02-03: Putrescibles – Resources

It is important to differentiate and carefully to evaluate the theoretical, technical, economical, and realizable potential of biomass or energy.

The **theoretical potential** comprises all the energy that could theoretically be generated within a defined time period and defined space.
The **technical potential** is the specific part of energy of the theoretical potential, which can be provided within the given structural and ecological boundaries and by respecting any legal restrictions. It may not always make sense to fully exhaust the technical potential, especially if there is no profitable return.
However, the **economic potential** may not be realizable without any administrative support from certain institutions.

There is a huge gap between the technical and profitable potential and the realizable potential. A lot of what is technically feasible is rejected for various reasons, mainly special interests, e.g., landscape protection or jobs safety. A lot can be explained rationally but a lot is just based on emotion. The total yield from biomass results from the maximum area available for cultivation and the energetic yield from the biomass cultivated on the specific area.

02-03-01: Over-all resources of digestible (putrescible) biomass (substrates)

According to a study published by the ATEE (Association Technique Energie Environnement) [1], the world's theoretical potential of biogas would increase 8.72 PWh per year if all waste was treated through anaerobic digestion. If agricultural by-products would be also used for biogas production, the biogas potential would reach 11.6 PWh/year (table 02-03 1). In comparison, world consumption of natural gas is around 2000 PWh per year [2].

World biogas resource	**Produced biogas (TWh/year)**	**Biogas which can be valued (TWh/year)**
Urban and industrial solid waste	8 723	700 to 1150
Urban and industrial waste water	582	460 to 580
Agricultural by-products	11 630	460 to 1750
TOTAL	20 934	1630 to 3500
Biogas/worldwide consumption of natural gas	*100%*	*8% to 17%*

Table 02-03 1: Worldwide resource in biogas*
According study of ADEME

Anaerobic micro-organisms can decompose all kinds of organic materials. Of these, short chain hydrocarbons, such as sugars, are easiest to decompose. Longer chain hydrocarbons, such as celluloses and hemicelluloses, are more difficult to decompose and the digestion process will therefore take longer. Woody materials that contain more complex hydrocarbons, such as lignin, are not suitable for decomposition by anaerobic micro-organisms.

Since the sources of feedstock suitable for AD are many and varied, many billions of tonnes are available worldwide. Within the EU, for example, there are over 1.2 billion tonnes of potential feedstock per annum as seen from this table [3].

Feedstock/Process	Produced
Animal manures	1 200
Paper production	2
Sugar beet processing	8
Olive oil production	3
Other fruit and vegetable processing	3
Other food and drink sectors	1
Leather production	0.25
Textile production	0.1
Mineral waste	15
Other sectors	4
Estimated total	1 236

Table 02-03 2: Estimates of quantities of waste recycled to land from main industrial sectors in fifteen member states (million tonnes fresh weight per annum) (derived from Gendebien et al., 2001)

The data in Table 02-03 2 exclude left over and out of date food from supermarkets, households and catering establishments as well as sewage sludge.

02-03-01a: Amounts of digestible from food residues

Figure 02-03 1 illustrates the 2007 production volumes of all commodity groups in their primary form, including animal feed products (which are then factored out using allocation factors).

