EMERGY SYNTHESIS

Theory and Applications of the Emergy Methodology
EMERGY SYNTHESIS 7:
Theory and Applications of the Emergy Methodology

Proceedings from the Seventh Biennial Emergy Conference,
Gainesville, Florida

Edited by
Mark T. Brown
University of Florida
Gainesville, Florida

Managing Editor
Sharlynn Sweeney
University of Florida
Gainesville, Florida

Associate Editors
Daniel E. Campbell
US EPA
Narragansett, Rhode Island

Shu-Li Huang
National Taipei University
Taipei, Taiwan

Daeseok Kang
Pukyong National University
Korea

Torbjorn Rydberg
Uppsala, Sweden

David Tilley
University of Maryland
College Park, Maryland

Sergio Ulgiati
Parthenope University of Napoli
Napoli, Italy

December 2013

The Center for Environmental Policy
Department of Environmental Engineering Sciences
University of Florida
Gainesville, FL
This book may be purchased for $30 from:
The Center for Environmental Policy
CONTENTS

Contributors viii
Acknowledgments xv
Introduction xvii

Theory and Conceptual Frameworks

1. Conversation in Cycles: The Dynamics of Culture Sharing
   Thomas Abel 1

2. The Maximum (Em)Power Principle as a Cross-Disciplinary Interpretational Key: From Ecology to Psychology
   Fabio Beni, Marco Raugei 23

3. Economic and Noneconomic Methods for Valuing Environmental Goods and Services
   Daniel E. Campbell 29

4. Toward a Mathematical Origin of Species
   Dennis G. Collins 31

5. The Relevance of Emerging Solutions for Thinking, Decision Making and Acting. The case of Smart Grids
   Corrado Giannantoni 37

6. Can Resource Pulses Improve Empower Acquisition of an Ecosystem?
   Seungjun Lee 39

7. Critical Analysis of Green Economy Proposals
   Enrique Ortega 51

8. A Different Take on the Emergy Baseline – Or Can There Really Be Any Such Thing
   Marco Raugei 61

9. Religion-Science Amalgam (Reliscience)
   David Scienceman, Dennis Collins 67

Ecology and Ecosystem Services

10. Water Hyacinth Biomass Valuation Using Emergy
    Luz S. Buller, Enrique Ortega, Ivan Bergier 79

11. Valuing Ecosystem Services from Maryland Forests
    Elliott Campbell, David R. Tilley 93

12. Environmental and Economic Consequences of the Overexploitation of Natural Capital and Ecosystem Services in Xilinguole League, China

13. Emergy and Evaluating Ecosystem Services in a Sumatran Peat Swamp, Indonesia
    John McLachlan-Karr, Daniel Campbell 107

    Salvatore Mellino, Maddalena Ripa, Amalia Zucaro, Sergio Ulgiati 123
15. Application of the Landscape Development Intensity (LDI) Index in Wetland Mitigation Banking
   Kelly Chinners Reiss, Erica Hernandez, Mark T. Brown
16. Energy Analysis of Using Macroalgae from Eutrophic Waters As a Bioethanol Feedstock
   Michele Seghetta, Hanne Østergård, Simone Bastianoni
17. Simulation of Carbon and Water Cycles in a Brazilian Watershed: The Impact of Land-Use Change
   Marcos Watanabe, Enrique Ortega

Emergy Evaluations of Industry, Technology and Sustainability

18. Environmental Building Design: Forms of Emergy
   William W. Braham
19. Emergy Evaluation of Biofuel Production from Water Hyacinth Biomass: Case Study of a Sub Region of Pantanal, Brazil
   Luz S. Buller, Enrique Ortega, Ivan Bergier
20. Emergy-based Sustainability Rating System for Canadian Construction Projects
   Navid Hossaini and Kasun Hewage
   Jina Im, Daeseok Kang
22. Eco-Environmental Assessment of Heat Plants: Biomass or Natural Gas?
   Nadia Jamali-Zghal, Nana Yaw Amponsah, Bruno Lacarriere, Olivier Le Corre, Michel Feidt
23. Emergy Evaluation of the Tidal Power Plant in Saemanguem, Korea
   Laura Hija J. Kim, Suk Mo Lee
24. Emergy Evaluation of Landfills for Methane Generation, Recoverability, and Sustainability
   Smiti Nepal, Elliott Campbell
25. The Solar Transformity of Power and Heat in Combined Heat and Power Production
   Sha Sha, Markku Hurme
26. Environmental Accounting of Limestone Rock Processing for Agricultural Use
   Carlos Cezar da Silva, Igor Corsini, Katia Tagliaferro, Geslaine Frimaio, Cecilia M. V. B. Almeida, Adrielle Frimaio, Silvia H. Bonilla
27. Electricity Production from Agricultural Wastes: An Emergy Evaluation
   Carlos Cezar da Silva, Biagio F. Giannetti, Cecilia M. V. B. Almeida, Geslaine F. Silva, Silvia H. Bonilla, José A. B. Grimoni
28. The Estimate of Sediment Loss in the EMergy-based Flows of a Hydropower Production System
   Juan Yang, Qiang Tu, Baolin Liu

