September 2008

First Annual Conference on Cellulosic Biofuels - PROGRAM

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Hosted by

The Institute for Massachusetts Biofuels Research (TIMBR)

of

The University of Massachusetts Amherst

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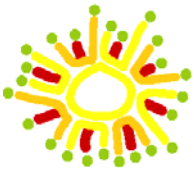

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September 19, 2008

Dear Colleagues:

Welcome to the First Annual Conference on Cellulosic Biofuels at the University of Massachusetts Amherst!

Clean energy has emerged as a priority for Massachusetts and for the nation, both in terms of the environmental and health benefits to local communities and the potential for widespread economic development. Advanced biofuels (also known as second generation biofuels) are an indispensable component of the nation's clean energy portfolio. The advanced biofuels industry is currently still in its infancy, but is poised for rapid growth. Academic and industrial research underway in laboratories today will feed the advanced biofuels industry of tomorrow.

The advanced biofuels industry will mature through a combination of technical breakthroughs, forward-looking policies and business leadership. Today's conference will feature speakers who will touch on each of these important components. We will begin this morning with the technical perspectives of experts from across the nation and conclude with an afternoon session featuring commentary on public policy trends and an advanced biofuels industry outlook.

Thank you to all of the speakers, presenters, and attendees for contributing to make this a terrific event. And, again, welcome!

Yours truly,

Michael Henson, Ph.D
Co-director, TIMBR
Professor of Chemical Engineering

Danny Schnell, Ph.D
Co-director, TIMBR
Professor of Biochemistry and Molecular Biology

Susan Leschine, Ph.D
Co-director, TIMBR
Professor of Microbiology

The First Annual TIMBR Conference on Cellulosic Biofuels

September 19, 2008

University of Massachusetts, Amherst

Program of Events

8:00-5:00 Registration

8:00-9:00 Continental breakfast

Morning: Biofuels Research Opportunities (Campus Center, Room 163)

9:00-9:05 Welcome

9:05-9:15 Overview of Conference Program, Michael Henson, Department of Chemical Engineering, UMass Amherst

9:15-10:15 Keynote, The Road to a Renewable Carbon Economy, Michael Ladisch, Purdue University, West Lafayette, IN

10:15-10:45 Break (with refreshments)

10:45-11:15 Biofuels Research Opportunities in Thermochemical Conversion of Biomass, Doug Elliott, Pacific Northwest National Laboratory, Richland, WA

11:15-11:35 Overview of TIMBR, Danny Schnell, Department of Biochemistry and Molecular Biology, UMass Amherst

11:35-11:55 Green Gasoline by Catalytic Fast Pyrolysis, George Huber, Department of Chemical Engineering, UMass Amherst

11:55-12:15 A Novel Biocatalyst for Cellulosic Ethanol Production, Susan Leschine, Department of Microbiology, UMass Amherst

12:15-2:00 Buffet lunch and Poster Session (Campus Center – 10th Floor “Amherst Room”)

Afternoon: The Massachusetts Biofuels Industry (Campus Center Room 163)

2:00-2:30 The Clean Energy Biofuels Act: Promoting Advanced Biofuels in Massachusetts, Dwayne Breger, Massachusetts Division of Energy Resources, Boston, MA

2:30-3:00 The Advanced Biofuels Policy Environment: Framing the Debate and Laying the Foundation for Industry Expansion, Andrew Schuyler, Northeast Biofuels Collaborative, Boston, MA

3:00-3:30 Break (with refreshments)

3:30-4:00 Fueling the Commercialization of Cellulosic Ethanol, John Howe, Verenium International, Cambridge, MA

4:00-5:00 Industry roundtable
Jeremy Johnson, Agrivida, Medford, MA
Jef Sharpe, SunEthanol, Amherst, MA
Colin South, Mascoma, Cambridge, MA
Corinne Young, BioEnergy International, Norwell, MA
Bruce Vrana, DuPont, Wilmington, DE

4:50-5:00 Closing, Michael Henson, Department of Chemical Engineering, UMass Amherst