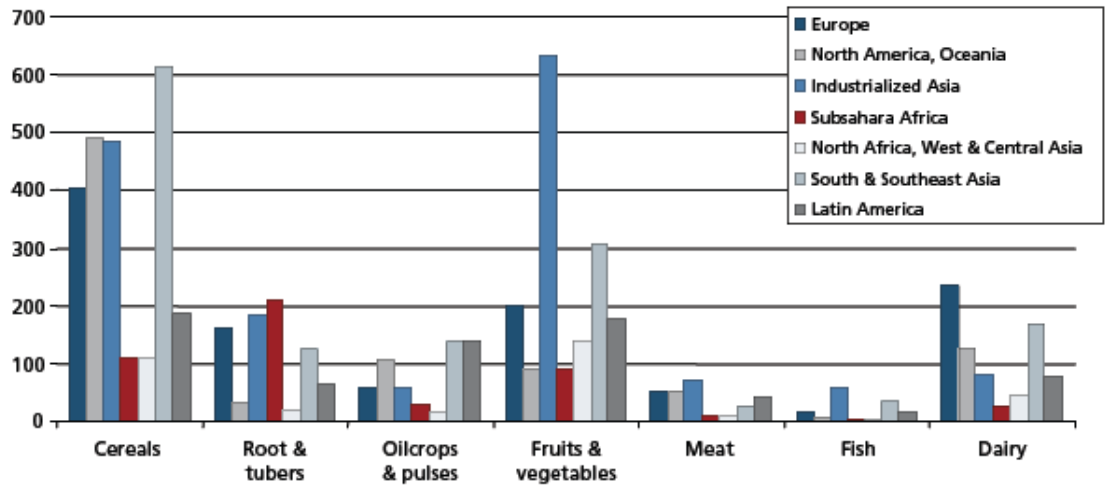

Figure 02-03 1: Production volumes of each commodity group per region (million tonnes) [4]

Roughly one-third of the edible parts of food produced for human consumption gets lost or wasted globally, which is about 1.3 billion ton per year. Food is wasted throughout the food supply chain, from initial agricultural production down to final household consumption.

In medium- and high-income countries food is to a great extent wasted, meaning that it is thrown away even if it is still suitable for human consumption. Significant food loss and waste do, however, also occur early in the food supply chain. In low-income countries food is mainly lost during the early and middle stages of the supply chain; much less food is wasted at the consumer level.

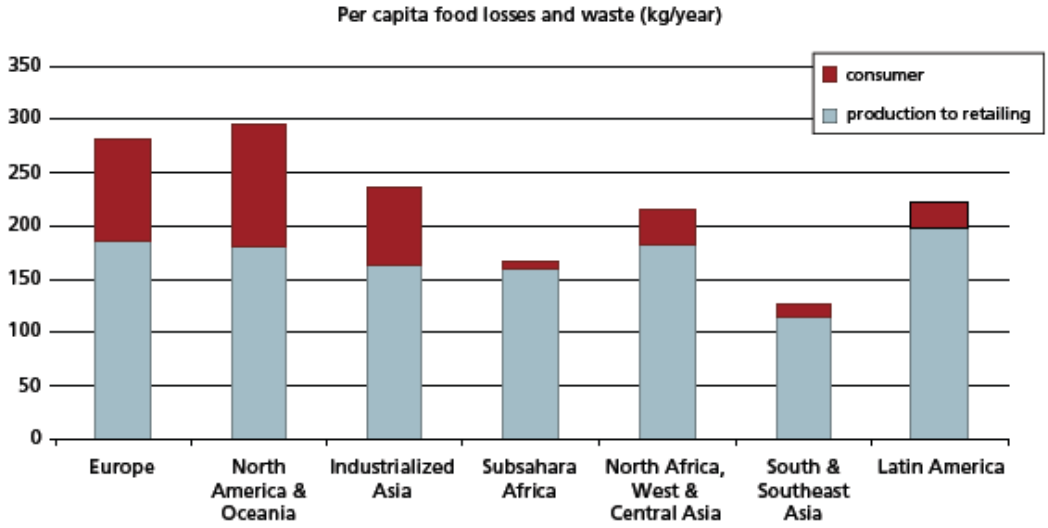

Figure 02-03 2: Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions [4]

Per capita food wasted by consumers in Europe and North-America is 95-115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year.

Food losses in industrialized countries are as high as in developing countries, but in developing countries more than 40 % of the food losses occur at post-harvest and processing levels, while in industrialized countries, more than 40 % of the food losses occur at retail and consumer levels.

In the case of cereals (Figure 02-03 3), wheat is the dominant crop supply in medium- and high-income countries, and the consumer phase is the stage with largest losses, between 40-50 % of total cereal food waste.

