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WORKSHOP
ENERGY CROPS & BIOGAS/BIOENERGY
PATHWAYS TO SUCCESS?

Utrecht the 22nd of September 2005, The Netherlands

Predicted energy crop potentials for biogas/bioenergy worldwide - regions – EU 25

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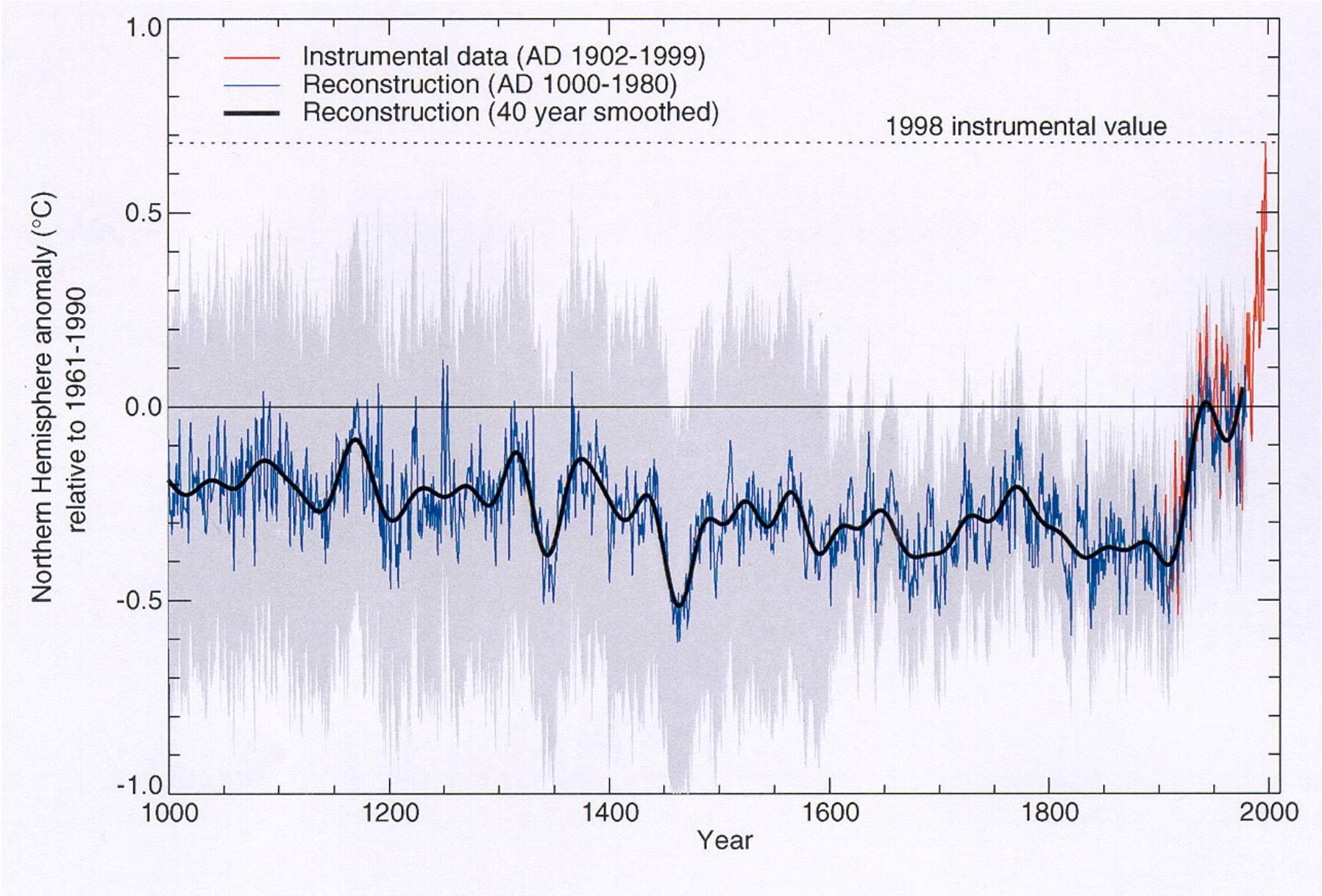
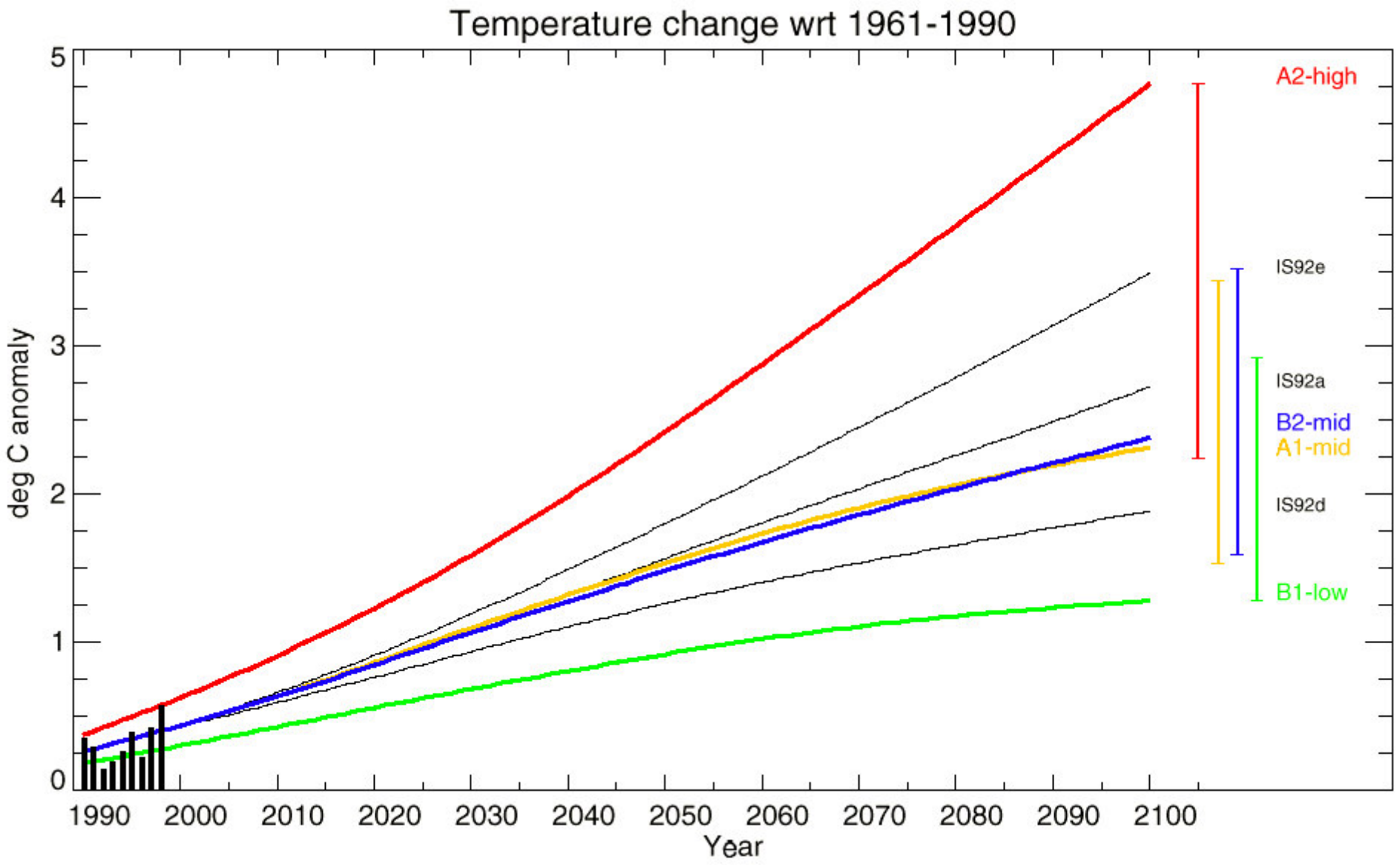
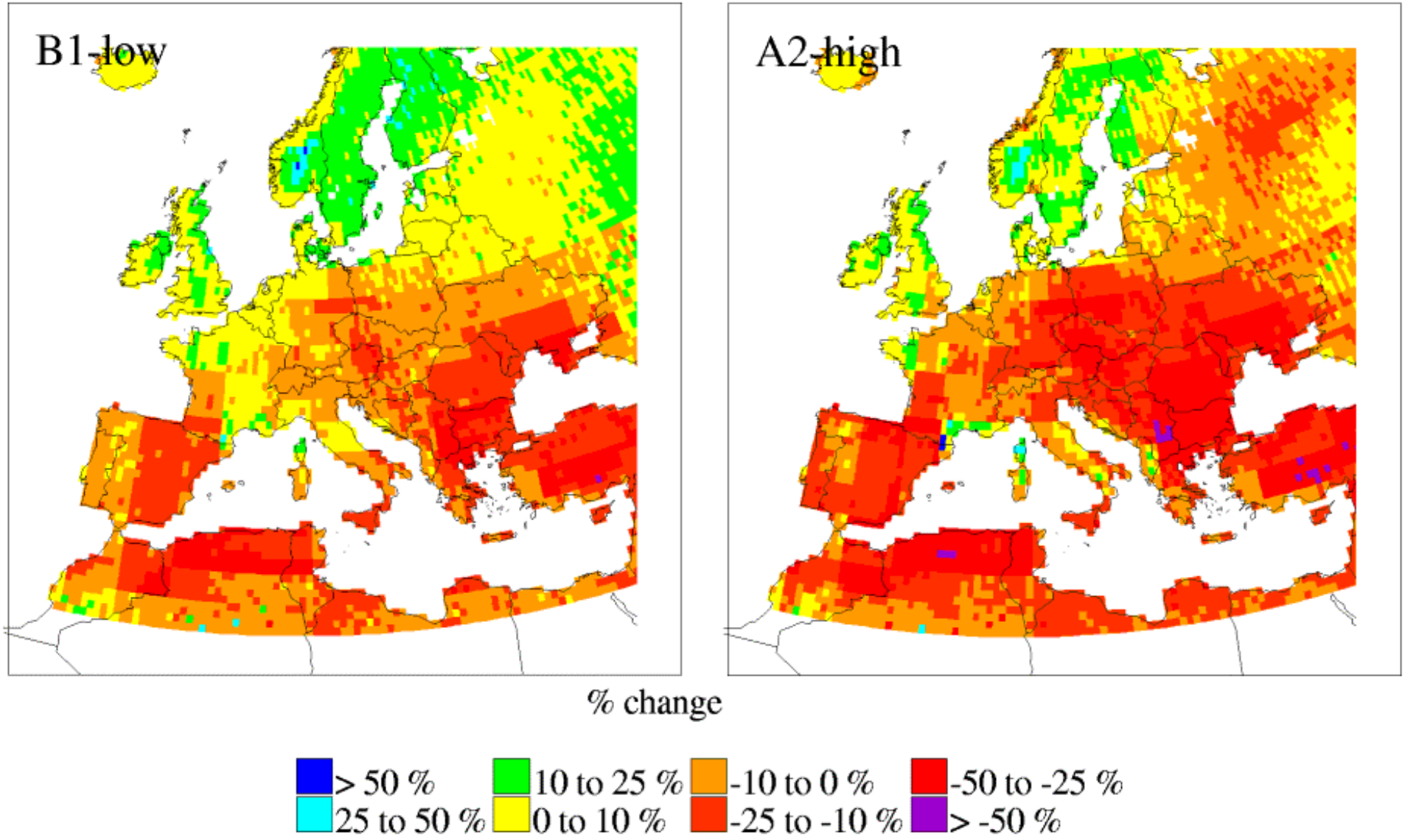
Development in global mean temperature