Agricultural and Rural Systems

29. Emergy Analysis of a Successional Agroforestry System (SAF)
   Teldes Corrêa Albuquerque, Enrique Ortega Rodriguez, Victor Salek Bosso
30. Sustainability of Extensive Livestock Systems in Alentejo: Viability in the Face of Rising Energy Prices
   Ana Margarida Fonseca, Teresa Pinto-Correia
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>31. Emergy-Based Sustainability Assessment and Perspectives of Regional Agriculture in Northern and Southern Italy</td>
<td>261</td>
</tr>
<tr>
<td>Patrizia Ghisellini, Amalia Zucaro, Sergio Ulgiati</td>
<td></td>
</tr>
<tr>
<td>32. Emergy Evaluation of Governmental Policies on Derelict Fishing Gears in South Korea</td>
<td>277</td>
</tr>
<tr>
<td>Sunwook Hong, Daeseok Kang, Jongmyoung Lee</td>
<td></td>
</tr>
<tr>
<td>33. Incorporation of Emergy Analysis into Decision-Making at the Farm Level: A Conceptual Model and its Implications for Agri-Environmental Policy Design</td>
<td>283</td>
</tr>
<tr>
<td>Tina Jaklič, Luka Juvančič, Marko Debeljak</td>
<td></td>
</tr>
<tr>
<td>34. The Maximum Empower Principle: An Invisible Hand Controlling the Self-Organizing Development of Forest Plantations in South China</td>
<td>293</td>
</tr>
<tr>
<td>Linjun Li, Hongfang Lu, David R. Tilley, Hai Ren, Weijun Shen</td>
<td></td>
</tr>
<tr>
<td>35. Comparison of an Energy Systems Mini-Model to a Process-Based Eco-Physiological Model for Simulating Forest Growth</td>
<td>295</td>
</tr>
<tr>
<td>Linjun Li, David R. Tilley, Hongfang Lu, Hai Ren, Guoyu Qiu</td>
<td></td>
</tr>
<tr>
<td>36. Spatial Emergy Synthesis of the Environmental Impacts from Agricultural Production System Change – A Case Study of Taiwan</td>
<td>297</td>
</tr>
<tr>
<td>Ying-Chen Lin, Shu-Li Huang</td>
<td></td>
</tr>
<tr>
<td>37. Sustainability of Milk and Orange Production Systems, Part I: Energy Analysis in the Annual Cycles of Production</td>
<td>321</td>
</tr>
<tr>
<td>Emdar Eduardo Bassan Mendes, Irineu Arcaro Jr., Luis Alberto Ambrosio</td>
<td></td>
</tr>
<tr>
<td>38. Sustainability of the Milk and Orange Production Systems, Part II: Analysis of La Niña Pulsing Effect on the Emergy Flows</td>
<td>333</td>
</tr>
<tr>
<td>Emdar Eduardo Bassan Mendes, Irineu Arcaro Jr., Luis Alberto Ambrosio</td>
<td></td>
</tr>
<tr>
<td>39. An Over Time Multi-Criteria Accounting of a Brazilian Bamboo Plantation</td>
<td>339</td>
</tr>
<tr>
<td>Luiz Ghelmandi Netto, Biagio F. Giannetti, Silvia H. Bonilla, Gloria Rótolo, Cecilia M. V. B. Almeida</td>
<td></td>
</tr>
<tr>
<td>40. Emergy Evaluation of a Mountain Socio-Economic System and Traditional Agroproduction: A Case Study in Indian Trans-Himalaya</td>
<td>347</td>
</tr>
<tr>
<td>Federico M. Pulselli, Vladimir Pellecicardi</td>
<td></td>
</tr>
<tr>
<td>41. Environmental Evaluation of Transgenic Corn Seed Production in Argentina</td>
<td>357</td>
</tr>
<tr>
<td>Gloria C. Rótoło, M. Mercedes Rivero P., Andrés Pereyra, Roque Craviotto, Silvio Viglia, Sergio Ulgiati</td>
<td></td>
</tr>
</tbody>
</table>