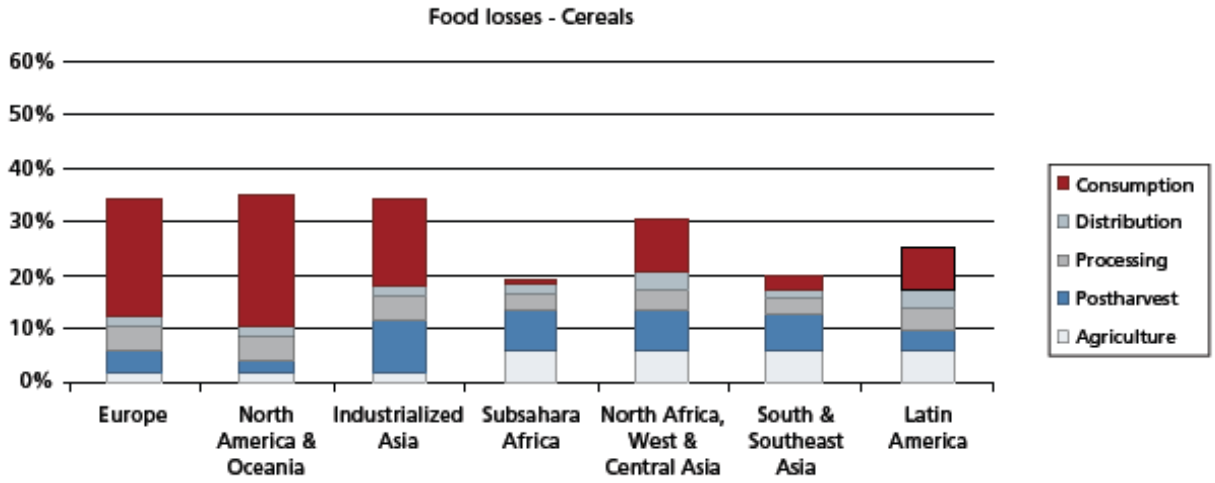

Figure 02-03 3: Part of the initial production lost or wasted, at different FSC stages, for cereals in different regions [4]

02-03-01b: Amounts of wastewater sludge from society

Sludge per capita (excluding dredging spoils) was highest in Finland, Austria and Denmark (more than 99 kg per capita) and lowest in Malta, Romania, Germany, Greece and Poland (less than 15 kg per capita) (Eurostat 2008). The percentage of population connected to wastewater collection and treatment systems varies from 29-30% in Romania and Cyprus to 90-99% in Austria, Germany, Spain, Switzerland and Netherlands (mixed reference years).

More than two thirds of the sludge was used as fertiliser in agriculture in Cyprus, Spain, Ireland and the United Kingdom, while another five member states (Lithuania, Bulgaria, Luxembourg, France and Latvia), as well as Norway, reported between one and two thirds of their total mass of sewage sludge being disposed of through agricultural uses.

In contrast, more than two thirds of sewage sludge was composted in Estonia, Finland and Slovakia.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	863 242	Estonia	72 383	Austria	847 453	Bulgaria	1 182 360
Denmark	541 749	Finland	818 011	Czech R	1 239 164	Cyprus	7 019
France	2 317 490	Latvia	95 593	Germany	2 033 096	Greece	161 732
Iceland	not available	Lithuania	57 038	Hungary	223 711	Italy	1 223 235
Ireland	154 242	Norway	101 398	Poland	401 277	Malta	173
Luxembourg	14 024	Sweden	669 486	Romania	216 883	Spain	1 945 536
Netherlands	26 870 584			Slovakia	1 164 067		
Portugal	792 182			Slovenia	607 186		
UK	19 888 143			Switzerland	not available		

Table 02-03 3: Common sludge in 2008 including dredging spoils, tons [4]

Atlantic		Boreal		Continental		Mediterranean	
Belgium	600	Estonia	6 356	Austria	1 574	Bulgaria	73
Denmark	not available	Finland	605	Czech R	2 277	Cyprus	35
France	17 080	Latvia	673	Germany	9 933	Greece	206
Iceland	18	Lithuania	543	Hungary	593	Italy	not available
Ireland	431	Norway	2 198	Poland	3 153	Malta	3
Luxembourg	270	Sweden	1 298	Romania	281	Spain	1 819
Netherlands	356			Slovakia	500		
Portugal	3 900			Slovenia	267		
UK	8 047			Switzerland	890		

Table 02-03 4: Number of urban waste water treatment plants (mixed years 2006-2009 [5]

02-03-01c: Amounts of digestible biomass from livestock

One of the largest raw material potential for biogas production comes from manure from animal (cattle, pigs, sheep, goats and horses) and poultry breeding (hens and broilers).