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Presentation Abstracts

The Road to a Renewable Carbon Economy,
Michael Ladisch, Purdue University

Renewable carbon is found in cell wall structures of wood, grasses, and agricultural residues of plant matter derived from CO_2 in the atmosphere. This carbon is sequestered in the form of cellulose and other closely associated plant polymers. The first wave of biofuels, i.e., corn ethanol and biodiesel, has resulted in heightened public awareness of the potential of such fuels while debates on competing uses of corn for food vs fuel have led to the realization that the amount of ethanol derived from grains will plateau. This limit is estimated to be between 12 and 15 billion gallons. A combination of global climate change and rising oil prices is catalyzing interest in alternative liquid fuels, and in particular, biofuels. The mandate for increasing alternate liquid fuels to supplant more of the current 140 billion gallons of gasoline currently being consumed in the US has led to examination of other, non-food feedstocks for fuel ethanol fermentations. These feedstocks consist of wood, agricultural residues, energy crops and grasses. The challenge is to discover and engineer cost effective processes for converting these non-food feedstocks to ethanol. Biotechnology applied to cellulosics (non-food feedstocks) provides a bridge for transition between renewable and non-renewable carbon. A strong fundamental base of science and engineering research, coupled with a global vision, will be needed to successfully develop and build bioprocesses for converting cellulose to ethanol. These factors are discussed and analysis of their potential impacts on overall fuel consumption in the US is presented in the context of the path forward to a renewable carbon economy.

Biofuels Research Opportunities in Thermochemical Conversion of Biomass,
Doug Elliott, Pacific Northwest National Laboratory

The presentation will focus on thermochemical methods to utilize biomass for biofuels production. The Department of Energy has identified thermochemical conversion technology as a key element of the federal research program for biomass utilization as a renewable energy source. A recent National Science Foundation sponsored study of the technology area identified a range of technology issues to be addressed. In this talk, the technology elements will be summarized and new initiatives highlighted. Some examples include:

- Selective thermal processing of lignocellulosic biomass to produce liquid fuels (bio-oils) in distributed biorefineries
- Utilization of petroleum refining technology for conversion of biomass-derived oxygenates within existing petroleum refineries
- Hydrocarbon production by liquid phase processing of sugars to “green” diesel and jet fuel via hydroxymethylfurfural
- Process intensification for diesel and gasoline production from synthesis gas (CO and H_2) from biomass gasification by Fisher-Tropsch synthesis
- Conceptual design of biorefining processes in conjunction with experimental studies at the beginning of research projects to allow rapid development of commercial biofuel technologies, and

- Design of recyclable, highly active and selective heterogeneous catalysts for biofuel production using advanced nanotechnology, synthesis methods and quantum chemical calculations.

The Institute for Massachusetts Biofuels Research,
Danny Schnell, UMass Amherst

The Institute for Massachusetts Biofuels Research (TIMBR) is composed of an interdisciplinary team of twenty-four principal investigators at the University of Massachusetts Amherst with a common goal of developing cost-effective technologies for producing alternative fuels and value-added materials from biomass. The assembled TIMBR team consists of experts in all areas of biofuels research and development. TIMBR is vertically integrated to span the areas of biomass feedstock development, biological and chemical conversion to fuels, and process development, by combining expertise in plant biology, microbiology, chemical catalysis, biorefinery engineering and design, and economic and environmental analysis. TIMBR is developing two main components. 1) A Biofuels Research and Development Laboratory will supply facilities and research capacity for collaborative bioenergy research and development projects. The Laboratory provides a physical and intellectual platform for the participants in TIMBR to directly interface with each other, their collaborators at other institutions, and with industrial partners. As such, the Laboratory serves as the catalyst for multidisciplinary research, provides a platform for student training and workforce development, and promotes the translation of TIMBR research into the private sector. 2) Development of the Massachusetts Bioenergy Partners (MBP) organization. This component will consist of an Advisory Board comprising bioenergy professionals from industry and academics, and a professional staff focused on promoting and facilitating technology transfer, workforce development, and industry, market and organizational research.