**Regional Economic and Social Systems**

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>42. Sustainability, Indicators, and Institutions of Higher Education</td>
<td>369</td>
</tr>
<tr>
<td>Tingting Cai, Thomas Olsen, Dan Campbell</td>
<td></td>
</tr>
<tr>
<td>43. Emergy of the Occupations</td>
<td>381</td>
</tr>
<tr>
<td>Daniel E. Campbell, Denis White, Carolyn Fonyo Boggess</td>
<td></td>
</tr>
<tr>
<td>44. Dengue Control in Florida and Transformity</td>
<td>405</td>
</tr>
<tr>
<td>Dennis G. Collins, Glenn H. Collins</td>
<td></td>
</tr>
<tr>
<td>45. Emergy Accounting of Brazilian States and Regions</td>
<td>413</td>
</tr>
<tr>
<td>Fernando J. C. Demétrio, Biagio F. Giannetti, Silvia H. Bonilla, Cecilia M. V. B. Almeida</td>
<td></td>
</tr>
<tr>
<td>46. Emergy-based Ecological Pressure Analysis of Land Use in China</td>
<td>419</td>
</tr>
<tr>
<td>Yang Gao, Shuangcheng Li, Zhe Feng</td>
<td></td>
</tr>
<tr>
<td>47. Emergy-Based Dynamic Mechanisms of Urban Development, Resource Consumption and Environmental Impacts</td>
<td>421</td>
</tr>
<tr>
<td>Gengyuan Liu, Zhifeng Yang, Bin Chen, Sergio Ulgiati</td>
<td></td>
</tr>
</tbody>
</table>
   Bo Lou, Sergio Ulgiati, Chaofan Sun  
49. Solar Emergy Evaluation of the Portuguese Economy  
   Carlos Oliveira, Cecília Martins, José Gonçalves, Francisco Veiga  
50. Assessment of Services in Emergy Accounting of Nations  
   Lucas Pereira, Enrique Ortega  
51. Study of the Environmental Sustainability of São Caetano do Sul Using Emergy Synthesis  
   Fábio Sevegnani, Cecília M.V.B. Almeida, Biagio F. Giannetti, Silvia H. Bonilla  

Advances in Methodology  
52. A Geobiosphere Baseline for LCA – Emergy Evaluations  
   Mark T. Brown, Sergio Ulgiati  
53. Emergy Evaluations of the Global Biogeochemical Cycles of Six Biologically Active Elements and Two Compounds  
   Daniel E. Campbell, Hongfang Lu, Bin-Le Lin  
54. Crustal Specific Emergy Scaled by ‘Transformity’ Enrichment  
   Chris De Vilbiss  
55. How to Manage Inputs from Co-production Processes in Emergy Accounting  
   Andreas Kamp & Hanne Østergård  
56. Development of Eco-Efficiency Index by Emergy Analysis  
   Dong Joo Lee, Suk Mo Lee  
57. Set Theory Applied to Uniquely Define the Inputs to Territorial Systems in Emergy Analyses  
   Fabiana Morandi, Daniel E. Campbell, Simone Bastianoni  
58. Evaluation of Matrix Algebra Methods for Calculating Transformities from Ecological and Economic Network Data  
   Murray Patterson  
59. The Added Value of Integrating Emergy into LCA  
   Marco Raugei, Benedetto Rugani, Enrico Benetto, Wesley W. Ingwersen  
60. A Fuzzy-Based Approach for Characterization of Uncertainties in Emergy Synthesis: An Example of Paved Road System  
   Bahareh Reza, Rehan Sadiq, Kasun Hewage  
61. Quantifying the Emergy of Resources: Challenges for a Bottom-up Approach  
   Benedetto Rugani, Enrico Benetto, Damien Arbault, Ligia Tiruta-Barna, Antonino Marvuglia  
   Benedetto Rugani, Enrico Benetto, Ligia Tiruta-Barna, Wesley W. Ingwersen, Antonino Marvuglia, Damien Arbault  
63. Labor and Services  
   Sergio Ulgiati, Mark T. Brown  
64. Comparison of Principles for Allocating Emergy to Recycled Materials in Natural and Managed Ecosystems  
   Brandon K. Winfrey, David R. Tilley  
65. Estimating Transformity (UEV) with Economic Input-Output Models  
   Lixiao Zhang, Zhifeng Yang, Guoqian Chen, Gengyuan Liu
THOMAS ABEL, Department of Human Development, Tzu Chi University, Hualien, Taiwan [tabel@mail.tcu.edu.tw]

