Linnæus University
Björn Zethræus

02-00: Biomass for energy – Resources

One very common misunderstanding when planning a biofuel-based energy system – even if it be a small scale and local system – is to forget the global aspect and concentrate only on local conditions. However, it must always be remembered that the local community – small as it may be – is a part of the world and that a sustainable energy system must always be compliant with that fact. Hence, let us turn to some global aspects for a moment.

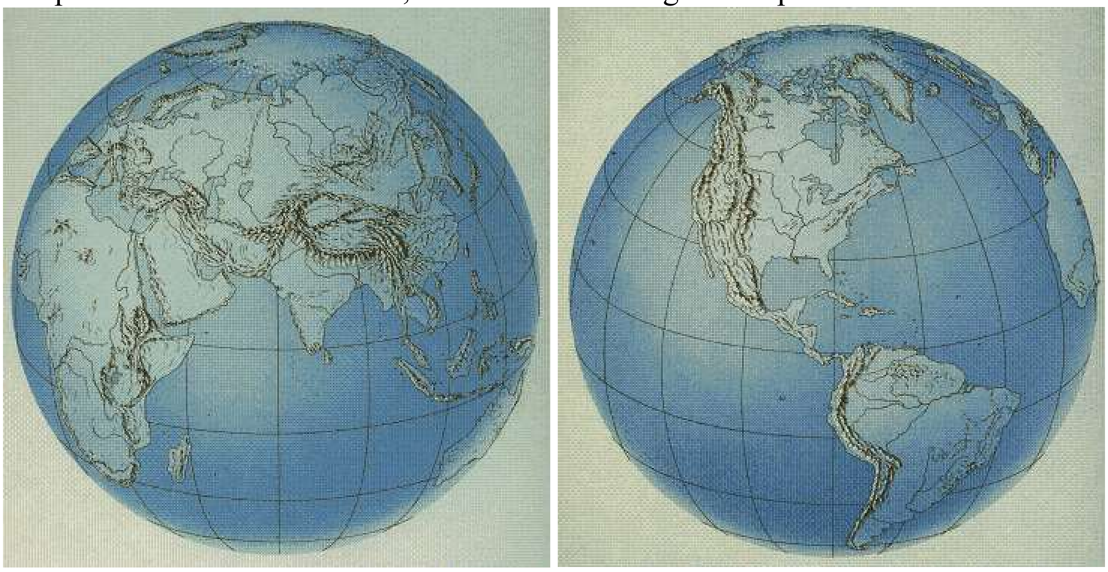

Figure 02-00 1: The common view of the world

The simplest starting point is to view our planet as a sphere with a circumference of 40000 km. From that assumption, it takes only the simplest math from secondary school to compute the total surface area – which becomes approximately 500 million square km. Now again return to school and remind yourself that approximately 70% of the earths' surface is covered with water – seas and major lakes. Hence the land area is approximately 150 million square km. Now divide this number by the number of people on this planet – a bit more than 7 000 million people, and you will find that the land area available to each of us is about 20 000 square meters which is just below 3 football fields. One football field is assumed as 100×70 m^2. So a bit less than three football fields is what every human being has as her "rightful share" of the land of this planet.

The next part of this exercise is more difficult, but if you go into encyclopaedias and databases, you'll be able to verify that the three football fields – still assuming that everybody has the "right" to an equal share – consist of about 0.85 football field of infertile land, about 0.85 football field of forested land, about 0.85 football field of dry grassland, about 0.3 football fields of rich grassland (good enough for grazing, that is) and, finally, about 0.15 football fields or arable land, arable without artificial irrigation. We will use "biomes" for these types of land: arable land, rich grassland, savannah, forest and infertile.

Linnæus University
Björn Zethræus

These are hard facts and cannot be denied. The change of the global climate will affect the distribution and may increase – or decrease – the amount of each biome – but it will not change the size of the planet. Rather, the three football fields are rapidly shrinking because of the population growth.

You will realize that this view of the world is extremely simplified – but it serves it purpose to illustrate in a simple way what “sustainability” is about: The first step towards a sustainable development is to adopt our use of resources and our use of natural resources to what our planet really has to offer. This puts a strict upper limit to how much biofuel is available. But it also puts focus on the qualities of biofuel attainable – unless we prefer to compete with agriculture about the 0.15 football fields.