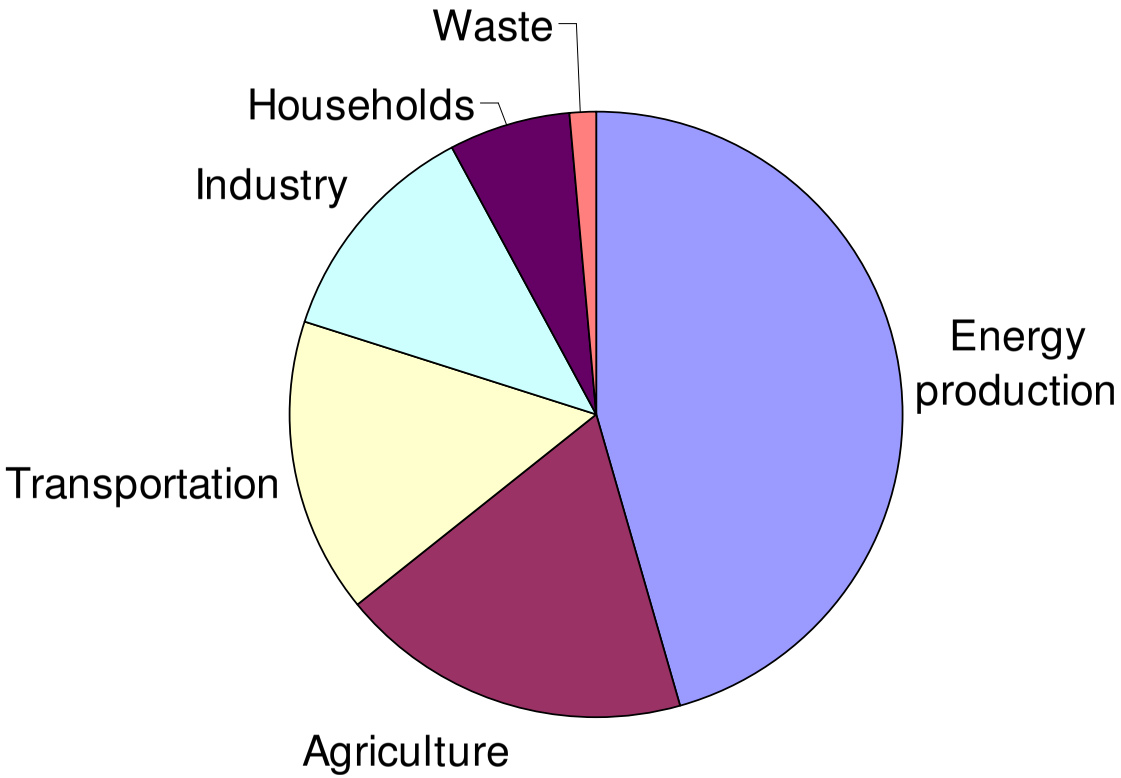
Scenarios for the global mean temperature