Animal and poultry breeding biodegradable residues are several types of manure. Manure can be classified according to the dry matter content. The type of produced manure depends on the animal type and size of the company. One of the most suitable raw materials for production of biogas is manure from animal farms. The following tables (5, 6 and 7) contain numbers of livestock in chosen countries.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	2 600 450	Estonia	237 900	Austria	1 997 210	Bulgaria	564 904
Denmark	1 540 340	Finland	918 268	Czech R	1 349 290	Cyprus	55 589
France	19 199 300	Latvia	380 200	Germany	12 944 900	Greece	620 000
Iceland	73 498	Lithuania	770 900	Hungary	701 000	Italy	6 446 700
Ireland	6 716 100	Norway	877 711	Poland	5 700 020	Malta	17 777
Luxemb.	196 470	Sweden	1 538 280	Romania	2 684 000	Spain	6 020 200
Netherl.	3 996 000			Slovakia	483 810		
Portugal	1 438 700			Slovenia	469 983		
UK	9 901 000			Switzerland	1 597 480		

Table 02-03 5: Number (head) of cattle in chosen countries, 2009 [6]

Atlantic		Boreal		Continental		Mediterranean	
Belgium	6 321 060	Estonia	364 900	Austria	3 064 230	Bulgaria	783 649
Denmark	12 369 100	Finland	1 381 210	Czech R	1 909 230	Cyprus	464 932
France	14 810 000	Latvia	383 700	Germany	26 886 500	Greece	942 000
Iceland	43 286	Lithuania	897 100	Hungary	3 383 000	Italy	9 252 400
Ireland	1 468 200	Norway	839 346	Poland	14 278 600	Malta	65 511
Luxemb.	80 217	Sweden	1 528 740	Romania	6 174 000	Spain	26 289 600
Netherl.	12 108 000			Slovakia	740 862		
Portugal	2 339 700			Slovenia	432 011		
UK	4 601 000			Switzerland	1 557 200		

Table 02-03 6: Number (head) of pigs in chosen countries, 2009 [6]

Atlantic		Boreal		Continental		Mediterranean	
Belgium	33 240	Estonia	1 757	Austria	14 500	Bulgaria	15 765
Denmark	19 224	Finland	4 918	Czech R	24 042	Cyprus	3 010
France	122 364	Latvia	3 920	Germany	118 000	Greece	31 800
Iceland	261	Lithuania	8 841	Hungary	31 165	Italy	120 000
Ireland	13 500	Norway	3 879	Poland	124 129	Malta	500
Luxemb.	97	Sweden	7 159	Romania	84 373	Spain	138 000
Netherl.	96 862			Slovakia	13 249		
Portugal	39 000			Slovenia	2 393		
UK	159 288			Switzerland	8 741		

Table 02-03 7: Number of (1000 heads) chickens in chosen countries, 2009 [6]

The gas yield (productivity) and content of volatile solids from agricultural biogas installations depends on the composition of the substrate, the technologies and conversion facilities.

	Mean production, m^3/tFM	**Mean methane content,** % by volume
Liquid manure from calves	23	55.7
Liquid manure from fatling herd	22	56.3
Liquid manure from dairy herd	20	61.9
Solid manure from cattle	21	57.1
Solid manure from pig	15	60.8
Manure from cattle	60	53.2
Manure from poultry	231	51.4

Table 02-03 8: Average data for biogas yield from different livestock [7]

The total animal waste per capita is the highest in Ireland, Austria, Belgium, Estonia and Poland (more than 40 kg per person) and lowest in Bulgaria, Romania, Italy and Germany and Greece (less than 5 kg per person), see the table below.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	498 265	Estonia	5 983	Austria	4 337	Bulgaria	9 624
Denmark	165 966	Finland	15 246	Czech Rep.	66 112	Cyprus	20 583
France	1 593 570	Latvia	35 985	Germany	333 343	Greece	40 414
Iceland	Not available	Lithuania	85 761	Hungary	230 927	Italy	93 455
Ireland	228 122	Norway	675 654	Poland	1 583 196	Malta	8 857
Luxembourg	2 263	Sweden	145 015	Romania	48 916	Spain	1 626 994
Netherlands	506 935			Slovakia	43 136		
Portugal	139 034			Slovenia	33 292		
UK	2 526 278			Switzerland	Not available		

Table 02-03 9: Animal waste from food preparation and products, 2008 (tonnes) [5]

02-03-01d: Amounts of digestible from landfilling

In the EU27, 513 kg of municipal waste was generated per person in 2009. The amount generated per person varied from 316 kg in the Czech Republic and Poland to 833 kg in Denmark.

On average in the EU27, 504 kg of municipal waste was treated per person in 2009. Municipal waste was treated in different ways: 38 % was landfilled, 20 % incinerated, 24 % recycled and 18 % composted. (Eurostat news release 2011). The highest shares of incinerated municipal waste were observed in Sweden (49 % of waste treated), Denmark (48 %), the Netherlands (39 %), Luxembourg (36 %), Belgium (35 %), Germany and France (each 34 %).