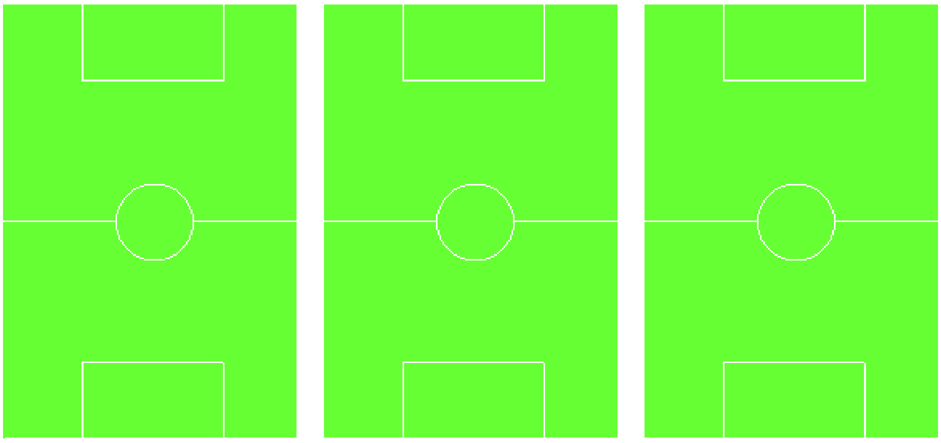

Figure 02-00 2: The world of the individual…

There is an intense debate about future biomass potentials, especially in the light of sustainability requirements. One estimate prepared for the IEA is shown in the table below, which provides an overview of the global potential of land-based bio-energy supply over the long-term. The potentials shown here are the estimated technical potentials for a number of biomass categories, and the result of a synthesis of several global assessments. Other reports come to radically different conclusions.

Biomass category	**Technical potential 2050 (EJ/year)**
Energy crop production on surplus agricultural land	0 – 700
Energy crop plantation on marginal land	<60 – 110
Agricultural residues	15 – 70
Forest residues	30 – 150
Dung	5 - 55
Organic wastes	5 – 50+
Total	**<50 - < 1 100**

Table 02-00 1: Overview of the global potential of bioenergy supply over the long-term for a number of categories, from reference [1]
To obtain TWh from EJ, divide by 3 600

Note: For comparison, current global primary energy consumption is about 500 EJ. Note also that bio-energy from macro- and micro-algae is not included owing to its early state of development.

02-00-01: Viewing the biomes – bottom-up

Provided we want to avoid competition with the production of food and fibre, the main biofuel fractions available are by-products from agriculture and from food and fibre processing, it's by-products from silviculture and from forest industry and it's by-products (i.e. organic waste fractions) from society. It may also be vegetational biomass from marginal land.

The use of fertile, agricultural land solely for energy farming is obviously not sustainable in a world where the ratio of such land per person is already only about 0.15 football fields and shrinking.

One should be careful not to regard the available fractions as "waste", because the word waste tends to suggest that these fractions are worthless – but they are not:

- Corn production yields straw as a by-product. This straw may be ploughed down as a green fertilizer, it may be dried and used as bedding or it may be dried and used as a fuel. Whichever use the straw finds – it is not worthless.
- Beef production yields manure as a by-product. The manure can be used directly as a fertilizer or it can first be used for biogas production and then the solid residue after the biogas process, the solid residue will still contain the nutrients, can be used as a fertilizer. Whichever use the manure finds – it is not worthless.
- Maize production yields stalks and leaves as a by-product. These are often left in the field and ploughed down as a green fertilizer but the leaves can also be removed and sold for basketry or similar. Or stalks and leaves can be dried and user for fuel.
  Whichever use the stalks and leaves may find – they are not worthless.
- Cotton production yields mainly stalks as a by-product. Again, these are often left in the field and ploughed down as a green fertilizer or they can be used for paper. But in this case, there is also a subsequent processing industry – the weaving industry – where cotton spills are produced as a by-product. Again, the stalks can be dried and used for fuel while the cotton spills are already dry and make up an excellent fuel as they are.
  Whichever use the stalks and spills may find – they are not worthless.
- …

Over the millennia, farmers have found use for the by-products from agriculture for bedding, cattle food supplements, green fertilizer… and it must be understood that any alternate use of the by-products for energy purposes will initially be regarded with suspicion. So any use of agricultural by-products for fuel and energy purposes must be carefully prepared to avoid negative reactions and it must be understood and respected that the farming community rests upon a solid base of experience collected over more than a hundred generations. Hence, if the by-products find a new market, the farmer has to find a replacement and the price of the by-product to the energy company/fuel retailer will have to cover the cost for the replacement with the farmer. Finally, the farming community is proud, well aware that they are the ones producing the food we all eat and the clothes we all wear.

