CHIMICA AMBIENTALE

CdL triennale in
Scienze e Tecnologie per l’Ambiente e la Natura

Cdl in Chimica

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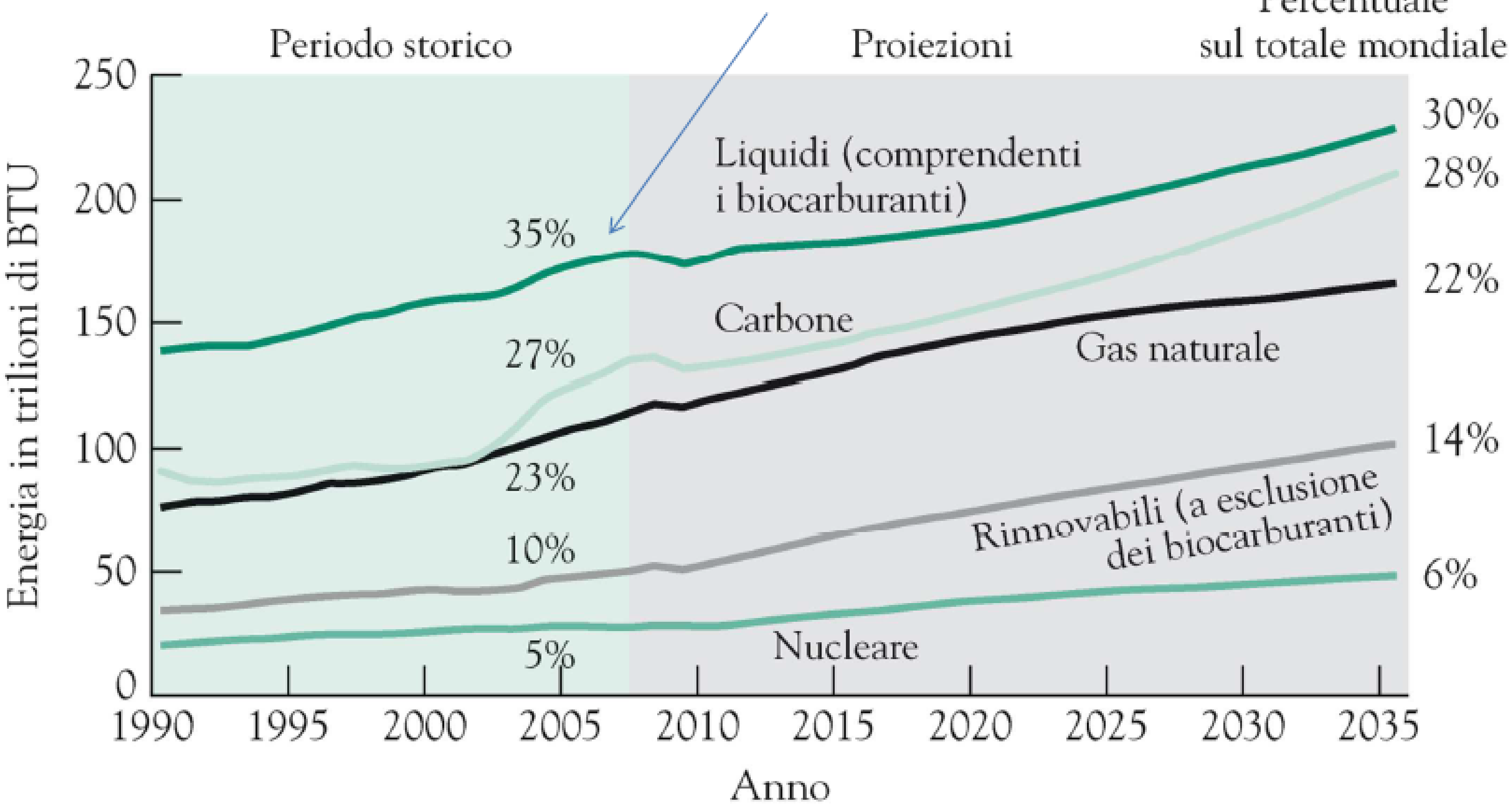
SSD Chimica dell’ambiente e dei beni culturali, CHIM/12

Fonti di energia



Il British thermal unit (BTU o Btu) è un'unità di misura dell'energia, usata negli Stati Uniti e nel Regno Unito (dove è generalmente usata nei sistemi di riscaldamento). La corrispondente unità di misura utilizzata nel Sistema Internazionale è, invece, il joule (J). Una BTU è definita dalla quantità di calore richiesta per alzare la temperatura di 1 libbra (ovvero 453,59237 grammi) di acqua da 39 °F a 40 °F (3.8 °C a 4.4 °C).

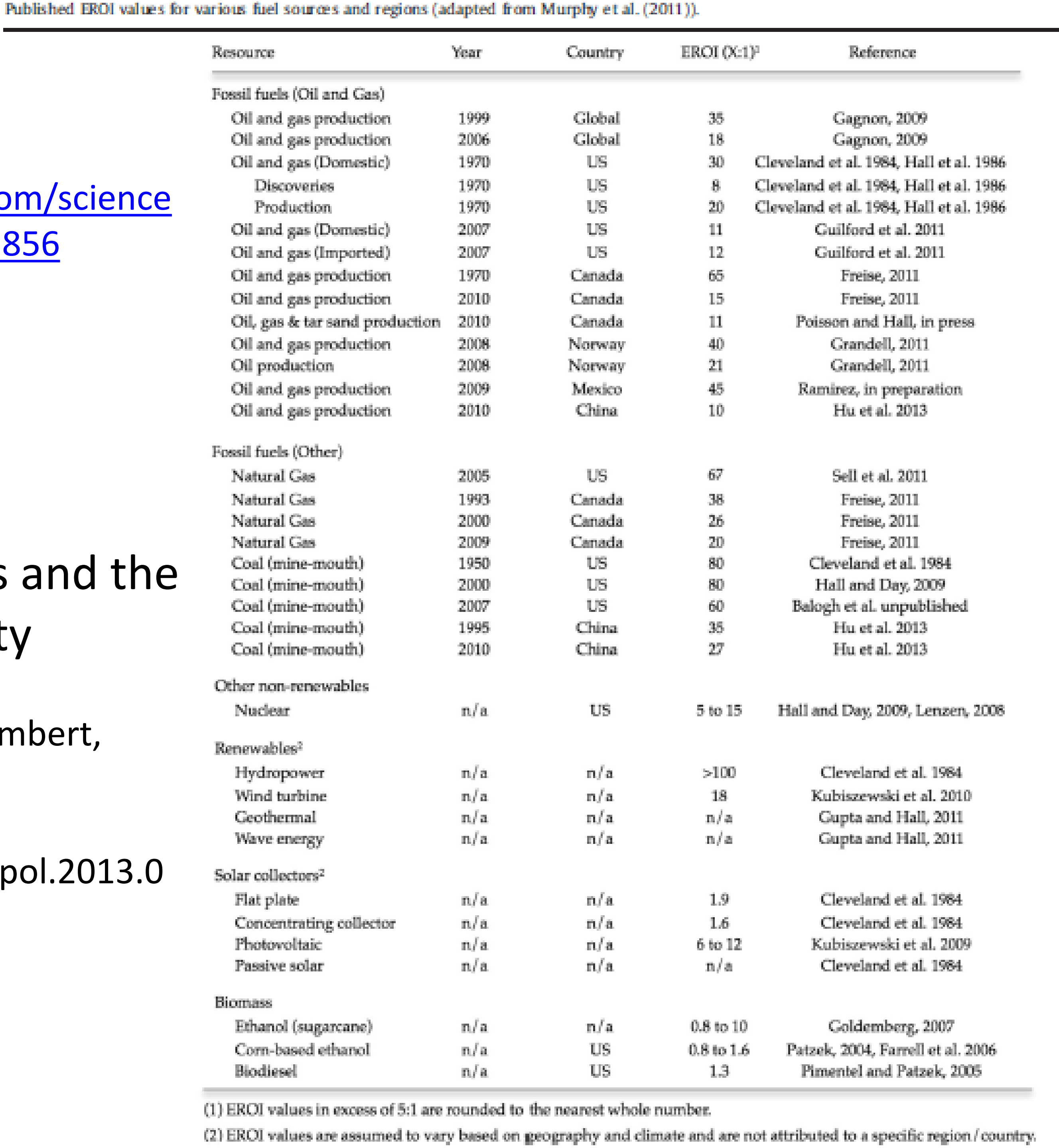
https://www.sciencedirect.com/science/article/pii/S0301421513003856