Green Gasoline by Catalytic Fast Pyrolysis,
George Huber, UMass Amherst

In this presentation we will discuss a new route to produce gasoline range aromatics from solid biomass by catalytic fast pyrolysis. Catalytic fast pyrolysis produces gasoline range aromatics from solid biomass (including cellulose, sugars and sugar alcohols) in a single catalytic reactor at short residence times (less than 60 s). The biomass is first rapidly heated to intermediate temperatures (400-600^{o}C) where it thermally decomposes to smaller fragments. These molecules then enter the zeolite based catalysts where they are converted to aromatics, carbon dioxide, carbon monoxide and water. The fast heating rates are essential in that they allow the thermally unstable compounds to be introduced into the zeolite material prior to thermal decomposition. The reactions involved for catalytic fast pyrolysis include dehydration, hydrogen transfer, decarbonylation, C-C bond forming reactions, isomerization, and aromatic production. These reactions must be properly balanced by using the proper catalytic material and reaction conditions to produce the desired products.

A Novel Biocatalyst for Cellulosic Ethanol Production,
Susan Leschine, UMass Amherst

At present, biomass is the only source of liquid transportation fuels that may replace the world's finite supply of oil. Cellulosic ethanol derived from non-food biomass, such as woodchips, switchgrass, and agricultural waste, is one of the most promising such fuels with major environmental and economic benefits in the form of reduced greenhouse gas emissions, improved rural economies, and decreased dependence on imported oil. The positive "energy return on investment" for cellulosic ethanol production derives from the fact that the process makes use of the whole plant. However, the recalcitrance of cellulosic biomass to breakdown and the scarcity of appropriate microbial catalysts capable of fermenting the wide range of carbohydrates found in biomass pose significant obstacles to the development of cellulosic ethanol technologies. To overcome these obstacles, a microbial bioprocessing strategy was developed at the University of Massachusetts Amherst, and is being commercialized by SunEthanol, Inc. The Complete Cellulose Conversion (C3™) technology under development at SunEthanol involves a strain of *Clostridium phytofermentans*, a novel microbe first isolated from forest soil. This bacterium possesses exceptional nutritional versatility. It decomposes all fermentable components of biomass, including the hemicellulosic portion, and produces ethanol as its primary fermentation product. Recently, the complete genome sequence of *C. phytofermentans* was determined. Gene expression microarray experiments based on the genome sequence have confirmed the importance of ethanol production in the overall metabolism of the microbe. Additionally, *C. phytofermentans* adjusts its metabolism and the production of degradative enzymes in response to growth substrate. Facile adaptation of metabolism to different feedstocks is a major strength of the C3™ technology. The properties of *C. phytofermentans* indicate that it is an ideal organism for use in the C3™ process, a biomass conversion scheme in which production of the cellulase enzymes, cellulose decomposition, and fermentation are consolidated in a single step, yielding significant economic advantages.

The Clean Energy Biofuels Act: Promoting Advanced Biofuels in Massachusetts,
Dwayne Breger, Massachusetts Division of Energy Resources

In July 2008, Governor Patrick signed into law the Clean Energy Biofuels Act, legislation that will encourage the growth of an advanced biofuels industry. The legislation was substantially informed by the Advanced Biofuels Task Force appointed by the Governor and leaders of both bodies of the legislature. The legislation gives preferential tax treatment to non-corn-based alternatives to ethanol, requires biofuel content in all the diesel and home heating fuel sold in the state, and calls for the state to reach out to the other northeast states to adopt a California-style Low Carbon Fuel Standard. The Task Force estimated that a mature advanced biofuels industry could contribute $280 million to $1 billion per year to the Massachusetts economy by 2025, generating 1,000 to 4,000 permanent jobs and 150 to 760 temporary construction jobs, while reducing the state’s reliance on petroleum imports.

The Advanced Biofuels Policy Environment: Framing the Debate and Laying the Foundation for Industry Expansion,
Andrew Schuyler, Northeast Biofuels Collaborative

Providing context to policy makers is critical, particularly in the biofuels space where misinformation runs rampant. Accordingly, legislators and other stakeholders generally respond to peer-reviewed research and the notion that there are substantial costs associated with our continued appetite for oil. Once it is recognized that alternative fuels should be competing on a level playing field with petroleum and that implementing sensible biofuels policy is not overly complicated, opportunities abound. While not all policies need to reinvent the wheel, there are untapped options worthy of consideration.