TELDES ALBUQUERQUE, College of Food Engineering, State University of Campinas, UNICAMP, Caixa Postal 6121, 13083-970 Brazil [teldesalbuquerque@gmail.com]

CECILIA MARIA VILLA BÓAS DE ALMEIDA, Post-graduation Program on Production Engineering, Paulista University, São Paulo SP Brazil [cmvbag@unip.br]

LUIS ALBERTO AMBRÓSIO, Center of Milk Bovines, Zootechnology Institute, Rua Heitor Penteado, 56. CEP 13460-000, Nova Odessa – São Paulo State – Brazil [ambrosio@iz.sp.gov.br]

DAMIEN ARBAULT, Public Research Centre Henri Tudor (CRPHT)/Resource Centre for Environmental Technologies (CRTE), Esch-sur-Alzette (Luxembourg); and Université de Toulouse, Institut National des Sciences Appliquées (INSA), UPS, INP - LISBP, Toulouse, France

IRINEU ARCARO JUNIOR, Center of Milk Bovines, Zootechnology Institute, Rua Heitor Penteado, 56. CEP 13460-000, Nova Odessa – São Paulo State – Brazil [irineu@iz.sp.gov.br]

SIMONE BASTIANONI, Ecodynamics Group, DEEPS Department of Earth, Environmental and Physical Sciences, University of Siena, Siena, Italy [bastianoni@unisi.it]

ENRICO BENETTO, Center for Life Cycle Analysis, Columbia University, New York (NY), USA [enrico.benetto@tudor.lu]

FABIO BENI, Public Health Department for Drug Addictions (SER.T.), Prato, Italy and Interpersonal Psychoanalytic Association of Florence (AFPI), Florence, Italy [fabio.beni@yahoo.it]

IVAN BERGIER, Embrapa Pantanal, Brazilian Agricultural Research Corporation,, MS, CEP 79320-900, Brazil [ivan.bergier@cpap.embrapa.br]

CAROLYN FONYO BOGGESS, Biological & Ecological Engineering, Oregon State University, USA [boggessc@onid.orst.edu]

SILVIA HELENA BONILLA, Post-graduation Program on Production Engineering, Paulista University, São Paulo SP Brazil [bonilla@unip.br]

VICTOR SALEK BOSSO, College of Food Engineering, State University of Campinas, UNICAMP, Caixa Postal 6121, 13083-970 Brazil [victorsalekb@gmail.com]

WILLIAM BRAHAM, The University of Pennsylvania School of Design, Philadelphia, PA [brahamw@design.upenn.edu]

MARK BROWN, Center for Environmental Policy, University of Florida, PO Box 116350, Gainesville, FL 32611 [mtb@ufl.edu]
ANTONINO MARVUGLIA, Public Research Centre Henri Tudor (CRPHT)/Resource Centre for Environmental Technologies (CRTE), Esch-sur-Alzette, Luxembourg

JOHN McLACHLAN-KARR, Consultant UNEP/AUSAID, Brisbane, Australia
[jmckarr@hotmail.com]

SALVATORE MELLINO, Department of Sciences for the Environment, Parthenope University of Naples, Italy [salvatore.mellino@gmail.com]

EDMAR EDUARDO BASSAN MENDES, Unit of Research and Development-APTA, Sao Jose do Rio Preto, SP, Brazil [ebassanmendes@apta.sp.gov.br]

FABIANA MORANDI, Ecodynamics Group, DEEPS Department of Earth, Environmental and Physical Sciences, University of Siena, Siena, Italy [morandi2@unisi.it]

SMITI NEPAL, Land Management Administration, Maryland Department of the Environment [SNepal@mde.state.md.us]

LUIZ GHELMANDI NETTO, Universidade Paulista, São Paulo, Brazil [luiznetto@unip.br]