The rich grassland – comprising approximately 0.3 football fields per person – is mainly used for grazing as the global situation is today. The main by-product from grazing cattle is manure, which is an excellent basis for biogas production and which has already been mentioned. If competition with cattle breeding can be accepted, this land might lend itself well for miscanthus cultivation. The reason that the rich grassland is not arable may be a lack of sunlight, lack of water or lack of nutrients.

The poor, in a global perspective dry grassland, amounts to approximately 0.85 football fields per person. In Europe, this is commonly used for sheep grazing or for goats. This land is typically too dry for any cultivation and the by-products from animals living on this poor land are too meagre to represent any value from an energy point of view.

Forest land – boreal forest in northern Europe, temperate forest in Continental Europe – is the biome that has the greatest potential by far with respect to energy. At a forest felling site, typically 10-50 % of the stem mass is left in the form of brash, branches and treetops, depending on the species at hand. Also in subsequent processing – saw-mills, joineries – by-products such as sawdust, cutter shavings and cut-offs are produced. Sawn planks typically represent only about 50 % of the mass of the original stem wood – the remaining 50 % being found in sawdust and in shavings. Added to this the brash that is commonly left at the felling site and that may be collected and used for energy. Also the forest represents one of the main biomes – 0.85 football fields per person.

Infertile land – the last one of the major biomes – is obviously useless for any type of biofuel production.

Organic fractions in societal waste consist of several different fractions, but disregarding household wastes one might identify trimmings from parks and from gardens as one major fraction easy to distinguish and scrapings from schools, restaurants and hospitals as the second one. The first of these fractions may be an excellent fuel as it is while the second fraction may be an excellent substrate for biogas production, possibly integrated with the municipal wastewater treatment plant.

02-00-02: Viewing the European biomes – climate

Obviously, the distribution between different biomes will be strongly related to the climate and for the purpose of this handbook, the following climatic division is used for Europe:
Atlantic climate. Atlantic climate is dominated by the presence of the Atlantic Ocean. It is a bit wetter than it would be if only latitude was determining and also the presence of the sea tends to make summers a bit cooler and winters a bit milder. The natural vegetation is mixed with some dominance of broadleaf trees and generally C_3.
Mediterranean climate. In spite of the Mediterranean Sea this climate is dry with – typically – hot summers. This is an area where C_4-plants start to appear, to some extent even CAM-plants. Arid grasslands can be found to quite an extensive amount.
Continental temperate. This is a continental climate with fairly large temperature variations between winter and summer, dominated by broadleaf trees as the natural vegetation. Precipitation is generally large enough not to give any extremely arid areas.
Boreal Taiga. This is the northern conifer belt extending east all the way through Russia. Cold winters, often with a significant number of frost days and warm or even hot summers to the eastern part. The Baltic Sea will, however, even out the temperatures to some extent. Tundra areas are extensive in the northernmost part.

Splitting the states in the European Federation into these categories yield:

Atlantic	Boreal	Continental	Mediterranean
Belgium	Estonia	Austria	Bulgaria
Denmark	Finland	Czech Republic	Cyprus
France	Latvia	Germany	Greece
* *Iceland*	Lithuania	Hungary	Italy
Ireland	* *Norway*	Poland	Malta
Luxembourg	Sweden	Romania	Spain
Netherlands		Slovakia	
Portugal		Slovenia	
UK		* *Switzerland*	

Table 02-00 2: States in the European Federation. Iceland, Norway and Switzerland are members of the EES treaty and hence, in a way, associated.
If you are un-comfortable with C_3, C_4 and CAM, refer to 01-00-02a.

One consideration behind this grouping is to sort whole states into categories rather than allowing any state to belong to two ore more climate categories. You may notice that this grouping is not fully consistent with other groupings found in literature, based on more fundamental climatic considerations. For example, Päivinen & al. [2] use only three zones throughout Europe, Atlantic, Mediterranean and Temperate+Boreal, splitting for example France into Atlantic and Temperate+Boreal and also splitting several other countries.

