environment, and it is incredibly pervasive within human communities. Biomass is commonly found associated with agricultural enterprises and it is consistently underutilized within the global renewable energy industry. Research presented by the IEA (2014), shown as Figure 1, indicates that current locally recoverable energy resources from biomass production within the world have not changed in the last 40 years. This is the amount of biomass that is available for use by humanity without doing anything other than collecting it. Current utilization of biomass is nowhere close to this level. Table 1 from World Energy Outlook (2012) shows how the demand for renewable energy could potentially grow under enlightened policies. Units presented are in *Mtoe,* which is defined as Million tonnes of oil equivalent. This short course will further identify the various types and sources of biomass, how it is produced, how it can be utilized, the issues surrounding biomass utilization, and the means to evaluate specific biomass utilization opportunities.

Simply expressed, biomass is matter collected and densified by a biologic process. As such, biomass is always an organic material that is primarily based upon combinations of Carbon molecules. These organic compounds typically have Hydrogen, Oxygen, and Nitrogen mixed-in as the major constituent components, but other elements may be present as well. Most of the potential energy from these commonly available materials is released from the oxidation of the Carbon and Hydrogen pieces. These two elements are so critical to life on Earth that we specifically identify their chemical pathways as the Carbon Cycle and Water Cycle, respectively. The route of Carbon through biomass into the environment and back uses the atmosphere and soil as its intermediate storehouses. Hydrogen moves through moisture held within the atmosphere and the planetary liquid reserves. Plants consolidate these elements into their body masses through biochemical processes driven by sunlight. All biomass, both plant- and animal-derived, is originally fixed by this means.



*World includes international aviation and international marine bunkers.
**In these graphs, peat and oil shale are aggregated with coal.
***Includes geothermal, solar, wind, heat, etc.

Figure 1 – Current Distribution of Energy Sources {IEA (2014)}.

Table 1 - Potential Biomass Demand (*Mtoe*) {WEO (2012)}.

	1990	2010	New Policies 2035	New Policies 2010-35*	Current Policies 2035	Current Policies 2010-35*	450 Scenario 2035	450 Scenario 2010-35*
OECD	**277**	**443**	**1005**	**3.3%**	**861**	**2.7%**	**1393**	**4.7%**
Americas	153	199	461	3.4%	402	2.9%	686	5.1%
United States	100	131	338	3.9%	298	3.3%	522	5.7%
Europe	98	208	423	2.9%	373	2.4%	533	3.8%
Asia Oceania	26	36	121	5.0%	86	3.6%	173	6.5%
Japan	15	18	63	5.2%	39	3.2%	89	6.7%
Non-OECD	**847**	**1241**	**2073**	**2.1%**	**1840**	**1.6%**	**2500**	**2.8%**
E. Europe/ Eurasia	40	47	103	3.2%	84	2.3%	165	5.2%
Russia	26	22	53	3.6%	41	2.6%	101	6.3%
Asia	497	676	1133	2.1%	955	1.4%	1412	3.0%
China	211	284	483	2.1%	401	1.4%	629	3.2%
India	140	182	287	1.8%	247	1.2%	335	2.5%
Middle East	2	2	33	11.5%	19	9.1%	68	14.8%
Africa	196	339	483	1.4%	478	1.4%	500	1.6%
Latin America	112	177	322	2.4%	305	2.2%	355	2.8%
Brazil	66	117	210	2.4%	200	2.2%	230	2.8%
World	**1124**	**1684**	**3079**	**2.4%**	**2702**	**1.9%**	**3925**	**3.4%**
European Union	74	184	384	3.0%	338	2.5%	481	3.9%

*Compound average annual growth rate.

Note: Includes traditional biomass.

In fact, biomass is the original primary source material for fossil fuels as well. The only difference between fossil fuels and biomass is the time span associated between their Carbon fixation and their use by humanity. Biomass is fixed and utilized within a fairly short time span, generally no longer than a few decades. On the other hand, fossil fuels were fixed geological eons ago, have undergone some significant physical transformations, and are currently being processed and utilized within the modern world. The Carbon released from fossil fuels has been effectively isolated from our environment and has not been an active participant in the Carbon cycle for millions of years. This circumstance alone causes many people to hold unfavorable views of traditional fossil fuel utilization.

Regardless of how particular members of society view specific energy sources, the plain and simple truth is that all energy utilized on this planet originates from the Sun. Plants and other physical processes capture this energy temporarily, and we manage to insert ourselves somewhere within the thermodynamic cascade of this energy, moving downhill toward being nothing more than the background heat of the Universe. Biomass and the botanical processes that fix Carbon from atmospheric CO_2 into growing plant tissue produce a broad category of compounds known as lignocellulosic molecules. These molecules can be further processed by plants or eaten by animals and processed within their bodies. In all cases, the energy stored within the complex chemical bonds of the plant material originated in the nuclear reactions of the

Sun. That energy, in all cases, will eventually be radiated into deep space as waste heat. Whether humanity gets any use from it as it travels along its way is really the central question of our time.