CARLOS ALBERTO REGO DE OLIVEIRA, Centro Lusíada para a Investigação e Desenvolvimento em Engenharia e Gestão Industrial (CLEGI), Faculdade de Engenharia e Tecnologias, Universidade Lusíada de V. N. de Famalicão, Portugal [carego@fam.ulusiada.pt]

THOMAS OLSEN, 1018 S. High St. Urbana, OH 43078 [ttcai1@gmail.com]

ENRIQUE ORTEGA, College of Food Engineering, State University of Campinas, UNICAMP, Brazil [ortega@fea.unicamp.br]

HANNE ØSTERGÅRD, Department of Chemical and Biochemical Engineering, Technical University of Denmark, DTU, Denmark [haqs@kt.dtu.dk]

MURRAY PATTERSON, School of People, Environment and Planning, Massey University, Palmerston North, New Zealand [m.g.patterson@massey.ac.nz]

VLADIMIRO PELLICCIARDI, CIRPS, University of Rome “La Sapienza” Italy [vladimiropelliciardi@tiscali.it]

LUCAS GONÇALVES PEREIRA, Ecological Engineering Laboratory, Departamento de Engenharia de Alimentos, Universidade Estadual de Campinas, São Paulo, Brazil [lucgpereira@gmail.com]

ANDRÉS PEREYRA, Criadero de semillas ACA C.L, Pergamino, Argentina [apereyra@acacoop.com.ar]

TERESA PINTO-CORREIA, Research Group on Mediterranean Ecosystems and Landscapes ICAAM, University of Évora, Núcleo da Mitra, Edifício Principal, Évora, Portugal [ana_margarida17@yahoo.com.br]

FEDERICO M. PULSELLI, Ecodynamics Group, Dept. of Chemistry, University of Siena, Italy [fpulselli@unisi.it]
GUOYU QUI, Key Laboratory of Urban Habitat Environmental Science and Technology, School of Environment and Energy, Peking University, Shenzhen, China

MARCO RAUGEI, Oxford Brookes University, Wheatley (Oxford), UK; and Center for Life Cycle Analysis, Columbia University, New York (NY), USA [marco.raugei@brookes.ac.uk]

HAI REN, Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystems, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, China

BAHAREH REZA, School of Engineering, University of British Columbia, Kelowna, BC, Canada [bahareh.reza@ubc.ca]

MADDALENA RIPA, Department of Sciences for the Environment, Parthenope University of Naples, Italy [maddalena.ripa@uniparthenope.it]

GLORIA C. RÓTOLO, Agricultural Experimental Station (EEA), National Institute of Agricultural Technology (INTA), Oliveros, Argentina [rotolo.gloria@gmail.com]

BENEDETTO RUGANI, Public Research Centre Henri Tudor (CRPHT)/Resource Centre for Environmental Technologies (CRTE), Esch-sur-Alzette (Luxembourg); and Center for Life Cycle Analysis, Columbia University, New York (NY), USA [Benedetto.Rugani@tudor.lu]

REHAN SADIQ, School of Engineering, University of British Columbia, Kelowna, BC, Canada [rehan.sadiq@ubc.ca]

DAVID M. SCIENCEMAN, New South Wales, Australia [dscienceman@bigpond.com]

MICHELE SEGHETTA, Department of Chemical and Biochemical Engineering, Technical University of Denmark, DTU, Denmark [micheleseghetta@gmail.com]

FÁBIO SEVEGNANI, Paulista University, Paulista University, São Paulo SP Brazil [proffabios@gmail.com]

SHA SHA, Aalto University, Department of Biotechnology and Chemical Technology, Espoo, Finland [sha.sha@aalto.fi]

WEIJUN SHEN, Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystems, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, China

CARLOS CEZAR DA SILVA, Instituto Federal de Educação Ciência e Tecnologia do Sul, de Minas Gerais – Departamento de Ciências Exatas, São Paulo SP, Brasil [cezardts@gmail.com]

GESLAINE FRIMAIO DA SILVA, Universidade Paulista [gfrimaio@gmail.com]

CHAOFAN SUN, Electric Power Research Institute of Guangdong Power Grid Corporation, Guangzhou, China [sun-cf@163.com]

KÁTIA TAGLIAFERRO, Federal Institute of Education, Science and Technology South Mine (IFSULDEMINAS) [ka_tagliaferro@hotmail.com]
DAVID TILLEY, Department of Environmental Science & Technology, University of Maryland, College Park, MD, USA [dtilley@umd.edu]