Fueling the Commercialization of Cellulosic Ethanol,
John Howe, Verenium International

In the face of rising energy prices, and mounting concern about how the world will handle growing demand for food and fuel, cellulosic ethanol appears increasingly viable as a solution. However, the commercial potential for cellulosic ethanol production will be a function of regional feedstock availability and economics. While some residual waste streams are available for ethanol production, many are questioning whether the biofuels industry can make a major contribution to the nation's and the world's energy needs without production methods based on large-scale, dedicated energy crops. Such crops have not been grown on a large scale in the past and do not have obvious alternative markets.

Massachusetts-based Verenium Corporation is a leading developer of cellulosic ethanol process technology. Verenium recently formed a partnership with BP to accelerate Verenium's technology development efforts, with the goal of near-term commercial deployment. This presentation will explain the basis for Verenium's focus on dedicated energy crops grown in the fertile Gulf Coast region of the United States. It will highlight the advantages, as well as some of the technical and policy issues, raised by this approach. A strategy of producing biofuels from dedicated energy crops may not appear to make sense in a northern, population-dense state like Massachusetts. Nevertheless, given the Commonwealth's leadership position in industrial biotechnology, our state's economy stands to benefit significantly from the growth of this field in other parts of the nation and the world.

Speaker Biographies

Michael Ladisch, Purdue University

Michael R. Ladisch, PhD is Director of the Laboratory of Renewable Resources Engineering, and Distinguished Professor of Agricultural and Biological Engineering with a joint appointment in the Weldon School of Biomedical Engineering and a courtesy appointment in Food Science. He earned his BS (1973) from Drexel University and MS (1974) and PhD (1977) from Purdue University, all in chemical engineering. He has a broad background in bioscience and bioengineering, and has authored a textbook in "Bioseparations Engineering: Principles, Practice and Economics" (Wiley, 2001), 150 journal and proceedings papers, 14 patents (issued and applied for), and has presented over 100 papers. In 2006 he received an Outstanding Chemical Engineer Award from Purdue University; was an inaugural recipient of Paul Dana Award of The Indianapolis (500) racing league for his work in fuel ethanol; and received the Agricultural Team Award (Biosensor Detection Team). He received the Marvin J. Johnson Award in Biochemical Technology of the American Chemical Society in 2002, the Food, Pharmaceutical and Bioengineering Division Award of the American Institute of Chemical engineers in 2001, and became fellow of the American Institute of Medical and Biological Engineers in 1994. In the area of biofuels, he co-founded Celsys together with Brian Stater and Bob Bowen at Bowen Engineering in Indianapolis in 2006. Celsys addressed cellulose processing for the production of fuel ethanol, was acquired in November, 2007 by Mascoma Corporation. Professor Ladisch is currently on a leave of absence from Purdue University to assist in the further development and commercialization of this technology, and to serve as the Chief Technology Officer at Mascoma. As a part of this arrangement he is continuing limited duties at Purdue University as director of LORRE and in his role as Distinguished Professor. Dr. Ladisch was elected to the National Academy of Engineering in 1999.

Doug Elliott, Pacific Northwest National Laboratory

Mr. Elliott has over 34 years of research and project management experience in the Battelle system at the Pacific Northwest National Laboratory (PNNL). His work has mainly been directed toward development of fuels and chemicals from biomass and waste. His experience is primarily in high-pressure batch and continuous-flow processing reactor systems. This research has also involved him in extensive study of catalyst systems. In addition to process development, chemical and physical analysis has also been a significant part of his work. While at Battelle, Mr. Elliott's research has involved such subject areas as biomass liquefaction and hydroprocessing of product oils, catalytic hydrothermal gasification of wet biomass and wastewaters, and chemicals production from renewable sources. His work in biomass liquefaction has involved him in the International Energy Agency as a Task representative for the U.S. under the Bioenergy Agreement. He also spent the summer of 1989 under contract working at the Technical Research Centre of Finland in Espoo on oil production from black liquor.

Mr. Elliott is a listed inventor on 15 U.S. patents and numerous related foreign patents. In 2004 he was designated a Battelle Distinguished Inventor. He has been recognized two times with R&D 100 awards for development of notable new technologies and an award from the Federal Laboratory Consortium for Technology Transfer. He was a member of the team that

received a Green Chemistry Challenge Award in 1999. He is the author of over 70 peer-reviewed journal publications and book chapters. In addition, he has made over 30 presentations at national and international meetings and conferences.