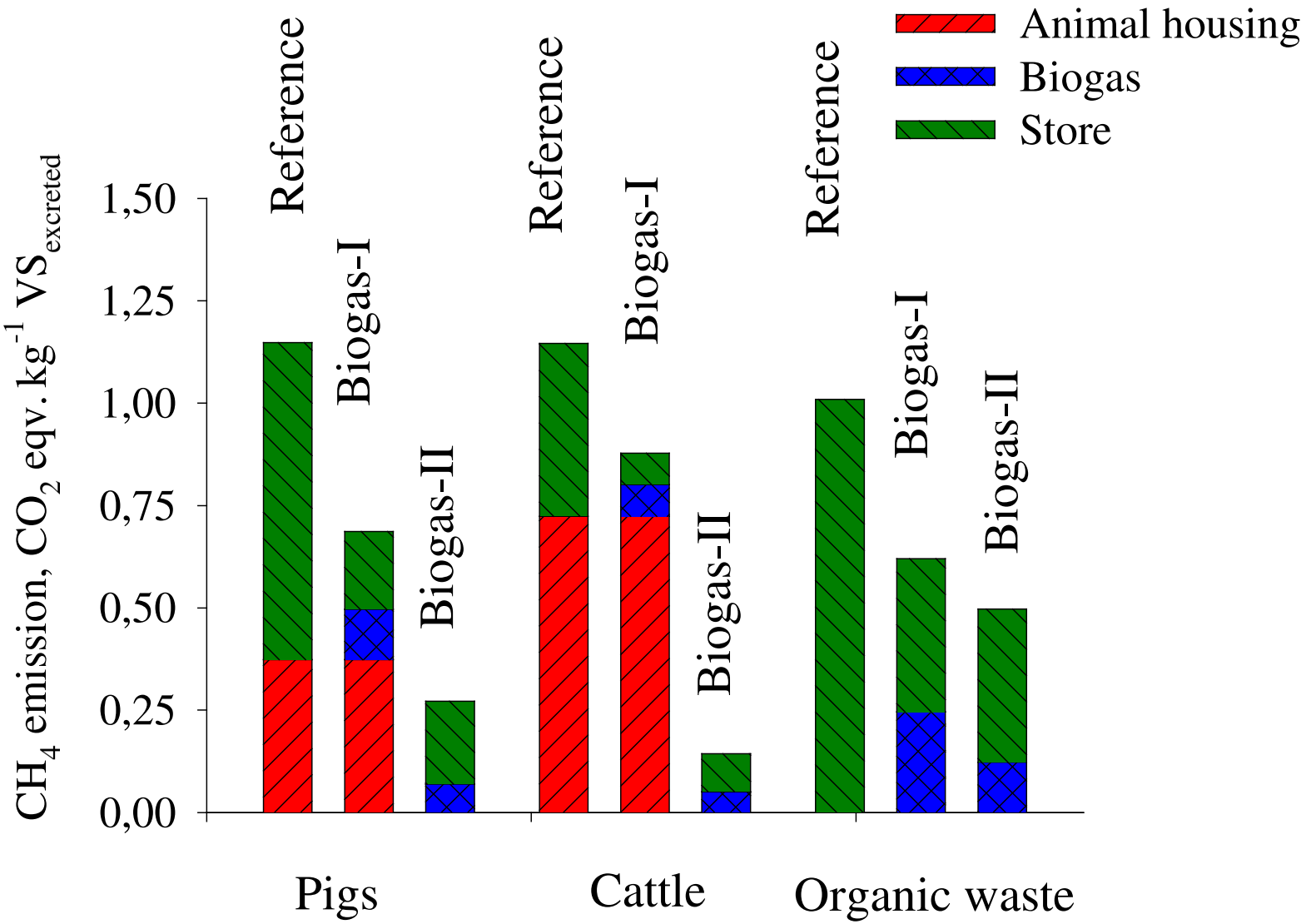
Changes in the water balance in the 2050'ties



Danish greenhouse-gas sources



Methane emission



Area usage in Denmark

Unit: 1.000 ha	**1995**	**2005**	**2025**
Arable land	2.290	2.035	1.770
Fallow	220	150	0
Non-food, single / multi-annual	30	150	300
Permanent grassland	200	325	450
Agriculture total	**2.740**	**2.660**	**2.520**
Forestry / woods	500	550	650
Fences, ditches, field roads	113	123	133
Heath, dune, bog	200	205	210
Lakes, streams	65	75	95
Buildings in rural areas	230	230	230
Cities, roads, holiday cottages	460	465	470
Total area	**4.308**	**4.308**	**4.308**

Source: The Danish Board of Technology, “Biomasse til energiformål – et strategisk oplæg”

Scenarios for the energy sector in Denmark

Unit: PJ per year	**1992 *)**	**2003 *)**	**2030 Light green scenario**	**2030 Dark green scenario**
Oil	348	342	246	0
Coal	324	176	22	0
Natural gas	95	191	146	0
Biomass	54	88	119	137
Biogas	<1	4	-	90
Liquid biofuels	-	2	-	47
Solar heating	<1	<1	4	40
PV (Solar cells)	-	-	4	25
Windpower	3	20	32	90
Net power import	13	- 31	0	0
Total	**839**	**793**	**573**	**292**

*) Figures from the Danish Energy Authority
Source: The Danish Board of Technology, “Fremtidens vedvarende energisystem”

Area usage in the EU-25

Unit: 1 000 ha Country	Total area	Agriculture area	Arable land (% of total area)		Forest (% of total area)		Permanent grass (% of total area)		Fallow
Austria	8 387	3 374	1 379	16	3 260	39	1 917	23	106
Belgium	3 053	1 393	833	27	607	20	536	18	28
Cyprus	925	137	87	9	N/A	N/A	1	<1	7
Czech Republic	7 887	3 652	2 767	35	2 643	34	839	11	83
Denmark	4 310	2 676	2 479	58	473	11	186	4	205
Estonia	4 523	698	613	14	2 251	50	67	1	25
Finland	33 815	2 236	2 204	7	22 487	66	27	<1	211
France	54 909	29 556	18 275	33	15 403	28	9 972	18	1 280
Germany	35 703	16 974	11 791	33	10 531	29	4 970	14	835
Greece	13 196	3 897	2 211	17	N/A	N/A	146	1	441
Hungary	9 303	5 867	4 516	49	1 772	19	1 063	11	195
Ireland	7 027	4 372	1 177	17	N/A	N/A	3 193	45	18
Italy	30 134	15 546	8 384	28	6 856	23	4 379	15	617
Latvia	6 459	1 596	973	15	2 862	44	610	9	94
Lithuania	6 530	2 903	1 639	25	1 997	31	1 203	18	193
Luxembourg	259	128	62	24	89	34	65	25	2
Malta	32	10	9	27	N/A	N/A	N/A	N/A	0
Netherlands	4 153	1 949	1 011	24	353	9	892	21	30
Poland	31 269	16 899	13 067	42	9 090	29	3 562	11	2 302
Portugal	9 191	3 846	1 589	17	3 465	38	1 468	16	539
Slovakia	4 903	2 236	1 377	28	2 002	41	799	16	4
Slovenia	2 027	505	168	8	1 283	63	307	15	1
Spain	50 532	25 289	13 081	26	16 493	33	7 125	14	3 195
Sweden	41 034	3 140	2 680	7	22 323	54	482	1	269
United Kingdom	24 291	16 352	6 397	26	N/A	N/A	9 906	41	33
Summary, EU-25	393 849	165 229	98 765	25	126 239	32	53 715	14	10 710

J.B. Holm-Nielsen, P.O. Popiel & M. Madsen, Department of Bioenergy, SDU, Denmark (2005)

Energy potential in biomass in the EU-25

Table 3a. Scenarios of area utilization of arable land for EU-25 in PJ

Area used for energy prod. / Yield pr. ha	10 % of arable land in EU-25	20 % of arable land in EU-25	30 % of arable land in EU-25
10 t TS pr. ha	1 778 PJ	3 556 PJ	5 333 PJ
20 t TS pr. ha	3 556 PJ	7 111 PJ	10 667 PJ
30 t TS pr. ha	5 333 PJ	10 667 PJ	16 000 PJ

* 1 PJ equals 10^{15} J

Note: The total area of the arable land in the EU-25 is assumed to be in the order of 98.765.000 ha (according to Eurostat figures 2002)