Energy Policy
Volume 64, January 2014,
Pages 141-152

EROI of different fuels and the implications for society

Charles A.S.Hall, Jessica G.Lambert,
Stephen B.Balogh

https://doi.org/10.1016/j.enpol.2013.05.049



Published EROI values for various fuel sources and regions (adapted from Murphy et al. (2011)).

Resource	Year	Country	EROI (X:1)¹	Reference
Fossil fuels (Oil and Gas)				
Oil and gas production	1999	Global	35	Gagnon, 2009
Oil and gas production	2006	Global	18	Gagnon, 2009
Oil and gas (Domestic)	1970	US	30	Cleveland et al. 1984, Hall et al. 1986
Discoveries	1970	US	8	Cleveland et al. 1984, Hall et al. 1986
Production	1970	US	20	Cleveland et al. 1984, Hall et al. 1986
Oil and gas (Domestic)	2007	US	11	Guilford et al. 2011
Oil and gas (Imported)	2007	US	12	Guilford et al. 2011
Oil and gas production	1970	Canada	65	Freise, 2011
Oil and gas production	2010	Canada	15	Freise, 2011
Oil, gas & tar sand production	2010	Canada	11	Poisson and Hall, in press
Oil and gas production	2008	Norway	40	Grandell, 2011
Oil production	2008	Norway	21	Grandell, 2011
Oil and gas production	2009	Mexico	45	Ramirez, in preparation
Oil and gas production	2010	China	10	Hu et al. 2013
Fossil fuels (Other)				
Natural Gas	2005	US	67	Sell et al. 2011
Natural Gas	1993	Canada	38	Freise, 2011
Natural Gas	2000	Canada	26	Freise, 2011
Natural Gas	2009	Canada	20	Freise, 2011
Coal (mine-mouth)	1950	US	80	Cleveland et al. 1984
Coal (mine-mouth)	2000	US	80	Hall and Day, 2009
Coal (mine-mouth)	2007	US	60	Balogh et al. unpublished
Coal (mine-mouth)	1995	China	35	Hu et al. 2013
Coal (mine-mouth)	2010	China	27	Hu et al. 2013
Other non-renewables				
Nuclear	n/a	US	5 to 15	Hall and Day, 2009, Lenzen, 2008
Renewables²				
Hydropower	n/a	n/a	>100	Cleveland et al. 1984
Wind turbine	n/a	n/a	18	Kubiszewski et al. 2010
Geothermal	n/a	n/a	n/a	Gupta and Hall, 2011
Wave energy	n/a	n/a	n/a	Gupta and Hall, 2011
Solar collectors²				
Flat plate	n/a	n/a	1.9	Cleveland et al. 1984
Concentrating collector	n/a	n/a	1.6	Cleveland et al. 1984
Photovoltaic	n/a	n/a	6 to 12	Kubiszewski et al. 2009
Passive solar	n/a	n/a	n/a	Cleveland et al. 1984
Biomass				
Ethanol (sugarcane)	n/a	n/a	0.8 to 10	Goldemberg, 2007
Corn-based ethanol	n/a	US	0.8 to 1.6	Patzek, 2004, Farrell et al. 2006
Biodiesel	n/a	US	1.3	Pimentel and Patzek, 2005

(1) EROI values in excess of 5:1 are rounded to the nearest whole number.

(2) EROI values are assumed to vary based on geography and climate and are not attributed to a specific region/country.

https://www.qualenergia.it/wp-content/uploads/attachments/King%20and%20van%20den%20Bergh%20-%20Implications%20of%20net%20EROI%20for%20low-carbon%20transition%20-%20Nature%20Energy%202018.pdf