In ten member states incineration was equal to or below 1%. Also refer to section 02-04-01.

Atlantic		Boreal		Continental		Mediterranean	
Belgium	159	Estonia	287	Austria	34	Bulgaria	3 421
Denmark	130	Finland	1 180	Czech Rep.	2 114 e	Cyprus	540 e
France	10 802	Latvia	694	Germany	176	Greece	4 181
Iceland	121 s	Lithuania	1 093	Hungary	3 212	Italy	15 488
Ireland	1 724	Norway	324	Poland	7 859	Malta	255
Luxembourg	61	Sweden	63	Romania	6 164	Spain	14 540
Netherlands	65			Slovakia	1 411		
Portugal	3 342			Slovenia	628		
UK	16 020			Switzerland	0		

Table 02-03 10: Deposit of municipal waste onto or into land in 2009, thousands of tonnes [5]
Comments: - not available, (e) - estimated, p -provisional value, s - Eurostat estimate

The total amount of waste deposited into landfills per capita is smallest in Switzerland, Germany, Austria, Netherlands, Sweden and Belgium (below 20 kg/person) and highest in Malta, Cyprus, Bulgaria, Ireland, Iceland and Greece (over 350 kg/person).

02-03-02: Market development in EU [8]

Biogas production rose across the EU in 2009, driven by the EU target of meeting 20 % of final energy consumption with renewable energies and the guidelines set forth in EU Directive 2008/98/EC for the handling of waste. On the basis of these political objectives, many countries have introduced incentive programmes for the generation of power from biogas (feed-in tariffs for electricity from biogas, green certificates, tenders or grants for the use of energy crops).

Power generation from biogas grew between 2008 and 2009 by almost 18 % and accounted for a total of 25 170 gigawatt hours (GWh) in 2009.

Total energy extraction from biogas rose over the same period by 4.3 % to just above 97 TWh.

Around 52 % of the plants produced biogas from agricultural waste, while landfills and sewage treatment plants generated 36 %, or 12 % of the biogas in the EU. In 2009, the largest biogas producers in Europe were Germany, the United Kingdom, France, Italy and the Netherlands. Rapid and dynamic growth can be observed in Greece, Slovenia, Slovakia, the Czech Republic and Belgium.

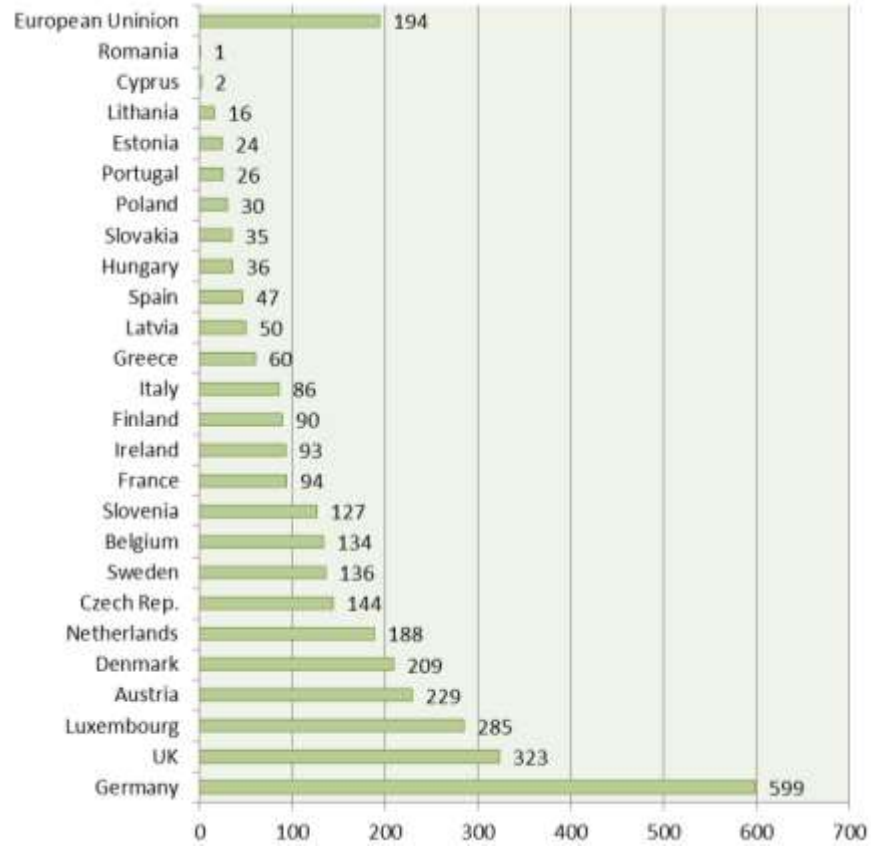

Figure 02-03 4: Primary energy production from biogas per capita in the EU in 2009 (MWh/1000 inhabitants) [9]