Table 3b. Scenarios of area utilization of arable land for EU-25 in MTOE

Area used for energy prod. / Yield pr. ha	10 % of arable land in EU-25	20 % of arable land in EU-25	30 % of arable land in EU-25
10 t TS pr. ha	40 MTOE	79 MTOE	119 MTOE
20 t TS pr. ha	79 MTOE	159 MTOE	238 MTOE
0 t TS pr. ha	119 MTOE	238 MTOE	357 MTOE

* MTOE: Million Ton Oil Equivalent. 1 MTOE equals 44.8 PJ

J.B. Holm-Nielsen, P.O. Popiel & M. Madsen, Department of Bioenergy, SDU, 2005

Area usage worldwide

Table 4. Total area and areas important for biomass production in the world, subdivided in continents and the most interesting countries

Unit: 1 000ha	Total area	Agriculture area	Arable land (% of total area)		Permanent crops (% of total area)		Permanent pasture (% of total area)		Forests and woodland (% of total area)	
World	13 427 880	5 012 266	1 404 130	10	136 578	1	3 471 729	26	4 172 435	31
Africa	3 030 974	1 110 974	184 905	6	25 792	1	900 448	30	712 676	24
Algeria	238 174	40 065	7 665	3	600	0	31 800	13	3 950	2
Cameroon	47 544	9 160	5 960	13	1 200	3	2 000	4	35 900	76
Ethiopia	110 430	30 671	9 936	9	735	1	20 000	18	13 300	12
Morocco	44 655	30 283	8 396	19	887	2	21 000	47	8 970	20
Nigeria	92 337	72 200	30 200	33	2 800	3	39 200	42	14 300	15
South Africa	121 909	99 640	14 753	12	959	1	83 928	69	8 200	7
Sudan	250 581	133 833	16 233	6	420	0	117 180	47	42 000	17
Asia	3 186 692	1 683 886	511 701	16	61 686	2	1 110 499	35	556 747	17
China	959 805	553 957	142 621	15	11 335	1	400 001	42	130 518	14
India	328 726	181 177	161 715	49	8 400	3	11 062	3	68 500	21
Indonesia	190 457	44 877	20 500	11	13 200	7	11 177	6	111 774	59
Japan	37 789	5 190	4 418	12	344	1	428	1	24 621	65
Kazakhstan	272 490	206 769	21 535	8	136	0	185 098	68	9 600	4
Pakistan	79 610	27 120	21 448	27	672	1	5 000	6	3 480	4
Thailand	51 312	20 167	15 867	31	3 500	7	800	2	14 500	28
Turkey	77 482	41 690	25 938	33	2 585	3	13 167	17	20 199	26

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Data from 2002 (forests and woodland – 1994)

Area usage worldwide

Table 4. Total area and areas important for biomass production in the world, subdivided in continents and the most interesting countries

Unit: 1 000ha	Total area	Agriculture area	Arable land (% of total area)		Permanent crops (% of total area)		Permanent pasture (% of total area)		Forests and woodland (% of total area)	
Europe	2 297 649	486 858	287 221	13	16 772	1	182 865	8	947 276	41
Belarus	20 760	8 924	5 606	27	124	1	3 194	15	7 200	35
Bulgaria	11 099	5 325	3 355	30	228	2	1 742	16	3 348	30
Romania	23 839	14 837	9 398	39	501	2	4 938	21	6 680	28
Russia	1 707 540	216 651	123 465	7	1 835	0	91 351	5	765 912	45
Serbia & Mont.	10 217	5 586	3 397	33	327	3	1 862	18	1 769	17
Ukraine	60 370	41 396	32 544	54	913	2	7 939	13	9 239	15
North& Central America	2 272 494	621 403	257 273	11	15 094	1	349 036	15	823 914	36
Canada	997 061	67 505	45 660	5	6 455	1	15 390	2	453 330	45
Cuba	11 086	6 655	2 668	24	1 120	10	2 867	26	2 608	24
Mexico	195 820	107 300	24 800	13	2 500	1	80 000	41	48 700	25
Nicaragua	13 000	6 976	1 925	15	236	2	4 815	37	3 200	25
USA	962 909	411 863	176 018	18	2 050	0	233 795	24	295 990	31
South America	1 783 361	642 482	112 642	6	13 952	1	515 888	29	931 570	52
Argentina	278 040	177 000	33 700	12	1 300	0	142 000	51	50 900	18
Bolivia	109 858	36 937	2 900	3	206	0	33 831	31	58 000	53
Brazil	851 488	263 580	58 980	7	7 600	1	197 000	23	555 000	65
Paraguay	40 675	24 815	3 020	7	95	0	21 700	53	12 850	32
Peru	128 522	31 410	3 700	3	610	0	27 100	21	84 800	66
Oceania	856 440	466 663	50 388	6	3 282	0	412 993	48	200 252	23
Australia	774 122	447 000	48 300	6	300	0	398 400	51	145 000	19
New Zealand	27 053	17 235	1 500	6	1 872	7	13 863	51	7 667	28

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Data from 2002 (forests and woodland – 1994)

Energy potential in biomass in worldwide

Table 4a. Scenarios of area utilization of arable land at the world and particular continents for energy crop production expressed in PJ

	Area used for energy production / Yield pr. ha	10% of arable land	20% of arable land	30% of arable land
World	10 tTS/ha	25 274 PJ	50 549 PJ	75 823 PJ
	20 tTS/ha	50 549 PJ	101 097 PJ	151 646 PJ
	30 tTS/ha	75 823 PJ	151 646 PJ	227 469 PJ
Africa	10 tTS/ha	3 328 PJ	6 657 PJ	9 985 PJ
	20 tTS/ha	6 657 PJ	13 313 PJ	19 970 PJ
	30 tTS/ha	9 985 PJ	19 970 PJ	29 955 PJ
Asia	10 tTS/ha	9 211 PJ	18 421 PJ	27 632 PJ
	20 tTS/ha	18 421 PJ	36 842 PJ	55 264 PJ
	30 tTS/ha	27 632 PJ	55 264 PJ	82 896 PJ
Europe	10 tTS/ha	5 170 PJ	10 340 PJ	15 510 PJ
	20 tTS/ha	10 340 PJ	20 680 PJ	31 020 PJ
	30 tTS/ha	15 510 PJ	31 020 PJ	46 530 PJ
North & Central America	10 tTS/ha	4 631 PJ	9 262 PJ	13 893 PJ
	20 tTS/ha	9 262 PJ	18 524 PJ	27 785 PJ
	30 tTS/ha	13 893 PJ	27 785 PJ	41 678 PJ
South America	10 tTS/ha	2 028 PJ	4 055 PJ	6 083 PJ
	20 tTS/ha	4 055 PJ	8 110 PJ	12 165 PJ
	30 tTS/ha	6 083 PJ	12 165 PJ	18 248 PJ
Oceania	10 tTS/ha	907 PJ	1 814 PJ	2 721 PJ
	20 tTS/ha	1 814 PJ	3 628 PJ	5 442 PJ
	30 tTS/ha	2 721 PJ	5 442 PJ	8 163 PJ

Lower combustion energy value is 18 MJ per kg TS; 1 PJ equals 10^{15} J

Energy potential in biomass in worldwide

Table 4b. Scenarios of area utilization of arable land at the world and particular continents for energy crop production expressed in MTOE