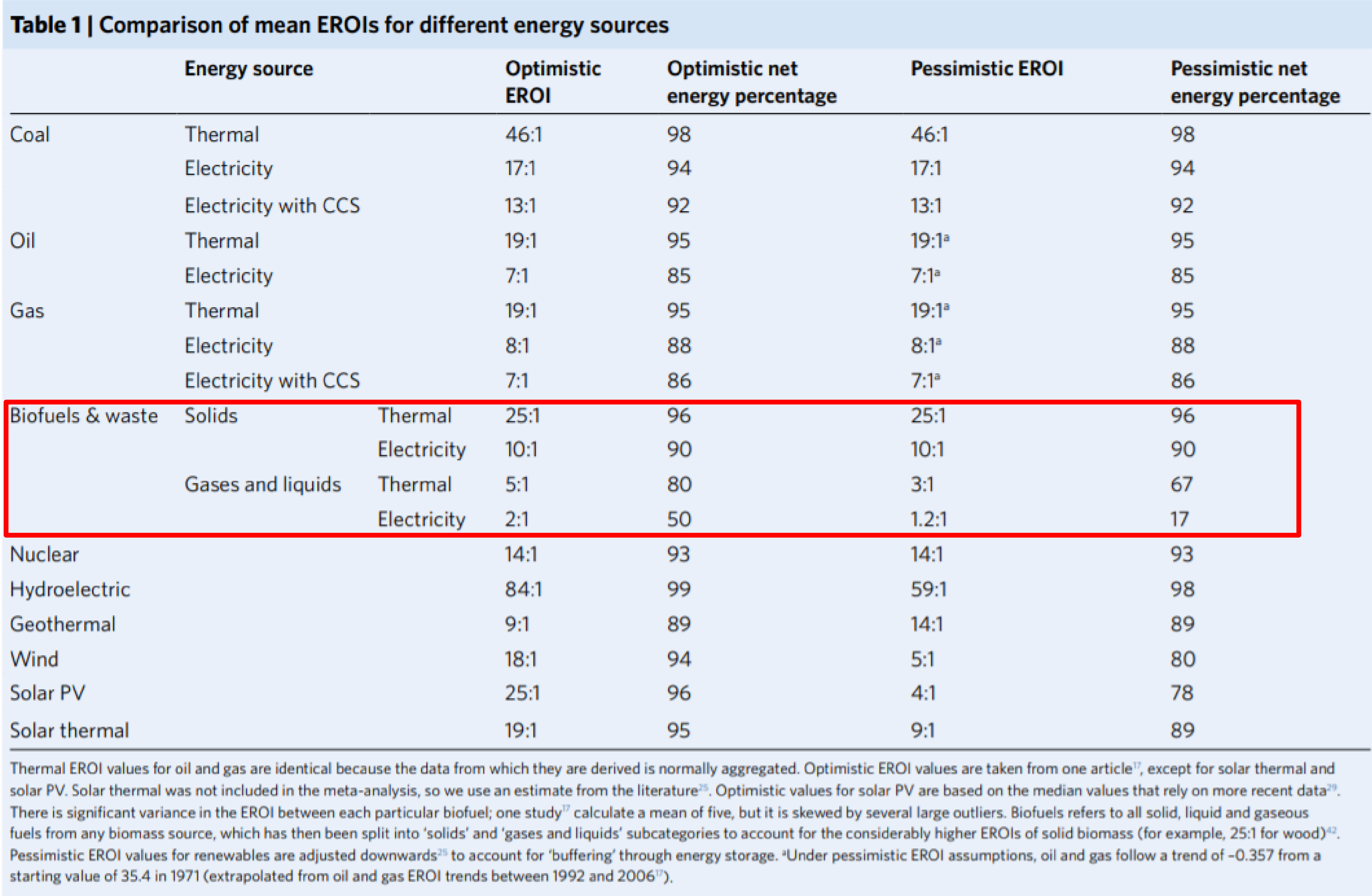
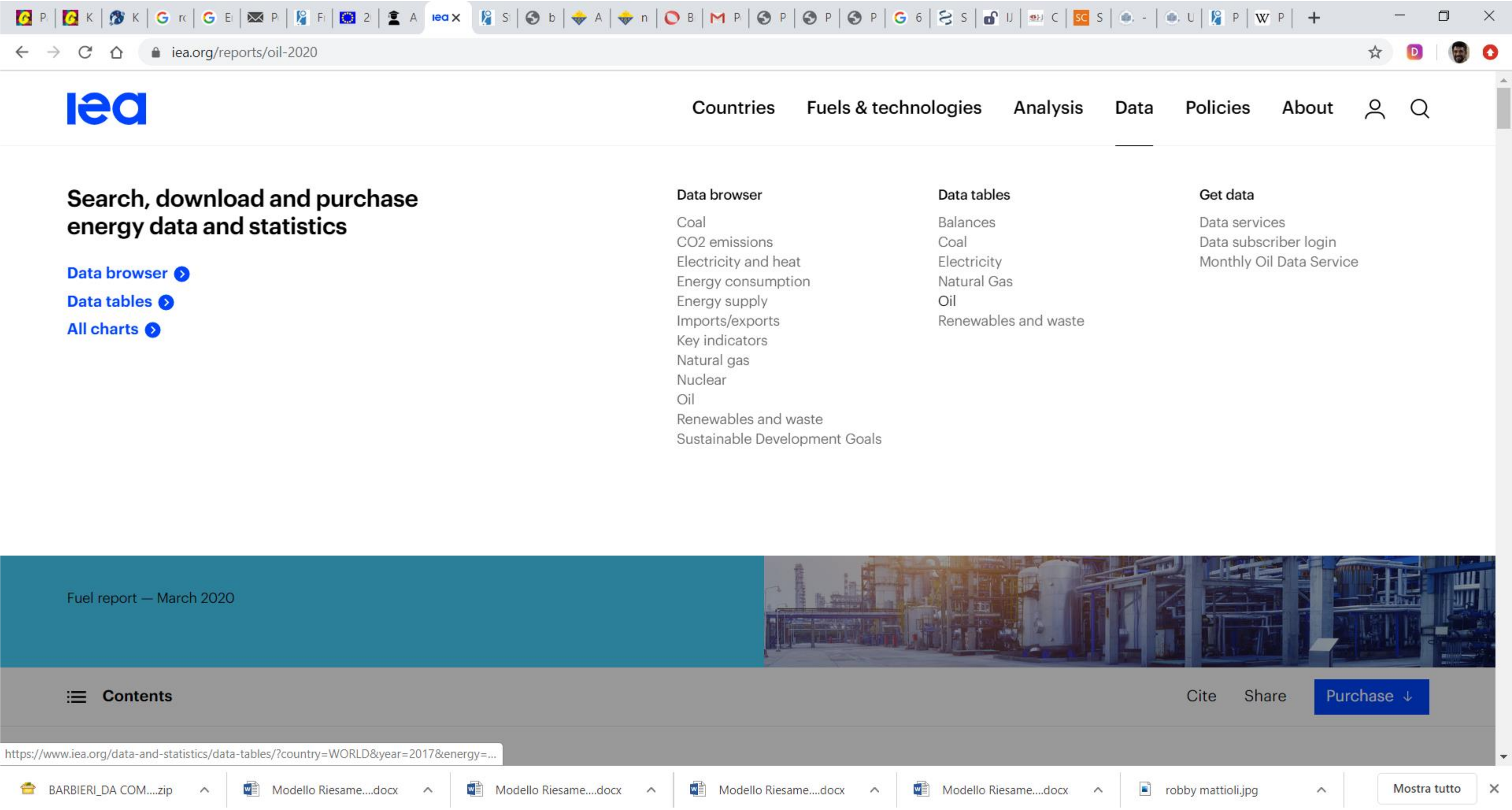


Table 1 | Comparison of mean EROIs for different energy sources

	Energy source		Optimistic EROI	Optimistic net energy percentage	Pessimistic EROI	Pessimistic net energy percentage
Coal	Thermal		46:1	98	46:1	98
	Electricity		17:1	94	17:1	94
	Electricity with CCS		13:1	92	13:1	92
Oil	Thermal		19:1	95	19:1[a]	95
	Electricity		7:1	85	7:1[a]	85
Gas	Thermal		19:1	95	19:1[a]	95
	Electricity		8:1	88	8:1[a]	88
	Electricity with CCS		7:1	86	7:1[a]	86
Biofuels & waste	Solids	Thermal	25:1	96	25:1	96
		Electricity	10:1	90	10:1	90
	Gases and liquids	Thermal	5:1	80	3:1	67
		Electricity	2:1	50	1.2:1	17
Nuclear			14:1	93	14:1	93
Hydroelectric			84:1	99	59:1	98
Geothermal			9:1	89	14:1	89
Wind			18:1	94	5:1	80
Solar PV			25:1	96	4:1	78
Solar thermal			19:1	95	9:1	89

Thermal EROI values for oil and gas are identical because the data from which they are derived is normally aggregated. Optimistic EROI values are taken from one article[17], except for solar thermal and solar PV. Solar thermal was not included in the meta-analysis, so we use an estimate from the literature[25]. Optimistic values for solar PV are based on the median values that rely on more recent data[29]. There is significant variance in the EROI between each particular biofuel; one study[17] calculate a mean of five, but it is skewed by several large outliers. Biofuels refers to all solid, liquid and gaseous fuels from any biomass source, which has then been split into 'solids' and 'gases and liquids' subcategories to account for the considerably higher EROIs of solid biomass (for example, 25:1 for wood)[42]. Pessimistic EROI values for renewables are adjusted downwards[25] to account for 'buffering' through energy storage. [a]Under pessimistic EROI assumptions, oil and gas follow a trend of −0.357 from a starting value of 35.4 in 1971 (extrapolated from oil and gas EROI trends between 1992 and 2006[17]).

