

# The Biobased ECONOMY

Biofuels, Materials and Chemicals  
in the Post-oil Era



Edited by Hans Langeveld,  
Johan Sanders and Marieke Meeusen

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**Harriëtte Bos** graduated in Physical Chemistry at the Rijksuniversiteit Groningen, after which she joined DSM. After working for six years at DSM, in the department of materials development, she joined ATO-DLO (presently part of Wageningen UR), where she held several positions as project leader and group head of the groups working on biopolymers and on agrofibre composites. She obtained her Ph.D. from Eindhoven University on the potential of flax as reinforcing fibre for composite materials in 2004. Since 2004 she has been responsible for the policy support research cluster Economically promising Agrochains from the Ministry of Agriculture. She is advisor to the Ministry of Agriculture and is currently based both at the Biobased Products department of A&F, and at the Food Security and Sustainable Development group of Wageningen University, both at Wageningen UR.

**Steven Brumbley** is a Senior Research Fellow and project leader of the Sugarcane Metabolic Engineering Group at the University of Queensland's Australian Institute for Bioengineering and Nanotechnology. He obtained his undergraduate degree at the University of Oregon in 1985 and a Ph.D. in Plant Pathology at the University of Georgia in 1991. His current research program is focused on the metabolic engineering of sugarcane for production of industrial chemicals, primarily bioplastics.

**Jan E.G. van Dam** is Senior scientist in the Biobased Products Division of Wageningen UR, specializing in application research for sustainable lignocellulosic fibre in industrial processes. He studied bio-organic chemistry at the Utrecht State University and has been working on chemical and biochemical carbohydrate modification and processing of plant fibres. He has been involved in a large number of projects addressing fibre formation, fibre processing and quality, application development in paper and pulp, textiles, composites and building materials and has also been initiating international cooperation for fibre crop innovation and sustainable development of biobased materials, including byproducts use and lignin application.

**Oene Dolstra** is a Senior scientist at Wageningen University and Research Centre – Plant Breeding, with a Ph.D. degree from this university. He has

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**Wolter Elbersen** studied crop science at Wageningen Agricultural University and obtained a Ph.D. from the University of Arkansas in Grass Physiology in 1994. He currently works at Agrotechnology and Food Sciences Group (AFSG) in Wageningen as Senior researcher on biomass, bioenergy and biofuels. He has more than 14 years experience in biomass production, biomass crops, by-product valorisation and biomass chain development and assessment. His main interest is the design of sustainable biomass supply systems for energy and products. He has been co-ordinator of the European switchgrass project and several projects on biomass from crops and on valorisation of by-products for non-food applications. Recently he has contributed to, or coordinated, projects on sustainable biomass and bioenergy production in The Netherlands, Brazil, Ukraine, Turkey and Mozambique.

**J. van Haveren** obtained his Ph.D. degree for a study on metal-ion complexation of carbohydrates, at the Technical University of Delft. He has been with Wageningen University and Research Centre for over 16 years in several positions. He is co-author of more than 15 patent applications and over 30 scientific publications. He is currently Programme Co-ordinator Sustainable Chemistry at WUR/A&F, responsible for setting up both fundamental and applied research programmes, in close interaction with industry, in the field of organic & polymer chemistry with a focus on exploring the possibilities to use renewable building blocks in polymer applications.

**John Jaworski** received his B.Sc. in Chemistry from McGill University in 1970 and his Ph.D. in Analytical Chemistry from Cornell University in 1974. At the National Research Council of Canada he studied the ecotoxicology of heavy metals and helped make the case for removal of lead from gasoline in Canada. In 1984, he joined the Industrial Research Assistance Program of the National Research Council where he helped launch the first generation of Canada's biotechnology companies. After he joined Industry Canada in 1992, he combined his interests in biotechnology and the environment by helping to promote the development and adoption of industrial biotechnology in Canada for the production of renewable fuels, chemicals and materials. From 1998–2008 he was Chairman of the OECD Task Force on Industrial Biotechnology. He is a founding member of the



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**Erik Steen Jensen** is Professor in Agricultural Sciences at the Swedish University of Agricultural Sciences. He obtained his Ph.D. and D.Sc. in Plant Nutrition and Soil Science from the University of Copenhagen. He has many years experience in studying nitrogen cycling in agricultural systems using stable isotopes, biological N<sub>2</sub> fixation and diversification of arable cropping systems, including organic farming systems. From 2003 to 2009 he was responsible for developing a research programme on sustainable bioenergy and biomass production as Risø. He has been the coordinator of several international and national research projects on the legumes in cropping systems and has published more than 100 papers in international journals.

**Ed de Jong** graduated from the Agricultural University Wageningen and obtained a Ph.D. at the Agricultural University Wageningen on the degradation of lignocellulose by white-rot fungi. He was research associate at the University of British Columbia and head of the Department of Fibre and Paper Technology, Wageningen University and Research Centre. Since 2007 he has been Vice-President Development at Avantium Chemicals in the Netherlands. He has been involved in biomass research for 15 years; (co-)authored over 50 papers in international journals and holds eight patents relating to biomass transformation. He was awarded a Shell study award in 1993 and acted as Editor in Chief of *Industrial Crops and Products* and is currently Task leader for IEA Bioenergy Task 42 on Biorefineries.