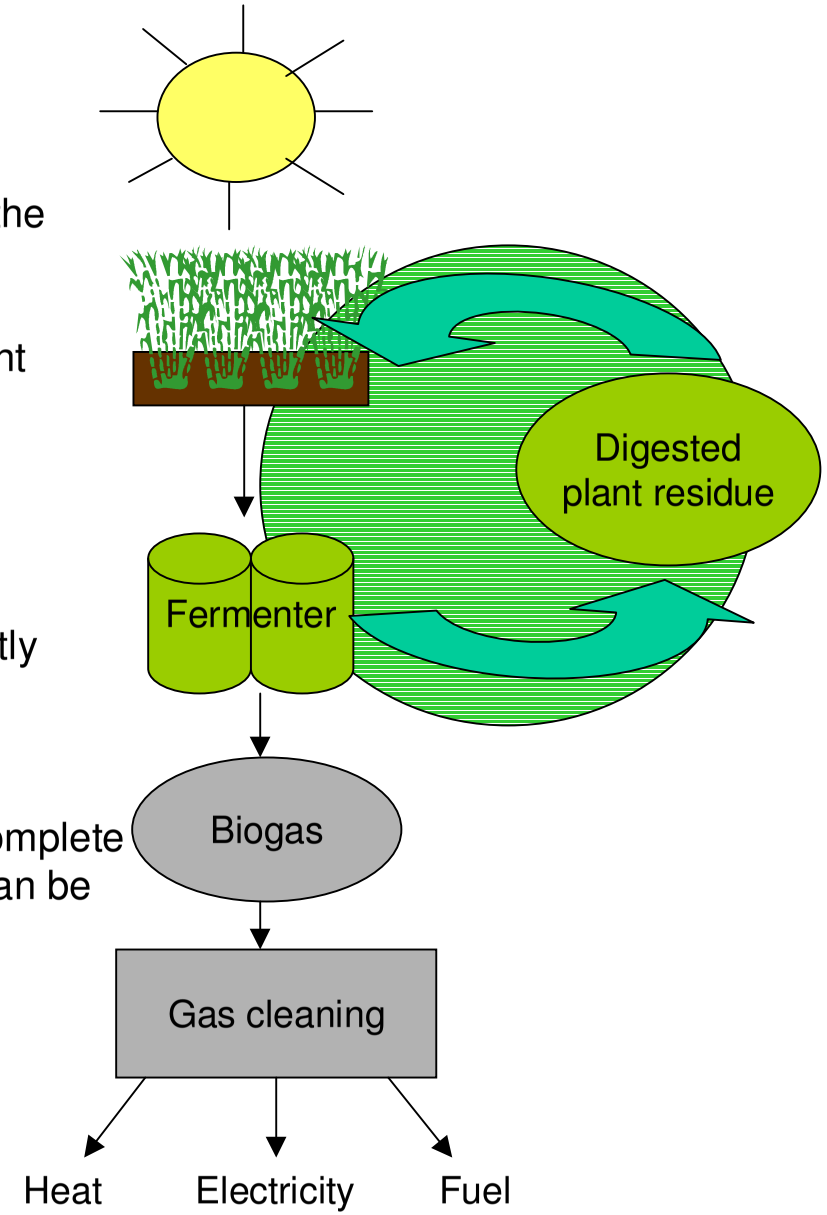
	Area used for energy production Yield pr. ha	10% of arable land	20% of arable land	30% of arable land
World	10 tTS/ha	564 MTOE	1 128 MTOE	1 693 MTOE
	20 tTS/ha	1 128 MTOE	2 257 MTOE	3 385 MTOE
	30 tTS/ha	1 693 MTOE	3 385 MTOE	5 077 MTOE
Africa	10 tTS/ha	74 MTOE	147 MTOE	223 MTOE
	20 tTS/ha	149 MTOE	297 MTOE	446 MTOE
	30 tTS/ha	223 MTOE	446 MTOE	669 MTOE
Asia	10 tTS/ha	206 MTOE	411 MTOE	617 MTOE
	20 tTS/ha	411 MTOE	822 MTOE	1 234 MTOE
	30 tTS/ha	619 MTOE	1 234 MTOE	1 850 MTOE
Europe	10 tTS/ha	115 MTOE	231 MTOE	346 MTOE
	20 tTS/ha	231 MTOE	462 MTOE	692 MTOE
	30 tTS/ha	346 MTOE	692 MTOE	1 039 MTOE
North & Central America	10 tTS/ha	103 MTOE	207 MTOE	310 MTOE
	20 tTS/ha	207 MTOE	414 MTOE	620 MTOE
	30 tTS/ha	310 MTOE	620 MTOE	930 MTOE
South America	10 tTS/ha	45 MTOE	91 MTOE	136 MTOE
	20 tTS/ha	91 MTOE	181 MTOE	272 MTOE
	30 tTS/ha	136MTOE	272 MTOE	407 MTOE
Oceania	10 tTS/ha	20 MTOE	41 MTOE	61 MTOE
	20 tTS/ha	41 MTOE	81 MTOE	122 MTOE
	30 tTS/ha	61 MTOE	122 MTOE	182 MTOE

TOE: 1 ton oil equivalent ~ 44.8 PJ

J.B. Holm-Nielsen, P.O. Popiel & M. Madsen, Department of Bioenergy, SDU, Denmark (2005)

Energy crops → Paradigm shift through land productivity and energy balance

- The Sun as energy source
- Special energy crops that use the entire vegetation period
- Total digestion of the whole plant
- Nutrient cycle possible
  Low Input → High Output
- Large installations work efficiently and are friendly towards the environment
- Upgrading of biogas enables complete utilisation of the crop (the gas can be stored)



Source: KWS

Requirement specification of energy crop cultivation

Maximum efficiency of the photosynthesis:

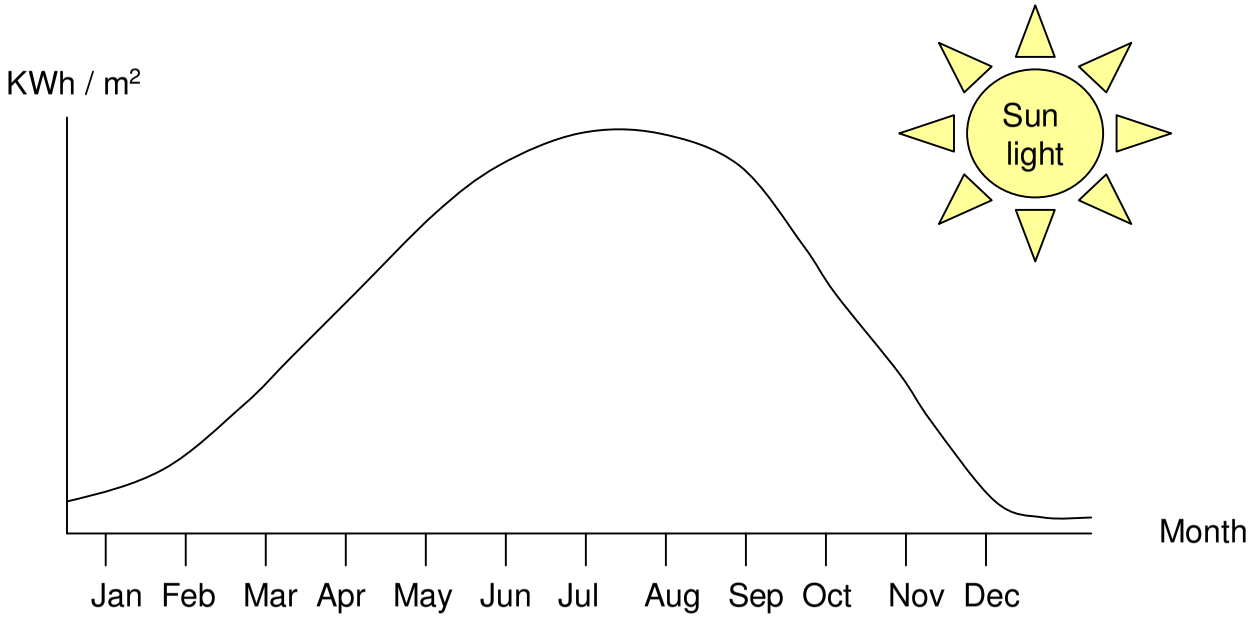
- using adjusted crop varieties
- in suitable crop rotations
- under different habitat conditions
- with optimal Input-Output-balances
- and with positive environmental impact