02-00-02a: Viewing the European biomes – Forests

Looking then at the total land covered with forests or "other wooded land" according to international forest statistics yields the following numbers for 2005, million hectares. The numbers referred here are only for such forest that is available for wood supply, so protected areas, and areas with limited accessibility are not included:

Atlantic		Boreal		Continental		Mediterranean	
Belgium	0.6	Estonia	1.9	Austria	3.4	Bulgaria	3.1
Denmark	0.4	Finland	20.7	Czech R	2.6	Cyprus	0.04
France	14.5	Latvia	2.4	Germany	10.1	Greece	3.1
Iceland	0.02	Lithuania	1.7	Hungary	1.7	Italy	6.0
Ireland	0.6	Norway	6.6	Poland	8.3	Malta	0.0
Luxembourg	0.1	Sweden	21.2	Romania	5.6	Spain	10.5
Netherlands	0.3			Slovakia	1.7		
Portugal	1.9			Slovenia	1.0		
UK	2.1			Switzerland	1.1		

Table 02-00 3: Forest areas (million hectares) in the mid-1990's to 2005, various years for various states. [3]

The report provided by UN-ECE/FAO in the year 2000, [4], provides the background data for the statistics, and in that reference the following data can be found for annual growth:

Atlantic		Boreal		Continental		Mediterranean	
Belgium	5.1	Estonia[2]	7.2	Austria	27.3	Bulgaria	10.2
Denmark	3.2	Finland	72.5	Czech R	20.4	Cyprus	0.04
France	92.3	Latvia	11.1	Germany	89.0	Greece[1]	-
Iceland[1]	0.04	Lithuania	8.5	Hungary	9.9	Italy	18.7
Ireland	3.4	Norway	22.0	Poland	39.4	Malta[1]	-
Luxembourg[1]	-	Sweden	85.4	Romania[2]	30.9	Spain[1]	28.6
Netherlands	2.2			Slovakia	12.3		
Portugal	12.9			Slovenia	6.1		
UK	14.6			Switzerland	8.2		

Table 02-00 4: Million m^3 of woody biomass over bark. Annual growth on the land areas from table 02-00 2, values generally valid in the mid-1990's.
[1] *These countries have low standing stock, less than 50 m^3/ha.*
[2] *Estimate based on data from [4], not reported values.*

The numbers from the above tables may now be used to estimate the specific growth on such forest land that is actually available for productive silviculture. It should be observed that the tree species of Europe are mainly C_3.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	8.0	Estonia[2]	3.8	Austria	8.2	Bulgaria	3.3
Denmark	7.3	Finland	3.5	Czech R	8.0	Cyprus	-
France	6.4	Latvia	4.6	Germany	8.8	Greece[1]	-
Iceland[1]	-	Lithuania	5.0	Hungary	5.8	Italy	3.1
Ireland	6.0	Norway	3.3	Poland	4.8	Malta[1]	-
Luxembourg[1]	-	Sweden	4.0	Romania[2]	5.5	Spain[1]	2.7
Netherlands	7.1			Slovakia	7.2		
Portugal	6.8			Slovenia	5.9		
UK	6.9			Switzerland	7.7		

Table 02-00 5: Specific forest growth rates, m^3 over bark/hectare and year.
[1] *These countries have low standing stock, less than 50 m^3/ha.*
[2] *Estimate based on data from [4], not reported values.*

The states dominating in Continental Europe will thus exhibit an average production rate of 6.9 m^3_{OB}/ha·year, the Atlantic zone 6.5, the states in the Boreal zone 3.8, and the Mediterranean region 2.9 m^3_{OB}/ha·year, totalling about 640 Mm^3_{OB}/year in Europe. The productivity numbers are subject to great local variations, values in excess of 14 m^3_{OB}/ha·year have been reported from areas with intensive silviculture, but the numbers in table 02-00 5 may serve as a indication.

In the north, the boreal region, will conifers be dominant, about 80 %, while broadleaf trees will be dominant in the south and south-east.