**Rob Jongman** is a landscape ecologist working as Senior scientist at Wageningen University and Research Centre, with experience in river ecology, nature conservation planning and environmental monitoring. He did his Ph.D. on Ecology, Planning and Policy in River Systems. His present activities concern the implementation of academic ecological knowledge into real world problems and the interaction between science and practice. He is focusing on this in the field of biodiversity monitoring ecosystem change monitoring and ecological network planning. With Biodiversity International and NASA he is co-lead in the GEO biodiversity Community of Practice GEO-BON and coordinator of the European pilot project on biodiversity monitoring EBONE.

**Andries Jurriaan Koops** is Manager of the business unit Bioscience (whose main research topics are plant genomics, plant cell metabolism and

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**Ad de Laat** studied Cell Biology at Wageningen University and obtained his Ph.D. on a thesis on the role of plant hormones in plant defense in 1982. During more than 15 years he was active in the development of transgenic crops both in public and private domain. Since 2000 he has been R&D Director for Cosun, a Dutch agro-industrial company, and responsible for the execution of a research project portfolio on process and product development for the companies that belong to the Cosun group.

**Johannes (Hans) W.A. Langeveld** is Director of Biomass Research. He studied tropical cropping systems at Wageningen University and Research Centre and has been working on global food production, crop and land use modelling, climate change and sustainability of cropping systems. He has been Senior Researcher at Plant Research International; Researcher at the Centre for World Food Studies; project leader of a large number of projects addressing biomass production and sustainability; is still active in the International Farming Systems Association (IFSA); the European Committee for Standardization (CEN); and is author of over 30 scientific papers and a book on European farming systems.

**E.N. van Loo (Robert)** is Senior scientist Biobased crops at Wageningen University and Research Centre – Plant Breeding. He is also Research director of Calendula Oil b.v. and has been Location manager Mushroom Research Unit of PPO (Praktijkonderzoek Plant en Omgeving, Experimental Plant Research), leading a mushroom research group. He has been co-ordinator of various EU-research projects on development of a production chain for Calendula seed oil for industrial uses (CARMINA) and use of molecular markers in breeding of forage grass. Currently, he is involved in projects aiming at changing plant oil qualities in Calendula and Crambe and he is co-ordinator of an EU-project on genetics/breeding of jatropha and development of sustainable agrosystems involving jatropha.

**Mads V. Markussen** is a research assistant at Risø National Laboratory for Sustainable Energy, The Technical University of Denmark. He works



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**Ingrid van der Meer** obtained her Ph.D. in Plant Molecular Genetics at the Free University, Amsterdam and has over 20 years research experience. She guided research projects on genetic regulation and modification of plant primary and secondary pathways such as phenyl propanoid-, fructan-, amino acid- and organic acid biosynthesis. She is currently Cluster Leader Applied Genomics and Proteomics at Plant Research International, focussing on plant genetic, metabolic, and physiological processes. For more than 10 years, she studied the use of plants for a Biobased Economy, notably the production of chemical building blocks by plants and organic acids. She is the author of over 50 publications in peer reviewed journals and has 10 patents.

**Marieke J.G. Meeusen** works as leader of the research program of socio-economics of the biobased economy at the Agricultural Economics Research Institute (LEI) at the Wageningen University and Research Centre. Since 2004 she has been Deputy Head of section markets & networks, leading a research group of approximately 20 persons. She is also leader of the research program of socio-economics of the biobased economy, and she leads the research program on market and chain management of the organic sector. She has conducted several studies on bio-energy, biobased products and organic products, with a focus on sustainability, markets and feasibility. She has been leader of many projects with emphasis on sustainable agricultural chains.

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**René van Ree** became Bachelor of Science in Chemical Engineering at the College of Utrecht in 1989. He became Master of Science in Chemistry at the Department of Chemistry, Technology and Society (Research Group Energy & Environment) of the University of Utrecht in 1992 and Registered Energy Consultant at the General Association of Energy Consultants (AEC) in 1998. From 1993 to 2007 he worked at the Energy Research Centre of the Netherlands (ECN) on clean fossil fuel technology and biomass technology developments. Since 2007 he has worked at Wageningen University and Research Centre as Programme Manager Bioenergy, Biofuels, and Biorefinery. He is co-chair of the European Biofuels TP; co-ordinator of IEA Bioenergy Task 42 on Biorefinery; KBBE-Net representative; initiator of a variety of running European projects (BIOPOL, BIOREF-INTEG, BIOSYNERGY, Green Biorefinery); and a number of national bio refinery initiatives.