Source: KWS

Optimisation of the biomass production

Vegetation period

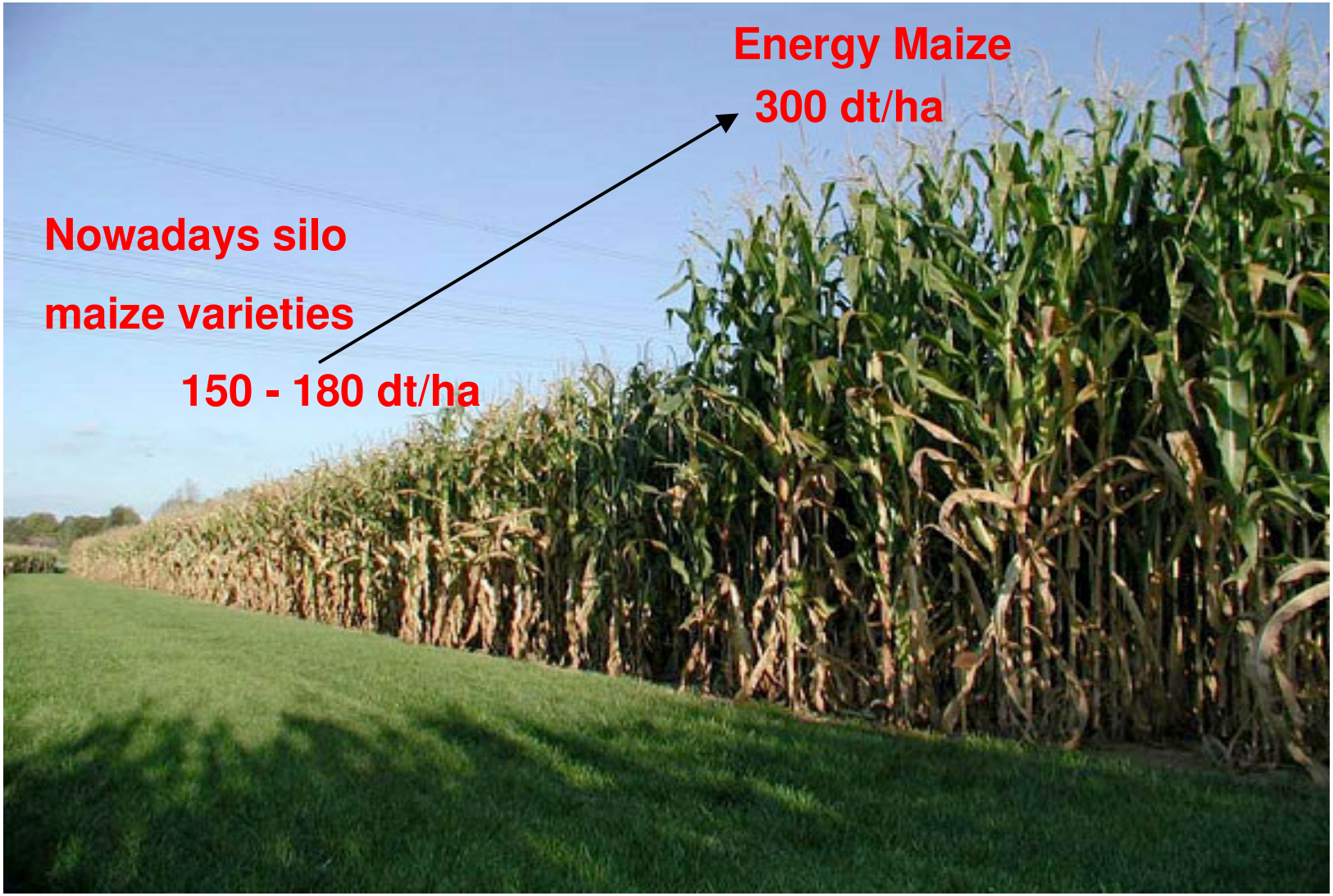
Average intensity of the sun radiation during the year
(Simplified model for Göttingen, Germany)



The global sun radiation reaches an average of approximately 1000 KWh/m^2 in the southern of Niedersachsen, Germany.
This energy is used by green plants in the photosynthesis to create biomass.
At the end of Juli in modern agriculture most of the fields are no longer green.There are no longer active parts available to conduct the photosynthesis.
Demand: In order to take full advantage of the energy contained in the sun radiation using photosynthesis, varieties that are utilising the vegetation period to its maximum should be developed and used. This means green fields all year round.

Source: KWS

Cultivation target:
Stepwise increase of the energy yield to approximately 100 % in 10 years



Source:
KWS

Objective of the energy maize cultivation

- Implementaion of short-day genes
- Cold tolerance in late varieties and late growing season
- Nutrient / water efficiency / drought resistance