Danny Schnell, UMass Amherst

Danny Schnell is Professor and Head of the Department of Biochemistry and Molecular Biology at the University of Massachusetts, Amherst. His cellular and molecular genetic approaches to understanding protein trafficking and membrane biogenesis have had a major impact on the fields of chloroplast biology, photosynthesis and plant cell biology in general. Danny Schnell is a co-director of The Institute of Massachusetts Biofuels Research. He currently serves on the editorial boards of *Plant Physiology* and *Molecular Biology of the Cell* and is the Secretary and Executive Committee member of the American Society of Plant Biologists.

George Huber, UMass Amherst

George W. Huber is the John and Elizabeth Armstrong Professional Development Professor of Chemical Engineering at University of Massachusetts-Amherst. His research focus is on Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels. He has authored over 29 peer-reviewed publications including two papers in Science. Three different companies (Virent, KiOR and Renewable Oil International) are commercializing biofuel technology that George has developed. His discovery of Raney-NiSn catalyst for hydrogen production from biomass-derived oxygenates was named as one of top 50 technology breakthroughs of 2003 by Scientific America. George is currently working with governmental, industrial, and academic institutions to help make cellulosic biofuels a reality. In June 2007, he chaired a NSF and DOE workshop entitled: Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels (www.ecs.umass.edu/biofuels). This workshop brought together leaders in academia, industry, national labs and governmental agencies to provide a unified national roadmap as to how to make lignocellulosic biofuels a practical reality. Prior to his appointment at UMass-Amherst, George did a post-doctoral stay with Avelino Corma at the Technical Chemical Institute at the Polytechnical University of Valencia, Spain (UPV-CSIC) where he studied bio-fuels production using petroleum refining technologies. He obtained his Ph.D. in Chemical Engineering from University of Wisconsin-Madison (2005) where he helped develop aqueous-phase catalytic processes for biofuels production under the guidance of James A. Dumesic. He obtained his B.S. (1999) and M.S. (2000) degrees from Brigham Young University, where he studied Fischer-Tropsch Synthesis under the direction of Calvin H. Bartholomew.

Susan Leschine, UMass Amherst

Susan Leschine is a Professor of Microbiology and Co-Director of The Institute for Massachusetts Biofuels Research (TIMBR) at the University of Massachusetts, Amherst. She is a Founder and Chief Scientist at SunEthanol, a biofuels technology company headquartered in Amherst. Susan earned a Bachelor's Degree in Biology and a Ph.D. in Biophysics and

Microbiology at the University of Pittsburgh. She conducted postdoctoral research at the University of Massachusetts on microbial communities that decompose plant biomass. Susan is acknowledged as a leading authority on the biology and diversity of cellulose-digesting microbes and their role in the global carbon and nitrogen cycles. She was recently recognized as a Top Ten Woman in Cleantech. Presently, research in her laboratory at UMass Amherst involves studies of bacteria that decompose cellulose and other components of biomass, research that has formed the basis for SunEthanol's Complete Cellulose Conversion (C3™) technology.

Dwayne Breger, Massachusetts Division of Energy Resources

Dwayne Breger is the Manager of the Renewable Energy and Climate Change Group at Massachusetts Department of Energy Resources (DOER). His group implements the state's Renewable Energy Portfolio Standard and other policies and programs to promote renewable energy in the region. Dwayne leads the state's Sustainable Forest Bioenergy Initiative and has served on the staff working group of the Regional Greenhouse Gas Initiative. Dwayne has worked in the renewable energy field for 25 years, with previous positions as a U.S. participant in the International Energy Agency and faculty member at Lafayette College. He holds a Ph.D. in Resource Economics from UMass Amherst, a master's in Technology and Policy from MIT, and an engineering undergraduate degree from Swarthmore College.