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**Geert Woltjer** worked as Assistant Professor at Maastricht University, the Netherlands upto 2006, and since then as Senior researcher at the Agricultural Economics Research Institute (LEI). He studied Economics at

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**Kornelius (Kor) B. Zwart** is senior soil scientist at Alterra, one of the Research Institutes of Wageningen-UR. He obtained his Ph.D. on Microbiology at the State University of Groningen and was a post-doc at the University of Nijmegen, where he was involved in the development of the RUDAD system (Rumen Derived Anaerobic Digestion). He has been involved in many research projects regarding the environmental impact of agriculture. Currently he is also involved in several projects regarding the sustainability of renewable energy, including its impact on soil properties. He is author or co-author of over 40 scientific papers.

# List of Acronyms and Abbreviations

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ABE	acetone, butanol, ethanol
ACTS	Advanced Catalytic Technology for Sustainability
ADM	Archer Daniels Midland
AEZ	Agro-Ecological Zones
AK	aspartate kinase
BDBP	biodiesel by-products
BIMAT	Biomass Inventory Mapping and Analysis Tool
BMELV	Federal Ministry of Agriculture (Germany)
BMU	Ministry of Environment (Germany)
BTL	biomass to liquid
C	carbon
CBB	Chemical Building Bloc
CBIN	Canadian Biomass Innovation Network
CCS	carbon capture and storage
CES	constant elasticity of substitution
CGE	computable general equilibrium
CH <sub>4</sub>	methane
CHP	combined heat and power
CO	carbon monoxide
CPL	chorismate pyruvate-lyase
DARCOF	Danish Research Centre for Organic Farming
DDGS	distiller's dried grains with solubles
DH	doubled haploids
DHDPS	dihydrodipicolinate synthase
DME	dimethylether
EEA	European Environment Agency
EEG	Renewable Energy Source Act
EMF	ethoxymethylfurfural
EPS	expanded polystyrene
ETBE	ethyl tertio butyl ether
EU	European Union
FAME	fatty acid methyl ester
FAO	Food and Agriculture Organization of the United Nations



FFV	flexible-fuel vehicles
FNR	Agency for Renewable Resources (Germany)
FT	Fischer-Tropsch
GBR	Green Biorefineries
GHG	greenhouse gas
GHI	Global Hunger Index
GM	genetic modification
H <sub>2</sub>	hydrogen
H <sub>2</sub> O	water
H <sub>2</sub> S	hydrogen sulphide
ha	hectare
HCHL	4-hydroxycinnamoyl-CoA hydratase/lyase
HHV	Higher Heating Value
HI	harvest index
HMF	hydroxymethylfurfural
HTU	hydrothermal upgrading
IAEA	International Atomic Energy Agency
ICI	Imperial Chemical Industries
IEA	International Energy Agency
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
KFA	Key Factor Analysis
LCA	life cycle assessment/analysis
LCFBR	Lignocellulosic Feedstock Biorefineries
LCP	liquid crystal polymers
LHV	Lower Heating Value
LPCP	liquid phase catalytic processing
LPG	liquefied petroleum gas
MBR	Marine Biorefineries
MEK	methylethylketone
MEVM	Methane Energy Value Model
MLP	multilevel perspective
MNP	The Netherlands Environmental Assessment Agency
MSA	Mean-Species-Abundance
MTBE	methyl tertiary butyl ether
N	nitrogen
N <sub>2</sub> O	nitrous oxide
NAFTA	North American Free Trade Agreement
NGO	non-governmental organization

NH <sub>3</sub>	ammonia
NO <sub>x</sub>	nitrogen oxide
NREL	National Renewable Energy Laboratory
NUE	Nutrient Use Efficiency
OCVCI	Ontario Chemical Value Chain Initiative
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
P	phosphorous
PDO	1,3-propanediol
PE	polyethylene
PHA	polyhydroxyalkanoate/polyhydroxy fatty acids
pHBA	parahydroxybenzoic acid
PHB	polyhydroxybutyrate
PLA	polylactic acid or polylactide
PNPB	National Program for Production and Use of Biodiesel
PPP	Public–Private Partnership
PPT	poly(propylene terephthalate)
PSA	Pressure Swing Absorption
PV	photovoltaic
RED	Renewable Energy Directive
RES	renewable energy sources
RME	rapeseed methyl ester
RSB	Round Table on Sustainable Biomass
RSPO	Round Table on Sustainable Palm Oil
RTFO	Renewable Transport Fuels Obligation
RTRS	Round Table on Responsible Soy
RUDAD	rumen-derived anaerobic digester
SBIR	Small Business Innovation Research
SDE	Promotion of Sustainable Energy Production
SME	soybean methyl ester
SNG	Substitute Natural Gas
SOM	soil organic matter
SRES	Special Report on Emission Scenarios
SSC	small-scale combustion
SSF	simultaneous saccharification and fermentation
SVO	straight vegetable oil
TS	total solid
UDP	uridine diphosphate
UNCED	United Nations Conference on Environment and Development
VFA	volatile fatty acid

VOC	Volatile Organic Compounds
VROM	Ministry of Housing, Spatial Planning and the Environment
VS	volatile solids
WCBR	Whole Crop Biorefinery
WPC	wood plastic composites
WTO	World Trade Organization
WUE	Water Use Efficiency
WWF	World Wildlife Fund
WWI	World Watch Institute
y	year