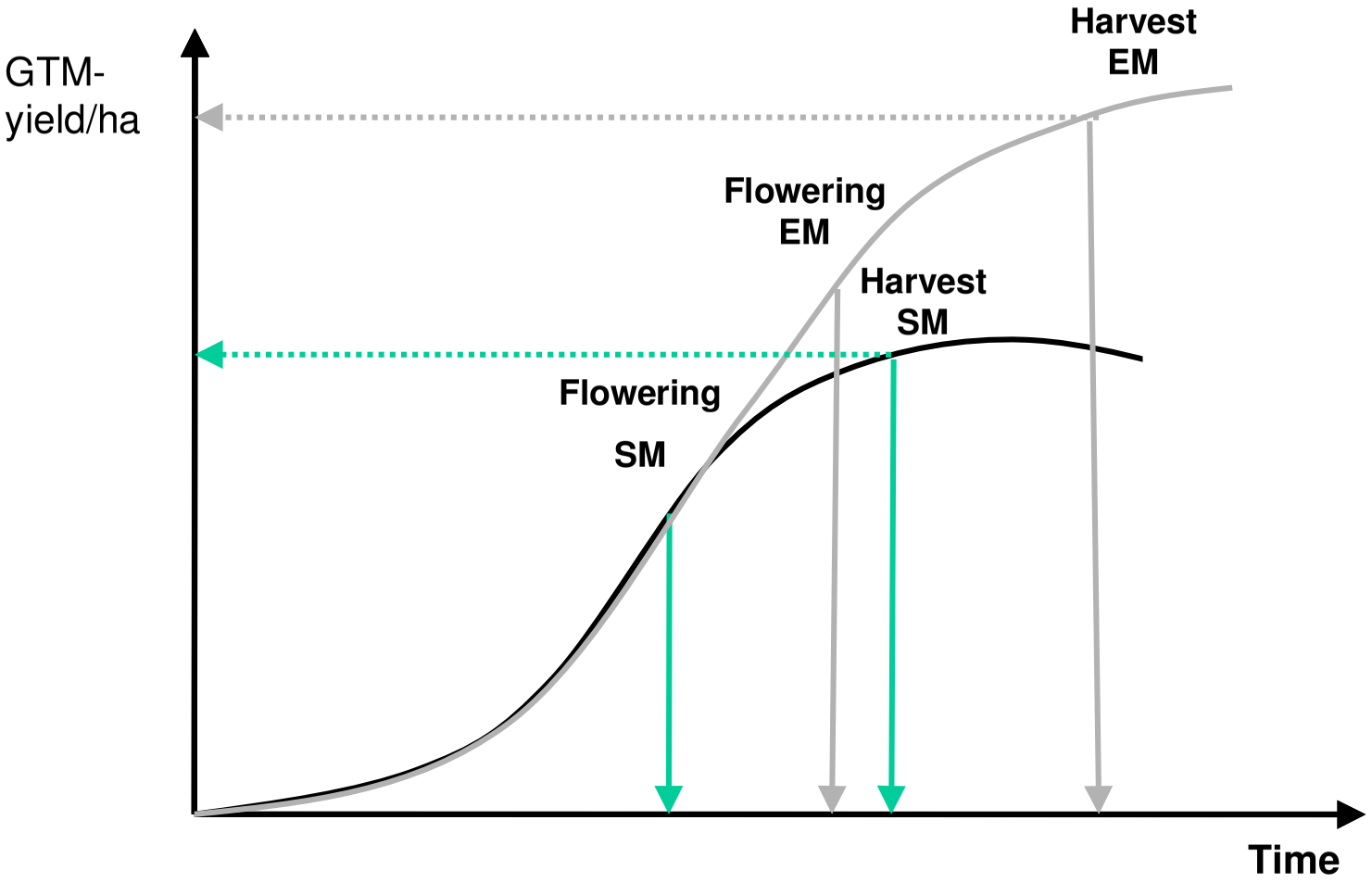
First variety announcement in 2005

Commerciel varieties available from 2007

Source: KWS

Growth Progress of a Conventional Silo Maize (SM) and an Energy Maize (EM)