LIGIA TIRUTA-BARNA, Université de Toulouse, Institut National des Sciences Appliquées (INSA), UPS, INP - LISBP, Toulouse (France)

QIANG TU, College of Oceanography and Environmental Science, Xiamen University, Xiamen, China [Tuqiang1975@gmail.com]

FRANCISCO JOSÉ ALVES COELHO VEIGA, Núcleo de Investigação em Políticas Económicas (NIPE), Departamento de Economia, Escola de Economia e Gestão, Universidade do Minho, Braga, Portugal [fjveiga@eeg.uminho.pt]

DENIS WHITE, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA

SERGIO ULGIATI, Department of Sciences for the Environment, Parthenope University of Naples, Centro Direzionale, Naples, Italy [sergio.ulgiati@uniparthenope.it]

SILVIO VIGLIA, Department of Sciences and Technologies, Parthenope University of Naples, Centro Direzionale, Naples. [silvio.viglia@gmail.com]

MARCOS DJUN-BARBOSA WATANBE, Brazilian Bioethanol Science and Technology Laboratory (CTBE/CNPEM), Campinas, Brazil [marcosdbwatanabe@gmail.com]

DENIS WHITE, College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, USA [whitede@onid.oregonstate.edu]

BRANDON K. WINFREY, University of California Los Angeles, Los Angeles [winfrey@gmail.com]

JUAN YANG, Department of Marine Science, China University of Geosciences, Beijing, China [Yangjuan.cn@gmail.com]

ZHIFENG YANG, State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing, China [zfyang@bnu.edu.cn]

B.H. YU, State Key Laboratory of Earth Surface Processes and Resource Ecology, College of Resources Science & Technology, Beijing Normal University, China

LIXIAO ZHANG, State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing, China [zhanglixiao@bnu.edu.cn]

X.S. ZHANG, State Key Laboratory of Earth Surface Processes and Resource Ecology, College of Resources Science & Technology, Beijing Normal University, China

Y.S. ZHANG, Guanghua School of Management, Peking University, Beijing, China

AMALIA ZUCARO, Department of Sciences for the Environment, Parthenope University of Naples, Naples, Italy [amalia.zucaro@uniparthenope.it]
Acknowledgments

I wish to thank all the participants to the conference who traveled far to disseminate their findings and contribute to the information exchange that is so vital to the application of the emergy theory. The organizing committee members - Daniel Campbell, Shu-Li Huang, Daeseok Kang, Torbjörn Rydberg, David Tilley, and Sergio Ulgiati – were helpful in all aspects of conference and helping to organize reviews of the papers in the proceedings. In addition, they were an invaluable source of ideas and assistance throughout the months preceding and following the conference. Students in the System Ecology Program at the University of Florida were, once again, involved in welcoming participants to our campus and providing support during the registration period. Carol Binello again provided invaluable coordination of conference receptions and food. Probably most important, the invaluable and most capable assistance of Sharlynn Sweeney is most gratefully acknowledged… the conference and publication of these proceedings resulted from her hard work and dedication.

Finally, the manuscripts in these proceedings have greatly benefited from the following reviewers, whose constructive criticism, ideas, and challenges heightened the quality level of this publication.