https://www.nature.com/articles/s41560-018-0116-1 https://www.iea.org/



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Fuel report — March 2020

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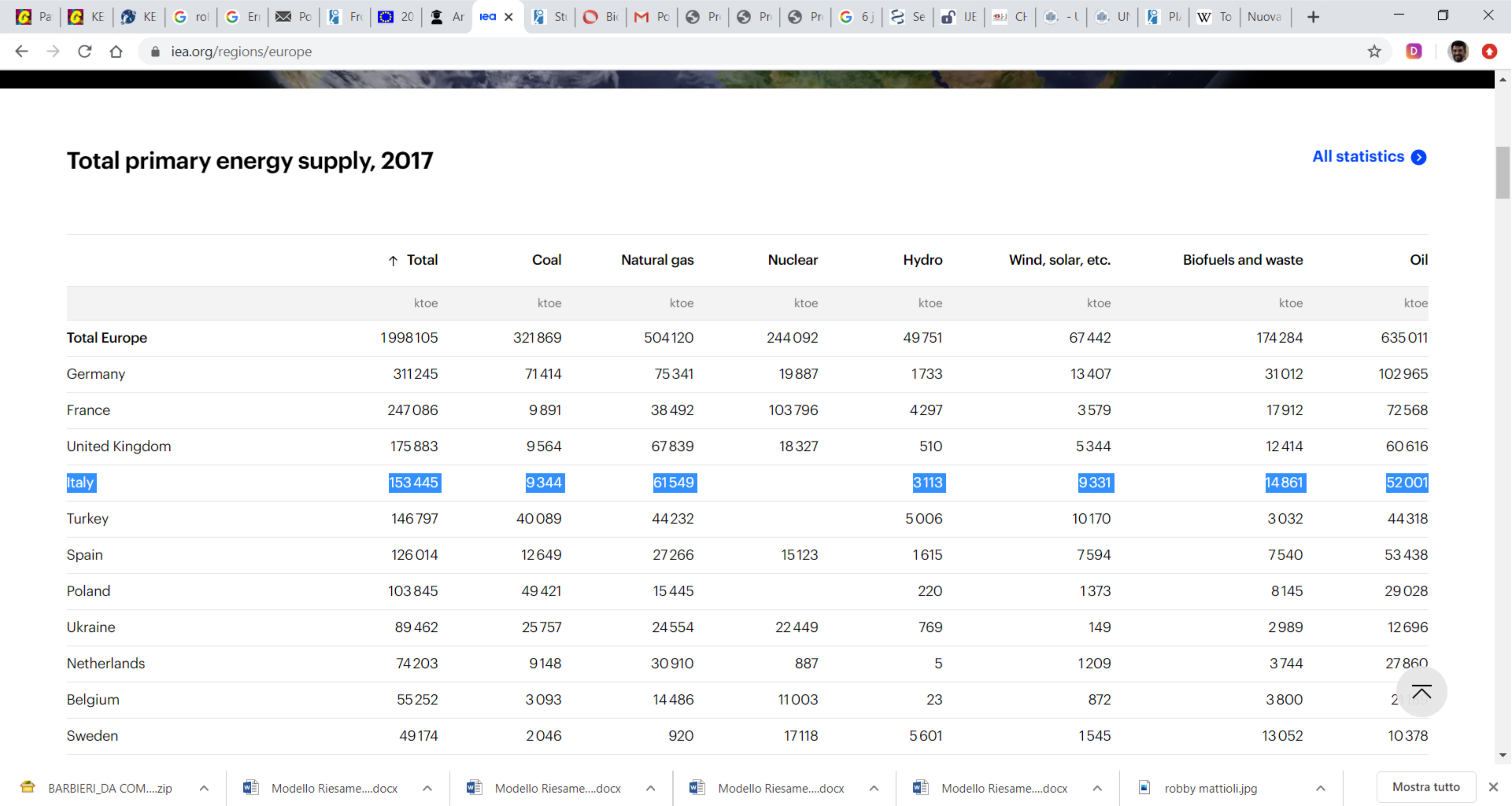


Total primary energy supply, 2017

	↑ Total	Coal	Natural gas	Nuclear	Hydro	Wind, solar, etc.	Biofuels and waste	Oil
	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe	ktoe
Total Europe	1 998 105	321 869	504 120	244 092	49 751	67 442	174 284	635 011
Germany	311 245	71 414	75 341	19 887	1 733	13 407	31 012	102 965
France	247 086	9 891	38 492	103 796	4 297	3 579	17 912	72 568
United Kingdom	175 883	9 564	67 839	18 327	510	5 344	12 414	60 616
Italy	153 445	9 344	61 549		3 113	9 331	14 861	52 001
Turkey	146 797	40 089	44 232		5 006	10 170	3 032	44 318
Spain	126 014	12 649	27 266	15 123	1 615	7 594	7 540	53 438
Poland	103 845	49 421	15 445		220	1 373	8 145	29 028
Ukraine	89 462	25 757	24 554	22 449	769	149	2 989	12 696
Netherlands	74 203	9 148	30 910	887	5	1 209	3 744	27 860
Belgium	55 252	3 093	14 486	11 003	23	872	3 800	2
Sweden	49 174	2 046	920	17 118	5 601	1 545	13 052	10 378

1 KTOE is approximately 42 gigajoules or 11.630 megawatt-hours,

Biogas e biometano

La produzione di biogas è una tecnologia consolidata principalmente per la generazione di energia rinnovabile e anche per la valorizzazione dei residui organici. Il biogas è il prodotto finale di un processo mediato da microorganismi, la **digestione anaerobica**, in cui diversi microrganismi seguono percorsi metabolici diversi per decomporre la materia organica. Il processo è conosciuto fin dai tempi antichi ed è stato ampiamente applicato alle abitazioni domestiche fornendo calore ed energia per centinaia di anni.

Oggigiorno, il settore del biogas sta crescendo rapidamente e nuovi risultati creano le basi per la costituzione di impianti di biogas come fabbriche di bioenergia avanzate. In questo contesto, gli impianti di biogas sono la base di un concetto di economia circolare che mira al riciclaggio dei nutrienti, alla riduzione delle emissioni di gas serra e ai fini della bioraffineria. …

Biogas and its opportunities—A review
Panagiotis G. Kougias
Irini Angelidaki
Frontiers of Environmental Science & Engineering
June 2018, 12:14
https://www.researchgate.net/publication/324835236_Biogas_and_its_opportunities-A_review