02-00-02b: Viewing the European biomes – Agricultural land

FAO [5] also provides statistical data for agriculture and the following table summarizes the specific, average and annual production rate of barley+oat+rye+wheat on agricultural land in the different states:

Atlantic		Boreal		Continental		Mediterranean	
Belgium	9.2	Estonia	2.8	Austria	4.7	Bulgaria	3.2
Denmark	6.8	Finland	3.8	Czech R	4.9	Cyprus[1]	0.9
France	7.2	Latvia	3.2	Germany	7.1	Greece	2.5
Iceland	-	Lithuania	3.6	Hungary	3.6	Italy	3.4
Ireland	6.9	Norway	3.1	Poland	3.5	Malta[2]	4.4
Luxembourg	6.2	Sweden	5.1	Romania	2.3	Spain	2.4
Netherlands	8.7			Slovakia	3.8		
Portugal	1.6			Slovenia	3.7		
UK	7.1			Switzerland	6.2		

Table 02-00 6: Cereal production rate, barley+oat+rye+wheat, ton/ha•year, data for 2009, reference [5]. All these crops are C_3.
[1] *No rye*
[2] *No rye, no barley*

The table reveals how the mean annual yield (MAY) in the Atlantic zone is 7.1 tons/ha•year decreasing to 4.6 in the Continental zone, 3.9 in the Boreal and 2.8 tons/ha•year in the Mediterranean states.

The numbers in table 02-00 5 not only reflect climatic differences but also differences in the state of agriculture, the use of artificial fertilizer and a number of other parameters, but again they may serve as indications as to which specific yields from C_3-crops may be expected in different regions.

In the warmer climates in Southern Europe C_3-crops may not be the best choice and the following table, again based on data from reference [5] may be a better reference:

Atlantic		Boreal		Continental		Mediterranean	
Belgium[1]	12.1	Estonia	-	Austria[1]	10.6	Bulgaria	4.7
Denmark	-	Finland	-	Czech R[1]	8.4	Cyprus	-
France	9.0	Latvia	-	Germany[1]	9.8	Greece	9.8
Iceland	-	Lithuania[1]	4.3	Hungary	6.4	Italy	8.5
Ireland	-	Norway[1]	3.6	Poland[1]	6.2	Malta	-
Luxembourg[1]	6.0	Sweden	-	Romania	3.4	Spain	10.0
Netherlands[1]	13.0			Slovakia	6.8		
Portugal	6.8			Slovenia[1]	7.8		
UK	-			Switzerland[1]	10.4		

Table 02-00 7: C_4–crops production rate, maize+sorghum, ton/ha•year, data for 2009, reference [5]. Production exclusively aimed for fodder excluded.
[1] *Maize only, no sorghum*

As seen from the table, the C_4-crops, adapted as they are for a warm and arid climate, brings up the mean annual yields in the Mediterranean region to an average of 8.4 tons/hectare and year. Still, though, the highly developed agriculture in the states in the Atlantic region takes a leading position – 9.0 tons/ha•year. For C_4-crops the boreal region is not well suited, 4.3 tons, while Continental Europe shows a wide span averaging 5.5.

To summarize, the mean annual yield from agricultural land is highly variable, not only depending on climate but also on the choice of crop. It must also be emphasized that international statistics like those shown here are not necessarily reliable. Statistics presented by FAO are first collected from the individual states and the individual states will have different definitions and standards with their national statistical institutes. Hence, again, the numbers presented above are only indicative and may not be used for any quantitative analysis – but they do give the orders of magnitude and may be used to illustrate what might be anticipated in different regions of Europe.

The numbers in the above tables represent the yield of grains, which shall not be mistaken for the yield of suitable energy by-products. The yield of by-products – stems, stalks, leaves, straw etc suitable for energy production – is proportional to the yield of primary products, but the ratio between them varies with the type of crop as well as with the standard of agricultural practices.

Ratios for energetic by-products to primary yield are hugely variable, from 10 % to values exceeding 200 % so that the by-products may actually amount to more tons than the primary yield for some crops. Therefore, no values are given, not even for indication, but the reader is referred to find relevant data for her or his region and crop. The statistics office of the European Federation, Eurostat, collects and presents large amounts of statistical data for the European states and the Eurostat statistics [6, search for *material flow*] contains data about the amounts of a number of biomasses and their residues.

In the early stages of energy system planning not only the demand for energy must be investigated but the available resources must also be mapped. In regions where agricultural by-products form an important fuel resource the collection of production statistics and the categorization of the resources will be one of the first and most important steps in the planning process. You may want to refer to section 04-00-08n.

The annual yield is strongly weather dependant and actual numbers for planning purposes can only be provided from local and regional statistics. Such statistics must be collected for a number of years, at least 10 to make them statistically significant. The statistics will produce a mean value for the period and also a standard deviation for the yields during the same period. The standard deviation is a measure of how much the annual yield may be expected to vary from one year to the other. Also such time dependant data are available from the Eurostat databases.