Tom Abel, Tzu-Chi University, Hualien, Taiwan
Nana Yaw Amponsah, Ecole des Mines de Nantes, Nantes, France
Silvia Bonilla, Paulista University, São Paulo SP Brazil
Elvira Buonocore, Parthenope University, Naples, Italy
Daniel E. Campbell, USEPA Narragansett, RI, USA
Elliott T. Campbell, University of Maryland, College Park, MD, USA
Maria Daniela Caprile, Univ. Nacional de General Sarmiento, Buenos Aires, Argentina
Otávio Cavaletti, Brazilian Center of Research in Energy and Materials, Campinas, Brazil
Dennis Collins, retired from University of Puerto Rico, PR
Vito Comar, Institute for Environment and Development - IMAD, Dourados, Brazil
Margarita Cuadra, Swedish University of Agricultural Sciences, Uppsala, Sweden
Christopher De Vilbiss, University of Florida, Gainesville, FL, USA
Stewart Diemont, Ohio State University, Columbus, OH, USA
Xiaobin Dong, Beijing Normal University, China
Gabriella Fiorentino, Parthenope University, Naples, Italy
Pier Paolo Franzese, Parthenope University, Naples, Italy
Ben Fusaro, Florida State Univ. Emeritus, FL, USA
Corrado Giannantoni, Duchenne Parent Project Onlus, Rome, Italy
Erik Grönlund, Mid Sweden University, Östersund, Sweden
Andrew Haden, Swedish University of Agricultural Sciences, Uppsala, Sweden
Shu-Li Huang, National Taipei University, Taiwan
Im Jina, Pukyong National University, Busan, South Korea
Wes Ingwersen, USEPA, Cincinnati, OH, USA
Tina Jaklic, University of Ljubljana, Domžale, Slovenia
Nadia Jamali-Zghal, Ecole des Mines de Nantes, Nantes, France
Pat Kangas, University of Maryland, College Park, MD, USA
Jana Laganis, University of Nova Gorica, Slovenia
Ying-Chen Lin, National Taipei University, Taiwan
Li Linjun, Peking University, ShenZhen, China
Pedro Lomas, Autonomus University of Barcelona, Spain
Bo Lou, South China University of Technology, Guangzhou, China
Hongfang Lu, Chinese Academy of Sciences, Guangzhou, China
As I thank all the participants and reviewers for this year’s contributions, I anxiously await our next conference; I am sure that our time together and exchange of ideas can only strengthen our work and commitment to better science. During these times of social and political unrest, increasing globalization of commerce, climate change, and peak oil, our work is ever more important. I would like to acknowledge the global emergy community and the contributions they are making to furthering our understanding of the biosphere and humanity’s place within it. Further, I would like to challenge everyone to use their science in the search for peace, justice, and rational patterns of material wealth that not only acknowledge our utter dependence on a healthy biosphere, but that protects it for this and succeeding generations. I urge you to speak loudly in favor of a prosperous way down.

Mark T. Brown
Gainesville, FL
Introduction

Emergy Synthesis

In this volume, 65 papers are presented that resulted from the Seventh Biennial Emergy Conference held in Gainesville, Florida in January 2012. Some of these were published elsewhere as journal articles, and for those papers, we include the abstract and the citation for the article. Because of the large numbers of papers, we have organized them into “Themes” or sections, spanning from theory, ecosystem analysis and technology applications to analysis of agricultural, rural, economic and social systems, and ending with advances in emergy methodology. A quick scan through the Table of Contents demonstrates the varied applicability of the emergy methodology, with papers addressing theoretical concepts, ecosystem services, urban waste issues, technology, agriculture, energy sources, regional and national analyses, and many other subjects.

Held every two years in Gainesville on the University of Florida campus, the “Emergy Conference” has grown steadily from about 35 participants in 1999 to over 100 participants in the January 2012 conference. The proceeding of the conference, published by the Center for Environmental Policy at the University of Florida has increased in size from a book of 26 papers resulting from the 1999 conference to 31 papers published in the 2003 proceedings, 46 papers in 2005, 52 papers from the 2008 conference, and 65 papers from the 2012 conference. The Conference is truly international, bringing together scientists representing over 25 countries from the continents of Asia, Australia, Europe, and North and South America.

General Introduction: Concepts and Principles

To simplify the tasks of all the authors whose papers appear in this proceedings, we provide introductory material that defines many of the terms and concepts used in the emergy field. We begin with clarifying the title of this series of conference proceedings:

Synthesis is the act of combining elements into coherent wholes. Emergy synthesis is a “top-down” approach to quantitative policy decision making and evaluation. Rather than dissect and break apart systems and build understanding from the pieces upward, emergy synthesis strives for understanding by grasping the wholeness of systems. We have named this series of conference proceedings “Emergy Synthesis” to reflect our commitment to building understanding rather than dissection of knowledge.