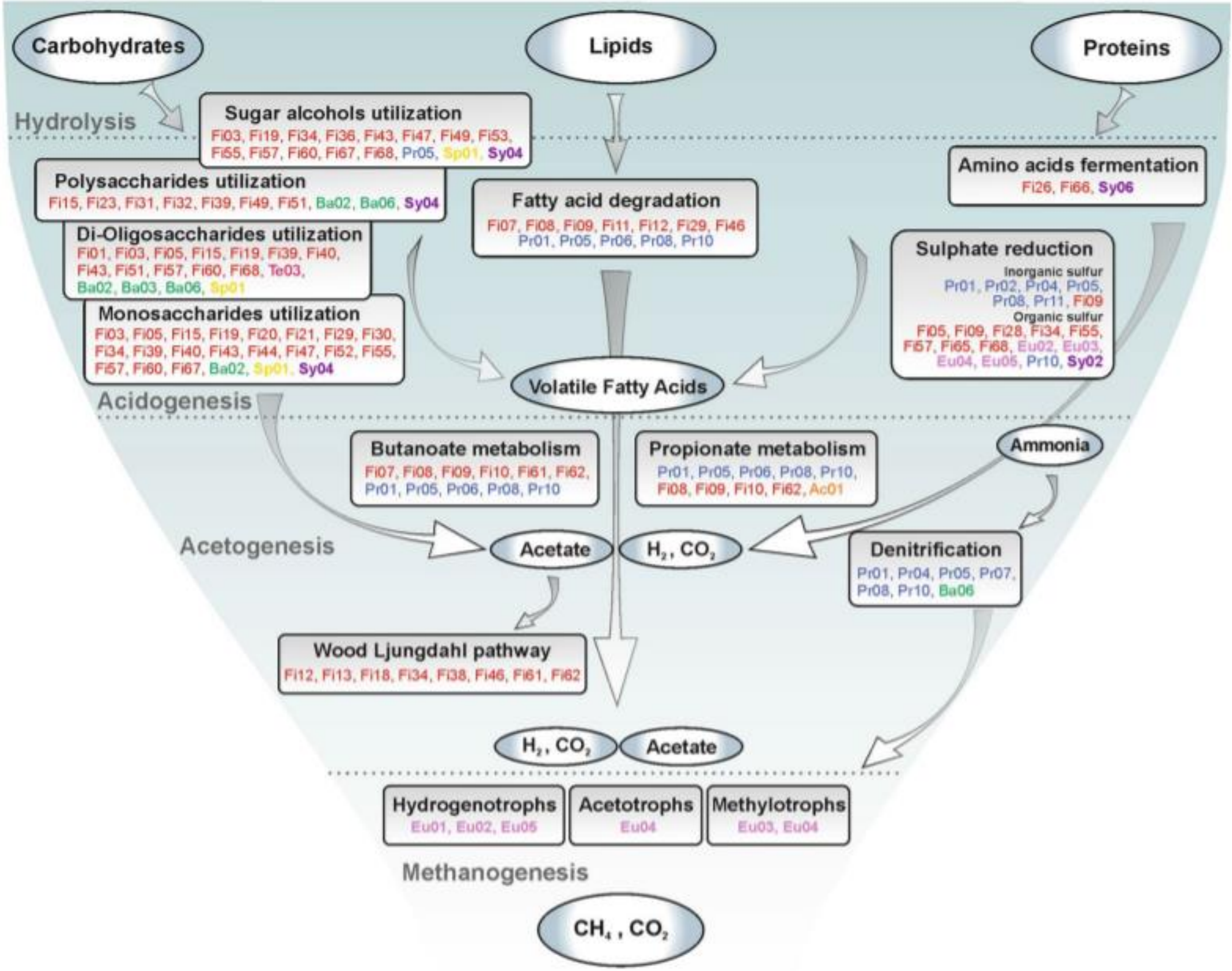


Fig. 3 Functional roles of the GBs in the biogas production "food chain." The main steps of the anaerobic degradation process are highlighted, together with the more relevant GBs involved. Functional roles were defined considering nearly complete KEGG pathways (Wood–Ljungdahl pathway, methanogenesis, propionate and butyrate metabolism), SEED categories (fatty acid degradation, carbohydrates utilization, denitrification, sulfate reduction), COG (amino acids fermentation) and Pfam (polysaccharides). Ovals refer to the compounds used by the microbial community (carbohydrates, fatty acids, proteins), intermediates (volatile fatty acids (VFA)-propionate, butyrate), and final products (carbon dioxide and methane)

https://biotechnologyforbiofuels.biomedcentral.com/track/pdf/10.1186/s13068-016-0441-1

Metagenomic analysis and functional characterization of the biogas microbiome using high throughput shotgun sequencing and a novel binning strategy