Clearly later harvest of the Energy Maize

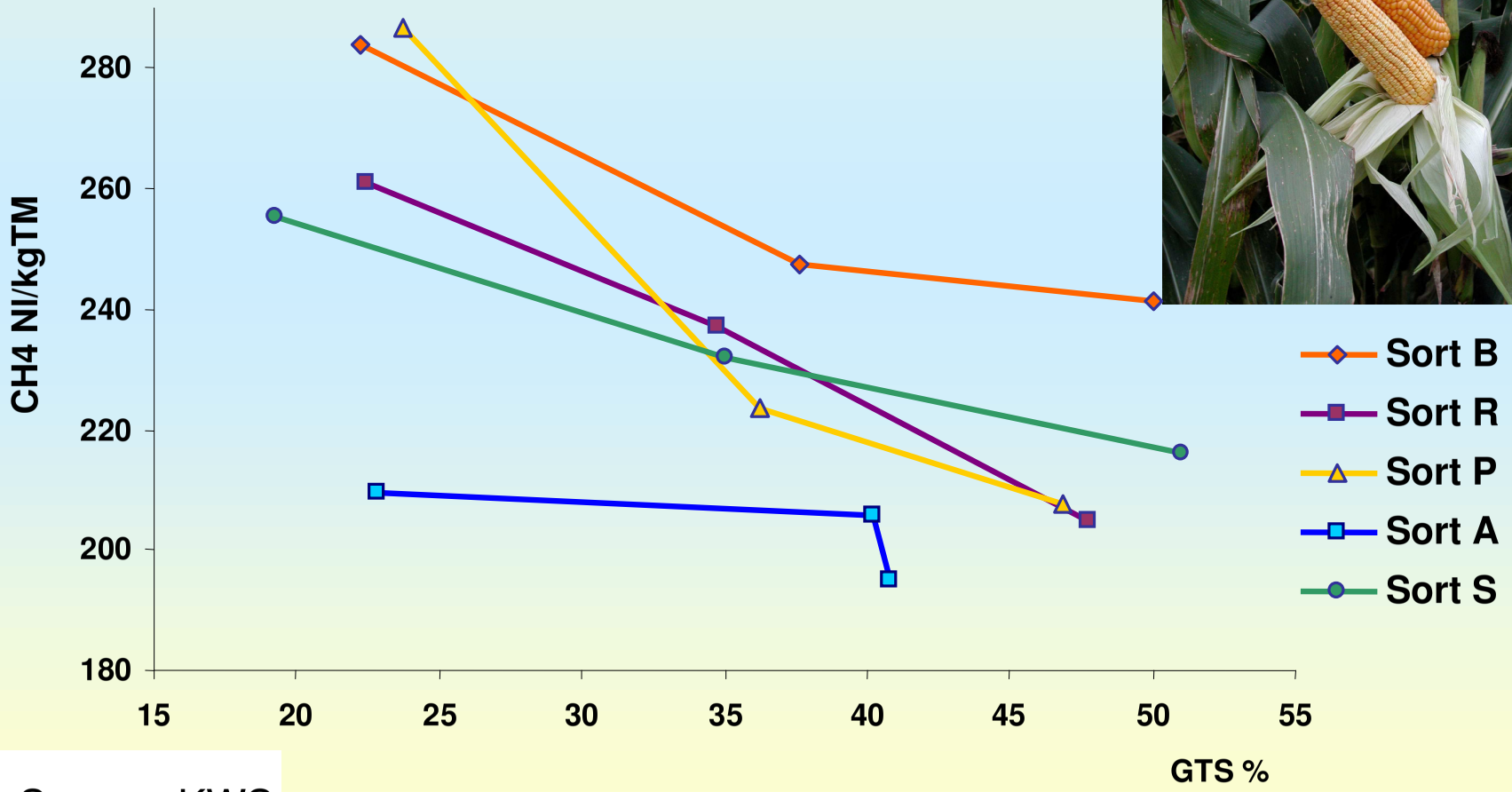


Source: KWS

Perspectives for crop cultivation

Effect of the variety and the ripeness on the methane production

Source: AMON et. al. 2003



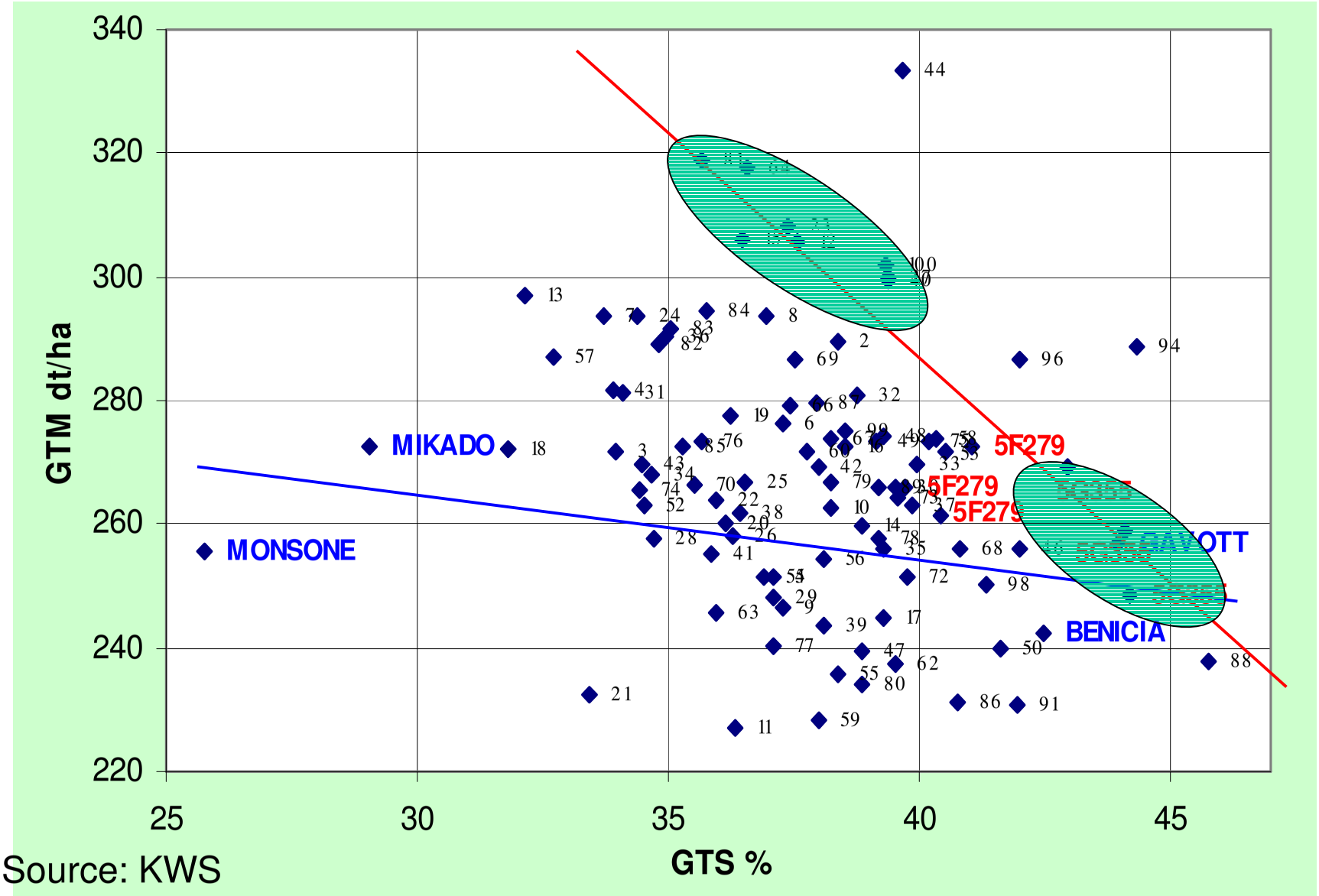
Source: KWS

Different degrees of tolerance towards dry climates between a South French and a Hungarian hybride in the facility Demo Nördlingen 2003

Source: KWS

LP92_ Wesel

90 BC1S1-lines from (5G355² x Mex) x Flinttester + 10 Standards



Source: KWS

Harvest of energy maize

Source: KWS

Source: R. Braun, IFA, Austria

Source: R. Braun, IFA, Austria

Source: R. Braun, IFA, Austria

Biogas and slurry separation

Digestate

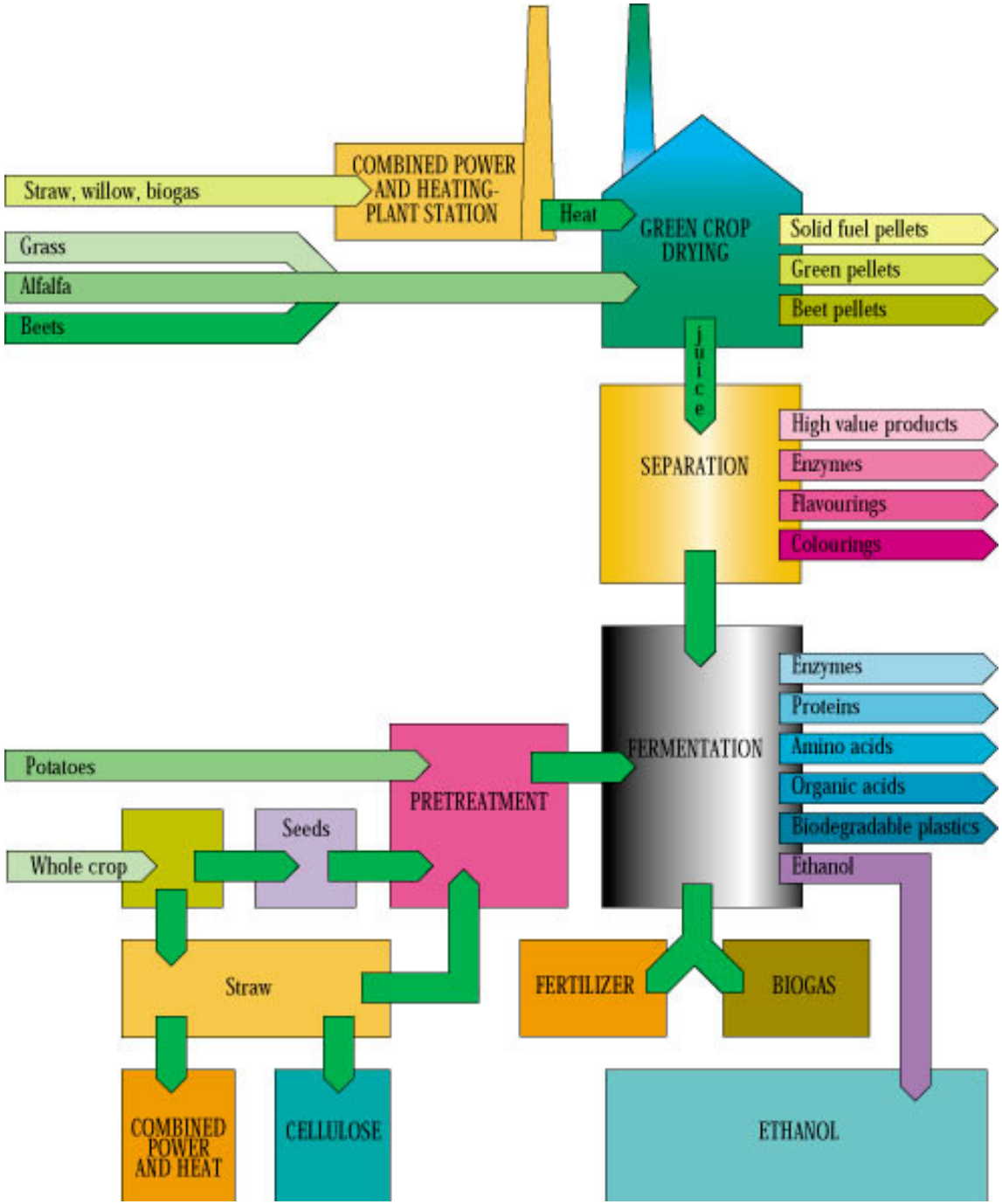
Fibre fraction ← Decanter → Liquid fraction

70 % of total P
25 % of total N, organic compounds
15 % of initial volume

75 % of total N, mainly as ammonia

No market fibre fraction. Costs of drying (50 eur/T) exceed nutrient value of fibres.
Heavy metals content could be a problem; removal expensive.
Incineration seen like the only alternative; Documentation and approvals needed.

Source: Teodorita Al Seadi, SDU


Straw, willow, biogas
COMBINED POWER AND HEATING-PLANT STATION
Heat
GREEN CROP DRYING
Solid fuel pellets
Green pellets
Beet pellets
Grass
Alfalfa
Beets
juice
SEPARATION
High value products
Enzymes
Flavourings
Colourings
FERMENTATION
Enzymes
Proteins
Amino acids
Organic acids
Biodegradable plastics
Ethanol
Potatoes
PRETREATMENT
Seeds
Whole crop
Straw
FERTILIZER
BIOGAS
COMBINED POWER AND HEAT
CELLULOSE
ETHANOL

Summary and Conclusion

Biorefineries are thoroughly integrated thinking and conversion of biomasses of any kind for new products for industrial and energy use

Technologies for conversion of biomass for food, feed, fuels, fibers and fertilisers is going to be realized and implemented at increasingly speed in this and the next decade.

A full paradigm shift is well under way from fossil fuel dependencies towards biomass and accompanying renewable energy resource based economies.

The world is getting greener and more sustainable by peoples will, urgent needs of new energy sources and environmental commitment.

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