The emergy concept and the maximum empower principle constitute powerful concepts, definitions and tools for investigation of systems at all scales, framing a system’s behavior and sustainability within the biosphere’s driving forces and evolutionary pattern. By expanding the scope of energy studies to the biosphere’s space and time scales, the emergy method is able to:

a) Investigate systems that are outside of human activities (ecosystems, global biosphere processes).

b) Focus on the role of the environment in support of human dominated processes, both on the resource supply side and on the sink side (dilution or uptake of pollutants).

c) Perform a donor-side quality assessment as a complement of generally used user-side assessments. This provides a measure of how much the system relies on the biosphere for support.

d) Evaluate processes that are directly based on small flows of physical carriers, but supported by huge indirect flows of resources, such as the creation and processing of information.
e) Expand the time scale of the evaluation, to include the memory of resource flows converging to the system.

f) Assess the renewability of resources based on both space and time convergence required to make them. The transformity quantifies this renewability in a continuous form, with higher values corresponding to higher convergence of environmental work and therefore lower renewability.

g) Evaluate in a quantitative way the (donor-) quality of those resource flows and storages that have no market (such as fresh water, biodiversity, fertile topsoil) and cannot be evaluated in monetary terms.

h) Assess the environmental impact of processes based on matching of high quality and low quality resources.

i) Include in the evaluation the emergy supporting human labor and services.

All of these properties provide a powerful and comprehensive tool for the investigation of systems on the larger scales of the biosphere, and, finally, help with understanding the dynamic interaction between human dominated processes and resources and services provided for free by nature.

Following are brief definitions of the emergy concepts. For a more complete introduction to the emergy methodology please refer to H.T. Odum’s Environmental Accounting (1996) text.

**Definitions**

*Energy is sometimes referred to as the ability to do work.* Energy is a property of all things which can be turned into heat, and is measured in heat units (BTUs, calories, or joules).

*Emergy is the availability of energy (exergy) of one kind that is used up in transformations directly and indirectly to make a product or service.* The unit of emergy is the *emjoule* (see below), a unit referring to the available energy of one kind consumed in transformations. For example, sunlight, fuel, electricity, and human service can be put on a common basis by expressing them all in the emjoules of solar energy that is required to produce each. In this case the value is a unit of *solar emergy* expressed in *solar emjoules* (abbreviated sej). Although other units have been used, such as coal emjoules or electrical emjoules, in most cases all emergy data are given in solar emjoules.

*Emdollar is a measure of the money that circulates in an economy as the result of some process; abbreviated as “em$” or “em$.” In practice, to obtain the emdollar value of an emergy flow or storage, the emergy is multiplied by the ratio of total emergy to Gross National Product for the national economy.*

*Emjoule* is the unit of measure of emergy, the term is short for emergy joule. An emjoule is an expression of the units of energy previously used to generate a product; for instance the solar emergy of wood is expressed as joules of solar energy that were required to produce the wood. Solar emjoules is abbreviated "sej."

*Empower* is a flow of emergy (ie emergy per time). Emergy flows are usually expressed in units of solar empower (solar emjoules per time).

*Unit Emergy Values* (UEV) are based on the emergy required to produce something. UEVs are calculated by dividing the sum of all emergy required by the units of product output. There are two types of unit emergy values appropriate for this chapter as follows:
Transformity is defined as the energy per unit of available energy (exergy). For example, if 4000 solar emjoules are required to generate a joule of wood, then the solar transformity of that wood is 4000 solar emjoules per joule (abbreviated sej/J). Solar energy is the largest but most dispersed energy input to the earth. The solar transformity of the sunlight absorbed by the earth is 1.0 by definition.

Specific emergy is the unit emergy value of matter defined as the emergy per mass, usually expressed as solar emergy per gram (sej/g). Solids may be evaluated best with data on emergy per unit mass for its concentration. Because energy is required to concentrate materials, the unit emergy value of any substance increases with concentration. Elements and compounds not abundant in nature therefore have higher emergy/mass ratios when found in concentrated form since more work was required to concentrate them, both spatially and chemically.

Emergy per unit money is a unit emergy value used to convert money payments into emergy units. The amount of resources that money buys depends on the amount of emergy supporting the economy and the amount of money circulating. An average emergy/money ratio in solar emjoules/$ can be calculated by dividing the total emergy use of a state or nation by its gross economic product. It varies by country and has been shown to decrease each year. This emergy/money ratio is useful for evaluating service inputs given in money units where an average wage rate is appropriate.

Emergy accompanying a flow of something (energy, matter, information, etc.) is calculated using a unit emergy value. The flow expressed in its usual units is multiplied by the emergy per unit of that energy or material. For example, the flow of a fuel input to a process, in joules per time, can be multiplied by the transformity of that fuel (emergy per unit energy in solar emjoules/joule), or the mass of a material input can be multiplied by its specific emergy (emergy per unit mass in solar emjoules/gram). The emergy of a storage is calculated by multiplying the storage quantity in its usual units by its unit emergy value.

Mark T. Brown