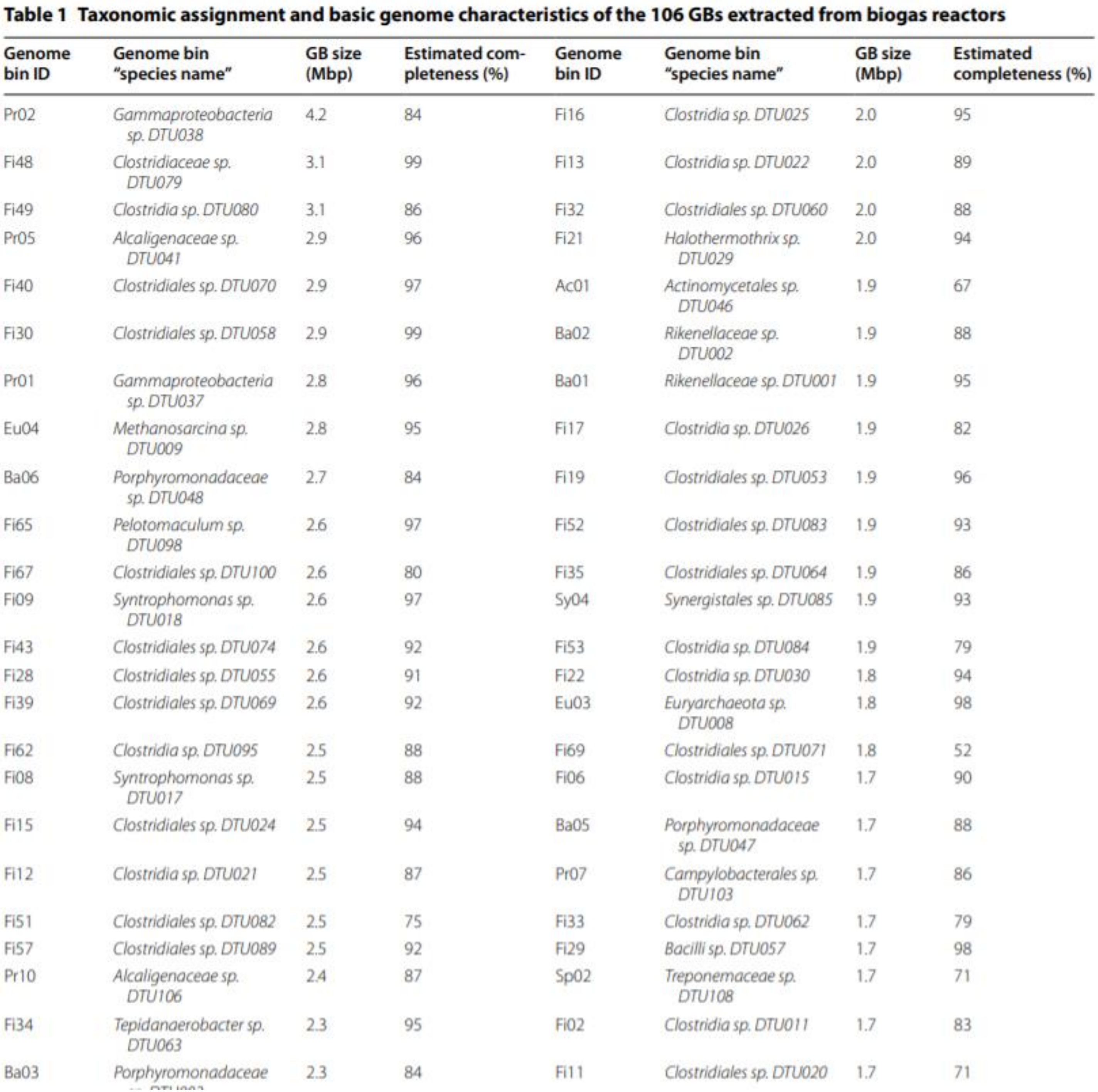


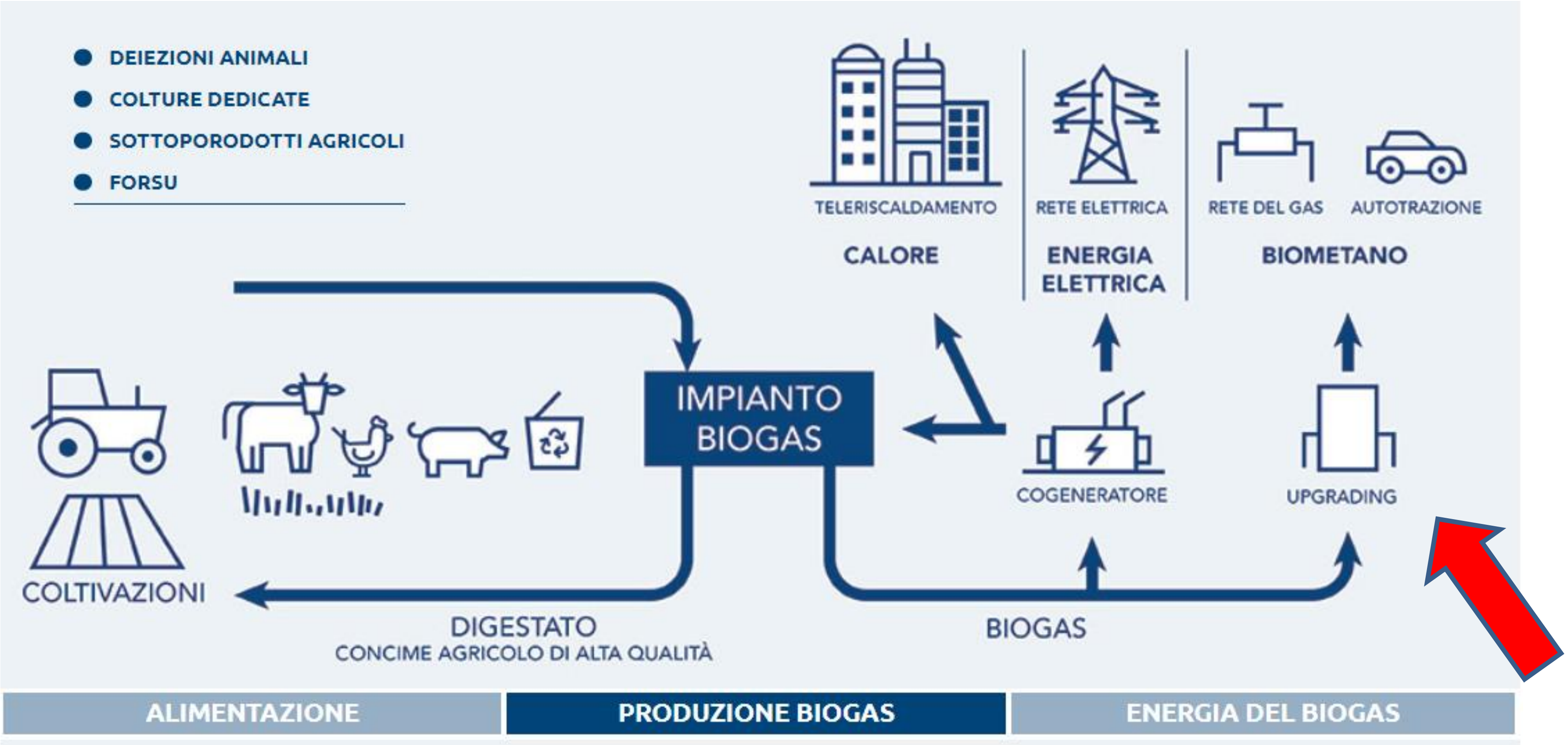
Table 1 Taxonomic assignment and basic genome characteristics of the 106 GBs extracted from biogas reactors

Genome bin ID	Genome bin "species name"	GB size (Mbp)	Estimated completeness (%)	Genome bin ID	Genome bin "species name"	GB size (Mbp)	Estimated completeness (%)
Pr02	*Gammaproteobacteria sp. DTU038*	4.2	84	Fi16	*Clostridia sp. DTU025*	2.0	95
Fi48	*Clostridiaceae sp. DTU079*	3.1	99	Fi13	*Clostridia sp. DTU022*	2.0	89
Fi49	*Clostridia sp. DTU080*	3.1	86	Fi32	*Clostridiales sp. DTU060*	2.0	88
Pr05	*Alcaligenaceae sp. DTU041*	2.9	96	Fi21	*Halothermothrix sp. DTU029*	2.0	94
Fi40	*Clostridiales sp. DTU070*	2.9	97	Ac01	*Actinomycetales sp. DTU046*	1.9	67
Fi30	*Clostridiales sp. DTU058*	2.9	99	Ba02	*Rikenellaceae sp. DTU002*	1.9	88
Pr01	*Gammaproteobacteria sp. DTU037*	2.8	96	Ba01	*Rikenellaceae sp. DTU001*	1.9	95
Eu04	*Methanosarcina sp. DTU009*	2.8	95	Fi17	*Clostridia sp. DTU026*	1.9	82
Ba06	*Porphyromonadaceae sp. DTU048*	2.7	84	Fi19	*Clostridiales sp. DTU053*	1.9	96
Fi65	*Pelotomaculum sp. DTU098*	2.6	97	Fi52	*Clostridiales sp. DTU083*	1.9	93
Fi67	*Clostridiales sp. DTU100*	2.6	80	Fi35	*Clostridiales sp. DTU064*	1.9	86
Fi09	*Syntrophomonas sp. DTU018*	2.6	97	Sy04	*Synergistales sp. DTU085*	1.9	93
Fi43	*Clostridiales sp. DTU074*	2.6	92	Fi53	*Clostridia sp. DTU084*	1.9	79
Fi28	*Clostridiales sp. DTU055*	2.6	91	Fi22	*Clostridia sp. DTU030*	1.8	94
Fi39	*Clostridiales sp. DTU069*	2.6	92	Eu03	*Euryarchaeota sp. DTU008*	1.8	98
Fi62	*Clostridia sp. DTU095*	2.5	88	Fi69	*Clostridiales sp. DTU071*	1.8	52
Fi08	*Syntrophomonas sp. DTU017*	2.5	88	Fi06	*Clostridia sp. DTU015*	1.7	90
Fi15	*Clostridiales sp. DTU024*	2.5	94	Ba05	*Porphyromonadaceae sp. DTU047*	1.7	88
Fi12	*Clostridia sp. DTU021*	2.5	87	Pr07	*Campylobacterales sp. DTU103*	1.7	86
Fi51	*Clostridiales sp. DTU082*	2.5	75	Fi33	*Clostridia sp. DTU062*	1.7	79
Fi57	*Clostridiales sp. DTU089*	2.5	92	Fi29	*Bacilli sp. DTU057*	1.7	98
Pr10	*Alcaligenaceae sp. DTU106*	2.4	87	Sp02	*Treponemaceae sp. DTU108*	1.7	71
Fi34	*Tepidanaerobacter sp. DTU063*	2.3	95	Fi02	*Clostridia sp. DTU011*	1.7	83
Ba03	*Porphyromonadaceae*	2.3	84	Fi11	*Clostridiales sp. DTU020*	1.7	71