John Howe, Verenium International

John Howe is Vice President of Public Affairs for Verenium Corporation, a leader in the development and commercialization of cellulosic ethanol. Prior to joining the company in 2006, he was Vice President, Electric Industry Affairs at American Superconductor, a leading developer of innovative power grid technologies. From 1995 to 1997 he served as Chairman of the Massachusetts Department of Public Utilities, where he spearheaded early stages of the state's energy restructuring process. Previously he was Vice President, Regulatory and Government Affairs for J. Makowski Associates Inc. and U.S. Generating Company, two leading independent power developers. Mr. Howe has held leadership roles in several energy-related organizations. He earned a Bachelor of Arts degree in Political Science, magna cum laude, from Amherst College in 1978 and a Master of Arts in Law and Diplomacy from the Fletcher School at Tufts University in 1984, with a concentration in energy and resource economics. He resides in Belmont.

Jeremy Johnson, Agrivida

Jeremy Johnson is a cofounder of Agrivida, Inc., where he leads process engineering, develops financial projections, assists in business and technical strategic planning, and performs internal human resources and accounting functions. Prior to Agrivida, Jeremy completed a Ph.D. in chemical engineering at MIT where his thesis work focused on life cycle, multi-objective assessment of alternative fuels production. During this time, he worked at the National

Bioenergy Center of the National Renewable Energy Laboratory. Jeremy was formerly a process engineer at Black and Veatch, where he focused on process design of gas processing plants.

Jef Sharpe, SunEthanol

Not available at press time.

Colin South, Mascoma

Not available at press time.

Corinne Young, BioEnergy International

Corinne Young is Director of Government Affairs for BioEnergy International, LLC in Quincy, MA. In this capacity, she most recently helped to craft and pass the historic Energy Independence and Security Act of 2007 and the 2008 Farm Bill, expanding the Renewable Fuels Standard and incentives for next generation biorefineries, as well as new biofuels legislation in the Commonwealths of Pennsylvania and Massachusetts. She has over 14 years of public service, leading significant domestic and international policy, legislation and funding initiatives, with particular expertise in sustainable development and energy policy. She served in various capacities in Washington, DC, including senior advisor within the Executive Office of the Presidency/Office of Management and Budget, Department of the Interior, and senior congressional adviser in the House and Senate. She has diverse private sector expertise in management and public relations, has an MPA from Cornell University, and has won prestigious fellowships and awards. In addition to recently joining the Advisory Board for TIMBR at UMass, she serves on the Board of Directors of the New England Wildlife Center in Weymouth, Massachusetts. She is a proud mother of twin girls, and wife to Barry Young, residing in Duxbury, Massachusetts.

Bruce Vrana, DuPont, Wilmington, DE

Bruce M. Vrana is a Senior Consultant in the DuPont Engineering function in the Engineering Evaluations & Sustainability group. He has a BS and MS in chemical engineering from the University of Pennsylvania and an MBA from the University of Houston. His 28 years with DuPont include assignments in research, manufacturing and engineering. In his 24 years in Engineering, he has worked with many businesses in DuPont on conceptual process design, flowsheets, research guidance and techno-economic evaluations of new processes and products. For the past 5 years, he has worked with R&D teams on both of DuPont's major biofuels thrusts: cellulosic ethanol ("ICBR" project with matching DOE funding and now with partner Genencor) and biobutanol (with partner BP).

The Institute for Massachusetts Biofuels Research (TIMBR)

The development of alternative, renewable fuel sources to reduce or replace our dependence on fossil fuels has emerged as a paramount challenge for maintaining the economic security of the United States. An essential component of the quest for energy independence is to develop renewable, environmentally friendly sources of energy via the conversion of biomass (agricultural and forestry residues) to biofuels (e.g. ethanol and biodiesel).

An interdisciplinary team of reseachers at the University of Massachusetts Amherst has been assembled to establish The Institute for Massachusetts Biofuels Research (TIMBR) with the goal of developing cost-effective technologies for producing ethanol, alternative fuels, and value-added materials from biomass. The TIMBR team consists of experts in all areas of biofuels research and development.

TIMBR is vertically integrated to span the areas of biomass feedstock development, biological and chemical conversion to fuels, and process development, by combining expertise in plant biology, microbiology, chemical catalysis, biorefinery engineering and design, and economic and environmental analysis. TIMBR provides a highly collaborative environment for accelerated biofuels research and development by building on this established base of excellence and vision.

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