Generally speaking, biomass can be categorized into six broad classifications: wood, energy crops, plant residues, animal residues, food and household waste, and industrial waste. Each of these expansive material categories can have several sub-categories.   Some of these sub-categories can be so different as to require vastly different utilization techniques. For instance, wood, the base plant material from trees, may be broadly classified as either a ‘hardwood’ or ‘softwood.’ Although the terminology does not exactly correspond to the density of the material, in general, hardwoods are more solid and heavy than softwoods. Different tree species have different calorific fuel values and ash content levels. It is well known throughout the solid wood fuel conversion industry that the species of tree used as feedstock greatly influences the design of the combustion chamber. Softwoods contain several volatile chemicals and burn ‘dirtier’ than hardwoods. Creosote deposits and other issues with the unburned biomass components in softwood fuel processes cause designs for these materials to incorporate excess air and other combustion tailoring techniques to improve their efficiencies. Hardwood devices are typically simpler to build and maintain in operation. Wood is essentially the original densified fuel source of the early industrial age. Considerable experience and engineering development has gone into equipment that can effectively handle a wide variety of wood feedstocks. In general, wood typically has higher value economic uses in the modern world than as a fuel source, but under certain specific conditions, it may be used quite successfully as a biomass feedstock for renewable energy processes.

Energy Crops are plants grown specifically for their rapid fixation of Carbon into plant matter. There is a variety of plant species that may be properly considered energy crops, including some extremely rapidly growing trees. The key distinction with this category of biomass is that the material is deliberately grown in an agricultural enterprise for its calorific value as an energy feedstock. Switchgrass, sorghum, miscanthus, hemp, and seaweed are outstanding choices for cultivated energy crops because of their high growth rates. Other species may be selected in certain situations if they provide a useful chemical or pre-cursor molecule within their plant masses. Sugar Beets and Sugarcane are examples of plants that generate significant amounts of sugars. Certain tree species are also being considered for cultivation on dedicated silviculture energy farms. Poplar, willow, sumac, bamboo, eucalyptus, and palm are among those being considered.

Plant residues are those portions of the plant leftover once the primary crop element has been harvested. Straw is the resulting plant residue from wheat production. Corn stover consists of corn stalks, leaves, and cobs. Bagasse is sugarcane stalk that has been processed to remove the sugars and syrups. There are numerous other examples of plant mass that are present in a primary crop harvest or could be made available for use with minimal work. Plant residues may be considered an unexploited ‘co-product’ of agricultural production, as the materials are created from the primary production effort with no additional input, but they are unutilized at the present time. Although some resources are required to collect these materials, they represent a fairly inexpensive source of renewable biomass energy as the costs for the plant's production have already been charged to the primary crop's production operations. The collection of these 'co-products' has increased dramatically in the last decade.

Although animal residues technically might include animal carcasses, typically, this category means animal manures. In North America, there are three major sub-divisions of animal residue: cattle manure, hog manure, and poultry litter. Cattle are rumens, and they have fairly inefficient digestive systems. The energy content of cattle manure on a dry mass basis is approximately half of utility-grade coal. Hog manure is similar to cattle, with a slightly reduced energy content level. Poultry litter does not quite have the same fuel value, as birds are more efficient converters of food to body mass than mammals. The energy level and specific chemical content for each variant of animal waste are different, but in general, manures are fairly energy-rich fuels. The difficulty lies in the manner of their collection. Manures from concentrated agricultural production enterprises tend to be very wet products, and most producers add water to facilitate handling the material. This is quite problematic for downstream processors that do not want water mixed into the biomass. If the water present in the material can be economically removed, animal residue is an outstanding renewable energy source. If the water cannot be removed, the material is generally too energy diffuse to be of much use.

Food and Household Waste is broadly classified as Municipal Solid Waste (MSW), and homes and small businesses typically generate the lion's share of this material. MSW is generally collected in aggregate through municipal and private service providers. This is unfortunate, as it mixes numerous types of material, which, if maintained separately, might have a higher value. The heterogeneous nature of MSW creates multiple headaches when attempting to utilize this material. The success of local recycling programs can aid in the utilization of MSW as a source of biomass since the separation of the various types of materials allows specialized processes to be planned that take advantage of each type of material. A unique path or process for each specific type of material guarantees that the substance will be used to its best potential. Solid food waste and packaging paper and cardboard account for the largest fractions of this MSW material. Food waste is usually very wet and is not of much use to the post-processor. Paper products have reasonably high fuel values, but they also have value as recycled paper fiber. Used cooking oils are typically kept separate and have a well-developed utilization pathway. The separation of plastics from the waste mix prevents many combustion problems from developing. Unfortunately, many communities do not have well-developed recycling programs, and much of this material winds-up in large landfills, where it decays and reaches its decomposed, chemical end state without providing any benefit to the community that placed it in the landfill.

Industrial waste is likely to be more homogeneous than household waste, and this means that it is far easier to utilize. The quantities of materials from most commercial and industrial facilities are large enough that special processes and handling protocols can be created to efficiently utilize the materials. Wood-based biomass wastes are commonly found at woodworking, furniture making, and pallet factories. Papermaking plants also produce a large amount of energy-rich fiber-based by-products. Grain, cotton, and sugar processing plants generate a significant amount of biomass waste, as do many other bioprocessing and pharmaceutical plants. In many ways, large-scale industrial plants represent the easiest biomass utilization scenario, since the volume of materials handled and the resources available for conversion are likely to be sufficient for a practical renewable energy implementation plan.

2) How is Biomass Produced?

Biomass is produced through the life processes of plants and animals. As such, agricultural
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