Data for primary energy production in the EU from landfill gas, sludge gas and other biogas is given in following tables (Table 02-03 11 and Figure 02-03 4).

State	2008 Landfill gas	2008 Sewage sludge gas[1]	2008 Other biogas[2]	2008 Total 2008	2009 – *Estimated numbers* Landfill gas	2009 Sewage sludge gas[1]	2009 Other biogas[2]	2009 Total 2009
Germany	3 392	4 474	41 323	49 189	3 088	4 497	41 417	49 002
UK	16 479	2 426	0	18 903	17 147	2 902	0	20 049
France[3]	4 411	529	329	5 270	5 144	526	450	6 120
Italy	3 952	35	782	4 768	4 208	58	901	5 167
Netherlands	516	568	1 541	2 625	456	569	2 091	3 116
Spain	1 826	229	309	2 363	1 639	116	383	2 136
Austria	56	255	1 719	2 029	57	220	1 642	1 920
Czech Rep.	342	392	314	1 047	340	392	779	1 511
Belgium	543	17	458	1 019	515	24	909	1 450
Sweden	383	655	155	1 191	401	698	171	1 270
Denmark	74	235	782	1 091	72	233	854	1 158
Poland	398	691	30	1 118	413	675	52	1 140
Greece	329	59	2	391	538	142	2	683
Finland	397	127	0	523	356	124	0	481
Ireland	301	94	16	412	274	94	48	416
Hungary	24	93	136	254	33	120	204	357
Portugal	0	0	267	267	0	0	277	277
Slovenia	95	36	31	164	97	35	128	261
Slovakia	2	110	7	120	9	172	8	190
Luxembourg	0	0	107	107	0	0	143	143
Latvia	77	26	0	102	81	31	0	113
Lithuania	5	20	10	35	15	24	14	55
Estonia	23	10	0	33	23	10	0	33
Romania	0	0	7	7	1	8	6	15
Cyprus	0	0	2	2	0	0	2	2
EU Total	**33 623**	**11 081**	**48 326**	**93 032**	**34 909**	**11 673**	**50 482**	**97 180**

Table 02-03 11: Primary biogas energy output in The EU25 in 2008 and 2009 (GWh) [9]

[1] Urban and industrial.

[2] Decentralised agricultural plant, municipal solid waste methanisation plant, and centralised co-digestion plant.

[3] French overseas departments excluded.

02-03-02a: Example: Biogas development in Asia

Production of biogas via anaerobic digestion is a relatively simple carbon-reducing technology that can be implemented at commercial, village and household scales. It allows for the controlled management of large amounts of animal dung and the safe production of gas for cooking, lighting or power generation.

In addition, as a by-product, it provides a valuable agricultural fertilizer.

Worldwide 25 million households obtain their energy for lighting and cooking from biogas, mainly 20 million households in China and 3.9 million in India.

In China, biogas is heavily promoted by the government by providing subsidies for biogas digesters. Some analysts estimate that more than 1 million biogas digesters are now being produced each year in China. Beyond the household scale, several thousand medium- and large-scale industrial biogas plants are installed at China livestock and poultry farms. This number is expected to increase following a recent national biogas action plan, under which the government aims to have 50 million rural people using biogas as their main fuel in 2010 and 300 million in 2020.

In Nepal, Vietnam, Cambodia, Laos and Bangladesh, with support from the SNV/Biogas Support Programme, more than 244 000 household biogas installations were installed between 2004 and 2008. This has benefited 1.6 million people by reducing household expenses and workload on fuel wood collection, by improving indoor health conditions and by producing high-quality organic fertilizers. In addition, reduced demand for fuel wood has a positive impact on the environment.

Dissemination of the digesters was made possible by the development of a tried and tested technology combined with a successful implementation strategy involving households, government services, non-governmental organisations, the private sector and external financing.

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