Since the energy supply system is one of the most fundamental infrastructures in society, the planning and the dimensioning must both be based on safety so that the energy supply does not suffer from lack of fuel, and it is highly recommended to use the mean annual yield minus the standard deviation as the dimensioning resource. As long as the agricultural structure remains the same, such a conservative estimate of the probable minimal annual yield (PMiAY) will be too optimistic (only 2-3 years out of 10). Even using this conservative number as a basis for planning, it is thus clear that planning also needs to take buffering and “plan-B” solutions into account to guarantee the fuel supply.

For energy systems based on woody biomass, the annual variations are much less crucial since trees are perennial. Hence, the available volumes of by-products from wood and timber industry are more dependent on the state of the market than on weather.

02-00-02c: Viewing the European biomes – Urban land

The western way of life is one of consumerism and a significant amount of the resources taken from the earth on an annual basis are only passing through society and soon end up as waste. Eurostat collects and presents data on waste streams, among other data, and the following diagram shows the “production” of household waste from the states in the European Federation in the year 2008:

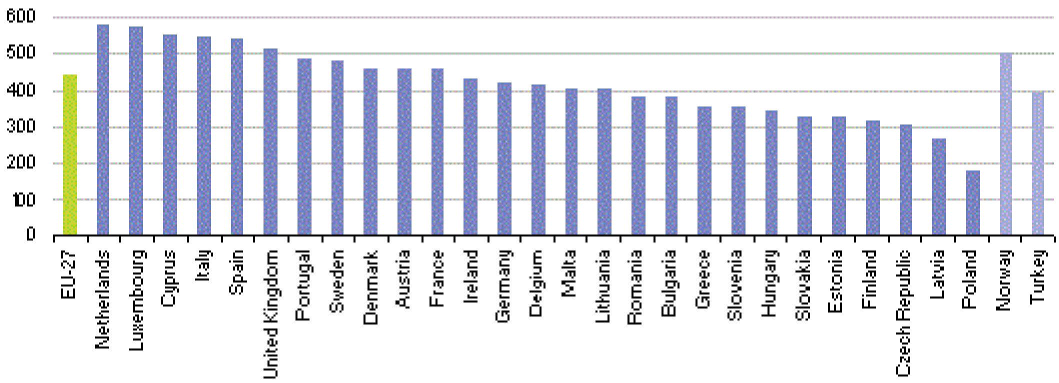

Figure 02-00 3: ”Production” of household waste (kg/person•year) for the states in the European Federation 2008. [6, search word *waste*]

Household and industrial wastes pose a number of problems as it comes to their use as fuels, since they consist of a large number of mixed fractions. Just like the statistics of agricultural production differ between states, so do the statistics for waste composition.

For the European Federation as a whole, the dominant waste producer is the construction sector (33 %) followed by the mining industry (28 %) and the manufacturing industry (13 %). Agricultural and forestry wastes amount only to less than 2 % of the total while household waste is just above 8 %.

A very rough split of household wastes will separate them into three groups, “Biodegradable”, “Paper+Textiles+Plastic+Glass+Metals” and “Other materials”.

The first group are such materials that may be treated by biochemical processes, yielding a combustible gas consisting mainly of methane and carbon dioxide but also minor amounts of other gases. The biochemical process will also produce a solid residue containing the main part of the heavy metals found in the waste together with minerals and organic compounds.

The second fraction consist the part of the wastes that are combustible, but in practical applications this fraction will not only contain combustible materials but also glass, ceramics and metals will be found in it. The combustion of this fraction for energy purposes is a mature technology but since the fuel quality cannot be guaranteed with respect to its cleanness there are federal directives as well as very strict laws and regulations in the individual states that the combustion plants have to meet. Hence, waste combustion is an expensive process and the ashes will be heavily contaminated and not suitable for soil improvement.