Biogas e biometano

Environmental impact of biogas: A short review of current knowledge
V.Paolini, F.Petracchini , M. Segreto , L.Tomassetti, N.Naja , A.Cecinato
Journal of Environmental Science and Health, Part A **2018**, Vol. 53, No. 10, 899–906
https://www.tandfonline.com/doi/pdf/10.1080/10934529.2018.1459076?needAccess=true

“Biogas can significantly contribute to abate greenhouse gas emissions. However, attention must be payed towards undesired emissions of **methane and nitrous oxide (N_2O).** The emission budgets of the two compounds are scarcely related to direct release from biogas/biomethane combustion, whilst **biomass storage and digestate management are the critical steps.** Similar considerations apply to ammonia: to reduce its impact storage should always be recommended. Among all the gaseous pollutants considered in direct emission from biogas combustion, nitrogen oxides (NOx) level were worth of some concern in several case studies. On the other hand, volatile organic compounds do not seem to constitute a critical issue. Considering the aftermaths of digestate spreading on soil quality, further studies are needed in order to fully assess the long-term impact. In the medium-short term, digestate seems to be preferable compared to untreated biomass. The upgrading to biomethane can generally improve air quality and reduce GHG emissions; however methane losses in the off-gas can affect the sustainability of the whole process.»

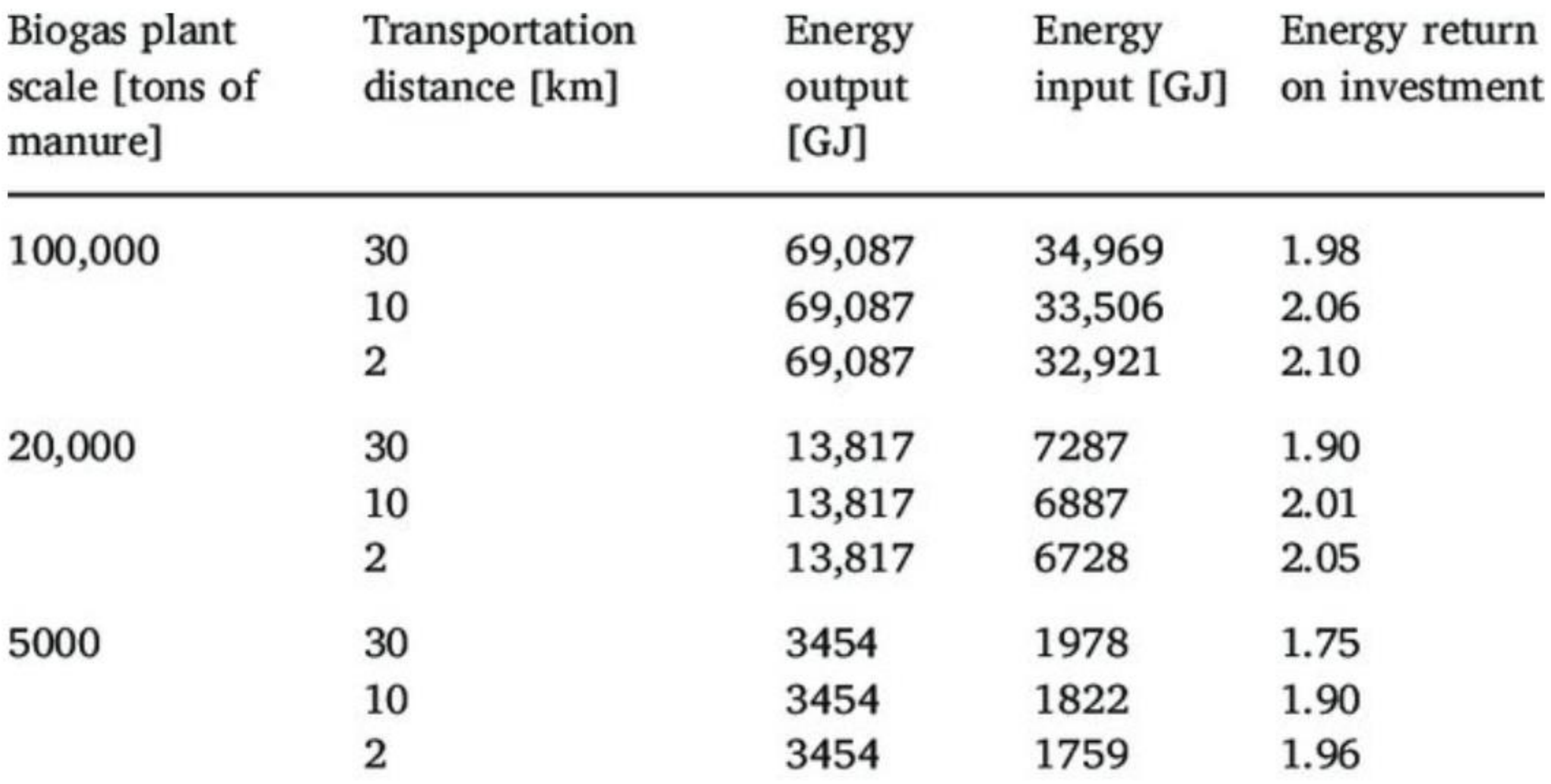


http://www.snam.it/it/gas-naturale/energia-verde/biometano/

https://www.consorziobiogas.it/wp-content/uploads/2019/03/cs-Eni-CIB_Sannazzaro_29-03-2019.pdf

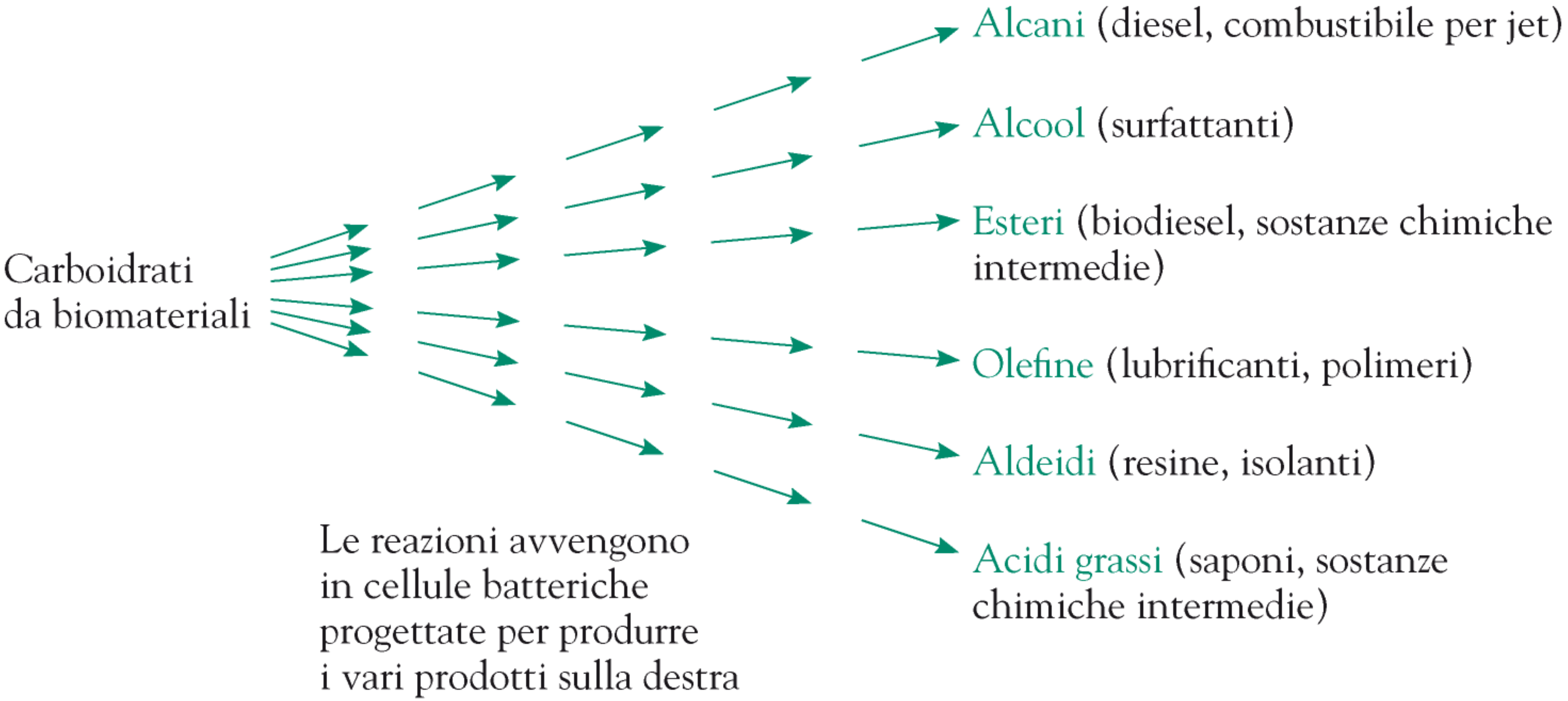
Cooperation in manure-based biogas production networks: An agent-based modeling approach December 2017