"Other materials" may include things like white-ware, electronics, broken windows or insulation material from house renovations, paint residues etc.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	39/36/25	Estonia	*no data*	Austria	38/37/25	Bulgaria	40/28/32
Denmark	36/29/35	Finland	38/32/30	Czech R	18/20/62	Cyprus	42/51/ 7
France	29/57/14	Latvia	48/36/16	Germany	36/31/33	Greece	51/38/11
Iceland	*no data*	Lithuania	50/38/12	Hungary	41/34/25	Italy	44/48/ 8
Ireland	37/52/11	Norway	38/53/ 9	Poland	*no data*	Malta	60/37/ 3
Luxemb.	44/48/ 8	Sweden	46/39/15	Romania	49/44/ 7	Spain	37/50/13
Netherl.	35/55/10			Slovakia	*no data*		
Portugal	34/42/24			Slovenia	*no data*		
UK	37/50/13			Switz.	18/20/62		

Table 02-00 8: Household waste composition, % in the three main fractions "Biodegradable"/"Combustible"/"Other"

The numbers in table 02-00 7 are compiled from a number of different sources and are only indicative for the distributions. However, the numbers indicate that the total amounts of materials suitable for energy production are significant and that waste fractions should be considered a significant resource in energy planning.

A grown up human also "produces" 100-200 grams (dry weight) of faeces every day. In modern cities, where this material is transported to a waste-water treatment plant this, too, is an energy resource. The combination of waste-water treatment and biogas production is successively gaining ground and becomes established in more and more places.

Hence, biomass resources are not only found in agricultural and in forest environments – but also urban areas are biomass producers. During the planning process for new and biomass-based energy supply systems, this may not be neglected.

02-00-03: Planning aspects

Obviously, one of the most important aspects in planning a sustainable energy system is the availability of fuel, the cost and the quality.

The most obvious fractions to be looked for are those originating from agriculture and from forestry but other sources must not be overlooked. In text section 03-00-04, these things will be dealt with in some more detail but roughly, the resources may be split into three major groups:
Annual crops. Herbaceous or agricultural resources are most often annual and the actual yield a specific year is strongly weather dependent. Since the mean annual yield (MAI) is per definition a value that is in the middle of the variation span, planning for the MAI will yield a deficit of fuel every second year (on average) while there will be a surplus every second year. However, some of these crops may also be perennial and in that case the variation will typically be easier to handle.
Societal, industrial and livestock resources, such as sorted waste fractions, fibre sludge, manure or similar residual products are not weather dependent but will exhibit a variation due to the state of the market and to the consumption patterns. The annual variations in these resources will typically be slower and less extreme than with annual crops.
Perennial crops, such as wood and forestry residues, will reflect the industrial structure of the region but will be depending on the actual state of the sectorial market, too. Hence, there will again be variations to the supply side of the market and the planner needs take this into due account.

The resources sought for are mainly such that are commonly referred to as waste or residues, since these will be the ones attainable at the lowest cost. The quantity of such material will usually not be available through normal statistics databases. To quantify the resources there are thus mainly two strategies:

- Collect fundamental data about the agricultural and silvicultural sectors in the region in terms of primary production rates. Use regional values for the residue-to-product ratio to estimate the total amount of residues. Doing this, one must be careful to take local variations into account since traditions, equipment and harvesting methods all affect not only the specific production rate but also the amounts of residuals produced per kg of primary product. For societal waste fractions, the strategy to collect fundamental data implies analysing detailed statistics of the regional waste streams and the analysis of each waste flow. The drawback with this strategy to map local and regional resources is that it typically involves applying statistical data deduced from a larger geographical area to local or regional conditions, such as data presented in the tables in this chapter. The errors introduced by such extrapolation cannot be estimated but may be significant. The advantage with this strategy is that the results can be traced back to their origin.
- The second main strategy is to perform surveys including a number of interviews with producers, logistic companies and others that are involved with the materials in question. The drawback with this method for local and regional mapping is that it may prove laborious and that the results cannot easily be traced. Neither can the quality of the numbers obtained be guaranteed. The main advantage is that up-to-date information is gained from professionals and experts actively working in the region and though the quality of any numbers cannot be guaranteed, they will all refer to the correct area and may thus be judged more relevant to the region than numbers extrapolated from official data covering larger areas.

References

1 Kampman B, Fritsche UR et al. BUBE: *Better Use of Biomass for Energy*. Background Report to the Position Paper of IEA RETD and IEA Bioenergy. Delft/Darmstadt, July 2010.

2 Päivinen, R & al 2001, *Combining Earth Observation Data and Forest Statistics*, European Forest Institute research report 14, EUR 19911 EN, ISBN 952-9844-84-0

3 FAO Forest statistics

4 *Forest resources of Europe, CIS, North America, Australia, Japan and New Zealand*, report ECE/TIM/SP/17, ISBN 92-1-116735-3

5 http://faostat.fao.org/

6 http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database