Applied Energy 212:820-833 10.1016/j.apenergy.2017.12.074



Biogas plant scale [tons of manure]	Transportation distance [km]	Energy output [GJ]	Energy input [GJ]	Energy return on investment
100,000	30	69,087	34,969	1.98
	10	69,087	33,506	2.06
	2	69,087	32,921	2.10
20,000	30	13,817	7287	1.90
	10	13,817	6887	2.01
	2	13,817	6728	2.05
5000	30	3454	1978	1.75
	10	3454	1822	1.90
	2	3454	1759	1.96

Dalle biomasse si possono ottenere sostanze organiche che sostituiscono quelle derivate da fonti fossili, grazie alla *green chemistry* ed alle sue implementazioni industriali nelle bioraffinerie



Carboidrati da biomateriali

Alcani (diesel, combustibile per jet)

Alcool (surfattanti)

Esteri (biodiesel, sostanze chimiche intermedie)

Olefine (lubrificanti, polimeri)

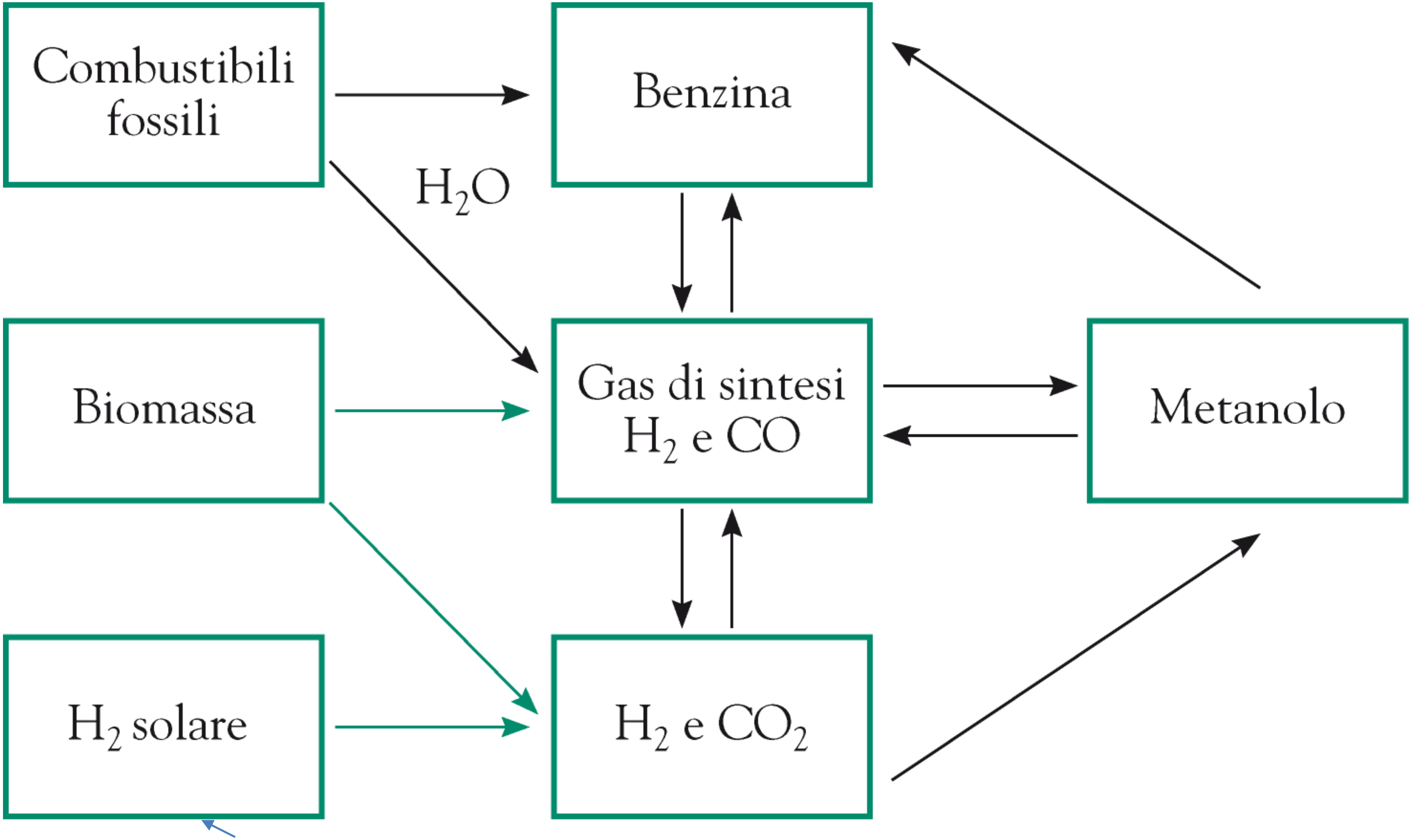
Aldeidi (resine, isolanti)

Acidi grassi (saponi, sostanze chimiche intermedie)

Le reazioni avvengono in cellule batteriche progettate per produrre i vari prodotti sulla destra

Bioeconomy and Bio-based Industry for the Rural Renaissance of Regions (3BiR3): focus regionale sulla bioeconomia e la bioindustria
Trieste, 23-24 Maggio 2019
http://eventi.regione.fvg.it/Eventi/dettaglioEvento.asp?evento=14122

Fonti energetiche diverse possono essere combinate per migliorare la sostenibilità dei sistemi economici



Combustibili fossili

Benzina

H_2O

Biomassa

Gas di sintesi H_2 e CO

Metanolo

H_2 solare

H_2 e CO_2

(Vedi prossima lezione)